JEPPIAAR INSTITUTE OF TECHNOLOGY

“Self-Belief| Self Discipline | Self Respect”

QUESTION BANK

REGULATION : 2017

YEAR : II

SEMESTER : 03

BATCH : 2017-2021

DEPARTMENT
OF
ELECTRICAL &ELECTRONICS
ENGINEERING

BLOOM'S TAXONOMY

Definition:

Bloom's taxonomy is a classification system used to define and distinguish different levels of human cognition like thinking, learning and understanding.

Objectives:

- To classify educational learning objectives into levels of complexity and specification. The classification covers the learning objectives in cognitive, affective and sensory domains.
- To structure curriculum learning objectives, assessments and activities.

Levels in Bloom's Taxonomy:

- **BTL 1** – **Remember** - The learner recalls, restate and remember the learned information.

- **BTL 2** – **Understand** - The learner embraces the meaning of the information by interpreting and translating what has been learned.

- **BTL 3** – **Apply** - The learner makes use of the information in a context similar to the one in which it was learned.

- **BTL 4** – **Analyze** - The learner breaks the learned information into its parts to understand the information better.

- **BTL 5** – **Evaluate** - The learner makes decisions based on in-depth reflection, criticism and assessment.

- **BTL 6** – **Create** - The learner creates new ideas and information using what has been previously learned.

TABLE OF CONTENT

MA8351 TRANSFORMS AND PARTIAL DIFFERENTIAL EQUATIONS

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OBJECTIVES :

- To introduce the basic concepts of PDE for solving standard partial differential equations.
- To introduce Fourier series analysis which is central to many applications in engineering apart from its use in solving boundary value problems.
- To acquaint the student with Fourier series techniques in solving heat flow problems used in various situations.
- To acquaint the student with Fourier transform techniques used in wide variety of situations.
- To introduce the effective mathematical tools for the solutions of partial differential equations that model several physical processes and to develop Z transform techniques for discrete time systems.

UNITI PARTIAL DIFFERENTIAL EQUATIONS 12

Formation of partial differential equations – Singular integrals - Solutions of standard types of first order partial differential equations - Lagrange's linear equation - Linear partial differential equations of second and higher order with constant coefficients of both homogeneous and non- homogeneous types.

UNIT II FOURIER SERIES 12

Dirichlet's conditions – General Fourier series – Odd and even functions – Half range sine series – Half range cosine series – Complex form of Fourier series – Parseval's identity – Harmonic analysis.

UNIT III APPLICATIONS OF PARTIAL DIFFERENTIAL EQUATIONS 12

Classification of PDE – Method of separation of variables - Fourier Series Solutions of one dimensional wave equation – One dimensional equation of heat conduction – Steady state solution of two dimensional equation of heat conduction.

UNIT IV FOURIER TRANSFORMS 12

Statement of Fourier integral theorem – Fourier transform pair – Fourier sine and cosine transforms – Properties – Transforms of simple functions – Convolution theorem – Parseval's identity.

UNIT V Z - TRANSFORMS AND DIFFERENCE EQUATIONS 12

Z-transforms - Elementary properties – Inverse Z-transform (using partial fraction and residues) – Initial and final value theorems - Convolution theorem - Formation of difference equations – Solution of difference equations using Z - transform.

TOTAL: 60 PERIODS

OUTCOMES :

Upon successful completion of the course, students should be able to:

- Understand how to solve the given standard partial differential equations.
- Solve differential equations using Fourier series analysis which plays a vital role in engineering applications.
- Appreciate the physical significance of Fourier series techniques in solving one and two dimensional heat flow problems and one dimensional wave equations.
- Understand the mathematical principles on transforms and partial differential equations would provide them the ability to formulate and solve some of the physical problems of engineering.
- Use the effective mathematical tools for the solutions of partial differential equations by using Z transform techniques for discrete time systems.

TEXTBOOKS:

1. Grewal B.S., "Higher Engineering Mathematics", 43rd Edition, Khanna Publishers, New Delhi, 2014.

2. Narayanan S., Manicavachagom Pillay.T.K and Ramanaiah.G "Advanced Mathematics for Engineering Students", Vol. II & III, S.Viswanathan Publishers Pvt. Ltd, Chennai, 1998.

REFERENCES :

1.. Andrews, L.C and Shivamoggi, B, "Integral Transforms for Engineers" SPIE Press, 1999.
2. Bali. N.P and Manish Goyal, "A Textbook of Engineering Mathematics", 9th Edition, Laxmi Publications Pvt. Ltd, 2014.
3. Erwin Kreyszig, "Advanced Engineering Mathematics ", 10th Edition, John Wiley, India, 2016.
4 . James, G., "Advanced Modern Engineering Mathematics", 3rd Edition, Pearson Education, 2007.
5 Ramana. B.V., "Higher Engineering Mathematics", McGraw Hill Education Pvt. Ltd, New Delhi, 2016.
6. Wylie, R.C. and Barrett, L.C., "Advanced Engineering Mathematics "Tata McGraw Hill Education Pvt. Ltd, 6th Edition, New Delhi, 2012.

UNIT-I PARTIAL DIFFERENTIAL EQUATIONS

Formation of Partial Differential Equations-Singular Integrals-Solution of Standard Types of First Order Partial Differential Equations- Lagranges Linear Equations-Linear Partial Differential Equations of the Second and Higher Order with constant Co-efficients of both Homogeneous and Non Homogeneous Types

PART*A

1. **Form a partial differential equation by eliminating the arbitrary constants from** $z = ax^2 + by^2$ **. [N/D13]** BTL6

Given $z = ax^2 + by^2$

(1)

Differentiating (1) partially with respect to x, we have

$$\frac{\partial z}{\partial x} = 2ax \implies p = 2ax \implies a = \frac{p}{2x} \qquad (2)$$

Differentiating (1) partially with respect to y, we have

$$\frac{\partial z}{\partial y} = 2by \implies q = 2by \implies b = \frac{q}{2y} \qquad (3)$$

using (2) and (3) in (1), we have

$$z = \left(\frac{p}{2x}\right)x^2 + \left(\frac{q}{2y}\right)y^2 \implies z = \frac{1}{2}\left[px + qy\right]$$

$2z = px + qy$, which is the required partial differential equation.

2 **Form a partial differential equation by eliminating the arbitrary constants from** $z = ax^3 + by^3$ **. [M/J14]** BTL6

Given $z = ax^3 + by^3$ (1)

Differentiating (1) partially with respect to x, we have

$$\frac{\partial z}{\partial x} = 3ax^2 \implies p = 3ax^2 \implies a = \frac{p}{3x^2} \qquad (2)$$

Differentiating (1) partially with respect to y, we have

$$\frac{\partial z}{\partial y} = 3by^2 \implies q = 3by^2 \implies b = \frac{q}{3y^2} \qquad (3)$$

using (2) and (3) in (1), we have

$$z = \left(\frac{p}{3x^2}\right)x^3 + \left(\frac{q}{3y^2}\right)y^3 \implies z = \frac{1}{3}\left[px + qy\right]$$

$3z = px + qy$, which is the required partial differential equation.

3	**Eliminate the arbitrary function f from $z = f\left(\frac{y}{x}\right)$ and form a p.d.e. [N/D12 ,*N/D14*]** BTL5 Given $z = f\left(\frac{y}{x}\right)$ **(1)** Differentiate (1) partially w.r.to x and y , we get $p = \frac{\partial z}{\partial x} = f'\left(\frac{y}{x}\right)\cdot\left(\frac{-y}{x^2}\right)$ (2) $q = \frac{\partial z}{\partial y} = f'\left(\frac{y}{x}\right)\cdot\left(\frac{1}{x}\right)$ (3) (2)/(3), we get the required p.d.e $\frac{p}{q} = \frac{-y}{x}$.
4	**Find the complete solution of the partial differential equation $p^3 - q^3 = 0$. [*M/J16*]** BTL5 Given $p^3 - q^3 = 0$ This is of the form $F(p, q) = 0$ Hence, the complete integral is $z = ax + by + c$ where $a^3 - b^3 = 0$ (ie) $b = a$ Therefore, the complete solution is $z = ax + ay + c$.
5	**Solve $(D^3 - 2D^2D')z = 0$. [N/D09].** BTL5 The auxiliary equation is $m^3 - 2m^2 = 0$ $m^2(m-2) = 0$ $m = 0, 0, 2$ Hence the solution is $z = \phi_1(y) + x\phi_2(y) + \phi_3(y + 2x)$.
6	**Solve $(D^4 - D'^4)z = 0$. [M/J14]** BTL5 The A.E. is $m^4 - 1 = 0$ Therefore, the roots are $m = 1, -1, i, -i$ Hence $z = f_1(y + x) + f_2(y - x) + f_3(y + ix) + f_4(y - ix)$.
7	**Solve $(D^3 - 4D^2D' + 4DD'^2)z = 0$. [A/M15]** BTL5 Auxiliary equation is $m^3 - 4m^2 + 4m = 0$ $m(m^2 - 4m + 4) = 0$ $m(m-2)(m-2) = 0$ $m = 0 , m = 2 , m = 2$ Hence the solution is $z = \phi_1(y + 0x) + \phi_2(y + 2x) + x\phi_3(y + 2x)$ $z = \phi_1(y) + \phi_2(y + 2x) + x\phi_3(y + 2x)$.

8	**Solve** $(D+D'-1)(D-2D'+3)z=0$ **.**[***N/D15***] BTL5 Given $(D+D'-1)(D-2D'+3)z=0$ Here $m_1=-1$, $c_1=1$, $m_2=2$, $c_2=-3$ Hence the solution is $z=e^{x}\phi_1(y-x)+e^{-3x}\phi_2(y+2x)$.
9	**Form the partial differential equation by eliminating a and b from $z=a^2x+ay^2+b$.** BTL6 Given $z=a^2x+ay^2+b$ Differentiating (1) partially with respect to x , we have $\frac{\partial z}{\partial x}=a^2 \Rightarrow p=a^2$ (2) Differentiating (1) partially with respect to y , we have $\frac{\partial z}{\partial y}=2ay \Rightarrow q=2ay \Rightarrow a=\frac{q}{2y}$ (3) Using (3) in (2) , we have $p=\left(\frac{q}{2y}\right)^2 \Rightarrow p=\frac{q^2}{4y^2} \Rightarrow 4py^2=q^2$ which is the required partial differential equation.
10	**Eliminate the arbitrary function f from $z=f\left(\frac{y}{x}\right)$ and form the partial differential equation.** BTL5 Given $z=f\left(\frac{y}{x}\right)$ (1) Differentiating (1) partially with respect to x , we have $\frac{\partial z}{\partial x}=f'\left(\frac{y}{x}\right)\left[-\frac{y}{x^2}\right]$ ==> $p=-\frac{y}{x^2}f'\left(\frac{y}{x}\right)$ (2) Differentiating (1) partially with respect to y , we have $\frac{\partial z}{\partial y}=f'\left(\frac{y}{x}\right)\left[\frac{1}{x}\right]$ ==> $q=\frac{1}{x}f'\left(\frac{y}{x}\right)$ (3) Equations $\frac{(2)}{(3)}$ implies $\frac{p}{q}=\frac{-\frac{y}{x^2}f'\left(\frac{y}{x}\right)}{\frac{1}{x}f'\left(\frac{y}{x}\right)}$ ==> $\frac{p}{q}=-\frac{y}{x}$ ==> $xp=-yq$ $xp+yq=0$, which is the required partial differential equation.
11	**Form the partial differential equation by eliminating the arbitrary function from $\phi\left(x^2-y^2,z\right)=0$.** [N/D14] BTL5 The given relation is of the form $\phi(u,v)=0$ where $u=x^2-y^2$ and $v=z$

	Hence the required pde is of the form $P p + Q q = R$ Where $P = \frac{\partial u}{\partial y}\frac{\partial v}{\partial z} - \frac{\partial u}{\partial z}\frac{\partial v}{\partial y}$ $P = (-2y)(1) - (0)(0)$ ==> $P = -2y$ $Q = \frac{\partial u}{\partial z}\frac{\partial v}{\partial x} - \frac{\partial u}{\partial x}\frac{\partial v}{\partial z}$ $Q = (0)(0) - (2x)(1)$ ==> $Q = -2x$ $R = \frac{\partial u}{\partial x}\frac{\partial v}{\partial y} - \frac{\partial u}{\partial y}\frac{\partial v}{\partial x}$ $R = (2x)(0) - (-2y)(0)$ ==> $R = 0$ Therefore, the required equation is $-2yp - 2xq = 0$ $y p + x q = 0$, which is the required partial differential equation.
12	**Find the complete integral of** $p + q = 1$. [***N/D14***] BTL5 Given $p + q = 1$ This is of the form $F(p, q) = 0$ Hence, the complete integral is $z = ax + by + c$ where $a + b = 1$ (ie) $b = 1 - a$ Therefore, the complete solution is $z = ax + (1 - a)y + c$.
13	**Find the complete integral of** $\sqrt{p} + \sqrt{q} = 1$. **[M/J16]** BTL5 Given $p + q = 1$ This is of the form $F(p, q) = 0$ Hence, the complete integral is $z = ax + by + c$ where $\sqrt{a} + \sqrt{b} = 1$ (ie) $\sqrt{b} = 1 - \sqrt{a} \Rightarrow b = (1 - \sqrt{a})^2$ Therefore, the complete solution is $z = ax + (1 - \sqrt{a})^2 y + c$.
14	**Find the complete solution of the partial differential equation** $p^3 - q^3 = 0$. [***M/J16***] BTL5 Given $p^3 - q^3 = 0$ This is of the form $F(p, q) = 0$ Hence, the complete integral is $z = ax + by + c$ where $a^3 - b^3 = 0$ (ie) $b = a$
15	**Find the complete integral of** $p + q = pq$.**[M/J13]** BTL5 Given $p + q = pq$ This is of the form $F(p, q) = 0$. Hence the complete integral is $z = ax + by + c$ *where* $a + b + = ab$

	$b - a b = - a$ $(1 - a) b = - a$ $b = \frac{-a}{1-a}$ $b = \frac{a}{a-1}$ Therefore, the complete solution is $z = a x + \frac{a}{a-1} y + c$.
16	**Find the complete integral of** $\frac{z}{pq} = \frac{x}{q} + \frac{y}{p} + \sqrt{pq}$ **.** [***N/D16***] BTL2 Given $\frac{z}{pq} = \frac{x}{q} + \frac{y}{p} + \sqrt{pq}$ (1) $(1) \times pq \Rightarrow z = px + qy + pq\sqrt{pq}$ This is of the form $z = px + qy + f(p,q)$ Hence, the complete solution is $z = ax + by + ab\sqrt{ab}$
17	**Solve** $p x^2 + q y^2 = z^2$ **. [N/D14]** BTL5 Given $p x^2 + q y^2 = z^2$ This is of Lagrange's type. Here $P = x^2$ $Q = y^2$ $R = z^2$ The subsidiary equations are $\frac{dx}{P} = \frac{dy}{Q} = \frac{dz}{R}$ $\frac{dx}{x^2} = \frac{dy}{y^2} = \frac{dz}{z^2}$ $\frac{dx}{x^2} = \frac{dy}{y^2}$ $\frac{dy}{y^2} = \frac{dz}{z^2}$ Integrating , we have $\frac{1}{x} - \frac{1}{y} = a$ $\frac{1}{y} - \frac{1}{z} = b$ Hence the solution is $\varphi\left(\frac{1}{x} - \frac{1}{y}, \frac{1}{y} - \frac{1}{z}\right) = 0$.
18	**Find the general solution of** $(4D^2 - 12DD' + 9D'^2)z = 0$ **.** BTL5 Auxiliary equation is $4m^2 - 12m + 9 = 0$ $(2m - 3)(2m - 3) = 0$ $m = \frac{3}{2}$, $m = \frac{3}{2}$ Hence the solution is $z = \phi_1\left(y + \frac{3}{2}x\right) + x\phi_2\left(y + \frac{3}{2}x\right)$.

19	**Solve** $(D^3 - 2D^2 D')z = 0$ **. [N/D09].** BTL5 The auxiliary equation is $m^3 - 2m^2 = 0$ $m^2(m-2) = 0$ $m = 0, 0, 2$ Hence the solution is $z = \phi_1(y) + x\phi_2(y) + \phi_3(y+2x)$.
20	**Solve** $(D^4 - D'^4)z = 0$ **. [M/J14]** BTL5 The auxiliary equation is $m^4 - 1 = 0$ $(m^2+1)(m^2-1) = 0$ $m = 1, -1, i, -i$ Hence the solution is $z = \phi_1(y+x) + \phi_2(y-x) + \phi_3(y+ix) + \phi_4(y-ix)$.
21	**Form the partial differential equation by eliminating the arbitrary constants** a **and** b **from** $\log(az-1) = x + ay + b$ **.** [***A/M15***] BTL6 Given $\log(az-1) = x + ay + b$ (1) Differentiating (1) partially with respect to x, we have $\frac{1}{az-1}\left(a\frac{\partial z}{\partial x}\right) = 1 \quad ==> \quad \frac{ap}{az-1} = 1$ (2) Differentiating (1) partially with respect to y, we have $\frac{1}{az-1}\left(a\frac{\partial z}{\partial y}\right) = a$ $\frac{aq}{az-1} = a$ (3) Dividing (2) by (3), we have $\frac{\left(\frac{ap}{az-1}\right)}{\left(\frac{aq}{az-1}\right)} = \frac{1}{a} \Rightarrow \frac{p}{q} = \frac{1}{a} \Rightarrow a = \frac{q}{p}$ Substituting the value of a in (2), we have $\frac{\left(\frac{q}{p}\right)p}{\left(\frac{q}{p}\right)z-1} = 1 \quad \frac{q}{\left(\frac{qz-p}{p}\right)} = 1 \Rightarrow \frac{pq}{qz-p} = 1 \Rightarrow pq = qz - p$ $\Rightarrow p + pq = qz \Rightarrow p(1+q) = qz$ which is the required partial differential equation.
22	**Form the partial differential equation by eliminating** a **and** b **from** $z = a^2x + ay^2 + b$ **.[N/D15]** BTL6 Given $z = a^2x + ay^2 + b$ (1) Differentiating (1) partially with respect to x, we have

	$\frac{\partial z}{\partial x} = a^2 \Rightarrow p = a^2$ (2) Differentiating (1) partially with respect to y , we have $\frac{\partial z}{\partial y} = 2ay \Rightarrow q = 2ay \Rightarrow a = \frac{q}{2y}$ (3) Using (3) in (2) , we have $p = \left(\frac{q}{2y}\right)^2 \Rightarrow p = \frac{q^2}{4y^2} \Rightarrow 4py^2 = q^2$ which is the required partial differential equation.
23	**Form the PDE by eliminating the arbitrary constants 'a ', 'b ' from the relation** $4(1+a^2)z = (x+ay+b)^2$ **. [A/M15]** BTL6 Given $4(1+a^2)z = (x+ay+b)^2$ (1) Differentiating (1) partially with respect to x , we have $4(1+a^2)\frac{\partial z}{\partial x} = 2(x+ay+b) \Rightarrow 4(1+a^2)p = 2(x+ay+b)$ (2) Differentiating (1) partially with respect to y , we have $4(1+a^2)\frac{\partial z}{\partial y} = 2(x+ay+b)(a) \Rightarrow 4(1+a^2)q = 2a(x+ay+b)$ (3) Dividing (2) by (3), we have $\frac{p}{q} = \frac{1}{a} \Rightarrow a = \frac{q}{p}$ (4) From (2), we have $x+ay+b = \frac{4(1+a^2)p}{2}$ ……….(5) Using (5) in (1), we have $4(1+a^2)z = \left(\frac{4(1+a^2)p}{2}\right)^2$ $4(1+a^2)z = \frac{16(1+a^2)^2p^2}{4} \Rightarrow z = (1+a^2)p^2$ Using (4) in (6), we have $\Rightarrow z = \left(1+\left(\frac{q}{p}\right)^2\right)p^2 \Rightarrow z = \left(\frac{p^2+q^2}{p^2}\right)p^2 \Rightarrow z = p^2+q^2$ which is the required partial differential equation.
24	**Form the partial differential equations of all planes passing through the origin.[M/J16]** BTL6 Let the equation of the plane be $ax+by+cz+d=0$ (1) where a ,b , c and d are constants. Since plane (1) passes through the origin, we have $a(0)+b(0)+c(0)+d=0$ ==> $d=0$ substituting $d=0$ in (1), we have $ax+by+cz=0$ (2) Differentiating (2) partially with respect to x , we have

	$a + c\frac{\partial z}{\partial x} = 0$ ==> $a + c\,p = 0$ ==> $a = -c\,p$ (3) Differentiating (2) partially with respect to y, we have $b + c\frac{\partial z}{\partial y} = 0$ ==> $b + c\,q = 0$ ==> $b = -c\,q$ (4) using (3) and (4) in (2), we have $(-c\,p)x + (-c\,q)y + c\,z = 0$ ==> $-c\,p\,x - c\,q\,y + c\,z = 0$ $-c\,[p\,x + q\,y - z] = 0$ ==> $x\,p + y\,q - z = 0$ $x\,p + y\,q = z$, which is the required partial differential equation.
25	**Find the PDE of all spheres whose centers lie on the x-axis. [*N/D16*]** BTL5 Let the centre of the sphere be $(a, 0, 0)$ a point on the x – axis and r be its radius. Hence, its equation is $(x-a)^2 + (y-0)^2 + (z-0)^2 = r^2$ $(x-a)^2 + y^2 + z^2 = r^2$ (1) Differentiating (1) partially with respect to x, we have $2(x-a) + 2z\frac{\partial z}{\partial x} = 0$ ==> $2(x-a) + 2z\,p = 0$ ==> $2[(x-a) + z\,p] = 0$ $(x-a) + z\,p = 0$ ==> $(x-a) = -z\,p$ (2) Differentiating (1) partially with respect to y, we have $2y + 2z\frac{\partial z}{\partial y} = 0$ ==> $2y + 2z\,q = 0$ ==> $2[y + z\,q] = 0$ $y + z\,q = 0$ ==> $y = -z\,q$ -----------------(3) Using (2) and (3) in (1), we have $(-z\,p)^2 + (-z\,q)^2 + z^2 = r^2$ ==> $z^2p^2 + z^2q^2 + z^2 = r^2$ $z^2(p^2 + q^2 + 1) = r^2$, which is the required partial differential equation.
	PART * B
1	
	Find the partial differential equation of all planes which are at a constant distance 'a' from the origin. (8 M) BTL5 **Answer : Page : 1.8- DR.A.SINGARAVELU** • $l = -(\sqrt{1 - l^2 - m^2})$ p $m = -(\sqrt{1 - l^2 - m^2})$ q **(4 M)** • $z = px + qy + a\sqrt{1 + p^2 + q^2}$ **(4 M)**
2	
	Solve $z = px + qy + \sqrt{1 + p^2 + q^2}.$ **(8 M)** BTL5 **Answer : Page :1.56- DR.A.SINGARAVELU**

	• $z = ax + by + \sqrt{1 + a^2 + b^2}$. **(2 M)** • $x^2 + y^2 + z^2 = 1$ **(4 M)** • $z = ax + \phi(a)y + \sqrt{1 + a^2 + \phi(a)^2}$ **(2 M)**
3	
	Find the singular integral of $z = px + qy + p^2 + pq + q^2$. **(8 M)** BTL5 **Answer : Page :1.59- DR.A.SINGARAVELU** • $z = ax + by + a^2 + ab + b^2$. **(2 M)** • $xy - x^2 - y^2 = 3z$ **(6 M)**
4	
	Solve $z = px + qy + p^2 - q^2$. **(8 M)** BTL5 **Answer : Page :1.58- DR.A.SINGARAVELU** • $z = ax + by + a^2 - b^2$. **(2 M)** • $y^2 - x^2 = 4z$ **(6 M)**
5	
	Form the partial differential equation by eliminating the arbitrary function ϕ **from** $\varphi(x^2 + y^2 + z^2, \; xyz) = 0$. **(8 M)** BTL5 **Answer : Page :1.28- DR.A.SINGARAVELU** • $\begin{vmatrix} yz + pxy & 2x + 2pz \\ xz + qxy & 2y + 2qz \end{vmatrix} = 0$ **(4 M)** • $x(y^2 - z^2)p + y(z^2 - x^2)q = z(x^2 - y^2)$ **(4 M)**
6	
	Solve $z = px + qy + p^2q^2$. **(8 M)** BTL5 **Answer : Page :1.60- DR.A.SINGARAVELU** • $z = ax + by + a^2b^2$. **(4 M)** • $z = -3\left(\frac{xy}{4}\right)^{2/3}$ **(4 M)**
7	
	Solve $p^2 + q^2 = x^2 + y^2$. **(8 M)** BTL5 **Answer : Page: 1.77- DR.A.SINGARAVELU** • $p^2 - x^2 = y^2 - q^2 = a$ **(2 M)** • $z = \frac{x}{2}\sqrt{x^2 + a} + \frac{a}{2}\log(x + \sqrt{x^2 + a}) + \frac{y}{2}\sqrt{y^2 - a} - \frac{a}{2}\log(y - \sqrt{y^2 - a}) + c$ **(6M)**
8	
	Solve $(mz - ny)p + (nx - lz)q = ly - mx$ **. (8 M)** BTL5 **Answer : Page :1.106- DR.A.SINGARAVELU** • $\frac{dx}{mz - ny} = \frac{dy}{nx - lz} = \frac{dz}{ly - mx}$ **(2 M)**

	• $\varphi(x^2+y^2+z^2,\ lx+my+nz)=0$ **(6 M)**
9	`
	Solve $x(z^2+y^2)p+y(x^2+z^2)q=z(y^2-x^2)$ **(8 M)** BTL5 **Answer : Page :1.108- DR.A.SINGARAVELU** • $\frac{dx}{x(z^2+y^2)}=\frac{dy}{y(x^2+z^2)}=\frac{dz}{z(y^2-x^2)}$ **(2 M)** • $\varphi(x^2-y^2+z^2,\frac{yz}{x})=0$ **(6 M)**
10	
	Solve $x(y-z)p+y(z-x)q=z(x-y)$ **(8 M)** BTL5 **Answer : Page: 1.126- DR.A.SINGARAVELU** • $\frac{dx}{x(y-z)}=\frac{dy}{y(z-x)}=\frac{dz}{z(x-y)}$ **(2 M)** • $\varphi(xyz, x+y+z)=0$ **(6 M)**
11	
	Find the general solution $(3z-4y)p+(4x-2z)q=2y-3x.$ **(8 M)** BTL5 **Answer : Page: 1.105- DR.A.SINGARAVELU** • $\frac{dx}{(3z-4y)}=\frac{dy}{(4x-2z)}=\frac{dz}{2y-3x}$ **(2 M)** • $\varphi(x^2+y^2+z^2,\ 2x+3y+4z)=0$ **(6 M)**
12	
	Solve $x^2(y-z)p+y^2(z-x)q=z^2(x-y).$ **(8 M)** BTL5 **Answer : Page: 1.103- DR.A.SINGARAVELU** • $\frac{dx}{x^2(y-z)}=\frac{dy}{y^2(z-x)}=\frac{dz}{z^2(x-y)}$ **(2 M)** • $\varphi(\frac{1}{x}+\frac{1}{y}+\frac{1}{z},\ xyz)=0$ **(6 M)**
13	
	Find the general solution of $z(x-y)=px^2-qy^2.$ BTL5 **(8 M)** **Answer : Page: 1.125- DR.A.SINGARAVELU** • $\frac{dx}{x^2}=\frac{dy}{y^2}=\frac{dz}{z(x-y)}$ **(2 M)** • $\varphi(\frac{1}{x}+\frac{1}{y},\frac{z}{x+y})=0$ **(6 M)**
14	
	Find the general solution of $(y+z)p+(z+x)q=x+y$ **. (8 M)** BTL5 **Answer : Page: 1.112- DR.A.SINGARAVELU**

	• $\frac{dx}{(y+z)}=\frac{dy}{(z+x)}=\frac{dz}{x+y}$ **(2 M)** • $\varphi(\frac{x-y}{y-z},(y-z)\sqrt{x+y+z})=0$ **(6 M)**
15	
	Solve $(D^2-DD'-20D'^2)z=e^{5x+y}+\sin(4x-y).$ **(8 M)** BTL5 **Answer : Page: 1.165- DR.A.SINGARAVELU** • $\text{C}.F=f_1(y+5x)+f_2(y-4x)$ **(2 M)** • $P.I=\frac{x}{9}\left(e^{5x+y}-\cos(4x-y)\right)$ **(5 M)** • $z=f_1(y+5x)+f_2(y-4x)+\frac{x}{9}\left(e^{5x+y}-\cos(4x-y)\right)$ **(1 M)**
16	
	Solve $(D^2-D'^2)z=e^{x-y}\sin(2x+3y).$ **(8 M)** BTL5 **Answer : Page :1.152- DR.A.SINGARAVELU** • $\text{C}.F=f_1(y+x)+f_2(y-x)$ **(3 M)** • $P.I=\frac{1}{25}e^{x-y}\left(\sin(2x+3y)-2\cos(2x+3y)\right)$ **(4 M)** • $z=f_1(y+x)+f_2(y-x)+\frac{1}{25}e^{x-y}\left(\sin(2x+3y)-2\cos(2x+3y)\right)$ **(1 M)**
17	
	Solve $(D^2-2DD'+D'^2)z=x^2ye^{x+y}.$ **(8 M)** BTL5 **Answer : Page :1.151- DR.A.SINGARAVELU** • $\text{C}.F=f_1(y+x)+xf_2(y+x)$ **(3 M)** • $P.I=e^{x+y}\left(\frac{x^4y^2}{12}+\frac{x^5y}{15}+\frac{x^6}{60}\right)$ **(4 M)** • $z=f_1(y+x)+xf_2(y+x)+e^{x+y}\left(\frac{x^4y^2}{12}+\frac{x^5y}{15}+\frac{x^6}{60}\right)$ **(1 M)**
18	
	Solve $\frac{\partial^2z}{\partial x^2}+2\frac{\partial^2z}{\partial x\partial y}+\frac{\partial^2z}{\partial y^2}=\sinh(x+y)+e^{x+2y}.$ **(8 M)** BTL5 **Answer : Page: 1.176- DR.A.SINGARAVELU** • $\text{C}.F=f_1(y-x)+xf_2(y-x)$ **(3 M)** • $P.I=\frac{e^{x+2y}}{9}+\frac{1}{4}\sinh(x+y)$ **(4 M)** • $z=f_1(y-x)+xf_2(y-x)+\frac{e^{x+2y}}{9}+\frac{1}{4}\sinh(x+y)$ **(1 M)**

	Solve $(D^2+DD'-6D'^2)z=y\cos x.$ **(8 M)** BTL5 **Answer : Page: 1.157 -DR.A.SINGARAVELU** • $C.F = f_1(y-3x)+f_2(y+2x)$ **(3 M)** • $P.I = \sin x - y\cos x$ **(4 M)** • $z = f_1(y-3x)+f_2(y+2x)+\sin x - y\cos x$ **(1 M)**
19	
	Solve $(D^2+D'^2+2DD'+2D+2D'+1)z=e^{2x+y}.$ **(8 M)** BTL5 **Answer :Page: 1.184 -DR.A.SINGARAVELU** • $C.F = e^{-x}f_1(y-x)+xe^{-x}f_2(y-x)$ **(3 M)** • $P.I = \frac{e^{2x+y}}{16}$ **(4 M)** • $z = e^{-x}f_1(y-x)+xe^{-x}f_2(y-x)+\frac{e^{2x+y}}{16}$ **(1 M)**
20	
	Solve $(D^2-D'^2-3D+3D')z=xy+7.$ **(8 M)** BTL5 **Answer :Page :1.185- DR.A.SINGARAVELU** • $C.F = f_1(y+x)+e^{3x}f_2(y-x)$ **(3 M)** • $P.I = \frac{-1}{3}\left[\frac{x^2y}{2}+\frac{xy}{3}+\frac{x^3}{6}+\frac{x^2}{3}+\frac{65x}{9}\right]$ **(4 M)** • $z = f_1(y+x)+e^{3x}f_2(y-x)-\frac{1}{3}\left[\frac{x^2y}{2}+\frac{xy}{3}+\frac{x^3}{6}+\frac{x^2}{3}+\frac{65x}{9}\right]$ **(1 M)**
21	
	Solve $\left(2D^2-DD'-D'^2+6D+3D'\right)z=xe^y$ **(8 M)** BTL5 **Answer : Page: 1.189- DR.A.SINGARAVELU** • $C.F = f_1(y-\frac{1}{2}x)+e^{-3x}f_2(y+x)$ **(3 M)** • $P.I = \frac{2e^y}{25}\left[5x-12\right]$ **(4 M)** • $z = f_1(y-\frac{1}{2}x)+e^{-3x}f_2(y+x)+\frac{2e^y}{25}\left[5x-12\right]$ **(1 M)**

	UNIT II-FOURIER SERTIES
	Dirichlets condition,General Fourier series,and Even functions,Half range Sine series,Half range Cosine series,Complex form of Fourier series,Parsevals Identity,Harmonic Analysis
	PART*A
1	**State Dirichlet's conditions for a given function to expand in Fourier series.** BTL1 A function $f(x)$ defined in $c \le x \le c+2l$ can be expanded as an infinite trigonometric series of the form $\frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos\left(\frac{n\pi}{l}\right)x + \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi}{l}\right)x$ provided (i) $f(x)$ is single-valued and finite in $(c, c+2l)$ (ii) $f(x)$ is continuous or piecewise continuous with finite number of finite discontinuities in $(c, c+2l)$. (iii) $f(x)$ has no or finite number of maxima or minima in $(c, c+2l)$.
2	**State Euler's formula for Fourier coefficients of a function defined in** $(c, c+2l)$**.** BTL1 If a function $f(x)$ defined in $(c, c+2l)$ can be expanded as the infinite trigonometric series $\frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos\left(\frac{n\pi}{l}\right)x + \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi}{l}\right)x$, then $a_0 = \frac{1}{l}\int_{c}^{c+2l} f(x)\,dx$ $a_n = \frac{1}{l}\int_{c}^{c+2l} f(x)\cos\left(\frac{n\pi}{l}\right)x\,dx$ $b_n = \frac{1}{l}\int_{c}^{c+2l} f(x)\sin\left(\frac{n\pi}{l}\right)x\,dx$
3	**Does** $f(x) = \tan x$ **possess a Fourier series expansion?** BTL1 No, $f(x) = \tan x$ does not possess a Fourier expansion. Because $f(x) = \tan x$ has an infinite discontinuity. (ie) Dirichlet's condition is not satisfied.
4	**If** $x^2 = \frac{\pi^2}{3} - 4\sum_{n=1}^{\infty}(-1)^{n+1}\frac{\cos nx}{n^2}$ **in** $-\pi < x < \pi$ **, then find** $\sum_{n=1}^{\infty}\frac{1}{n^2}$**.** BTL5 Given $x^2 = \frac{\pi^2}{3} - 4\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{n^2}\cos nx$ $x^2 = \frac{\pi^2}{3} - 4\left[\frac{1}{1^2}\cos x - \frac{1}{2^2}\cos 2x + \frac{1}{3^2}\cos 3x + ...\ ...\right]$ The point $x = \pi$ is the point of discontinuity (right extreme point)

	$\pi^2 = \frac{\pi^2}{3} - 4\left[\frac{1}{1^2}\cos\pi - \frac{1}{2^2}\cos 2\pi + \frac{1}{3^2}\cos 3\pi + \dots\dots\dots\dots\right]$ $\frac{2\pi^2}{3} = 4\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots\dots\right]$ $\frac{\pi^2}{6} = \frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots\dots$ Therefore, $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots = \frac{\pi^2}{6}$
5	**Find the constant term in the Fourier series corresponding to** $f(x)=\cos^2 x$ **expressed in the interval** $(-\pi,\pi)$**.** BTL5 Given $f(x)=\cos^2 x$ $f(x) = (\cos x)^2$ $f(x) = (\cos(-x))^2 = \cos^2 x = f(x)$ Therefore, $f(x)$ is an even function. The constant term in the Fourier series is $\frac{a_0}{2}$ where $a_0 = \frac{2}{\pi}\int_0^{\pi} \cos^2 x\,d\,x$ $= \frac{2}{\pi}\int_0^{\pi} \frac{1+\cos 2x}{2}\,d\,x$ $= \frac{1}{\pi}\left[(x)_0^{\pi} + \left(\frac{\sin 2x}{2}\right)_0^{\pi}\right] = \frac{1}{\pi}\left[(\pi-0)+\frac{1}{2}(0-0)\right] = \frac{1}{\pi}(\pi) = 1$ Therefore, the constant term $\frac{a_0}{2}$ is $\frac{1}{2}$.
6	**If** $f(x)=x^2+x$ **is expressed as a Fourier series in the interval** $(-2,2)$**, to which value this series converges at** $x=2$ **?** BTL2 Fourier series of $f(x)$ converges at $x=2$ is $= \frac{f(-2)+f(2)}{2}$ $= \frac{\left[(-2)^2-2\right]+\left[2^2+2\right]}{2} = \frac{4-2+4+2}{2} = 4$.
7	**Find the half range sine series expansion of** $f(x)=1$ **in** $(0,2)$**.** BTL5 Here $l=2$. Fourier sine series is given by $f(x) = \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi}{l}\right)x$ $f(x) = \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi}{2}\right)x$

	where $b_n = \frac{2}{l}\int_0^l f(x)\sin\left(\frac{n\pi}{l}\right)x\,dx = \frac{2}{2}\int_0^2 1\sin\left(\frac{n\pi}{2}\right)x\,dx = \int_0^2 \sin\left(\frac{n\pi}{2}\right)x\,dx$ $= -\frac{2}{n\pi}\left[\cos\left(\frac{n\pi}{2}\right)x\right]_0^2 = -\frac{2}{n\pi}[\cos n\pi - 1] = -\frac{2}{n\pi}[(-1)^n - 1] = \begin{cases}\frac{4}{n\pi}, & if\ \ n\ is\ odd\\ 0, & if\ \ n\ is\ even\end{cases}$ Therefore $f(x) = \sum_{n=1,3,5}^{\infty}\frac{4}{n\pi}\sin\left(\frac{n\pi}{2}\right)x = \frac{4}{\pi}\sum_{n=1,3,5}^{\infty}\frac{1}{n}\sin\left(\frac{n\pi}{2}\right)x$.
8	**If the function $f(x) = x$ in the interval $0 < x < 2\pi$, then find the constant term of the Fourier series expansion of the function f . [N/D15]** BTL5 $a_0 = \frac{1}{\pi}\int_0^{2\pi} f(x)dx = \frac{1}{\pi}\int_0^{2\pi} x\,dx = \frac{1}{\pi}\left[\frac{x^2}{2}\right]_0^{2\pi} = \frac{1}{\pi}[2\pi^2 - 0] = \frac{2\pi^2}{\pi} = 2\pi$ The constant term of the Fourier series expansion $= \frac{a_0}{2} = \frac{2\pi}{2} = \pi$.
9	**If $x^2 = \frac{\pi^2}{3} - 4\sum_{n=1}^{\infty}(-1)^{n+1}\frac{\cos nx}{n^2}$ in $-\pi < x < \pi$, then find $\sum_{n=1}^{\infty}\frac{1}{n^2}$. [M/J16]** BTL5 Given $x^2 = \frac{\pi^2}{3} - 4\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{n^2}\cos nx$ $x^2 = \frac{\pi^2}{3} - 4\left[\frac{1}{1^2}\cos x - \frac{1}{2^2}\cos 2x + \frac{1}{3^2}\cos 3x + \ldots\ldots\ldots\ \ldots\right]$ The point $x = \pi$ is the point of discontinuity (right extreme point) $\pi^2 = \frac{\pi^2}{3} - 4\left[\frac{1}{1^2}\cos\pi - \frac{1}{2^2}\cos 2\pi + \frac{1}{3^2}\cos 3\pi + \ldots\ldots\ldots\ \ldots\right]$ $\pi^2 - \frac{\pi^2}{3} = -4\left[\frac{1}{1^2}(-1) - \frac{1}{2^2}(1) + \frac{1}{3^2}(-1) + \ldots\ldots\ldots\ \ldots\right]$ $\frac{2\pi^2}{3} = 4\left[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \ldots\ldots\ldots\ \ldots\right]$ $\frac{\pi^2}{6} = \frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \ldots\ldots\ldots\ \ldots.$ Therefore, $\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \ldots\ldots\ldots = \frac{\pi^2}{6}$
10	**If $(\pi - x)^2 = \frac{\pi^2}{3} + 4\sum_{n=1}^{\infty}\frac{\cos nx}{n^2}$ in $0 < x < 2\pi$, then deduce that the value of $\sum_{n=1}^{\infty}\frac{1}{n^2}$.[*<u>N/D14</u>*]** BTL5 Given $(\pi - x)^2 = \frac{\pi^2}{3} + 4\sum_{n=1}^{\infty}\frac{\cos nx}{n^2}$ $(\pi - x)^2 = \frac{\pi^2}{3} + 4\left[\frac{1}{1^2}\cos x + \frac{1}{2^2}\cos 2x + \frac{1}{3^2}\cos 3x + \ldots\ldots\ldots\ \ldots\right]$

	The point $x = 0$ is the left extreme point of discontinuity $\frac{f[0]+f[2\pi]}{2} = \frac{\pi^2}{3} + 4\left[\frac{1}{1^2}\cos 0 + \frac{1}{2^2}\cos 0 + \frac{1}{3^2}\cos 0 + ... \quad ...\right]$ $\frac{(\pi-0)^2+(\pi-2\pi)^2}{2} = \frac{\pi^2}{3} + 4\left[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + ...\ ...\right]$ $\frac{(\pi-0)^2+(\pi-2\pi)^2}{2} = \frac{\pi^2}{3} + 4\left[\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + ...\ ...\right]$ $\pi^2 - \frac{\pi^2}{3} = 4\left[-\frac{1}{1^2}(-1) + \frac{1}{2^2}(1) - \frac{1}{3^2}(-1) + ... \quad ...\right]$ $\frac{2\pi^2}{3} = 4\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+..........\ ...\right]$ $\frac{\pi^2}{6} = \frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+..........\ ....$ Therefore, $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+.......... = \frac{\pi^2}{6}$.
11	**If the Fourier series of the function $f(x) = x, -\pi < x < \pi$ with period 2π is given by $f(x) = 2\left(\sin x - \frac{\sin 2x}{2} + \frac{\sin 3x}{3} - \frac{\sin 4x}{4} + ...\right)$, then find the sum of the series $1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + ...\ ....$. [*A/M15*]** BTL5 Given $f(x) = 2\left(\sin x - \frac{\sin 2x}{2} + \frac{\sin 3x}{3} - \frac{\sin 4x}{4} + ...\right)$…….(1) The point $x = \frac{\pi}{2}$ is the point of continuity. Substitute $x = \frac{\pi}{2}$ in (1), we have $\frac{\pi}{2} = 2\left(1 - 0 - \frac{1}{3} - 0 + \frac{1}{5} - 0 - \frac{1}{7} - 0 + ... \quad ....\right)$ Hence, $1 - \frac{1}{3} + \frac{1}{5} - \frac{1}{7} + ...\ .... = \frac{\pi}{4}$.
12	**Give the expression for the Fourier series co-efficient b_n for the function $f(x)$ defined in $(-2, 2)$. [A/M11].** BTL5 The Fourier series co-efficient b_n for the function $f(x)$ defined in $(-2, 2)$ is given by $b_n = \frac{1}{2}\int_{-2}^{2} f(x)\sin\left(\frac{n\pi}{2}\right)x\,dx$.

13	**State TRUE or FALSE: Fourier series of period 20 for the function $f(x) = x\cos x$ in the interval $(-10, 10)$ contains only sine terms. Justify your answer. [M/J16]** BTL2 Fourier series of period 20 for the function $f(x) = x\cos x$ in the interval $(-10, 10)$ contains only sine terms is TRUE. Since $f(x) = x\cos x$ $f(-x) = (-x)\cos(-x) = -x\cos x = -f(x)$ $f(x)$ is an odd function. The constant term in the Fourier series is $\frac{a_0}{2}$ where $a_0 = \frac{2}{\pi}\int_0^{\pi} \cos^2 x\,dx$ $= \frac{2}{\pi}\int_0^{\pi} \frac{1+\cos 2x}{2}\,dx$ $= \frac{1}{\pi}\left[\int_0^{\pi} dx + \int_0^{\pi} \cos 2x\,dx\right]$ $= \frac{1}{\pi}\left[(x)_0^{\pi} + \left(\frac{\sin 2x}{2}\right)_0^{\pi}\right] = \frac{1}{\pi}\left[(\pi - 0) + \frac{1}{2}(0 - 0)\right] = \frac{1}{\pi}(\pi) = 1$ Therefore, the constant term $\frac{a_0}{2}$ is $\frac{1}{2}$.
14	**If $f(x)$ is an odd function defined in $(-l, l)$, what are the values of a_0 and a_n ?** BTL5 Given $f(x)$ is an odd function, the values of $a_0 = a_n = 0$. Obtain the first term of the Fourier series for the function $f(x) = x^2, -\pi < x < \pi$ [N/D09]. Solution: Here $2l = 2\pi$ implies $l = \pi$ Given $f(-x) = (-x)^2 = x^2 = f(x)$ Therefore $f(x)$ is an even function. $a_0 = \frac{2}{l}\int_0^{l} f(x)\,dx = \frac{2}{\pi}\int_0^{\pi} x^2\,dx = \frac{2}{\pi}\left(\frac{x^3}{3}\right)_0^{\pi} = \frac{2}{3\pi}\left(\pi^3 - 0\right) = \frac{2}{3}\pi^2$ Therefore the first term of Fourier series is $\frac{a_0}{2} = \frac{\frac{2}{3}\pi^2}{2} = \frac{\pi^2}{3}$.

15	**Find the value of b_n in the Fourier series expansion of $f(x) = \begin{cases} x+\pi & in \ (-\pi, 0) \\ -x+\pi & in \ (0, \pi) \end{cases}$. [<u>*M/J16*</u>]** BTL2 Given $f(x) = \begin{cases} x+\pi & in \ (-\pi, 0) \\ -x+\pi & in \ (0, \pi) \end{cases}$ Let $\varphi_1(x) = x+\pi$ $\varphi_2(x) = -x+\pi$ $\varphi_1(-x) = -x+\pi = \varphi_2(x)$ Therefore, $f(x)$ is an even function. Hence, $b_n = 0$.
16	**Find the value of the Fourier series of $f(x) = \begin{cases} 0 & in \ (-c, 0) \\ 1 & in \ (0, c) \end{cases}$ at the point of discontinuity $x = 0$.**BTL2 [<u>***M/J16***</u>] Given $f(x) = \begin{cases} 0 & in \ (-c, 0) \\ 1 & in \ (0, c) \end{cases}$ $[Value \ \ of \ \ f(x)]_{x=0} = \lim_{h\to 0} \frac{1}{2}[f(0-h) + f(0+h)]$ $= \lim_{h\to 0} \frac{1}{2}[0+1] = \frac{1}{2}$.
17	**Find the Fourier constants b_n for $x \sin x$ in $(-\pi, \pi)$.** BTL2 Given $f(x) = x\sin x$ $f(-x) = -x\sin(-x) = -x(-\sin x) = x\sin x = f(x)$ Therefore, $f(x)$ is an even function. Hence, $b_n = 0$.
18	**Find the co-efficient b_n of the Fourier series for the function $f(x) = x\sin x$ in $(-2, 2)$. [N/D12].** BTL5 Given $f(x) = x\sin x$ $f(-x) = -x\sin(-x) = -x(-\sin x) = x\sin x = f(x)$ Therefore, $f(x)$ is an even function. Hence, $b_n = 0$.

19	**Write down Parseval's formula on Fourier coefficients. [N/D14]** BTL5 If $y = f(x)$ can be expanded as Fourier series of the form $\frac{a_0}{2} + \sum_{n=1}^{\infty} a_n \cos\left(\frac{n\pi}{l}\right)x + \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi}{l}\right)x$ in $(0, 2l)$, then the root-mean square value $\bar{y}$ of $y = f(x)$ in $(0, 2l)$ is given by $\bar{y}^2 = \frac{1}{4}a_0^2 + \frac{1}{2}\sum_{n=1}^{\infty} a_n^2 + \frac{1}{2}\sum_{n=1}^{\infty} b_n^2$ where $\bar{y}^2 = \frac{1}{2l}\int_0^{2l} [f(x)]^2\, dx$.
20	**Find the root mean square value of $f(x) = x^2$ in $(0, l)$. [N/D10].** BTL5 The root mean square value of $f(x) = x^2$ in $(0, l)$ is given by $\bar{y} = \sqrt{\frac{1}{l-0}\int_0^l \left[x^2\right]^2 dx} = \sqrt{\frac{1}{l}\int_0^l x^4\, dx} = \sqrt{\frac{1}{l}\left[\frac{x^5}{5}\right]_0^l} = \sqrt{\frac{1}{l}\left[\frac{l^5}{5} - 0\right]} = \sqrt{\frac{l^4}{5}}$.
21	**Find the root mean square value of the function $f(x) = x$ in the interval $(0, l)$. [N/D11].** BTL5 The root mean square value of $f(x) = x$ in $(0, l)$ is given by $\bar{y} = \sqrt{\frac{1}{l-0}\int_0^l [x]^2\, dx} = \sqrt{\frac{1}{l}\left[\frac{x^3}{3}\right]_0^l} = \sqrt{\frac{1}{l}\left[\frac{l^3}{3} - 0\right]} = \sqrt{\frac{l^2}{3}}$.
22	**Find the root mean square value of $f(x) = x(l-x)$ in $0 \le x \le l$.[*N/D15*]** BTL5 The root mean square value of a function $f(x) = lx - x^2$ in $0 \le x \le l$ is given by $\bar{y} = \sqrt{\frac{1}{l-0}\int_0^l [f(x)]^2\, dx} = \sqrt{\frac{1}{l}\int_0^l \left[lx - x^2\right]^2 dx} = \sqrt{\frac{1}{l}\int_0^l \left[l^2x^2 + x^4 - 2lx^3\right]dx}$ $= \sqrt{\frac{1}{l}\left[l^2\left(\frac{x^3}{3}\right)_0^l + \left(\frac{x^5}{5}\right)_0^l - 2l\left(\frac{x^4}{4}\right)_0^l\right]} = \sqrt{\frac{1}{l}\left[\frac{l^5}{3} + \frac{l^5}{5} - \frac{l^5}{2}\right]} = \sqrt{\frac{1}{l}\left(\frac{l^5}{30}\right)} = \sqrt{\frac{l^4}{30}} = \frac{l^2}{\sqrt{30}}$.
23	**Define root mean square value of a function $f(x)$ over the interval (a, b). [M/J12 , N/D12].** BTL5 The root mean square value of a function $f(x)$ over the interval (a, b) is

given by

$$\bar{y} = \sqrt{\frac{1}{b-a}\int_a^b [f(x)]^2 \, dx}\ .$$

24

Expand $f(x)=1$ **as a half range sine series in the interval** $(0,\pi)$**.** BTL5 [**M/J14,A/M15, N/D15, N/D16**]

Here $l = \pi$

Fourier sine series is given by

$$f(x) = \sum_{n=1}^{\infty} b_n \sin\left(\frac{n\pi}{l}\right)x$$

$$f(x) = \sum_{n=1}^{\infty} b_n \sin nx$$

where $$b_n = \frac{2}{\pi}\int_0^{\pi} f(x)\sin nx\,dx = \frac{2}{\pi}\int_0^{\pi} 1 \sin nx\, dx = \frac{2}{\pi}\left[-\frac{\cos nx}{n}\right]_0^{\pi}$$

$$= -\frac{2}{n\pi}[\cos n\pi - 1] = -\frac{2}{n\pi}\left[(-1)^n - 1\right] = \begin{cases} \dfrac{4}{n\pi} & , if\ \ n\ is\ odd \\ 0 & , if\ \ n\ is\ even \end{cases}$$

Therefore $$f(x) = \sum_{n=1,3,5}^{\infty} \frac{4}{n\pi}\sin nx = \frac{4}{\pi}\sum_{n=1,3,5}^{\infty} \frac{1}{n}\sin nx\ .$$

25

Give the expression for the Fourier series co-efficient b_n **for the function** $f(x)$ **defined in** $(-2,2)$**. [A/M11].** BTL5

The Fourier series co-efficient b_n for the function $f(x)$ defined in $(-2,2)$ is given by $b_n = \frac{1}{2}\int_{-2}^{2} f(x)\sin\left(\frac{n\pi}{2}\right)x\,dx$.

PART*B

1

Express $\mathbf{f(x)} = \left(\frac{\boldsymbol{\pi} - \mathbf{x}}{2}\right)^2$ **as a Fourier Series of period 2π in the interval**

0< x< 2π. Hence deduce the sum of the series $\mathbf{\frac{1}{1^2} + \frac{1}{2^2} + \frac{1}{3^2} + \ldots}$ **.** BTL5 **(8 M)**

Answer : Page 2.12-DR.A.SINGARAVELU

- $a_0 = \frac{\pi^2}{6}; a_n = \frac{1}{n^2}; \mathrm{b}_n = 0$ **(6 M)**

	• $f(x)=\frac{\pi^{2}}{12}+\sum_{n=1}^{\infty}\frac{\cos nx}{n^{2}}$ **(1 M)** • $1/1^{2}+1/2^{2}+1/3^{2}+\ldots\ldots=\frac{\pi^{2}}{6}$ **(1 M)**
2	
	Obtain the Fourier Series of period 2π for the function f(x) = x^2 in (-π, π). Deduce that (i) $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\ldots$ (ii) $\frac{1}{1^2}-\frac{1}{2^2}+\frac{1}{3^2}-\ldots$ (iii) $\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\ldots$ BTL5 **(8 M)** **Answer : Page 2.40-DR.A.SINGARAVELU** • $a_{0}=\frac{2\pi^{2}}{3};a_{n}=\frac{4}{n^{2}}(-1)^{n};b_{n}=0$ **(6 M)** • $f(x)=\frac{\pi^{2}}{3}+\sum_{n=1}^{\infty}\frac{4}{n^{2}}(-1)^{n}\cos nx$ **(1 M)** $1/1^{2}+1/2^{2}+1/3^{2}+\ldots\ldots=\frac{\pi^{2}}{6};$ • $1/1^{2}-1/2^{2}+1/3^{2}-\ldots\ldots=\frac{\pi^{2}}{12};$ **(1 M)** $1/1^{2}+1/3^{2}+1/5^{2}+\ldots\ldots=\frac{\pi^{2}}{8}$
3	
	Obtain the Fourier Series to represent the function f(x) = $\lvert x\rvert$, -π < x < π and deduce $\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\ldots=\frac{\pi^2}{8}$. BTL5 **(8 M)** **Answer : Page 2.52--DR.A.SINGARAVELU** • $a_{0}=\pi;a_{n}=\frac{2}{n^{2}\pi}\left[(-1)^{n}-1\right];b_{n}=0$ **(6 M)** • $f(x)=\frac{\pi}{2}+\sum_{n=1}^{\infty}\frac{2}{n^{2}\pi}\left[(-1)^{n}-1\right]\cos nx$ **(1 M)** • $1/1^{2}+1/3^{2}+1/5^{2}+\ldots\ldots=\frac{\pi^{2}}{8}$ **(1 M)**
4	
	Obtain the Fourier Series of f(x) = x sinx in (-π,π). BTL5 **(8 M)** **Answer : Page 2.58-DR.A.SINGARAVELU** • $a_{0}=2;a_{n}=\frac{2}{(n+1)(\mathrm{n}-1)}\left[(-1)^{n+1}\right];b_{n}=0$ $a_{1}=\frac{-1}{2}$ **(6 M)**

	• $f(x) = 1 - \frac{\cos x}{2} + \sum_{n=2}^{\infty} \frac{2}{(n+1)(n-1)}\left[(-1)^{n+1}\right]\cos nx$ **(2 M)**
5	
	Obtain the Fourier Series of $f(x) = \begin{cases} 1+\frac{2x}{\pi}, & -\pi \le x \le 0 \\ 1-\frac{2x}{\pi}, & 0 \le x \le \pi \end{cases}$ **and hence deduce** $\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\dots=\frac{\pi^2}{8}.$ BTL5 **(8 M)** **Answer : Page 2.72-DR.A.SINGARAVELU** • $a_0 = 0; a_n = \frac{4}{n^2\pi^2}\left[1-(-1)^n\right]; b_n = 0$ **(6 M)** • $f(x) = \frac{8}{\pi^2}\sum_{n\ is\ ODD}^{\infty}\frac{\cos nx}{n^2}$ **(1 M)** • $1/1^2 + 1/3^2 + 1/5^2 + \dots\dots = \frac{\pi^2}{8}$ **(1 M)**
6	
	If f(x) = $\begin{cases} 0, & -\pi \le x \le 0 \\ sinx, & 0 \le x \le \pi \end{cases}$ **, Prove that f(x) =** $\frac{1}{\pi}+\frac{1}{2}$ **sinx -** $\frac{2}{\pi}\sum_{n=1}^{\infty}\frac{\cos nx}{4n^2-1}$ **Hence show that (i)** $\frac{1}{1.3}+\frac{1}{3.5}+\frac{1}{5.7}-\dots=\frac{1}{2}$ (ii) $\frac{1}{1.3}-\frac{1}{3.5}+\frac{1}{5.7}-\dots=\frac{\pi-2}{4}.$ BTL5 **(8 M)** **Answer :Page 2.64-DR.A.SINGARAVELU** • $a_0 = \frac{2}{\pi}; a_n = \frac{-1}{(n^2-1)\pi}\left[1+(-1)^n\right]; b_n = \begin{cases} 0 & if \quad n \ne 1 \\ \frac{1}{2} & if \quad n = 1 \end{cases}$ **(6 M)** $a_1 = 0$ • $f(x) = \frac{1}{\pi} + \frac{\sin x}{2} - \frac{1}{\pi}\sum_{n=2}^{\infty}\frac{\cos nx}{(n^2-1)}\left[1+(-1)^n\right]$ **(1 M)** • $\frac{1}{1.3}+\frac{1}{3.5}+\frac{1}{5.7}-\dots=\frac{1}{2}$ and $\frac{1}{1.3}-\frac{1}{3.5}+\frac{1}{5.7}-\dots=\frac{\pi-2}{4}$ **(1 M)**
7	
	Find half range sine series for *f(x) = x(π – x)* in (0,π). Deduce $\frac{1}{1^3}-\frac{1}{3^3}+\frac{1}{5^3}-\dots$ BTL5 **(8 M)** **Answer :Page 2.144-DR.A.SINGARAVELU** • $b_n = \frac{4}{n^3\pi}\left[1-(-1)^n\right]$ **(6 M)** • $f(x) = \frac{8}{\pi}\left[\frac{\sin x}{1^3}+\frac{\sin 3x}{3^3}+\frac{\sin 5x}{5^3}+\dots\dots\right]$ **(1 M)** • $1/1^3 - 1/3^3 + 1/5^3 - \dots\dots = \frac{\pi^3}{32}$ **(1 M)**
8	

	Obtain the Fourier Series of $\boldsymbol{f(x)}=\left\{\begin{matrix}\boldsymbol{l-x}, & 0<x\le l\\ \boldsymbol{0}, & l\le x\le 2\boldsymbol{l}\end{matrix}\right.$ **and hence deduce** $\sum_{\mathbf{n=0}}^{\infty}\frac{\mathbf{1}}{(\mathbf{2n+1})^{\mathbf{2}}}$ **(8 M)** BTL5 **Answer :Page 2.85-DR.A.SINGARAVELU** • $a_0=\frac{l}{2};a_n=\left\{\begin{matrix}\frac{2l}{n^2\pi^2} & \text{if n is } Odd\\ 0 & if\ n\ is\ even\end{matrix}\right\};\mathrm{b}_n=\frac{l}{n\pi}$ **(6 M)** • $f(x)=\frac{l}{4}+\sum_{n=1,3,5..}^{\infty}\frac{2l}{n^2\pi^2}\cos\frac{n\pi x}{l}+\sum_{n=1}^{\infty}\frac{1}{n\pi}\sin\frac{n\pi x}{l}$ **(1 M)** • $\sum_{\mathbf{n}=0}^{\infty}\frac{1}{(2\mathbf{n}+1)^2}=\frac{\pi^2}{8}$ **(1 M)**
9	
	Obtain the half range sine series of the function f(x) = $\left\{\begin{matrix}\boldsymbol{x}, & 0<x\le\frac{\boldsymbol{l}}{\mathbf{2}}\\ \boldsymbol{l-x}, & \frac{\boldsymbol{l}}{\mathbf{2}}\le\boldsymbol{x}\le\boldsymbol{l}\end{matrix}\right.$**. (8 M)** BTL5 **Answer :Page 2.153-DR.A.SINGARAVELU** • $b_n=\frac{4l}{n^2\pi^2}\sin\frac{n\pi}{2}$ **(7 M)** • $f(x)=\frac{4l}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\sin\frac{n\pi}{2}\sin\frac{n\pi x}{l}$ **(1 M)**
10	
	Obtain the half range sine series of the function f(x) = $lx-x^2$ **in** $\mathbf{0}\le\boldsymbol{x}\le\boldsymbol{l}$**. (8 M)** BTL5 **Answer :Page 2.157-DR.A.SINGARAVELU** • $b_n=\left\{\begin{matrix}\frac{8l^2}{n^3\pi^3} & If\ \ n\ \ is\ Odd\\ 0 & Otherwise\end{matrix}\right\}$ **(7 M)** • $f(x)=\frac{8l^2}{\pi^3}\left[\frac{\sin\left(\pi x/l\right)}{1^3}+\frac{\sin\left(3\pi x/l\right)}{3^3}+\frac{\sin\left(5\pi x/l\right)}{5^3}+......\right]$ **(1 M)**
11	
	Obtain the Fourier series for $f(x)=1+x+x^2$ **in** $(-\pi,\pi)$**. Deduce that** $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+.........=\frac{\pi^2}{6}$**.** BTL5 **(8 M)** **Answer : Page 2.44-DR.A.SINGARAVELU**

	• For $f_1(x)$ $a_0 = 0; b_n = \frac{2}{n}\left[(-1)^{n+1}\right]; a_n = 0$ For $f_2(x)$ $a_0 = 2+\frac{2\pi^2}{3}; a_n = \frac{4}{n^2}\left[(-1)^n\right]; b_n = 0$ **(6 M)** • $f(x) = 1+\frac{\pi^2}{3}+4\sum_{n=1}^{\infty}\frac{(-1)^n\cos nx}{n^2}+2\sum_{n=1}^{\infty}\frac{(-1)^{n+1}\sin nx}{n^2}$ **(1 M)** • $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots = \frac{\pi^2}{6}$ **(1 M)**
12	
	Find the Fourier series of periodicity 2π **for** $f(x)=x^2$**, in** $-\pi<x<\pi$ **. Hence show that** $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+\dots\dots\dots\dots = \frac{\pi^4}{90}$**.** **[M/J13,A/M15,N/D15,*N/D16*]** BTL5 **(8 M)** **Answer :Page 2.166-DR.A.SINGARAVELU** • $a_0 = \frac{2\pi^2}{3}; a_n = \left\{\frac{4(-1)^n}{n^2}\right\}; b_n = 0$ **(6 M)** • $f(x) = \frac{\pi^2}{3}+\sum_{n=1}^{\infty}\left\{\frac{4(-1)^n}{n^2}\right\}\cos nx$ **(2 M)** • $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+\dots\dots\dots\dots = \frac{\pi^4}{90}$ **(1 M)**
13	
	By using cosine series for $f(x) = x$ **in** $0 < x < \pi$ **, show that** $\frac{\pi^4}{96} = 1+\frac{1}{3^4}+\frac{1}{5^4}+\dots\dots$ **. [N/D14]** **(8 M)** BTL5 **Answer :Page 2.169-DR.A.SINGARAVELU** • $a_0 = l; a_n = \left\{\begin{matrix}\frac{-4l}{n^2\pi^2} & if\ n\ is\ Odd \\ 0 & Otherwise\end{matrix}\right\}$ **(6 M)** • $f(x) = \frac{l}{2}+\sum_{n=1,3,5\dots}^{\infty}\left\{\frac{-4l}{n^2\pi^2}\right\}\cos\frac{n\pi x}{l}$ **(1 M)** • $\frac{\pi^4}{96} = 1+\frac{1}{3^4}+\frac{1}{5^4}+\dots\dots$ **(1 M)**
14	
	Compute the first three harmonics of the fourier series of f(x) given by the following table:

x	**0**	$\frac{\pi}{3}$	$\frac{2\pi}{3}$	π	$\frac{4\pi}{3}$	$\frac{5\pi}{3}$	2π
f(x)	**1**	**1.4**	**1.9**	**1.7**	**1.5**	**1.2**	**1.0**

BTL5 **(8 M)**

(MAY/JUNE 2014)

Answer : Page 2.182-DR.A.SINGARAVELU

- $a_0 = 2.9; a_1 = -0.366; a_2 = -0.10; a_3 = 0.033$ **(6 M)**
  $b_1 = 0.173; \mathrm{b}_2 = -0.058; \mathrm{b}_3 = 0$
- $f(x) = 1.45 - 0.37\cos x + 0.17\sin x - 0.10\cos 2x - 0.06\sin 2x + 0.03\cos 3x + \ldots\ldots$ **(2 M)**

15

Compute the first two harmonics of the fourier series of f(x) given by the following table:

x	**0**	$\frac{T}{6}$	$\frac{T}{3}$	$\frac{T}{2}$	$\frac{2T}{3}$	$\frac{5T}{6}$	T
f(x)	**1.98**	**1.3**	**1.06**	**1.3**	**-0.88**	**-0.5**	**1.98**

BTL5 **(8 M)**

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- $a_0 = 1.42; a_1 = 0.33; a_2 = 0.93;$ **(6 M)**
  $b_1 = 1.08; \mathrm{b}_2 = -0.04;$
- $f(x) = 0.71 + 0.33\cos\theta + 1.08\sin\theta + 0.93\cos 2\theta - 0.04\sin 2\theta + \ldots..$ **(2 M)**
  $where \quad \theta = \frac{2\pi x}{T}$

	UNIT-III APPLICATION OF PARTIAL DIFFERENTIAL EQUATIONS
	Classification Of PDE-Method of Separation Of Variables-Solution Of One Dimentional Wave Equations-One Dimentional Heat Equations-Steaty State Solution Of Two Dimentional Equation Of Heat Conduction
	PART*A
1	**Write down all possible solutions of one dimensional wave equation. [N/D09,M/J14,N/D14].**BTL2 (i) $y(x,t)=\left(c_1e^{px}+c_2e^{-px}\right)\left(c_3e^{pat}+c_4e^{-pat}\right)$ (ii) $y(x,\ t)=(c_5\cos px+c_6\sin px)(c_7\cos pat+c8\sin pat)$ (iii) $y(x,t)=(c_9x+c_{10})(c_{11}t+c_{12})$
2	**Classify the PDE** $4u_{xx}=u_t$ **.** BTL2 Given $4u_{xx}-u_t=0$ **.** Here $A=4,\ B=0,\ C=0$ then $B^2-4AC=0$ Therefore the given PDE is *parabolic.*
3	**Classify the PDE** $x^2u_{xx}+2xyu_{xy}+\left(1+y^2\right)u_{yy}-2u_x=0$ **.** BTL2 Given $x^2u_{xx}+2xyu_{xy}+\left(1+y^2\right)u_{yy}-2u_x=0$ Here $A=x^2,\ B=2xy,\ C=1+y^2$ then $B^2-4AC=-4x^2<0$ **Therefore the given PDE is *Elliptic.***
4	**Classify the PDE** $x^2u_{xx}+2xyu_{xy}+\left(1+y^2\right)u_{yy}-2u_x=0$ **.** BTL2 Given $x^2u_{xx}+2xyu_{xy}+\left(1+y^2\right)u_{yy}-2u_x=0$ Here $A=x^2,\ B=2xy,\ C=1+y^2$ then $B^2-4AC=-4x^2<0$ **Therefore the given PDE is *Elliptic.***
5	**What is the basic difference between the solutions of one dimensional wave equation and one dimensional heat equation? [M/J12]** BTL2 Solution of the one dimensional wave equation is of periodic in nature. But Solution of the one dimensional heat equation is not of periodic in nature.
6	**Classify the PDE** $u_{xx}+2u_{xy}+u_{yy}=e^{(2x+3y)}$ **.** BTL2 Here $A=1,B=2,\ C=1$ $B^2-4AC=0$ Then the given PDE is *parabolic.*
7	**In the wave equation** $u_{tt}=c^2u_{xx}$**, what does** c^2 **stand for? [M/J13]** BTL5 $c^2={T}\big/{m}={Tension}\big/{mass\ per\ unit\ length}$.
8	**What are the basic assumption in 2-d heat equation (or) Laplace equation?** BTL5 When the heat flow is along curves instead of straight lines,the curves lying in parallel planes the flow is called two dimensional.
9	**State any two laws which are assumed to derive one dimensional heat equation. [M/J14]** BTL1 (i) The sides of the bar are insulated so that the loss or gain of heat from the sides by

	conduction or radiation is negligible. (ii) The same amount of heat is applied at all points of the face.
10	**Classify the PDE** $u_{xx} + x u_{yy} = 0$ **.** BTL2 Here $A = 1,\ B = 0,\ C = x$ therefore $B^2 - 4AC = -4x$ (i) If $x = 0$ then the given PDE is $Parabolic$ (ii) If $x < 0$ then the given PDE is $Elliptic$ (iii) If $x > 0$ then the given PDE is $Hyperbolic$
11	**Define steady state temperature distribution. [N/D13]** BTL5 If the temperature will not change when time varies is called steady state temperature distribution.
12	**In one dimensional heat equation** $u_t = \alpha^2 u_{xx}$ **. What does** α^2 **stands for? [M/J13]** BTL5 α^2 = thermal diffusivity.
13	**Write the steady state heat flow equation in two dimension in Cartesian equation and polar form. [M/J12].** BTL5 The Cartesian equation of two dimensional heat flow is $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$. The polar form of two dimensional heat flow is $r^2 \frac{\partial^2 u}{\partial r^2} + r \frac{\partial u}{\partial r} + \frac{\partial^2 u}{\partial \theta^2} = 0$.
14	**Write down the governing equation of two dimensional steady state heat conduction.** BTL5 $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = 0$ is the governing equation of two dimensional steady state heat conduction.
15	**An insulated rod of length** $60\ cm$ **has its ends at** A **and** B **maintained at** $20^\circ c$ **and** $80^\circ c$ **respectively. Find the steady state solution of the rod. [N/D12,M/J12].** BTL5 The steady state equation of one dimensional heat flow is $\frac{d^2u}{dx^2} = 0$ …..(1) The solution of (1) is $u(x) = ax + b$ ………..(2) Here $l = 60$ The boundary conditions are $(i)\ \ u(0) = 20$ $(ii)\ \ u(l) = 80$ Applying condition (i) in (2), we have $u(0) = a(0) + b$ ==> $20 = 0 + b$ ==> $b = 20$ Substituting $b = 20$ in (2) , we have $u(x) = ax + 20$ …………………(3) Applying condition (ii) in (3), we have

	$u(l) = a(l) + 20$ ==> $80 = a(60) + 20$ ==> $60a = 60$ ==> $a = 1$ Substituting $a = 1$ in (3) , we have $u(x) = x + 20$.
16	**The ends A and B of a rod $20\ cm$ long have the temperature at $30\,^{\circ}C$ and $80\,^{\circ}C$ until steady state prevails. Find the steady state temperature. [N/D14]** BTL5 The steady state equation of one dimensional heat flow is $\frac{d^2u}{dx^2} = 0$ …..(1) The solution of (1) is $u(x) = ax + b$ ……….(2) Here $l = 20$ The boundary conditions are $(i)\ u(0) = 30$ $(ii)\ u(l) = 80$ Applying condition (i) in (2), we have $u(0) = a(0) + b$ ==> $30 = 0 + b$ ==> $b = 30$ Substituting $b = 30$ in (2) , we have $u(x) = ax + 30$ …………………(3) Applying condition (ii) in (3) and substituting $l = 20$, we have $u(l) = a(l) + 30$ ==> $80 = a(20) + 30$ ==> $20a = 50$ ==> $a = \frac{5}{2}$ Substituting $a = \frac{5}{2}$ in (3) , we have $u(x) = \frac{5}{2}x + 30$.
17	**State the three possible solutions of the one dimensional heat flow (unsteady state)equation. [N/D10,*N/D14,M/J16,N/D16*].** BTL5 The various possible solutions of one dimensional heat equation are $(i)\ u(x,t) = \left(A_1 e^{\lambda x} + B_1 e^{-\lambda x}\right)e^{-\alpha^2\lambda^2 t}$ $(ii)\ u(x,t) = \left(A_2 \cos \lambda x + B_2 \sin \lambda x\right)e^{-\alpha^2\lambda^2 t}$ $(iii)\ u(x,t) = A_3 x + B_3$.
18	**State Fourier law of heat conduction.** BTL5 The rate at which heat flows through any area is proportional to the area and to the temperature gradient normal to the area. This constant of proportionality is known as the thermal conductivity (k) of the material. It is known as Fourier law of heat conduction.
19	**State any two laws which are assumed to derive one dimensional heat equation. [M/J14]** BTL5 The laws which are assumed to derive one dimensional heat equation are (i) Heat flows from a higher to lower temperature. (ii) The amount of heat required to produce a given temperature change in a body is proportional to the mass of the body and to the temperature change. This constant of proportionality is known as the specific heat (c) of the conducting material. (iii) The rate at which heat flows through any area is proportional to the area and to the temperature gradient normal to the area. This constant of proportionality is known as

	the thermal conductivity (k) of the material.
20	**How many conditions are required to solve $\frac{\partial u}{\partial t} = \alpha^2 \frac{\partial^2 u}{\partial x^2}$.** BTL5 Three conditions are required to solve $\frac{\partial u}{\partial t} = \alpha^2 \frac{\partial^2 u}{\partial x^2}$.
21	**Write the partial differential equation governing one dimensional heat conduction.** BTL5 The partial differential equation governing one dimensional heat conduction is given by $\frac{\partial u}{\partial t} = \alpha^2 \frac{\partial^2 u}{\partial x^2}$.
22	**A tightly stretched string with fixed end points $x = 0$ and $x = l$ is initially in a position given by $y(x,0) = y_0 \sin^3\left(\frac{\pi x}{l}\right)$. If it is released from rest in this position, write the undary conditions. [A/M10].** BTL 5 The boundary conditions are $(i)\ y(0,t) = 0$ $(ii)\ y(l,t) = 0$ $(iii)\ \frac{\partial y}{\partial t}(x,0) = 0$ $(iv)\ y(x,0) = y_0 \sin^3\left(\frac{\pi x}{l}\right),\ 0 < x < l$.
23	**Solve $3x\frac{\partial u}{\partial x} - 2y\frac{\partial u}{\partial y} = 0$ by method of separation of variables. [*N/D15*]** BTL5 Given $3x\frac{\partial u}{\partial x} - 2y\frac{\partial u}{\partial y} = 0$ …….(1) Let the solution of (1) be $u = X(x)Y(y)$ ………….(2) $\frac{\partial u}{\partial x} = X'Y$ and $\frac{\partial u}{\partial y} = XY'$ ………(3) Using (3) in (1), we have $3xX'Y - 2yXY' = 0$ $3xX'Y = 2yXY'$ $3x\frac{X'}{X} = 2y\frac{Y'}{Y}$

	L.H.S is a function of x alone and R.H.S is a function of y alone. They are equal for all values of x and y. This is possible if each is a constant. $3x\frac{X'}{X} = 2y\frac{Y'}{Y} = k$ $3x\frac{X'}{X} = k \quad \Rightarrow \quad 3\frac{X'}{X} = \frac{k}{x}$ ……(4) $2y\frac{Y'}{Y} = k \quad \Rightarrow \quad 2\frac{Y'}{Y} = \frac{k}{y}$ …….(5) Integrating (4) with respect to x and (5) with respect to y, we have $3\log X = k\log x + \log A \qquad 2\log Y = k\log y + \log B$ $\log X^3 = \log x^k + \log A \qquad \log Y^2 = \log y^k + \log B$ $\log X^3 = \log Ax^k \qquad \log Y^2 = \log By^k$ $X^3 = Ax^k \qquad Y^2 = By^k$ $X = a\,x^{\frac{k}{3}} \qquad Y = b\,y^{\frac{k}{2}}$ Hence the solution of (1) is $u = a\,x^{\frac{k}{3}}\,b\,y^{\frac{k}{2}} = a\,b\,x^{\frac{k}{3}}\,y^{\frac{k}{2}}$.
24	**Write the one dimensional heat equation.** BTL5 The one dimensional heat equation is $\frac{\partial u}{\partial t} = \alpha^2\frac{\partial^2 u}{\partial x^2}$ where $\alpha^2 = \frac{k}{\rho c}$.
25	**Classify the following partial differential equation:** BTL5 **(a)** $\frac{\partial^2 u}{\partial x^2} = \frac{\partial^2 u}{\partial y^2}$ **(b)** $\frac{\partial^2 u}{\partial x\partial y} = \left(\frac{\partial u}{\partial x}\right)\left(\frac{\partial u}{\partial y}\right) + xy$. Given $\frac{\partial^2 u}{\partial x^2} - \frac{\partial^2 u}{\partial y^2} = 0$ Here $A = 1\ ,\ B = 0\ ,\ C = -1$ $B^2 - 4AC = 0 - 4(1)(-1) = 4 > 0$ Therefore, the given pde is hyperbolic. (b) $\frac{\partial^2 u}{\partial x\partial y} = \left(\frac{\partial u}{\partial x}\right)\left(\frac{\partial u}{\partial y}\right) + xy$ Here $A = 0\ ,\ B = 1\ ,\ C = 0$ $B^2 - 4AC = (1)^2 - 4(0)(0) = 1 > 0$ Therefore, the given pde is hyperbolic.

	Part*B
1	
	A string is stretched and fastened to two points l apart. Motion is started by displacing the string into the form $y = k\,(\,lx - x^2)$ from which it is released at time $t = 0$. Find the displacement of any point of the string at a distance x from one end at any time t. (16 M) BTL5 **Answer : Page 3.20-DR.A.SINGARAVELU** $(i)\, y(0,t) = 0 \quad \forall t > 0$ $(ii)\, y(l,t) = 0 \quad \forall t > 0$ - $(iii)\, \frac{\partial y}{\partial t}(x,0) = 0 \quad \forall t > 0$ **(2 M)** $(iv)\, y(x,0) = \boldsymbol{k}\left(\boldsymbol{lx} - \boldsymbol{x}^2 \right)$ *The Most general Solution is* - $y(x,t) = \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l}\cos\frac{n\pi at}{l}$ **(8 M)** - $y(x,t) = \frac{8kl^2}{\pi^3}\sum_{n=1,3,5...}^{\infty}\frac{1}{n^3}\sin\frac{n\pi x}{l}\cos\frac{n\pi at}{l}$ **(6 M)**
2	
	A tightly stretched string with fixed end points x = 0 and x = l is initially in a position given by y = $y_0 \sin^3(\pi x/l)$. If it is released from rest from this position, find the displacement y(x, t). (16 M) BTL5 **Answer : Page :3.25-DR.A.SINGARAVELU** - Boundry Conditions **(2 M)** *The Most general Solution is* - $y(x,t) = \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l}\cos\frac{n\pi at}{l}$ **(8 M)** - $y(x,t) = \frac{3y_0}{4}\sin\frac{\pi x}{l}\cos\frac{\pi at}{l} - \frac{y_0}{4}\sin\frac{3\pi x}{l}\cos\frac{3\pi at}{l}$ **(6 M)**
3	
	A tightly stretched string of length $2l$ is fixed at both ends. The midpoint of the string is displaced by a distance "h" transversely and the string is released from rest in this position. Find the displacement of any point of the string at any subsequent time. (16 M) **Answer :Page 3.26-DR.A.SINGARAVELU** BTL5

	$(i)\, y(0,t)=0 \quad \forall\, t>0$ $(ii)\, y(l,t)=0 \quad \forall\, t>0$ $(iii)\, \frac{\partial y}{\partial t}(x,0)=0 \quad \forall\, t>0$ ● $(iv)\, y(x,0)=\left\{\begin{array}{ll} \frac{3hx}{l} & for \ \left(0,\frac{l}{3}\right) \\ \frac{3h(l-x)}{2l} & for \ \left(\frac{l}{3},l\right) \end{array}\right\}$ **(2 M)** *The Most general Solution is* ● $y(x,t)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{L}\cos\frac{n\pi at}{L}$ **(8 M)** ● $y(x,t)=\frac{8h}{\pi^2}\sum_{n=1}^{\infty}\frac{(-1)^n}{(2n-1)^2}\sin\frac{(2n-1)\pi x}{2l}\cos\frac{(2n-1)\pi at}{2l}$ **(6 M)**
3	
	A taut string of length l has its ends $x = 0$, $x = l$ fixed. The point where $x = \frac{l}{3}$ is drawn aside a small distance h, the displacement $y(x,t)$ satisfies $\frac{\partial^2 y}{\partial t^2} = a^2 \frac{\partial^2 y}{\partial x^2}$. Determine $y(x,t)$ at any time t. (16 M) BTL5 **Answer :Page 3.40-DR.A.SINGARAVELU** $(i)\, y(0,t)=0 \quad \forall\, t>0$ $(ii)\, y(l,t)=0 \quad \forall\, t>0$ $(iii)\, \frac{\partial y}{\partial t}(x,0)=0 \quad \forall\, t>0$ ● $(iv)\, y(x,0)=\left\{\begin{array}{ll} \frac{3hx}{l} & for \ \left(0,\frac{l}{3}\right) \\ \frac{3h(l-x)}{2l} & for \ \left(\frac{l}{3},l\right) \end{array}\right\}$ **(2 M)** *The Most general Solution is* ● $y(x,t)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l}\cos\frac{n\pi at}{l}$ **(8 M)** ● $y(x,t)=\frac{9h}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\sin\frac{n\pi}{3}\sin\frac{n\pi x}{l}\cos\frac{n\pi at}{l}$ **(6 M)**
4	
	A tightly stretched string with fixed end points x = 0 and x = l is initially at rest in its equilibrium position. . It is set vibrating by giving each point a velocity $\lambda x(l-x)$, find the displacement $y(x,t)$ at any distance x and at any time t. (16 **M)** BTL5 **Answer : Page 3.42-DR.A.SINGARAVELU**

	• $(i)\, y(0,t)=0 \quad \forall t>0$ $(ii)\, y(l,t)=0 \quad \forall t>0$ $(iii)\, \frac{\partial y}{\partial t}(x,0)=\lambda x\left(l-x\right)$ **(2 M)** $(iv)\, y(x,0)=0$ *The Most general Solution is* • $y(x,t)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l}\sin\frac{n\pi at}{l}$ **(8 M)** • $y(x,t)=\frac{8\lambda l^3}{a\pi^4}\sum_{n=1,3,5,....}^{\infty}\frac{1}{n^4}\sin\frac{n\pi x}{l}\sin\frac{n\pi at}{l}$ **(6 M)**
5	
	If a string of length l is initially at rest in its equilibrium position and each of its points is given the velocity $\left(\frac{\partial y}{\partial t}\right)_{t=0}=v_0\sin^3\frac{\pi x}{l}, 0<x<l$. Determine the displacement function y(x,t). (16 M) BTL5 **Answer :Page 3.46-DR.A.SINGARAVELU** • $(i)\, y(0,t)=0 \quad \forall t>0$ $(ii)\, y(l,t)=0 \quad \forall t>0$ $(iii)\, \frac{\partial y}{\partial t}(x,0)=v_0\sin^3\frac{\pi x}{l}, 0<x<l$ **(2 M)** $(iv)\, y(x,0)=0$ *The Most general Solution is* • $y(x,t)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l}\sin\frac{n\pi at}{l}$ **(8 M)** • $y(x,t)=\frac{3v_0 l}{4\pi a}\sin\frac{\pi x}{l}\sin\frac{\pi at}{l}-\frac{v_0}{12\pi a}\sin\frac{3\pi x}{l}\sin\frac{3\pi at}{l}$ **(6 M)**
6	
	A string is stretched between two fixed points at a distance $2l$ apart and the points of the string are given initial velocities $v=\begin{cases}\frac{cx}{l}\ in\ 0<x<l\\ \frac{c}{l}\left(2l-x\right)\ in\ l<x<2l\end{cases}$, where x being the distance from an end point. Find the displacement of the string at any time. (16 M) BTL5 **Answer : Page 3.44-DR.A.SINGARAVELU**

$(i)\, y(0,t) = 0 \quad \forall\, t > 0$

$(ii)\, y(l,t) = 0 \quad \forall\, t > 0$

- $(iii)\, \dfrac{\partial y}{\partial t}(x,0) = \begin{cases} \dfrac{cx}{l} & in \quad 0 < x < l \\ \dfrac{c}{l}(2l - x) & in \quad l < x < 2l \end{cases}$ **(2 M)**

$(iv)\, y(x,0) = 0$

The Most general Solution is

- $$y(x,t) = \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l} \sin\frac{n\pi at}{l}$$ **(8 M)**
- $$y(x,t) = \frac{8c}{\pi^2 a}\sum_{n=1}^{\infty}\frac{(-1)^{n-1}}{(2n-1)^3}\sin\frac{(2n-1)\pi x}{2l}\sin\frac{(2n-1)\pi at}{2l}$$ **(6 M)**

7

A rod of length l has its ends A and B kept at 0^0C and 120^0C until steady state condition prevail. If the temperature at B is suddenly reduced to 0^0C and kept so while that of A is maintained, find the temperature u(x,t) at a distance x from A at time t. (16 M) BTL5

Answer : Page :3.71-DR.A.SINGARAVELU

$(i)\, u(0,t) = 0 \quad \forall\, t \geq 0$

- $(ii)\, u(l,t) = 0 \quad \forall\, t \geq 0$ **(2 M)**

$(iii) u(x,0) = \dfrac{120x}{l}$

The Most general Solution is

- $$u(x,t) = \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l} e^{-\frac{c^2n^2\pi^2 t}{l^2}}$$ **(8 M)**
- $$u(x,t) = \frac{240}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{n}\sin\frac{n\pi x}{l} e^{\frac{-c^2n^2\pi^2 t}{l^2}}$$ **(6 M)**

8

A rod, 30 cm long has its ends A and B kept at 20^0C and 80^0C respectively, until steady state conditions prevail. The temperature at each end is then suddenly reduced to 0C and kept so. Find the resulting temperature function $u\,(x,t)$ taking $x = 0\ at\ A$. (16 M) BTL5

Answer : Page 3.68-DR.A.SINGARAVELU

$(i)\, u(0,t) = 0 \quad \forall\, t \geq 0$

- $(ii)\, u(30,t) = 0 \quad \forall\, t \geq 0$ **(2 M)**

$(iii) u(x,0) = 2x + 20$

The Most general Solution is

- $$u(x,t) = \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{30} e^{-\frac{c^2n^2\pi^2 t}{900}}$$ **(8 M)**

	• $u(x,t)=\frac{40}{\pi}\sum_{n=1}^{\infty}\frac{\left[1-4(-1)^n\right]}{n}\sin\frac{n\pi x}{30}e^{\frac{-c^2n^2\pi^2t}{900}}$ **(6 M)**
9	
	A metal bar 20 cm long with insulated sides, has its ends A and B kept at 30^0C and 80^0C respectively until steady state conditions prevail. The temperature at A is then suddenly raised to 40^0C and at the same instant B is lowered to 60^0C. Find the subsequent temperature at any point at the bar at any time. (16 M) BTL5 **Answer : Page 3.76-DR.A.SINGARAVELU** $(i)\ u(0,t)=0\quad \forall t\geq 0$ $(ii)\ u(20,t)=0\quad \forall t\geq 0$ • $(iii)u_s(x,0)=x+40$ **(2 M)** $and\quad u_T(x,0)=\frac{3x}{2}-10$ *The Most general Solution is* • $u(x,t)=\sum_{n=1}^{\infty}b_n\sin\frac{n\pi x}{20}e^{-\frac{c^2n^2\pi^2t}{400}}$ **(8 M)** • $u(x,t)=x+40-\frac{20}{\pi}\sum_{n=1}^{\infty}\frac{\left[1+2(-1)^n\right]}{n}\sin\frac{n\pi x}{20}e^{\frac{-c^2n^2\pi^2t}{400}}$ **(6 M)**
10	
	An infinitely long rectangular plate with insulated surface is 10cm wide. The two long edges and one short edge are kept at zero temperature while the other short edge x = 0 is kept at temperature given by $u=\begin{cases}20y & for\quad y\in[0,5]\\ 20(10-y) & for\quad y\in[5,10]\end{cases}$ **Find the steady state temperature distribution in the plate. (16 M)** BTL5 **Answer : Page 3.106-DR.A.SINGARAVELU** $(i)\ u(x,0)=0$ $(ii)\ u(x,10)=0$ • $(iii)u(\infty,y)=0$ **(2 M)** $(iv)\ u(0,y)=\begin{cases}20y & for\quad y\in[0,5]\\ 20(10-y) & for\quad y\in[5,10]\end{cases}$ *The Most general Solution is* • $u(x,y)=\sum_{n=1}^{\infty}b_n\sin\frac{n\pi y}{10}e^{\frac{-n\pi x}{10}}$ **(8 M)** • $u(x,y)=\frac{800}{\pi^2}\sum_{n=1,3,5,....}^{\infty}\frac{\left[\sin\frac{n\pi}{2}\right]}{n^2}\sin\frac{n\pi y}{10}e^{\frac{-n\pi x}{10}}$ **(6 M)**
11	

	An infinitely long rectangular plate with insulated surface is 10cm wide. The two long edges and one short edge are kept at zero temperature while the other short edge y = 0 is kept at temperature given by $u = 20x \ for \ 0 \le x \le 5$ $= 20(10-x) \ for \ 5 \le x \le 10$ **Find the steady state temperature distribution in the plate. (16 M)** BTL5 **Answer : Page :3.100-DR.A.SINGARAVELU** $(i) \ u(0, y) = 0$ $(ii) \ u(10, y) = 0$ • $(iii) u(x, \infty) = 0$ **(2 M)** $(iv) u(x,0) = \left\{ \begin{array}{ll} 20x & for \ \ x \in [0,5] \\ 20(10-x) & for \ \ x \in [5,10] \end{array} \right\}$ *The Most general Solution is* • $u(x, y) = \sum_{n=1}^{\infty} b_n \sin \frac{n\pi x}{10} e^{\frac{-n\pi y}{10}}$ **(8 M)** • $u(x, y) = \frac{800}{\pi^2} \sum_{n=1,3,5,....}^{\infty} \frac{\left[\sin \frac{n\pi}{2} \right]}{n^2} \sin \frac{n\pi x}{10} e^{\frac{-n\pi y}{10}}$ **(6 M)**
12	
	A tightly stretched string with fixed end points $x = 0$ **and** $x = l$ **is initially displaced to the form** $k \sin\left(\frac{3\pi x}{l}\right)\cos\left(\frac{2\pi x}{l}\right)$ **and then released. Find the displacement of the string at any distance** x **from one end at any time** t **. [M/J16] (16 M)** BTL5 **Answer : Page 3.40-DR.A.SINGARAVELU** $(i) y(0,t) = 0 \quad \forall t > 0$ $(ii) y(l,t) = 0 \quad \forall t > 0$ • $(iii) \frac{\partial y}{\partial t}(x,0) = 0 \quad \forall t > 0$ **(2 M)** $(iv) y(x,0) = k \sin\left(\frac{3\pi x}{l}\right)\cos\left(\frac{2\pi x}{l}\right)$ *The Most general Solution is* • $y(x,t) = \sum_{n=1}^{\infty} b_n \sin \frac{n\pi x}{l} \cos \frac{n\pi at}{l}$ **(8 M)** • $y(x,t) = \frac{k}{2}\left[\sin \frac{\pi x}{l} \cos \frac{\pi at}{l} + \sin \frac{5\pi x}{l} \cos \frac{5\pi at}{l} \right]$ **(6 M)**
13	
	A tightly stretched string with fixed end points $x = 0$ **and** $x = l$ **is initially at rest in its equilibrium position. If it is set vibrating giving each point a initial velocity** $3x(l-x)$**, find the displacement.(16 M)** BTL5 **Answer : Page 3.54-DR.A.SINGARAVELU**

	$(i)\, y(0,t) = 0 \quad \forall t > 0$ $(ii)\, y(l,t) = 0 \quad \forall t > 0$ • $(iii)\, \frac{\partial y}{\partial t}(x,0) = 3x(l-x)$ **(2 M)** $(iv)\, y(x,0) = 0$ *The Most general Solution is* • $y(x,t) = \sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l}\sin\frac{n\pi at}{l}$ **(8 M)** • $y(x,t) = \frac{24l^3}{\pi^4 a}\sum_{n=1}^{\infty}\frac{1}{(2n-1)^4}\sin\frac{(2n-1)\pi x}{l}\sin\frac{(2n-1)\pi at}{l}$ **(6 M)**
14	
	Solve the problem of heat conduction in a rod given that the temperature function $u(x,t)$ **is subjected to the condition,** $\frac{\partial u}{\partial t} = \alpha^2\frac{\partial^2 u}{\partial x^2}$**,** $0 \le x \le l, t > 0$ **(i)** u **is finite as** $t \to \infty$ **(ii)** $\frac{\partial u}{\partial x} = 0 \; for \; x = 0 \; and \; x = l, t > 0$ **(iii)** $u = lx - x^2 \; for \; t = 0,\ 0 \le x \le l$ **.[A/M15]** BTL5 **(16 M)** **Answer :Page :3.91-DR.A.SINGARAVELU** $(i)\, \frac{\partial u}{\partial t}(0,t) = 0 \quad \forall t \ge 0$ • $(ii)\, u(l,t) = 0 \quad \forall t \ge 0$ **(2 M)** $(iii)\, u(x,0) = l\,x - x^2 \;,\; 0 \le x \le l$ • $u(x,t) = \frac{l^2}{6} - \frac{l^2}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\cos\frac{2n\pi x}{l}e^{\frac{-4c^2\pi^2 t}{l^2}}$ **(14 M)**
15	
	A square plate is bounded by the lines $x = 0$ **,** $x = a$ **,** $y = 0$ **and** $y = b$ **. Its surfaces are insulated and the temperature along** $y = b$ **is kept at** $100\ ^\circ C$ **, while the temperature along other three edges are at** $0\ ^\circ C$ **. Find the steady state temperature at any point in the plate.[*N/D14*] (16 M)** **Answer :Page :3.116-DR.A.SINGARAVELU** BTL5 $(i)\, u(x,0) = 0$ $(ii)\, u(x,b) = 0$ • $(iii)\, u(0,y) = 0$ **(2 M)** $(iv)\, u(a,y) = 100 \quad for \;\; y \in [0,b]$

The Most general Solution is

- $$u(x,y)=\sum_{n=1}^{\infty} b_n \sinh\frac{n\pi x}{b}\sin\frac{n\pi y}{b}$$ **(8 M)**
- $$u(x,y)=\frac{400}{\pi}\sum_{n=1,3,5,....}^{\infty}\frac{1}{n\sinh\frac{n\pi a}{b}}\sinh\frac{n\pi x}{b}\sin\frac{n\pi y}{b}$$ **(6 M)**

16

Find the steady state temperature distribution in a rectangular plate of sides a and b insulated at the lateral surface and satisfying the boundary conditions $u(0,y)=u(a,y)=0$ **for** $0\le y\le b$ **and** $u(x,0)=0$ and $u(x,a)=x(a-x)$ **for** $0\le x\le a$ **.**
[N/D12]. (16 M)

Answer : Page :3.111-DR.A.SINGARAVELU BTL5

The Most general Solution is

- $$u(x,y)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{a}\sinh\frac{n\pi y}{a}$$ **(10 M)**

$$u(x,y)=\frac{8a^2b}{\pi^3}\sum_{n=1,3,5,....}^{\infty}\frac{1}{n^3\sinh n\pi}\sin\frac{n\pi x}{a}\sinh\frac{n\pi y}{a}$$ **(6 M)**

UNIT-IV FOURIER TRANSFORM

State of Fourier Integral Theorem-Fourier Transform Pair-Sine and Cosine Transforms-Properties-Transform of Simple Functions-Convolution Theorem-Parsevals Identity

PART*A

1 **State the Fourier integral theorem. [M/J14,A/M15,M/J16]** BTL1

If $f(x)$ is piecewise continuous , has piecewise continuous derivatives in every finite interval in $(-\infty,\infty)$ and absolutely integrable in $(-\infty,\infty)$, then $f(x)=\frac{1}{2\pi}\int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(t)e^{is(x-t)}\,dt\,ds$ or

equivalently $f(x)=\frac{1}{\pi}\int_{0}^{\infty}\int_{-\infty}^{\infty} f(t)\cos s(x-t)dt\,ds$.

2 **Find the Fourier transform pair. [N/D10 , N/D11].** BTL1

The Fourier transform pair is

$$F(s)=F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx \qquad and$$

$$f(x)=F^{-1}[F(s)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} F(s)e^{-isx}\,ds$$

.

3 **Define self reciprocal with respect to Fourier transform. [N/D13]** BTL1

If $f(s)$ is the Fourier transform of $f(x)$, then $f(x)$ is said to be self reciprocal under Fourier transform.

4 **Prove that Fourier transform is linear. [N/D15]** BTL1

We have to prove that $F[a\,f(x)+b\,g(x)]=a\,F(f(x))+b\,F(g(x))$

By definition, we have $F[a\,f(x)+b\,g(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}(a\,f(x)+b\,g(x))e^{isx}\,dx$

$$F[a\,f(x)+b\,g(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} a\,f(x)e^{isx}\,dx+\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} b\,g(x)e^{isx}\,dx$$

$$F[a\,f(x)+b\,g(x)]=a\,\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx+b\,\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} g(x)e^{isx}\,dx$$

$$F[a\,f(x)+b\,g(x)]=a\,F(f(x))+b\,F(g(x)).$$

5 **Find the Fourier transform of** $f(x)=\begin{cases} e^{ikx} & , a<x<b \\ 0 & , x<a \;\; and \;\; x>b \end{cases}$ **. [N/D09]** BTL1

$$F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx$$

$$F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{a}^{b} e^{ikx}e^{isx}\,d\,x=\frac{1}{\sqrt{2\pi}}\int_{a}^{b} e^{i(s+k)x}\,d\,x$$

$$=\frac{1}{\sqrt{2\pi}}\left[\frac{e^{i(s+k)x}}{i(s+k)}\right]=\frac{1}{\sqrt{2\pi}}\left[\frac{e^{i(s+k)b}-e^{i(s+k)a}}{i(s+k)}\right].$$

6	**If $F(s)$ is the Fourier transform of $f(x)$, write the formula for the Fourier transform of $f(x)\cos ax$ in terms of F .[OR] State and prove modulation theorem on Fourier transforms.[N/D14]** BTL1 By definition, $F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx$ $F[f(x)\cos ax]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)\cos ax\; e^{isx}\,dx$ $F[f(x)\cos ax]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)\left(\frac{e^{iax}+e^{-iax}}{2}\right)e^{isx}\,dx$ $=\frac{1}{2}\left[\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{iax}e^{isx}\,dx+\int_{-\infty}^{\infty} f(x)e^{-iax}e^{isx}\,dx\right]$ $=\frac{1}{2}\left[\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{i(s+a)x}\,dx+\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{i(s-a)}\,dx\right]$ $=\frac{1}{2}[F(s+a)+F(s-a)]$ (ie) $F[f(x)\cos ax]=\frac{1}{2}[F(s+a)+F(s-a)]$.
7	**State the shifting property on Fourier transform.** BTL1 If $F(s)$ is the Fourier transform of $f(x)$, then $F(s)e^{ias}$ will be the Fourier transform of $f(x-a)$. (ie) $F\left[f(x-a)\right]=e^{ias}F(s)$.
8	**If $F(s)$ is the Fourier transform of $f(x)$, obtain the Fourier transform of** $f(x-2)+f(x+2)$.[M/J16] BTL1 $F[f(x-2)+f(x+2)]=F[f(x-2)]+F[f(x+2)]$ $=e^{-i2s}F(s)+e^{i2s}F(s)=F(s)\left[e^{i2s}+e^{-i2s}\right]=F(s)(2\cos h2s)=2F(s)\cos h2s$.
9	**What is the Fourier transform of $f(x-a)$ if the Fourier transform of $f(x)$ is $F(s)$.** [A/M 10 , M/J 12 , N/D13]. BTL1 By definition, $F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx$ $F[f(x-a)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x-a)e^{isx}\,dx$ $x-a=t$ $\quad$ $when\ \ x=-\infty, t=-\infty$ Put $x=\mathbf{t}+a$ $\quad$ $when\ \ x=\infty, t=\infty$ $dx=dt$

	$F[f(x-a)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{is(t+a)}\,dt \quad = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{ist}e^{ias}\,dt$ $= e^{ias}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{ist}\,dt \quad = e^{ias}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx \quad = e^{ias}F(s)\cdot$
10	**State the Fourier transforms of the derivatives of a function.** BTL1 If the Fourier transform of $f(x)$ is $F(s)$, then the Fourier transform of the derivatives of a function $f(x)$ (ie) $F[f'(x)] = -isF(s)$, if $f(x)\to 0 \text{ as } x\to\pm\infty$.
11	**If $F[f(x)] = F(s)$, then give the value of $F[f(ax)]$.** BTL1 By definition, $F[f(x)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx$ $F[f(ax)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(ax)e^{isx}\,dx$ $put \quad ax = t \quad when \quad x = -\infty,\ t = -\infty$ when $a > 0$, $\quad x = \frac{t}{a} \quad when \quad x = \infty,\ t = \infty$ $dx = \frac{dt}{a}$ $F[f(ax)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{is\left(\frac{t}{a}\right)}\frac{dt}{a} \quad = \frac{1}{a}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{i\left(\frac{s}{a}\right)t}\,dt$ $= \frac{1}{a}F\left[\frac{s}{a}\right]$ -----------------------(1) when $a < 0$, $put \quad ax = t \quad when \quad x = -\infty,\ t = \infty$ $x = \frac{t}{a} \quad when \quad x = \infty,\ t = -\infty$ $dx = \frac{dt}{a}$ $F[f(ax)] = \frac{1}{\sqrt{2\pi}}\int_{\infty}^{-\infty} f(t)e^{is\left(\frac{t}{a}\right)}\frac{dt}{a} \quad = \frac{1}{a}\frac{1}{\sqrt{2\pi}}\int_{\infty}^{-\infty} f(t)e^{i\left(\frac{s}{a}\right)t}\,dt$ $= -\frac{1}{a}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(t)e^{i\left(\frac{s}{a}\right)t}\,dt \quad = -\frac{1}{a}F\left[\frac{s}{a}\right]$ ------------(2) From (1) and (2) , we have $F[f(ax)] = \frac{1}{\|a\|}F\left(\frac{s}{a}\right).$
12	**If $F\{f(x)\} = F(s)$, then find $F\{e^{iax}f(x)\}$. [N/*D14*]** BTL1

	By definition, $F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx$ $F\left[e^{iax}f(x)\right]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} e^{iax}f(x)e^{isx}\,dx$ $F\left[e^{iax}f(x)\right]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{i(s+a)x}\,dx = F(s+a)$
13	**Write down the Fourier cosine transform pair.** BTL1 Fourier cosine transform pair is $F_C[f(x)] = F_C(s) = \sqrt{\frac{2}{\pi}}\int_0^{\infty} f(x)\cos sx\,dx$ and $f(x) = F_C^{-1}(F(s)) = \sqrt{\frac{2}{\pi}}\int_0^{\infty} F_C(s)\cos sx\,ds$
14	**If** $F_C(s)$ **is the Fourier cosine transform of** $f(x)$**, prove that Fourier cosine transform of** $f(ax)$ is $\frac{1}{a}F_C\left(\frac{s}{a}\right)$. [A/M11]. BTL1 $F_C[f(ax)] = F_C(s) = \sqrt{\frac{2}{\pi}}\int_0^{\infty} f(ax)\cos sx\,dx$ $put \quad ax = t \qquad when \quad x=0,\ t=0$ $x=\frac{t}{a} \qquad when \quad x=\infty,\ t=\infty$ $dx=\frac{dt}{a}$ $=\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(t)\cos s\left(\frac{t}{a}\right)\frac{dt}{a} = \frac{1}{a}\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(t)\cos\left(\frac{s}{a}\right)t\,dt$ $=\frac{1}{a}\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(x)\cos\left(\frac{s}{a}\right)x\,dx$ (ie) $F_C[f(ax)] = \frac{1}{a}F_C\left(\frac{s}{a}\right)$
15	**Given that** $F_S\{f(x)\} = \frac{s}{s^2+a^2}$ **for** $a>0$ **, hence find** $F_C\{x\ f(x)\}$**. [M/J16]** BTL1 $F_C\{x\ f(x)\} = \frac{d}{ds}F_S(f(x)) = \frac{d}{ds}\left(\frac{s}{s^2+a^2}\right)$ $=\frac{(s^2+a^2)(1)-s(2s)}{(s^2+a^2)^2} = \frac{s^2+a^2-2s^2}{(s^2+a^2)^2} = \frac{a^2-s^2}{(s^2+a^2)^2}$.
16	**Find the Fourier cosine transform of** $f(x)=e^{-ax}$ **,** $a>0$ **.[N/D15]** BTL1

	$F_C\left(e^{-ax}\right) = \sqrt{\frac{2}{\pi}}\int_0^\infty e^{-ax}\cos sx\,dx = \sqrt{\frac{2}{\pi}}\left[\frac{e^{-ax}}{(-a)^2+s^2}(-a\cos sx + s\sin sx)\right]_0^\infty$ $= \sqrt{\frac{2}{\pi}}\left[0 - \frac{1}{a^2+s^2}(-a+0)\right] = \sqrt{\frac{2}{\pi}}\,\frac{a}{s^2+a^2}\,.$
17	**Find the Fourier sine transform of $\frac{1}{x}$. [N/D09,M/J14,*A/M15,N/D16*].** BTL1 $F_s\left[\frac{1}{x}\right] = \sqrt{\frac{2}{\pi}}\int_0^\infty \frac{1}{x}\sin sx\,dx$ $put \quad sx = \theta \qquad when \quad x = 0,\ \theta = 0$ $x = \frac{\theta}{s} \qquad when \quad x = \infty,\ \theta = \infty$ $dx = \frac{d\theta}{s}$ $= \sqrt{\frac{2}{\pi}}\int_0^\infty \frac{1}{\left(\frac{\theta}{s}\right)}\sin\theta\,\frac{d\theta}{s} = \sqrt{\frac{2}{\pi}}\int_0^\infty \frac{s}{\theta}\,\frac{\sin\theta}{s}\,d\theta$ $= \sqrt{\frac{2}{\pi}}\int_0^\infty \frac{\sin\theta}{\theta}\,d\theta = \sqrt{\frac{2}{\pi}}\,\frac{\pi}{2} = \sqrt{\frac{\pi}{2}}\,.$
18	**Find the Fourier sine transform of $e^{-ax},\ a > 0$. [N/D10 , M/J12].** BTL1 $F_s\left(e^{-ax}\right) = \sqrt{\frac{2}{\pi}}\int_0^\infty e^{-ax}\sin sx\,dx = \sqrt{\frac{2}{\pi}}\left[\frac{e^{-ax}}{(-a)^2+s^2}(-a\sin sx - s\cos sx)\right]_0^\infty$ $= \sqrt{\frac{2}{\pi}}\left[0 - \frac{1}{a^2+s^2}(0-s)\right] = \sqrt{\frac{2}{\pi}}\,\frac{s}{s^2+a^2}\,.$
19	**Find the Fourier sine transform of e^{-3x}. [M/J13].** BTL1 $F_s\left(e^{-3x}\right) = \sqrt{\frac{2}{\pi}}\int_0^\infty e^{-3x}\sin sx\,dx = \sqrt{\frac{2}{\pi}}\left[\frac{e^{-3x}}{(-3)^2+s^2}(-3\sin sx - s\cos sx)\right]_0^\infty$ $= \sqrt{\frac{2}{\pi}}\left[0 - \frac{1}{9+s^2}(0-s)\right] = \sqrt{\frac{2}{\pi}}\,\frac{s}{s^2+9}\,.$
20	**Find the Fourier sine transform of $f(x) = e^{-\frac{x}{2}}$. [A/M15]** BTL1 $F_s[f(x)] = \sqrt{\frac{2}{\pi}}\int_0^\infty f(x)\sin sx\,dx$

	$F_s\left[e^{-\frac{x}{2}}\right] = \sqrt{\frac{2}{\pi}}\int_0^\infty e^{-\frac{x}{2}}\sin s x\, d x = \sqrt{\frac{2}{\pi}}\left[\frac{e^{-\frac{x}{2}}}{\left(-\frac{1}{2}\right)^2+s^2}\left(-\frac{1}{2}\sin s x - s\cos sx\right)\right]_0^\infty$ $= \sqrt{\frac{2}{\pi}}\left[0-\frac{1}{\left(\frac{1+4s^2}{4}\right)}(0-s)\right] = \sqrt{\frac{2}{\pi}}\left[\frac{4s}{1+4s^2}\right] = \sqrt{\frac{2}{\pi}}\left[\frac{4s}{4s^2+1}\right]$
21	**State Convolution theorem on Fourier transforms. [N/D12].** BTL1 If $F(s)$ and $G(s)$ are the Fourier transforms of $f(x)$ and $g(x)$ respectively, then the Fourier transform of the convolution of $f(x)$ and $g(x)$ is the product of their Fourier transforms. (ie) $F[f(x)*g(x)] = F[f(x)].F[g(x)]$.
22	**State Parseval's identity on Fourier transform. [N/D11].** BTL1 If $F(s)$ is the Fourier transform of $f(x)$, then $\int_{-\infty}^{\infty}\left\|f(x)\right\|^2 dx = \int_{-\infty}^{\infty}\left\|F(s)\right\|^2 ds$.
23	**Solve the integral equation $\int_0^\infty f(x)\cos\lambda x\, dx = e^{-\lambda}$.** BTL1 Given $\int_0^\infty f(x)\cos\lambda x\, dx = e^{-\lambda}$ Multiplying both sides by $\sqrt{\frac{2}{\pi}}$, we have $\sqrt{\frac{2}{\pi}}\int_0^\infty f(x)\cos\lambda x\, dx = \sqrt{\frac{2}{\pi}}e^{-\lambda}$ $F_C[f(x)] = \sqrt{\frac{2}{\pi}}e^{-\lambda}$ $f(x) = F_C^{-1}\left[\sqrt{\frac{2}{\pi}}e^{-\lambda}\right] = \sqrt{\frac{2}{\pi}}\int_0^\infty\sqrt{\frac{2}{\pi}}e^{-\lambda}\cos x\lambda\, d\lambda = \frac{2}{\pi}\int_0^\infty e^{-\lambda}\cos x\lambda\, d\lambda$ $= \frac{2}{\pi}\left[\frac{e^{-\lambda}}{(-1)^2+x^2}(-\cos x\lambda + x\sin x\lambda)\right]_0^\infty = \frac{2}{\pi}\left[0-\frac{1}{1+x^2}(-1+0)\right] = \frac{2}{\pi}\frac{1}{1+x^2}$.
24	**State and prove the change of scale property of Fourier transform. [A/M11,M/J13, N/D16**]. B By definition, $F[f(x)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\, dx$ $F[f(ax)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(ax)e^{isx}\, dx$

put $ax = t$ when $x = -\infty\ ,\ t = -\infty$

when $a > 0$, $x = \frac{t}{a}$ when $x = \infty\ , t = \infty$

$dx = \frac{dt}{a}$

$$F\left[f\left(a\ x\right)\right] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(t\right) e^{is\left(\frac{t}{a}\right)}\frac{dt}{a} \quad = \frac{1}{a}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(t\right) e^{i\left(\frac{s}{a}\right)t}\, dt$$

$$= \frac{1}{a}F\left[\frac{s}{a}\right]$$ -----------------------(1)

when $a < 0$,

put $ax = t$ when $x = -\infty\ ,\ t = \infty$

$x = \frac{t}{a}$ when $x = \infty\ , t = -\infty$

$dx = \frac{dt}{a}$

$$F\left[f\left(a\ x\right)\right] = \frac{1}{\sqrt{2\pi}}\int_{\infty}^{-\infty} f\left(t\right) e^{is\left(\frac{t}{a}\right)}\frac{dt}{a} \quad = \frac{1}{a}\frac{1}{\sqrt{2\pi}}\int_{\infty}^{-\infty} f\left(t\right) e^{i\left(\frac{s}{a}\right)t}\, dt$$

$$= -\frac{1}{a}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(t\right) e^{i\left(\frac{s}{a}\right)t}\, dt \quad = -\frac{1}{a}F\left[\frac{s}{a}\right]$$ ------------(2)

From (1) and (2) , we have

$$F\left[f\left(ax\right)\right] = \frac{1}{\left|a\right|}F\left(\frac{s}{a}\right).$$

25

Prove that $F\left[f\left(x-a\right)\right] = e^{isa}F\left(s\right)$**. [N/D14,*A/M15*]** BTL1

By definition, $F\left[f\left(x\right)\right] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(x\right) e^{isx}\, dx$

$$F\left[f\left(x-a\right)\right] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(x-a\right) e^{isx}\, dx$$

$x - a = t$ when $x = -\infty\ , t = -\infty$

Put $x = \mathbf{t} + a$ when $x = \infty\ , t = \infty$

$dx = dt$

$$F\left[f\left(x-a\right)\right] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(t\right) e^{is\left(t+a\right)}\, dt \quad = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(t\right) e^{ist} e^{ias}\, dt$$

$$= e^{ias}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(t\right) e^{ist}\, dt \quad = e^{ias}\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f\left(x\right) e^{isx}\, dx \ = e^{ias}F\left(s\right).$$

PART*B

1	
	Find the Fourier transform of $f(x)=\begin{cases}1\,; & \lvert x\rvert<1\\ 0\,; & otherwise\end{cases}$ **. Hence prove that** $\int_0^\infty \frac{\sin x}{x}dx=\int_0^\infty \frac{\sin^2 x}{x^2}dx=\frac{\pi}{2}$ **. (16M)** BTL5 **Answer : Page :4.34-DR.A.SINGARAVELU** $F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$ • $f(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} F(s)e^{-isx}ds$ **(2 M)** $\int_{-\infty}^{\infty}\lvert F(s)\rvert^2 ds=\int_{-\infty}^{\infty}\lvert f(x)\rvert^2 dx$ $F(s)=\sqrt{\frac{2}{\pi}}\frac{\sin as}{s}$ • **(6 M)** $f(x)=\frac{2}{\pi}\int_0^\infty \frac{\sin as}{s}\cos sx\ ds$ • $\int_0^\infty \frac{\sin x}{x}dx=\int_0^\infty \frac{\sin^2 x}{x^2}dx=\frac{\pi}{2}$ **(8 M)**
2	
	Find the Fourier transform of $e^{-a\lvert x\rvert}$**, if** $a>0$ **. Deduce that** $\int_0^\infty \frac{dx}{(x^2+a^2)^2}=\frac{\pi}{4a^3}$ **if** $a>0$ **.** BTL5 **(8 M)** **Answer : Page :4.46 and 4.48- DR.A.SINGARAVELU** • $F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$ **(2 M)** $F(s)=\sqrt{\frac{2}{\pi}}\frac{a}{s^2+a^2}$ • **(4 M)** $f(x)=\frac{2}{\pi}\int_0^\infty \frac{a}{s^2+a^2}\cos sx\ ds$ • $\int_0^\infty \frac{dx}{(x^2+a^2)^2}=\frac{\pi}{4a^3}$ **(2 M)**
3	
	Find the Fourier transform of $f(x)=\begin{cases}a^2-x^2\ , & \lvert x\rvert<a\\ 0\ , & \lvert x\rvert>a>0\end{cases}$ **. Hence evaluate**

$(i)\int_0^\infty\left(\frac{\sin x - x\cos x}{x^3}\right)dx$ **and** $(ii)\int_0^\infty\left(\frac{x\cos x - \sin x}{x^3}\right)^2 dx$ **.** BTL1 **(16 M)**

Answer : Page :4.40- DR.A.SINGARAVELU

$$F(s) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$$

- $$f(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} F(s)e^{-isx}ds$$ **(2 M)**

$$\int_{-\infty}^{\infty}|F(s)|^2 ds = \int_{-\infty}^{\infty}|f(x)|^2 dx$$

- $$F(s) = 2\sqrt{\frac{2}{\pi}}\left(\frac{\sin as - as\cos as}{s^3}\right)$$ **(8 M)** $$f(x) = \frac{4}{\pi}\int_0^\infty\left(\frac{\sin as - as\cos as}{s^3}\right)\cos sx\ ds$$

- $$\int_0^\infty\left(\frac{\sin x - x\cos x}{x^3}\right)dx = \frac{\pi}{4}$$ **(6 M)** $$\int_0^\infty\left(\frac{\sin x - x\cos x}{x^3}\right)^2 dx = \frac{\pi}{15}$$

4

Find the Fourier transform of the function defined by $f(x) = \begin{cases} 1 - x^2 \ ; & |x| < 1 \\ 0 \ ; & |x| \geq 1 \end{cases}$ **. Hence prove that** $\int_0^\infty\left\{\frac{\sin s - s\cos s}{s^3}\right\}\cos\left(\frac{s}{2}\right)ds = \frac{3\pi}{16}$ **and** $\int_0^\infty\left\{\frac{\sin s - s\cos s}{s^3}\right\}^2 ds = \frac{\pi}{15}$ **.**

[A/M11,N/D13,M/J16] BTL1 **(16 M)**

Answer : Page :4.42- DR.A.SINGARAVELU

$$F(s) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$$

- $$f(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} F(s)e^{-isx}ds$$ **(2 M)**

$$\int_{-\infty}^{\infty}|F(s)|^2 ds = \int_{-\infty}^{\infty}|f(x)|^2 dx$$

- $$F(s) = 2\sqrt{\frac{2}{\pi}}\left(\frac{\sin s - s\cos s}{s^3}\right)$$ $$f(x) = \frac{4}{\pi}\int_0^\infty\left(\frac{\sin s - s\cos s}{s^3}\right)\cos sx\ ds$$ **(8 M)**
- $$\int_0^\infty\left(\frac{\sin s - s\cos s}{s^3}\right)\cos\frac{s}{2}\,ds = \frac{3\pi}{16}$$ $$\int_0^\infty\left(\frac{\sin s - s\cos s}{s^3}\right)^2 ds = \frac{\pi}{15}$$ **(6 M)**

5

Find the Fourier transform of $f(x) = \begin{cases} 1 - |x| \ ; \ if \ |x| < 1 \\ 0 \quad ; \ if \ |x| \ge 1 \end{cases}$**. Hence deduce that** $\int_0^\infty\left(\frac{\sin t}{t}\right)^4 dt = \frac{\pi}{3}$ **and** $\int_0^\infty\left(\frac{\sin t}{t}\right)^2 dt = \frac{\pi}{2}$**. [N/D 11 , N/D12 , N/D*14*, N/D *15,M/J16*, N/D*16]*.** BTL1 **(16 M)**

Answer : Page :4.38- DR.A.SINGARAVELU

- $$F(s) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$$ $$f(x) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} F(s)e^{-isx}ds$$ $$\int_{-\infty}^{\infty}|F(s)|^2 ds = \int_{-\infty}^{\infty}|f(x)|^2 dx$$ **(2 M)**
- $$F(s) = \sqrt{\frac{2}{\pi}}\frac{(1-\cos s)}{s^2}$$ $$f(x) = \frac{2}{\pi}\int_0^\infty\frac{(1-\cos s)}{s^2}\cos sx\ ds$$ **(6 M)**
- $\int_0^\infty\left(\frac{\sin t}{t}\right)^4 dt = \frac{\pi}{3}$ and $\int_0^\infty\left(\frac{\sin t}{t}\right)^2 dt = \frac{\pi}{2}$. **(8 M)**

6

Find the Fourier transform of $e^{-a^2x^2}$**,** $a > 0$ **. Hence show that** $e^{-\frac{x^2}{2}}$ **is self reciprocal under the Fourier transform. [N/D*14*, N/D*16]*.*** BTL1 **(8 M)**

Answer : Page :4.53- DR.A.SINGARAVELU

- $$F(s) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$$ **(2 M)**

	• $F(s)=\frac{1}{a\sqrt{2}}e^{\frac{-s^2}{4a^2}}$ **(4 M)** • **Put** $a=\frac{1}{\sqrt{2}}$ $We\ get\ e^{-\frac{x^2}{2}}$ **(2M)**
7	
	Find the Fourier transform of $e^{-a\lvert x\rvert},\ a>0$ **and hence deduce that** **(1)** $\int_0^\infty \frac{\cos xt}{a^2+t^2}dt=\frac{\pi}{2a}e^{-a\lvert x\rvert}$ **(2)** $F\left\{xe^{-a\lvert x\rvert}\right\}=i\sqrt{\frac{2}{\pi}}\frac{2as}{\left(s^2+a^2\right)}$**, here** F **stands for Fourier transform.** **[M/J14,N/D14]** BTL1 **(8 M)** **Answer : Page :4.46- DR.A.SINGARAVELU** • $F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(x)e^{isx}dx$ **(2 M)** $F(xf(x))=-i\frac{d}{ds}(F(f(x))$ • $F(s)=\sqrt{\frac{2}{\pi}}\frac{a}{s^2+a^2}$ **(4 M)** $f(x)=\frac{2}{\pi}\int_0^\infty\frac{a}{s^2+a^2}\cos sx\ ds$ • $\int_0^\infty \frac{\cos xt}{a^2+t^2}dt=\frac{\pi}{2a}e^{-a\lvert x\rvert}$ and $F\left\{xe^{-a\lvert x\rvert}\right\}=i\sqrt{\frac{2}{\pi}}\frac{2as}{\left(s^2+a^2\right)}$ **(2 M)**
8	
	Show that the Fourier transform of $e^{-\frac{x^2}{2}}$ **is** $e^{-\frac{s^2}{2}}$**. [A/M10,N/D11,M/J13].[OR]Find the Fourier transform of** $f(x)=e^{-\frac{x^2}{2}}$ **in** $(-\infty,\infty)$**. [M/J16]** BTL1 **(8 M)** **Answer : Page :4.57**- DR.A.SINGARAVELU • $F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(x)e^{isx}dx$ **(2 M)** • $F(s)=\frac{1}{\sqrt{2\pi}}e^{\frac{-s^2}{2}}\sqrt{2}\Gamma(1/2)=e^{\frac{-s^2}{2}}$ **(6 M)**
9	
	Find the Fourier sine transform of $f(x)=e^{-ax}$ **where** $a>0$ **and hence deduce that**

	$\int_0^\infty \frac{s\sin sx}{a^2+s^2}\,ds=\frac{\pi}{2}e^{-ax}$. BTL1 **(8 M)** **Answer : Page :4.14-** DR.A.SINGARAVELU • $f(x)=\frac{2}{\pi}\int_0^\infty \sin sx\int_0^\infty f(t)\sin st\,dt\,ds$ **(2 M)** • $\int_0^\infty \frac{s\sin sx}{a^2+s^2}\,ds=\frac{\pi}{2}e^{-ax}$ **(6 M)**
10	
	Evaluate $\int_0^\infty \frac{dx}{(x^2+a^2)(x^2+b^2)}$ **using Fourier cosine transforms of** e^{-ax} **and** e^{-bx}**.** **[N/D10 , A/M11, N/D14,N/D15,M/J16].** BTL1 **(8 M)** **Answer :Page :4.47- DR.A.SINGARAVELU** • $F_c(s)=\sqrt{\frac{2}{\pi}}\int_0^\infty f(x)\cos sx\,dx$ **(2 M)** • $F_c(\mathrm{e}^{-ax})=\sqrt{\frac{2}{\pi}}\left[\frac{a}{a^2+s^2}\right]$ $F_c(\mathrm{e}^{-bx})=\sqrt{\frac{2}{\pi}}\left[\frac{b}{a^2+s^2}\right]$ **(2 M)** • $\int_0^\infty \frac{dx}{(x^2+a^2)(x^2+b^2)}=\frac{\pi}{2ab(a+b)}$ **(4 M)**
11	
	Find the Fourier cosine transform of $f(x)=e^{-ax}$ $(a>0)$ **and using Parseval's identity for cosine transform evaluate** $\int_0^\infty \frac{dx}{(a^2+x^2)^2}$ **.[M/J13,N/D13]** BTL1 **(8 M)** **Answer :Page :4.48- DR.A.SINGARAVELU** • $F_c(s)=\sqrt{\frac{2}{\pi}}\int_0^\infty f(x)\cos sx\,dx$ **(2 M)** • $F_c(\mathrm{e}^{-ax})=\sqrt{\frac{2}{\pi}}\left[\frac{a}{a^2+s^2}\right]$ **(2 M)** • $\int_0^\infty \frac{dx}{(x^2+a^2)^2}=\frac{\pi}{4a^3}$ **(4 M)**
12	
	State and prove convolution theorem for Fourier transforms. [N/D11 , M/J12].BTL1 **(8 M)** **Answer : Page :4.25- DR.A.SINGARAVELU**

	• $If\ F(f(x)) = F(s)\ and\ F(g(x)) = G(s)\ then$ $F(f(x)*g(x)) = F(f(x))*F(g(x))$ **(2 M)** • $F(s) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$ **(2 M)** • For Proving $F(f(x)*g(x)) = F(f(x))*F(g(x))$ **(4 M)**
13	
	Derive the Parseval's identity for Fourier transforms. [N/D10 , M/J12]. BTL1 **(8 M)** **Answer : Page :4.26- DR.A.SINGARAVELU** $If\ f(x) is\ a\ given\ function\ defined\ in\ (-\infty,\infty) then$ • $\int_{-\infty}^{\infty} \lvert F(s)\rvert^2 ds = \int_{-\infty}^{\infty} \lvert f(x)\rvert^2 dx$ **(2 M)** • $F(s) = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$ **(2 M)** • For Proving $\int_{-\infty}^{\infty} \lvert F(s)\rvert^2 ds = \int_{-\infty}^{\infty} \lvert f(x)\rvert^2 dx$ **(4 M)**

	UNIT-V - Z-TRANSFORM AND DIFFERENCE EQUATIONS
	Z-Transform,Elementry Properties,Inverse Z-Transform using Partial Fraction and Residues Convolution Theorem,Formation of Difference equations,Solution of Difference Equations
Q.No	**PART*A**
1	**Define Z-transform of the sequence** $\{f(n)\}$ **.** BTL1 Let $\{f(n)\}$ be a sequence defined for $n = 0, \pm 1, \pm 2, \ldots\ldots\ldots \ \ldots$, then the two-sided Z-transform of the sequence $f(n)$ is defined as $Z\{f(n)\} = F[z] = \sum_{n=-\infty}^{\infty} f(n) z^{-n}$, where z is a complex variable. If $\{f(n)\}$ is a casual sequence, then the z-transform reduces to one-sided Z-transform and its definition is $Z\{f(n)\} = F[z] = \sum_{n=0}^{\infty} f(n) z^{-n}$.
2	**State the final value theorem in Z-transform.[*N/D15*]** BTL1 If $Z[f(t)] = F[z]$, then $\lim_{t \to \infty} f(t) = \lim_{z \to 1} (z-1) F[z]$.
3	**Find** $Z\{n\}$ **.[M/J13 , *N/D14*]** BTL1 $Z\{n\} = \sum_{n=0}^{\infty} n z^{-n} = \sum_{n=0}^{\infty} \frac{n}{z^{n}}$ $= 0 + \frac{1}{z} + \frac{2}{z^{2}} + \frac{3}{z^{3}} + \ldots\ldots\ldots \ \ldots$ $= \frac{1}{z}\left[1 + \frac{2}{z} + \frac{3}{z^{2}} + \ldots\ldots\ldots\right] = \frac{1}{z}\left[1 + 2\left(\frac{1}{z}\right) + 3\left(\frac{1}{z}\right)^{2} + \ldots\ldots\ldots\right]$ $= \frac{1}{z}\left[1 - \frac{1}{z}\right]^{-2} = \frac{1}{z}\left[\frac{z-1}{z}\right]^{-2} = \frac{1}{z} \cdot \frac{z^{2}}{(z-1)^{2}} = \frac{z}{(z-1)^{2}}$ $Z\{n\} = \frac{z}{(z-1)^{2}}$.
4	**If** $Z\{n^{2}\} = \frac{z^{2}+z}{(z-1)^{3}}$**, then find** $Z\{(n+1)^{2}\}$**. [M/J16]** BTL1 $Z\{(n+1)^{2}\} = Z\{n^{2} + 2n + 1\} = Z[n^{2}] + 2Z[n] + Z[1]$ $= \frac{z^{2}+z}{(z-1)^{3}} + 2\frac{z}{(z-1)^{2}} + \frac{z}{z-1}$.
5	**Find** $Z\{(\cos\theta + i\sin\theta)^{n}\}$**. [*M/J16*]** BTL1 $Z\{(\cos\theta + i\sin\theta)^{n}\} = Z\{\cos n\theta + i\sin n\theta\}$ $= Z\{\cos n\theta\} + i Z\{\sin n\theta\} = \frac{z(z - \cos\theta)}{z^{2} - 2z\cos\theta + 1} + i\frac{z\sin\theta}{z^{2} - 2z\cos\theta + 1}$.

