JEPPIAAR INSTITUTE OF TECHNOLOGY

Self Belief | Self Discipline | Self Respect

QUESTION BANK

ACADEMIC YEAR : 2019-20

REGULATION: 2017

II YEAR – 03rd SEMESTER

DEPARTMENT OF MECHANICAL 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

MA8353 TRANSFORMS AND PARTIAL DIFFERENTIAL EQUATIONS L T P C
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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.

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- Use the effective mathematical tools for the solutions of partial differential equations by using Z transform techniques for discrete time systems.

REGULATION :2017 **ACADEMIC YEAR : 2019-2020**

Subject Code: MA8353 **Year/Semester: II /03**
Subject Name: TRANSFORMS AND PDE **Subject Handler:Dr.A.Shenbaga Ezhil**

	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 $\frac{\partial z}{\partial x} = 2ax ==> p = 2ax ==> a = \frac{p}{2x}$ (2) Differentiating (1) partially with respect to y, we have $\frac{\partial z}{\partial y} = 2by ==> q = 2by ==> b = \frac{q}{2y}$ (3) using (2) and (3) in (1), we have $z = \left(\frac{p}{2x}\right)x^2 + \left(\frac{q}{2y}\right)y^2 ==> z = \frac{1}{2}\left[px+qy\right]$ $2z = px+qy$, 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 $\frac{\partial z}{\partial x} = 3ax^2 ==> p = 3ax^2 ==> a = \frac{p}{3x^2}$ (2) Differentiating (1) partially with respect to y, we have $\frac{\partial z}{\partial y} = 3by^2 ==> q = 3by^2 ==> b = \frac{q}{3y^2}$ (3) using (2) and (3) in (1), we have $z = \left(\frac{p}{3x^2}\right)x^3 + \left(\frac{q}{3y^2}\right)y^3 ==> z = \frac{1}{3}\left[px+qy\right]$

	$3z = px+qy$, 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 $p = \frac{\partial z}{\partial x} = f'\left(\frac{y}{x}\right).\left(\frac{-y}{x^2}\right)$ (2) $q = \frac{\partial z}{\partial y} = f'\left(\frac{y}{x}\right).\left(\frac{1}{x}\right)$ (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** $\left(D^3 - 2D^2D'\right)z = 0$ **. [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** $\left(D^4 - D'^4\right)z = 0$ **. [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** $\left(D^3 - 4D^2D' + 4DD'^2\right)z = 0$ **. [A/M15]** BTL5 Auxiliary equation is $m^3 - 4m^2 + 4m = 0$ $m\left(m^2 - 4m + 4\right) = 0$ $m(m-2)(m-2) = 0$ $m = 0\ ,\ m = 2\ ,\ m = 2$ 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** $\phi(x^2-y^2,z)=0$**.** [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 $-2yp - 2xq = 0$ $yp + xq = 0$, 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* $a + b + = ab$

	$b-ab=-a$ $(1-a)b=-a$ $b=\frac{-a}{1-a}$ $b=\frac{a}{a-1}$ Therefore, the complete solution is $z=ax+\frac{a}{a-1}y+c$.
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** $px^2+qy^2=z^2$ **. [N/D14]**BTL5 Given $px^2+qy^2=z^2$ This is of Lagrange's type. Here $P=x^2\ Q=y^2\ R=z^2$ The subsidiary equations are $\frac{dx}{P}=\frac{dy}{Q}=\frac{dz}{R}$ $\frac{dx}{x^2}=\frac{dy}{y^2}=\frac{dz}{z^2}$ $\frac{dx}{x^2}=\frac{dy}{y^2}\quad \frac{dy}{y^2}=\frac{dz}{z^2}$ Integrating , we have $\frac{1}{x}-\frac{1}{y}=a\quad \frac{1}{y}-\frac{1}{z}=b$ 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** $\left(4D^2-12DD'+9D'^2\right)z=0$ **.**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** $\left(D^3-2D^2D'\right)z=0$**. [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** $\left(D^4-D'^4\right)z=0$**. [M/J14]**BTL5 The auxiliary equation is $m^4-1=0$ $\left(m^2+1\right)\left(m^2-1\right)=0$ $m=1\,,-1\,,\,i\,,-i$ 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 $\frac{1}{az-1}\left(a\ \frac{\partial z}{\partial x}\right)=1 ==> \frac{ap}{az-1}=1$ (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 $\frac{\left(\frac{q}{p}\right)p}{\left(\frac{q}{p}\right)z-1}=1\ \frac{q}{\left(\frac{qz-p}{p}\right)}=1\Rightarrow \frac{pq}{qz-p}=1\Rightarrow pq=qz-p$ $\Rightarrow p+pq=qz\Rightarrow p(1+q)=qz$ 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 $4(1+a^2)z = \left(\frac{4(1+a^2)p}{2}\right)^2$ $4(1+a^2)z = \frac{16(1+a^2)^2 p^2}{4} \Rightarrow z = (1+a^2)p^2$ 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 $b+c\frac{\partial z}{\partial y}=0 ==> b+cq=0 ==> b=-cq$ (4) using (3) and (4) in (2), we have $(-c\,p)x+(-cq)y+cz=0 ==> -c\,px-cqy+cz=0$ $-c\,[px+qy-z]=0 ==> xp+yq-z=0$ $xp+yq=z$, 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 $2y+2z\frac{\partial z}{\partial y}=0 ==> 2y+2zq=0 ==> 2[y+zq]=0$ $y+zq=0 ==> y=-zq$ -----------------(3) Using (2) and (3) in (1), we have $(-z\,p)^2+(-zq)^2+z^2=r^2 ==> z^2p^2+z^2q^2+z^2=r^2$ $z^2(p^2+q^2+1)=r^2$, 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** • $l=-(\sqrt{1-l^2-m^2})\mathrm{p}$ $m=-(\sqrt{1-l^2-m^2})\mathrm{q}$ **(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** • $C.F = f_1(y+5x)+f_2(y-4x)$ **(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** • $C.F = f_1(y+x)+f_2(y-x)$ **(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 $(D^2-2DD'+D'^2)z=x^2y\,e^{x+y}.$ **(8 M)**BTL5 **Answer : Page :1.151- DR.A.SINGARAVELU** • $C.F = f_1(y+x)+xf_2(y+x)$ **(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 $\frac{\partial^2 z}{\partial x^2}+2\frac{\partial^2 z}{\partial x\partial y}+\frac{\partial^2 z}{\partial y^2}=\sinh(x+y)+e^{x+2y}.$ **(8 M)**BTL5 **Answer : Page:1.176- DR.A.SINGARAVELU** • $C.F = f_1(y-x)+xf_2(y-x)$ **(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 $x^2=\frac{\pi^2}{3}-4\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{n^2}\cos nx$ $x^2=\frac{\pi^2}{3}-4\left[\frac{1}{1^2}\cos x-\frac{1}{2^2}\cos 2x+\frac{1}{3^2}\cos 3x+\ldots\ldots\ldots\ldots\right]$ The point $x=\pi$ is the point of discontinuity (right extreme point) $\pi^2=\frac{\pi^2}{3}-4\left[\frac{1}{1^2}\cos\pi-\frac{1}{2^2}\cos 2\pi+\frac{1}{3^2}\cos 3\pi+\ldots\ldots\ldots\ldots\right]$ $\frac{2\pi^2}{3}=4\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\ldots\ldots\ldots\ldots\right]$ $\frac{\pi^2}{6}=\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\ldots\ldots\ldots\ldots\ldots$

	Therefore, $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+.......... = \frac{\pi^2}{6}$
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 urier series of $f(x)$ converges at $x=2$ is $= \frac{f(-2)+f(2)}{2}$ $= \frac{\left[(-2)^2-2\right]+\left[2^2+2\right]}{2} = \frac{4-2+4+2}{2} = 4\cdot$
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 $b_n = \frac{2}{l}\int_0^{l} f(x)\sin\left(\frac{n\pi}{l}\right)x\,dx = \frac{2}{2}\int_0^{2} 1\sin\left(\frac{n\pi}{2}\right)x\,d\,x = \int_0^{2}\sin\left(\frac{n\pi}{2}\right)x\,d\,x$ $= -\frac{2}{n\pi}\left[\cos\left(\frac{n\pi}{2}\right)x\right]_0^2 = -\frac{2}{n\pi}\left[\cos n\pi - 1\right] = -\frac{2}{n\pi}\left[(-1)^n - 1\right] = \begin{cases}\frac{4}{n\pi}, & if\ \ n\ is\ odd\\ 0, & if\ \ n\ is\ even\end{cases}$

	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 $a_0=\frac{1}{\pi}\int_0^{2\pi}f(x)dx=\frac{1}{\pi}\int_0^{2\pi}x\,dx=\frac{1}{\pi}\left[\frac{x^2}{2}\right]_0^{2\pi}=\frac{1}{\pi}\left[2\pi^2-0\right]=\frac{2\pi^2}{\pi}=2\pi$ 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 $x^2=\frac{\pi^2}{3}-4\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{n^2}\cos nx$ $x^2=\frac{\pi^2}{3}-4\left[\frac{1}{1^2}\cos x-\frac{1}{2^2}\cos 2x+\frac{1}{3^2}\cos 3x+\dots\dots\dots\dots\right]$ The point $x=\pi$ is the point of discontinuity (right extreme point) $\pi^2=\frac{\pi^2}{3}-4\left[\frac{1}{1^2}\cos\pi-\frac{1}{2^2}\cos 2\pi+\frac{1}{3^2}\cos 3\pi+\dots\dots\dots\dots\right]$ $\pi^2-\frac{\pi^2}{3}=-4\left[\frac{1}{1^2}(-1)-\frac{1}{2^2}(1)+\frac{1}{3^2}(-1)+\dots\dots\dots\dots\right]$ $\frac{2\pi^2}{3}=4\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots\dots\right]$ $\frac{\pi^2}{6}=\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots\dots\dots$ Therefore, $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots=\frac{\pi^2}{6}$
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 $\sum_{n=1}^{\infty}\frac{1}{n^2}$.[*N/D14*]** BTL5 Given $(\pi-x)^2=\frac{\pi^2}{3}+4\sum_{n=1}^{\infty}\frac{\cos nx}{n^2}$ $(\pi-x)^2=\frac{\pi^2}{3}+4\left[\frac{1}{1^2}\cos x+\frac{1}{2^2}\cos 2x+\frac{1}{3^2}\cos 3x+\dots\dots\dots\dots\right]$ The point $x=0$ is the left extreme point of discontinuity $\frac{f[0]+f[2\pi]}{2}=\frac{\pi^2}{3}+4\left[\frac{1}{1^2}\cos 0+\frac{1}{2^2}\cos 0+\frac{1}{3^2}\cos 0+\dots\dots\dots\dots\right]$ $\frac{(\pi-0)^2+(\pi-2\pi)^2}{2}=\frac{\pi^2}{3}+4\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots\dots\dots\dots\right]$

	$\frac{(\pi-0)^2+(\pi-2\pi)^2}{2}=\frac{\pi^2}{3}+4\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+............\right]$ $\pi^2-\frac{\pi^2}{3}=4\left[-\frac{1}{1^2}(-1)+\frac{1}{2^2}(1)-\frac{1}{3^2}(-1)+............\right]$ $\frac{2\pi^2}{3}=4\left[\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+............\right]$ $\frac{\pi^2}{6}=\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+.............$ 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 $\frac{\pi}{2}=2\left(1-0-\frac{1}{3}-0+\frac{1}{5}-0-\frac{1}{7}-0+.............\right)$ 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

$$a_0=\frac{2}{\pi}\int_0^{\pi}\cos^2 x\,d\,x$$

$$=\frac{2}{\pi}\int_0^{\pi}\frac{1+\cos 2x}{2}\,d\,x$$

$$=\frac{1}{\pi}\left[\int_0^{\pi}d\,x+\int_0^{\pi}\cos 2x\,d\,x\right]$$

$$=\frac{1}{\pi}\left[(x)_0^{\pi}+\left(\frac{\sin 2x}{2}\right)_0^{\pi}\right]=\frac{1}{\pi}\left[(\pi-0)+\frac{1}{2}(0-0)\right]=\frac{1}{\pi}(\pi)=1$$

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].

lution: Here $2l=2\pi$ implies $l=\pi$

Given

$f(-x)=(-x)^2=x^2=f(x)$

Therefore $f(x)$ is an even function.

$$a_0=\frac{2}{l}\int_0^{l}f(x)d\,x=\frac{2}{\pi}\int_0^{\pi}x^2\,d\,x=\frac{2}{\pi}\left(\frac{x^3}{3}\right)_0^{\pi}=\frac{2}{3\pi}\left(\pi^3-0\right)=\frac{2}{3}\pi^2$$

erefore 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 $f(x)=\begin{cases}x+\pi & in\ (-\pi,0)\\ -x+\pi & in\ (0,\pi)\end{cases}$. [*M/J16*]** 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 [***M/J16***] Given $f(x)=\begin{cases}0 \ \ in\ (-c,0)\\ 1\ \ in\ (0,c)\end{cases}$ $[Value\,of\ f(x)]_{x=0}=\lim_{h\to0}\frac{1}{2}[f(0-h)+f(0+h)]$ $=\lim_{h\to0}\frac{1}{2}[0+1]=\frac{1}{2}$.
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 $b_n = \frac{2}{\pi}\int_0^{\pi} f(x)\sin nx\,dx = \frac{2}{\pi}\int_0^{\pi} 1 \sin nx\, dx = \frac{2}{\pi}\left[-\frac{\cos nx}{n}\right]_0^{\pi}$ $= -\frac{2}{n\pi}[\cos n\pi - 1] = -\frac{2}{n\pi}\left[(-1)^n - 1\right] = \begin{cases} \frac{4}{n\pi}, if\ \ n\ is\ odd \\ 0 \quad , if\ \ n\ is\ even \end{cases}$ 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 $f(x) = \left(\frac{\pi - x}{2}\right)^2$ as a Fourier Series of period 2π in the interval **0< x< 2π. Hence deduce the sum of the series $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\ldots$.**BTL5 **(8 M)** **Answer : Page 2.12-DR.A.SINGARAVELU** • $a_0 = \frac{\pi^2}{6}; a_n = \frac{1}{n^2}; b_n = 0$ **(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) $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+\dots$ (ii) $\frac{1}{1^2}-\frac{1}{2^2}+\frac{1}{3^2}-\dots$ (iii) $\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\dots$ BTL5 **(8 M)** **Answer : Page 2.40-DR.A.SINGARAVELU** • $a_0=\frac{2\pi^2}{3}; a_n=\frac{4}{n^2}(-1)^n; \mathrm{b}_n=0$ **(6 M)** • $f(x)=\frac{\pi^2}{3}+\sum_{n=1}^{\infty}\frac{4}{n^2}(-1)^n\cos nx$ **(1 M)** $1/1^2+1/2^2+1/3^2+......=\frac{\pi^2}{6};$ • $1/1^2-1/2^2+1/3^2-......=\frac{\pi^2}{12};$ **(1 M)** $1/1^2+1/3^2+1/5^2+......=\frac{\pi^2}{8}$
3	
	Obtain the Fourier Series to represent the function f(x) = | x|, -π < x <π and deduce $\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\dots=\frac{\pi^2}{8}$.BTL5 **(8 M)** **Answer : Page 2.52--DR.A.SINGARAVELU** • $a_0=\pi; a_n=\frac{2}{n^2\pi}\left[(-1)^n-1\right]; \mathrm{b}_n=0$ **(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)** • $1/1^2+1/3^2+1/5^2+......=\frac{\pi^2}{8}$ **(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** • $a_0=2; a_n=\frac{2}{(n+1)(\mathrm{n}-1)}\left[(-1)^{n+1}\right]; \mathrm{b}_n=0$ **(6 M)** $a_1=\frac{-1}{2}$ • $f(x)=1-\frac{\cos x}{2}+\sum_{n=2}^{\infty}\frac{2}{(n+1)(\mathrm{n}-1)}\left[(-1)^{n+1}\right]\cos nx$ **(2 M)**
5	
	Obtain the Fourier Series of $\boldsymbol{f(x)}=\begin{cases}\mathbf{1}+\frac{\mathbf{2x}}{\boldsymbol{\pi}}, & -\pi\le x\le 0\\ \mathbf{1}-\frac{\mathbf{2x}}{\boldsymbol{\pi}}, & 0\le x\le\pi\end{cases}$ **and hence deduce**

	$\frac{1}{1^2}+\frac{1}{3^2}+\frac{1}{5^2}+\ldots=\frac{\pi^2}{8}$.BTL5**(8 M)** **Answer : Page 2.72-DR.A.SINGARAVELU** • $a_0=0; a_n=\frac{4}{n^2\pi^2}\left[1-(-1)^n\right]; \mathrm{b}_n=0$ **(6 M)** • $f(x)=\frac{8}{\pi^2}\sum_{n\ is\ ODD}^{\infty}\frac{\cos nx}{n^2}$ **(1 M)** • $1/1^2+1/3^2+1/5^2+......=\frac{\pi^2}{8}$ **(1 M)**
6	
	If f(x) = $\begin{cases}\mathbf{0}, & -\pi\le x\le 0\\ \boldsymbol{\sin x}, & 0\le x\le\pi\end{cases}$ **, 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)** $\frac{1}{1.3}+\frac{1}{3.5}+\frac{1}{5.7}-\ldots=\frac{1}{2}$ (ii) $\frac{1}{1.3}-\frac{1}{3.5}+\frac{1}{5.7}-\ldots=\frac{\pi-2}{4}$.BTL5 **(8 M)** **Answer :Page2.64-DR.A.SINGARAVELU** • $a_0=\frac{2}{\pi}; a_n=\frac{-1}{(n^2-1)\pi}\left[1+(-1)^n\right]; \mathrm{b}_n=\begin{Bmatrix}0\ \ if\ \ \ n\ne 1\\ \frac{1}{2}\ \ if\ \ \ n=1\end{Bmatrix}$ **(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)** • $\frac{1}{1.3}+\frac{1}{3.5}+\frac{1}{5.7}-\ldots=\frac{1}{2}$ and $\frac{1}{1.3}-\frac{1}{3.5}+\frac{1}{5.7}-\ldots=\frac{\pi-2}{4}$**(1 M)**
7	
	Find half range sine series for ***f(x) = x(π – x)*** **in (0,π). Deduce** $\frac{1}{1^3}-\frac{1}{3^3}+\frac{1}{5^3}-\ldots$ BTL5 **(8 M)** **Answer :Page2.144-DR.A.SINGARAVELU** • $b_n=\frac{4}{n^3\pi}\left[1-(-1)^n\right]$ **(6 M)** • $f(x)=\frac{8}{\pi}\left[\frac{\sin x}{1^3}+\frac{\sin 3x}{3^3}+\frac{\sin 5x}{5^3}+......\right]$ **(1 M)** • $1/1^3-1/3^3+1/5^3-$ ....$=\frac{\pi^3}{32}$ **(1 M)**
8	
	Obtain the Fourier Series of $\boldsymbol{f(x)}=\begin{cases}\boldsymbol{l-x}, & 0<x\le l\\ \mathbf{0}, & l\le x\le 2\boldsymbol{l}\end{cases}$ **and hence deduce** $\sum_{n=0}^{\infty}\frac{1}{(2n+1)^2}$ **(8 M)** BTL5 **Answer :Page2.85-DR.A.SINGARAVELU** • $a_0=\frac{l}{2}; a_n=\begin{Bmatrix}\frac{2l}{n^2\pi^2}\ \ \text{if}\ \ \text{n is}\ Odd\\ 0\ \ \ \ if\ n\ is\ \ even\end{Bmatrix}; \mathrm{b}_n=\frac{l}{n\pi}$ **(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)** • $\sum_{\mathbf{n}=0}^{\infty}\frac{1}{\left(2\mathbf{n}+1\right)^2}=\frac{\pi^2}{8}$ **(1 M)**
9	
	Obtain the half range sine series of the function f(x) = $\begin{cases} \boldsymbol{x}, & 0<x\le\frac{l}{2} \\ \boldsymbol{l-x}, & \frac{l}{2}\le\boldsymbol{x}\le\boldsymbol{l}\end{cases}$**. (8 M)** BTL5 **Answer :Page2.153-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** $\boldsymbol{0\le x\le l}$**. (8 M)** BTL5 **Answer :Page2.157-DR.A.SINGARAVELU** • $b_n=\left\{\begin{array}{ll}\frac{8l^2}{n^3\pi^3} & If\ \ n\ \ is\ Odd \\ 0 & Otherwise\end{array}\right\}$ **(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** $For\ \ f_1(x)$ $a_0=0;b_n=\frac{2}{n}\left[(-1)^{n+1}\right];a_n=0$ • $For\ \ f_2(x)$ **(6 M)** $a_0=2+\frac{2\pi^2}{3};a_n=\frac{4}{n^2}\left[(-1)^n\right];b_n=0$ • $f(x)=1+\frac{\pi^2}{3}+4\sum_{n=1}^{\infty}\frac{(-1)^n\cos nx}{n^2}+2\sum_{n=1}^{\infty}\frac{(-1)^{n+1}\sin nx}{n^2}$ **(1 M)**

- $\frac{1}{1^2}+\frac{1}{2^2}+\frac{1}{3^2}+.........=\frac{\pi^2}{6}$ **(1 M)**

12

Find the Fourier series of periodicity 2π for $f(x)=x^2$, in $-\pi<x<\pi$. Hence show that $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+.............=\frac{\pi^4}{90}$. [M/J13,A/M15,N/D15,*N/D16*] BTL5 **(8 M)**

Answer :Page2.166-DR.A.SINGARAVELU

- $a_0=\frac{2\pi^2}{3}; a_n=\left\{\frac{4(-1)^n}{n^2}\right\}; \mathrm{b}_n=0$ **(6 M)**
- $f(x)=\frac{\pi^2}{3}+\sum_{n=1}^{\infty}\left\{\frac{4(-1)^n}{n^2}\right\}\cos nx$ **(2 M)**
- $\frac{1}{1^4}+\frac{1}{2^4}+\frac{1}{3^4}+.............=\frac{\pi^4}{90}$ **(1 M)**

13

By using cosine series for $f(x)=x$ in $0<x<\pi$, show that $\frac{\pi^4}{96}=1+\frac{1}{3^4}+\frac{1}{5^4}+......$ [N/D14]

(8 M) BTL5

Answer :Page2.169-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)**
- $f(x)=\frac{l}{2}+\sum_{n=1,3,5...}^{\infty}\left\{\frac{-4l}{n^2\pi^2}\right\}\cos\frac{n\pi x}{l}$ **(1 M)**
- $\frac{\pi^4}{96}=1+\frac{1}{3^4}+\frac{1}{5^4}+......$ **(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

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

(MAY/JUNE 2014)

Answer : Page 2.182-DR.A.SINGARAVELU

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

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) $y(x,t) = \left(c_1 e^{px} + c_2 e^{-px}\right)\left(c_3 e^{pat} + c_4 e^{-pat}\right)$

(ii) $y(x,\ t) = \left(c_5 \cos px + c_6 \sin px\right)\left(c_7 \cos pat + c8 \sin pat\right)$

(iii) $y(x,t) = \left(c_9 x + c_{10}\right)\left(c_{11} t + c_{12}\right)$

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** $x^2 u_{xx} + 2xyu_{xy} + \left(1 + y^2\right)u_{yy} - 2u_x = 0$ **.** BTL2

Given $x^2 u_{xx} + 2xyu_{xy} + \left(1 + y^2\right)u_{yy} - 2u_x = 0$

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** $x^2 u_{xx} + 2xyu_{xy} + \left(1 + y^2\right)u_{yy} - 2u_x = 0$ **.** BTL2

Given $x^2 u_{xx} + 2xyu_{xy} + \left(1 + y^2\right)u_{yy} - 2u_x = 0$

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 $c^2 = T/m = Tension/mass\ per\ unit\ length.$
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** $u_{xx}+xu_{yy}=0$ **.** 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** $u_t=\alpha^2u_{xx}$ **. 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) $u(x,t)=\left(A_1e^{\lambda x}+B_1e^{-\lambda x}\right)e^{-\alpha^2\lambda^2t}$

	$(ii)\ u(x,t) = (A_2 \cos \lambda x + B_2 \sin \lambda x) e^{-\alpha^2 \lambda^2 t}$ $(iii)\ u(x,t) = A_3 x + B_3$.
18	**State Fourier law of heat conduction.** BTL5 he 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 e 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 he 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. [*<u>N/D15</u>*]** 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. $3x\frac{X'}{X} = 2y\frac{Y'}{Y} = k$ $3x\frac{X'}{X} = k \quad \Rightarrow 3\frac{X'}{X} = \frac{k}{x}$ ……(4) $2y\frac{Y'}{Y} = k \quad \Rightarrow 2\frac{Y'}{Y} = \frac{k}{y}$ …….(5) Integrating (4) with respect to x and (5) with respect to y, we have $3\log X = k\log x + \log A \; 2\log Y = k\log y + \log B$ $\log X^3 = \log x^k + \log A \; \log Y^2 = \log y^k + \log B$ $\log X^3 = \log Ax^k \; \log Y^2 = \log By^k$ $X^3 = Ax^k \; Y^2 = By^k$ $X = ax^{\frac{k}{3}} \; Y = by^{\frac{k}{2}}$ Hence the solution of (1) is $u = ax^{\frac{k}{3}}by^{\frac{k}{2}} = abx^{\frac{k}{3}}y^{\frac{k}{2}}$.
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 :Page3.26-DR.A.SINGARAVELU** BTL5 • $(i) y(0,t)=0 \quad \forall t>0$ $(ii) y(l,t)=0 \quad \forall t>0$ $(iii) \frac{\partial y}{\partial t}(x,0)=0 \quad \forall t>0$ $(iv) y(x,0)=\left\{\begin{matrix} \frac{3hx}{l} & for & \left(0,\frac{l}{3}\right) \\ \frac{3h(l-x)}{2l} & for & \left(\frac{l}{3},l\right) \end{matrix}\right\}$ **(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 $\boldsymbol{l}$ has its ends $\boldsymbol{x=0}$, $\boldsymbol{x=l}$ fixed. The point where $\boldsymbol{x=\frac{l}{3}}$ is drawn aside a small distance $\boldsymbol{h}$, the displacement $\boldsymbol{y(x,t)}$ satisfies $\boldsymbol{\frac{\partial^2 y}{\partial t^2}=a^2\frac{\partial^2 y}{\partial x^2}}$. Determine $\boldsymbol{y(x,t)}$ at any time $\boldsymbol{t}$. (16 M) BTL5 **Answer :Page3.40-DR.A.SINGARAVELU**

- $$(i) y(0,t)=0 \quad \forall t>0$$
  $$(ii) y(l,t)=0 \quad \forall t>0$$
  $$(iii) \frac{\partial y}{\partial t}(x,0)=0 \quad \forall t>0$$
  $$(iv) y(x,0)=\begin{Bmatrix} \frac{3hx}{l} & for \ \left(0,\frac{l}{3}\right) \\ \frac{3h(l-x)}{2l} & for \ \left(\frac{l}{3},l\right) \end{Bmatrix}$$
  (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 $\lambda x\left(l-x\right)$, find the displacement $y\left(x,t\right)$ at any distance x and at any time t. (16 **M)** BTL5

Answer : Page 3.42-DR.A.SINGARAVELU

- $$(i) y(0,t)=0 \quad \forall t>0$$
  $$(ii) y(l,t)=0 \quad \forall t>0$$
  $$(iii) \frac{\partial y}{\partial t}(x,0)=\lambda x\left(l-x\right)$$
  $$(iv) y(x,0)=0$$
  (2 M)

  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 :Page3.46-DR.A.SINGARAVELU

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

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

- $(iii)\, \dfrac{\partial y}{\partial t}(x,0)=v_0 \sin^3 \dfrac{\pi x}{l}, 0<x<l$ **(2 M)**

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

The Most general Solution is

- $y(x,t)=\sum_{n=1}^{\infty} b_n \sin \dfrac{n\pi x}{l} \sin \dfrac{n\pi at}{l}$ **(8 M)**
- $y(x,t)=\dfrac{3v_0 l}{4\pi a} \sin \dfrac{\pi x}{l} \sin \dfrac{\pi at}{l} - \dfrac{v_0}{12\pi a} \sin \dfrac{3\pi x}{l} \sin \dfrac{3\pi at}{l}$ **(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 $v=\begin{cases} \dfrac{cx}{l} \; in\, 0<x<l \\ \dfrac{c}{l}(2l-x) \; in \; l<x<2l \end{cases}$ **, 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

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

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

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

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

The Most general Solution is

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

	$(i)\,\mathrm{u}(0,t)=0 \quad \forall t\geq 0$ - $(ii)\,\mathrm{u}(l,t)=0 \quad \forall t\geq 0$ **(2 M)** $(iii)u(x,0)=\frac{120x}{l}$ *The Most general Solution is* - $\mathrm{u}(x,t)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{l} e^{-\frac{c^2n^2\pi^2t}{l^2}}$ **(8 M)** - $\mathrm{u}(x,t)=\frac{240}{\pi}\sum_{n=1}^{\infty}\frac{(-1)^{n+1}}{n}\sin\frac{n\pi x}{l} e^{\frac{-c^2n^2\pi^2t}{l^2}}$ **(6 M)**
8	
	A rod, 30 cm long has its ends A and B kept at 20^{0}C and 80^{0}C 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** $(i)\,\mathrm{u}(0,t)=0 \quad \forall t\geq 0$ - $(ii)\,\mathrm{u}(30,t)=0 \quad \forall t\geq 0$ **(2 M)** $(iii)u(x,0)=2x+20$ *The Most general Solution is* - $\mathrm{u}(x,t)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{30} e^{-\frac{c^2n^2\pi^2t}{900}}$ **(8 M)** - $\mathrm{u}(x,t)=\frac{40}{\pi}\sum_{n=1}^{\infty}\frac{\left[1-4(-1)^n\right]}{n}\sin\frac{n\pi x}{30} e^{\frac{-c^2n^2\pi^2t}{900}}$ **(6 M)**
9	
	A metal bar 20 cm long with insulated sides, has its ends A and B kept at 30^{0}C and 80^{0}C respectively until steady state conditions prevail. The temperature at A is then suddenly raised to 40^{0}C and at the same instant B is lowered to 60^{0}C. Find the subsequent temperature at any point at the bar at any time. (16 M) BTL5 **Answer : Page 3.76-DR.A.SINGARAVELU** $(i)\,\mathrm{u}(0,t)=0 \quad \forall t\geq 0$ $(ii)\,\mathrm{u}(20,t)=0 \quad \forall t\geq 0$ - $(iii)u_s(x,0)=x+40$ **(2 M)** $and \;\; u_T(x,0)=\frac{3x}{2}-10$ *The Most general Solution is* - $\mathrm{u}(x,t)=\sum_{n=1}^{\infty} b_n \sin\frac{n\pi x}{20} e^{-\frac{c^2n^2\pi^2t}{400}}$ **(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

$$u = \begin{cases} 20y & for\ \ y \in [0,5] \\ 20(10-y) & for\ \ y \in [5,10] \end{cases}$$

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)**

$$(iv)\, u(0,y) = \begin{cases} 20y & for\ \ y \in [0,5] \\ 20(10-y) & for\ \ y \in [5,10] \end{cases}$$

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)**

$$(iv)\, u(x,0) = \begin{cases} 20x & for\ \ x \in [0,5] \\ 20(10-x) & for\ \ x \in [5,10] \end{cases}$$

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)** $u=l\,x-x^2\ for t=0$, $0\le x\le l$ **.[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)**