6	**State damping rule related to Z-transform and then find** $Z\left(n\,a^n\right)$**. [M/J16]** BTL1 Damping rule: If $Z[\,f(n)\,] = F[z]$, then $Z\left[a^n\ f(n)\right] = Z[\,f(n)]_{z\to\frac{z}{a}}$ $Z\left[n\,a^n\ \right] = Z\left[a^n\,.\,n\right] = \left(Z\,[n]\right)_{z\to\frac{z}{a}}$ $= \left(\frac{z}{(z-1)^2}\right)_{z\to\frac{z}{a}} = \frac{\left(\frac{z}{a}\right)}{\left(\frac{z}{a}-1\right)^2} = \frac{\left(\frac{z}{a}\right)}{\left(\frac{z-a}{a}\right)^2} = \frac{\left(\frac{z}{a}\right)}{\frac{(z-a)^2}{a^2}} = \frac{a\,z}{(z-a)^2}$.
7	**Find** $Z\left\{\frac{1}{n}\right\}$ **.[N/D13]** BTL1 $Z\left\{\frac{1}{n}\right\} = \sum_{n=0}^{\infty}\frac{1}{n}z^{-n} = \sum_{n=1}^{\infty}\frac{1}{n\,z^n}$ $= \frac{1}{z}+\frac{1}{2\,z^2}+\frac{1}{3\,z^3}+ ....\ \ ...$ $= \frac{\left(\frac{1}{z}\right)}{1}+\frac{\left(\frac{1}{z}\right)^2}{2}+\frac{\left(\frac{1}{z}\right)^3}{3}+ ....\ .$ $= -\log\left(1-\frac{1}{z}\right) = -\ \log\left(\frac{z-1}{z}\right) = \log\left(\frac{z-1}{z}\right)^{-1} = \log\left(\frac{z}{z-1}\right)$ $Z\left\{\frac{1}{n}\right\} = \log\left(\frac{z}{z-1}\right)$.
8	**Find the Z-transform of** $\frac{1}{n+1}$ **.[A/M15,*N/D15*]** BTL1 $Z\left[\frac{1}{n+1}\right] = \sum_{n=0}^{\infty}\frac{1}{n+1}z^{-n} = \sum_{n=0}^{\infty}\frac{\left(\frac{1}{z}\right)^n}{n+1} = 1+\frac{\left(\frac{1}{z}\right)}{2}+\frac{\left(\frac{1}{z}\right)^2}{3}+ ....\ \ .$ $= \frac{z}{z}\left[1+\frac{\left(\frac{1}{z}\right)}{2}+\frac{\left(\frac{1}{z}\right)^2}{3}+ ....\right] = z\left[\frac{\left(\frac{1}{z}\right)}{1}+\frac{\left(\frac{1}{z}\right)^2}{2}+\frac{\left(\frac{1}{z}\right)^3}{3}+ ....\right]$ $= z\left[-\log\left(1-\frac{1}{z}\right)\right] = z\left[-\log\left(\frac{z-1}{z}\right)\right] = z\left[\log\left(\frac{z-1}{z}\right)^{-1}\right] = z\log\left(\frac{z}{z-1}\right)$.
9	**Find** $Z\left\{\frac{a^n}{n\,!}\right\}$ **in Z-transform. [N/D 09 , M/J 12].** BTL1

	$Z\left\{\frac{a^n}{n!}\right\} = \sum_{n=0}^{\infty}\frac{a^n}{n!}z^{-n} = \sum_{n=0}^{\infty}\frac{a^n}{n!\,z^n} = \sum_{n=0}^{\infty}\frac{\left(\frac{a}{z}\right)^n}{n!}$ $= 1+\frac{\left(\frac{a}{z}\right)}{1!}+\frac{\left(\frac{a}{z}\right)^2}{2!}+\frac{\left(\frac{a}{z}\right)^3}{3!}+\dots\dots\dots\ \dots = e^{\frac{a}{z}}$ **.**
10	**Find the Z-transform of $\frac{1}{n!}$. [N/D11,*M/J16*]** BTL1 $Z\left\{\frac{1}{n!}\right\} = \sum_{n=0}^{\infty}\frac{1}{n!}z^{-n} = \sum_{n=0}^{\infty}\frac{1}{n!\,z^n} = \sum_{n=0}^{\infty}\frac{\left(\frac{1}{z}\right)^n}{n!}$ $= 1+\frac{\left(\frac{1}{z}\right)}{1!}+\frac{\left(\frac{1}{z}\right)^2}{2!}+\frac{\left(\frac{1}{z}\right)^3}{3!}+\dots\dots\dots\ \dots = e^{\frac{1}{z}}$**.**
11	**Find the Z-transform of 3^n.** BTL1 $Z\{3^n\} = \sum_{n=0}^{\infty}3^n z^{-n} = \sum_{n=0}^{\infty}\frac{3^n}{z^n} = \sum_{n=0}^{\infty}\left(\frac{3}{z}\right)^n$ $= 1+\frac{3}{z}+\left(\frac{3}{z}\right)^2+\left(\frac{3}{z}\right)^3+\dots\dots\dots\ \dots\dots = \left(1-\frac{3}{z}\right)^{-1} = \left(\frac{z-3}{z}\right)^{-1} = \frac{z}{z-3}$
12	**Find the Z-transform of a^n. [A/M11,N/D12].** BTL1 $Z\{a^n\} = \sum_{n=0}^{\infty}a^n z^{-n} = \sum_{n=0}^{\infty}\frac{a^n}{z^n} = \sum_{n=0}^{\infty}\left(\frac{a}{z}\right)^n$ $= 1+\frac{a}{z}+\left(\frac{a}{z}\right)^2+\left(\frac{a}{z}\right)^3+\dots\dots\dots\ \dots\dots$ $= \left(1-\frac{a}{z}\right)^{-1} = \left(\frac{z-a}{z}\right)^{-1} = \frac{z}{z-a}$
13	**Find the Z-transform of $(n+1)(n+2)$.** BTL1 $Z\,[(n+1)(n+2)] = Z\,[n^2+3n+2]$ $= Z\,[n^2]+3\,Z\,[n]+2\,Z\,[1]$ $= \frac{z\,(z+1)}{(z-1)^3}+\frac{3\,z}{(z-1)^2}+\frac{2\,z}{z-1}$
14	**Find** $= \left[\frac{z}{z-1}\right]_{z\to ze^{iaT}} = \frac{z\,e^{iaT}}{z\,e^{iaT}-1}$ $Z\,[e^{-iat}]$ **using Z-transform.** BTL1 $Z\left[e^{-iat}\right] = Z\left[e^{-iat}.1\right] = \left[Z\,(1)\right]_{z\to ze^{iaT}}$
15	**Find $Z\left[e^t\sin\ 2t\right]$. [N/D15]** BTL1

	$Z\left[e^{t}\sin 2t\right] = Z\left[\sin 2t\right]_{z\to ze^{-T}} = \left[\frac{z\sin 2T}{z^{2} - 2z\cos 2T + 1}\right]_{z\to ze^{-T}}$ $Z\left[e^{t}\sin 2t\right] = \frac{ze^{-T}\sin 2T}{z^{2}e^{-2T} - 2ze^{-T}\cos 2T + 1}$
16	**If** $F(z) = \frac{z^{2}}{\left(z-\frac{1}{2}\right)\left(z-\frac{1}{4}\right)\left(z-\frac{3}{4}\right)}$**, find** $f(0)$**. [N/D09].** BTL1 Given $F(z) = \frac{z^{2}}{\left(z-\frac{1}{2}\right)\left(z-\frac{1}{4}\right)\left(z-\frac{3}{4}\right)}$ By initial value theorem , we have $f(0) = \lim_{z\to\infty} F(z) = \lim_{z\to\infty}\frac{z^{2}}{\left(z-\frac{1}{2}\right)\left(z-\frac{1}{4}\right)\left(z-\frac{3}{4}\right)}$ $= \lim_{z\to\infty}\frac{z^{2}}{z\left(1-\frac{1}{2z}\right).z\left(1-\frac{1}{4z}\right)\left(z-\frac{3}{4}\right)}$ $= \lim_{z\to\infty}\frac{1}{\left(1-\frac{1}{2z}\right)\left(1-\frac{1}{4z}\right)\left(z-\frac{3}{4}\right)} = \frac{1}{\infty} = 0\cdot$
17	**Find the inverse Z-transform of** $\frac{z}{(z+1)^{2}}$**. [N/D13]** BTL1 Let $X(z) = \frac{z}{(z+1)^{2}}$ $X(z)z^{n-1} = \frac{z\ .\ z^{n-1}}{(z+1)^{2}} = \frac{z^{n}}{(z+1)^{2}}$ $z = -1$ is a pole of order 2 $x(n) = \sum R$ where $\sum R$ is the sum of residue of $X(z)z^{n-1}$ Re $s\left[X(z)z^{n-1}\right] = \lim_{z\to -1}\frac{1}{(2-1)!}\frac{d}{dz}\left[(z+1)^{2}\frac{z^{n}}{(z+1)^{2}}\right] = \lim_{z\to -1}\frac{d}{dz}\left[z^{n}\right] = \lim_{z\to -1} nz^{n-1}$ $= n(-1)^{n-1} = -n(-1)^{n}$.
18	**State convolution theorem of Z-transform. [M/J14,A/M15,*A/M15*,*N/D16*]** BTL1 If $w(n)$ is the convolution of two sequences $x(n)$ and $y(n)$, then $Z[w(n)] = W(z) = Z[x(n)]\ .\ Z[y(n)]$.
19	**Form a difference equation by eliminating arbitrary constant from** $u_{n} = A2^{n+1}$**. [N/D11,N/D15].** BTL1 Given $u_{n} = A2^{n+1}$

	$u_n = A2^n.2$ $u_n = 2A2^n$ ....(1) $u_{n+1} = A2^{n+2}$ $u_{n+1} = A2^n.2^2$ $u_{n+1} = 4A2^n$ ....(2) Eliminating A from (1) and (2), we have $\begin{vmatrix} u_n & 2 \\ u_{n+1} & 4 \end{vmatrix} = 0 \Rightarrow 4u_n - 2u_{n+1} = 0 \Rightarrow u_{n+1} - 2u_n = 0$.
20	**Form the difference equation generated by $y_n = a + b2^n$. [A/M10].** BTL1 Given $y_n = a + b2^n$ --------------------(1) $y_{n+1} = a + b2^{n+1} = a + b2^n 2$ $y_{n+1} = a + 2b2^n$ ---------------(2) $y_{n+2} = a + b2^{n+2} = a + b2^n 4$ $y_{n+2} = a + 4b2^n$ ---------------(3) Eliminating a and b from (1) , (2) and (3) , we have $\begin{vmatrix} y_n & 1 & 1 \\ y_{n+1} & 1 & 2 \\ y_{n+2} & 1 & 4 \end{vmatrix} = 0$ $y_n(4-2) - y_{n+1}(4-1) + y_{n+2}(2-1) = 0$ $2y_n - 3y_{n+1} + y_{n+2} = 0$ $y_{n+2} - 3y_{n+1} + 2y_n = 0$
21	**Solve $y(n+1) - 2y(n) = 0$ given $y(0) = 2$. [N/D12]** BTL1 Given $y(n+1) - 2y(n) = 0$ Taking Z-transform on both sides of the above equation, we have $z[y(n+1)] - 2Z[y(n)] = 0$ $zY(z) - zy(0) - 2Y(z) = 0$ $zY(z) - z(2) - 2Y(z) = 0$ $(z-2)Y(z) = 2z$ $Y(z) = \frac{2z}{z-2}$ implies $Z[y(n)] = \frac{2z}{z-2}$ $y(n) = 2Z^{-1}\left[\frac{z}{z-2}\right] = 2.2^n = 2^{n+1}$.
22	**Define unit step sequence. Write its Z-transform.** BTL1 The unit step sequence $u(n)$ is defined as $u(n) = \begin{cases} 1 & for\ n \geq 0 \\ 0 & for\ n < 0 \end{cases}$. Its Z-transform is given by

	$Z[u(n)] = \frac{z}{z-1}$.
23	**Find the Z-transform of** n^2**. [M/J14]** BTL1 $Z[n^2] = Z[n.n] = -z\frac{d}{dz}Z[n] = -z\frac{d}{dz}\left[\frac{z}{(z-1)^2}\right]$ $= -z\left[\frac{(z-1)^2(1) - z.2(z-1)}{(z-1)^4}\right] = -z\left[\frac{(z-1)(z-1-2z)}{(z-1)^4}\right]$ $= -z\left[\frac{-z-1}{(z-1)^3}\right] = \frac{z(z+1)}{(z-1)^3}$.
24	**Prove that** $Z[a^n f(n)] = \bar{f}\left(\frac{z}{a}\right)$**. [N/D14] (OR) If** $Z(x(n)) = X(z)$**, then show that** $Z(a^n x(n)) = X\left(\frac{z}{a}\right)$**. [*A/M15*]** BTL1 By definition, $Z[a^n f(n)] = \sum_{n=0}^{\infty} a^n f(n) z^{-n} = \sum_{n=0}^{\infty} f(n)\frac{z^{-n}}{a^{-n}}$ $= \sum_{n=0}^{\infty} f(n)\left(\frac{z}{a}\right)^{-n} = \bar{f}\left(\frac{z}{a}\right)$.
25	**If** $Z[f(n)] = \bar{f}(z)$**, then prove that** $Z[f(-n)] = \bar{f}\left(\frac{1}{z}\right)$**. [N/D14]** BTL1 $Z[f(-n)] = \sum_{n=0}^{\infty} f(-n)z^{-n}$ $put\ -n = u \Rightarrow n = -u$ $n = 0 \ , \ u = 0 \quad and \quad n = \infty \ , \ u = \infty$ $Z[f(-n)] = \sum_{u=0}^{\infty} f(u)z^{-(-u)} = \sum_{u=0}^{\infty} f(u)(z^{-1})^{-u} = \sum_{u=0}^{\infty} f(u)\left(\frac{1}{z}\right)^{-u} = \sum_{n=0}^{\infty} f(n)\left(\frac{1}{z}\right)^{-n} = \bar{f}\left(\frac{1}{z}\right)$.
	PART * B
1	
	Find the Z-transform of $\frac{1}{n(n+1)(n+2)}$ **.[N/D13] (8 M)** BTL1 **Answer : Page :5.24- DR.A.SINGARAVELU** • $\frac{1}{n(n+1)(n+2)} = \frac{A}{n} + \frac{B}{(n+1)} + \frac{C}{(n+2)}$ **(2 M)** • $A = \frac{1}{2}; B = -1; C = \frac{1}{2}$ **(2 M)** • $Z\left[\frac{1}{n(n+1)(n+2)}\right] = \frac{1}{2}(z-1)^2\log\left(\frac{z}{z-1}\right) - \frac{z}{2}$ **(4 M)**

2	
	Find $Z\left[\frac{2n+3}{(n+1)(n+2)}\right]$ **. [N/D15] (8 M)** BTL1 **Answer : Page :5.23- DR.A.SINGARAVELU** • $\frac{2n+3}{(n+1)(n+2)} = \frac{A}{n+1} + \frac{B}{n+2}$ **(2 M)** • $A = 1; B = 1;$ **(2 M)** • $Z\left[\frac{2n+3}{(n+1)(n+2)}\right] = z^2 \log\left(\frac{z}{z-1}\right) - z$ **(4 M)**
3	
	Find $Z(\cos n\theta)$ **and** $Z(\sin n\theta)$**. [*N/D14*] (8 M)** BTL1 **Answer : Page :5.13- DR.A.SINGARAVELU** • $Z(a^n) = \frac{z}{z-a}$ **(2 M)** • $Z(\cos n\theta) = \frac{z(z-\cos\theta)}{z^2 - 2z\cos\theta + 1}$ $Z(\sin n\theta) = \frac{z(\sin\theta)}{z^2 - 2z\cos\theta + 1}$ **(6 M)**
4	
	Find $Z\left[e^{-t}t\right]$**. [*N/D16*] (8 M)** BTL1 **Answer : Page :5.42- DR.A.SINGARAVELU** • $Z(e^{-at} f(t)) = Z[f(t)]_{z \to ze^{aT}}$ **(2 M)** • $Z\left[e^{-t}t\right] = \frac{Tze^T}{(ze^T - 1)^2}$ **(6 M)**
5	
	Find $Z^{-1}\left[\frac{z^3}{(z-1)^2(z-2)}\right]$ **using partial fraction. (8 M)** BTL1 **Answer :Page :5.68- DR.A.SINGARAVELU** • $\frac{z^2}{(z-1)^2(z-2)} = \frac{A}{z-1} + \frac{B}{(z-1)^2} + \frac{C}{(z-2)}$ **(2 M)** • $A = -3; B = -1; C = 4$ **(2 M)** • $Z^{-1}\left[\frac{z^3}{(z-1)^2(z-2)}\right] = -3 - n + 2^{n+2}$ **(4 M)**
6	
	Find $Z^{-1}\left[\frac{z^2}{(z+2)(z^2+4)}\right]$ **by the method of partial fractions. (8 M)** BTL1

	Answer : Page :5.62- DR.A.SINGARAVELU • $\frac{z}{(z^2+4)(z+2)}=\frac{A}{z+2}+\frac{Bz+c}{(z^2+4)}$ **(2 M)** • $A=-\frac{1}{4};B=\frac{1}{4};C=\frac{1}{2}$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z^2+4)(z+2)}\right]=-\frac{1}{4}(-2)^n+\frac{1}{4}2^n\cos\frac{n\pi}{2}+\frac{1}{4}2^n\sin\frac{n\pi}{2}$ **(4 M)**
7	
	Find the inverse Z-transform of $\frac{10z}{z^2-3z+2}$. [N/D09]. (8 M) BTL1 **Answer : Page :5.70- DR.A.SINGARAVELU** • $\frac{1}{(z-1)(z-2)}=\frac{A}{z-1}+\frac{B}{(z-2)}$ **(2 M)** • $A=-1;B=1$ **(2 M)** $Z^{-1}\left[\frac{10z}{(z-1)(z-2)}\right]=10(2^n-1)$ **(4 M)**
8	
	Find the inverse Z-transform of $\frac{z^3-20z}{(z-2)^3(z-4)}$. [N/D09]. (8 M) BTL1 **Answer :Page :5.71- DR.A.SINGARAVELU** • $\frac{z^2-20}{(z-2)^3(z-4)}=\frac{A}{z-2}+\frac{B}{(z-2)^2}+\frac{C}{(z-2)^3}+\frac{D}{(z-4)}$ **(2 M)** • $A=\frac{1}{2};B=2;C=8;D=-\frac{1}{2}$ **(2 M)** • $Z^{-1}\left[\frac{z^3-20z}{(z-2)^3(z-4)}\right]=2^n(\frac{1}{2}+n^2)-\frac{4^n}{2}$ **(4 M)**
9	
	Find the inverse Z-transform of $\frac{z^2+z}{(z-1)(z^2+1)}$, using partial fraction.[*N/D14*] (8 M) BTL1 **Answer : Page :5.65- DR.A.SINGARAVELU** • $\frac{z+1}{(z^2+1)(z-1)}=\frac{A}{z-1}+\frac{Bz+c}{(z^2+1)}$ **(2 M)** • $A=1;B=-1;C=0$ **(2 M)** • $Z^{-1}\left[\frac{z^2+z}{(z^2+1)(z-1)}\right]=1-\cos\frac{n\pi}{2}$ **(4 M)**
10	

	Find the inverse Z-transform of $\frac{z(z+1)}{(z-1)^3}$ **by residue method. [N/D10]. (8 M)** BTL1 **Answer :Page :5.86- DR.A.SINGARAVELU** • $\left.\begin{array}{l} Res\ f(z) \\ @\ z=1\ of\ order\ 3 \end{array}\right\} = \frac{1}{2!}\underset{z\to1}{Lim}\left[\frac{d^2}{dz^2}(z-1)^3X(z)z^{n-1}\right]$ **(2 M)** • $Z^{-1}\left[\frac{z^2+z}{(z-1)^3}\right] = n^2$ **(6 M)**
11	
	Using residue method, find $Z^{-1}\left[\frac{z}{(z-1)(z-2)}\right]$ **. [*A/M15,M/J16*] (8 M)** BTL1 **Answer : Page :5.83- DR.A.SINGARAVELU** • $\left.\begin{array}{l} Res\ f(z) \\ @\ z=1\ of\ order1 \end{array}\right\} = \underset{z\to1}{Lim}\left[(z-1)X(z)z^{n-1}\right]$ $\left.\begin{array}{l} Res\ f(z) \\ @\ z=2\ of\ order1 \end{array}\right\} = \underset{z\to2}{Lim}\left[(z-2)X(z)z^{n-1}\right]$ **(2 M)** • $Z^{-1}\left[\frac{z}{(z-1)(z-2)}\right] = 2^n - 1$ **(6 M)**
12	
	Using convolution theorem Find $Z^{-1}\left[\frac{z^2}{(z+a)(z+b)}\right]$ **[M/J13,M/J14,A/M15,N/D15,*N/D16*] (8 M)** BTL1 **Answer : Page :5.79- DR.A.SINGARAVELU** • $Z^{-1}\left[\frac{z^2}{(z+a)(z+b)}\right] = Z^{-1}\left(\frac{z}{z+a}\right)Z^{-1}\left(\frac{z}{z+b}\right)$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z+a)(z+b)}\right] = (-a)^n * (-b)^n$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z-a)(z-b)}\right] = \frac{(-1)^n}{b-a}(b^{n+1} - a^{n+1})$ **(4 M)**
13	
	Using convolution theorem evaluate inverse Z-transform of $\left[\frac{z^2}{(z-1)(z-3)}\right]$**.** **[A/M11,N/D13]. (8 M)** BTL1 **Answer :Page :5.75- DR.A.SINGARAVELU** • $Z^{-1}\left[\frac{z^2}{(z-1)(z-3)}\right] = Z^{-1}\left(\frac{z}{z-1}\right)Z^{-1}\left(\frac{z}{z-3}\right)$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z-1)(z-3)}\right] = 1^n * 3^n$ **(2 M)**

	• $Z^{-1}\left[\frac{z^2}{(z-1)(z-3)}\right] = \frac{1}{2}(3^{n+1}-1)$ **(4 M)**
14	
	Using convolution theorem find $Z^{-1}\left[\frac{z^2}{(z+a)^2}\right]$**. [N/D12].** BTL1 **(8 M)** BTL1 **Answer : Page :5.76- DR.A.SINGARAVELU** • $Z^{-1}\left[\frac{z^2}{(z+a)^2}\right] = Z^{-1}\left(\frac{z}{z+a}\right)Z^{-1}\left(\frac{z}{z+a}\right)$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z+a)^2}\right] = (-a)^n * (-a)^n$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z+a)^2}\right] = (-a)^n(n+1)$ **(4 M)**
15	
	Find the inverse Z-transform of $\frac{8z^2}{(2z-1)(4z-1)}$ **by convolution theorem.** **[M/J12,N/D14] (8 M)** BTL1 **Answer : Page :5.77- DR.A.SINGARAVELU** • $Z^{-1}\left[\frac{8z^2}{(2z-1)(4z+1)}\right] = Z^{-1}\left(8\frac{z}{(2z-1)}\right)Z^{-1}\left(\frac{z}{(4z+1)}\right)$ **(2 M)** • $Z^{-1}\left[\frac{8z^2}{(2z-1)(4z+1)}\right] = \frac{2}{3}\left(\frac{1}{2}\right)^n + \frac{1}{3}\left(-\frac{1}{4}\right)^n$ **(6 M)**
16	
	Using convolution theorem, find $Z^{-1}\left[\frac{z^2}{(z-4)(z-3)}\right]$**. [N/D 09,*N/D15*]. (8 M)** BTL1 **Answer : Page :5.79- DR.A.SINGARAVELU** • $Z^{-1}\left[\frac{z^2}{(z-4)(z-3)}\right] = Z^{-1}\left(\frac{z}{z-4}\right)Z^{-1}\left(\frac{z}{z-3}\right)$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z-4)(z-3)}\right] = 4^n * 3^n$ **(2 M)** • $Z^{-1}\left[\frac{z^2}{(z-4)(z-3)}\right] = [(-3)^{n+1} - (-4)^{n+1}]$ **(4 M)**
17	
	Solve the difference equation $y(n+3) - 3y(n+1) + 2y(n) = 0$ **given that** $y(0) = 4$ **,** $y(1) = 0$ **and** $y(2) = 8$ **, by the method of Z-transform. [A/M11,N/D12,N/D14]. (8 M)** BTL1 **Answer :Page :5.121- DR.A.SINGARAVELU**

	$Z(y(n+3)) = Z^3Y(z) - Z^3\ y(0) - Z^2\ y(1) - Zy(2)$ • $Z(y(n+2)) = Z^2Y(z) - Z^2\ y(0) - Zy(1)$ **(2 M)** $Z(y(n+1)) = ZY(z) - Zy(0)$ • $y(n) = \frac{8}{3} + \frac{4}{3}(-2)^n$ **(6 M)**
18	
	Solve $y_{n+2} + 6y_{n+1} + 9y_n = 2^n$ **given** $y_0 = y_1 = 0$ **, using Z-transform. (8 M) [N/D09,N/D12,M/J16,*N/D16*].** BTL1 **Answer :Page :5.119- DR.A.SINGARAVELU** $Z(y(n+3)) = Z^3Y(z) - Z^3\ y(0) - Z^2\ y(1) - Zy(2)$ • $Z(y(n+2)) = Z^2Y(z) - Z^2\ y(0) - Zy(1)$ **(2 M)** $Z(y(n+1)) = ZY(z) - Zy(0)$ • $y(n) = \frac{1}{25}\left[2^n - (-3)^n + \frac{5}{3}n(-3)^n\right]$ **(6 M)**
19	
	Solve $y_{n+2} + 4y_{n+1} + 3y_n = 3^n$ **with** $y_0 = 0$ **and** $y_1 = 1$ **, using Z-transform. [N/D10,N/D15]. (8 M)** BTL1 **Answer :Page :5.114- DR.A.SINGARAVELU** $Z(y(n+3)) = Z^3Y(z) - Z^3\ y(0) - Z^2\ y(1) - Zy(2)$ • $Z(y(n+2)) = Z^2Y(z) - Z^2\ y(0) - Zy(1)$ **(2 M)** $Z(y(n+1)) = ZY(z) - Zy(0)$ • $y(n) = \frac{1}{24}(3)^n - \frac{5}{12}(-3)^n + \frac{3}{8}(-1)^n$ **(6 M)**
20	
	Using Z-transform solve $y_{n+2} - 7y_{n+1} + 12y_n = 0$ **,** $y_0 = 0$ **and** $y_1 = 0$ **.[M/J13 , M/J14] (8 M)** BTL1 **Answer : Page :5.106- DR.A.SINGARAVELU** $Z(y(n+3)) = Z^3Y(z) - Z^3\ y(0) - Z^2\ y(1) - Zy(2)$ • $Z(y(n+2)) = Z^2Y(z) - Z^2\ y(0) - Zy(1)$ **(2 M)** $Z(y(n+1)) = ZY(z) - Zy(0)$ • $y(n) = (2)^{n-1} - (3)^n + \frac{1}{2}(4)^n$ **(6 M)**
21	
	Form the difference equation whose solution is $y_n = (A + Bn)2^n$ **.[N/D13] (8 M)** BTL1 **Answer : Page :5.103- DR.A.SINGARAVELU**

	• $\begin{vmatrix} y_n & 1 & 2n \\ y_{n+1} & 2 & 2n+2 \\ y_{n+2} & 4 & 4n+8 \end{vmatrix} = 0$ **(4 M)** • $y_{n+2} - 4y_{n+1} + 4y_n = 0$ **(4 M)**
22	
	Derive the difference equation from $y_n = (A + Bn)(-3)^n$ **. [A/M11]. (8 M)** BTL1 **Answer : Page :5.119- DR.A.SINGARAVELU** • $\begin{vmatrix} y_n & 1 & 3n \\ y_{n+1} & -3 & -(3n+3) \\ y_{n+2} & 9 & 9n+18 \end{vmatrix} = 0$ **(4 M)** • $y_{n+2} + 6y_{n+1} + 9y_n = 0$ **(4 M)**
23	
	Form the difference equation from the relation $y_n = a + b3^n$ **. [N/D10]. (8 M)** BTL1 **Answer :Page :5.125 - DR.A.SINGARAVELU** • $\begin{vmatrix} y_n & 1 & 1 \\ y_{n+1} & 1 & 3 \\ y_{n+2} & 1 & 9 \end{vmatrix} = 0$ **(4 M)** • $y_{n+2} - 4y_{n+1} + 3y_n = 0$ **(4 M)**

REGULATION :2017 **ACADEMIC YEAR : 2018-2019**

EE8351 **DIGITAL LOGIC CIRCUITS** **L T P C**

2 2 0 3

OBJECTIVES:

- To study various number systems and simplify the logical expressions using Boolean functions.
- To study combinational circuits.
- To design various synchronous and asynchronous circuits.
- To introduce asynchronous sequential circuits and PLDs.
- To introduce digital simulation for development of application oriented logic circuits.

UNIT I NUMBER SYSTEMS AND DIGITAL LOGIC FAMILIES **6+6**

Review of number systems, binary codes, error detection and correction codes (Parity and Hamming code) - Digital Logic Families - comparison of RTL, DTL, TTL, ECL and MOS families -operation, characteristics of digital logic family.

UNIT II COMBINATIONAL CIRCUITS **6+6**

Combinational logic - representation of logic functions-SOP and POS forms, K-map representations - minimization using K maps - simplification and implementation of combinational logic – multiplexers and de multiplexers - code converters, adders, subtractors, Encoders and Decoders.

UNIT III SYNCHRONOUS SEQUENTIAL CIRCUITS **6+6**

Sequential logic- SR, JK, D and T flip flops - level triggering and edge triggering - counters -asynchronous and synchronous type - Modulo counters - Shift registers - design of synchronous sequential circuits – Moore and Melay models- Counters, state diagram; state reduction; state assignment.

UNIT IV ASYNCHRONOUS SEQUENTIAL CIRCUITS AND PROGRAMMABILITY LOGIC DEVICES 6+6

Asynchronous sequential logic circuits-Transition tability, flow tability-race conditions, hazards &errors in digital circuits; analysis of asynchronous sequential logic circuits introduction to Programmability Logic Devices: PROM – PLA –PAL, CPLD-FPGA.

UNITV VHDL **6+6**

RTL Design – combinational logic – Sequential circuit – Operators – Introduction to Packages – Subprograms – Test bench. (Simulation /Tutorial Examples: adders, counters, flip flops, Multiplexers & De multiplexers).

TOTAL (L:45+T:15): 60 PERIODS

OUTCOMES:

- Ability to design combinational and sequential Circuits.
- Ability to simulate using software package.
- Ability to study various number systems and simplify the logical expressions using Boolean functions

- Ability to design various synchronous and asynchronous circuits.
- Ability to introduce asynchronous sequential circuits and PLDs.
- Ability to introduce digital simulation for development of application oriented logic circuits.

TEXT BOOKS:

1. James W. Bignel, Digital Electronics, Cengage learning, 5th Edition, 2007.
2. M. Morris Mano, 'Digital Design with an introduction to the VHDL', Pearson Education, 2013.
3. Comer "Digital Logic & State Machine Design, Oxford, 2012.

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1. Mandal, "Digital Electronics Principles & Application, McGraw Hill Edu, 2013.
2. William Keitz, Digital Electronics-A Practical Approach with VHDL, Pearson, 2013.
3. Thomas L.Floyd, 'Digital Fundamentals', 11th edition, Pearson Education, 2015.
4. Charles H.Roth, Jr, Lizy Lizy Kurian John, 'Digital System Design using VHDL, Cengage, 2013.
5. D.P.Kothari,J.S.Dhillon, 'Digital circuits and Design',Pearson Education, 2016.

REGULATION :2017 **ACADEMIC YEAR : 2018-2019**

Subject Code : EE 8351 **Year/Sem: II/03**
Subject Name : Digital Logic Circuits **Subject Handler: Mrs. L. Pattathurani**

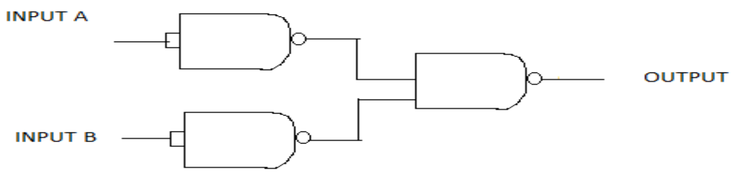
UNIT I NUMBER SYSTEMS AND DIGITAL LOGIC FAMILIES

Review of number systems, binary codes, error detection and correction codes (Parity and Hamming code) - Digital Logic Families -comparison of RTL, DTL, TTL, ECL and MOS families -operation, characteristics of digital logic family.

PART * A

Q.No.	Questions
1.	**What is meant by parity bit?** BTL1 A parity bit is an extra bit included with a message to make the total number of 1's either even or odd. Consider the following two characters and their even and odd parity: With even parity with odd parity ASCII A = 1000001 01000001 11000001, ASCII T = 1010100 11010100 01010100. In each case we add an extra bit in the left most position of the code to produce an even number of 1's in the character for even parity or an odd number of 1's in the character for odd parity. The parity bit is helpful in detecting errors during the transmission of information from one location to another.
2.	**Define binary logic.** BTL1 Binary logic consists of binary variables and logical operations. The variables are designated by the alphabets such as A, B, C, x, y, z, etc., with each variable having only two distinct values: 1 and 0. There are three basic logic operations: AND, OR, and NOT.
3.	**Define are logic gates.**BTL1 Logic gates are electronic circuits that operate on one or more input signals to produce an output signal. Electrical signals such as voltages or currents exist throughout a digital system in either of two recognizable values. Voltage- operated circuits respond to two separate voltage levels that represent a binary variable equal to logic 1 or logic 0.
4.	**State duality property.** BTL1 Duality property states that every algebraic expression deducible from the postulates of Boolean algebra remains valid if the operators and identity elements are interchanged. If the dual of an algebraic expression is desired, we simply interchange OR and AND operators and replace 1's by 0's and 0's by 1's.
5.	**Reduce $A'B'C' + A'BC' + A'BC$.** BTL3 $A'B'C' + A'BC' + A'BC = A'C'(B' + B) + A'B'C = A'C' + A'BC$ [$A + A' = 1$] $= A' (C' + BC) = A' (C' + B)$ [$A + A'B = A + B$]
6.	**Reduce $AB + (AC)' + AB'C (AB + C)$.** BTL3 $AB + (AC)' + AB'C (AB + C) = AB + (AC)' + AAB'BC + AB'CC$ $= AB + (AC)' + AB'CC$ [$A.A' = 0$] $= AB + (AC)' + AB'C$ [$A.A = 1$] $= AB + A' + C' =AB'C$ [$(AB)' = A' + B'$] $= A' + B + C' + AB'C$ [$A + AB' = A + B$] $= A' + B'C + B + C'$ [$A + A'B = A + B$] $= A' + B + C' + B'C$ $=A' + B + C' + B'$

	=A’ + C’ + 1 = 1 [A + 1 =1]
7.	**Simplify the following expression Y = (A + B) (A + C’)(B’ + C’).** BTL3 Y = (A + B) (A + C’) (B’ + C’) = (AA’ + AC +A’B +BC) (B’ + C’) [A.A’ = 0] = (AC + A’B + BC) (B’ + C’) = AB’C + ACC’ + A’BB’ + A’BC’ + BB’C + BCC’ = AB’C + A’BC’
8.	**Show that (X + Y’ + XY)(X + Y’)(X’Y) = 0.** BTL3 (X + Y’ + XY)(X + Y’)(X’Y) = (X + Y’ + X) (X + Y’) (X’ + Y) [A + A’B = A + B] = (X + Y’) (X + Y’)(X’Y) [A + A = 1] = (X + Y’) (X’Y) [A.A = 1] = X.X’ + Y’.X’.Y = 0 [A.A’ = 0]
9.	**Prove that ABC + ABC’ + AB’C + A’BC = AB + AC + BC.** BTL3 ABC + ABC’ + AB’C + A’BC =AB (C + C’) + AB’C + A’BC =AB + AB’C + A’BC =A(B + B’C) + A’BC =A(B + C) + A’BC =AB + AC + A’BC =B(A + C) + AC =AB + BC + AC =AB + AC +BC ...Proved
10.	**Convert the given expression in canonical SOP form Y = AC + AB + BC.** BTL3 Y = AC + AB + BC =AC (B + B’) + AB(C + C’) + (A + A’)BC =ABC + ABC’ + AB’C + AB’C’ + ABC + ABC’ + ABC =ABC + ABC’ +AB’C + AB’C’ [A + A =1]
11.	**Convert the given expression in canonical POS form Y = (A + B)(B + C)(A + C).** BTL3 Y = (A + B)(B + C)(A + C) = (A + B + C.C’)(B + C + A.A’)(A + B.B’ + C) = (A + B + C)(A + B + C’)(A + B +C)(A’ + B +C)(A + B + C)(A + B’ + C) [A + BC = (A + B)(A + C) Distributive law] = (A + B + C)(A + B + C’)(A’ + B + C)(A’ + B + C)(A + B’ + C)
12.	**List the steps in implementing a Boolean function with levels of NAND Gates.** BTL2 ➢ Simplify the function and express it in sum of products. ➢ Draw a NAND gate for each product term of the expression that has at least two literals. The inputs to each NAND gate are the literals of the term. ➢ Draw a single gate using the AND-invert or the invert-OR graphic symbol in the second level, with inputs coming from outputs of first level gates. ➢ A term with a single literal requires an inverter in the first level. However if the single literal is complemented, it can be connected directly to an input of the second level NAND gate.
13.	**What is overflow?. How can it be deducted?** BTL1 Over flow is a problem in digital computers. The number of bits that hold the number is finite and a result that contains n + 1 bits cannot be accommodated. For this reason many computers detect the occurrence of an overflow, and when it occurs a corresponding flip flop is set that can be checked by the user.

	An overflow condition can be detected by observing the carry into sign bit position and the carry out of the sign bit position. If these two carries are not equal, an overflow has occurred.
14.	**Write the names of Universal gates. Why is it so called?** BTL1 The NAND and NOR gates are known as universal gates, since any logic function can be implemented using NAND or NOR gates.
15.	**Construct OR gate using NAND gates.(AU MAY 2013)** BTL3 
16.	**Binary to Decimal conversion.** BTL2 1.$10101_2 = 10101B = 1×2^4+0×2^3+1×2^2+0×2^1+1×2^0 = 16+4+1= 21$ 2.$10111_2 = 10111B = 1×2^4+0×2^3+1×2^2+1×2^1+1×2^0 = 16+4+2+1= 23$ 3.$100011_2 = 100011B = 1×2^5+0×2^4+0×2^3+0×2^2+1×2^1+1×2^0=32+2+1= 35$
17.	**Octal to Decimal conversion.** BTL2 1. $27_8 = 2×8^1+7×8^0 = 16+7 = 23$ 2. $30_8 = 3×8^1+0×8^0 = 24$ 3. $4307_8 = 4×8^3+3×8^2+0×8^1+7×8^0= 2247$
18.	**What is the advantage of using Schottky TTL gate?** BTL1 The junction of the transistor is prevented from heavy forward bias when it is turned ON and hence the transistor is kept out of deep / hard saturation. This has been achieved by connecting a diode across the base-to-collector junction of the transistor. Otherwise, the deep saturation would cause surplus of carriers to be stored in the base region of the transistor which causes increased propagation delay. The diode used here is the schottky diode that has very little junction capacitance and fast recovery time.
19.	**Mention the classification of saturated bipolar logic families.** BTL1 The bipolar logic family is classified as follows: 1. RTL- Resistor Transistor Logic 2. DTL- Diode Transistor logic 3. I2L- Integrated Injection Logic 4. TTL- Transistor Transistor Logic 5. ECL- Emitter Coupled Logic
20.	**Mention the important characteristics of digital IC's.** BTL1 1. Fan out 2. Power dissipation 3. Propagation Delay 4. Noise Margin 5. Fan In 6. Operating temperature
21.	**Define Fan in and Fan out.** BTL1

	Fan out specifies the number of standard loads that the output of the gate can drive with out impairment of its normal operation. Fan in is the number of inputs connected to the gate without any degradation in the voltage level.
22.	**How schottky transistors are formed and state its use?** BTL1 A schottky diode is formed by the combination of metal and semiconductor. The presence of schottky diode between the base and the collector prevents the transistor from going into saturation. The resulting transistor is called as schottky transistor. The use of schottky transistor in TTL decreases the propagation delay without a sacrifice of power dissipation.
23.	**State advantages and disadvantages of TTL.** BTL1 **Advantages:** 1. Easily compatible with other ICs. 2. Low output impedance. **Disadvantages:** 1. Wired output capability is possible both tristate and open collector types. 2. Special circuits in Circuit layout and system design.
24.	**State De Morgan's theorem. (A.U.MAY-2011)** BTL1 De Morgan suggested two theorems that form important part of Boolean algebra. They are, 1) The complement of a product is equal to the sum of the complements. (AB)' = A' + B' 2) The complement of a sum term is equal to the product of the complements. (A + B)' = A'B'
25.	**What is a unit distance code? (Nov/Dec 2015) BTL1** The Gray code is a single-step code (i.e. a unit-distance code). It's often used in analog/digital conversion devices. Adjacent code patterns of Gray code differ in just only one bit to avoid ambiguity, i.e. consecutive code elements have a hamming distance of one.
26.	**Define Propagation delay**. BTL1 The Propagation delay of a gate is basically the time interval between the application of an input pulse and occurrence of the resulting output pulse.
	PART * B
1.	**State the postulates and theorems of Boolean algebra. (13M) (May 2008)**.BTL1 **Answer : Page 1.2 - Godse** ➢ **Postulates (9M)** 1.A + 0 = A A · 1 = A identity 2.A + $^{\text{NOT}}$[A] = 1 A · $^{\text{NOT}}$[A] = 0 complement 3.**Commutative Property:** For every a and b in K, a + b = b + a a. b = b . a 4.**Associative Property:**

	For every a, b, and c in K, $a + (b + c) = (a + b) + c$ $a. (b. c) = (a. b). c$ 5.**Distributive Property**: For every a, b, and c in K, $a + (b. c) = (a + b). (a + c)$ $a. (b + c) = (a . b) + (a . c)$ ➢ **Demorgan's theorems (4M)** **A key theorem in simplifying Boolean algebra expression is DeMorgan's Theorem. It states:** **1.$(a + b)' = a'b'$** **2. $(ab)' = a' + b'$**
2.	**Deduce the odd parity hamming code for the data : 1010. Introduce an error in the LSB of the hamming code and deduce the steps to detect the error. (13M) (May 16)** BTL3 **Answer : Page 1.51 - Godse** ➢ **Procedure (5M)** 1. Bit locations 3, 5 & 7 have two ones an odd parity P1 must be 1. 2. Bit locations 3, 6 & 7 have single one an odd parity P2 must be 0. 3. Bit locations 5, 6 & 7 have two ones an odd parity P4 must be 1. 4. Hamming code **1011001.** ➢ **Error checking (5M)** 1. P1 check locations 1, 3, 5 & 7 have two one's, Parity check for odd parity wrong…..1(LSB). 2. P2 check locations 2, 3, 6 & 7 have single one ,Parity check for odd parity correct…..0. 3. P4 check locations 4, 5, 6 & 7 have single one ,Parity check for odd parity correct…..0. ➢ **Correct word is 0 0 1**, bit **number 1 location is in error (3M)**
3.	**Detect and correct error in the following received even parity hamming code 0 0 1 1 1 1 0 1 0 1 0.Also find out the correct message. (13M)** BTL3

Answer : Page 1.52 - Godse

- **Find no. of parity bits and information bits (2M)**

  1. X+P=11, P=4.

  2. For given hamming code 7 information bits and 4 parity bits.

- **Construct bit location table (4M)**
- **Check parity bits (5M)**

  1. P1 check locations 1, 3,5,7,9 & 11 have two ones, Parity check for even parity correct…..0(LSB).

  2. P2 check locations 2, 3, 6,7,10 & 11 have three one's, Parity check for even parity wrong…..1.

  3. P4 check locations 4, 5, 6 & 7 have three one's, Parity check for even parity wrong…..1.

  4. P8 check locations 8,9,10 & 11 have two one's, Parity check for even parity correct…..0.

- **The resultant word is 0 1 1 0, bit 6 location is an error. Correct message is 0 0 1 1 1 0 0 1 0 1 0 (2M)**

4.

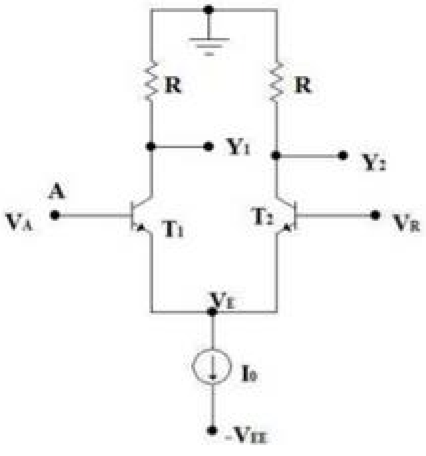
Explain the basic working principles of ECL logic families. (13M) BTL3

Answer : Page 7.6 - Godse

- **Definition of ECL(2M)**

  1. Increasing overall speed by using different structure called current mode logic, also called as Emitter coupled circuit.

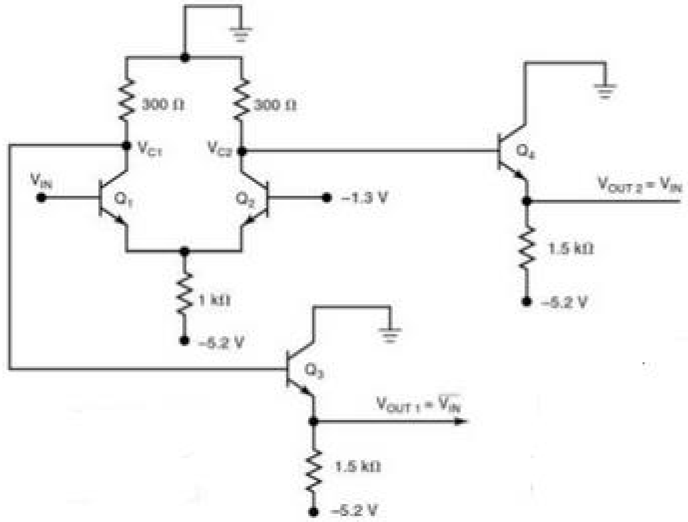
- **Basic structure of ECL(4M)**



1. When input high, T1 ON, but not saturated and transistor T2 OFF.

2. When input low, T2 ON, but not saturated and transistor T1 OFF.

- **ECL NOR gate(3M)**



1. If any input as high corresponding transistor active, output as low, Q3 OFF.

2. Input and output voltage levels are not same, 0.6v difference.

- **Advantages and disadvantages of ECL family (2M)**

1. Fastest logic family offers propagation delay about 1ns.

2. Transistors are not allowed to go into complete saturation, thus eliminating storage delays.

3. Less switching transients since power supply as more stable.

4. Large fan out.

5. Low noise immunity.

6. High power dissipation.

- **Characteristics of ECL family (2M)**

1. Offers maximum delay under 0.5ns.

2. Logic levels kept close each other, noise margin reduced.

3. Power consumption more, transistors are not completely saturated.

4. Switching transients are less because power supply current as more stable.

5. **What are the types of digital logic families? Explain briefly any two logic family with circuit diagram. (13M)** BTL3

Answer : Page 7.17,7.2 - Godse

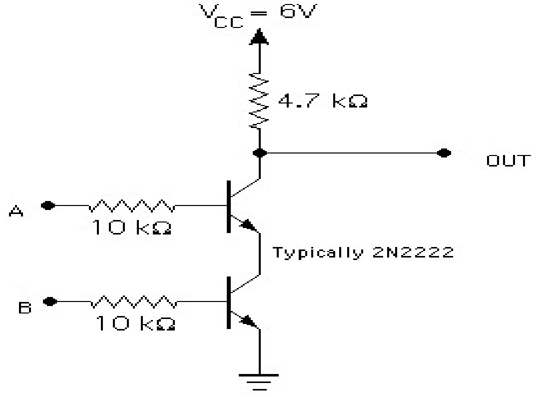
- **Types of digital logic families (2M)**

  1.RTL 2.DTL 3.TTL 4.ECL

- **Resistor-Transistor Logic (RTL) (5M)**

  1. RTL circuit consists of resistors and transistors.
  2. Emitters of both transistors are connected to a common ground and C.
  3. Collectors of both transistors, tied through a common collector resistor Rc to a supply voltage Vcc.
  4. Resistor Rc known as **passive pull up resistor**.
  5. Input voltage corresponding to LOW level must require to be low for the corresponding transistor to be cut off.
  6. Input voltage corresponding to HIGH level should be high enough to drive the corresponding transistor to saturation.
  7. When both inputs are low, Q1 and Q2 are cut off and the output as high.
  8. A HIGH level on any input drives corresponding transistor to saturation, causing output LOW.
  9. A HIGH level output voltage depends on the number of gates connected to output.
  10. Number of gates connected to output affects Fan out and Propagation delay.

- **Diagram and truth table (2M)**



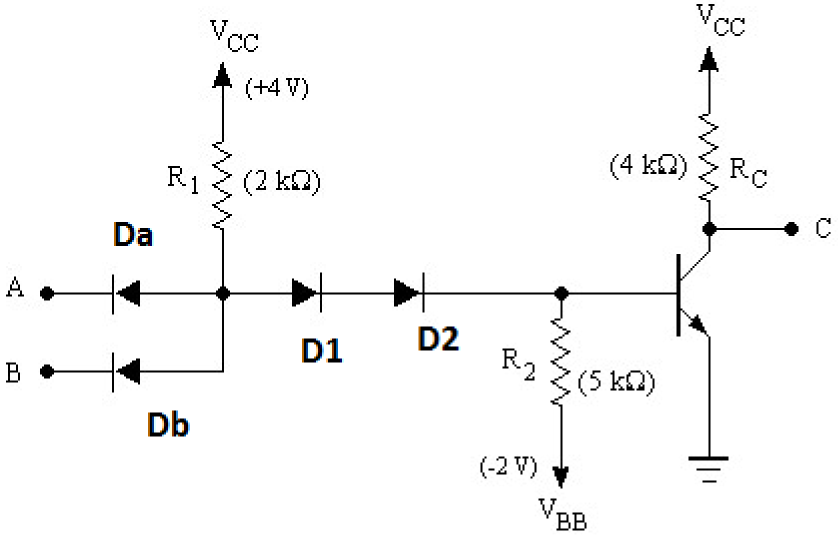
A	B	Out
0	0	1
0	1	0
1	0	0
1	1	0

- **Diode-Transistor Logic (DTL) (2M)**

  1. For improved Fan out and Noise margin DTL has replaced RTL.
  2. Input diodes and resistor R1 forming an AND gate.
  3. When both inputs are LOW diode Da and Db conduct resulting 0.7V at point P. This voltage not sufficient to drive Q1.

4. Q1 cut off giving output voltage Vcc logic 1.
5. When A and B inputs are HIGH Q1 is driven in saturation and its base to emitter junction capacitance charged.
6. If any of the input goes low, voltage at node becomes 0.7V and transistor Q1 will try to come out of saturation.
7. To drive transistor from saturation to cut off, necessary to discharge stored charge on internal capacitance.
8. Resistance R2 provides a discharge path for charge stored in transistor.

- **Diagram (2M)**



6.

Draw the circuit diagram of CMOS NOR,NAND and inverter gate and explain briefly. (13M) BTL1

Answer : Page 7.6 - Godse

- **Definition of CMOS (2M)**

1. CMOS circuit consists of both PMOS and NMOS devices to speed switching of capacitive loads.

2. Consumes low power and operated at high voltages, resulting in improved noise immunity.

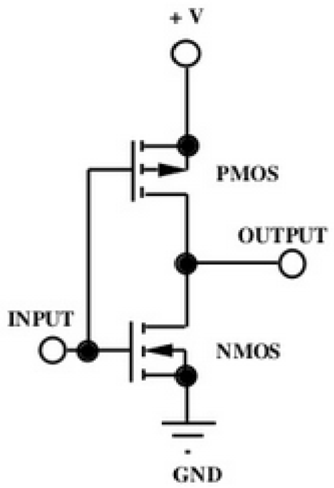
- **Circuit diagram of CMOS inverter (3M)**

1. Two MOSFET's connected in series. P channel connected to +Vdd, N channel connected to source.

2. Input high, gate of Q1 at zero relative to the source Q1 OFF.

3. Input low, gate of Q1 at negative potential relative to its source Q2 OFF.

4. Produces output voltage approximately +Vdd.



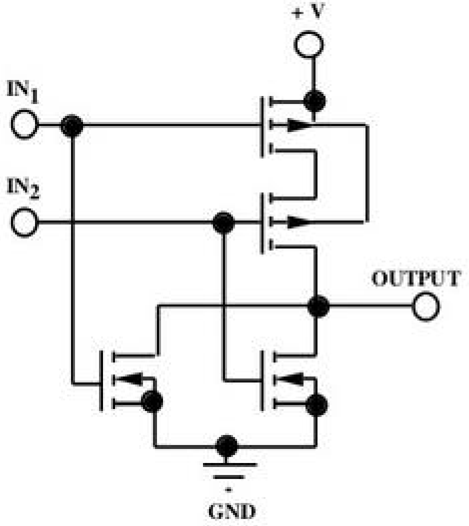
- **Circuit diagram of CMOS NOR gate (3M)**

  1.Two P channel MOSFETs Q1 and Q2 connected in series.

  2.Two N channel MOSFETs Q3 and Q4 connected in parallel.

  3.Any of input LOW, **turns on** corresponding P channel MOSFET, **turns off** corresponding N channel MOSFET.

  4.Any of input HIGH **turns off** corresponding P channel MOSFET, **turns on** corresponding N channel MOSFET.



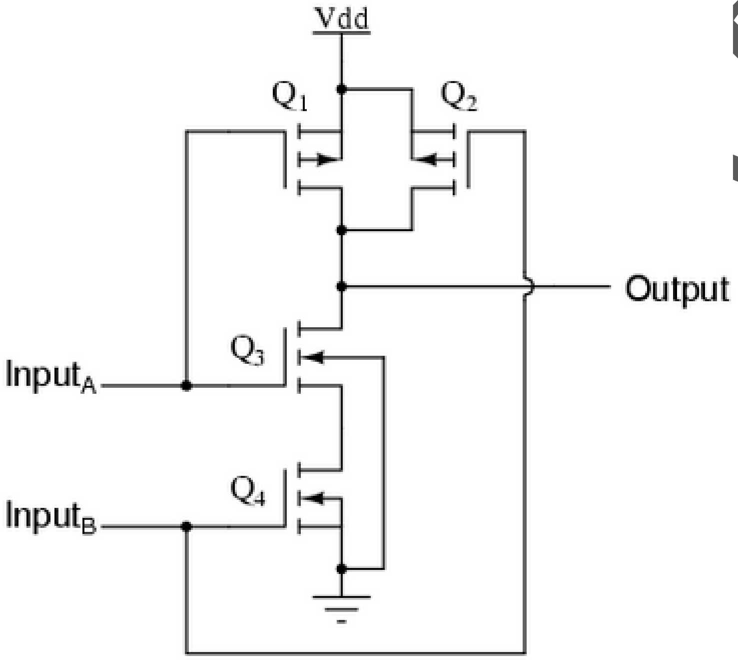
- **Circuit diagram of CMOS NAND gate (3M)**

  1. Two P channel MOSFETs Q1 and Q2 connected in parallel.

2. Two N channel MOSFETs Q3 and Q4 connected in series.

3. Any - input LOW, **turns on** corresponding P channel MOSFET, **turns off** corresponding N channel MOSFET.

4. All inputs HIGH, **turns off** corresponding P channel MOSFET, **turns on** corresponding n channel MOSFET.



- **Advantages and disadvantages of CMOS family (2M)**

1. Consumes less power.

2. Can be operated at high voltages, resulting in improved noise immunity.

3. Fan out as more.

4. Better noise margin.

5. Switching speed low.

6. Greater propagation delay.

7.

Determine the minimum sum of products and minimum product of sums for the following functions. (13M) BTL3

i) F(A,B,C)=AC+AB+BC

ii) F(A,B,C)=A+ABC

iii) F(A,B,C)=(A+B)(B+C)(A+C)

iv) F(A,B,C)= A.(A+B+C)

Answer : Page 1.12,1.14 - Godse

- **Procedure for Sum of Product (6M)**

  1. Find missing literals in each product term.
  2. AND product term with missing literal and its complement.
  3. Expand terms and reorder literals.

- **Procedure for Product of Sum (7M)**

  1. Find missing literals in each sum term.
  2. OR sum term with missing literal and its complement.
  3. Expand terms and reorder literals.
  4. Omit repeated sum terms.

8.

A 12 bit hamming code word containing 8 bits of data and 4 parity bits is read from memory. What was the original 8 bit data word that was written into memory if the 12 bit word read out is as 1)101110010100 2)1111111110100. (13M) (Nov/Dec 2015) BTL3

Answer : Page 1.55 - Godse

- **Out of 12 bits in the hamming code , 4 bits located in positions 1,2,4,8 from left are parity bits (2M)**
- **Remaining 8 bits are data bits , 8 bit word bits 3,5,6,7,9,10,11 and 12 are left (3M)**
- **Data words (8M)**

P1	P2	D3	P4	D5	D6	D7	P8	D9	D10	D11	D12	Data word
1	0	1	1	1	0	0	1	0	1	0	0	1 1 0 0 0 1 0 0
1	1	1	1	1	1	1	1	0	1	0	0	1 1 1 1 0 1 0 0

9.

Explain in detail about characteristics of digital logic families. (13M) BTL2

Answer : Page 2.6, 2.8 - Godse

- **Characteristics of Logic family (2M)**

  1. Propagation delay, Power dissipation, Current and voltage parameter, Noise margin, Fan in and Fan out, Speed power product**.**

- **Current and voltage parameters (3M)**

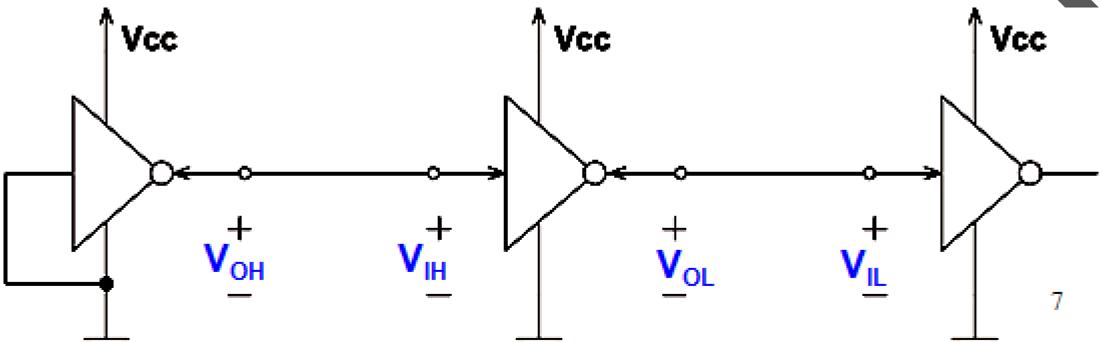
  1. V_{OH}(min) – The minimum voltage level at an output in the logical "1" state under defined

load conditions.

2. V_{OL}(max) – The maximum voltage level at an output in the logical "0" state under defined load conditions.

3. V_{IH}(min) – The minimum voltage required at an input to be recognized as "1" logical state.

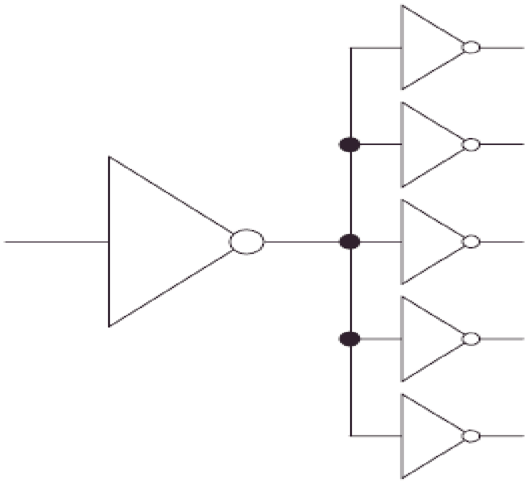
4. V_{IL}(max) – The maximum voltage required at an input that still will be recognized as "0" logical state.



- **Fan in Fan out (2M)**

1. Fan out specifies the number of standard loads that the output of the gate can drive with out impairment of its normal operation.

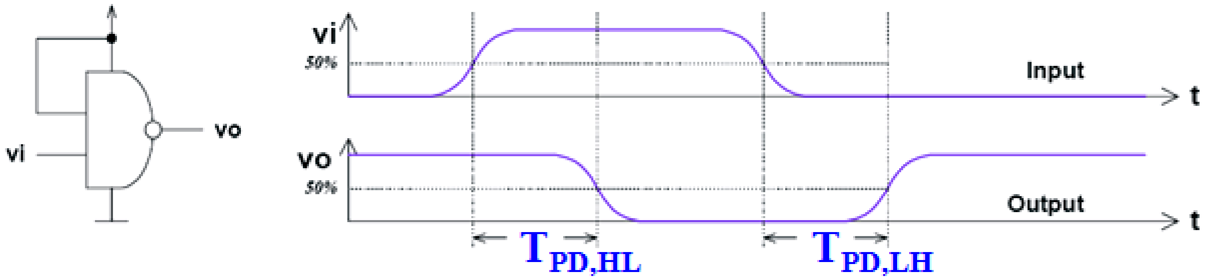
2. Fan in number of inputs connected to the gate without any degradation in the voltage level.



$$\text{DC fanout} = \min\left(\frac{I_{OH}}{I_{IH}}, \frac{I_{OL}}{I_{IL}}\right)$$

- **Propagation delay (2M)**

1. Propagation delay of a gate time interval between the application of an input pulse and occurrence of the resulting output pulse.



2. $T_{PD,HL}$ – input-to-output propagation delay from HI to LO output.

3. $T_{PD,LH}$ – input-to-output propagation delay from LO to HI output.

- **Speed-power product (2M)**

1. SPP=TPD × Pavg. Comparing and measuring overall performance of an IC family.

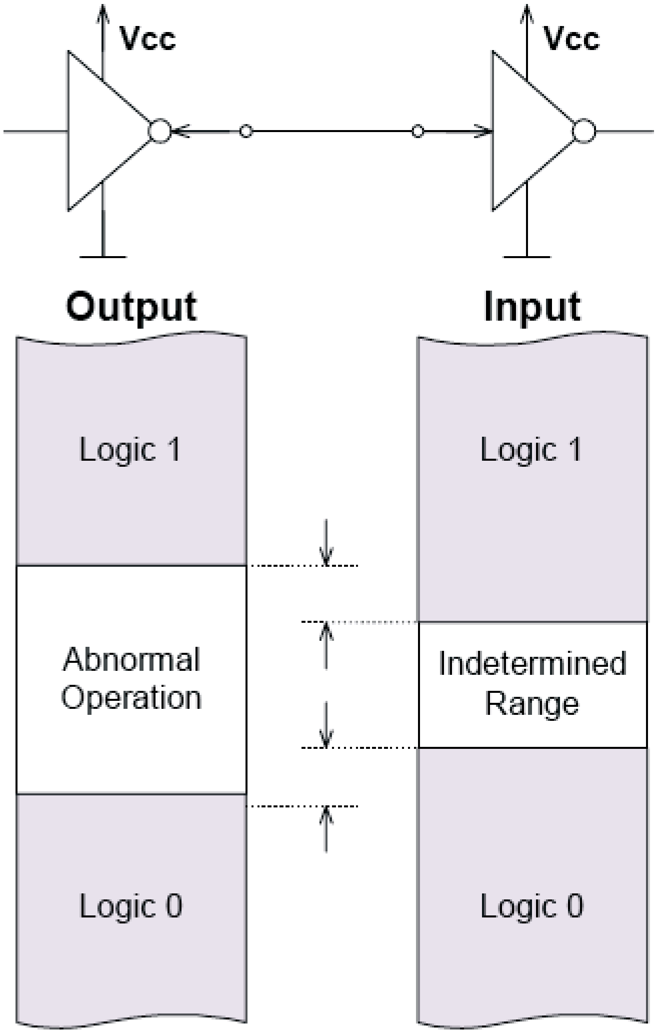
- **Noise Margin (2M)**

1. Noise margin amount by which the signal exceeds threshold for a proper '0' or '1'.

2. VNH = VOH(min) – VIH(min)

3. VNL = VIL(max) – VOL(max)

4. VN = min(VNH,VNL)



PART * C

1.

Explain about TTL, its wired logic and about the totem pole output, three state output TTL. (15M) BTL1

Answer : Page 7.6 - Godse

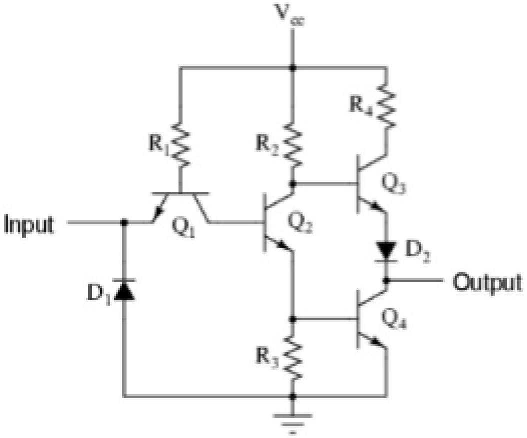
- **Definition of TTL (2M)**

  1.Transistor Transistor Logic means transistors alone to perform basic logic operations.

  2.Basic design modified to improve its performance in several aspects.

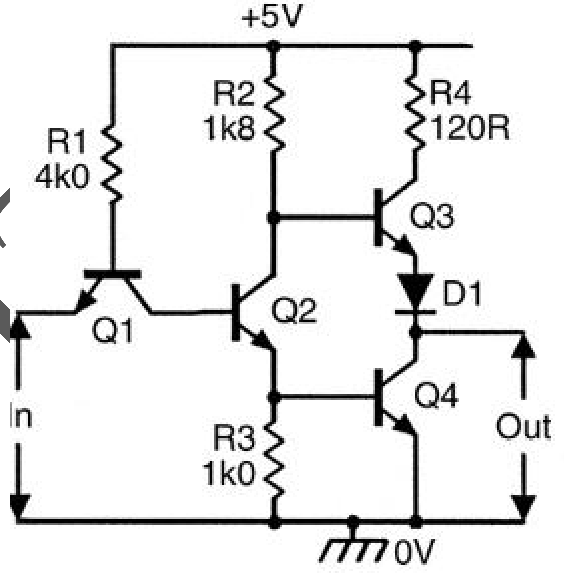
- **TTL Inverter (2M)**

  1. Input voltage low, output voltage high and vice versa.



- **TTL NAND gate (3M)**

1. Input structure multiple emitter transistor and output structure totem pole output.
2. Q1 NPN transistor with two emitters, one for each input to gate.
3. If either A or B or both low, corresponding diode conducts and base of Q1 pulled down to 0.7V.
4. Q2 and Q4 turns OFF and Q3 turns ON, output as HIGH.
5. When A and B both HIGH, emitter diode of Q1 reversed biased making them off.
6. Causes collector diode D4 go into forward conduction.
7. Q2 and Q4 turns ON and Q3 turns OFF, output as LOW.



- **Totem Pole Output (3M)**

1. TTL NAND gate circuit transistor Q3 and Q4 form a totem pole also known as **active pull up.**

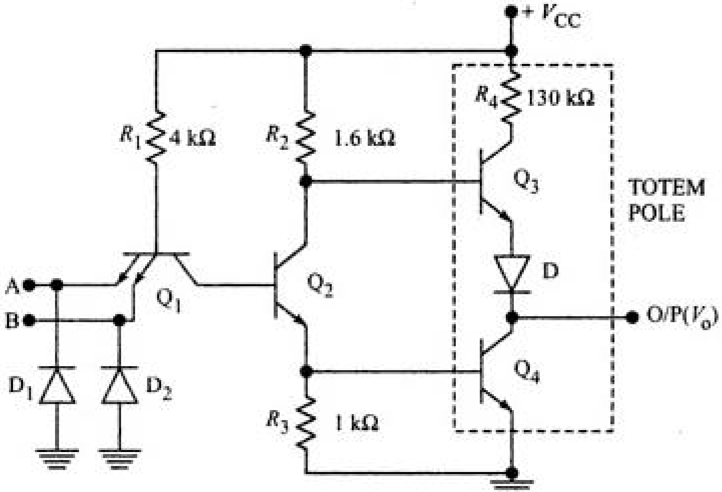
2. Totem pole transistors produce low output impedance.

3. Either Q3 acts as emitter follower or Q4 saturated.

4. When Q3 conducts output impedance 70 ohm.

5. Q4 saturated output impedance 12 ohm.

6. Output voltage change quickly from one state to other because any stray output capacitance charged or discharged through low output impedance.



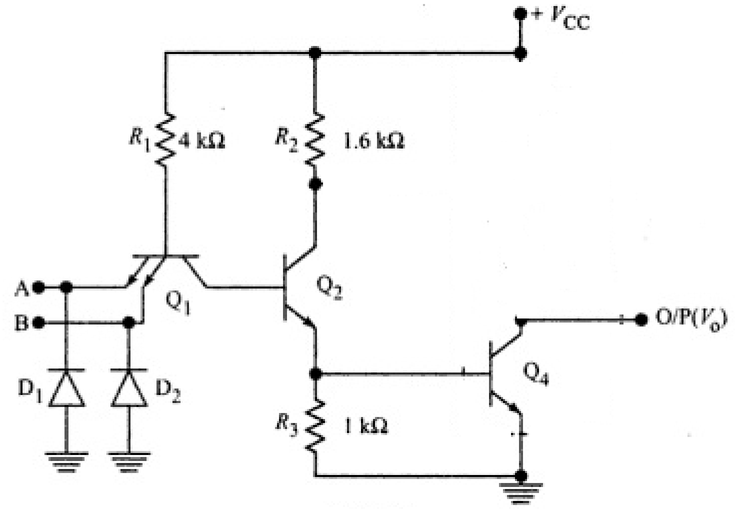
- **Open collector output (3M)**

1. Outputs of two different gates with open collector output tied together known as wired logic.

2. Open collector output eliminates pull up transistor Q3, D1 and R4.

3. Output taken from open collector terminal of transistor Q4.

5. Q4 ON, output LOW and when Q4 OFF, output tied to Vcc through an external pull up resistor.



- **Advantages and Disadvantages of TTL family (2M)**

  1. Moderate power dissipation, low cost, available in commercial and military versions.

  2. Higher power dissipation than CMOS, Lower noise immunity than CMOS, Less fan out than CMOS

2.

Explain in detail about binary codes. (15M) BTL2

Answer : Page 1.17 – Morris Mano

- **Definition of Binary codes (2M)**

  1. Numbers , alphabets or words are represented by a specific group of symbols.

- **Binary codes Types (4M)**

  1. Weighted codes such as BCD (8421), 6311, 2421.

  2. Non Weighted codes such as Excess-3 ,Gray. Alphanumeric codes such as EBCDIC ,ASCII. Error detection codes (Parity).

- **Weighted and Non Weighted code (3M)**

  1.Weighted codes and non-weighted codes used to represent decimal numbers.

  2.Use 4 binary digits to represent (0-9) decimal numbers.

  3.BCD used in interfacing between a digit device and a human being, e.g. digital voltmeter (DVM). For example

  1) 5648 =0101 0110 0100 1000

  2) 141=0001 0100 0001

- **Alphanumeric codes (4M)**

	1. A complete alphanumeric code would include the 26 lowercase characters, 26 uppercase characters, 10 numeric digits, etc. 2. Many choices of codes represent alphanumeric characters and several control characters. 3. Information coding as EBCDIC code(extended binary coded decimal interchange code) 4. ASCII Code(American standard code for information interchange). 5. ASCII code seven-bit code, 128 possible code groups. ➢ **Error detection codes and correction codes (2M)** 1. Used to detect and correct errors during the data transmission. 2. Parity bit and hamming codes error detection and error correction code.
3.	**Explain in detail about error detecting and error correcting codes. (15M)** BTL2 **Answer : Page 1.81 - Godse** ➢ **Definition of error correction and error detection codes (2M)** 1. Codes which allow only error detection called error detecting codes. 2. Codes which allow error correction and detection called error detecting and error correcting codes. ➢ **Types of error correction and error detection codes (1M)** 1. Parity bit 2. Hamming code ➢ **Parity bit (6M)** 1. Circuit that generates parity bit in the transmitter called parity generator. 2. Circuit that checks parity bit in the receiver called parity checker. 3. Parity bits assigned to both rows and columns, generates block parity. 4. Add even parity bits to rows and columns of a 4*8 data block. 5. Parity errors in the third column and second row, third bit second word as error. 6. Parity errors in two columns two errors have occurred in one data word. ➢ **Hamming code (6M)** 1. Find no. of parity bits and information bits. X+P=11, P=4, in a given hamming

	code there are 7 information bits and 4 parity bits. 2. Locations of parity bit code as **D7 D6 D5 P4 D3 P2 P1. Pn** designates particular information bit. 3. Check all bit locations one's in same location binary numbers. 4. Check all bit locations one's in middle bit. 5. Check all bit locations one's in left most bit.

	UNIT II COMBINATIONAL CIRCUITS
	Combinational logic - representation of logic functions-SOP and POS forms, K-map representations - minimization using K maps - simplification and implementation of combinational logic – multiplexers and de multiplexers - code converters, adders, subtractors, Encoders and Decoders.
	PART * A
Q.No.	**Questions**
1.	**What are the methods adopted to reduce Boolean function?** BTL1 1. Karnaug map 2. Tabular method or Quine Mc-Cluskey method 3. Variable entered map technique
2.	**State the limitations of karnaugh map.** BTL1 1. Generally it is limited to six variable map (i.e) more than six variable involving expressions are not reduced. 2. The map method is restricted in its capability since they are useful for simplifying only boolean expression represented in standard form.
3.	**What is a karnaugh map?** BTL1 A karnaugh map or k map is a pictorial form of truth table, in which the map diagram is made up of squares, with each squares representing one minterm of the function.
4.	**Define don't care conditions.** BTL1 In some logic circuits certain input conditions never occur, therefore the Corresponding output never appears. In such cases the output level is not defined, it can be either high or low. These output levels are indicated by 'X' or'd' in the truth table and are called don't care conditions or incompletely specified functions.
5.	**What is a prime implicant?** BTL1 A prime implicant is a product term obtained by combining the maximum possible number of adjacent squares in the map.
6.	**Define combinational logic.** BTL1 When logic gates are connected together to produce a specified output for certain specified combinations of input variables, with no storage involved, the resulting circuit is called combinational logic.
7.	**Write the design procedure for combinational circuits.** BTL1 1. Problem definition. 2. Determine the number of available input variables & required O/P variables. 3. Assigning letter symbols to I/O variables. 4. Obtain simplified Boolean expression for each O/P. 5. Obtain the logic diagram.
8.	**Define Decoder and Encoder.** BTL1 A decoder is a multiple - input multiple output logic circuit that converts coded inputs into coded outputs where the input and output codes are different. An encoder has 2n input lines and n output lines. In encoder the output lines generate the binary

	code corresponding to the input value.
9.	**What is binary decoder?** BTL1 A decoder is a combinational circuit that converts binary information from n input lines to a maximum of 2n output lines.
10.	**What is priority Encoder?** BTL1 A priority encoder is an encoder circuit that includes the priority function. In priority encoder, if 2 or more inputs are equal to 1 at the same time, the input having the highest priority will take precedence.
11.	**Define multiplexer.** BTL1 Multiplexer is a digital switch. If allows digital information from several sources to be routed onto a single output line.
12.	**What do you mean by comparator?** BTL1 A comparator is a special combinational circuit designed primarily to compare the relative magnitude of two binary numbers.
13.	**Write down the steps in implementing a Boolean function with levels of NAND Gates.** BTL3 1. Simplify the function and express it in sum of products. 2. Draw a NAND gate for each product term of the expression that has at least two Literals. 3. The inputs to each NAND gate are the literals of the term. This constitutes a group of first level gates. 4. Draw a single gate using the AND-invert or the invert-OR graphic symbol in the second level, with inputs coming from outputs of first level gates. 5. A term with a single literal requires an inverter in the first level. How ever if the single literal is complemented, it can be connected directly to an input of the second level NAND gate.
14.	**Give the general procedure for converting a Boolean expression in to multilevel NAND diagram.** BTL2 1. By another circle along the same line, insert an inverter or complement the input Draw the AND-OR diagram of the Boolean expression. 2. Convert all AND gates to NAND gates with AND-invert graphic symbols. 3. Convert all OR gates to NAND gates with invert-OR graphic symbols. 4. Check all the bubbles in the same diagram. For every bubble that is not compensated.
15.	**What are the major categories of digital circuits?** BTL1 The digital circuits basically of two types namely 1. Combinational circuits 2. Sequential circuits
16.	**Define logic gates.** BTL1 Logic gates are the basic elements that make up a digital system. The electronic gate is a circuit that is able to operate on a number of binary inputs in order to perform a particular logical function. The types of gates available are the NOT, AND, OR, NAND, NOR, exclusive-OR, and exclusive-NOR.
17.	**Write the Boolean function of an XOR gate give its truth table**. BTL3 Boolean Expression: Y = AB’ + A’B Truth Table: A B Y

0	**0**	**0**
0	**1**	**1**
1	**0**	**1**
1	**1**	**0**

18\. **Differentiate combinational and sequential circuits.** BTL3

S. No	Combinational circuits	Sequential circuits
1.	In combinational circuits, the output variables are at all times dependent on the combination of input variables.	In sequential circuits, the output variables depend not only on the present input variables but they also depend upon the past history of input variables.
2.	Memory unit is not required in combinational circuits.	Memory unit is required to store the past history of input variables in sequential Circuits.
3.	Combinational circuits are faster in speed because the delay between input and output is due to propagation delay of gates.	Sequential circuits are slower than the combinational circuits.
4.	Combinational circuits are easy to design.	Sequential circuits are comparatively harder to design.
5.	Parallel adder is combinational Circuit.	Serial adder is a sequential circuit.

19\. **Write the combinational circuit design procedure.** BTL1

1. Problem definition.
2. Determination of number of available input variables and required output variables.
3. Assigning letter symbols to input and output variables.
4. Derivation of truth table indicating the relationships between input and output variables.
5. Obtain simplified Boolean expression for each output.
6. Obtain logic diagram.

20\. **What are the limitations of half adder?** BTL1

In multi-digit addition we have to add two bits along with the carry of the previous digit addition. Effectively such addition requires addition of three bits. This is not possible with half-adder. Hence half-adders are seldom used in practice.

21\. **What is parallel Adder?** BTL1

A single full-adder is capable of adding two one-bit numbers and an input carry. In order to add binary numbers with more than one bit, additional full-adders must be employed. An-bit parallel can be constructed using number of full adder circuits connected in parallel.

22\. **What is the drawback in binary parallel adder? How it can be rectified?** BTL1

The parallel adder is ripple carry adder in which the carry output of each full- adder stage is connected to the carry input of the next higher-order stage. Therefore, the sum and carry outputs of any stage cannot be produced until the input carry occurs; this leads to time delay in the addition process. The delay is known as carry propagation delay.

One method of speeding up the process by eliminating inter stage carry delay is called look-ahead

<table>
<tr><td></td><td>carry addition. This method utilizes logic gates to look at the lower order bits of the augend and addend to see if a higher-order carry is to be generated.</td></tr>
<tr><td>23.</td><td>**Write short note on 1-bit multiplier.** BTL1

1-Bit multiplier truth table:
<table>
<tr><td>A</td><td>B</td><td>Y</td></tr>
<tr><td>0</td><td>0</td><td>0</td></tr>
<tr><td>0</td><td>1</td><td>0</td></tr>
<tr><td>1</td><td>0</td><td>0</td></tr>
<tr><td>1</td><td>1</td><td>1</td></tr>
</table></td></tr>
<tr><td>24.</td><td>**What is Lock out? (A.U.MAY-2012)** BTL1
In a counter, if the next state of some unused state is again some unused state, it may happen that the counter remains in unused state never to arrive at a used state. Such a condition is called Lock out condition</td></tr>
<tr><td>25.</td><td>**How to avoid Lock out Condition? (A.U.MAY-2012)** BTL1
1. The counter should be provided with an additional circuit. This will force the counter from an unused state to the next state as initial state.
2. It is not always necessary to force all unused states into an initial state. Because from unused states which are not forced, the circuit may eventually arrive at a forced unused state. This frees the circuit from the Lock out condition.</td></tr>
<tr><td>26.</td><td>**What are combinational circuits?**BTL1
A combinational circuit consists of logic gates whose outputs at any time are determined from the present combination of inputs. A combinational circuit performs an operation that can be specified logically by a set of Boolean functions. It consists of input variables, logic gates, and output variables.</td></tr>
<tr><td>27.</td><td>**Why is MUX called as data selector? (A.U.MAY-2011)** BTL1
A multiplexer is combinational circuit that selects binary information from one of many input lines and directs it to a single output line. The selection of a particular input line is controlled by a set of selection lines. Normally there are 2n input lines and n selection lines whose bit combinations determine which input is selected. So MUX is called as data selector.</td></tr>
<tr><td>28.</td><td>**How does don’t care condition in k-map help for circuit simplification? (A.U.DEC-2011)** BTL1
In some logic circuits certain input conditions never occur, therefore the corresponding output never appears. In such cases the output level is not defined, it can be either high or low. These output levels are indicated by ‘X’ or‘d’ in the truth tables and are called don’t care conditions or incompletely specified functions.</td></tr>
<tr><td colspan="2">**PART * B**</td></tr>
<tr><td>1.</td><td>**Obtain the minimum SOP using Tabulation method and verify using K map. F=(0,2,4,8,9,10,11,12,13).(13M)**</td></tr>
</table>

(May/June2009).BTL3

Answer : Page 1.66 - Godse

- **List & arrange Minterms (3M)**

1. Arrange minterms according to categories of ones by binary representation.
2. Construct table for minterms.

- **Compare binary number, differ only by one position (3M)**

1. Compare each binary number with every term in next higher category.
2. Differ only one position put check mark.
3. Copy that term in next column with '-' in position that they differed.
4. Apply same process for all resultant columns.
5. Continues this cycle until no further elimination of literals.

- **List prime implicants (2M)**

1. List all prime implicants along with table.
2. Select minimum number of prime implicants cover all minterms**.**

- **Verify Prime implicants using K map (4M)**

1. Group should not include any cell containing zero.
2. Number of cells in a group must be powers of 2.
3. Grouping may be horizontal , vertical but not diagonal.
4. Cell containing at least one group.
5. A cell may be grouped more than once**.**

- **Answer (1M)**

1. F(A,B,C,D)=C'D'+AC'+AB'+B'D

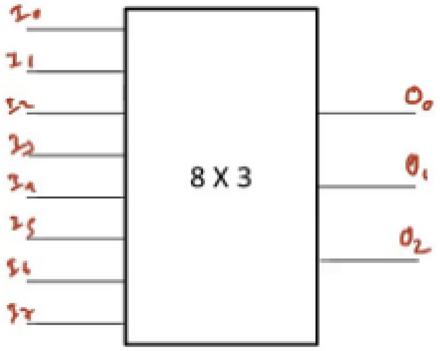
2\.

Design octal to binary encoder. (13M) BTL3

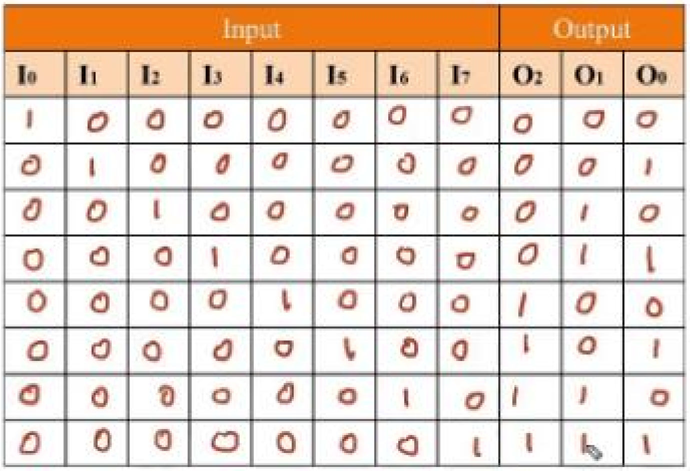
Answer : Page 2.29 - Godse

- **Definition of encoder (3M)**

1. An encoder is digital circuit that performs inverse operation of decoder.



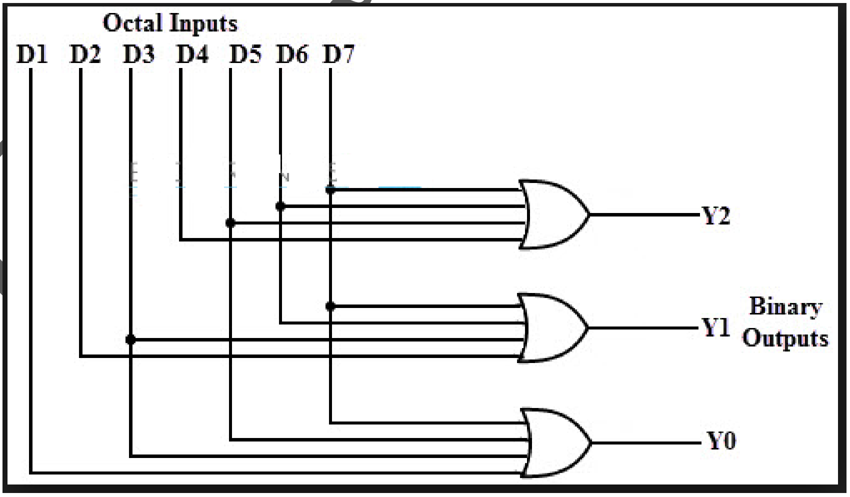
- **Truth table & Expression (5M)**



Input								Output		
I_0	I_1	I_2	I_3	I_4	I_5	I_6	I_7	O_2	O_1	O_0
1	0	0	0	0	0	0	0	0	0	0
0	1	0	0	0	0	0	0	0	0	1
0	0	1	0	0	0	0	0	0	1	0
0	0	0	1	0	0	0	0	0	1	1
0	0	0	0	1	0	0	0	1	0	0
0	0	0	0	0	1	0	0	1	0	1
0	0	0	0	0	0	1	0	1	1	0
0	0	0	0	0	0	0	1	1	1	1

- **Logic diagram (5M)**

1. Use basic AND, OR, NOT gates.



3.

Implement the full subtractor using demultiplexer. (13M) BTL3

Answer : Page 2.59 - Godse

- **Procedure (5M)**

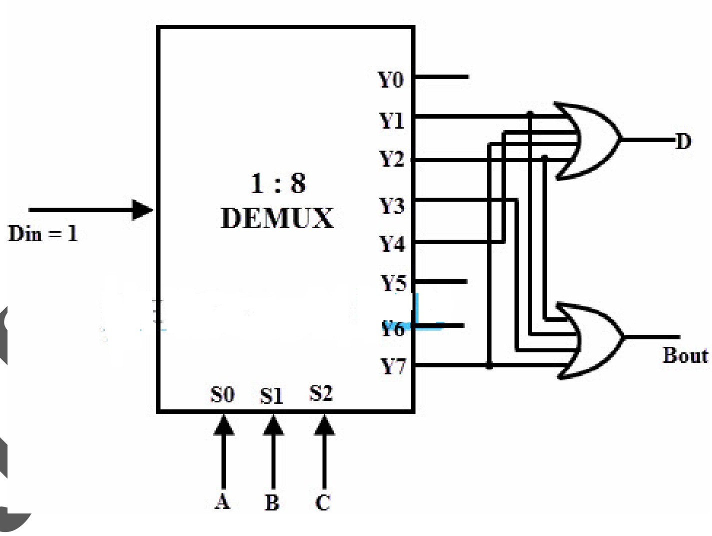
1. Write truth table of full subtractor.
2. Represent output of full subtractor in minterm form.
3. Difference= Σm(1,2,4,7).
4. Bout= Σm(1,2,3,7).
5. Logically OR outputs corresponding to minterms.

- **Truth table (4M)**

1. Assign input as A, B, Bin.
2. Output as D, Bout.

Minuend (A)	Subtrahend (B)	Borrow In (B_{in})	Difference (D)	Borrow Out (B_o)
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

- **Implementation diagram(4M)**



4. **Draw the circuit for 3 to 8 decoder and explain. (13M)** BTL3

Answer : Page 2.31 - Godse

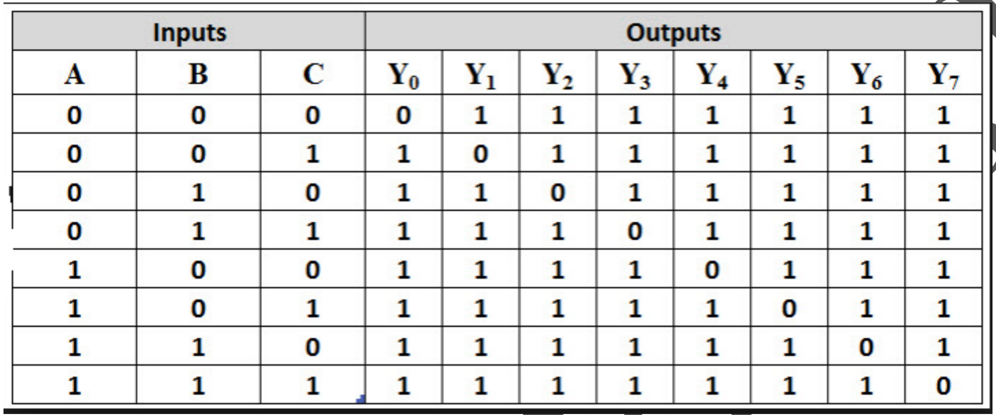
- **Definition of decoder (2M)**

1. A decoder is a multiple input , multiple output logic circuit which converts coded inputs into

coded outputs, where the input, output codes are different.

- **Truth table of 3 to 8 decoder (5M)**

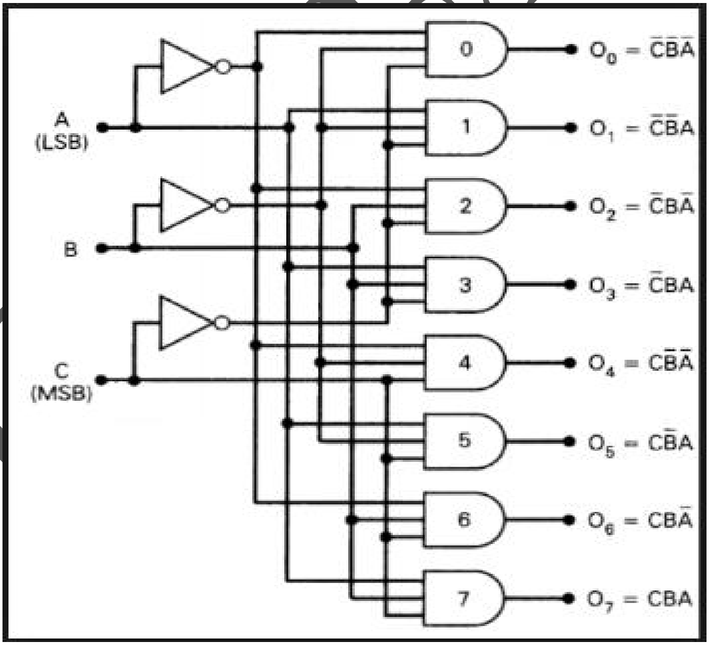
1. Assign inputs as A,B,C.
2. Assign outputs as Y0 TO Y7.
3. Apply rule for converting 3 to 8 decoder.



Inputs			Outputs							
A	B	C	Y_0	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7
0	0	0	0	1	1	1	1	1	1	1
0	0	1	1	0	1	1	1	1	1	1
0	1	0	1	1	0	1	1	1	1	1
0	1	1	1	1	1	0	1	1	1	1
1	0	0	1	1	1	1	0	1	1	1
1	0	1	1	1	1	1	1	0	1	1
1	1	0	1	1	1	1	1	1	0	1
1	1	1	1	1	1	1	1	1	1	0

- **Logic diagram & expression (6M)**

1. Find expression for Q0 to Q7.
2. Use basic AND, OR, NOT gates.

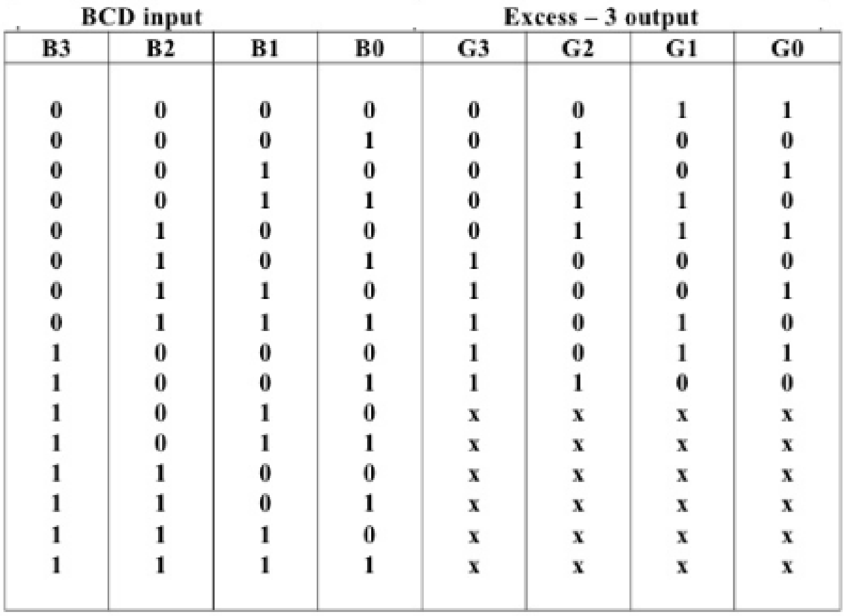


5. **Design a logic circuit to convert the 8421 BCD code to excess-3 code. (13M) (May 10)** BTL3

Answer : Page 2.21 - Godse

➢ **Truth table (4M)**

1. Assign inputs as b3, b2, b1, b0.
2. Assign outputs as e3, e2, e1, e0.
3. Apply rule for converting binary to excess 3 code.

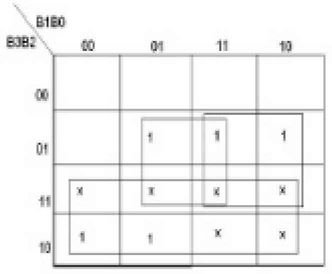


BCD input				Excess – 3 output			
B3	**B2**	**B1**	**B0**	**G3**	**G2**	**G1**	**G0**
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
0	1	1	0	1	0	0	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	0	1	1	1	0	0
1	0	1	0	x	x	x	x
1	0	1	1	x	x	x	x
1	1	0	0	x	x	x	x
1	1	0	1	x	x	x	x
1	1	1	0	x	x	x	x
1	1	1	1	x	x	x	x

➢ **K map simplification (5M)**

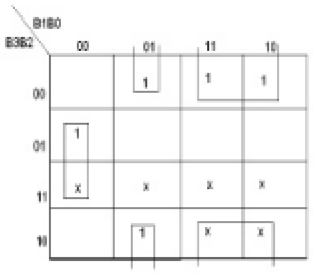
1. Find expression for e3, e2, e1, e0.

K-Map for E_3:



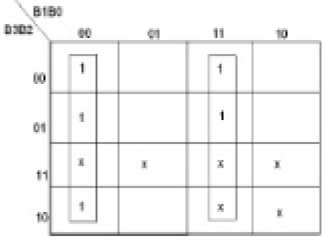
E3 = B3 + B2 (B0 + B1)

K-Map for E_2:



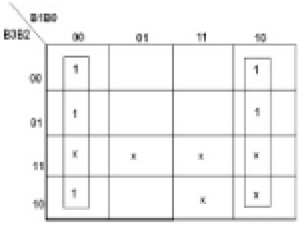
E2 = B2 ⊕ (B1 + B0)

K-Map for E_1:



$E1 = B1 \odot B0$

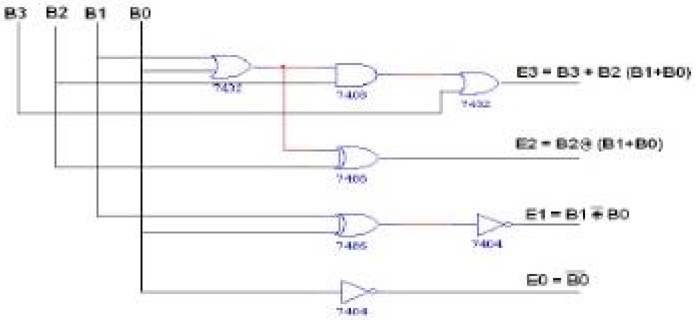
K-Map for E_0:



$E0 = \overline{B0}$

- **Logic diagram (4M)**

1. Use basic AND, OR, NOT gates.
2. Draw corresponding output for e3, e2, e1, e0.

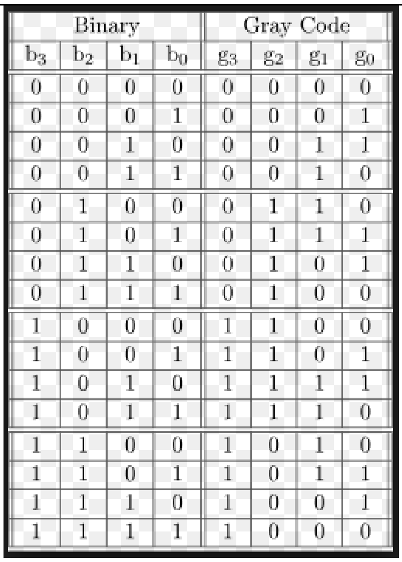


6. **Design a 8421 code to gray code converter. (13M)** BTL3

Answer : Page 2.24 - Godse

- **Truth table (4M)**

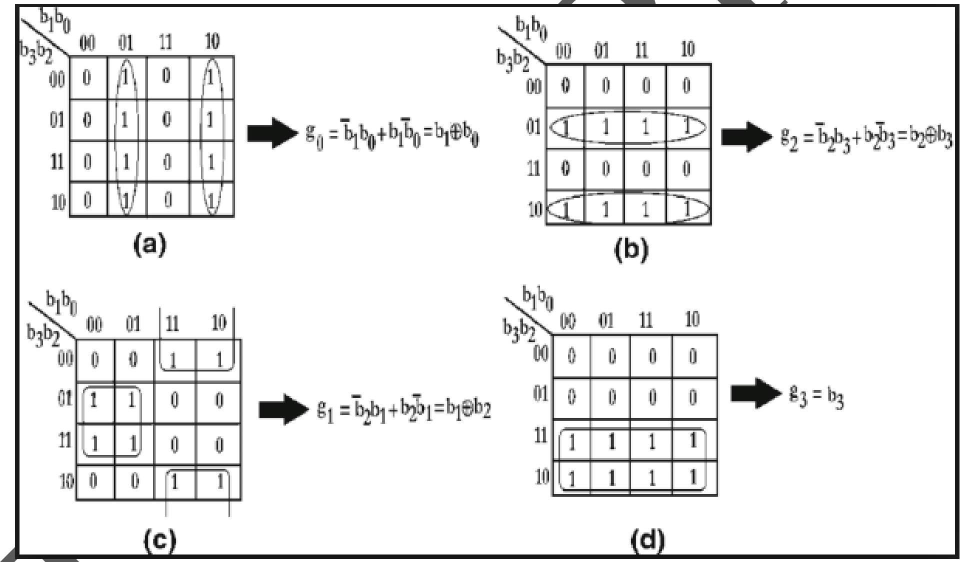
1. Assign inputs as b3, b2, b1, b0.
2. Assign outputs as g3, g2, g1, g0.
3. Apply rule for converting binary to gray code.



Binary				Gray Code			
b_3	b_2	b_1	b_0	g_3	g_2	g_1	g_0
0	0	0	0	0	0	0	0
0	0	0	1	0	0	0	1
0	0	1	0	0	0	1	1
0	0	1	1	0	0	1	0
0	1	0	0	0	1	1	0
0	1	0	1	0	1	1	1
0	1	1	0	0	1	0	1
0	1	1	1	0	1	0	0
1	0	0	0	1	1	0	0
1	0	0	1	1	1	0	1
1	0	1	0	1	1	1	1
1	0	1	1	1	1	1	0
1	1	0	0	1	0	1	0
1	1	0	1	1	0	1	1
1	1	1	0	1	0	0	1
1	1	1	1	1	0	0	0

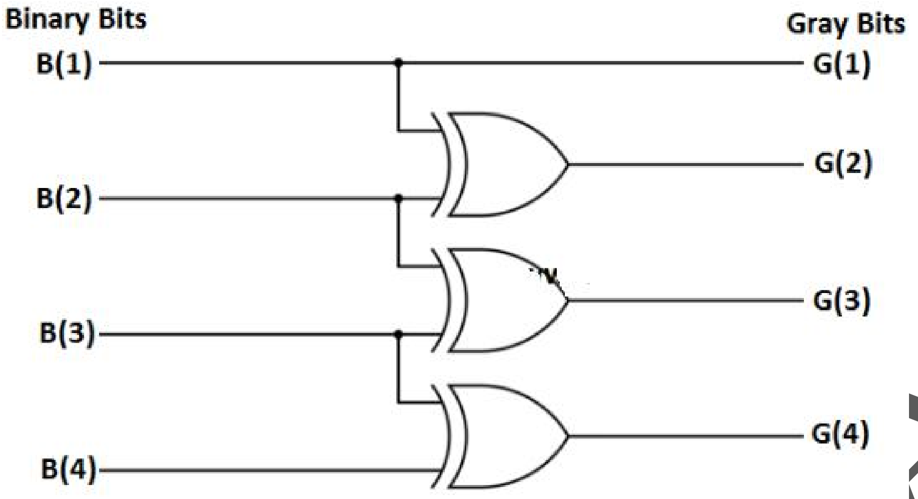
- **K map simplification (5M)**

1. Find expression for g0, g1, g2, g3.



- **Logic diagram (4M)**

1. Use basic AND, OR, NOT gates.
2. Draw corresponding output for g0, g1, g2, g3.



7.

Design Priority encoder. (13M) BTL3

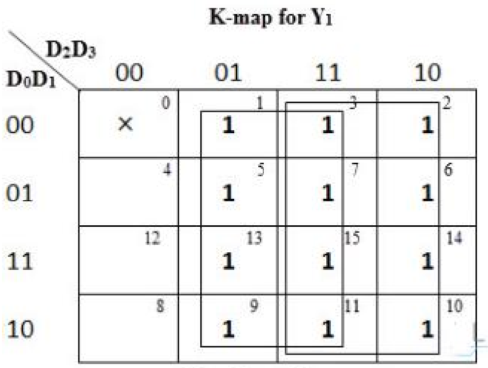
Answer : Page 2.28 - Godse

- **Truth table (4M)**

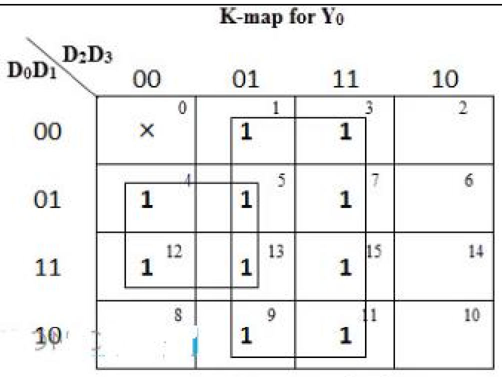
3. Assign inputs as D0,D1,D2,D3.
4. Assign outputs as Y1,Y2,V.

Inputs				Outputs		
D_0	D_1	D_2	D_3	Y_1	Y_0	V
0	0	0	0	×	×	0
1	0	0	0	0	0	1
×	1	0	0	0	1	1
×	×	1	0	1	0	1
×	×	×	1	1	1	1

- **K map simplification (5M)**



$Y_1 = D_3 + D_2$

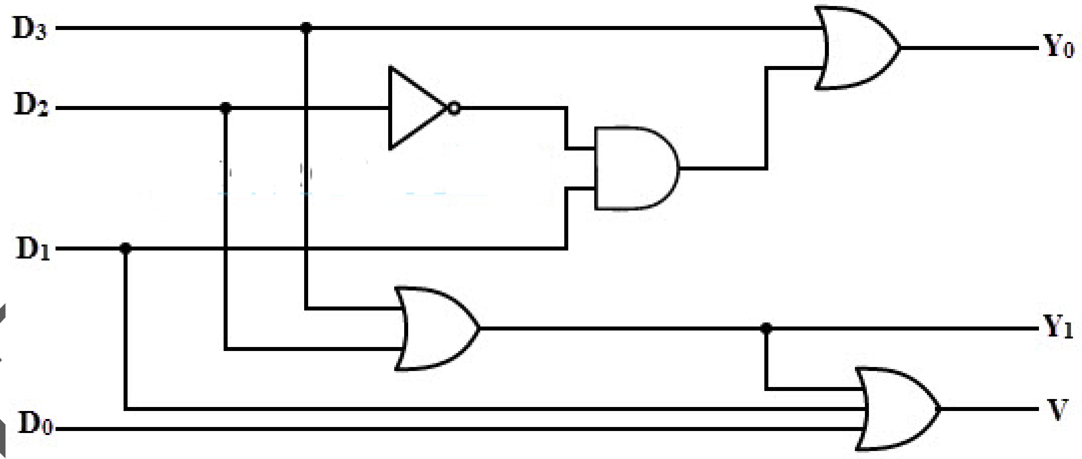


$Y_0 = D_3 + \overline{D2}\,D1$

1. Group two octets in Y1..
2. Group one quads and one octet in Y0.
3. Y1=D2+D3.
4. Y0=D3+D1D2’.
5. V=D0+D1+D3.

- **Logic diagram (4M)**

1. Use basic AND, OR, NOT gates.
2. Draw corresponding output for Y1,Y0 and V.



8.

i) Implement the following function using a suitable multiplexer. (6M) BTL3
F1(a,b,c,d) = Σm (1,3,4,5,6,11,15)

i) F2(a,b,c) = ΠM (0,3,5,8,9,10,12,14)

Answer : Page 2.50- Godse

- **Write implementation table (3M)**

1. Circle given number.
2. No circle in any of column considered as 0.
3. First row is circled assign as A'.
4. Second row is circled assign as A**.**

D0	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8	**9**	**10**	**11**	**12**	**13**	**14**	**15**

- **Draw multiplexer implementation diagram (3M)**

ii) Implement the following function using a suitable multiplexer. (7M) BTL3
F2(a,b,c) = ΠM (0,3,5,8,9,10,12,14)

Answer : Page 2.51- Godse

- **Write implementation table (3M)**

1. Uncircle given number.
2. No circle in any of column considered as 0.
3. First row is circled, assign as A'.
4. Second row is circled, assign as A**.**

D0	**D1**	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**
0	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8	**9**	**10**	**11**	**12**	**13**	**14**	**15**

- **Draw multiplexer implementation diagram (4M)**

9.

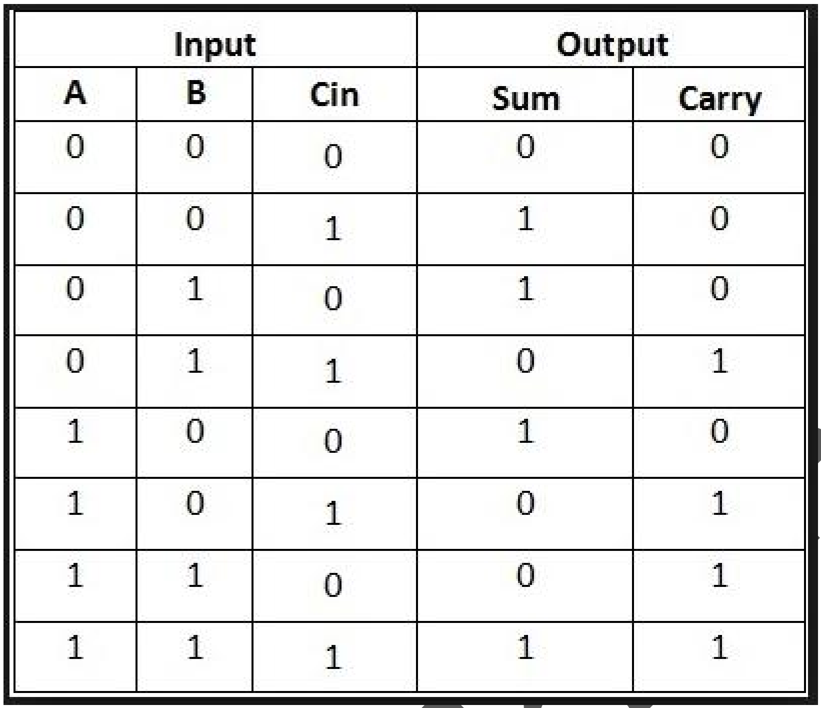
Implement the full adder circuit using 8:1 multiplexer. (13M) BTL3

Answer : Page 2.52 - Godse

- **Write truth table (5M)**

1. Assign input bits as A, B, Cin.

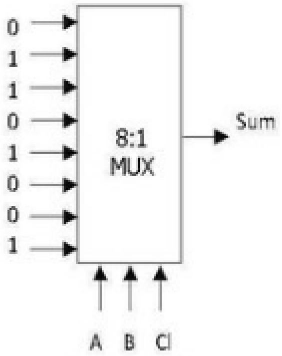
2. Output bits as sum, carry.
3. Add bits according to binary addition.



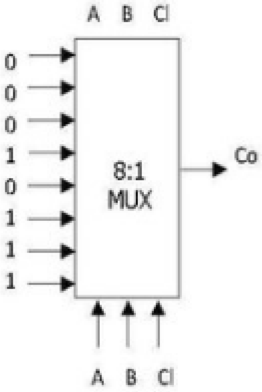
Input			Output	
A	B	Cin	Sum	Carry
0	0	0	0	0
0	0	1	1	0
0	1	0	1	0
0	1	1	0	1
1	0	0	1	0
1	0	1	0	1
1	1	0	0	1
1	1	1	1	1

- **Draw multiplexer implementation diagram (8M)**

1. Sum implementation diagram:



2. Carry implementation diagram:

	
10.	**Reduce the following function using K map technique. (13M)** BTL3 **F(a,b,c,d,e,f)= Σm (0,5,7,8,9,12,13,23,24,25,28,29,37,40,42,44,46,55,56,57,60,61)** **Answer : Page 1.53 - Godse** ➢ **Form K map table (3M)** 1. Group should not include any cell containing zero. 2. Number of cells in a group must be powers of 2. 3. Grouping may be horizontal , vertical but not diagonal. 4. Cell containing at least one group. 5. A cell may be grouped more than once. ➢ **Groping of 2,4,8 (5M)** 1. Group 1 and group 2 are two pairs of 1's in the first 16 cell map. 2. Group 3 is formed by two isolated 1's from 16 cell map and third 16 cell map. 3. Group 4 is combination of two quads from first 16 cell and second 16 cell map. 4. Group 5 is combination of two quads from second 16 cell map and fourth 16 cell map. 5. Group 6 is combination of isolated 1's from second and fourth 16 cell maps. 6. Group 7 is quad within third 16 cell map. ➢ **Find expression with logic diagram (5M)** **F=A'B'D'E'F'+A'B'C'DF+B'C'DE'F+A'CE'+BCE'+BC'DEF+AB'CF'**
11.	**Find a minimum sum of products expression for the following function using Quine-McClusky method and also verify by using K map technique. (13M)** BTL3 **F (A,B,C,D,) = ∑(3,4,,5,7,9,13,14,15)** **Answer : Page 1.67 - Godse**

- **List & arrange Minterms (3M)**

1. Arrange minterms according to categories of ones by binary representation.
2. Construct table for minterms.

- **Compare binary number, differ only by one position (3M)**

1. Compare each binary number with every term in next higher category.
2. Differ only one position put check mark.
3. Copy that term in next column with '-' in position that they differed.
4. Apply same process for all resultant columns.
5. Continues this cycle until no further elimination of literals.

- **List prime implicants (2M)**

1. List all prime implicants along with table.
2. Select minimum number of prime implicants cover all minterms**.**

- **Verify Prime implicants using K map (4M)**

1. Group should not include any cell containing zero.
2. Number of cells in a group must be powers of 2.
3. Grouping may be horizontal , vertical but not diagonal.
4. Cell containing at least one group.
5. A cell may be grouped more than once**.**

- **Answer (1M)**

1. F(A,B,C,D)=A'CD+A'BC'+ABC+AC'D

PART * C

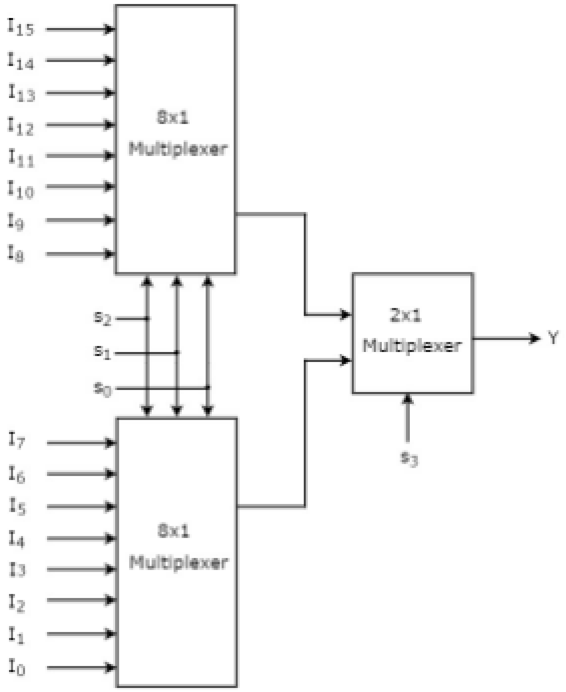
1\.

i)Construct a 16 x 1 multiplexer using 8 x 1 multiplexers. (8M) BTL3
Answer : Page 2.45 - Godse

- **Procedure (4M)**

1. Connect select lines of two multiplexers in parallel.
2. S3=0, Mux1 is enabled.
3. S3=1, Mux 2 is enabled.
4. Logically OR outputs of two multiplexers to obtain final output Y.

- **Logic diagram (4M)**

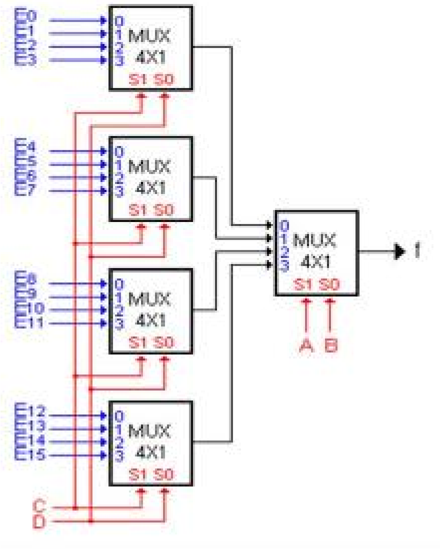


ii)Construct a 16 x 1 multiplexer using 4 x 1 multiplexers. (7M) BTL3
Answer : Page 2.45 - Godse

- **Procedure (3M)**

1. Connect select lines of four multiplexers in parallel.
2. Connect S2 and S3 to Mux5.
3. Connect outputs Y0, Y1,Y2 and Y4 of four multiplexer as data inputs for Mux 5.

- **Logic diagram (4M)**



2.

Design 2 bit comparator using gates. (15M) BTL3

Answer : Page 2.17 - Godse :

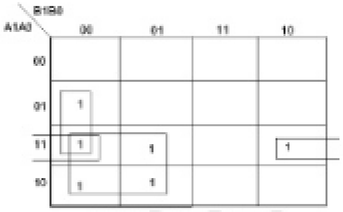
- **Definition of comparator (2M)**

1. A comparator is special combinational circuit designed to compare relative magnitude of two binary numbers.

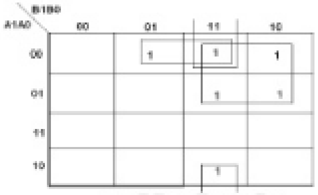
- **Truth table (4M)**

A1	A0	B1	B0	A > B	A = B	A < B
0	0	0	0	0	1	0
0	0	0	1	0	0	1
0	0	1	0	0	0	1
0	0	1	1	0	0	1
0	1	0	0	1	0	0
0	1	0	1	0	1	0
0	1	1	0	0	0	1
0	1	1	1	0	0	1
1	0	0	0	1	0	0
1	0	0	1	1	0	0
1	0	1	0	0	1	0
1	0	1	1	0	0	1
1	1	0	0	1	0	0
1	1	0	1	1	0	0
1	1	1	0	1	0	0
1	1	1	1	0	1	0

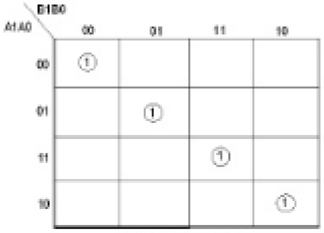
- **K map simplification (5M)**



$A > B = A0\,\overline{B0}\,B1 + A1\,\overline{B1} + A1\,A0\,\overline{B0}$

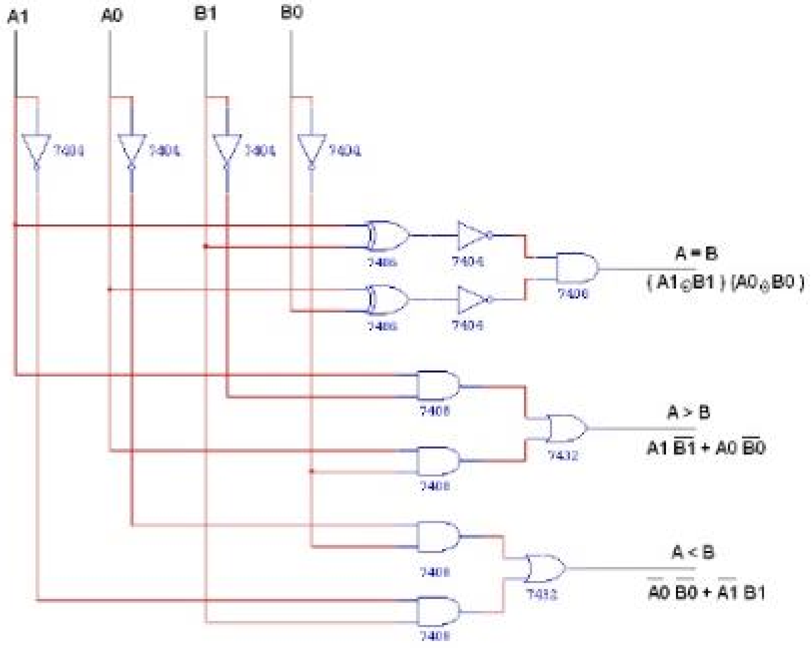


$A < B = \overline{A1}\,\overline{A0}\,B0 + \overline{A0}\,B0\,B1 + \overline{A1}\,B1$



$A = B = (A0 \odot B0)(A1 \odot B1)$

- **Logic diagram (4M)**



3. **Design 4 bit binary to BCD code. (15M)** BTL3

Answer : Page 2.20 - Godse

- **Select input code and output code (2M)**
- **Truth table (4M)**

1. $Y_0 = D_1 + D_3 + D_5 + D_7 + D_{9s}$
2. $Y_1 = D_2 + D_3 + D_6 + D_7$

3. $Y_2 = D_4 + D_5 + D_6 + D_7$
4. $Y_3 = D_8 + D_9$

- **K map simplification (5M)**
- **Logic diagram (4M)**

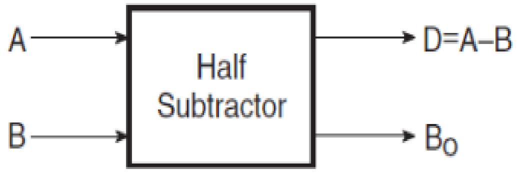
4.

Explain in detail about half subtractor and full subtractor circuit. (15M) BTL1
Answer : Page 2.10,2.11 - Godse

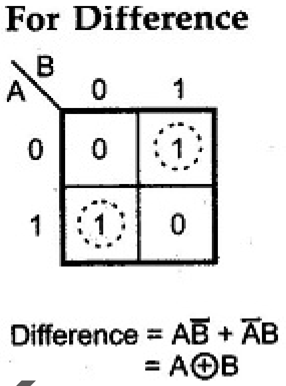
- **Definition of half subtractor and truth table (3M)**

1. A half subtractor is a combinational circuit that subtracts two input bits and produces their difference. It consists of two outputs.

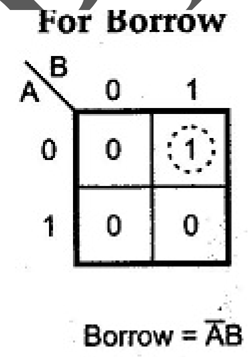
A	B	D	B_0
0	0	0	0
0	1	1	1
1	0	1	0
1	1	0	0



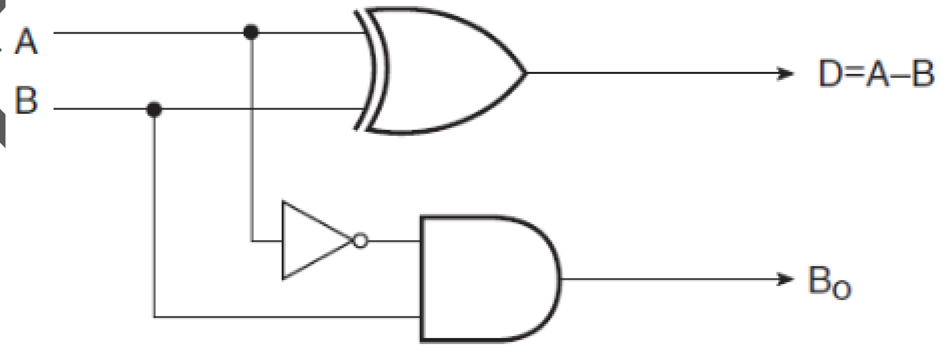
- **K map expression and logic diagram (4M)**



Difference = $A\overline{B} + \overline{A}B$
= $A \oplus B$



Borrow = $\overline{A}B$



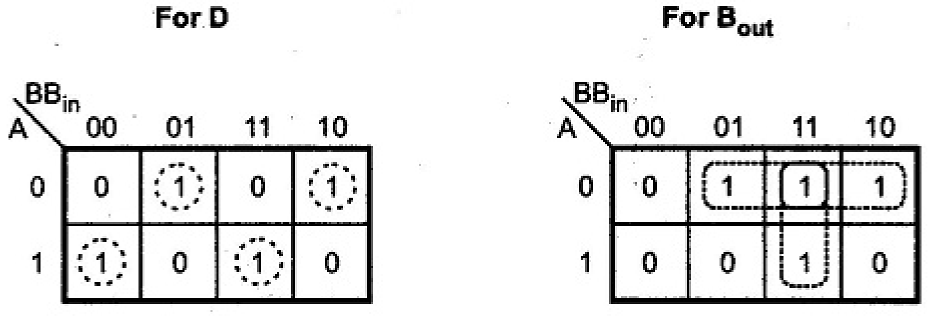
- **Definition of full subtractor and truth table (4M)**

1. A half subtractor is a combinational circuit that subtracts three input bits and produces their

difference. It consists of two outputs.

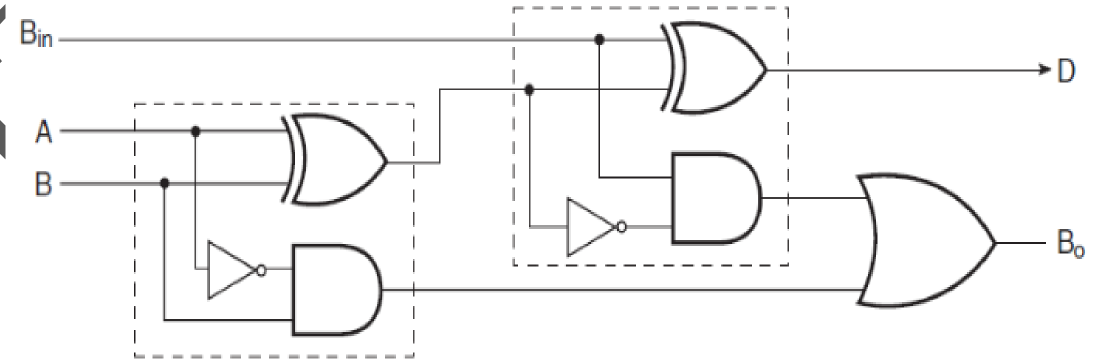
Inputs			Outputs	
A	B	B_{in}	D	B_{out}
0	0	0	0	0
0	0	1	1	1
0	1	0	1	1
0	1	1	0	1
1	0	0	1	0
1	0	1	0	0
1	1	0	0	0
1	1	1	1	1

- **K map expression and logic diagram (4M)**



$D = \overline{A}\overline{B}B_{in}+\overline{A}B\overline{B}_{in}+A\overline{B}\,\overline{B}_{in}+ABB_{in}$

$B_{out} = \overline{A}B_{in}+\overline{A}B+BB_{in}$



5.	**Explain in detail about half adder and full adder circuit. (15M)** BTL1 **Answer : Page 2.6, 2.7 - Godse**

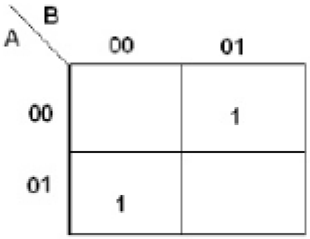
- **Definition of half adder and truth table (3M)**

1. A half adder is a combinational circuit that forms the arithmetic sum of two input .It consists of two outputs.

A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

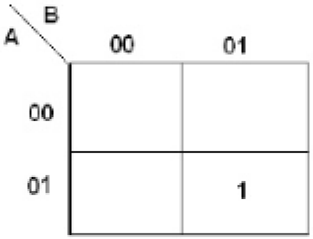
- **K map expression and logic diagram (4M)**

K-Map for SUM

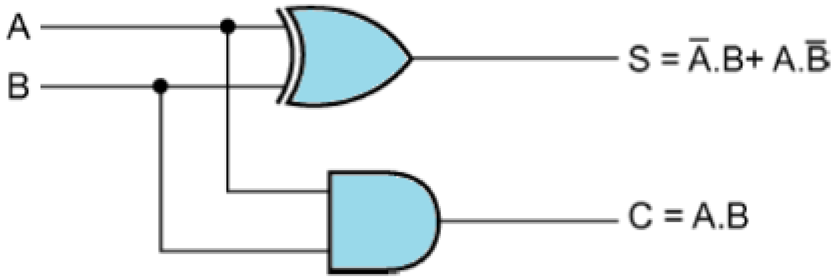


SUM = A'B + AB'

K-Map for CARRY



CARRY = AB



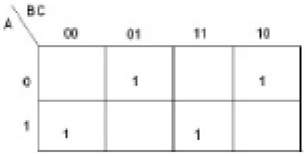
- **Definition of full adder and truth table (4M)**

1. A full adder is a combinational circuit that forms the arithmetic sum of three input bits. It consists of two outputs.

A	B	C	CARRY	SUM
0	0	0	0	0
0	0	1	0	1
0	1	0	0	1
0	1	1	1	0
1	0	0	0	1
1	0	1	1	0
1	1	0	1	0
1	1	1	1	1

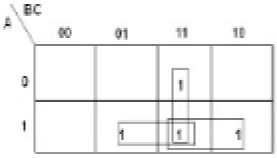
- **K map expression and logic diagram (4M)**

K-Map for SUM

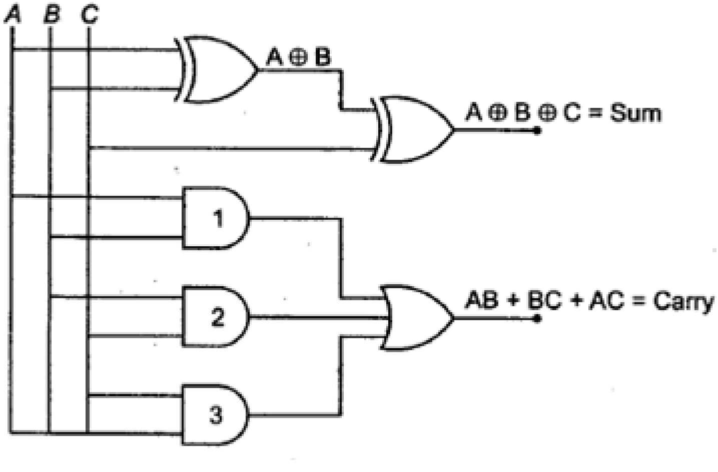


SUM = A'B'C + A'BC' + ABC' + ABC

K-Map for CARRY



CARRY = AB + BC + AC



UNIT III SYNCHRONOUS SEQUENTIAL CIRCUITS

Sequential logic- SR, JK, D and T flip flops - level triggering and edge triggering - counters - asynchronous and synchronous type - Modulo counters - Shift registers - design of synchronous sequential circuits – Moore and Melay models- Counters, state diagram; state reduction; state assignment

PART * A

Q.No.	Questions
1.	**Define synchronous sequential circuit. (A.U.DEC-2010)** BTL1 In synchronous sequential circuits signals can affect the memory elements only at discrete instant of time
2.	**Define cycle and merging.** BTL1 When *a* circuit goes through a u*n*ique sequence of unstable states, *i*t is said to have a cyc*l*e. The grouping of stab*l*e states from s*e*parate rows into o*n*e common row is called merging.
3.	**Give state – reduction procedure.** BTL1 The state – reduction procedure for completely specified st*a*te tables is based on the algorithm that two stat*e*s in a state table can be combined in to one if they can be shown to be equi*va*le*n*t.
4.	**Does Hazard occur in sequential circuit? If so what is the problem caused?** BTL1 Yes, Hazards occur in sequential circuit that is Asynchronous sequential circuit. It may result in a transition to a wrong state.
5.	**Give the procedural steps for determining the compatibles used for the purpose of merging a flow table.** BTL1 The purpose that must be applied in order to find a suitable group of compatibles for the purpose of merging a flow table can be divided into 3 procedural steps. ➢ Determine all compatible pairs by using the implication table. ➢ Find the maximal compatibles using a Merger diagram ➢ Find a minimal collection of compatibles that covers all the states and is closed.
6.	**Define cycles.** BTL1 If an input change includes a feedback transition through more than unstable state then such a situation is called a cycle.
7.	**Define primitive flow table.** BTL1 A primitive flow table is a flow table with only one stable total state in each row. Remember that a total state consists of the internal state combined with the input.
8.	**Write a short note on pulse mode circuit.** BTL1 Pulse mode circuit assumes that the input variables are pulses instead of level. The width of the pulses is long enough for the circuit to respond to the input and the pulse width must not be so long that it is still present after the new state is reached.
9.	**Define secondary variables.** BTL1 The delay elements provide a short term memory for the sequential circuit. The present state and next state variables in asynchronous sequential circuits are called secondary variables.

10. **Write a short note on shared row state assignment.** BTL1

Races can be avoided by making a proper binary assignment to the state variables. Here, the state variables are assigned with binary numbers in such a way that only one state variable can change at any one state variable can change at any one time when a state transition occurs. To accomplish this, it is necessary that states between which transitions occur be given adjacent assignments. Two binary are said to be adjacent if they differ in only one variable.

11. **Write short note on one hot state assignment.** BTL1

The one hot state assignment is another method for finding a race free state assignment. In this method, only one variable is active or hot for each row in the original flow table, ie, it requires one state variable for each row of the flow table. Additional row are introduced to provide single variable changes between internal state transitions.

12. **How does the state transition diagram of a Moore model differ from Mealy model? (A.U.DEC-2011)** BTL2

Moore model	Mealy model
Its output is a function of present state only	Its output is a function of present state as well as present input
Input changes does not affect the Output.	Input changes may affect the output of the circuit
Moore model requires more Number of states for implementing same function	It requires less number of states for implementing same function

13. **How does the operation of a synchronous input differ from that of a asynchronous input? (AU MAY-2012)** BTL2

Synchronous sequential circuits	**Asynchronous sequential circuits**
Memory elements are clocked flip flops	Memory elements are either unlocked flip-flops or time delay elements.
Easier to design	More difficult to design

14. **Define flip-flop . List various types of flip-flop.** BTL1

Flip - flop is a sequential device that normally. Samples its inputs and changes its outputs only at times determined by clocking signal.

- S.R. latch
- D latch
- Clocked J.K. flip-flop
- T flip-flop

15. **What is race around condition in Flipflop? (A.U.DEC-2011)** BTL1

In the JK latch, the output is feedback to the input, and therefore change in the output results change in the input. Due to this in the positive half of the clock pulse if J and K are both high then output toggles continuously. This condition is known as race around condition.

16. **Define shift Registers.** BTL1

The binary information in a register can be moved from stage to stage within the register or into or out of the register upon application of clock pulses. This type of bit movement or shifting is essential for certain arithmetic and logic operations used in microprocessors. This gives rise to a group of registers called shift registers

17. **What is moore circuit?** BTL1

When the output of the sequential circuit depends only on the present state of the flip-flop, the sequential circuit is referred to as moore circuit.

18. **What is Mealy circuit?** BTL1

When the output of the sequential circuit depends on both the present state of flip- flop and on the input, the sequential circuit is referred to as mealy circuit

19. **Name the different types of counter.** BTL1

- Synchronous counter
- Asynchronous counter
  1. Up counter
  2. Down counter
  3. Modulo – N counter
  4. Up/Down counter

20. **Write the characteristics table for SR flip flop. (A.U.MAY-2011)** BTL1

Qn	Qn+1	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

21. **Write the excitation table for JK flip flop. (A.U.MAY-2011)** BTL1

Q(t)	**Q(t+1)**	**J**	**K**
0	**0**	**0**	**X**
0	**1**	**1**	**X**
1	**0**	**X**	**1**
1	**1**	**X**	**0**

22. **What is an excitation table?** BTL1

During the design process we usually know the transition from present state to next state and wish to find the flip-flop input conditions that will cause the required transition. A table which lists the required inputs for a given chance of state is called an excitation table

PART * B

1. **Using positive edge triggering SR flip flops design a counter which counts in the following sequence: 000, 111, 110, 101, 100, 011, 010, 001, 000….. (13M) (May 04)** BTL3

Answer : Page 4.48 - Godse

- **Determine no. of flip flops & type of flip flop (2M)**

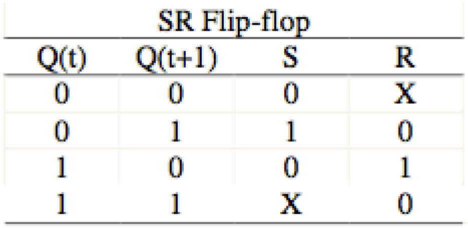
1. Determine no of flip flops needed

   $2^n > N$, here N=8,n=3

2. Type of flip flop to be used SR

- **Determine the excitation table for counter (4M)**

1. Choose Present state as A,B,C.
2. Next state as A^+,$B^{+,}C^+$.
3. Choose flip flop inputs S_A,R_A,S_B,R_B,S_C,R_C.



SR Flip-flop

Q(t)	Q(t+1)	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

- **K map simplification (4M)**

1. $S_{A=}$A'B'C'
2. R_A=AB'C'
3. S_B =B'C'
4. R_B=BC
5. S_C=C'
6. R_C=C

- **Logic diagram (3M)**

1. Four AND gates are used.
2. Three SR flip flops are used.
3. Choose Qa as MSB, Qc as LSB.

2. **Design a synchronous decade using D FF. (13M) (Dec 07)** BTL3

Answer : Page 4.49 - Godse

- **Determine no. of flip flops & type of flip flop (2M)**

1. Determine no. of flip flops needed.

   2^n>N, here N=10,n=4.

2. Type of flip flop to be used D.

- **Determine the excitation table for counter (4M)**

1. Choose Present state as Q_A,Q_B,Q_C,Q_D.
2. Next state as $Q_{A+1},Q_{B+1},Q_{C+1},Q_{D+1}$.

D Flip-flop		
Q(t)	Q(t+1)	DR
0	0	0
0	1	1
1	0	0
1	1	1

- **K map simplification (4M)**

1. $Q_{A+1}= Q_DQ_A'+Q_CQ_BQ_A$
2. $Q_{C+1}= =Q_CQ_B'+Q_CQ_A'+Q_C'Q_BQ_A$
3. $Q_{B+1}=Q_D'Q_B'Q_A+Q_BQ_A'$
4. $Q_{D+1}=QA'$

- **Logic diagram (3M)**

1. Seven AND gates are used.
2. Four D flip flops are used.
3. Choose Qd as MSB, Qa as LSB.

3.

Design a counter with a sequence of 0, 1, 3, 7, 6, 0. (13M) (Dec 10) BTL3

Answer : Page 4.51 - Godse

- **Determine no. of flip flops & type of flip flop (2M)**

1. Determine no of flip flops needed

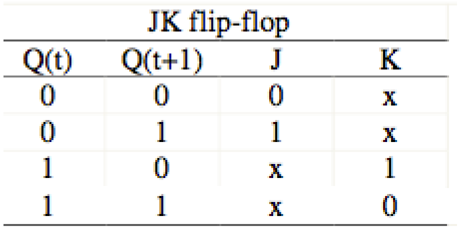
   Counter should count maximum 7, here N=8,n=3

2. Type of flip flop to be used JK

- **Determine the excitation table for counter (4M)**

1. Choose Present state as A,B,C.

2. Next state as A^+,$B^{+,}C^+$.
3. Choose flip flop inputs J_A,K_A,S_B,K_B,J_C,K_C.



JK flip-flop

Q(t)	Q(t+1)	J	K
0	0	0	x
0	1	1	x
1	0	x	1
1	1	x	0

- **K map simplification (4M)**

1. $J_{A=}$B
2. K_A=B’
3. J_B =C
4. K_B=C’
5. J_C=A’
6. K_C=A

- **Logic diagram (3M)**

1. Four D flip flops are used.
2. Choose A as MSB, B as LSB.

4.

Design a BCD up/down counter using SR flip flops. (13M) **(Nov/Dec 08)(Dec 10)** BTL3

Answer : Page 4.52 - Godse

- **Determine no. of flip flops & type of flip flop (2M)**

1. Determine no of flip flops needed

   2^n>N, here N=10,n=4

2. Type of flip flop to be used SR

- **Determine the excitation table for counter (4M)**

1. Choose Present state as A,B,C,D.
3. Next state as A^+,$B^{+,}C^+$,D^+.
4. Choose flip flop inputs S_A,R_A,S_B,R_B,S_C,R_C, S_D,R_D.

SR Flip-flop			
Q(t)	Q(t+1)	S	R
0	0	0	X
0	1	1	0
1	0	0	1
1	1	X	0

- **K map simplification (4M)**

1. S_A=M’A’B’C’D’+MBCD
2. R_A=M’AD’+MAD
3. S_B =M’AD’+MB’CD
4. R_B=M’BC’D’+MBCD
5. S_C=M’BC’D’+MA’C’D
6. R_C=M’CD’+MCD
7. S_D=D’
8. R_D=D

- **Logic diagram (3M)**

1. 12 AND gates & 6 OR gates are used.
2. Three SR flip flops are used.
3. Choose Q_A as MSB, Q_D as LSB.

5.

Design a BCD ripple counter JK flip flops. (13M) (May 2010,2011) BTL3

Answer : Page 4.59 - Godse

- **Determine no. of flip flops & type of flip flop (2M)**

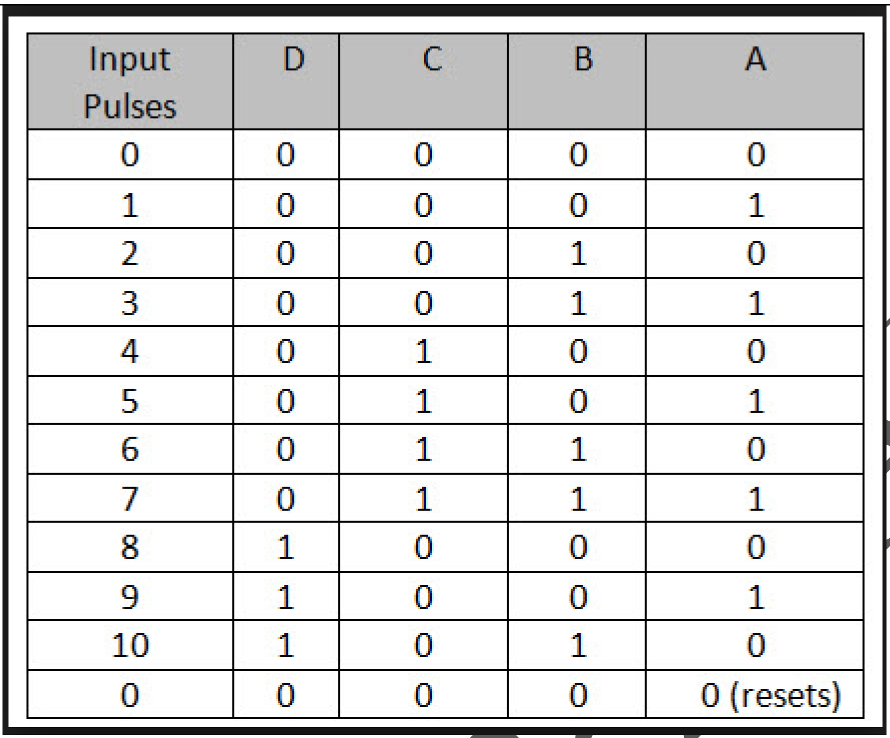
1. Determine no of flip flops needed

   Counter should count maximum as 0-9, here N=10,n=4

2. Type of flip flop to be used JK

- **Determine the truth table for counter (4M)**

1. Reset input of each flip flop is active low input.
2. By making clear input of all flip flops logic 0, reset the counter.
3. Reset logic is designed for valid states, Y=0.

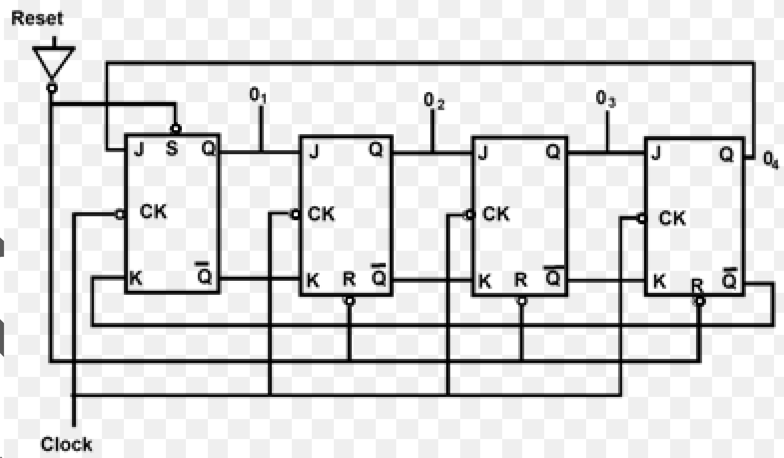


Input Pulses	D	C	B	A
0	0	0	0	0
1	0	0	0	1
2	0	0	1	0
3	0	0	1	1
4	0	1	0	0
5	0	1	0	1
6	0	1	1	0
7	0	1	1	1
8	1	0	0	0
9	1	0	0	1
10	1	0	1	0
0	0	0	0	0 (resets)

- **K map simplification (4M)**

1. Y=A’+B’C’

- **Logic diagram (3M)**



6. **For a four bit even parity bit generator, inputs come serially. The four bits of the input sequence are to be examined by the circuit and circuit produces a parity bit which is to be added in the original sequence. The circuit should get ready for receiving another four bits after producing a parity bit for the last sequence. Draw the state diagram and write down the state transition table. (13M) (May 08)** BTL3

Answer : Page 4.40 - Godse

- **Draw the state diagram (2M)**

1. State diagram consists of eight states as S0,S1,S2,S3,S4,S5,S6,S7,S8.
2. Input and outputs are either zero or one.

- **Determine the state table (4M)**

1. Select Present state as S0 to S8.
2. Calculate next state for X=0 and X=1.
3. Calculate output Z.

- **Assign states (3M)**

1. Assign states for S0=0000,S1=0001 & S8=1000.

- **Determine the state transition table (4M)**

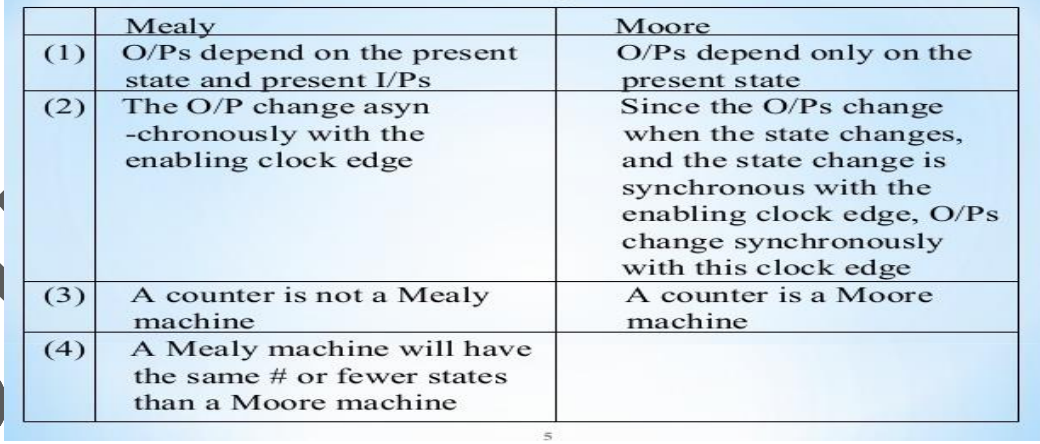
1. S0 can be replaced by 0000 in stable table.
2. Next state can be replaced by 0000 to 1000 for various values of X.
3. Output will be same.

7.

Compare Moore and Mealy circuit and also Draw and explain the block diagram of Mealy circuit.(13M) (May 05) BTL5

Answer : Page 4.4, 4.5 - Godse

- **Comparison of Moore and Mealy circuit (3M)**

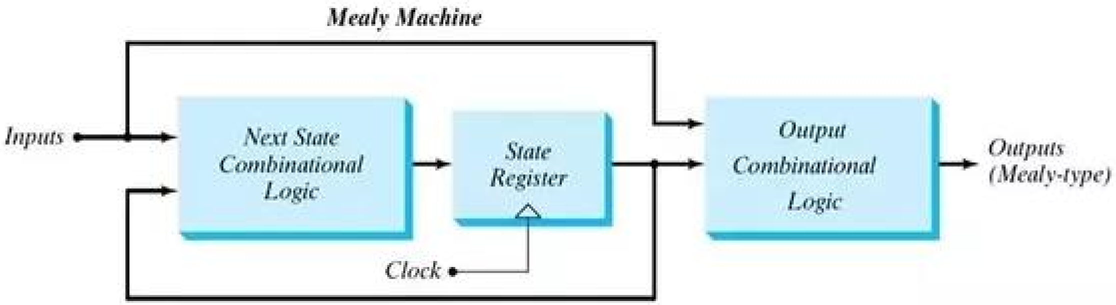


Difference Between Mealy and Moore Machine

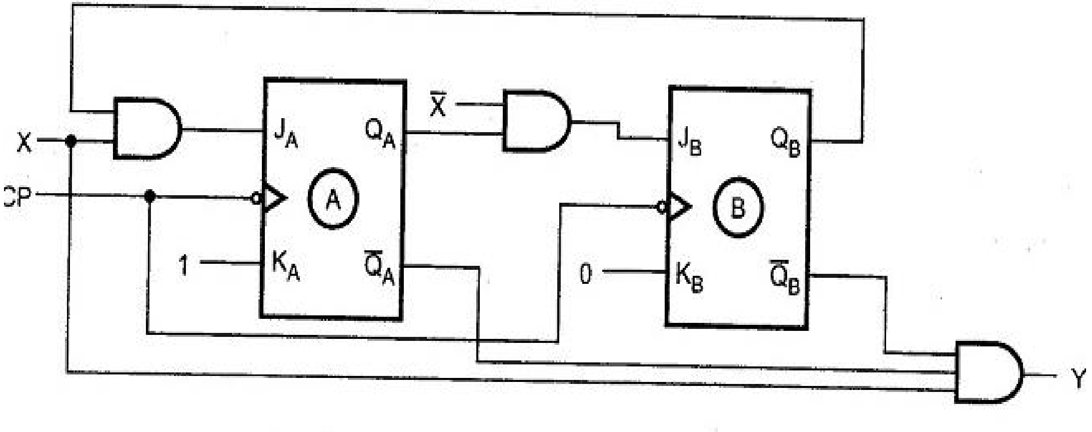
	Mealy	Moore
(1)	O/Ps depend on the present state and present I/Ps	O/Ps depend only on the present state
(2)	The O/P change asyn -chronously with the enabling clock edge	Since the O/Ps change when the state changes, and the state change is synchronous with the enabling clock edge, O/Ps change synchronously with this clock edge
(3)	A counter is not a Mealy machine	A counter is a Moore machine
(4)	A Mealy machine will have the same # or fewer states than a Moore machine	

5

- **Mealy circuit model (5M)**

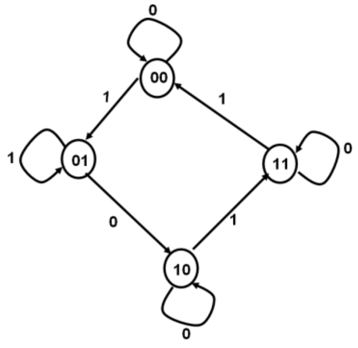


- **Example of Mealy model (5M)**



PART * C

1\. **Design the clocked sequential circuit using JK flip-flops whose state diagram is given below. (15M)(May2010)**BTL3



Answer : Page 4.42 - Godse

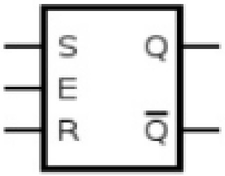
- **Determine no. of flip flops & type of flip flop (2M)**
- **Determine the excitation table (4M)**

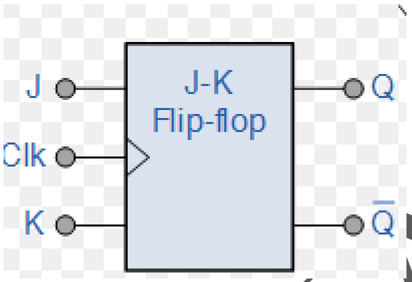
- **K map simplification (4M)**
- **Logic diagram (5M)**

2. **Explain in detail about SR and JK FF. (15M)** BTL1

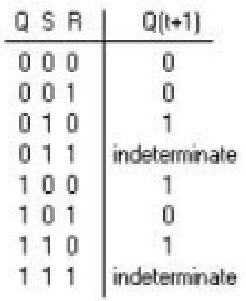
Answer : Page 3.6, 3.11 - Godse

- **Logic symbol of SR and JK FF (2M)**

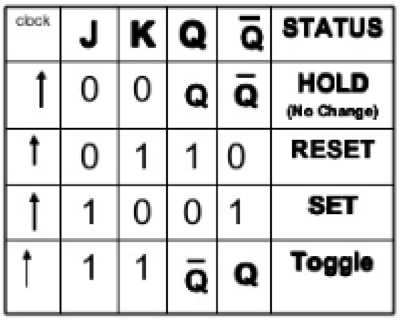




- **Truth table of SR and JK FF (4M)**

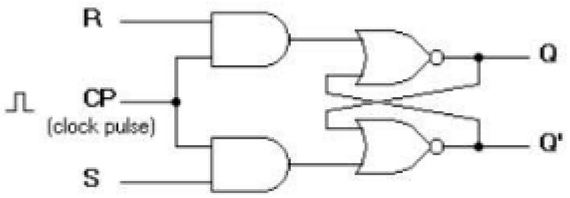


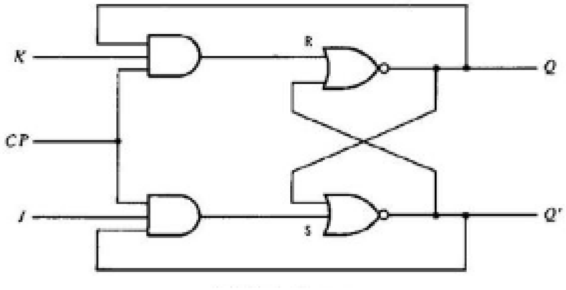
Q S R	Q(t+1)
0 0 0	0
0 0 1	0
0 1 0	1
0 1 1	indeterminate
1 0 0	1
1 0 1	0
1 1 0	1
1 1 1	indeterminate



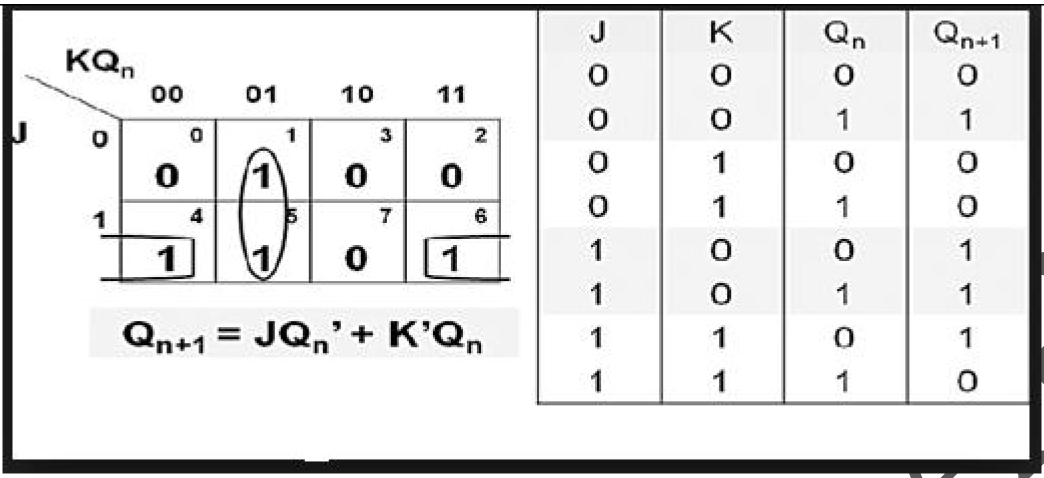
clock	J	K	Q	$\bar{Q}$	STATUS
↑	0	0	Q	$\bar{Q}$	HOLD (No Change)
↑	0	1	1	0	RESET
↑	1	0	0	1	SET
↑	1	1	$\bar{Q}$	Q	Toggle

- **Logic diagram SR and JK FF (5M)**



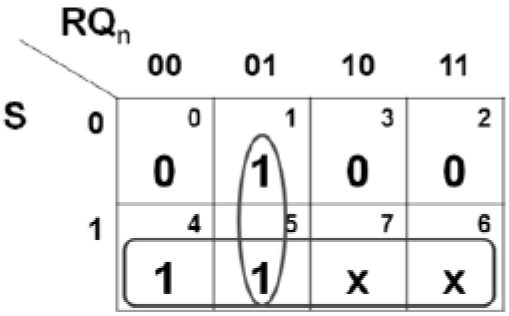


- **Characteristic equation of JK and SR FF (4M)**



$Q_{n+1} = JQ_n' + K'Q_n$

J	K	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	1
1	1	1	0



$Q_{n+1} = S + R'Q_n$

S	R	Q_n	Q_{n+1}
0	0	0	0
0	0	1	1
0	1	0	0
0	1	1	0
1	0	0	1
1	0	1	1
1	1	0	x
1	1	1	x

3. **Reduce the number of states in the following state table and tabulate the reduced state table. Starting from state a, and the input sequence 01110010011, determine the output sequence for the given and reduced state stable .(15M)(Dec 07,May 10)**BTL4

Present state	**Next State**		**Output**	
	x = 0	**x = 1**	**x = (**	**x = 1**
A	**F**	**B**	**0**	**0**
B	**D**	**C**	**0**	**0**
C	**F**	**E**	**0**	**0**
D	**G**	**A**	**1**	**0**

E	**D**	**C**	**0**	**0**
F	**F**	**B**	**1**	**1**
G	**G**	**H**	**0**	**1**
H	**G**	**A**	**1**	**0**

Answer : Page 4.19 - Godse

- **Reduced state table (8M)**

1. According to given state table state B & E, state D & H are equal.

Present State	**Next State**		**Output**	
	x =	**x = 1**	**x = 0**	**x = 1**
A	**F**	**B**	**0**	**0**
B	**D**	**C**	**0**	**0**
C	**F**	**E**	**0**	**0**
D	**G**	**A**	**1**	**0**
E	**D**	**C**	**0**	**0**
F	**F**	**B**	**1**	**1**
G	**G**	**H**	**0**	**1**
H	**G**	**A**	**1**	**0**

2. **Reduced state table.**

Present state	**Next State**		**Output**	
	x =	**x = 1**	**x = 0**	**x = 1**
A	**F**	**B**	**0**	**0**
C	**F**	**E**	**0**	**0**
F	**F**	**B**	**1**	**1**
G	**G**	**H**	**0**	**1**

- **Output sequence for reduced state table (7M)**

Input sequence	**State transition**	**Output**
0	A – F	0
1	F – B	1
1	B – A	0
1	A – B	0
0	B – D	0
0	D – G	1
1	G – D	1
0	D – G	1
0	G – G	0
1	G – D	1
1	D – A	0

4.

A sequential circuit with 2 D flip-flops A and B and input X and output Y is specified by following next state and output equations. (15M) (Dec 06,May) BTL3

A (t + 1) = AX + BX, B (t + 1) = A'X, Y = (A + B) X'

i. Draw the logic diagram of the circuit

ii. Derive the state table

iii. Derive the state diagram

Answer : Page 4.11 - Godse

- **Logic diagram (5M)**

1. Use D flipflop to draw logic diagram.

- **State table (5M)**

1. Plot next state map for each flip flop.
2. Plot transition table.
3. Draw state table.

- **State diagram (5M)**

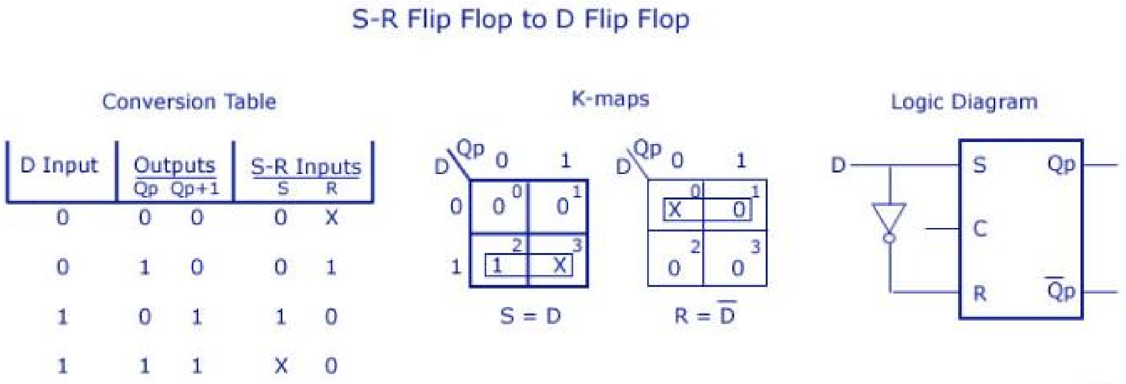
5.

Convert the following Flip flop. (8M) BTL2

a) SR FF to D FF

Answer : Page 3.22 - Godse

- **Write conversion table (3M)**
- **Derive K map (3M)**
- **Logic diagram (2M)**

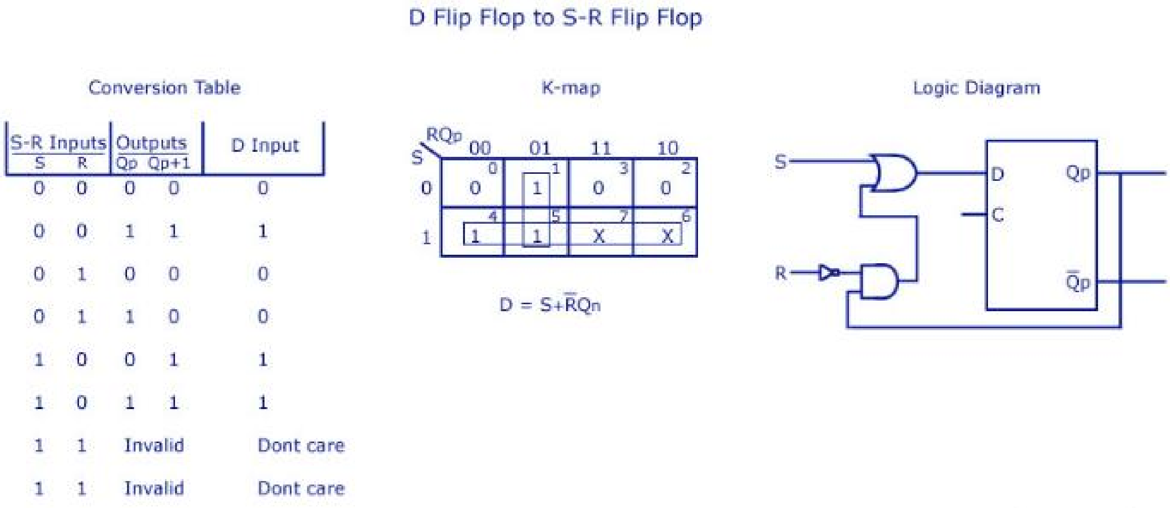


D Input	Outputs Qp	Outputs Qp+1	S-R Inputs S	S-R Inputs R
0	0	0	0	X
0	1	0	0	1
1	0	1	1	0
1	1	1	X	0

b) JK FF to D FF (7M) BTL2

Answer : Page 3.26 - Godse

- **Write conversion table (3M)**
- **Derive K map (2M)**
- **Logic diagram (2M)**



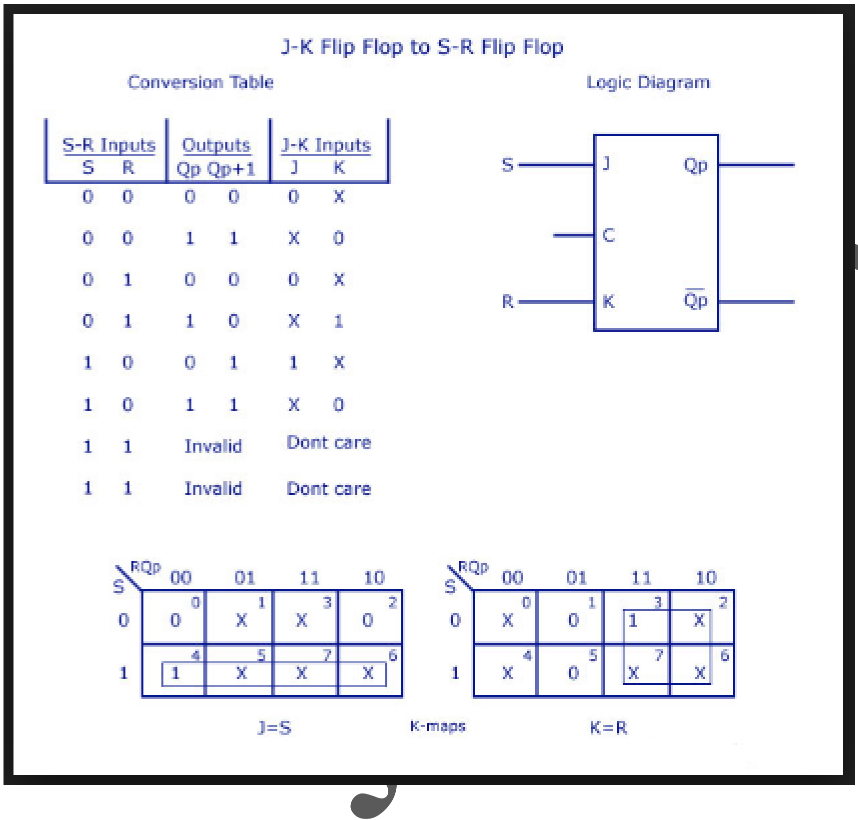
S-R Inputs S	S-R Inputs R	Outputs Qp	Outputs Qp+1	D Input
0	0	0	0	0
0	0	1	1	1
0	1	0	0	0
0	1	1	0	0
1	0	0	1	1
1	0	1	1	1
1	1	Invalid		Dont care
1	1	Invalid		Dont care

6. **Convert the following Flip flop. (8M)** BTL2

a) JK FF to SR FF

Answer : Page 3.28 - Godse

- **Write conversion table (3M)**
- **Derive K map (3M)**
- **Logic diagram (2M)**



J-K Flip Flop to S-R Flip Flop

Conversion Table

S-R Inputs		Outputs		J-K Inputs	
S	R	Qp	Qp+1	J	K
0	0	0	0	0	X
0	0	1	1	X	0
0	1	0	0	0	X
0	1	1	0	X	1
1	0	0	1	1	X
1	0	1	1	X	0
1	1	Invalid		Dont care	
1	1	Invalid		Dont care	

S \ RQp	00	01	11	10
0	0	X	X	0
1	1	X	X	X

J=S

K-maps

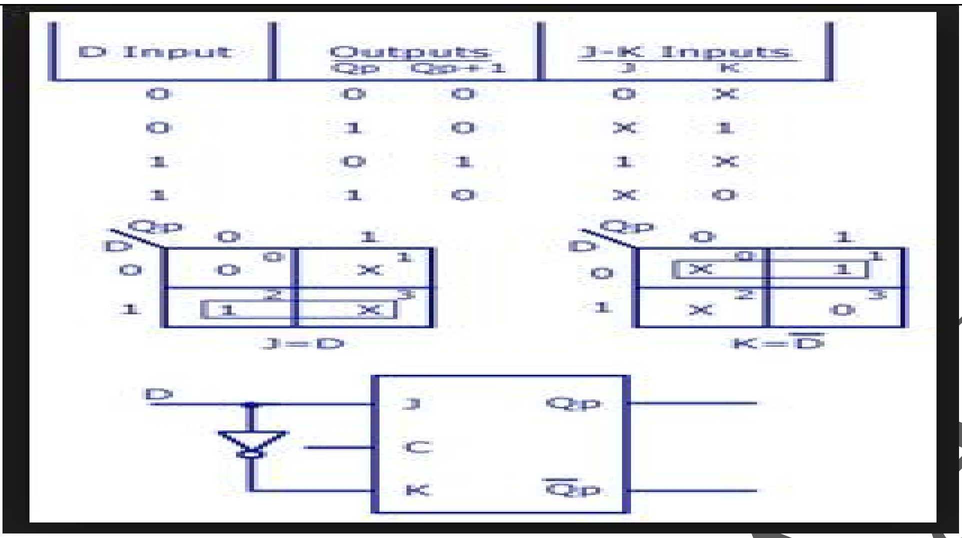
S \ RQp	00	01	11	10
0	X	0	1	X
1	X	0	X	X

K=R

b) JK FF to D FF (7M) BTL2

Answer : Page 3.26 - Godse

- **Write conversion table (3M)**
- **Derive K map (2M)**
- **Logic diagram (2M)**



D Input	Outputs		J-K Inputs	
	Qp	Qp+1	J	K
0	0	0	0	X
0	1	0	X	1
1	0	1	1	X
1	1	0	X	0

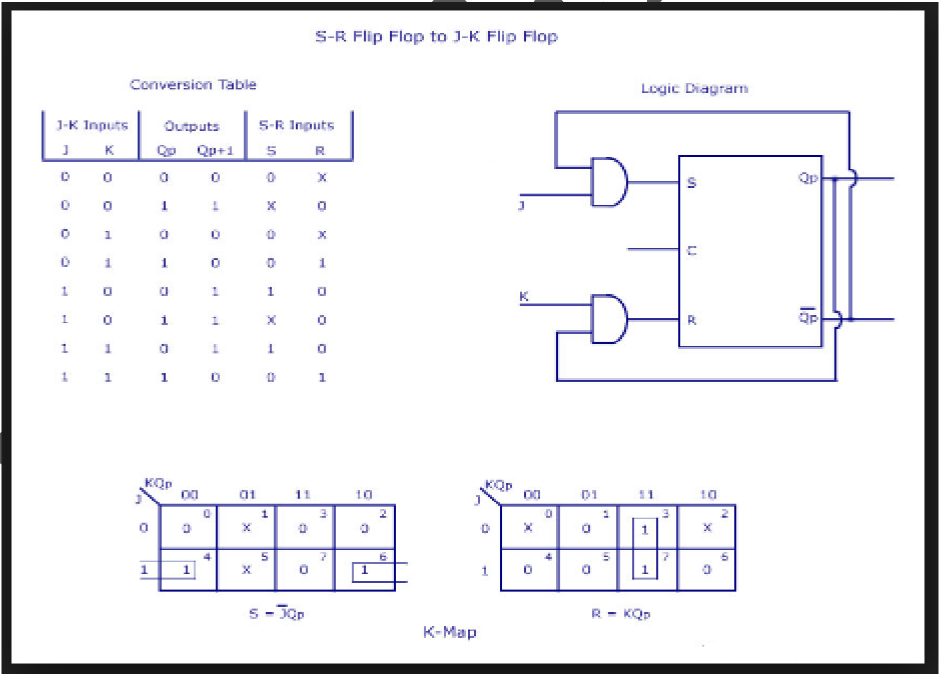
7.

Convert the following Flip flop. (8M) BTL2

a) SR FF to JK FF

Answer : Page 3.23 - Godse

- **Write conversion table (3M)**
- **Derive K map (3M)**
- **Logic diagram (2M)**



S-R Flip Flop to J-K Flip Flop

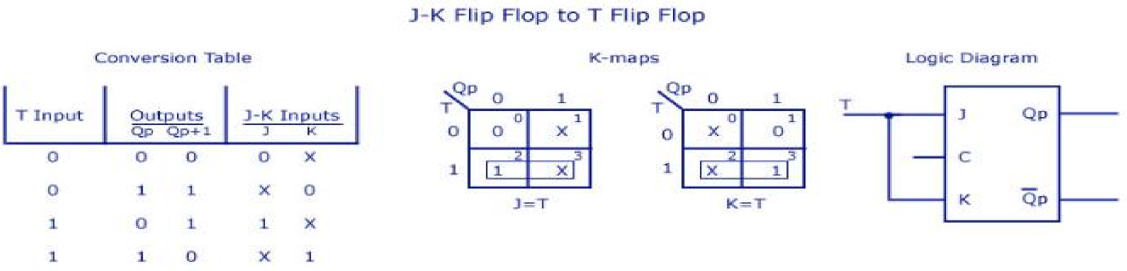
Conversion Table

J-K Inputs		Outputs		S-R Inputs	
J	K	Qp	Qp+1	S	R
0	0	0	0	0	X
0	0	1	1	X	0
0	1	0	0	0	X
0	1	1	0	0	1
1	0	0	1	1	0
1	0	1	1	X	0
1	1	0	1	1	0
1	1	1	0	0	1

b) JK FF to T FF (7M) BTL2

Answer : Page 3.25 - Godse

- **Write conversion table (3M)**
- **Derive K map (3M)**
- **Logic diagram (2M)**


J-K Flip Flop to T Flip Flop

Conversion Table

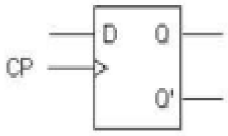
T Input	Outputs		J-K Inputs	
	Qp	Qp+1	J	K
0	0	0	0	X
0	1	1	X	0
1	0	1	1	X
1	1	0	X	1

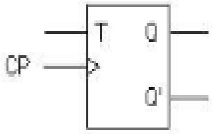
8.

Explain in detail about D and T FF. (15M) BTL1

Answer : Page 3.9, 3.16 - Godse

- **Logic symbol of D and T FF (2M)**



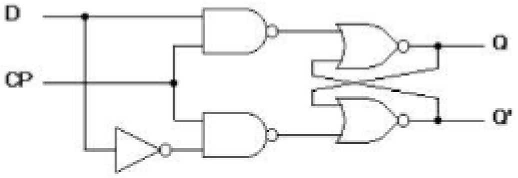


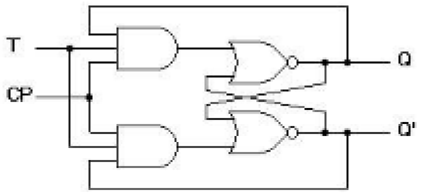
- **Truth table of D and T FF (4M)**

Q D	Q(t+1)
0 0	0
0 1	1
1 0	0
1 1	1

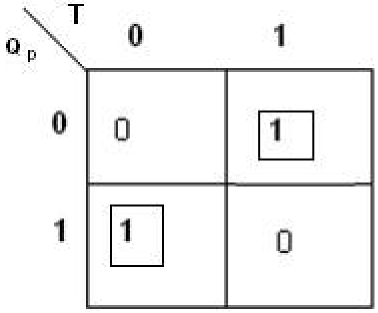
Q T	Q(t+1)
0 0	0
0 1	1
1 0	1
1 1	0

- **Logic diagram D and T FF (5M)**





- **Characteristic equation of D and T FF (4M)**

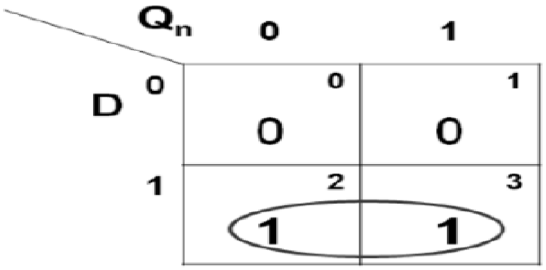


The Equation we get i

$Q = T\,Q_p{}' + T'\,Q_p$

$= T \text{ XOR } Q_p$

D	Q_n	Q_{n+1}
0	0	0
0	1	0
1	0	1
1	1	1



$$Q_{n+1} = D$$

UNIT IV ASYNCHRONOUS SEQUENTIAL CIRCUITS AND PROGRAMMABILITY LOGIC DEVICES

Asynchronous sequential logic circuits-Transition tability, flow tability -race conditions, hazards & errors in digital circuits; analysis of asynchronous sequential logic circuits-introduction to Programmability Logic Devices: PROM – PLA –PAL, CPLD-FPGA.

PART * A

Q.No.	Questions
1.	**List basic types of programmable logic devices.** BTL1 - Programmable Read only memory (PROM) - Programmable logic Arrays (PLA) - Programmable Array Logic (PAL) - Field Programmable Gate Array (FPGA) - Complex Programmable Logic Devices (CPLD)
2.	**What is the address and word of ROM?** BTL1 A read only memory is a device that includes both the decoder and the OR gates within a single IC package. In ROM, each bit combination of the input variable is called on address. Each bit combination that comes out of the output lines is called a word.
3.	**Name the types of ROM. (AU MAY-2011)** BTL1 - Masked ROM. - Programmable Read only Memory - Erasable Programmable Read only memory. - Electrically Erasable Programmable Read only Memory.
4.	**What is programmable logic array(PLA)? How it differs from ROM? (AU MAY-2012)** BTL1 In some cases the number of don't care conditions is excessive, it is more economical to use a second type of LSI component called a PLA A PLA is similar to a ROM in concept; however it does not provide full decoding of the variables and does not generates all the minterms as in the ROM.
5.	**What is mask - programmable?** BTL1 With a mask programmable PLA, the user must submit a PLA program table to the manufacturer.
6.	**Give the comparison between PROM and PLA. (AU MAY 2012)** BTL4 **PROM** : AND array is fixed and OR array is programmable. Cheaper and simple to use. **PLA :** Both AND and OR arrays are Programmable .Costliest and complex than PROMS.
7.	**What is field programmable logic array?** BTL1 The second type of PLA is called a field programmable logic array. The EPLA can be programmed by the user by means of certain recommended procedures.
8.	**Differentiate ROM & PLD's.** BTL3

ROM (Read Only Memory)	PLD's (Programmable Logic Array)
1.It is a device that includes both the decoder and the OR gates with in a single	1.It is a device that includes both AND and OR gates with in a single IC

IC package	package
2.ROM does not full decoding of the variables and does generate all the minterms	2.PLD's does not provide full decoding of the variable and does not generate all the minterms

9. **Write different types of RAM.** BTL1

The different types of RAM are

- NMOS RAM (Nitride Metal Oxide Semiconductor RAM)
- CMOS RAM (Complementary Metal Oxide
- Semiconductor RAM)
- Schottky TTL RAM
- ELL RAM.

10. **What are the types of arrays in RAM?** BTL1

RAM has two type of array namely,

- Linear array
- Coincident array

11. **State DRAM.** BTL1

- The dynamic RAM (DRAM) stores the binary information in the form of electric charges on capacitors. The capacitors are provided inside the chip by MOS transistors.
- The stored charges on the capacitors tend to discharge with time and the capacitors must be tending to discharge with time and the capacitors must be periodically recharged by refreshing the dynamic memory.
- DRAM offers reduced power consumption and larger storage capacity in a single memory chip.

12. **What is SRAM?** BTL1

- Static RAM (SRAM) consists of internal latches that store the binary information. The stored information remains valid as long as the power is applied to the unit.
- SRAM is easier to use and has shorter read and write cycle.
- The memory capacity of a static RAM varies from 64 bit to 1 mega bit.

13. **Differentiate volatile and non-volatile memory.** BTL3

Volatile memory	Non-volatile memory
They are memory units which lose stored information when power is turned off. E.g. SRAM and DRAM	It retains stored information when power is turned off. E.g. Magnetic disc and ROM

14. **What are the advantages of RAM?** BTL1

The advantages of RAM are

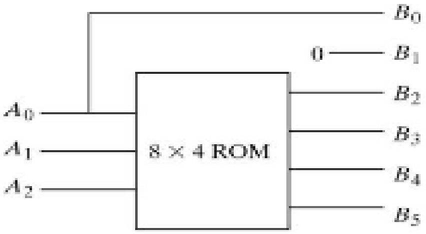
- Non-destructive read out
- Fast operating speed
- Low power dissipation
- Compatibility
- Economy

15. **What is FPGA?** BTL1

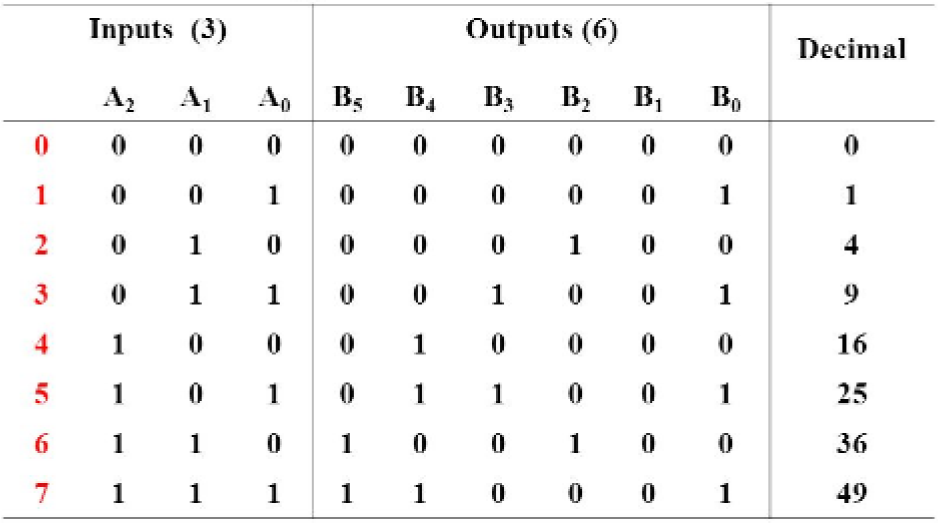
A field programmable gate array (FPGA) is a programmable logic device that supports

	implementation of relatively large logic circuits. FPGAs can be used to implement a logic circuit with more than 20,000 gates .
16.	**What are the terms that determine the size of a PAL?** BTL1 The size of a PLA is specified by the ➢ Number of inputs ➢ Number of products terms ➢ Number of outputs
17.	**Define flow table in asynchronous sequential circuit. (A.U.MAY-2012)** BTL1 In asynchronous sequential circuit state table is known as flow table because of the behaviour of the asynchronous sequential circuit. The stage changes occur in independent of a clock, based on the logic propagation delay, and cause the states to flow from one to another.
18.	**Define race condition. How can a race be avoided?** BTL1 A race condition is said to exist in a synchronous sequential circuit when two or more binary state variables change, the race is called non-critical race. Races can be avoided by directing the circuit through intermediate unstable states with a unique state – variable change.
19.	**What are the types of hazards? What are hazards in Asynchronous sequential circuit? (A.U.MAY-2011,DEC-2011)** BTL1 The 3 types of hazards are ➢ Static – 0 hazards ➢ Static – 1 hazard ➢ Dynamic hazards Hazards are unwanted switching transients that may appear at the output of a circuit because different paths exhibit different propagation delays.
20.	**Define critical & non-critical race with example.** BTL1 The final stable state that the circuit reaches does not depend on the order in which the state variables change, the race is called non-critical race. The final stable state that the circuit reaches depends on the order in which the state variables change, the race is called critical race.
21.	**What are hazards? Mention the causes of essential hazards.** BTL1 The unwanted switching transients that may occur at the output of a circuit called Hazards. It is caused by unequal delays among two or more paths that originate from the same input. It can be eliminated by adjusting amount of delays in the affected path.
22.	**Differentiate static and dynamic hazard.** BTL2 **Static hazard:** If a signal is supposed to remain at particular logic value when an input variable changes its value, but signal undergoes change in its required value. **Dynamic hazard:** If output changes three or more times when it should change from 1to 0 or from 0 to 1.
	PART * B
1.	**Design a combinational circuit using ROM. The circuit accepts 3-bit number and generates an output binary number equal to square of input number. (13M)** BTL3 **Answer : Page: 6.18 - Godse** ➢ **Block diagram (6M)**

1. Select binary inputs as A0,A1,A2.
2. Square outputs as B0 to B5.



- **ROM truth table (7M)**



	Inputs (3)			Outputs (6)						Decimal
	A_2	A_1	A_0	B_5	B_4	B_3	B_2	B_1	B_0	
0	0	0	0	0	0	0	0	0	0	0
1	0	0	1	0	0	0	0	0	1	1
2	0	1	0	0	0	0	1	0	0	4
3	0	1	1	0	0	1	0	0	1	9
4	1	0	0	0	1	0	0	0	0	16
5	1	0	1	0	1	1	0	0	1	25
6	1	1	0	1	0	0	1	0	0	36
7	1	1	1	1	1	0	0	0	1	49

2.

Implement the following Boolean function using PAL. (13M) BTL3

- **w(A,B,C,D) = ∑m(0,2,6,7,8,9,12,13)**
- **x(A,B,C,D) = ∑m(0,2,6,7,8,9,12,13,14)**
- **y(A,B,C,D) = ∑m(2,3,8,9,10,12,13)**
- **z(A,B,C,D) = ∑m(1,3,4,6,9,12,14)**

Answer : Page: 6.36 - Godse

- **Simplify four sections using K map (3M)**

1. Using K map techniques simplify expression for w,x,y and z.
2. w=A'B'D'+A'BC+AC'
3. x=A'B'D'+A'BC+AC'+BCD'
4. y=A'B'C+B'CD'+AC'
5. z=A'B'D+B'C'D+BD'

- **Implementation of PAL program table (5M)**

1. Four groups consist of three terms.
2. A’ is considered as 0 and A is considered as 1.
3. The above rule is applicable to all variables such as B, C, D and w.

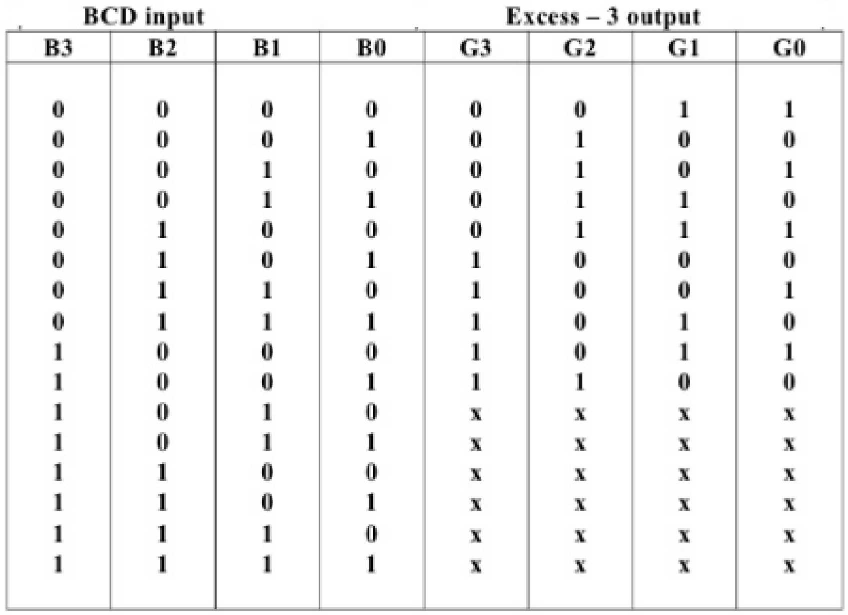
- **Logic diagram (5M)**

1. For First group output, three AND gates ,one OR gate and one Not gate is required.
2. For Second group output, three AND gates and one OR gate is required.
3. For Third group output, three AND gates and one OR gate is required.
4. For Fourth group output, three AND gates and one OR gate is required.

3.

Design BCD to Excess-3 converter using PAL. (13M) BTL3
Answer : Page: 6.38 - Godse

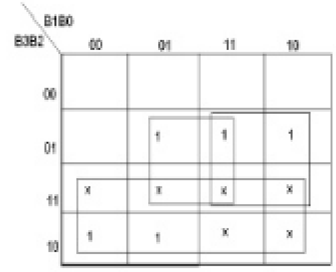
- **Derive truth table of BCD to Excess 3 converter (3M)**



BCD input				Excess – 3 output			
B3	B2	B1	B0	G3	G2	G1	G0
0	0	0	0	0	0	1	1
0	0	0	1	0	1	0	0
0	0	1	0	0	1	0	1
0	0	1	1	0	1	1	0
0	1	0	0	0	1	1	1
0	1	0	1	1	0	0	0
0	1	1	0	1	0	0	1
0	1	1	1	1	0	1	0
1	0	0	0	1	0	1	1
1	0	0	1	1	1	0	0
1	0	1	0	x	x	x	x
1	0	1	1	x	x	x	x
1	1	0	0	x	x	x	x
1	1	0	1	x	x	x	x
1	1	1	0	x	x	x	x
1	1	1	1	x	x	x	x

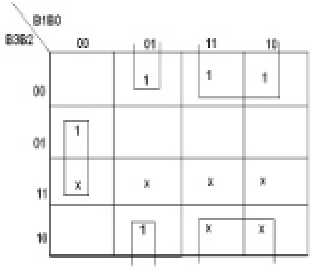
- **Simplify four sections using K map (3M)**

K-Map for E₃:



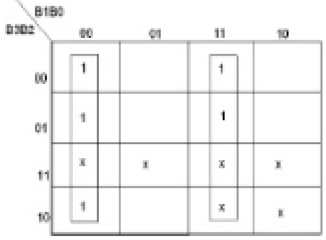
E3 = B3 + B2 (B0 + B1)

K-Map for E₂:



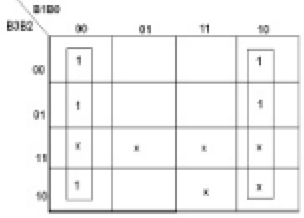
$E2 = B2 \oplus (B1 + B0)$

K-Map for E₁:



$E1 = B1 \overline{\oplus} B0$

K-Map for E₀:



$E0 = \overline{B0}$

- **Implementation of PAL program table (3M)**

1. Four inputs are B3,B2,B1,B0.
2. Four outputs are E3,E2,E1,E0.
3. Reduce expression using table.

- **Logic diagram (4M)**

1. For First group output, two AND gates ,one OR gate is required**.**
2. For Second group output, two AND gates and one OR gate is required.
3. For Third group output, three AND gates and one OR gate is required.
4. For Fourth group output, three AND gates and one OR gate is required.

4. **Realize the functions given using a PLA with 6 inputs, 4 outputs and 2 product terms. (13M)** BTL4

F1(A,B,C) = ∑m(0,1,3,5)
F2(A,B,C) = ∑m(3,5,7).

Answer : Page: 6.24 - Godse

- **Simplify Boolean functions (3M)**

1. Find F1 and F2 .
2. To examine product terms by grouping 0's instead of 1.
3. F1=A'B'+A'C+B'C
4. F2=AC+BC
5. F1'=AC;+BC'+AB
6. F2'=A'B'+BC'+AC'

- **Implementation of PLA program table (5M)**

1. PLA table consists of 3 inputs, 4 product terms and 2 outputs.
2. Four groups consist of two terms.
3. A' is considered as 0 and A is considered as 1.
4. The above rule is applicable to all variables such as B and C.

- **Logic diagram (5M)**

1. 3 NOT gates, 4 AND gates and 2 OR gates are required.
2. EX-OR gate is programmed to invert function, to get the desired function outputs.

5. **An asynchronous sequential circuit has two internal states and one output. The excitation and output function describing the circuit are as follows. Draw the logic diagram, derive state transition table and output map. (13M)** BTL1

- **Y1=x1x2+x1y2+x2y1**
- **Y2=x2+x1y1y2+x1y1**
- **Z=x2+y1**

Answer : Page: 5.19 - Godse

- **Logic diagram (2M)**

1. Draw logic diagram for given problem**.**
2. 5 AND gates and 3 OR gates are required.

- **State table (5M)**

1. State table consists of PS,NS, stable state and output.
2. Present state consists of Y1,Y2,X1 and X2.
3. Next state consists of Y1,Y2,X1 and X2.
4. If system is stable, mention state as YES otherwise NO.

	➢ **Transition table (4M)** 1. Using K map substitute variables. 2. Circle represents stable state. 3. Remaining variables are considered as unstable states. ➢ **Output map (2M)** 1. Output is mapped for all stable states. 2. For unstable states output is mapped unspecified.
6.	**Illustrate the analysis procedure of asynchronous sequential circuit with an example. (13M) (MAY 2013)** BTL4 **Answer : Page :5.10,5.16 - Godse** ➢ **Types of asynchronous sequential circuits (2M)** **1. Fundamental mode:** ✓ Input variable can change only when system is stable. ✓ Only one input variable can change at a given time. ✓ Inputs are levels not pulses. **2. Pulse mode:** ✓ Inputs are pulses instead of levels. ✓ Width must be long enough for the circuit to respond to the input. ✓ Pulse width must not be so long. ✓ Pulses should not occur on two or more input lines. ➢ **Design procedure (5M)** 1. Define states and draw a state diagram of the circuit. 2. Minimize state table. 3. Do State assignment. 4. Choose the type of flip flop to be used to determine excitation equations. 5. Construct excitation table for the circuit. 6. Determine the output equation and the flip flop input equations using K map simplification.

	7. Draw logic diagram. ➢ **Example (6M)** **1.** Design a pulse mode circuit having two input lines x1,x2 and output line z. The circuit should produce an output pulse to coincide with the last input pulse in the sequence x1-x2-x2.No other input sequence should produce an output pulse. ➢ Select three present states s0,s1,s2. ➢ Next state as x1,x2. ➢ Minimize state table. ➢ Assign state (00,01,10) for all present states. ➢ Flip flop to be used as T. ➢ Construct excitation table. ➢ Ta=Ax1+Bx2. ➢ Tb=Bx1+A'x2. ➢ Z=Bx2. ➢ Draw logic diagram.
7.	**Implement the following two Boolean functions with a PLA. (13M) (MAY 2011).**BTL5 **F1(A,B,C) = ∑m (3,5,7)** **F2 (A,B,C) = ∑m(4,5,7)** **Answer : Page: 6.22 – Godse** ➢ **Simplify Boolean functions using K map (3M)** 1. F1=AC+BC 2. F2=AB'+AC ➢ **Implementation of PLA program table (5M)** 1. PLA table consists of 3 inputs, 2 product terms and 2 outputs. 2. Each group consists of single terms. 3. Under each output variable write T/C. 4. Output inverter is to be bypassed , write T. 5. Function is to be complemented, write C. 6. A' is considered as 0 and A is considered as 1.

7. The above rule is applicable to all variables such as B and C.

- **Logic diagram (5M)**

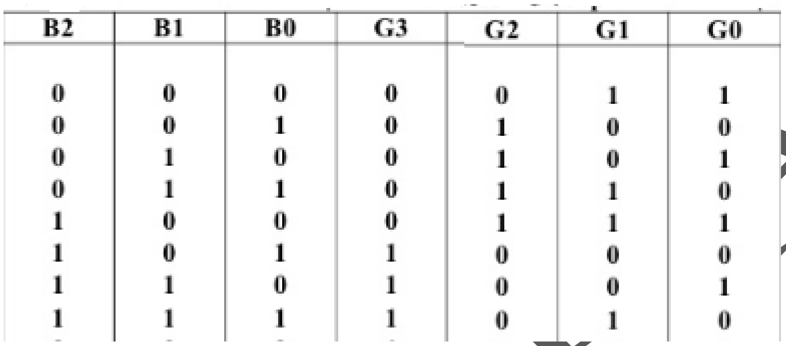
1. 3 NOT gates, 3 AND gates and 2 OR gates are required.

8.

Design a combinational circuit using PROM. The circuit accepts 3-bit binary number and generates its equivalent Excess-3 code. (13M) BTL3

Answer : Page: 6.17 - Godse

- **Truth table for Binary to Excess-3 (4M)**



B2	B1	B0	G3	G2	G1	G0
0	0	0	0	0	1	1
0	0	1	0	1	0	0
0	1	0	0	1	0	1
0	1	1	0	1	1	0
1	0	0	0	1	1	1
1	0	1	1	0	0	0
1	1	0	1	0	0	1
1	1	1	1	0	1	0

- **Block diagram of 8*4 PROM (2M)**

1. Binary inputs are B2,B1,B0.
2. Excess 3 Outputs are G3,G2,G1,G0.

- **PROM truth table (3M)**
- **Logic diagram (4M)**

1. 3 NOT gates, 8 AND gates and four OR gates are used**.**

9.

Using PROM realize the following expressions. (13M) BTL3

F1(A,B,C)= ∑m(0,1,3,5,7)

F2(A,B,C)= ∑m(1,2,5,6)

Answer : Page: 6.15 - Godse

- **Block diagram (2M)**

1. Three inputs are A0,A1,A2.
2. Two outputs are F1,F2.

- **PROM truth table (4M)**

1. The given function has three inputs are A0,A1,A2.

2. Generates 8 minterms and since there are two functions and two outputs.

- **Logic diagram (7M)**

1. 3 NOT gates, 8 AND gates and 2 OR gates.
2. Product terms are m0,m1,m2,m3,m4,m5,m6 and m7.

PART * C

1.

Design an asynchronous sequential circuit that has two inputs X1 and X2 and one output Z. When X1=0, the output Z is 0. The first change in X2 that occurs while X1 is 1 will cause output Z to be 1. The output Z will remain 1 until X1 returns to 0. (15M) (Dec 08,June 09).BTL3

Answer : Page: 5.37 – Godse

- **Draw state diagram and primitive flow table (3M)**

X1	X2	Z
0	0	0
0	1	0
1	0	1
1	1	1

1. Based on truth table draw state diagram.
2. Consists of 6 states for various x1, x2 and output Z.
3. Primitive flow table is constructed from state diagram.
4. Equivalent states are eliminated from primitive flow table.

- **Reduction of primitive flow table (3M)**

1. Merger graph gives two pairs as a set of maximal compatibles.
2. A,B=S0, C,E=S1,D,F=S2.
3. Set of maximal compatible covers all original states.

- **State assignment (3M)**

1. S0=00, S1=01, S2=10.
2. Choose S3=11 to prevent critical race during transition.
3. Derive flow table with state assignment.

4. Flow table can be converted as transition table.

- **K Map simplification (3M)**

1. $F1^{+}$=F2'F1X1X2X1'
2. $F2^{+}$=F1'X2X1+F1X2'X1+F2X1+F2F1'X2
3. Z=F2

- **Logic diagram (3M)**

1. 4 NOT gates, 6 OR gates and 2 OR gates are required.

2.

Design a pulse mode circuit having two input lines X1 and X2 and one output line Z. The circuit should produce an output pulse to coincide with the last input pulse in the sequenceX1, X2, X2. No other input sequence should produce an output pulse. (15M) (May 08) BTL3

Answer : Page :5.11 - Godse

- **Select three present states s0,s1,s2 (2M)**

1. **S**0 indicates last input was x1.
2. **S1** indicates sequence x1-x2 occurred.
3. **S2** indicates sequence x1-x2-x2 occurred.
4. Next state as x1,x2.

- **Minimize state table (2M)**

1. State table is minimum.

Present state	**Next state**	
	X1	**X2**
S0	**S0/0**	**S1/0**
S1	**S0/0**	**S2/1**
S2	**S0/0**	**S2/0**

- **Assign states and choose FF (1M)**

1. S0=00, S1=01, S2=10.
2. Flip flop to be used as T.

- **Construct excitation table (3M)**

1. Present states are A and B.
2. Next states are x1 and x2.
3. Flip flop inputs are TA and TB.
4. Output is Z.

- **K Map simplification (3M)**

3. Ta=Ax1+Bx2.
4. Tb=Bx1+A'x2.
5. Z=Bx2.

- **Draw logic diagram (4M)**

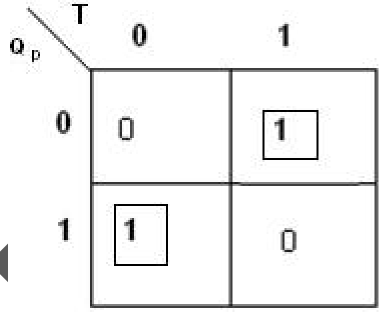
1. 4 AND gates, 2 OR gates and two flip flops are required.

3.

Design a T FF using logic gates. Draw the state diagram and obtain the primitive flow table for a circuit with two inputs x_1 and x_2 and two outputs z_1 and z_2 that satisfies the following conditions. When x_1 x_2 = 00 output z_1 z_2 = 00, when x_1= 1 and x_2 changes from 0 to 1 the output z_1 z_2 = 01, when x_2= 1 and x_1 changes from 0 to 1 the output z_1 z_2 = 10 otherwise output does not change. (15M) BTL3

Answer : Page: 5.45 - Godse

- **Draw state diagram and primitive flow table (3M)**



The Equation we get

$Q = T\,Q_p' + T'\,Q_p$

$= T \text{ XOR } Q_p$

1. Based on truth table draw state diagram.
2. Consists of 8 states for various x1, x2 and output Z.
3. Primitive flow table is constructed from state diagram.
4. Equivalent states are eliminated from primitive flow table.

- **Reduction of primitive flow table (3M)**

1. Merger graph gives two pairs as a set of maximal compatibles.

2. A,B,C=S0, D=S1,E,F,H=S2, G=S3.
3. Set of maximal compatible covers all original states.

- **State assignment (3M)**

1. S0=00, S1=01, S2=10.
2. Choose S3=11 to prevent critical race during transition.
3. Derive flow table with state assignment.
4. Flow table can be converted as transition table.

- **K Map simplification (3M)**

1. $F1^{+}$=F1'P'+F2T'+F2P
2. $F2^{+}$=F2TP+F1P'+F2T'
3. Z=F2

- **Logic diagram (3M)**
- 4 NOT gates, 6 OR gates and 2 OR gates are required.

4.

Design an asynchronous sequential circuit that has two inputs X and Y and one output Z. When Y=1 the input is transferred to Z. When Y is 0, the output does not change for any change in X. (15M) (June 03) BTL3

Answer : Page :5.34- Godse

- **Draw state diagram and primitive flow table (3M)**

1. Based on truth table draw state diagram.
2. Consists of 5 states for various x, y and output Z.
3. Primitive flow table is constructed from state diagram.
4. Equivalent states are eliminated from primitive flow table.

X	Y	Z
0	0	0
0	1	0
1	0	1
1	1	1

	Reduction of primitive flow table (3M) 1. Merger graph gives two pairs as a set of maximal compatibles. 2. A,B,C=S0, D,E,F=S1. 3. Set of maximal compatible covers all original states. **State assignment (3M)** 1. S0=00, S1=01. **6.** Derive flow table with state assignment. **7.** Flow table can be converted as transition table. **K Map simplification (3M)** 1. F^{+}=FY'+XY 2. S=XY 3. R=X'Y **Logic diagram (3M)** 1. 4 NOT gates, 6 OR gates and 2 OR gates are required.

UNIT V VHDL

RTL Design – combinational logic – Sequential circuit – Operators – Introduction to Packages – Subprograms – Test bench. (Simulation /Tutorial Examples: adders, counters, flip flops, Multiplexers & De multiplexers).

PART * A

Q.No. **Questions**

1. **Write the VHDL code for AND gate.(Nov/Dec 2010)** BTL2

```
LIBRARY ieee:
USE ieee.std_logic_1164.all;
Entity And1 is
Port(x:in std_logic;
        Y: in std_logic;);
END And1;
architecture beha2 of And1 is
begin
F<=x and y;
End beha2
```

2. **List the operators available in VHDL**.BTL1
   - Logical Operators
   - Arithmetic Operators
   - Relational Operators
   - Operators

3. **Write HDL for half adder. (May/June 2010,2012)** BTL3

```
Entity half is
Port(a,b:in bit;sum,carry:out bit);
End half;
Architecture half_adder of half is
begin
(Sum<= a xor b;
Carry<=a and b);
End half_adder
```

4. **What are the various modeling techniques in HDL?(MAY 2010,2012,DEC 2012)** BTL1
   - Structural modeling
   - Dataflow modeling
   - Behavioural modeling

5. **When can RTL be used to represent digital systems?(MAY 2011)** BTL3
Designs using the Register-Transfer Level specify the characteristics of a circuit by operations and the transfer of data between the registers. An explicit clock is used. RTL design contains exact timing possibility, operations are scheduled to occur at certain times. Any code that is synthesizable can used RTL .

6. **What are ASM?(MAY 2011)** BTL1
Algorithmic State Machine (ASM) method is a method for designing finite state machines. It is used to represent diagrams of digital integrated circuits. The ASM diagram is like a state diagram but less formal and thus easier to understand. An ASM chart is a method of describing the sequential operations of a digital system.

7. **Write the VHDL coding for a sequential statement (d-flipflop).** BTL3

```
entity dff is
port(clk,d:in std_logic;
q:out std_logic);
end;
architecture dff of dff is
begin
process(clk,d)
begin
if clk' event and clk=' 1' then
q<=d;
end process;
end;
```

8. **What are the different kinds of the test bench?** BTL1

- Stimulus only
- Full test bench
- Simulator specific
- Hybrid test bench
- Fast test bench

9. **What is Moore FSM?** BTL1

The output of a Moore finite state machine(FSM) depends only on the state and not on its inputs. This type of behaviour can be modeled using a single process with the case statement that switches on the state value.

10. **What is packages and what is the use of these packages?** BTL1

A package declaration is used to store a set of common declaration such as components, types, procedures and functions. These declaration can then be imported into others design units using a use caluse.

11. **What is variable class ?Give example for variable.** BTL1

An object of variable class can also hold a single value of a given type , However in this case different values can be assigned to a variable at different time.

Ex: Integer

12.

What are the data types available in VHDL? BTL1

- Scalar type
- Composite type
- Access type
- File type

13.

Write the VHDL code for 1 to 4 demultiplexer. BTL3

```
entity demux is
port (
 D0  : in  std_logic_vector(7 downto 0);
D1  : in  std_logic_vector(7 downto 0);
 D2  : in  std_logic_vector(7 downto 0);
D3  : in  std_logic_vector(7 downto 0);
SEL : in  std_logic_vector(1 downto 0);
 Y   : out std_logic_vector(7 downto 0));
end demux;
architecture behave of demux is
begin  -- behave
with SEL select
Y <= D0 when "00",
D1 when "01",
D2 when "10",
 D3 when "11",
(others => 'X') when others;
end behave;
```

14.

Write the VHDL code for half adder.(MAY 2010,2012) BTL3

```
entity ha1 is
Port ( a : in STD_LOGIC;
b : in STD_LOGIC;
sum : out STD_LOGIC;
carry : out STD_LOGIC);
end ha1;
architecture Behavioral of ha1 is
begin
sum<= a xor b;
carry<=a and b;
end Behavioral;
```

15.

What are sequential statements? BTL1

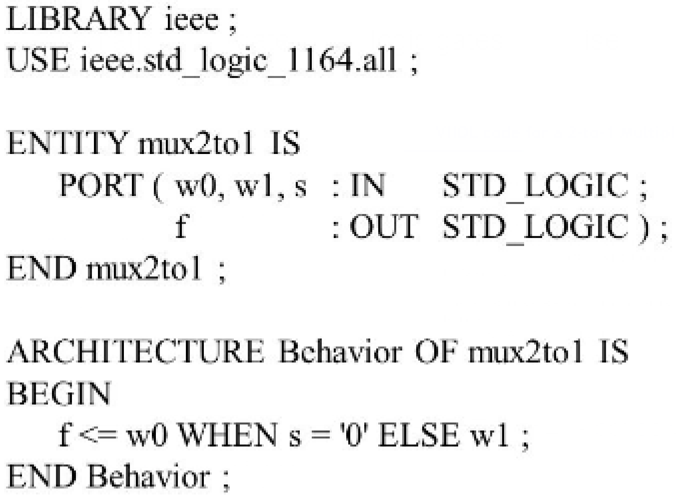
While using these statements, the ordering of the statements is important because ordering may affect the meaning of the code. As name suggests, the sequential statements are evaluated in the order in which they appear in the code.

16.

What are the features of sequential statement? BTL2

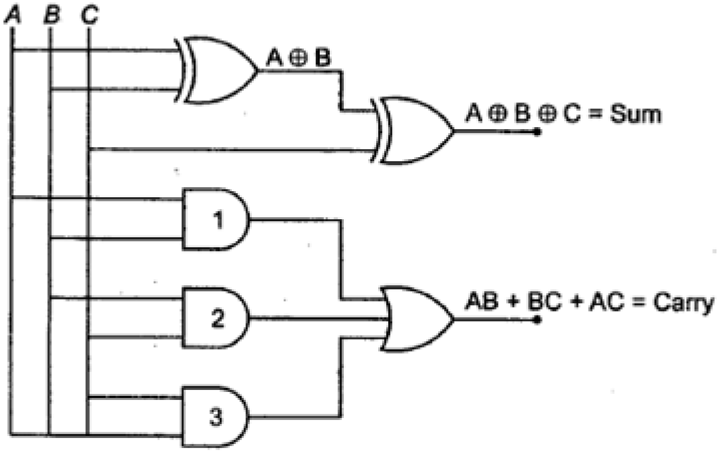
- The sequential statements execute one after another as per the writing order.
- They must be placed inside a “process statement”.

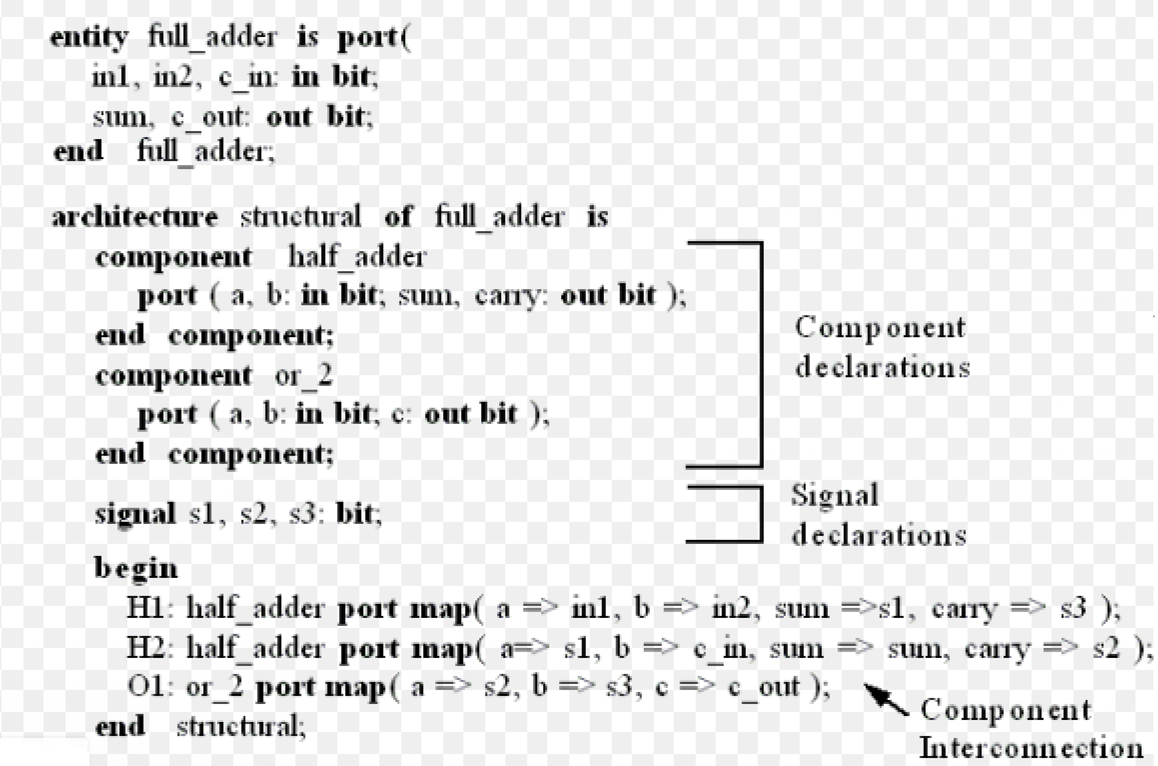
	➢ Variables are only used in sequential statements. ➢ Sequential statements do not generate sequential hardware.
17.	**What is Process statement?** BTL1 Process is main concurrent statement in VHDL code which describe the sequential behaviour of design. All statements within process execute sequentially in zero time. Only one driver is placed on a signal. The signal is updated with the last value assigned to it within the process.
18.	**Define CASE statement.** BTL1 The case statement selects one of the benches for execution based on the value of the expression. The expression value must be of a discrete type of a one dimensional array type. Choice may be expressed as a single values, as a range of values, by using "1"(vertical bar) represents an "OR" choice.
19.	**What is Test Bench?** BTL1 A test bench is the stimulus that tests the functionality of the design, This is a test program in VHDL. Thus for the simulation of a digital logic system, the design is first described in HDL, it is then verified by simulating the design and then using a test bench which is written in HDL, it is tested and its response is observed.
20.	**What is need for VHDL?(MAY 2013)** BTL2 When used for systems design, is that it allows the behaviour of the required system to be described (modelled) and verified (simulated) before synthesis tools translate the design into real hardware (gates and wires).VHDL allows the description of a concurrent system.
21.	**Write a VHDL code for 2*1 MUX.** BTL3



```
LIBRARY ieee ;
USE ieee.std_logic_1164.all ;

ENTITY mux2to1 IS
    PORT ( w0, w1, s  : IN    STD_LOGIC ;
              f        : OUT   STD_LOGIC ) ;
END mux2to1 ;

ARCHITECTURE Behavior OF mux2to1 IS
BEGIN
    f <= w0 WHEN s = '0' ELSE w1 ;
END Behavior ;
```

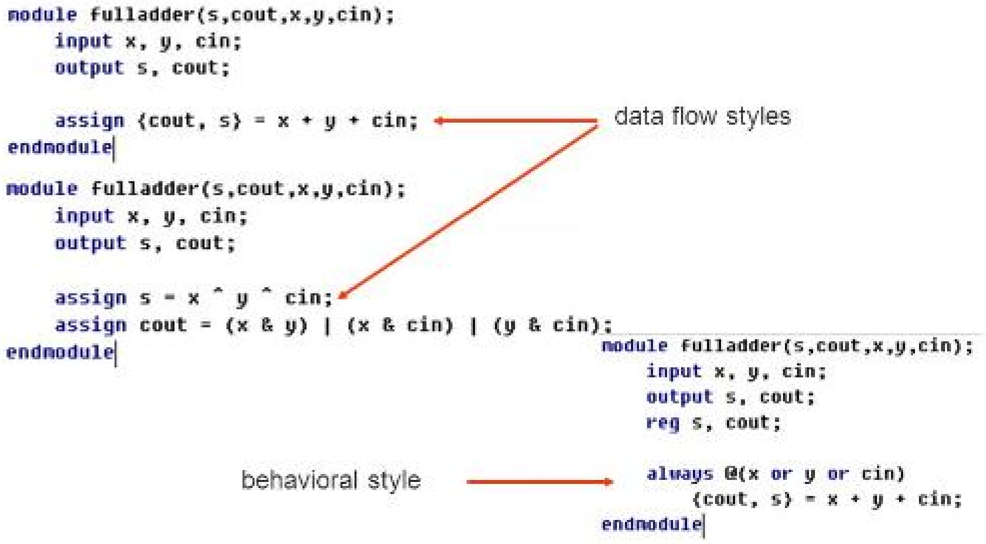
22.	**What are sequential and concurrent statements?** BTL1 ➢ Sequential statements are executed one after other, like in software programming languages. Subsequent programs can override the effect of previous statements this way. The order of assignment must be considered when sequential statements are used. ➢ Concurrent statements are active continuously. So the order of the statements is not relevant. Concurrent statements are especially suite demodel the parallelism of hardware.
23.	**What are the languages that are combined together to get VHDL language?** BTL1 ➢ Sequential language ➢ Concurrent language

	➢ Net-list language ➢ Timing specification ➢ Waveform generation language
24.	**What are the RTL description processes?** BTL1 The pure combinational process and the clocked process. All clocked processes infer flip-flops and can be described in terms of state machine syntax.
PART * B	
1.	**Write a VHDL code to realize a full adder using behavioural modeling and structural modeling. (13M) (Nov/Dec 2017)** BTL3 **Answer : Page 8.9, 8.11 - Godse** ➢ **Circuit diagram of full adder (3M)**  ➢ **Structural modeling (5M)**



```
entity  full_adder  is  port(
   in1, in2, c_in: in bit;
   sum, c_out: out bit;
end   full_adder;

architecture  structural  of  full_adder  is
   component   half_adder
      port ( a, b: in bit; sum, carry: out bit );
   end  component;
   component  or_2
      port ( a, b: in bit; c: out bit );
   end  component;

   signal s1, s2, s3: bit;

   begin
     H1: half_adder port map( a => in1, b => in2, sum =>s1, carry => s3 );
     H2: half_adder port map( a=> s1, b => c_in, sum => sum, carry => s2 );
     O1: or_2 port map( a => s2, b => s3, c => c_out );
   end   structural;
```

- **Behavioural modeling (5M)**



```
module fulladder(s,cout,x,y,cin);
    input x, y, cin;
    output s, cout;

    assign {cout, s} = x + y + cin;
endmodule
```

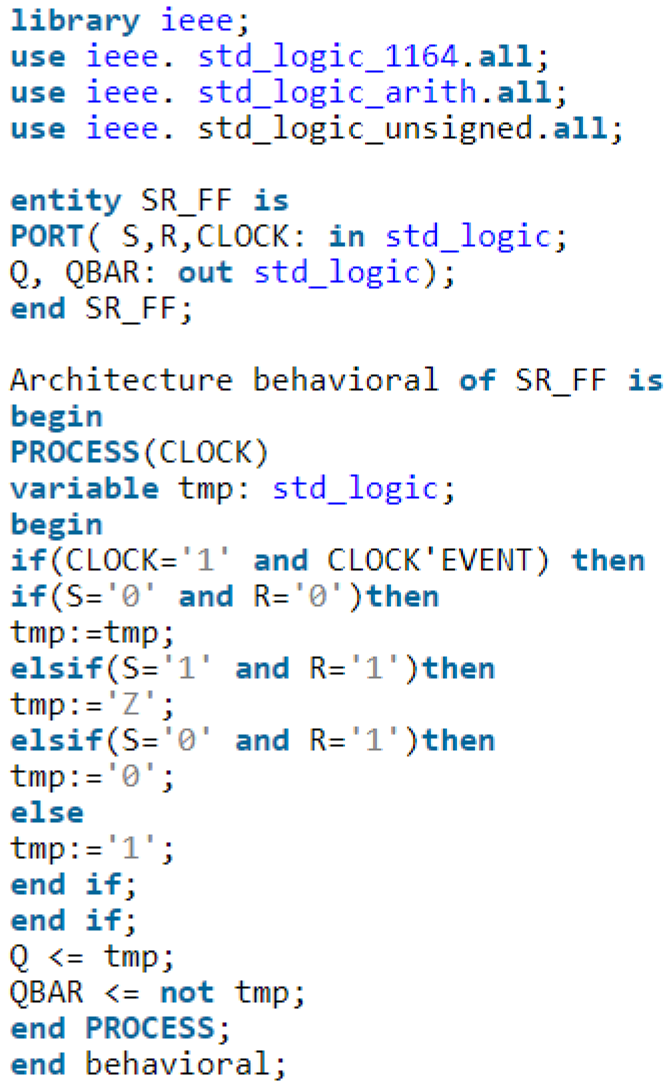
```
module fulladder(s,cout,x,y,cin);
    input x, y, cin;
    output s, cout;

    assign s = x ^ y ^ cin;
    assign cout = (x & y) | (x & cin) | (y & cin);
endmodule
```

```
module fulladder(s,cout,x,y,cin);
    input x, y, cin;
    output s, cout;
    reg s, cout;

    always @(x or y or cin)
       {cout, s} = x + y + cin;
endmodule
```

2. **Write an VHDL coding for realization of clocked SR flip flop. (13M) (Nov/Dec 2017)** BTL3

Answer : Page 8.9, 8.11 - Godse

- **Logic symbol SR FF & Truth table (4M)**
- **Program (9M)**



```
library ieee;
use ieee. std_logic_1164.all;
use ieee. std_logic_arith.all;
use ieee. std_logic_unsigned.all;

entity SR_FF is
PORT( S,R,CLOCK: in std_logic;
Q, QBAR: out std_logic);
end SR_FF;

Architecture behavioral of SR_FF is
begin
PROCESS(CLOCK)
variable tmp: std_logic;
begin
if(CLOCK='1' and CLOCK'EVENT) then
if(S='0' and R='0')then
tmp:=tmp;
elsif(S='1' and R='1')then
tmp:='Z';
elsif(S='0' and R='1')then
tmp:='0';
else
tmp:='1';
end if;
end if;
Q <= tmp;
QBAR <= not tmp;
end PROCESS;
end behavioral;
```

3\.

Design a 3 bit magnitude comparator and write the VHDL code to realize it using structural modeling. (13M) (April/May 2017) BTL6

Answer : Page 8.24- Godse

- **Circuit diagram & truth table (5M)**
- **Program (8M)**

4\.

Write the VHDL code for decade counter. (13M) (May/June 2016) BTL6

Answer : Page 8.30 - Godse

- **Synchronous counter (7M)**

library ieee;
use ieee.std_logic_1164.all;

```
use work.pkgdecade.all;
entity decade_counter is
  port ( clock    : in  std_logic;
         clear_L  : in  std_logic;
         enable_L : in  std_logic := '0';
         en_nxt   : out std_logic;
         DigOut   : out natural range 9 downto 0 );
   end decade_counter;
architecture behav of decade_counter is
begin
  process ( clock, clear_L, enable_L )
  variable int_count : integer range 0 to 9;
  begin
    if clock = '1' and clock'event then
      if clear_L = '0' then
        int_count := 0;
      elsif enable_L = '0'  then
        if int_count = 9 then
          int_count := 0;
        else
          int_count := int_count + 1;
        end if; --int_count = 9
      end if; -- clear_L = '0'
    end if; --clock transition
    if enable_L = '0' and int_count = 9 then
      en_nxt <= '1';
    else
      en_nxt <= '0';
    end if;
    DigOut <= int_count;
  end process;
end behav;
```

- **Asynchronous counter (6M)**

```
library ieee;
use ieee.std_logic_1164.all;
use ieee.std_logic_unsigned.all;
use std.textio.all;

entity rmatrix is
  port(
          clock   : in std_logic;
          reset  : in std_logic;
          data_out : out std_logic_vector(7 downto 0)
        );
end rmatrix;
```

```
architecture behaviour of rmatrix is
begin

process
      file infile           : text is in
"G:\QuartusPrograms\VHDL\File\ReadMatrix\a.txt";
      variable row          : line;
      variable element      : bit_vector(7 downto 0);
      variable end_of_line : boolean := true;
   begin
      if(reset='1')then
         data_out <= (others => '0');
      else
         while(not endfile(infile))loop
            readline(infile, row);
            read(row, element, end_of_line);
            while(end_of_line)loop
               data_out <= to_stdlogicvector(element);
               read(row, element, end_of_line);
               wait until rising_edge(clock);
            end loop;
            end_of_line := true;
         end loop;
         wait;
      end if;
   end process;
 end behaviour;
```

7.

Write the VHDL code for 4 bit parallel adder. (13M) (May/June 2016) BTL6

Answer : Page 8.36 - Godse

- **Circuit diagram 4 bit parallel binary adder (5M)**
- **Truth table (3M)**
- **Program for any modeling (5M)**

```
entity pa is
port(a :in STD_LOGIC_VECTOR(3downto0);
b :in STD_LOGIC_VECTOR(3downto0);
ca :out STD_LOGIC;
sum :out STD_LOGIC_VECTOR(3downto0)
);
end pa;
architecturevcgandhi of pa is
```

```
Componentfais
port(a :in STD_LOGIC;
b :in STD_LOGIC;
c :in STD_LOGIC;
sum :out STD_LOGIC;
ca :out STD_LOGIC
);
end component;
signal s :std_logic_vector(2downto0);
signal temp:std_logic;
begin
temp<='0';
u0 :fa port map (a(0),b(0),temp,sum(0),s(0));
  u1 :fa port map (a(1),b(1),s(0),sum(1),s(1));
  u2 :fa port map (a(2),b(2),s(1),sum(2),s(2));
ue:fa port map (a(3),b(3),s(2),sum(3),ca);
endvcgandhi;
```

4. **Explain various operators and subprograms in detail. (13M) (May/June 2016)** BTL2

Answer : Page 8.25 - Godse

- **Operators (7M)**

1. Every language has operators whose functions are to operate on operands and produce some results.
   - ✓ Assignment Operators
   - ✓ Shift Operators
   - ✓ Logical Operators
   - ✓ Relational Operators
   - ✓ Arithmetic Operators
   - ✓ Misc Operators

ASSIGNMENT OPERATORS	
<=	Signal assignment: <target_identifier> <= <expression> Ex: c <= a **NAND** b; To initialise the signal use ':=' ex:

	Signal Enable: **Bit :=** '0';
:=	Constant and variable assignments: <target_identifier> **:=** <expression> Ex: **Constant** a: a_type **:=** "1001"; **Variable** temp_a : **integer**; temp_a **:=** a;
SHIFT OPERATOR	
SLL **SRL** **SLA** **SRA** **ROL** **ROR**	Shift left, right most bits replaced with zeros Shift right, left most bits replaced with zeros Shift left arithmetic Shift right arithmetic Rotate left Rotate Right Examples: "1001" sll 2 => 0100, "1001" srl 2 => 0010 "0101" sla 2 => 0111, "1010" sra 2 => 1110 "0111" rol 2 => 1101, "1011" ror 2 => 1110
LOGICAL OPERATORS	
AND **OR** **NAND** **NOR** **XOR** **XNOR** **NOT**	Logical operators work on predefined types, either Bit or Boolean. The resul has the same type as the type of operand(s). Ex: z := x **AND** y; -- variables c <= a **AND** b; -- signals
RELATIONAL OPERATORS	
= **eq** /= **noteq** <= **lt or eq** >= **gr or eq**	Relational operators compare two operands of the same type and produce a Boolean type. Ex: z <= x **<=** y; -- If x less than or equal to y, the Boolean result will be assigned to the signal z.
ARITHMETIC OPERATORS	
**	Exponentiation
rem	Remainder
mod	Modulus
/	Division
*	Multiplication
-	Subtraction
+	Addition
abs	Absolute Value
-	Unary Minus

+	Unary Plus
MISCELLANEOUS OPERATORS	
&	Concatenation operator Example: "ABC" & "DEF" => ABCDEF "1010" & "0101" => 10100101

- **Sub program (6M)**

1. VHDL provides two kinds of subprograms: **procedures** and **functions**.

- ✓ **Procedures** are called as sequential statements. Functions are called within expressions, and return a result.
- ✓ VHDL distinguishes between a subprogram declaration and a corresponding subprogram body.
- ✓ The subprogram declaration contains only interface information, while the subprogram body contains.
- ✓ Interface information
- ✓ Local declarations
- ✓ Statements

2. **Functions:**

- ✓ Functions are intended to be used strictly for computing values and not for changing the value of any objects associated with the function's formal parameters; therefore, all parameters of functions must be of mode **in** and must be of class **signal** or **constant**.
- ✓ Procedures on the other hand, are permitted to change the values of the objects associated with the procedure formal parameters; therefore, parameters of procedures may be of mode **in**, **out** and **in out**.
- ✓ If no mode is specified for a subprogram parameter, the parameter is interpreted as having mode **in**. If no class is specified, parameters of mode **in** are interpreted as being of class **constant**, and parameters of mode **out** or **in out** are interpreted as being of class **variable**.
- ✓ It is possible to define a procedure or function with no parameters; in this case, the interface list is simply omitted from the subprogram specification.

5. **Write a VHDL program for Mux, full adder . (13M) (Nov/Dec 2015)** BTL3

Answer : Page 8.57 - Godse

- **Circuit diagram of full adder ,Truth table and Program (6M)**

```
entityfull_adderis port(a,b,c:in bit;sum,carry:out bit);
endfull_adder;

architecture data of full_adderis
begin
sum<= a xor b xor c;
carry<=((a and b)or(b and c)or(a and c));
end data;
```

- **Circuit diagram of Multiplexer ,Truth table and Program (7M)**

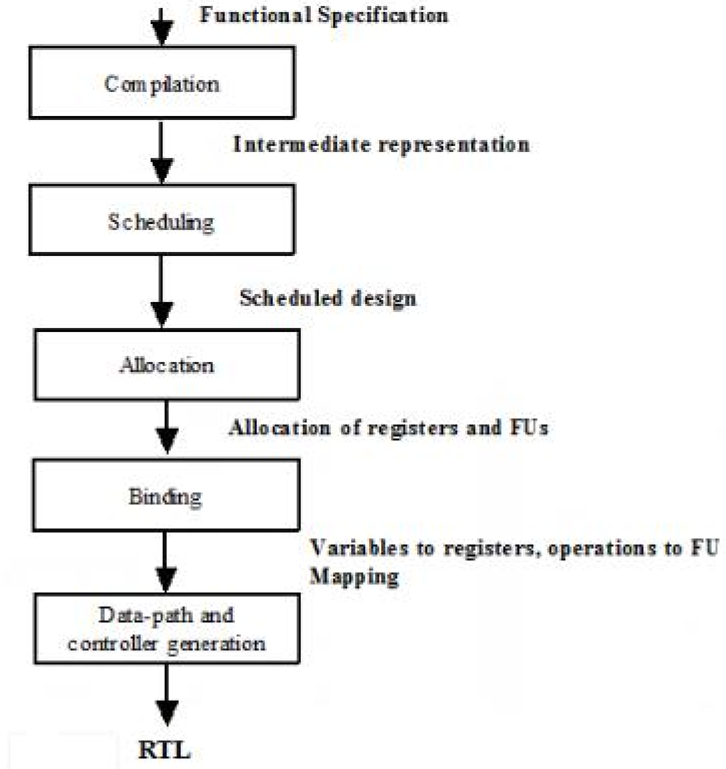
```
entity mux is
port(S1,S0,D0,D1,D2,D3:in bit; Y:out bit);
end mux;

architecture data of mux is
begin
  Y<=(not S0 andnot S1 and D0)or
(S0 andnot S1 and D1)or
(not S0 and S1 and D2)or
(S0 and S1 and D3);
end data;
```

PART * C

1. **Explain in detail RTL design procedure. (15M) (Nov/Dec 2015)** BTL2

Answer : Page 105 - Godse

- **Steps involved in RTL Design (7M)**

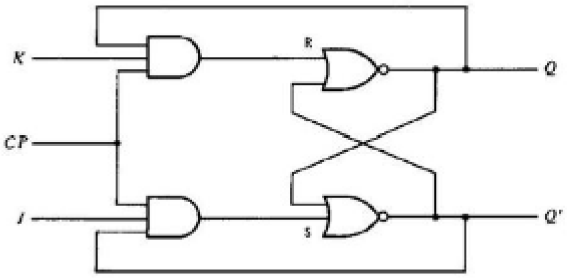


- **Adder circuit with explanation (4M)**
- **Generic component in data path with explanation (4M)**

2. **Construct a VHDL module for a JK flipflop. (15M) (AU DEC 2010,2011)** BTL3

Answer : Page 105 - Godse

- **Circuit diagram of JK FF (4M)**



- **Program for any modeling (11M)**

```
entityjkis
port(
j :in STD_LOGIC;
```

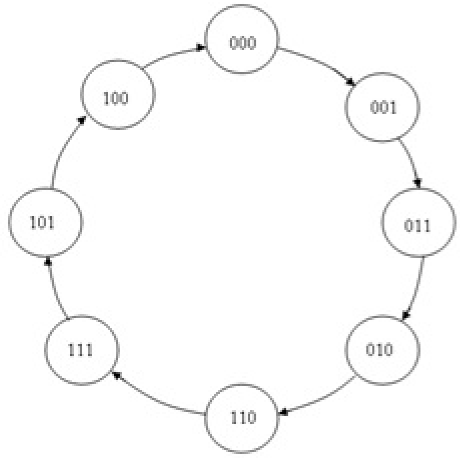
```
k :in STD_LOGIC;
clk:in STD_LOGIC;
reset :in STD_LOGIC;
q :out STD_LOGIC;
qb:out STD_LOGIC
);
endjk;
architecturevirat of jkis
begin
jkff: process (j,k,clk,reset)is
variable m :std_logic:='0';
begin
if(reset ='1')then
m :='0';
elsif(rising_edge(clk))then
if(j/= k)then
m := j;
elsif(j ='1'and k ='1')then
m :=not m;
endif;
endif;
   q <= m;
qb<=not m;
end process jkff;
endvirat;
```

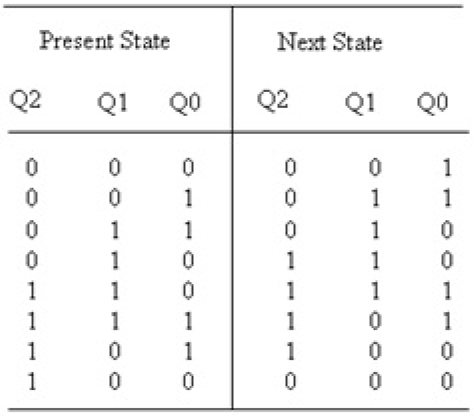
3. **Write the VHDL code to realize a 3 bit gray code counter using case statement. (15M)** BTL3

Answer : Page 105 - Godse

- **State diagram and state table (6M)**

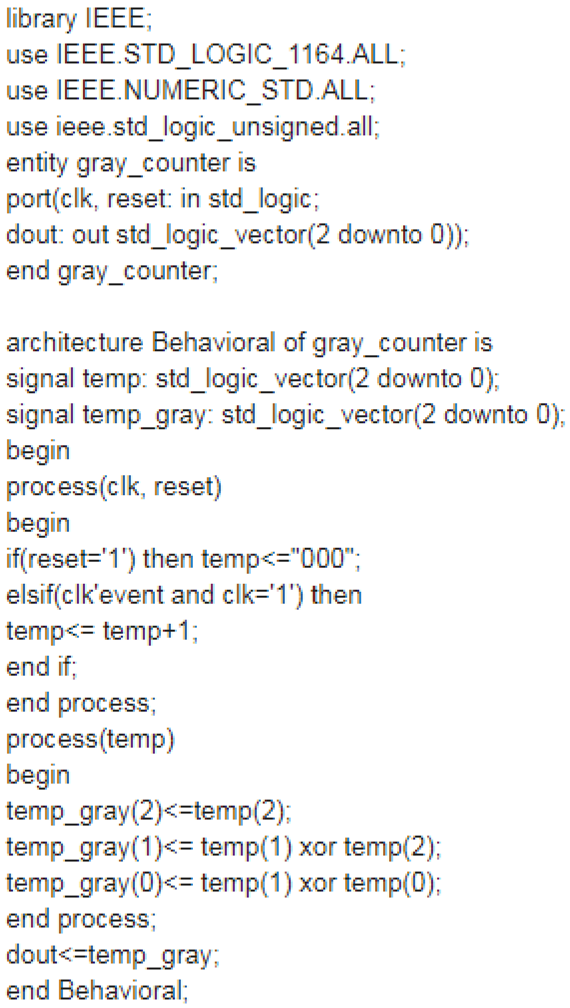
	See below





Present State			Next State		
Q2	Q1	Q0	Q2	Q1	Q0
0	0	0	0	0	1
0	0	1	0	1	1
0	1	1	0	1	0
0	1	0	1	1	0
1	1	0	1	1	1
1	1	1	1	0	1
1	0	1	1	0	0
1	0	0	0	0	0

- **Program (9M)**



```
library IEEE;
use IEEE.STD_LOGIC_1164.ALL;
use IEEE.NUMERIC_STD.ALL;
use ieee.std_logic_unsigned.all;
entity gray_counter is
port(clk, reset: in std_logic;
dout: out std_logic_vector(2 downto 0));
end gray_counter;

architecture Behavioral of gray_counter is
signal temp: std_logic_vector(2 downto 0);
signal temp_gray: std_logic_vector(2 downto 0);
begin
process(clk, reset)
begin
if(reset='1') then temp<="000";
elsif(clk'event and clk='1') then
temp<= temp+1;
end if;
end process;
process(temp)
begin
temp_gray(2)<=temp(2);
temp_gray(1)<= temp(1) xor temp(2);
temp_gray(0)<= temp(1) xor temp(0);
end process;
dout<=temp_gray;
end Behavioral;
```

4.	**Write the structural VHDL description for a 2 to 4 decoder in details. (15M) (Nov/Dec 2013)** BTL3

Answer : Page 8.59 - Godse

- **Truth table and logic diagram (3M)**
- **Using case statement (4M)**

```
 library IEEE;
 use IEEE.STD_LOGIC_1164.all;

entity decoder is
port(
a : in STD_LOGIC_VECTOR(1 downto 0);
b : out STD_LOGIC_VECTOR(3 downto 0)
 );
end decoder;
architecture bhv of decoder is
begin
process(a)
begin
case a is
when "00" => b <= "0001"; when "01" => b <= "0010"; when "10" => b <= "0100"; when "11"
=> b <= "1000";
end case;
end process;
end bhv;
```

- **Using Test Bench (8M)**

```
LIBRARY ieee;

USE ieee.std_logic_1164.ALL;

 ENTITY tb_decoder IS

END tb_decoder;

 ARCHITECTURE behavior OF tb_decoder IS

  -- Component Declaration for the Unit Under Test (UUT)

  COMPONENT decoder

 PORT(

 a : IN std_logic_vector(1 downto 0);

 b : OUT std_logic_vector(3 downto 0)

 );

 END COMPONENT;
```

```
 --Inputs
signal a : std_logic_vector(1 downto 0) := (others => '0');
 --Outputs
signal b : std_logic_vector(3 downto 0);
-- appropriate port name
BEGIN
 -- Instantiate the Unit Under Test (UUT)
uut: decoder PORT MAP (
a => a,
b => b
);
 -- Stimulus process
stim_proc: process
begin
-- hold reset state for 100 ns.
wait for 100 ns;
 a <= "00";
 wait for 100 ns;
 a <= "01";
 wait for 100 ns;
 a <= "10";
 wait for 100 ns;
 a <= "11";
 wait;
end process;
END;
```

ME8792 POWER PLANT ENGINEERING L T P C 3 0 0 3

OBJECTIVES:

- Providing an overview of Power Plants and detailing the role of Mechanical Engineers in their operation and maintenance.