	$\mathrm{u}(x,\mathrm{y})=\frac{8a^2b}{\pi^3}\sum_{n=1,3,5,....}^{\infty}\frac{1}{n^3\sinh n\pi}\sin\frac{n\pi x}{a}\sinh\frac{n\pi y}{a}$ **(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 $F(s)=F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(x)e^{isx}\,dx \quad and$ $f(x)=F^{-1}[F(s)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}F(s)e^{-isx}\,ds$.
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 $F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(x)e^{isx}\,dx$

	$F[f(x)] = \frac{1}{\sqrt{2\pi}}\int_a^b e^{ikx}\, e^{isx}\, dx = \frac{1}{\sqrt{2\pi}}\int_a^b e^{i(s+k)x}\, dx$ $= \frac{1}{\sqrt{2\pi}}\left[\frac{e^{i(s+k)x}}{i(s+k)}\right] = \frac{1}{\sqrt{2\pi}}\left[\frac{e^{i(s+k)b} - e^{i(s+k)a}}{i(s+k)}\right].$
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) $F[f(x-a)]=e^{ias}F(s).$
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, $F[f(x)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\, dx$ $F[f(x-a)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x-a)e^{isx}\, dx$

	$x-a=t$ when $x=-\infty,t=-\infty$ Put $x=\mathbf{t}+a$ when $x=\infty,t=\infty$ $dx=dt$ $F[f(x-a)]=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(t)e^{is(t+a)}\,dt \quad =\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(t)e^{ist}\,e^{ias}\,dt$ $=e^{ias}\,\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(t)e^{ist}\,dt=e^{ias}\,\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(x)e^{isx}\,dx=e^{ias}\,F(s)$.
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 $f(x)\to 0 \ as \ x\to\pm\infty$.
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 $a<0$, $put \quad ax=t \quad when \quad x=-\infty,\ t=\infty$ $x=\frac{t}{a} \quad when \quad x=\infty,t=-\infty$ $dx=\frac{dt}{a}$ $F[f(ax)]=\frac{1}{\sqrt{2\pi}}\int_{\infty}^{-\infty}f(t)e^{is\left(\frac{t}{a}\right)}\frac{dt}{a} \quad =\frac{1}{a}\,\frac{1}{\sqrt{2\pi}}\int_{\infty}^{-\infty}f(t)e^{i\left(\frac{s}{a}\right)t}\,dt$ $=-\frac{1}{a}\,\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(t)e^{i\left(\frac{s}{a}\right)t}\,dt=-\frac{1}{a}F\left[\frac{s}{a}\right]$ ------------(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 $F_C[f(ax)]=F_C(s)=\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(ax)\cos sx\,dx$ $put\quad ax=t \qquad when\ x=0,\ t=0$ $x=\frac{t}{a} \qquad when\ x=\infty, t=\infty$ $dx=\frac{dt}{a}$ $=\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(t)\cos s\left(\frac{t}{a}\right)\frac{dt}{a}=\frac{1}{a}\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(t)\cos\left(\frac{s}{a}\right)t\ dt$ $=\frac{1}{a}\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(x)\cos\left(\frac{s}{a}\right)x\ dx$ (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 $F_S\left[\frac{1}{x}\right]=\sqrt{\frac{2}{\pi}}\int_0^\infty\frac{1}{x}\sin\ sx\,dx$ $put\ \ sx=\theta \qquad when\ x=0,\ \theta=0$ $x=\frac{\theta}{s} \qquad when\ x=\infty,\theta=\infty$ $dx=\frac{d\theta}{s}$ $=\sqrt{\frac{2}{\pi}}\int_0^\infty\frac{1}{\left(\frac{\theta}{s}\right)}\sin\theta\frac{d\theta}{s}=\sqrt{\frac{2}{\pi}}\int_0^\infty\frac{s}{\theta}\frac{\sin\theta}{s}\,d\theta$ $=\sqrt{\frac{2}{\pi}}\int_0^\infty\frac{\sin\theta}{\theta}\,d\theta=\sqrt{\frac{2}{\pi}}\frac{\pi}{2}=\sqrt{\frac{\pi}{2}}.$
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 $F_s[f(x)]=\sqrt{\frac{2}{\pi}}\int_0^\infty f(x)\sin sx\,dx$

	$F_s\left[e^{-\frac{x}{2}}\right] = \sqrt{\frac{2}{\pi}}\int_0^{\infty} e^{-\frac{x}{2}}\sin sx\,dx = \sqrt{\frac{2}{\pi}}\left[\frac{e^{-\frac{x}{2}}}{\left(-\frac{1}{2}\right)^2+s^2}\left(-\frac{1}{2}\sin sx - s\cos sx\right)\right]_0^{\infty}$ $= \sqrt{\frac{2}{\pi}}\left[0 - \frac{1}{\left(\frac{1+4s^2}{4}\right)}(0-s)\right] = \sqrt{\frac{2}{\pi}}\left[\frac{4s}{1+4s^2}\right] = \sqrt{\frac{2}{\pi}}\left[\frac{4s}{4s^2+1}\right]$
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 $\int_{-\infty}^{\infty}\lvert f(x)\rvert^2 dx = \int_{-\infty}^{\infty}\lvert F(s)\rvert^2 ds$.
23	**Solve the integral equation $\int_0^{\infty} f(x)\cos\lambda x\,dx = e^{-\lambda}$.** BTL1 $\int_0^{\infty} f(x)\cos\lambda x\,dx = e^{-\lambda}$ Multiplying both sides by $\sqrt{\frac{2}{\pi}}$, we have $\sqrt{\frac{2}{\pi}}\int_0^{\infty} f(x)\cos\lambda x\,dx = \sqrt{\frac{2}{\pi}}\,e^{-\lambda}$ $F_C[f(x)] = \sqrt{\frac{2}{\pi}}\,e^{-\lambda}$ $(x) = F_C^{-1}\left[\sqrt{\frac{2}{\pi}}\,e^{-\lambda}\right] = \sqrt{\frac{2}{\pi}}\int_0^{\infty}\sqrt{\frac{2}{\pi}}\,e^{-\lambda}\cos x\lambda\,d\lambda = \frac{2}{\pi}\int_0^{\infty} e^{-\lambda}\cos x\lambda\,d\lambda$ $= \frac{2}{\pi}\left[\frac{e^{-\lambda}}{(-1)^2+x^2}(-\cos x\lambda + x\sin x\lambda)\right]_0^{\infty} = \frac{2}{\pi}\left[0 - \frac{1}{1+x^2}(-1+0)\right] = \frac{2}{\pi}\,\frac{1}{1+x^2}$.
24	**State and prove the change of scale property of Fourier transform. [A/M11,M/J13, N/D16].B** By definition, $F[f(x)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}\,dx$ $F[f(ax)] = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(ax)e^{isx}\,dx$

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

when $a>0$,

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

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

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

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

when $a<0$,

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

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

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

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

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

From (1) and (2) , we have

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

25

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

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

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

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

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

$$dx=dt$$

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

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

PART*B

1

Find the Fourier transform of $f(x) = \begin{cases} 1; \; |x| < 1 \\ 0; \; otherwise \end{cases}$ **. 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)**

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

$$F(s) = \sqrt{\frac{2}{\pi}} \frac{\sin as}{s}$$

- **(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 $e^{-a|x|}$**, 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 $f(x) = \begin{cases} a^2 - x^2 \;, |x| < a \\ 0 \qquad , |x| > a > 0 \end{cases}$**. 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)** $\int_{-\infty}^{\infty}\lvert F(s)\rvert^2 ds=\int_{-\infty}^{\infty}\lvert f(x)\rvert^2 dx$ $F(s)=2\sqrt{\frac{2}{\pi}}\left(\frac{\sin as-as\cos as}{s^3}\right)$ • **(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 $f(x)=\begin{cases}1-x^2\,; & \lvert x\rvert<1\\ 0\quad ; & \lvert x\rvert\geq 1\end{cases}$**. 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)** $\int_{-\infty}^{\infty}\lvert F(s)\rvert^2 ds=\int_{-\infty}^{\infty}\lvert f(x)\rvert^2 dx$

	$F(s)=2\sqrt{\frac{2}{\pi}}\left(\frac{\sin s-s\cos s}{s^3}\right)$ • **(8 M)** $f(x)=\frac{4}{\pi}\int_0^\infty\left(\frac{\sin s-s\cos s}{s^3}\right)\cos sx\ ds$ $\int_0^\infty\left(\frac{\text{sins}-s\cos\text{s}}{s^3}\right)\cos\frac{s}{2}ds=\frac{3\pi}{16}$ • **(6 M)** $\int_0^\infty\left(\frac{\text{sins}-s\cos\text{s}}{s^3}\right)^2 ds=\frac{\pi}{15}$
5	
	Find the Fourier transform of $f(x)=\begin{cases}1-\lvert x\rvert\ ;\ if\ \lvert x\rvert<1\\ 0\quad\ ;\ if\ \lvert x\rvert\geq 1\end{cases}$ **. Hence deduce that** $\int_0^\infty\left(\frac{\sin t}{t}\right)^4dt=\frac{\pi}{3}$ **and** $\int_0^\infty\left(\frac{\sin t}{t}\right)^2dt=\frac{\pi}{2}$ **. [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** $F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(x)e^{isx}dx$ • $f(x)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}F(s)e^{-isx}ds$ **(2 M)** $\int_{-\infty}^{\infty}\lvert F(s)\rvert^2ds=\int_{-\infty}^{\infty}\lvert f(x)\rvert^2dx$ $F(s)=\sqrt{\frac{2}{\pi}}\frac{(1-\cos s)}{s^2}$ • **(6 M)** $f(x)=\frac{2}{\pi}\int_0^\infty\frac{(1-\cos s)}{s^2}\cos sx\ ds$ • $\int_0^\infty\left(\frac{\sin t}{t}\right)^4dt=\frac{\pi}{3}$ and $\int_0^\infty\left(\frac{\sin t}{t}\right)^2dt=\frac{\pi}{2}$. **(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 $e^{-a\|x\|}$, $a>0$ **and hence deduce that** **(1)** $\int_0^\infty \frac{\cos xt}{a^2+t^2}\,dt=\frac{\pi}{2a}e^{-a\|x\|}$ **(2)** $F\left\{xe^{-a\|x\|}\right\}=i\sqrt{\frac{2}{\pi}}\;\frac{2as}{\left(s^2+a^2\right)}$**, here** F **stands for Fourier transform.** **[M/J14,N/D14]**BTL1 **(8 M)** **Answer : Page :4.46-DR.A.SINGARAVELU** • $F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty}f(x)e^{isx}dx$ $F(xf(x))=-i\frac{d}{ds}(F(f(x))$ **(2 M)** • $F(s)=\sqrt{\frac{2}{\pi}}\frac{a}{s^2+a^2}$ $f(x)=\frac{2}{\pi}\int_0^\infty\frac{a}{s^2+a^2}\cos sx\ ds$ **(4 M)** • $\int_0^\infty \frac{\cos xt}{a^2+t^2}\,dt=\frac{\pi}{2a}e^{-a\|x\|}$ and $F\left\{xe^{-a\|x\|}\right\}=i\sqrt{\frac{2}{\pi}}\;\frac{2as}{\left(s^2+a^2\right)}$**(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**

	$\int_0^\infty \frac{s\sin sx}{a^2+s^2}\,d\,s=\frac{\pi}{2}\,e^{-a\,x}$. 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)** • $\int_0^\infty \frac{s\sin sx}{a^2+s^2}\,d\,s=\frac{\pi}{2}\,e^{-a\,x}$ **(6 M)**
10	
	Evaluate $\int_0^\infty \frac{dx}{\left(x^2+a^2\right)\left(x^2+b^2\right)}$ **using Fourier cosine transforms of** $e^{-a\,x}$ **and** $e^{-b\,x}$**.** **[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 $f\,(x)=e^{-a\,x}$ $(a>0)$ **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** $If\ f(x)\, is\, a\, given\ function\ defined\ in\ (-\infty,\infty)\, then$ - $\int_{-\infty}^{\infty}\|F(s)\|^2\, ds=\int_{-\infty}^{\infty}\|f(x)\|^2\, dx$ **(2 M)** - $F(s)=\frac{1}{\sqrt{2\pi}}\int_{-\infty}^{\infty} f(x)e^{isx}dx$ **(2 M)** - For Proving $\int_{-\infty}^{\infty}\|F(s)\|^2\, ds=\int_{-\infty}^{\infty}\|f(x)\|^2\, dx$ **(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 $n=0,\pm1,\pm2,$............, 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 $\lim_{t\to\infty} f(t)=\lim_{z\to1}(z-1)F[z]$.
3	**Find** $Z\{n\}$**.[M/J13 ,*N/D14*]**BTL1 $Z\{n\}=\sum_{n=0}^{\infty} n\,z^{-n}=\sum_{n=0}^{\infty}\frac{n}{z^n}$ $=0+\frac{1}{z}+\frac{2}{z^2}+\frac{3}{z^3}+$............ $=\frac{1}{z}\left[1+\frac{2}{z}+\frac{3}{z^2}+.........\right]=\frac{1}{z}\left[1+2\left(\frac{1}{z}\right)+3\left(\frac{1}{z}\right)^2+.........\right]$

	$= \frac{1}{z}\left[1-\frac{1}{z}\right]^{-2} = \frac{1}{z}\left[\frac{z-1}{z}\right]^{-2} = \frac{1}{z}.\frac{z^2}{(z-1)^2} = \frac{z}{(z-1)^2}$ $Z\{n\} = \frac{z}{(z-1)^2}$.
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 $Z\{(\cos\theta+i\sin\theta)^n\} = Z\{\cos n\theta+i\sin n\theta\}$ $= Z\{\cos n\theta\}+iZ\{\sin n\theta\} = \frac{z(z-\cos\theta)}{z^2-2z\cos\theta+1} + i\frac{z\sin\theta}{z^2-2z\cos\theta+1}$.
6	**State damping rule related to Z-transform and then find** $Z(na^n)$**. [M/J16]** BTL1 Damping rule: If $Z[f(n)] = F[z]$, then $Z[a^n f(n)] = Z[f(n)]_{z\to\frac{z}{a}}$ $Z[na^n] = Z[a^n.n] = (Z[n])_{z\to\frac{z}{a}}$ $= \left(\frac{z}{(z-1)^2}\right)_{z\to\frac{z}{a}} = \frac{\left(\frac{z}{a}\right)}{\left(\frac{z}{a}-1\right)^2} = \frac{\left(\frac{z}{a}\right)}{\left(\frac{z-a}{a}\right)^2} = \frac{\left(\frac{z}{a}\right)}{\frac{(z-a)^2}{a^2}} = \frac{az}{(z-a)^2}$.
7	**Find** $Z\left\{\frac{1}{n}\right\}$**.[N/D13]** BTL1 $Z\left\{\frac{1}{n}\right\} = \sum_{n=0}^{\infty}\frac{1}{n}z^{-n} = \sum_{n=1}^{\infty}\frac{1}{nz^n}$ $= \frac{1}{z}+\frac{1}{2z^2}+\frac{1}{3z^3}+.............$ $= \frac{\left(\frac{1}{z}\right)}{1}+\frac{\left(\frac{1}{z}\right)^2}{2}+\frac{\left(\frac{1}{z}\right)^3}{3}+...........$ $= -\log\left(1-\frac{1}{z}\right) = -\log\left(\frac{z-1}{z}\right) = \log\left(\frac{z-1}{z}\right)^{-1} = \log\left(\frac{z}{z-1}\right)$ $Z\left\{\frac{1}{n}\right\} = \log\left(\frac{z}{z-1}\right)$.

8	**Find the Z-transform of** $\frac{1}{n+1}$ **.[A/M15,*N/D15*]** BTL1 $Z\left[\frac{1}{n+1}\right]=\sum_{n=0}^{\infty}\frac{1}{n+1}z^{-n}=\sum_{n=0}^{\infty}\frac{\left(\frac{1}{z}\right)^n}{n+1}=1+\frac{\left(\frac{1}{z}\right)}{2}+\frac{\left(\frac{1}{z}\right)^2}{3}+\ldots\ldots\ldots\ldots$ $=\frac{z}{z}\left[1+\frac{\left(\frac{1}{z}\right)}{2}+\frac{\left(\frac{1}{z}\right)^2}{3}+\ldots\ldots\right]=z\left[\frac{\left(\frac{1}{z}\right)}{1}+\frac{\left(\frac{1}{z}\right)^2}{2}+\frac{\left(\frac{1}{z}\right)^3}{3}+\ldots\ldots\ldots\right]$ $=z\left[-\log\left(1-\frac{1}{z}\right)\right]=z\left[-\log\left(\frac{z-1}{z}\right)\right]=z\left[\log\left(\frac{z-1}{z}\right)^{-1}\right]=z\log\left(\frac{z}{z-1}\right).$
9	**Find** $Z\left\{\frac{a^n}{n!}\right\}$ **in Z-transform. [N/D 09 , M/J 12].** BTL1 $Z\left\{\frac{a^n}{n!}\right\}=\sum_{n=0}^{\infty}\frac{a^n}{n!}z^{-n}=\sum_{n=0}^{\infty}\frac{a^n}{n!\,z^n}=\sum_{n=0}^{\infty}\frac{\left(\frac{a}{z}\right)^n}{n!}$ $=1+\frac{\left(\frac{a}{z}\right)}{1!}+\frac{\left(\frac{a}{z}\right)^2}{2!}+\frac{\left(\frac{a}{z}\right)^3}{3!}+\ldots\ldots\ldots\ldots=e^{\frac{a}{z}}.$
10	**Find the Z-transform of** $\frac{1}{n!}$**. [N/D11,*M/J16*]** BTL1 $Z\left\{\frac{1}{n!}\right\}=\sum_{n=0}^{\infty}\frac{1}{n!}z^{-n}=\sum_{n=0}^{\infty}\frac{1}{n!\,z^n}=\sum_{n=0}^{\infty}\frac{\left(\frac{1}{z}\right)^n}{n!}$ $=1+\frac{\left(\frac{1}{z}\right)}{1!}+\frac{\left(\frac{1}{z}\right)^2}{2!}+\frac{\left(\frac{1}{z}\right)^3}{3!}+\ldots\ldots\ldots\ldots=e^{\frac{1}{z}}.$
11	**Find the Z-transform of** 3^n**.** BTL1 $Z\{3^n\}=\sum_{n=0}^{\infty}3^n z^{-n}=\sum_{n=0}^{\infty}\frac{3^n}{z^n}=\sum_{n=0}^{\infty}\left(\frac{3}{z}\right)^n$ $=1+\frac{3}{z}+\left(\frac{3}{z}\right)^2+\left(\frac{3}{z}\right)^3+\ldots\ldots\ldots\ldots\ldots=\left(1-\frac{3}{z}\right)^{-1}=\left(\frac{z-3}{z}\right)^{-1}=\frac{z}{z-3}$
12	**Find the Z-transform of** a^n **. [A/M11,N/D12].** BTL1 $Z\{a^n\}=\sum_{n=0}^{\infty}a^n z^{-n}=\sum_{n=0}^{\infty}\frac{a^n}{z^n}=\sum_{n=0}^{\infty}\left(\frac{a}{z}\right)^n$

	$=1+\frac{a}{z}+\left(\frac{a}{z}\right)^2+\left(\frac{a}{z}\right)^3+...............$ $=\left(1-\frac{a}{z}\right)^{-1}=\left(\frac{z-a}{z}\right)^{-1}=\frac{z}{z-a}$
13	**Find the Z-transform of** $(n+1)(n+2)$**.** BTL1 $Z[(n+1)(n+2)]=Z[n^2+3n+2]$ $=Z[n^2]+3Z[n]+2Z[1]$ $=\frac{z(z+1)}{(z-1)^3}+\frac{3z}{(z-1)^2}+\frac{2z}{z-1}$
14	**Find** $=\left[\frac{z}{z-1}\right]_{z\to ze^{iaT}}=\frac{ze^{iaT}}{ze^{iaT}-1}$ $Z[e^{-iat}]$ **using Z-transform.** BTL1 $Z[e^{-iat}]=Z[e^{-iat}.1]=[Z(1)]_{z\to ze^{iaT}}$
15	**Find** $Z[e^t\sin 2t]$**. [N/D15]** BTL1 $Z[e^t\sin 2t]=Z[\sin 2t]_{z\to ze^{-T}}=\left[\frac{z\sin 2T}{z^2-2z\cos 2T+1}\right]_{z\to ze^{-T}}$ $Z[e^t\sin 2t]=\frac{ze^{-T}\sin 2T}{z^2e^{-2T}-2ze^{-T}\cos 2T+1}$
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

et $X(z)=\frac{z}{(z+1)^2}$

$(z)z^{n-1}=\frac{z\,.\,z^{n-1}}{(z+1)^2}=\frac{z^n}{(z+1)^2}$

$=-1$ is a pole of order 2

$n)=\sum R$ where $\sum R$ is the sum of residue of $X(z)z^{n-1}$

$s\left[X(z)z^{n-1}\right]=\lim_{z\to -1}\frac{1}{(2-1)!}\frac{d}{dz}\left[(z+1)^2\;\frac{z^n}{(z+1)^2}\right]=\lim_{z\to -1}\frac{d}{dz}\left[z^n\right]=\lim_{z\to -1}n\,z^{n-1}$

$n(-1)^{n-1}=-n(-1)^n$.

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 $y_n=a+b\,2^n$. [A/M10]. BTL1

Given $y_n=a+b\,2^n$ --------------------(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 $z[y(n+1)]-2\,Z[y(n)]=0$ $zY(z)-z\,y(0)-2Y(z)=0$ $zY(z)-z(2)-2Y(z)=0$ $(z-2)Y(z)=2z$ $Y(z)=\frac{2z}{z-2}$ 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 $Z\left[n^{2}\right]=Z[n.n]=-z\frac{d}{dz}Z[n]=-z\frac{d}{dz}\left[\frac{z}{(z-1)^{2}}\right]$ $=-z\left[\frac{(z-1)^{2}(1)-z.2(z-1)}{(z-1)^{4}}\right]=-z\left[\frac{(z-1)(z-1-2z)}{(z-1)^{4}}\right]$ $=-z\left[\frac{-z-1}{(z-1)^{3}}\right]=\frac{z(z+1)}{(z-1)^{3}}$.
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 $Z[f(-n)]=\sum_{n=0}^{\infty}f(-n)z^{-n}$ $put\ -n=u\Rightarrow n=-u$ $n=0\ ,\ u=0\ \ and\ \ n=\infty\ ,\ u=\infty$

	$Z\left[f(-n)\right] = \sum_{u=0}^{\infty} f(u) z^{-(-u)} = \sum_{u=0}^{\infty} f(u)\left(z^{-1}\right)^{-u} = \sum_{u=0}^{\infty} f(u)\left(\frac{1}{z}\right)^{-u} = \sum_{n=0}^{\infty} f(n)\left(\frac{1}{z}\right)^{-n} = \bar{f}\left(\frac{1}{z}\right).$
	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** • $\left.\begin{array}{l}\operatorname{Re}s\ f(z)\\ @\mathrm{z}=1\ \ of\ \ order\,3\end{array}\right\}=\frac{1}{2!}\underset{z\to1}{Lim}\left[\frac{d^2}{dz^2}(z-1)^3X(z)z^{n-1}\right]$ **(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** $\left.\begin{array}{l}\operatorname{Re}s\ f(z)\\ @\mathrm{z}=1\ \ of\ \ order\,1\end{array}\right\}=\underset{z\to1}{Lim}\left[(z-1)X(z)z^{n-1}\right]$ • **(2 M)** $\left.\begin{array}{l}\operatorname{Re}s\ f(z)\\ @\mathrm{z}=2\ \ of\ \ order\,1\end{array}\right\}=\underset{z\to2}{Lim}\left[(z-2)X(z)z^{n-1}\right]$ • $Z^{-1}\left[\frac{z}{(z-1)(z-2)}\right]=2^n-1$ **(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** $Z(y(n+3))=Z^3Y(z)-Z^3\text{ y}(0)-Z^2\text{ y}(1)-\text{Zy}(2)$ • $Z(y(n+2))=Z^2Y(z)-Z^2\text{ y}(0)-Zy(1)$ **(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** $Z(y(n+3))=Z^3Y(z)-Z^3\text{ y}(0)-Z^2\text{ y}(1)-\text{Zy}(2)$ • $Z(y(n+2))=Z^2Y(z)-Z^2\text{ y}(0)-Zy(1)$ **(2 M)** $Z(y(n+1))=ZY(z)-Zy(0)$ • $y(n)=\frac{1}{25}\left[2^n-(-3)^n+\frac{5}{3}\text{n}(-3)^n\right]$ **(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** $Z(y(n+3))=Z^3Y(z)-Z^3\text{ y}(0)-Z^2\text{ y}(1)-\text{Zy}(2)$ • $Z(y(n+2))=Z^2Y(z)-Z^2\text{ y}(0)-Zy(1)$ **(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** $Z(y(n+3))=Z^3Y(z)-Z^3\text{ y}(0)-Z^2\text{ y}(1)-\text{Zy}(2)$ • $Z(y(n+2))=Z^2Y(z)-Z^2\text{ y}(0)-Zy(1)$ **(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)**

ME8391 ENGINEERING THERMODYNAMICS

L	T	P	C
3	2	0	4

OBJECTIVES:

● To familiarize the students to understand the fundamentals of thermodynamics and to perform thermal analysis on their behavior and performance.
● (Use of Standard and approved Steam Table, Mollier Chart, Compressibility Chart and Psychrometric Chart permitted)

UNIT I BASIC CONCEPTS AND FIRST LAW 9+6

Basic concepts - concept of continuum, comparison of microscopic and macroscopic approach. Path and point functions. Intensive and extensive, total and specific quantities. System and their types. Thermodynamic Equilibrium State, path and process. Quasi-static, reversible and irreversible processes. Heat and work transfer, definition and comparison, sign convention. Displacement work and other modes of work .P-V diagram. Zeroth law of thermodynamics – concept of temperature and thermal equilibrium– relationship between temperature scales –new temperature scales. First law of thermodynamics –application to closed and open systems – steady and unsteady flow processes..

UNIT II SECOND LAW AND AVAILABILITY ANALYSIS 9+6

Heat Reservoir, source and sink. Heat Engine, Refrigerator, Heat pump. Statements of second law and its corollaries. Carnot cycle Reversed Carnot cycle, Performance. Clausius inequality. Concept of entropy, T-s diagram, Tds Equations, entropy change for - pure substance, ideal gases - different processes, principle of increase in entropy. Applications of II Law. High and low grade energy. Available and non-available energy of a source and finite body. Energy and irreversibility. Expressions for the energy of a closed system and open systems. Energy balance and entropy generation. Irreversibility. I and II law Efficiency.

UNIT III PROPERTIES OF PURE SUBSTANCE AND STEAM POWER CYCLE 9+6

Formation of steam and its thermodynamic properties, p-v, p-T, T-v, T-s, h-s diagrams. p-v-Tsurface. Use of Steam Table and Mollier Chart. Determination of dryness fraction. Application of I and II law for pure substances. Ideal and actual Rankine cycles, Cycle Improvement Methods - Reheat and Regenerative cycles, Economiser, preheater, Binary and Combined cycles.

UNIT IV IDEAL AND REAL GASES, THERMODYNAMIC RELATIONS 9+6

Properties of Ideal gas- Ideal and real gas comparison- Equations of state for ideal and real gases- Reduced properties. Compressibility factor-.Principle of Corresponding states. –Generalised Compressibility Chart and its use-. Maxwell relations, Tds Equations, Difference and ratio of heat capacities, Energy equation, Joule-Thomson Coefficient, Clausius Clapeyron equation, Phase Change Processes. Simple Calculations.

UNIT V GAS MIXTURES AND PSYCHROMETRY 9+6

Mole and Mass fraction, Dalton’s and Amagat’s Law. Properties of gas mixture – Molar mass, gas constant, density, change in internal energy, enthalpy, entropy and Gibbs function. Psychrometric properties, Psychrometric charts. Property calculations of air vapour mixtures by using chart and expressions. Psychrometric process – adiabatic saturation, sensible heating and cooling, humidification, dehumidification, evaporative cooling and adiabatic mixing. Simple Applications.

TOTAL: 75 PERIODS

OUTCOMES:

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

CO1	Apply the first law of thermodynamics for simple open and closed systems under steady and unsteady conditions.	Unit 1
CO2	Apply second law of thermodynamics to open and closed systems and calculate entropy and availability.	Unit 2
CO3	Apply Rankine cycle to steam power plant and compare few cycle improvement methods	Unit 3
CO4	Derive simple thermodynamic relations of ideal and real gases	Unit 4
CO5	Calculate the properties of gas mixtures and moist air and its use in psychometric processes	Unit 5

TEXT BOOK:

1. R.K.Rajput, “A Text Book Of Engineering Thermodynamics “,Fifth Edition,2017.
2. Yunus a. Cengel&michael a. Boles, “Thermodynamics”, 8th edition 2015.

REFERENCE BOOKS:

1. Nag.P.K., “Engineering Thermodynamics”, 5thEdition, Tata McGraw-Hill, New Delhi, 2013.
2. Arora C.P, “Thermodynamics”, Tata McGraw-Hill, New Delhi, 2003.
3. Borgnakke&Sonnatag, “Fundamental of Thermodynamics”, 8th Edition , 2016.
4. Michael J. Moran, Howard N. Shapiro, “Fundamentals of Engineering Thermodynamics”, 8th Edition.
5. Chattopadhyay, P, "Engineering Thermodynamics", Oxford University Press, 2016.

REGULATION: 2017 **ACADEMICYEAR: 2019-2020**

Subject Code: ME 8391 **Year/ Semester: II / 03**

Subject Name: Engineering Thermodynamics **Subject Handler: Mr.S.Manimaran**

<table>
<tr><td colspan="2">UNIT I BASIC CONCEPTS AND FIRST LAW 9+6</td></tr>
<tr><td colspan="2">Basic concepts - concept of continuum, comparison of microscopic and macroscopic approach. Path and point functions. Intensive and extensive, total and specific quantities. System and their types. Thermodynamic Equilibrium State, path and process. Quasi-static, reversible and irreversible processes. Heat and work transfer, definition and comparison, sign convention. Displacement work and other modes of work .P-V diagram. Zeroth law of thermodynamics – concept of temperature and thermal equilibrium– relationship between temperature scales –new temperature scales. First law of thermodynamics –application to closed and open systems – steady and unsteady flow processes.</td></tr>
<tr><td>Q.No</td><td>Part-A</td></tr>
<tr><td>1.</td><td>Define thermodynamics system. How do you classify it.BTL1
A thermodynamic system is defined as a definite space or area on which the study of energy transfer and energy conversions is made. It is classified into three types.
a) Open system
b) Closed system
c) Isolated system</td></tr>
<tr><td>2</td><td>Distinguish between Open and Closed systems. BTL1
<table>
<tr><th>S.No.</th><th>Closed System</th><th>Open System</th></tr>
<tr><td>1.</td><td>There is no mass transfer. Only heat and work will transfer.</td><td>Mass transfer will take place in addition to the heat and work transfer.</td></tr>
<tr><td>2.</td><td>System boundary is a fixed one.</td><td>System boundary may or may not change.</td></tr>
<tr><td>3.</td><td>Ex: Piston & cylinder arrangement, thermal power plant.</td><td>Ex: Air compressor, boiler.</td></tr>
</table></td></tr>
<tr><td>3</td><td>Define thermodynamic property.BTL2
Thermodynamic property is any characteristic of the substance which is used to identify the state of the system and can be measured, when the system remains in an equilibrium state.</td></tr>
<tr><td>4</td><td>Define Intensive and Extensive properties. (Nov/Dec 16) BTL1
The properties which are “independent on the mass of the system” is called Intensive properties.
Eg: Pressure, Temperature, Specific Volume etc.</td></tr>
</table>

<table>
<tr><td></td><td>The properties which are “dependent on the mass of the system” is called Extensive properties.