UNIT I COAL BASED THERMAL POWER PLANTS 9

Rankine cycle - improvisations, Layout of modern coal power plant, Super Critical Boilers, FBC Boilers, Turbines, Condensers, Steam & Heat rate, Subsystems of thermal power plants – Fuel and ash handling, Draught system, Feed water treatment. Binary Cycles and Cogeneration systems.

UNIT II DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS 9

Otto, Diesel, Dual & Brayton Cycle - Analysis & Optimisation. Components of Diesel and Gas Turbine power plants. Combined Cycle Power Plants. Integrated Gasifier based Combined Cycle systems.

UNIT III NUCLEAR POWER PLANTS 9

Basics of Nuclear Engineering, Layout and subsystems of Nuclear Power Plants, Working of Nuclear Reactors : Boili*ng Water Reactor* (BWR), P*ressurized Water Reactor* (PWR), Canada Deuterium- Uranium reactor (CANDU), Breeder, Gas Cooled and Liquid Metal Cooled Reactors. Safety measures for Nuclear Power plants.

UNIT IV POWER FROM RENEWABLE ENERGY 9

Hydro Electric Power Plants – Classification, Typical Layout and associated components including Turbines. Principle, Construction and working of Wind, Tidal, *Solar* Photo Voltaic (SPV), Solar Thermal, Geo Thermal, Biogas and Fuel Cell power systems.

UNIT V ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANTS 9

Power tariff types, Load distribution parameters, load curve, Comparison of site selection criteria, relative merits & demerits, Capital & Operating Cost of different power plants. Pollution control technologies including Waste Disposal Options for Coal and Nuclear Power Plants.

TOTAL : 45 PERIODS

OUTCOMES:

Upon the completion of this course the students will be able to

- CO1 - Discuss different power generation methods and boilers and estimate load curves and load duration curves (Unit I)
- CO2 - Explain the layout, construction and working of the components inside a thermal power plant (Unit II)
- CO3 - Explain the layout, construction and working of the components inside nuclear and hydro-electric power plants (Unit III)
- CO4 - Explain the layout, construction and working of the components inside diesel and gas turbine power plants (Unit IV)
- CO5 - Explain the applications of renewable energy on power plants while extend their knowledge to power plant economics and environmental hazards and estimate the costs of electrical energy production (Unit V)

TEXT BOOK:

1. Nag. P.K., "Power Plant Engineering", Third Edition, Tata McGraw – Hill Publishing Company Ltd., 2008.

REFERENCES:

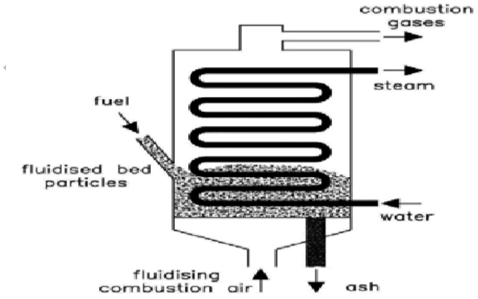
1. El-Wakil. M.M., "Power Plant Technology", Tata McGraw – Hill Publishing Company Ltd., 2010.
2. Godfrey Boyle, "Renewable energy", Open University, Oxford University Press in association with the Open University, 2004.
3. Thomas C. Elliott, Kao Chen and Robert C. Swanekamp, "Power Plant Engineering", Second Edition, Standard Handbook of McGraw – Hill, 1998.

REGULATION:2017 **ACADEMIC YEAR:2018-2019**

Subject Code: ME8792 **Year/Semester: II/03**
Subject Name: Power Plant Engineering **Subject Handler: Mrs.A.Ramya**

	UNIT I – COAL BASED THERMAL POWER PLANTS
	Rankine cycle - improvisations, Layout of modern coal power plant, Super Critical Boilers, FBC Boilers, Turbines, Condensers, Steam & Heat rate, Subsystems of thermal power plants – Fuel and ash handling, Draught system, Feed water treatment. Binary Cycles and Cogeneration systems.
	PART*A
1	**Name the processes of Rankine Cycle.** BTL1 ➢ Process 1-2 : Reversible adiabatic or isentropic expansion in the turbine ➢ Process 2-3 : Constant Pressure or isobaric heat rejection in the condenser ➢ Process 3-4 : Reversible adiabatic or isentropic pumping process in the feed pump ➢ Process 4-1 : Constant Pressure or isobaric heat supplied in the boiler.
2	**List the four important circuits of Steam Power Plant.** BTL1 ➢ Coal and ash circuit ➢ Air and flue gas circuit ➢ Water and steam circuit ➢ Cooling water circuit
3	**Define steam rate and heat rate. AU DEC 2016** BTL2 ➢ **Steam rate (also called Specific Steam Consumption(SSC))** - It is defined as the rate of steam flow (kg/h) required for producing unit shaft output (1 kW) Steam rate indicates the capacity of a steam plant. Steam rate, SSC = Mass of steam / Work Output in kg/kWh ➢ **Heat rate** – It is defined as the heat input needed to produce one unit of power output. It indicates the amount of fuel required to generate one unit of electricity. Heat rate = Heat supplied / Work output
4	**Why thermal power plants are not suitable for supplying fluctuating loads?** BTL4 Thermal plants are not suitable for supplying fluctuating loads because any change in load demand requires the corresponding change in the output energy. In thermal plants, the input energy is produced by burning the coal. So, there is always a large time lapse between change in energy output and input which is not desirable. Therefore, such power stations are used only as base load stations and it supplies the constant power.
5	**Define the function of boiler and turbine.** BTL2 ➢ Boiler – A boiler is a closed vessel in which the steam is generated from water by applying heat.

	➢ Turbine – Steam turbine is a device which is used to convert the kinetic energy of steam into mechanical energy.
6	**Define superheated steam.** BTL2 If the dry steam is further heated, then the process is called superheating and the steam is known as superheated steam. **Uses:** ➢ It has more heat energy and more work can be obtained using it. ➢ Thermal efficiency increases as the temperature of superheated steam is high. ➢ Heat losses are due to condensation of steam and cylinder wall friction.
7	**What is super critical boilers? AU DEC-2015** BTL2 ➢ Boilers only with economizer and superheater are called super critical boilers. ➢ It operates at supercritical pressure. ➢ The supercritical boilers are above 300 MW capacity. ➢ Ex – Velox Boiler and Loeffler boiler Advantages: ➢ High thermal efficiency ➢ Heat transfer rate is high ➢ Erosion and corrosion are minimized.
8	**Define the merits of pulverized fuel firing system.** BTL1 ➢ Coal is pulverized to increase its surface exposure and complete combustion. ➢ High combustion temperature can be obtained. ➢ It has more heating surface area. ➢ Low grade fuel can also be used. ➢ Clean combustible gases can be produced. ➢ Fuel feed rate is increased.
9	**What is stoker? Classify it.** BTL2 Stoker is a feeding device which feeds solid fuels into the furnace in medium and large size power plants. Types: ➢ Overfeed stoker ➢ Underfeed stoker
10	**What is the necessity of feed pump in thermal power plant?** BTL2 Feed pump is a pump which is used to deliver the feed water to the boiler. The quantity of water supplied should be at least equal to the amount of evaporation which is supplied to the engine.
11	**Mention the various modern ash handling systems.** BTL1 ➢ Gravitational separator ➢ Cyclone separator ➢ Packed type scrubber ➢ Spray type wet collector ➢ Electrostatic precipitator(ESP)
12	**List the methods used for handling of coal.** BTL1 ➢ Out plant handling of coal done by sea or river, ropes, rail, road, pipeline etc ➢ In plant handling of coal.

13	**State the function of cooling tower.** BTL2 ➢ Cooling tower discharges the warm water from the condenser and feed the cooled water back to the condenser. ➢ There are two types: (a)Wet type (b) Dry type
14	**List the requirements of a modern surface condenser.** BTL2 ➢ The steam should be evenly distributed over the whole cooling surface of the condenser with minimum pressure loss. ➢ The deposition of dirt on the outer surface of tubes should be prevented. It is achieved by passing the cooling water through tubes and allowing the steam to flow over tubes. ➢ There should be no under cooling of condensate. ➢ There should be no air-leakage into the condenser because it destroys the vacuum in the condenser. So, it reduces the work obtained per kg of steam.
15	**Define the term boiler draught. AU DEC-2016** BTL2 Draught is defined as the movement of air through full bed which produces a flow of hot gases through the boiler and the chimney, which requires a pressure difference between gas pressure and atmospheric pressure. This difference in pressure required to maintain the constant flow of air and discharge the gases known as draught.
16	**Define pulveriser and why it is used**? **AU DEC-2015** BTL2 A pulveriser or grinder is a mechanical device for grinding many different types of materials. Pulveriser mill is used to pulverize the coal for combustion in the steam generating furnaces of fossil fuel power plants.
17	**List the factors affecting cooling of water in cooling tower.** BTL1 ➢ The exposing time ➢ Amount of water surface exposed ➢ Relative humidity of air ➢ Velocity of air ➢ Accessibility of air to various parts of cooling tower.
18	**What is compounding of steam turbine?** BTL2 ➢ Compounding is a method of absorbing the jet velocity in stages when the steam flows over moving blades. ➢ It reduces the velocity of steam at the exit of turbine and also the speed of rotor.
19	**Draw a neat sketch of basic principle of FBC.** BTL5 
20	**What is Cogeneration systems?** BTL4 Cogeneration is also called combined heat power. Cogeneration works based on the concept of producing two different forms of energy by using a single source of fuel. Out of these two forms, one must be heat or thermal energy and other one is either electrical or mechanical energy.

21	**What is reheat cycle?** BTL2 In reheat cycle, the steam is extracted from a suitable point in the turbine and it is reheated with the help of flue gases in the boiler.
22	**List the advantages of reheat cycle.** BTL1 ➢ The reheating reduces from 4 to 5% fuel consumption. ➢ The reheat cycle reduces the steam flow of 15% to 20% with corresponding reduction in boiler, turbine and feed heating equipment capacity.
23	**Name the methods of reheating.** BTL1 ➢ Gas reheating ➢ Live steam reheating ➢ Combined gas and live steam reheating
24	**What is regenerative cycle?** BTL2 The feed water is heated with the help of steam in a reversible manner. Steam temperature and water temperature are same at any section. Such type of heating is known as regenerative cycle.
25	**Where is reheat-regenerative cycle used?** BTL2 Reheat – regenerative cycle is used in the actual thermal power plant with high steam pressure (above 90kgf/cm^2), which increases the overall efficiency of the cycle.
	PART*B
1	**Draw a general layout of thermal power plant and explain the working of different circuits. (13 M) AU DEC-2015/2016** BTL2 **Answer: Page: 1.2 - Dr.G.K.Vijayaraghavan** **Principle:** Heat Energy → Mechanical Energy → Electrical Energy **(1 M)** **Layout**: **(4 M)** **Working:** Steam power plant consists of four main circuits ➢ Coal and Ash circuit **(2 M)** ➢ Air and Flue gas circuit **(2 M)** ➢ Water and steam circuit **(2 M)** ➢ Cooling water circuit **(2 M)**
2.	**Write short notes on: AU DEC-2015** BTL2 **(i)Ash handling system (6 M)** **Answer: Page: 1.46 - Anup Goel** The Disposal of ash and dumping it at a distance from the power plant is important for the following reasons: **(2 M)** 1). The ash is very hot when it comes out of the boiler furnace. 2). The ash is dusty, therefore it is irritating and annoying to handle. 3). When mixed with water, the ash produces poisonous gases and corrosive acids. **Types of ash handling system:** 1). Mechanical handling system. 2). Hydraulic system. 3). Pneumatic system. 4). steam jet system. 1). **Mechanical hand ling system: (1 M)** This system is applied for low capacity power plants using coal as fuel.

2). **Hydraulic system: (1 M)**

In this system the ash is carried with the flow of water with high velocity through a channel and finally dumped in the sump.

3). **Pneumatic system**: **(1 M)**

This system can handle abrasive ash, fly-ash and soot.

4). **Steam jet system: (1 M)**

In this system, the high velocity steam is passed through a pipe.

(ii)Different draught systems (7 M)

Answer: Page: 1.52 - Anup Goel

Draught is defined as the difference between absolute gas pressure at any point in a gas flow passage and the ambient (same elevation) atmospheric pressure.

Necessity of Draught: (2 M)

- To supply required amount of air to the furnace for the combustion of fuel.
- The amount of fuel that can be burnt per square root of grate area depends upon the quantity of air circulated through fuel bed.
- To remove the gaseous products of combustion.

Classification of Draught: (5 M)

- **Natural Draught:** The draught is produced by this tall chimney due to temperature difference of hot gases in the chimney and cold external air outside the chimney.
- **Artificial Draught:** The draught is produced by steam jet or fan.
- **Steam jet draught:** The draught is produced by steam.
- **Mechanical draught:** The draught is produced by blowers or fan.
- **Induced draught:** The flue is drawn(sucked) through the system by a fan or steam jet.
- **Forced draught:** The air is forced into system by a blower or steam jet.

3. **Explain the following with neat diagram: AU DEC-2016** BTL2

(i)Benson boiler (6 M)

Answer: Page: 1.22 - Anup Goel

Diagram: (3 M)

Explanation: (3 M)

- The feed pump circulates the water to the evaporator through economizer.
- The drum is eliminated in this type of boiler
- The major portion of water is converted into the steam in radiant evaporator
- The remaining portion of water is evaporated in the convective evaporator and pressure of steam rises up to 225 bar.

Advantages:

Easy and quick erection of boiler, require less floor space, lower explosion hazards

(ii)Cogeneration plant (7 M)

Answer: Page: 1.10 - Anup Goel

Explanation: (3 M)

- A cogeneration system is the simultaneous generation of multiple forms of useful energy in a single integrated system.
- The useful energy usually is in the form of mechanical/electrical and thermal(heat) energy. It is also known as combined Heat and Power (CHP) system.

Classification of Cogeneration systems: (4 M)

A cogeneration system can be classified on the basis of the sequence of energy use as follows:

	A topping cycle In a topping cycle, the fuel supplied is first used to produce power and thermal energy. Types: Combined – cycle topping system, Steam – turbine topping system, Heat recovery topping system, Gas turbine topping system. **A bottoming cycle** In a bottoming cycle, the primary fuel produces high temperature thermal energy.
4.	**Explain the following: (13 M)** BTL2 **(i) Types of Turbines** **(ii) Types of Condensers** **(i)Types of Turbines (7 M)** **Answer: Page: 1.110 – Dr.G.K.Vijayaraghavan** Steam turbines are classified as follows. **1.On the basis of method of steam expansion** (a)Impulse turbine (b)Reaction turbine (c)Combination of impulse and reaction turbine **2.On the basis of number of stages** (a)Single stage turbines (b)Multi-stage turbines **3.On the basis of steam flow directions** (a)Axial turbine (b)Radial turbine (c)Tangential turbine (d)Mixed flow turbine **4.On the basis of pressure of steam** (a)High pressure turbine (b)Low pressure turbine (c)Medium pressure turbine **(ii)Types of Condensers (6 M)** **Answer: Page: 1.157 – Dr.G.K.Vijayaraghavan** **1.Based on the contact shell and tube fluid** (a)Direct Contact Condenser (b)Indirect Contact Condenser **2.Based on the type of cooling** (a)Water cooled condenser (b)Air cooled condenser **3.Based on the type of flow** (a)Down flow type (b)Central flow condenser (c)Evaporation condenser
5.	**Analyze the following:** BTL 4 **(i) Coal Handling System (7 M)** **(ii)Feed water treatment (6 M)** **(i)Coal Handling System (7 M)** **Answer: Page: 1.172 – Dr.G.K.Vijayaraghavan**

	Two Types: **(1 M)** ➢ Out plant handling of coal ➢ In plant handling of coal The out plant handling of coal is done by **(3 M)** ➢ Transportation by sea or river ➢ Transportation by ropes ➢ Transportation by rail ➢ Transportation by road ➢ Transportation by pipelines ➢ In plant handling of coal Steps in Inplant handling of coal: **(3 M)** ➢ Coal Delivery ➢ Unloading ➢ Transfer ➢ Outdoor storage ➢ Covered storage ➢ In plant handling ➢ Weighing and measuring ➢ Furnace **(ii)Feed water treatment (6 M)** **Answer: Page: 1.238 – Dr.G.K.Vijayaraghavan** **Necessity to treat the Raw water: (3 M)** ➢ The deposition of dissolved salts and suspended impurities will form a scale on the inside wall of different heat exchangers. So, it will create excessive pressure and thermal stress inside heat exchangers. It may lead to the explosion and serious hazards to boilers. ➢ The harmful dissolved salts may react with various parts of boilers. So, it might corrode the surfaces. ➢ Corrosion damage may occur to turbine blades. **Two Types: (3 M)** ➢ Demineralization Plant (DM plant) - It employs a chemical method to separate the dissolved salt in fresh water. ➢ Reverse Osmosis Plant (RO plant) - It employs a simple physical method to separate salts.
	PART*C
1.	**Analyze the working of binary vapour cycle with a neat diagram. (15 M)** BTL4 **Answer: Page: 1.245 - Dr.G.K.Vijayaraghavan** Two working fluids – Mercury and water **(2 M)** **Characteristics of working fluid & Diagram: (8 M)** ➢ High enthalpy of vaporization ➢ Good heat transfer characteristics ➢ High critical temperature with a low corresponding saturation temperature. ➢ High condenser temperature ➢ Freezing temperature should be below room temperature **Types: (5 M)** ➢ Topping cycle - Condenser at the high temperature region

- Bottoming cycle – Con denser at the low temperature region

2. **(i) With a neat diagram explain the function of FBC boilers. (7 M) AU DEC-2017** BTL2

Answer: Page: 1.17 - Anup Goel

A fluidized bed may be defined as the bed of solid particles behaving as a fluid.

Principle: (2 M)

- When a gas is passed through a packed bed of finely divided solid particles, it experiences a pressure d rop across the bed.
- At low velocity, this pressure drop is small and does not disturb the particles.
- But if the gas velocity is increased further, a stage will come when the particles are suspended in the gas stream and the packed bed becomes a fluidized bed.

Types: (5 M)

Pressurised FBC boilers – Double shell design is used

Circulating FBC boilers – It has three zones of furnace – lower zone, upper zone, solid –separator zone

Atmospheric fluidized bed combustor boilers – They are known as fully developed boiler and therefore are widely used.

Two types – Underfeed and Overfeed.

(ii) Super critical boilers (8 M)

Answer: Page: 1.21 - Anup Goel

Explanation: (5 M)

- Generates steam above critical pressure are called super critical once through boilers.
- At critical pressure latent heat vapourization becomes zero. In this case, the saturated liquid is directly converted into superheated steam.
- The separator vessel cannot be used in these boilers.
- They are also known as “drumless boilers”.

Advantages: (3 M)

- Rate of heat transfer is more
- Higher thermal efficiency
- Pressure is more stable.

3. **Explain the working of Rankine cycle with a neat diagram. (15 M)** BTL 2

Answer: Page: 1.3 - Anup Goel

Explanation: (5 M)

- Rankine cycle is a modified cycle of carnot.
- In Rankine cycle heat supplied and heat rejection occurs at constant pressure.
- This cycle is practically used in steam power plant.

Working principle: (5 M)

- Process 1-2: Reversible isentropic
- Process 2-3: Heat supplied (P=C)
- Process 3-4: Reversible isentropic
- Process 4-1: Heat rejection (P=C)

Diagram: (5 M)

	UNIT – II DIESEL, GAS TURBINE AND COMBINED CYCLE POWER PLANTS
	Otto, Diesel, Dual & Brayton Cycle - Analysis & Optimisation. Components of Diesel and Gas Turbine power plants. Combined Cycle Power Plants. Integrated Gasifier based Combined Cycle systems.
	PART*A
1	**List the applications of diesel engine power plant.** BTL1 ➢ Peak load plant ➢ Mobile plants ➢ Stand by units ➢ Emergency plant ➢ Starting station ➢ Nursery station
2	**Analyze the purpose of air intake system in a diesel engine power plant.** BTL4 The purpose of air intake system conveys fresh air through pipes or ducts to ➢ Air intake manifold of four stroke engine ➢ Scavenging pump inlet of a two stroke engine ➢ Supercharge inlet of a supercharged engine
3	**Name the commonly used fuel injection system in a diesel power station.** BTL3 ➢ Common rail injection system ➢ Individual pump injection system ➢ Distributor
4	**Write the processes of Otto cycle.** BTL5 ➢ Process 1-2: Isentropic Compression process ➢ Process 2-3: Constant Volume heat addition process ➢ Process 3-4: Isentropic Expansion process ➢ Process 4-1: Constant Volume heat rejection process
5	**List the processes of dual cycle.** BTL2 ➢ Process 1-2: Isentropic Compression process ➢ Process 2-3: Constant Volume heat addition process ➢ Process 3-4: Constant pressure heat addition process ➢ Process 4-5: Isentropic Expansion process ➢ Process 5-1: Constant Volume heat rejection process
6	**Name the various gas power cycle.** BTL1 ➢ Carnot cycle ➢ Otto cycle ➢ Diesel cycle ➢ Brayton cycle ➢ Dual combustion cycle ➢ Atkinson cycle
7	**Write the different types of Engines used in diesel power plants.** BTL1 ➢ Small size Diesel engine ➢ Medium size Diesel engine ➢ Large size Diesel engine

8 **List the processes of diesel cycle.** BTL5

- Process 1-2: Isentropic Compression process
- Process 2-3: Constant pressure heat addition process
- Process 3-4: Isentropic Expansion process
- Process 4-1: Constant Volume heat rejection process

9 **List the various processes of Brayton cycle.** BTL6

- Process 1-2: Isentropic Compression process
- Process 2-3: Constant pressure heat addition process
- Process 3-4: Isentropic Expansion process
- Process 4-1: Constant pressure heat rejection process

10 **Classify the various types of cooling system used in diesel power plant.** BTL4

- Air cooling
- Liquid cooling
    - (a)Thermo – syphon cooling
    - (b)Forced or pump cooling
    - (c)Cooling with thermostatic regulator
    - (d)Pressurised water cooling
    - (e)Evaporative cooling

11 **Write any two drawbacks of a stationary gas turbine power plant for generation of electricity**. BTL1

- The part load efficiency is poor
- The unit is operated at high temperature and pressure, so special metals are required to maintain the unit.
- Major part of the work (about 66%) developed in the turbine is used to drive the compressor.
- The devices that are operated at high temperature are complicated.

12 **Name the Components of Gas Turbine Power plants**. BTL1

- Air compressor
- Combustion chamber
- Gas Turbine
- Generator

13 **Point out the major difference between Otto cycle and Diesel cycle.** BTL4

S.NO	OTTO CYCLE	DIESEL CYCLE
1	It consists of two adiabatic and two constant volume processes.	It consists of two adiabatic, one constant pressure and one constant volume processes.
2	Compression ratio is equal to expansion ratio.	Compression ratio is not equal to expansion ratio.
3	Heat addition takes place at constant volume processes	Heat addition takes place at constant pressure processes
4	Efficiency depends on compression ratio only	Efficiency depends on compression ratio and cut off ratio
5	Heat rejected is less	Heat rejected is more

14 **Write the effect of inter cooling in a gas turbine plant.** BTL1

- Heat supply is increased

	➢ It decreases the thermal efficiency ➢ Work ratio will be increased ➢ Specific volume of air is reduced
15	**List the advantages and disadvantages of a diesel power plant.** BTL1 Advantages: ➢ The location of the plant is near the load center. ➢ It has no stand by losses. ➢ It provides quick starting and easy pick-up of loads. ➢ Skilled manpower is not required. Disadvantages: ➢ Noise is a serious problem. ➢ High operating cost ➢ The plant capacity is limited to about 50MW of power. ➢ The efficiency of the Diesel engine is about 33% only.
16	**Analyze the process in combined cycle power plant.** BTL4 The combined power cycles are introduced by superposing a high temperature power plant as a topping unit and the low temperature power plant as a bottoming unit. It increases the efficiency and reduces the fuel consumption. Eg: Gas Turbine – Steam Turbine plant in which Gas turbine as bottoming unit and steam turbine as topping unit.
17	**List the advantages of combined cycle power plants.** BTL2 ➢ It produces low environmental effect ➢ It needs less amount of water ➢ Investment cost is low ➢ It gives high ratio of power output to fuel ➢ It produces less smoke when compared with ordinary steam plant. ➢ High efficiency than open cycle power plant.
18	**Give examples of combined cycle power plant.** BTL1 ➢ Gas turbine – steam turbine power plant ➢ Thermionic – steam power plant ➢ Thermo electric-steam power plant ➢ M.H.D – steam power plant ➢ Nuclear – steam combined power plant ➢ MHD – gas turbine power plant
19	**Illustrate the advantages of Integrated Gasifier based combined cycle power plants.** BTL3 ➢ It produces higher efficiencies and lower emissions ➢ Improvements in efficiency dramatically reduce the emissions from coal combustion. ➢ Product flexibility is ensured.
20	**Define air standard efficiency of Diesel cycle.** BTL1 Air standard efficiency is defined as the ratio of work done by the cycle to the heat supplied to the cycle.
21	**What is Compression ratio?** BTL1 It is the ratio of volume when the piston is at BDC to the Volume when the piston is at TDC.

	PART*B
1.	**Explain the working of open cycle and closed cycle gas turbine power plant and discuss its advantages and disadvantages. (13 M) AU DEC-2015** BTL2 **Answer: Page: 2.31 - Anup Goel** A simple gas turbine cycle consists of the following components **(3 M)** ➢ Compressor ➢ Combustion chamber ➢ Turbine **Open cycle gas turbine power plant: (5 M)** ➢ Consists of air compressors, combustion chamber and turbine. ➢ Air is drawn from the atmosphere to compressor. ➢ The compressed air is passed to combustion chamber where heat is added by spraying fuel into the air stream. ➢ The hot gases expand through the turbine and the product of combustion which is coming out of the turbine is exhausted to the atmosphere. Advantages: ➢ Low maintenance Disadvantages: ➢ Turbine blades wear out earlier **Closed cycle gas turbine power plant: (5 M)** ➢ Consists of compressor, Combustion chamber, cooling chamber (cooler) and turbine. ➢ The product of combustion which is coming out of the turbine is cooled in the cooling chamber and sent again to the compressor. Advantages: ➢ Improves the heat transmission and part load efficiency. Disadvantages: ➢ Large amount of cooling water is required. ➢ Requires the use of heater.
2.	**(i) Explain in detail about the construction and working of IGCC. (7 M) AU DEC-2015** BTL1 **Answer: Page: 2.182 - Dr.G.K.Vijayaraghavan** ➢ One of the most promising technologies in power generation. ➢ Extremely clean and more efficient than traditional coal-fired gasification systems. **Construction of IGCC: (3 M)** Consists of the following four major units. ➢ ASU (Air separation Unit) ➢ Gasification ➢ Gas clean up ➢ Combined power block **Working: (4 M)** ➢ First coal is gasified either partially or fully. ➢ The synthetic gas is produced. ➢ Then, it is cleaned. ➢ After that, it is burnt in the combustion chamber. **(ii) Draw and explain PV and TS diagrams of Brayton cycle. (8 M) AU DEC-2015** BTL1 **Answer: Page: 2.76 - Dr.G.K.Vijayaraghavan** Brayton cycle - theoretical cycle for gas turbine.

Four Processes: Two reversible adiabatic Processes and two constant pressure Processes. Therefore this cycle is also called constant pressure cycle. **(4 M)**

- Process 1-2: Isentropic Compression Process
- Process 2-3: Constant Pressure heat addition Process
- Process 3-4: Isentropic expansion process
- Process 4-1: Constant pressure heat rejection process.

PV and TS diagram: (4 M)

3. **Discuss the essential components of the diesel power plant with neat layout. (13 M)** BTL2

Answer: Page: 1.3 - Anup Goel

Diagram: (5 M)

Components: (8 M)

The essential components of diesel power plant are

(i) Diesel Engine – Main component to generate the mechanical energy from the heat energy which is obtained by burning diesel fuel.
(ii) Air Intake system – It provides the air required for the combustion of fuel.
(iii) Exhaust system – To reduce the noise produced by the exhaust gases coming out of the engine.
(iv) Cooling system – To lower the temperature of the burning fuel
(v) Fuel supply system – It supplies the fuel required for combustion.
(vi) Lubrication system – To reduce the wear of the moving parts of the engine.
(vii) Diesel engine starting system – To start the engine from cold condition with the help of an air compressor.
(viii) Governing system – Used to control the flow of the fuel.

PART*C

1. **(i)Derive an expression for the work ratio using Brayton cycle. (8 M)** BTL4

Answer: Page: 2.79 - Dr.G.K.Vijayaraghavan

Work Ratio: (3 M)

It acts as useful parameter for power plant cycles.

It is defined as the ratio of net work transfer in a cycle to the positive work transfer or turbine work in the cycle.

Expression: (5 M)

Work ratio = Net work transfer / Positive work transfer

$= [mC_p(T_3 – T_4) - mC_p(T_2 – T_1] / mC_p(T_3 – T_4)$

$= 1- (T_1/T_3) (R_P)^{\gamma-1}\gamma$

The work ratio depends not only on the pressure ratio but also on the ratio of the minimum and maximum temperatures.

(ii)Discuss the working of any one type of combined cycle power plant. (8 M) BTL2

Answer: Page: 2.17 - Dr.G.K.Vijayaraghavan

Explanation: (3 M)

To increase the efficiency and reduce the fuel consumption, the combined power cycles are introduced by superposing a high temperature power plant as a topping unit and the low temperature power plant as a bottoming unit.

Types: (2 M)

- Gas turbine – steam turbine power plant
- Thermionic – ste am power plant
- Thermo electric – steam power plant

- M.H.D – steam power plant
- Nuclear – steam combined power plant
- MHD – gas turbine power plant

Gas Turbine – Steam Turbine plant: (3 M)

- Bottoming Unit – Gas Turbine plant
- Topping Unit – Steam Power plant

The efficiency of this combined unit is 45%.

2. **(i)Enlist the advantages and disadvantages of a diesel engine power plant. (8 M)** BTL1

Answer: Page: 2.31 - Anup Goel

Advantages: (4 M)

- Very simple in design and also simple in installation.
- Limited Cooling water requirement.
- Standby losses are less as compared to the other Power plants.
- Low fuel cost.
- Quickly started and put on load.

Disadvantages: (4 M)

- High maintenance and operating cost
- Fuel cost is more, since in India diesel is costly.
- The plant cost per KW is comparatively low.
- The life of diesel power plant is small due to high maintenance.
- Noise is a serious problem in diesel power plant.

(ii)Compare the merits and demerits of open and closed cycle gas turbine power plant. (8 M) BTL4

Answer: Page: 2.162 - Dr.G.K.Vijayaraghavan

Open Cycle Gas Turbine Power Plant	Closed Cycle Gas Turbine Power Plant
Merits: (4 M) No pre-cooler is required. Size and weight of the open cycle gas turbine unit are less. Combustion efficiency is more. Response to load variation is greater than closed cycle gas turbine. **Demerits: (4 M)** Part load efficiency rapidly decreases for the considerable % of power developed by the turbine and it is used to drive the compressor. Turbine blades are fouled by combustion products. Starting of the plant is difficult. Thermal stresses are high.	**Merits:** Efficiency is same throughout the cycle. Starting of the plant is easy. Thermal stresses are low. There is no need for internal cleaning. **Demerits:** A separate pre-cooler arrangement is necessary. The size and weight are more. Initial cost and maintenance are more. The response to load variation is less

3. **(i) Explain the PV and TS diagrams of Otto cycle. (8 M)** BTL4

Answer: Page: 2.3 - Dr.G.K.Vijayaraghavan

Four Processes: (4 M)

Two reversible adiabatic or isentropic processes and
Two constant volume processes

- Process 1-2: Isentropic Compression Process.
- Process 2-3: Constant Volume heat addition Process
- Process 3-4: Isentropic expansion process
- Process 4-1: Constant Volume heat rejection process.

Diagram: (4 M)

(ii) Explain the PV and TS diagrams of diesel cycle. (8 M) BTL4

Answer: Page: 2.27 - Dr.G.K.Vijayaraghavan

- This cycle is used in Diesel engines.

Four processes: (4 M)

Two reversible adiabatic or isentropic
One Constant Volume and
One Constant Pressure processes.

- Process 1-2: Isentropic Compression Process.
- Process 2-3: Constant Pressure heat addition Process
- Process 3-4: Isentropic expansion process
- Process 4-1: Constant Volume heat rejection process.

Diagram: (4 M)

	UNIT III – NUCLEAR POWER PLANTS
	Basics of Nuclear Engineering, Layout and subsystems of Nuclear Power Plants, Working of Nuclear Reactors: B*oiling Water Reactor* (BWR), P*ressurized Water Reactor* (PWR), CANada Deuterium- Uranium reactor (CANDU), Breeder, Gas Cooled and Liquid Metal Cooled Reactors. Safety measures for Nuclear Power plants.
	PART * A
1	**Write the advantages of nuclear power plant.** BTL1 ➢ There is no atmospheric pollution by combustion products. ➢ They are not affected by adverse weather conditions. ➢ Water requirement is very less. ➢ Space requirement is less as compared to other conventional power plants of equal size. ➢ It is well suited to meet large power demands. They give better performance at high load factors (80 to 90%)
2	**Name the three moderators used in nuclear power plants.** BTL1 ➢ Heavy water (D_2O) ➢ Water (H_2O) ➢ Beryllium (Be) ➢ Graphite (C) ➢ Helium (He)
3	**Write the function of the moderator.** BTL2 Moderator is a material which is used to slow down the neutrons from high velocities without capturing them. The fast moving neutrons are far less effective in causing the fission and for the escape from the reactor.
4	**List the function of control rods.** BTL1 ➢ To control the rate of fission. ➢ To start the nuclear chain reaction when the reactor is started from cold. ➢ To shut down the reactor under emergency condition.
5	**What is nuclear fission?** BTL2 Nuclear fission is the process of splitting the nucleus into two almost equal fragments accompanied by the release of heat. In other words, it is the process of splitting the unstable heavy nucleus into two fragments of approximately equal mass when bombarded with neutrons.
6	**Mention the fuels used in nuclear power plants.** BTL1 ➢ U^{235} – Primary fuel ➢ U^{233} and PU^{239} – Secondary fuels
7	**Write the conditions satisfied to sustain nuclear fission process (or) Requirements of Fission process**. BTL2 ➢ The chain reaction should be self – sustaining or self – propagating only. ➢ At least one fission neutron becomes available for causing fission of another nucleus. ➢ The fission process must liberate the energy. ➢ The neutrons emitted in fission must have adequate energy to cause fission of other nuclei. ➢ It must be possible to control the rate of energy liberation.
8	**List down the basic factors those are to be considered for the design of a nuclear power reactor.** BTL1 ➢ Proximity to load center ➢ Population distribution

- Land use
- Meteorology
- Geology
- Hydrology
- Seismology

9 **What is "half-life" of nuclear fuels?** BTL2

The radioactive half-life for a given radioisotope is a measure of the tendency of nucleus to "decay" or "disintegrate" and it is based purely upon that probability.

10 **Distinguish between PHWR and LMFBR.** BTL2

S.NO.	PHWR	LMFBR
1	A nuclear power reactor commonly uses enriched natural uranium as its fuel which uses heavy water(D_2O) as its coolant and moderator.	A nuclear reactor is capable of generating more fissile material than it consumes.
2	PHWR running on natural Uranium have a conversion ratio of 0.8	The conversion ratio is higher than 1.
3	It is costly.	Its cost is comparatively less.

11 **Define the term "Breeding".** BTL2

In a fast breeder reactor, the process of producing energy to self-sustain the nuclear fission chain reaction without using moderator is known as breeding. Enriched Uranium (U^{235}) or Plutonium is used as fuels which are surrounded by a thick blanket of fertile Uranium (U^{238}).

12 **Name the components of pressurized water reactor nuclear power plant**. BTL1

- Reactor
- Pressurizer
- Heat exchanger
- Coolant pump

13 **Classify the nuclear reactors.** BTL2

1.According to the neutrons energy.	**2.According to the fuel used**	**3.According to the type of coolant used**
Fast reactors Intermediate or epithermal reactors Low energy or Thermal reactors	Natural fuel reactor Enriched Uranium reactor	Water cooled reactors Gas cooled reactors Liquid metal cooled reactors

4.According to the type of moderators used	**5.According to the construction of core**	
➢ Graphite moderator reactor ➢ Beryllium moderator reactor ➢ Water moderator reactor	➢ Cubical core reactor ➢ Cylindrical core reactor ➢ Spherical core reactor ➢ Annulus core reactor ➢ Slab core reactor	

14 **Write the safety measures of nuclear power plant**. BTL2

Nuclear safety and security cover the actions taken to prevent nuclear and radiation accidents or to limit their consequences. The main safety concern is the emission of uncontrolled radiation into the environment which could cause harm to human both at the reactor and off-site. The nuclear power industry has improved the safety and performance of reactors and it has proposed new and safer reactor designs.

15 **Write down the various types of fast breeders.** BTL2

- GFR: Gas cooled Reactor system cooled with helium
- LFR: Lead fast Reactor cooled with lead or lead – bismuth eutectic
- MSR: Molten Salt Reactor Fueled with molten salts
- SFR: Sodium Fast Reactor
- SCWR: Super-Critical Water-cooled Reactor
- VHTR: Very High Temperature Reactor cooled with helium at 1000^{o}C at the core outlet for efficient production of hydrogen.

16 **List some of the disadvantages of Nuclear Power Plant.** BTL1

- Similar to fossil fuels, nuclear fuels are non-renewable energy resources.
- If the accident occurs, large amounts of radioactive material could be released into the environment.
- Nuclear waste also remains radioactive and it is hazardous to health for thousands of years.

17 **Mention the function of nuclear reactor.** BTL2

A nuclear reactor is similar to the furnace of a steam power plant or combustion chamber of a gas turbine plant. In the nuclear reactor, heat is produced due to nuclear chain reaction.

18 **What is known as moderating ratio?** BTL2

Moderating ratio (also known as multiplication ratio or reproduction ratio) of the system is defined as the ratio of the number of neutrons in any particular generation to the total number of neutrons in the preceding generation.

$$K = \frac{\text{Number of neutrons in any particular generation}}{\text{Number of neutrons in the preceding generation}}$$

19 **What is four factor formula?** BTL2

The four-factor formula is also known as Fermi’s four factor formula used in nuclear engineering to determine the multiplication of a nuclear chain reaction in an infinite medium.

20 **What do you mean by mass defect?** BTL2

During the interaction of two or more particles to combine together, the total mass of the system will decrease and it will be less than the sum of the masses of the individual particles. The stronger the interaction becomes and more the mass will decrease. It decreases the mass of the system called mass defect.

21 **What is known as binding energy?** BTL2

The energy released at the moment of combination of two nucleons to form nucleus of an atom is called binding energy.

PART*B

1. **Explain with a neat diagram the various parts of nuclear power plant and mention the function of each part. (13 M) AU DEC-2015** BTL2

Answer: Page: 3.4 - Anup Goel

Elements of Nuclear power plant: (3 M)

- Nuclear reactor
- Steam generator (Heat Exchanger)
- Steam turbine
- Steam Condenser
- Water and coolant feed pumps
- Electric generator

Diagram: (5 M)

Working: (5 M)

- The nuclear reactor works as a furnace that produces heat.
- The heat generated in the reactor by the nuclear fission is absorbed by the circulating coolant through the reactor core.
- The hot coolant leaving the reactor is passed to the heat exchanger.
- Steam is produced and is supplied to the turbine for expansion to produce work.

2. **(i) Explain CANDU reactor with neat sketch. Give its advantages and disadvantages. (8 M) AU DEC-2015** BTL2

Answer: Page: 3.9 - Anup Goel

Diagram: (3 M)

- Moderator – Heavy water
- Coolant – Heavy water
- Reflector – Heavy water
- Fuel – Natural Uranium

Explanation: (5 M)

- The Coolant heavy water is passed through the pressurized fuel tubes and then to the moderator heat exchanger through the primary circuit.
- The steam is generated first in moderator heat exchanger and then passed to the secondary heat exchanger to improve its quality.
- Control rods are not required because control can be achieved by controlling the flow of heavy water in primary circuit.

Advantages:

- Less cost.
- Very short time period for construction.

Disadvantages:

- Cost of heavy water is high.
- Low power density.

(ii)Explain what is chain reaction in connection with a nuclear reactor. (8 M) BTL4

Answer: Page: 3.2 - Anup Goel

Diagram: (3 M)

Explanation: (5 M)

- It mainly includes splitting and recombining of neutrons and producing sub elements of Uranium.
- The elements whose nucleus easily fusions is ${}_{92}U^{235}$
- All the other naturally available elements are stable and the nucleus of this cannot split easily.
- If the neutrons enter the nucleus of U^{235}, the nucleus splits into two sub elements and also releases two neutrons per fission.
- The obtained neutrons are having high velocity and to control this velocity, moderators are used.
- This process is continued step by step and product smaller fragments of Uranium by releasing large amount of heat energy.
- This heat energy is used for power generation in power plants.

PART*C

1. **Compare the working, merits and demerits of PWR and BWR. (15 M)** BTL4

Answer: Page: 3.6 - Anup Goel

PWR – Pressurized Water Reactor (8 M)

Diagram: (3 M)

Explanation: (3 M)

- PWR is a water cooled thermal reactor having special core design using natural and highly enriched fuel.
- Moderator – water
- Coolant – water
- Reflector – water
- Fuel – Uranium Oxide

Advantages: (1 M)

- Less quantity of control rods.
- Inspection and maintenance of the components used is easy.
- Reactor is compact in size.
- Power density is high.

Disadvantages: (1 M)

- Thermal efficiency of the plant is low.
- Fabrication of fuel element is costly.
- Requires strong pressure vessel in primary circuit so the capital cost is high.

BWR – Boiling Water Reactor (7 M)

Diagram: (3 M)

Explanation: (2 M)

- Moderator – water
- Coolant – water
- Reflector – water
- Fuel – Enriched Uranium

Advantages: (1 M)

- More stable than PWR.
- Lower pressure vessel can be used for reactor.
- Cost of BWR is also reduced compared to PWR.

Disadvantages: (1 M)

- Power density is 50% of PWR.

- Desired output cannot be achieved with a single pass circuit.

2. **(i)Discuss about the safety measures adopted in modern nuclear plants. (8 M)** BTL2

Answer: Page: 3.81 – Dr.G.K.Vijayaraghavan

Components of Nuclear Safety: (3 M)

- Technical Safety
- Human Factors and Organizational Safety
- Programmatic and cross-cutting Safety

Components of Technical Safety: (2 M)

- Knowledge on the nuclear technology
- Safety assessments of all changes and back fits are made during the life of the facility.
- Radiological protection program

Components of Human Factors and Organizational Safety: (2 M)

- Sufficient properly qualified, trained and fit-for-duty personnel
- Strong Cooperative management organization
- Facility management organization

Components of Programmatic and Cross-Cutting Safety: (1 M)

- Programmes such as fire protection and surveillance testing
- Programme of Operating experience analysis
- Ageing management programme

(ii)Explain the working of Gas Cooled Reactor (GCR) with a neat sketch. (8 M) BTL2

Answer: Page: 3.8 - Anup Goel

Diagram: (3 M)

Explanation: (3 M)

- Moderator – Graphite
- Coolant – Gases like air, helium, CO_2 and H_2.
- Reflector – water
- Fuel – Uranium Oxide

Types: (2 M)

- Gas cooled Graphite Moderator (GCGM) reactor – Uses Natural Uranium as fuel
- High Temperature Gas Cooled (HTGC) reactor – Uses highly enriched Uranium fuel graphite moderator

Advantages:

- Simple fuel processing.
- Less corrosion.

Disadvantages:

- Leakage of gas.
- Fuel loading is very costly.

	UNIT IV – POWER FROM RENEWABLE ENERGY
	Hydro Electric Power Plants – Classification, Typical Layout and associated components including Turbines. Principle, Construction and working of Wind, Tidal, *Solar* Photo Voltaic (SPV), Solar Thermal, Geo Thermal, Biogas and Fuel Cell power systems.
S.NO.	**PART*A**
1	**Mention the necessity of tall tower in horizontal axis wind turbine.** BTL2 ➢ To withstand the power house during heavy wind ➢ Supporting structure for energy house
2	**Write the advantages and disadvantages of hydropower plants.** BTL2 **Advantages:** ➢ There is no air pollution. ➢ Water is the renewable source of energy. It is neither consumed nor converted into something else. ➢ There is no problem of handling the fuel and ash. ➢ The running cost is low when compared to thermal or nuclear power stations. **Disadvantages:** ➢ Hydropower projects are capital-intensive with a low rate of return. ➢ Power generation is dependent on the quantity of water available which may vary season-to-season and year-to-year. ➢ Initial cost of the plant is high. ➢ It takes considerably long time for its installation as compared with thermal power plants.
3	**Define the function of surge tank in hydro plants.** BTL2 Surge tank is used to reduce the sudden rise of water in the penstock, stabilize the velocity and pressure in penstock and reduce water hammer effect.
4	**Classify the hydro-electric turbines with respect to high medium and low head**. BTL1 ➢ High head Turbine. ➢ Medium head Turbine. ➢ Low head Turbine.
5	**List the three main factors of power output of hydroelectric plant**. BTL1 ➢ Available head of water ➢ Speed of the turbine ➢ Pressure of the water flow
6	**Give the main parts of pelton wheel.** BTL1 ➢ Penstock ➢ Spear and nozzle ➢ Runner with buckets ➢ Break nozzle ➢ Outer casing ➢ Governing mechanism
7	**What is the function of spear & nozzle?** BTL2 The nozzle is used to convert the whole hydraulic energy into kinetic energy. Thus, the nozzle delivers the high-speed jet. To regulate the water flow through nozzle and to obtain a good jet of water, spear or nozzle is arranged.

8 **Define water hammer.** BTL2

If water is flowing through a channel and it is stopped abruptly i.e., its momentum is broken so a pressure surge or wave results, this effect produced is called water hammer.

9 **List the essential factors which should be considered while selecting a site for a hydroelectric power plant.** BTL1

- Water availability
- Water Storage
- Water head
- Geological investigations
- Environmental aspects
- Consideration of water pollution effects

10 **Name the basis of classification of turbines**. BTL1

The turbines are classified according to the following basis

- According to the action of the water flowing.
- According to the main direction of flow of water.
- According to head and quantity of water required.
- According to the specific speed.

11 **List the difference between Francis and Kaplan turbine**. BTL5

S.NO	**FRANCIS TURBINE**	**KAPLAN TURBINE**
1	Correct disposition of the guide and moving vanes is obtained at full load only.	Correct disposition of the guide and moving blades is obtained at any load.
2	System may have one or two servomotors depending on the size of the unit.	Two servomotors respective of the size of the unit always do governing.
3	Since the guide vanes are only controlled and high efficiency is obtained.	Both guide and runner vanes are controlled and high efficiency is obtained even at partial loads.
4	Servomotors are kept outside the turbine shaft.	Both servomotors are kept inside the hollow shaft of the turbine runner.

12 **Write the limitations of tidal power plant.** BTL1

- The tidal ranges are highly variable and therefore, turbines have to work on a wide range of head variation.
- Construction in sea is found difficult.
- The output is not uniform.
- More corrosion will occur due to corrosive sea water.
- Massive construction leads to more consumption to start the plant.

13 **List the components of Tidal power plants**. BTL1

- The dam or dyke
- Sluice ways

	➢ The power house
14	**Define fuel cell and state its advantages.** BTL4 A fuel cell is a device which uses hydrogen (or a hydrogen – rich fuel) and oxygen to create an electric current. In other words, it can be defined as an electrochemical device in which the chemical energy of a conventional fuel is converted directly and efficiently into low voltage direct current electrical energy. Advantages: ➢ Fuel cells have the potential to replace the internal combustion engine in vehicles. ➢ They can be used in transportation applications such as powering automobiles, buses, cycles and other vehicles. ➢ Many portable devices can be powered by fuel cells such as laptop computers and cell phones ➢ They can also be used for stationary applications such as providing electricity to power homes and businesses.
15	**What is geothermal energy?** BTL2 Geothermal energy is the heat energy from high pressure steam stored in deep earth. It is a renewable source of energy derived from the rain water in the earth heated to over 180^{o}C by subterranean hot rocks.
16	**Write the applications of geothermal energy.** BTL1 ➢ Generation of electric power ➢ Space heating for buildings ➢ Industrial process heat
17	**List the important criteria while selecting the geothermal energy**. BTL1 ➢ Temperature of geothermal fluid, ^{o} C ➢ Discharge rate, m^3 / day ➢ Useful life of production well, years ➢ Mineral contents gram / m^3
18	**Identify the different types of geothermal fluid and give its temperature range**. BTL1 ➢ Dry steam – Steam-turbine cycle ➢ Hot water, temperature > 180^{o}C – Steam – Turbine cycle ➢ Hot water, temperature > 150^{o}C – Binary – cycle ➢ Hot brine (pressurized) – Binary cycle ➢ Hot brine (flashed) – Special turbines, Impact turbines, Screw expander, Bladeless turbine
19	**What is Solar cell?** BTL2 A solar cell is a device which directly converts the energy of light into electrical energy through the process of photovoltaic effect.
20	**List down the performance factors in wind energy generators**. BTL2 ➢ Solidity ➢ Tip speed ratio ➢ Performance Coefficient ➢ Torque
	PART *B
1	**(i) Draw the schematic diagram of hydro plant and explain the operation. (7 M) AU DEC-2015** BTL2 **Answer: Page: 4.2 – Anup Goel** **Diagram: (3 M)** ➢ Hydroelectric power plant is a conventional renewable source of power generation.

- In hydroelectric power plants, kinetic (or potential) energy of water is converted into mechanical energy of the turbines which is further converted into electric energy.
- It is a clean and pollution free way of power generation.

Site selection for Hydroelectric Power plant: (2 M)

- Availability of water
- Storage of water
- Available head of water
- Distance from load centre
- Access of the site
- Type of land of the site

Essential Elements: (2 M)

- The catchment area
- The reservoir
- The dam
- Spillways
- Conduits
- Surge tanks
- Prime movers
- Draft tubes
- Power generation station

Advantages:

- No fuel charges.
- No stand by losses.
- Less supervising staff.

Disadvantages:

- It takes very long time for erection of such plants.
- Initial cost of installation is very high.

(ii) Write a short note on Bio energy. (8 M) AU DEC-2015 BTL2

Answer: Page: 4.190 - Dr.G.K.Vijayaraghavan

Diagram: (3 M)

The energy obtained from organic matter derived from biological organisms (plants and animals) is known as bioenergy.

Explanation: (3 M)

Sources of Biomass energy:

Rural applications of biomass energy

Urban and Industrial applications of biomass energy

Biomass as a primary source for large scale electrical power generation.

Advantages: (1 M)

- Renewable source.
- Reduce the problems of waste disposal.
- Pollutant emissions from combustion of biomass is low.

Disadvantages: (1 M)

- Low energy density.
- Labour intensive.
- Dispersed and land intensive source.

2. **(i)Briefly explain Solar PV system. (8 M) AU DEC-2015** BTL2

Answer: Page: 4.18 – Anup Goel

Diagram: (3 M)

Explanation: (3 M)

- Converts energy from solar radiation directly into electricity using semiconductor materials.
- No mechanical moving parts, so it lasts for decades and requires only minimal maintenance.
- Ranges from small-scale projects for lighting and pumping to large-scale projects for whole buildings and even utility-scale photovoltaic farms.

Working: (2 M)

- When light energy or photons strike a photovoltaic cell, electrons are knocked loose from a layer in the cell designed to give up electrons easily.
- The charge difference that is built into the cell pulls the loose electrons to another cell layer before they can recombine in their originating layer.
- This migration of electrons creates a charge between layers in the photovoltaic cell.
- Electrically connecting the positively and negatively charged layers of a photovoltaic cell through a load will produce electricity.
- This energy is converted through the inverter to be used by electrical machines, appliances, lights, and so on.

(ii)What are the various kinds of fuel cell and explain the working of anyone? (7 M)
AU DEC-2015 BTL2

Answer: Page: 4.245 - Dr.G.K.Vijayaraghavan

Types of Fuel cells: (3 M)

- Hydrogen-oxygen cell
- Polymer Electrolyte Membrane (PEM) fuel cell
- Direct Methanol fuel cell
- Alkaline fuel cell
- Phosphoric acid fuel cell
- Molten Carbonate fuel cell
- Solid Oxide fuel cell
- Regenerative fuel cell

Hydrogen – Oxygen cell: (4 M)

- Anode: Hydrogen
- Cathode: Oxygen
- Electrolyte: Water

<u>Reactions:</u>

Anode: $2H_2 + 4(OH)^- \Longrightarrow 4H_2O + 4e^-$

Cathode: $O_2 + 2H_2O + 4e^- \Longrightarrow 4(OH)^-$

$4KOH \Longrightarrow 4K^+ + 4(OH)^-$

Cell reaction: $2H_2 + O_2 \Longrightarrow 2H_2O$

<u>Two types:</u>

- Low temperature cell
- High pressure cell

3. **Explain the working of solar thermal power plant with a neat diagram. (13 M)** BTL2

Answer: Page: 4.13 – Anup Goel

Diagram: (4 M)

Explanation: (3 M)

Solar energy:

- The energy liberated from solar radiation is known as solar energy.
- If the electrical energy generated from solar energy by using solar collectors is known as

solar power plant.

Important components of Solar Power Plant: (3 M)

- Solar collector
- Heat exchanger
- Steam turbine
- Condenser
- Pump
- Cooling tower

Solar Collectors – Device for collecting solar radiation and transfers the energy to a fluid passing in it.

Types – Flat plate type, cylindrical parabolic collectors, Parabolloid collectors

Solar Ponds – It combines solar energy collection and sensible heat storage

Types of Solar power plant: (3 M)

- Low temperature solar power plant.
  - (a) Using solar pond.
  - (b) Using flat plate collector.
- Medium temperature solar power plant.
- High temperature solar power plant.

PART*C

1. **(i)Explain the construction and working of fuel cell also mention its merits and demerits. (8 M)** BTL2

Answer: Page: 4.238 - Dr.G.K.Vijayaraghavan

Principle: (1 M)

A fuel cell is an electromechanical device in which the chemical energy of a conventional fuel is directly converted and efficiently into low voltage DC electrical energy.

Diagram: (2 M)

Parts of a fuel cell: (3 M)

- **Membrane electrode assembly** – Electrodes, catalyst and polymer electrolyte membrane together form the membrane electrode assembly.
- **Anode** – Negative side of the fuel cell
- **Cathode** – Positive side of the fuel cell
- **Polymer Electrolyte membrane** – Specially treated material which looks similar to ordinary kitchen plastic wrap which conducts only positively charged ions and blocks electrons.
- **Catalyst**-All electromechanical reactions in the fuel cell consist of two separate reactions such as an oxidation half-reaction at the anode and a reduction half-reaction at the cathode.
- **Chemistry of a fuel cell** - Anode, cathode and cell reaction.
- **Hardware**-The backing layers, flow fields and current collectors are designed to maximize the current from a membrane/electrode assembly.

Major sections of Fuel Cell Power Plants:(2 M)

It consists of six major sections which are as follows:

- Fuel processing section
- Fuel cell power pack
- Power conditioning section
- Switchgear and supply section
- Control subsystem section
- Heating section

	(ii)List the advantages and disadvantages of Wind Energy system. (7 M) BTL2 **Answer: Page: 4.8 – Anup Goel** **Advantages: (3 M)** ➢ It is a renewable source of energy ➢ Wind power systems are non-polluting, so it has no influence on the environment ➢ Wind is economically free energy. ➢ The wind blows day and night, which allows windmills to produce electricity throughout the day. **Disadvantages: (4 M)** ➢ Wind energy available is not consistent and steady, fluctuating in nature. ➢ Wind energy requires expensive storage capacity because of its irregularity. ➢ Wind energy systems are noisy in operation; a large unit can be heard many kilometers away. ➢ Requires large open areas for setting up wind farms.
2	**Explain the working of tidal power plant with a neat diagram. (15 M)** BTL2 **Answer: Page: 4.19 – Anup Goel** **Diagram: (3 M)** Tidal power generators derive their energy from movement of the tides. **Explanation: (5 M)** **Types of Tides: (3 M)** ➢ High tide or flood tide: the highest level of tidal water ➢ Low tide or ebb tide: the lowest level of tidal water ➢ The difference between high and low tides is known as tidal range. ➢ The tidal range varies from season to season and location to location. ➢ The maximum tidal range occurs at the time of new moon called spring tide. **Types of Tidal Power Plant: (4 M)** (a)Single basin system or one-way system Components – Dam, Power house, Basin, Sluice ways The power house and turbine located between sea and basin (b)Double basin system or two-way system Components – Dam, Power house, Upper and lower basin, Sluice gate The system contains two basins between these two power house **Advantages:** Renewable source, Pollution free **Disadvantages:** Expensive to build, Barrage has environmental effects.

	UNIT V ENERGY, ECONOMIC AND ENVIRONMENTAL ISSUES OF POWER PLANT
	Power tariff types, Load distribution parameters, load curve, Comparison of site selection criteria, relative merits & demerits, Capital & Operating Cost of different power plants. Pollution control technologies including Waste Disposal Options for Coal and Nuclear Power Plants.
	PART*A
Q.No.	**Questions**
1	**Define demand factor.** BTL2 Demand factor is the ratio of actual maximum demand of the system to the total connected demand of the system. Demand factor = Actual maximum demand / Total connected demand
2	**Define Load factor.** BTL2 Load factor is the ratio of average load over a given time interval to the peak load during the same time interval. Load factor = Average load over a given time interval / Peak load during the same time interval.
3	**Define demand for electricity.** BTL2 It is defined as the electricity requirement during the period of time of high price or more stress.
4	**Define diversity factor.** BTL2 Diversity factor is defined as the ratio of sum of the individual maximum demands to the actual peak load of the system. Diversity factor = Sum of individual maximum demand / Actual peak load of the system.
5	**What are the main factors that decide the economics of power plants?** BTL2 ➢ Connected load ➢ Demand ➢ Maximum demand ➢ Demand factor ➢ Load factor ➢ Capacity factor or plant capacity factor ➢ Utilisation factor ➢ Reserve factor ➢ Diversity factor ➢ Plant use factor
6	**What do you understand by load duration curves?** BTL2 Re-arrangement of all load elements of load curve is in the order of decreasing magnitude is called load duration curve.
7	**State the importance of load curves.** BTL2 ➢ To obtain the average load on the power station and the maximum demand of the power station ➢ To know the incoming load thereby helping to decide the installed capacity of the power station ➢ To decide the economical sizes of various generating units.

8	**What is the significance of load curve?** BTL2 The load curve gives full information about the incoming load and it helps to decide the installed capacity of the power station. It is also useful to decide the economical sizes of various generating units.
9	**What are the various types of load?** BTL2 ➢ Residential load ➢ Commercial load ➢ Industrial load ➢ Municipal load ➢ Irrigation load ➢ Traction load
10	**How does the fuel cost relate to the load and the cost of power generation?** BTL2 The cost of power generation is directly proportional to the fuel cost because the operating cost is directly linked with the fuel cost.
11	**What are fixed and operating costs?** BTL2 Fixed costs are the cost required for the installation of complete power plant. This cost includes the cost of land, buildings, equipment, transmission and distribution lines, cost of planning and designing the plant and many others. It also consists of interest, taxes, depreciation, insurance etc. Operating cost includes the cost of fuel, cost of lubricating oil, greases, cooling water, cost of maintenance and repairs, operating labour cost, supervision cost and taxes.
12	**Define flat rate tariff.** BTL2 The charging of amount depending only on the connected load and fixed number of hours of use per month or year is called flat tariff.
13	**List the types of tariffs to calculate energy rate.** BTL2 ➢ Flat demand rate ➢ Straight line meter rate ➢ Block-meter rate ➢ Hopkinson demand rate or two-part tariff ➢ Doherty rate or three part tariff
14	**How the tariff for electrical energy is arrived?** BTL2 Tariff is calculated by the following equation. Z= ax + by + c Where, z- Total amount of bill for the period considered a- Rate per KW of maximum demand x- Maximum demand in KW b- Energy rate per KWh y- Energy consumed in KWh during the period considered c- Constant amount charged to the consumer during each billing period
15	**Mention any four methods for calculating depreciation.** BTL2 ➢ Straight line method ➢ Sinking fund method ➢ Diminishing value method ➢ Net percent value method ➢ Double sinking fund method
16	**List down the nuclear waste disposal methods.** BTL2 ➢ Disposal in sea ➢ Disposal in land

	➢ Disposal by reduction process through chemical reaction ➢ Disposal by solidification process
17	**What are the elements of fixed costs?** BTL2 ➢ Land, building and equipment cost ➢ Interest ➢ Depreciation cost
18	**What are the elements of operating costs?** BTL2 ➢ Cost of fuel ➢ Lubricating oil, grease and water cost ➢ Cost of maintenance and repairs ➢ Cost of operating labour ➢ Cost of supervision and ➢ Taxes
19	**What is the significance of two-part tariff and three-part tariff?** BTL2 **Two-part tariff:** This method of charging depends on the maximum demand and energy consumption. **Three-part tariff:** This method is proposed by Henry L. Doherty. In this method of charging, the consumer has to pay some fixed amount in addition to charges for maximum demand and energy consumed. The fixed amount to be charged depends on the occasional increase in price and wage charge of workers etc.
20	**Define depreciation**. BTL2 It is the amount to be set aside per year from income to meet the depreciation caused by the age of service, wear and tear of machinery.
	PART * B
1	**Explain the methods to control pollution in thermal and nuclear power plants. (13 M)** BTL2 **Answer: Page: 5.42 & 5.46 - Anup Goel** **Control of Thermal Pollution: (6 M)** The industrial heated waste water can be controlled by using following measure: ➢ **Use of cooling ponds:** Water is cooled by evaporation, convection and radiation. ➢ **Use of cooling towers:** Heat from the water is transferred to the atmosphere through evaporation. ➢ **Cogeneration:** Heat from the water is utilized for domestic or industrial heating purposes. ➢ Use of spray ponds and artificial lakes. **Control of Nuclear Pollution: (7 M)** ➢ The most reliable technique for disposal and long term storage of nuclear waste is vetrification. ➢ In this process, the waste is mixed with the glass forming chemicals in melter. ➢ After solidification the waste gets trapped inside the coating formed. ➢ The waste can be stored for long term in the containers free from air and water. ➢ The most long lived radioactive wastes including spent nuclear fuel must be isolated from humans and environment in deep underground. ➢ The liquid waste is reprocessed continuously. ➢ Gases waste from low level radioactive waste is filtered, compressed and stored to allow decay, diluted. ➢ They can be discharged at the regulated rate. ➢ Solid waste can be disposed off by placing it where it will not be disturbed for years.

2 **(i)Explain site selection criterion of hydro power plant. (6 M)** BTL2

Answer: Page: 4.2 - Anup Goel

The factors which can be considered for selection of site for a hydro-electric power plant are as follows:

- **Availability of water**: The design of Hydro-electric power plant and the amount of power generation depends upon the availability of water.
- **Storage of water**: Water is stored in the catchment area for continuous power generation.
- **Availability head of water:** To generate required quantity of power, the large quantity of water at sufficient head must be available.
- **Distance from the load centre:** The plant must be commissioned near the load centre which reduces the cost of erection and maintenance of transmission lines.
- **Access of the site:** The site of the plant should be easily accessible.
- **Type of land of the site:** The site should be rocky and the rock must be strong enough to carry the stresses from the dam structures and thrust of water when reservoir is full.

(ii)A peak load on the thermal power plant is 75 MW. The loads having maximum demands of 85 MW, 20 MW, 15 MW and 18 MW are connected to the power plant. The capacity of the plant is 90 MW and annual load factor is 0.53. Calculate the average load on power plant, energy supplied per year, demand factor and diversity factor. (8 M) BTL3

Answer: Page: 5.48 – Dr.G.K.Vijayaraghavan

Formula: (4 M)

Solution: (4 M)

Load factor = Average load / Peak load
Average load = 0.53 * 75 = 39.75 MW
Energy supplied per year = Average load * 24 * 365
= 39.75 * 8760
= 348210 MWh
Demand factor = Maximum demand / Connected load
= 75 / (35+20+15+18)
= 0.852
Diversity factor = Sum of the individual maximum demand / Annual peak load of the system
= (35 + 20 +15 + 18)/ 75
= 1.173

3. (i)**Explain the analysis of pollution from thermal power plants. (6 M)** BTL4

Answer: Page: 5.45 - Anup Goel

The thermal pollution of water refers to the degradation of the water quality due to increase in its temperature.

Sources of Thermal pollution: (2 M)

- Nuclear power plants
- Thermal power plants
- Industrial effluents
- Domestic sewage
- Hydro-electric power plants
- Human activities

Effects of Thermal pollution: (2 M)

- Reduction in dissolved oxygen
- Increase in toxicity of water
- Interference in biological activities of aquatic life such as metabolism, biochemical

processes.
- Interference in reproduction of aquatic life.
- Responsible for extinction of aquatic species.
- Responsible for food shortage for fish.

Control of Thermal Pollution: (2 M)

The industrial heated waste water can be controlled by using following measure:

- Use of cooling ponds: Water is cooled by evaporation, convection and radiation.
- Use of cooling towers: Heat from the water is transferred to the atmosphere through evaporation.
- Cogeneration: Heat from the water is utilized for domestic or industrial heating purposes.
- Use of spray ponds and artificial lakes.

(ii)Elucidate the objectives and requirements to tariff and general form of tariff. (7 M)

Answer: Page: 5.10 - Anup Goel

The different methods of charging the consumers for electricity consumption is known as "Tariffs" or "Energy Rates".

Objective: (1 M)

The electricity generated by the power plants is to be supplied to consumers. There-fore the total cost of generation has to be recovered from the consumers.

General Tariff form:(4 M)

$Z= ax + by + c$

Where, z- Total amount of bill for the period considered
c- Rate per KW of maximum demand
x- Maximum demand in KW
d- Energy rate per KWh
y- Energy consumed in KWh during the period considered
c- Constant amount charged to the consumer during each billing period

Types: (2 M)

Flat demand rate, Straight meter rate, Block meter rate, Hopkinson demand rate (two part tariff), Doherty rate (three part tariff), Wright demand rate.

PART*C

1. **(i)Write short note on Nuclear Waste disposal. (7 M)** BTL2

Answer: Page: 5.42 - Anup Goel

The nuclear power plant has an impact on surrounding environment from nuclear waste which comes from a number of sources.

These sources are as follows: (3 M)

- Nuclear explosions performed while conducting nuclear tests.
- Operations performed by nuclear power plant produce radioactive waste.
- Mining and refining radioactive materials such as uranium and thorium.
- Nuclear fuel cycle used in industrial, medical and scientific processes.

Radioactive waste: **(2 M)**

Includes high level and low level waste.

Radioactive Emission: **(2 M)**

Consists of the radiation from the radioactive sources such as nuclear weapons, handled radioactive material, nuclear accidents.

(ii)A central power station has annual factors as follows. Load factor = 60%, Capacity factor = 40% and Use factor = 45%. Power station has a maximum demand of 15000 KW. Determine annual energy production, reserve capacity over and above load and hours per year not in service. (8 M) BTL3

Answer: Page: 5.38 - Anup Goel

Formula: (4 M)

Solution: (4 M)

Load Factor = 60 % = 0.6
Capacity Factor = 40 % = 0.4
Use factor = 45 % = 0.45
Maximum demand = 15000 KW
Average load = Maximum demand * Load Factor
= 15000 * 0.6 = 9000 KW
Energy produced per year = Average load * 365 * 24
= 9000 * 365 * 24
= $78.84 * 10^6$ kWhr
Reverse Capacity over and above peak load
Capacity factor = Average load / Installed capacity
Installed capacity = 9000 / 0.4 = 22500 Kw
Reverse capacity = Installed capacity – Maximum demand
= 22500 – 15000
= 7500 Kw

2. **List various pollutants released by the coal based thermal power plants and detail the techniques adopted to mitigate them. (15 M)** BTL2

Answer: Page: 5.39 - Anup Goel

Explanation: (5 M)

The burning of coal in thermal power plant produces number of pollutants. They are as follows:

- Carbon dioxide (CO_2)
- Sulphur dioxide (SO_2)
- Nitrogen Oxides (NO_x)
- Ash
- Particulate matter

Control of Particulate matter: (3 M)

The solid particulate matter can be separated from the gases by using settling chamber or a cyclone collector.

Control of SO_2: (4 M)

- Use of scrubbers.
- Reducing Sulphur content from the fuel.
- Froth floatation Process.
- Use of Fluidized Bed Combustion (FBC).
- Integrated Gasification Combined Cycle (IGCC).

Control of Nitrogen Oxides (NO_x): (3 M)

- By altering temperature and oxygen content.
- Modifying combustion process.
- Converting NO_x to N_2 Using any reducing agent or catalyst such as platinum – rhodium, ammonia etc.

3.

(i) Discuss any four methods adopted for the disposal of radioactive waste materials. (7 M) BTL2

Answer: Page: 5.42 - Anup Goel

Explanation: (3 M)

- Radioactive waste – Includes high level and low level waste
- High level waste consists of irritated spent fuel at reactor site including fission products and plutonium waste.
- Low level waste is produced through chemical and volume control system. This includes gaseous, liquid and solid waste.

Techniques for the disposal of radioactive waste materials: (4 M)

- The most reliable technique for disposal and long term storage of nuclear waste is vetrification.
- In this process, the waste is mixed with the glass forming chemicals in melter.
- After solidification the waste gets trapped inside the coating formed.
- The waste can be stored for long term in the containers free from air and water.
- The most long lived radioactive wastes including spent nuclear fuel must be isolated from humans and environment in deep underground.
- The liquid waste is reprocessed continuously.
- Gases waste from low level radioactive waste is filtered, compressed and stored to allow decay, diluted.
- They can be discharged at the regulated rate.
- Solid waste can be disposed off by placing it where it will not be disturbed for years.

(ii)A generating station supplies four feeders with maximum demands (in MW) 16, 10, 12 and 7. The overall maximum demand of the station is 20 MW and the annual load factor is 45%. Calculate the diversity factor and number of units generated annually. (8 M) BTL3

Formula: (4 M)

Solution: (4 M)

Diversity factor = sum of the individual maximum demand / peak load of the system
= (16+10+12+7) / 20
= 2.75

Load factor = Average load / Peak load
Average load = 0.45 * 20 = 9 MW
Number of units generated annually = Average load * 24 * 365
= 9 * 24 * 365 = 78840 MWh

EE8301 ELECTRICAL MACHINES – I L T P C 3 1 0 4

OBJECTIVES:

- To introduce techniques of magnetic-circuit analysis and introduce magnetic materials
- To familiarize the constructional details, the principle of operation, prediction of performance, the methods of testing the transformers and three phase transformer connections.
- To study the working principles of electrical machines using the concepts of electromechanical
- energy conversion principles and derive expressions for generated voltage and torque developed in all Electrical Machines.
- To study the working principles of DC machines as Generator types, determination of their no load/ load characteristics, starting and methods of speed control of motors.
- To estimate the various losses taking place in D.C. Motor and to study the different testing
- methods to arrive at their performance.

UNIT I MAGNETIC CIRCUITS AND MAGNETIC MATERIALS 9

Magnetic circuits –Laws governing magnetic circuits - Flux linkage, Inductance and energy – Statically and Dynamically induced EMF - Torque – Properties of magnetic materials, Hysterisis and Eddy Current losses - AC excitation, introduction to permanent magnets-Transformer as a magnetically coupled circuit.

UNIT II TRANSFORMERS 9

Construction – principle of operation – equivalent circuit parameters – phasor diagrams, losses – testing – efficiency and voltage regulation-all day efficiency-Sumpner's test, per unit representation – inrush current - three phase transformers-connections – Scott Connection – Phasing of transformer– parallel operation of three phase transformers-auto transformer – tap changing transformers- tertiary winding.

UNIT III ELECTROMECHANICAL ENERGY CONVERSION AND CONCEPTS IN ROTATING MACHINES 9

Energy in magnetic system – Field energy and co-energy-force and torque equations – singly and multiply excited magnetic field systems-mmf of distributed windings – Winding Inductances-, magnetic fields in rotating machines – rotating mmf waves – magnetic saturation and leakage fluxes.

UNIT IV DC GENERATORS 9

Construction and components of DC Machine – Principle of operation - Lap and wave windings-EMF equations– circuit model – armature reaction –methods of excitation-commutation and inter poles - compensating winding –characteristics of DC generators

UNIT V DC MOTORS 9

Principle and operations - types of DC Motors – Speed Torque Characteristics of DC Motors-starting and speed control of DC motors –Plugging, dynamic and regenerative braking- testing and efficiency – Retardation test- Swinburne's test and Hopkinson's test - Permanent magnet dc motors(PMDC)-DC Motor applications.

TOTAL (L:45+T:15): 60 PERIODS

OUTCOMES:

- Ability to model and analyze electrical apparatus and their application to power system

TEXT BOOKS:

1. Nagrath I. J and Kothari D. P. 'Electric Machines', Fourth Edition, Tata McGraw Hill Publishing Company Ltd, 2010.
2. M.N. Bandyo padhyay, Electrical Machines Theory and Practice, PHI Learning PVT LTD., New Delhi, 2009.
3. Fitzgerald. A.E., Charles Kingsely Jr, Stephen D.Umans, 'Electric Machinery', Sixth edition, Tata McGraw Hill Books Company, 2003.

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1. P. C. Sen., 'Principles of Electrical Machines and Power Electronics', John Wiley & Sons, 1997.
2. Syed A. Nasar, Electric Machines and Power Systems: Volume I, Mcgraw-Hill College; International Edition, January 1995.
3. Desh pande M. V., "Electrical Machines" PHI Learning Pvt. Ltd., New Delhi, 2011.
4. P.S. Bimbhra, 'Electrical Machinery', Khanna Publishers, 2003.

Subject Code:EE8301 **Year/Semester: II /03**
Subject Name: ELECTRICAL MACHINES - I **Subject Handler: Ms. P. Vinnarasi Ponnury**

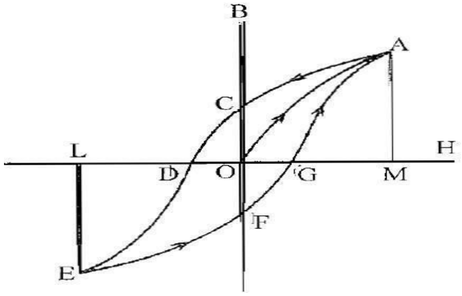
UNIT I MAGNETIC CIRCUITS AND MAGNETIC MATERIALS

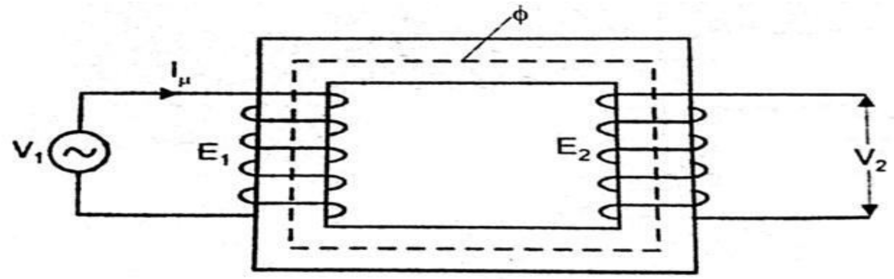
Magnetic circuits – Laws governing magnetic Circuits-Flux linkage, Induction and Energy-Statically and dynamically induced emf-Torque-Properties of magnetic materials , Hysteresis and Eddy current loss-AC Excitation ,Introduction of Permanent magnets-Transformer as an magnetically coupled circuit.

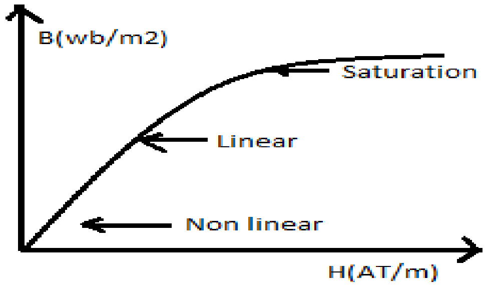
Part*A

Q.No	Question
1.	**What is magnetic circuit?** BTL1 The closed path followed by magnetic flux is called magnetic circuit
2.	**Mention the types of electrical machines. (MAY/JUNE 2013)** BTL1 There are three basic rotating machines types, namely a. The dc machines b. the poly phase synchronous machine (ac) c. Poly and single phase induction machine (ac)and a stationary machine, namely Transformer
3.	**Mention the magnetic materials with example. (APRIL/MAY 2015)** BTL1 Dia Magnetic Materials –organic martial , light elements Para Magnetic Materials – Alkali metals (Na,K) Ferro Magnetic Materials – Fe, Ni, and Co Antiferro Magnetic Materials - FeO Permanent Magnet - Ferrous ferrite and Nickal ferrite
4.	**Relate magnetostriction and coercivity. (APRIL/MAY 2015)** BTL1 When ferromagnetic materials are subjected to magnetizing mmf, these may undergo small changes in dimension; this phenomenon is known as magnetostriction It is the measure of mmf which, when applied to the magnetic circuit would reduce its flux density to zero, i.e., it demagnetizes the magnetic circuit.
5.	**Why the core of an electrical machines are laminated? (NOV/DEC 2015)** BTL1

	When the core is laminated, it gets divided into thin laminations. The path of the eddy currents is broken due to the insulating sheets present between the laminations. This eddy current through the core and reduces the eddy current losses.
6.	**Distinguish between leakage flux and fringing flux.(MAY/JUNE 2014,MAY/JUNE 2013)** BTL2 The small amount of flux always leak to the air gap that flux is called as leakage flux. The Flux spread out the edge of the air gap that flux is called as fringing flux
7.	**Write a notes on quasi static fields.(NOV/DEC 2015,MAY/JUNE 2014)** BTL1 All the electromechanical energy conversion devices are slow moving devices because of inertia associated with the moving parts. Therefore, the fields in the device are also slow in nature.
8.	**Correlate core loss and eddy current loss. (NOV/DEC 2015)** BTL1 When a magnetic material undergoes cyclic magnetization, two kinds of power losses occur on it is called Hysteresis loss. Hysteresis and eddy current losses are called as core loss. It is important in determining heating, temperature rise, rating & efficiency of transformers, machines & other A.C run magnetic devices. when a magnetic field is varied are known as eddy current and have power loss known as eddy current loss.
9.	**How will you find the direction of force produced using Fleming's left hand rule? (NOV/DEC 2015)** BTL2 The thumb, forefinger & middle finger of left hand is held so that these fingers are mutually perpendicular to each other, then forefinger gives the direction of magnetic field, middle finger gives the direction of the current and thumb gives the direction of the force experienced by the conductor.
10.	**How hysteresis and eddy current losses are minimized? (APRIL/MAY 2015)** BTL2 Hysteresis loss can be minimized by selecting materials for core such as silicon steel & steel alloys with low hysteresis co-efficient and electrical resistivity. Eddy current losses are minimized by laminating the core.
11.	**Draw the typical normal magnetization curve of ferromagnetic material.(MAY/JUNE 2013)** BTL6

	
12.	**Define stacking factor.(NOV/DEC 2015)** BTL1 The stacking factor is defined as the ratio of the net cross section area of magnetic core to gross cross section area of magnetic core. Due to laminations net cross section area will be always less than gross cross section area.
13.	**State faradays law of electromagnetic induction. (NOV/DEC 2008)** BTL1 Whenever the current carrying conductor placed in a magnetic field the flux cut by the conductor it produces torque and dynamically induced emf. The magnitude of induced emf is proportional to rate of change flux linkage.
14.	**Define relative permeability. (May 2011)** BTL1 Relative permeability of a material is equal to the ratio of flux density produced in that material to the flux density produced in air by the same magnetizing force. $\mu_{r} = \mu/\mu_0$
15.	**What are the magnetic losses? (April/May 2018)** BTL1 Eddy Current losses and Hysteresis losses
16.	**Write a note on statically induced emf. (April/May 2015)** BTL1 Conductor is stationary and the magnetic field is moving or changing the induced emf is called stationary induced emf
17.	**State self inductance.** BTL1 The property of a coil that opposes any change in the amount of current flowing through it is called self inductance
18.	**State Lenz law.** BTL1 The law states that induced emf always opposite to applied voltage source.

19.	**State faraday's law of electromagnetic induction.** BTL1 **Whenever a flux linking in the coil changes emf always induced in the conductor the magnitude of induced emf is proportional to rate of change flux linkage** **e=NdΦ/dt**
20.	**Define co-efficient of coupling. (May 2008)** BTL1 Co-efficient of coupling between two coils is defined as the fraction of of magnetic flux produced by the current in one coil that links other coil.
Part*B	
Q.No	**Question**
1.	**Explain in detail about magnetic circuit. (MAY/JUNE 2014, MAY/JUNE 2013)**BTL2**(13M)** **Answer: Page No.1.4 - J.Gnanavadivel** ➢ Explanation Magnetic circuit (3 M) ➢ Closed path followed by the flux lines. F=I N(AT) I=Current through the coil. N=Number of turn in the coil. ➢ Simple Magnetic (2 M) ➢ Composite Magnetic (3M) ➢ Parallel Magnetic circuits (3 M) ➢ Diagram (2 M) 



2. **State the following Magnetic field properties (i) Magnetic Field intensity (ii) Magnetic Flux (iii) Flux Density (iv) Magnetic Motive Force (v) Magnetic reluctance.**BTL1**(13M)**

Answer: Page No.1.4 - J.Gnanavadivel

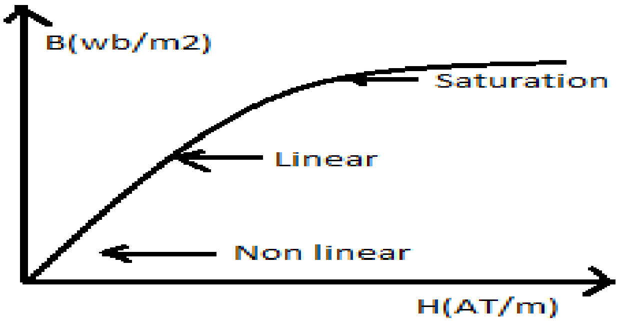
- Define each terms
- Magnetic Field intensity (3 M)
  - ✓ mmf per unit length of the magnetic flux path
  - ✓ denoted by H
  - ✓ unit - AT/m.
  - ✓ H=NI/l
- Magnetic Flux (2 M)
  - ✓ The magnetic lines of force produced by a magnet
  - ✓ Denoted by ϕ
  - ✓ unit - weber.
- Flux Density (3 M)
  - ✓ the flux per unit area of right angles to the flux
  - ✓ denoted by B
  - ✓ unit weber / meter^2.
- Magnetic Motive Force (3 M)
  - ✓ cause for producing flux in a magnetic circuit
  - ✓ Amount of flux set up in the core depends upon current (I) , number of turns (N).
  - ✓ product of NI
  - ✓ MMF=NI Ampere turns (AT)
- Magnetic reluctance (2 M)
  - ✓ Opposition that the magnetic circuit offers to flux

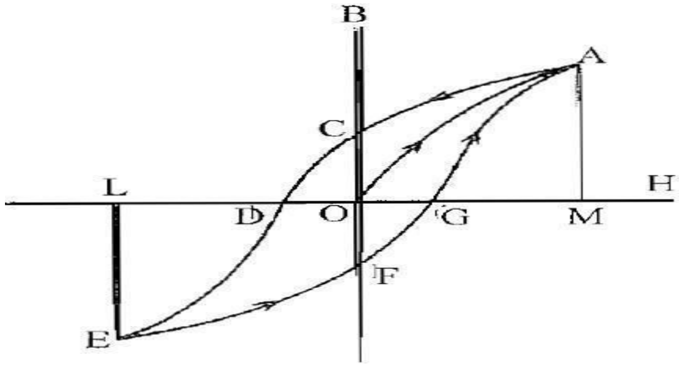
- ✓ ratio of MMF to Flux
- ✓ Reluctance =MMF/Flux AT/wb

3. **Explain AC operation of magnetic circuits and derive the energy stored in magnetic field. (MAY/JUNE 2014)** BTL2 **(13M)**

Answer: Page No.1.89 - J.Gnanavadivel

- ➢ Explain Magnetic Hysteresis (8 M)
- ➢ Hysteresis loop(5 M)
  - ✓ Many applications – machines , transformer and a.c machines,
  - ✓ The magnetic circuits - excited by a.c supply.
  - ✓ The exciting current has to adjust itself - B-H relationship satisfaction.
  - ✓ B always lags behind H.
  - ✓ Value of H required - wipe off residual magnetism - coercive force.
  - ✓ Iron bar - complete cycle of reversal of magnetization - Hysteresis loop.
  - ✓ Closed Loop ACDEFGA.





4. **Explain the core losses that occurs in magnetic circuits in detail. (MAY/JUNE**

2015,NOV/DEC 2015,NOV/DEC 2012) (BTL2) **(13M)**

Answer: Page No.1.92 - J.Gnanavadivel

- Losses occur - the armature , d.c. machine
- They are of two types
  - ✓ Hysteresis loss
  - ✓ Eddy current loss.
- Explain Hysteresis Loss(7 M)
  - ✓ Hysteresis loss, Ph=B^{16}maxfV watts
  - ✓ Bmax = Maximum flux density in armature
  - ✓ f = Frequency of magnetic reversals
  - ✓ V = Volume of armature in m3
  - ✓ h = Steinmetz hysteresis co-efficient
- Explain Eddy current Loss(6 M)
  - ✓ Eddy current loss, Pe = KeB^2maxf^2t^2V watts
  - ✓ Ke = Constant
  - ✓ Bmax = Maximum flux density in Wb/m^2
  - ✓ f = Frequency of magnetic reversals in Hz
  - ✓ t = Thickness of lamination in m
  - ✓ V = Volume of core in m^3

5. **List the properties of magnetic material suitable for Fabrication Permanent Magnet. (April/May 2015,May /June 2016)** BTL2 **(13M)**

Answer: Page No.1.95 - J.Gnanavadivel

- Introduction of magnetic materials (4 M)

Attracted by a magnet used in electrical design - equipment must have following properties.

- Different types of magnetic materials (9 M)
  - ✓ High permeability
  - ✓ High Electrical resistivity
  - ✓ Narrow hysteresis loop
  - ✓ Energy stored
  - ✓ Role of B-H curve
  - ✓ Hard material and soft material

	✓ Special purpose alloy
6.	**The total core loss of a specimen of silicon steel is found to be 1500W at 50 Hz, keeping the flux density to be constant, the loss become 3000W. When the frequency is raised to 75 Hz. Calculate the separately hysteresis loss and eddy current losses at each frequency. (Dec 2008,May 2010,Dec 2010,Non/Dec 15)**(BTL5) **(13M)** **Answer: Page No.1.93 - J.Gnanavadivel** ➢ Write the formula(5 M) ➢ Hysteresis loss = $(BM\ )^{1.6}VkHf$ ✓ Wh=Af ✓ Eddy current Loss = $Ke(BM\ )^2\ t^2Vf^2$ ✓ $W_e= Bf^2$ Substitution steps with answer (8 M) ➢ At 50 Hz ✓ Hysteresis loss = Af = 10*50=500W ✓ Eddy current loss= $Bf^2=0.4*(50)^2=1000W$ ➢ At 75 Hz ✓ Hysteresis loss = Af = 10*75=750W ✓ Eddy current loss= $Bf^2=0.4*(75)^2=2250W$
7.	**Explain the eddy current and eddy current losses in the magnetic circuit. (April/may 2015,May/June 2016)** BTL2**(13M)** **Answer:Page No.1.93 - J.Gnanavadivel** ➢ Explain Eddy current with expression(6 M) ✓ Due to change of magnetic field eddy current loss will occur ✓ It will increase the temperature ✓ Laminating a core increases the core resistance which decreases the eddy current loss. ➢ Eddy current loss, Pe = $KeB^2maxf^2t^2V$ watts (7 M) ✓ Ke = Constant ✓ Bmax = Maximum flux density in Wb/m^2 ✓ f = Frequency of magnetic reversals in Hz ✓ t = Thickness of lamination in m

- ✓ V = Volume of core in m^3

8. **Compare the similarities and dissimilarities between electric and magnetic circuits.**BTL2 **(13M)**

Answer: Page No.1.13 - J.Gnanavadivel

- ➢ Tabulate and compare magnetic and electric circuit .Each point (2 M)
- ➢ Electric Circuit : (5M)
  - ✓ Current
  - ✓ Resistance
  - ✓ Conductance
  - ✓ Many insulators
  - ✓ Current density
- ➢ Magnetic circuit: (6M)
  - ✓ Flux
  - ✓ Reluctance
  - ✓ Permeance
  - ✓ Flux density
  - ✓ No insulators

Part*C

Q.No	Question

1. **Explain in detail about statically and dynamically induced emf . (NOV/DEC 2015)** BTL2 **(15M)**

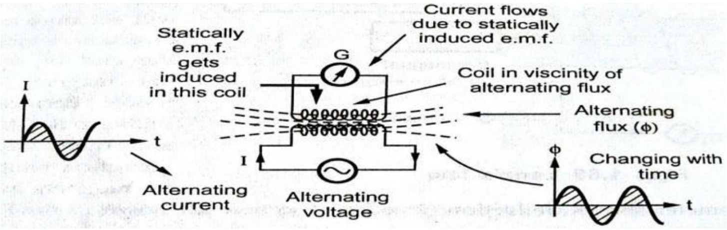
Answer: Page No.1.33 - J.Gnanavadivel

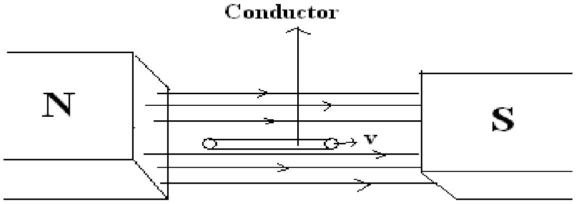
- ➢ **induced EMF(2 M)**

Magnitude of the induced emf - directly proportional to the rate of change of flux linkages

- ➢ **Statically induced(6 M)**

"The flux produced by one coil - getting linked with another coil and due to change in flux produced



	➢ **Dynamically induced (7 M)** "The change in flux lines - statically induced emf" 
2.	**Explain the following terms (i)Force acts on the current carrying conductor lying in a magnetic field (ii) Faraday's Law of Electro Magnetic Induction .**BTL2 **(15M)** **Answer: Page No1.82,1.29 - J.Gnanavadivel** ➢ (i)Explain the Force acts on the current carrying conductor lying - magnetic field (7 M) ✓ F=q(E+v* B) ✓ F = qE ✓ F = q(v*B) ➢ (ii)State the faraday's law of electro magnetic induction (8 M) ✓ Whenever the magnetic flux linking a conductor changes , an emf - always induce in it ✓ Induced emf = $N\phi_1 - N\phi_1 / t$ volts ✓ e = -N dϕ/dt ✓ e = Magnitude of induced emf ✓ N = Number of turns ✓ dϕ/dt = Rate of change of flux
3.	**A steel ring of 25 cm mean diameter and of circular section 3 cm in diameter has an air gap of 1.5 mm length. It is wound uniformly with 700 turns of wire carrying a current of 2 A. Calculate mmf , flux density , reluctance.(May 2008)** BTL4 **(15M)** **Answer: Page No.1.19 -J.Gnanavadivel** ➢ Mmf = NI AT (2 M) =1400 AT (1 M) ➢ Flux Density $B_g = {}_{AT_g} \mu_o \mu_r / l_g$ wb/m^2 (2 M)

$=1.172 \text{ wb/m}^2$ (1 M)

- Magnetic Flux ϕ

$= Bg\ a$ (2 M)

$a = \frac{\Pi}{4} d^2$ (2 M)

$= 0.828$mwb (2 M)

- Reluctance = mmf/flux (2 M)

$=1.69*10^6$ AT/wb (1 M)

UNIT-II TRANSFORMERS

Construction-Principle of operation-equivalent circuit parameters- phasor diagram , losses- testing-Efficiency and voltage regulation-all day Efficiency - sumpner test, per unit representation-inrush current-three phase transformer-connections - schoot connections-phasing of transformers - parallel operation of three phase transformers-auto transformer-tap changing transformer-tertiary winding

Part*A

Q.No **Questions**

1. **What are the typical uses of auto transformer? (NOV/DEC 2012)** BTL1
   - To give small boost to a distribution cable to correct for the voltage drop.
   - As induction motor starters.
   - As furnace transformers
   - As interconnecting transformers
   - In control equipment for single phase and 3 phase elective locomotives

2. **Write the Comparison of Core and Shell type transformers. (MAY/JUNE 2014)** BTL2

CORE TYPE	SHELL TYPE
The winding encircles the core	The core encircles most part of the winding
It has single magnetic circuits	It has double magnetic circuits
The cylindrical type of coil are used	Multilayer dick type or sandwich coil are used
The construction preferred for low voltage transformer	The construction preferred for High voltage transformer
In single phase type ,the core has two limbs	In single phase type ,the core has three limbs

3. **Why the SC test on transformer is performed on HV side?(May 2009,June 2007)** BTL4

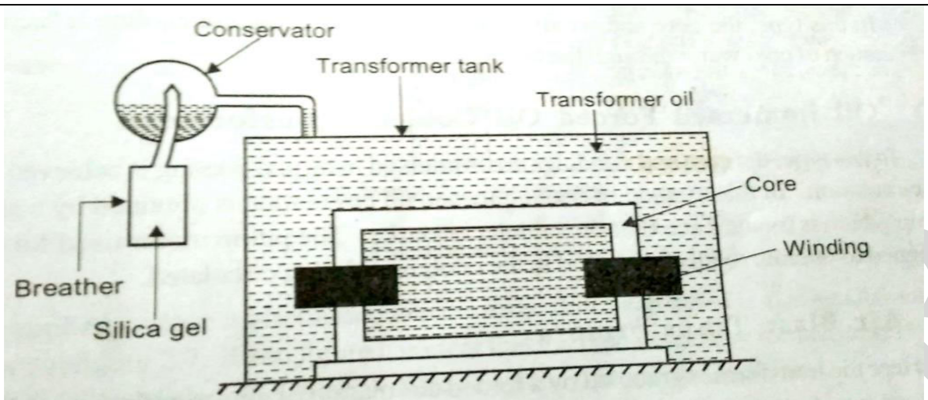
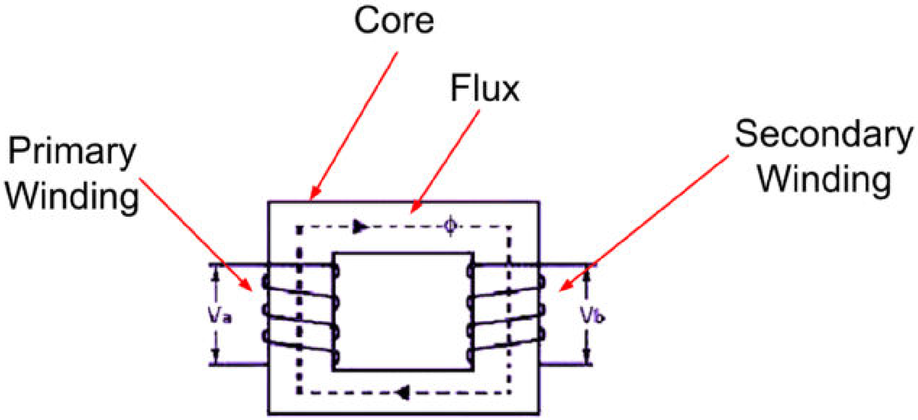
The Short Circuit test is normally conducted on HV side of the transformer and LV side is short circuited, because on the high voltage side the current rating is low .So we can use normally available meter range

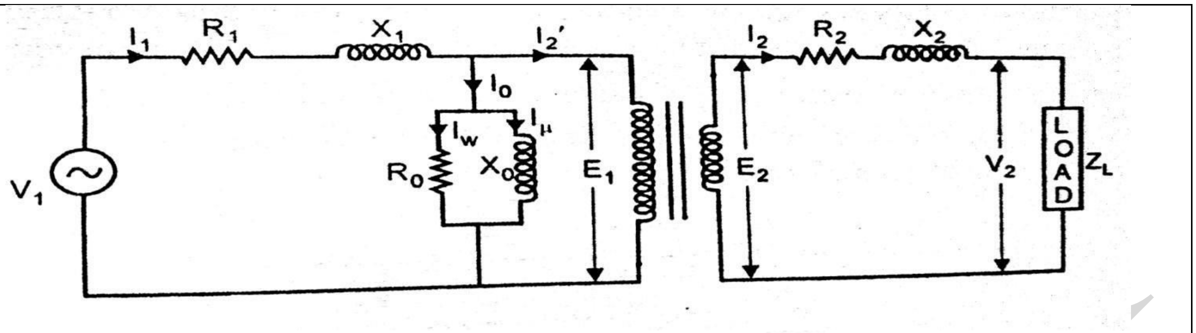
4. **Give the emf equation of a transformer and define each term.**BTL2

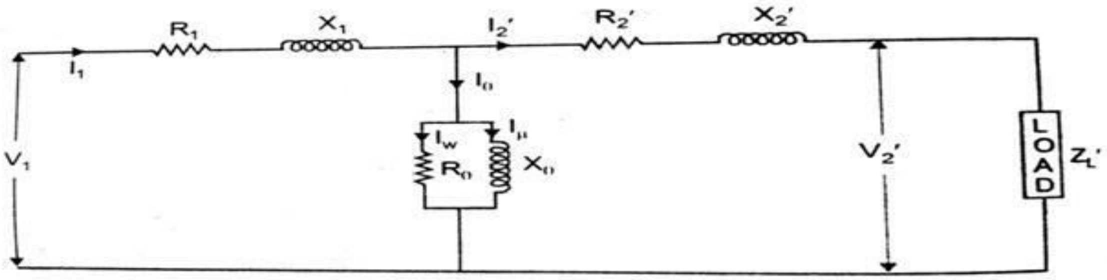
Emf induced in primary coil $E_1=4.44f\Phi_m N_1$ volt

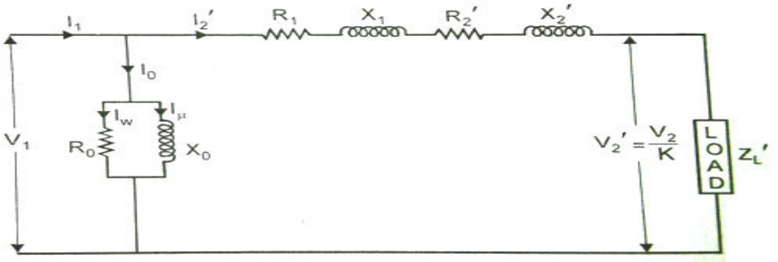
	Emf induced in secondary Coil $E_2=4.44f\Phi_mN_2$. f-----------freq of AC input Φ-------maximum value of flux in the core N_1,N_2----Number of primary &secondary turns.
5.	**Does transformer draw any current when secondary is opened? Why?**BTL2 Yes, it (primary) will draw the current from the main supply in order to magnetize the core and to supply for iron and copper losses on no load .There will not be any current in the secondary since secondary is open.
6.	**Define voltage regulation of a transformer.**BTL1 When a transformer is loaded with a constant primary voltage, the secondary voltage decreases for lagging PF load, and increases for leading PF load because of its internal resistance and leakage reactance. The change in secondary terminal voltage from no load to full load expressed as a percentage of no load or full load voltage is termed as regulation.
7.	**What happen when a DC supply is applied to a transformer? (NOV/DEC 2015)** BTL1 Due to saturation of magnetic core a large current flows through the windings, without induced any emf. This large current burns the windings of the transformer.
8.	**Why transformers are rated in kVA? (NOV/DEC 2015,MAY/JUNE 2009)**BTL4 Copper loss of a transformer depends on current &iron loss on voltage. Hence total losses depend on Volt-Ampere and not on PF. That is why the rating of transformers is in kVA and not in kW.
9.	**Mention the applications of single phase auto transformer. (APRIL/MAY 2015)** BTL2 Variable voltage regulators, variable voltage rectifiers and laboratories.
10.	**What are the applications of step-down transformer?**BTL1 Step-down transformers are used in receiving stations. The voltage are stepped down to11kV or 22kV are stepped down to 3 phase 400V by means of a distribution transformer and made available at consumer premises. The transformers used at generating stations are called power transformers.
11.	**What are the applications of step-up transformer?**BTL1 Step-up transformers are used in generating stations. Normally the generated voltage will be either 11kV. This voltage (11kV) is stepped up to 110kV or 220kV or 400kV and transmitted through transmission lines (simply called as sending end voltage).
12.	**How transformers are classified according to the construction?**BTL2 ➢ Core type. ➢ Shell type. In core type, the winding (primary and secondary) surround the core and in shell type , the core surround the winding.
13.	**Explain on the material used for core construction.**BTL2 The core is constructed by sheet steel laminations assembled to provide a continuous magnetic path with minimum of air gap included .The steel use is of high silicon content sometimes heat treated to produce a high permeability and allow hysteresis loss at the usual operating flux densities. The eddy current loss is minimized by laminating the core , the

	laminations being used from each other by light coat of core – plate vanish or by oxide layer on the surface. The thickness of lamination varies from 0.35mm for a frequency of 50Hz and 0.5mm for a frequency of 25H
14.	**How frequency affect the operation of a given transformer?**BTL2 With a change in frequency ,iron and copper loss, regulation, efficiency & heating varies so the operation of transformer is highly affected.
15.	**What is the angle by which no –load current will lag the ideal applied voltage?**BTL1 In an ideal transformer , there are no copper &core loss i.e. loss free core . The no load current is only magnetizing current therefore the no load current lags behind by angle 90 . However the winding possess resistance and leakage reactance and therefore the no load current lags the applied voltages lightly less than 90.
16.	**Why are breathers used in transformers?**BTL1 Breathers are used to entrap the atmospheric moisture and there by not allowing it to pass on to the transformer oil . Also to permit the oil inside the tank to expanded contract as its temperature increases and decreases.
17.	**Distinguish between power transformers & distribution transformers. (MAY/JUNE 2012)** BTL2 Power transformers have very high rating in the order of MVA. They are used in generating and receiving stations. Sophisticated controls are required. Voltage ranges will be very high. Distribution transformers are used in receiving side. Voltage levels will be medium. Power ranging will be small in order of kVA. Complicated controls are not needed.
18.	**Name the factors on which hysteresis loss depends.**BTL2 ➢ Frequency ➢ volume of the core and ➢ Maximum flux density
19.	**What is the purpose of providing Taps in transformer and where these are provided?**BTL1 In order to attain the required voltage, taps are provided, normally at high voltages side (low current).
20.	**State all day efficiency of a transformer. (NOV/DEC 2012, MAY/JUNE 2009)** BTL1 It is computed on the basis of energy consumed during a certain period, usually a day of 24 hrs. all day efficiency = output in kWh/input in kWh tor 24 hrs.
Part*B	
Q.No	**Question**
1.	**Describe the Construction and working principle of a transformer. (MAY/JUNE 2014, MAY/JUNE 2013,MAY/JUNE 2011)** BTL2 **(13M)** **Answer: Page :2.2 - J.Gnanavadivel** ➢ Draw the diagram(4 M)

	 ➢ Explain the parts(5 M) ✓ Magnetic core ✓ Primary and Secondary Winding ✓ Insulation of winding ✓ Expansion tank and Conservator ✓ Lead and tappings for coils – support, terminal and terminal insulator ✓ Tank , Oil , cooling arrangements , temperature gauge , oil gauge ✓ Buchhols relay ✓ Silica gel breather ➢ Explain the working Principle(4 M)  ✓ Electromagnetic induction Principle ✓ Faradays law
2.	**Explain the Equivalent circuit of Transformer . (NOV/DEC 2012,NOV/DEC 2009,May/June 2016)** BTL1 **(13M)** **Answer: Page : 2.57 in J.Gnanavadivel** ➢ Draw the equivalent circuit(7 M) ➢ Reduce the circuit for primary and secondary side with formula (6 M)







Formula:

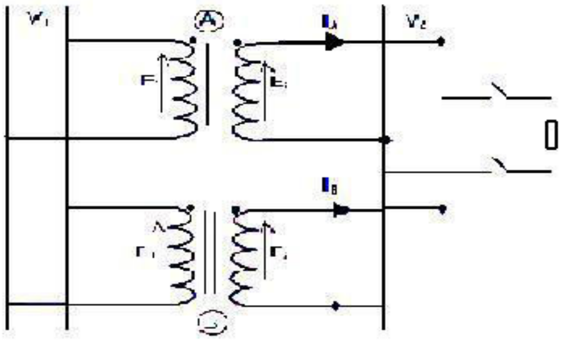
- ✓ $R'_1 = R_1 K^2$
- ✓ $X'_1 = X_1 K^2$
- ✓ $R_{02} = R_2 + R'_1$
- ✓ $X_{02} = X_2 + X'_1$
- ✓ $\mathbf{R'_2 = R_2}/ K^2$
- ✓ $\mathbf{X'_1 = X_2}/ K^2$
- ✓ $R_{01} = \mathbf{R_1 + R'_2}$
- ✓ $\mathbf{X_{01} = X_1 + X'_2}$

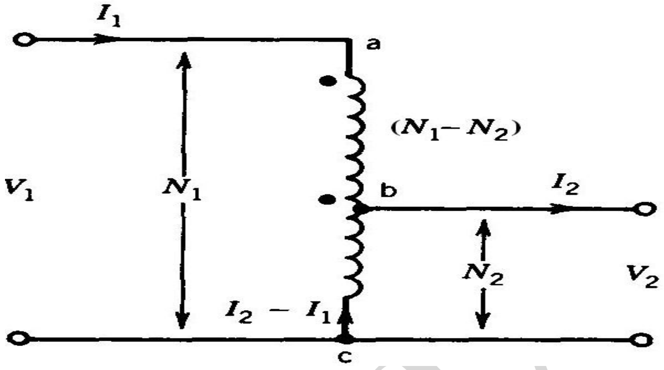
3. **Find all day efficiency of a transformer having maximum efficiency of 98% at 15 Kva at unity power factor and loaded as follows:**
12 hours – 2 KW at 0.5 p.f lag
6 hours – 12 KW at 0.8 p.f lag
6 hours – at no load.
(May 2006,April 2010,Dec 2006)BTL4 **(13M)**

Answer: Page : 3.63 - J.Gnanavadivel

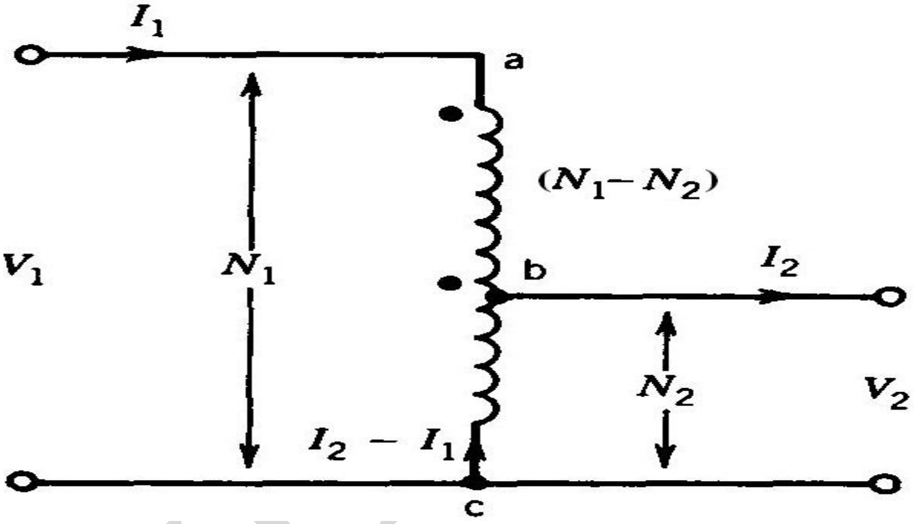
- ➢ Write the formula (7M)
- ➢ Answer (6M)

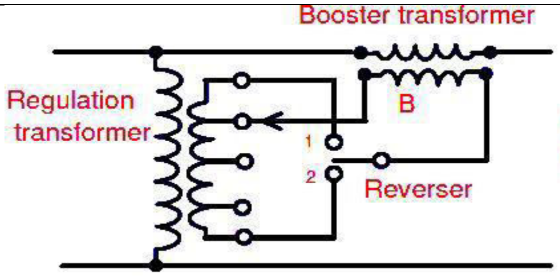
Input power = output power / efficiency (2 M)
= 5.306 kW (1 M)
Total losses = Input power – output power (2 M)
= 0.306 kW (1 M)
Full load copper loss = Iron loss = Total loss / 2 (1 M)

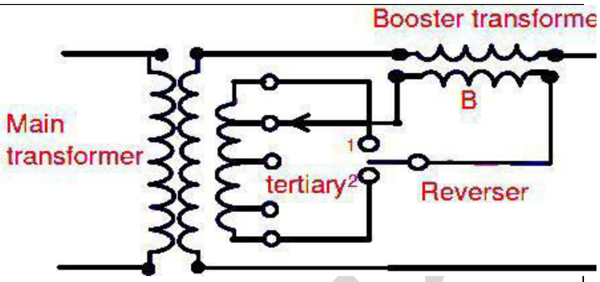
	= 0.153 kW (2 M) η all-day = Output power in Kwh/Input power in kWh *100 (2 M) =95.31% (2 M)
4.	**Explain parallel operation of single phase transformer. and derive the emf equation of transformers. (APRIL/MAY 2015,MAY/JUNE 2014,NOV/DEC 2012,MAY/JUNE 2011)**BTL1 **(13M)** **Answer: Page : 2.72 - J.Gnanavadivel** ➢ Draw the parallel 1 phase transformer connection (5 M) ➢ State the condition (4 M) ➢ Explain the working with diagram (4 M)  Condition: ✓ Voltage rating : Primary = secondary ✓ Polarities – connection proper ✓ Ratio: equivalent resistance = Equivalent reactanc ✓ Equivalent impedance = 1/respective KvA rating Working: ✓ Withstand more than rated power – parallel operation ✓ Power handling capacity – more
5.	**The maximum efficiency of a single phase 250 kVA,2000/250 V transformer occurs at 80% of full load and is equal to 97.5% at 0.8 p.f .Determine the efficiency and regulation on full lad at 0.8 pf lagging if the impedance of the transformer is 9 percent.(Dec 2004,Dec 2010)** BTL4 **(13M)** **Answer: Page : 3.37 - J.Gnanavadivel** ➢ Write the formula (5M) ➢ Answer (8 M) η_{max} = 97.5% (1 M) Output power at η_{max} = (250*0.8)*0.8 (1M) =160 kW (1M) Input power = output power/η (2 M) =160/0.975 =164.10 kW (1M) Total loss = 164.10-160 = 4.10 kW (1 M) % R= copper loss /V_2I_2 *100 = 2.05/250*100 = V_r =0.82% (2 M) %Regulation = (V_r * cosϕ + V_x sinϕ)/V_2 *100 (1M)

	= 2.42% (2 M)
6.	**Explain the working and construction of auto transformer in detail. (NOV/DECV2015,MAY/JUNE 2012,NOV/DEC 2009)** BTL2 **(13M)** **Answer: Page : 2.90 - J.Gnanavadivel** ➢ Draw the diagram (5 M) ➢ Explain the working (8 M)  ➢ Working: ✓ Primary and secondary – interrelated ✓ Connected electrically as well as magnetically ✓ Single continuous winding – commom for primary -Secondary ✓ $V_2/V_1 = N_2/N_1 = I_1/I_2 = K$ ✓ Weight of copper in auto transformer (W_a)/ Weight of copper in ordinary transformer(W_o) ✓ $(N_1-N_2)I_1 + (I_2 – I_1)N_2/N_1I_1 + N_2I_2$ ✓ Saving in copper = K* weight of copper in ordinary transformer ✓ Higher Efficiency ✓ Small size ✓ Lower cost ✓ Better voltage regulation ✓ Required less copper
7.	**A 2000/200 V transformer has primary resistance and reactance of 2Ω and 4 Ω respectively. The corresponding secondary values are 0.025 Ω and 0.04 Ω. Determine (1) equivalent resistance and reactance of primary referred to secondary (2)total resistance and reactance referred to secondary (3) Equivalent resistance and reactance of secondary referred to primary (4) Total resistance and reactance referred to primary. (June 2007)**BTL4 **(13M)** **Answer: Page : 2.47 -J.Gnanavadivel** ➢ Write the formula ➢ Answer $K = V_1/V_2$ (1 M) =0.1 (1 M) (1) $R'_1 = R_1 K^2$ =0.02 **Ω** (1 M) $X'_1 = X_1 K^2$ (1 M) =0.04 **Ω** (1 M)

	(2) $R_{02} = R_2 + R'_1$ $=0.045$ **Ω** (1 M) $X_{02} = X_2 + X'_1$ (1 M) $=0.08$ **Ω** (1 M) **(3)** $R'_2 = R_2/K^2$ (1 M) **=2.5 Ω** (1 M) $X'_1 = X_2/K^2$ **=4 Ω** (1M) **(4)** $R_{01} = R_1 + R'_2$ (1 M) $=4.5$ **Ω** $X_{01} = X_1 + X'_2$ **=8 Ω** (1 M)
Part*C	
Q.No	**Question**
1.	**The OC and SC test of the transformer is rated at 4 Kv,200/400 V and 50 Hz. The open circuit readings are V=200 V, I=1 A, Pac=100W. The short circuit readings are I=10 A, V=15V and Pac=85W. Find the equivalent circuit parameters.(Dec 2005,Dec 2006)**BTL4 **(15M)** **Answer: Page : 3.27 - J.Gnanavadivel** ➢ Write the formula ➢ Answer - O.C Test $W_0 = V_1 I_0 \cos\phi_0$ $\cos\phi_0 = W_0/V_1 I_0$ (1 M) $=0.5$ (1 M) $\cos\phi_0 = 0.5$ $\sin\phi_0 = 0.866$ $I_w = I_0 \cos\phi_0$ (1 M) $= 0.5$ A (1 M) $R_0 = V_1/I_w$ $=400\Omega$ $I_\mu = I_0 \sin\phi_0$ (1 M) $= 0.866$ A (1 M) $X_0 = V_1/I_\mu$ (1 M) $= 231\ \Omega$ (1 M) - S.C Test $Z_{02} = V_{sc}/I_{sc}$ (1 M) $=1.5\ \Omega$ (1 M) $W_{sc} = I^2_{sc} R_{02}$ $R_{02} = W_{sc}/I^2_{sc}$ (1 M) $=0.85\ \Omega$ (1 M) $K = V_2/V_1$ $=2$ $Z_{01} = Z_{02}/K^2$ $R_{01} = R_{02}/K^2$ (1 M) $X_{01} =$ root of $(Z_{01}^2 - R_{01}^2)$ (1 M)

	=0.308Ω (1 M)
2.	**(i)Explain about the all day efficiency of transformer .**(BTL1) **(7M)** **(ii)Derive the expression and explain the auto transformer . (Nov/Dec 2015)** BTL3 **(8M)(15M)** **Answer :Page : 3.2 , 2.90 - J.Gnanavadivel** (i)Explain with expression (7 M) ✓ η = Output power/ Input Power ✓ η = Output power/ Output Power + Losses ✓ η = Output power/ Output Power + Iron Losses + Copper Losses ✓ $\eta = nV_2I_2\cos\phi / nV_2I_2\cos\phi + P_i + n^2P_{cu}$ (ii) Draw the diagram , Explain the working. (8 M)  ➢ Working: ✓ Primary and secondary – interrelated ✓ Connected electrically as well as magnetically ✓ Single continuous winding – commom for primary -Secondary ✓ $V_2/V_1 = N_2/N_1 = I_1/I_2 = K$ ✓ Weight of copper in auto transformer (W_a)/ Weight of copper in ordinary transformer(W_o) ✓ $(N_1-N_2)I_1 + (I_2 – I_1)N_2/N_1I_1 + N_2I_2$ ✓ Saving in copper = K* weight of copper in ordinary transformer ✓ Higher Efficiency ✓ Small size ✓ Lower cost ✓ Better voltage regulation ✓ Required less copper
3.	**(i)Explain tap changing transformer concept.** BTL1 **(7M)** **(ii)Derive an expression for maximum efficiency of a Transformer .** BTL3 **(8M)(15M)** **Answer : Page : 2.117,3.3 - J.Gnanavadiel** ➢ (i) explain tap changing transformer with diagram (7 M)





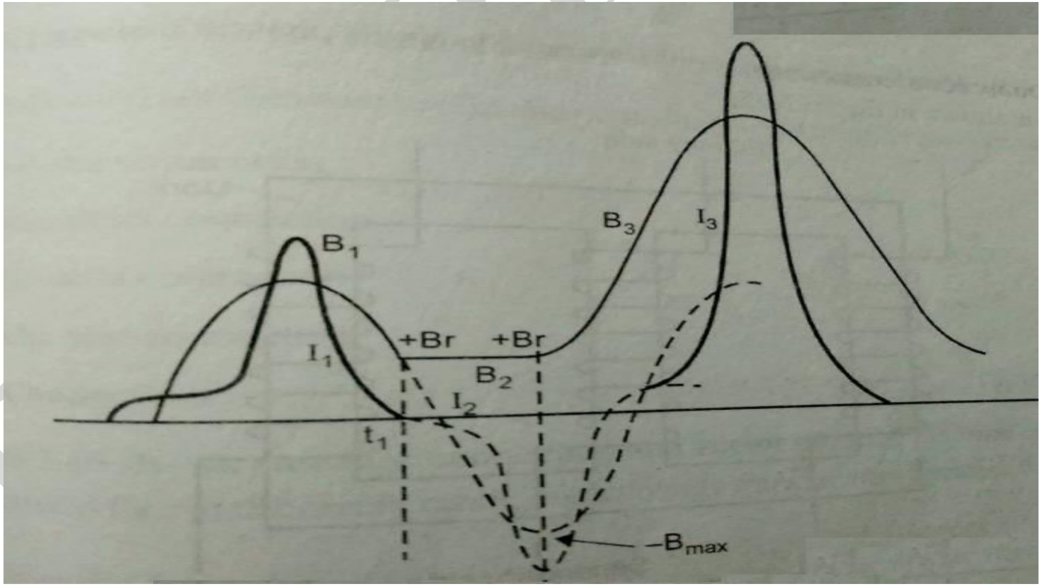
- ➢ Explain types of tap changing transformer
  - ✓ On load tap changer
  - ✓ Off load tap changer
- ➢ (ii) Explain with expression for maximum efficiency. (8 M)
  - ✓ η = Output power/ Output Power + Losses (2 M)
  - ✓ η = Output power/ Output Power + Iron Losses + Copper Losses (2 M)
  - ✓ $\eta = nV_2I_2\cos\phi / nV_2I_2\cos\phi + P_i + n^2P_{cu}$ (2 M)
  - ✓ $\eta = nV_2I_2\cos\phi / nV_2I_2\cos\phi + P_i + I_1^2R_{02}$ (2 M)
  - ✓ Efficiency maximum , Iron loss = Core loss

4.

(i)Explain the Inrush current in transformer .(April/may 2015) BTL1 **(7M)**
(ii)Explain the condition for parallel operation of transformer. (April/may 2015) BTL1 **(8M)**

Answer: Page : 2.98,2.72 - J.Gnanavadivel

- ➢ (i)write a note on inrush current (7 M)



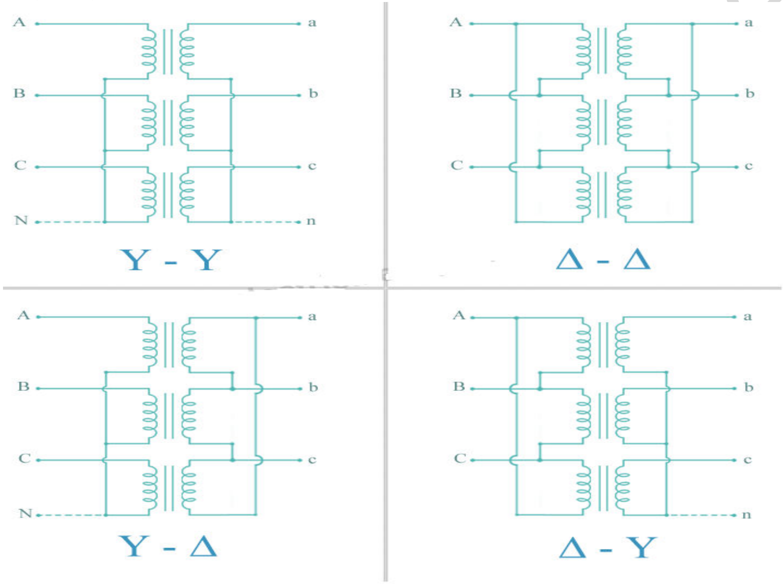
  - ✓ Transient current with complete offset shape
  - ✓ After few cycle sudden dip in the voltage
  - ✓ Sudden rise – Cause harmonics.
- ➢ (ii)state the condition of parallel operation (8 M)
  - ✓ Voltage rating for both primary and secondary same
  - ✓ Polarities may connect properly
  - ✓ Ratio of equivalent resistance and reactance must be same
  - ✓ Equivalent impedance should be inversely proportional to kVA rating of transformer

5.

Describe the various three phase transformer connection and parallel operation of three phase transformer .(May/June 2016) BTL2 **(15M)**

Answer: Page : 2.101 - J.Gnanavadivel

- Types of three phase transformer connection (7 M)
  - ✓ Star to Star
  - ✓ Star to Delta
  - ✓ Delta to Delta
  - ✓ Delta to Star
  - ✓ Open Delta or V-V connection – supply will be equal in primary and secondary
  - ✓ Scott or T-T connection - Taps - primary and secondary Main transformer , connected to main transformer – teaser transformer
- Diagrams (8 M)

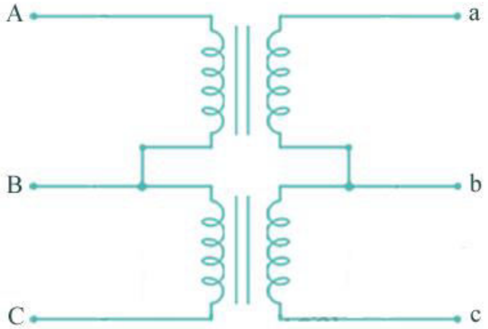


Y - Y

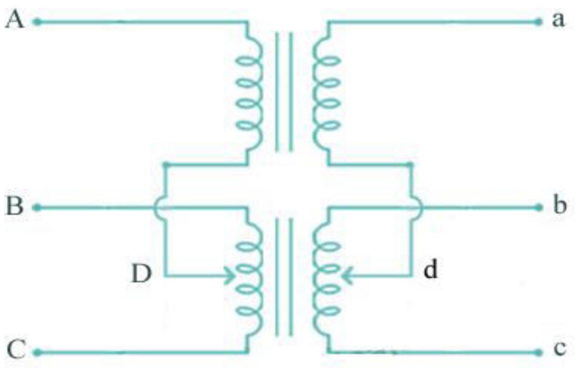
Δ - Δ

Y - Δ

Δ - Y



Open Delta (V-V) Connection

	 Scott (T-T) Connection
6.	**A 100 KVA, 6.6 kV/415 V ,single phase transformer has an effective impedance of (3+j8)Ω referred to HV side. Estimate the full load voltage regulation at (1) 0.8 pf lagging and (2) 0.8 pf leading. (Dec 2007,june 2007)** BTL5 **(15 M)** **Answer: Page : 2.101 - J.Gnanavadivel** ➢ 0.8 pf lagging % Regulation = I_1 R_{01} Cosϕ + I_1 X_{01} sin ϕ / V_1 * 100 (3M) I_1 = kVA rating / V_1 (3M) = 15015 A (2M) % Reg = 1.653 % (2M) ➢ 0.8 pf leading % Regulation = I_1 R_{01} Cosϕ - I_1 X_{01} sin ϕ / V_1 * 100 (3M) =-0.55% (2M)

UNIT 3 ELECTRO MECHANICAL ENERGY CONVERTION AND CONCEPT IN ROTATING MACHINE

Energy in magnetic System-Field energy and co energy-Force and torque equation-Singly and multiply excited magnetic field system - mmf of distributed Winding-winding inductance-magnetic field in rotating machine-rotating mmf wave-magnetic saturation and leakage flux.

Part*A

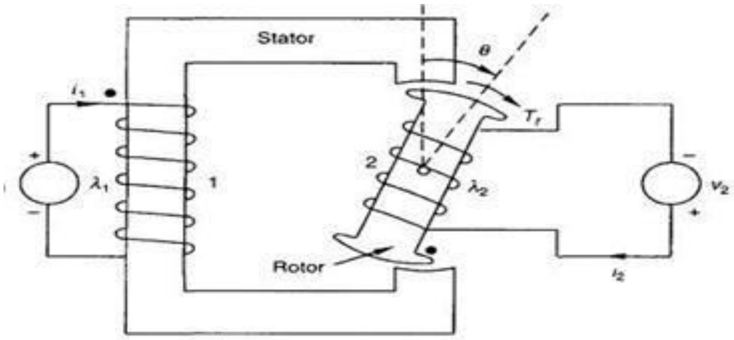
Q.No	Question
1.	**What is the significance of winding factor? (NOV/DEC 2012)** BTL1 Winding factor gives the net reduction in emf induced due to short pitched coil wound in distributed type Winding factor kw=kp kd kp= pitch factor kd= distribution factor kp= cos(α/2) kd= sin(mγ/2)/msin(γ/2)
2.	**Write the application of single and doubly fed magnetic systems. (MAY/JUNE 2013)** BTL2 Singly excited systems are employed for motion through a limited distance rotation through a prescribed angle. Whereas multiply excited systems are used where continues energy

	conversion take place and in ease of transducer where one coil when energized the care of setting up of flux and the other coil when energized produces a proportional signal either electrical or mechanical
3.	**What is meant by SPP? What is its significance ? (NOV/DEC 2015)** BTL1 SPP = Slots/Pole /Phase The parameter is used to design the poles and inter poles of a machine core.
4.	**Give example for single and multiple excited systems. (MAY/JUNE 2013,MAY/JUNE 2009)** BTL2 Single excited system-reluctance motor, single phase transformer, relay coil Multiply excited system-alternator, electro mechanical transducer.
5.	**Why do all practical energy conversion devices make use of the magnetic field as a coupling medium rather than electric field?(APRIL/MAY 2015,MAY/JUNE 2014)** BTL5 When compared to electric field energy can be easily stored and retrieved form a magnetic system with reduced losses comparatively. Hence most all practical energy conversion devices make use of magnetic medium as coupling
6.	**State necessary condition for production of steady torque by the interaction of stator and rotor field in electric machines.**BTL1 • The stator and rotor fields should not haveany relative velocity or speed between each other • Air gap between stator and rotor should be minimum • Reluctance of iron path should be negligible • Mutual flux linkages should exist between stator and rotor windings
7.	**Why the open circuit test of the transformer is conducted with rated voltage?**BTL2 The open circuit test of the transformer is conducted with rated voltage because the core loss depends on the voltage. The open circuit test gives only the core loss and iron loss of the transformer.
8.	**What is meant by Pole pitch and Chording angle?(NOV/DEC 2008)** BTL1 **Pole pitch:** The distance between the centers of two adjacent poles is called pole pitch. One pole pitch is equal to 180 electrical degrees. It is also defined as the number of slots per pole. **Chording angle:** It is defined as that angle by which the coil pitch departs from 180 electrical degrees.
9.	**Why energy stored in a magnetic material always occur in air gap?** BTL2 In iron core or steel core the saturation and aging effects form hindrance to storage . Built in air gap as reluctance as well permeability is constant , the energy storage takes place linearly without any complexity . Hence energy is stored in air gap in a magnetic medium.
10.	**What is the significance of co energy? (MAY/JUNE 2014,MAY/JUNE 2013)** BTL1 When electrical energy is fed to coil not the whole energy is stored as magnetic energy. the co energy gives a measure of other energy conversion which takes place in coil then magnetic energy storage are field energy and Co energy
11.	**Write the relation between electrical mechanical degrees. (APRIL/MAY 2015)** BTL2 $\theta e = \theta m$ for two pole machine $\theta e = \theta P/ 2 * \theta m$ for 4 pole a.c machines
12.	**Define pitch factor.** BTL1 It is defined as the ratio of resultant emf when coil is short pitch to the resultant emf

	when coil is full pitched . It is always less than one. Pitch factor is always termed as coil span (Kc) factor $kc=\cos\alpha/2$ where α=angle of short pitch
14.	**Define the term breadth factor.** BTL1 The breadth factor is also called distribution factor or winding factor . The factor by which there is a reduction in the emf due to distribution of coil is called distribution Factor denoted as kd.
15.	**Write down the advantages of short pitched coil.** BTL2 (i)The length required for the end connection of coils is less i.e., inactive length of winding is less . So less copper is required. Hence economical. (ii)Short pitching eliminated high frequency harmonics which distort the V sinusoidal nature of emf . Hence wave form of an induced emf is motor sinusoidal due to short pitching. (iii)As high frequency harmonics get eliminated , eddy current and hysteresis losses which depend on frequency also get minimized . This in creases the efficiency.
16.	**Why fractional pitched winding is required than full pitched winding? (NOV/DEC 2015)** BTL2 Fractional pitch winding require less copper compare to full pitch coil. It improves the commutation, and the mutual inductance of fractional pitch coil is smaller than full pitch coil.
17.	**Define field energy.** BTL1 The energy drawn by virtue of change in the distance moved by the rotor in electrical machines in field configuration is known as field energy.
18.	**Describe multiply excited magnetic field system. (MAY/JUNE 2011)** BTL2 The specially designed transducers have the special requirement of producing an electrical signal proportional to forces or velocities of producing force proportional to electrical signal. Such transducers require two or more excitation called as multiply excited magnetic field system.
19.	**What is an electro mechanical system?** BTL1 The system in which the electro mechanical energy conversion takes palace via the medium of a magnetic or electric field is called electro mechanical system.
20.	**What are the two components in transformer no load current?** BTL1 ➢ Active or working component (I_w) ➢ passive or magnetizing component (I_μ)
Part*B	
Q.No	**Question**
1.	**Explain in detail doubly excited magnetic system . (APRIL/MAY 2015,NOV/DEC 2015, MAY/JUNE 2013,NOV/DEC 2012,NOV/DEC 2009,May/June 2016)**BTL1 **(13M)** **Answer: Page 4.20 - J.Gnanavadivel** ➢ Draw the diagram (4 M) ➢ Explain the working (4 M) ➢ Derive the expression for independent variables (5 M)

$$\begin{pmatrix}\text{Energy input}\\ \text{form electric}\\ \text{sources}\end{pmatrix} = \begin{pmatrix}\text{Mechanical}\\ \text{energy}\\ \text{output}\end{pmatrix} + \begin{pmatrix}\text{Increase in energy}\\ \text{stored in magnetic}\\ \text{field}\end{pmatrix} + \begin{pmatrix}\text{Energy}\\ \text{converted}\\ \text{into heat}\end{pmatrix}$$

- ✓ System has two independent sources of excitations
- ✓ Source is connected to coil on stator while other is connected to coil on rotor.
- ✓ $dW_e = dW_m + dW_f$
- ✓ $Wf\ (\lambda_1, \lambda_2,\theta) = \beta_{11}\, \lambda^2{}_1 + \beta_{12}\, \lambda_1\, \lambda_2 + \beta_{22}\, i^2{}_2$
- ✓ $Wf\ '(i_1, i_2,\theta) = L_{11}\, i^2{}_1 + L_{12}\, i1\ i2 + L_{22}\, i^2{}_2$



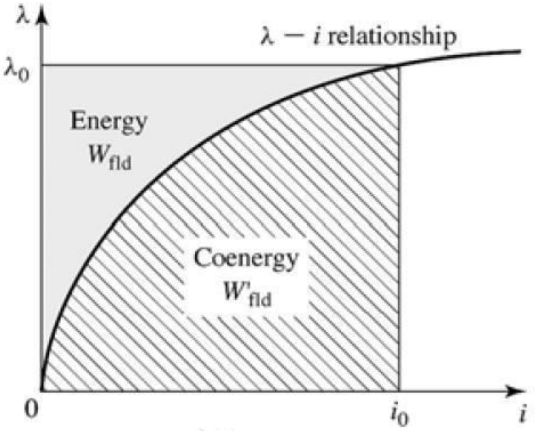
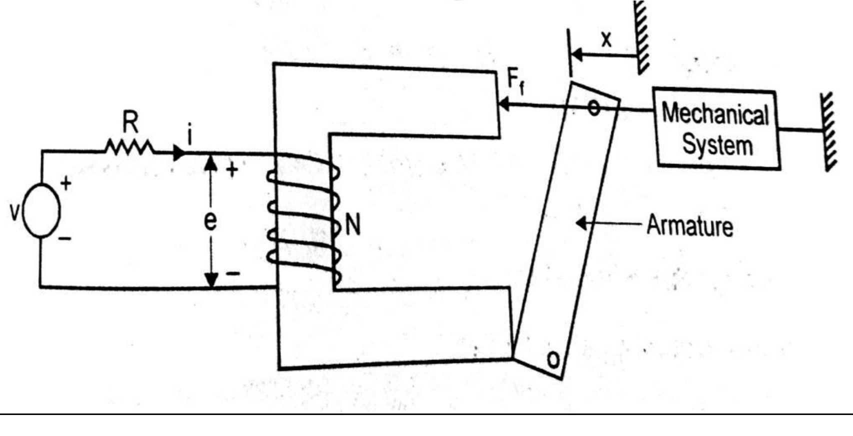
- ✓ Flux λ and the mechanical terminal position *x*
- ✓ electromechanical-energy conversion processs takes place through the medium of the electro magnetic field
- ✓ Transducers :microphone, pickup, sensor, loudspeaker
- ✓ Force producing devices :solenoid, relay ,electromagnet
- ✓ Continuous energy conversion equipment :motor ,generator
- ✓ Equation for flux linkage as independent variable
- ✓ Equation for current as independent variable

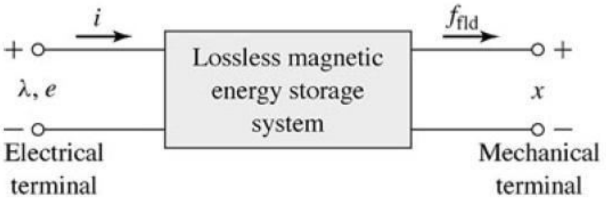
2.

Formulate the torque equation of around rotor machine. Also clearly state the assumptions made. (Nov/Dec 2015) (April/May 2015) BTL6 **(13M)**

Answer: Page 4.45 - J.Gnanavadivel

- ➢ Derive the expression with assumption (10 M)
- ➢ Consider a two pole machine i.e stator and rotor has two poles
    - ✓ F1=MMF produced by stator
    - ✓ F2=MMF produced by rotor.
    - ✓ FR=Resultant MMF
- ➢ Assumptions: (3 M)
    - ✓ The rotor - assumed to be smooth cylindrical, so that the air gap is unifom.
    - ✓ The MMF produced by stator and rotor is assumed to be sinusoidal.
    - ✓ The radial length of air gap(g) is very small when compared to the radius of stator.
    - ✓ MMF in air gap, Fr= Hr * g
    - ✓ Hr = Fr/g.
    - ✓ The reluctance of air gap is negligible.
    - ✓ The sinusoidal MMF space wave produces sinusoidal flux density wave is in phase with it.
- ➢ Let,

	✓ α-Angle between F1 and F2 ✓ D-Diameter of the air gap. ✓ l- Axial length of air gap. ✓ g-Radial length of air gap. ✓ Total Co-energy produced= Average Co-energy produced * Volume
3.	**Explain in detail about singly excited magnetic system. (MAY/JUNE 2014, MAY/JUNE 2011,NOV/DEC 2009)**BTL1 **(13M)** **Answer: Page 4.2 - J.Gnanavadivel** ➢ Draw the diagram (4 M) ➢ Explain the working (4 M) ➢ Derive the expression for independent variables (5 M) ✓ $dW_e = dW_m + dW_f$ ✓ $F_f\,dx = id\text{ʎ} - (\partial W_f/\partial\text{ʎ}).d\text{ʎ} + (\partial W_f/\partial).d\text{ʎ}$ ✓ $F_f\,dx = -(\partial W_f/\partial\text{ʎ}).d\text{ʎ} + (i - \partial W_f/\partial\text{ʎ})\,d\text{ʎ}$ Since dʎ , the independent differential , is not present on the left hand side of this equation ✓ $I = \partial W_f(\text{ʎ},x)/\partial\text{ʎ} = 0$ ✓ $F_f = -(\partial W_f\,\text{ʎ},x)/\partial\text{ʎ}$ ✓ Theforceactsinadirectiontodecreasethemagneticfieldstoredenergyatconstantfluxortoincreasetheco energyatconstantcurrent  



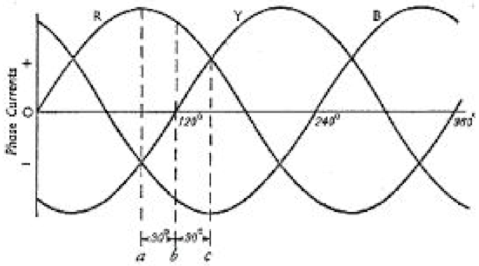
- ✓ $f_m = \frac{-dW_f}{dx}$
- ✓ dW_e-change in electrical energy
- ✓ dW_m- change in mechanical energy
- ✓ dW_f-change in magnetic field energy

4.

Explain briefly the production of rotating magnetic field. What are the speed and direction of rotation of the field.Is the speed uniform? BTL1 **(13M)**

Answer: Page 4.41 - J.Gnanavadivel

- ➢ Explain the working (7 M)
  - ✓ Magnetic field produced - the three phase system is balanced supply with 120^0
- ➢ expression for MMF (6 M)



- ✓ $N_s = 120f/p$ (rpm)
- ✓ $I_a= I_m \cos\omega t \cos\theta$
- ✓ $I_b= I_m \cos(\omega t-120)$
- ✓ $I_c= I_m \cos(\omega t-240)$
- ✓ $F_a= F_m \cos\omega t \cos\theta$
- ✓ $F_b= F_m \cos(\omega t-120) \cos(\theta-120)$
- ✓ $F_c= F_m \cos(\omega t-240) \cos(\theta-240)$
- ✓ $F = F_a+F_b+F_c$
- ✓ $F = F_m \cos\omega t \cos\theta + F_m \cos(\omega t-120) \cos(\theta-120) + F_m \cos(\omega t-240) \cos(\theta-240)$
- ✓ $F(\Theta,t) = 3 \frac{2\sqrt{2}}{\Pi} N_{ph}/P\ k_w I_{rms} \cos(\Theta-\omega t)$
- ✓ $F(\Theta,0) = 3 \frac{2\sqrt{2}}{\Pi} N_{ph}/P\ k_w I_{rms} \cos\Theta$

5.

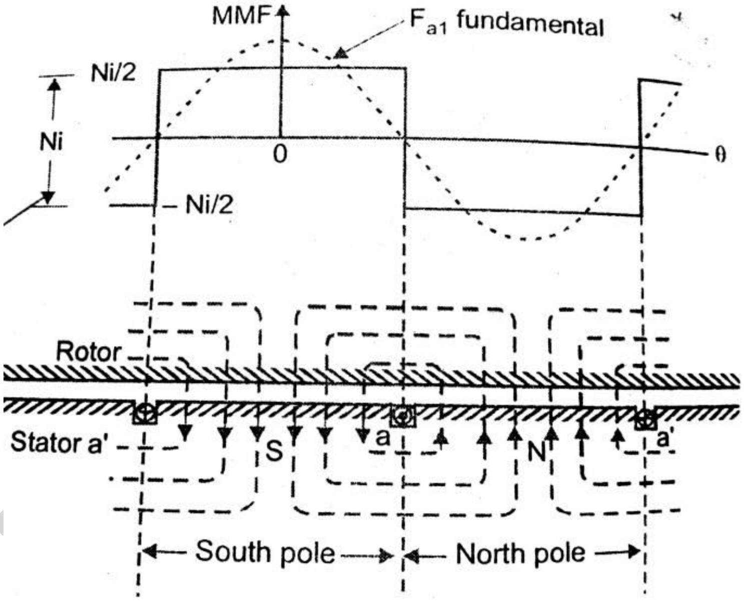
With neat diagrams, explain the mmf space wave of one phase of a three phase distributed winding in a 2-pole machine and derive the expression for the fundamental

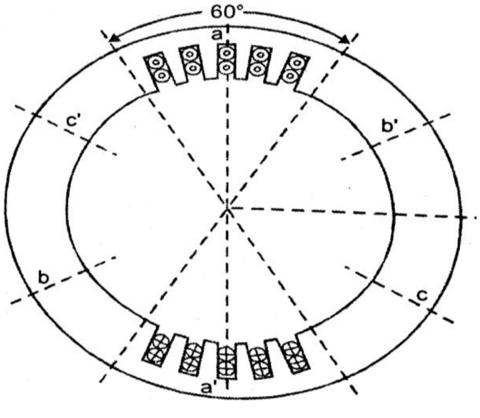
mmf wave of the distributed winding in it. (NOV/DEC 2012,NOV/DEC 2009)BTL2 **(13M)**

Answer: Page 4.28 – 4.31 - J.Gnanavadivel

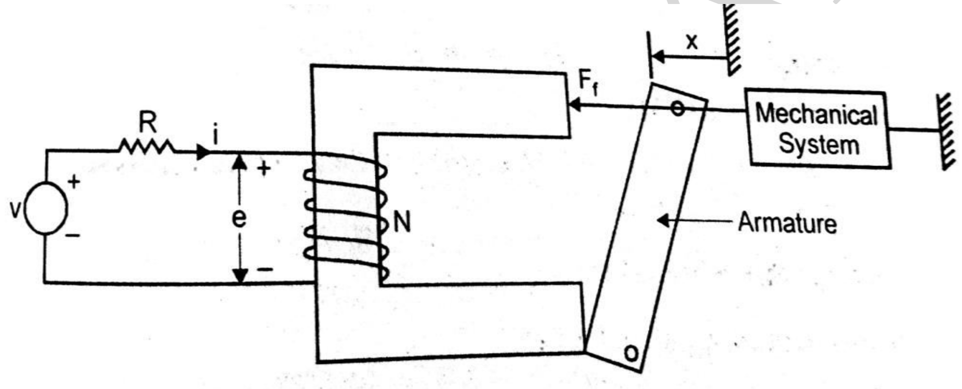
- Draw the diagram (4 M)
- Explain the working (5 M)
- Derive the expression (4 M)
  - ✓ $F_a = F_m \cos\omega t \cos\theta$
  - ✓ $F_b = F_m \cos(\omega t-120) \cos(\theta-120)$
  - ✓ $F_c = F_m \cos(\omega t-240) \cos(\theta-240)$
  - ✓ Field distribution and zero crossing - same – standing wave
  - ✓ The field strength amount changes periodically with current frequency
  - ✓ Amplitudes of fundamental waves and harmonics show proportional dependency to the current
  - ✓

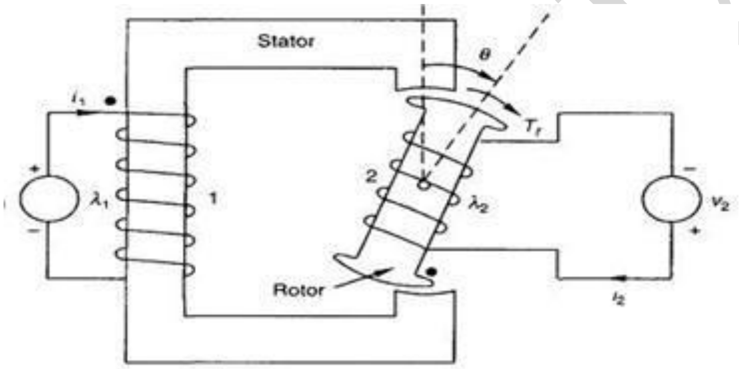
$$F_m = \frac{4\sqrt{2}}{\Pi} N_{ph}/P \quad k_w \quad I_{rms}$$





Part*C

Q.No	**Question**
1.	**Derive the expression of energy through in magnetic field. (May/June 2014,May/June 2016)**BTL5 **(15M)** **Answer: Page 4.2 - J.Gnanavadivel** ➢ Draw the diagram (5 M) ➢ Explain the working (4 M) ➢ Derive the expression for independent variables (6 M) ✓ $F_f\,dx = id\lambda - (\partial W_f/\partial\lambda).d\lambda + (\partial W_f/\partial).d\lambda$ ✓ $F_f\,dx = -(\partial W_f/\partial\lambda).d\lambda + (i-\partial W_f/\partial\lambda)\,d\lambda$ ✓ Since $d\lambda$, the independent differential , is not present on the left hand side of this equation ✓ $I = \partial W_f(\lambda,x)/\partial\lambda = 0$ ✓ $F_f = -(\partial W_f\,\lambda,x)/\partial\lambda$  ✓ $dW_e = dW_m + dW_f$ ✓ $F_f\,dx = id\lambda - (\partial W_f/\partial\lambda).d\lambda + (\partial W_f/\partial).d\lambda$ ✓ $F_f\,dx = -(\partial W_f/\partial\lambda).d\lambda + (i-\partial W_f/\partial\lambda)\,d\lambda$ Since $d\lambda$, the independent differential , is not present on the left hand side of this equation ✓ $I = \partial W_f(\lambda,x)/\partial\lambda = 0$ ✓ $F_f = -(\partial W_f\,\lambda,x)/\partial\lambda$ ✓ The for a direction to decrease the magnetic field stored energy at constant flux or to increase the co energy at constant current
2.	**With neat sketch explain multiple excited magnetic field system in electro mechanical energy conversion systems. Also obtain the expression for field energy in the system.(April/May 2015)** BTL2 **(15M)** **Answer: Page 4.20 - J.Gnanavadivel** ➢ Draw the diagram (4 M) ➢ Explain the working (5 M) ➢ Derive the expression for independent variables (6 M)

	$\begin{pmatrix}\text{Energy input}\\ \text{form electric}\\ \text{sources}\end{pmatrix} = \begin{pmatrix}\text{Mechanical}\\ \text{energy}\\ \text{output}\end{pmatrix} + \begin{pmatrix}\text{Increase in energy}\\ \text{stored in magnetic}\\ \text{field}\end{pmatrix} + \begin{pmatrix}\text{Energy}\\ \text{converted}\\ \text{into heat}\end{pmatrix}$ ✓ System has two independent sources of excitations ✓ Source – connected to stator while other is connected to coilon rotor. ✓ $dW_e = dW_m + dW_f$ ✓ W_f '$(i_1, i_2,\theta) =1/2\ L_{11}\ i_{12} + L_{12}\ i_1\ i_2 + 1/2 L_{22}\ i_{22}$ ✓ Flux λ and the mechanical terminal position *x* ✓ electromechanical-energy conversion processs takes place through the medium of the electro magnetic field ✓ Transducers :microphone, pickup, sensor, loudspeaker ✓ Force producing devices :solenoid, relay ,electromagnet ✓ Continuous energy conversion equipment :motor ,generator ✓ Equation for flux linkage as independent variable ✓ Equation for current as independent variable 
4.	**A 50 Hz synchronous salient pole generator is driven at 125 rpm .There are 576 stator slots with two conductors per slot .Air gap diameter is 6.1 m and stator length is 1.2 m. Sinusoidal flux density has a peak of 1.14T . Calculate the line voltage induced for star connection.** BTL4 **(15M)** **Answer: Page 4.77 - J.Gnanavadivel** ➢ Write the formula ➢ Substitution and answer $P=120f/N_s$ (2 M) =48 $\gamma = \pi P/S$ (1 M) $=15^0$ $K_p=\cos(\Theta_{sp}/2)$ (2 M) =1 M=slot/pole/phase (2 M) =4 $K_b=\sin(m\ \gamma/2)/m\ \sin(m\ \gamma/2)$ (2 M) =0.95766 Total no.of conductor =2*S (2 M)

	=1152 N_{ph} =Z/(2*3) =192 $E_{ph} = 4.44f\ K_b\ K_p\ N_{ph}\phi$ V (2 M) =14192.8 V (2 M)

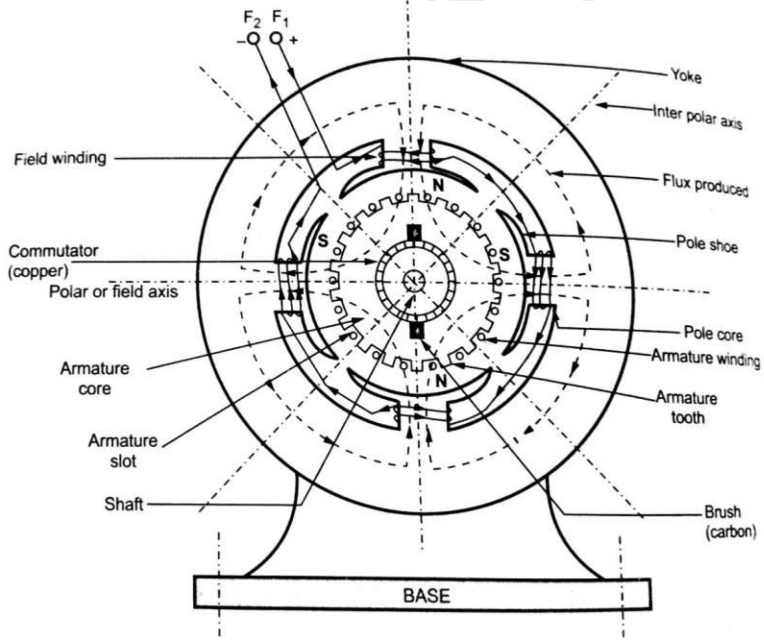
UNIT –IV DC GENERATOR

Construction and components of DC Machine– Principle of operation –Lap and wave windings- EMF equations– circuit model–armature reaction–methods of excitation-commutation and inter poles - compensating winding–characteristics of DC generators

Part*A

Q.No	Question
1.	**Why the armature core in dc machines is constructed with laminated steel sheets instead of solid steel sheets? (MAY/JUNE 2013) BTL2** Lamination highly reduces the eddy current loss and steel sheets provide low reluctance path to magnetic field.
2.	**Write down the emf equation for DC generator. (MAY/JUNE 2015,MAY/JUNE 2009)** BTL2 $e = \frac{PN\phi Z}{60A}$ P-No of poles: Z-Total no of conductor Φ-flux per pole, N-speed in rpm.
3.	**Why commutator is employed in d.c. machines? (MAY/JUNE 2011,MAY/JUNE 2009)** BTL2 Conduct electricity between rotating armature and fixed brushes, convert alternating emf into unidirectional emf (mechanical rectifier).
4.	**What are the major parts of DC generator?** BTL1 ➢ Magnetic frame or yoke ➢ Poles ➢ Armature ➢ Commutator, pole shoes , armature winding , inter poles ➢ Brushes , bearings and shaft
5.	**Why pole shoe has been given a specific shape? (MAY/JUNE 2013)** BTL2 It is necessary that maximum area of the armature comes across the flux produced by the field winging. Pole shoe enlarges the area of armature core to come across flux, which is necessary to produce larger induced emf.
6.	**What is prime mover?**BTL1 The basic source of mechanical power, which drives the armature of the generator, is called prime mover.
7	**How will you change the direction of rotation of a DCmotor?**BTL1 Either the direction of the main field or the direction of current through the armature conductors is to be reserved by reversing the supply polarity.
8.	**How does DC motor differ from DC generator in construction? (MAY/JUNE 2013)** BTL1 Generators are normally placed in closed room and accessed by skilled operators only.

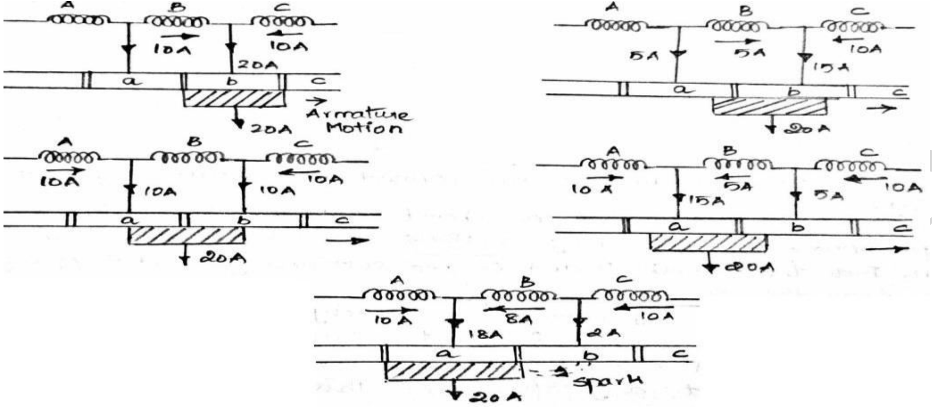
	Therefore, on ventilation point of view they may be constructed with large opening in the frame. Motors have to be installed right in the place of use which may have dust, dampness, inflammable gases, chemical.etc.to protect the motors against these elements, the motor frames are made either partially closed or totally closed or flame proof.
9.	**List the advantages and disadvantages of Hopkinson's test.(MAY/JUNE 2014)** BTL1 **Advantages:** ➢ Power required for the test is small as compared to full load powers of the two machines. ➢ The machines can be tested under full load conditions for long duration, the performance of the machines grading commutation and temperature rise can be studied. **Disadvantage:** ➢ Two identical machines are required. ➢ Two machines should have same rating.
10.	**What is the purpose of yoke in d.c machine? (MAY/JUNE 2013)** BTL1 ➢ It acts as a protecting cover for the whole machine and provides mechanical support for the poles. ➢ It carries magnetic flux produced by the poles
11.	**Why is Swinburne's test preferred to determine the efficiency of a dc machine? (MAY/JUNE 2012,NOV/DEC 2009)** BTL2 This method involves purely electrical measurements which are capable of being carried out with a high degree of accuracy. This method requires only a small fraction of the rated output the motor.
12.	**Name any 2 non-loading method of testing dc machines.** BTL2 ➢ Swinburne's test ➢ Hopkinson's test
13.	**What is the necessity of starter in D.Cmotors?**BTL1 When a dc motor is directly switched on ,atthe time of starting ,the motor back emf is zero .Due to this, the armature current is very high. Due to the very high current,the motor gets damaged. To reduce the starting current of the motor a starter is used.
14.	**How does a series motor develop high starting torque?** BTL2 A dc series motor is always started with some load. Therefore the motor armature current increases .Dueto this,series motor develops high starting torque.
15.	**If speed is decreased in a DCmotor ,what happens to the back emf decreases and armature current .** BTL2 If speed is decreased in a dc motor, the back emf decreases and armature current increases.
16.	**When is a four point DC starter required in DC motors?** BTL1 A four point DC starter is required for dc motor under field control
17.	**Specify the role of inter-poles in DC machines . (APRIL/MAY 2015)**BTL2 In modern DC machines inter-poles are provided to improve the commutation and to reduce the spark
18.	**Why an induction motor never runs at its synchronous speed?**BTL2

	If it runs at **sy**.speed then there would be no relative speed between the two, hence no rotor emf ,so no rotor current , then no rotor torque to maintain rotation.
19.	**Why an induction motor is called as rotating transformer?** BTL2 The rotor receives same electrical power in exactly the sameway as the secondary of a two winding transformer receiving its power from primary.That is why induction motor is called as rotating transformer.
20.	**What is meant by residual emf in DC generator? (APRIL/MAY 2015)** BTL1 It is induced emf in the self-excited dc generator due to the residual magnetism.
Part*B	
Q.No	**Question**
1.	**Describe the construction and principle of operation of DC generator. (13M) (MAY/JUNE 2013)**BTL2 **Answer: Page :5.1,5.5 – I by J.Gnanavadivel** ➢ Draw the diagram (7 M) ➢ Explain the parts in detail (6M)  ➢ The major parts can be identified as ✓ Frame/Yoke -Protecting cover ✓ Poles ✓ Armature – laminated sheet so silicon steel ✓ Main pole and inter pole ✓ Winding –small section copper ✓ Commutator – DC to AC ✓ Brush gear – supply to external circuit ✓ Commutating poles ✓ Compensating winding- reduce the sparking
2.	**Explain in about detail about commutation of D.C machines. (13M) (NOV/DEC**

2015,NOV/DEC 2012,MAY/JUNE 2009)BTL1

Answer: Page :5.83 -J.Gnanavadivel

- Draw the diagram (7 M)
- Explain the process in detail (6 M)



- ✓ Copper segment stightly fastened together with mica/micanite
- ✓ commutator – AC(bidirectional) to DC(unidirectional)
- ✓ commutation period – time taken to convert AC to DC
- ✓ commutation current – $2I_c$
- ✓ Brush current - I_b
- ✓ Commutator segment is split into commutator segment and mica layer .
- ✓ $I_b= 2I_c$

3. **A 8pole DC shunt generator with 778 wave connected armature conductors and running at 500 rpm supplies a load of 12.5Ω resistance at a terminal voltage of 250 V. The armature resistance is 0.24 Ω and field resistance is 250 Ω respectively. Calculate the armature current and induced emf and flux per pole. (13M) (Nov 2002)** BTL4

Answer: Page :5.39 J.Gnanavadivel

- Write the formula
- Substitution with answer

Load current $I_L =V/R_L$

= 20 A (2 M)

Shunt field current $I_{sh}=V/R_{sh}$

=1 A (2 M)

Armature current Ia= $I_L + I_{sh}$ (2 M)

=21 A (1 M)

Induced EMF Eg = V+ IaRa (2M)

=255.04 A (1M)

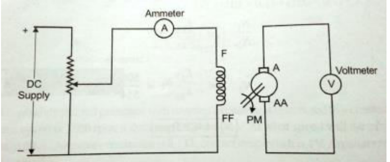
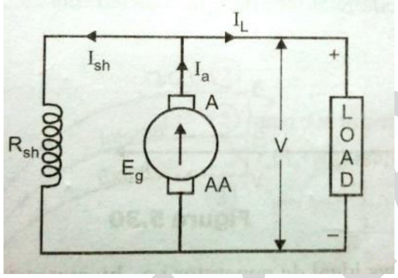
Flux per pole (ϕ) = P ϕZN/60A (2M)

=19.66 mwb (1M)

4. **Describe briefly the different methods of excitation and characteristics of a DC Generators with suitable diagrams. (13M)(NOV/DEC 2015,APRIL/MAY 2015 , MAY/JUNE 2011)**BTL2

Answer: Page :5.51 -J.Gnanavadivel

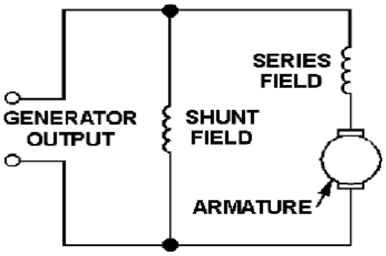
- Draw the diagram (4 M)
- Draw the graphs (4 M)

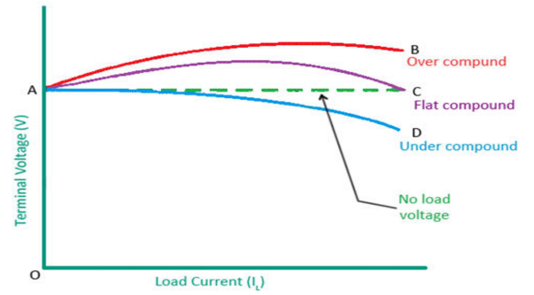
	➢ Write the voltage equation (5 M) Separately excited:  ✓ Armature – excited by different source ✓ Filed – excited by different source ✓ Energization - delay ✓ Residual magnetization - delay Self Excited:  ✓ Armature and field – excited by single source ✓ Residual magnetization – fast ✓ Energization – fast
5.	**Derive the EMF equation of a DC generator and explain about the significance of back emf .(13M) (APRIL/MAY 2015,MAY/JUNE 2013)**BTL3 **Answer: Page :5.17 - J.Gnanavadivel** ➢ Derive the DC generator EMF equation (10 M) ✓ Ø = flux/pole in Wb (weber) ✓ Z = total no. of armature conductors ✓ P = No. of generator poles ✓ A = No. of parallel paths in armature ✓ N = rotational speed of armature in revolutions per min. (rpm) ✓ E = emf induced in any parallel path in armature By Faradays law, $e=PN\phi/60$ $= PN\phi/60 * Z/A$ (3 M) For wave A = 2 wound $e=PN\phi Z/120$ for lap A=P wound $e= N\phi Z/60$
Part*C	
Q.No	**Question**
1.	**(i)Draw and explain the differential and cumulative compound DC generator. (6M)(April/May 2015)**BTL6

(ii)A 8 pole DC generator has flux per pole of 40 mwb and winding is connected in lap with 960 conductors. Calculate the generated E.M.F on open circuit when it runs at 400 rpm .If the armature is wave wound at what speed must the machine be driven to generate the same voltage. (9M) (Nov 2006,May 2009)BTL4

Answer: Page :5.28,5.27- J.Gnanavadivel

- (i)Explain the long shunt and short shunt compound generator (6M)





External characteristic of DC compound generator

COMPOUND-WOUND
DC GENERATOR

- ✓ Long shunt –cumulative
- ✓ Shunt field flux and series field flux aiding
- ✓ Short shunt – differential
- ✓ Shunt field flux and series filed flux opposing

(ii)**Write the formula**

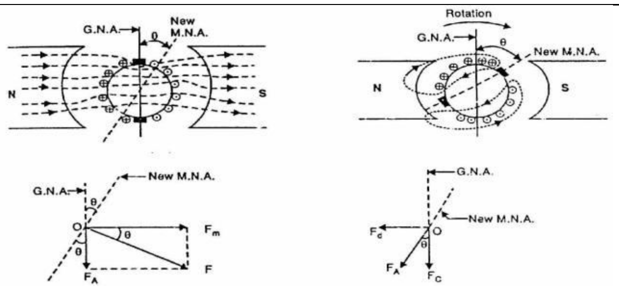
- Substitution with answer

Eg=PϕZN/60A (3 M)
=256 V (2 M)
For wave connected A=2
Speed N
= Eg 60A/PϕZ (3 M)
=100 rpm (1 M)

2. **Explain in about detail about the effect of armature reaction of D.C machines.(15M)(NOV/DEC 2015, NOV/DEC 2009,Nov/Dec 2016,May/June 2016)** BTL2

Answer:Page :5.59 - J.Gnanavadivel

- Draw the diagram (8 M)
- Explain the process of armature reaction in detail (7 M)

	 ✓ At no load condition – Main field flux ✓ At loaded condition – Armature field flux ✓ Interaction between main field flux and armature field flux – armature reactio ✓ Demagnetization – opposes the main field flux ✓ Cross magnetization – One side more flux and one side less flux ✓ Armature reaction – causes shifting of brush from one pole to next pole ✓ Continuous rotation
3.	**(i)Write the EMF equation of DC generator.(5M) (Apr/May 15)** BTL3 **(ii)A Dc compound generator the resistance of armature, series and shunt windings are 0.10,0.05 and 100 ohms respectively. Supplies 5 kW at 230 V. Calculate the induced emf and armature current, when the generator is connected in** **(1) Short shunt** **(2) Long shunt. Allow brush contact drop of 2V per brush. (10M) (Dec 2004)** BTL4 **Answer: Page :5.17,5.47 -J.Gnanavadivel** ➢ (i)write the emf equation (5 M) Ø = flux/pole in Wb (weber) Z = total no. of armature conductors P = No. of generator poles A = No. of parallel paths in armature N = rotational speed of armature in revolutions per min. (rpm) E = emf induced in any parallel path in armature By Faradays law, $e=PN\phi/60 * Z/A$ For wave A = 2 wound $e=PN\phi Z/120$ for lap A=P wound $e= N\phi Z/60$ ➢ (ii)write the formulae ➢ Substitution with answer Shunt field current $I_{sh}=V/R_{sh}=4.6A$ (2 M) Load current $I_L=P_0/V =21.74A$ (2 M) Armature current $Ia= I_{sh} + I_L =26.34A$ $Eg= V+Ia(R_{se} +R_a)$ + brush drop = 256.34V (2 M) $I_{sh}= V+I_LR_{se}/R_{sh}=4.68$ A (2 M) $Ia= I_{sh} + I_L =26.42A$ $Eg= V+IaR_a + I_{se}R_{se}=255.48$ V (2 M)

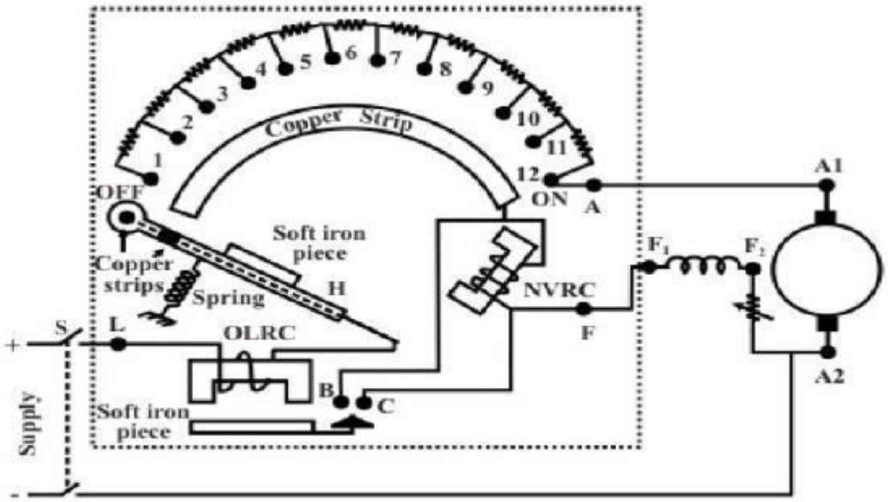
4.	**A 240 kW,500 V,6-pole,lap wound DC generator has 63 slots with 10 conductors/slot. The brushes are advanced through 4 mechanical degrees. Ignoring shunt field current, find** **i)Demagnetizing ampere turns / pole** **ii)Cross magnetizing ampere turns / pole.(15M)(May 2009)**BTL4 **Answer: Page :5.79 -J.Gnanavadivel** ➢ write the formulae ➢ Substitution with answer $I_L = P_0 /V$ (2M) =480A (2 M) $I_a = I_L = 480A$ (2 M) $I= I_a/A$ (2 M) =80A (2M) Demagnetization ampere turns/pole = $ZI\Theta_m/360$ (2M) =560 (1 M) Cross magnetization ampere turns/pole = $ZI(1/2P - \Theta_m/360)$ (2M) =3640 (2 M)

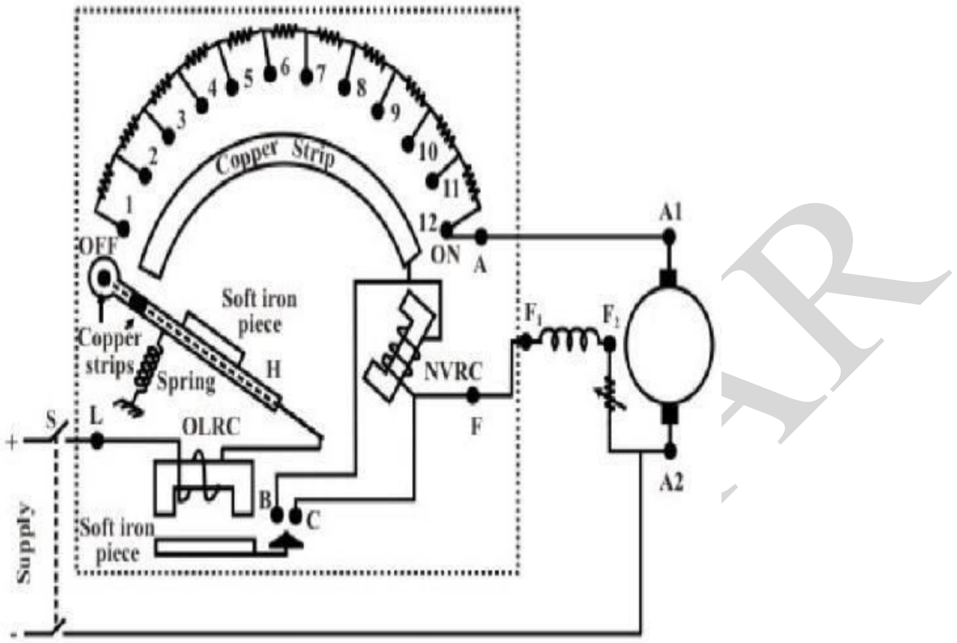
UNIT V DCMOTORS	
Principle and operations- types of DC Motors – Speed Torque Characteristics of DC Motors- starting and speed control of DC motors–Plugging, dynamic and regenerative braking-testing and efficiency-Retradation Test-Swinburne’s test and Hopkinson’s test-permanent magnetic DC motors (PMDC)-DC motor application	
Part*A	
Q.No	**Question**
1.	**What is back emf in d.c. motor? (MAY/JUNE 2012,MAY/JUNE 2009)** BTL1 ➢ As the motor armature rotates, the system of conductor come across alternate north and south pole magnetic fields causing an emf induced in the conductors. ➢ The direction of the emf induced in the conductor is in opposite to current. As this emf always opposes the flow of current in motor operation it is called as back emf.
2.	**Why DC motors are not operated to develop maximum power in practice?** BTL2 The current obtained will be much higher than the rated current . The efficiency of operation will be below 50%
3.	**What is the function of no-voltage release coil in D.C. motor starter? (NOV/DEC 2015)** BTL1 As long as the supply voltage is on healthy condition the current through the NVR coil produce enough magnetic force of attraction and retain the starter handle in ON position against spring force. When the supply voltage fails or becomes lower than a prescribed value then electromagnet may not have enough force to retain so handle will come back to OFF position due to spring force automatically.
4.	**Name any four applications of DC series motor.(MAY/JUNE 2013)** BTL2 ➢ Electric traction ➢ Mixies ➢ Hoists ➢ Drilling machines

5.	**What are the conditions to be fulfilled by for a dc shunt generator to build back emf? (MAY/JUNE 2012,MAY/JUNE 2009)** BTL1 The generator should have residual flux, the field winding should be connected in such a manner that the flux setup by field in same direction as residual flux, the field resistance should be less than critical field resistance, load circuit resistance should be above critical resistance.
6.	**What are the modification in ward Leonard linger system?** BTL1 Ward Leonard linger system has smaller motor and generator set. Addition offwheel whose function is to reduce fluctuations in the power demand from the supply circuit.
7.	**What is the necessity of starter in dc motors?(NOV/DEC 2015)** BTL1 When a dc motor is directly switched on, at the time of starting, the motor back emf is zero. Due to this, the armature current is very high. Due to the very high current, The motor gets damaged. To reduce the starting current of the motor a starter is used.
8.	**To what polarity are the inter poles excited in dc generators.** BTL1 The polarity of the inter poles must be that of then ext main pole along the direction of rotation in the case of generator.
9.	**Why are carbon brushes preferred for dc machines?** BTL2 The high contact resistance carbon brushes help the current in the coil under going commutation to attain its full value in the reverse direction at the end of commutation.The carbon brushes also lubricate and give less wear and tear on commutator surface.
10.	**Name the two methods of improving commutation.** BTL2 ➢ Emf commutation. ➢ Resistance commutation
11.	**Why DC series motor is suited for traction applications? (APRIL/MAY 2015,NOV/DEC 2015)** BTL2 DC series motor provides high starting torque. So DC series motor is suited for traction applications
12.	**Define the term commutation in dc machines.** BTL1 The changes that take place in winding elements during the period of short circuit by a brush is called commutation.
13.	**Howandwhythecompensatingwindingindcmachineexcited?** BTL2 Asthecompensationrequiredisproportionaltothearmaturecurrentthecompensatingwindingisexcitedbythearmaturecurrent.
14.	**What is an electric motor?** BTL1 Electric motor is a machine which converts the electrical energy to mechanical energy.
15.	**What is DC motor?** BTL1 DC motor will convert DC input into mechanical output.
16.	**What is the nature of the current flowing in the armature conductor of a DC motor?** BTL1 Alternating current is flowing through the armature this direct current is converted by commutator.
17.	**What is the compound motor?** BTL1 A DC motor consisting of both series and shunt field winding is called compound motor They are two types long shunt and short shunt compound motors.
18.	**List out different parts of DC Motor.** BTL1 Yoke, Armature ,Poles ,Field winding ,Armature winding ,commutator and brushes

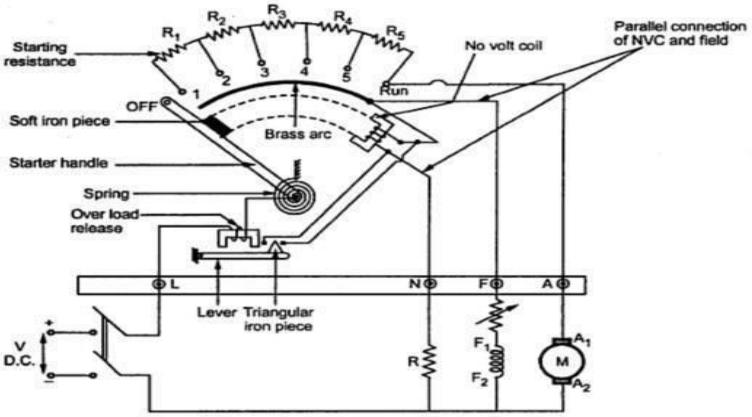
19.	**What are the characteristics of DC machine?**BTL1 ➢ Speed - Armature current ➢ Torque - Armature current ➢ Speed - torque
20.	**When you will say the motor is running a base speed?(Dec 2007)** BTL1 The motor is operated at rated voltage and rated field current , then it runs at base speed or rated speed of the motor.

Part*B

Q.No	Questions
1.	**Explain in detail about the working of starter with the help of diagram. (13M) (NOV/DEC2015,APRIL/MAY 2015,NOV/DEC 2012)**BTL1 **Answer: Page : 6.47 - J.Gnanavadivel** ➢ Define starter any one type (3M) ➢ Types of starter(any one type) ➢ Draw the diagram (5 M) ➢ Explain the working (5 M) **Starter:** ✓ Restrict the flow of high starting current ✓ Protective device **Need :** ✓ High current will cause sparks – brushes ✓ Sparks will damage the commutator **Diagram:** Two point starter  ✓ Used in series motor ✓ Starts with load ✓ Supply – given the NVR(no Voltage release) coil will energies and attracts the soft iron piece ✓ OLR(over load release) coil – associated with one iron piece ✓ OFF position to ON position – connects all resistance ✓ Overload – occur respective coil will release **Three point starter**



FOUR POINT STARTER:



- ✓ OLR(over load release) coil – associated with one iron piece.
- ✓ NVR(no Voltage release) coil - associated with one iron piece.
- ✓ Used – compound motor.
- ✓ NVR – Field in parallel connection.
- ✓ NVR - attracts the iron piece associated with it

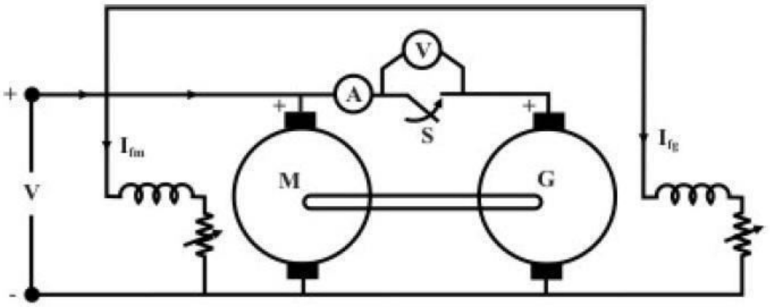
2. **Explain any one methods of testing of DC machines. (13M) (NOV/DEC2015, MAY/JUNE2014) (May/June 2016)**BTL1

Answer: Page :7.19 - J.Gnanavadivel

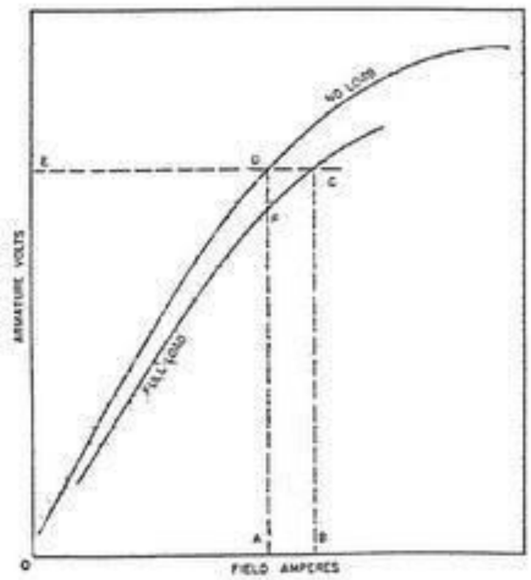
- ➢ Write any types of testing
- ➢ Draw the diagram (6 M)
- ➢ Explain the working (7 M)

Hopkinson's test

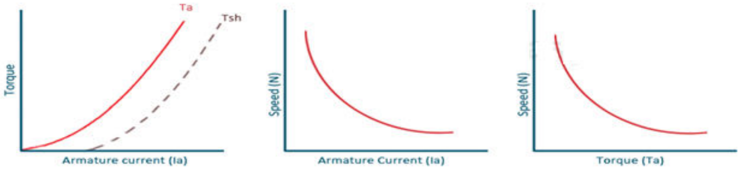
- ✓ Two identical machines are chosen
- ✓ One machine acts as motor and one machine acts as generator

	✓ Both will connected as parallel to operate to found the efficiency. ✓ Anelegantmethodoftestingd.cmachines. ✓ Hereitwillbeshownthatwhilepowerdrawnfromthesupplyonlycorrespondstonoloadlossesofthemachines ✓ Thearmaturephysicallycarriesanyamountofcurrent(whichcanbecontrolledwithease). ✓ Suchascenariocanbecreatedusingtwosimilarmechanicallycoupledshuntmachines.  **AdvantagesofHopkinson'sTest** ✓ This test requires very small power compared to full-load power of themotor-generatorcoupledsystem.Thatiswhyitiseconomical. ✓ Temperatureriseandcommutationcanbeobservedandmaintainedinthelimitbecausethistestisdoneunderfullloadcondition. ✓ Changeinironlossduetofluxdistortioncanbetakenintoaccountduetotheadvantageofitsfullloadcondition **DisadvantagesofHopkinson'sTest** ✓ DifficulttofindtwoidenticalmachinesneededforHopkinson'stest. ✓ Bothmachinescannotbeloadedequallyallthetime. ✓ Notpossibletogetseparateironlossesforthetwomachinesthoughtheyaredifferentbecauseoftheirexcitations. ✓ Difficulttooperatethemachinesatratedspeedbecausefieldcurrentsvarywidely.
3.	**Explain in detail about the Characteristics and types of DC motors. (13M) (APRIL/MAY 2015,MAY/JUNE 2012)**BTL1 **Answer: Page :6.42 - J.Gnanavadivel** ➢ Draw the circuits (7 M) ➢ Write the voltage equation (6 M) **Open Circuit Characteristic(O.C.C.)** ✓ Relationbetweenthegeneratedemf.atno-load(E_0)andthefieldcurrent(I_f)atconstantspeed ✓ Alsoknownasmagneticcharacteristicorno-loadsaturationcurve ✓ Shapeispracticallythesameforallgeneratorswhetherseparatelyorself-excited **InternalorTotalcharacteristic(E/I_a)** ✓ Showstherelationbetweenthegeneratedemf.Onload(E)andthe armaturecurrent(I_a). ✓ LessthanE0duetothedemagnetizingeffectofarmaturereaction. **ExternalCharacteristic(V/IL)** ✓ Therelationbetweentheterminalvoltage(V)andloadcurrent (IL).

- ✓ The terminal voltage V will be less than E due to voltage drop in the armature circuit.

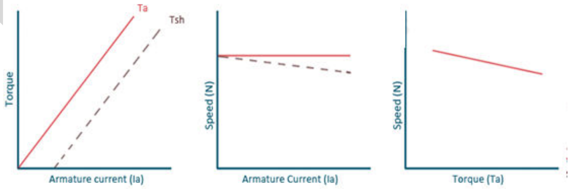


Speed vs. torque (N-Ta)

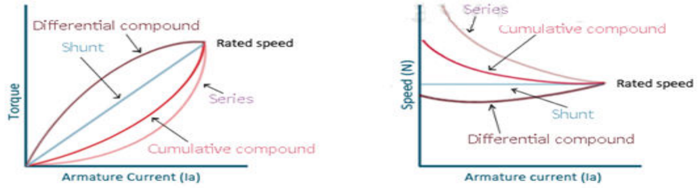


Characteristics of DC series motor

Torque vs. armature current (Ta-Ia)



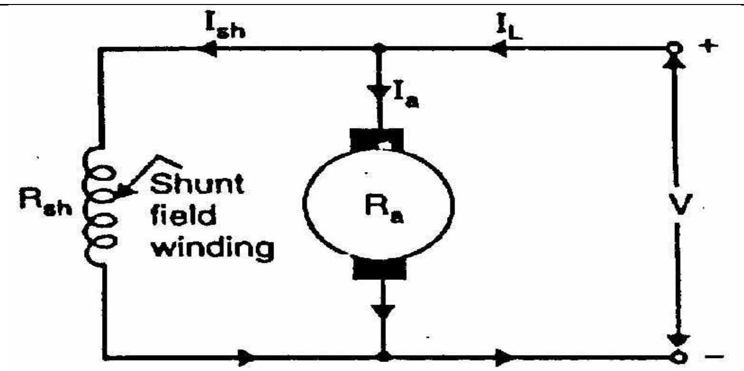
Characteristics of DC shunt motor

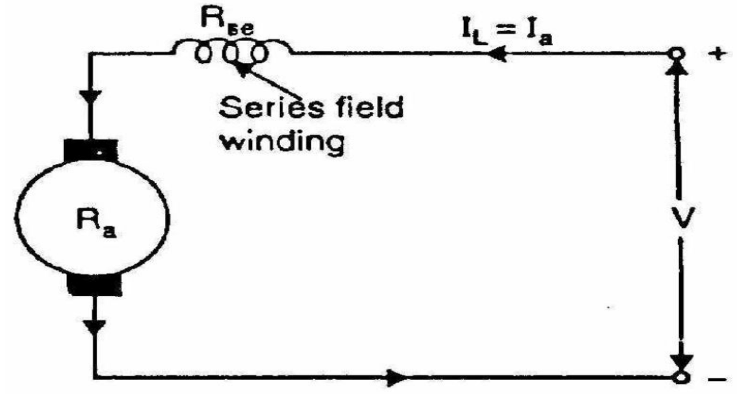


Characteristics of DC compound motor

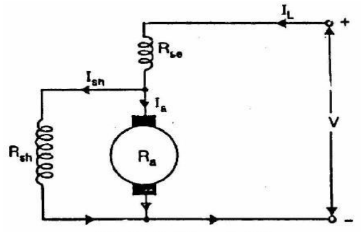
TYPES:

SERIES AND SHUND MOTOR:

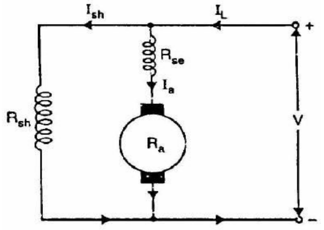




COMPOUND MOTOR



Short-shunt connection



Long-shunt connection

4. **With neat sketch explain four point starter to start the DC Shunt Motor. (13M) (Nov/Dec 2015)** BTL2

Answer: Page :6.52 - J.Gnanavadivel

- ➢ Draw the diagram (6 M)
- ➢ Explain the construction and working (7 M)

Starting:

- ✓ Thespeedofthemachinehastobeincreasedfromzeroandbroughttothe operatingspeed - startingofthemotor.

Starter:

- ✓ Restrict the flow of high starting current
- ✓ Protective device

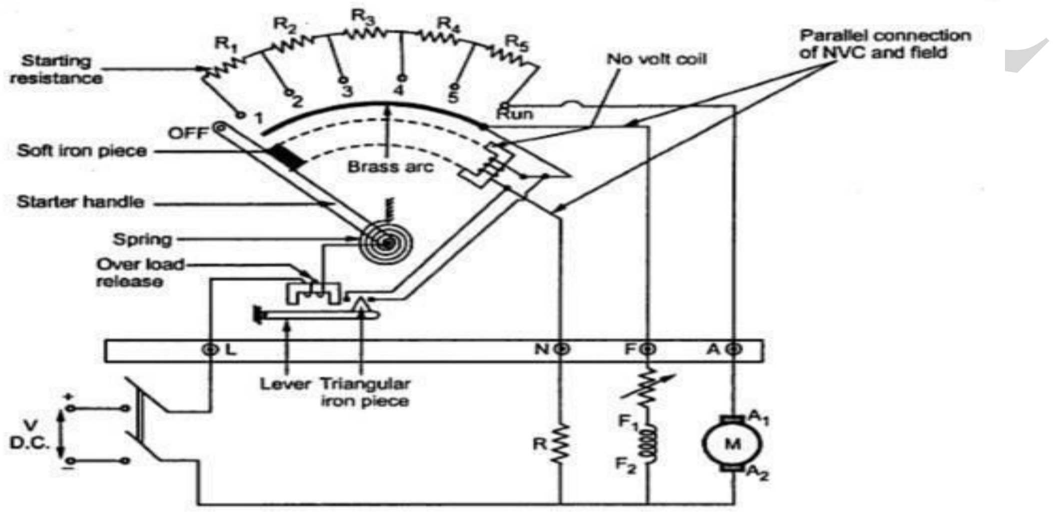
Need :

- ✓ High current will cause sparks – brushes
- ✓ Sparks will damage the commutator

Explanation:

- ✓ OLR(over load release) coil – associated with one iron piece.

- ✓ NVR(no Voltage release) coil - associated with one iron piece.
- ✓ Used – compound motor.
- ✓ NVR – Field in parallel connection.
- ✓ NVR - attracts the iron piece associated with it
- ✓ Used – compound motor



5. **Describe the following methods of speed control of DC Shunt Motor (i) Flux Control Method (ii) Armature Rheostat Control Method (iii)Ward Leonard Method. (13M)** BTL2

Answer: Page :6.54 - J.Gnanavadivel

- ➢ Draw the circuit (6 M)
- ➢ Explain the speed control (7 M)

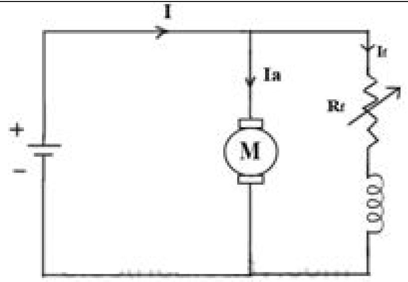
Flux control method:

- ✓ SpeedControlOfDcShuntMotor - Vaisthevoltageappliedacrossthearmature, Nistherotorspeedandφisthefluxper poleandisproportionaltothefieldcurrentI_f.
- ✓ ArmaturecurrentIa is decidedbythemechanicalloadpresentontheshaft.
- ✓ VaryingVaand$I_f$wecan varyn.

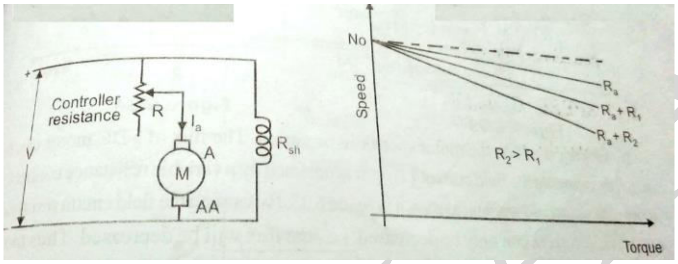
VaryingArmatureResistance

- ✓ FixedsupplyvoltageandthemotorconnectedasshuntwecanvaryVa by controllinganexternalresistanceconnectedinserieswiththearmature.
- ✓ Ifofcoursecanbe variedbycontrollingexternalfieldresistanceRf connectedwiththefieldcircuit
- ✓ The inherent armature resistance Ra being small, speed n versus armature current(Ia)characteristicwillbeastraightlinewithasmallnegativeslopeasshowninfigure.

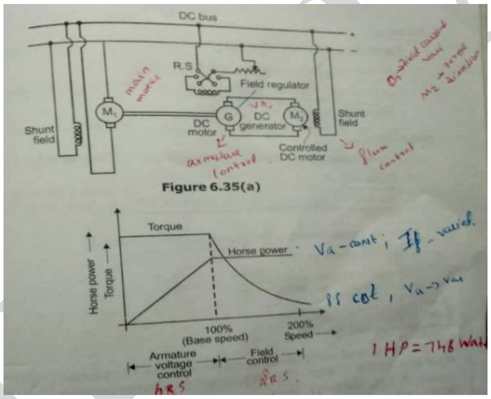
Flux Control Method



Armature Rheostat Control Method



Ward Leonard Method



Part*C

Q.No	Question
1.	**A 6 pole DC motor has a wave connected armature with 87 slots, each slot containing 6 conductors. The flux per pole is 20 mwb and the armature has a resistance of 0.13 Ω when the motor is connected to 240 V supply and the armature draws a current of 80 A driving a load of 16 Kw .calculate i) Speed, ii)Armature torque, iii) Shaft torque. (15M)** BTL4

Answer: Page : 6.39 - J.Gnanavadivel

- Write the formula
- Substitution and answer

Speed:

Back EMF $E_b=V-I_a R_a$ =229.6 V (3 M)

$E_b = P\phi ZN/60A$ (2 M)

$N= E_b 60A/P\phi Z$ =439.8 rpm (3 M)

Armature torque :

$T_a=0.159\phi I_a PZ/A$ (2 M)

=398.4 N-m (2 M)

Shaft Torque:

$T_{sh}=9.55\ P_{out}/N$ (2 M)

$=347.43$ N-m (1 M)

2. **A 200 V DC shunt motor running at 1000 rpm takes an armature current of 17.5 A. It is required to reduce the speed to 600 rpm. What must be the value of resistance to be inserted in the armature circuit if the original armature resistance is 0.4Ω ? take armature current to be constant during this process. (15M) (May 2009)** BTL4

Answer: Page :6.64 - J.Gnanavadivel

- Write the formula
- Substitution and answer

$E_{b1}=V- I_a R_a$ (2 M)

$=193$ V (1 M)

$E_{b2}=200- I_a R_t$ (2 M)

$=200-17.5 R_t$ (1 M)

$N1/N2 = E_{b2} / E_{b1}$ (2 M)

$600/1000 = 200- I_a R_t /193$ (1 M)

$=4.81\Omega$ (2 M)

Additional resistance required = $R = R_t-R_a$ (2 M)

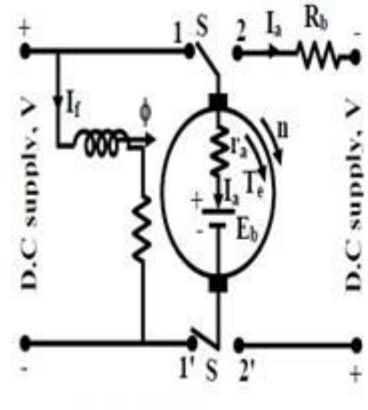
$=4.41\ \Omega$ (2 M)

3. **(i)Draw the speed torque characteristics of DC Shunt and series motor. Also from the characteristics specify the application for each motor. (6M) (April/May 2015)** BTL6

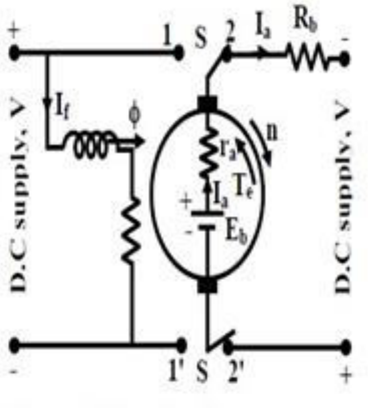
(ii)Explain the breaking of the electric motor. (9M) BTL2

Answer: Page :6.26,5.59,6.111 - J.Gnanavadivel

- (i)write the equation (6 M)
- Any two application of each types off motor
- (ii)Explain with example (9 M)



Machine operates as motor



Machine operates as generator during braking (plugging).

- ✓ Oftennecessaryinmanyapplicationstostoparunningmotorratherquickly.
- ✓ Weknowthatanymovingorrotatingobjectacquireskineticenergy.
- ✓ Howfastwecanbringtheobjecttorestwilldependessentiallyuponhowquicklywecanextract Itskineticenergyandmakearrangementtodissipatethatenergysomewhereelse.
- ✓ Ifyoustoppedalingyourbicycle,itwilleventuallycometoastopeventuallyaftermovingquite

	somedistance. ✓ Theinitialkineticenergystored,inthiscasedissipatesasheatinthefrictionoftheroad.However,tomakethestoppingfaster,brakeisappliedwiththehelpofrubberbrakeshoesontherimofthe wheels. ✓ ThusstoredK.Enowgetstwowaysofgettingdissipated,oneatthewheel-brakeshoeinterface(wheremostoftheenergyisdissipated)andtheotherattheroad-tierinterface.Thisisagoodmethodnodoubt,butregularmaintenanceofbrakeshoesduetowearandtearisnecessary ✓ Ifamotor-simplydisconnectedfromsupplyitwilleventuallycometostopnodoubt,butwilltakelongertimeparticularlyforlargemotorshavinghighrotationalinertia. ✓ Becauseherethestoredenergyhastodissipatemainlythroughbearingfrictionandwindfriction. ✓ Thesituationcanbeimproved,byforcingthemotortooperateasageneratorduringbraking. ✓ Theideacanbeunderstoodrememberingthatinmotormodeelectromagnetictorqueactsalongthedirectionofrotationwhileingeneratortheelectromagnetictorqueactsin theoppositedirectionofrotation. ✓ Thusbyforcingthemachinetooperateasgeneratorduringthebrakingperiod,atorqueoppositetothedirectionofrotationwillbeimposedontheshaft,therebyhelpingthemachinetocometo stopquickly. ✓ Duringbrakingaction,theinitialK.Estoredintherotoriseitherdissipatedinanexternalresistanceorfedbacktothesupplyorboth.

OBJECTIVE TYPE QUESTIONS

UNIT I MAGNETIC CIRCUITS AND MAGNETIC MATERIALS

1) Iron losses are considered to be the constant losses. It depends on

a. Voltage

b. Frequency

c. Both (a) and (b)

d. None of these

ANSWER: Both (a) and (b)

2) Copper losses in a rotating machine are

a. Variable losses

b. Constant losses

c. Both (a) or (b)
d. None of these

ANSWER: Variable losses

3) For low reluctance path for the flux in armature, the permeability of the material should be

a. High
b. Low
c. Both (a) and (b)
d. None of these

ANSWER: Low

4) When we plot the magnitude of the induced emf against the time, the nature of the induced emf will be

a. Sinusoidal
b. Square
c. Triangular
d. Parabolic

ANSWER: Sinusoidal

5) Due to short pitching, the induced emf gets

a. Reduced
b. Increased
c. Remains same
d. None of these

ANSWER: Reduced

6) Mention the magnetic materials

a. Dia Magnetic Materials

b. Para Magnetic Materials

c. Ferro Magnetic Materials

d. All the above

ANSWER: All the above

7) Relative permeability is

a. $\mu_{r\,=}\,\mu{*}\mu_0$

b. $\mu_{r\,=}\,\mu+\mu_0$

c. $\mu_{r\,=}\,\mu-\mu_0$

d. $\mu_{r\,=}\,\mu/\mu_0$

ANSWER: $\mu_{r\,=}\,\mu/\mu_0$

8)Faraday's law of electromagnetic induction is

a. e=NdΦ

b. e=Nd+Φ

c. e= - NdΦ/dt

d. e=NdΦ/dt

ANSWER: e=NdΦ/dt

9)Unit of Magnetic Field intensity is

a. AT/m.

b. m/AT.

c. m^2.

d. AT.

ANSWER: AT/m.

10)Unit of Magnetic Flux is

a. AT/m.

b. m/AT.

c. m^2.

d. weber.

ANSWER: weber

11)Unit of Flux Density is

a. weber / $meter^2$.

b. weber

c. $meter^2$ / weber .

d. $meter^2$

ANSWER: weber / $meter^2$.

12)Unit of Magnetic Motive Force is

a. AT/m.

b. m/AT.

c. m^2.

d. AT.

ANSWER: AT.

13) Magnetic Field intensity is

a. H= NI +l AT/m.

b. H=NI-l AT/m.

c. H=NI/l AT/m.

d. H=NI*l AT/m.

ANSWER: H=NI/l AT/m.

14) Magnetic Motive Force is

a. MMF=N Ampere turns (AT)
b. MMF=I Ampere turns (AT)
c. MMF=N/I Ampere turns (AT)
d.MMF=NI Ampere turns (AT)
ANSWER: H= MMF=NI Apere turns (AT)

15) Hysteresis loss is

a.Ph=B^{16}maxfV watts

b. Ph=B^{18}maxfV watts

c. Ph=B^{16}maxf/I watts

d. Ph=B^{16}maxV watts

ANSWER: Ph=B^{16}maxfV watts

UNIT II TRANSFORMERS

1) The hysteresis motor are mainly used in tape recorders because

a. Of its extremely steady torque
b. Constant speed
c. Reduced initial current
d. None of these

ANSWER: Of its extremely steady torque

2) If % ηm is the mechanical efficiency of a DC machine and % ηe is the electrical efficiency. Then the overall efficiency of DC machine is given by

a. % η m + % η e
b. % η m X % η e
c. (% η m + % η e) / % η m
d. (% η m + % η e) / % η e

ANSWER: % η m X % η e

3) Name the factors on which hysteresis loss depends?

a. Frequency

b. volume of the core and

c. Maximum flux density

d.All the above

ANSWER: All the above

4)All day efficiency is

a. η all-day = Output power in Kwh + Input power in kWh *100 %

b. η all-day = Output power in Kwh/Input power in kWh *100 %

c. η all-day = Output power in Kwh * Input power in kWh *100 %

d. η all-day = Output power in Kwh - Input power in kWh *100 %

ANSWER: η all-day = Output power in Kwh/Input power in kWh *100 %

5)Regulation of transformer is

a. % R= copper loss /I_2

b.% R= copper loss /V_2

c. % R= $V_{2\,-}\,I_2$ /V_2I_2

d. % R= copper loss /V_2I_2

ANSWER: % R= copper loss /V_2I_2

6)transformation ratio is

a. $K = V_1 + V_2$

b. $K = V_1 - V_2$

c. $K = V_1/V_2$

d. $K = V_1 * V_2$

ANSWER: $K = V_1/V_2$

7)Power factor Cos ϕ_0 =

a. Cos $\phi_0 = W_0/V_1I_0$

b. Cos $\phi_0 = W_0/I_0$

c. Cos $\phi_0 = W_0/V_1$

d. Cos $\phi_0 = W_0/V_2I_1$

ANSWER:Cos $\phi_0 = W_0/V_1I_0$

8)When cos ϕ_0 = 0.5 find the value of sin ϕ_0

a. sin $\phi_0 = 0.866$

b. sin $\phi_0 = 0.967$

c. sin $\phi_0 = 0.428$

d. sin $\phi_0 = 0.849$

ANSWER:sin $\phi_0 = 0.866$

9)Three Phase transformer connections are

a.Star to Star

b.Star to Delta

c.Delta to Star

d.Delta to Delta

ANSWER: a,b,c,d

10)Total loss in the machine is

a. Total losses = Input power + output power

b. Total losses = Input power /output power

c. Total losses = Input power * output power

d. Total losses = Input power – output power

ANSWER: Total losses = Input power – output power

11)Input power of the AC machine is

a. Input power = output power / efficiency

b. Input power = output power - efficiency

c. Input power = output power +efficiency

d. Input power = output power * efficiency

ANSWER:Input power = output power / efficiency

12)How transformers are classified according to the construction

a. Core type

b. Shell Type

c. both a and b

d. only a

ANSWER:both a and b

13)What is a step up transformer

a.$N_1 > N_2$

b.$N_1 < N_2$

c.$N_1 = N_2$

d. All the above

ANSWER: $N_1 < N_2$

14)What is a step down transformer

a.$N_1 > N_2$

b.$N_1 < N_2$

c.$N_1 = N_2$

d. All the above

ANSWER: $N_1 > N_2$

15)Give the emf equation of a transformer is

a. $E_1=1.11\Phi_mN_1$

b. $E_1=4.44fN_1$

c. $E_1=4.44f\Phi_m$

d. $E_1=4.44f\Phi_mN_1$

ANSWER: $E_1=4.44f\Phi_mN_1$

UNIT III ELECTROMECHANICAL ENERGY CONVERSION AND CONCEPTS IN ROTATING MACHINES

1) The rotational or stray losses includes

a. Iron losses only
b. Iron losses, friction and windage losses
c. Iron losses, copper losses, friction and windage losses
d. None of these

ANSWER: Iron losses, copper losses, friction and windage losses

2) If A is the number of parallel paths and P is the number of poles, then the number of parallel path in lap winding and in wave winding is

a. A = P, A = 2
b. A = 2P, A = P
c. A = 2, A = P
d. A = P, A = 2P

ANSWER: A = P, A = 2

3) In a three phase induction motor, the direction of rotation of rotating magnetic field can be reversed by

a. Interchanging any two terminals of three phase winding while connecting it to ac supply
b. by reversing the direction of rotating magnetic field
c. Cannot be changed
d. None of these

ANSWER: Interchanging any two terminals of three phase winding while connecting it to ac supply

4) For connecting the rotating member of machine to the external stationary circuit,

a. Slip rings and brush assembly is used
b. Only slip ring is used
c. Only brushes are used
d. Directly connected to the external stationary circuit

ANSWER: Slip rings and brush assembly is used

5) If coil side in one slot is connected to a coil side in another slot which is one pole pitch distance away from first slot, the winding is said to be

a. Short pitched
b. Full pitched
c. Concentrated
d. Distributed

ANSWER: Full pitched

6) Among the following sentences which is/are true about short pitch coils

a. Less amount of copper is required
b. Eliminates high frequency harmonics
c. Minimizes eddy current and hysteresis losses
d. All of the above

ANSWER: All of the above

7) In practice, which combination of armature winding is preferred for the alternators?

a. Single layer, full pitched and concentrated type
b. Single layer, short pitched and distributed type
c. Double layer, full pitched and concentrated type
d. Double layer, short pitched and distributed type

ANSWER: Double layer, short pitched and distributed type

8) Due to short pitching, the induced emf gets

a. Reduced
b. Increased
c. Remains same
d. None of these

ANSWER: Reduced

9) The factor by which there is reduction in the emf due to distribution of coils is called distribution factor. It is given by

a. sin (β / 2m) / msin(β / 2)
b. sin(β / m) / msin(mβ / 2)
c. sin(m β/2) / msin(β / 2)
d. msin(β / 2) / sin(m β / 2)

ANSWER: sin(m β/2) / msin(β / 2)

10) In a 4 pole, 3 phase alternator, armature has 40 slots. It is using an armature winding which is short pitched by one slot. Its coil span factor is

a. 0.9
b. 0.9243
c. 0.9476

d. 0.9876

ANSWER: 0.9876

11) The generalized expression for emf equation of an alternator is

a. Eph = 4.44f φ Tph

b. Eph = 4.44 KcKdf φ E

c. Eph = 4.44 KcKdfφTph

d. Eph =4 KcKdf φ Tph

ANSWER: Eph = 4.44 KcKdfφTph

12) For a short pitch and distributed winding, the value of coil span factor and distributed factor

a. Both are less than unity

b. Less than unity, greater than unity

c. Greater then unity, less than unity

d. Both are greater than unity

ANSWER: Both are less than unity

13) For reducing the slot harmonics in an alternator, the length of air gap is

a. Reduced

b. Increased

c. Not related to harmonics

d. None of these

ANSWER: Increased

14)If Øf is the main flux produced by the field winding of alternator is responsible for producing Eph, then

a. Eph leads Øf by 90 degree

b. Eph leads Øf by 45 degree

c. Eph lags Øf by 45 degree

d. Eph lags Øf by 90 degree

ANSWER: Eph lags Øf by 90 degree

15) To minimize the harmonics from the voltage waveform, the suitable steps is / are

a. Using distributed type of winding instead of concentrated type

b. Using fractional slot windings

c. Skewing the pole face

d. All of these

e. None of these

ANSWER: All of these

UNIT IV DC GENERATORS

1) Stray losses are the losses which vary with the load but their relationship with load current cannot be identified. Stay losses is maximum in

a. Synchronous machines

b. D.C. machines

c. Induction machines

d. Equal in all types of machines

ANSWER: D.C. machines

2) The brush contact losses in a d.c. Machine is

a. Inversely proportional to the square of current

b. Directly proportional to the square of current

c. Inversely proportional to the current

d. Directly proportional to the current

ANSWER: Directly proportional to the current

3) Electrical power output in a d.c. generator is equal to

a. Electrical power developed in armature – copper losses

b. Mechanical power input – iron and friction losses

c. Electrical power developed in armature – iron and copper losses

d. Mechanical power input – iron and friction losses – copper losses

ANSWER: Mechanical power input – iron and friction losses – copper losses

4) A 120 V shunt generator running at 850 rpm has its armature and shunt field resistance of 0.15 ohm and 50 ohm respectively. It supplies 200 lamps each rated at 60 W, 100 V. The friction and windage and core loss of the machine is 400 W. its armature copper loss on full load and shunt field loss is

a. 2156.7 W, 200 W

b. 2232.6 W, 200 W

c. 2156.7 W, 240 W

d. 2232.6 W, 240 W

ANSWER: 2232.6 W, 200 W

5) A d.c. shunt generator delivers 190 A at a terminal voltage of 220 V. The copper losses and stray losses are 2000 W and 1000 W respectively. The efficiency of the

Generator is

a. 91.35 %
b. 92.60 %
c. 93.30 %
d. 94.23 %

ANSWER: 93.30 %

6) A 4 pole d.c. shunt generator having a wave winding supplies 45 lamps, each of 50
W at 100 V. The armature and field resistance are 0.15 ohm and 50 ohm respectively . The current in armature conductor is

a. 11.25 A
b. 11.50 A
c. 12.25 A
d. 13.50 A

ANSWER: 12.25 A

7) The speed in d.c. machine can be measured by using

a. Anemometer
b. Tachometer
c. Voltmeter
d. Ammeter

ANSWER: Tachometer

8) The rotational losses in d.c. machines is equal to the

a. Kinetic energy of armature
b. Half of the kinetic energy of armature
c. Square of the kinetic energy of armature
d. Rate of change of kinetic energy

ANSWER: Rate of change of kinetic energy

9) To have an induced emf in the d.c. generator, there should be relative motion between the conductor and flux. The plane of rotation and plane of flux

a. Should be parallel to each other
b. Should not be parallel to each other
c. Both (a) & (b)
d. None of these

ANSWER: Should not be parallel to each other

10) To have d.c. voltage, a device is used in a d.c. generator to convert alternating
emf to unidirectional emf. This device is called

a. Armature
b. Commutator
c. Brushes
d. All of these

ANSWER: Commutator

11) Yoke in d.c. machine serves the outermost cover. For magnetic flux it provides

a. A low reluctance path
b. A high reluctance path
c. Both (a) & (b)
d. Does not provide path for magnetic flux

ANSWER: A low reluctance path

12) Functions of commutator in d.c. machines are

a. To facilitate the collection of current from armature conductors
b. To convert internally developed induced emf to unidirectional emf
c. To produce unidirectional torque in case of motors
d. All of these
e. None of these

ANSWER: All of these

13) Brushes in d.c. machines are made up of

a. Cast iron
b. Mild steel
c. Copper
d. Carbon

ANSWER: Carbon

14) A 4 pole, d.c. generator has a wave wound armature with 812 conductors. The flux per pole is 0.014 Wb. The speed at which it should be run to generate 240 V on no load is

a. 623.23 rpm
b. 633.35 rpm
c. 643.36 rpm
d. 645.53 rpm

ANSWER: 633.35 rpm

15) A 4 pole, lap wound d.c. generators has 40 coils with 8 turns per coils. It is
driven at 1200 rpm. If the flux per pole is 0.022 Wb, then the generated emf is

a. 265.8 V
b. 276.3 V
c. 281.6 V
d. 287.9 V

ANSWER: 281.6 V

16) Practically in d.c. machines, it may happen that the emf induced in different
parallel paths may not be same. This will cause inequality in brush arm

currents and will give rise to copper losses. These effects can be avoided by using

a. Compensating windings
b. Interpoles
c. Equalizer rings
d. All of these

ANSWER: Equalizer rings

17) In d.c. machines, the interpoles have tapering shape which results in

a. Simpler design
b. Reduction in the weight
c. Increase in acceleration of commutation
d. All of these

ANSWER: Increase in acceleration of commutation

18) The generating action and motoring action in d.c. motor is determined by

a. Fleming’s left hand rule, Fleming’s right hand rule
b. Both by Fleming’s left hand rule
c. Both by Fleming’s right hand rule
d. Fleming’s right hand rule, Fleming’s left hand rule

ANSWER: Fleming’s right hand rule, Fleming’s left hand rule

UNIT V DC MOTORS

1) Mechanical power developed in armature of a d.c. motor is given by

a. Electrical power input to motor – copper losses
b. Motor output + iron and friction losses
c. Both (a) & (b)
d. None of these

ANSWER: Both (a) & (b)

2) Out of electrical, mechanical and magnetic losses, the losses which is minimum is

a. All are equal
b. Electrical losses
c. Magnetic losses
d. Mechanical losses

ANSWER: Mechanical losses

3) The current flowing through the armature of a d.c. shunt machine at maximum efficiency is given by

a. √(Pi / Ra)
b. √(Ra / Pi)
c. √(Pi / R2a)
d. √(Ra / P2i)

ANSWER: √(Pi / Ra)

4) A 120 V d.c. shunt motor runs at speed of 1200 rpm. When the motor is operated
unloaded but an additional resistance of 4 ohm is connected in series with the shunt field, then the speed increases and reaches to 1370 rpm with the same terminal voltage. The value of series resistance is

a. 28.23 ohm
b. 32.48 ohm
c. 35.72 ohm
d. 36.82 ohm

ANSWER: 28.23 ohm

5) A 240 V, 17 kW d.c. shunt motor draws an armature current of 80 A at full load. The armature and shunt field resistances are 0.2 ohm and 195 ohm respectively. The rotational losses and efficiency of motor at full load is

a. 87.20 %
b. 89.32 %
c. 89.67 %
d. 90.03 %

ANSWER: 87.20 %

6) Out of different methods available for testing of d. c. motors, Swinburne's test and Hopkinson's test are commonly used in practice on

a. Shunt generators

b. Series motors
c. Shunt motors
d. All of these

ANSWER: Shunt motors

7) Swinburne's test and brake tests

a. Both are direct method of testing
b. Direct method of testing, indirect method of testing
c. Indirect method of testing, direct method of testing
d. Both are indirect method of testing

ANSWER: Indirect method of testing, direct method of testing

8) Swinburne's test can be performed at

a. Any load
b. Only no load
c. Only full load
d. Only half load

ANSWER: Only no load

9) While performing Swinburne's test, the iron losses are assumed to be

a. Constant
b. Absent

c. Variable
d. None of these

ANSWER: Constant

10) While performing retardation tests, the machine whose test is to be taken is run at a speed which is

a. Slightly less than its rated speed
b. Equal to its rated speed
c. Slightly greater than its rated speed
d. All of these

ANSWER: Slightly greater than its rated speed

11) The starting torque developed in the d.c. series motor and in d.c. shunt motor is

a.High, low
b. High, moderate
c. Moderate, low
d. Moderate, high

ANSWER: High, moderate

12) The speed of a d.c. series motor is

a. Directly proportional to the both armature current and torque developed

b. Inversely proportional to the armature current and square root of torque developed

c. Directly proportional to the square of the armature current and square root of torque developed

d. Inversely proportional to the square of the armature current and square of torque developed

ANSWER: Inversely proportional to the armature current and square root of torque developed

13) The speed armature current characteristics of a d.c. series motor is

a. Rectangular hyperbola
b. Linear
c. Parabolic
d. Parabolic till saturation and then linear

ANSWER: Rectangular hyperbola

14) If a d.c. series motor is started on very light load or on no load then

a. It will run at dangerously high speed which may damage the motor mechanically
b. It will run at very low speed
c. Load does not effect the speed of d.c. series motor
d. None of these

15) A long shunt compound motor and a short shunt compound

motor can be

a. Cumulative type, differential type

b. Differential type, cumulative type

c. Both can be either cumulative or differential type

d. None of these

ANSWER: Both can be either cumulative or differential type

16) In electric traction, which type of motor is generally used?

a. Shunt motor

b. Series motor

c. Cumulative compound motor

d. Differential compound motor

ANSWER: Series motor

17) Differential compound motors are mainly used in

a. Drilling machines

b. Elevators

c. Electric traction

d. Not suitable for any practical application

ANSWER: Not suitable for any practical application

18) Which motor is not suitable for the application of centrifugal pumps?

a. Shunt motor
b. Series motor
c. Cumulative compound motor
d. Differential compound motor

ANSWER: Series motor

19) Ward-Leonard system is used for

a. Wide range of speed control
b. Very sensitive speed control
c. Both (a) & (b)
d. None of these

ANSWER: Both (a) & (b)

20) For frequent starting, stopping and reversals, which motor is commonly used?

a. Permanent d.c. motor
b. Ward-Leonard system
c. Brushless d.c. motor
d. All of these

ANSWER: Ward-Leonard system

EC8351 **ELECTRONIC DEVICES AND CIRCUITS** **L T P C**
3 0 0 3

OBJECTIVES:

The student should be made to:

- Understand the structure of basic electronic devices.
- Be exposed to active and passive circuit elements.
- Familiarize the operation and applications of transistor like BJT and FET.
- Explore the characteristics of amplifier gain and frequency response.
- Learn the required functionality of positive and negative feedback systems.

UNIT I PN JUNCTION DEVICES **9**

PN junction diode –structure, operation and V-I characteristics, diffusion and transition capacitance - Rectifiers – Half Wave and Full Wave Rectifier,– Display devices- LED, Laser diodes, Zener diodecharacteristics- Zener Reverse characteristics – Zener as regulator

UNIT II TRANSISTORS AND THYRISTORS **9**

BJT, JFET, MOSFET- structure, operation, characteristics and Biasing UJT, Thyristors and IGBT - Structure and characteristics.

UNIT III AMPLIFIERS **9**

BJT small signal model – Analysis of CE, CB, CC amplifiers- Gain and frequency response –MOSFET small signal model– Analysis of CS and Source follower – Gain and frequency response- High frequency analysis.

UNIT IV MULTISTAGE AMPLIFIERS AND DIFFERENTIAL AMPLIFIER **9**

BIMOS cascade amplifier, Differential amplifier – Common mode and Difference mode analysis – FET input stages – Single tuned amplifiers – Gain and frequency response – Neutralization methods, power amplifiers –Types (Qualitative analysis).

UNIT V FEEDBACK AMPLIFIERS AND OSCILLATORS **9**

Advantages of negative feedback – voltage / current, series , Shunt feedback –positive feedback – Condition for oscillations, phase shift – Wien bridge, Hartley, Colpitts and Crystal oscillators.

TOTAL : 45 PERIODS
OUTCOMES:

Upon Completion of the course, the students will be ability to:

- Explain the structure and working operation of basic electronic devices.
- Able to identify and differentiate both active and passive elements
- Analyze the characteristics of different electronic devices such as diodes and transistors
- Choose and adapt the required components to construct an amplifier circuit.
- Employ the acquired knowledge in design and analysis of oscillators

TEXT BOOKS:

1. David A. Bell ,"Electronic devices and circuits", Oxford University higher education, 5th edition 2008.

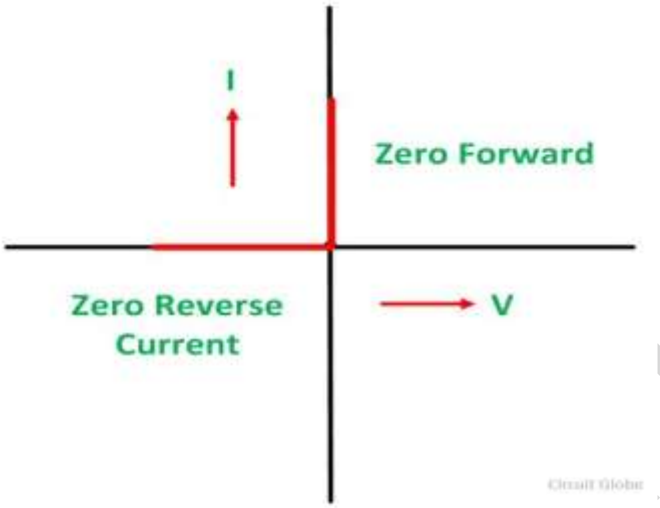
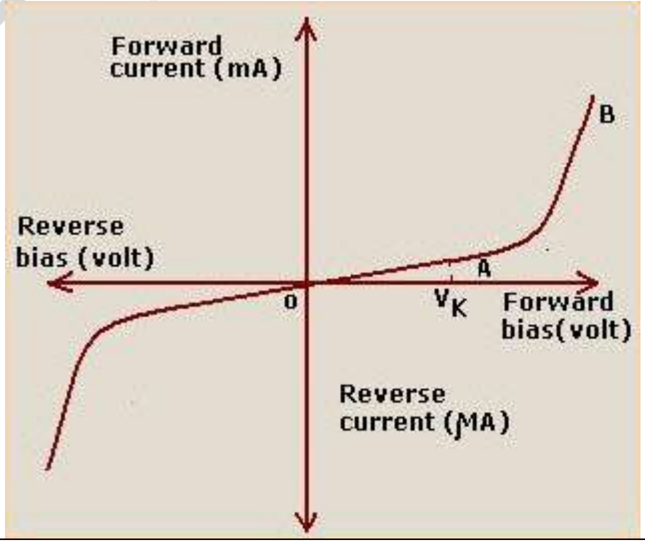
2. Sedra and smith, “Microelectronic circuits”,7th Ed., Oxford University Press

:ENCES:

1. Balbir Kumar, Shail.B.Jain, “Electronic devices and circuits” PHI learning private limited, 2nd edition 2014.
2. Thomas L.Floyd, “Electronic devices” Conventional current version, Pearson prentice hall, 10th Edition, 2017.
3. Donald A Neamen, “Electronic Circuit Analysis and Design” Tata McGraw Hill, 3rd Edition, 2003.
4. Robert L.Boylestad, “Electronic devices and circuit theory”, 2002.
5. Robert B. Northrop, “Analysis and Application of Analog Electronic Circuits to Biomedical Instrumentation”, CRC Press, 2004.

Subject Code:EC8351 Year/Semester: II/03
Subject Name: ELECTRONIC DEVICES AND CIRCUITS Subject Handler: Mrs.R. Durga

<table>
<tr><th colspan="2">UNIT I PN JUNCTION DEVICES</th></tr>
<tr><td colspan="2">PN junction diode –structure, operation and V-I characteristics, diffusion and transition capacitance - Rectifiers – Half Wave and Full Wave Rectifier,– Display devices- LED, Laser diodes, Zener diode characteristics- Zener Reverse characteristics – Zener as regulator</td></tr>
<tr><td colspan="2">PART * A</td></tr>
<tr><td>Q.No</td><td>Questions</td></tr>
<tr><td>1</td><td>What is an ideal diode? (BTL 1)
An ideal diode is one which offers zero resistance when forward biased and infinite resistance when reverse biased.</td></tr>
<tr><td>2</td><td>Compare ideal diode as a switch. (BTL 4)
An ideal diode when forward biased is equivalent a closed (ON) switch and when reverse biased, it is equivalent to an open (OFF) switch.</td></tr>
<tr><td>3</td><td>State the mathematical equation which relates voltage applied across the PN junction diode and current flowing through it. (BTL 2)
$I = I_0 (e^{v/\eta \; v_T} - 1)$</td></tr>
<tr><td>4</td><td>Define knee/cut-in/threshold voltage of a PN diode. (BTL 1)
It is the forward voltage applied across the PN diode below which practically no current flows.</td></tr>
<tr><td>5</td><td>What is the effect of junction temperature on cut-in voltage of a PN diode? (BTL 2)
Cut-in voltage of a PN diode decreases as junction temperature increases.</td></tr>
<tr><td>6</td><td>What is the effect of junction temperature on forward current and reverse current of a PN diode? (BTL 2)
For the same forward voltage, the forward current of a PN diode increases and reverse saturation current increases with increase in junction temperature.</td></tr>
<tr><td>7</td><td>Differentiate between breakdown voltage and PIV of a PN diode. (BTL 4)
The breakdown voltage of a PN diode is the reverse voltage applied to it at which the PN junction breaks down with sudden rise in reverse current. Whereas, the peak inverse voltage (PIV) is the maximum reverse voltage that can be applied to the PN junction without damage to the junction.</td></tr>
<tr><td>8</td><td>Differentiate between avalanche and zener breakdowns. (BTL 4)
Avalanche Breakdown
1. Breakdown occurs due to heavily doped junction and applied strong electric field.</td></tr>
</table>

	2. Doping level is high. 3. Breakdown occurs at lower voltage compared to avalanche breakdown Zener Breakdown 1. Breakdown occurs due to avalanche multiplication between thermally generated ions. 2. Doping level is low. Breakdown occurs at higher voltage.
9	**Draw the V-I characteristics of an ideal diode.** (BTL 3) 
10	**Differentiate between drift and diffusion currents.** (BTL 4) **Drift Current** 1. It is developed due to potential gradient. 2. This phenomenon is found both in metals and semiconductors **Diffusion Current** 1. It is developed to charge concentration gradient. 2. It is found only in semiconductors.
11	**Draw the V-I characteristics of a practical PN diode.** (BTL 3) 
12	**List the PN diode parameters**. (BTL 1) 1. Bulk Resistance.

2. Static Resistance/Junction Resistance (or) DC Forward Resistance
3. Dynamic Resistance (or) AC Forward Resistance
4. Reverse Resistance
5. Knee Voltage
6. Breakdown Voltage
7. Reverse Current (or) Leakage Current

13 **State the PN diode ratings.** (BTL 1)

Even PN-Junction has limiting values of maximum forward current, peak inverse voltage and maximum power rating.

14 **Define reverse recovery time.** (BTL 1)

It is maximum time taken by the device to switch from ON to OFF stage.

15 **Define transition capacitance of a diode.** (BTL 1)

Transition Capacitance (C_T) or Space-charge Capacitance: When a PN-junction is reverse-biased, the depletion region acts like an insulator or as a dielectric.

The P- and N-regions on either side have low resistance and act as the plates. Hence it is similar to a parallel-plate capacitor. This junction capacitance is called transition or space-charge capacitance (C_T).

It is given by

$$C_T = \frac{\varepsilon A}{d}$$

Where, A = Cross-sectional area of depletion region. D = Width (or) thickness of depletion region.

Its typical value is 40 pF.

Since the thickness of depletion layer depends on the amount of reverse bias, C_T can be controlled with the help of applied bias.

This property of variable capacitance is used in varicap or varactor diode. This capacitance is is voltage dependent and is given by

$$C_T = \frac{k}{(V_k + V_R)^n}$$

Where, V_K= Knee voltage, V_R= Applied reverse voltage,

K = Constant depending on semiconductor material, n =1/2 for alloy junction,

= 1/3 for diffused junction.

16 **Define diffusion capacitance of a diode.** (BTL 1)

Diffusion or Storage Capacitance (CD): This capacitive effect is present when the junction is forward-biased.

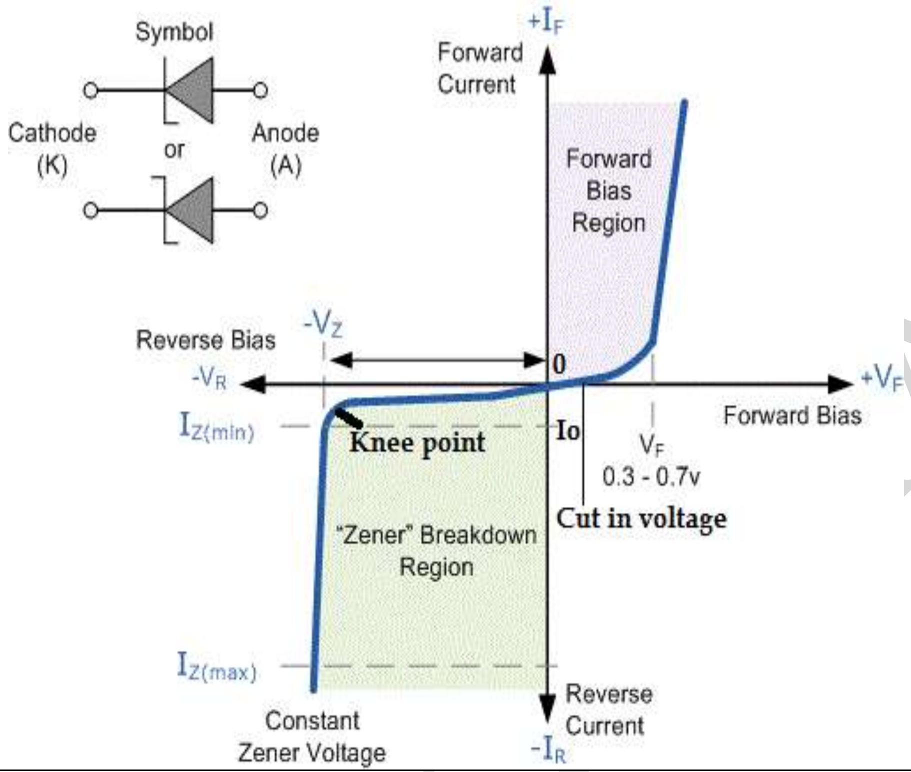
It is called diffusion capacitance due to the time delay in minority charges across the junction by diffusion process. Due to this fact, this capacitance cannot be identified in terms of a dielectric and plates. It varies directly with forward current. When a forward-biased PN-junction is suddenly reverse biased, a reverse current flows which is large initially, but gradually decreases to the level of saturation current, I0.

This effect can be likened to the discharging, of a capacitor and is, therefore called diffusion capacitance, CD. Its typical value is 0.02 F

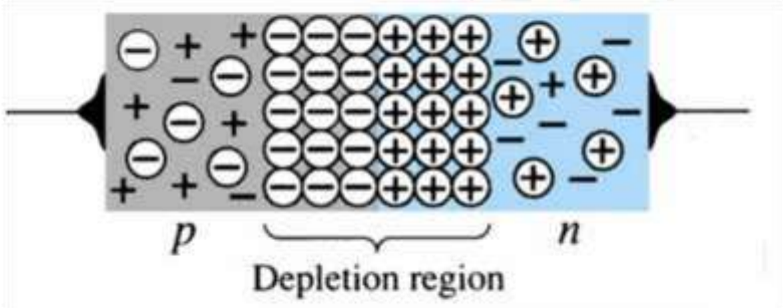
It is given by:

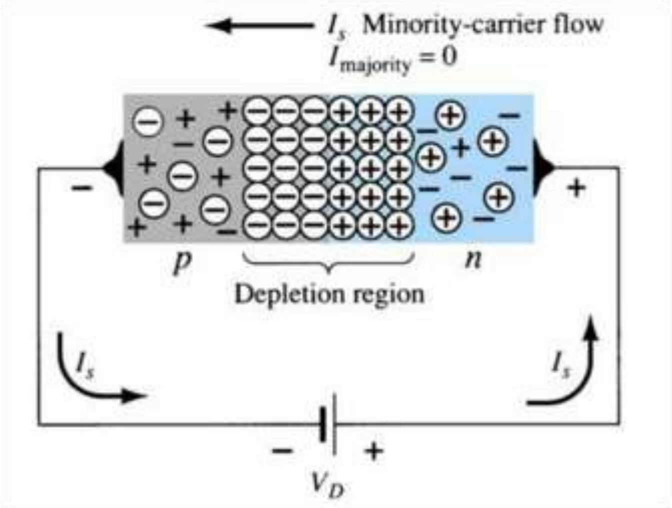
$$C_D = \frac{dQ}{dV} = \frac{\tau I_0}{\eta V_T} e^{V/\eta V_T} \approx \frac{\tau I}{\eta V_T}$$

Where, ج = Mean life time of carrier η= Constant =2 for Si and 1 forGe I = Forward current

	I_0 = Reverse saturation current V_T = Volt equivalent of temperature
17	**Draw the V-I characteristics of a zener diode.** (BTL 3) 
18	**List some applications of zener diode**. (BTL 1) Zener diode find wide commercial and industrial applications. Some of their common applications are: • As voltage regulators. • As peak clippers or voltage limiters. • For wave shaping. • For meter protection against damage from accidental application of excessive voltage. • As a fixed :ence voltage in a network for biasing and comparison purposes and for calibrating voltmeters.
19	**State the ratings of zener diode.** (BTL 1) **Zener voltage (Vz):** The voltage at which a zener diode breaks in the reverse bias condition is called zener voltage. In fact, it is the voltage at which a zener diode is to operate. The value of zener voltage depends upon doping-more the doping, lesser the breakdown voltage. **Tolerance:** The range of voltages about the breakdown voltage in which a zener diode conducts in reverse direction is called tolerance. **Power Rating (P_{ZM}):** The maximum power which a zener diode can dissipate (or handle) without damage is called its power rating. $P_{ZM} = I_{ZM} \times V_Z$ **Maximum Current Rating (I_{ZM}):** The maximum value of current which a zener diode can handle at its rated voltage without damage is called maximum current rating (I_{ZM}). **Zener resistance (R_Z):** The opposition offered to the current flowing through the zener diode in

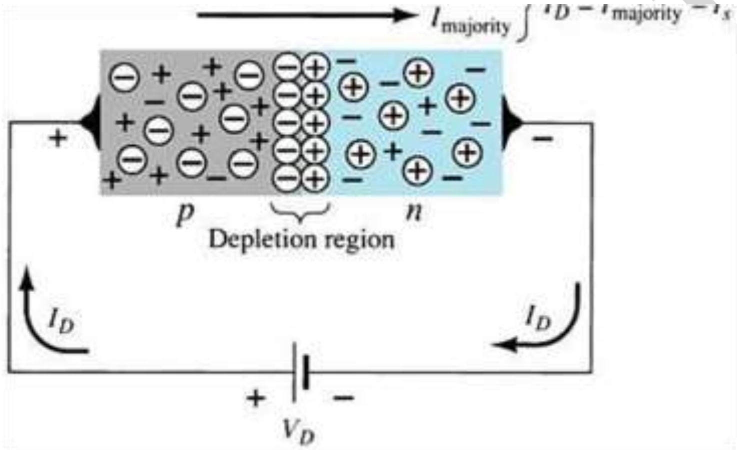
	the operating region is called zener resistance (R_Z) or zener impedance (Z_Z).
20	**State the principle of operation of an LED.** (BTL 1) When a free electron from the higher energy level gets recombined with the hole , it gives out the light output. Here, in case of LEDs, the supply of higher level electrons is provided by the battery connection.
21	**State any four advantages of LED.** (BTL 1) • They are small in size. • Light in weight. • Mechanically rugged. • Low operating temperature. • Switch on time is very small. • Available in different colours. • They have longer life compared to lamps. • Linearity is better. • Compatible with ICs. • Low cost.
22	**Define ripple factor of a rectifier.** (BTL 1) The purpose of a rectifier is to convert AC into DC. But the pulsating output of a rectifier contains a DC component and an AC component, called ripple. The ratio of RMS value of AC components to the DC component in the rectifier output is called ‘ripple factor’. The ripple factor is very important in deciding the effectiveness of a rectifier. It indicates the purity of the DC power output. The smaller the ripple factor, the lesser the effective AC component and hence more effective is the rectifier.
23	**Define TUF of a rectifier.** (BTL 1) Most of the rectifier circuits make use of transformer whose secondary feeds the AC power. The transformer rating is necessary to design a power supply. Transformer utilization factor (TF) id defined as the ratio of DC power delivered to the load to the AC power rating of transformer secondary.
24	**Give the advantages and disadvantages of HWR** .(BTL 1) **Half Wave Rectifier (HWR)** Advantages Simple circuit. low cost. Disadvantages. Rectification efficiency is low (40.6%). Very high amount of ripple ($\gamma = 1.21$) Low TUF (0.287) Saturation of transformer core occurs.
25	**Define (i) Voltage regulation (ii) Minimum load resistance**. (BTL 1**)** The variation of output voltage with respect to the amount of load current drawn from the power supply is called voltage regulation. The change in DC output voltage from no load to full load with respect to full load voltage of a power supply is called its voltage regulatin. % voltage regulation = $\frac{V_{NL}-V_{FL}}{V_{FL}}\ X\ 100$

	Where , VNL = DC output voltage at no load VFL = DC output voltage at full load Smaller the percentage regulation better is the power supply. For a well-designed power supply, the percentage regulation should be less than 1%.
26	**Define static resistance of a diode.** (BTL 1) The resistance offered by a p-n junction diode when it is connected to a DC circuit is called static resistance. R_f = V/I
27	**Define dynamic resistance of a diode** (BTL 1) The dynamic resistance is the resistance offered by the p-n junction diode when AC voltage is applied. Dynamic resistance is also defined as the ratio of change in voltage to the change in current. It is denoted as r_f. r_f= change in voltage/ change in current.
28	**Define reverse resistance of a diode** (BTL 1) It is the resistance offered by the PN junction diode under reverse bias condition. It is very large compared to the forward resistance, which is in the range of several MΩ.
	PART * B
1.	
	With a neat diagram, explain the construction, working of a PN junction diode in forward bias and reverse bias and explain its VI characteristics. (13 M) [May 2010, Nov 2012] BTL 2 **Answer: Page: 1.1- T. JOEL** **Diagram**: (2 M)  **Construction:** *p*-*n* junction, excess conduction-band electrons on the *n*-type side attracted to the valence-band holes on the *p*-type side. The electrons in the *n*-type material migrate across the junction to the *p*-type material (electron flow). The electron migration, negative charge on the p-type side of the junction, positive charge on the n-type side of the junction. drift, diffusion, depletion of mobile charge carriers. depletion region around the junction. (3 M) **Reverse Bias:** External voltage, applied across the *p*-*n* junction , opposite polarity of the *p*- and *n*-type materials. (2 M)



Forward Bias:

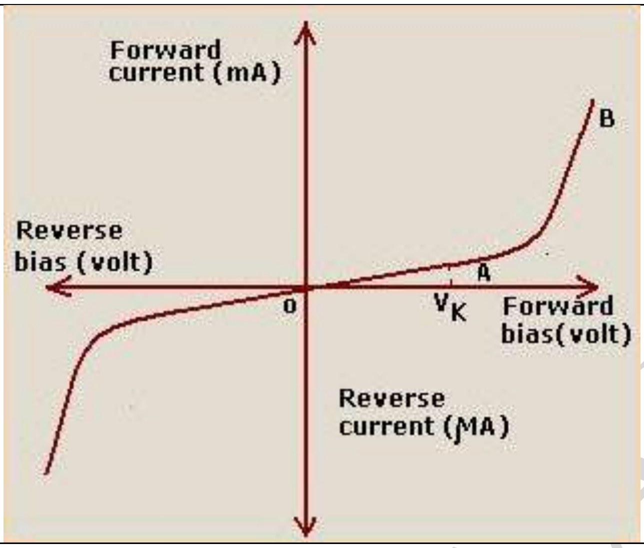
External voltage, applied across the *p*-*n* junction, same polarity as the *p*- and *n*-type materials. (2 M)



VI characteristics: (4 M)

Cut in Voltage: Minimum voltage, device turn on

Reverse saturation current: Reverse current flow, after breakdown, leakage current.



2.

Explain the VI characteristics of Zener diode. (13 M) [May 2010] BTL 2

Answer: Page: 1.43 - T. JOEL

1. **Definition and Symbol** (2 M)

Zener diode: The Zener region, diode’s reverse-bias region.

Reverse bias voltage, so large, the diode breaks down, reverse current increases dramatically.

- The maximum reverse voltage - peak inverse voltage or peak reverse voltage.

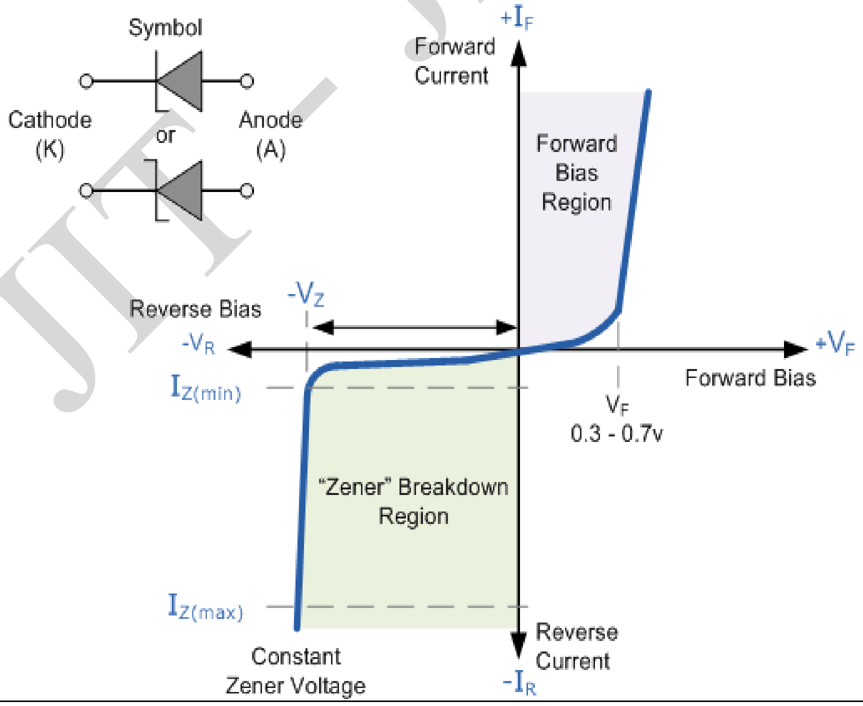
The voltage that causes a diode to enter the zener region of operation- zener voltage (V_Z).

2. **Forward Bias:** Acts as normal diode (3 M)

3. **Reverse Bias:** Acts as voltage regulator after breakdown, Zener voltage. (3 M)

4. **VI characteristics** (3 M)

5. **Zener diode as voltage regulator**: Reverse bias, zener breakdown, current varying, voltage constant. (2 M)



3.

Draw the circuit diagram and explain the working of full wave rectifier and derive the expression of average output voltage and rectification efficiency. (13 M) [May 2010] BTL 3

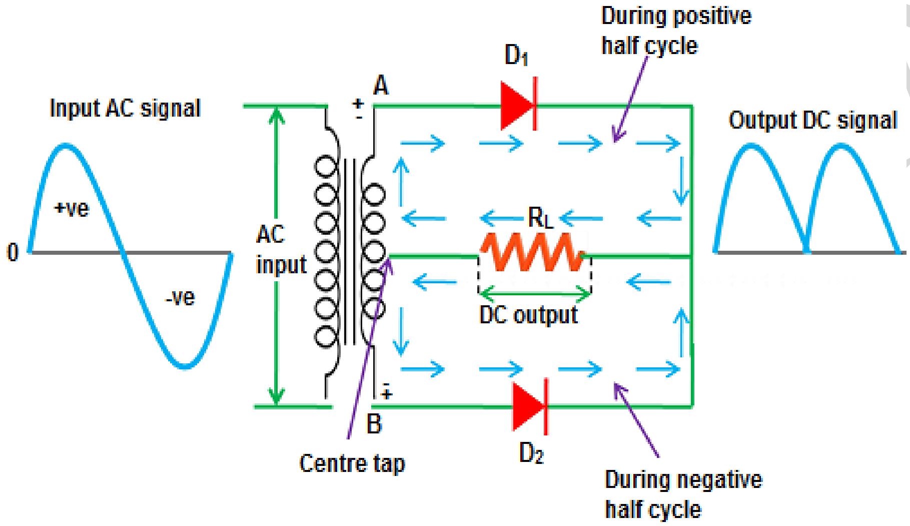
Answer: Page: 1.23 - T. JOEL

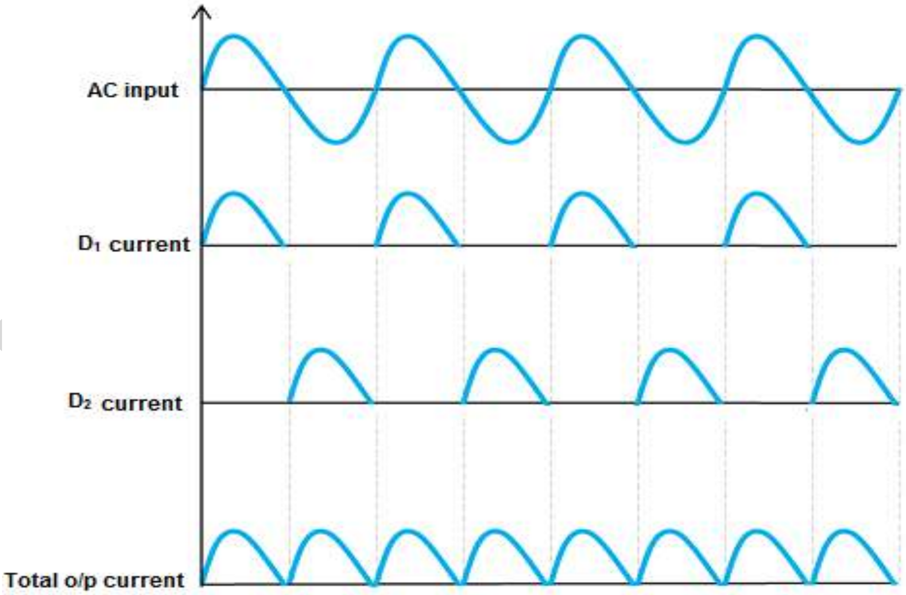
Construction and working: Two types- center tapped and bridge rectifier. Input AC signal, Center tapped transformer, Two diodes,

Positive half cycle: diode 1 conducts, diode 2 does not conduct. Current flow through diode 1,load resistor R_L , upper half of secondary winding.

Negative half cycle: diode 2 conducts, diode 1 does not conduct. Current flow through diode 1,load resistor R_L , lower half of secondary winding. (5 M)

Derivation: (8 M)





Ripple factor γ : Ratio of rms value of ac voltage to dc voltage.

Ripple factor = 0.48

Rectifier efficiency: output power/ input power = 81.2%.

$\mathbf{V_{DC} = 2V_m /\pi}$

4.