Eg: Total energy, Total volume, weight etc.</td></tr>
<tr><td>5</td><td>Differentiate Intensive and Extensive properties. BTL2

<table>
<tr><th>Sl. No.</th><th>Intensive Properties</th><th>Extensive Properties</th></tr>
<tr><td>1.</td><td>Independent on the mass of the system.</td><td>Dependent on the mass of system.</td></tr>
<tr><td>2.</td><td>The considered part of these properties remains same. e.g. Pressure, temperature, specific volume, etc.</td><td>The considered part of the system will have a lesser value e.g. Total energy, Total Volume, weight, etc.</td></tr>
</table>
</td></tr>
<tr><td>6</td><td>When a system is said to be in “Thermodynamic Equilibrium”? (May/June 14) BTL4

When a system is in thermodynamic equilibrium, it should satisfy the following three conditions

a. Mechanical Equilibrium : ‘Pressure’ remains constant
b.Thermal Equilibrium : ‘Temperature’ remains constant
c. Chemical equilibrium : There is no chemical reaction</td></tr>
<tr><td>7</td><td>State Zeroth law and First law of thermodynamics.(Apr/May 15),(Nov/Dec 15). BTL1

Zeroth law of thermodynamics states that “When two systems are separately in thermal equilibrium with a third system, then they themselves is in thermal equilibrium with each other”.

First Law of thermodynamics states that “When system undergoes a cyclic process net heat transfer is equal to work transfer”.

$\int Q = \int W$</td></tr>
<tr><td>8</td><td>State First Law of thermodynamics and any two of its corollaries. BTL1

First Law of thermodynamics states that “When system undergoes a cyclic process net heat transfer is equal to work transfer”.

$\int Q = \int W$</td></tr>
</table>

	Corollaries of first law of thermodynamics **Corollary I :** There exists a property of a closed system such that a change in its value is equal to the difference between the heat supplied and the work done at any change of state. **Corollary II :** The Internal energy of a closed system remains unchanged if the system is isolated from its surroundings. **Corollary III :** A Perpetual Motion Machine of first kind (PMM-1) is impossible.
9	**Explain in short "Perpetual Motion Machine of First Kind"(PMM -I)?** BTL1 PMM of first kind delivers work continuously without any input thus violatingthe first law of thermodynamics. It is impossible to construct an engine working with this principle.
10	**Prove that for an isolated system, there is no change in internal energy.** BTL5 For any isolated system there is no heat, work and mass transfer. $Q = W = 0$ According to the first law of thermodynamics, $Q=W+\Delta U$ $\therefore \Delta U=0$
11	**Determine the molecular volume of any perfect gas at 600 N/m^2 and 30°C. Universal gas constant may be taken as 8314 J/kg mole – K.** BTL5 **Given data:** $P = 600 N/m^2$ $T = 30°C=30+273=303K$ R=8314 J/kg mole – K To find: Molecular volume, V=? Solution: Ideal gas equation, $PV=mRT$

	$600 \times V = 1 \times 8314 \times 303$ $V=4198.57\ m^3/kg$ mole Result:Molecular volume, $V=4198.57\ m^3/kg$ mole
12	**An insulated rigid vessel is divided into two parts by a membrane. One part of the vessel contains air at 10 MPa and other part is fully evacuated. The membrane ruptures and the air fills the entire vessel. Is there any heat and / or work transfer during this process? Justify your answer.**BTL5 For rigid vessel and unrestrained expansion Change in volume $dV = 0$ Work transfer. $W = \int pdV = 0$ For insulated vessel, heat transfer, $Q = 0$ According to the first law of thermodynamics the sum of work transfer is equal to the sum of heat transfer. $\therefore\ W = Q = 0$
13	**DescribeReversible and Irreversible process?**BTL2 A process is said to be Reversible if it retraces the same path in the reverse direction when the process is reversed and it is possible only when the system passes through a continuous series of equilibrium state. If a system does not pass through continuous equilibrium state, then the process is said to be Irreversible.
14	**Define Point and Path function. (May/June 14)**BTL2 The quantity which is 'independent **on** the process or path' followed by the system is known as Path functions. Example: Heat transfer, Work transfer
15	**Explain Quasi- static Process.**BTL2 The process is said to be Quasi –Static, if it proceeds infinitesimally slow and follows continuous series of equilibrium states. Therefore the quasi-static process may be a reversible process.
16	**Define the term Enthalpy.** BTL1 The combination of internal energy and flow energy is known as Enthalpy of the system. Mathematically, Enthalpy (h) = U + pVkJ Where U –Internal energy

	P – Pressure (N/m^2 or kPa) V – Volume (m^3) In terms of C_p&T→ H = $mC_p (T_2 – T_1)$kJ
17	**Define the term Internal Energy.**BTL1 Internal energy of a gas is the energy stored in a gas due to its molecular interactions. It is also defined as the energy possessed by a gas at a given temperature.
18	**Prove that the difference in specific heat capacities equal to $C_p – C_v = R$.** BTL5 Consider a gas heated at constant pressure So, heat supplied, $Q = mC_p (T_2 – T_1)$ Work done, $W = p(V_2 – V_1)= m R (T_2 – T_1)$ Change in internal energy, $\Delta U = mC_v (T_2 – T_1)$ According to the first law of thermodynamics, $Q = W + \Delta U$ So, $mC_p (T_2 – T_1) = mR (T_2 – T_1)+mC_v(T_2 – T_1)$ $\therefore C_p = r + C_v$ $C_p – C_v = R$
19	**DefineThermodynamic work. (Nov/Dec 15)**BTL2 It is the work done by the system when the energy transferred across the boundary of the system. It is mainly due to intensive property difference between the system and surrounding.
20	**Differentiate between Open and Closed cycle.** BTL2 In a closed cycle, the same working substance will be**recirculated** again and again. In an open cycle, the same working substance will be exhausted to the surrounding after expansion.
	Part * B
1	**A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During the cycle, the sum of all heat transfers is -170 kJ. The system completes 100 cycles per minute. Complete the following table showing the method for each item, and complete the net rate of work output in kW. (13 M)AU Nov'02.** BTL3

Process	**Q(kJ//min)**	**W (kJ/min)**	**ΔE(kJ/min)**
a-b	**0**	**2170**	**----**
b-c	**21000**	**0**	**----**
c-d	**-2100**	**----**	**-36600**
d-a	**----**	**----**	**----**

Answer:Page 1.120-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

Using the first law of thermodynamics, Q=W+ΔE, (2M)

$\sum Qcycle$= -170*100 = -17000kJ/min (1M)

$\sum Qcycle = Q_{a-b} + Q_{b-c} + Q_{c-d} + Q_{d-a}$ (3M)

Q_{d-a} = -35,900kJ/min

Cyclic process $\sum Q = \sum W$(2M)

$\sum W = W_{a-b} + W_{b-c} + W_{c-d} + W_{d-a}$(1M)

W_{d-a} = -53670 kJ/min

ΔE= Q-W = 17770kJ/min; (2M)

$\sum W$ = -283.3 kW (2M)

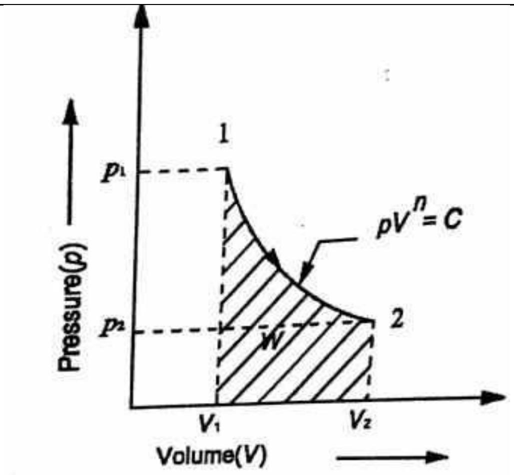
Ans: Q_{d-a}= -35900KJ/min; W_{d-a}=-53670KJ/min;ΔE=17770kJ/min;

$\sum W$=-283.3kW

2 **A mass of air is initially at 260°C and 700 kPa and occupies 0.028m^3. The air is expanded at constant pressure to 0.084 m^3. A polytropic process with n=1.5 is then carried out, followed by a constant temperature process. All the processes are irreversible. (i) Sketch the cycle in the P-V and T-s diagrams (ii) find the heat received and rejected in the cycle and (iii) Find the efficiency of the cycle. (13 M) AU Apr'03,(R-13 May/June 2016)**BTL5

Answer:Page 1.135-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

To draw P-V and T-s diagram (2M)



Process 1-2 : $(V_1/V_2) = (T_1/T_2)$ find T_2=1599K (1M)

m= pV/RT =0.128kg(1M)

$W_{1-2} = p(V_2 - V_1) =$ 39.2kJ (1M)

$Q_{1-2} = mCp(T_2-T_1) = 137.13kJ = Q_s$(2M)

Process 2-3: $T_3/T_2 = (P_3/P_2)^{(n-1)/n}$

to find P_3=25.93kPa (1M)

pV=mRT;V_3=0.755 m^3 (1M)

$W_{2-3} = (p_2V_2 - p_3V_3)/(n-1) = 78.446kJ$ (1M)

$Q_{2-3} = (\gamma - n/\gamma - 1) * W_{2-3} = -19.612kJ$ (1M)

Process 3-1 to find $W_{3-1,} = P_3 V_3 \ln(p_1/p_3) = -64.52kJ$(1M)

Efficiency of the cycle, η=Work done/Heat supplied or 1-$\left(\frac{Q_R}{Q_S}\right)$(1M)

Answer= 38.74%

3

A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During the cycle, the sum of all heat transfers is -340 kJ. The system completes 200 cycles per minute. Complete the following table showing the method for each item, and complete the net rate of work output in kW. (13 M)BTL3

Process	**Q(kJ//min)**	**W (kJ/min)**	**ΔE(kJ/min)**
a-b	**0**	**4340**	**----**
b-c	**42000**	**0**	**----**
c-d	**-4200**	**----**	**-73200**
d-a	**----**	**----**	**----**

Answer :Page 1.120 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

Using the first law of thermodynamics, Q=W+ ΔE

Process b-c and c-d (3M)

$\sum Qcycle = Q_{a-b} + Q_{b-c} + Q_{c-d} + Q_{d-a}$(2M)

$\sum Q$ =Cyclic process $\sum Q = \sum W$=74550kJ/min (2M)

$\sum W$ = W$_{a-b}$ + W$_{b-c}$ + W$_{c-d}$ + W$_{d-a}$(2M)

ΔE= Q-W = 73440kJ/min (2M)

$\sum W = -1133.33kW$ (2M)

4

Air flows steadily at the rate of 0.5 kg/s through an air compressor, entering at 7 m/s velocity, 100 kPa pressure and 0.95 m^3/kg volume and leaving at 5 m/s, 700 kPa and 0.19 m^3/kg. The internal energy of the air leaving is 90 kJ/kg greater than that of air entering. Cooling water in the compressor jackets absorbs heat from the air at the rate of 58 kW. (i) Compute the rate of shaft work input to the air in kW and (ii) find the ratio of inlet pipe diameter to outlet pipe diameter.(Nov/Dec 15) (13M)BTL3

Answer :Page 1.106 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

Steady flow energy equation

$$m\left(u_1 + p_1v_1 + \frac{C_1{}^2}{2} + Z_1g\right) + Q = m\left(u_2 + p_2v_2 + \frac{C_2{}^2}{2} + Z_2g\right) + w,$$

W=-121.994 kW (7M)

Continuity equation $\frac{A_1C_1}{V_1} = \frac{A_2C_2}{V_2}$, ➔$\frac{D_1}{D_2} = 1.89$ (5M)

Ans: W=-121.994 kW;$\frac{D_1}{D_2}$= 1.89 (1M)

5

A piston and cylinder machine contains a fluid system which passes through a complete cycle of four processes. During the cycle, the sum of all heat transfers is -255 kJ. The system completes 150 cycles per minute. Complete the following table showing the method for each item, and complete the net rate of work output in kW. (Nov/Dec 16), (13 M). BTL3

Process	**Q(kJ//min)**	**W (kJ/min)**	**ΔE(kJ/min)**
a-b	**0**	**3255**	**----**
b-c	**31500**	**0**	**----**
c-d	**-3150**	**----**	**-54900**
d-a	**----**	**----**	**----**

Answer:Page 1.120-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

Use the first law of thermodynamics, Q=W+ ΔE (2M)

For processes b-c,c-d,d-a, find ΔE and W (2M)

$\sum Qcycle$ = Q$_{a-b}$ + Q$_{b-c}$ + Q$_{c-d}$ + Q$_{d-a}$(1M)

Cyclic process $\sum Q = \sum W$ =-66670kJ/min (4M)

ΔE= Q –W = 17770kJ/min (3M)

$\sum W = -283.3kW$ (1M)

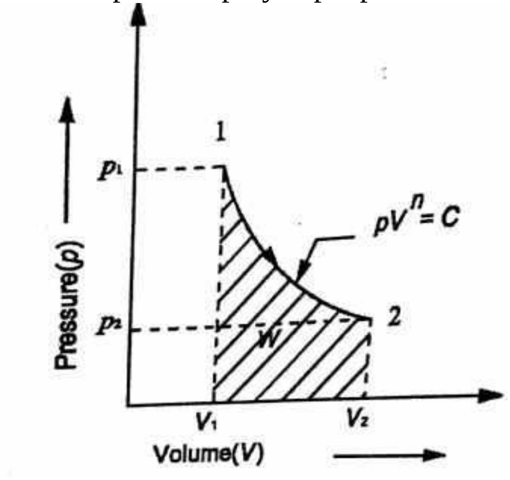
6

A mass of air is initially at 270°C and 750 kPa and occupies 0.029m^3. The air is expanded at constant pressure to 0.086 m^3. A polytropic process with n=1.55 is then carried out, followed by a constant temperature process. All the processes are irreversible. (i) Sketch

the cycle in the P-V and T-s diagrams (ii) find the heat received and rejected in the cycle and (iii) Find the efficiency of the cycle. (May/June 16)(13 M)BTL3

Answer :Page 1.135- Dr.G.K.Vijayaraghavan &Dr.S.Sundaravalli

To draw p –Vfor polytropic process



(2M)

Process 1-2 const pressure: $V_1/V_2 = T_1 / T_2$
to find T_2=1610k , m= = pV/RT =0.139kg (2M)
W_{1-2}= p(V_2 - V_1) = 42.75 kJ
Q_{1-2}= mCp(T_2-T_1) =149.05 kJ =Q_s (2M)
Process 2-3: polytropic process: $T_3 / T_{2 =} (p_{3 /}p_2)^{(n-1)/n}$ (n=1.55)
to find p_3= 34.80kPa, V_3= mR T_3 / P_3 =0.622 m^3(2M)
W_{2-3}= (p_1V_1 - p_2V_2)/ (n-1) = 77.917kJ(1M)
Q_{2-3}=(γ- n/ γ -1)* W_{2-3} =-29.218kJ (2M)
Process 3-1 to find $W_{3-1,}$ = -P_3 V_3ln(p_1/p_3) = -55.7kJ (1M)

Q_r=-29.218+55.8 = 85 kJ

Efficiency of the cycle, η=Work done/Heat supplied or 1-$\left(\frac{Q_R}{Q_S}\right)$ = (2M)

Ans: η= 43.45%

7 **A gas occupies 0.3 m3 at 2 bar. It executes a cycle consisting of processes: (i) 1-2 constant pressure with work interaction of 15 kJ. (ii) 2-3 compression process which follows the law pV=Constant, and U3=U2, (iii) 3-1 Constant volume process and change in internal energy is 40 kJ. Neglect change in KE and PE. Draw p-V diagram for the process and determine network transfer for the cycle. Also show that first law is obeyed by the cycle. (April/ May 15)(13M)**BTL5

Answer : Page 1.134 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.

Process 1-2:W_{1-2}=P (V_1-V_2) ➔ V_2= 0.375 m3 (2M)

	Process 2-3 :$W_{2-3} = p_2 V_2 \ln(V_2/ V_3) =$, W= -13.388kJ (4M) P2V2= P3V3; P3= 250kN/m2 (3M) Process 3-1 V2=V3, W=0, Q=ΔU=40kJ (4M) Ans: W= -13.388kJ ; Q = 40kJ
8	**Determine the heat transfer and its direction for a system in which a perfect gas having molecular weight of 17.76 is compressed from 101.3 kPa, 20ºC to a pressure of 600 kPa following the law $pV^{1.3}$=constant. Take specific heat at constant pressure of gas as 1.7 kJ/kgK.(Nov/Dec 17)(13 M)**BTL5 Answer**: Page 1.132 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Gas Constant R=$\frac{R_U}{M}$, = 0.468kJ/kgK (2M) Find $\gamma = Cp/Cv$ =1.38 (1M) find $T_2 = T_1(P_2/P_1)(n-1)/n$ =441.72k (2M) Work transfer W=$\frac{mR(T_1-T_2)}{n-1}$ =-232 kJ/kg (4M) $Q = \frac{(\gamma-n)}{(\gamma-1)}$W=-48.842 kJ/kg (4M) Ans: Q = -48.842 kJ/Kg
9	**A gas of mass 1.5 kg undergoes a quasi-static expansion which follows a relationship p= a+bV, where a and b are constants. The initial and final pressures are 1000 kPa and 200 kPa respectively and the corresponding volumes are 0.2 m^3 and 1.2 m^3. The specific internal energy of the gases is given by the relation u=1.5pv-85 kJ/kg. Where p is in kPa and V is in m^3. Calculate the net heat transfer and the maximum internal energy of the gas attained during expansion. (13M)**BTL5 **Answer : Page No 1.123 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** To find a=1160, b=-800 (2M) W=$\int_1^2 pdv = 600\ kJ$ (2M) Change in internal energy $\Delta U = U_2 - U_1$, =60kJ (3M) first law of thermodynamics, Q=W+ΔE=660 kJ (2M) Find U, differentiate U w.r.t. V du/dV=0 (2M) V=0.725 m^3, U_{max}= 503.25 kJ (2M)

Ans: Q = 660 kJ ;U_{max}= 503.25 kJ

10

In a gas turbine installation, the gases enter the turbine at the rate of 5 kg/s with a velocity of 50 m/s and enthalpy of 900 kJ/kg and leave the turbine with 150 m/s and enthalpy of 400 kJ/kg. The loss of heat from the gases to the surroundings is 25 kJ/kg. Assume R=0.285 kJ/kgK and inlet conditions to be at 100 kPa and 27°C. Determine the work done and diameter of the inlet pipe.. (13M).AU Apr'08BTL5

Answer :Page 1.147-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

Steady flow energy equation

$$m\left(u_1 + p_1v_1 + \frac{{C_1}^2}{2} + Z_1g\right) + Q = m\left(u_2 + p_2v_2 + \frac{{C_2}^2}{2} + Z_2g\right) + w,$$

W=2425 kW, (6M)

Ideal gas eq $p_1v_1=mRT_1,$ $v_1= 4.275m^3$ /s (3M)

Continuity equation $m = \frac{A_1C_1}{V_1},$ ➔d_1 = 1.89(4M)

Ans: W=; $d_1 = 1.89$

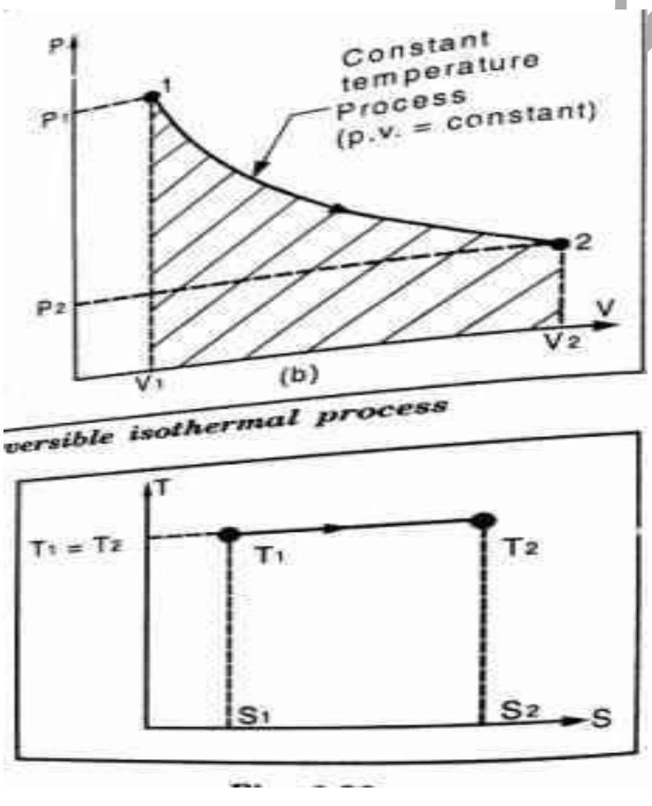
Part * C

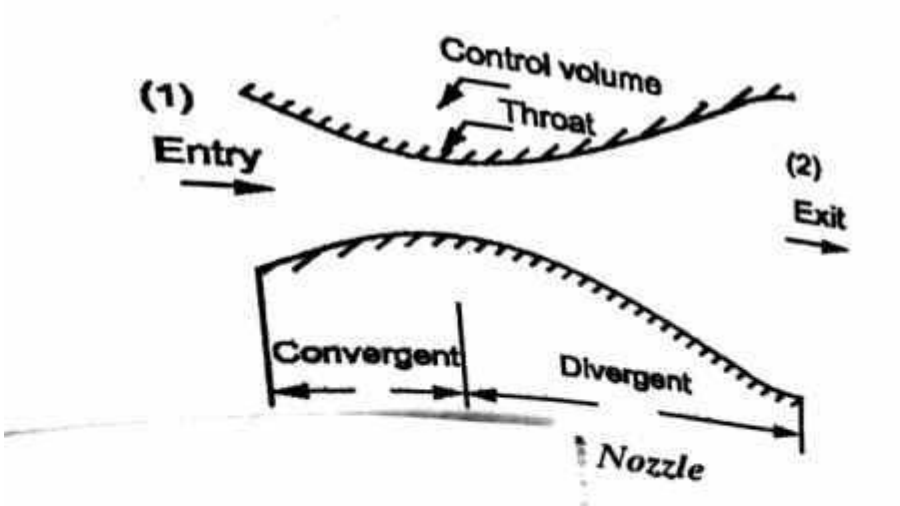
1

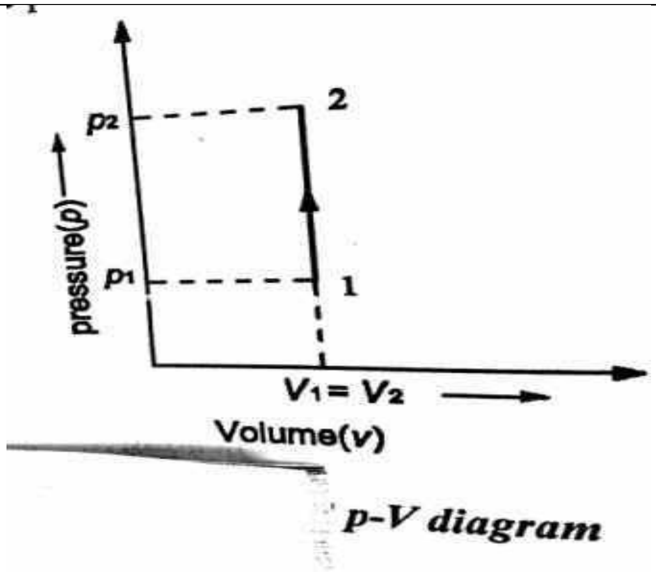
Derive the equation for the work done, change in internal energy, and heat transferred for the following process (i) Isothermal and Isentropic processes.(April/May 2018)(15M)BTL1

Answer : Page 1.59 & 1.61- Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

To draw p-v and T-s diagram (4M)



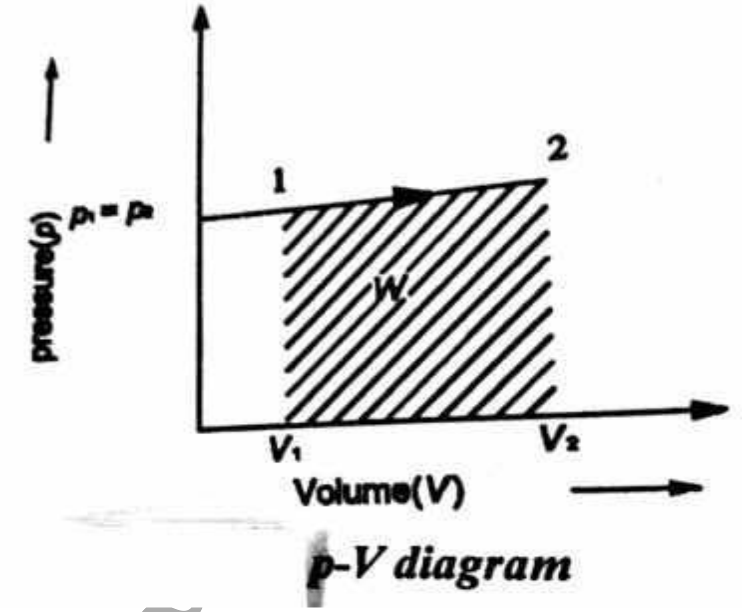
	Relation between p,V,T: $p_1v_1/T_1 = p_2v_2/T_2$(2M) Work done(W)= mRT $\ln(V_2/V_1)$ (3M) Change in internal energy= 0 (2M) Heat transferred(Q)= mRT $\ln(V_2/V_1)$ (2M) Change in Enthalpy= 0 (2M)
2	**Derive the general energy equation for a steady flow system and apply the equation to nozzle and derive an equation for velocity at exit. (Nov/Dec 2013) (15M)**BTL1 **Answer : Page 1.91 & 1.94-Dr.G.K.Vijayaraghavan &Dr.S.Sundaravalli** To draw Steady Flow system and Nozzle diagram (4M)  Energy entering and leaving the system equations m$\left(u_1+p_1v_1+\frac{C_1{}^2}{2}+Z_1g\right)+Q=m\left(u_2+p_2v_2+\frac{C_2{}^2}{2}+Z_2g\right)+w$(2M) First law of TD equating both $Q=W+\Delta E$ (3M) Applying SFEE to nozzle (W=0,Q=0, $z_1=z_2$) (2M) $C_2=\surd2(h_1-h_2$ (2M) Isentropicexpansion $C_2= \surd(2C_pT_1(1-(p_2/p_1)^{(\surd-1)} / ^{\surd} +C_1^2$ (2M)
3	**Derive the relationship between P,V and T for the following processes(i) Isobaric(ii) Isochoric (iii) Isothermal (iv) Isentropic and (v) Polytropic.(Nov/Dec 14)(15M)** BTL1 **Answer:Page1.56 to1.67 Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** For isochoric process p-v diagram(3M)



p-V diagram

$P_1/P2 = T1/T2$

For isobaric process, p-v diagram: (3M)



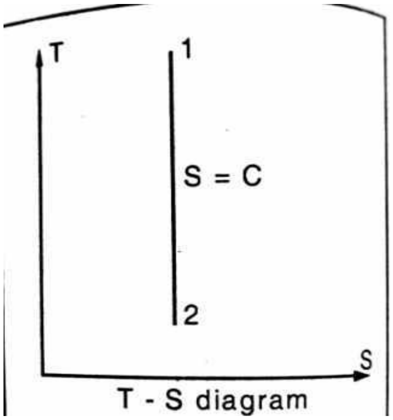
p-V diagram

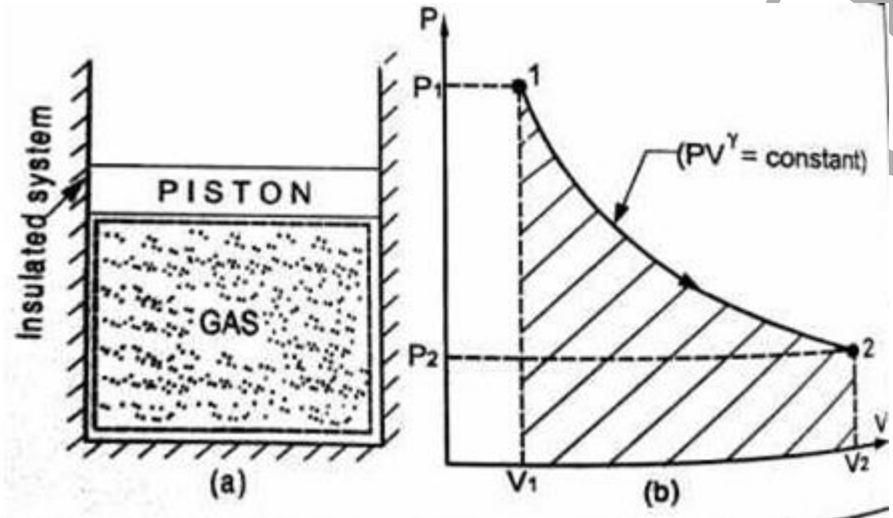
$V_1/V_2 = T_1/T_2$

For isothermal process-v diagram: (3M)

$P_1/P_2 = V_2/V_1$

For isentropic Process p-v diagram:

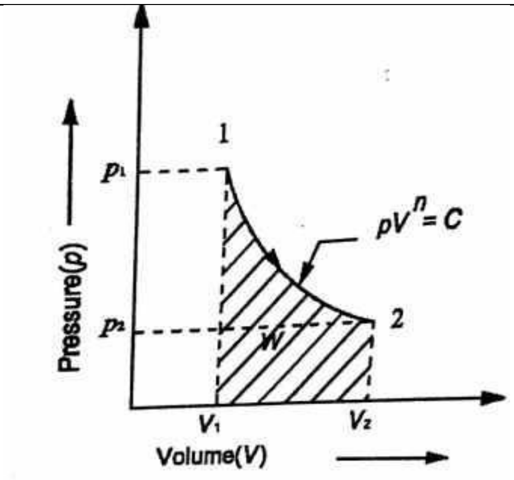


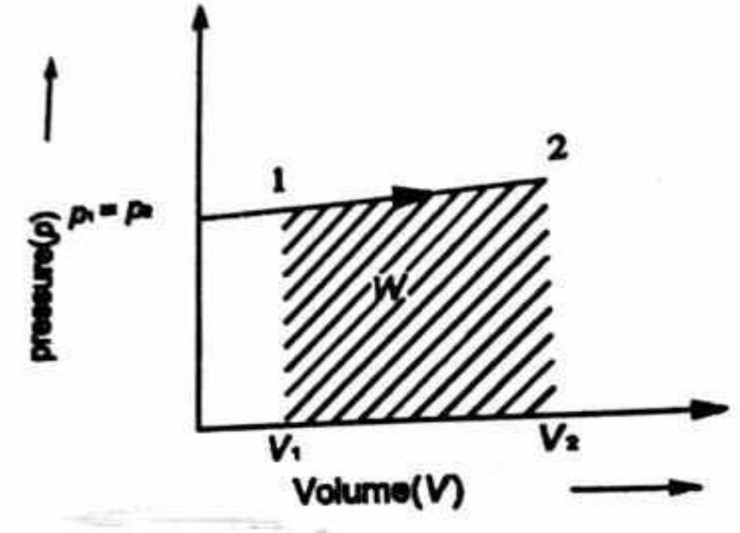


Reversible adiabatic process

$P_2/P_1 = (T_1/T_2)^{\surd/\surd-1}$ (3M)

For polytropic Process p-v diagram: (3M)

	 $P_1/P_2 = (V_2/V_1)^n$
4	**Derive the equation for the work done, change in internal energy, and heat transferred for the following process (i) Isobaric, (ii) Isochoric, (iii) Isothermal (iv) Isentropic and (v) Polytropic (Nov/dec15)(15M)**BTL1 **Answer:Page 1.56 to 1.67- Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** (i) For isochoric process p-v diagram, (3M) $W=0, \Delta U=mCv(T2-T1), Q=\Delta U, \Delta H= mCv(T2-T1)$ (ii) For isobaric process,p-v diagram: (3M)



p-V diagram

W= mR(T2-T1), ΔU= mCv(T2-T1), Q = mCp(T2-T1), ΔH = mCp(T2-T1)

(iii) For isothermal process,p-v diagram:

W=mRTln(V2/V1); ΔU=0,Q= mRTln(V2/V1); ΔH=0 (3M)

(iv) For polytropic Process p-v diagram:

W= mR(T1-T2)/(n-1); ΔU=mCv(T2-T1),Q =W[(√-n)/(√-1)] (3M)

(v)For isentropic Process p-v diagram: (3M)

W = mR(T1-T2)/(√-1); ΔU = mCv(T2-T1),,Q=0,ΔH = mCp(T2-T1)

5

The electric heating system used in many houses consists of a simple duct with resistance wire. Air is heated as it flows over resistance wires. Consider a 15 kWelectric heating system. Air enters the heating system at 100 kPa and 17ºC with a volume flow rate of 150 m^3/min. If heat is lost from the air in the duct to the surroundings at a rate of 200 W, determine the exit temperature of air. (15M)BTL5

Answer :Page 1.149- Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

To find specific volume of air at inlet by using ideal gas equation and mass of air,
$v_1 = RT_1/P_1 = 0.832 m^3/kg$,m=3kg/s (5M)
Steady flow energy equation

$$m\left(u_1 + p_1v_1 + \frac{{C_1}^2}{2} + Z_1g\right) + Q = m\left(u_2 + p_2v_2 + \frac{{C_2}^2}{2} + Z_2g\right) + w \qquad (7M)$$

	W_m-Q_{out} =m(h_2-h_1) ➔ T_2=21.9°C (3M)
6	**A gas occupies 0.3m3 at 2 bar. It executes a cycle consistingof processes** **(i) 1-2 constant pressure with work interaction of 15kJ** **(ii)2-3 compression process which follows the law pV=C andU3=U2 and** **(iii) 3-1, constant Volume process and reduction in internal energy is 40 kJ.** **Neglecting the changes in K.E and P.E .Draw p-V diagrams for the process and determine the net work transfer for the cycle.Also show that first law is obeyed by the cycle.** **(15M (Apr/May 2017)**BTL5 **Answer: Page 1.125 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Process 1-2 :Const pressure process $W_{1-2}=P(V_2-V_1) => V_2 = 0.375\ m^3$ (3M) Process 2-3 : Isothermal process W_{2-3} =P_2 V_2ln(V_3/V_2) = -16.736kJ (3M) Process 3-1 : Constant volume process W_{3-1} =0;Q_{3-1} =U_1 – U_3 =-40 kJ (3M) $\sum_{cycle}\Delta U$ =0; U_2 – U_1 =40 ; $\sum_{cycle}$ W = -1.766kJ (3M) Acc, to first law, $\sum_{cycle}$ W = $\sum_{cycle}\Delta U$ (3M) Hence verified.

UNIT II SECOND LAW AND AVAILABILITY ANALYSIS

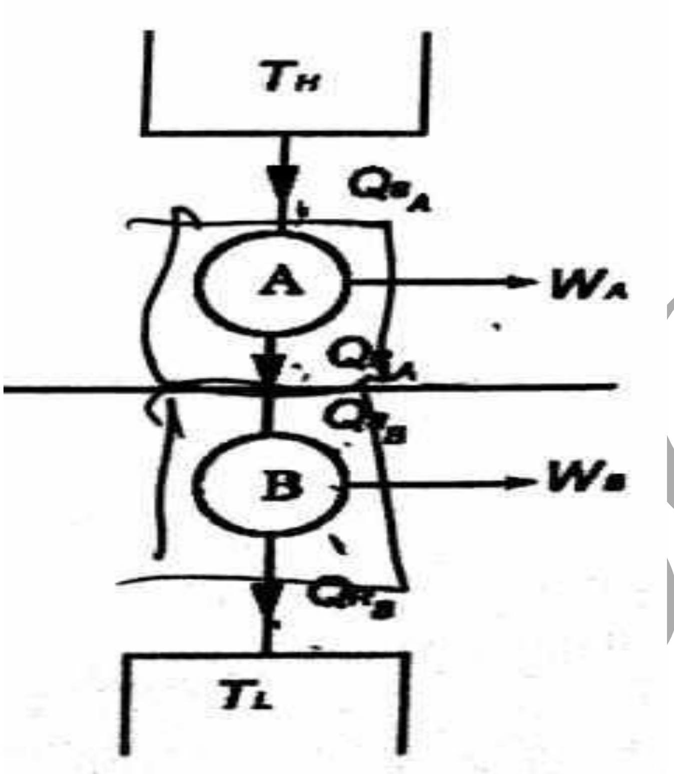
Heat Reservoir, source and sink. Heat Engine, Refrigerator, and Heat pump. Statements of second law and its corollaries. Carnot cycle Reversed Carnot cycle, Performance. Clausius inequality. Concept of entropy, T-s diagram, Tds Equations, entropy change for - pure substance, ideal gases - different processes, principle of increase in entropy. Applications of II Law. High and low grade energy. Available and non-available energy of a source and finite body. Energy and irreversibility. Expressions for the energy of a closed system and open systems. Energy balance and entropy generation. Irreversibility. I and II law Efficiency.

Q.No	Part *A
1.	**State the Kelvin – Planck statement of second law of thermodynamics. (May/June 2014)**BTL1 Kelvin – Planck states that it is impossible to construct a heat engine working on a cyclic process, which converts the entire heat energy supplied to it into equivalent amount of useful work.
2	**State Clausius statement of Second law of Thermodynamics.(April/May 2015)** BTL1 It states that heat can flow from hot body to cold body without any external aid but heat cannot flow from cold body to hot body without any external aid.

3	**State Carnot's theorem.(May/June 2014)** BTL1 No heat engine operating in a cyclic process between two – fixed temperatures can be more efficient that a reversible engine operating between the same temperature limits.
4	**Give the Corollaries of Carnot theorem. (May/June 2014)** BTL2 All the reversible engines operating between the two given thermal reservoirs with fixed temperature have the same efficiency. The efficiency of any reversible heat engine operating between two reservoirs is independent of the nature of the working fluid and depends only on the temperature of the reservoirs.
5	**Define – PMM of second kind. (PMM-II).** BTL1 Perpetual motion of second kind draws heat continuously from single reservoir and converts it into equivalent amount of work. Thus it gives 100% efficiency.
6	**Differentiate between a heat pump and refrigerator.** BTL2 Heat pump is a device which is operated in a cyclic process, maintains the temperature of a hot body at temperature higher that the temperature of surrounding. A refrigerator is a device which operating in a cycle process maintains the temperature of a cold body temperature lower than the temperature of the surrounding.
7	**Define the term COP.** BTL1 Coefficient of performance is defined as the ratio of heat extracted or rejected to work input. $\text{COP} = \frac{\text{Heat extracted rejected}}{\text{Work input}}$
8	**Write the expression for COP of a Heat pump and a Refrigerator.** BTL1 Coefficient of Performance - COP of heat pump: $\text{COMP}_{\text{HP}} = \frac{\text{Heat rejected}}{\text{Work input}} = \frac{T_2}{T_2 - T_1}$ COP for refrigerator $\text{COP}_{\text{ref}} = \frac{\text{Heat extracted}}{\text{Heat input}} = \frac{T_1}{T_2 - T_1}$
9	**Why Carnot cycle cannot be realized in practice?** BTL4 i) In a Carnot cycle all the four processes are reversible but in actual practice there is no process which is reversible. ii) There are two processes to be carried out during compression and expansion. For isothermal process the piston moves very slowly and for adiabatic process the piston moves as fast as possible. This speed variation during the same stroke of the piston is not possible. **iii)** It is not possible to avoid friction between moving parts completely.
10	**Name two alternative methods by which the efficiency of a Carnot cycle can be increased.** BTL6 Efficiency can be increased as the higher temperature T_2 increases. Efficiency can be increased as the lower temperature T_1 decreases.
11	**Why a Heat engine cannot have 100% efficiency?** BTL4 For all the heat engines there will be a heat loss between system and surroundings. Thereforethe entire heat input supplied to the engine cannot be converted into useful work.

12	**Write the processes involved in Carnot cycle.** BTL2 Carnot cycle consist of i) Reversible adiabatic compression. ii) Reversible isothermal heat addition. iii) Reversible adiabatic expansion. **iv)** Reversible isothermal heat rejection.
13	**Write the expression for efficiency of the Carnot cycle.** BTL1 Carnot efficiency: $\eta_{\text{Carnot}} = \frac{T_2 - T_1}{T_2}$
14	**Is the second law independent of first law? Explain.** BTL4 Yes. The second law speaks about the quality of energy and the first law is based on energy interactions.
15	**Define entropy.(Apr/May 18)**BTL1 Entropy is an index of unavailability or degradation of energy. đS= đQ/T (kJ/kgK)
16	**Define the terms source, sink and heat reservoir.(April/May2015)**BTL1 **Source:** The part where the heat to be rejected to absorbing or work developing device is called Source. **Sink:** The part which receives heat from work absorbing or working developing device is called Sink. **Reservoir:** The part which supplies or receives heat continuously without change in its temperature is called as Reservoir.
17	**Explain in short the principle of Increase of Entropy. (Nov/Dec17)** BTL2 For any infinitesimal process undergone by a system, change in entropy, dS>dQ/T For reversible dQ = 0, hence, dS=0 For irreversible dS>0 So the entropy of an isolated system would never decrease. It will always increase and remains constant if the pressure is reversible is called as Principle of increase of Entropy.
18	**State "Clausius Inequality".** BTL2 It is impossible for a self-acting machine working in a cyclic process unaided by any external agency to convey heat from a body at a low temperature to a body at a higher temperature.
19	**Explain briefly Clausius Inequality.** BTL1 $\oint \frac{dQ}{T} \leq 0$ is known as Inequality of Clausius. If 1. $\oint \frac{dQ}{T} = 0$ the cycle is reversible. 2. $\oint \frac{dQ}{T} < 0$, the cycle is irreversible and possible . 3. $\oint \frac{dQ}{T} > 0$, the cycle is impossible (Violation of second law).
20	**A heat pump pumps 10MJ/KW-hr to the high temperature reservoir. Find its C.O.P ?** BTL5 C.O.P. = $\frac{\text{Heat Supplied}}{\text{Work input}}$

	$= \frac{10\times10^3}{3600} = 2.78$
21	**Find the entropy of universe when 1000 KJ of heat is transferred from 800K to 500K?**BTL5 Entropy of universe, $\Delta S_{univ} = \frac{-Q}{T_1} + \frac{Q}{T_2}$ $= \frac{-1000}{800} + \frac{1000}{500}$ $= 0.75KJ/K$
	Part * B
1	**A reversible heat engine operating between reservoirs at 900K and 300K drives a reversible refrigerator operating between reservoirs at 300K and 250K. The heat engine receives 1800kJ heat from 900K reservoir. The net output from the combined engine refrigerator is 360kJ.Find the heat transferred to the refrigerator and the net heat rejected to the reservoir at 300K.(13M)(Apr/May 2015**) BTL3 **Answer:Page: 2.20 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** $\eta_{max} = \frac{T_H - T_L}{T_H} =$ 66.6% (3M) $\eta_{max} = \frac{W_1}{Q_{S_1}} = 0.66$, $W_1 = Q_{s1} * \eta_{max}$(3M) $W_1 = Q_{S_1} - Q_{R_1}$ =>$Q_{R_1} = 600$kJ $W_2 = Q_{S_2} - Q_{R_2}$ (3M) $COP_{ref} = \frac{T_L}{T_H - T_L} = \frac{Q_{R_2}}{Q_{S_2} - Q_{R_2}}$=5(2M) Q_{R_2}/ W_2 = 5 ; W_2 =840kJ =>Q_{R_2}= 4200kJ $W_2 = Q_{S_2} - Q_{R_2}$=>$Q_{S_2} = 5040$kJ $Q_{R_1} + Q_{S_2} = 5640kJ$ (2M) Ans:Q_{S_2}=5040kJ ,Q_{R_1}+Q_{R_2} =5640kJ
2	**Two Carnot engines A and B are operated in series. The first one (A) receives heat at 870K and rejects heat to a reservoir at temperature T. The second engine (B) receives the heat rejected by the first engine and in turn rejects to a heat reservoir at 300K. Calculate the intermediate temperatures T in ºC between two heat engines for the following cases.(13M)(Nov/Dec 2013)** BTL3 **(i) The work output of the two engines are equal.** (ii) **The efficiencies of the two engines are equal** **Answer:Page: 2.25 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Diagram (3M)



Case(i) $W_A = W_B, W_A = Q s\text{b} - Qrb$; W_B= Q_{SB} – Q_{RB}

2Q_{RA} = Qsa +Q_{RB}= 870+300 =585K

$W_A = W_B$, T=312ºC (5M)

Case(ii)$\eta_A = \eta_B$,

$\eta_A = W_A\ /Qsa$ = (870-T/870)

$\eta_b = \ W_b\ /Qsb$ = (T-300/T)

T=237.88ºC(5M)

Ans: T=312˚C and T=237.88˚C

3

An inventor claims that his proposed engine has the following specification: Power developed = 50 kW, fuel burnt = 3kg/hr, Calorific value of the fuel = 75000 kJ/kg, Temperature limits =27ºC and 627ºC. Find out whether it is possible or not.(13M)(Nov/Dec2016)BTL3

Answer:Page: 2.16 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

Heat supplied to the engine = Fuel burnt * CV

Qs = m * C.V = 62.5 kW (5M)

$\eta_{Carnot} = \frac{T_H - T_L}{T_H}$=66.6% (4M)

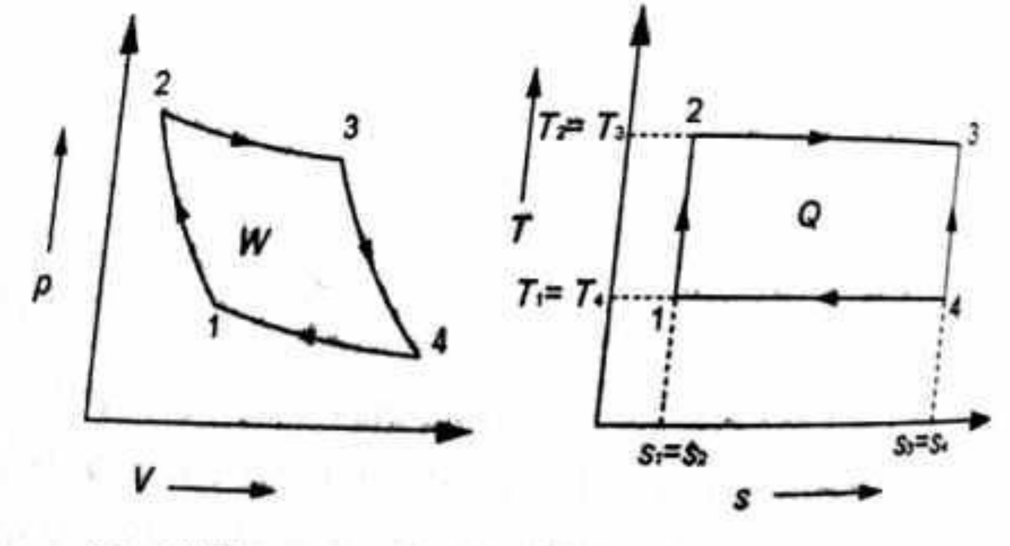
$\eta_{CActual} = \frac{Workdone}{Heat\ supplied} = \frac{W}{Q_S} = 80\%$ (2M)

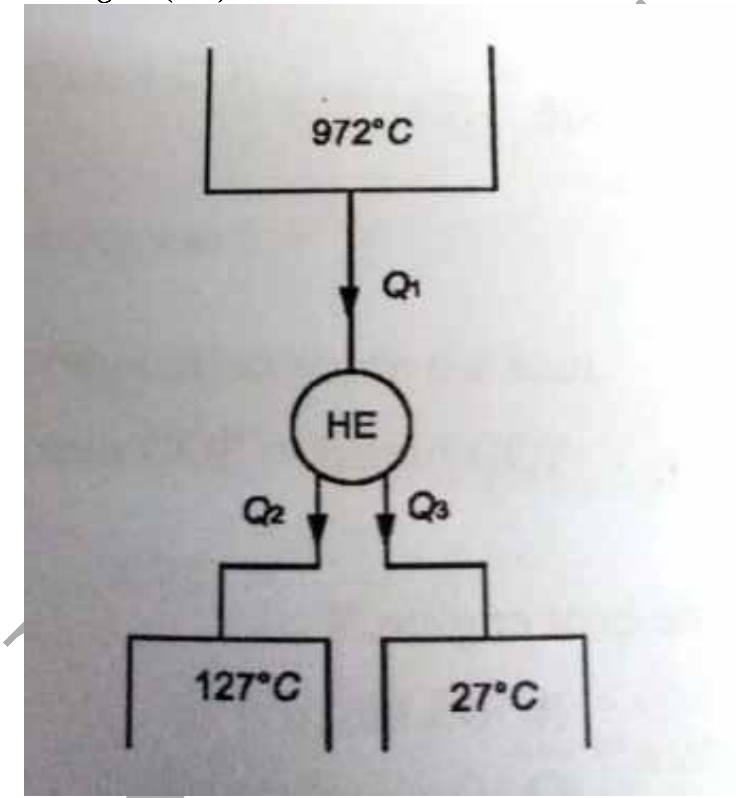
Ans: Here the inventor’s claim engine has higher efficiency than maximum engine efficiency which is impossible. (2M)

4

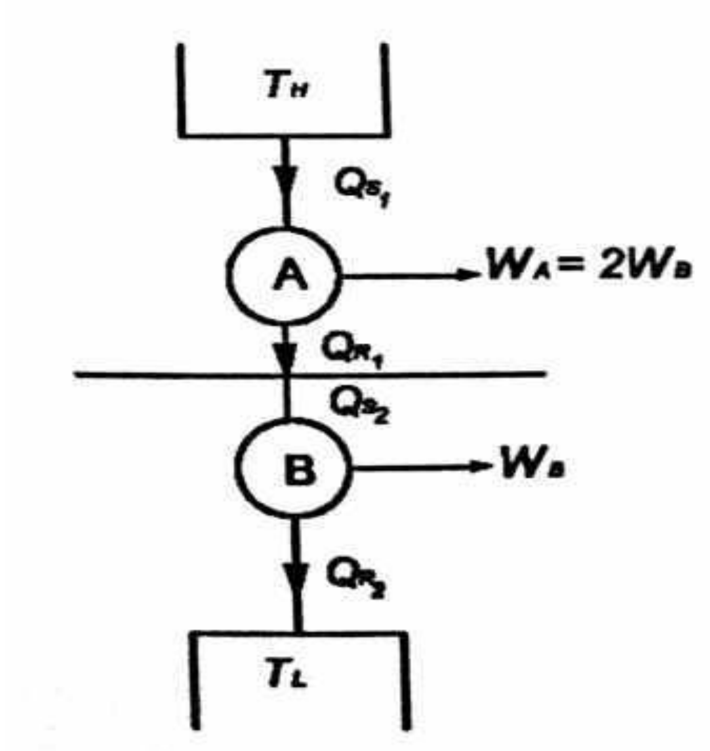
1.6 kg of air compressed according to the law $pV^{1.3}$ = C from a pressure of 1.2 bar and temperature of 20ºC to a pressure of 17.5 bar. Calculate (a) the final volume and temperature (b) work done (c) heat transferred and (d) change in entropy. (13M)BTL5

Answer : Page: 2.51 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

	From general gas equation :$p_1V_1=mRT_1$ $V_1= mRT_1 /p_1 =1.121$ m^3, (2M) $p_1V_1^{1.3} = p_2V_2^{1.3}$ =>V_2=0.1427 m^3(2M) From Polytropicrelation: $T_2 = T_1 *(p_2 /p_1)^{(n-1) / n}$ (a) V_2= 0.1427m^3;$T_{2==}$543.82K, (2M) (b)Work done$W = \frac{p_1v_1-p_2v_2}{n-1}$= -384.02 kJ (2M) (c) Heat transfer Q = W(√-n/√-1) (2M) (d) Change in entropy $\Delta s = mRl_n\frac{V_2}{V_1} + mC_vl_n\frac{T_2}{T_1}$ = 1.657 kJ/K (3M) Ans: V_2=0.1427 m^3, T_2=543.82 K , W=-384.02 kJ , Q = -96 kJ.
5	**A single stage air turbine is to operate with air inlet pressure and temperature of 1 bar and 600K. During the expansion, the turbine losses are 20 kJ/kg to the surroundings which is at 1 bar and 300 K. For 1 kg of mass flow rate determine (i) decrease in availability (ii) maximum work (iii) the irreversibility.(13M)**BTL5 **Answer: Page: 2.73 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Change in entropy $\Delta s = mC_pl_n\frac{T_2}{T_1} + Rl_n\frac{P_2}{P_1}$ =-0.697 kJ/K (4M) (i)Decrease in availability, $\psi_1 - \psi_2 = m[(h_1 - h_2) - T_0(S_1 - S_2)]$ (ii)W max = 510.6KJ/kg (3M) From SFEE, h_1 + Q = h_2 + W => W = 281.5 kJ/kg (3M) (iii)Irreversibility I = $W_{max} - W$ = 229.1kJ/kg (3M) Ans:Δs = -0.697 kJ/K, $\psi_1 - \psi_2$ =510.6KJ/kg, I= 229.1kJ/kg
6	**In a Carnot cycle the maximum pressure and temperature are limited to 18 bar and 410°C. The volume ratio of isentropic compression is 6 and isothermal expansion is 1.5. Assume the volume of the air at the beginning of isothermal expansion as 0.18 m^3. Show the cycle on p-V and T-s diagrams and determine the pressure and temperature at main points and Thermal efficiency of the cycle. (13M)**BTL5 **Answer : Page 2.77-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Draw p-V and T-s diagram (2M)  (a) p-V diagram (b) T-s diagram Process 1-2: Isentropic Compression

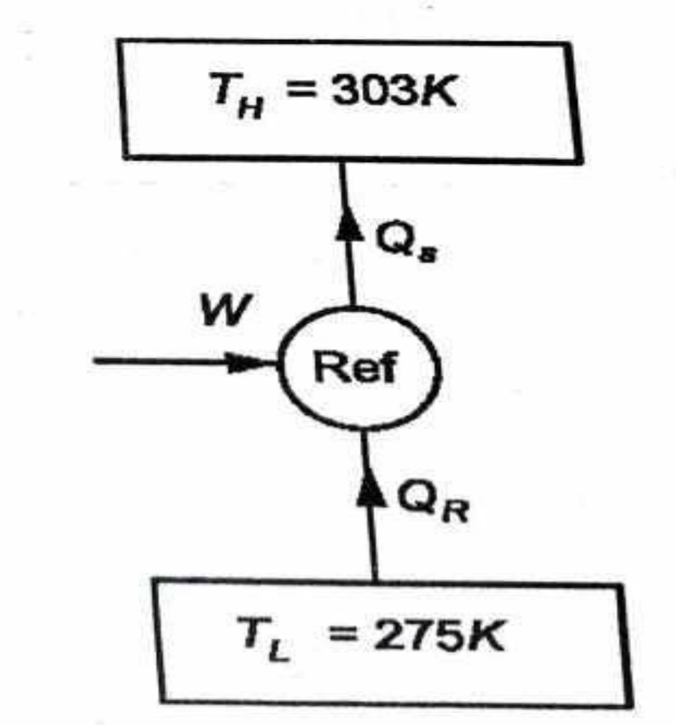
	$T_2/T_1 = (V_1/V_2)^{\gamma -1} =$ 333.55 K (2M) $T_1 = T_4$; $p_2 / p_1 = (V_1/V_2)^{\gamma}$, p_1= 1.46 bar (2M) Process 2-3:Isothermal expansion process $p_2V_2= p_3V_3$,p_3=12 bar(2M) Process 3-4:Isentropic Expansion $p_3V_3^{\surd}= p_4V_4^{\surd}$,$p_4$= 0.977 bar(2M) Heat supplied $Q_s = p_2V_2 \ln(V_3/V_2)$= 131. 37 kJ (1M) Heat Rejected$Q_r = p_4V_4 \ln(P_1/ P_4)$= 63.341 kJ (1M) Thermal efficiency $\eta = \frac{Q_S-Q_R}{Q_S}$ = 51.78 % (1M) Ans:Q_s =131. 37 kJ, Q_r =63.341 kJ, η =51.78 %
7	**A reversible engine operates between a source at 972ºC and two sinks, one at 127ºC and another at 27ºC. The energy rejected is same at both the sinks. What is the ratio of heat supplied to the heat rejected? Also calculate the efficiency.** **(13 M)(May/June 2016)**BTL5 **Answer: Page :2.84- Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** Flow diagram(3M)  Condition :$Q_2=Q_3$; $Q_1 = Q_2 + Q_3 = 2\ Q_2$ =1.78 (4M) $\eta = \frac{Q_1-(Q_2+Q_3)}{Q_1}$ = η =43.82 % (6M)
8	**A Carnot heat engine takes heat from an infinite reservoir at 550ºC and rejects it to a sink at 275ºC. Half of the work delivered by the engine is used to run generator and the other half is used to run heat pump which takes heat at 275ºC and rejects it at 440ºC. Express the heat rejected at 440ºC by the heat pump as % of heat supplied to the engine at 550ºC. If the operation of the generator is 500 kW, find the heat rejected per hour by the heat pump at 440ºC.(13M)**BTL5

	Answer : Page: 2.90 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli. For Carnot Heat engine $\frac{Q_{S_1}}{T_1} = \frac{Q_{R_1}}{T_2}$ = 1.502Q_{r1}(3M) W_{HE}= $Q_{S_1} - Q_{R_1}$, =0.502Q_{r1}(3M) Generator input = W/2=Work input to the heat pump = 0.251 Q_{r1}(3M) Heat rejected by the heat pump, $\frac{Q_{R_2}}{Q_{S_1}}$= Q_{S_1}+0.251 Q_{r1}(3M) $Ans: Q_{S_1} = 2992.03\ kW, Q_{R_2} = 7830.74\ MJ/hr$ (1M)
9	**A metal block with m=5kg,C=0.4 kJ/kgK at 40ºC is kept in a room at 20ºC.It is cooled naturally. In each case, calculate the change in entropy of the block, of the air of the room and of the universe. Assume that the metal block has constant specific heat. (13M)**BTL5 **Answer : Page: 2.114 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** Heat absorbed by air = Heat released by the metal block δQ= m C(T_1-T_2)(3M) entropy change of the block=$\int_{313}^{293} mc\frac{dT}{T}$ = -0.132kJ/K(3M) Entropy change of atmosphere = $\frac{\delta Q}{T} = 0.1365\frac{kJ}{K}$(2M) Entropy of the universe = 0.0045 kJ/K (3M) Cooling using Carnot engine: $\eta_{Carnot} = \frac{T_H - T_L}{T_H}$ = W/ δQ W = 2.556 kJ (2M) Ans:ΔS=-0.132kJ/K, ΔQ $_{air}$= $0.1365\ kJ/K$, ΔQ $_{univ}$= 0.0045 kJ/K
10	**One kg of air is contained in a piston cylinder assembly at 10 bar pressure and 500 K temperature. The piston moves outwards and the air expands to 2 bar pressure and 350K temperature. Determine the maximum work obtainable, Assume the environmental conditions to be 1 bar and 290 K. Also make calculation for the availability in the initial and final states. (13M)(Nov/Dec 2014)**BTL5 **Answer : Page: 2.117-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Availability in the initial state$\psi_1 = m\left\{C_pT_1 - T_0\left[C_pln\left(\frac{T_1}{T_0}\right) - Rln\left(\frac{P_1}{P_0}\right)\right]\right\}$(5M) Availability in the final state$\psi_2 = m\left\{C_pT_2 - T_0\left[C_pln\left(\frac{T_2}{T_0}\right) - Rln\left(\frac{P_2}{P_0}\right)\right]\right\}$(5M) Maximum work = $\psi_1 - \psi_2$ =180.75 (3M) Ans:$\psi_1 = 535.38kJ$,ψ_2= $354.63\ kJ$,W_{max} = $180.75\ kJ/kg$
	Part * C
1	**An office room which was heated by electric resistance heater consumed 1200 kW-hr of electrical energy in a winter month. Instead of this heater if the same office room is heated by a heat pump which is having 20% of COP of the ideal Carnot pump. The room temperature is 24ºC while surrounding is at 0ºC. If heat supplied from the surrounding by the heat pump is 0.65 kJ, determine COP and money saved per month. Assume cost of electricity is Rs. 1.75 kW/hr.(15M)**BTL5 **Answer : Page: 2.27 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** Electricity using electric heater = 1200 * 1.75 = Rs. 2100 / month (1M) $COP_{HP} = \frac{T_H}{T_H - T_L} = 12.375$(3M) COP of heat pump = 20% of COP of Carnot Pump(3M)

	$W = Q_s / COP = 0.26$ kW (3M) Power required by heat pump in kW-hr= work done* 3600= 945.45 (2M) Electricity charge for running heat pump = P * 1.75 = Rs. 1654.50(3M) Ans:Money saved per month= Rs. 445.50
2	**Two reversible heat engines A and B are arranged in series. A rejecting heat directly to B. engine receives 200 kJ at a temperature of 421°C from a hot source, while engine B is in communication with a cold sink at a temperature of 4.4°C, if the work output of A is twice that of B, find (i) The intermediate temperature between A and B, (ii) The efficiency of each engine, and (iii) The heat rejected to the cold sink. (15M)(Nov/Dec 2013)**BTL5 **Answer : Page: 2.80 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** Flow diagram (3M)  Work output from engines , $W_A = Q_{s1} - Q_{R1}$; $W_B = Q_{s2} - Q_{R2}$(2M) For Reversible engine B, $T/T_L = Q_{s2} / Q_{R2}$ (i) T=143.42C $Q_{R_1} = 119.93\ kJ, Q_{R_2} = 79.89\ kJ$ (4M) (ii) $\eta_A = 1 - Q_{R1} / Q_{s1} =$40.04 % (4M) $\eta_B = 1 - Q_{s2} / Q_{R2} =$ 33.39 % (2M) (iii) $Q_{R_1} = 119.93\ kJ, Q_{R_2} = 79.89\ kJ$
3	**A house hold refrigerator is maintained at a temperature of 275K. Every time the door is opened, warm material is placed inside, introducing an average of 420 kJ, but making only small changes in the temperature of the refrigerator. The door is opened 20 times a day, and the refrigerator operates at 15% of the ideal COP. The cost of work is 2.50 per kW/hr. What is the bill for the month of April for this refrigerator? The atmosphere is at 303K.(15M)(Apr/May 2015)** BTL5

Answer :Page : 2.87 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

Flow diagram(3M)



$COP_{ref} = \frac{T_L}{T_H - T_L} = 9.82$ (3M)

Actual COP of Ref. = 15% of COP of Carnot Ref. (3M)

Work done $= \frac{Q_{R_1}}{cop} = 0.066$ kW= 237.6 kW-hr (3M)

Electricity charge for running heat pump= 237.6*2.50= Rs. 594 (3M)

Ans: Electricity charge = Rs. 594

4

5 kg of air at 2 bar and 30°C is compressed to 24 bar pressure according to the law $pV^{1.2}$ = Constant. After compression of air is cooled at constant volume to 30°C. Determine(i)volume and temperature at the end of compression (ii) change of entropy during compression (iii) Change in entropy during constant volume cooling.TakeC_p=1.005kJ/kgK, C_v=0.718kJ/kgK.(15M)(Nov/Dec 2014)BTL5

Answer: Page:2.103- Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli

$pV^{1.2} = C \Rightarrow p_1v_1^{1.2} = p_2 v_2^{1.2}$ (1M)

m= pv/Rt = 1.2 kg (2M)

Characteristic Gas equation :

pV = mRT =>V_1= 2.17 m^3, V_2= $(p_1/p_2)^{1.2-1/1.2}$*V1=0.274 m^3(3M)

$T_2=(p_2/p_1)^{0.2/1.2}$ = 185.47C (3M)

(i) V_2= 0.274m^3 ,T_2 = 185.47°C

(ii) Change in entropy during compression,

S_2-S_1=$\Delta s = mRl_n \frac{V_2}{V_1} + mC_v l_n \frac{T_2}{T_1}$= -1.483kJ/K(3M)

(iii) Change in entropy S_3-S_1= $mC_v l_n \frac{T_3}{T_2}$ = - 1.487 kJ/K (3M)

Ans: $\Delta s =$ -1.483 kJ/K, S_3-S_1 =- 1.487 kJ/K

5	**One kg of ice at -5ºC is exposed to the atmosphere which is at 20ºC.The ice melts and comes into thermal equilibrium with the atmosphere (i) Determine the entropy increase of the universe. (ii) What is the minimum amount of work necessary to convert the water back to ice at -5ºC? Assume Cp for ice as 333.3 kJ/kg.(15M)(Apr/May2018)** BTL5 **Answer :Page: 2.111 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli**. Heat absorbed by air from atmosphere= Heat absorbed in solid phase + Latent heat + Heat absorbed in liquid phase $\delta Q=mC_{pi}(T_0 - Ti) + mL + mC_{pw}(T_a - T_0) = 427.535$ kJ (4M) Entropy change of atm. = -1.46 kJ/K (3M) Entropy change of system = $\Delta S_{ice} + \Delta S_{fusion} + \Delta S_{liquid} =$1.556 kJ/K (3M) (i)Entropy of universe =ΔS_{univ} = 0.096 kJ/K (2M) If water is to be converted back to ice using a reversible refrigerator, heat to be removed from water. $\Delta S_{Univ} = \Delta S_{sys} + \Delta S_{ref} + \Delta S_{atm} \geq 0$ (ii)$Q+W \geq 445.908\ kJ$, W_{min} = 28.373 KJ(3M) Ans: Δs_{univ} =0.096 kJ/K , W_{min} = 28.373 KJ

UNIT III PROPERTIES OF PURE SUBSTANCE AND STEAM POWER CYCLE

Formation of steam and its thermodynamic properties, p-v, p-T, T-v, T-s, h-s diagrams. p-v-Tsurface. Use of Steam Table and Mollier Chart. Determination of dryness fraction. Application of I and II law for pure substances. Ideal and actual Rankine cycles, Cycle Improvement Methods - Reheat and Regenerative cycles, Economizer, preheater, Binary and Combined cycles.