What is half wave rectifier? Explain the working with neat sketch. Derive the dc voltage, rms voltage, ripple factor and efficiency (13 M) [May 2011, May 2012] BTL 2

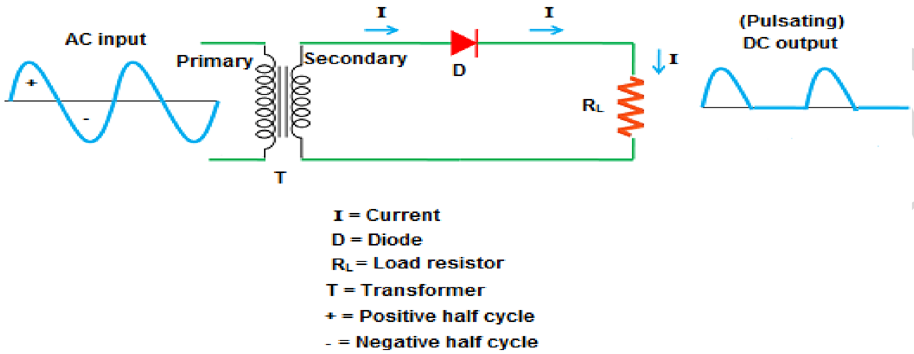
Answer: Page: 1.16- T. JOEL

Construction and working: Input AC signal, transformer, One diode.

Positive half cycle: diode conducts. Current flow through diode ,load resistor R_L , secondary winding. Output follows input.

Negative half cycle: diode does not conducts. No Current flow through diode and load resistor R_L , Output- zero (5 M)

Derivation: (8 M)



Half wave rectifier

V_{dc}= V_m/π

V_{rms}= $V_m/2$

Ripple factor: $\gamma = 1.21$

Rectifier efficiency: 40.6%

5.

Derive the transformer utilization factor, form factor, peak inverse voltage, peak factor of half wave rectifier. (8 M) BTL 3

Answer: Page: 1.21- T. Joel

PIV= V_m (1 M)

Transformer utilization factor = dc power delivered to the load/ ac rating of transformer secondary= 28.7% (3 M)

Form factor = rms value/ average value= 1.57 (2 M)

Peak factor= 2 (2 M)

6.

Derive the transformer utilization factor, form factor, peak inverse voltage, peak factor of half wave rectifier. (8 M) BTL 3

Answer: Page: 1.21- T. Joel

PIV= $2V_m$ (1 M)

Transformer utilization factor = dc power delivered to the load/ ac rating of transformer secondary= 69.2% (3 M)

Form factor = rms value/ average value= 1.57 (2 M)

Peak factor= 2 (2 M)

7.

Explain in detail about diffusion capacitance and transient capacitance. (13 M) BTL 3

Answer : Page- 1.10- T.Joel

Space charge or Transition capacitance (C_T): Reverse bias, majority carriers, move away from the junction, thickness of depletion layer increases, reverse voltage at the junction,

Capacitive effect.
Transition region, space charge, barrier, depletion region capacitance (3 M)
Derivation: $eN_AW_P= eN_DW_n$
E= $\frac{qND}{\varepsilon}$(x-W)
$C_T= \frac{\varepsilon A}{W}$ (5 M)

Diffusion Capacitance or storage capacitance: Forward biased PN junction, capacitance, diffusion of minority carriers, carriers accumulate near junction, diffuse and recombine with majority carriers, incremental capacitance, rate of change of injected charge with voltage. (3 M)
Derivation: $C_D= \frac{dQ}{dV}$
$C_{D=} \frac{\tau I}{\eta VT}$ (2 M)

PART*C

1.

With neat diagram, explain the working of LED. (15 M) BTL 2
Answer: Page: 1.37 - T. JOEL
LED Diagram and explanation: Emits photons when it is forward biased, Infrared or visible spectrum.The forward bias voltage range: 2 V to 3 V. (4 M)

Output characteristics: (3 M)

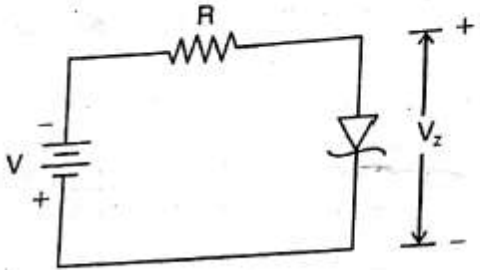
- Materials used and color LEDs: Gallium Phosphide and Gallium Arsenide Phosphide

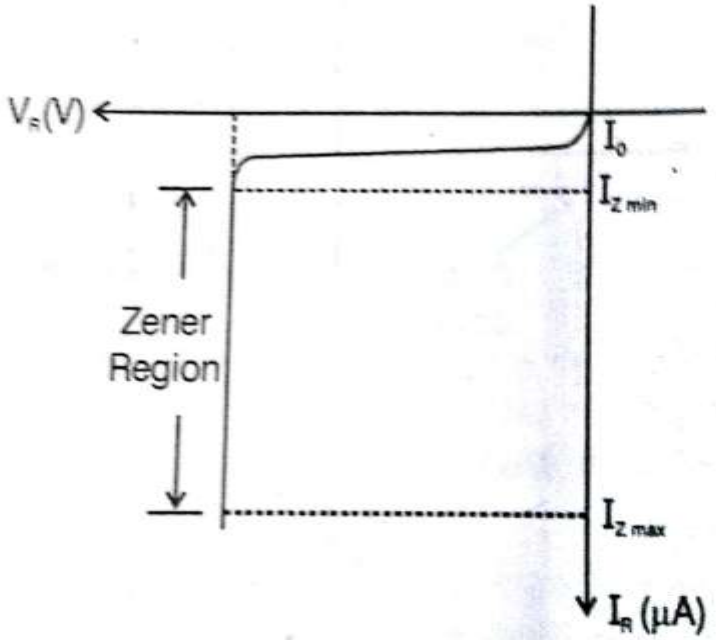
(4 M)
Characteristics: The colour: neither coherent nor monochromatic. (2 M)
Applications: (2 M)

- Visual signals where light goes more or less directly from the source to the human eye, to convey a message or meaning
- Illumination where light is reflected from objects to give visual response of these objects
- Measuring and interacting with processes involving no human vision.
- Narrow band light sensors where LEDs operate in a reverse-bias mode and respond to incident light, instead of emitting light

2.

Explain how zener diode is used as a regulator. (15 M) BTL 3
Answer: Page: 1.48- T.JOEL
Reverse bias of Zener diode: (3 M)
VI characteristics: (3 M)
Zener diode as voltage regulator waveform and expression: (9 M)
Zener diode when reverse biased behave as voltage regulator.
zener breakdown





3.

Explain the construction and working of Laser diode (15 M) (BTL 2)

Answer : Page: 1.41- T.JOEL

Definition: A **laser diode**, (**LD**), **injection laser diode** (**ILD**), or **diode laser** is a semiconductor device similar to a light-emitting diode in which the laser beam is created at the diode's junction. Convert electrical to light signal (3 M).

Construction and working: (5 M)

Characteristics: (2 M)

Types, explanation, advantages and disadvantages: (5 M)

Working: Electron hole recombination, Spotaneous emission, energy released.

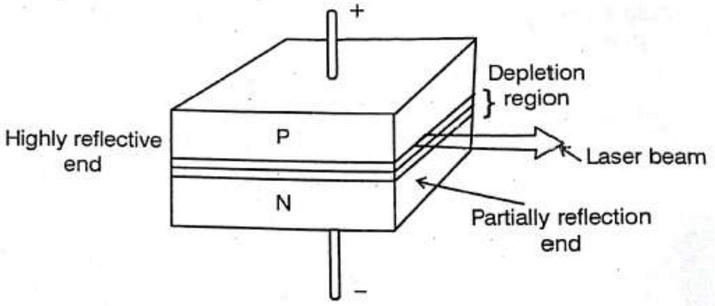
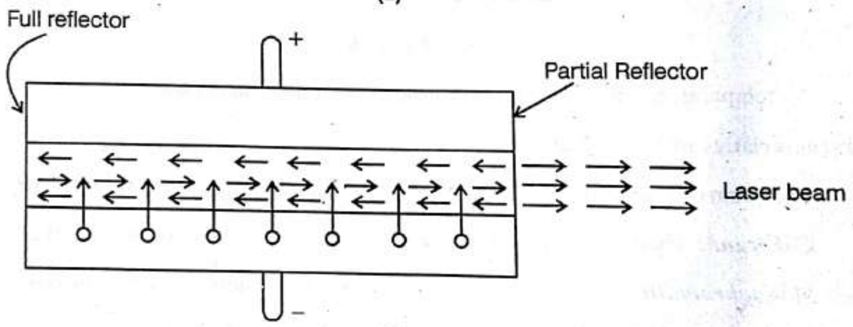
Applications: Fiber optic communications, barcode readers, laser pointers, CD/DVD/Blu-ray disc reading/recording, laser printing, laser scanning and light beam illumination.

Categories:

1. Surface emitting laser diodes
2. Edge emitting laser diodes

Made of gallium arsenide

Characteristics: Coherant, Monochromatic, Collimated.

	 **(a)**  **(b)**
4.	**An AC supply of 230 V is applied to a HWR circuit through transformer of turns ratio 5:1. Assume the diode is an ideal one. The load resistance is 300 Ω. Find a) d.c output voltage b)PIV c) maximum and d) average values of power delivered to the load. e) rms value of voltage (13 M)** BTL 3 **Answer : Page: 1.34- T.Joel** a) The transformer secondary voltage = 230/5 = 46 V (3 M) Maximum value of secondary volt, V_m= √2 x 46 = 65 V d.c output voltage V_{dc}= V_m/π = 20.7 V b) PIV of the diode= V_m = 65 V (2 M) c) Maximum value of load currents, I_m= V_m/R_L = 0.217 A Maximum power delivered to the load = 14.1 W (3 M) d) The average value of load current I_{dc}= V_{dc}/R_L= 0.069 A Average value of power delivered to the load = 1.43 W (3 M) e)rms value of voltage= Vm/2 = 65/2 = 32.5 V (2 M)
5.	**A 230 V, 60 Hz voltage is applied to the primary of a 5:1 step down center tap transformer used in a full- wave rectifier having a load of 900 Ω. If the diode resistance and secondary coil resistance together has a resistance of 100 Ω, determine a) dc voltage across the load b) dc current flowing through the load c) dc power delivered to the load d) PIV across each diode and e) ripple voltage and its frequency.(15 M)** BTL 3 **Answer : Page: 1.36- T.Joel** a) dc voltage across the load = 20.7 V (3 M) b) dc current flowing through the load =20.7 mA (3 M) c) dc power delivered to the load = 0.386 W (3 M) d) PIV across each diode= 65 V (3 M) e) Ripple voltage = 10.05 V (3 M)

	Frequency of ripple voltage = 120 Hz

UNIT II TRANSISTORS AND THYRISTORS

BJT, JFET, MOSFET- structure, operation, characteristics and Biasing UJT, Thyristors and IGBT - Structure and characteristics.

PART * A

Q.No.	Questions
1	**Exhibit the relation between the 'currents of a transistor'?** (BTL 1) $I_E = I_B + I_C$
2	**List the types of circuit connections known as configurations, for operating a transistor.** (BTL 1) • Common-Base (CB) • Common-Emitter (CE) • Common-Collector (CC)
3	**What is the relation between α and β of a transistor?** (BTL 1) $\alpha = \frac{\beta}{\beta + 1}$
4	**Identify the regions of BJT when used as a switch.** (BTL 1) Saturation and cut-off regions.
5	**Why must the base be narrow for the transistor (BJT) action ?** (BTL 2) Beta (β) is the ratio of I_C to I_B .I_B becomes less if the base width is narrow. Higher value of β can be obtained with lower value of base current.
6	**Elucidate the value of cut-in voltage for a BJT. (**BTL 1) For Silicon BJT - 0.7V For Germanium - 0.3V
7	**Why an ordinary transistor is called bipolar ?** (BTL 2) Because the transistor operation is carried out by two types charge carriers— majority and minority carriers.
8	**Why transistor (BJT) is called current controlled device ?** (BTL 2) The output voltage, current or power is controlled by the input current in a transistor. So , it is

	called the current controlled device.
9	**What are "emitter injection efficiency" and "base transport factor" of a transistor?** (BTL 1) The ratio of current of injected carriers at emitter junction to the total emitter current is called the emitter injection efficiency. Transport factor, $\beta = I_c/I_B$
10	**State why collector is made larger than emitter and base.** (BTL 2) Collector is made physically larger than emitter and base because collector is to dissipate much power.
11	**Why CE configuration is most popular in amplifier circuits?** (BTL 2) CE configuration is most popular in amplifier circuits because its current, voltage and power gains are quite high and the ratio of output impedance and input impedance are quite moderate.
12	**Why is CC configuration seldom used?** (BTL 2) CC configuration has its voltage gain is always less than unity, hence it is seldom used.
13	**What is the typical value of h_{ie}?** (BTL 2) The typical value of h_{ie} is 1 KΩ
14	**Which of the BJT configuration is suitable for impedance matching application and why?** (BTL 2) CC configuration is suitable for impedance matching applications because of very high input impedance and low output impedance.
15	**What are the tools used for small signal analysis of BJT?** (BTL 2) i. h – Parameter circuit model. ii. z – Parameter circuit model. iii. y – Parameter circuit model. iv. Transconductance parameter circuit model. v. Physical model. vi. T-model.
16	**What is the significance of I_{CBO} and I_{CO}?** (BTL 2) I_{CBO} is the leakage current from the collector to base with emitter open. I_{CO} is the leakage current from collector to emitter with base open ($I_{CO} = I_{CEO}$).
17	**Differentiate between FET and BJT (any two).** (BTL 4)

FET	BJT
Unipolar device (that is current conduction by only one type either by electron or hole)	Bipolar device (that is current conduction by both electrons and hole)
High input impedance due to reverse bias	Low input impedance due to forward bias
Gain is characterized by transconductance gain.	Gain is characterized by voltage
Low noise level	High noise level.

18	**State the biasing conditions to operate transistor in active region.** (BTL 1) Emitter-base junction has to be forward biased and collector-base junction to be reverse biased.
19	**What is thermal runaway?** (BTL 1) The power loss in transistor is primarily at the collector junction because the voltage there is high compared to the low voltage at the forward biased emitter junction. If the collector current increases, the power developed tends to raise the junction temperature. This causes an increase in β and α further increase in collector current in temperature may occur resulting in “thermal run away.”
20	**Define bipolar junction transistors.** (BTL 1) These devices operate with both holes and electrons and hence are called bipolar junction.
21	**Why FET’s are so called? (or) Why FETs are voltage controlled devices?** (BTL 2) The output characteristics of a FET can be controlled by the applied electric field (voltage) and hence the name FET and are voltage controlled devices.
22	**Define pinch-off voltage in a JFET.** (BTL 1) The value of VDS at which the channel is pinched-off, i.e., all the free charges from the channel get removed, is called the pinch-off voltage in a JFET.
23	**List the parameters that control the pinch-off voltage of JFET.** (BTL 1) Electron charge, donor/acceptor concentration density, permittivity of channel material and half-width of channel bar.
24	**Why MOSFET is called IGFET?** (BTL 2) MOSFET is constructed with the gate terminal insulated from the channel. So it is called as insulated gate FET or IGFET

25 **Name the factors which make the JFET superior to BJT?** (BTL 1)

High input impedance, low output impedance and low noise level.

26 **Define pinch off voltage.** (BTL 1)

When the reverse bias is increased above a certain value, the effective width of the channel decreases, the depletion region or the space charge region widens, reaching further into the channel and restricting the passage of electrons from the source to drain. Finally at a certain gate to source voltage $V_{GS} = V_P$.

27 **Write the relative disadvantages of an FET over that of a BJT**. (BTL 1)

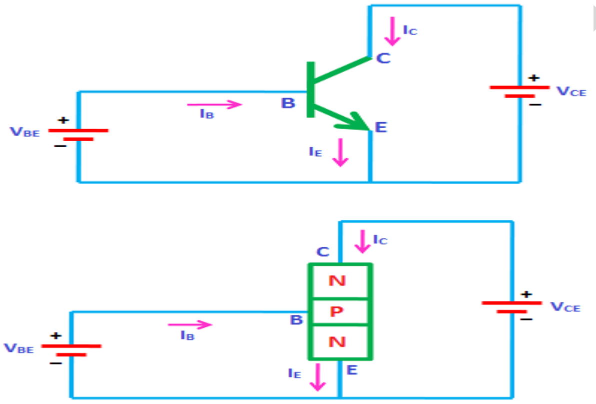
The gain bandwidth product in case of a FET is low as compared with a BJT.

The category, called MOSFET, is extremely sensitive to handling therefore additional precautions have to be considered while handling.

PART * B

1. **Draw and explain the input and output characteristics of a BJT in CE configuration. Compare the performance of CE configuration with other characteristics. (13 M) (NOV. 2009, MAY 2011, NOV 2011, MAY 2013)** BTL 2

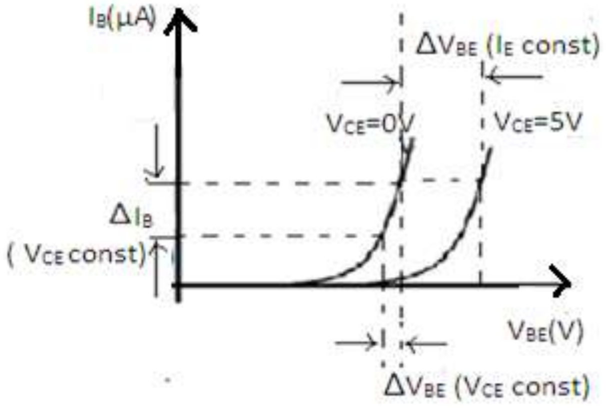
Answer : Page: 2.11- T.Joel



Common emitter configuration (3 M)

Input characteristics: (4 M)

- ➢ Output voltage $\mathbf{V_{CE}}$ - maintained constant, input voltage $\mathbf{V_{BE}}$, set at several convenient levels. For each level of input voltage, the input current $\mathbf{I_B}$.
- ➢ $\mathbf{I_B}$ plotted versus $\mathbf{V_{BE}}$, common-base input characteristics.



Output characteristics: (4 M)

- Base current I_B constant, output voltage V_{CE} , collector current I_C are recorded
- For each I_B level, I_C plotted versus V_{CE}.

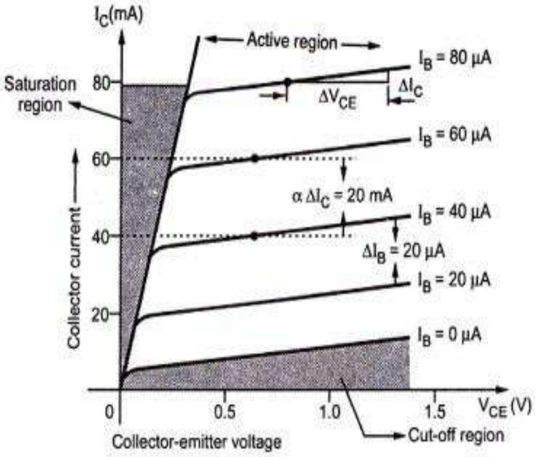


Fig 3.3: Output characteristics of the transistor in CE configuration

Characteristic	Common Base	Common Emitter	Common Collector
Input Impedance	Low	Medium	High
Output Impedance	Very High	High	Low
Phase Shift	0^o	180^o	0^o

Voltage Gain	High	Medium	Low
Current Gain	Low	Medium	High
Power Gain	Low	Very High	Medium

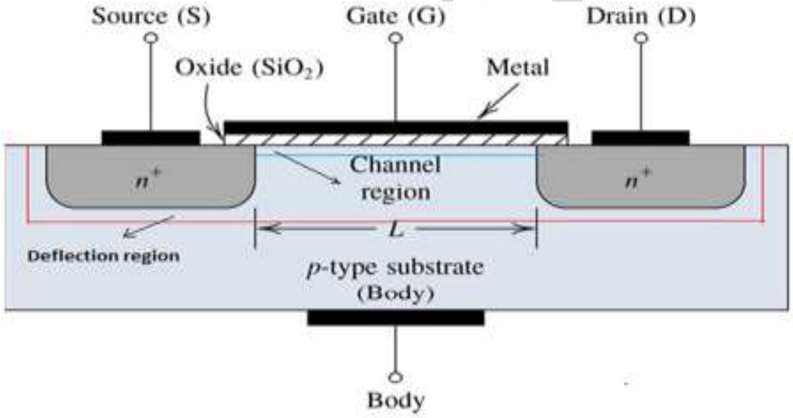
(2 M)

2. **Explain in detail the construction and working principle of depletion MOSFET. Also, explain how depletion MOSFET can act both in enhancement mode and depletion mode. (13 M) [MAY, NOV 2011, MAY 2013)** BTL 3

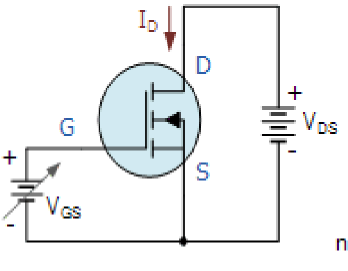
Answer : Page: 2.40- T.Joel

Construction: (5 M)

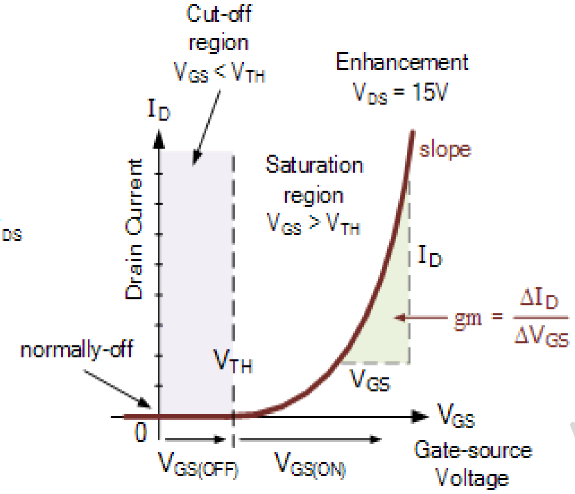
- Terminals: Source, Gate and Drain
- Heavily Doped with n type material on a p type layer.
- A metal oxide layer above the p type substrate.
- The electrons flow from source to drain through the channel

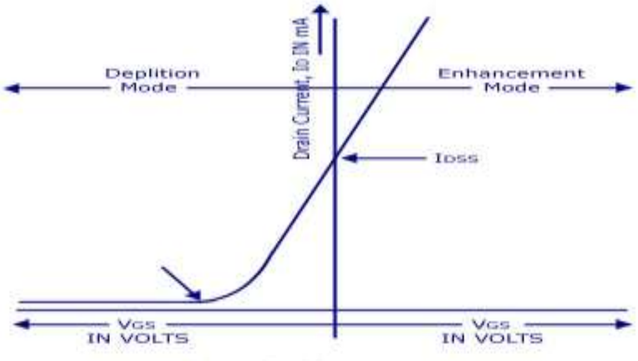


Drain characteristics and transfer characteristics: (8 M)



eMOSFET test circuit





Transfer Characteristics

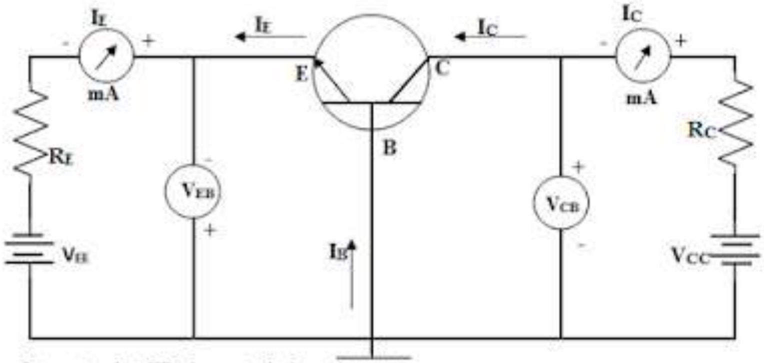
www.CircuitsToday.com

3. **Explain the input and output characteristics in CB configuration and explain the early effect. (13 M) [NOV 2009, NOV 2010, NOV 2011]** BTL 2

Answer : Page: 2.6- T.Joel

CB configuration diagram and explanation, early effect: (5 M)

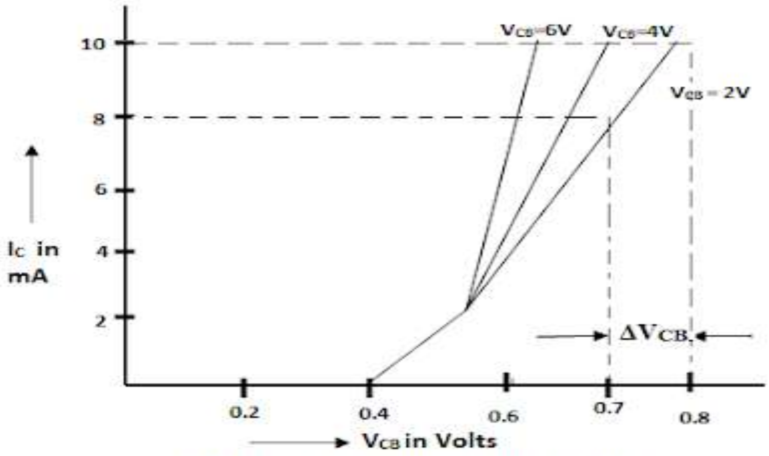
Input and output characteristics: (8 M) (Diagram- each 2, explanation- each 2)



Setup to plot CB charscteristic

Input characteristics:

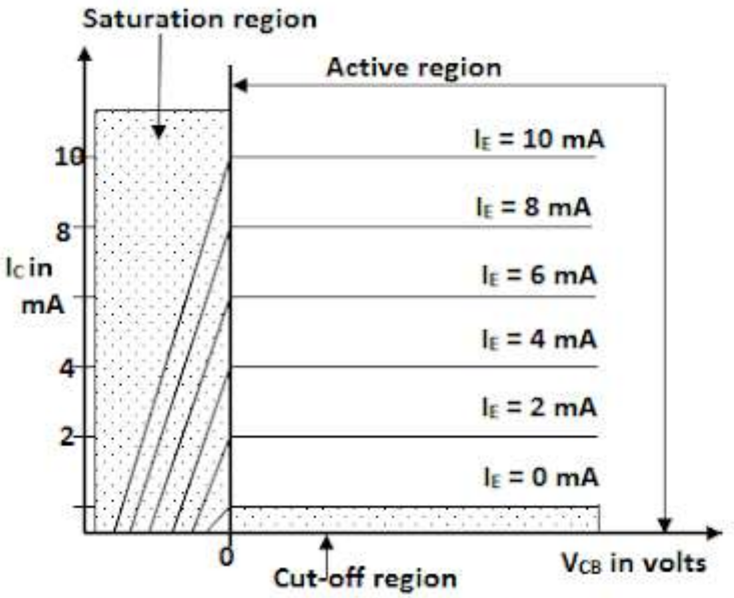
- The output(CB) voltage, maintained constant, input voltage (EB) set at several convenient levels.
- For each level of input voltage, the input current $\mathbf{I_E}$ is recorded.
- $\mathbf{I_E}$ plotted versus $\mathbf{V_{EB}}$ to give the common-base input characteristics.



Input Characteristic of CB configuration

Output characteristics:

- The emitter current $\mathbf{I_E}$ held constant , fixed levels. For each fixed value of $\mathbf{I_E}$ **,** the output voltage $\mathbf{V_{CB}}$ is adjusted in convenient steps and the corresponding levels of collector current $\mathbf{I_C}$ are recorded
- For each fixed value of $\mathbf{I_E}$, $\mathbf{I_C}$ is almost equal to $\mathbf{I_E}$ and appears to remain constant when $\mathbf{V_{CB}}$ is increased



Output characteristic of common base configuration

Early effect:

- The variation in the effective width of the base in a bipolar junction transistor (BJT), variation in the applied base-to-collector voltage.
- A greater reverse bias across the collector–base junction, increases the collector–base depletion width, decreasing the width of the charge carrier portion of the base.

4. **Explain the construction of N-channel JFET, also explain the drain and transfer characteristics of the same. (13 M) [Nov 2010, May 2012]** (BTL 2)

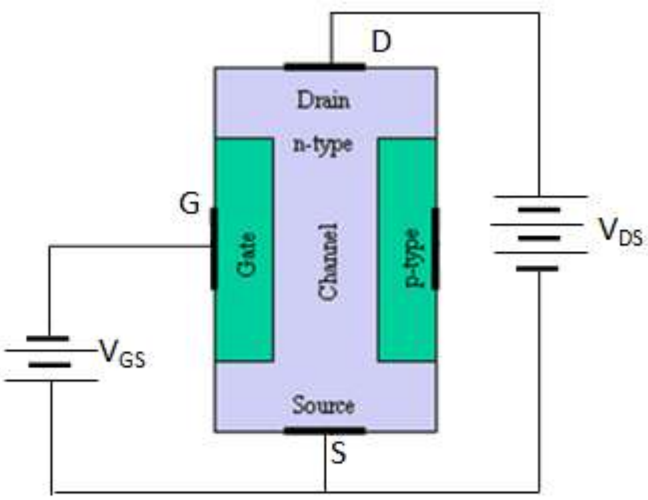
Answer : Page: 2.28- T.Joel

Construction and working: (5 M)

Drain and transfer characteristics: (8 M)

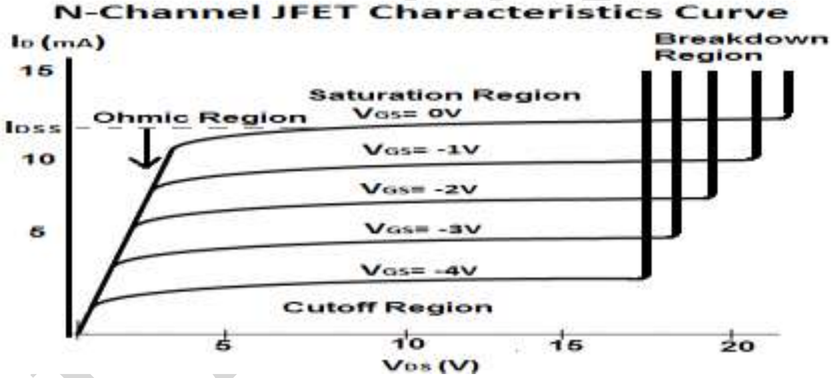
Construction and characteristics curve:

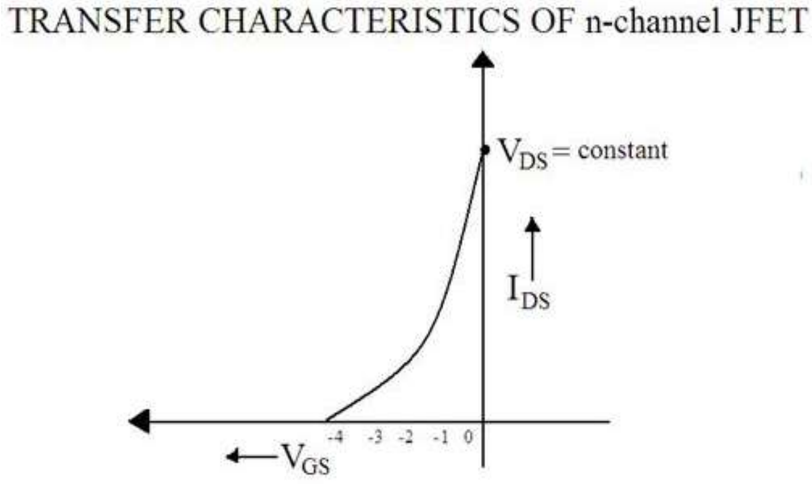
- Terminals: Source, Gate and Drain.
- The region forming diodes are connected internally and a single wire is taken out in the form of a terminal called Gate.



Drain characteristics and Transfer characteristics.

FET Type	V GS = (-)	V GS = 0	V GS = (+)
n-channel JFET	OFF	ON	ON




TRANSFER CHARACTERISTICS OF n-channel JFET

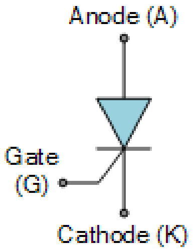
PART*C

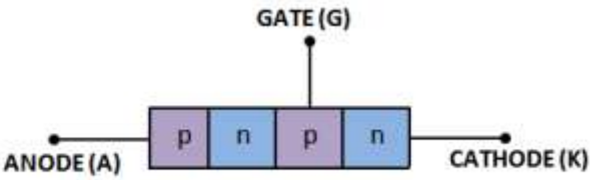
1. **Sketch the four layer construction of an SCR and the two transistor equivalent circuit. Explain the device operation. (13 M) [Nov 2015]** BTL 2

Answer : Page: 2.184- T.Joel

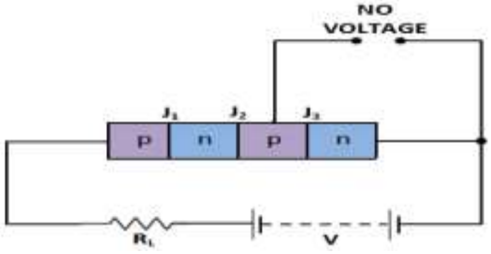
SCR construction: (3 M)

- PNPN device
- Three terminals: Anode, cathode and Gate.

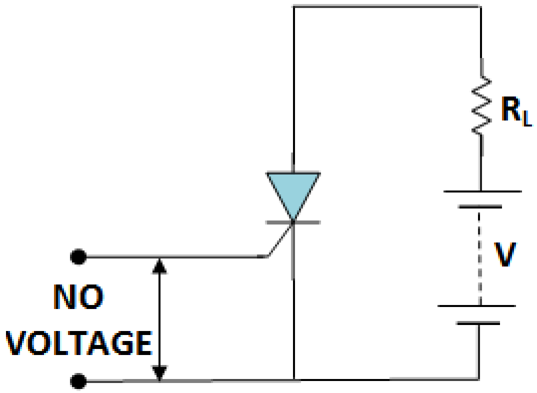




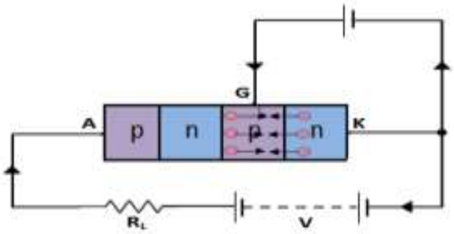
Working: (3M)

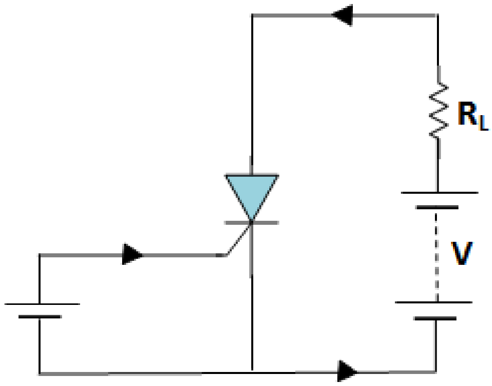


When Gate is open

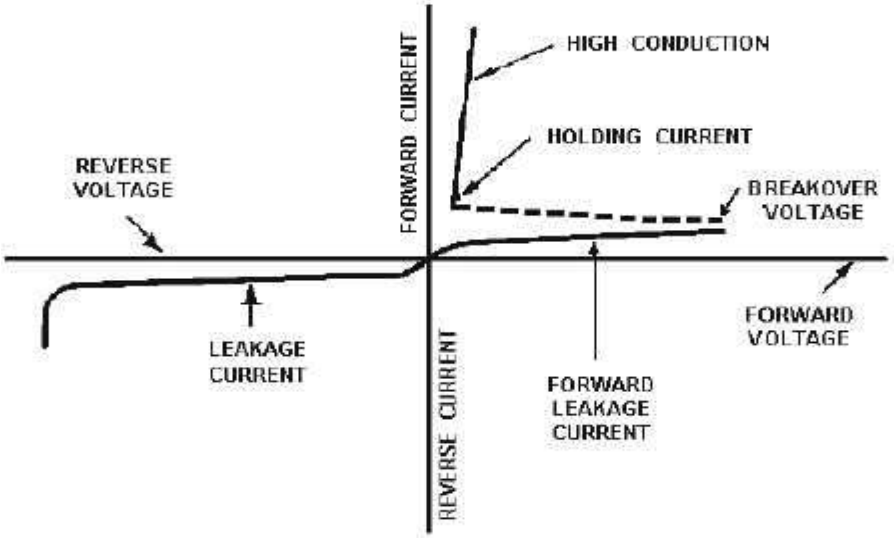


When gate is positive with respect to cathode



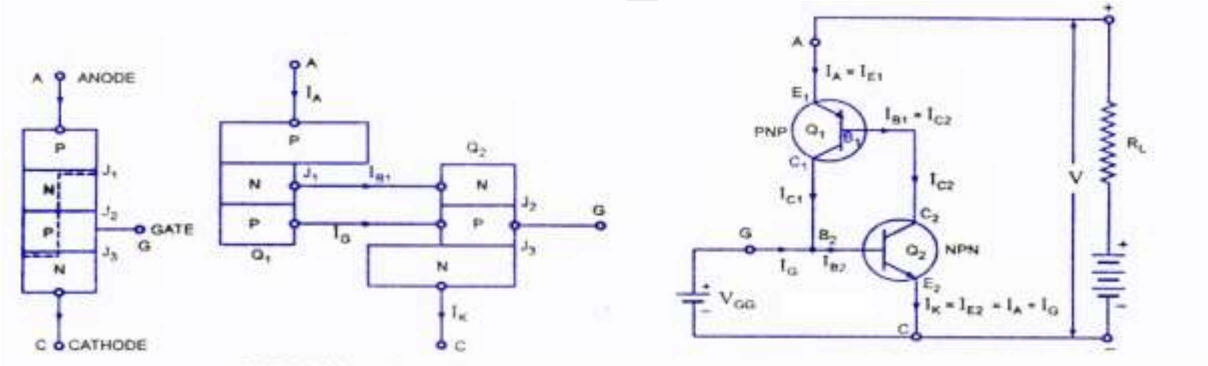


Characteristics curve: (3 M)



- Latching current, Holding current, high conduction, break-over voltage, forward leakage current, leakage current.

Two transistor model of SCR: (3 M)



SCR Split-up into Two Transistors *Two Transistor Equivalent Circuit of An SCR*

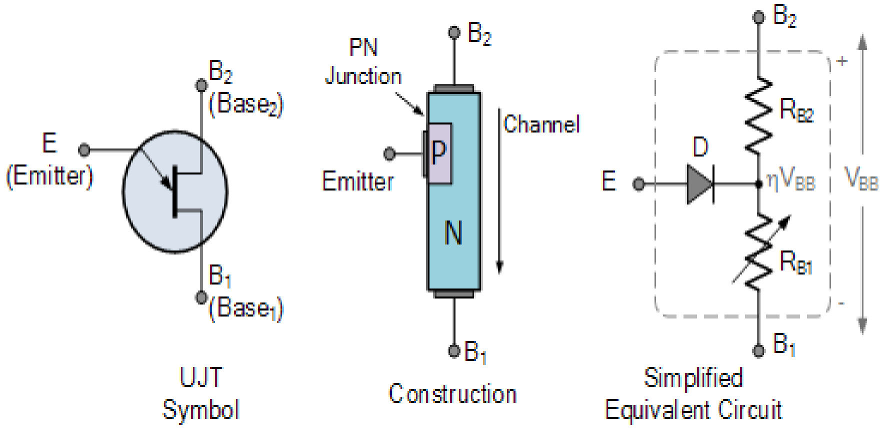
Two Transistor Model of An SCR

2. **Describe the operation of UJT and its emitter characteristics. (7 M) [May 2010, Nov 2015]** BTL 2

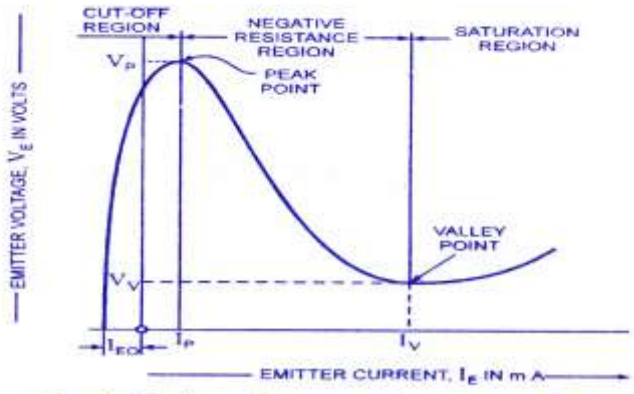
Answer : Page: 2.174- T.Joel

UJT construction: (3 M)

- Terminals: Base 1, Base 2 and Emitter
- Resistivity of the base material is very high.



Characteristics curve: (4 M)



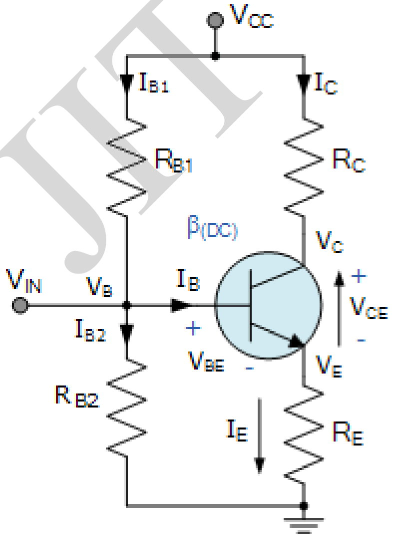
Static Emitter-Characteristic For a UJT

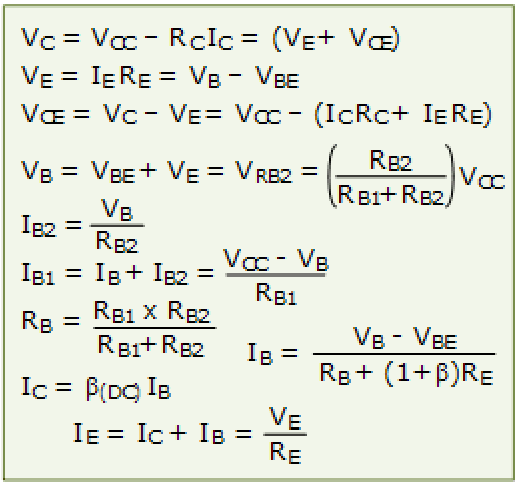
3. **Explain the emitter bias method used in transistor amplifier circuits. (5 M)** BTL 3

Answer : Page: 2.106- T.Joel

Emitter bias diagram- (2 M)

Derivation- (3 M)





$$V_C = V_{CC} - R_C I_C = (V_E + V_{CE})$$

$$V_E = I_E R_E = V_B - V_{BE}$$

$$V_{CE} = V_C - V_E = V_{CC} - (I_C R_C + I_E R_E)$$

$$V_B = V_{BE} + V_E = V_{RB2} = \left(\frac{R_{B2}}{R_{B1} + R_{B2}}\right) V_{CC}$$

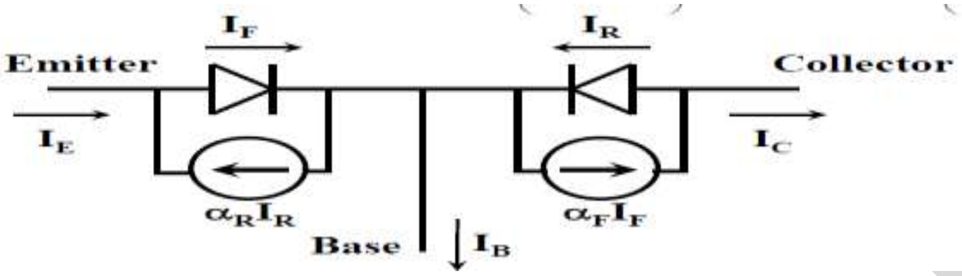
$$I_{B2} = \frac{V_B}{R_{B2}}$$

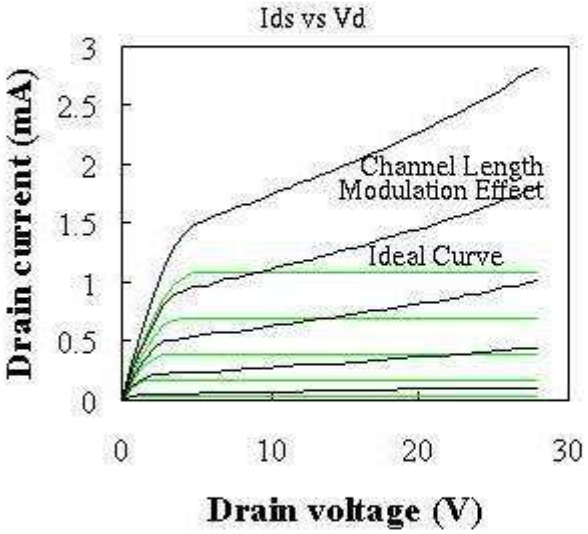
$$I_{B1} = I_B + I_{B2} = \frac{V_{CC} - V_B}{R_{B1}}$$

$$R_B = \frac{R_{B1} \times R_{B2}}{R_{B1} + R_{B2}} \qquad I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta)R_E}$$

$$I_C = \beta_{(DC)} I_B$$

$$I_E = I_C + I_B = \frac{V_E}{R_E}$$

4.	**Draw the eber molls model of PNP transistor and explain its significance. (6 M)** BTL 3 Eber molls model: Two diodes connected back to back cannot act as a transistor. (1 M)  (2 M) $I_E = I_{F0}\left(e^{V_{BB}/V_T} - 1\right) - \alpha_R I_{R0}\left(e^{V_{BC}/V_T} - 1\right)$ $I_C = \alpha_F I_{F0}\left(e^{V_{BE}/V_T} - 1\right) - I_{R0}\left(e^{V_{BC}/V_T} - 1\right)$ (3 M)
5.	**i) A transistor with I_B= 100 µA, and I_C= 2 mA, find,** **a) ß of transistor,** **b) α of transistor,** **c) emitter current I_E,** **d) if I_B changes by 25 µA and I_C changes by 0.6 mA. Find the new values of ß. (10 M)** BTL 3 **Answer : Page: 2.29- Salivahanan** ß= 20 α= 0.952 I_E= 2.01 mA new values of ß= 20.08 **ii) Justify transistor as an amplifier. (5 M)** BTL 3 Transistor in active region- amplifier. (2 M) Input side- forward bias, output side- reverse bias. (2 M) Current gain, voltage gain, amplification factor. (1 M)
6.	**Discuss the effect of channel length modulation. (6 M)** BTL 3



(2 M)

- MOSFET, increase in depletion layer width at the drain , drain voltage is increased, a shorter channel length and increased drain current,
- Channel length of MOSFET is decreased and MOSFET operated beyond channel pinch-off, the relative importance of pinch-off length with respect to physical length increased. (2 M)
- This effect included in saturation current as:

$$I'_{DS_{Sat}} = \frac{I_{DSSat}}{1 - \frac{\Delta L}{L}} \qquad (6.31)$$

$$I_{DSSat} = \mu_n \frac{W}{L} C_{ox} \frac{(V_{GS} - V_T)^2}{2} (1 + \lambda V_{DS}) \qquad (6.32)$$

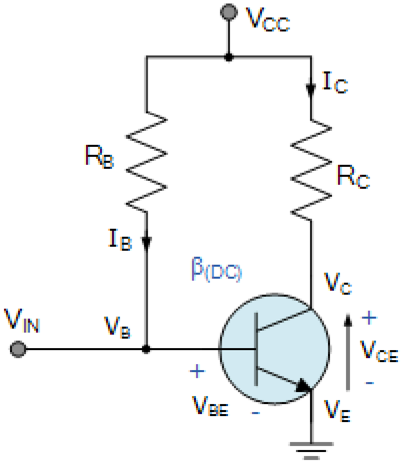
ƛ = Channel length modulation co-efficient. (2 M)

7. **Explain the method of fixed biasing and derive the value of stability factor and explain its advantages. (8 M)** BTL 3

Answer : Page: 2.68- T.Joel

Fixed biasing circuit diagram: (2 M)

Derivation: (2 M)



$$V_C = V_{CC} - (I_C R_C)$$
$$V_{CE} = V_C - V_E$$
$$V_E = 0v$$
$$V_B = V_{BE}$$
$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$
$$I_C = \beta_{(DC)} I_B$$
$$I_E = (I_C + I_B) \cong I_C$$

Stability factor, S= 1+ ß (2 M)

Advantages: (2 M)

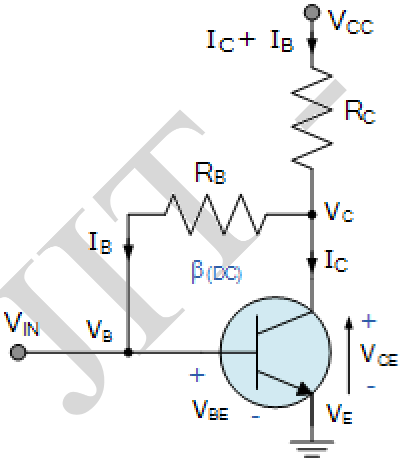
- Simplicity
- Small number of components required
- if supply voltage large compared to V_{BE}, then base current become independent of $V_{BE.}$

8. **Explain the method of collector to base bias and derive the value of stability factor and explain its advantages. (8 M)** BTL 3

Answer : Page: 2.92- T.Joel

Feedback biasing circuit diagram: (2 M)

Derivation: (2 M)



$$V_C = V_{CC} - R_C(I_C + I_B)$$
$$V_E = 0v$$
$$V_B = V_{BE}$$
$$I_B = \frac{V_C - V_B}{R_B}$$
$$I_C = \beta_{(DC)} I_B$$
$$I_E = (I_C + I_B) \cong I_C$$

Stability factor, S= $\frac{1+ß}{1+ß(\frac{Rc}{Rc+RB})}$ (2 M)

Disadvantages: (2M)

- Not suitable for transformer coupled amplifiers, dc load resistance in collector circuit is

	very small.
9.	**State the advantage of self bias over other types of biasing. (4 M)** BTL 2 ➢ Fixed bias- not used for biasing base, poor stability. ➢ Collector to base bias- R_C is very small, equal to fixed bias. ➢ Self bias, S= 1, good stability.
10.	**For a voltage divider bias with the following parameters, R_1= 56 kΩ, R_2= 12.2 kΩ, R_C= 2 kΩ, R_E= 400 Ω, V_{CC}= 10 V, V_{BE}(on)= 0.7 V and ß=150. (8 M)** BTL 3 **Answer : Page: 190- Salivahanan** $R_{TH} = R_1 \parallel R_2$ = 10 kΩ (2 M) V_{TH} = 1.79 V (2 M) I_{BQ}= 15.5 µA (2 M) Q point is V_{CEQ} = 4.426 V and I_{CQ}= 2.32 (2 M)

UNIT III AMPLIFIERS

BJT small signal model – Analysis of CE, CB, CC amplifiers- Gain and frequency response –MOSFET small signal model– Analysis of CS and Source follower – Gain and frequency response- High frequency analysis.

PART * A

Q.No	Questions
1	**Why h-parameters are called hybrid parameters?** BTL 2 h parameters are so called because they have different units are mixed with other parameters.
2	**What is the typical value of hie?** BTL 1 1 kΩ
3	**Write the equation for the output voltage and voltage gain for CS amplifier.** BTL 1 The output voltage is given by $V_o = \frac{-R_D}{R_D + r_d} \mu V_{gs}$ Where µ is the amplification factor, R_d is the drain resistance

$V_{gs} = V_i$, the input voltage

The voltage gain for CS amplifier is given by

$$\mathbf{Av = (V_o|V_i) = \frac{-\mu R_D}{R_D + r_d}}$$

4 **Write the equations for the output voltage and voltage gain for CD amplifier.** BTL 1

The output voltage is given by

$$\mathbf{V_o = \frac{\mu\, R_s V_{gd}}{(\mu + 1)R_s + r_d}}$$

Where $V_{gd} = V_i$, the input voltage.

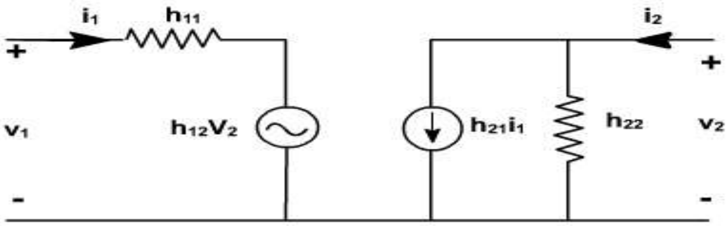
The voltage gain for CD amplifier is given by

$$\mathbf{A_v = \frac{\mu\, R_s}{(\mu + 1)R_s + r_d}}$$

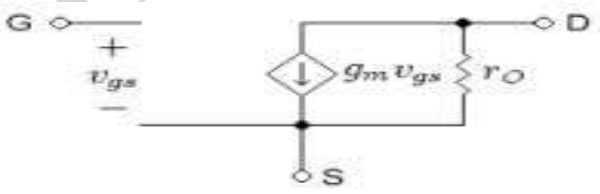
5 **What are the benefits of h-parameters?** BTL 1

- Real numbers at audio frequency
- Easy to measure
- Can be obtained from the transistor state characteristics curves
- Convenient to use in circuit analysis and design.

6 **Draw hybrid model of BJT. (MAY2015)** BTL 3

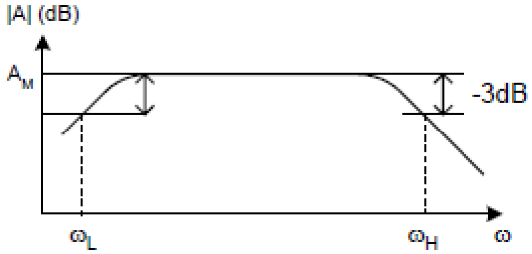
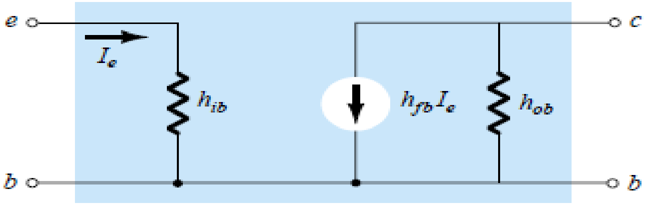
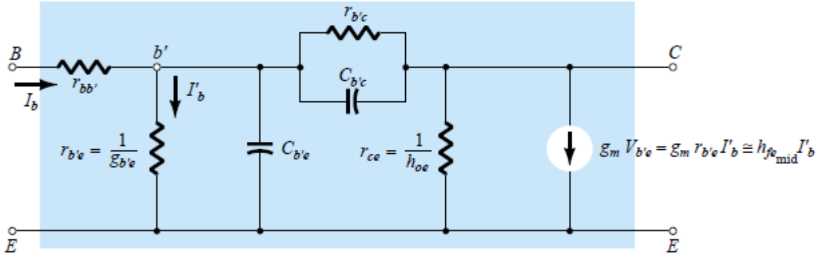


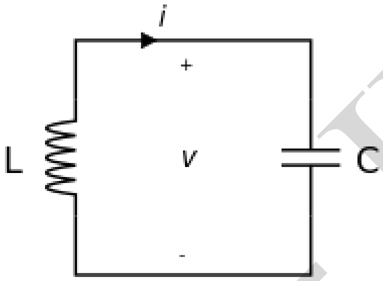
7 **Draw High frequency model of JFET** BTL 3

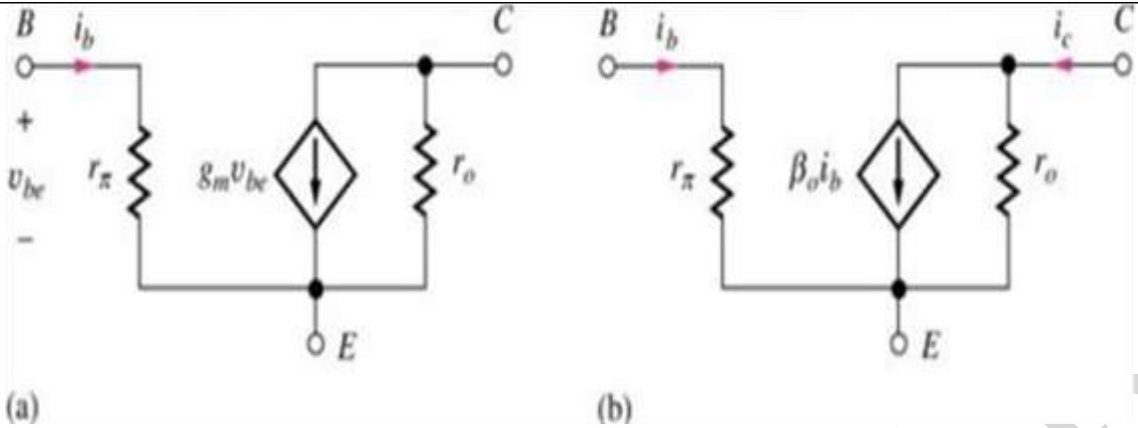
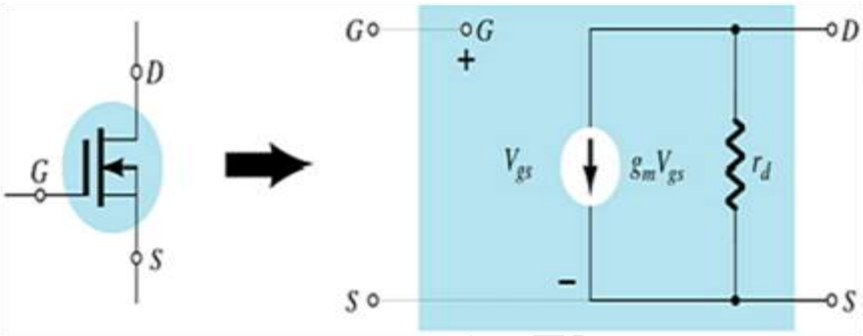
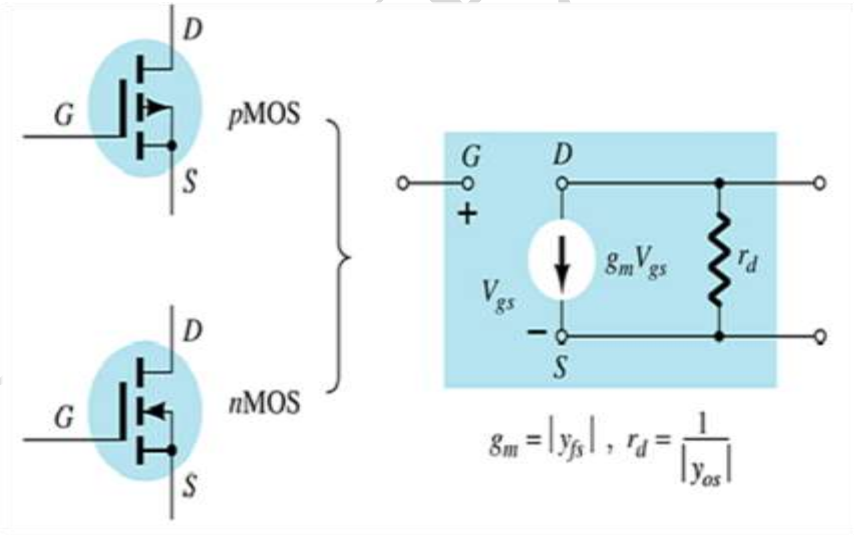


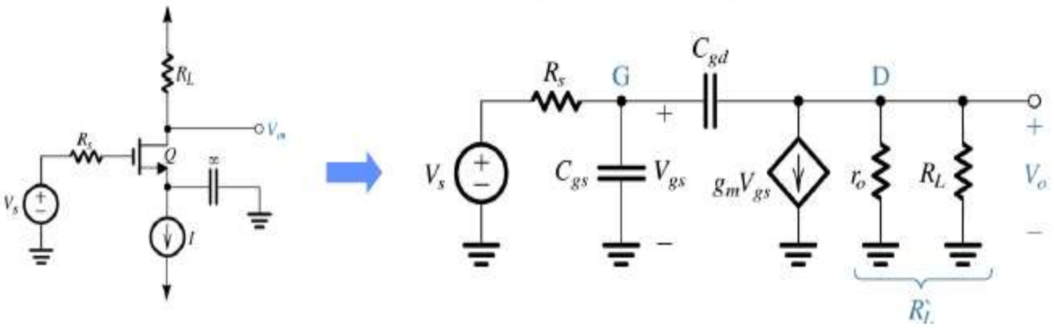
8 **Define transistor action.** BTL 1

A transistor consists of 2 coupled PN junctions. The base is a common region to both junctions and makes a coupling between them. Since the base regions are smaller, a significant interaction

	between junctions will be available. This is called transistor action.
9	**Draw the frequency response of an amplifier. (DEC 2007)** BTL 3 
10	**With small signal equivalent circuit, derive the input impedance of CB amplifier. (NOV 2005)** BTL 1  $h_{ie} = \beta r_e,$
11	**What is bandwidth of an amplifier?** BTL 1 The range of frequencies between the upper cut off frequency and lower cut off frequency is known as bandwidth
12	**Define f_T in a high frequency transistor.** BTL 1 It is the frequency at which short circuit CE current gain becomes unity.
13	**Draw the ac equivalent circuit of small signal HF common emitter amplifier (NOV 2006) or Draw the high frequency equivalent circuit of a BJT. (NOV 2004)** BTL 3 
14	**What are high frequency effects?** BTL 1 At high frequencies, the internal capacitance of the transistors C_{be} and C_{bc} will output voltage as well as reduces the circuit gain

15	**What is the effect of C_{be} on the input circuit of a BJT amplifier at high frequency?** BTL 1 The capacitor connected between input and output cause the variation of output voltage known as bypass capacitor
16	**Give the significance of coupling and bypass capacitor in Bandwidth of amplifiers.** BTL 1 At low frequency the bypass capacitor makes gain to lower value and at high frequency the coupling capacitor decreases the gain so at low and high frequencies the frequency response curves is varied and mid range of frequencies the gain is nearly constant.
17	**What is the need of coupling capacitors in amplifier design?** BTL 2 In amplifier design, the source and load cannot be subjected to a DC voltage or permitted to conduct DC current. To prevent the DC component of an amplifier, output voltage from producing DC current in the load, a capacitor is connected in series with the load. This capacitor is called coupling capacitor or blocking capacitor, because they block the flow of DC current.
18	**What is the need to go for simplified hybrid model?** BTL 2 The equivalent circuit of a transistor can be drawn using simple approximation by retaining its essential features. These equivalent circuits will aid in analyzing transistor circuits easily and rapidly.
20	**Draw the ideal tuned circuit and write its expression for resonant frequency.** BTL 3  $f_0 = \frac{1}{2\pi\sqrt{LC}}$
21	**What are amplifiers? Write its uses.** BTL 1 An amplifier is an electronic device that increases the voltage, current, or power of a signal. Amplifiers are used in wireless communication and broadcasting, and in audio equipment of all kinds. They can be categorized as either weak-signal amplifiers or power amplifiers. Transistors are used as audio amplifiers in a home stereo or PA system. RF high power generation for semiconductor equipement, to RF and Microwave applications such as radio transmitters.
22	**Draw the small signal model of BJT.** BTL 3

	
23	**Draw the D- Type MOSFET ac equivalent circuit.** BTL 3 
24	**Draw the ac equivalent circuit of E-type MOSFET** BTL 3 
25	**Draw the high frequency response of CS amplifier.** BTL 3



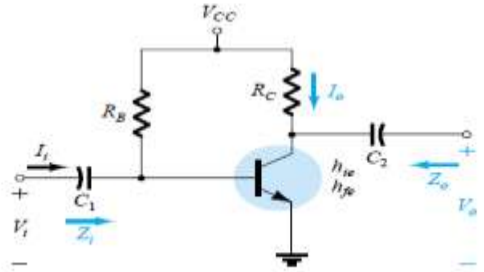
PART * B

1. **Draw the equivalent circuit of a CE amplifier with fixed bias using h- parameter model and derive the equation for input impedance, output impedance and voltage gain. (13 M)**

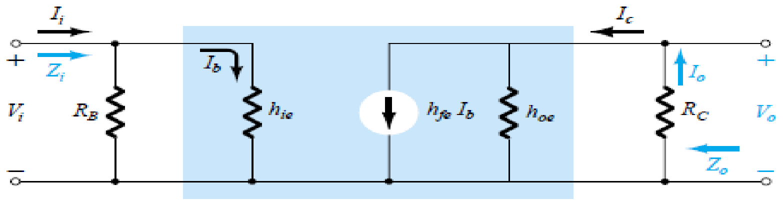
BTL 3

Answer: Page: 3.27- T.Joel

CE amplifier with fixed bias- (2 M)



Equivalent circuit: (3 M)



Derivation: (8 M) (each 2)

$$\boxed{Z_i = R_B \| h_{ie}}$$

$$Z_o = R_C \| 1/h_{oe}$$

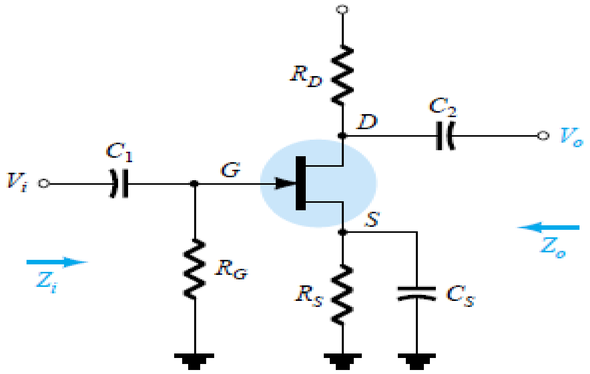
$$A_v = \frac{V_o}{V_i} = -\frac{h_{fe}(R_C \| 1/h_{oe})}{h_{ie}}$$

$$\boxed{A_i = \frac{I_o}{I_i} \cong h_{fe}}$$

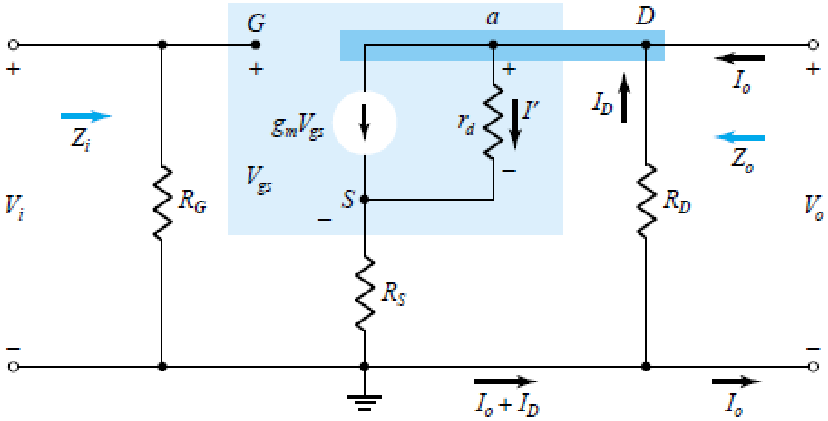
2. **Derive the expression for the voltage gain of CS amplifier. (13 M) [Nov 2014]** BTL 4

Answer: Page: 4 (annexure) - T.Joel

CS amplifier with fixed bias- (2 M)



Equivalent circuit: (3 M)



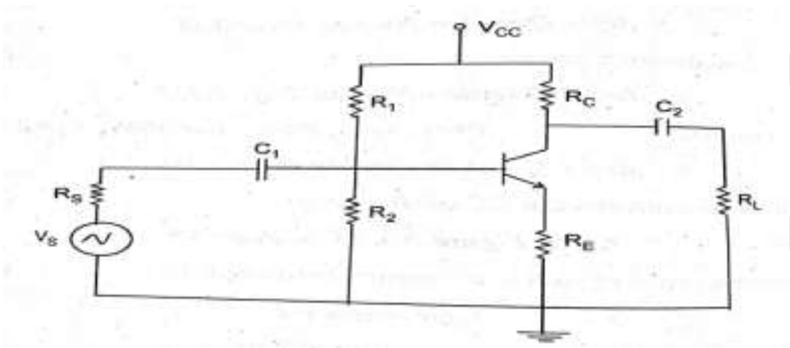
Derivation: (8 M)

$$I_D = g_m V_{gs} + \frac{V_o - V_{R_S}}{r_d}$$

$$I_D = \frac{g_m V_i}{1 + g_m R_S + \dfrac{R_D + R_S}{r_d}}$$

$$A_v = \frac{V_o}{V_i} = -\frac{g_m R_D}{1 + g_m R_S + \dfrac{R_D + R_S}{r_d}}$$

3. **Consider a single stage CE amplifier as shown in fig with R_s= 1 KΩ, R_1= 50 KΩ, R_2= 2 KΩ, R_C= 1 KΩ, R_L= 1.2 KΩ, h_{fe}= 1.1 KΩ, h_{oe}= 25 µA/V and h_{re}= 2.5 x $10^{\wedge-4}$. Find A_1, A_v, Z_i, A_{vs}, A_{1S} and Y_0. (13 M) [Nov 2007]** BTL 3



Answer: Page: 3.14- T.Joel

A_i= -49.32

R_i=1093 Ω

A_v= -24.61

A_{vs}= 10.1

A_{1s}= -14.29

4. **Give the guidelines for the analysis of transistor circuit for its small signal behavior. Explain with an example. (13 M)** BTL 3

Answer: Page: 3.12- T.Joel

- Draw the original circuit diagram
- Coupling capacitors and emitter bypass capacitor – replaced by short circuit.
- For ac analysis- replace dc source by short circuit.
- Mark the points B, C and E on the circuit diagram and locate these points as the start of equivalent circuit.
- Replace the transistor by its h- parameter model
- Example: Common emitter amplifier with emitter bias circuit
- Circuit with transistor replaced by h parameter equivalent

5. **Derive the low frequency response of BJT amplifier. (13 M)** BTL 3

Answer: Page: 519- Boylestad

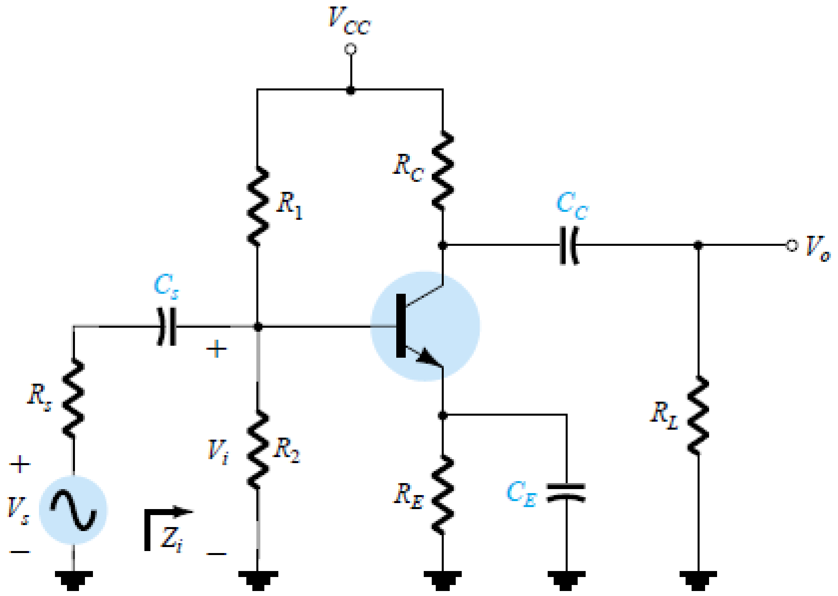


Diagram: (3 M)

Derivation: (10 M)

$$f_{L_s} = \frac{1}{2\pi\,(R_s + R_i)C_s}$$

$$V_i\big|_{\text{mid}} = \frac{R_i V_s}{R_i + R_s}$$

$$R_i = R_1 \| R_2 \| \beta r_e$$

$$f_{L_C} = \frac{1}{2\pi\,(R_o + R_L)C_C}$$

$$R_o = R_C \| r_o$$

$$f_{L_E} = \frac{1}{2\pi R_e C_E}$$

$$R_e = R_E \| \left(\frac{R'_s}{\beta} + r_e\right)$$

$$A_v = \frac{-R_C}{r_e + R_E}$$

PART * C

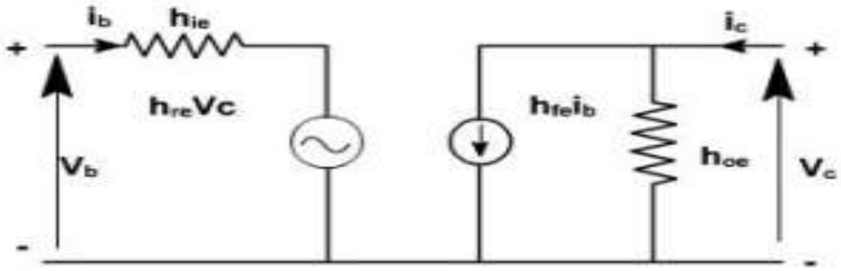
1. **Draw the hybrid model of CE amplifier and obtain its gain, input impedance and output impedance. Compare the performance of this CE amplifier with CC and CB configuration. (15 M) [Nov 2013, May 2015]** BTL 3

Answer: Page: 3.5-T.Joel

CE hybrid model: (3 M)

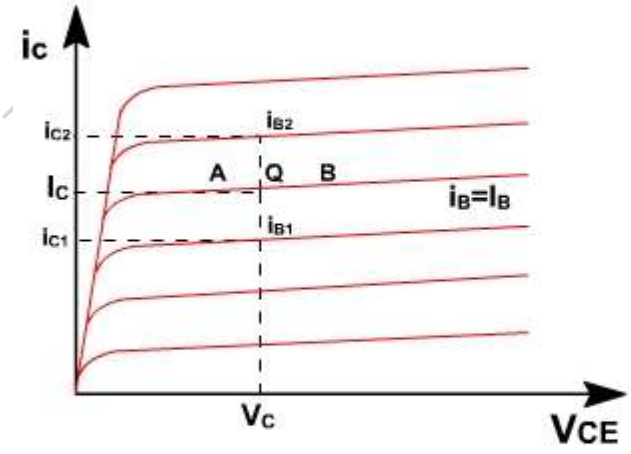
Derivation: (8 M)

Comparison: (4 M)



To determine the four h-parameters of transister amplifier, input and output characteristic are used. Input characteristic depicts the relationship between input voltage and input current with output voltage as parameter. The output characteristic depicts the relationship between output voltage and output current with input current as parameter.

$$h_{fe} = \left.\frac{\partial i_C}{\partial i_B}\right|_{V_C} = \frac{i_{C2} - i_{C1}}{i_{b2} - i_{b1}}$$

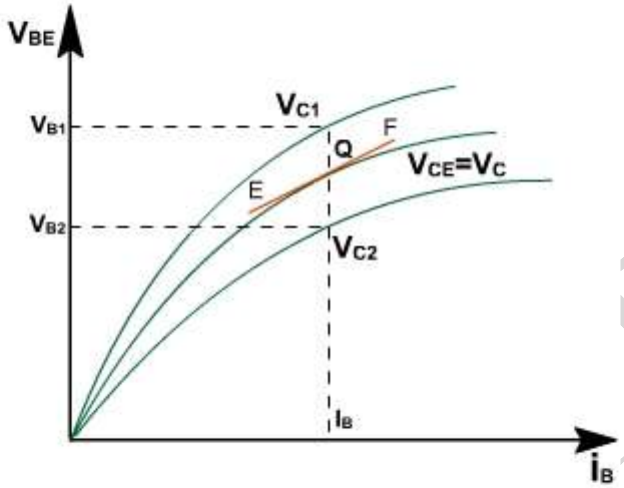


The current increments are taken around the quiescent point Q which corresponds to $i_B = I_B$ and to the collector voltage $V_{CE} = V_C$

$$h_{oe} = \left.\frac{\partial i_C}{\partial V_C}\right|_{i_B}$$

$$h_{ie} = \frac{\partial V_B}{\partial i_B} \approx \left.\frac{\Delta V_B}{\Delta i_B}\right|_{V_C}$$

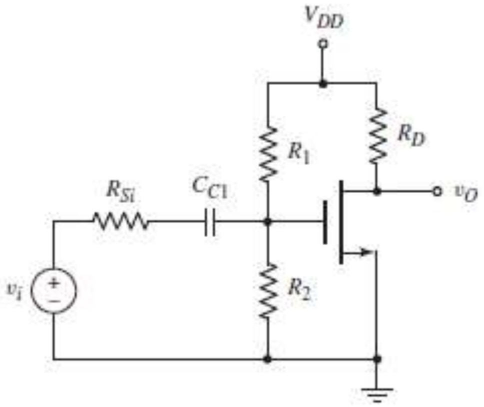
$$h_{re} = \frac{\partial V_B}{\partial V_C} = \left.\frac{\Delta V_B}{\Delta V_C}\right|_{I_B} = \frac{V_{B2} - V_{B1}}{V_{C2} - V_{C1}}$$



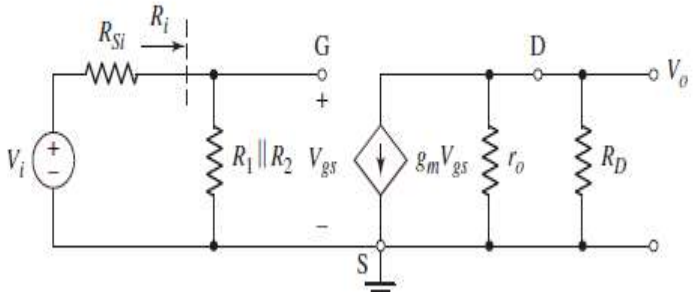
2. **i) With neat circuit diagram, perform ac analysis for common source using equivalent circuit NMOSFET amplifier. (8 M) [Nov 2015]** BTL 4

Answer:Page: 3.14- T.Joel

Common source circuit with voltage divider biasing (2 M)



Small signal Equivalent Circuit: (4 M)



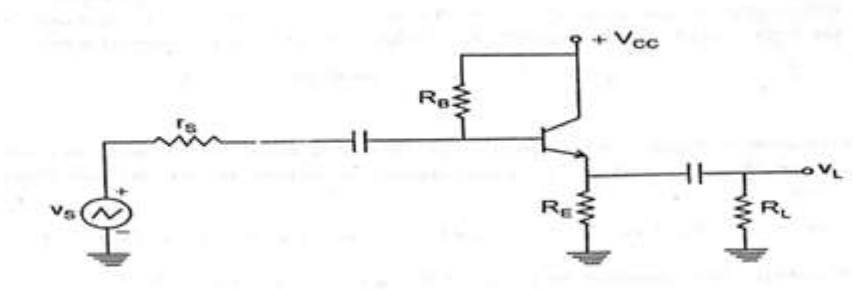
Voltage gain: (9 M)

$$A_V = -g_m(r_o||R_D)\left(\frac{R_1||R_2}{R_1||R_2 + R_{si}}\right)$$

3. **i) A CC amplifier shown in below Fig has V_{cc}= 15 V, R_B= 75kΩ and R_E=910Ω. The ß of the silicon transistor is 100 and the load resistor is 600 Ω. Find r_{in} and A_v. (8 M) [Nov 2015]** BTL 3

Formula: (4 M)

Steps and answer: (4 M)



Let h_{ie}= 1.1 kΩ

R_{in}= 50.39 kΩ

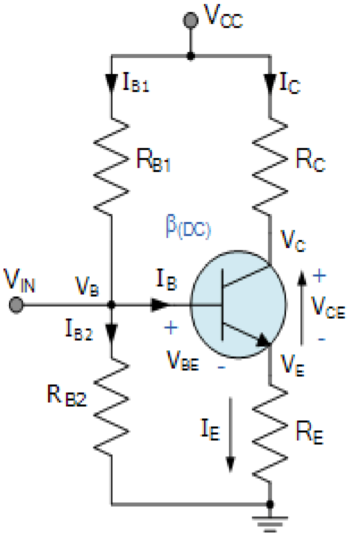
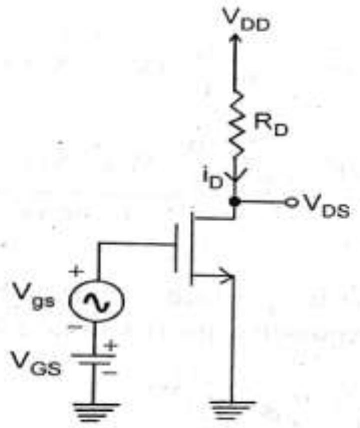
A_V= 0.99

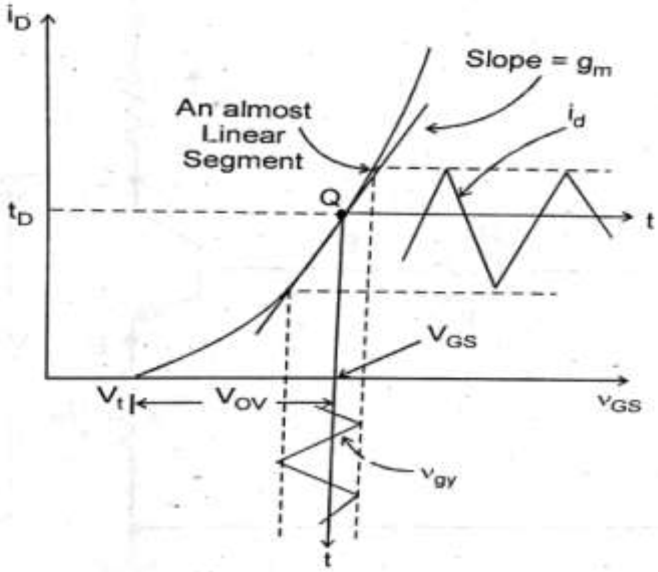
ii) Discuss the factors involved in the selection of I_C, R_C and R_E for a single stage common emitter BJT amplifier circuit, using voltage divider bias. (7 M) BTL 1

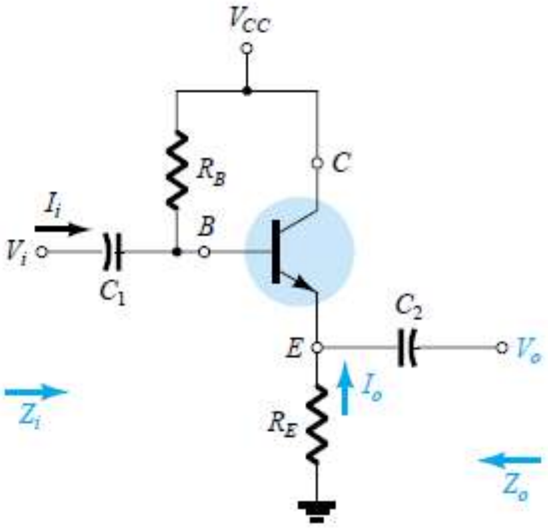
Answer : Pg. No: 2.106

Diagram: (3 M)

Explanation: (4 M)

	 $V_C = V_{CC} - R_C I_C = (V_E + V_{CE})$ $V_E = I_E R_E = V_B - V_{BE}$ $V_{CE} = V_C - V_E = V_{CC} - (I_C R_C + I_E R_E)$ $V_B = V_{BE} + V_E = V_{RB2} = \left(\frac{R_{B2}}{R_{B1}+R_{B2}}\right) V_{CC}$ $I_{B2} = \frac{V_B}{R_{B2}}$ $I_{B1} = I_B + I_{B2} = \frac{V_{CC} - V_B}{R_{B1}}$ $R_B = \frac{R_{B1} \times R_{B2}}{R_{B1}+R_{B2}}$ $I_B = \frac{V_B - V_{BE}}{R_B + (1+\beta)R_E}$ $I_C = \beta_{(DC)} I_B$ $I_E = I_C + I_B = \frac{V_E}{R_E}$
4.	**Describe about small signal MOSFET amplifiers (NMOS) and obtain the expression for its transconductance. (15 M) [May 2015]** BTL 3 **Answer: Page:6 (annexure): T.Joel** MOSFET amplifier diagrram: (3 M) Graph: (3 M) Expression: (9 M)  **Fig. 1**

	$g_m \equiv \left.\frac{\partial i_D}{\partial v_{GS}}\right\|_{v_{gs}=V_{GS}}$  Fig. 2 $\frac{v_d}{v_{gs}} = -g_m R_D$ Consequently, $A_v \propto g_m$.
5.	**With small signal equivalent circuit of emitter follower, derive its input impedance, A_V and output impedance.** **Answer: Page: 3.43- T.Joel** Output is taken from the emitter terminal of the transistor

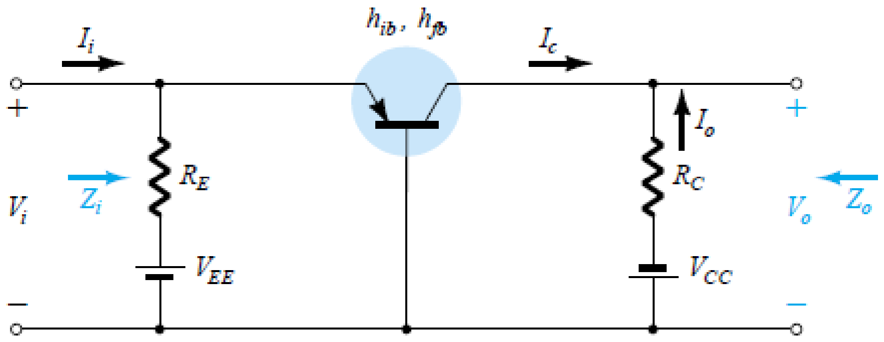


$$\boxed{Z_i = R_B \| Z_b}$$

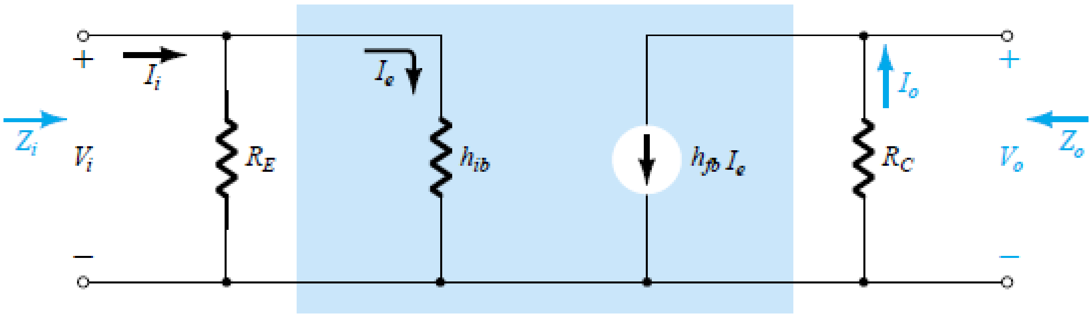
6. **Draw the hybrid model of CB amplifier and obtain its gain, input impedance and output impedance. (13 M)** BTL 3

Answer: Page: 385: Boylestad

CE configuration- Diagram: (2 M)



Approximate Hybrid Equivalent Circuit: (3 M)



Derivation: (8 M)

$$Z_i = R_E \| h_{ib}$$

$$Z_o = R_C$$

$$A_v = \frac{V_o}{V_i} = -\frac{h_{fb} R_C}{h_{ib}}$$

$$A_i = \frac{I_o}{I_i} = h_{fb} \cong -1$$

7. **Derive the input and output impedance of Source follower circuit using h parameter model. (8 M)** BTL 3

Answer: Page: 449: Boylestad

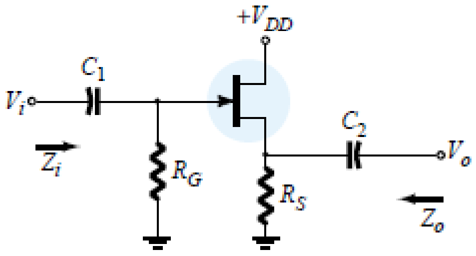


Diagram: (3 M)

Derivation: (5 M)

$Z_i = R_G$

$Z_0 = R_s \| (1/g_m)$

UNIT IV MULTISTAGE AMPLIFIERS AND DIFFERENTIAL AMPLIFIER

BIMOS cascade amplifier, Differential amplifier – Common mode and Difference mode analysis – FET input stages – Single tuned amplifiers – Gain and frequency response – Neutralization methods, power amplifiers –Types (Qualitative analysis).

PART * A	
Q.No.	**Questions**
1	**What is a differential amplifier?** BTL 1 An amplifier, which is designed to give the difference between two input signals, is called the differential amplifier.
2	**What is the function of a differential amplifier?** BTL 1 The function of a differential amplifier is to amplify the difference of two signal inputs, i.e., $V_0 = A_D(V1 \quad - V_2),$ where Ad is the differential gain
3	**When two signals V_1 and V_2 are connected to the two inputs of a difference amplifier, define a difference signal V_d and common-mode signal Vc.** BTL 1 The difference signal V_d is defined as the difference of the two signal inputs, i.e., $V_d = V_1 - V_2$ The common-mode signal V_c is defined as the average of the two signals, I.e., $V_c = 1/2\ (V_1 + V_2)$
4.	**What is the need for neutralization?** BTL 2 Neutralization circuit is used to convert unstable system to stable system by process of cancelling Miller effect. Miller effect is cancelled by adding neutralization capacitor which will provide equal magnitude and out of phase voltage or current with that of Millers capacitance.
5	**What are the advantages of differential amplifier?** BTL 1 It has high gain and high CMRR.
6.	**Give the purpose of using coupling networks.** BTL 2 The coupling networks serve the following two purposes ➢ It transfers the a.c. output of one stage to the input of the next stage. ➢ It isolates the d.c. conditions of one stage to the next.
7.	**What are the coupling schemes that are used in the multistage amplifiers?** BTL 1 The coupling schemes that are used in the multistage amplifiers are: ➢ Resistance- capacitance (RC) coupling. ➢ Transformer coupling.
9.	**Define Common Mode Rejection Ratio. (MAY 2014)** BTL 1 The relative sensitivity of an op-amp to a difference signal as compared to a common mode signal is called common-mode and gives the figure of merit for the differential amplifier. CMRR, $\rho = \lvert Ad/Ac \rvert$
10.	**Write the classification of amplifiers based on Q point (operating point).** BTL 1 ➢ Class A amplifier. ➢ Class B amplifier. ➢ Class AB amplifier. ➢ Class C amplifier.
11	**What is the drawback of class B amplifier? How this could be minimized?** BTL 2 The drawback of class B amplifier is cross over distortion To overcome the cross over distortion, a small forward bias is kept applied to the transistors. So that when input is zero, this additional forward bias can make the transistor ON immediately, eliminating cross over distortion.

12	**Which is the most commonly used feedback arrangement in cascaded amplifier and why?** BTL 2 Voltage series feedback increases input resistance and decreases output resistance. Increase in input resistance reduces the loading effect of amplifier itself for driving the next stage.
13	**Write the Advantages of differential amplifier.** BTL 1 A differential amplifier helps to increase the CMRR which in turn helps avoid unwanted signals that couple into the input to get propagated. IT also helps to increase the signal to noise ratio. Further more it provides larger output voltage swings.
14	**What are the advantages of class B amplifier compared to class A amplifier?** BTL 1 ➢ Possible to obtain greater power output. ➢ Efficiency is higher. ➢ Negligible power loss.
15	**What is class AB operation?** BTL 1 ➢ The power amplifier is said to be class AB amplifier, if the Q point and the input signal are selected such that the output signal is obtained for more than 180˚ but less than 360˚, for a full input signal. ➢ The efficiency of class AB is more than class A but less than class B operation. The class AB is important to eliminate cross over distortion.
16	**State about Class D amplifier.** BTL 2 In the class D amplifier the input signal is converted to a sequence of higher voltage output pulses. The averaged-over-time power values of these pulses are directly proportional to the instantaneous amplitude of the input signal. The frequency of the output pulses is typically ten or more times the highest frequency in the input signal to be amplified. The output pulses contain inaccurate spectral components (that is, the pulse frequency and its harmonics) which must be removed by a low-pass passive filter. The resulting filtered signal is then an amplified replica of the input.
17	**Define Class A amplifier.** BTL 2 100% of the input signal is used (conduction angle Θ = 360° or 2π); i.e., the active element remains conducting (works in its "linear" range) all of the time. Where efficiency is not a consideration, most small signal linear amplifiers are designed as class A. Class A amplifiers are typically more linear and less complex than other types, but are very inefficient. This type of amplifier is most commonly used in small-signal stages or for low-power applications (such as driving headphones).
18	**Write about Class B amplifier.** BTL 2 50% of the input signal is used (Θ = 180° or π; i.e., the active element works in its linear range half of the time and is more or less turned off for the other half). In most class B, there are two output devices (or sets of output devices), each of which conducts alternately (push–pull) for exactly 180° (or half cycle) of the input signal; selective RF amplifiers can also be implemented using a single active element. These amplifiers are subject to *crossover distortion* if the transition from one active element to the other is not perfect, as when two complementary transistors (i.e., one PNP, one NPN) are connected as two emitter followers with their base and emitter terminals in common, requiring the base voltage to slew across the region where both devices are turned off.
19	**What is Class C amplifier?** BTL 2 Class C amplifiers conduct less than 50% of the input signal and the distortion at the output is high, but high efficiencies (up to 90%) are possible. Some applications (for example,

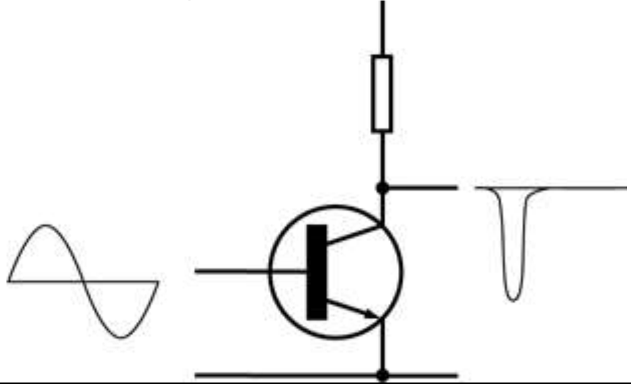
	megaphones) can tolerate the distortion. A much more common application for class C amplifiers is in RF transmitters, where the distortion can be vastly reduced by using tuned loads on the amplifier stage 
20	**What is conversion efficiency?** BTL 1 It is a measure of the ability of an active device in converting the d.c. power of the supply into the a.c. power delivered to the load. Conversion efficiency is also :red to as theoretical efficiency and collector circuit efficiency (for transistor amplifier) and it is denoted by η.
21	**Why class A amplifier must not be operated under no signal conditions?** BTL 2 Under no signal condition, the entire d.c. power input $P_{DC} = V_{CC}\ I_{CQ}$, is dissipated as the heat. Thus the power dissipation is maximum under no signal condition. This may increase the transistor junction temperature beyond safe value, which may lead to transistor damage. To avoid this, class A amplifier must not be operated under no signal condition.
22	**Define Miller's theorem. (APR/MAY 2010)** BTL 1 The Miller theorem :s to the process of creating equivalent circuits. It asserts that a floating impedance element, supplied by two voltage sources connected in series, may be split into two grounded elements with corresponding impedances. There is also a dual Miller theorem with regards to impedance supplied by two current sources connected in parallel. The two versions are based on the two Kirchhoff's circuit laws.
23	**Define multistage amplifier.** BTL 1 Additional amplification can be required to provide a signal having some specified level. The first stage can be designed for input impedance, the last for output impedance, and one or more intermediate stages for voltage gain. if a single stage of amplification will provide a maximum gain of 100 and the desired gain from the device is 1000, two stages of amplification will be required. The two stages might have gains of 10 and 100, 20 and 50, or 25 and 40. (The overall gain is the product of the individual stages-10 X 100 = 20 X 50 = 25 X 40 = 1000.)
25	**Mention the advantages which are specific to Darlington connection.** BTL 2 The major advantage of a Darlington connection is high gain, typically ranging from over 100 to 1000. The forward voltage drop from the base to the emitter of the Darlington is approximately two times the forward voltage drop of a single transistor. It is a beta multiplier therefore it has higher emitter current capability.
	PART*B
1.	**With neat sketch explain two staged cascaded amplifier and derive its overall A_v, A_i, R_i, R_o. (13 M) [Nov 2014]** BTL 3 **Answer:Page: 8 (Annexure)- T.Joel**

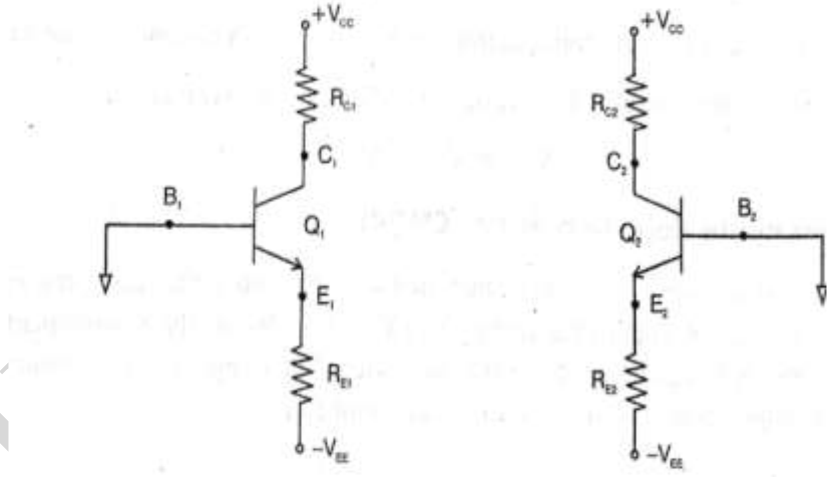
Diagram of darlington circuit:
(3 M)

AC equivalent circuit: (3 M)
Approximate h-parameter for CE configuration.
Overall gain and resistance calculation: (7 M)
Analysis for second stage:
Current gain: $A_{i2}= 1+h_{fe}$
Input resistance(R_{ix})
$R_{i2}= (1+h_{fe}) R_E$
Analysis of first stage:
Current gain(A_{i1})
$A_{i1}= \frac{1+hfe}{1+hoe .hfe .RE}$
$h_{fe}>>1$
Input resistance, overall current gain
Overall voltage gain:
$A_v=1-\frac{hie}{Ri}$
Output Impedance:
$R_{01}=\frac{hie +Rs}{1+hfe}$

2. **With neat sketch, explain the BJT differential amplifier with active load and derive for common mode gain, differential mode gain and CMRR. (13 M) [Nov 2015]** BTL 3

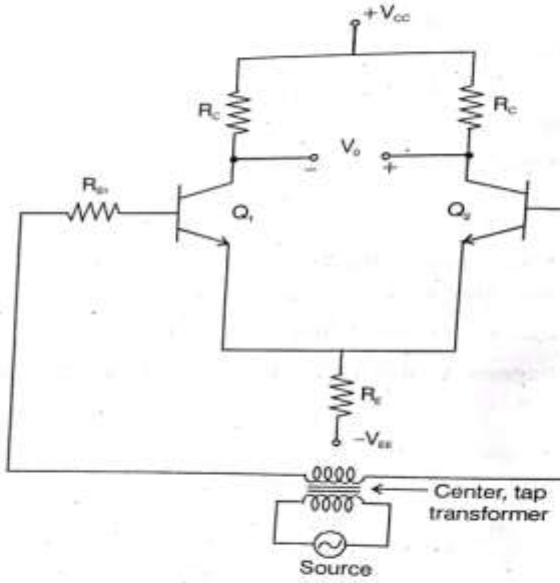
Answer: Page: 4.4-T. Joel

BJT differential amplifier diagram: (3 M)

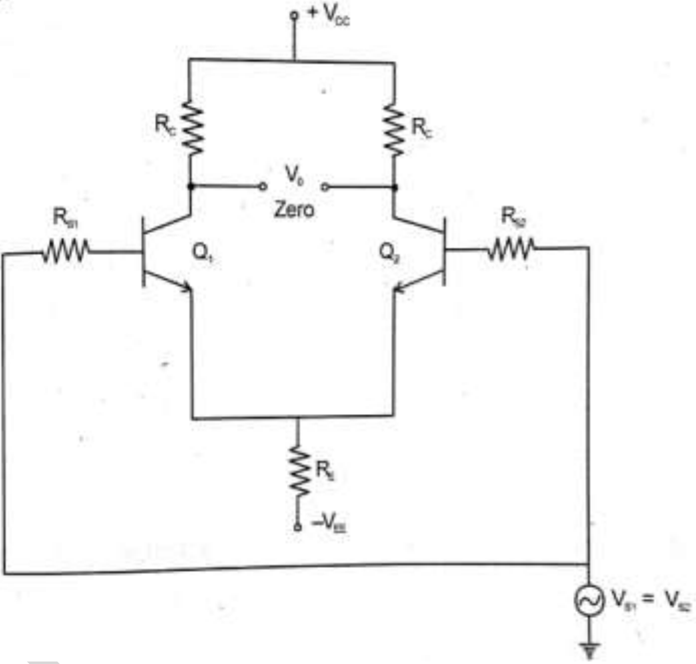


Differential mode, common mode explanation: (6 M)

1.1 Differential mode operation



Common mode operation:



CMRR: (4 M)

CMRR =|differential gain/common mode gain|

=|Ad/Ac|

Unit of CMRR is dB

CMRR = 20log|Ad/Ac|

3. **What is Neutralization? Explain hazeltine neutralization and narrow band neutralization methods in brief. (13 M) [May 2015]** BTL 2

Answer: Page: 4.40- T.Joel

Neutralization:

- Neutralization circuit is used to convert unstable system to stable system by process of cancelling Miller effect.
- Miller effect is cancelled by adding neutralization capacitor which will provide equal magnitude and out of phase voltage or current with that of Millers capacitance.
- To improve stability. (3 M)

Methods (Diagram and explanation)

Broad banding using Hazeltine Neutralization (5 M)

Narrow band neutralization using coil (5 M)

4 **Perform DC analysis and AC analysis of FET differential amplifiers with appropriate circuit diagrams. (13 M)** BTL 4

Answer: Page: 4.26: T.Joel

Dual input unbalanced output FET differential amplifier:

DC analysis: (3 M)

Short circuit the sources.

$V_{DS}= V_{DD}+V_{EE}-I_DR_D-I_SR_S$ (4 M)

AC analysis: (6 M)

Determine the gain in both differential- mode and common mode.

Differential mode gain:

$A_d= g_mR_D$

Common mode gain:

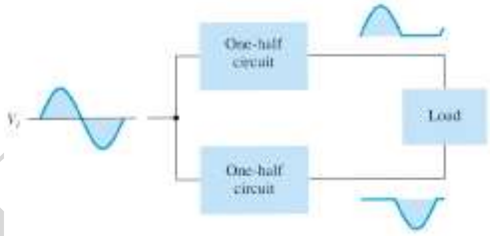
$A_C= V_0/V_i= -g_mR_D/(1+2\ g_mR_S)$

CMRR= $1+2g_mR_S$

PART*C

1. **i) Explain with circuit diagram class B power amplifier and derive its efficiency.(13 M) [Nov 2015]** BTL 2

Answer:Page: 4.44: T. Joel



(3 M)

Derivation: (10 M)

$$P_i(\text{dc}) = V_{CC}I_{\text{dc}}$$

$$I_{\text{dc}} = \frac{2}{\pi}I(\text{p})$$

$$P_i(\text{dc}) = V_{CC}\left(\frac{2}{\pi}I(\text{p})\right)$$

$$P_o(\text{ac}) = \frac{V_L^2(\text{rms})}{R_L}$$

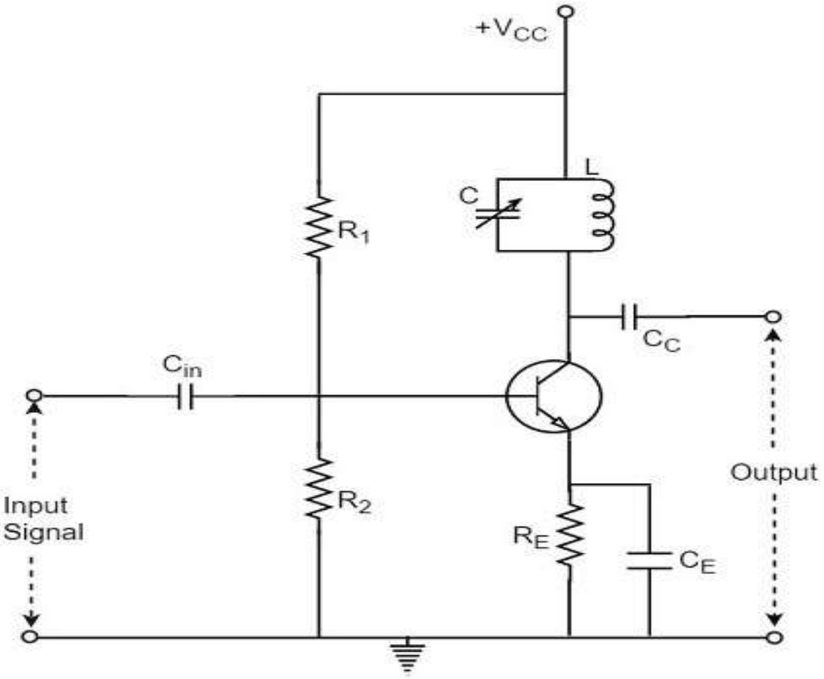
$$\% \ \eta = \frac{P_o(\text{ac})}{P_i(\text{dc})} \times 100\%$$

$$\text{maximum efficiency} = \frac{\pi}{4} \times 100\% = 78.5\%$$

2. **With neat circuit, explain and derive the gain and bandwidth of a single tuned amplifier. (15 M) [Nov 2015]** BTL 3

Answer:Page: 4.31- T.Joel

Diagram: (5 M)



Equivalent circuit

Modified equivalent circuit

$\Delta \acute{\omega} = \acute{\omega}_0 / R_1 \acute{\omega}_0 C = 1/R_1 C$ rad/S

$\Delta f = 1/2\,\Pi R_1 C$

Response of tuned amplifier. (10 M)

3. **Calculate the operating point values, differential gain, common mode gain, CMRR, output voltage if V_{s1}= 60mV (p-p) at 1KHz and V_{s2}= 40mV (p-p) at 1 KHz for the differential amplifier shown in Fig. Assume the transistor is made of Silicon with h_{ie} = 3.2 KΩ. (15 M)** BTL 1

Answer: Page: 122- Notes

Operating point (1.009mA, 8.16V), (3 M)

A_d= 135.54 A, (3 M)

A_c=0.3966, (3 M)

CMRR=50.67 dB, (3 M)

V_0= 2.73 V(p-p) (3

	M)
4.	**What is power amplifier? List the various classes of power amplifiers. Explain in detail the Position of Q point for class A amplifier with its current and voltage waveforms. (13 M)** BTL 3 **Answer: Page: 4.42: T.Joel** Power amplifier: Draws power from d.c power supply and converts to a.c signal. Efficiency- Conversion efficiency, action controlled by input signal. Classification: Class A, Class B, Class C, Class AB. (2 M) Diagram: Position of Q point for Class A amplifier. Current and voltage waveforms. (4 M) Explanation: (6 M) Q point and input signal selected, output signal is obtained for a full input cycle. Q point approximately at the midpoint of the load line. Transistor remains in the active region and never enters into cut-off and saturation region. a.c input signal applied, collector voltage varies sinusoidally, collector current varies sinusoidally. The collector current flows for 360^0, full cycle, input signal. Efficiency- very small. (1M)
5.	**Explain in detail the Position of Q point for class C amplifier with its current and voltage waveforms. Also describe the working of Class C tuned amplifier with neat diagram. (13 M)** BTL 3 **Answer: Page: 4.45: T.Joel** **Diagram:** Position of Q point for Class C amplifier, Current and voltage waveforms. (3 M) **Explanation:** (10 M) ➢ Q point and input signal selected, output signal is obtained for less than a half cycle. ➢ Q point shifted below x-axis. ➢ Transistor remains in the active region. ➢ For the remaining cycle, transistor remains cut off, no signal produced at output, current flow less than 180^0. ➢ Output is much more distorted. ➢ Never used for A.F power amplifiers. ➢ Efficiency much higher- very close to 100%. **Applications:** ➢ Not suitable for audio frequency power amplifiers. ➢ Used in Tuned circuits, used in communication areas and in radio frequency amplifiers. ➢ Also used in mixer or converter circuits used in radio receivers and wireless communication system.

UNIT V FEEDBACK AMPLIFIERS AND OSCILLATORS

Advantages of negative feedback – voltage / current, series , Shunt feedback –positive feedback – Condition for oscillations, phase shift – Wien bridge, Hartley, Colpitts and Crystal oscillators.

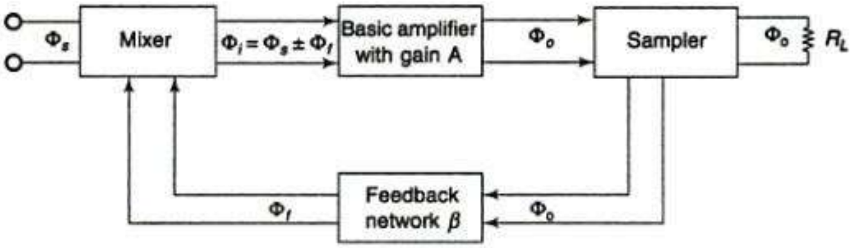
PART * A

Q.No.	Questions

1	**Define (i) feedback (ii) positive feedback and (iii) negative feedback.** BTL 1 **i. Feedback:** The process of combining a fraction of the output (of a Device- amplifier) back to its input is called feedback. **ii. Positive Feedback:** If the feedback is in phase to the input, it is called positive feedback. **iii. Negative Feedback:** When the feedback is in opposition (out of phase) to the input, it is called negative feedback.
2	**Mention the four connections in Feedback.** BTL 1 Voltage series feedback. Voltage shunt feedback Current series feedback. Current shunt feedback.
3	**Write the effects of negative feedback.** BTL 1 The gain becomes stabilized with respect to changes in the amplifier active device parameters like hfe. The non-linear distortion is reduced there by increasing the signal handling capacity or the dynamic range of the amplifier.
4	**Write the conditions for a circuit to oscillate.** BTL 1 The oscillator circuit should consist of an amplifier and a portion of the output should be feedback to the input. For sustained oscillations, the feedback voltage must be in phase with the input, i.e., total phase shift around the loop must be 360°. The amount of energy or power feedback to the input must be sufficient to the input circuit.
5	**Mention the classification of oscillators.** BTL 1 **According to the frequency determining networks,** RC oscillators LC oscillators Crystal oscillators
6	**List the advantages of phase shift oscillator.** BTL 1 The phase shift oscillator does not required conductance or transformers. It is suitable for the low frequency range i.e., from a few hertz to several hundred KHz. The upper frequency is limited because the impedance of RC network may become so small that it loads the amplifier heavily.

7	**Write the disadvantages of Phase shift oscillator.** BTL 1 It is necessary to change the C or R in all the three RC networks simultaneously for changing the frequency of oscillations. This is practically difficult. It is not suitable for high frequencies.
8	**Write the main drawback of LC oscillators.** BTL 1 The frequency stability is not very good. They are too bulky and expensive and cannot be used to generate low frequencies.
9	**Why the capacitor in a high pass RC circuit is called blocking capacitor?** BTL 2 Because of the blocking property of the capacitor for DC or low frequency input signals, the capacitor acts like an open circuit and blocks the signal. So the capacitor in high-pass RC circuits is called “blocking capacitor”.
10	**Write the voltage series feedback.** BTL 2 In this case, the feedback voltage is derived from the output voltage and fed in series with input signal. The input of the amplifier and the feedback network are in series is also known as series parallel in parallel, hence this configuration is also known as series parallel feedback network.
11	**State the voltage shunt feedback.** BTL 2 The input of amplifier and the feedback network are in parallel and known as parallel – parallel feedback network. This type of feedback to the ideal current to voltage converter, a circulating having very low input impedance and very low output impedance.
12	**Write the current series feedback.** BTL 2 When the feedback voltage derived from the load current and is fed in series with the input signal, the feedback is said to be current series feedback, the inputs of the amplifier and the feedback network are in series and the output are also in series. This configuration is also called as series-series feedback configuration.
13	**Define the current shunt feedback.** BTL 2 When the feedback voltage is derived from the load current and a fed in parallel with the input signal, the feedback is said to be current shunt feedback. Herein the inputs of the amplifier and the feedback network are in parallel and the outputs are in series. This configuration is also known as parallel series feedback.
14	**Give the barkhausen criterion for oscillator. (NOV 2012) (MAY 2013)** BTL 1

	When AB = -1, the gain is infinite this represents the condition for oscillation The requirements for oscillation are described by the Barkhausen criterion: The magnitude of the loop gain AB must be 1 The phase shift of the loop gain AB must be 180°,or 180° plus an integer multiple of 360°. It should be mentioned that the criterion is necessary but not sufficient. The criterion is just an observation based on the assumption of a linear circuit.
15	**Write the advantages of negative feedback amplifier.** BTL 1 Better frequency response, less distortion, less gain or voltage drift, less temperature drift, better CMRR, SVRR, bias point stability
16	**Define frequency stability of an oscillator.** BTL 1 The term "frequency stability" is used to define the ability of the oscillator to maintain a single fixed frequency as long as possible over a time interval. These deviations in frequency are caused due to variations in the values of circuit features (circuit components, transistor parameters, supply voltages, stray-capacitances, output load etc.) that determine the oscillator frequency.
17	**Mention two high frequency LC oscillators.** BTL 1 • Hartley oscillator • Colpitts oscillator
18	**Mention the types of feedback.** BTL 1 1. Positive or regenerative feedback. 2. Negative of degenerative feedback.
19	**Define feedback.** BTL 1 The process of injecting a fraction of the output voltage of an amplifier into the input so that it becomes a part of the input is known as feedback.
20	**Draw the block diagram of feedback amplifier**.[A/M − 11] [N/D − 11] BTL 2 The block diagram of feedback amplifier



21 **What are the impacts of negative feedback on noise in circuit? [A/M − 10]** BTL 1

The impacts of negative feedback on noise in circuit are

Signal feedback reduces the amount of noise signal and non linear distortion.

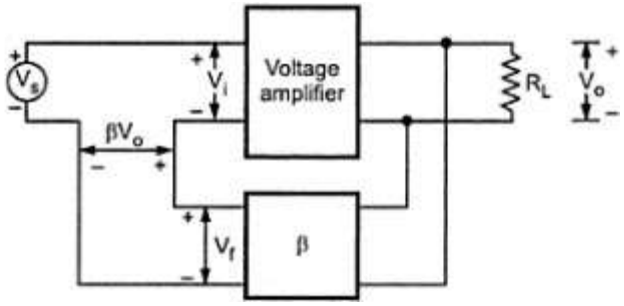
The factor ($1 + \beta A$) reduces both input noise and resulting non linear distortion for considerable improvement.

22 **What are the effects of negative feedback on input and output impedance of an amplifier? [N/D − 11] [A/M − 12]** BTL 1

The effects of negative feedback on input and output impedance of an amplifier:

Parameter	**Voltage series**	**Current series**	**Voltage shunt**	**Current shunt**
Input resistance	Increases	Increases	Decreases	Decreases
Output resistance	Decreases	Increases	Decreases	Increases

23 **Draw a block diagram of voltage series feedback amplifier and write the expression for its input resistance.** BTL 2

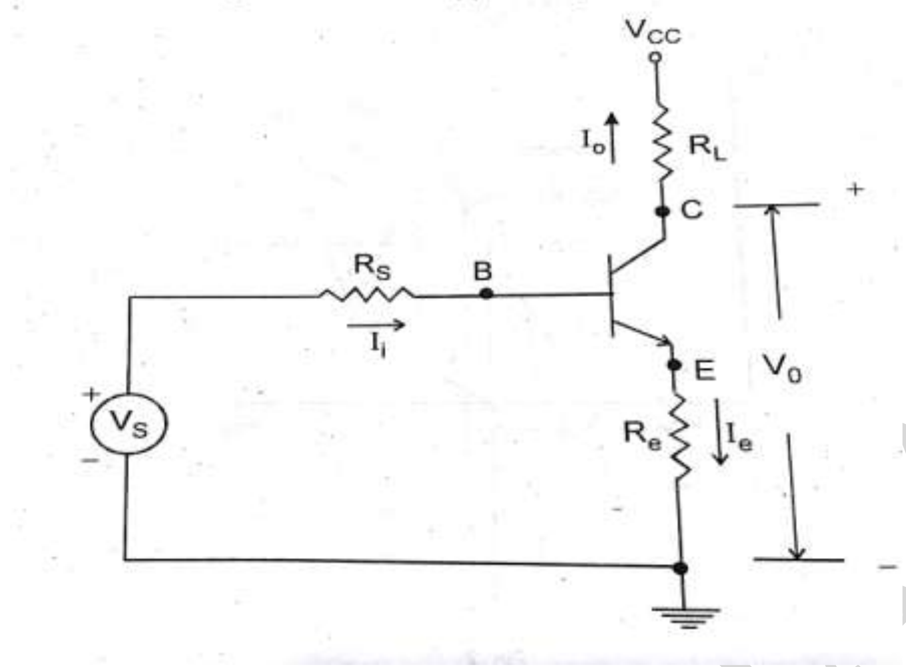


The block diagram of voltage series feedback amplifier

The input resistance of voltage series feedback amplifier is $R_{if} = R_i (1+\beta A_V)$ Where Rif - Input resistance with feedback.

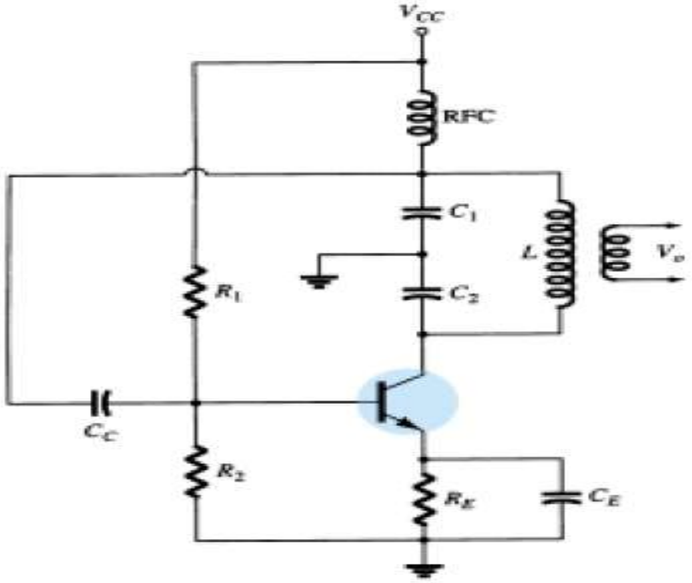
Ri - Input resistance without feedback. Av - Voltage gain without feedback.