Q.No	Part-A
1.	**Define latent heat of ice.** BTL1 It is defined as the total amount of heat added during conversion of ice of 0^0C into water of 0^0C.
2	**Write about pure substance.(Nov/Dec 2013)**BTL2 Pure substance is a substance which has a fixed chemical composition throughout its mass. Examples: Water, Nitrogen, Carbon dioxide, and Helium. A pure substance does not have to be of single chemical element or compound. A mixture of various chemical elements or compounds is also called as a pure substance as long as the mixture is homogeneous.
3	**Define Saturation Temperature and Saturation Pressure.** BTL2 At a given pressure, the temperature at which a liquid boils is called the Saturation Temperature. At a given temperature, the pressure at which the liquid boils is called the Saturation Pressure. It is also called as Vapour Pressure.
4	**Define latent heat of vaporization.**BTL1 The amount of heat added during heating of water from boiling point or dry saturated stage is called as Latent Heat of Vaporization or Enthalpy of Vaporization or latent heat of steam.
5	**Find the Saturation temp and latent heat of vaporization of steam at MPa.**BTL5 From steam table of 1 MPa or 10 bar Saturation temperature, $T_{sat} = 179.88^0$C Latent heat of vaporization, h_{fg} = 2013.6 kJ/kg

6	**Define the terms 'Boiling point' and 'Melting point'.** BTL1 **Boiling point:**It is the temperature at which the liquid starts to change its state from liquid to vapor. **Melting point:**It is the temperature at which the solid starts to change its state from solid to liquid.
7	**Write a short note on Superheated steam and indicate its use.**BTL2 Superheated Steam is the condition in which the dry steam is further heated, this process is called Superheating and the steam obtained is known as Superheated steam. **Uses:** 1. Superheated steam has more heat energy and more work can be obtained using it. 2. Thermal efficiency increases as the temperature of superheated steam is high. **3.** Heat losses be to condensation of steam a cylinder wall is reduced.
8	**Define Sensible heat of water.** BTL1 The amount of heat required to raise the temperature of unit mass of water from 0^0C to the saturation temperature under a constant pressure. It is denoted by h_f.
9	**Define the term "Super heat enthalpy".** BTL1 The heat supplied to the dry steam at saturation temperature to convert it into superheated steam at the temperature T_{sup} is called Superheat Heat of Enthalpy.
10	**Define Wet and Dry steam.** BTL2 The steam which partially evaporated and having water particles in suspension is called Wet Steam. The steam which is completely in evaporated state without any water particles is called Dry steam.
11	**State Phase rule of pure substances. (May/June 2016)**BTL1 The number of independent variables associated with a multi component, multiphase system is given by the phase rule. It is also called as Gibbs phase rule. It is expressed by the equation as $n = C - \varphi + 2$ Where, n = the number of independent variable. C = the number of components. φ = the number of phase present in equilibrium.
12	**Define Dryness fraction of Steam and Quality of steam.**BTL1 It is defined as the ratio of the mass of the total steam actually present to the mass of the total mixture steam. Dryness fraction = $\frac{\text{mass of dry stream}}{\text{mass of toal mixture}}$
13	**Define the terms Degree of super heat, Degree of sub-cooling.**BTL1 **Degree of Superheat:** It is the difference between superheated temperatures and saturated temperature at the same pressure. **Degree of Sub-Cooling:** It is the amount of which the water is cooled beyond the saturated temperature at the same pressure.
14	**Define Triple point and Critical point for pure substance. (Nov/Dec 2013)**BTL1

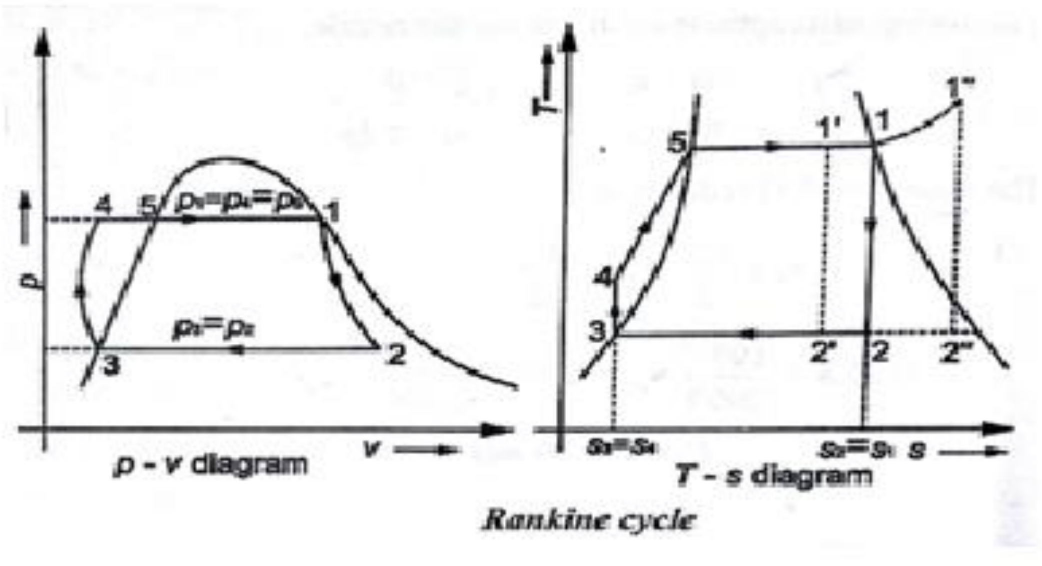
	Triple point: Triple point is the state at which all the three phases i.e.solid, liquid and vapour to exist in equilibrium. **Critical point:** It represents the highest pressure and temperature at which the liquid and vapour phases coexist in equilibrium. At the critical point the liquid and vapour phases are indistinguishable i.e. Liquid is directly converted into vapour.
15	**Write the formula for calculating entropy change from saturated water to superheat steam condition.** BTL3 Entropy of Superheated steam, $S_{sup} = S_g + C_{ps} \log_c \left(\frac{T_{sup}}{T_s} \right)$ where S_g – entropy of dry steam T_{sup}-Super heated temperature T_s-Saturated temperature C_{ps}-Specific heat of super heated steam
16	**Determine the condition of steam of 2 bar whose entropy is 6.27 KJ/kg.** BTL5 From steam Table at 2 bar s_g=7.1268 kJ/Kg K Since entropy of given steam of pressure 2 bar is less than entropy of dry steam at that pressure, the steam is in wet condition.
17	**Determine specific enthalpy and specific entropy of 120^0 C saturated steam.** BTL5 From steam table at 120^0C Specific enthalpy, h_g=2706kJ/kg Specific entropy, s_g =7.1293 kJ/kgK
18	**Find the mass of 0.1 m^3 of wet steam at a temperature of 160^0 and 0.94 dry.** BTL5 From steam table at 160^0C V_g=0.30676 m^3/kg Specific volume of wet steam = x,v_g=0.94x0.30676 m^3/kg =0.2884 m^3/kg $Mass\text{ of steam, m=}\frac{\text{Volume of given west steam}}{Specific\text{ volume of wet steam}} = \frac{0.1}{0.2884}$ $M = 0.35kg$
19	**One kg of steam at 10 bar has an enthalpy of 2500kJ/kg. Find its quality.** BTL5 H=2500kJ/kg $H = h_r + x \times h_{fg}$ At 10 bar from steam tables H_f = 762.6kJ/kg;h_{fg}=2013.6kJ/kg $\therefore$2500=762.6+x+2013.6 $x = \frac{2500-762.6}{2013.6} = 0.862$
20	**Define the term Efficiency ratio.** BTL1 The ratio of actual cycle efficiency to that of ideal cycle efficiency is termed efficiency ratio.

	Efficiency ratio = $\frac{\text{Actual cylcle efficiency}}{\text{Ideal rankine efficiency}}$
21	**Define the term Isentropic efficiency.** BTL2 For an expansion process Isentropic efficiency = $\frac{\text{Actual work done}}{\text{Isentropic work done}}$ For an compression process Isentropic efficiency = $\frac{\text{Isentropic work done}}{\text{Actual work done}}$
22	**Give the effects of Condenser pressure on the Rankine Cycle.** BTL2 By lowering the condenser pressure, we can increase the cycle efficiency. The main disadvantages are lowering the backpressure is to increases the wetness of steam. Isentropic compression of wet vapour is very difficult.
23	**Mention the improvements made to increase the ideal efficiency of Rankine Cycle.** BTL3 1. Lowering the Condenser pressure. 2. Superheated steam is supplied to the turbine. 3. Increasing the boiler pressure to certain limit. **4.** Implementing reheat and regeneration in the cycle.
24	**List the advantages of Reheat cycle.** BTL2 1. Marginal increase in thermal efficiency. 2. Increase in work done per kg of steam which results in reduced size of boiler and auxiliaries for the same output. **3.** It prevents the turbine from erosion.
25	**Give the function of feed water heaters in the Regenerative cycle with bleeding.** BTL2 The main function of feed water heater is to increase the temperature of feed water to the saturation temperature corresponding to the boiler pressure before it enters into the boiler.
Part * B	
1	**One kg of steam contains 1/3 liquid and 2/3 vapour by volume. The temperature of the steam is 150°C. Find the quality, specific enthalpy of mixture.(13M)** BTL5 **Answer: Page: 3.28 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Dryness fraction of steam $x=m_s/(m_s+m_w) = 0.005529$ (4M) Wetness fraction of steam=1-x=0.99447 (3M) Volume of mixture = $v=xv_g+ y\, v_f=0.00325\ m^3/kg$ (3M) Enthalpy of mixture $h = xhf_g+ y\, h_{f=}640.289$ kJ/kg (3M)
2	**A closed vessel of 0.2 m^3 contains steam at 1 MPa and temperature 250°C. If the vessel is cooled so that pressure falls to 350 kPa. Determine the final temperature, heat transfer, and change of entropy during the process. (April/May 15),(N0v/Dec 15) (13M)** BTL5 **Answer :Page: 3.31 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli**. $T_1 > T_s$ – Super heated, Mass of steam m= 0.8591 kg (2M) Dryness fraction of steam x= V_1/ V_{g2}=0.444 (3M)

	T_2=139.9ºC, h_1= 2943 kJ/kg, h_2=1537.7 kJ/kg (3M) Q_1=m(h_1-h_2)=1207.15 kJ (3M) s_2= s_{f2}+ s_{fg2}, Change in entropy = Δs=m(s_{2-} s_1)= -2.48 kJ/kgK(2M)
3	**One kg of steam at a pressure of 700 kPa and 0.6 dry is heated at constant pressure until it becomes dry saturated. Determine change in internal energy and work done.(Nov/Dec 13)(13M)** BTL5 **Answer:Page: 3.38 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli**. Properties of steam at 7 bar from steam tables v_2= 0.27288 m3/kg, V_2= mv_{g1}= 0.27288 m^3(3M) h_2=$mh_{g1=}$ 2762 kJ/kg(3M) Change in internal energy =ΔU=u_2-u_1= 749.66 kJ (4M) Work done=p(V_2- V_1) =76.3 kJ (3M) Ans: ΔU= 749.66 kJ,W= 76.3 KJ
4	**A steam initially at a pressure of 15 bar and 0.95 dry expands isentropically to 7.5 bar and is then throttled until it is dry. Determine per kg of steam: (i) Change in entropy (ii) Change in enthalpy and (iii) Change in internal energy. (May/June 16)(Nov/Dec17)(13M)** BTL5 **Answer:Page 3.51 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** From Mollier chart h_1=2680 kJ/kg, v_1=0.1318 m3/kg, s_1= 6.2 kJ/kgK, h_2=2560 kJ/kg, x_2=0.9, h_2=h_3(4M) (i)Change in entropy=Δs=(s_{3-} s_1)=2.13 kJ/kgK(3M) (ii)Change in enthalpy= Δh=(h_{1-} h_3)=120 kJ/kg (3M) (iii)Change in internal energy= u_{3-} $u_{1=}$-141.7 kJ/kg (3M) Ans: Δs=2.13 kJ/kgK, Δh= 120 kJ/kg, ΔU= -141.7 kJ/kg
5	**A nozzle is supplied with steam of 1 MPa at 200C with a velocity of 100 m/s. The expansion takes place to a pressure of 300 kPa. Assuming isentropic efficiency of nozzle to be 90%, find the final velocity.(13M)** BTL5 **Answer :Page: 3.55 - Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** From Steam table Ts = 179.9C, h1= 2826.8 kJ/kg (4M) x_{2s}=0.94, h_{2s}= 2594.91 kJ/kg From Isentropic efficiency ➔h2=2625.79 kJ/kg, (5M) From SFEE

	$\left(u_1+p_1v_1+\frac{{C_1}^2}{2}+Z_1g\right)+Q=\left(u_2+p_2v_2+\frac{{C_2}^2}{2}+Z_2g\right)+w$ C_2= 641.89 m/s (4M) Ans: C_2= 641.89 m/s
6	**Dry saturated steam is supplied to a steam turbine at 12 bar and after the expansion its condenser pressure is 1 bar. Find the Rankine cycle efficiency, specific steam consumption. Neglect feed pump work.(May/June14)(13M)** BTL5 **Answer:Page: 3.61- Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** Using steam tables at 12 bar S_1=S_2, x_2=0.86, h_2= 2359.28 kJ/kg (5M) Rankine cycle efficiency =(h_1- $h_{2)}$/(h_1- h $_{f2}$)=17.97%(5M) Specific steam consumption= 3600/W=8.46 kg/kW-hr (3M) Ans:η_{ran}= 17.97%,SSC=8.46 kg/kW-hr.
7	**Determine the Rankine cycle efficiency working between 6 bar and 0.4 bar when supplied with dry saturated steam. By what percentage is the efficiency increased by supplying superheated steam of 300^{0}C?(April/May15)(13M)**BTL5 **Answer:Page: 3.68 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** (1) At 0.4 bar steam table values (2M) (2) Rankineefficiencywithdrysaturatedsteam:S_1=S_2,x_2=0.86 (3M) (3) h_2= h $_{f2}$+ x_2h $_{fg2}$= 2312.212 kJ/kg (3M) (4) Wp= v $_{f2(}$ p_2 $_–$ p_1) =0.575 kJ/kg (2M) (5) Rankine efficiency=(h_1- $h_{2)}$/(h_1- h $_{f2}$) η_{ran} =18.16% (3M)
8	**Consider a steam power plant operating on an ideal reheat Rankine cycle. The steam enters the H.P turbine at 30 bar and 350C. After expansion to 5 bar, the steam is reheated to 350C and then expanded the L.P turbine to the condenser pressure of 0.075 bar. Determine the thermal efficiency of the cycle and the quality of the steam at the outlet of the L.P turbine**. **(Apil/May 15)(May/June14) (13M)** BTL3 **Answer:Page: 3.75 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** Using steam tables At 30 bar and 350^{0}C, find values h_1=3115.3 kJ/kgK, S_1=S_2, x_2=0.98, h_2=2706.56 kJ/kgK, h_3=3167.7 kJ/kgK, s_3=s_4, x_4=0.919, h_4=2380.89 kJ/kgK, h_5=168.79 kJ/kgK, (6M) Wp= $v_{f4(}$ $p_{1–}$ p_4) =3.0164 kJ/kg, (3M)

	Efficiency=$(h_1-h_{2)}/(h_1-h_{f2})$ = 35% (4M) Ans: x_4 = 0.919, $\eta_{rh\,=}$ 35%
9	**Steam is supplied to a turbine at 4 MPa and 450^{0}C and the condenser is 6 kPa. The machine runs at 300 rpm and the power-developed 3 MW. The expansion is in two stages, the steam being reheated to 410^{0}C between H.P and L.P stages. If all the stages develop the same power with a same isentropic efficiency, determine reheat pressure, thermal efficiency of the cycle and steam flow rate.(Nov/Dec 15)(13M)** BTL3 **Answer :Page:3.82 Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** T_1-T_2= T_3-T_4, T_2=76.18C, Tsat=76.18^{0}C at 0.4 bar , h_1=3330.15 kJ/kgK, S_1=S_2, x_2=0.89 (2M) h_2= h_2= h $_{f2}$+ x_2h $_{fg2\,=}$ 2637.79 kJ/kgK h_2'=2776.26 kJ/kgK, h_3=3300 kJ/kgK(4M) s3=s4=8.9971 kJ/kgK, h_4=2800 kJ/kgK, h_5=155.5 kJ/kgK (3M) Wp= $v_{f4(}\,p_{1-}\,p_4\,)$ = 4.018 kJ/kg(2M) Efficiency=$(h_1-h_{2)}/(h_1-h_{f2})$=25.68%,SSC=3600/W=3.79kg/kW-hr (2M) Ans: η = 25.68%
10	**The net power output of the turbine in ideal reheat regenerative cycle is 100 MW. Steam enters the H.P turbine at 90 bar and 550^{0}C. After expansion to 7 bar some of the steam goes to an open heater and balance is reheated to 400^{0}C, after which it expands to 0.07 bar. Calculate the steam flow rate in HP turbine and thermal efficiency of cycle.(Nov/Dec16)(13M)** BTL5 **Answer :Page 3.104- Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Use superheated steam tables at 90 bar and 550^{0}C h_1=3508.95 kJ/kg, S_1= 6.0885 kJ/kgK (1M) At 7 bar and 400^{0}C h_3 = 3269 kJ/kg, s_3=7.636 kJ/kgK(1M) At 7 bar h_f= 697.1 kJ/kg, h_g = 2762 kJ/kg, s_f = 1.992 kJ/kgK, s_g =6.705 kJ/kgK, T_{sat} = 438K (1M) At 0.07 bar

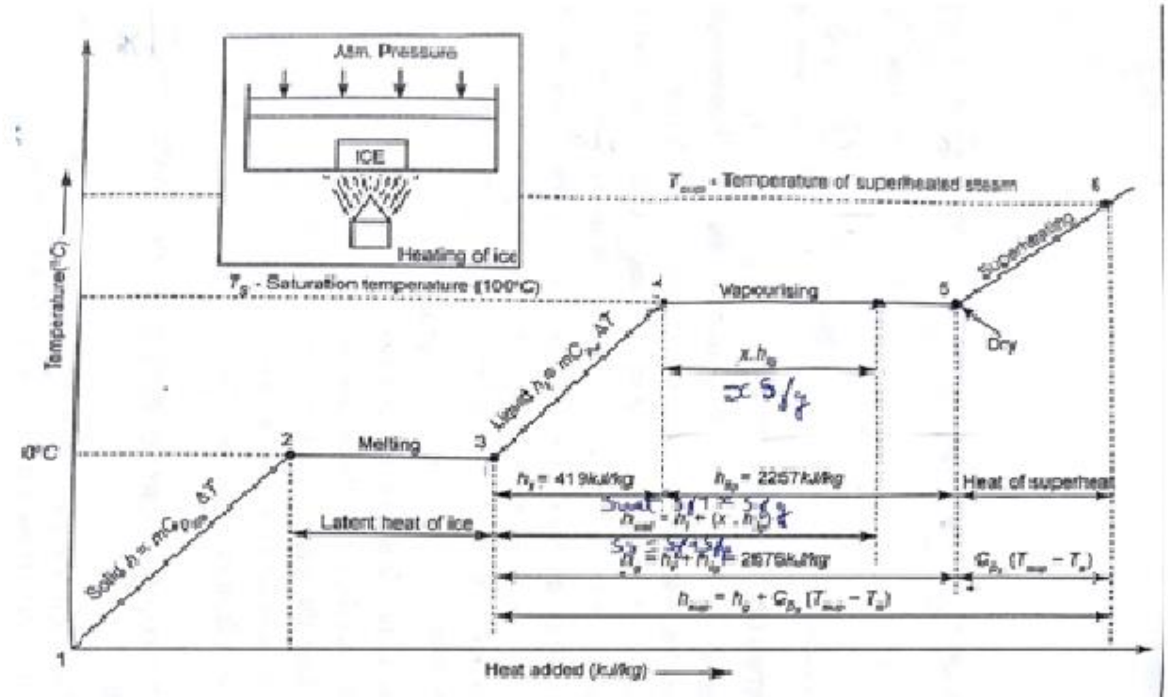
	h_{f4}=163.64kJ/kgK,h_{fg4}=2409.2kJ/kg, s_{f4}= 0.559 kJ/kgK, s_{fg4} =7.718 kJ/kgK (1M) At 7 bar 193.6 ^{0}C ,h_2 = 2827.76 kJ/kg From process 3-4: s_3=s_4=7.636 kJ/kgK, x_4 = 0.917, h_4 = 2372.64 kJ/kg, h_6=697.1 kJ/kg, h_6= m_1 h_2 +(1- m_1)h_5(2M) m_1=0.2003 kJ/kg of steam (2M) Mass flow rate in HP turbine P= m_{st}[(h_1– h_2) + (1- m_1) (h_3 – h_4)] m_{st}=105.654kg/s,Wnet=[(h_1–h_2)+(1-m_1)(h_3–h_4)]=946.46kJ/kg (2M) Net heat supplyQ_{net}=[(h_1–h_6)+(1-m_1)(h_3–h_4)]=2713.96kJ/kg (2M) Efficiency= W/Q = 34.874 %. (1M)
11	**Draw the T-S diagrams and theoretical lay out for Rankine cycle and hence deduce the expression for its efficiency. (13 M)** BTL2  *Rankine cycle* (4M)

	$\eta = \frac{Net\ Work\ output}{Heat\ supplied} = \frac{W_T - W_p}{Q_S}$ (2M) $W_T = h_1 - h_2$ kJ, $W_p = h_4 - h_3$ kJ, (2M) $Q_s = h_1 - h_4$ kJ, (2M) $\eta = \frac{Net\ Work\ output}{Heat\ supplied} = \frac{W_T - W_p}{Q_S} = \frac{(h_1 - h_2) - (h_4 - h_3)}{(h_1 - h_2)}$ (3M)
Part * C	
1	**2.5 kg of steam is heated at constant pressure of 250 kPa and 100ºC until temperature is 250ºC. Find the amount of heat added and change in entropy.(15M)** BTL5 **Answer :Page: 3.37 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** From Mollier chart At p = 250kPa= 2.5 bar and 100ºC h_1=2700 kJ/kg, S_1=S_2=7.04 kJ/kgK (3M) h_2=2950 kJ/kg (3M) S_2=7.65 kJ/kgK (3M) Heat added, Q=m(h_2-h_1)= 625 kJ (3M) Change in entropy=Δs = m(s_2-s_1)=1.525 kJ/K (3M)
2	**A mass of 0.9 kg of steam initially at a pressure of 1.5 MPa and temperature of 250ºC expands to 150 kPa. Assume the process as isentropic. Find the condition of steam and work transfer**.BTL3 **Answer:Page: 3.40 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** At p_1= 1.5 MPa and T_1 = 250ºC v_1=0.152 m^3/kg, h_1=2923.5 kJ/kg(2M) s_1=6.71 kJ/kgK, s_1= s_2=6.71 kJ/kgK (1M) From Steam Tables at 150kPa h_{f2} = 467.1 kJ/kg; h_{fg2} = 2226.2 kJ/kg, s_{f2} = 1.434 kJ/kgK s_{fg2} = 5.79 kJ/kgK, sg_2 = 7.223 kJ/kgK ,V_{g2} = 0.159 m^3/kg (2M) $s_2 = s_{f2} + x_2 s_{fg2}$,$h_2 = h_{f2} + x_2 h_{fg2}$ x_2=0.912, h_2= 2497.39 kJ/kg (3M)

	v_2=x2 * V_{g2} = 1.057 m3/kg (2M) Q= Δu +W , Q = 0 ; W = - Δu = $u_2 – u_1$ Work Transfer= W = u_1 - u_2 = (h_1– h_2) (p_1v_1 – p_2 v_2) = 356.66 kJ/kg(3M) W $_{Total}$ = mW = 321 kJ(2M)
3	**Steam at 1 MPa and 0.9 dry is throttled to a pressure of 200 kPa. Using Steam Table, find the quality of steam and change in entropy. Check your answer using Mollier chart. State whether this process is reversible or irreversible**.BTL5 **Answer:Page: 3.48 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** At 1Mpa or 10 bar take the values of $h_{f1,}$ hfg$_{1,}$ $s_{f1,}$ s_{fg1} h_1= h_{f1} + x_1 hfg$_1$= 2574.84 kJ/kg, s_1 = s_{f1} + x_1 s_{fg1} h_1=h_2, x_2= 0.94(3M) s_1 =6.13 kJ/kgK(2M) At 200kPa or 2 bar h_{f2} = 504.7 kJ/kg; h_{fg2} = 2201.6 kJ/kg, s_{f2} = 1.534 kJ/kgK s_{fg2} = 5.59 kJ/kgK (3M) h_2 = h_{f2} + x_2 h_{fg2} , x_2 = 0.94 (2M) Steam is wet so s_2 = 6.76 kJ/kgK Change in entropy = Δs = s_2 - s_1= 0.652 kJ/kgK(3M) s_1= 6.1 kJ/kgK, s_2 = 6.76 Change in entropy = 0.66 kJ/kgK Since ds is +ve, the process is irreversible.(2M)
4	**Find the efficiency of the prime mover operating on the Rankine cycle between 7 bar and 1 bar for the following initial conditions. (i) The steam has a dryness fraction of 0.8, (ii) The steam is dry and saturated and (iii) The steam is superheated to 350ºC. Draw the T-s diagram for each case. Neglect the pump work.**BTL5 **Answer:Page: 3.63Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** Using Steam tables at 7 bar T_{s1} = 164.9ºC and take all values of $h_{f1,}$ hfg$_{1,}$ $s_{f1,}$ s_{fg1},s_{g1} (3M) At 1 bar T_{s2} = 99.63 ºC and $h_{f2,}$ hfg$_{2,}$ $s_{f2,}$ s_{fg2},s_{g2} (3M) (i) if x = 0.8 x_2= 0.736, h_2=2079.85 kJ/kg, Rankineefficiency=(h_1–h_2)/(h_1–h_{f2})=13.93% (3M)

	(ii) When steam is dry x_2=0.89, h_2= 2427 kJ/kg, Rankine efficiency = 14.28 % (3M) (iii) x_2>1 superheated steam, h_2=2272.246 kJ/kg Rankine efficiency= 16.075 % (3M)
5	**A regenerative cycle utilizes steam as the working fluid. Steam is supplied to the turbine at 40 bar and 450ºC and the condenser pressure is 0.03 bar. After expansion in the turbine to 3 bar, some of the steam is extracted from the turbine for heating the feed water from the condenser in an open heater. The pressure in the boiler is 40 bar and the state of the fluid leaving the heater is saturated liquid water at 3 bar. Assuming isentropic heat drop in the turbine and pumps, compute the efficiency of the cycle.**BTL5 **Answer:Page: 3.89 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Use superheated steam tables at 40 bar and 450ºC h_1= 3330.3 kJ/kg, S_1= 6.9363 kJ/kgK (1M) At p_2 = 3 bar taking all the values x_2=0.9895, h_2 = 2702.65 kJ/kg x_3=0.8, h_3 = 2057.63 kJ/kg (2M) h_4= h_{f3} = 101.05 kJ/kg (2M) pump Work : (1-m) (h_5– h_4) = (1-m)*v_{f3} (p_2 - p_3) h_5= 101.35 kJ/kg(2M) Amount of steam bleed m=(h_{f2}– h_5)/ (h_2– h_5) = 0.117 kg (3M) $W_{p\ 6-7}$ = (h_7– h_6) = v_{f2} (p_1 - p_2) = 565.44 kJ/kg (2M) Regenerative Rankine efficiency= [(h_1– h_7)-(1-m) (h_3– h_{f3})] /(h_1– h_7) = 41.75%(3M)
6	**Steam enters the turbine at 3 MPa and 400ºC and is condensed at 10 kPa. Some quantity of steam leaves the turbine at 0.6 MPa and enters open feed water heater. Compute the fraction of the steam extracted per kg of steam and cycle thermal efficiency.(Nov/Dec15)**BTL5 **Answer: Page: 3.163 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli.** At 3 MPa and 400ºC h_1= 3232.5kJ/kg,S_1= 6.925kJ/kgK (1M) s_1 = s_2 = 6.9256.925kJ/kgK At p_2 = 6 bar s_g = 6.758kJ/kgK (1M)

	From Mollier chart h_2= 2630 kJ/kg , $s_1 = s_3$(1M) p_3 = 0.1 bar take values of h_{f3}, hfg_3, s_{f3}, s_{fg3},s_{g3} x_3=0.837, $h_3 = h_{f3} + x_3 h_{fg3}$ =2194.66 kJ/kg (2M) $h_4 = h_{f3}$ = 191.8 kJ/kg, (1M) $(h_5 - h_4) = v_{f3} (p_2 - p_3) = h_5$= 192.4 kJ/kg (2M) m= $(h_6 - h_5)/(h_2 - h_5)$ = 0.196 kg/kg of steam(2M) At 6 bar $W_{p\,6\text{-}7} = (h_7 - h_6) = v_{f2} (p_1 - p_2)$ => h_7= 672.824 kJ/kg(2M) Regenerative Rankine efficiency= $[(h_1 - h_7)-(1-m)(h_3 - h_{f3})]/(h_1 - h_7)$ = 37.09%. (3M)
7	**Explain steam formation with relevant sketch and label all salient points and explain every point in detail**.BTL2



Formation of steam (Under atmospheric pressure 1.01325 bar)

(10 M)

1-2 Solid $Q = mC_p\Delta T$ kJ
2-3 Melting Latent heat of ice=333.3 kJ/kg
3-4 Enthalpy of liquid h_f
4-5 Vaporization hg=2257 kJ/kg
5-6 Superheating (5 M)

UNIT IV IDEAL AND REAL GASES, THERMODYNAMIC RELATIONS

Properties of Ideal gas- Ideal and real gas comparison- Equations of state for ideal and real gases- Reduced properties. Compressibility factor-.Principle of Corresponding states. –Generalised Compressibility Chart and its use-. Maxwell relations, Tds Equations, Difference and ratio of heat capacities, Energy equation, Joule-Thomson Coefficient, Clausius Clapeyron equation, Phase Change Processes. Simple Calculations.

Q.No.	Part-A
	Questions
1.	**State Avogadro's law.** BTL1 Avogadro's law states that "Equal volumes of different perfect gases at the same temperature and pressure, contain equal number of molecules".
2	**State Dalton's law of partial pressure.** BTL1 Dalton's law of partial pressure states that "The total pressure of a mixture of gases is equal to the sum of the partial pressures exerted by individual gases if each one of them occupied separately in the total volume of the mixture at mixture temperature".

	$P = P_1 + P_2 + P_3 + \ldots\ldots P_k$
3	**Distinguish between ideal and real gas.** BTL2 An ideal gas is one which strictly follows the gas laws under all conditions of temperature and pressure. In actual practice, there is no real gas which strictly follows the gas laws over the entire range of temperature and pressure. However hydrogen, oxygen, nitrogen and air behave as an ideal gas under certain temperature and pressure limits.
4	**Write the Maxwell relations.** BTL1 $\left(\frac{\partial T}{\partial v}\right)_s = \left(\frac{\partial P}{\partial S}\right)_v$ $\left(\frac{\partial T}{\partial P}\right)_s = \left(\frac{\partial v}{\partial S}\right)_p$ $\left(\frac{\partial P}{\partial T}\right)_v = \left(\frac{\partial S}{\partial v}\right)_T$ These are known as Maxwell relations $\left(\frac{\partial v}{\partial T}\right)_p = \left(\frac{\partial S}{\partial P}\right)_T$
5	**Define Joule – Thomson Co – efficient.** BTL1 The Joule – Thomson co – efficient is defined as the change in temperature with change in pressure keeping the enthalpy remains constant. It is denoted by the $\mu = \left(\frac{\partial T}{\partial P}\right)_h$
6	**Define co-efficient of volume expansion and isothermal compressibility.** BTL1 **Co-efficient of Volume expansion:** The co – efficient of volume expansions is defined as the change in volume with change in temperature per unit volume keeping the pressure constant. It is denoted by β $\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$ **Isothermal compressibility:** It is defined as the change in volume with change in pressure per unit volume keeping the temperature constant. It is denoted by K $K = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_T$
7	**Write a short note on compressibility factor.** BTL2 We know that, the perfect gas equation is pv = RT. But for real gas, a correction factor has to be introduced in the perfect gas equation to take into account the deviation of real gas from the perfect gas equation. The factor is known as compressibility factor (z) and is defined by $Z = \frac{Pv}{RT}$
8	**Give the Clausius-Clapeyron equation.** BTL2 Clapeyron equation which involves relationship between the saturation pressure, saturation temperature, the enthalpy of evaporation and the specific volume of the two phases involved.

	$\frac{dP}{dT}=\frac{h_{fg}}{Tv_{fg}}$
9	**State Tds equations.** BTL1 Tds Equation are $Tds = C_P dT - T\left(\frac{\partial v}{\partial T}\right)_p dp$ $Tds = C_v dT + T\left(\frac{\partial P}{\partial T}\right)_T dv$
10	**State Helmholtz function.** BTL1 Helmholtz function is property of a system and given by subtracting the product of absolute temperature (T) and entropy (S) from the internal energy U.
11	**State Gibbs function.** BTL1 Gibbs function is property of a system and is given by G = U – TS + pv = H – TS [h = u + pv] Where H – Enthalpy, T – Temperature, S – Entropy
12	**State third law of Thermodynamics.** BTL1 It is states that the entropy of any pure substance in thermodynamics equilibrium approaches zero as the absolute temperature approaches zero.
13	**State the assumptions made in kinetic theory gases.** BTL1 1. There is no intermolecular force between particles. **2.** The volume of the molecules is negligible comparison with the gas
14	**State Regnault's law.** BTL1 Regnault's law states that C_P and C_v of a gas always remains constant.
15	**State Joule's Law.** BTL1 Joule's law states, "The internal energy a given quantity of gas depends only on the temperature".
16	**State Charle's law.** BTL1 Charle's law states, "The volume of a given mass of a gas varies directly as its absolute temperature, when the pressure remains constant.
17	**State Boyle's law.** BTL1 Boyle's law states. "The volume of a given mass of gas varies inversely as its absolute pressure, when the temperature remains constant. $v \alpha \frac{1}{p}$
Part * B	
1	**A vessel of volume 0.3 m^3 contains 15 kg of air at 303K. Determine the pressure exerted by the air using (i) Perfect gas equation (ii) Vanderwalls equation and (iii) Generalized compressibility chart. Take critical temperature of air is 132.8 K and critical pressure of air is 37.7 bar.** BTL5 **Answer: Page:4.23-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** (i) Perfect gas equationpv = mRT => P= 4348.05 kPa(3M)

	(ii) Vanderwaal's equation $(p+ a/v^2)(v-b)$ => P = 4235.4 kPa (3M) Reduced temperature $T_r = T/_{Tc} = 2.28$ (1M) $V_r = v/v_c = 1.98$ m3/kg (1M) Z=0.99(2M) (iii) Generalized compressibility chart P=4304.6 kPa (3M)
2	**A perfect gas of 0.5 kg has a pressure of 300 kPa, a temperature of 100°C, and a volume of 0.06 m^3. The gas undergoes an irreversible adiabatic process to a final pressure of 400 kPa and final volume of 0.15 m^3, work done on the gas is 50 kJ. Find C_p, C_v** BTL5 **Answer:Page: 4.28-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** pv = mRT =>R=pv/RT = 0.288 kJ/kgK (4M) T_2=pv/mR = 1041.67 K (3M) $Q=\Delta U+W$; $Q=W+mC_v(T_2-T_1)$; Q = 0 Cv=0.343 kJ/kgK, (3M) $R = C_p - C_v$ C_p=0.631 kJ/kgK. (3M)
3	**Derive the Maxwell relations .** BTL1 **Answer:Page4.32-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** du = Tds-pdv (4M) dh = Tds+vdp (3M) da = -pdv-SdT (3M) dg=vdp-SdT. (3M)
4	**From the basic principles, prove the following Cp-Cv = -T$\left(\frac{\partial v}{\partial T}\right)_p^2 \left(\frac{\partial p}{\partial v}\right)_T^2$** BTL3 **Answer:Page4.40 Q8-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Derive the above relation using first and second Tds equations with the help of Maxwell relations.
5	**Derive Vander Waals equation in terms of reduced parameters**. BTL2 **Answer :Page4.17-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** $(p+ a/v^2)(v-b)=RT$

6	**Derive Clausius –Clapeyron equation. What assumptions are made in this equation?** BTL1 **Answer :Page 4.72 Q19-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Clausius Clapeyron equation involves the relationship between the saturation pressure, saturation temperature, the enthalpy of evaporation and the specific volume of two phases involved. This equation provides a basis for calculation of properties in a two phase diagram. It gives the slope of a curve separating the two phases in p-T diagram. (10M) $dp/dT = (s_g – s_f\ ) / (v_g – v_f\ )$ (3M)
7	**Derive Tds equation when (i) T and V independent (ii) T and P independent (iii) p and v independent**.BTL1 **Answer :Page No. 4.38 Q26-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** (iii)$Tds = C_vdT +T((\partial p/\partial T)_vdv$ (5M) (iv)$Tds = CpdT –T((\partial v/\partial T)_pdp$ (4M) (v) $Tds = CpdT + C_vdT$(4M)
8	**(i) Derive any two Maxwell's relation (ii) Draw a neat schematic of a compressibility chart and indicate its salient features. Page No. Q-24-25 Q14 (b) (i) &(ii)** BTL 1 **Answer:Page 4.32, 4.22-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** The generalized compressibility chart is plotted with compressibility factor (Z) versus reduced pressure for various values of reduced temperatures. $(\partial T/\partial v)_s=-(\partial p/\partial s)_v$ (7M) $(\partial T/\partial p)_s=-(\partial s/\partial v)_v$ (6 M)
9	**The gas neon has a molecular weight of 20.183 and its critical temperature, pressure and volume are 46K, 2.5 MPa and 0.05 m3/kg mol. Reading from a compressibility chart for a reduced pressure if 2 and a reduced temperature of 1.2, the compressibility factor Z is 0.75. What are the corresponding specific volume, pressure, temperature and reduced volume?** BTL5 **Answer :Page4.26-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** Pressure $p=p_r * p_c$ = 5MPa, (4M) $T/T_c = 1.2 \Rightarrow T = 55.2K$ $Pv=ZRT$ From Ideal gas equation $v=3.213x10^{-3}\ m^3/kg$ (4M) Volume ratio $v_r= v/v_c = 0.219$ (5M)
10	**Compute the specific volume of steam at 0.9 bar and 550 K using Vander Walls equation. Take critical temperature of steam is 647.3 and critical pressure is 220.9 bar.** BTL 5 **Answer:Page 4.27-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli**

	Vanderwaal's equation $\left(P+\frac{a}{v^2}\right)(v-b)=RT$ (4M) a=1.7, b=1.69x10^{-3}, (4M) By trial and error method, specific volume v=0.25 m^3/kg. (5M)
	Part * C
1	**Obtain the expression for ds in terms of dT and dp**. BTL3 **Answer: Page: 4.52 -Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** s=f(T,P) $ds=\left(\frac{\partial s}{\partial T}\right)_p dT-\left(\frac{\partial v}{\partial T}\right)dp$ (5M) $ds=Cp\frac{dT}{T}-\left(\frac{\partial v}{\partial T}\right)_p dp$ But $\beta=\frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_p$(5M) $ds=Cp\frac{dT}{T}-\beta v dp$ (5M)
2	**Prove that the difference in specific heat capacities equal to C_p-C_v=R and** **C_p-C_v = $\boldsymbol{\frac{TV}{k_T}\beta^2}$** BTL1 **Answer: Page 4.43-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** $C_p-C_v=T\left[\left(\frac{\partial P}{\partial T}\right)_v-\left(\frac{v}{\partial T}\right)_p\right]$(5M) $\left(\frac{\partial P}{\partial T}\right)_v=\frac{\beta}{K},\left(\frac{\partial v}{\partial T}\right)_p=\beta v$ (5M) $C_p-C_v=\frac{TV}{k_T}\beta^2$(5M)
3	**One kg of ideal gas is heated from 50°C to 150°C. If R=280 J/kgK and γ=1.32 for the gas, determine: (i) C_p and C_v(ii) Change in internal energ (iii) Change in enthalpy (iv) Change in flow energy** BTL5 **Answer: Page 4.59-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** R=$C_p-C_v=280, \gamma=1.32$ $C_v=0.875\frac{kJ}{kgK},C_p=1.155\frac{J}{kgK},$ $\Delta U=mC_v(T_2-T_1)=87.5\ kJ,$ (5M)

4	$\Delta H = mC_p(T_2 - T_1) = 115\ kJ,$ (5M) $Flow\ energy = \Delta H - \Delta U = 27.5\ kJ$ (5M)
4	**Derive expressions $\left(\frac{\partial u}{\partial p}\right)_T$ and $\left(\frac{\partial h}{\partial v}\right)_T$ in terms of p, v and T only.**BTL1 **Answer:Page 4.58-Dr.G.K.Vijayaraghavan&Dr.S.Sundaravalli** $du = C_v dT + T\left(\frac{\partial p}{\partial T}\right)_v dv - pdv$ (5M) Differentiating each term in this equation with respect to p at T=constant yields$\left(\frac{\partial u}{\partial p}\right)_T = T\left(\frac{\partial p}{\partial T}\right)_v\left(\frac{\partial v}{\partial p}\right)_T - p\left(\frac{\partial v}{\partial p}\right)_T$, Using the properties p,T,v the cyclic, relation can be expressed as $\left(\frac{\partial h}{\partial v}\right)_T = v\left(\frac{\partial p}{\partial v}\right)_T + T\left(\frac{\partial T}{\partial p}\right)_v$(10M)

Unit 5 GAS MIXTURES AND PSYCHROMETRY

Mole and Mass fraction, Dalton's and Amagat's Law. Properties of gas mixture – Molar mass, gas constant, density, change in internal energy, enthalpy, entropy and Gibbs function. Psychrometric properties, Psychrometric charts. Property calculations of air vapour mixtures by using chart and expressions. Psychrometric process – adiabatic saturation, sensible heating and cooling, humidification, dehumidification, evaporative cooling and adiabatic mixing. Simple Applications

Q.No.	Part-A
1.	**Define Psychrometry.**BTL1 The science which deals with the study of behaviour of moist air (mixture of dry air and water vapour) is known as Psychrometry.
2	**Define dry bulb temperature (DBT).** BTL1 The temperature which is measured by an ordinary thermometer is known as dry bulb temperature. It is generally denoted by t_d.
3	**Define wet bulb temperature.**BTL1 It is the temperature of air measured by a thermometer when its bulb is covered with wet cloth and is exposed to a current rapidly moving air. It is denoted by t_w.
4	**Define Dew point temperature.**BTL1 The temperature at which the water vapour present in air begins to condense when the air is cooled is known as dew point temperature. It is denoted by t_{d_p}.
5	**Define specific humidity.** BTL1 It is defined as the mass of water vapour present in one kg of dry air. Specific humidity (W) or Humidity ratio (or) Moisture content $= \frac{\text{Mass of water vapour}}{\text{Mass of dry air}}$

6	**Write in short aboutSaturation ratio.** BTL1 It is defined as the ratio of specific humidity of the moist air to the specific humidity of saturation air at the same temperature. Degree saturation (or) Percentage humidity (or) Saturation ratio $\mu = \frac{\text{Specific humidity of moist air}}{\text{Specific humidity of saturated air}}$
7	**Define Relative humidity.**BTL1 It is defined as the ratio between mass of water vapour in a given volume and saturated mass of water in same volume and temperature. Relative humidity (ϕ) $= \frac{\text{Mass of water vapour in a given volume}}{\text{Saturated mass of water vapour in sazme volume and temperature}}$
8	**State Dalton's law of Partial pressure.**BTL1 The total pressure exerted by air and water vapour mixture is equal to the barometric pressure. i.e. $p_b = p_a + p_v$ Where, p_b = Barometric pressure p_a = Partial pressure of dry air, p_v = Partial pressure of water vapour
9	**What is meant by Humidification?** BTL2 The addition of water vapour to the air is known as humidification.
10	**Define Sensible heat factor.** BTL1 The ratio of sensible heat to the total heat is known as sensible heat ratio (or) Sensible heat factor. $\text{Sensible heat factor} = \frac{\text{Sensible heat}}{\text{Total heat}}$
11	**Define the following: a) Approach b) Range.** BTL1 **Approach:** The difference in temperature of cooled-water temperature and the wet bulb temperature of the entering the air is known as the approach. **Range:** The range is the temperature difference between the inlet and exit states of water.
Part * B	
1	**Find the increase in entropy when 5 kg of oxygen at 60ºC are mixed with 7.5 kg of nitrogen at the same temperature. The initial pressure of each constituent is 103 kPa and is the same as that of mixture.(13M)**BTL5 **Answer: Page: 5.20-Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** Mass fraction of O_2= 0.368 (2M) Mass fraction of N_2= 0.632 (2M) Entropy increase $\Delta S_m = \Delta S_{O_2} + \Delta S_{N_2}$(2M) ΔS_m=1.3+1.022= 2.322 kJ/K (7M)

2

A closed rigid cylinder is divided by a diaphragm into two equal compartments, each of volume 0.1 m^3. Each compartment contains air at a temperature of 20°C. The pressure in one compartment is 2.5 MPa and in the other compartment is 1 MPa. The diaphragm is ruptured so that the air in both the compartments mixes to bring the pressure to a uniform value throughout the cylinder which is insulated. Find the net change of entropy for the mixing process.(13M) BTL5

Answer:Page :5.24 -Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli

A	B

Mass of air in A, $m_A = \frac{P_A v_A}{RT} = 2.973\ kg$ (2M)

$m_B = \frac{P_B v_B}{RT} = 1.189\ kg$ (2M)

$m_m = m_A + m_B = 4.162\ kg$ (2M)

$V_m = V_A + V_B = 0.2\ m3$ (2M)

From equation of state, $P_m = \frac{m_m RT}{V_m}$=1.75 MPa (2M)

Net change in entropy, $\Delta S_m = \Delta S_A + \Delta S_B = 0.2016 \frac{kJ}{K}$(3M)

3

A mixture of perfect gases at 23°C contains 60% N$_2$, 15% O$_2$ and 25% Ch$_4$ by volume. If the partial of CH$_4$ is 60 kPa, determine (i) the partial pressure of N$_2$ and O$_2$ (ii) mass proportion of mixture (iii) gas constant for the mixture and (iv) volume per mole of mixture. (13M) BTL5

Answer:Page:5.28-Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli

O2	CH4	N2
15%	25%	60%

Volume Fraction of O$_2$,yO_2 = Vo$_2$ /V = 0.15 (2M)

Partial pressure of O$_2$=$Y_{O_2} * P$ =36 kPa (2M)

Partial pressure of N$_2$=$Y_{N_2} * P$ =144 kPa (2M)

Molecular weight of Mixture M = $Y_{O_2} * MO_2 + y_{CH4} + Y_{N_2} * M_{N2}$

= 2506kg/kgmole (2M)

Mass Fraction of O$_2$, xO_2= y$_{o2}$ * Mo$_2$ / M = 18.75% (1M)

Mass Fraction of CH$_4$ = 15.63% (1M)

	Mass Fraction of N_2 = 65.63% (1M) Gas Constant R = 8.314/25.6 = 0.325kJ/kgK (1M) Volume ,$V = \frac{RT}{P} = 0.0103\ m^3/kg$ (1M)
4	**The moist air is at 45ºC dry bulb temperature and 30ºC wet bulb temperature. Calculate (i) Vapour pressure (ii) Dew Point temperature (iii) Specific Humidity (iv) Relative humidity (v) Degree of saturation (vi) Vapour density (vii) Enthalpy of mixture (13M)**BTL5 **Answer: Page: 5.46 - Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** Vapour pressure =$P_v = P_{sw} - \frac{(P_b-P_{sw})(t_d-t_w)}{1527.4-1.3t_w}$= 0.03277 bar (2M) Dew Point temperature - from steam table ,$t_{dp} = 25.26^{o}C$ (1M) Specific Humidity, $\omega = 0.622\frac{P_v}{P_b-P_v} = 0.02107\frac{kg}{kg} of\ dry\ air$ (2M) Relative humidity, $\Phi = \frac{P_v}{P_v} = 34.2\ \%$ (2M) Degree of saturation, $\mu = \frac{P_v}{P_s}\left(\frac{P_b-P_s}{P_b-P_v}\right) = 0.3197$ (2M) Vapour density , from steam table, $\rho_v = 0.06546\frac{kg}{m3}, hence\ vapour\ density\ at\ 34.2\% = 0.0224\ kg/m^3$(2M) Enthalpy of mixture$h = C_P t_d + \omega h_g = 99.65\frac{kJ}{kg}$(2M)
5	**An air conditioning system is designed under the following condition** **Outdoor condition – 32ºC DBT and 75% RH** **Required indoor condition -22ºC DBT and 70% RH** **Amount of free air circulated – 200 m^3/min** **Coil dew point temperature – 14ºC** **The required condition is achieved by first cooling and dehumidifying and then by heating. Calculate the following** (i) **Capacity of cooling coil in tone (ii) Capacity of heating coil in kW and** (j) **(iii) Capacity of water vapour removed in kg/s. (13M)**BTL3 **Answer:Page :5.98-Dr.G.KVijayaraghavan and Dr. K Sundaravalli**, From Psychrometric chart, $h_1 = 82\frac{kJ}{kg}, h_2 = 53\frac{kJ}{kg}, h_3 = 48\frac{kJ}{kg}, h_4 = 41\frac{kJ}{kg},$ (4M) Cooling coil capacity =$m_a(h_1 - h_3) = 36.72\ tonne$ (3M)

	Heating coil capacity $=m_a(h_2-h_3)=18.9\ kW$ (3M) Mass of water vapour removed $m_a(\omega_2-\omega_3)=0.03213\frac{kg}{s}$(3M)
6	**A mixture of 2kg oxygen and 2 kg Argon is an insulated piston cylinder arrangement at 100 kPa, 300 K. The piston now compresses the mixture to half its initial volume. Molecular weight of oxygen is 32 and for argon is 40. Ratio of specific heats for oxygen is 1.39 and for argon in 1.667. (13M)**BTL5 **Answer: Page: 5.110-Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** X o_2 = 0.56, p $o_{2\ =}$ 556 kPa (2M) X $_{Ar}$= 0.44, $p_{Ar\ =}$ 44.4 kPa (2M) V o_2= 2.804m^3, V $_{Ar}$ = 2.81m^3 (2M) Volume of mixture before compression = V_1 = V o_{2+} V_{Ar} = 5.614 m^3 (1M) Volume after compression = V_2 = $V_1/2$ = 2.807 m^3 (1M) $P_2=P_1\left(\frac{V_1}{V_2}\right)^{\gamma}=285.4\ kPa$ (1M) $T_2=T_1\left(\frac{P_1}{P_2}\right)^{\frac{\gamma-1}{\gamma}}=2040.19\ K$ (2M) Piston Work, W=$\frac{P_1V_1-P_2PV_2}{n-1}=-1000.23\ kJ$ (The negative sign indicates the work input to the piston) (2M)
7	**An insulated rigid tank is divided into two compartments by a partition. One compartment contains 7 kg of oxygen gas at 40ºC and 100 kPa, and the other compartment contains 4 kg of nitrogen gas at 20ºC and 150 kPa. Now the partitionis removed, and the two gases are allowed to mix. Determine (i) The mixture temperature and (ii) The mixture pressure after equilibrium has been established. (AU Nov'10, Nov'12) (13M)**BTL5 **Answer: Page: 5.112-Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** The mixture temperature $T_m=\frac{m_{O_2}c_{vO_2}T_{O_2}-m_{N_2}c_{vN_2}T_{N_2}}{m_{O_2}c_{v_{O_2}}m_{N_2}c_{vN_2}}$=32.16 ºC (5M) The mixture pressure after equilibrium, $P_m=\frac{N_mR_uT_m}{v_m}=114.5\ kPa$ (8M)
8	**Air at 20ºC, 40% RH is mixed adiabatically with air at 40ºC, 40% RH in the ratio of 1 kg of the former with 2 kg of the later (on dry basis). Find the final condition of**

	air. (13M)BTL5 **Answer: Page : 5.130-Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** $m_1 + m_2 = m_3$(2M) $m_1\omega_1 + m_2\omega_2 = m_3\omega_3$ (2M) $m_1h_1 + m_2h_2 = m_3h_3$ (2M) $\omega_3 = 0.0144\frac{kg}{kg\ of\ dry\ air}$(4M) $h_3 = 71.67\frac{kJ}{kg}$ (3M)
9	**30 m^3/min of moist air at 15ºC DBT and 13ºC WBT are mixed with 12 m^3/min of moist air at 25ºC DBT and 18ºC WBT. Determine DBT and WBT of the mixture assuming the barometric pressure is one atmosphere.(13M)**BTL5 **Answer: Page :5.136 - Dr.G.KVijayaraghavan and Dr. K Sundaravalli** Using Psychometric Chart $\omega_1 = 0.0076\frac{kg}{kg\ of\ dry\ air}$(2M) $\omega_2 = 0.0014\frac{kg}{kg\ of\ dry\ air}$(2M) From Psychrometric chart $v_{S_1} = 0.835\frac{m^3}{kg}$(2M) $v_2 = 0.845\frac{m^3}{kg}$(2M) $\omega_3 = 0.00943\frac{kg}{kg}of\ dry\ air$ (2M) Dry bulb temperature = 24.02ºC Wet bulb temperature=18.2ºC (3M)
10	**It is required to design an air-conditioning system for an industrial process for the following hot and summer conditions.** **Outdoor condition – 32ºC DBT and 65% RH** **Required indoor condition -25ºC DBT and 60% RH** **Amount of free air circulated – 250 m^3/min** **Coil dew point temperature – 13ºC** **The required condition is achieved by first cooling and dehumidifying and then by heating. Calculate the following (solve this problem with the use of Psychrometric chart)** **(i) the capacity of cooling coil (ii) Capacity of heating coil in kW and surface temperature of the heating coil if the by-pass factor is 0.3 and (iii) mass of water vapour removed per hour.**(13M)BTL5

	Answer: Page: 5.142 -Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli Cooling coil capacity= 41 tonne (3M) Heating coil capacity = 39.36 kW (3M) Mass of water vapour removed=0.03241 kg/s (3M) Bypass factor of heating coil = $\frac{(T_{d3}-T_{d2})}{(T_{d3}-T_{d1})} = 0.3, T_{d3}$=35°C (4M)
	Part * C
1	**Methane at 1 bar and 25°C enters an insulated mixing chamber at a rate of 2.5 kg/s. It is mixed with air at 1 bar in an air/methane mass ratio of 18. The flow is steady and kinetic energy changes are negligible. The ambient pressure and temperature are 1 bar and 25°C, determine (i) temeperature of the mixture leaving the chamber and (ii) irreversibility of the mixing per kilogram of methane. Take C_v and C_p of methane as 1.7354 kJ/kgK and 2.2537 kJ/kgK respectively. (15M)**BTL5 **Answer : Page: 5.10-Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** Temperature of the mixture $T_m = \frac{m_{ch_4}c_{v,ch_4T_{ch_4}}+m_ac_{v,aT_a}}{m_{ch_4}c_{v,ch_4}+m_ac_{v,a}}$= 408.2 K (6M) $\Delta S_{ch4} = 1.773\frac{kJ}{K}$(3M) $\Delta S_a = -1.61\frac{kJ}{K}$(3M) Irreversibility = $\Delta S_m = \Delta S_{ch4} + \Delta S_a$ =0.163 kJ/K (3M)
2	**A mixture of gases contains 50% N_2, 40% O_2 and 10% CO_2 by mass. 2 kg of the mixture is compressed from 200 kPa and 293 K to 400 kPapolytropicallywhichfollows the $pV^{1.2}$ =C. Determine the workdone, heat transferred and change in entropy. Take $(C_p)_{N2}$=1.04 kJ/kgK, $(C_p)_{O2}$=0.918 kJ/kgK. (15M)**BTL5 **Answer: Page :5.25- Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** $C_{P_m} = \sum x_i C_{P_i} = 0.972\frac{kJ}{kgK}$, (4M) R=$\sum x_i R_i = 0.2713\frac{kJ}{kgK}$,$C_{P_m} = 0.7\frac{kJ}{kgK}$, (4M)

	$T_2 = T_1\left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = 336.57\ K$ (2M) Work done = W=$\frac{P_1V_1-P_2PV_2}{n-1} = -94.56\ kJ$ (5M)
3	**A sling Psychrometer reads 40ºC DBT and 30ºC WBT. Calculate specific humidity, relative humidity, dew point temperature, enthalpy, and specific volume of air mixture. Assume atmospheric air pressure as 1.01325 bar. (15M)** BTL5 **Answer: Page:5.48- Dr.G.KVijayaraghavan and Dr. K Sundaravalli** (i) Specific Humidity, $\omega = 0.622\frac{P_v}{P_b-P_v} = 0.0228\frac{kg}{kg} of\ dry\ air$ (2M) (ii) Dew point temperature= 27ºC (2M) (iii) Relative humidity, $\Phi = \frac{P_v}{P_v} = 48.7\ \%$ (2M) (iv) Specific volume of air = 0.919 $0.919\frac{m3}{kg}$(2M) (v) density $\rho_a = 0.05116\frac{kg}{m3}$(2M) (vi) $vapour\ density\ = 0.025\frac{kg}{m^3}$(2M) (vii) Enthalpy of mixture$h = C_P t_d + \omega h_g = 99.65\frac{kJ}{kg}$(3M)
5	**Atmospheric air at 760 mm of Hg has 45ºC dry bulb temperature and 30ºC wet bulb temperature using psychrometric chart, calculate the following (i) Relative humidity (ii) Humidity ratio (iii) Dew point temperature (iv) Enthalpy and (v) Specific volume of air.(15M)**BTL5 **Answer: Page :5.62 -Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** From Psychrometric chart (i) Relative humidity = 34% (2M) (ii) Humidity ratio =0.021 kg/kg of dry (3M) (i) Dew point temperature = 27ºC (3M) (ii) Enthalpy and =100 kJ/kg (3M) (iii) Specific volume of air=0.935 m3/kg (4M)
6	**A room 7m X 4m X4m is occupied by an air water vapour mixture at 38ºC. The atmospheric pressure is 1 bar and the relative humidity is 70%. Determine humidity ratio, dew point temperature mass of dry air and mass of water vapour. If the mixture is 10ºC. Find the amount of water vapour condensed. AU Nov/Dec '06(15M)**BTL3 **Answer: Page: 5.119-Dr.G.K.Vijayaraghavan and Dr. K Sundaravalli** Relative humidity, $\Phi = \frac{P_v}{P_v} = 0.7\ 2$ (2M)

	(i) Specific humidity $\omega = 0.622\frac{P_v}{P_b - P_v} = 0.0305\frac{kg}{kg} of\ dry\ air$ (2M) (ii) Dew point temperature = 36.5ºC (2M) (iii) Mass of dry air = Total volume / actual volume = 20.48 kg (3M) (iv) Mass of water vapour = $m_v = 0.6246\ kg$ (3M) (v) Amount of water vapour condensed $= 0.622\frac{P_v}{P_b - P_v} = 7.726\ x\ 10^{-3}$ (3M)

ME8351 MANUFACTURING TECHNOLOGY L T P C

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OBJECTIVES:

To introduce the concepts of basic manufacturing processes and fabrication techniques, such as metal casting, metal joining, metal forming and manufacture of plastic components.

UNIT I METAL CASTING PROCESSES 9

Sand Casting : Sand Mould – Type of patterns - Pattern Materials – Pattern allowances – Mouldingsand Properties and testing – Cores –Types and applications – Moulding machines– Types andapplications; Melting furnaces : Blast and Cupola Furnaces; Principle of special castingprocesses : Shell - investment – Ceramic mould – Pressure die casting - Centrifugal Casting -CO2 process – Stir casting; Defects in Sand casting

UNIT IIJOINING PROCESSES 9

Operating principle, basic equipment, merits and applications of: Fusion welding processes: Gaswelding - Types – Flame characteristics; Manual metal arc welding – Gas Tungsten arc welding- Gas metal arc welding – Submerged arc welding – Electro slag welding; Operating principle andapplications of: Resistance welding - Plasma arc welding – Thermit welding – Electron beamwelding – Friction welding and Friction Stir Welding; Brazing and soldering; Weld defects: types,causes and cure.