	β - Feedback factor.
24	**Determine the gain with feedback for an amplifier with open loop gain of 300 and feedback factor of 0.1. [N/D – 09]** BTL 1 Solution: Given: Av = 300 and $\beta = 0.1$ Avf = $\frac{Av}{1+\beta Av}$ Avf = 300/ (1+0.1 x 300) = 9.677
25	**An amplifier has a voltage gain of 1000. With negative feedback, the voltage gain reduces to 10. Calculate the fraction of the output that is feedback to the input. [A/M – 07]** BTL 1 Solution: Given Av = 1000 and Avf = 10 Avf = $\frac{Av}{1+\beta Av}$ 10 = 1000 / β) β = 0.099
	PART*B
1.	**Draw circuit of CE amplifier with current series feedback and obtain the expression for feedback ratio, voltage gain, input and output resistances.(13 M) [May 2015]** BTL 3 **Answer: Page: 10 (annexure)** Diagram with explanation: (5 M) Derivation: (8 M)

	 Step 1: Identify Topology Step 2 and 3: Find input and output circuit Step 4: Replace transistor with its approximate h parameter equivalent circuit. Step 5: Find open loop transfer gain Step 6: Indicate I_0 and V_f and calculate ß Step 7: Calculate D, $G_{M7,}$ A_{vf}, R_{if}, $R_{of,}$ and $R^{\vert}_{of}$ $G_m = \frac{-hfe}{Rs+hie+Re}$, ß = $-R_{e,}$ $R^{\vert}_{of} = R_{of} \parallel R_L = R_L$
2.	**Explain the operation of Colpitts oscillator with neat circuit diagram. Also derive the expressions for the frequency of oscillation and the condition for maintenance of oscillation. (13 M) [May 2015]** BTL 3 **Answer: Page: 5.86- T.Joel** General equation for the oscillator: (2 M) Diagram: (3 M) Derivation: (8 M)

$$\boxed{f_o = \frac{1}{2\pi\sqrt{LC_{\text{eq}}}}}$$

$$C_{\text{eq}} = \frac{C_1C_2}{C_1 + C_2}$$



3. **Explain the operation of Hartley oscillator with neat circuit diagram. Also derive the expressions for the frequency of oscillation and the condition for maintenance of oscillation. (13 M)** BTL 3

Answer: Page: 5.80- T.Joel

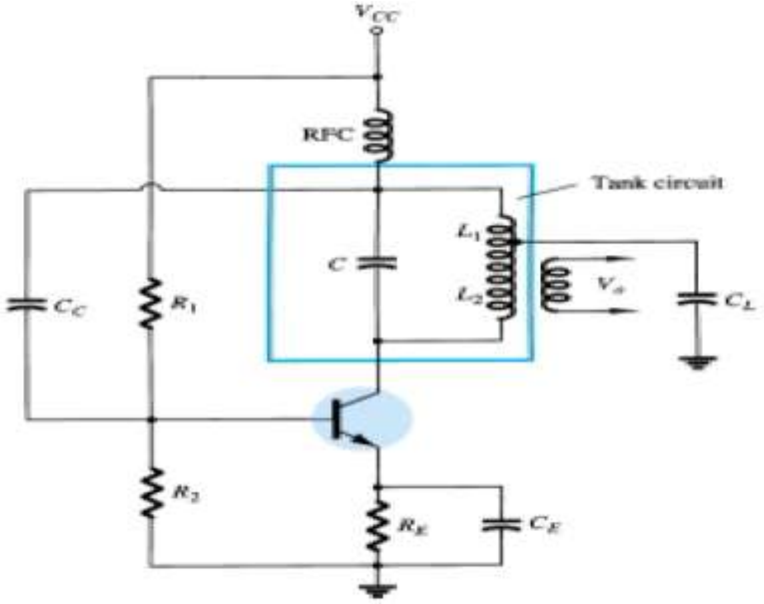
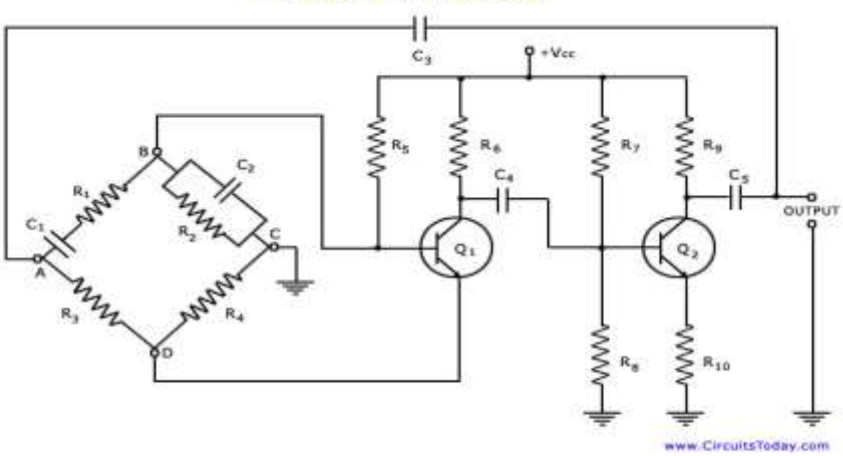
General equation for the oscillator: (2 M)

Diagram: (3 M)

Derivation: (8 M)

$$\boxed{f_o = \frac{1}{2\pi\sqrt{L_{\text{eq}}C}}}$$

$$L_{\text{eq}} = L_1 + L_2 + 2M$$

	
	PART*C
1.	**Describe and explain the operation of the following oscillators.** BTL 3 **i) Wien Bridge Oscillator (5 M)** **Answer: Page:5.61- T.Joel** Diagram- (2 M) Frequency answer- (3 M) Wien Bridge Oscillator Circuit  www.CircuitsToday.com $f_o = \frac{1}{2\pi RC}$

$$\frac{R_3}{R_4} = 2$$

$$f_o = \frac{1}{2\pi\sqrt{R_1C_1R_2C_2}}$$

ii) Design a Wien Bridge oscillator to oscillate at a frequency of 20KHz. (5 M)

Answer: Page: 18 (annexure) - T.Joel

Assume C and substitute the formula

$$R = \frac{1}{2\pi \mathrm{fC}}$$

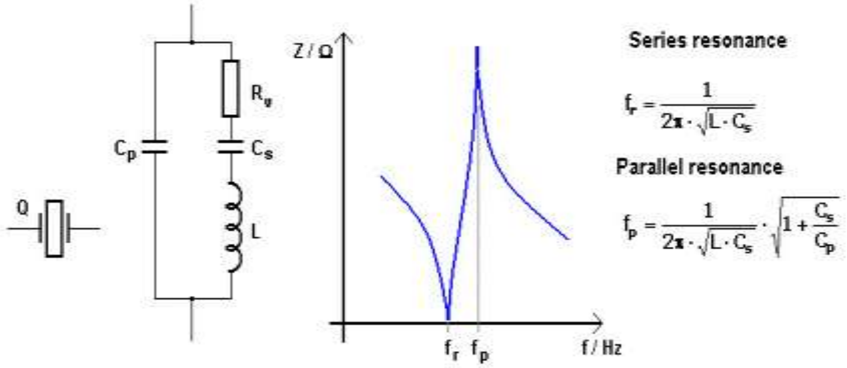
$$Design\ R\ and\ C\ for\ 20kHz$$

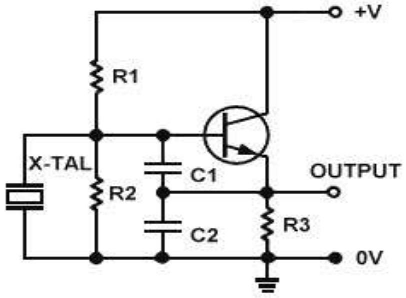
iii) Crystal oscillator. (5 M)

Answer: Page: 5.100- T.Joel

Diagram- (2 M)

Frequency answer- (3 M)



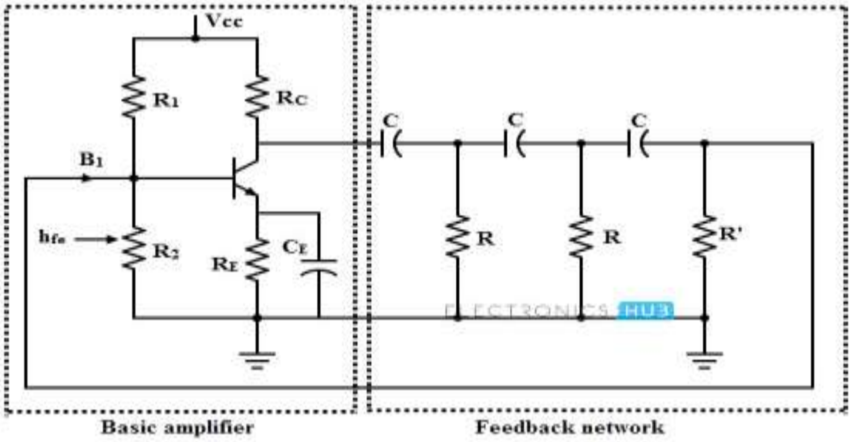


2. **Explain the operation of RC phase shift oscillator with neat circuit diagram. Also derive the expressions for the frequency of oscillation and the condition for maintenance of oscillation. (15 M)** BTL 3

Answer: Page:10 (annexure) - T.Joel

Diagram and explanation: (5 M)

Derivation: (10 M)



Oscillator with a feedback network consisting of three RC high-pass networks connected in serie that produce 180° phase shift.

$$\boxed{f = \frac{1}{2\pi RC\sqrt{6}}}$$

$$\beta = \frac{1}{29}$$

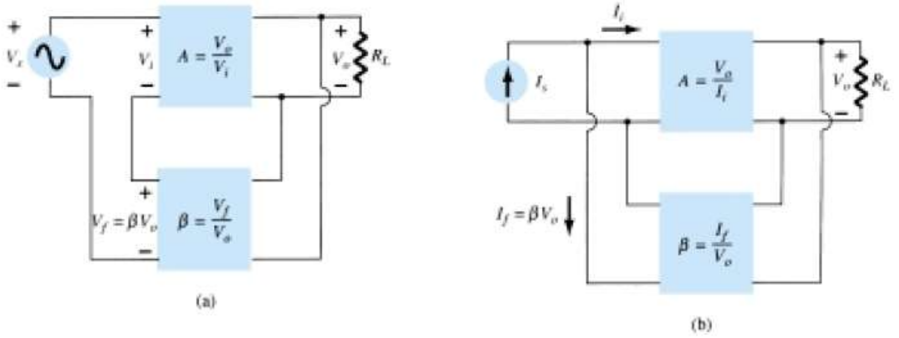
$$A > 29$$

3. **Describe the operation of voltage series and shunt feedback amplifier circuit. (15 M) [May 2010, 2011]** BTL 1

Answer: Page: 10 (Annexure) - T.Joel

Feedback amplifiers- introduction: (3 M)

Diagram and explanation:

	 (5 M) Fig: a) Series feedback b) shunt feedback Voltages to connecting the output voltage as input to the feedback network; current s to tapping off some output current through the feedback network. Series to connecting the feedback signal in series with the input signal voltage; shunt to connecting the feedback signal in shunt (parallel) with an input current source. Series feedback connections tend to increase the input resistance, while shunt feedback connections tend to decrease the input resistance. Voltage feedback tends to decrease the output impedance, while current feedback tends to increase the output impedance. (7 M)
4.	**Calculate the voltage gain, input and output resistance of a voltage series feedback amplifier having A=400, R_i=1 kΩ, R_o=20 kΩ and ß=0.02. (15 M)** BTL 1 **Answer: Page:5.40 (Annexure) - T.Joel** $A_f = \frac{A}{Aß+1}$= 44.44 (5 M) R_{if}= R_i(($Aß + 1$)= 9 KΩ (5 M) R_{0f}= R_0/(($Aß + 1$) = 2.2KΩ (5 M)

OBJECTIVE TYPE QUESTIONS	
1	Semicoductor material have _________ bonds. a)Ionic **b) Covalent** c) mutual d) Metallic
2	The process of adding impurities to pure semiconductor is called ________ a) mixing **b) doping** c) diffusing d) Refining
3	The most widely used semiconducting materials in electronic devices is_____ a) Germanium **b) Silicon** c) Copper d) Carbon
4	The leakage current of the P-N diode is caused by_______

	a) heat energy b) Chemical energy c) barrier potential d) majority carriers
5	Any voltage that is connected across a P-N junction is called ________ voltage. a) breakdown voltage b) barrier voltage **c) bias voltage** d) Reverse voltage.
6	The depletion region of semiconductor diode is due to a) Reverse biasing b) forward biasing c) crystal doping **d) migration of mobile charge carriers.**
7	A LED emits visible light when its__________ a) PN junction is reverse biased b) depletion region widens **c) holes and electrons recombine** d) P-N junction becomes hot.
8	GaAs, LEDs emit radiation in the _______ a) ultra violet region b) violet blue green range og the visible region c) visible region **d) infra-red region**
9	The ripple factor of a Half Wave Rectifier is_________ a) 0.406 **b) 0.812** c) 1.21 d) 1.11
10	Which stage of a dc power supply uses zener diode as the main component? a) rectifier b) voltage divider **c) regulator** d) filter
11	In case of bipolar transistor, α is ________ a) positive and >**1 b) positive and <1** c) negative and >1 d) negative and <1
12	When a BJT operates in cut off a) V_{CE}=0, **b) V_{CE}= V_{CC}** c) V_{CE} has negative value d) I_C is maximum
13	Improper biasing of a transistor circuit leads to a) Excessive heat production at collector terminal **b) Distortion in input Signal** c) Faulty loacation of load line d) Heavy loading of emitter terminal
14	When a BJT is employed as an amplifier, it operates a) cutoff b) saturation c) well into saturation **d) Over the active region.**
15	The smallest of the four h-parameters of a transistor is a) h_i b)h_r **c)h_0** d) h_f

16	FETs have similar properties to a) PNP transistors **b) NPN transistors** c) Thermonic valves d) Unijunction Transistors
17	A JFET has the disadvantage of a) being noisy **b) having small gain- bandwidth product** c) possessing positive temperature co-efficient d) Having low input impedance
18	A JFET can be cut-off with the help of **_____** **a) V_{GS}** b) V_{DS} c) V_{DG} d) V_{DD}
19	If properly biased JFET acts as a a) Current controlled current source **b) Voltage controlled current source** c) voltage controlled voltage source d) current controlled voltage source
20	The main factor which differentiates a DEMOSFET and EMOSFET is the absence of a) Insulated gate b) electrons **c) channel** d) P-N junctions
21	The polarity of V_{GS} for E- MOSFET is a) positive b) negative c) zero **d) depends on P or N-channel.**
22	A unijunction transistor has a) anode, cathode and a gate **b) two bases and one emitter** c) two anodes and one gate d) anode, cathode and two gates
23	After firing the SCR, the gating pulse is removed, the current in the SCR will **a) remains the same**, b) Immediately falls to zero c) rise up d) rise a little and then fall to zero.
24	An SCR may be turned off by ________ a) interrupting its anode current b) reversing polarity of its anode-cathode voltage c) low current dropout **d) all the above**
25	Which device acts like a diode and two resistors? a) SCR b) triac c) DIAC **d) UJT**
26	A CC amplifier has the highest a) voltage gain **b) current gain** c) power gain d) output impedance
27	In a class A amplifier, worst case conditions occur with **a) zero signal input** b) maximum signal input c) high load resistance d) transformer coupling.
28	CE amplifier is characterized by a) low voltage gain b) moderate power gain **c) signal phase reversal** d) very high output impedance

29	The decibel is a measure of a) Power b) Voltage c) Current **d) power level**
30	The main reason for the variation of amplifier gain with frequency is **a) the presence of capacitances, both external and internal** b) due to interstage transformers c) the logarithmic increase in its output power d) the miller effect
31	When power output of an amplifier doubles, the increase in its power level is _____ decibels a) 2 b) 20 **c) 3** d) 10
32	An ideal amplifier is one which ____a) has infinite voltage gain **b) responds only to signals at its input terminals** c) has positive feedback d) gives uniform frequency response
33	The voltage gain of a single stage CE amplifier is increased when _____ a) its ac load is decreased b) resistance of signal source is increased c) emitter resistance R_E is increased. **d) ac load resistance is increased.**
34	Unique features of a CC amplifier circuit is that it _____a) steps up the impedance level b) does not increase signal voltage c) acts as an impedance matching device **d) all of the above**.
35	The h-parameters of a transistor depends on its _________ a) configuration b) operating point c) temperature **d) all of the above.**
36	The voltage gain of a given common source JFET amplifier depends on its ____a) input impedance b) amplification factor c) dynamic drain resistance **d) drain load resistance**
37	A transconductance amplifier has ____ **a) high input impedance and low output impedance** b) low input impedance and high output impedance c) high input and output impedances d) low input and output impedances
38	For the operation of enhancement only N-channel MOSFET, value of gate voltage has to be _____ **a) high positive** b) high negative c) low positive d) zero
39	When emitter bypass capacitor in a CE amplifier is removed, its _____ is considerably reduced. a) input resistance b) output load resistance c) emitter current **d) voltage gain**.
40	In an ac amplifier, larger the internal resistance of the ac signal source________ a) greater the overall voltage gain b) greater the input impedance c) smaller the current gain **d) smaller the circuit voltage gain**
41	RC coupling is used for ………………. amplification **Voltage** b) Current c) Power d) None of the above
42	In an RC coupled amplifier, the voltage gain over

	mid-frequency range ……………. a)Changes abruptly with frequency **b) Is constant** c) Changes uniformly with frequency d) None of the above
43	In an RC coupling scheme, the coupling capacitor CC must be large enough ……….. a) To pass d.c. between the stages **b) Not to attenuate the low frequencies** c) To dissipate high power d) None of the above
44	When a multistage amplifier is to amplify d.c. signal, then one must use …….. coupling a) RC b) Transformer **c) Direct** d) None of the above
45	………….. coupling provides the maximum voltage gain a) RC **b) Transformer** c) Direct d Impedance
46	Transformer coupling is generally employed when load resistance is ……… a) Large b) Very large **c) Small** d) None of the above
47	If a three-stage amplifier has individual stage gains of 10 db, 5 db and 12 db, then total gain in db is ………. a) 600 db b) 24 db c) 14 db **d) 27 db**
48	The lower and upper cut off frequencies are also called ………………… frequencies a) Sideband b) Resonant c) Half-resonant

	d) Half-power
49	In transistor amplifiers, we use ……………. transformer for impedance matching a) Step up **b) Step down** c) Same turn ratio d) None of the above
50	RC coupling is not used to amplify extremely low frequencies because ……… a) There is considerable power loss b) There is hum in the output **c) Electrical size of coupling capacitor becomes very large** d) None of the above
51	The purpose of RC or transformer coupling is to ………… a) Block a.c. **b) Separate bias of one stage from another** c) Increase thermal stability d) None of the above
52	The number of stages that can be directly coupled is limited because …….. **a) Changes in temperature cause thermal instability** b) Circuit becomes heavy and costly c) It becomes difficult to bias the circuit d) None of the above
53	An amplifier receives 0.1 W of input signal and delivers 15 W of signal power. What is the power gain in db? **a) 8 db** b) 6 db c) 5 db d) 4 db
54	The noise factor of an ideal amplifier expressed in db is ………….. **a) 0** b) 1 c) 1 d) 10
55	In RC coupling, the value of coupling capacitor is about ……….

	a) 100 pF b) 0.1 μF c) 0.01 μF **d) 10 Mf**
56	The value of negative feedback fraction is always ……………. **a) Less than 1** b More than 1 c) Equal to 1 d) None of the above
57	If the output of an amplifier is 10 V and 100 mV from the output is fed back to the input, then feedback fraction is ……….. a) 10 b) 1 **c) 0.1** d) 15
58	A feedback circuit usually employs …………….. network **a) Resistive** b) Capacitive c) Inductive d) None of the above
59	The gain of an amplifier with feedback is known as ………….. gain a) Resonant b) Open loop **c) Closed loop** d) None of the above
60	When current feedback (negative) is applied to an amplifier, its input impedance …………..

	a) Is decreased b) Is increased c) Remains the same d) None of the above
61	Negative feedback is employed in …………….. a) Oscillators b) Rectifiers **c) Amplifiers** d) None of the above
62	When a negative voltage feedback is applied to an amplifier, its bandwidth………. **a) Is increased** b) Is decreased c) Remains the same d) Insufficient data
63	In an LC oscillator, the frequency of oscillator is ……………. L or C. a) Proportional to square of b) Directly proportional to c) Independent of the values of **d) Inversely proportional to square root of**
64	An oscillator produces……………. oscillations a) Damped **b) Undamped** c) Modulated d) None of the above
65	An oscillator employs ……………… feedback

	a) Positive b) Negative c) Neither positive nor negative d) Data insufficient
66	Hartley oscillator is commonly used in ……………… **a) Radio receivers** b) Radio transmitters c) TV receivers d) None of the above
67	In a phase shift oscillator, we use …………. RC sections a) Two **b) Three** c) Four d) None of the above
68	In a phase shift oscillator, the frequency determining elements are ………… a) L and C b) R, L and C **c) R and C** d) None of the above
69	A Wien bridge oscillator uses ……………. feedback a) Only positive b) Only negative **c) Both positive and negative** d) None of the above
70	The piezoelectric effect in a crystal is ……………

	a) A voltage developed because of mechanical stress b) A change in resistance because of temperature c) A change in frequency because of temperature d) None of the above

EE8391 ELECTROMAGNETIC THEORY L T P C
2 2 0 3

OBJECTIVES:

- To introduce the basic mathematical concepts related to electromagnetic vector fields
- To impart knowledge on the concepts of
- Electrostatic fields, electrical potential, energy density and their applications.
- Magneto static fields, magnetic flux density, vector potential and its applications.
- Different methods of emf generation and Maxwell's equations
- Electromagnetic waves and characterizing parameters

UNIT I ELECTROSTATICS – I 6+6

Sources and effects of electromagnetic fields – Coordinate Systems – Vector fields –Gradient, Divergence, Curl – theorems and applications - Coulomb's Law – Electric field intensity – Field due to discrete and continuous charges – Gauss's law and applications.

UNIT II ELECTROSTATICS – II 6+6

Electric potential – Electric field and equipotential plots, Uniform and Non-Uniform field, Utilization factor – Electric field in free space, conductors, dielectrics - Dielectric polarization – Dielectric strength - Electric field in multiple dielectrics – Boundary conditions, Poisson's and Laplace's equations, Capacitance, Energy density, Applications.

UNIT III MAGNETOSTATICS 6+6

Lorentz force, magnetic field intensity (H) – Biot–Savart's Law - Ampere's Circuit Law – H due to straight conductors, circular loop, infinite sheet of current, Magnetic flux density (B) – B in free space, conductor, magnetic materials – Magnetization, Magnetic field in multiple media Boundary conditions, scalar and vector potential, Poisson's Equation, Magnetic force, Torque, Inductance, Energy density, Applications.

UNIT IV ELECTRODYNAMIC FIELDS 6+6

Magnetic Circuits - Faraday's law – Transformer and motional EMF – Displacement current - Maxwell's equations (differential and integral form) – Relation between field theory and circuit theory – Applications.

UNIT V ELECTROMAGNETIC WAVES 6+6

Electromagnetic wave generation and equations – Wave parameters; velocity, intrinsic impedance, propagation constant – Waves in free space, lossy and lossless dielectrics, conductors- skin depth - Poynting vector – Plane wave reflection and refraction.

TOTAL : 60 PERIODS

OUTCOMES:

- Ability to understand the basic mathematical concepts related to electromagnetic vector fields.
- Ability to understand the basic concepts about electrostatic fields, electrical potential, energy density and their applications.
- Ability to acquire the knowledge in magneto static fields, magnetic flux density, vector potential and its applications.
- Ability to understand the different methods of emf generation and Maxwell's equations
- Ability to understand the basic concepts electromagnetic waves and characterizing parameters
- Ability to understand and compute Electromagnetic fields and apply them for design and analysis of electrical equipment and systems

TEXT BOOKS:

1. Mathew N. O. Sadiku, 'Principles of Electromagnetics', 6th Edition, Oxford University Press Inc. Asian edition, 2015.
2. William H. Hayt and John A. Buck, 'Engineering Electromagnetics', McGraw Hill Special Indian edition, 2014.
3. Kraus and Fleish, 'Electromagnetics with Applications', McGraw Hill International Editions, Fifth Edition, 2010.

REFERENCES

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2. J.P.Tewari, 'Engineering Electromagnetics - Theory, Problems and Applications', Second Edition, Khanna Publishers.
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Subject Code: EE8391 **Year/Semester: II/03**
Subject Name: Electromagnetic Theory **Subject Handler: Mr. K. Jayavelu**

UNIT I ELECTROSTATICS – I

Sources and effects of electromagnetic fields – Coordinate Systems – Vector fields –Gradient, Divergence, Curl – theorems and applications - Coulomb's Law – Electric field intensity – Field due to discrete and continuous charges – Gauss's law and applications.

Q. No	Questions
1	**Define scalar and vector.** (BTL 1) **Scalar:** A quantity that is characterized only by magnitude is called a scalar. **Vector:** A quantity that is characterized both by magnitude and direction is called a vector.
2	**Define Gradient.** (BTL 1) The gradient of any scalar function is the maximum space rate of change of that function. If the scalar V represents electric potential, ∇ V represents potential gradient. ∇ V= $\frac{\partial V}{\partial x}\bar{a}_x + \frac{\partial V}{\partial y}\bar{a}_y + \frac{\partial V}{\partial z}\bar{a}_z$. This operation is called the gradient.
3	**Define divergence and curl.** (BTL 1) **Divergence:** The divergence of a vector 'A' at any point is defined as the limit of its surface integrated per unit volume as the volume enclosed by the surface shrinks to zero. ∇ .A =Lt$_{V\to 0}\frac{1}{v}\oiint_S A \cdot \bar{n}$ ds. ∇ .A = $\frac{\partial A_X}{\partial x}+\frac{\partial A_Y}{\partial y}+\frac{\partial A_Z}{\partial z}$. This operation is called divergence. Divergence of a vector is a scalar quantity **Curl:**

	The curl of a vector 'A' at a any point is defined as the limit of its cross product with normal over a closed surface per unit volume as the volume shrinks to zero. ∇ x A =$Lt_{V \to 0} \frac{1}{v} \oiint_{S} \overline{n}$ x Ads.
4	**Show that the vector $\overline{H}$ = $3y^4z\,\overline{a}_x + 4x^3z^2\,\overline{a}_y + 2\,x^3y^2\,\overline{a}_z$ is solenoidal.** (BTL 1) ∇ .H= $\left(\frac{\partial}{\partial x}\overline{a}_x + \frac{\partial}{\partial y}\overline{a}_y + \frac{\partial}{\partial z}\overline{a}_z \right)$. $(3y^4z\,\overline{a}_x + 4x^3z^2\,\overline{a}_y + 2\,x^3y^2\,\overline{a}_z)$ $= \frac{\partial}{\partial x}(3y^4z) + \frac{\partial}{\partial y}(4x^3z^2) + \frac{\partial}{\partial z}(2\,x^3y^2) = 0 + 0 + 0 = 0$;Hence $\overline{H}$ is solenoidal.
5	**Determine the angle between A = 2 $\overline{a}_x$ + 4 $\overline{a}_y$ and B=6 $\overline{a}_y$ - 4 $\overline{a}_z$. (Nov 2016)** (BTL 5) $\theta = Cos[\bar{A}.\bar{B}/(\lvert\bar{A}\rvert.\lvert\bar{B}\rvert)]$ $\lvert\bar{A}\rvert = \sqrt{2^2 + 4^2} = 4.47$ $\lvert\bar{B}\rvert = \sqrt{6^2 + 4^2} = 7.21$ $\bar{A}.\bar{B} = 2 * 6 + 4 * 4 = 28$ θ=0.5182°
6	**Define Stoke's and divergence Theorem. (Nov 2013, May 2014, Nov 2016)** (BTL 1) **Stoke's Theorem** The line integral of a vector around a closed path is equal to the surface integral of the normal component of its equal to the integral of the normal component of its curl over any closed surface. $\oint H.dl = \iint_S \nabla \times HdS$ **Divergence theorem** The volume integral of the divergence of a vector field over a volume is equal to the surface integral of the normal component of this vector over the surface bounding the volume. $\iiint_v \nabla .AdV = \oiint_s A.dS$
7	**Write down the expression for conversion of Cylindrical to Cartesian system.** (BTL 1) The Cylindrical co-ordinates (r , Φ , z) can be converted into Cartesian co-ordinates(x, y, z). **Given** **Transform** r x = r cosθ Φ y = r sinθ z z = z
8	**What is the physical significance of curl in a vector field? (Nov 2011)** (BTL 1) The curl of a vector is an axial vector whose magnitude is the maximum circulation of A per unit area as the area tends to zero and whose direction is the direction normal direction of the area when the area is oriented to make the circulation maximum.
9	**Write down the expression for conversion of Cartesian to Spherical system.** (BTL 1) The Cartesian co-ordinates (x, y, z) can be converted into Spherical co-ordinates (r, θ, Φ).

	Given **Transform** x r = $\sqrt{x^2+y^2+z^2}$ y θ =$\cos^{-1}\left(\frac{z}{\sqrt{x^2+y^2+z^2}}\right)$ z Φ = $\tan^{-1}$(y/x)
10	**Write down the expression for conversion of Spherical to Cartesian system.** (BTL 1) The Spherical co-ordinates (r, θ, Φ) can be converted into Cartesian co-ordinates (x, y, z). **Given** **Transform** r x = rsinθ.cosΦ θ y = r sinθ.sin Φ Φ z = rcosθ
11	**Transform the Cartesian co-ordinates x = 2, y = 1, z = 3 into spherical co-ordinates.** (BTL 5) **Given** **Transform** x = 2 r = $\sqrt{x^2+y^2+z^2} = \sqrt{4+1+9}$ = 3.74 y = 1 θ =$\cos^{-1}\left(\frac{z}{\sqrt{x^2+y^2+z^2}}\right)$ = cos-1($\frac{3}{\sqrt{14}}$)=36.7° z = 3 Φ = $\tan^{-1}$(y/x) = $\tan^{-1}$(1/2) = 26.56° The spherical co-ordinates are (3.74, 36.7° , and 26.56°).
12	**Define electric flux, electric flux density and electric field intensity. (May 2016)** (BTL 1) **Electric flux:** The lines of electric force are known as electric flux. It is denoted byΨ. Ψ = Q (charge) Coulomb. **Electric flux density:** Electric flux density or displacement density is defined as the electric flux per unit area. D = Q/A **Electric field intensity:** Electric field intensity is defined as the electric force per unit positive charge. It is denoted by E. E = $\frac{F}{Q} = \frac{Q}{4\pi\varepsilon r^2}$ V/m.
13	**Two vectors are given P=3i+5j+2k and Q=2i-4j+3k.Determine the angular separation between them. (November 2011)** (BTL 5) P. Q= IPIIQI cosθ, P.Q=-8, IPI=6.1644 IQI=5.38516, Cosθ=-0.2409, θ=103.94.
14	**Two vector quantities A=4i+3j+5k and B=i-2j-2k.are oriented in two different directions. Determine the angular separation between them. (Nov 2012) (May 2012)** (BTL 5) $A.B = IAI\ IBI\ \cos\theta$ $\theta = \cos^{-1}\frac{A.B}{IAI\ IBI}$ = 67.84°
15	**What are the different sources of Electromagnetic fields? (May 2012)** (BTL 1) Electromagnetic fields are present everywhere in our environment but are invisible to the human eye. Electric fields are produced by the local build-up of electric charges in the

	atmosphere associated with thunderstorms. The earth's magnetic field causes a compass needle to orient in a North-South direction and is used by birds and fish for navigation.
16	**Define the unit vector in cylindrical co-ordinate systems. (Nov 2013)** (BTL 6) A vector A in cylindrical coordinates can be written as (A_ρ,A_φ,A_z) Where $a_{\rho,}a_\phi$and a_z are unit vectors in the ρ, ϕ and z directions.
17	**State the condition for the vector to be solenoidal and irrotational. (Nov 2012)** (BTL 1) A.B=0 and AX B=0
18	**State Gauss's law and Coulomb's law (May 2016)** (BTL 1) **Gauss's law:** The electric flux passing through any closed surface is equal to the total charge enclosed by that surface. $\Psi = Q$ **Coulomb's law.** Coulomb's law states that the force between two very small charged objects separated by a large distance compared to their size is proportional to the charge on each object and inversely proportional to the square of the distance between them. $F\alpha\ Q_1Q_2$ $F\alpha\ \frac{1}{r^2}$ $F\alpha\ \frac{Q_1Q_2}{r^2} = \frac{Q_1Q_2}{4\pi\varepsilon r^2}\overline{a_{12}}$ Newton
19	**Name a few applications of Gauss's law in electrostatics. (Nov 2013)** (BTL 1) Gauss's law is applied to determine the electric field intensity from a closed surface. (e.g) Electric field can be determined for shell, two concentric shell or cylinders, etc.
20	**What is the electric field intensity at a distance of 20cm from a charge of 20μc/m^2 lying on the z=0 plane. in vacuum?(Nov/Dec 2014)** (BTL 5) $E = \frac{\rho_s}{2\varepsilon_0}a_z = \frac{20\ x10^{-6}}{2\,x8.854\ x10^{-12}}a_z$ $=1.12 \text{ x } 10^6 a_z$V/m.
21	**Points P and Q are located at (0,2,4) and (-3,1,5). Calculate the distance vector from P to Q. (Nov/Dec 2014)** (BTL 5) $R_{pq}=r_q - r_p$ = (-3,1,5) – (0,2,4) = (-3,-1,1)
22	**Given $\overline{A}$ =4$\overline{a_x}$ +6$\overline{a_y}$ - 2$\overline{a_z}$ and $\overline{B}$ =-2$\overline{a_x}$ +4$\overline{a_y}$ +8$\overline{a_z}$. Show that the vectors are orthogonal. (April /May 2015)** (BTL 5) $\overrightarrow{A}.\overrightarrow{B}$=(4*-2)+(6*4)+(-2*8)= -8+24-16 = 0. Therefore, $\overrightarrow{A},\overrightarrow{B}$ are orthogonal.
23	**Express in matrix form the unit vector transformation from the rectangular to cylindrical co-ordinate system. (April /May 2015)** (BTL 1) $\begin{bmatrix} a_\rho \\ a_\emptyset \\ a_z \end{bmatrix} = \begin{bmatrix} cos\varphi & sin\varphi & 0 \\ -sin\varphi & cos\varphi & 0 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} a_x \\ a_y \\ a_z \end{bmatrix}$
24	**What are the practical applications of electromagnetic fields? (Nov/Dec 2015)** (BTL 1) Electric fans, electric motors, magnetic tape, mobiles and telephones.
25	**Write the expression for differential displacement and volume in spherical co-ordinates. (Nov/Dec 2015)** (BTL 1)

	Differential displacement dl = $\sqrt{(dr)^z + (rd\theta)^2 + (r\sin\theta d\Phi)^2}$ Differential volume dv = $r^2 \sin\theta\ dr\ d\theta\ d\phi$
	PART * B
1	**Given that D = (10 ρ^3/4) cylindrical coordinates, evaluate both sides of divergence theorem for the volume enclosed by ρ = 4, z = 0 and z = 5. (13 M)** (BTL 5) **Answer: Page 1.10 - Dr. P. Dananjayan** **L.H.S.** $\iint D\cdot dS = \int_{z=0}^{5}\int_{\phi=0}^{2\pi}\left(\frac{10\rho^3}{4}\right)_{\rho=4} a_\rho\cdot\rho\, d\phi\, dz\, a_\rho$ $= \int_{z=0}^{5}\int_{\phi=0}^{2\pi}\frac{10\times4^4}{4}\,d\phi\, dz$ $= 640 \times 5 \times 2\pi = 6400\pi.$ (6 M) **R.H.S** $\iiint\nabla\cdot DdV = \int_{z=0}^{5}\int_{\phi=0}^{2\pi}\int_{\rho=0}^{4}\nabla.D\rho d\rho\, d\phi\, dz$ $\nabla\cdot D = \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho D_\rho)$ $= \frac{1}{\rho}\frac{\partial}{\partial\rho}\left(\frac{10\rho^4}{4}\right)=\frac{1}{\rho}(10\rho^3)=10\rho^2$ $\therefore \iiint\nabla\cdot DdV = \int_{z=0}^{5}\int_{\phi=0}^{2\pi}\int_{\rho=0}^{4}10\rho^3\, d\rho\, d\phi\, dz$ $= 10\left[\frac{\rho^4}{4}\right]_{\rho=0}^{4}\int_{z=0}^{5}\int_{\phi=0}^{2\pi}d\phi\, dz$ $= 640 \times 2\pi \times 5$ $= 6400\pi.$ L.H.S. = R.H.S. Hence, divergence theorem is verified. (7 M)

2

State and prove Divergence theorem and Stokes's Theorem. (Nov 2011, Nov 2012, May 2012, Nov 2014, Nov 2016) (13M) (BTL 1)

Answer: Page No. 1.16 - Dr. P. Dananjayan

Statement:**(**2 M)

The volume integral of the divergence of a vector field over a volume is equal to the surface integral of the normal component of this vector over the surface bounding the volume.

$$\iiint_v \nabla . A dV = \oiint_S A.dS$$

Proof:

- Divergence of any vector A is given by

$$\nabla . A = \frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z}$$

- Taking volume integral on both sides

$$\iiint_v \nabla . A \; dv = \iiint \left[\frac{\partial A_x}{\partial x} + \frac{\partial A_y}{\partial y} + \frac{\partial A_z}{\partial z} \right] .dv$$

- Consider an element volume in x direction

$$\iiint_v \frac{\partial A_x}{\partial x} dx \; dy \; dz = \iint \left[\int \frac{\partial A_x}{\partial x} .dx \right] dy \; dz$$

- Where

$$\int_{x_1}^{x_2} \frac{\partial A_x}{\partial x} dx = A_{x_2} - A_{x_1} = A_x$$

- Then

$$\iiint_v \frac{\partial A_x}{\partial x} dx \; dy \; dz = \iint_S A_x dy \; dz = \iint_S A_x ds_x$$

Similarly, the following integrals become

$$\iiint_v \frac{\partial A_y}{\partial y} dx \; dy \; dz = \iint_S A_y ds_y$$

$$\iiint_v \frac{\partial A_z}{\partial z} dx\ dy\ dz = \iint_S A_z ds_z$$

- Then,

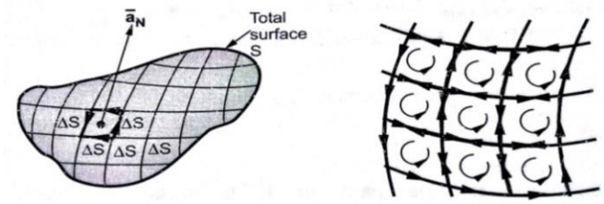
$$\iiint_v \nabla . A\ dv = \oiint A.ds$$

(4 M)

Stoke's Theorem (2 M)

The line integral of a vector around a closed path is equal to the surface integral of the normal component of its equal to the integral of the normal component of its curl over any closed surface.

$$\oint_L \vec{F} .\ d\vec{L} = \int_S \left(\nabla \times \vec{F}\right).\overline{ds}$$



<u>Proof of stokes theorem</u>

- Consider a surface S which is splitted in to number of incremental surfaces.
- Each incremental surface is having area Δs .
- Applying definition of curl to any of these incremental surfaces we can write
  - $\left(\nabla \times \overline{F}\right)_N = \dfrac{\oint \overline{F}.\overline{dL}_{\Delta s}}{\Delta S}$
  - Where N → Normal to ΔS according to right hand rule

$\overline{dL}_{\Delta s}$ → Perimeter of the incremental surface ΔS

- Curl of $\vec{F}$ in normal direction is dot product of curl of $\vec{F}$ with $\bar{a}_N$.
- $\bar{a}_N$ = Unit vector, normal to the surface ΔS .
  - $\left(\nabla \times \overline{F}\right)_N = \left(\nabla \times \overline{F}\right).\bar{a}_N$
  - $\oint \overline{F}.\overline{dL}_{\Delta s} = \left(\nabla \times \overline{F}\right).\bar{a}_N \Delta S$
  - $\oint \overline{F}.\overline{dL}_{\Delta s} = \left(\nabla \times \overline{F}\right).\Delta S$

- Obtain total curl for every incremental surface, add closed line integrals for each ΔS .
- Hence summation of all closed line integrals for each and every ΔS ends up.
- Single closed line integral to be obtained for outer boundary of total surface S

$$\oint_L \overline{F}.\overline{dL} = \int_S \left(\nabla \times \overline{F}\right).dS$$

(5 M)

3

Transform 4ā

Transform $4\bar{a}_x$-$2\bar{a}_y$-$4\bar{a}_z$ at (2, 3, 5) to spherical coordinates. (Nov 2016) (13 M) (BTL 5)

Answer: Page - 1.58 -Dr. P. Dananjayan

Formula: (3 M)

$$\begin{bmatrix} A_r \\ A_\theta \\ A_\phi \end{bmatrix} = \begin{bmatrix} \sin\theta\,\cos\phi & \sin\theta\sin\phi & \cos\theta \\ \cos\theta\cos\phi & \cos\theta\sin\phi & -\sin\theta \\ -\sin\phi & \cos\phi & 0 \end{bmatrix} \begin{bmatrix} A_x \\ A_y \\ A_z \end{bmatrix}$$

$$A_x = 4 \quad A_y = -2 \quad A_z = -4$$

$$A_\rho = A_x \cos\phi + A_y \sin\phi = 4\cos\phi - 2\sin\phi$$

$$\phi = \tan^{-1}\left(\frac{y}{x}\right) = \tan^{-1}\left(\frac{3}{2}\right) = 56.31°$$

$$A_\rho = 4\cos 56.31° - 2\sin 56.31° = 2.219 - 1.664 = 0.555$$

$$A_\phi = -A_x \sin\phi + A_y \cos\phi$$

$$= -4\sin 56.31° - 2\cos 56.31° = -3.328 - 1.109 = -4.44$$

The vector in cylindrical system can be written as $0.555\, a_\rho - 4.44\, a_\phi - 4\, a_z$.

(10 M)

4

Write short notes on the following (i) Gradient (ii) Divergence (iii) Curl and (iv) Strokes theorem. (Nov 2013, Nov 2011) (13 M) (BTL 1)

Answer: Page -1.05- Dr. P. Dananjayan

(i) Gradient. (3M)

The gradient of any scalar function is the maximum space rate of change of that function. If the scalar V represents electric potential, ∇ V represents potential gradient.

∇ V= $\frac{\partial V}{\partial x}\overline{a}_x + \frac{\partial V}{\partial y}\overline{a}_y + \frac{\partial V}{\partial z}\overline{a}_z$. This operation is called the gradient.

(ii) Divergence: (3M)

The divergence of a vector ‘A’ at any point is defined as the limit of its surface integrated per unit volume as the volume enclosed by the surface shrinks to zero.

$\nabla .A = Lt_{V \to 0} \frac{1}{v} \oint\!\!\oint_S A \,.\, \bar{n}$ ds.

$\nabla .A = \frac{\partial A_X}{\partial x} + \frac{\partial A_Y}{\partial y} + \frac{\partial A_Z}{\partial z}$. This operation is called divergence. Divergence of a vector is a scalar quantity.

(iii) Curl: (3 M)

The curl of a vector 'A' at a any point is defined as the limit of its cross product with normal over a closed surface per unit volume as the volume shrinks to zero.

∇ x A $= Lt_{V \to 0} \frac{1}{v} \oint\!\!\oint_S \bar{n}$ x Ads.

(iv) Stoke's Theorem (4M)

The line integral of a vector around a closed path is equal to the surface integral of the normal component of its equal to the integral of the normal component of its curl over any closed surface.

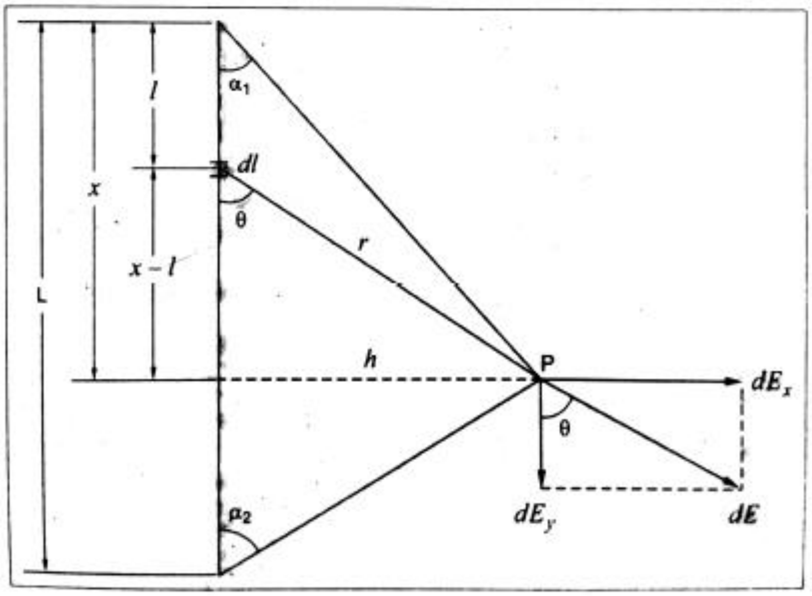
$$\oint H .dl = \iint_S \nabla \times HdS$$

5

Derive an expression for Electric field intensity due to a line charge which has a uniform linear charge density of ρLC/m. Also extend it to a conductor of infinite length. (Nov 2014, Nov 2015, April 2015) (13 M) (BTL 1)

Answer: Page - 1.23-Dr. P. Dananjayan

Diagram: (3M)



- Consider a uniformly charged line of length L.
- Linear charge density is ρl c/m
- Consider a small element dl
- P be any point at a distance r from dl. (2M)
  - dEx =dE sinθ
  - dEy =dE cosθ

- Ex = ρl/(4πεh) *[cos α1 + cos α2] (2 M)
- Ey = ρl/(4πεh) *[sin α1 +sin α2] (2 M)
- Case (i) If the point is at bisector of a line, then α1=α2 = α
  - Ey = 0, E becomes Ex
  - E = ρl/(2πεh) (2 M)
- Case (ii) If the line is infinitely long the α = 0
  - Ey = 0, E becomes Ex
  - E = ρl/(2πεh) (2 M)

6

State and prove the Gauss law. (April 2015) (13 M) (BTL 1)

Answer: Page -1.28 -Dr. P. Dananjayan

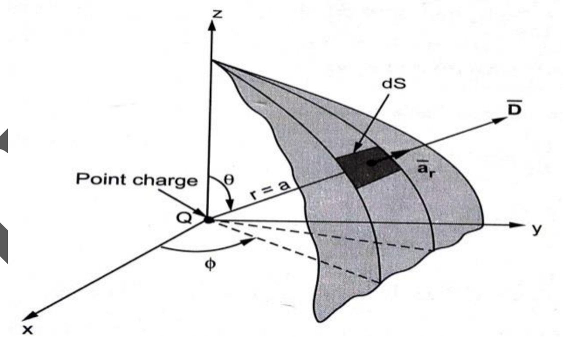
Statement: (2 M)

Diagram: (4 M)

Expression: (7M)

Gauss's law: The electric flux passing through any closed surface is equal to the total charge enclosed by that surface. $\Psi = Q$

Proof:



- Spherical surface = Gaussian surface
- Ds is normal to $\overline{a_r}$ direction
  - $\psi = \int D.ds$
  - $D = \frac{Q}{4\pi r^2}.\overline{a_r}$
  - $ds = r^2 \sin\theta \; d\theta \; d\phi \; \overline{a_r}$
  - $\psi = \int_0^{2\pi}\int_0^{\pi} \frac{Q}{4\pi r^2} \times r^2.\overline{a_r} \sin\theta \; d\theta \; d\phi \; \overline{a_r}$
  - $\psi = \frac{4\pi Q}{4\pi} = \mathrm{Q}$

7

Explain the applications of Gauss Law. (13 M) (BTL 1)

Answer: Page - 1.32 - Dr. P. Dananjayan

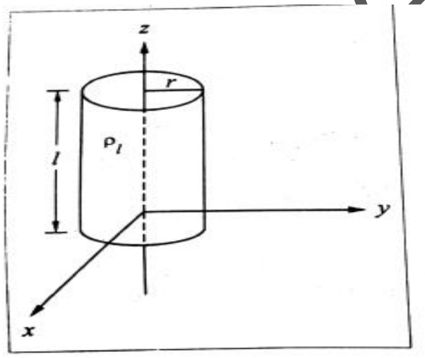
Application: (2 M)

Explain any two types:

- The surface is closed.
- Electric flux density is either normal or tangential to surface.
- Electric flux density is constant over surface where D is normal.
  - Infinite line charge.
  - Single shell of charge.

Infinite line charge. (6 M)

- Consider an infinite line charge of ρl c/m.
- Consider a circular cylinder of radius ‘r’
- length ‘l’ as Gaussian surface
- Flux density Ds is normal to the surface.



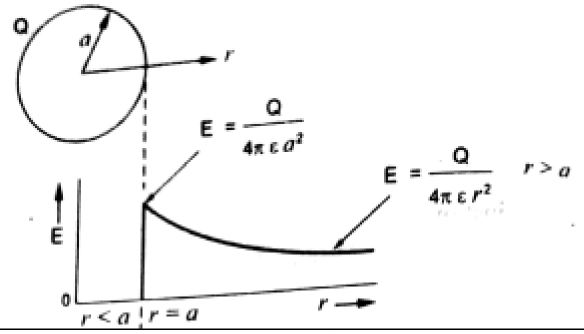
- By applying Gauss’s Law to closed surface.

$$Q = \oint D_s \cdot ds$$

$$= D_s \int_{\text{sides}} ds + D_s \int_{\text{top}} ds + D_s \int_{\text{bottom}} ds$$

- Ds = Q / 2πr l
- Ds = ρl / 2πr
- E = ρl / 2πε0r

Single shell of charge (5 M)



	➢ Charge Q is uniformly distributed over surface. ➢ Apply Gauss's law inside shell. ➢ Flux density is zero. • $\int D.ds = 0$ • $\varepsilon \int E.\ ds = 0$ • $E = 0$ ➢ By applying Gauss's law just outside shell. ➢ Integral of flux density D over a spherical surface. • $\int D.\ ds = Q$ • $\varepsilon \int E.\ ds.\ Q$ • $E = Q / 4 \pi \varepsilon r^2$
8	**A vector field D = [5r^2 / 4] Ir given in spherical coordinates. Evaluate both sides of divergence theorem for the volume enclosed between r = 1 and r = 2. (13 M)** (BTL 5) **Answer: Page - 1.33 - Dr. P. Dananjayan** Divergence theorem is $\iint D \cdot ds = \iiint \nabla \cdot D dv$. **L.H.S.:** $\iint D \cdot ds = \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} \left(\frac{5r^2}{4}\right)_{r=1} I_r \cdot (r^2 \sin\theta d\theta d\phi) (-I_r) + \int_{\phi=0}^{2\pi} \int_{\theta=0}^{\pi} \left(\frac{5r^2}{4}\right)_{r=2} I_r [r^2 \sin\theta\ d\theta d\phi] (I_r)$ $= \int_0^{2\pi} \int_0^{\pi} -\frac{5}{4} \sin\theta d\theta d\phi + \int_0^{2\pi} \int_0^{\pi} 5 \times 4 \sin\theta d\theta d\phi$ $= +\frac{5}{4} \int_0^{2\pi} (+\cos\theta)_0^{\pi} d\phi + 20 \int_0^{2\pi} (-\cos\theta)_0^{\pi} d\phi$ (3 M)

	$= \frac{5}{2}(-2)[\phi]_0^{2\pi} + 20(2)[\phi]_0^{2\pi}$ $= -\frac{5}{2} \times 2\pi + 40 \times 2\pi$ $= 80\pi - 5\pi$ $\iint D \cdot dS = 75\pi$ **R.H.S.:** $\iiint \nabla \cdot D\, dv$ $\nabla \cdot D = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 D_r) = \frac{1}{r^2}\frac{\partial}{\partial r}\left[r^2 . \frac{5}{4} . r^2\right]$ $= \frac{1}{r^2} 5r^3$ $= 5r$ $dV = r^2 \sin\theta\, dr\, d\theta\, d\phi$ $= \int_{\phi=0}^{2\pi}\int_{\theta=0}^{\pi}\int_{r=1}^{2} 5r \times r^2 \sin\theta\, dr\, d\theta\, d\phi$ $= \int_0^{2\pi}\int_0^{\pi}\int_1^{2} 5r^3 \sin\theta\, dr\, d\theta\, d\phi$ (5 M) $= 5\int_0^{2\pi}\int_0^{\pi}\left(\frac{r^4}{4}\right)_1^2 \sin\theta\, d\theta\, d\phi$ $= 5 \times \left(\frac{16}{4} - \frac{1}{4}\right)\int_0^{2\pi}\int_0^{\pi} \sin\theta\, d\theta\, d\phi$ $= 5 \times \frac{15}{4}\int_0^{2\pi}(-\cos\theta)_0^{\pi}\, d\phi$ $= 5 \times \frac{15}{4}(+2) \cdot [2\pi]$ $\iiint \nabla \cdot D dv = 75\pi$. L.H.S = R.H.S. Hence Divergence Theorem is verified. (5 M)
9	**Show that the vector E= $(6xy+z^2)a_x + (3x^2 - z)a_y + (3xz^2 - y)a_z$ is irrotational and find its scalar potential. (April 2015) (13 M)** (BTL 3) **Answer: Page -1.44 - Dr. P. Dananjayan**

	$\nabla \times E = \begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 6xy+z^3 & 3x^2-z & 3xz^2-y \end{vmatrix}$ $= \bar{a}_x\left[\frac{\partial}{\partial y}(3xz^2-y) - \frac{\partial}{\partial z}(3x^2-z)\right] - \bar{a}_y\left[\frac{\partial}{\partial x}(3xz^2-y) - \frac{\partial}{\partial z}(6xy+z^3)\right]$ $+ \bar{a}_z\left[\frac{\partial}{\partial x}(3x^2-z) - \frac{\partial}{\partial y}(6xy+z^2)\right]$ $= \bar{a}_x \cdot [-1+1] - \bar{a}_y \cdot [3z^2-3z^2] + \bar{a}_z \cdot [6x-6x]$ $= 0$ Hence E is irrotational. (6 M) $-\nabla \cdot V = E = (6xy+z^3)\bar{a}_x + (3x^2-z)\bar{a}_y + (3xz^2-y)\bar{a}_z$ $-\left[\bar{a}_x\frac{\partial v}{\partial x} + \bar{a}_y\frac{\partial v}{\partial y} + \bar{a}_z\frac{\partial v}{\partial z}\right] = (6xy+z^3)\bar{a}_x + (3x^2-z)\bar{a}_y + (3xz^2-y)\bar{a}_z$ Equating on both sides, $-\frac{\partial v}{\partial x} = 6xy+z^3$ $-\frac{\partial v}{\partial y} = 3x^2-z$ $-\frac{\partial v}{\partial z} = 3xz^2-y$ Then, $-\partial v = (6xy+z^3)\partial x$ $-v = \int(6xy+z^3)\partial x$ $= 3x^2y + xz^3 + c_1$ where c_1 is constant. $-\partial v = (3x^2-z)\partial y$ $-v = 3x^2y - yz + c_2$ $-\partial v = (3xz^2-y)\partial z$ $-v = xz^3 - yz + c_3$ Then, adding these values of v $v = -2(3x^2y + xz^3 - yz) + c$ where $c = c_1 + c_2 + c_3$ (7 M)
10	**Check validity of the divergence theorem considering the field D=2xy ax + x^{2}ay c/m^2 and the rectangular parallelepiped formed by the planes x=0,x=1,y=0,y=2 &z=0,z=3 (13 M)** (BTL 2) **Answer: Page -1.60 - Dr. P. Dananjayan** Formula: The volume integral of the divergence of a vector field over a volume is equal to the surface integral of the normal component of this vector over the surface bounding the volume. (3 M) Verification: (10 M) $\iiint_v \nabla . A dV = \oint\!\!\oint_S A . dS$

☺***Solution:*** By divergence theorem,

$$\iint \bar{D} \cdot n\, ds = \iiint_V \nabla \cdot \bar{D}\, dv$$

$$\nabla \cdot \bar{D} = \left(\bar{a}_x \frac{\partial}{\partial x} + \bar{a}_y \frac{\partial}{\partial y} + \bar{a}_z \frac{\partial}{\partial z} \right) \cdot (2\,xy\ \bar{a}_x + x^2\,\bar{a}_y)$$

$$= \frac{\partial}{\partial x}(2\,xy) + \frac{\partial}{\partial y}(x^2) + 0$$

$$= 2\,y + 0 = 2\,y$$

$$\iiint \nabla \cdot \bar{D}\, dv = \int_{x=0}^{1} \int_{y=0}^{2} \int_{z=0}^{3} 2\,y\, dx\, dy\, dz$$

$$= \int_0^1 \int_0^2 [\,2\,yz\,]_0^3\, dx\, dy = \int_0^1 \int_0^2 6\,y\, dx\, dy$$

$$= \int_0^1 \left[6\,\frac{y^2}{2} \right]_0^2 dx = \int_0^1 12\, dx = [\,12\,x\,]_0^1 = 12$$

Evaluation of $\iint D \cdot n\, ds$

$$\iint D \cdot n\, ds = \iint D \cdot \bar{a}_x\, dy\, dz + \iint D \cdot (-\bar{a}_x)\, dy\, dz + \iint D \cdot \bar{a}_y\, dx\, dz$$

$$+ \iint D \cdot (-\bar{a}_y)\, dx\, dz + \iint D \cdot \bar{a}_z\, dx\, dy + \iint D \cdot (-\bar{a}_z)\, dx\, dy$$

$$\iint D \cdot \bar{a}_x\, dy\, dz = \iint (2\,xy\,\bar{a}_x + x^2\,\bar{a}_y)\ (\bar{a}_x)\, dy\, dz$$

$$= \int_0^2 \int_0^3 2\,xy\, dy\, dz$$

$$= \int_0^2 [\,2\,xyz\,]_0^3\, dy = \int_0^2 6\,xy\, dy$$

$$= \left[6\,x\,\frac{y^2}{2} \right]_0^2 = 12\,x = 12 \qquad [\because x = 1]$$

$$\iint D \cdot (-\bar{a}_x)\, dy\, dz = \iint (2xy\,\bar{a}_x + x^2\,\bar{a}_y)(-\bar{a}_x)\, dy\, dz$$

$$= 0 \qquad [\because x = 0]$$

$$\iint D \cdot \bar{a}_y\, dx\, dz = \iint (2xy\,\bar{a}_x + x^2\,\bar{a}_y)(\bar{a}_y)\, dx\, dz$$

$$= \int_0^1 \int_0^3 x^2\, dx\, dz = \int_0^1 [x^2 z]_0^3\, dx$$

$$= \int_0^1 3x^2\, dx = 3\,\frac{x^3}{3}\Big|_0^1 = 1$$

$$\iint D \cdot (-\bar{a}_y)\, dx\, dz = \iint (2xy\,\bar{a}_x + x^2\,\bar{a}_y)(-\bar{a}_y)\, dx\, dz$$

$$= -\int_0^1 \int_0^3 x^2\, dx\, dz = -\int_0^1 [x^2 z]_0^3\, dx$$

$$= -3\int_0^1 x^2\, dx = -3\,\frac{x^3}{3}\Big|_0^1 = 1$$

$$\iint D \cdot \bar{a}_z\, dx\, dy = \iint D \cdot (-\bar{a}_z)\, dx\, dy$$

$$= 0 \qquad [\because \bar{a}_z =$$

$$\therefore \iint D \cdot n\, ds = 12 + 0 + 1 - 1 = 12$$

$$\text{Hence, } \iint D \cdot n\, ds = \iiint_v \nabla \cdot D\, dv$$

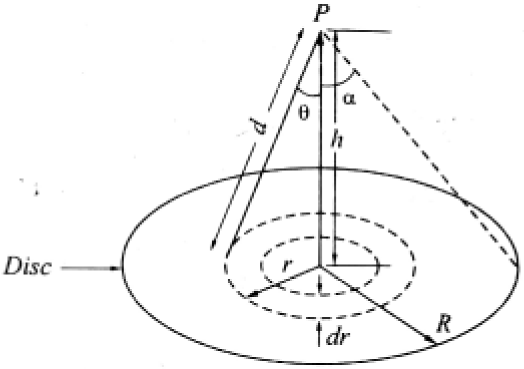
PART * C

1

Derive expression for electric field intensity due to uniformly charged circular disc of σ C/m^2. (Nov 2016) (15 M) (BTL 2)

Answer: Page - 1.25 - Dr. P. Dananjayan

Diagram: (3 M)



- Consider a circular disc radius R.

	➢ Charge density ρs c/m^2 ➢ Annular ring of radius r. ➢ Radial thickness dr. ➢ Area of annular ring ds = 2 π r dr ➢ dE = ρs ds / 4πε d^2 ➢ dEy = ρs ds cos θ/ 4πε d^2 ➢ E = [ρs / 2ε] * [1 – h/(√(h^2 + R^2))] (12 M)
2	**State and verify Divergence theorem for the vector A = 4x i – 2y^2 j + z^2 k, taken over the cube bounded by x = 0, x = 1, y = 0, y = 1. (15 M)** (BTL 3) **Answer: Page - 1.67 - Dr. P. Dananjayan** Statement: (3 M) Verification: LHS = RHS = 3 (12 M) The volume integral of the divergence of a vector field over a volume is equal to the surface integral of the normal component of this vector over the surface bounding the volume. $\iiint_v \nabla . A dV = \oiint_S A . dS$ **Given:** $A = 4x\vec{i} - 2y^2\vec{j} + z^2\vec{k}$ $\nabla \cdot A = \left(\vec{i}\frac{\partial}{\partial x} + \vec{j}\frac{\partial}{\partial y} + \vec{k}\frac{\partial}{\partial z}\right) \cdot (4x\vec{i} - 2y^2\vec{j} + z^2\vec{k})$ $= 4 - 4y + 2z$ $\iiint \nabla \cdot A = \int_0^1\int_0^1\int_0^1 (4 - 4y + 2z)\, dx\, dy\, dz$ $= \int_0^1\int_0^1 4z - 4yz + \frac{2}{2}z^2 \Big\|_0^1 dx\, dy$ $= \int_0^1\int_0^1 (5 - 4y)\, dx\, dy$ $= \int_0^1 (5y - \frac{4}{2}y^2) \Big\|_0^1 dx$ $= \int_0^1 3\, dx$ $= 3x \Big\|_0^1 = 3$

$$\oiint A\cdot ds = \iint A\cdot\vec{i}\;dy\,dz + \iint A\,(-\vec{i}\,)\,dy\,dz + \iint A\,\vec{j}\;dx\,dz$$

$$+ \iint A\,(-\vec{j}\,)\,dx\,dz + \iint A\,\vec{k}\;dx\,dy + \iint A\,(-\vec{k}\,)\,dx\,dy$$

$$\iint A\cdot\vec{i}\;x\,dy\,dz = \int_0^1\int_0^1 (4x\,\vec{i} - 2y^2\vec{j} + z^2\vec{k}\,)\,\vec{i}\;dy\,dz$$

$$= \int_0^1\int_0^1 4x\,dy\,dz$$

$$= \int_0^1 4xy\,\Big|_0^1\,dz$$

$$= 4xz\,\Big|_0^1 = 4x$$

$$= 4 \qquad [\because x = 1]$$

$$\iint A(-\vec{i}\,)\,dy\,dz = 0 \qquad [\because x = 0]$$

$$\iint A(\vec{j}\,)\,dx\,dz = \int_0^1\int_0^1 (4x\,\vec{i} - 2y^2\vec{j} + z^2\vec{k}\,)\;\vec{j}\;dy\,dz$$

$$= \int_0^1\int_0^1 -2y^2\,dx\,dz$$

$$= \int_0^1 -2xy^2\,\Big|_0^1\,dz$$

$$= -2y^2z\,\Big|_0^1$$

$$= -2y^2$$

$$= -2 \qquad [\because y = 1]$$

$$\iint A(-\vec{j}\,)\,dx\,dz = 0 \qquad [\because y = 0]$$

	$\iint A\,\vec{k}\,dx\,dy = \int_0^1\int_0^1 (4x\,\vec{i} - 2\,y^2\vec{j} + z^2\vec{k})\;\vec{k}\;dx\,dy$ $= \int_0^1\int_0^1 z^2\,dx\,dy$ $= \int_0^1 z^2\,x\,dy\,\Big\vert_0^1$ $= z^2\,y\,\Big\vert_0^1 = z^2 = 1 \qquad [\because z = 1]$ $\iint A\cdot(-\vec{k})\,dx\,dy = 0 \qquad [\because z = 0]$ $\oiint A\cdot ds = 4-2+1=3$ Hence it is verified. ☺☺
3	**Determine the divergence of these vector fields. (15 M)** (BTL 3) **(i) $P = x^2yz\,a_x + xz\,a_z$ (3 M)** **(ii) $Q = \rho\sin\varphi\,a_\rho + \rho^2 z\,a_\varphi + z\cos\varphi\,a_z$ (6 M)** **(iii) $T = (1/r^2)\cos\theta\,a_r + r\sin\theta\cos\varphi\,a_\theta + \cos\theta\,a_\varphi$ (6 M)** **Answer: Page - 1.42 - Dr. P. Dananjayan** ***(i)*** $\nabla.P = \frac{\partial P_x}{\partial x} + \frac{\partial P_y}{\partial y} + \frac{\partial P_z}{\partial z}$ $= \frac{\partial}{\partial x}(x^2y\,z) + 0 + \frac{\partial}{\partial z}(xz)$ $= \mathbf{2\,xyz + x}$ ***(ii)*** $\nabla.Q = \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho Q_\rho) + \frac{1}{\rho}\frac{\partial Q_\phi}{\partial\phi} + \frac{\partial Q_z}{\partial z}$ $= \frac{1}{\rho}\frac{\partial}{\partial\rho}(\rho^2\sin\phi) + \frac{1}{\rho}\frac{\partial}{\partial\phi}(\rho^2 z) + \frac{\partial}{\partial z}(z\cos\phi)$ $= \frac{1}{\rho}\cdot 2\rho\sin\phi + 0 + \cos\phi$ $= \mathbf{2\sin\phi + \cos\phi}$

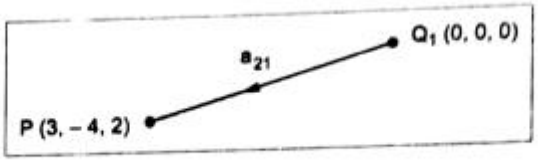
	$\nabla.T = \frac{1}{r^2}\frac{\partial}{\partial r}(r^2 T_r) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(\sin\theta\, T_\theta) + \frac{1}{r\sin\theta}\frac{\partial T_\phi}{\partial\phi}$ (Spherical) $= \frac{1}{r^2}\frac{\partial}{\partial r}(r^2\cdot\frac{1}{r^2}\cos\theta) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(\sin\theta\cdot r\sin\theta\cos\phi) + \frac{1}{r\sin\theta}\frac{\partial}{\partial\phi}(\cos\theta)$ $= 0 + \frac{1}{r\sin\theta}\frac{\partial}{\partial\theta}(r\cos\phi\sin^2\theta) + 0$ $= \cos\phi\frac{\partial}{\partial\theta}(\sin^2\theta) = \cos\phi\cdot 2\cdot\sin\theta\cdot\cos\theta$ $= \mathbf{2\cos\phi\sin\theta\cdot\cos\theta}$ ☺☺
4	**A charge Q**

(c) Q1 = 2 µC at (0, 0, 0) and Q2 = 3 µC at (-1, 2, 3) (7 M)(BTL 5)

Answer: Page -1.80 - Dr. P. Dananjayan

Solution:

(*a*)



$$\text{Unit vector } \bar{a}_{21} = \frac{r_1 - r_2}{|r_1 - r_2|}$$

$$= \frac{3\,\bar{a}_x - 4\,\bar{a}_y + 2\,\bar{a}_z}{\sqrt{9+16+4}}$$

$$= \frac{3\,\bar{a}_x + 4\,\bar{a}_y + 2\,\bar{a}_z}{\sqrt{29}}$$

Electric field intensity at P due to Q_1

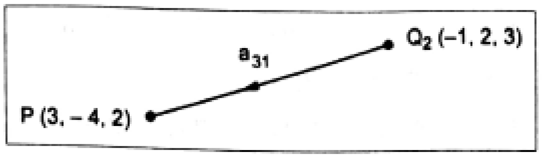
$$E = \frac{Q_1}{4\pi\,\varepsilon_0\,r^2}\,\bar{a}_{21}$$

$$= \frac{2 \times 10^{-6}}{4\pi \times \frac{1}{36\pi \times 10^9} \times (\sqrt{29})^2} \cdot \frac{3\,\bar{a}_x + 4\,\bar{a}_y + 2\,\bar{a}_z}{\sqrt{29}}$$

$$= \frac{2 \times 9 \times 10^3}{29\sqrt{29}}\,(3\,\bar{a}_x + 4\,\bar{a}_y + 2\,\bar{a}_z)$$

$$\mathbf{E} = 345\,\bar{a}_x - 460\,\bar{a}_y + 230\,\bar{a}_z \quad \text{V/m}$$

(b)



$$\bar{a}_{31} = \frac{\bar{a}_x(3-(-1)) + \bar{a}_y(-4-(2)) + \bar{a}_z(2-3)}{(3+1)^2 + (-4-2)^2 + (2-3)^2}$$

$$= \frac{4\bar{a}_x - 6\bar{a}_y - \bar{a}_z}{\sqrt{16+36+1}} \cdot \frac{4\bar{a}_x - 6\bar{a}_y - \bar{a}_z}{\sqrt{53}}$$

Electric intensity at P due to Q_2

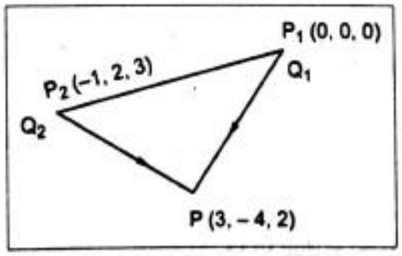
$$E = \frac{Q}{4\pi\varepsilon_0 r^2}\bar{a}_{31}$$

$$= \frac{3\times10^{-6}}{4\pi\times\frac{1}{36\pi\times10^9}\times(\sqrt{53})^2} \cdot \frac{4\bar{a}_x - 6\bar{a}_y - \bar{a}_z}{\sqrt{53}}$$

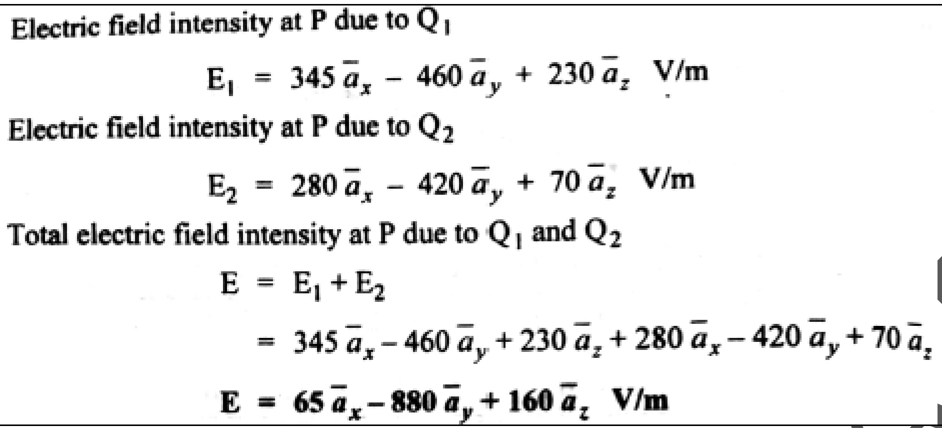
$$= \frac{3\times9\times10^3}{53\sqrt{53}}(4\bar{a}_x - 6\bar{a}_y - \bar{a}_z)$$

$$\mathbf{E} = 280\,\bar{a}_x - 420\,\bar{a}_y - 70\,\bar{a}_z \text{ V/m}$$

(c)



$$\bar{a}_{31} = \frac{3\bar{a}_x - 4\bar{a}_y + 2\bar{a}_z}{\sqrt{9+16+4}} = \frac{3\bar{a}_x - 4\bar{a}_y + 2\bar{a}_z}{\sqrt{29}}$$

	 Electric field intensity at P due to Q_1 $E_1 = 345\,\bar{a}_x - 460\,\bar{a}_y + 230\,\bar{a}_z$ V/m Electric field intensity at P due to Q_2 $E_2 = 280\,\bar{a}_x - 420\,\bar{a}_y + 70\,\bar{a}_z$ V/m Total electric field intensity at P due to Q_1 and Q_2 $E = E_1 + E_2$ $= 345\,\bar{a}_x - 460\,\bar{a}_y + 230\,\bar{a}_z + 280\,\bar{a}_x - 420\,\bar{a}_y + 70\,\bar{a}_z$ $\mathbf{E = 65\,\bar{a}_x - 880\,\bar{a}_y + 160\,\bar{a}_z}$ **V/m**

UNIT II ELECTROSTATICS – II

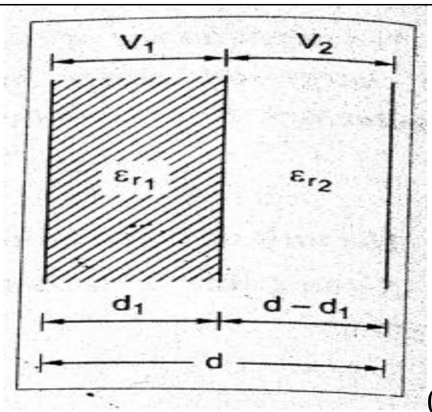
Electric potential – Electric field and equipotential plots, Uniform and Non-Uniform field, Utilization factor – Electric field in free space, conductors, dielectrics - Dielectric polarization – Dielectric strength - Electric field in multiple dielectrics – Boundary conditions, Poisson's and Laplace's equations, Capacitance, Energy density, Applications.

Q. No	Part * A
	Questions
1	**What do you understand by linear, surface and volume charge densities?**(BTL 1) **Linear Charge density:** It is the charge per unit length (Col / m) at a point on the line of charge. ρ_l= Lt $_{\Delta l \to 0}$ $\left(\frac{\Delta Q}{\Delta l}\right)$ **Surface charge density:** It is the charge per surface area (C/m^2) at a point on the surface of the charge. ρ_s= Lt $_{\Delta s \to 0}$ $\left(\frac{\Delta Q}{\Delta s}\right)$ **Volume charge density:** It is the charge per volume (C/m^3) at a point on the volume of the charge. ρ_V= Lt $_{\Delta v \to 0}$ $\left(\frac{\Delta Q}{\Delta v}\right)$
2	**Define potential and potential difference. (Nov 2012)(May2012) (Nov 2013)**(BTL 1) **Potential:** Potential at any point as the work done in moving a unit positive charge from infinity to that point in an electric field = $\frac{Q}{4\pi\varepsilon r}$ Volts. **Potential Difference:** Potential difference is defined as the work done in moving a unit positive charge from one point in an electric field. V= $\frac{Q}{4\pi\varepsilon}\left(\frac{1}{r_A} - \frac{1}{r_B}\right)$ Volts.
3	**Find the electric potential at a point (4 , 3) m due to a charge of 10^{-9} C located at the origin in free space.**(BTL 5) V=$\frac{Q}{4\pi\varepsilon_O r}$; r = $\sqrt{4^2+3^2}$ = 5m. V=$\frac{10\ -\ 9}{4\pi x 8.854\ x10\ -\ 12\ x(5)}$ = 1.8V
4	**Define Capacitance.** (BTL 1) The capacitance of two conducting planes is defined as the ratio of magnitude of charge on either of the conductor to the potential difference between conductors. It is given by, $C = \frac{Q}{V}$ Farad.
5	**What is meant by conduction current?** (BTL 1) Conduction current is nothing but the current flows through the conductor. Conduction current density is given by Jc = σE Amp / m^2.
6	**Write the Poisson's equation and Laplace equation. (May 2014, May 2016)**(BTL 1) **Poisson equation;** $\nabla^2 V = -$ ρ/ε

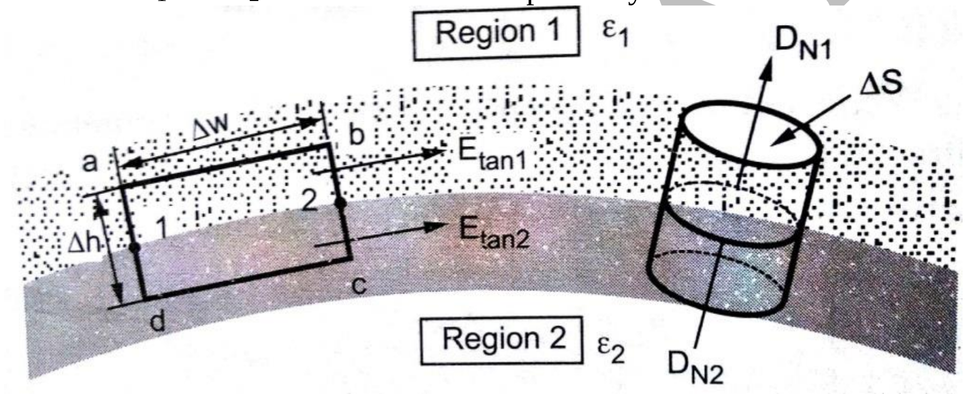
	where ρ – Volume charge density ,ε - Permittivity of the medium,∇ - Laplacian operator. $\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial Y^2}+\frac{\partial^2 V}{\partial z^2}$ = - ρ/ε **Laplace equation:** $\nabla^2 V = 0$; $\frac{\partial^2 V}{\partial x^2}+\frac{\partial^2 V}{\partial Y^2}+\frac{\partial^2 V}{\partial z^2}$ =0
7	**Give the relationship between potential gradient and electric field.** (BTL 1) E = $-\nabla V$; E = -($\frac{\partial}{\partial x}\bar{a}_x+\frac{\partial}{\partial y}\bar{a}_y+\frac{\partial}{\partial z}\bar{a}_z$) V.
8	**Define dipole and dipole moment.** (BTL 1) Dipole or electric dipole is nothing but two equal and opposite point charges are separated by a very small distance. The product of electric charge and distance (spacing) is known as dipole moment. It is denoted by m where Q is the charge and l is the length (m) =Q. l C/m
9	**What is meant by conservative property of Electric field? (Nov 2011)**(BTL 1) The line integral of electric field along a closed path is zero. Physically this implies that no net work is done in moving a charge along a closed path in an electrostatic field. Thus an electrostatic field is said to have conservative property.
10	**What is meant by Displacement current density?**(BTL 1) Displacement current is nothing but the current flows through the Capacitor. Displacement current density is given by $J_d = \frac{\partial D}{\partial t}$ Amp / m^2
11	**State the boundary conditions at the interface between two perfect dielectrics.**(BTL 1) The tangential component of electric field E is continuous at the surface. That is E is the same just outside the surface as it is just inside the surface.$E_{t1} = E_{t2}$ The normal component of electric flux density is continuous if there is no surface charge density. Otherwise D is discontinuous by an amount equal to the surface charge density. $D_{n1} = D_{n2}$
12	**Find the energy stored in a parallel plate capacitor of 0.5m by 1m has a separation of 2cm and a voltage difference of 10V.**(BTL 5) C= $\varepsilon_o \frac{A}{d} = \frac{8.854 \times 10^{-12} \times 0.5 \times 1}{2 \times 10^{-2}}$ =2.2135x10^{-10}F Energy stored in a capacitor E=1/2 CV^2 =1/2 X 2.2135 X 10^{-10} X10^2=1.10675 X 10^{-8}Joules.
13	**Express the value of capacitance for a co-axial cable.**(BTL 5) C= $\frac{2\pi\varepsilon_o\varepsilon_r}{\ln\frac{b}{a}}$; Where b – outer radius: a – inner radius.

14	**Determine the capacitance of a parallel plate capacitor with two metal plates of size 30cm x 30cm separated by 5mm in air medium.** (BTL 5) Given data: A = 0.3 X0.3 = 0.09m^2; d=5 x 10^{-3}m. ε_o = 8.854 x 10^{-2};C= $\frac{A}{2}$ ε_o= $\frac{0.09 \times 8.854 \times 10^{-12}}{5 \times 10^{-3}}$ = 15.9nF
15	**What is the physical significance of divD?** (BTL 1) $\nabla . D = \rho_v$. The divergence of a vector flux density is electric flux per unit volume leaving a small volume. This is equal to the volume charge density.
16	**A parallel plate capacitor has a charge of 10-3 C on each plate while the potential difference between the plates is 1000V.Calaculate the value of capacitance. (Nov 2012)(May2012)**(BTL 5) Given data, Q = 10-3C, V = 1000V, C = $\frac{Q}{V} = \frac{10^{-3}}{10^{3}}$ = 1μF.
17	**Give the significant physical difference between Poisson's and Laplace equation. (Nov 2011, Nov/Dec14)** (BTL 2) **Poisson equation:** $\nabla^2 V = -\rho/\varepsilon$ Where ρ – Volume charge density, ε – Permittivity of the medium, ∇^2- Laplacian operator. $\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial z^2}$ = - ρ/ε **Laplace equation:** $\nabla^2 V = 0$; $\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial Y^2} + \frac{\partial^2 V}{\partial z^2}$ =0 The Laplace equation is defined only for the region which is free of charges.
18	**State the properties of electric flux lines. (Nov/Dec 2014)** (BTL 1) a.It must be independent of the medium. b.Its magnitude solely depends upon the charge from which it originates, c.If a point charge is enclosed in an imaginary sphere of radius R, the electric flux must pass perpendicularly and uniformly through the surface of the sphere and d.The electric flux density, the flux per unit area is then inversely proportional to R^2.
19	**What is the electric field intensity at a distance of 20 cm from a charge of 2 μC in vacuum? (Nov/Dec 2015)** (BTL 5) E=$\frac{Q}{4\pi\epsilon r^2}$ V/m ; E=$\frac{2*10^{-6}}{4\pi*8.854*10^{-12}*0.02^2}$ V/m ; E = 4.49 * 10^7 V/m
20	**Calculate the capacitance per Km between a pair of parallel wires each of diameter 1cm at a spacing of 50cms. (Nov/Dec 2015)**(BTL 5) $c = \frac{\epsilon A}{d} F/km$; A = 2π rh = 2π * 1*10^{-5}*1= 6.28 *10^{-5} km^2; d = 50 *10^{-3} km; c = $\frac{8.854\times10^{-12}\times6.28\times10^{-5}}{50\times10^{-3}}$ F/km = 1.112 *10^{-4} F/km.
21	**Find the electric field intensity in free space if D=30a$_Z$ C/m^2. (April /May 2015)**(BTL 5) D= ϵE ; E = $\frac{D}{\epsilon}$; E = $\frac{30}{8.854*10^{-12}}$ = 3.388*10^{12} V/m

22	**What is the practical significance of Lorentz's Force?(April /May 2015)(Nov/Dec 2015)**(BTL 1) When an electric charge element is moving in a uniform magnetic field (B) with velocity V, the charge experience a force (dF). This force is called as Lorentz's force. $dF = dQVBsin\theta$, θ is angle between V and B. The direction of lorentz's force is maximum if the direction of movement of charge is perpendicular to the orientation of field lines.
23	**Find the capacitance of an isolated spherical shell of radius α. (Nov 2016)**(BTL 5) $C = 4\pi\varepsilon_0\alpha$
24	**Find the magnitude of D for a dielectric material in which E=0.15MV/m and ε_r=5.25. (Nov 2016)**(BTL 5) $D = \varepsilon_0\varepsilon_r E$; $D = 8.854 \times 10^{-12} \times 5.25 \times 0.15 \times 10^6 = 6.97\mu V/m$
25	**Define capacitor and capacitance. (May 2016)**(BTL 1) Capacitor is a passive element that stores electrical energy in an electric field. Capacitance is the ability of a body to store an electric charge.
	PART * B
1.	**Derive the expression for energy and energy density in the static electric field.(Nov 2013, Nov 2015) (13 M)** (BTL 2) **Answer: Page - 2.24 – Dr. P. Dananjayan** Energy: (7 M) ➢ Capacitor stores the electrostatic energy. ➢ Voltage connected across the capacitor, capacitor charges. ➢ Potential is defined as work done per unit charge. ➢ V = dW/dQ ➢ dW = V. dQ ➢ but V = Q/C ➢ $W = \int_0^Q \frac{Q}{C}\, dQ$ ➢ $W = Q^2/2C$ ➢ But Q = CV ➢ Energy = ½ C V^2 Energy Density: (6 M) ➢ Consider a elementary cube of side Δd. ➢ ΔC = εA/Δd = εΔd ➢ $\Delta W = ½\, \Delta C\, (\Delta V)^2$ ➢ But ΔV = E. Δd ➢ $\Delta W = ½\, \varepsilon\, E^2\, \Delta V$ ➢ Energy Density = ½ DE
2.	**Deduce an expression for the capacitance of a parallel plate capacitor with two dielectrics of relative permittivity ε_1 and$\varepsilon_2$respectively interposed between the plates.(Nov 2013, May 2015, May 2016) (13 M)**(BTL 2) **Answer: Page - 2.16–Dr. P. Dananjayan**

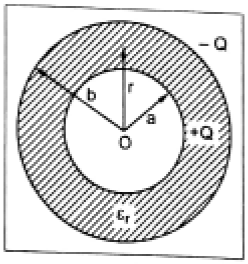
	 (2M) - Consider a parallel plate capacitor consist of two dielectrics. - εr1 and εr2 relative permittivity of medium 1 and 2. - V = V1 + V2 - V1 = E1 d1 - V2 = E2 (d – d1) - V = E1 d1 + E2 (d – d1) (5 M) $E_1 = \frac{D}{\varepsilon_0 \varepsilon_{r_1}} = \frac{Q}{A \varepsilon_{r_1} \varepsilon_0}$ $E_2 = \frac{D}{\varepsilon_0 \varepsilon_{r_2}} = \frac{Q}{A \varepsilon_{r_2} \varepsilon_0}$ - $V = \frac{Q}{A \varepsilon_0} \left[\frac{d_1}{\varepsilon_{r_1}} + \frac{d - d_1}{\varepsilon_{r_2}} \right]$ $\frac{Q}{V} = \frac{A \varepsilon_0}{\frac{d_1}{\varepsilon_{r_1}} + \frac{d - d_1}{\varepsilon_{r_2}}}$ $C = \frac{A \varepsilon_0}{\frac{d_1}{\varepsilon_{r_1}} + \frac{d - d_1}{\varepsilon_{r_2}}}$ - Capacitance = A ε0 εr / (d_1 εr + (d – d_1) (6 M)
3.	**Derive the electrostatic boundary conditions at the interface between two dielectrics and a conductor to dielectric medium. (Nov2013, Nov 2014, Nov 2015) (13 M)**(BTL 1) **Answer: Page- 2.25 - Dr. P. Dananjayan** - The boundary conditions at an interface separating - Dielectric (ε_{r1}) and dielectric (ε_{r2}) - Conductor and dielectric - Conductor and free space - To determine the boundary conditions, we need to use Maxwell's equations:

- $\oint E.dl = 0$-----(1)
- $\oint_s \; D.ds = Q_{enc}$ ------(2)
- Where Q_{enc} is the free charge enclosed by the surface S.
- Electric field intensity is decomposed into two orthogonal components.
- $E = E_t + E_n$ -------(3)
- Where E_t and E_n are tangential and normal components of E to the interface of interest.
- **Dielectric to Dielectric Boundary Conditions:**
- Consider E field existing in a region that consists of two different dielectrics.
- The fields E_1 and E_2 in media 1 and 2 respectively.

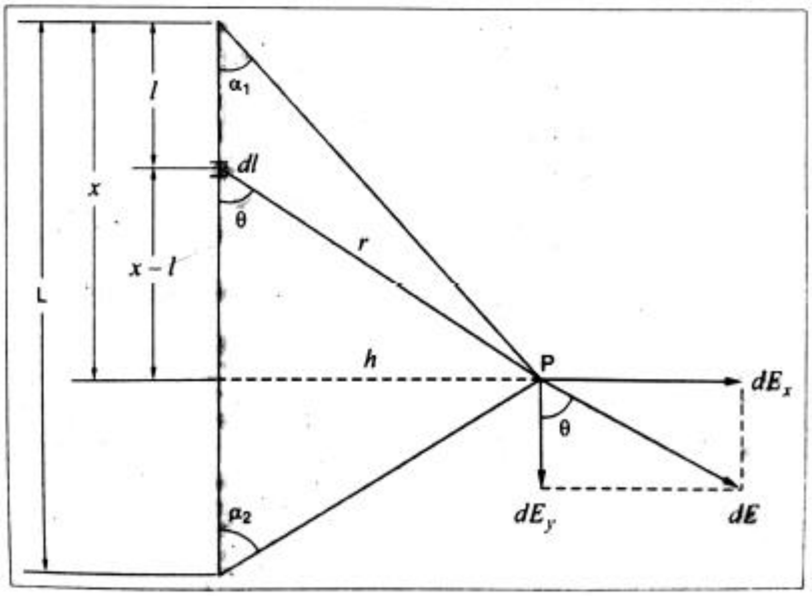


Boundary between two perfect dielectrics

- $E_1 = E_{1t} + E_{1n}$ ------(4a)
- $E_2 = E_{2t} + E_{2n}$ ------(4b)
- Apply equation (1) to the closed path abcda, assuming that the path is very small with respect to the spatial variation of E. we obtain,
- $0 = E_{1t}\Delta w - E_{1n}\frac{\Delta h}{2} - E_{2n}\frac{\Delta h}{2} - E_{2t}\Delta w + E_{2n}\frac{\Delta h}{2} + E_{1n}\frac{\Delta h}{2} ------ (5)$
- Where $E_t = |E_t|$ and $E_n = |E_n|$
- The $\frac{\Delta h}{2}$ terms cancel and equ (5)becomes,
- $0 = (E_{1t} - E_{2t})\Delta w$
- $\boxed{\boldsymbol{E_{1t} = E_{2t}}}$-----(6) (6 M)
- Tangential components of E are the same on the two sides of the boundary.
- Since D = ε E = D_t+ D_n, equation (6) can be written as,
- $\frac{D_{1t}}{\varepsilon_1} = E_{1t} = E_{2t} = \frac{D_{2t}}{\varepsilon_2}$
- $\frac{D_{1t}}{\varepsilon_1} = \frac{D_{2t}}{\varepsilon_2} ------ (7)$
- D_t undergoes some change across the interface. Hence D_t is said to be discontinuous across the interface.
- Similarly, we apply equation (2) to the pillbox (Cylindrical Gaussian Surface), the contribution due to the sides vanishes. Allowing Δh → 0 gives,
- $\Delta Q = \rho_S \Delta S = D_{1n}\Delta S - D_{2n}\Delta S$

	➢ $\boxed{D_{1n} - D_{2n} = \rho_S}$ -----(8) ➢ Where ρ_s is the free charge density placed deliberately at the boundary. ➢ If no free charges exist at the interface (i.e., charges are not deliberately placed there), $\rho_s = 0$ and equation (8) becomes, ➢ $\boxed{D_{1n} = D_{2n}}$ ----- (9) ➢ Thus the normal component of D is continuous across the interface; that is, D_n undergoes no change at the boundary. Since $D = \varepsilon E$, equation (9) becomes, ➢ $\varepsilon_1 E_{1n} = \varepsilon_2 E_{2n} - - - - - - (10)$ ➢ Showing that the normal component of E is discontinuous at the boundary. ➢ Consider D_1 or E_1 and D_2 or E_2 making angles θ_1 and θ_2 with the normal to the interface. ➢ Using equation (6) we have, ➢ $E_1 \sin\theta_1 = E_{1t} = E_{2t} = E_2 \sin\theta_2$ ➢ $E_1 \sin\theta_1 = E_2 \sin\theta_2 - - - - - - (11)$ ➢ Similarly by applying equation (9) or (10), we get ➢ $\varepsilon_1 E_1 \cos\theta_1 = D_{1n} = D_{2n} = \varepsilon_2 E_2 \cos\theta_2$ ➢ Or ➢ $\varepsilon_1 E_1 \cos\theta_1 = \varepsilon_2 E_2 \cos\theta_2 - - - - - - (12)$ ➢ Dividing equation (11) by (12) gives, ➢ $\frac{tan\theta_1}{\varepsilon_1} = \frac{tan\theta_2}{\varepsilon_2} - - - - - - (13)$ ➢ Since $\varepsilon_1 = \varepsilon_0 \varepsilon r_1$ and $\varepsilon_2 = \varepsilon_0 \varepsilon r_2$, equation (13) becomes, ➢ $\boxed{\frac{tan\theta_1}{tan\theta_2} = \frac{\varepsilon_{r1}}{\epsilon_{r2}}}$ (7 M)
4.	**A capacitor consists of two parallel metal plates 30cm x 30cm surface area, separated by 5mm in air. Determine its capacitance. Find the total energy stored by the capacitor and the energy density if the capacitor is charged to a potential difference of 500V?(Nov 2014) (6M)** (BTL 5) **Answer: Page - 2.73 - Dr. P. Dananjayan** ➢ Energy = ½ C V^2 = 19.92 μ Joules (2 M) ➢ Energy Density = ½ DE = 0.0442 (2 M) ➢ Potential = V/d = 500/(5*10^{-3}) (2 M)
5.	**Derive an expression for capacitance of concentric spheres. (Nov 2015) (7M)** (BTL 2) **Answer:Page - 2.19 - Dr. P. Dananjayan**  ➢ Consider two concentric spheres. ➢ Inner radius 'a' and outer radius 'b'.

	➢ εr be permittivity of dielectric medium. ➢ Charge Q distributed uniformly over the outer surface of inner sphere. (3 M) $E = \frac{Q}{4\pi \varepsilon r^2} \quad (a \le r \le b)$ The potential difference between the sphere is $V = -\int_b^a \frac{Q}{4\pi \varepsilon r^2} \cdot dr = -\frac{Q}{4\pi \varepsilon} \int_b^a \frac{dr}{r^2}$ $= \frac{Q}{4\pi \varepsilon} \left[\frac{1}{r} \right]_b^a$ $= \frac{Q}{4\pi \varepsilon} \left[\frac{1}{a} - \frac{1}{b} \right]$ $= \frac{Q}{4\pi \varepsilon} \left[\frac{b-a}{ab} \right]$ *The capacitance of two concentric sphere is* $C = \frac{Q}{V} = 4\pi \varepsilon \left[\frac{a\,b}{b-a} \right]$ $C = 4\pi \varepsilon \left[\frac{a\,b}{b-a} \right]$ (4 M)
6.	**Derive an expression for polarization ‘p’ and thus obtain electric field intensity and potential of a dipole (Nov 2015, April 2015) (6 M)** (BTL 2) **Answer: Page 2.12 & 2.08 - Dr. P. Dananjayan** ➢ Q is charge and l is length. ➢ Dipole moment P = Q.l ➢ Polarization is defined as dipole moment per unit volume. ➢ Consider a bounded charge Qb. ➢ Small element ds. (3M) ➢ Qb = $-\int P.ds$ ➢ QT = Qb + Q ➢ By Gauss’s Law QT = $\int \varepsilon 0\, E.ds$ ➢ Q = QT – Qb ➢ But Q = $\int D.ds$ ➢ D = ε0 E + P ➢ Polarization P = χ ε0 E ➢ χ= electric susceptibility ➢ D = εo εr E (3 M)
7.	**Explain the potential at a point in an electric field. Derive the electric field intensity at any point in a field due to a point charge. (May 2016) (13 M)** (BTL 2) **Answer: Page - 2.03 - Dr. P. Dananjayan**



- Consider a uniformly charged line of length L.
- Linear charge density is ρl c/m
- Consider a small element dl
- P be any point at a distance r from dl. (2M)
    - dEx =dE sinθ
    - dEy =dE cosθ
- Ex = ρl/(4πεh) *[cos α1 + cos α2] (2 M)
- Ey = ρl/(4πεh) *[sin α1 +sin α2] (3 M)
- Case (i) If the point is at bisector of a line, then α1=α2 = α
    - Ey = 0, E becomes Ex
    - E = ρl/(2πεh) (3 M)
- Case (ii) If the line is infinitely long the α = 0
    - Ey = 0, E becomes Ex
    - E = ρl/(2πεh)
- V = ρl/(2πε) ln (r1/r2) (3 M)

8. **Find the potential at a point (3,5,2) due to two-point charges one located at (2,0,0) and the other at (-2,0,0). The charges are 4 μc AND -5 μc respectively. (6 M)** (BTL 5)

Answer: Page - 2.30 - Dr. P. Dananjayan

- r 1 = 7.35 m
- r 2 = 5.48 m
- VA = Q/4πε0r1 = -6122 V (2 M)
- VB = Q/4πε0r2 = 6569 V (2 M)
- V = VA + VB
- Answer – 447 V (2 M)

9. **Find the capacitance of a parallel plate capacitor with dielectric ε_{r1}=3 and ε_{r2}=3 each occupy one half of the space between the plates of area 2 m^2 and d=10^{-3} m. (Nov 2016) (7 M)** (BTL 5)

	Answer: Page-2.56 - Dr. P. Dananjayan ➢ C1 = ε0 εr1(A/2) / d = 17.708 nF (2M) ➢ C2 = ε0 εr2(A/2) / d = 26.562 nF (2M) ➢ C = C1 + C2 ➢ C = 44.270 nF (3M)
10.	**Derive the Poisson'sand Laplace's Equations. (May/June 2014, Nov/Dec 16, April/May 2018) (13 M)**(BTL 1) ➢ $\nabla.D = \rho_v \;;\; D = \varepsilon E$ ➢ $\nabla.(\varepsilon E) = \rho_v$ ➢ $\varepsilon.\nabla.E = \rho_v$ ➢ $\nabla.E = \frac{\rho_v}{\varepsilon}$ ➢ $E = -\nabla V$ ➢ $\nabla.(-\nabla V) = \frac{\rho_v}{\varepsilon}$ ➢ $\nabla.\nabla V = \frac{\rho_v}{\varepsilon}$ ➢ $\nabla^2 V = -\frac{\rho_v}{\varepsilon}$ This is Poisson's equation. (6 M) ➢ In a certain region, volume charge density is zero, $\rho_v = 0$ which is true for dielectric medium. ➢ Then the Poisson's equation takes the form, ➢ $\nabla^2 V = 0$ $\nabla^2 V$ is laplacian of 'V' ➢ This is special case of Poisson's equation and is called Laplace equation. ➢ <u>∇^2Operation / Laplace equation in different co-ordinate system:</u> ➢ The potential 'V' can be expressed in any of the 3-co-ordinate system as $V(x,y,z),(r,\phi,z)$ & (r,θ,ϕ) . ➢ <u>Cartesian co-ordinate system or Rectangular co-ordinate system</u> ➢ $\nabla^2 V = \frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$ ➢ <u>Cylindrical co-ordinate system</u> ➢ $\nabla^2 V = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial V}{\partial r}\right) + \frac{1}{r^2}\left(\frac{\partial^2 V}{\partial \phi^2}\right) + \frac{\partial^2 V}{\partial z^2} = 0$ ➢ <u>Spherical co-ordinate system</u> ➢ $\nabla^2 V = \frac{1}{r^2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right) + \frac{1}{r^2 \sin\theta}\frac{\partial}{\partial \theta}\left(\sin\theta\frac{\partial V}{\partial \theta}\right) + \frac{1}{r^2 \sin^2\theta}\frac{\partial^2 V}{\partial \phi^2} = 0$ (7M)
	PART * C
1.	**If** $V = 2x^2 y + 20z - \frac{4}{x^2 + y^2}$ **V, find electric field & flux density at P(6,–2,3). (7 M)** (BTL 5)

Answer: Page - 2.35 - Dr. P. Dananjayan

☺*Solution:* $E = -\nabla V$

$$= -\left[\bar{a}_x \frac{\partial}{\partial x} + \bar{a}_y \frac{\partial}{\partial y} + \bar{a}_z \frac{\partial}{\partial z}\right]\left(2x^2 y + 20z - \frac{4}{x^2+y^2}\right)$$

$$= -\left[\bar{a}_x\left(4xy + \frac{8x}{(x^2+y^2)^2}\right) + \bar{a}_y\left(2x^2 + \frac{8y}{(x^2+y^2)^2}\right) + \bar{a}_z 20\right]$$

$$E(6, -2.5, 3) = -[(-60 + 0.0268)\,\bar{a}_x + (72 - 0.012)\,\bar{a}_y + 20\,\bar{a}_z$$

$$= \mathbf{59.97\,\bar{a}_x - 71.99\,\bar{a}_y - 20\,\bar{a}_z} \quad \text{V/m}$$

(4M)

$$D = \varepsilon_0 E$$

$$D(6, -2.5, 3) = 8.854 \times 10^{-12} \times [59.97\,\bar{a}_x - 71.99\,\bar{a}_y - 20\,\bar{o}.]$$

$$= \mathbf{0.53\,\bar{a}_x - 0.637\,\bar{a}_y - 0.177\,\bar{a}_z} \quad \textbf{nc/m}^2$$

(3 M)

2.

If a potential $V = x^2yz + Ay^3z$ find the value of A so that Laplace's equation is satisfied and electric field (2, -2, 1) (7M) (BTL 5)

Answer: Page – 2.41 - Dr. P. Dananjayan

Laplace's **equation** $\nabla^2 V = 0$

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 0$$

$$\frac{\partial V}{\partial x} = 2xyz \quad \text{and} \quad \frac{\partial^2 V}{\partial x^2} = 2yz$$

$$\frac{\partial V}{\partial y} = x^2 z + 3Ay^2 z \quad \text{and} \quad \frac{\partial^2 V}{\partial y^2} = 6Ayz$$

$$\frac{\partial V}{\partial z} = x^2 y + Ay^3 \quad \text{and} \quad \frac{\partial^2 V}{\partial z^2} = 0$$

$\therefore$ Laplace's equation

$$\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2} + \frac{\partial^2 V}{\partial z^2} = 2yz + 6Ayz = 0$$

At (2, – 2, 1),

$$2(-2)1 + 6A(-2)1 = 0$$

$$-4 - 12A = 0$$

$$\mathbf{A} = -1/3$$

$$\therefore \mathbf{V} = x^2 yz - \frac{y^3 z}{3}$$

(4 M)

Electric field $E = -\nabla \mathbf{V}$

$$= -\left[\frac{\partial V}{\partial x}\bar{a}_x + \frac{\partial V}{\partial y}\bar{a}_y + \frac{\partial V}{\partial z}\bar{a}_z\right]$$

$$= -[(2xyz)\bar{a}_x + (x^2 z - y^2 z)\bar{a}_y + (x^2 y - \frac{y^3}{3})\,\bar{a}_z]$$

$$E(2, -2, 1) = -[2(2)(-2)\bar{a}_x + (2^2 - (-2)^2)\bar{a}_y + (2^2(-2) - \frac{(-2)^3}{3})\,\bar{a}_z]$$

$$= \mathbf{8\,\bar{a}_x + \frac{32}{3}\,\bar{a}_z} \quad \textbf{Ans.}$$ ☜ ☺☺

(3 M)

3.	**Given an electric field** $E = -\frac{6y}{x^2}\hat{a}_x + \frac{6}{x}\hat{a}_y + 5\hat{a}_z$ **V/m, find the potential difference** V_{AB} **between A(-7,2,1) and B(4,1,2). (8 M)** (BTL 5) **Answer: Page - 2.34 -Dr. P. Dananjayan** Potential difference $V_{AB} = -\int_B^A E \cdot dl$ $= -\int_4^{-7} -\frac{6y}{x^2}\,dx - \int_1^2 \frac{6}{x}\,dy - \int_2^1 5\,dx$ $= 6y\left[\frac{-1}{x}\right]_4^{-7} - \frac{6}{x}\left[y\right]_1^2 - 5\left[x\right]_2^1$ $= \frac{66}{28}y - \frac{6}{x} + 5$ $x = 4, \quad y = 1$ $V_{AB} = 2.357 - 1.5 + 5 = \mathbf{5.857\ volts}$ (8 M)
4.	**Given that the potential** $V = \frac{120\sin\theta}{r^2}$ **find the E and V at r = 3, θ = 60 , φ = 25 (8 M)**(BTL 5) **Answer: Page - 2.38 - Dr. P. Dananjayan** For spherical co-ordinates, $\nabla V = \frac{\partial V}{\partial r}\bar{a}_r + \frac{1}{r}\frac{\partial V}{\partial \theta}\bar{a}_\theta + \frac{1}{r\sin\theta}\frac{\partial V}{\partial \phi}\bar{a}_\phi$ $\frac{\partial V}{\partial r} = \frac{-240\sin\theta}{r^3}$ $\frac{\partial V}{\partial \theta} = \frac{120\cos\theta}{r^2}$ $\frac{\partial V}{\partial \phi} = 0$ $\nabla V = \frac{-240\sin\theta}{r^3}\bar{a}_r + \frac{120\cos\theta}{r^3}\bar{a}_\theta$ $E = -\nabla V = \frac{240\sin 60°}{3^3}\bar{a}_r - \frac{120\cos 60°}{3^3}\bar{a}_\theta$ $= 7.7\,\bar{a}_r - 2.22\,\bar{a}_\theta$ $\lvert E \rvert = \sqrt{(7.7)^2 + (2.22)^2} = \mathbf{8.014\ V/m}$ (8 M)
5.	**Given V =** $x^2y + 10z + 2\log(x^2 + y^2)$ **find V, E, D at (1, 2, 3). (15 M)** (BTL 5) **Answer: Page - 2.36 -Dr. P. Dananjayan** **(i)** $\mathbf{V = x^2y + 10z + 2\log(x^2 + y^2)}$ $\mathbf{V(1,2,3)} = 1 \times 2 + 10 \times 3 + 2\log(1+4) = 2 + 30 + 2\log(5)$ $= \mathbf{32 + 2\log 5 = 33.4\ V}$ (3M)

(*ii*) $\mathrm{E} = -\nabla \mathrm{V}$

$$= -\left[\bar{a}_x \frac{\partial}{\partial x}(x^2 y + 2\log(x^2+y^2)) + \bar{a}_y \frac{\partial}{\partial y}(x^2 y + 2\log(x^2+y^2)) + \bar{a}_z \frac{\partial}{\partial z}(10z)\right]$$

$$= -(4.8\,\bar{a}_x + 2.6\,\bar{a}_y + 10\,\bar{a}_z) \quad \mathrm{V/m}$$

(4 M)

(*iii*) $\mathrm{D} = \varepsilon \cdot \mathrm{E}$

$$\mathrm{D} = \varepsilon_0\left[\left(2xy + \frac{4x}{x^2+y^2}\right)\bar{a}_x + \left(x^2 + \frac{4y}{x^2+y^2}\right)\bar{a}_y + 10\,\bar{a}_z\right]$$

$$\mathrm{D}(1,2,3) = -8.854 \times 10^{-12}\,(4.8\,\bar{a}_x + 2.6\,\bar{a}_y + 10\,\bar{a}_z) \quad \mathrm{c/m^2}$$

(4 M)

$$\nabla \cdot \mathrm{D} = -\varepsilon_0\left[\bar{a}_x \frac{\partial}{\partial x} + \bar{a}_y \frac{\partial}{\partial y} + \bar{a}_z \frac{\partial}{\partial z}\right] \times \left[\bar{a}_x\left(2xy + \frac{4x}{x^2+y^2}\right) + \bar{a}_y\left(x^2 + \frac{4y}{x^2+y^2}\right) + \bar{a}_z(10)\right]$$

$$= -\varepsilon_0\left[\frac{\partial}{\partial x}\left(2xy + \frac{4x}{x^2+y^2}\right) + \frac{\partial}{\partial y}\left(x^2 + \frac{4y}{x^2+y^2}\right) + \frac{\partial}{\partial z}(10)\right]$$

$$\rho_v(1,2,3) = -8.854 \times 10^{-12} \times 2 \times 2$$

$$= 35.416 \times 10^{-12} \quad \mathrm{c/m^3}$$

(4 M)

6.

Calculate the capacitance of a parallel plate capacitor with the following details:
Plate area A = 100 cm^2
Dielectric 1, ε_{r1} = 4, d_1 = 2 mm
Dielectric 2, ε_{r2} = 3, d_2 = 3 mm
If 200 V is applied across the plates, what will be the voltage gradient across each dielectric? (8 M)(BTL 5)

Answer: Page - 2.44 - Dr. P. Dananjayan

- D = Q/A
- E = D / εo εr
- C = Q / V
- C = 59 pf (2 M)
- V1 = 66.66 V (2 M)
- V2 = 133.33 V (2 M)
- E1 = 33.33 kV/m (2M)
- E2 = 44.44 kV/m

7.

A parallel plate capacitor with d = 1 m and plate area 0.8 m^2 and a dielectric relative permittivity of 2.8. A dc voltage of 500 V is applied between the plates, find the capacitance and energy stored. (8 M)(BTL 5)

Answer: Page - 2.61 – Dr. P. Dananjayan

- d = 1m

A = 0.8 m^2

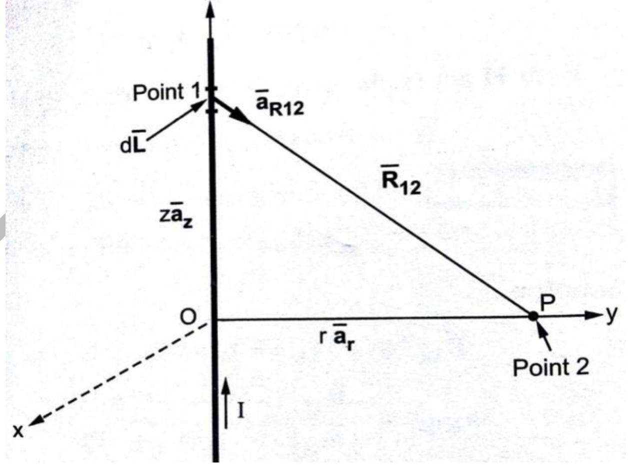
	➢ εr = 2.8 ➢ C = ε A / d ➢ Energy Stored = ½ C V^2 = 0.99 J (8 M)

UNIT III - MAGNETOSTATICS	
Lorentz force, magnetic field intensity (H) – Biot–Savart's Law - Ampere's Circuit Law – H due to straight conductors, circular loop, infinite sheet of current, Magnetic flux density (B) – B in free space, conductor, magnetic materials – Magnetization, Magnetic field in multiple media Boundary conditions, scalar and vector potential, Poisson's Equation, Magnetic force, Torque, Inductance, Energy density, Applications.	
Q. No	**Part * A**
	Questions
1	**Define magnetic flux and magnetic flux density.** (BTL 1) **Magnetic flux:** Magnetic flux is defined as the flux passing through any area. Its unit is Weber. $\Phi = \int_a B.da$ Weber. **Magnetic flux density.** Magnetic flux density is defined as the magnetic flux density passing per unit area. Its unit is Weber / meter or Tesla. $B=\frac{\Phi}{A}$; B=μH
2	**Define magnetic Gauss's Law.** (BTL 1) The total magnetic flux passing thorough any closed surface is equal to zero. $\oint_a B.da = 0$
3	**State Biot- Savart law.** (BTL 1) It states that the magnetic flux density at any point due to current element is proportional to the current element and sine of the angle between the elemental length and the line joining and inversely proportional to the square of the distance between them. $dB = \frac{\mu_o Idl \sin\theta}{4\pi r^2}$
4	**State the Lorentz force equation. (Nov 2013)** (BTL 1) The force on a moving particle due to combined electric and magnetic field is given by F = Q $\left[\vec{E} + \vec{V} \times \vec{B}\right]$.This force is called Lorentz force.
5	**State Ampere's circuital law. (May 2014, May 2016, Nov 2016)** (BTL 1) Ampere's circuital law states that the line integral of magnetic field intensity H about any closed path is exactly equal to the direct current enclosed by the path. $\oint H.dl = I$
6	**Distinguish between diamagnetic, paramagnetic and ferromagnetic materials.** (BTL 1) **Diamagnetic:** In diamagnetic materials magnetization is opposed to the applied field. It has magnetic field. **Paramagnetic:** In paramagnetic materials magnetization is in the same direction as the field. It has weak magnetic field. **Ferro magnetic:** In Ferromagnetic materials is in the same direction as the field. It has strong magnetic field.
7	**Compare scalar magnetic potential with vector magnetic potential.(Nov/Dec 2014)** (BTL 1)

<table>
<tr><td></td><td>
<table>
<tr><th>Scalar magnetic potential</th><th>Magnetic vector potential</th></tr>
<tr><td>It is defined as dead quantity whose negative gradient gives the magnitude intensity if there is no current source present.
$H = -\nabla V_m$ where,Vm is the magnetic scalar potential.
$V_m = -\int H.dl$</td><td>It is defined as that quantity whose curl gives the magnetic flux density.
$B = \nabla$ x A; where A is the magnetic vector potential.
$A = \frac{\mu}{4\pi} \iiint_V \frac{J}{r} dr$ Web / m</td></tr>
</table>
</td></tr>
<tr><td>8</td><td>A solenoid with a radius of 2cm is wound with 20 turns per cm length and carries 10mA. Find H at the centre if the total length is10cm. (BTL 5)
Given data,N=nl = 20 x 10 = 200 turns; l =10 X 10^{-2} m; I = 10 x 10^{-3}A;
$H = \frac{NI}{l} =$ 20AT/m.</td></tr>
<tr><td>9</td><td>Determine the force per unit length between two long parallel wires separated by 5 cm in air and carrying currents 40A in the same direction. (BTL 5)
Force / length = $\frac{\mu_o I_1 I_2}{2\pi D} = \frac{40 \times 40}{2\pi \times 5 \times 10^{-2}} x 4\pi x 10^{-7}$
=6.4 x 10^{-3} N/m.</td></tr>
<tr><td>10</td><td>Define magnetic susceptibility and their relation with relative permeability. (BTL 1)
Magnetic susceptibility is defined as the ratio of magnetization to the magnetic field intensity. It is dimensionless quantity. $\chi_m = \frac{M}{H}$
$\mu_r = 1 + \chi_m$ Where μ_r is relative permeability; χ_m is susceptibility</td></tr>
<tr><td>11</td><td>Give four similarities between Electrostatic field and Magnetic field. (Nov/Dec 2014) (BTL 1)
<table>
<tr><th>Electrostatic field</th><th>Magnetic field</th></tr>
<tr><td>1. Electric field intensity E (volts/m)
2. Electric flux density D=εE c/m
3. Energy stored is $1/2CV^2$
4. Charges are rest</td><td>1. Magnetic field intensity H (Amp/m)
2. Magnetic flux density B=μH (web / m2)
3. Energy stored is $1/2LI^2$
4. Charges are in motion</td></tr>
</table>
</td></tr>
<tr><td>12</td><td>What will be effective inductance, if two inductors are connected in (a) series and (b) parallel? (BTL 2)
(a) For series L = $L_1 + L_2 \pm 2M$
(b)For Parallel L = $\frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$
Where, (+) sign for aiding , (-) sign for opposition</td></tr>
<tr><td>13</td><td>Distinguish between solenoid and toroid. (BTL 1)</td></tr>
</table>

Solenoid	Toroid
Solenoid is a cylindrically shaped coil consisting of a large number of closely spaced turns of insulated wire wound usually on a non – magnetic frame.	If a long, slender solenoid is bent into the form of a ring and thereby closed on itself, it becomes toroid
Inductance of solenoid is given by $L = \frac{\mu_o N^2 A}{l}$	Inductance of solenoid is given by $L = \frac{\mu_o N^2 A}{2\pi R} = \frac{\mu_o N^2 r^2}{2R}$;

14	**Define magneto-static energy density. (Nov 2011)** (BTL 1) It is defined as the ratio of magnetic energy per unit volume.
15	**Write the expression for the inductance per unit length of a long solenoid of N turns and having a length 'L' meter carrying a current of I amperes. (May/June 2014)** (BTL 1) H= $\frac{NI}{2l}[\text{Cos } \theta_2 - \text{Cos } \theta_1]$
16	**State the boundary condition at the interface between two magnetic materials of different permeability. (May 2012)** (BTL 1) $H_{t1}=H_{t2}$, $B_{n1}=B_{n2}$, H_{t1}, H_{t2} are the tangential magnetic field in region 1 and 2 respectively. B_{n1}, B_{n2} are the normal magnetic flux density in region 1 and 2 respectively.
17	**Write down the magnetic boundary conditions. (Nov 2013, May 2016)** (BTL 1) 1. The tangential component of magnetic field intensity is continuous across the boundary.$H_{t1} = H_{t2}$. 2. The normal component of magnetic flux density is continuous across the boundary.$Bn_1 = B_{n2}$
18	**State Ohm's law for magnetic circuits. (Nov 2012, Nov/Dec14)** (BTL 1) Sum of Magnetic motive force (mmf) in a closed path is zero.
19	**State Lorentz Law of force. (May 2012)** (BTL 1) When a current carrying conductor is placed in a magnetic field, it experiences a force given by,dF = I x B dl = BI dl sinθ Newton.
20	**State the law of conservation of magnetic flux. (Nov 2011)** (BTL 1) An isolated magnetic charge does not exist. Thus, the total flux through a closed surface is zero. $\iint B.ds = \text{o}$ .This is called as law of conservation of magnetic flux.
21	**Determine the value of magnetic field intensity at the centre of a circular loop carrying a current of 10A. The radius of the loop is 2m. (Nov/Dec 2014)** (BTL 5) H= $\frac{I}{2a} = \frac{10}{2x2} = 2.5\text{A/m}$
22	**What is the mutual inductance of two inductively tightly coupled coils with self - inductance of 25mH and 100mH? (Nov/Dec2015)** (BTL 5) L_1 = 25mH, L_2 = 100mH, M=K $\sqrt{L_1 L_2}$ $=\sqrt{25\ X\ 100}$ = 50mH
23	**Find the force of interaction between two charges 4*10^{-3} and 6*10^{-3} spaced 10cm**

	apart n kerosene ($\varepsilon_r = 2$).(April /May 2015) (BTL 5) Force of repulsion = $\frac{Q_1Q_2}{4\pi\varepsilon_0 R^2}a_r$ = 1.07908 N
24	**Find the maximum torque on an 100 turns rectangular coil of 0.2 m by 0.3m, carrying current of 2A in the field of flux density 5 Wb/m^2 .(April /May 2015)** (BTL 5) T_{max} = NBIA = 60 Nm
25	**A conductor 4m long lies along the y-axis with the current of 10A in $a_y$direction, if the field is B=0.05a_x Tesla. Calculate the force on the conductor. (Nov 2016)** (BTL 5) $F = IlB\sin\theta = 10 \times 4 \times 0.05 \times \sin 90 = 2N$
	Part * B
1.	**Derive an expression for the magnetic field intensity and magnetic flux density at a point P in a medium of permeability ‘μ’ due to (i) an infinitely long current carrying conductor at a distance ‘r’ meters from the point.(ii) a finite length conductor. (April 2015, Nov 2011, Nov 2012, May 2012) (13 M)** (BTL 2) **Answer: Page –303- Dr. P. Dananjayan** ➢ Consider an infinite long straight conductor along z-axis. ➢ Current passing through a conductor is a direct current of I. ➢ The field intensity $\overline{H}$ at the point ‘p’ is to be calculated, which is at the distance ‘r’ from the z-axis. ➢ Consider small differential element at point 1, along the z-axis at a distance z from origin. $I\overline{dL} = Idz\overline{a_z}$ (4 M)  ➢ (2 M) ➢ The distance vector joining point 1 to point 2 is $\overline{R_{12}}$ can be written as • $\overline{R}_{12} = -z\overline{a_z} + r\overline{a_r}$ • $\overline{a}_{R12} = \frac{\overline{R}_{12}}{\lvert\overline{R}_{12}\rvert} = \frac{r\overline{a_r} - z\overline{a_z}}{\sqrt{r^2 + z^2}}$

- $\overline{dL} \times \overline{a}_{R12} = \begin{pmatrix} \overline{a_r} & \overline{a_\phi} & \overline{a_z} \\ 0 & 0 & dz \\ r & 0 & -z \end{pmatrix} = rdz\overline{a_\phi}$
- $I\overline{dL} \times \overline{a}_{R12} = \dfrac{Irdz\overline{a_\phi}}{\sqrt{r^2+z^2}}$

➢ According to Biot-savart law $\overline{dH}$ at point 2 is

- $\overline{dH} = \dfrac{I\overline{dL} \times \overline{a}_{R12}}{4\pi R_{12}^2}$
- $\overline{dH} = \dfrac{Irdz\overline{a_\phi}}{4\pi\sqrt{r^2+z^2}\left(\sqrt{r^2+z^2}\right)^2}$

➢ Thus total field intensity $\overline{H}$ can be obtained by integrating $\overline{dH}$ over the entire length of the conductor.

- ▪ $\overline{H} = \int\limits_{z=-\infty}^{\infty} \overline{dH} = \int\limits_{z=-\infty}^{\infty} \dfrac{Irdz\overline{a_\phi}}{4\pi\left(r^2+z^2\right)^{3/2}}$
- Put $z = r\tan\theta, z^2 = r^2\tan^2\theta$
- $dz = r\sec^2\theta d\theta$
- $z = -\infty;\ \theta = -\dfrac{\pi}{2}$ and $z = \infty;\ \theta = +\dfrac{\pi}{2}$
- $\overline{H} = \int\limits_{\theta=-\frac{\pi}{2}}^{\frac{\pi}{2}} \dfrac{I.r.r\sec^2\theta.d\theta.\overline{a_\phi}}{4\pi\left(r^2+r^2\tan^2\theta\right)^{3/2}}$
- $\overline{H} = \dfrac{I}{4\pi r}\int\limits_{\theta=-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos\theta.d\theta.\overline{a_\phi}$
- $\overline{H} = \dfrac{I}{4\pi r}\left[\sin\theta\right]_{\pi/2}^{\pi/2}.\overline{a_\phi}$
- $\overline{H} = \dfrac{I}{2\pi r}.\overline{a_\phi}$ A/m

➢ $B = \mu\overline{H} = \dfrac{\mu I}{2\pi r}.\overline{a_\phi}$ wb/m^2 (7 M)

2. **Derive the expression for force between two parallel conductors. (7M)** (BTL 1)

Answer: Page - 3.17 - Dr. P. Dananjayan

➢ According to amperes force law, the force F between two parallel wires carrying currents I_1 and I_2 is directly proportional to the individual currents and inversely proportional to the square of the distance between them.

➢ $F \propto \frac{I_1 I_2}{R^2}$(3 M)

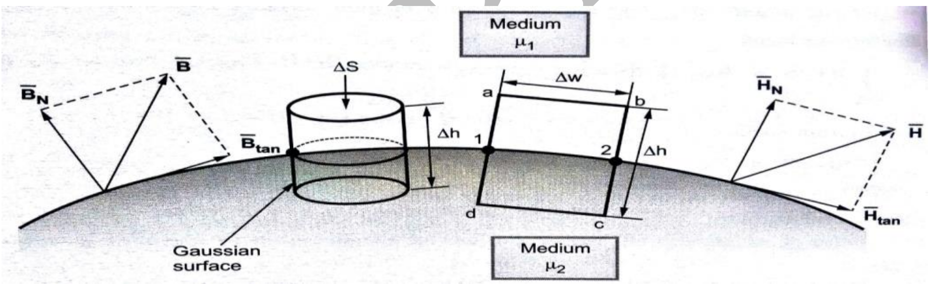
- $F = K\frac{I_1 I_2}{R^2}$
- Where K is proportionality constant depending upon the medium $K = \frac{\mu}{4\pi}$
- $F = \frac{\mu}{4\pi}\frac{I_1 I_2}{R^2}$
- The force F is attractive if the two currents I_1 and I_2 are the same directions.

Repulsive if in opposite direction.(4 M)

3.