UNIT III METAL FORMING PROCESSES 9

Hot working and cold working of metals – Forging processes – Open, impression and closed dieforging – forging operations. Rolling of metals– Types of Rolling – Flat strip rolling – shape rollingoperations – Defects in rolled parts. Principle of rod and wire drawing – Tube drawing – Principlesof Extrusion – Types – Hot and Cold extrusion.

UNIT IVSHEET METAL PROCESSES 9

Sheet metal characteristics – shearing, bending and drawing operations – Stretch formingoperations – Formability of sheet metal – Test methods –special forming processes- Workingprinciple and applications – Hydro forming – Rubber pad forming – Metal spinning– Introductionof Explosive forming, magnetic pulse forming, peen forming, Super plastic forming – Micro forming

UNIT V MANUFACTURE OF PLASTIC COMPONENTS 9

Types and characteristics of plastics – Moulding of thermoplastics – working principles and typicalapplications – injection moulding – Plunger and screw machines – Compression moulding,Transfer Moulding – Typical industrial applications – introduction to blow moulding – Rotationalmoulding – Film blowing – Extrusion – Thermoforming – Bonding of Thermoplastics.

TOTAL: 45 PERIODS

OUTCOMES:

CO1 Explain different metal casting processes, associated defects, merits and Demerits Unit 1
CO2 Compare different metal joining processes. Unit 2
CO3 Summarize various hot working and cold working methods of metals. Unit 3
CO4 Explain various sheet metal making processes. Unit 4
CO5 Distinguish various methods of manufacturing plastic components. Unit 5

TEXT BOOK:

1. HajraChouldhary S.K and Hajra Choudhury. AK., "Elements of workshop Technology", volume I and II, Media promoters and Publishers Private Limited, Mumbai, 2008
2. Kalpakjian. S, “Manufacturing Engineering and Technology”, Pearson Education India Edition, 2013

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1. Gowri P. Hariharan, A.SureshBabu, "Manufacturing Technology I", Pearson Education, 2008
2. Paul Degarma E, Black J.T and Ronald A. Kosher, "Materials and Processes, in Manufacturing" Eight Edition, Prentice – Hall of India, 1997.
3. Rao, P.N. "Manufacturing Technology Foundry, Forming and Welding", 4 thEdition, TMH-2013
4. Roy. A. Lindberg, "Processes and Materials of Manufacture", PHI / Pearson education, 2006
5. Sharma, P.C., "A Text book of production Technology", S.Chand and Co. Ltd., 2014.

Subject Code: ME8351 **Year/Semester: II /03**
Subject Name: MANUFACTURINGTECHNOLGY-I **Subject Handler: D.Christopher Selvam**

UNIT I - METAL CASTING PROCESS

Sand Casting : Sand Mould – Type of patterns - Pattern Materials – Pattern allowances –Moulding sand Properties and testing – Cores –Types and applications – Moulding machines– Types and applications; Melting furnaces : Blast and Cupola Furnaces; Principle of special casting processes : Shell - investment – Ceramic mould – Pressure die casting - Centrifugal Casting - CO2 process – Stir casting; Defects in Sand

PART * A

Q.No.	Questions
1.	**Define the characteristics of core.** BTL 1 A **core** is a device used in **casting** and moulding processes to produce internal cavities and reentrant angles (an interior angle that is greater than 180°). The **core** is normally a disposable item that is destroyed to get it out of the piece. ... For example, **cores define** multiple passages inside **cast** engine blocks.
2	**Write the requirements of good pattern.** BTL 5 Simple in design • Cheap and readily available • Light in mass • Surface id smooth • Have high strength
3	**What is core venting**? BTL 6 While pouring the mould with molten metal mould walls and cores heat up rapidly and releases large amount of gases. In order to prevent casting defects these gases must be vented out. For this purpose core venting are used. Core venting are incorporated in the core box itself.
4	**Define core print.** BTL 1 The part of a foundry pattern which makes an opening in a mold to receive a **core** and to support it while the metal is being poured.
5	**Which process is called lost waxing method? Why?** BTL 4 Investment casting process is also known as Lost-wax process. The term investment refers to a clock or special covering apparel. In investment casting, the clock is a refractory mould which surrounds the precoated wax pattern.
6	**Write the application of core prints.**BTL 6 **Core prints** are used to serve this purpose. The **core print** is an added projection on the pattern and it forms a seat in the mold on which the sand **core** rests during pouring of the mold.
7	**What are the advantages and applications of ceramic moulds?** BTL 4 Advantages: a) It is less expensive b) Intricate objects can be casted. c) Castings of thin sections and which do not require machining can be produced. Applications: a) It is mainly used for all material using better ingredient in slurry.
8	**State the main functions of tuyeres in cupola furnace.** BTL 1 The tuyers are used to supply air to the coke bed for complete burning.
9	**Examine the causes for the formation of blow holes in the sand casting.** BTL 2 Gases entrapped by solidifying metal on the surface of the **casting**, which results in a rounded or oval **blowhole** as a cavity. Frequently associated with slag's or oxides. The defects are nearly always located in the cope part of the mould in poorly vented pockets and undercuts

10	**Differentiate Shrinkage and Porosity.** BTL 2 The definition of **porosity** is any void or hole in a casting. But this definition does not describe or give direction on the root cause of **porosity**. Casting **porosity** can be caused by gas formation or solidification **shrinkage** while the metal is a liquid
11	**Name the Materials used for making Patterns** BTL 1 Some materials used for making patterns are: wood, metals and alloys, plastic, plster of Paris, plastic and rubbers, wax, and resins.
12	**What are the applications of casting?** BTL 4 a)Transportation vehicles (in automobile engine and tractors) b)Machine tool structures c)Turbine vanes and power generators d)Mill housing e)pump filter and valve
13	**Classify moulding Machines.** BTL 3 a).Squeezer Machine b)Jolt machine c)Jolt – squeezer Machine d)Slinging Machines e)Patten draw Machines.
14	**Describe the essential requirements of a core sand briefly** BTL 2 The BASIC properties REQUIRED in molding SAND and CORE SAND are adhesiveness, cohesiveness, collapsibility, flowability, dry strength, green strength, permeability, refractoriness
15	**Explain the term fettling.** BTL 5 Fettling is the name given to cover all those operations which help the casting to give a good appearance. It includes the removal of cores, sand, gates, risers, runners and other Unwanted projections from the casting.
16	**Define AFS grain- fineness number.** BTL 1 It is defined as the ratio between the total products and total percentage of sand retained on pan and each sieve.AFS grain fineness number =sum of products /total sum of the % of sand retained on pan and each sieve.
17	**What are the different types of furnaces used for casting.** BTL 6 a)Cupola Furnace b)Open Hearth furnace c)Crucible Furnace d)Pot Furnace e)Electric Furnace.
18	**State the various methods for testing moulding sand.** BTL 1 **a)** Moisture content test b) clay content test c) Grain fitness test d) Permeability test e) strength test f) Deformation test g) toughness test
19	**Which type of furnaces are suitable for melting of ferrous material and why?** BTL1 Cupola furnace, Air furnace (Reverberatory Furnace) Rotary and Electrical furnace
20	**What are the various methods of non-destructive testing used in foundries?** BTL2 a) Visual Inspection b) Dimensional inspection c) Mechanical Testing d) Metallurgical Inspection e) Flow detection by NDT
	PART * B
1.	**Describe the properties of sand molding process (8M)** BTL 2 **Answer: Page 1.42 – Dr.Ramachandran** **Refractoriness:** Refractoriness is defined as the ability of molding sand to withstand high temperatures without breaking down or fusing thus facilitating to get sound casting. (2M) **Permeability:** It is also termed as porosity of the molding sand in order to allow the escape of any air, gasesor moisture present or generated in the mould when the molten metal is poured into it. Permeability of mold can be increased by venting using vent rods. (2M)

Cohesiveness: It is property of molding sand by virtue which the sand grain particles interact and attract each other within the molding sand. (2M)

Flowability or plasticity: It is the ability of the sand to get compacted and behave like a fluid. It will flow uniformly to all portions of pattern when rammed and distribute the ramming pressure evenly all around in all directions. (2M)

Adhesiveness: It is property of molding sand to get stick or adhere with foreign material such sticking of molding sand with inner wall of molding box. Collapsibility: It is the property due to which the sand automatically collapses after freezing of the casting, to allow contraction of the metal.

Explain the various types of pattern used in Mould Making. (5M)

One piece solid pattern
Two piece or split pattern
Loose piece pattern
Match plate pattern
Sweep pattern
Three piece or multi piece pattern
Follow board pattern
Gated pattern

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2. **Classify the materials used for pattern making and write about them. (9M)** BTL 5

Answer: Page 1.4.4 – Dr.Ramachandran

Wood (3M)

- It should be properly dried and seasoned
- Should be free from knots, insects, excessive sap wood

Types: a) Deodar b)Teak Woodc)Mahogany

Metal (3M)

- Where durability and strength is required
- It is either made from master wooden pattern or by machined by machines
- Metal patterns are usually made in machine moulding

Types :

Aluminium (light in weight,corrosion resistant, easily worked)
Brass (smooth structure , easily worked , it is expensive used in small casting)
White steel (low melting point, cast easily , low shrinkage , light weight)
Cast iron (cheaper and durable .low corrosion resistance unless protected)

Plastic(3M)

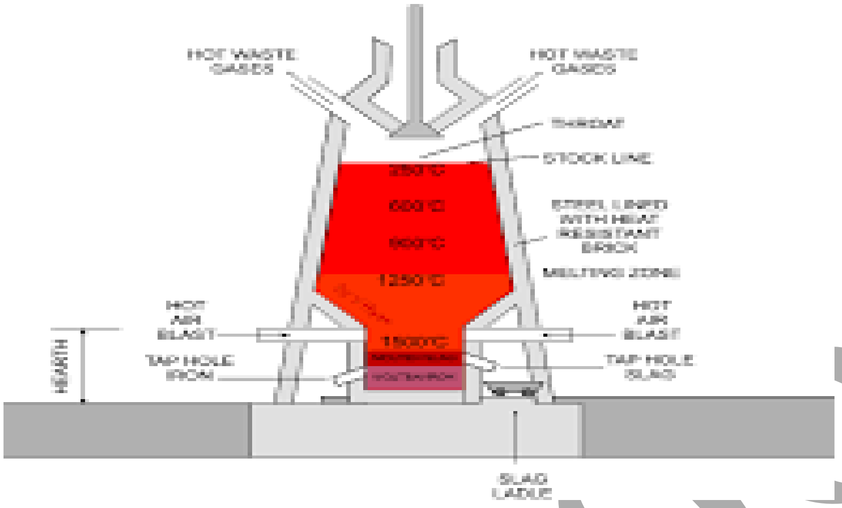
- High resistant to corrosion
- Lighter and stronger than wood pattern
- Dimensionally stable
- Smooth surface
- No moisture absorption

Types

Epoxy, phenol formaldehyde and polyester resins

	(ii)What are the allowances given while making Pattern? Explain (4M)BTL5 Pattern Allowances (1M) Shrinkage Allowances (1M) Machining allowance (1M) Draft or Taper allowance (1M) Distortion or camber allowance The difference in the dimension of the pattern and the cast component is called as **pattern allowances**. TYPES: **Shrinkage allowance**: Shrinks on solidification and contracts on cooling. To compensate this, the pattern is made larger than the required casting. Cast Iron 10 mm/mt.. Brass 16 mm/mt., aluminum Alloys. 15 mm/mt., Steel 21 mm/mt., Lead 24 mm/mt. **Machining allowance**: To get required surface finish the pattern is made larger than cast product. **Draft or Taper allowance**: Vertical faces are made taper for easy removal of pattern. **Distortion or camber allowance**: This is a result of uneven shrinkage or improper exposure of surfaces during cooling so that the patterns are made slightly bend. Rapping allowance It is also called as shake allowance to remove the pattern out of mould, so the pattern is made slightly smaller than the cast product. It is called as negative allowance.
3	**Classify the different types of moulding sand and explain. (6M)** BTL5
	Answer: Page 1.39 – Dr.S.Ramachandran Green sand Dry sand Loam sand Facing sand Backing sand system sand parting sand Core sand **(ii) Explain the method of moulding sand testing (7M)**BTL5 Moisture content test Clay content test Chemical composition of sand Grain shape and surface texture of sand Grain size distribution of sand Specific surface of sand grains Water absorption capacity of sand Refractoriness of sand Strength test Permeability test Flow ability test Shatter index test Mould hardness test
4	**Describe the various properties required for the moulding sand. (7M)** BTL1

	Answer: Page 1.42 – Dr.S.Ramachandran Refractoriness Permeability Cohesiveness Green strength Dry strength Flowability or plasticity Adhesiveness Collapsibility **(ii) Explain types of cores and its application (6M)**BTL4 **Types** (4M) i) Based on State or condition of core a) Green sand core b) dry sand core ii) Based on nature of core material employed a) oil bonded core b) resin bonded core c) shell core d) sodium silicate core iii) Based on types of core hardening process employed a) CO2 process b) hot box core c) cold set pressure d) oil No bake core iv) According to Shape and position of core a) horizontal core b) vertical core c) hanging core d) balanced core e) drop core **Applications** (2M) They are most commonly used in sand casting, but are also used in injection molding.
5	**Identify and Explain the various steps involved in sand core manufacturing. (13M)** BTL1
	Answer: Page 1.57 – Dr.Ramachandran Various steps (1M) Core sand preparation (2M) Core making (2M) Core baking (2M) Core finishing (2M) Setting the cores (2M) Remembering (2M)
6	
	Explain construction and operation of Blast furnace with necessary sketch (13M) BTL4 **Answer: Page 1.92- Dr.S.Ramachandran** **Diagram (4M)** **Construction & Operation (9M)** Preheating Zone Melting zone Slag Zone Tap hole



7 **Explain stir casting method with a sketch. (13M)** BTL5

Answer: Page 1.157- Dr.S.Ramachandran

Diagram (4M)

Construction & Operation (9M)

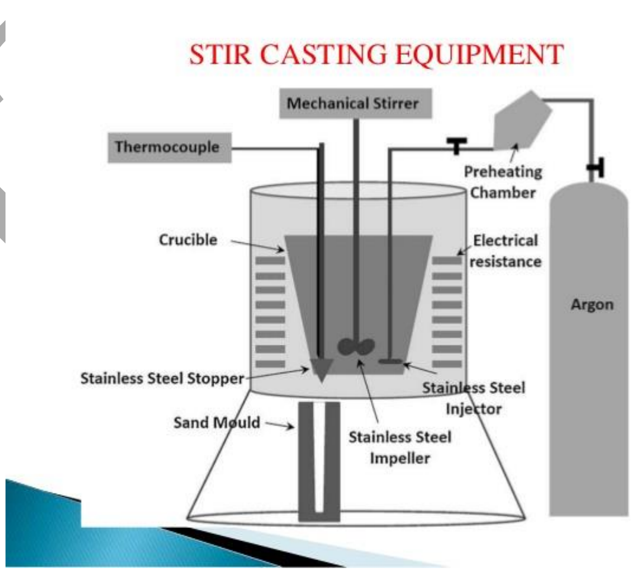
Crucible Furnace

Preheating chamber

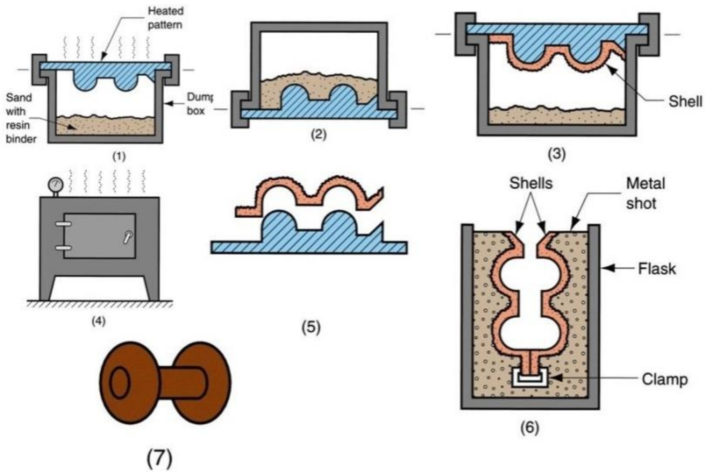
Stainless Steel Impeller

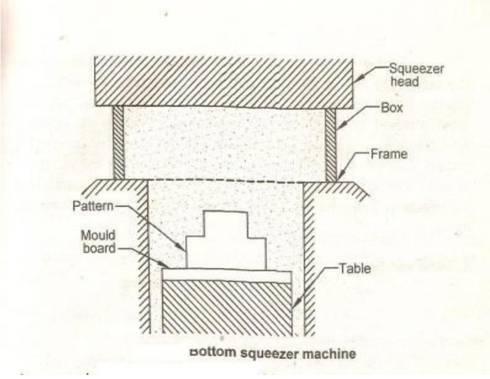
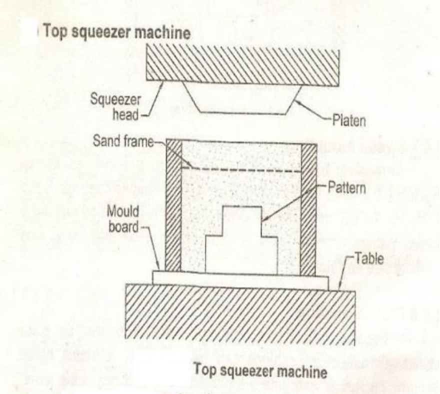
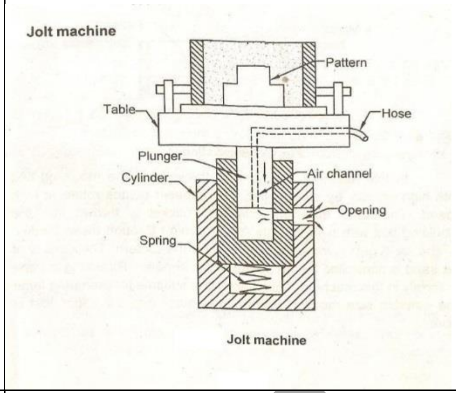
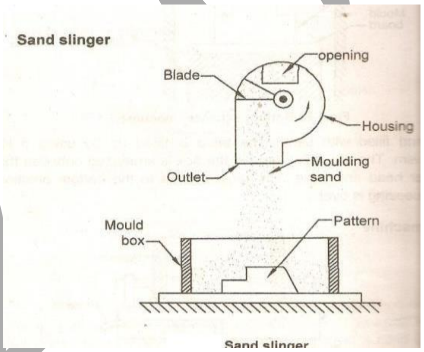
Thermocouple

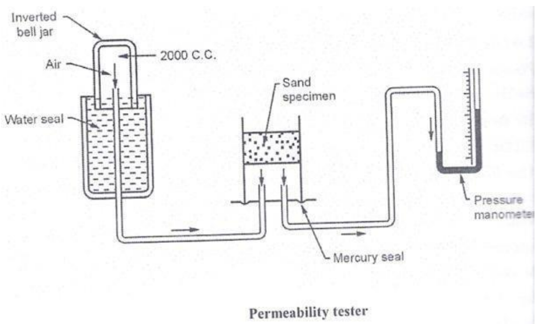
Mechanical Stirrer



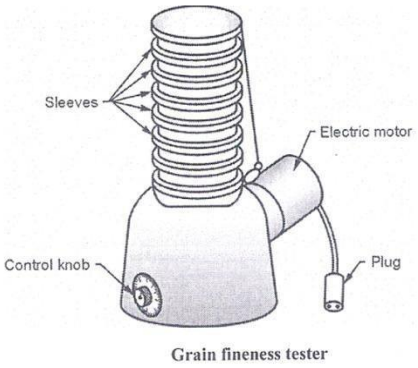
8 **Enumerate the steps in sequence for producing Shell Moulding. (13M)** BTL5

	Answer: Page 1.131- Dr.S.Ramachandran **Diagram (4M)** **Construction & Operation (9M)** Match plate heated Box is inverted Sand shell heating Shell mould stripped Assembled 
	PART * C
1	**Explain the different type of moulding machines withneatsketch.(15M)** BTL5
	Answer: Page 1.136- Dr.S.Ramachandran **Diagram (5M)** **Construction & Operation (10M)** Bottom Squeezer Machine Top Squeezer Machine Jolt machine Sand Slinger

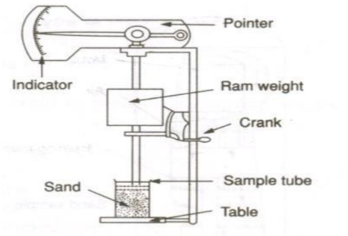
	   
2	**Explain the different types of Sand testing withneatsketch.(15M)** BTL5
	Answer Page no. 1.47- Dr.S.Ramachandran **Diagram (5M)** **Construction & Operation (10M)** **MOISTURE CONTENT TEST** **CLAY CONTENT TEST** **GRAIN FINENESS TEST** **REFRACTORINESS TEST** **PERMEABILITY TEST**



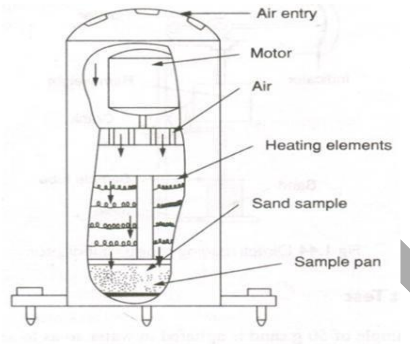
Permeability tester



Grain fineness tester



Direct reading moisture indicator.



Sand moisture drying device.

3 **Explain the different types inspection methods usedinfoundries.(15M)** BTL5

Answer Page 1.102- Dr.S.Ramachandran

Diagram (5M)

Construction & Operation (10M)

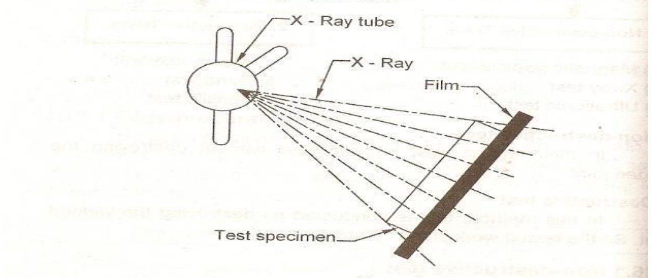
Magnetic Particle Inspection

Dye-Penetrant Inspection

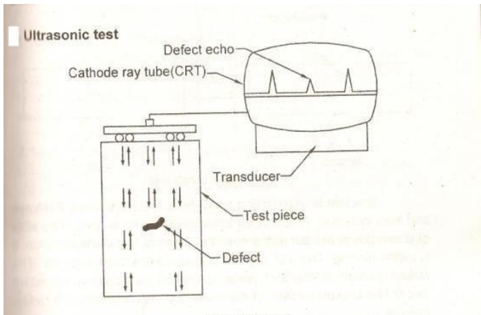
Radiographic Inspection

Ultrasonic Inspection

X – ray test or radiographic test



X- ray test



Ultrasonic test

UNIT II - JOINING PROCESSES

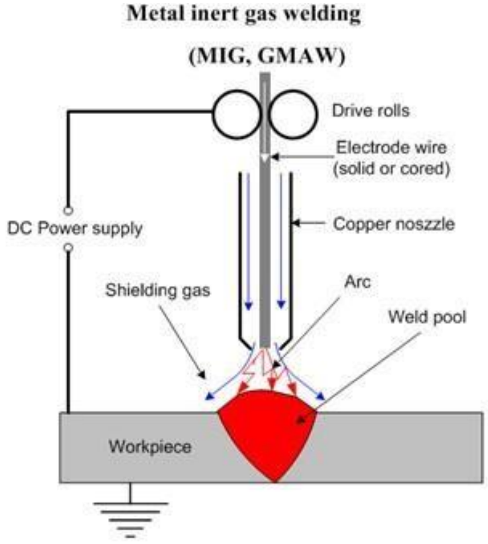
Operating principle, basic equipment, merits and applications of : Fusion welding processes Gas welding - Types – Flame characteristics; Manual metal arc welding – Gas Tungsten arc welding- Gas metal arc welding – Submerged arc welding – Electro slag welding; **Operating principle andapplicationsof** : Resistance welding - Plasma arc welding – Thermit welding – Electron beamwelding – Friction welding and Friction Stir Welding; Brazing and soldering; **Weld defects:** types,causes and cure

PART * A

Q.No.	Questions
1.	**How can slag inclusions in welding be avoided? (May 2008)** BTL4 (a)Avoid multi layer welding (b) Reduce arc length (c) Increase electrode angle (d) Avoid using large electrode
2	**What is the purpose of flux? (May 2008)** BTL1 (a) It acts as shield to weld. (b) To prevent atmospheric reaction of molten metal with atmosphere.
3	**How can slag inclusions in welding be avoided? (May 2008)** BTL4 (a)Avoid multi layer welding (b)Reduce arc length (c)Increase electrode angle (d)Avoid using large electrode
4	**List out any four arc welding equipment. (May 2006)** BTL1 (a) A.C or D.C. machine (b) Wire brush (c) Cables and connectors (d) Ear thing clamps (e) Chipping hammer
5	**Why flux is coated on filler rods? (Dec. 2008)** BTL1 (a) The coating improves penetration and surface finish. (b) Suitable coating will improve metal deposition rates.
6	**Classify various ARC welding processes.** BTL1 (a) Arc welding (b) Carbon arc (c) Metal arc (d) Metal inert gas (e) Tungsten inert gas (f) Plasma arc (g) Submerged arc (h) Electro-slag
7	**Classify various GAS welding processes.** BTL1 (a) Gas Welding (b) Oxy-acetylene (c) Air-acetylene (d) Oxy-hydrogen
8	**Name the various methods of Resistance Welding.** BTL1 (a) BUTT (b) Spot Seam Projection (c) Percussion.
9	**How does brazing differ from braze welding? (Dec. 2008)** BTL5 Brazing The filler alloy is fed to one or more points in the assembly and it is drawn into the rest of the joint by capillary action. Braze Welding The filler alloy is deposited directly at the point where it is desired.
10	**What are the special features of friction welding? (May 2007)** BTL1 (a) Friction welding is a solid-state welding process where coalescence is produced by the heat obtained from mechanically induced sliding motion between rubbing surfaces.(b) The work parts are held together under pressure. (c) Its operating is simple. (d) Power required for the operation is low. (e) It is used for joining steels, super alloys, non-ferrous metals and combinations of metals.
11	**Define resistance welding process. (May 2006, May 2007)** BTL1 Resistance welding is a process where coalescence is produced by the heat obtained from

	resistance offered by the workpiece to the flow of electric current in a circuit of which the workpiece is a part and by the application of pressure.
12	**What is the application of carburizing flame? (Dec. 2009)** BTL1 (a) Welding of low alloy steel rods (b) Non-ferrous metals (c) High carbon steel
13	**Mention the applications of friction welding.**BTL1 (a) Used in refrigeration. (b) Used in super alloys. (c) Production of taper and reamer drills (d) Production of axle shafts (e) valves and gears.
14	**Name the chemicals used in flux.** BTL1 (a) Chlorides (b) Borax and boric acid(c) Borates (d) Fluorides.
15	**Differentiate between transferred and non transferred plasma arc welding.** BTL2 (a) Transferred arc process The arc is formed between the electrode(-) and the work piece(+). In other words, arc is transferred from the electrode to the work piece. A transferred arc possesses high energy density and plasma jet velocity. (b) Non-transferred arc process The arc is formed between the electrode(-) and the water cooled constricting nozzle(+). Arc plasma comes out of the nozzle as a flame. The arc is independent of the work piece and the work piece does not form a part of the electrical circuit
16	**Evaluate why is spot welding commonly used in automotive bodies and in large appliances.** BTL5 In Automotive bodies in your driveway was manufactured with hundreds of spot welds, on the frame, the body, the suspension, etc.When you see those big robotic machines welding cars in automobile factories, what they're most-likely doing is spot welding
17	**Show that the seam welding is an application of spot welding.**BTL1 The difference is that two wheel-shaped electrodes are used, rolling along (and usually feeding) the workpiece The two wheels should be of the same size, in order to prevent the part from being deflected towards one of them. The actual contact profile can be designed in a number of ways, in order to suit the shape of the part to be welded. The current may flow continuously while welding is being carried out, or intermittently to produce a series of spots that are so closely positioned as to produce a single, continuous weld. An unavoidable problem of seam welding is that some of the current 'leaks' through the completed weld.
18	**Give the meaning of Nugget in Electric Resistance Welding.**BTL2 In resistance spot welding, "the welding of overlapping pieces of metal at small points by application of pressure and electric current" creates a pool of molten metal that quickly cools and solidifies into a round joint known as a "nugget."
19	**List any four welding defects.** BTL1 (a) Cracks (b) Porosity (c) Solid Inclusion (d) Lack of Fusion and Inadequate or incomplete penetration:
20	**Examine the causes of Welding defects.** BTL3 (a) Lack of Fusion. (b) Incomplete Penetration. (c) Excessive Penetration. (d) Porosity. (e)Inclusion.
	PART * B
1	**Explain MIG & TIG Welding with neat sketch. (13M)** BTL 1

MIG-Metal Inert Gas Welding (GMAW-Gas Metal Arc Welding)arc welding process, working and construction (2M)



(1M)

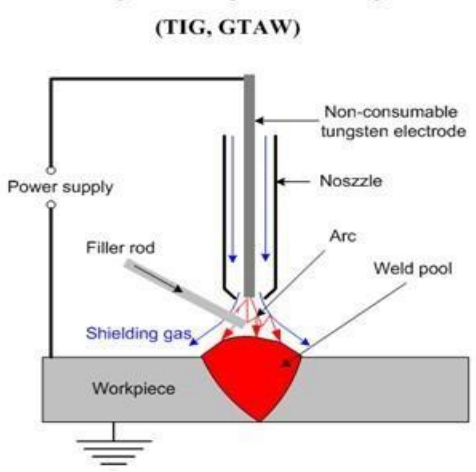
Advantages of Metal Inert Gas Welding (MIG, GMAW)(2M)

(a) Continuous weld may be produced (b)High level of operators skill is not required
(c) Slag removal is not required.

Disadvantages of Metal Inert Gas Welding (MIG, GMAW)(2M)

(a)Expensive and non-portable equipment is required (b) Outdoor application are limited because of effect of wind (c)dispersing the shielding gas.