Derive the magneto-static boundary conditions. (May 2014, April 2015) (13 M) (BTL 1)

Answer: Page -3.23 - Dr. P. Dananjayan

- The condition at the magnetic field exiting at the boundary of the two media when the magnetic field passes from one medium to other are called boundary condition for magnetic fields.
- The condition of $\overline{B}$ and $\overline{H}$ are studied at the boundary.
- The vectors are resolved in to two components:
- Tangential to the boundary
- Normal (perpendicular) to boundary
- Consider a boundary between two isotropic, homogeneous linear materials with different permeability's μ_1 and μ_2
- 

(2 M)

- **Boundary conditions for Normal Component**
- According to the Gauss law for the magnetic field,

$$\int_S \overline{B}.\overline{ds} = 0 \text{ ------------------------------(1)}$$

- Let the area of the top and bottom is same, equal to Δs

$$\oiint_{top} \overline{B}.\overline{ds} + \oiint_{bottom} \overline{B}.\overline{ds} + \oiint_{bottom} \overline{B}.\overline{ds} = 0 \text{ ----------------------(2)}$$

- For top surfaces

$$\oiint_{top} \overline{B}.\overline{ds} = BN_1 \oiint_{top} \overline{ds} = BN_1 \Delta s \text{ ---------------------------(3)}$$

- For bottom surfaces

$$\oiint_{bottom} \overline{B}.\overline{ds} = BN_2 \oiint_{bottom} \overline{ds} = BN_2 \Delta s \text{ -----------------------(4)}$$

- For lateral surface

$$\oiint_{lateral} \overline{B}.\overline{ds} = 0 \text{ ----------------------------(5)}$$

- Putting values of surface integral in equation (2) we get

$$BN_1\Delta s - BN_2\Delta s = 0$$ ---------------------(6)

$$\left(\therefore \text{ BN}_1 \text{ and BN}_2 \text{ are in opposite direction } \right)$$

$$BN_1 = BN_2$$ ----------------------(7)

- Thus the normal component of b is continuous at the boundary. (4 M)

Boundary conditions for tangential Component

- According to ampere's circuital law

$$\oint \overline{H}.dl = I$$

- Consider a closed rectangular path a b c d, length Δl and height Δh.

$$\oint \overline{H}.\overline{dL} = \int_a^b \overline{H}.\overline{dL} + \int_b^c \overline{H}.\overline{dL} + \int_c^d \overline{H}.\overline{dL} + \int_d^a \overline{H}.\overline{dL} = I$$

- Allowing ΔH to zero

$$\int_b^c \overline{H}.\overline{dL} + \int_d^a \overline{H}.\overline{dL} = 0$$

$$\overline{H}_{\tan 1}\Delta l - \overline{H}_{\tan 2}\Delta l = I$$

$$\overline{H}_{\tan 1} - \overline{H}_{\tan 2} = \frac{I}{\Delta l}$$

$$\overline{a}_N \times \left(\overline{H}_{\tan 1} - \overline{H}_{\tan 2}\right) = J_s$$ $J_s =$ surface current density

- In vector form

$$\overline{H}_{\tan 1} - \overline{H}_{\tan 2} = \overline{a}_N \times J_s$$

$$\overline{H}_{\tan 1} - \overline{H}_{\tan 2} = J_s$$

- Where $\overline{a}_N$ – unit vector in the direction normal at the boundary form medium1 to medium2.
- For B, the tangential components can be related with permeabilities of two media

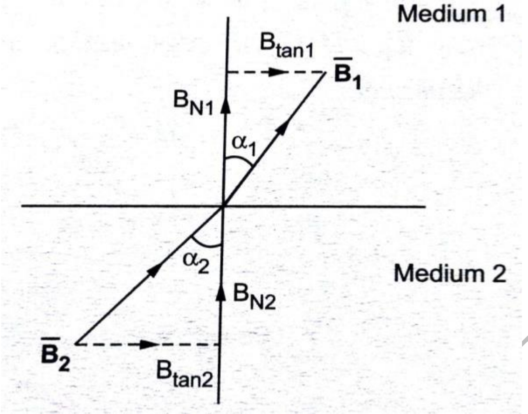
$$\frac{B\tan_1}{\mu_1} - \frac{B\tan_2}{\mu_2} = J_s$$

- Consider a special case that the boundary is free of current in other words, media are not conductors. So $J_s = 0$

$$\overline{H}_{\tan 1} - \overline{H}_{\tan 2} = 0$$

$$\overline{H}_{\tan 1} = \overline{H}_{\tan 2}$$

(4 M)



- **In medium 1,**

$$\tan\alpha_1 = \frac{B_{\tan 1}}{B_{N_1}}$$

- **In medium 2,**

$$\tan\alpha_2 = \frac{B_{\tan 2}}{B_{N_2}}$$

$$\frac{\tan\alpha_1}{\tan\alpha_2} = \frac{B_{\tan 1}}{B_{N_1}} \cdot \frac{B_{N_2}}{B_{\tan 2}}$$

- We know that $B_{N_1} = B_{N_2}$

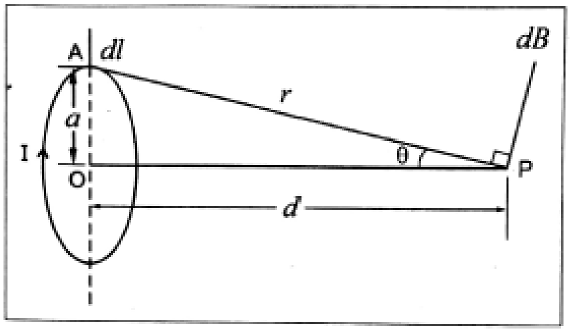
$$\frac{\tan\alpha_1}{\tan\alpha_2} = \frac{B_{\tan 1}}{B_{\tan 2}} = \frac{\mu_{r_1}}{\mu_{r_2}}$$

(3 M)

4.

Develop an expression for the magnetic field intensity at any point on the line through the centre at a distance ‘h’ m from the centre and perpendicular to the plane of a circular loop (in XY plane) of radius ‘a’ m and carrying a current I Ampere in the anti-clockwise direction. (May 2016) (13 M) (BTL 2)

Answer: Page – 3.05 - Dr. P. Dananjayan



(4 M)

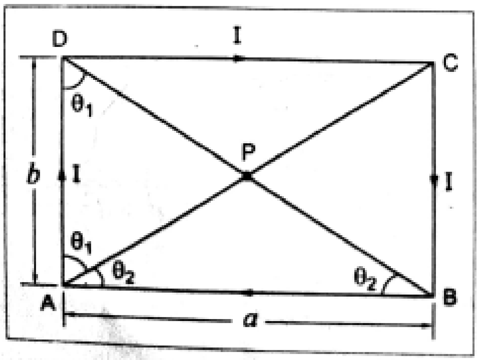
- Let a = circular coil radius
- I = current
- Idl = current element
- d = distance between point P to centre of the coil
- $dB = \mu 0 \ I \ dl \sin\theta / (4 \pi r^2)$
- $\sin\theta = a / (\sqrt{(a^2 + d^2)}$

- if d = 0, the field at the center B = μ0I/2a
- H = I/2a (9 M)

5.

Derive an expression for magnetic field intensity in a rectangular loop which is carrying a current of 'I' amperes and is situated in a uniform magnetic field 'B' Wb/m^2. (Nov 2014) (8 M) (BTL 2)

Answer: Page -3.06 - Dr. P. Dananjayan



(2 M)

The magnetic field intensity at the centre P due to segment AB or CD.

$$H = \frac{I}{4\pi d} [\cos\theta_1 + \cos\theta_2]$$

$$\text{But} \quad d = \frac{b}{2}, \quad \theta_1 = \theta_2 = \theta$$

$$\therefore \; H = \frac{2I}{4\pi b} \cdot 2\cos\theta$$

$$= \frac{I}{\pi b} \cos\theta$$

$$\text{where} \quad \cos\theta = \frac{b}{\sqrt{a^2 + b^2}}$$

The magnetic field intensity at P due to AB and CD

$$H_1 = \frac{2I}{\pi b} \cos\theta$$

$$H_1 = \frac{2I}{\pi \sqrt{a^2 + b^2}}$$

Similarly, the magnetic field intensity at P due to segment BC or DA

$$H = \frac{I}{4\pi d}\,[\cos\phi_1 + \cos\phi_2]$$

$$\text{But } d = \frac{a}{2}, \qquad \phi_1 = \phi_2 = \phi$$

$$\therefore\; H = \frac{2I}{4\pi a}\,2\cos\phi$$

$$= \frac{I}{\pi a}\cos\phi$$

$$\text{where } \cos\phi = \frac{a}{\sqrt{a^2+b^2}}$$

For square loop of side a,

$$a = b$$

$$H = \frac{4I}{\pi a\sqrt{2}} = \frac{2\sqrt{2}\,I}{\pi a} \quad \text{A/m}$$

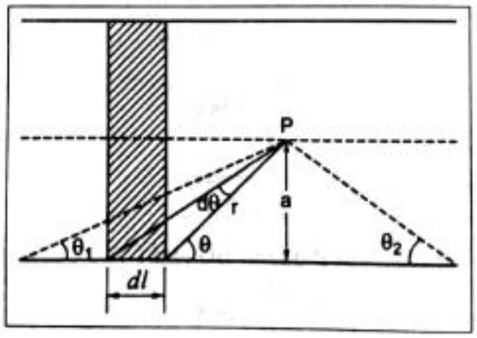
(6 M)

6.

Derive the expression for magnetic field intensity due to long solenoidal. (13 M) (BTL 2)

Answer: Page – 3.08 - Dr. P. Dananjayan

- Let N = no. of turns
- L = length
- a = mean radius
- I = current
- Idl = Current element
- Solenoid carrying a current I = NIdl/l (2 M)



(4 M)

$$dB = \frac{\mu_0 a^2}{2r^3}\frac{NI}{l}\cdot dl$$

From the Fig., $$\frac{a}{r} = \sin\theta$$

$$r = \frac{a}{\sin\theta}$$

then $$dB = \frac{\mu_0 a^2}{2a^3}\sin^3\theta\,\frac{NI}{l}\cdot dl$$

$$= \frac{\mu_0 \sin^3\theta}{2a}\frac{NI}{l}\cdot dl$$

From the Fig., $$r\,d\theta = dl\sin\theta$$

$$dl = \frac{r\,d\theta}{\sin\theta} \quad \text{and}$$

$$a = r\sin\theta$$

Substituting these values in 'dB' equation

$$dB = \frac{\mu_0\sin^3\theta}{2r\sin\theta}\frac{NI}{l}\cdot\frac{r\,d\theta}{\sin\theta}$$

$$= \frac{\mu_0 NI\sin\theta\,d\theta}{2l}$$

The total magnetic flux density at point P due to whole solenoid is given by

$$B = \frac{\mu_0 NI}{2l}\int_{\theta_1}^{\pi-\theta_2}\sin\theta\,d\theta$$

$$B = \frac{\mu_0 NI}{2l}[\cos\theta_1 + \cos\theta_2]$$

The magnetic field intensity due to solenoid at P is given by

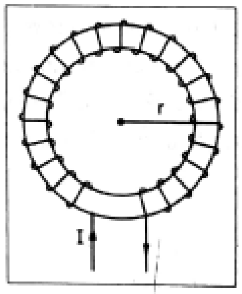
$$H = \frac{NI}{2l}[\cos\theta_1 + \cos\theta_2]$$

(7 M)

7.

Derive the expression for magnetic field intensity due to the centre of the Toroidal coil. (7M)((BTL 2)

Answer: Page – 3.11 - Dr. P. Dananjayan



(2 M)

- **Consider a toroidal coil of mean radius 'r'**

- **Current = 1**
- **No. of turns = N**

$$\oint H \cdot dl = N I$$

$$H \int_0^{2\pi r} dl = N I$$

$$H\, 2\pi r = N I$$

$$\text{The magnetic field } H = \frac{N I}{2\pi r}$$

$$\text{The magnetic flux density is } B = \mu_0 H = \frac{\mu_0 N I}{2\pi r}$$

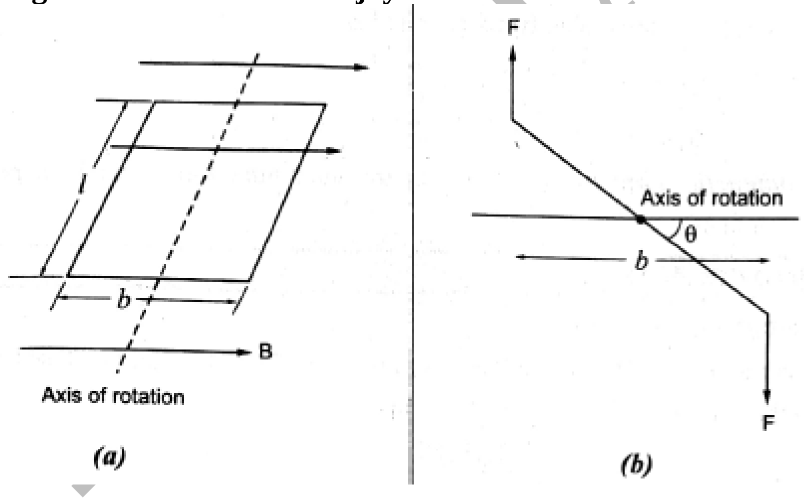
$$B = \frac{\mu_0 N I}{2\pi r}$$

(5 M)

8.

Obtain the expression for torque in terms of magnetic moment. (7M) (BTL 2)

Answer: Page – 3.18 - Dr. P. Dananjayan



(a) (b)

(3 M)

- Consider the rectangular loop.
- Length = l
- Breath = b
- Current = I
- F = BIl sin θ
- T = 2 * Torque on each side
- T = 2 * Force * Distance
- T = BIA sin θ
- Magnetic moment of loop is IA
- m = IA
- T = m B sin θ
- m = T/B

(4 M)

9.

Derive an expression for Scalar magnetic potential and vector magnetic potential. (13 M) (BTL 2)

Answer: Page - 3.20 - Dr. P. Dananjayan

	Scalar Magnetic Potential: Ampere's circuital law states that the line integral of magnetic field intensity H about any closed path is exactly equal to the direct current enclosed by the path. $\oint H .dl = I$ (2 M) If there is no current is enclosed. J = 0 $\oint H .dl = 0$ Magnetic field H can be expressed as negative gradient of a scalar function. $H = -\nabla V_m$ where, V_m is called scalar magnetic potential. $V_m = -\int H \cdot dl$ Magnetic field H can be expressed as negative gradient of a scalar function. $H = -\nabla V_m$ where, V_m is called scalar magnetic potential. $V_m = -\int H \cdot dl$ This scalar potential also satisfies Laplace's equation. In free space, $\nabla \cdot B = 0$ $\mu_0 \nabla \cdot H = 0$ But, $H = -\nabla V_m$ $\mu_0 \nabla \cdot (-\nabla V_m) = 0$ $-\mu_0 \nabla^2 V_m = 0$ $\nabla^2 V_m = 0$ (5 M) **Vector Magnetic Potential** **Divergence of vector is scalar, vector potential is expressed in terms of curl.**(2 M) *i.e.,* $\nabla \cdot B = 0$ $B = \nabla \times A$ where, A is magnetic vector potential. Take curl on both sides, $\nabla \times B = \nabla \times \nabla \times A$ By the identity, $\nabla \times \nabla \times A = \nabla (\nabla \cdot A) - \nabla^2 A$

But $$\nabla \times B = \mu J$$

$$\nabla(\nabla \cdot A) - \nabla^2 A = \mu J$$

For the steady dc, $$(\nabla \cdot A) = 0$$

then, $$-\nabla^2 A = \mu J$$

$$\bar{a}_x \nabla^2 A_x + \bar{a}_y \nabla^2 A_y + \bar{a}_z \nabla^2 A_z = -\mu(\bar{a}_x J_x + \bar{a}_y J_y + \bar{a}_z J_z)$$

Equating $$\nabla^2 A_x = -\mu J_x$$

$$\nabla^2 A_y = -\mu J_y$$

$$\nabla^2 A_z = -\mu J_z$$

The general, magnetic vector potential can be expressed as

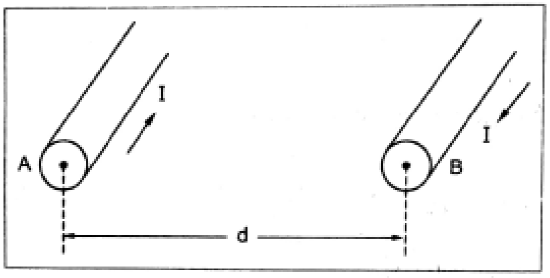
$$A = \frac{\mu}{4\pi} \iiint \frac{J}{r}\, dv$$

(4 M)

10.

Determine the inductance per unit length of a two-wire transmission line with separation distance d. Each wire has a radius a. (8 M) (BTL 1)

Answer: Page - 3.40 - Dr. P. Dananjayan



(2 M)

The internal flux linkage of the conductor A is given by

$$\phi_1 = \frac{\mu_0 \mu_r I}{8\pi}$$

The external flux linkage with the conductor A is given by

$$\phi_2 = \frac{\mu_0 I}{2\pi} ln\left(\frac{d}{a}\right)$$

The total flux linkage of A is $$\phi = \phi_1 + \phi_2$$

$$= \frac{\mu_0 \mu_r I}{8\pi} + \frac{\mu_0 I}{2\pi} ln\left(\frac{d}{a}\right)$$

$$L_A = \frac{\phi}{I}$$

$$L_A = \frac{\mu_0}{4\pi}\left[\frac{\mu_r}{2} + 2\, ln\left(\frac{d}{a}\right)\right] \text{ H/m}$$

	Similarly for conductor B, the total flux linkage is $\phi = \frac{\mu_0 \mu_r I}{8\pi} + \frac{\mu_0 I}{2\pi} ln\left(\frac{d}{a}\right)$ The total inductance of conductor B is $L_B = \frac{\mu_0}{4\pi}\left[\frac{\mu_r}{2} + 2\, ln\left(\frac{d}{a}\right)\right]$ $L = L_A + L_B$ **L =** $\mu_0 / 4\pi * [\ \mu r + 4 \ln (d/a)]$ (6 M)
	PART * C
1.	**Evaluate the inductance of a solenoid of 2500 turns wound uniformly over a length of 0.5 m on a cylindrical paper tube 4 cm in diameter. The medium is air. (Nov 2016) (8 M)** (BTL 3) **Answer: Page - 3.70 - Dr. P. Dananjayan** N = 2500 l = 0.5 m d = 4 cm $A = \pi d^2/4 = 12.566 * 10^{-4}$ (4 M) Inductance $L = \mu 0\ N^2 A / l = 19.7386$ mh (4 M)
2.	**At a point P(x,y,z) the components of vector magnetic potential A are given as A_x = (4x + 3y + 2z) ; A_y = (5x + 6y + 3z) and A_z = (2x + 3y + 5z). Determine magnetic flux density B at any point P. (7 M)** (BTL 3) **Answer: Page – 3.58 - Dr. P. Dananjayan** $B = \nabla \times A = \begin{bmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 4x+3y+2z & 5x+6y+3z & 2x+3y+5z \end{bmatrix}$ (2 M) $B = 2\ a_z$ (5 M)
3.	**In cylindrical co-ordinates, $A = 50\rho^2 \hat{a}_z$ Wb/m is a vector magnetic potential in a certain region of free space. Find the magnetic field intensity H, magnetic flux density B and current density J. (15 M) (**BTL 5) **Answer: Page – 3.59 -Dr. P. Dananjayan** $B = \nabla \times A = \frac{1}{\rho}\begin{vmatrix} \vec{a}_\rho & \rho\,\vec{a}_\phi & \vec{a}_z \\ \frac{\partial}{\partial\rho} & \frac{\partial}{\partial\phi} & \frac{\partial}{\partial z} \\ 0 & 0 & 50\,\rho^2 \end{vmatrix}$ $= \frac{1}{\rho}\vec{a}_\rho\left[\frac{\partial}{\partial\phi}(50\,\rho^2)\right] - \vec{a}_\phi\left[\frac{\partial}{\partial\rho}(50\,\rho^2)\right]$ $= 0 - 100\,\rho\,\vec{a}_\phi$ $\mathbf{B} = -100\,\rho\,\vec{a}_\phi$ **Wb/m²** (7 M)

	$H = \frac{B}{\mu_0} = \frac{-100}{\mu_0}\rho\,\vec{a_\phi} = \frac{-100}{4\pi\times10^{-7}}\rho\,\vec{a_\phi}$ A/m $J = \nabla\times H$ $= \frac{1}{\rho}\begin{vmatrix} \vec{a_\rho} & \rho\,\vec{a_\phi} & \vec{a_z} \\ \frac{\partial}{\partial\rho} & \frac{\partial}{\partial\phi} & \frac{\partial}{\partial z} \\ 0 & \frac{\rho(-100\,\rho)}{\mu_0} & 0 \end{vmatrix}$ $J = \frac{-200}{\mu_0}\vec{a_z}$ A/m^2 (8 M)
4.	**If the vector magnetic potential is given by** $A = \frac{10}{x^2+y^2+z^2}\hat{a}_x$ **, obtain the magnetic flux density in vector form. (8 M)** (BTL 5) **Answer: Page – 3.60 & notes - Dr. P. Dananjayan** Magnetic flux density, $\vec{B} = \nabla\times\vec{A}$ $\Rightarrow \vec{B} = \begin{vmatrix} \vec{a_x} & \vec{a_y} & \vec{a_z} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ 10(x^2+y^2+z^2)^{-1} & 0 & 0 \end{vmatrix}$ (4 M) $\boxed{\vec{B} = -\frac{20\,z}{(x^2+y^2+z^2)^2}\vec{a_y} + \frac{20\,y}{(x^2+y^2+z^2)^2}\vec{a_z}}$ (4 M)
5.	**A wire carrying a current of 100 A is bend into the form of a circle of diameter 10 cm. Calculate (a) flux density at the center of the coil, (b) flux density at a point on the axis of the coil and 12 cm from it. (8 M) (**BTL 5) **Answer: Page - 3.46 - Dr. P. Dananjayan** B = μ_0 N I / 2 a = 1.256 m Wb/m^2 (4 M) **B= 0.0714** m Wb/m^2 (4 M)
6.	**Derive the expression for energy and energy density stored in magnetic field. (15 M) (**BTL 1) **Answer: Page - 3.41 - Dr. P. Dananjayan** **Energy** ➢ current through an inductor is increased from 0 to I ➢ potential across the inductor is v. ➢ energy supplied by the source in time is dv. ➢ dW = vi dt ➢ W = $\int_0^I vi\,dt$

- $W = \frac{1}{2} LI^2$ (7 M)

Energy Density:

The energy stored in a magnetic field is given by

$$W = \frac{1}{2} L I^2$$

The inductance of the solenoid (for example) is given by

$$L = \frac{\mu_0 N^2 A}{l}$$

Substituting the value of L in the above equation

$$W = \frac{1}{2} \frac{\mu_0 N^2 A}{l} I^2$$

$$= \frac{1}{2} \mu_0 \left(\frac{N I}{l}\right)^2 l A$$

$$W = \frac{1}{2} \mu_0 H^2 l A$$

Energy stored per unit volume

$$W = \frac{1}{2} \mu_0 H^2 \quad J/m^3$$

$$= \frac{1}{2} (\mu_0 H) H$$

Magnetic energy density

$$W = \frac{1}{2} B H \quad joules/m^3$$

The energy stored in a magneto static field is

$$W = \int_v w \; dv$$

$$W = \frac{1}{2} \int_v B \cdot H \cdot dv = \frac{1}{2} \int \mu H^2 dv$$

(8 M)

UNIT IV ELECTRODYNAMIC FIELDS

Magnetic Circuits - Faraday's law – Transformer and motional EMF – Displacement current - Maxwell's equations (differential and integral form) – Relation between field theory and circuit theory – Applications.

Q. No	Part * A
1	**State Faraday's law of electromagnetic induction. (May 2016, Nov 2016)** BTL 1 Faraday's law states that electromagnetic force induced in a circuit is equal to the rate of change of magnetic flux linking the circuit. Emf= $\frac{d\Phi}{dt}$
2	**Define mmf and reluctance.** BTL 1 Magnetic motive force (mmf) is given by mmf = flux x reluctance mmf = $\Phi\Re$ Amp.turns. Reluctance is the ratio of mmf of magnetic circuit to the flux through it. $\Re = \frac{mmf}{flux\ (\Phi)}$. It is also written as $\Re = \frac{l}{\mu A}$;Where l is the length, A is the area of cross-section, μ is permeability
3	**What is the expression for energy stored and energy density in magnetic field?** BTL1 Energy W = $\frac{1}{2}LI^2$;WhereL is the inductance, I is the current. Energy density (w) = $\frac{1}{2}BH = \frac{1}{2}\mu H^2$
4	**State Lenz's law.** BTL 1 Lenz's law states that the induced emf in a circuit produces a current which oppose the change in magnetic flux producing it.emf = -$\frac{d\Phi}{dt}$
5	**What is meant by Displacement current? (Nov 2013, May 2016)**BTL 1 Displacement current is nothing but the current flows through the Capacitor. I_c=C dV/dt.
6	**State Ampere's circuital law. Should the path of integration be circular?** BTL 1 The integral of the tangential component of the magnetic field strength around a closed path is equal to the current enclosed by the path. $\oint H.dl = I$ .The path of integration must be enclosed one. It must be any shape and it need not be circular alone.
7	**Write the fundamental postulate for electromagnetic induction.** BTL 1 A changing magnetic flux (Φ) through a closed loop, produces an emf or voltage at the terminals as given by $v = -\frac{d\Phi}{dt}$ where the voltage is the integral of the electric field E around the loop.For uniform magnetic field Φ = B.A where B is the magnetic flux density and A is the area of the loop. $v = \oint E.dl = -\iint \frac{\partial B}{\partial t} ds$ .This is Faraday's law. It states that the line integral of the electric field around a stationary loop equals the surface integral of the time rate of change of the magnetic flux density B integrated over the loop area.

<table>
<tr><td>8</td><td>Write down the Maxwell’s equation in point form. BTL 1
From Ampere’s Law
$\nabla X H = J + \frac{\partial D}{\partial t}$
From Faraday’s Law
$\nabla X E = -\frac{\partial B}{\partial t}$
From Electric Gauss’s Law, $\nabla . D = \rho$,
From Magnetic Gauss’s Law, $\nabla . B = 0$</td></tr>
<tr><td>9</td><td>Write down the Maxwell’s equation in integral form. BTL 3
From Ampere’s Law
$\oint H.dl = \iint_s \left(J + \frac{\partial D}{\partial t} \right) ds$
From Faraday’s Law
$\oint E.dl = -\iint_s \frac{\partial B}{\partial t} ds$
From Electric Gauss’s Law
$\oiint_s D.ds = \iiint_v \rho dv$
From Magnetic Gauss’s Law
$\oiint_s B.ds = 0$</td></tr>
<tr><td>10</td><td>Mention four similarities between electric circuit and magnetic circuit.(Nov/Dec 2014) BTL 1
<table>
<tr><th>Electric circuit</th><th>Magnetic circuit</th></tr>
<tr><td>1.emf (volts)
2.current = $\frac{\text{emf}}{\text{resistance}}$
3.resistance R = $\frac{\rho l}{A}$
4.Conductance G = $\frac{1}{R}$</td><td>1. mmf(Amp-turns)
2.magnetic flux = $\frac{\text{mmf}}{\text{reluctance}}$
3. Reluctance $\Re = \frac{l}{\mu A}$
4. Permeance P = $\frac{1}{\Re}$</td></tr>
</table></td></tr>
<tr><td>11</td><td>Write down the Maxwell’s equations in point phasor forms. BTL 1
$\nabla x H = J + j\omega D = (\sigma + j\omega\varepsilon)E$
$\nabla x E = -j\omega B = -j\omega\mu H$
$\nabla . D = \rho$
$\nabla . B = 0$</td></tr>
<tr><td>12</td><td>Write the expression for total current density. (May 2012) BTL 1
$J = J_C + J_D$
J_C is conduction current density, J_D is displacement current density.</td></tr>
<tr><td>13</td><td>Why $\nabla . B = 0$ and $\nabla x E = 0$. ? BTL 1</td></tr>
</table>

$\nabla . B = 0$ States that there is no magnetic charge. The net magnetic flux emerging through any closed surface is zero.
In a region in which there is no time changing magnetic flux, the voltage around the loop would be zero. By Maxwell's equation, $\nabla \times E = -\frac{\partial B}{\partial t}$=0 (irrotational).

14 **Why $\nabla . D = 0$?**BTL 4
In a free space there is no charge enclosed by the medium. The volume charge density is zero. By Maxwell's equation $\nabla . D = \rho_v = 0$.

15 **Find the emf induced in a circuit having an inductance of 700µH if the current through it varies at the rate of 5000A/sec. (Nov 2011)** BTL 3
E=L di/dt= 700 µH X 5000A/sec.=3.5 volts

16 **Compare the relation between Circuit theory and Field theory. (Nov/Dec 2014)** BTL 1

Circuit Theory	Field Theory
This analysis originated by its own.	Evolved from Transmission theory.
Applicable only for portion of RF range.	Beyond RF range (Microwave)
The dependent and independent parameters I, V are directly obtained for the given circuit.	Not directly, through E and H.
Parameters of medium are not involved.	Parameter of medium (permittivity and permeability) are involved in the analysis.
Laplace Transform is employed.	Maxwell's equation is employed
Z, Y, and H parameters are used.	S parameter is used.
Low power is involved.	Relatively high power is involved.
Simple to understand.	Needs visualization ability
Two-dimensional analysis	Three – dimensional analysis
Frequency is used as reference.	Wave length is used as reference
Lumped components are involved	Distributed components are involved.

17 **Distinguish between conduction and displacement current. (Nov 2011)** BTL 1

Conduction current.	Displacement current
Conduction current is nothing but the current flows through the conductor.	Displacement current is nothing but the current flows through the Capacitor.
$I_c = \sigma E$.	$I_d = \quad = \int_s \frac{\partial D}{\partial t} .ds$

18 **A conductor of 1m length is moved with a velocity of 100m/sec. perpendicular to a field of 1 tesla. What is the value of emf induced? (Nov 2012)** BTL 3
$E_{induced} = vlB$, where v=100m/sec, l=1m, B=1 tesla, Therefore $E_{induced}$=100x1x1 =100

19 **What is the significance of displacement current? (Nov 2012)** BTL 1
The displacement current I_D through a specified surface is obtained by integration of the

	normal component of J_D over the surface. $I_d = \int_S J_D . ds = \int_S \frac{\partial D}{\partial t} . ds$ $I_d = \varepsilon \frac{\partial E}{\partial t} ds$ This is a current which directly passes through the capacitor.
20	**A loop is rotating about the Y axis in a magnetic field B= B₀sinwt i web/m². What is the type the voltage induced in the loop? (May 2012)** BTL 3 Motional or Generator emf is induced in the conductor as the conductor position varies with respect to time.
21	**Calculate the characteristics impedance of free space and of the medium whose relative permeability is 1 and relative permittivity is 3. (Nov 2012) (Nov/Dec2015)**BTL 3 $\eta = \frac{E}{H} = \sqrt{\frac{\mu}{\varepsilon}}$ $= \sqrt{\frac{4\pi \times 10^{-7} \times 1}{8.854 \times 10^{-12} \times 3}}$ =217.4
22	**A parallel plate capacitor with plate area of 5 cm² and plate separation of 3 mm has a voltage 50 sin 10³t V applied to its plates. Calculate the displacement current assuming$\epsilon = 2\ \epsilon_0$.(Nov/Dec2015)**BTL 3 $I_d = \frac{\partial D}{\partial t} = \epsilon \frac{\partial E}{\partial t}; E = \frac{V}{d}$ $I_d = \frac{\epsilon}{d} \frac{\partial v}{\partial t} = \frac{2\epsilon_0}{d} \frac{\partial v}{\partial t}$ $= \frac{2 \times 8.854 \times 10^{-12}}{3 \times 10^{-3}} \frac{\partial (50 \sin 10^3 t)}{\partial t}$ = $2.951*10^{-4} \cos 10^3 t$ A/m²
23	**Define mutual inductance and self-inductance. (Apr/May2015)** BTL 1 **Mutual inductance.** The mutual inductance between two coils is defined as the ratio of induced magnetic flux linkage in one coil to the current through in other coil(M) = $\frac{N_2 \Phi_{12}}{i_1}$;Where N_2 is number of turns in coil 2; Φ_{12} is magnetic flux links in coil 2 and i_1 is the current through coil 1. **Self -inductance.** The self -induction of a coil is defined as the ratio of total magnetic flux linkage in the circuit to the current through the coil (L) = $\frac{N\Phi}{i}$ Where Φ is magnetic flux; N is number of turns of coil; i is the current.
24	**Distinguish between transformer emf and motional emf. (Nov 2013)(Apr/May 2015)**BTL 1 The emf induced in a stationary conductor due to the change in flux linked with it, is called transformer emf or static induced emf. emf = $-\iint \frac{\partial B}{\partial t} . ds$ eg. Transformer. The emf induced due to the movement of conductor in a magnetic field is called motional

	emf or dynamic induced emf. emf =-$\oint_c v \times B.dl$ eg. Generator
25	**Moist soil has conductivity of 10^{-3} S/m and ε_r=2.5, determine the displacement current density if E=6.0x10^{-6} sin 9.0x10^9 t (V/m). (Nov 2016)** BTL 4 $J_D = \varepsilon_0 \varepsilon_r \frac{\partial E}{\partial t} = 8.854 \times 10^{-12} \times 2.5 \times 6 \times 10^{-6} \times 9 \times 10^9 \times \cos 9 \times 10^9 t = 1.195 \times 10^{-6} \cos 9 \times 10^9 t$
	PART * B
1	**Derive the Maxwell's equations in both point and integral forms. (Nov 2014, May 2014, Nov 2015, May 2015, Nov 2015, May 2016, Nov 2016) (13 M)** BTL 1 **Answer: Page :4.13 - Dr. P. Dananjayan** **Maxwell's equation from ampere's law (Maxwell's equation-I):**(4 M) ➢ Ampere's circuital law states that the line integral of magnetic field intensity H on any closed path is equal to current enclosed by that path. $\oint_l H.dl = I = \iint_S J.ds$ ➢ Total current involves both conduction current and displacement current. ➢ A current through resistive element is called conduction current. ➢ Current through capacitive element is called displacement current. $\therefore J = J_C + J_D$ ➢ Conduction current density $J_C = \sigma E$ ➢ Displacement current density = $J_D = \frac{\partial D}{\partial t}$ ▪ $\therefore \oint_l H.dl = \iint_S (J_C + J_D) ds$ ➢ Then $\oint_l H.dl = \iint_S \left(\sigma E + \frac{\partial D}{\partial t} \right) ds$ ▪ $\oint_l H.dl = \iint_S \left(\sigma E + \varepsilon \frac{\partial E}{\partial t} \right) ds$ --------------(1) where $D = \varepsilon E$ ➢ This is Maxwell's equation in integral form from Ampere's law. ➢ By applying stoke's theorem, ▪ $\oint_l H.dl = \iint_S (\nabla \times H).ds$ ----------------(2) ➢ Comparing equations (1) and (2) ▪ $\iint_S (\nabla \times H).ds = \iint_S \left(J + \frac{\partial D}{\partial t} \right).ds$ ▪ $\nabla \times H = J + \frac{\partial D}{\partial t}$ ▪ $\nabla \times H = \sigma E + \varepsilon \frac{\partial E}{\partial t}$ ➢ This is Maxwell's equation in differential form or point form from Ampere's law. **Maxwell's equation from Faraday's law (Maxwell's equation-II):**(3 M)

- Faraday's law states that electromotive force induced in a circuit is equal to rate of decrease of magnetic flux linkage in the circuit.
  - $e = -\frac{d\phi}{dt} = -\frac{d}{dt}\iint_S B.ds$
  - But $e = \oint E.dl$
  - $\oint E.dl = -\frac{d}{dt}\iint_S B.ds$
  - $\oint E.dl = -\iint \frac{\partial B}{\partial t}.ds$ ----------------------(3) $[\because B = \mu H]$
- This is Maxwell's equation in integral form from Faraday's law.
- By applying stoke's theorem,
  - $\oint E.dl = \iint_S (\nabla \times E).ds$ ---------------------(4)
- Comparing equations (3) and (4)
  - $\iint_S (\nabla \times E).ds = -\iint \frac{\partial B}{\partial t}.ds$
  - $\nabla \times E = -\frac{\partial B}{\partial t}$
  - $\nabla \times E = -\mu\frac{\partial H}{\partial t}$
- This is Maxwell's equation in differential form or point form from Faraday's law.

Maxwell's equation from Electric Gauss's law (Maxwell's equation-III):(3 M)

- Electric Gauss law states that electric flux passing through any closed surface is equal to the charge enclosed by that surface.
  - $\psi = Q$
- $\iint D.ds = Q$
  - $\iiint \rho_v.\,dv = Q$
  - Then $\iint_S D.ds = \iiint_v \rho_v.\,dv$ -------------------(5)
- This is Maxwell's equation in integral form from electric Gauss's law.
- By applying divergence theorem
  - $\iint_S D.ds = \iiint_v \nabla.D\ dv$ ----------------------(6)
- Comparing equations (5) and (6)
  - $\iiint_v \nabla.D\ dv = \iiint_v \rho.\,dv$
  - $\nabla.D = \rho$
- This is Maxwell's equation in differential form or point form from electric Gauss's law.

Maxwell's equation from Magnetic Gauss's law (Maxwell's equation-IV):(3 M)

- Magnetic Gauss law states that the total magnetic flux through any closed surface is equal to zero.
  - $\phi = 0$
  - $\iint_S B.\,ds = 0$ ----------------------(7)
- This is Maxwell's equation in integral form from Magnetic Gauss's law.
- By applying divergence theorem
  - $\iint_S B.ds = \iiint_v \nabla.B \; dv$ -----------------(8)
- Comparing equations (7) and (8)
  - $\iiint_v \nabla.B = 0$
  - $\nabla.B = 0$
- This is Maxwell's equation in differential form or point form from Magnetic Gauss's law.

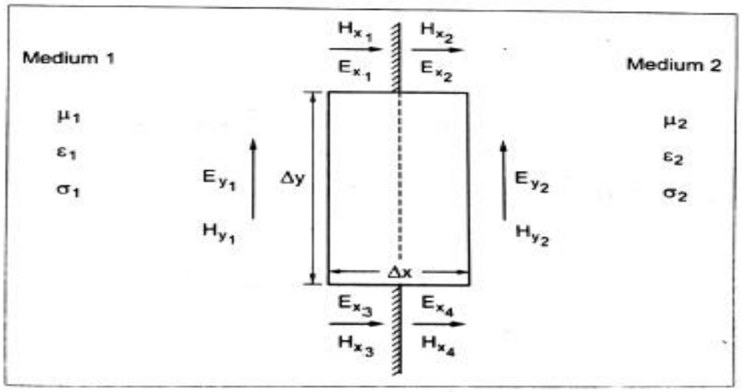
2

State the boundary conditions of time varying fields at the interface between two dielectric media, between a dielectric medium and a perfect metal. (13 M) BTL 1

Answer: Page : 4.21- Dr. P. Dananjayan

Boundary condition:(3M)

- Tangential component of E is continuous at the surface.
- Tangential component of H is continuous at the surface of perfect conductor; otherwise H is discontinuous by an amount equal to linear current density.
- Normal component of D is continuous if there is no surface charge density, otherwise D is discontinuous by an amount equal to surface current density
- Normal component of B is continuous at the surface.



	The integral form of the second Maxwell's equation is

The integral form of the second Maxwell's equation is

$$\oint E \cdot dl = \iint_S \frac{\partial B}{\partial t} \cdot ds$$

This is applied to a rectangle

$$E_{y_1} \Delta y + E_{x_1} \frac{\Delta x}{2} + E_{x_2} \frac{\Delta x}{2} - E_{y_2} \Delta y - E_{x_4} \frac{\Delta x}{2} - E_{x_3} \frac{\Delta x}{2} = \frac{\partial B}{\partial t} \Delta x \, \Delta y$$

Consider the area of the rectangle is made to approach zero by reducing the width Δx to approach zero.

Then, $$E_{y_1} \Delta y - E_{y_2} \Delta y = 0$$

$$E_{y_1} = E_{y_2}$$

The tangential component of E is continuous.

The integral form of first Maxwell's equation is

$$\oint_l H \cdot dl = \iint_S \left(J + \frac{\partial D}{\partial t} \right) ds$$

Applying to the rectangle,

$$H_{y_1} \Delta y + H_{x_1} \frac{\Delta x}{2} + H_{x_2} \frac{\Delta x}{2} - H_{y_2} \Delta y - H_{x_4} \frac{\Delta x}{2} - H_{x_3} \frac{\Delta x}{2} = \left(J + \frac{\partial D}{\partial t} \right) \Delta x \, \Delta y$$

If $\Delta x \to 0$, then $$H_{y_1} \Delta y - H_{y_2} \Delta y = 0$$

$$H_{y_1} = H_{y_2}$$

$$\underset{\Delta x \to 0}{\text{Lt}} \; J \cdot \Delta x = J_l \quad \text{A/m}$$

If the Maxwell's I equation is applied to the rectangle, then

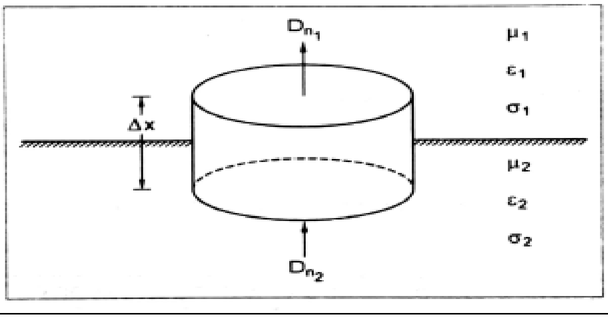
$$H_{y_1} \Delta y + H_{x_1} \frac{\Delta x}{2} + H_{x_2} \frac{\Delta x}{2} - H_{y_2} \Delta y - H_{y_4} \frac{\Delta x}{2} - H_{y_3} \frac{\Delta x}{2} = \left(J + \frac{\partial D}{\partial x} \right) \Delta x \, \Delta y$$

$$= J \, \Delta x \, \Delta y + \frac{\partial D}{\partial x} \, \Delta x \, \Delta y$$

$$H_{y_1} \Delta y - H_{y_2} \Delta y = J_l \, \Delta y$$

$$H_{y_1} - H_{y_2} = J_l$$

(5 M)



The integral form of the Maxwell's 3rd equation

$$\oiint_s D \cdot ds = \iiint_v \rho\, dv$$

Apply to the pill box at the boundary

$$D_{n_1} ds - D_{n_2} ds = \rho\, ds \cdot \Delta x$$

As $\Delta x \to 0$ *i.e.*, the flat surfaces of the box are squeezed together

$$D_{n_1} ds - D_{n_2} ds = 0$$

$$D_{n_1} = D_{n_2}$$

$$\underset{\Delta x \to 0}{\mathrm{Lt}}\ \rho_v \cdot \Delta x = \rho_s$$

If the Maxwell's third equation is applied to the pill box

$$D_{n_1} ds - D_{n_2} ds = \rho_v\, ds \cdot \Delta x = \rho_s \cdot ds$$

As $\Delta x \to 0$, $$D_{n_1} - D_{n_2} = \rho_s$$

The integral form of Maxwell's fourth equation is

$$\iint B \cdot ds = 0$$

Apply to the Pill box at the boundary,

$$B_{n_1} ds - B_{n_2} ds = 0$$

$$B_{n_1} = B_{n_2}$$

(5 M)

3

State and derive the Maxwell's equations for free space in point and integral forms for time varying field. (Nov2011&2013) (13 M) BTL 1

Answer: Page : 4.20 - Dr. P. Dananjayan

Maxwell's equation from ampere's law (Maxwell's equation-I):(4 M)

- Ampere's circuital law states that the line integral of magnetic field intensity H on any closed path is equal to current enclosed by that path.

$$\oint_l H.dl = I = \iint_S J.ds$$

- Total current involves both conduction current and displacement current.
- A current through resistive element is called conduction current.
- Current through capacitive element is called displacement current.

$$\therefore\ J = J_C + J_D$$

- Conduction current density $J_C = \sigma E$
- Displacement current density = $J_D = \dfrac{\partial D}{\partial t}$
- Then $\oint_l H.dl = \iint_S \left(\sigma E + \dfrac{\partial D}{\partial t} \right) ds$

- $\oint_l H.dl = \iint_s \left(\sigma E + \varepsilon \frac{\partial E}{\partial t}\right) ds$ --------------(1) where $D = \varepsilon E$

- This is Maxwell's equation in integral form from Ampere's law.
- By applying stoke's theorem,
  - $\oint H.dl = \iint_s (\nabla \times H).ds$ ----------------(2)
- Comparing equations (1) and (2)
  - $\iint_s (\nabla \times H).ds = \iint_s \left(J + \frac{\partial D}{\partial t}\right).ds$
  - $\nabla \times H = J + \frac{\partial D}{\partial t}$
  - $\nabla \times H = \sigma E + \varepsilon \frac{\partial E}{\partial t}$
- This is Maxwell's equation in differential form or point form from Ampere's law.

Maxwell's equation from Faraday's law (Maxwell's equation-II): (3 M)

- Faraday's law states that electromotive force induced in a circuit is equal to rate of decrease of magnetic flux linkage in the circuit.
  - $e = -\frac{d\phi}{dt} = -\frac{d}{dt}\iint_s B.ds$
  - But $e = \oint E.dl$
  - $\oint E.dl = -\frac{d}{dt}\iint_s B.ds$
  - $\oint E.dl = -\iint \frac{\partial B}{\partial t}.ds$ -----------------------(3) $[\because B = \mu H]$
- This is Maxwell's equation in integral form from Faraday's law.
- By applying Stoke's theorem,
  - $\oint E.dl = \iint_s (\nabla \times E).ds$ ---------------------(4)
- Comparing equations (3) and (4)
  - $\iint_s (\nabla \times E).ds = -\iint \frac{\partial B}{\partial t}.ds$
  - $\nabla \times E = -\frac{\partial B}{\partial t}$
  - $\nabla \times E = -\mu \frac{\partial H}{\partial t}$
- This is Maxwell's equation in differential form or point form from Faraday's law.

Maxwell's equation from Electric Gauss's law (Maxwell's equation-III): (3 M)

- Electric Gauss law states that electric flux passing through any closed surface is equal to the charge enclosed by that surface.

  - $\psi = Q$
- $\iint D.ds = Q$
  - $\iiint \rho_v . dv = Q$
  - Then $\iint_S D.ds = \iiint_v \rho_v . dv$ -------------------(5)
- This is Maxwell’s equation in integral form from electric Gauss’s law.
- By applying divergence theorem
  - $\iint_S D.ds = \iiint_v \nabla .D \; dv$ -----------------------(6)
- Comparing equations (5) and (6)
  - $\iiint_v \nabla .D \; dv = \iiint_v \rho . dv$
  - $\nabla .D = \rho$
- This is Maxwell’s equation in differential form or point form from electric Gauss’s law.

Maxwell’s equation from Magnetic Gauss’s law (Maxwell’s equation-IV): (3 M)

- Magnetic Gauss law states that the total magnetic flux through any closed surface is equal to zero.
  - $\phi = 0$
  - $\iint_S B . ds = 0$ ----------------------(7)
- This is Maxwell’s equation in integral form from Magnetic Gauss’s law.
- By applying divergence theorem
  - $\iint_S B.ds = \iiint_v \nabla .B \; dv$ -----------------(8)
- Comparing equations (7) and (8)
  - $\iiint_v \nabla .B = 0$
  - $\nabla .B = 0$

This is Maxwell’s equation in differential form or point form from Magnetic Gauss’s law.

$$E(x,t) = \text{Real part of } [\, E(x)\, e^{j\omega t}]$$

$$\frac{\partial E}{\partial t}(x,t) = \text{Real part of } [\, j\omega\, E(x)\; e^{j\omega t}\,]$$

Apply for Maxwell’s equation,

$$\text{Real part of } [\nabla \times H] = \text{Real part of } [(\sigma\, E + j\,\omega\,\varepsilon\, E)\, e^{j\omega t}]$$

$$\nabla \times H = \sigma\, E + j\omega\varepsilon E$$

$$\nabla \times H = (\sigma + j\,\omega\,\varepsilon)\, E$$

For magnetic field, $H(x,t) = \text{Re}\, [\, H(x)\, e^{j\omega t}\,]$

$$\frac{\partial H}{\partial t}(x,t) = \text{Re}\, [\, j\omega H(x)\, e^{j\omega t}\,]$$

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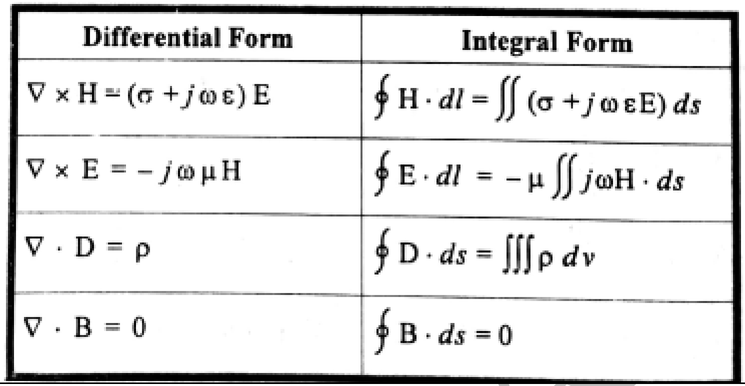
Apply for Maxwell's equation

$$\text{Re}\,[\nabla \times E] = -\text{Re}\,[j\omega\mu\ H e^{j\omega t}]$$

$$\nabla \times E = -j\omega\mu H$$



<table>
<tr><th>Differential Form</th><th>Integral Form</th></tr>
<tr><td>$\nabla \times H = (\sigma + j\omega\varepsilon)\,E$</td><td>$\oint H \cdot dl = \iint (\sigma + j\omega\varepsilon E)\, ds$</td></tr>
<tr><td>$\nabla \times E = -j\omega\mu H$</td><td>$\oint E \cdot dl = -\mu \iint j\omega H \cdot ds$</td></tr>
<tr><td>$\nabla \cdot D = \rho$</td><td>$\oint D \cdot ds = \iiint \rho\, dv$</td></tr>
<tr><td>$\nabla \cdot B = 0$</td><td>$\oint B \cdot ds = 0$</td></tr>
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<tr>
<td>4</td>
<td>
For 1 A conductor current in copper wire, find the corresponding displacement current at 100 MHz. Assume for copper σ = $5.8 * 10^7$ mho/m. (7M) BTL 3

Answer: Page : 4.25 - Dr. P. Dananjayan

Conduction current $I_C = J_C A = 1$ Amp

$$J_C = \frac{I}{A} = \sigma E$$

$$E = \frac{J_C}{\sigma} = \frac{1/A}{\sigma} = \frac{0.172 \times 10^{-7}}{A} \text{ V/m}$$

(4 M)

Displacement current $I_D = \omega\,\varepsilon\, E \cdot A = \omega\,\varepsilon_0\,\varepsilon_r\, E\, A$

For copper $\varepsilon_r = 1$, $I_D = 2\pi \times 100 \times 10^6 \times \frac{10^{-9}}{36\,\pi} \times \frac{0.172 \times 10^{-7}}{A}$

$$\mathbf{I_D = 9.556 \times 10^{-11}\ A}$$ **Ans.** ☜

(3 M)
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<td>5</td>
<td>
A parallel plate capacitor with plate area of 0.01 m^2 and plate separation of 5 cm has a voltage 100 sin 314 t V applied to its plates. Calculate the displacement current assuming $\varepsilon = 10\varepsilon_0$(May 2012, Nov 2014) (8 M) BTL 3

Answer: Page : 4.32 - Dr. P. Dananjayan

Displacement current density

$$J_D = \frac{\partial D}{\partial t} = \varepsilon \frac{\partial E}{\partial t}$$

$$E = \frac{V}{d}$$

$$J_D = \frac{\varepsilon}{d} \cdot \frac{\partial V}{\partial t} = \frac{\varepsilon}{d} \frac{\partial}{\partial t} (100 \sin 314\, t)$$
</td>
</tr>
</table>

	$= \frac{100\,\varepsilon}{d}\cos(314\,t)\cdot 314$ $= \frac{100}{5\times10^{-2}}\times\frac{10}{36\,\pi\times10^{9}}\times 314\cos(314\,t)$ $= 5.55\times10^{-5}\cos(314\,t)$ A/m^2 (4 M) Displacement current $I_D = J_D\cdot A$ $= 5.55\times10^{-5}\times 0.01\cos(314\,t)$ A **$= 5.55\times10^{-7}\cos(314\,t)$ A Ans.** ☜ (4 M)
6	**Explain in detail conduction current and displacement currents. (April 2015, Nov 2015) (13 M)** BTL 1 **Answer: Page : 4.10 - Dr. P. Dananjayan** Conduction current:(6 M) ➢ Current flowing through resistive element. ➢ Ic = V/R ➢ R = ρ l/A ➢ R = l/σA ➢ V = E l ➢ Ic = V/R = El/l = EσA ➢ Jc = Ic/A = σE ➢ J = σE Displacement Current:(7 M) ➢ Current flowing through capacitor element. ➢ I_D = dQ/dt = C dv/dt ➢ C = ε A/d ➢ I_D = ε A/d * dV/dt ➢ A * əD/ət ➢ J_D = I_D/A ➢ J_D = ə$_D$/ət
7	**Do the fields E = Em sin x sin t a_y and H = (Em/μo)*(cos x cos t) $a_z$satisfy Maxwell's equations. (8 M)** BTL 1 **Answer: Page : 4.36 - Dr. P. Dananjayan** $\nabla\times E = -\frac{\partial B}{\partial t} = -\mu_0\frac{\partial H}{\partial t}$ $\nabla\times E = \begin{bmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & E_m\sin x\sin t & 0 \end{bmatrix}$ $= \bar{a}_x\left[-\frac{\partial}{\partial z}(E_m\sin x\sin t)\right]+\bar{a}_z\left[\frac{\partial}{\partial x}(E_m\sin x\sin t)\right]$ $= E_m\cos x\sin t\,\bar{a}_z$ (4 M)

	$-\mu_o \frac{\partial H}{\partial t} = -\mu_o \frac{\partial}{\partial t}\left[\frac{E_m}{\mu_o}\cos x \cos t\right]\bar{a}_z$ $= -E_m \cos x\,(-\sin t)\,\bar{a}_z = E_m \cos x \sin t\,\bar{a}_z$ Hence $\nabla \times E = -\mu \frac{\partial H}{\partial t}$ (4 M)
8	**In a material for which σ =5.0 S/m and Ɛr=1 with E=250 sin 10^{10} t (V/m). Find J_c and $J_D$and the frequency at which they equal magnitudes. (8 M)** BTL 3 **Answer: Page :-4.28 - Dr. P. Dananjayan** ☺ ***Solution:*** $\sigma = 5$ s/m, $\varepsilon_r = 1$ $E = 250 \sin 10^{10} t$ (V/m) Conduction current density $J_C = \sigma E$ $= \mathbf{1250 \sin 10^{10} t}$ **(V/m) Ans.** ☜ (4 M) Displacement current density $J_D = \frac{\partial D}{\partial t} = \varepsilon_0 \frac{\partial E}{\partial t}$ $= \frac{10^{-9}}{36\pi} \times 10^{10} \times 250 \cos 10^{10} t$ (V/m) $J_D = \mathbf{22.1 \cos 10^{10} t}$ **V/m Ans.** ☜ ☺ (4 M)
	PART * C
1	$\vec{H} = 3\cos x\vec{a}_x + z\cos x\vec{a}_y$ **A/m for** $z \geq 0$ **and** $\vec{H} = 0$ **for z<0. This magnetic field is applied to a perfectly conducting surface in xy plane. Find the current density on the conductor surface. (8 M) (May/June 2015)** BTL 3 **Answer: Page :4.33 - Dr. P. Dananjayan** From Ampere's circuit law, Current density $J = \nabla \times H$ In cartesian form, $J = \begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ H_x & H_y & H_z \end{vmatrix}$ $= \left[\frac{\partial H_z}{\partial y} - \frac{\partial H_y}{\partial z}\right]\bar{a}_x + \left[\frac{\partial H_x}{\partial z} - \frac{\partial H_z}{\partial x}\right]\bar{a}_y + \left[\frac{\partial H_y}{\partial x} - \frac{\partial H_x}{\partial y}\right]\bar{a}_z$ (3 M) From H (given), $H_x = 3\cos x$ $H_y = z\cos x$ $H_z = 0$ $J = \left[0 - \frac{\partial z\cos x}{\partial z}\right]\bar{a}_x + \left[\frac{\partial\, 3\cos x}{\partial z} - 0\right]\bar{a}_y + \left[\frac{\partial z\cos x}{\partial x} - \frac{\partial\, 3\cos x}{\partial y}\right]\bar{a}_z$ $= -\cos x\,\bar{a}_x - z\sin x\,\bar{a}_z$ A/m^2 $\mathbf{J = -\cos x\,\bar{a}_x - z\sin x\,\bar{a}_z}$ **A/m²,** **for $z \geq 0$** **= 0, for $z < 0$ Ans.** ☜ ☺☺ (5 M)
2	**If the magnetic field H = (3x cos β + 6 y sin α)$a_z$find current density J if fields are**

	invariant with time. (8 M) BTL 5 **Answer: Page: 4.35 - Dr. P. Dananjayan** $\nabla \times H = J + \frac{\partial D}{\partial t}$ If the fields are invariant with time $\frac{\partial D}{\partial t} = 0.$ $\nabla \times H = J$ (3 M) $J = \begin{vmatrix} \bar{a}_x & \bar{a}_y & \bar{a}_z \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & 0 & 3x\cos\beta + 6y\sin\alpha \end{vmatrix}$ $J = \frac{\partial}{\partial y}(3x\cos\beta + 6y\sin\alpha)\,\bar{a}_x - \frac{\partial}{\partial x}(3x\cos\beta + 6y\sin\alpha)\,\bar{a}_y$ $\mathbf{J} = 6\sin\alpha\,\bar{a}_x - 3\cos\beta\,\bar{a}_y$ **A/m^2 Ans.** ☜ ☺☺ (5 M)
3	**The conduction current flowing through a wire with conductivity σ = 3 * 10^7 s/m and relative permittivity εr = 1 is given by Ic 3 sin ωt (mA). If ω = 10^{8}ras/sec. Find the displacement current. (8 M)** BTL 3 **Answer: Page:4.33 - Dr. P. Dananjayan** $I_C = \sigma E A$ $E = \frac{I_C}{\sigma A} = \frac{3 \times 10^{-3} \sin \omega t}{3 \times 10^{7} \times A} = \frac{1 \times 10^{-10}}{A} \sin \omega t$ $\frac{\partial E}{\partial t} = \frac{1 \times 10^{-10}}{A} \omega \cos \omega t$ $J_D = \varepsilon \frac{\partial E}{\partial t}$ $J_D = \varepsilon \omega \cdot \frac{1 \times 10^{-10}}{A} \cos \omega t$ $= 8.85 \times 10^{-12} \times 10^{8} \times \frac{10^{-16}}{A} \cos 10^{8} t$ (4 M) Displacement current $I_D = J_D \cdot A$ $= 8.85 \times 10^{-12} \times 10^{8} \times \frac{10^{-16}}{A} \cos 10^{8} t$ A $\mathbf{I_D = 8.85 \times 10^{-4} \cos 10^{8} t}$ **Amperes Ans.** ☜ (4 M)
4	**Given the conduction current density in a lossy dielectric ad Jc = 0.02 sin 10^{9}t A/m^2. Find the displacement current density if σ = 10^3 mho/m and εr = 6.5 (8 M)** BTL 5 **Answer: Page: 4.35 – Dr. P. Dananjayan**

	$J_C = 0.02 \sin 10^9 t$ A/m^2 $\sigma = 10^3$ mho/m $\varepsilon_r = 6.5$ $J_C = \sigma E$ $E = \frac{J_C}{\sigma}$ $= \frac{0.02 \sin 10^9 t}{10^3} = 2 \times 10^{-5} \sin 10^9 t$ V/m (4 M) Displacement current density $J_D = \frac{\partial D}{\partial t} = \varepsilon \frac{\partial E}{\partial t}$ $\frac{\partial E}{\partial t} = 2 \times 10^{-5} \times 10^9 \cos 10^9 t$ $J_D = \varepsilon \frac{\partial E}{\partial t} = \varepsilon_0 \varepsilon_r \frac{\partial E}{\partial t}$ $= 8.854 \times 10^{-12} \times 6.5 \times 2 \times 10^{-5} \times 10^9 \cos 10^9 t$ A/m $= 115.1 \times 10^{-8} \cos 10^9 t$ A/m Ans. ☚ (4 M)
5	**Derive the emf equations for transformer and motional emf. (15 M)** BTL1 **Answer: Page : 4.04 – Dr. P. Dananjayan** **EMF Equation of The Transformer**(7 M) ➢ Let, N_1 = Number of turns in primary winding N_2 = Number of turns in secondary winding Φ_m = Maximum flux in the core (in Wb) = (B_m x A) f = frequency of the AC supply (in Hz) ➢ As, shown in the fig., the flux rises sinusoidally to its maximum value Φ_m from 0. ➢ It reaches to the maximum value in one quarter of the cycle i.e in T/4 sec (where, T is time period of the sin wave of the supply = 1/f). ➢ average rate of change of flux = $^{\Phi}{}_{m} /_{(T/4)} = {}^{\Phi}{}_{m}/_{(1/4f)}$ ➢ average rate of change of flux = 4f Φ_m .... (Wb/s). ➢ Induced emf per turn = rate of change of flux per turn. ➢ Therefore, average emf per turn = 4f Φ_m ....(Volts). ➢ Now, we know, Form factor = RMS value / average value ➢ Therefore, RMS value of emf per turn = Form factor X average emf per turn. ➢ As, the flux Φ varies sinusoidally, form factor of a sine wave is 1.11 ➢ Therefore, RMS value of emf per turn = 1.11 x 4f Φ_m = 4.44f Φ_m. ➢ RMS value of induced emf in whole primary winding (E_1) = RMS value of emf per turn X Number of turns in primary winding $E_1 = 4.44f\, N_1\, \Phi_m$ .... eq 1

Similarly, RMS induced emf in secondary winding (E_2) can be given as

$E_2 = 4.44f\ N_2\ \Phi_m$. .... eq 2

from the above equations 1 and 2,

$$\frac{E_1}{N_1} = \frac{E_2}{N_2} = 4.44f\ \Phi m$$

- This is called the **emf equation of transformer**, which shows, emf / number of turns is same for both primary and secondary winding.

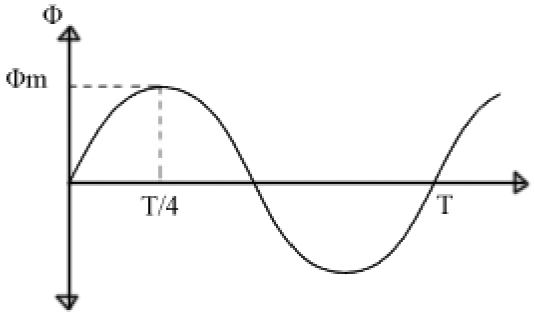
  For an ideal transformer on no load, $E_1 = V_1$ and $E_2 = V_2$.
  where, V_1 = supply voltage of primary winding
  V_2 = terminal voltage of secondary winding

- **Voltage Transformation Ratio (K)**
- As derived above,

$$\frac{E_1}{N_1} = \frac{E_2}{N_2} = K$$

- Where, K = constant
  This constant K is known as **voltage transformation ratio**.

- If $N_2 > N_1$, i.e. $K > 1$, then the transformer is called step-up transformer.
- If $N_2 < N_1$, i.e. $K < 1$, then the transformer is called step-down transformer.



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Motional EMF (8 M)

- When a conductor is moved across a magnetic field, a potential difference is setup across its ends.
- This potential difference is called **'motional EMF'.**

EXPRESSION FOR MOTIONAL EMF

- Consider a wire of length "**L**" moving across the magnetic field of induction **B** with a velocity **v** as shown in diagram.

- Each free electron of the wire is moving within the wire and experience a force exerted by magnetic field.
- $$\vec{F} = q\,(\vec{V} \times \vec{B})$$
- For electron we have
  q = -e
- $$\vec{F} = -e(\vec{V} \times \vec{B})$$
  $$\vec{F} = e(\vec{B} \times \vec{V})$$ from b to a
- These electrons gradually accumulate at the end "a" and leaving the other end "b".In this way point "b" acquires positive charge and point "a" acquires equal negative charge.
  This accumulation of electrons will continue till the force of electric field balances the force due to the motion of wire. Thus, a potential difference is setup form point **b** to point **a**.

POTENTIAL DIFFERENCE

- We know
  Potential Difference = work done per unit charge
  Let the total charge flows through the wire is "**q**" therefore
- This is called motional EMF.
  - Therefore, motional EMF = BVlsinq
  - If the wire is moving at right angle to the field, **q** = 90
  - **Motional EMF = BVL**

UNIT V ELECTROMAGNETIC WAVES	
Electromagnetic wave generation and equations – Wave parameters; velocity, intrinsic impedance, propagation constant – Waves in free space, lossy and lossless dielectrics, conductors- skin depth - Poynting vector – Plane wave reflection and refraction.	
Q. No	**Part * A**
1	**Mention the properties of uniform plane wave. (Nov 2016)** BTL 1 The properties of uniform plane wave are as follows: ➢ At every point in space, the electric field E and Magnetic field H are perpendicular to each other and to the direction of the travel. ➢ The fields vary harmonically with the time and at the same frequency, everywhere in space. ➢ Each field has the same direction, magnitude and phase at every point in any plane perpendicular to the direction of wave travel.
2	**Write down the wave equations for E and H in a non-dissipative (free space) and conducting medium. (May 2012)** BTL 1 **In Free space.** $\nabla^2 E - \mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2} = 0$; $\nabla^2 H - \mu_0 \varepsilon_0 \frac{\partial^2 E}{\partial t^2} = 0$ **In conducting medium.** $\nabla^2 E - \mu\varepsilon \frac{\partial^2 E}{\partial t^2} - \mu\sigma \frac{\partial E}{\partial t} = 0$; $\nabla^2 H - \mu\varepsilon \frac{\partial^2 H}{\partial t^2} - \mu\sigma \frac{\partial H}{\partial t} = 0$
3	**Define uniform plane wave.(Nov 2013)** BTL 1 If the phase of a wave is the same for all points on a plane surface it is called plane wave. If the amplitude is also constant in a plane wave, it is called uniform plane wave.
4	**Define intrinsic impedance or characteristic impedance.** BTL 1 It is the ratio of electric field to magnetic field. Or It is the ratio of square root of permeability to permittivity of the medium. $\eta = \frac{E}{H} = \sqrt{\frac{\mu}{\varepsilon}}$ Ohms
5	**Calculate intrinsic impedance or characteristic impedance of free space. (Nov 2011)** BTL 3 $\eta = \frac{E}{H} = \sqrt{\frac{\mu_o}{\varepsilon_o}} = \sqrt{\frac{4\pi \times 10^{-7}}{8.854 \times 10^{-12}}} = 120\pi = 377$ ohms
6	**Define polarization.** BTL 1 Polarization is defined as the polarization of a uniform plane wave refers to the time varying nature of the electric field vector at some fixed point in space.
7	**Define Surface impedance.** BTL 1 Surface impedance is defined as the ratio of tangential component of electric field at the surface of a conductor to the linear current density. $Zs = \frac{E_{\tan}}{J_s} = \frac{\gamma}{\sigma}$; Where γ is propagation constant. σ is conductivity medium.

8	**Define Poynting vector. (May 2014, May 2016)** BTL 1 The pointing vector is defined as rate of floe of energy of a wave as it propagates. It is the vector product of electric field and magnetic field. P = E x H
9	**State Slepian vector.** BTL 1 Slepian vector is a vector which defined at every point, such that its flux coming out of any volume is zero. $(\nabla . S) = 0$. Slepian vector is given by $S = \nabla \times (\nabla \mathrm{H})$ Where, V is electric potential, H is magnetic field intensity.
10	**State Poynting theorem. (Nov 2013)** BTL 1 The vector product of electric field intensity at any point is a measure of the rate of energy flow per unit area at that point. P = E x H
11	**Fine the skin depth at a frequency of 2MHz is Aluminum where σ = 38.2M s/m and $\mu_{r=}$ 1.** BTL 3 **Solution:** Given data:σ = 38.2M s/m = 38.2 x 10^6 s/m; $\mu_{r=}$ 1; $\omega = 2\pi f = 2\pi x 2 x 10^{6}$ For Good conductor, Skin depth $\delta = \frac{1}{\alpha} = \sqrt{\frac{2}{\omega\mu\sigma}}$ = $\sqrt{\frac{2}{2\pi \times 2 \times 10^{6} \times 1 \times 4\pi \times 10^{-7} \times 38.2 \times 10^{6}}}$ =5.758 x 10^{-5} m.
12	**State Snell's law.** BTL 1 When a wave is travelling from one medium to another medium, the angle of incidence is related to angle of reflection as follows. $\frac{\sin\theta_i}{\sin\theta_t} = \sqrt{\frac{\eta_1}{\eta_2}} = \sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$ $(\mu_1 = \mu_2 = \mu_0)$ Where θ_i is angle of incidence; θ_t is angle of refraction; ε_1 is dielectric constant of medium 1 ε_2 is dielectric constant of medium 2 .
13	**Write Helmholtz's equation.** BTL 1 $\nabla^2 E - \gamma^2 E = 0$; where $\gamma = \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$
14	**What is Brewster angle?** BTL 1 Brewster angle is an incident angle at which there is no reflect wave for parallel polarized wave. $\theta = \tan^{-1}\sqrt{\frac{\varepsilon_2}{\varepsilon_1}}$ Where, ε_1 is dielectric constant of medium 1, ε_2 is dielectric constant of medium
15	**What do you meant by total internal reflection?** BTL 1 When a wave is incident from the denser medium to rarer medium at an angle equal to or greater than the critical angle, the wave will be totally internally reflected back. This phenomenon is called Total internal reflection.
16	**Write the expression for poynting theorem in integral form and in point form.** BTL 1 **Integral form**

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$$-\oint_{s} P.ds = \int_{v} \sigma E^{2} + \frac{\partial}{\partial t}\int_{v} \frac{1}{2}\frac{\partial}{\partial t}[\mu H^{2} + \varepsilon E^{2}]$$

Point form:

$$-\nabla.\overline{P} = \sigma E^{2} + \frac{1}{2}\frac{\partial}{\partial t}[\mu H^{2} + \varepsilon E^{2}]$$

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<tr><td>**17**</td><td>

What is practical significance of skin depth? (Nov 2015, May 2016) BTL 1

Skin depth or depth of penetration (δ) is defined as that of depth in which the wave has been attenuated to 1 / e or approximately 37% of its original value.

$\delta = \frac{1}{\alpha} = \sqrt{\frac{2}{\omega\mu\sigma}}$ for good conductor. $\delta = \sqrt{\frac{1}{\pi f \mu\sigma}}$; δ α $\frac{1}{f}$

For low frequency, the skin depth δ is large. For High or microwave frequency range, the skin depth δ is small.

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<tr><td>**18**</td><td>

Define normal incidence and oblique incidence. BTL 1

Normal incidence: When a uniform plane wave incidences normally to the boundary between the media, then it is known as normal incidence.

Oblique incidence: When a uniform plane wave incidences obliquely to the boundary between the two media, then it is known as oblique incidence.

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<tr><td>**19**</td><td>

Define voltage reflection coefficient at the load end of the transmission line.(Nov 2011) BTL 1

It is defined as the ratio of the magnitude of the reflected wave to that of the incident wave.

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<tr><td>**20**</td><td>

What is ‘standing wave ratio’? (Nov 2012, May 2014, Nov 2016) BTL 1

It is defined as the ratio of maximum to minimum amplitudes of voltage.

S = $\frac{E_{1s\,max}}{E_{1s\,min}} = \frac{1+|\Gamma|}{1-|\Gamma|}$

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<tr><td>**21**</td><td>

The capacitance and inductance of an overhead transmission line are 0.0075μF/km and 0.8mH/km respectively. Determine the characteristic impedance of the line.(Nov/Dec 2014) BTL 3

The characteristic impedance of a transmission line is equal to the square root of the ratio of the line's inductance per unit length divided by the line's capacitance per unit length

$Z_0 = \sqrt{\frac{L}{C}}$ =326.5Ω

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<tr><td>**22**</td><td>

Compare the equi-potential plots of uniform and non-uniform fields. (April /May 2015) BTL 1

<table>
<tr><td>Uniform field</td><td>Non-uniform field</td></tr>
<tr><td>The equipotential surface are perpendicular to $\vec{E}$ and are equidistant for fixed increment of voltages</td><td>The equipotential surface are perpendicular to $\vec{E}$ and are no equidistant for fixed increment of voltages</td></tr>
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<tr><td>**23**</td><td>

What is the wavelength and frequency of a wave propagation in free space when β=2? (April /May 2015) BTL 3

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	β = $\sqrt{\omega\mu}$ = $\omega\sqrt{\mu_0\omega_0}$; 2 = $2\pi f\sqrt{\mu_0\omega_0}$; f = 0.955 *10^8 Hz; wavelength = 3.14m
24	**If a plane wave is incident normally from medium 1 to medium2, write the reflection and transmission co-efficients. (Nov/Dec 2014)** BTL 3 Reflection Co-efficients $Er_0 = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} Ei_0$ Transmission Co-efficients $Et_0 = = \frac{2\eta_2}{\eta_2 + \eta_1} Ei_0$
25	**A plane wave travelling in air is normally incident on a block of paraffin with $\epsilon_r = 2.3$. Find the reflection co-efficient. (Nov/Dec 2015)**BTL 3 Reflection co-efficient = $\frac{\sqrt{\epsilon_1}-\sqrt{\epsilon_2}}{\sqrt{\epsilon_1}+\sqrt{\epsilon_2}}$ == $\frac{\sqrt{2.3}-\sqrt{1}}{\sqrt{2.3}+\sqrt{1}}$ = 0.5165/2.565 = 0.2053
	PART * B
1	**Obtain the electromagnetic wave equation for free space in terms of electric field and magnetic fields.(13 M) (Nov 2012, Nov 2015)** BTL 2 **Answer: Page:5.03 - P. Dananjayan** ➢ For free space (dielectric medium) the conductivity of the medium is zero. (i.e., $\sigma = 0$) and there is no charge containing in it (i.e., $\rho = 0$). ➢ The electromagnetic wave equations for free space can be obtained from Maxwell's equations. ➢ The Maxwell's equation from Faraday's law for free space in point form is $\nabla \times E = -\frac{\partial B}{\partial t} = -\mu \frac{\partial H}{\partial t}$ ➢ Taking curl on both sides, ● $\nabla \times \nabla \times E = -\mu \nabla \times \frac{\partial H}{\partial t}$ ---------------------------(1) ➢ But Maxwell's equation from ampere's law for free space in point form is $\nabla \times H = -\frac{\partial D}{\partial t} = -\varepsilon \frac{\partial E}{\partial t}$ $\nabla \times \frac{\partial H}{\partial t} = \frac{\partial \nabla \times H}{\partial t} = \frac{\partial}{\partial t}\left(\varepsilon \frac{\partial E}{\partial t}\right)$ $\nabla \times \frac{\partial H}{\partial t} = \left(\varepsilon \frac{\partial^2 E}{\partial t^2}\right)$ --------------------------------(2) ➢ Substituting the equation (2) in (1) $\nabla \times \nabla \times E = -\mu \varepsilon \times \left(\frac{\partial^2 E}{\partial t^2}\right) - - - - - - - - - - - - - - - (3)$ ➢ But the identity is given by, ● $\nabla \times \nabla \times E = \nabla(\nabla . E) - \nabla^2 E$ ● $\nabla . E = \frac{1}{\varepsilon} \nabla . D = \frac{\rho}{\varepsilon} = 0$ $\nabla \times \nabla \times E = \nabla(\nabla . E) - \nabla^2 E$

$$\nabla \times \nabla \times E = -\nabla^2 E \text{ ----------------- } (4)$$

- Comparing equations (3) and (4)

$$\nabla^2 E = \mu\varepsilon \frac{\partial^2 E}{\partial t^2}$$

●

$$\nabla^2 E - \mu\varepsilon \frac{\partial^2 E}{\partial t^2} = 0 \text{ ----------------- } (5)$$

(6 M)

- This is the wave equation for free space in terms of electric field.
- The wave equation for free space in terms of magnetic field H is obtained in a similar manner as follows.
- The Maxwell's equation from ampere's law for free space in point form is given by

$$\nabla \times H = \varepsilon \frac{\partial E}{\partial t}$$

- Taking curl on both sides

$$\nabla \times \nabla \times H = -\varepsilon \ \nabla \times \frac{\partial E}{\partial t} \text{ -------------- } (6)$$

- But Maxwell's equation from faraday's law

$$\nabla \times E = -\mu \frac{\partial H}{\partial t}$$

●

- Differentiating,

$$\nabla \times \frac{\partial E}{\partial t} = -\mu \frac{\partial^2 H}{\partial t^2} \text{ ------- } (7)$$

- Substituting equation (7) in (6)

$$\nabla \times \nabla \times H = -\mu\varepsilon \ \frac{\partial^2 H}{\partial t^2} \text{ -------------- } (8)$$

- By the identity is given by

$$\nabla \times \nabla \times H = \nabla(\nabla . H) - \nabla^2 H \text{ ---------- } (9)$$

○

But $\nabla . H = \frac{1}{\mu} \nabla . B = 0$

Then $\nabla \times \nabla \times H = -\nabla^2 H \text{ ------------- } (10)$

- Comparing equations (8) and (10)

$$\nabla^2 H = \mu\varepsilon \frac{\partial^2 H}{\partial t^2}$$

$$\nabla^2 H - \mu\varepsilon \frac{\partial^2 H}{\partial t^2} = 0 \text{ ----------- } (11)$$

- This wave equation for free space in terms of H.
- For free space $\mu_r = 1$ and $\varepsilon_r = 1$ (air) then wave equation becomes

○ $$\nabla^2 H - \mu_o \varepsilon_o \frac{\partial^2 H}{\partial t^2} = 0$$

○ $$\mu_o \varepsilon_o = 4\pi \times 10^{-7} \times \frac{1}{36\pi \times 10^{-9}} = \frac{1}{9 \times 10^{16}}$$

○ $$\frac{1}{\sqrt{\mu_o \varepsilon_o}} = 3 \times 10^8 \ m / s = v_o$$

- Where v_o is the velocity of light.
- Then the wave equation,
- $\nabla^2 H - \frac{1}{v_o^2}\frac{\partial^2 H}{\partial t^2} = 0$ (or) $\nabla^2 E - \frac{1}{v_o^2}\frac{\partial^2 E}{\partial t^2} = 0$ (7 M)

2

State Poynting theorem and thus obtain an expression for instantaneous power density vector associated with electromagnetic field. (13M) (Nov2011, May2012, Nov 2014, April 2015, Nov 2015) BTL 1

Answer: Page: 5.42- P. Dananjayan

- The vector product of electric field intensity at any point is a measure of the rate of energy flow per unit area at that point. P = E x H
- The instantaneous power w can be written in terms of instantaneous voltage v and current I as

$$v = \text{Re}\,[\,\text{V}\, e^{j\omega t}\,] = |\,\text{V}\,| \cos(\omega t + \theta_v)$$

$$i = \text{Re}\,[\,\text{I}\, e^{j\omega t}\,] = |\,\text{I}\,| \cos(\omega t + \theta_i)$$

The instantaneous power is given by

$$\text{W} = |\,\text{V}\,|\,|\,\text{I}\,| \cos(\omega t + \theta_v) \cos(\omega t + \theta_i)$$

$$\text{W} = \frac{|\,\text{V}\,|\,|\,\text{I}\,|}{2} [\cos(\theta_v - \theta_i) + \cos(2\,\omega t + \theta_v + \theta_i)]$$

The instantaneous power flow per square meter *i.e.*, Poynting vector is

$$\tilde{\text{P}} = \tilde{\text{E}} \times \tilde{\text{H}}$$

The average power is given by

$$\text{W}_{av} = \frac{|\,\text{V}\,|\,|\,\text{I}\,|}{2} \cos(\theta_v - \theta_i)$$

If $\theta_v - \theta_i = \theta$, the angle between voltage and current, then

- $$\text{W}_{av} = \frac{|\,\text{V}\,|\,|\,\text{I}\,|}{2} \cos\theta$$ (6 M)

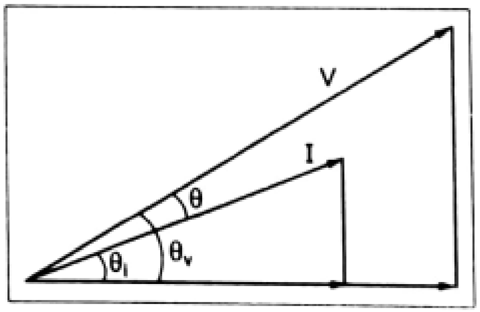


Fig. 5.11.

The reactive power is given by

$$W_{rea} = \frac{|V||I|}{2} \sin\theta$$

➢

The complex power *w* is defined as

$$W = \frac{1}{2} V I^*$$

Where I* is complex conjugate of I.

$$W = \frac{|V||I|}{2} e^{j\theta}$$

$$W = W_{av} + j W_{rea}$$

➢

The complex Poynting vector P is

$$P = \frac{1}{2} E \times H^*$$

It consists of real and imaginary power flow per square meter.

The real Poynting vector (average Poynting vector) is

$$P_{av} = \frac{1}{2} \text{Re} [E \times H^*]$$

➢

The imaginary Poynting vector (reactive Poynting vector) is

$$P_{rea} = \frac{1}{2} I_m [E \times H^*]$$

In rectangular co-ordinates, the complex Poynting vector normal to *y–z* plane is

$$P_x = \frac{1}{2} [E_y H_z^* - E_z H_y^*]$$

➢ (7 M)

3

Deduce the wave equations for conducting medium. **(13M)(May 2016, Nov 2016)**BTL 1

Answer: Page: 5.01 - P. Dananjayan

- Maxwell's equations in the differentialformas

$$\nabla\times\overrightarrow{H}=\overrightarrow{J}+\frac{\partial\overrightarrow{D}}{\partial t}$$

$$\nabla\times\overrightarrow{E}=-\frac{\partial\overrightarrow{B}}{\partial t}$$

$$\nabla\cdot\overrightarrow{D}=\overrightarrow{\rho}$$

$$\nabla\cdot\overrightarrow{B}=0$$

- Let us consider a source free uniform medium having dielectric constant, ε magnetic permeability μand conductivity σ. The above set of equations can be written as

$$\nabla\times\overrightarrow{H}=\sigma\overrightarrow{E}+\varepsilon\frac{\partial\overrightarrow{E}}{\partial t}\qquad(5.29(a))$$

$$\nabla\times\overrightarrow{E}=-\mu\frac{\partial\overrightarrow{H}}{\partial t}\qquad(5.29(b))$$

$$\nabla\cdot\overrightarrow{E}=0\qquad(5.29(c))$$

$$\nabla\cdot\overrightarrow{H}=0\qquad(5.29(d))$$

- Using the vector identity,

$$\nabla\times\nabla\times\overrightarrow{A}=\nabla\cdot\left(\nabla\cdot\overrightarrow{A}\right)-\nabla^2 A$$

$$\nabla\times\nabla\times\overrightarrow{E}=\nabla\cdot\left(\nabla\cdot\overrightarrow{E}\right)-\nabla^2\overrightarrow{E}$$

$$=-\nabla\times\left(\mu\frac{\partial\overrightarrow{H}}{\partial t}\right)$$

- We can write from 5.29(b)

$$\nabla\cdot\left(\nabla\cdot\overrightarrow{E}\right)-\nabla^2\overrightarrow{E}=-\mu\frac{\partial}{\partial t}\left(\nabla\times\overrightarrow{H}\right)$$

$$\nabla\cdot\left(\nabla\cdot\overrightarrow{E}\right)-\nabla^2\overrightarrow{E}=-\mu\frac{\partial}{\partial t}\left(\sigma\overrightarrow{E}+\varepsilon\frac{\partial\overrightarrow{E}}{\partial t}\right)$$

- $\nabla\cdot\overrightarrow{E}=0$
- $\nabla^2\overrightarrow{E}=\mu\sigma\frac{\partial\overrightarrow{E}}{\partial t}+\mu\varepsilon\frac{\partial^2\overrightarrow{E}}{\partial t^2}$

- But in source free medium (eqn 5.29(c))
- In the same manner for equation eqn5.29(a) (6 M)

$$\nabla\times\nabla\times\vec{H} = \nabla\cdot\left(\nabla\cdot\vec{H}\right)-\nabla^2\vec{H}$$

$$= \sigma\left(\nabla\times\vec{E}\right)+\varepsilon\frac{\partial}{\partial t}\left(\nabla\times\vec{E}\right)$$

$$= \sigma\left(-\mu\frac{\partial\vec{H}}{\partial t}\right)+\varepsilon\frac{\partial}{\partial t}\left(-\mu\frac{\partial\vec{H}}{\partial t}\right)$$

- Since $\nabla\cdot\vec{H} = 0$ fromeqn5.29(d),wecanwrite

$$\nabla^2\vec{H} = \mu\sigma\left(\frac{\partial\vec{H}}{\partial t}\right)+\mu\varepsilon\left(\frac{\partial^2\vec{H}}{\partial t^2}\right)$$

- Thesetwo equations

$$\nabla^2\vec{E} = \mu\sigma\frac{\partial\vec{E}}{\partial t}+\mu\varepsilon\frac{\partial^2\vec{E}}{\partial t^2}$$

$$\nabla^2\vec{H} = \mu\sigma\left(\frac{\partial\vec{H}}{\partial t}\right)+\mu\varepsilon\left(\frac{\partial^2\vec{H}}{\partial t^2}\right)$$

- Are known as wave equations.
- It may be noted that the field components are functions of both space and time. For example, if we consider a Cartesian coordinate system, $\vec{E}\,\text{and}\,\vec{H}$ essentially represents $\vec{E}(x,y,z,t)$ and $\vec{H}(x,y,z,t)$ .For simplicity, we consider
- Propagation in free space, i.e. , $\sigma = 0$ $\mu = \mu_0$ and $\varepsilon = \varepsilon_0$.
- The wave equation in equations 5.30 and 5.31reduces to

$$\nabla^2\vec{E} = \mu_0\varepsilon_0\left(\frac{\partial^2\vec{E}}{\partial t^2}\right) \qquad (5.32(\text{a}))$$

$$\nabla^2\vec{H} = \mu_0\varepsilon_0\left(\frac{\partial^2\vec{H}}{\partial t^2}\right) \qquad (5.32(\text{b}))$$

-
- Further simplifications can be made if we consider in Cartesian coordinate system a special case where $\vec{E}\,\text{and}\,\vec{H}$ are considered to be independent in two dimensions, say $\vec{E}\,\text{and}\,\vec{H}$ are assumed to be independent of *y* and *z*. Such waves are called plane waves. (7 M)

4

Discuss group velocity, phase velocity and propagation constant of electromagnetic waves.(13M) (May 2016)BTL 2

Answer:Page: 5.12 - P. Dananjayan

- The wave equation for free space is

$$\nabla^2 E = \mu \varepsilon \frac{\partial^2 E}{\partial t^2}$$

- The phasor value of E is

- $$E(x, t) = \text{Re}[E(x) e^{j\omega t}]$$

$$\nabla^2 \text{Re}[E e^{j\omega t}] = \mu \varepsilon \frac{\partial^2}{\partial t^2} \text{Re}[E e^{j\omega t}]$$

$$\nabla^2 \text{Re}[E e^{j\omega t}] = \mu \varepsilon \text{Re}[-\omega^2 E e^{j\omega t}]$$

$$\text{Re}[(\nabla^2 E + \mu \varepsilon \omega^2 E) e^{j\omega t}] = 0$$

$$\nabla^2 E + \mu\varepsilon \omega^2 E = 0$$

$$\nabla^2 E + \beta^2 E = 0$$

where $\beta^2 = \mu \varepsilon \omega^2$

$$\beta = \sqrt{\mu \varepsilon}\ \omega$$

β is called phase shift constant.

The velocity of propagation is $v = \frac{\omega}{\beta} = \frac{1}{\sqrt{\mu \varepsilon}}$

The wave propagates in x direction *i.e.*, no variation in y and z.

$$\frac{\partial^2 E}{\partial x^2} + \beta^2 E = 0$$

The solution of the equation is $E = C_1 e^{-j\beta x} + C_2 e^{j\beta x}$

- The wave equation for conducting medium is

$$\nabla^2 E - \mu \varepsilon \frac{\partial^2 E}{\partial t^2} - \mu \sigma \frac{\partial E}{\partial t} = 0$$

(6 M)

The phasor form of wave equation is

$$\nabla^2 E - \mu\varepsilon\omega^2 E - j\omega\mu\sigma E = 0$$

$$\nabla^2 E - j(\omega\mu\sigma + j\mu\varepsilon\omega^2)\, E = 0$$

$$\nabla^2 E - j\omega\mu\,(\sigma + j\omega\varepsilon)\, E = 0$$

$$\nabla^2 E - \gamma^2 E = 0$$

$$\text{where} \quad \gamma^2 = j\omega\mu\,(\sigma + j\omega\varepsilon)$$

γ is called ***propagation constant***, which has both real and imaginary parts.

$$\gamma = \alpha + j\beta$$

where α is attenuation constant

β is phase shift

$$\gamma = \alpha + j\beta = \sqrt{j\omega\mu\,(\sigma + j\omega\varepsilon)}$$

Attenuation factor is given by

$$\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1 + \frac{\sigma^2}{\omega^2\varepsilon^2}} - 1\right]}$$

By subtracting $\alpha^2 - \beta^2$ from $\alpha^2 + \beta^2$, the value of β becomes

$$\beta = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1 + \frac{\sigma^2}{\omega^2\varepsilon^2}} + 1\right]}$$

(7 M)

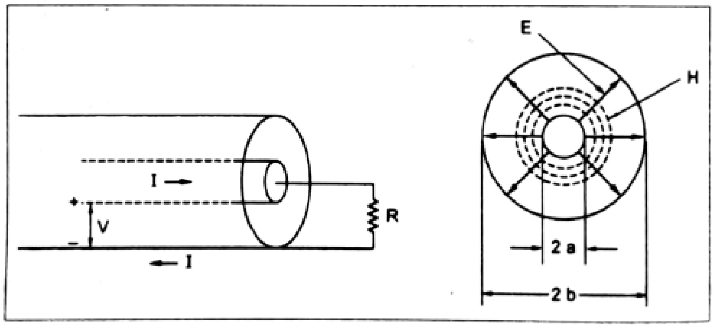
5

Derive the expression for total power flow in a coaxial cable.(8 M)BTL 3

Answer: Page: 5.40 - P. Dananjayan

Let

- Co-axial cable inner radius - a
- Outer radius - b
- Current - I



	$\oint H \cdot dl = I$ $\oint H \cdot dl = H \cdot (2\pi r)$ where, r is the radius of the circle $H \cdot (2\pi r) = I$ ➢ $H = \frac{I}{2\pi r}$ (4 M) The electric field strength of coaxial cable is given by $E = \frac{V}{r\, ln\,(b/a)}$ ➢ The Poynting vector $P = E \times H$ $W = \int_s E \times H \cdot ds = \int_s E\, H \cdot ds$ ➢ $= \int_a^b \frac{V}{r\, ln\,(b/a)} \left(\frac{I}{2\pi r}\right) 2\pi r \cdot dr$ $= \frac{V\, I}{ln\,(b/a)}\, ln\,[b/a]$ ➢ $W = V\, I$ (4 M)
	PART * C
1	**A medium is characterized by $\sigma = 10^{-3}$, $\mu = \mu_0$ and $\varepsilon = 80\varepsilon_0$. If the frequency of 10 kHz. Calculate parameter of the wave. (8 M)** BTL 5 **Answer: Page: 5.66 - P. Dananjayan** $\sigma = 10^{-3}\, s/m \qquad \varepsilon = 80\, \varepsilon_0$ $\mu = \mu_0 \qquad f = 10 \times 10^3\ Hz$ $\frac{\sigma}{\omega\, \varepsilon} = \frac{10^{-3}}{2\pi \times 10 \times 10^3 \times 80 \times 8.854 \times 10^{-12}} \leq 1$ $\therefore$ Medium is a dielectric medium Attenuation constant, $\alpha = \frac{\sigma}{2}\sqrt{\frac{\mu}{\varepsilon}} = \frac{10^{-3}}{2}\sqrt{\frac{\mu_0}{80\, \varepsilon_0}}$ $= \frac{10^{-3}}{2} \cdot \frac{1}{\sqrt{80}} \cdot 120\, \pi = \mathbf{21.07 \times 10^{-3}\ nepers}$ (4 M)

$$\beta = \omega\sqrt{\mu\,\varepsilon}\left[1+\frac{1}{2}\left(\frac{\sigma}{2\,\omega\,\varepsilon}\right)^2\right]$$

$$= 2\,\pi\,(10\times10^3)\sqrt{4\pi\times10^{-7}\times80\times8.854\times10^{-12}}$$

$$\left[1+\frac{1}{2}\left(\frac{10^{-3}}{2\times2\pi\times10^4\times80\times8.854\times10^{-12}}\right)^2\right]$$

$$\boldsymbol{\beta = 0.12\ \text{rad}}$$

$$\lambda = \frac{2\pi}{\beta} = \mathbf{52.35\ m}$$

(4 M)

2

Derive the expression for characteristics Impedance. (15 M) BTL 1

Answer: Page: 5.07 - P. Dananjayan

- $$\frac{\partial^2 E}{\partial x^2} = \mu\,\varepsilon\,\frac{\partial^2 E}{\partial t^2}$$

The general solution of this differential equation is in the form

$$E = f_1(x - v_0 t) + f_2(x + v_0 t)$$

- where $$v_0 = \frac{1}{\sqrt{\mu_0\,\varepsilon_0}}$$

$$E = f(x - v_0 t)$$

$$\nabla\times E = \begin{vmatrix} \vec{x} & \vec{y} & \vec{z} \\ \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ E_x & E_y & E_z \end{vmatrix}$$

$$E_x = H_x = 0 \text{ and } \frac{\partial E}{\partial y} = \frac{\partial E}{\partial z} = 0$$

- $$\nabla\times E = -\frac{\partial E_z}{\partial x}\vec{y} + \frac{\partial E_y}{\partial x}\vec{z}$$

(5 M)

Comparing these two equations,

$$-\frac{\partial H_z}{\partial x}\vec{y} + \frac{\partial H_y}{\partial x}\vec{z} = \varepsilon\left[\frac{\partial E_y}{\partial t}\vec{y} + \frac{\partial E_z}{\partial t}\vec{z}\right] \quad [\because E_x = 0]$$

Equating $\vec{y}$ and $\vec{z}$ terms

$$-\frac{\partial H_z}{\partial x} = \varepsilon\,\frac{\partial E_y}{\partial t}$$

- $$\frac{\partial H_y}{\partial x} = \varepsilon\,\frac{\partial E_z}{\partial t}$$

	From second Maxwell's equation for free space $\nabla \times E = -\mu \frac{\partial E}{\partial t}$ ➢ But $\nabla \times E = -\frac{\partial E_z}{\partial x} \vec{y} + \frac{\partial E_y}{\partial x} \vec{z}$ (5 M) Let the solution of this equation is given by $E_y = f(x - v_0 t)$ Differentiating $\frac{\partial E_y}{\partial t} = \frac{\partial f}{\partial(x - v_0 t)} \cdot \frac{\partial(x - v_0 t)}{\partial t}$ ➢ $= f'(x - v_0 t)(-v_0)$ Simplify $f'(x - v_0 t)$ can be written as f'. $\frac{\partial E_y}{\partial t} = -v_0 f'$ But, $-\frac{\partial H_z}{\partial x} = \varepsilon \frac{\partial E_y}{\partial t}$ ➢ $\frac{\partial H_z}{\partial x} = -\varepsilon(-v_0 f') = v_0 \varepsilon f'$ $H_z = \sqrt{\frac{\varepsilon}{\mu}} f = \sqrt{\frac{\varepsilon}{\mu}} E_y$ $\frac{E_y}{H_z} = \sqrt{\frac{\mu}{\varepsilon}}$ ➢ $\eta = \frac{E}{H} = \sqrt{\frac{\mu}{\varepsilon}}$ (5 M)
3	**Define and derive skin depth. Calculate the skin depth for a medium with conductivity 100 mho/m, relative permeability 2, relative permittivity3 at 50 Hz, 1 Mhz and 1GHz. (8 M)** BTL 5 **Answer: Page: 5.65 – P. Dananjayan** $\sigma = 100$ mho/m $f = 50$ Hz $\mu_r = 2$ $f = 1$ MHz ➢ $\varepsilon_r = 3$ $f = 1$ GHz ➢ Skin depth $= \delta = \sqrt{\frac{2}{\omega\mu\sigma}}$ (3 M)

$$\text{At } f = 50\text{ Hz}, \quad \delta = \sqrt{\frac{2}{2\pi \times 50 \times 2 \times 100}} = \mathbf{0.564 \times 10^{-2}\ m}$$

$$\text{At } f = 1\text{ MHz}, \quad \delta = \sqrt{\frac{2}{2\pi \times 10^{6} \times 2 \times 100}} = \mathbf{0.4 \times 10^{-4}\ m}$$

$$\text{At } f = 1\text{ GHz}, \quad \delta = \sqrt{\frac{2}{2\pi \times 10^{9} \times 2 \times 100}} = \mathbf{0.126 \times 10^{-5}\ m}$$

(5 M)

4

State and prove poynting theorem. (8 M) BTL 1

Answer: Page: 5.38 - P. Dananjayan

- Let us consider Maxwell's Curl Equations:

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

- Using vector identity

$$\nabla.\left(\vec{E} \times \vec{H}\right) = \vec{H}.\nabla \times \vec{E} - \vec{E}.\nabla \times \vec{H}$$

- The above curl equations we can write

$$\nabla.\left(\vec{E} \times \vec{H}\right) = -\vec{H}.\frac{\partial \vec{B}}{\partial t} - \vec{E}.\left(\vec{J} + \frac{\partial \vec{D}}{\partial t}\right)$$

$$or,\ \nabla.\left(\vec{E} \times \vec{H}\right) = -\vec{H}.\frac{\partial \vec{B}}{\partial t} - \vec{E}.\vec{J} - \vec{E}.\frac{\partial \vec{D}}{\partial t}$$

$$\vec{H}.\frac{\partial \vec{B}}{\partial t} = \frac{\partial}{\partial t}\left(\frac{1}{2}\mu H^2\right)$$

- $$\vec{E}.\frac{\partial \vec{D}}{\partial t} = \frac{\partial}{\partial t}\left(\frac{1}{2}\mu E^2\right)$$ and $$\vec{E}.\vec{J} = \sigma E^2$$

$$\therefore \nabla.\left(\vec{E} \times \vec{H}\right) = -\frac{\partial}{\partial t}\left(\frac{1}{2}\in E^2 + \frac{1}{2}\mu H^2\right) - \sigma E^2$$

- Applying Divergence theorem, we can write

$$\oint_S \left(\vec{E} \times \vec{H}\right).d\vec{S} = -\frac{\partial}{\partial t}\int_V \left(\frac{1}{2}\in E^2 + \frac{1}{2}\mu H^2\right)dV - \int_V \sigma E^2 dV$$

..........................(6.36) (4 M)

- The term $\frac{\partial}{\partial t}\int_V \left(\frac{1}{2}\in E^2 + \frac{1}{2}\mu H^2\right)dV$ represents the rate of change of energy

	stored in the electric and magnetic fields and the term $\int_V \sigma E^2 dV$ represents the power dissipation within the volume. ➢ Hence righthand side of the equation (6.36) represents the total decrease in power within the volume under consideration. ➢ The left hand side of equation (6.36) can be written as $\oint_S \left(\vec{E}\times\vec{H}\right).d\vec{S} = \oint_S \vec{P}.d\vec{S}$ ➢ where $\vec{P} = \vec{E}\times\vec{H}$ (W/mt^2) is called the Poynting vector and it represents the power density vector associated with the electromagnetic field. ➢ The integration of the Poynting vector over any closed surface gives the net power flowing out of the surface. ➢ Equation (6.36) is referred to as Poynting theorem and it states that the net power flowing out of a given volume is equal to the time rate of decrease in the energy stored within the volume minus the conduction losses. (4 M)

OBJECTIVE TYPES QUESTIONS WITH ANSWER

ELECTROSTATICS -I

1. The force between two charges is 120 N. If the distance between the charges is doubled, the force will be
(a) 60 N
(b) 30 N
(c) 40 N
(d) 15 N
Ans: b
2. The electric field intensity at a point situated 4 meters from a point charge is 200 N/C. If the distance is reduced to 2 meters, the field intensity will be
(a) 400 N/C
(b) 600 N/C
(c) 800 N/C
(d) 1200 N/C
Ans: c
3. The lines of force due to charged particles are
(a) always straight
(b) always curved
(c) sometimes curved
(d) none of the above
Ans: b
4. The electric field at a point situated at a distance d from straight charged conductor is
(a) proportional to d
(b) inversely proportional to d
(c) inversely proportional to d
(d) none of the above
Ans: b
5. The direction of electric field due +0 positive charge is .
(a) away from the charge
(b) towards the charge
(c) both (a) and (6)
(d) none of the above
Ans: a
6. A field line and an equipotential surface are
(a) always parallel
(b) always at 90°
(c) inclined at any angle 0
(d) none of the above
Ans: b
7. The ability of charged bodies to exert force on 6ne another is attributed to the existence of
(a) electrons
(b) protons

(c) neutrons
(d) electric field
Ans: d
8. If the sheet of a Bakelite is inserted between the plates of an air capacitor, the capacitance will
(a) decrease
(b) increase
(c) remains unchanged
(d) become zero
Ans: b
9. A capacitor stores 0.24 coulombs at 10 volts. Its capacitance is
(a) 0.024 F
(b) 0.12 F
(c) 0.6 F
(d) 0.8 F
Ans: a
10. For making a capacitor, it is better to select a dielectric having
(a) low permittivity
(b) high permittivity
(c) permittivity same as that of air
(d) permittivity slightly more than that of air
Ans: b
11. The units of capacitance are
(a) volts/coulomb
(b) coulombs/volt
(c) ohms
(d) henry/Wb
Ans: b
12. If three 15 uF capacitors are connected in series, the net capacitance is
(a) 5 uF
(6) 30 uF
(c) 45 uF
(d) 50 uF
Ans: a
13. If three 10 uF capacitors are connected in parallel, the net capacitance is
(a) 20 uF
(b) 30 uE
(c) 40 uF
(d) 50 uF
Ans: b
14. A dielectric material must be
(a) resistor
(b) insulator
(c) good conductor
(d) semi conductor

Ans: b
15. An electrolytic capacitor can be used for
(a) D.C. only
(b) AC. only
(c) both D.C. as well as A.C.
Ans: a
16. The capacitance of a capacitor is not affected by
(a) distance between plates
(6) area of plates
(c) thickness of plates
(d) all of the above
Ans: c
17. Which of the following is not a vector?
(a) Linear momentum
(b) Angular momentum
(c) Electric field
(d) Electric potential
Ans: b
18. Two plates of a parallel plate capacitor after being charged from a constant voltage source are separated apart by means of insulated handles, then the
(a) Voltage across the plates increases
(b) voltage across the plates decreases
(c) charge on the capacitor decreases
(d) charge on the capacitor increases
Ans: b
19. If A.C. voltage is applied to capacitive circuit; the alternating current can flow in the circuit because
(a) varying voltage produces the charging and discharging currents
(b) of high peak value
(c) charging current can flow
(d) discharge current can flow
Ans: a
20. Voltage applied across a ceramic dielectric produces an electrolytic field 100 times greater than air. What will be the value of dielectric constant?
(a) 50
(6) 100
(c) 150
(d) 200
Ans: b
21. Which of the following statements is correct?
(a) Air capacitors have a blackband to indicate the outside foil
(b) Electrolytic capacitor must be connected in the correct polarity
(c) Ceramic capacitors must be connected in the correct polarity
(d) Mica capacitors are available in capacitance value of 1 to 10 pF
Ans: b

22. The dissipation factor of a good dielectric is of the order of
(a) 0.0002
(b) 0.002
(c) 0.02
(d) 0.2
Ans: a
23. "The total electric flux through any closed surface surrounding charges is equal to the amount of charge enclosed".
The above statement is associated with
(a) Coulomb's square law
(b) Gauss's law
(c) Maxwell's first law
(d) Maxwell's second law
Ans: b
24. Three capacitors each of the capacity C are given. The resultant capacity 2/3 C can be obtained by using them
(a) all in series
(b) all in parallel
(c) two in parallel and third in series with this combination
(d) two in series and third in parallel across this combination
Ans: c
25. For which of the following parameter variation, the capacitance of the capacitor remains unaffected?
(a) Distance between plates
(b) Area of the plates
(c) Nature of dielectric
(d) Thickness of the plates
Ans: d

Unit -II

1. Which of the following statement is true?
(a) The current in the discharging capacitor grows linearly
(b) The current in the discharging capacitor grows exponentially
(c) The current in the discharging capacitor decays exponentially
(d) The current in the discharging capacitor decreases constantly
Ans: b
2. Which of the following expression is correct for electric field strength?
(a) E = D/E
(b) E = D2/t
(c) E = jtD
(d) E= nD2
Ans: a
3. In a capacitor the electric charge is stored in
(a) metal plates
(b) dielectric
(c) both (a) and (6)

(d) none of the above
Ans: b
4. Which of the following materials has the highest value of dielectric constant?
(a) Glass
(b) Vacuum
(c) Ceramics
(d) Oil
Ans: c
5. Which of the following capacitors will have the least variation?
(a) Paper capacitor
(b) Ceramic capacitor
(c) Silver plated mica capacitor
(d) None of the above
Ans: c
6. Which of the following statements is incorrect?
(a) The leakage resistance of ceramic capacitors is generally high
(b) The stored energy in a capacitor decreases with reduction in value of capacitance
(c) The stored energy in a capacitor increases with applied voltage
(d) A wire cable has distributed capacitance between the conductors
Ans: b
7. Which of the following capacitors has relatively shorter shelf life?
(a) Mica capacitor
(b) Electrolytic capacitor
(c) Ceramic capacitor
(d) Paper capacitor
Ans: b
8. The sparking between two electrical contacts can be reduced by inserting a
(a) capacitor in parallel with contacts
(6) capacitor in series with each contact
(c) resistance in line
(d) none of the above
Ans: a
9. In the case of a lossy capacitor, its series equivalent resistance value will be
(a) small
(b) very small
(c) large
(d) zero
Ans: c
10. The power dissipated in a pure capacitor is
(a) zero
(b) proportional to applied voltage
(c) proportional to value of capacitance
(d) both (b) and (c) above
Ans: a
11. In a capacitive circuit

(a) a steady value of applied voltage causes discharge
(b) an increase in applied voltage makes a capacitor charge
(c) decrease in applied voltage makes a capacitor charge
(d) none of the above
Ans: b
12. When a dielectric slab is introduced in a parallel plate capacitor, the potential difference between plates will
(a) remain uncharged
(b) decrease
(c) increase
(d) become zero
Ans: b
13. Capacitance increases with
(a) increase in plate area and decrease in distance between the plates
(b) increase in plate area and distance between the plates
(c) decrease in plate area and value of applied voltage
(d) reduction in plate area and distance between the plates
Ans: a
14. A capacitor consists of
(a) two insulators separated by a conductor
(b) two conductors separated by an insulator
(c) two insulators only
(d) two conductors only
Ans: b
15. A gang condenser is a
(a) polarized capacitor
(6) variable capacitor
(c) ceramic capacitor
(d) none of the above
Ans:
16. A paper capacitor is usually available in the form of
(a) tubes
(b) rolled foil
(c) disc
(d) meshed plates
Ans: b
17. Air capacitors are generally available in the range
(a) 10 to 400 pF
(b) 1 to 20 pF
(c) 100 to 900 pF
(d) 20 to 100 pF
Ans: a
18. The unit of capacitance is
(a) henry
(b) ohm

(c) farad
(d) farad/m
Ans: c
19. A capacitor charged to 200 V has 2000 (iC of charge. The value of capacitance will be
(a) 10 F
(6) 10 uF
(c) 100 nF
(d) 1000 uF
Ans: b
20. A capacitor in a circuit became hot and ultimately exploded due to wrong con¬nections, which type of capacitor it could be ?
(a) Paper capacitor
(b) Ceramic capacitor
(c) Electrolytic capacitor
(d) Any-of the above
Ans: c
21. Energy stored in the electric field of a capacitor C when charged from a D.C source of voltage V is equal to joules
(a) CV2
(b) C2V
(c) CV2
(d) CV
Ans: a
22. The absolute permittivity of free space is given by
(a) 8.854 x 1(T9 F/m)
(6) 8.854 x 1(T10 F/m)
(c) 8.854 x KT11 F/m
(d) 8.854 x 10"12 F/m
Ans: b
23. The relative permittivity of free space is given by
(a) 1
(b) 10
(c) 100
(d) 1000
Ans: a
24. Electric field intensity is a quantity
(a) scalar
(b) vector
(c) both (a) and (6)
(d) none of the above
Ans: b
25. When 4 volts e.m.f. is applied across a 1 farad capacitor, it will store energy of
(a) 2 joules
(b) 4 joules
(c) 6 joules

(d) 8 joules
Ans: d

UNIT III MAGNETOSTATICS

1. Tesla is a unit of
(a) field strength
(b) inductance
(c) flux density
(d) flux
Ans: c

2. A permeable substance is one
(a) which is a good conductor
(6) which is a bad conductor
(c) which is a strong magnet
(d) through which the magnetic lines of force can pass very easily
Ans: d

3. The materials having low retentivity are suitable for making
(a) weak magnets
(b) temporary magnets
(c) permanent magnets
(d) none of the above
Ans: b

4. A magnetic field exists around
(a) iron
(b) copper
(c) aluminum
(d) moving charges
Ans: d

5. Ferrites are materials.
(a) paramagnetic
(b) diamagnetic
(c) ferromagnetic
(d) none of the above
Ans: c

6. Air gap has_______ reluctance as compared to iron or steel path
(a) little
(b) lower
(c) higher
(d) zero
Ans: b

7. The direction of magnetic lines of force is
(a) from south pole to north pole
(b) from north pole to south pole
(c) from one end of the magnet to another
(d) none of the above
Ans: b

8. Which of the following is a vector quantity?
(a) Relative permeability
(b) Magnetic field intensity
(c) Flux density
(d) Magnetic potential
Ans: b
9. The two conductors of a transmission line carry equal current I in opposite directions. The force on each conductor is
(a) proportional to 7
(b) proportional to X
(c) proportional to distance between the conductors
(d) inversely proportional to I
Ans: b
10. A material which is slightly repelled by a magnetic field is known as
(a) ferromagnetic material
(b) diamagnetic material
(c) paramagnetic material
(d) conducting material
Ans: b
11. When an iron piece is placed in a magnetic field
(a) the magnetic lines of force will bend away from their usual paths in order to go away from the piece
(b) the magnetic lines of force will bend away from their usual paths in order to pass through the piece
(c) the magnetic field will not be affected
(d) the iron piece will break
Ans: b
12. Fleming's left hand rule is used to find
(a) direction of magnetic field due to current carrying conductor
(b) direction of flux in a solenoid
(c) direction of force on a current carrrying conductor in a magnetic field
(d) polarity of a magnetic pole
Ans: c
13. The ratio of intensity of magnetisation to the magnetisation force is known as
(a) flux density
(b) susceptibility
(c) relative permeability
(d) none of the above
Ans: b
14. Magnetising steel is normals difficult because
(a) it corrodes easily
(6) it has high permeability
(c) it has high specific gravity
(d) it has low permeability
Ans: d

15. The left hand rule correlates to
(a) current, induced e.m.f. and direction of force on a conductor
(b) magnetic field, electric field and direction of force on a conductor
(c) self induction, mutual induction and direction of force on a conductor
(d) current, magnetic field and direction of force on a conductor
Ans: d
16. The unit of relative permeability is
(a) henry/metre
(b) henry
(c) henry/sq. m
(d) it is dimensionless
Ans: d
17. A conductor of length L has current I passing through it, when it is placed parallel to a magnetic field. The force experienced by the conductor will be
(a) zero
(b) BLI
(c) B2LI
(d) BLI2
Ans: a
18. The force between two long parallel conductors is inversely proportional to
(a) radius of conductors
(b) current in one conductor
(c) product of current in two conduc¬tors
(d) distance between the conductors
Ans: d
19. Materials subjected to rapid reversal of magnetism should have
(a) large area oiB-H loop
(b) high permeability and low hysteresis loss
(c) high co-ercivity and high reten-tivity
(d) high co-ercivity and low density
Ans: b
20. Indicate which of the following material does not retain magnetism permanently.
(a) Soft iron
(b) Stainless steel
(e) Hardened steel
(d) None of the above
Ans: a
21. The main constituent of permalloy is
(a) cobalt
(b) chromium
(c) nickel
(d) tungsten
Ans: c
22. The use of permanent magnets is. not made in
(a) magnetoes

(6) energy meters
(c) transformers
(d) loud-speakers
Ans: c
23. Paramagnetic materials have relative permeability
(a) slightly less than unity
(b) equal to unity
(c) slightly more than unity
(d) equal to that ferromagnetic materials
Ans: c

UNIT IV ELECTRODYNAMIC FIELDS

1. An air gap is usually inserted in magnetic circuits to
(a) increase m.m.f.
(b) increase the flux
(c) prevent saturation
(d) none of the above
Ans: c
2. The relative permeability of a ferromagnetic material is
(a) less than one
(b) more than one
(c) more than 10
(d) more than 100 or 1000
Ans: d
3. The unit of magnetic flux is
(a) henry
(b) weber
(c) ampereturn/weber
(d) ampere/metre
Ans: b
4. Permeability in a magnetic circuit corresponds to______ in an electric circuit.
(a) resistance
(b) resistivity
(c) conductivity
(d) conductance
Ans: c
5. Point out the wrong statement.
Magnetic leakage is undesirable in electric machines because it
(a) lowers their power efficiency
(b) increases their cost of manufacture
(c) leads to their increased weight
(d) produces fringing
Ans: a
6. Relative permeability of vacuum is
(a) 1
(b) 1 H/m

(c) 1/4JI
(d) 4n x 10-' H/m
Ans: a
7. Permanent magnets are normally made of
(a) alnico alloys
(b) aluminium
(c) cast iron
(d) wrought iron
Ans: a
8. Energy stored by a coil is doubled when its current is increased by percent.
(a) 25
(b) 50
(c)41.4
(d) 100
Ans: c
9. Those magnetic materials are best suited for making armature and transformer cores which have____permeability and_______hystersis loss.
(a) high, high
(b) low, high
(c) high, low
(d) low, low
Ans: c
10. The rate of rise of current through an inductive coil is maximum
(a) at 63.2% of its maximum steady value
(b) at the start of the current flow
(c) after one time constant
(d) near the final maximum value of current
Ans: b
11. When both the inductance and resistance of a coil are doubled the value of
(a) time constant remains unchanged
(b) initial rate of rise of current is doubled
(c) final steady current is doubled
(d) time constant is halved
Ans: a
12. The initial rate of rise of current through a coil of inductance 10 H when suddenly connected to a D.C. supply of 200 V is_______Vs
(a) 50
(b) 20
(c) 0.05
(d) 500
Ans: b
13. A material for good magnetic memory should have
(a) low hysteresis loss
(b) high permeability
(c) low retentivity

(d) high retentivity
Ans: d
14. Conductivity is analogous to
(a) retentivity
(b) resistivity
(c) permeability
(d) inductance
Ans: c
15. In a magnetic material hysteresis loss takes place primarily due to
(a) rapid reversals of its magnetisation
(b) flux density lagging behind magnetising force
(c) molecular friction
(d) it high retentivity
Ans: d
16. Those materials are well suited for making permanent magnets which have______retentivity and _______coercivity.
(a) low, high
(b) high, high
(c) high, low
(d) low, low
Ans: b
17. If the area of hysteresis loop of a material is large, the hysteresis loss in this material will be
(a) zero
(b) small
(c) large
(d) none of the above
Ans: c
18. Hard steel is suitable for making permanent magnets because
(a) it has good residual magnetism
(b) its hysteresis loop has large area
(c) its mechanical strength is high
(d) its mechanical strength is low
Ans: a
19. Silicon steel is used in electrical machines because it has
(a) low co-ercivity
(b) low retentivity
(c) low hysteresis loss
(d) high co-ercivity
Ans: c
20. Conductance is analogous to
(a) permeance
(b) reluctance
(c) flux
(d) inductance

Ans: a

21. The property of a material which opposes the creation of magnetic flux in it is known as
(a) reluctivity
(b) magnetomotive force
(c) permeance
(d) reluctance
Ans: d

22. The unit of retentivity is
(a) weber
(b) weber/sq. m
(c) ampere turn/metre
(d) ampere turn
Ans: b

23. Reciprocal of reluctance is
(a) reluctivity
(b) permeance
(c) permeability
(d) susceptibility
Ans: b

24. While comparing magnetic and electric circuits, the flux of magnetic circuit is compared with which parameter of electrical circuit ?
(a) E.m.f.
(b) Current
(c) Current density
(d) Conductivity
Ans: b

25. The unit of reluctance is
(a) metre/henry
(b) henry/metre
(c) henry
(d) 1/henry
Ans: d

UNIT – V ELECTROMAGNETIC WAVES

1. The property of coil by which a counter e.m.f. is induced in it when the current through the coil changes is known as
(a) self-inductance
(b) mutual inductance
(c) series aiding inductance
(d) capacitance
Ans: a

2. As per Faraday's laws of electromagnetic induction, an e.m.f. is induced in a conductor whenever it
(a) lies perpendicular to the magnetic flux
(b) lies in a magnetic field
(e) cuts magnetic flux

(d) moves parallel to the direction of the magnetic field
Ans: c
3. Which of the following circuit element stores energy in the electromagnetic field ?
(a) Inductance
(b) Condenser
(c) Variable resistor
(d) Resistance
Ans: a
4. The inductance of a coil will increase under all the following conditions except
(a) when more length for the same number of turns is provided
(6) when the number of turns of the coil increase
(c) when more area for each turn is provided
(d) when permeability of the core increases
Ans: a
5. Higher the self-inductance of a coil,
(a) lesser its weber-turns
(b) lower the e.m.f. induced
(c) greater the flux produced by it
(d) longer the delay in establishing steady current through it
Ans: d
6. In an iron cored coil the iron core is removed so that the coil becomes an air cored coil. The inductance of the coil will
(a) increase
(b) decrease
(c) remain the same
(d) initially increase and then decrease
Ans: b
7. An open coil has
(a) zero resistance and inductance
(b) infinite resistance and zero inductance
(c) infinite resistance and normal inductance
(d) zero resistance and high inductance
Ans: b
8. Both the number of turns and the core length of an inductive coil are doubled. Its self-inductance will be
(a) unaffected
(b) doubled
(c) halved
(d) quadrupled
Ans: b
9. If current in a conductor increases then according to Lenz's law self-induced voltage will
(a) aid the increasing current
(b) tend to decrease the amount of cur-rent
(c) produce current opposite to the in-creasing current
(d) aid the applied voltage

Ans: c
10. The direction of incVicede.m.f. can be found by
(a) Laplace's law
(b) Lenz's law
(c) Fleming's right hand rule
(d) Kirchhoff s voltage law
Ans: b
11. Air-core coils are practically free from
(a) hysteresis losses
(b) eddy current losses
(c) both (a) and (b)
(d) none of the above
Ans: c
12. The magnitude of the induced e.m.f. in a conductor depends on the
(a) flux density of the magnetic field
(b) amount of flux cut
(c) amount of flux linkages
(d) rate of change of flux-linkages
Ans: d
13. Mutually inductance between two magnetically-coupled coils depends on
(a) permeability of the core
(b) the number of their turns
(c) cross-sectional area of their com-mon core
(d) all of the above
Ans: d
14. A laminated iron core has reduced eddy-current losses because
(a) more wire can be used with less D.C. resistance in coil
(b) the laminations are insulated from each other
(c) the magnetic flux is concentrated in the air gap of the core
(d) the laminations are stacked vertf-cally
Ans: b
15. The law that the induced e.m.f. and current always oppose the cause producing them is due to
(a) Faraday
(b) Lenz
(c) Newton
(d) Coulomb
Ans: b
16. Which of the following is not a unit of inductance ?
(a) Henry
(b) Coulomb/volt ampere
(c) Volt second per ampere
(d) All of the above
Ans: b
17. In case of an inductance, current is proportional to

(a) voltage across the inductance
(b) magnetic field
(c) both (a) and (b)
(d) neither (a) nor (b)
Ans: b

18. Which of the following circuit elements will oppose the change in circuit current ?
(a) Capacitance
(b) Inductance
(c) Resistance
(d) All of the above
Ans: b

19. For a purely inductive circuit which of the following is true ?
(a) Apparent power is zero
(b) Relative power is.zero
(c) Actual power of the circuit is zero
(d) Any capacitance even if present in the circuit will not be charged
Ans: c

20. Which of the following is unit of inductance ?
(a) Ohm
(b) Henry
(c) Ampere turns
(d) Webers/metre
Ans: b

21. An e.m.f. of 16 volts is induced in a coil of inductance 4H. The rate of change of current must be
(a) 64 A/s
(b) 32 A/s
(c) 16 A/s
(d) 4 A/s
Ans: d

22. The core of a coil has a length of 200 mm. The inductance of coil is 6 mH. If the core length is doubled, all other quantities, remaining the same, the in ductance will be
(a) 3 mH
(b) 12 mH
(c) 24mH
(d)48mH
Ans: a

23. The self inductances of two coils are 8 mH and 18 mH. If the co-efficients of coupling is 0.5, the mutual inductance of the coils is
(a) 4 mH
(b) 5 mH
(c) 6 mH
(d) 12 mH
Ans: c

24. Two coils have inductances of 8 mH and 18 mH and a co-efficient of coupling of 0.5. If

the two coils are connected in series aiding, the total inductance will be
(a) 32 mH
(b) 38 mH
(c) 40 mH
(d) 48 mH
Ans: b

25. A 200 turn coil has an inductance of 12 mH. If the number of turns is increased to 400 turns, all other quantities (area, length etc.) remaining the same, the inductance will be
(a) 6 mH
(b) 14 mH
(c) 24 mH
(d) 48 mH
Ans: d