TIG - Tungsten Inert Gas Arc Welding (GTAW - Gas Tungsten Arc Welding) working and construction(2M)

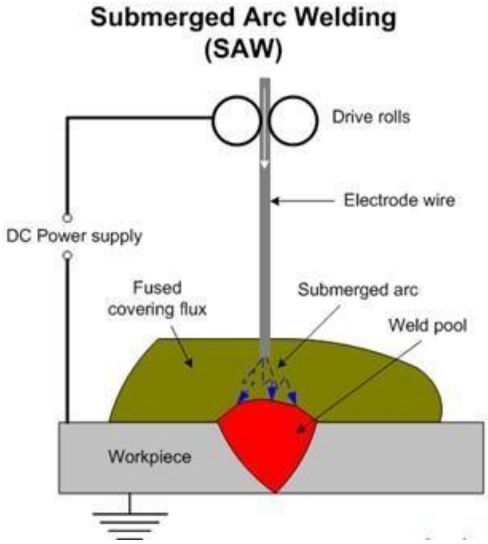


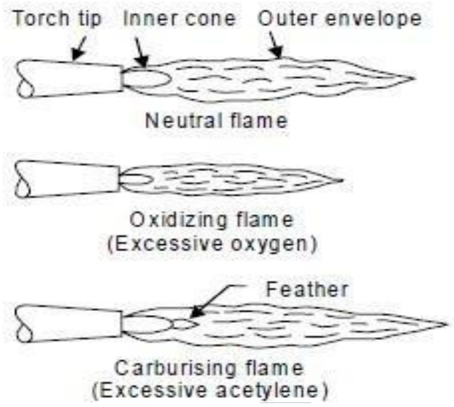
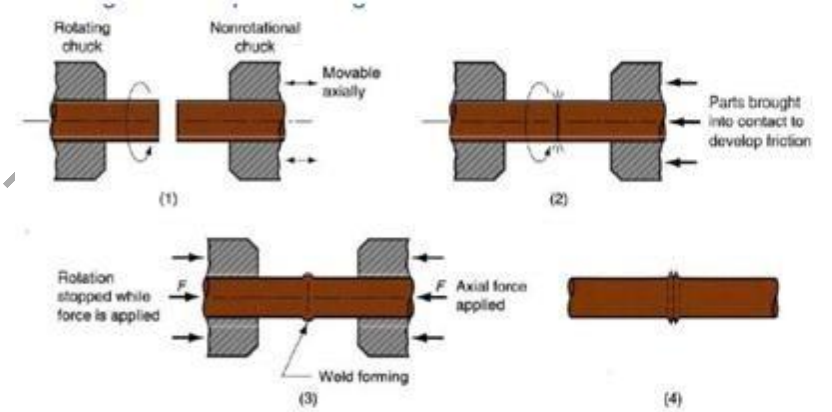
(2M)

Advantages of Tungsten Inert Gas Arc Welding (TIG, GTAW)

(a) Weld composition is close to that of the parent metal (b) High quality weld structure (c)Slag removal is not required (no slag) (d)Thermal distortions of work pieces are minimal due to concentration of heat in small zone. (2M)

Disadvantages of Tungsten Inert Gas Arc Welding (TIG, GTAW)

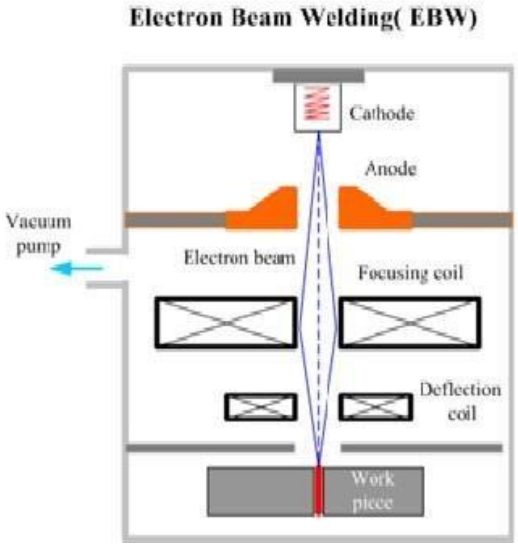
	(a)Low welding rate (b)Relatively expensive (c) Requires high level of operators skill. (2M)
2	**Explain submerged arc welding with neat sketch. (APRIL/MAY 2015) (9M)** BTL 5
	Answer: Page 1.4.4 – Dr.S.Ramachandran SAW - Submerged Arc WeldingConstruction working Power supply Drive roll Electrode wire Work piece (6M)  (3M) Advantages of Submerged Arc Welding (SAW) (a)Very high welding rate (b)The process is suitable for automation High quality weld structure.(2M) Disadvantages of Submerged Arc Welding (SAW) (a)Weld may contain slag inclusions (b) Limited applications of the process - mostly for welding horizontally located plates.(2M)
3	**Explain the flame characteristics in gas welding with neat sketch and its applications.(13M)**BTL5
	Answer: Page 1.39 – Dr.Ramachandran **NEUTRAL WELDING FLAME**(4M) A neutral flame results when approximately equal volumes of oxygen and acetylene are mixed in the welding torch and burnt at the torch tip. The temperature of the neutral flame is of the order of about 5900°F (3260°C). It has a clear, well defined inner cone, indicating that the combustion is complete. **CARBURIZING OR REDUCING WELDING FLAME**(4M) The carburizing or reducing flame has excess of acetylene and can be recognized by acetylene feather, which exists between the inner cone and the outer envelope. The outer flame envelope is longer than that of the neutral flame and is usually much

	brighter in color. With iron and steel, carburizing flame produces very hard, brittle substance known as iron carbide. **OXIDIZING WELDING FLAME**(5M) The oxidizing flame has an excess of oxygen over the acetylene. An oxidizing flame can be recognized by the small cone, which is shorter, much bluer in color and more pointed than that of the neutral flame. The outer flame envelope is much shorter and tends to fan out at the end  Gas welding flames
4	**Write short notes on Friction welding , Electron beam Welding with neat sketches. (13M)** BTL1
	Answer: Page 1.42 – Dr.Ramachandran Friction Welding working and construction (3M)  (1) rotating part, no contact; (2) parts brought into contact to generate friction heat; (3) rotation stopped and axial pressure applied; and (4) weld created. (1M) Advantages of Friction Welding (a) Simple operation andLowcost. (b) Power Requirement is Low (c)Time required isveryless. (d) No flux, Filler, Smoke and fumes (e) Heat dissipated is very quick. (1M)

Disadvantages of Friction Welding

(a) Heavy rigid machine is required for work holding. (b) Flat and angular joints are not possible. (c) Continuous joints are not possible.(1M)

Electron Beam Welding working and construction (3M)



(2M)

Advantages of Electron Beam Welding (EBW)

(a) Tight continuous weld (b) Low distortion

(c) Narrow weld and narrow heat affected zone(d) Filler metal is not required.(1M)

Disadvantages of Electron Beam Welding (EBW)

(a) Expensiveequipment (b) Highproductionexpenses (c) X-rayirradiation.(1M)

5 **(i) Discuss about soldering & Brazing with neat sketch.(8M)** BTL1

Answer: Page 1.57 – Dr.Ramachandran

SOLDERING

Soldering is a method of joining similar or dissimilar metals by heating them to a suitable temperature and by means of a filler metal, - temperuatre not exceeding 450°C and below the solidus of the base material.

BASIC OPERATIONS IN SOLDERING

(1) SHAPING AND FITTING OF METAL PARTSTOGETHER

(2) CLEANING OFSURFACES

BRAZING:

Brazing is a process of joining metals without melting the base metal. filler material used for brazing has liquidus temperature above 450°c and below the temperature of the base metal.

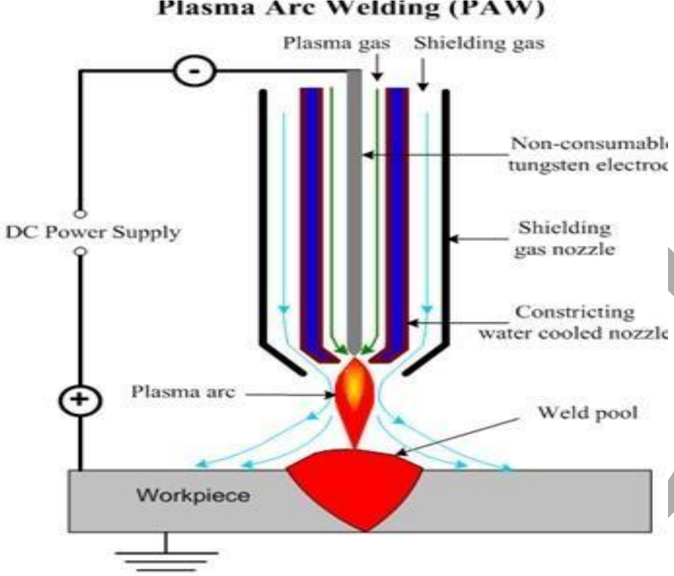
METHODS OF BRAZING : (4M)

TORCH BRAZING

FURNACE BRAZING

BRAZE WELDING

PAW - Plasma Arc Welding is the welding process utilizing heat generated by a constricted arc struck between a tungsten non-consumable electrode and either the work piece (transferred arc process) or water cooled constricting nozzle (non-transferred arc process).Transferred arc process produces plasma jet of high energy density and may be used for high speed welding and cutting ofCeramics, steels, Aluminum alloys, Copper alloys, Titanium alloys, Nickel alloys.



Advantages of Plasma Arc Welding (PAW): (4M)

Requires less operator skill due to good tolerance of arc to misalignments; High welding rate; High penetrating capability (keyhole effect);

Disadvantages of Plasma Arc Welding (PAW): Expensive equipment;

High distortions and wide welds as a result of high heat input.

6 **Explain construction and operation of Blast furnace with necessary sketch (13M)** BTL4

Answer: Page 1.92- Dr.S.Ramachandran

Diagram (4M)

Construction & Operation (9M)

Preheating Zone	(2M)
Melting zone	(2M)
Slag Zone	(2M)
Tap hole	(2M)

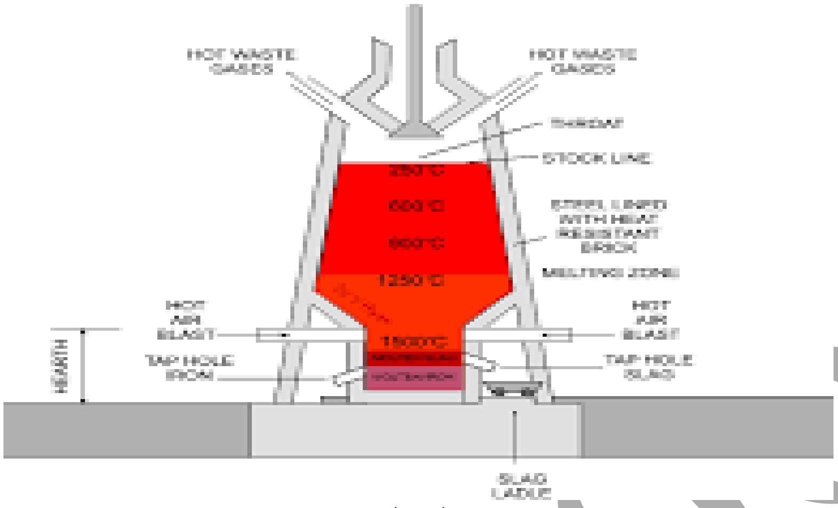
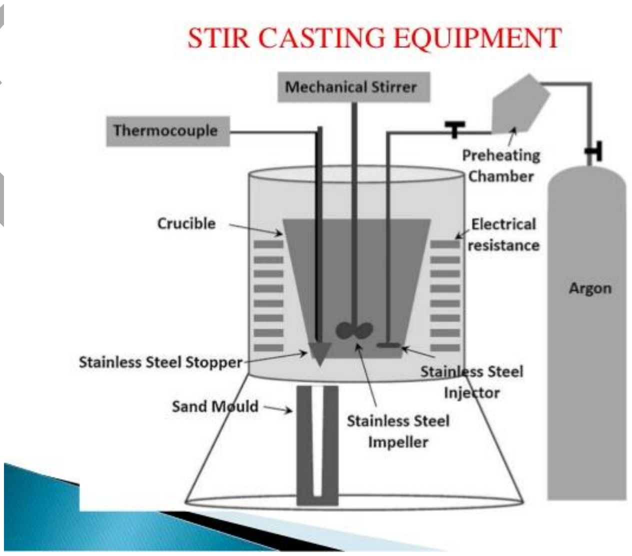
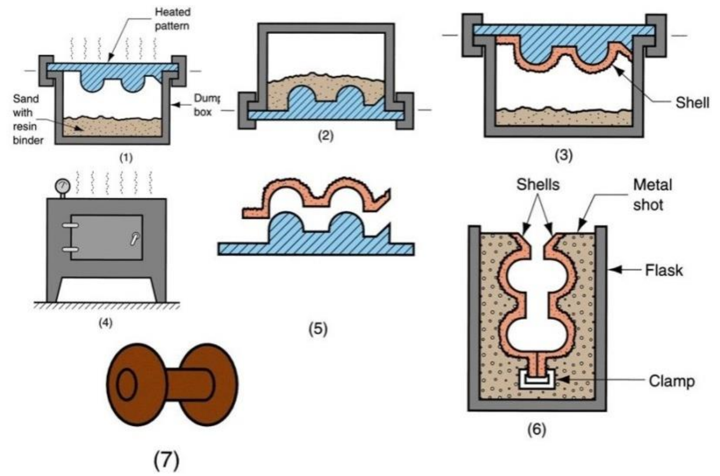
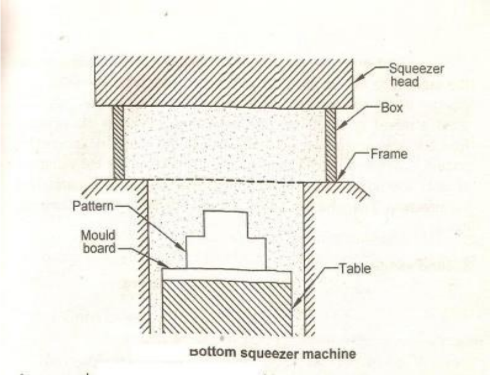
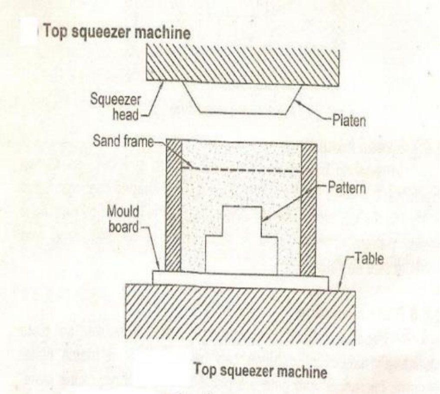
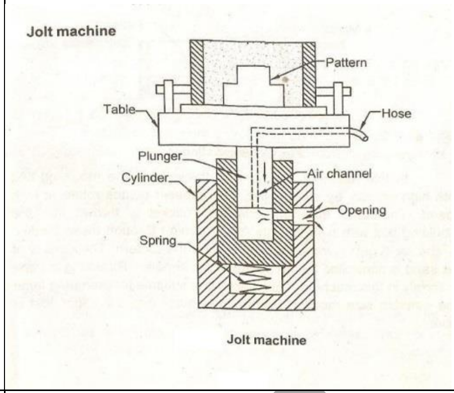
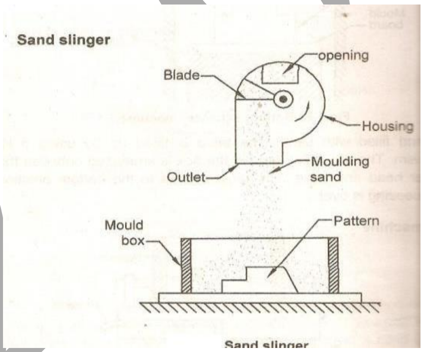
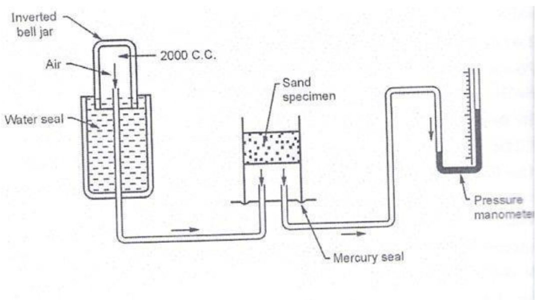
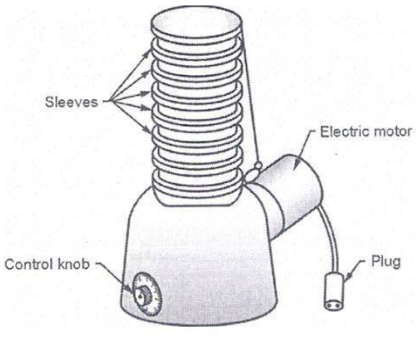
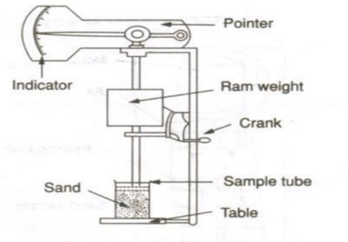
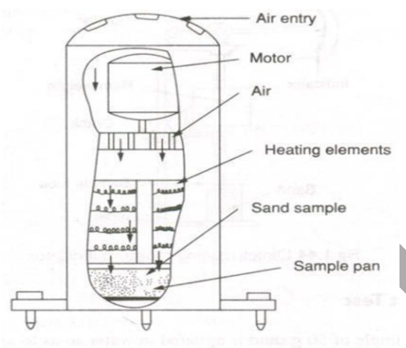
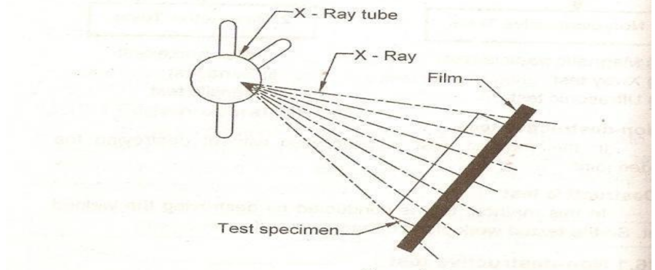
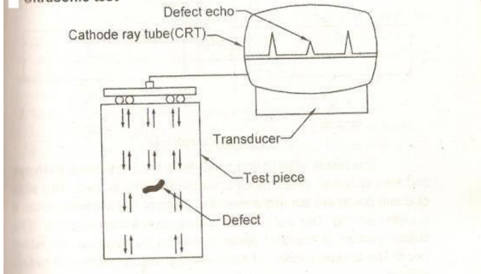
	 (5M)
7	**Explain stir casting method with a sketch. (13M)** BTL5
	Answer: Page 1.157- Dr.S.Ramachandran **Diagram (4M)** **Construction & Operation (9M)** Crucible Furnace Preheating chamber Stainless Steel Impeller Thermocouple Mechanical Stirrer 
8	**Enumerate the steps in sequence for producing Shell Moulding. (13M)** BTL5 **Answer Page no. 1.131- Dr.S.Ramachandran**

	Diagram (4M) **Construction & Operation (9M)** Match plate heated Box is inverted Sand shell heating Shell mould stripped Assembled 
	PART * C
1	**Explain the different type of moulding machines withneatsketch.(15M)** BTL5
	Answer: Page 1.136- Dr.S.Ramachandran **Diagram (5M)** **Construction & Operation (10M)** Bottom Squeezer Machine Top Squeezer Machine Jolt machine Sand Slinger

	 Bottom squeezer machine  Top squeezer machine  Jolt machine  Sand slinger
2	**Explain the different types of Sand testing withneatsketch.(15M)** BTL5
	Answer :Page 1.47- Dr.S.Ramachandran **Diagram (5M)** **Construction & Operation (10M)** Moisture Content Test Clay Content Test Grain Fineness Test Refractoriness Test Permeability Test

	 Permeability tester  Grain fineness tester MECH  Direct reading moisture indicator.  Sand moisture drying device.
3	**Explain the different types inspection methods usedinfoundries.(15M)** BTL5
	Answer: Page 1.102- Dr.S.Ramachandran **Diagram (5M)** **Construction & Operation (10M)** Magnetic Particle Inspection Dye-Penetrant Inspection Radiographic Inspection Ultrasonic Inspection X – ray test or radiographic test  X- ray test Ultrasonic test  Ultrasonic test

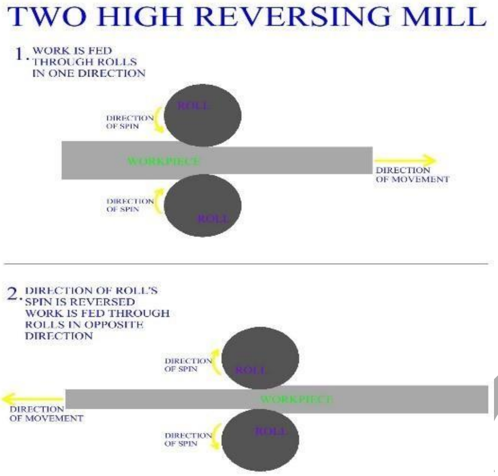
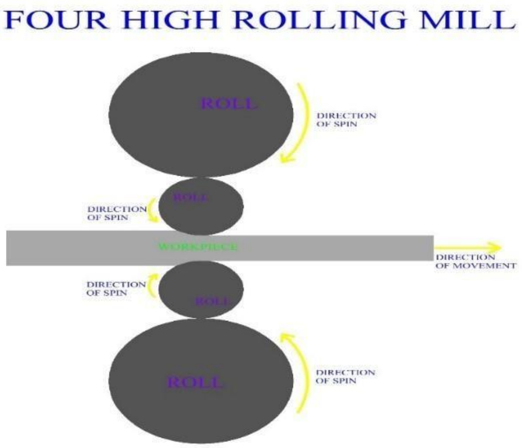
UNIT III - METAL FORMING PROCESSES

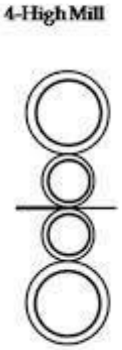
Hot working and cold working of metals – Forging processes – Open, impression and closed die forging – forging operations. Rolling of metals– Types of Rolling – Flat strip rolling – shape rolling operations – Defects in rolled parts. Principle of rod and wire drawing – Tube drawing – Principles of Extrusion – Types – Hot and Cold extrusion.

PART * A

Q.No.	Questions
1.	**Define hot working of metals.** BTL1 Hot working process metals are plastically deformed above their recrystallization temperature. Being above the recrystallization temperature allows the material to recrystallize during deformation. This is important because recrystallization keeps the materials from strain hardening, which ultimately keeps the yield strength and hardness low and ductility high. Many kinds of working, including rolling, forging, extrusion, and drawing, can be done with hot metal.
2	**Define cold working of metals.** BTL 1 Cold working is the plastic deformation of metals below the recrystallization temperature. In most cases, such cold forming is done at room temperature. The major cold-working operations can be classified basically as squeezing, bending, shearing and drawing.
3	**Analyse why surface finish of a rolled products better in cold rolling than in hot rolling.** BTL 4 All cold products provide a superior surface finish, and are superior in tolerance, concentricity, and straightness when compared to hot rolled. Cold finished bars are typically harder to work with than hot rolled due to the increased carbon content.
4	**Define angle of bite in rolling.** BTL 1 Definition of angle of bite. In rolling metals where all the force is transmitted through the rolls, maximum attainableangle between roll radius at the first contact and the rollcenters. If the operating angle is less, it is called the contact angle or roll angle.
5	**Define lateral Extrusion.** BTL1 Lateral Extrusion: In this process, the material flows in the perpendicular direction of the punch displacement. The material, which is enclosed by the punch and die, is forced to flow through orifices that are radially placed.
6	**Identify various defects in rolled parts.** BTL1 In hot rolling, if the temperature of the workpiece is not uniform the flow of the material will occur more in the warmer parts and less in the cooler. If the temperature difference is great enough cracking and tearing can occur.
7	**Classify the various forming processes.** BTL3 a. Bulk forming b. sheet forming c. Powder metal forming
8	**Summarizes the effects of cold working.** BTL 5 This leads to an increase in the yield strength of the material and a subsequent decrease in ductility. ... The effects of cold working may be reversed by annealing the material at high

	temperatures where recovery and recrystallization reduce the dislocation density.
9	**Define forging.** BTL 1 Manufacturing process in which a piece of (usually hot) metal is formed into the desired shape by hammering, pressing, rolling, squeezing, and other such operations in one or more forging equipment.
10	**Differentiate between compound dies and progressive dies.** BTL 4 Compound dies :Simple dies are also known as single operation dies as a single operation is performed for each stroke of the die press. These are generally used for very simple operations listed under cutting or forming dies. progressive dies :Progressive dies also known as follow on dies have a series of operations. At every station on the work piece, an operation is performed during the stroke of press. However, in between the two presses, the work piece gets transferred to the next station and is worked there. In this operation thus, each press operation develops a finished piece.
11	**List out some common applications where extrusion is used.** BTL 1 Extrusion is common in the application of adding colorant to molten plastic thus creating specific custom color. A multitude of polymers are used in the production of plastic tubing, pipes, rods, rails, seals, and sheets or films.
12	**Point out the advantage of cold extrusion.** BTL 4 Cold extrusion is done at room temperature or near room temperature. The advantages of this over hot extrusion are the lack of oxidation, higher strength due to cold working, closer tolerances, better surface finish, and fast extrusion speeds if the material is subject to hot shortness.
13	**Name the types of forging machines.** BTL 1 a. Press forging b. Upset forging c. Automatic hot forging d. Roll forging e. Induction forging f. Multidirectional forging g. Isothermal forging
14	**Define upsetting and Drawing down in forging operation.** BTL 1 Upsetting :This is applied to increase the cross seat ional area of the stock at the expanse of the length. To achieve the length of upsetting force is applied in a direction parallel to the length axis, For example forming of a bolt head.
15	**Different types of rolling mills.** BTL 3 a) Two high rolling mills b) Three high rolling mills c) Four high rolling mills d) Tandem rolling mills e) Cluster rolling mills
16	**Differentiate between hot and cold forging.** BTL 4 Strengthening mechanism in cold forging is strain hardening, while at high temperature during hot forging, strain hardening is avoided resulting in optimum yield strength, low hardness and high ductility. The process delivering desired quality more economically is chosen. The decision is based on the required properties of the desired component, its cost of production and customer's requirements.
17	**Differentiate extrusion and forging.** BTL 4 Extrusion is a process used to create objects of a fixed cross-sectional profile. A material is pushed through a die of the desired cross-section. Forging is a manufacturing process involving the shaping of metal using localized compressive forces. The blows are delivered with a hammer (often a power hammer) or a die.
18	**Define fullering.** BTL 1 A half-round hammer used for grooving and spreading iron. a tool or part of a die for reducing

	the sectional area of a piece of work.
19	**What is recrystallisation temperature?**BTL 4 Recrystallization temperature is defined as temperature to attain the process in which grains of a crystal structure come in a new structure or new crystal shape.
20	**List out any four parts that can be manufactured by shape rolling operations.** BTL 1 a. Flatteners b. Work pieces c. Rollers
	PART * B
1	**Classify three types of rolling mills and sketch them (8M)** BTL 4
	Answer: Page 3.35 – Dr.Ramachandran   



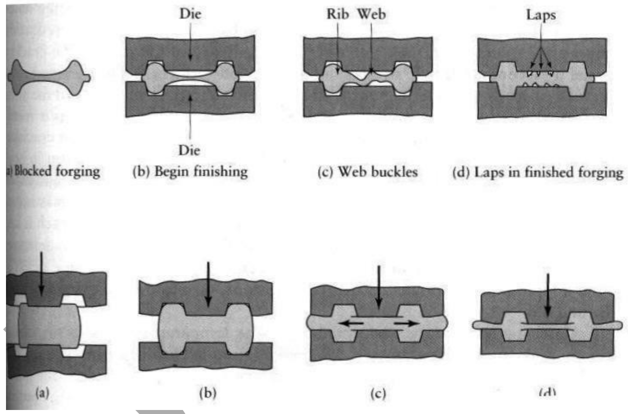
(4M)

Working principle (4M)

(ii)What are forging defects? Explain any four defects with the help of sketches. (5M)BTL 4

Answer: Page 3.35 – Dr.Ramachandran

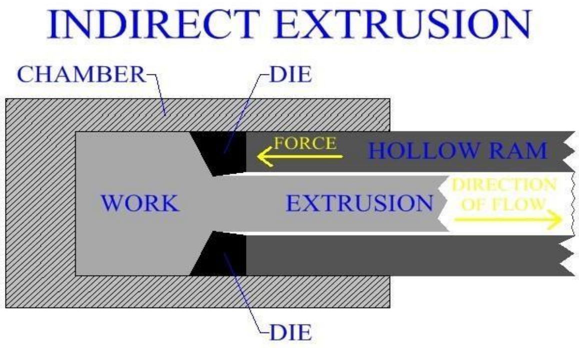
Defective metal structure
Presence of cold shuts, forging and faulty die design
Incomplete components
Mismatched forging
Burnt and overheated metal
Fibre flow lines discontinued
Scale pits
Oversized components (3M)



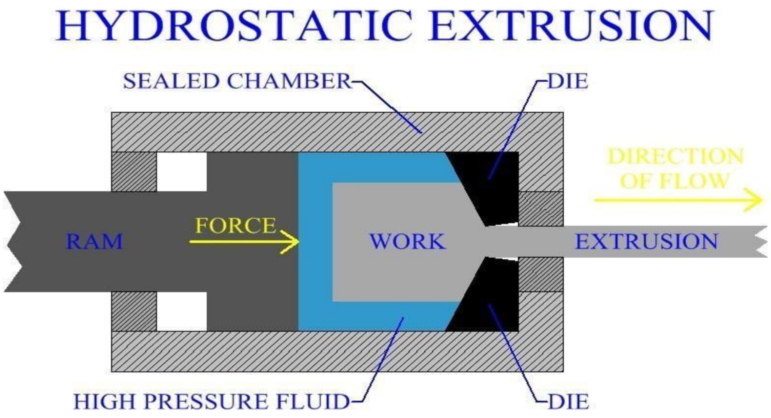
(2M)

2 **Describe the indirect extrusion process for solid and hollow work piece and hydrostatic extrusion process. (8M)** BTL 4

Answer: Page 3.59 – Dr.Ramachandran



Working principle: Heated metal is placed in the die and the force is applied by the power operated hollow ram. So, the extruded metal is pass through the hollow ram and it requires less force compared to the direct extrusion. Also known as backward extrusion. The extruded part is forced through the hollow ram (4M)



Ram is operated in horizontal hydraulic drive. The billet is surrounded by a working fluid which is pressurized by the ram to apply the extrusion force

In this process, the hydraulic fluid remains between the billet and the chamber walls hence eliminating the contact between them. It avoids friction between the billet and the walls of the chamber. (4M)

3 **Distinguish hot and cold extrusion process and briefly explain one in each. (7M)** BTL 4

Answer: Page 3.56 – Dr.Ramachandran

S.N	HOT EXTRUSION	COLD EXTRUSION
1.	Hot extrusion is the process done at fairly elevated temperature, usually 50 to 75% of the melting point of the metal	Cold extrusion is the process carried out in room temperature or slightly elevated temperature.
2.	During the process, residual stresses are not developed in the metal	Residual stresses are developed in the metal
3.	Because of higher deformation temperature used, the stress required for deformation is less	The stress required to cause deformation is much higher
4.	Oxidation of the metal takes place	No oxidation takes place
5.	Poor surface finish	Good surface finish with the use of proper lubricants

6.	Fair mechanical properties are obtained	Good mechanical properties as the materials are worked below the recrystallization temperature.
7.	Tooling and handling costs are more.	Tooling and handling costs are less

(7M)

(ii)With suitable examples, explain open-die and closed-die forging. (6M) BTL 4

Answer: Page 3.52 – Dr.Ramachandran

OPEN DIE FORGING: Open die forging is the process of deforming a piece of metal between multiple dies that do not completely enclose the material. The metal is altered as the dies ―hammer or ―stamp the material through a series of movements until the desired shape is achieved. Products formed through open forging often need secondary machining and refining to achieve the tolerances required for the finished specifications. (2M)

CLASSIFICATION OF OPEN DIE FORGING:

1.Hammer forging
2.Power press (1M)

CLOSED DIE FORGING: Closed die forging (also referred to as impression die forging) is a metal deformation process that uses pressure to compress a piece of metal to fill an enclosed die impression. In some closed die forging processes, a succession of impression dies are used to modify the shape of the material into the final desired shape and form. (2M)

CLASSIFICATION OF CLOSED DIE FORGING:

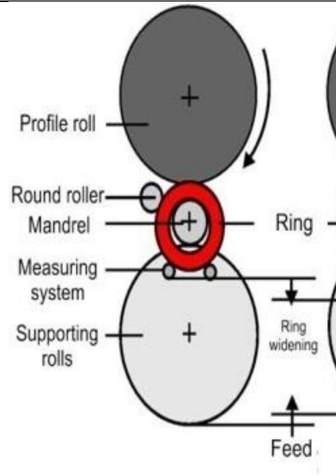
1. Drop Forging
2. Press Forging
3. Upset Forging (1M)

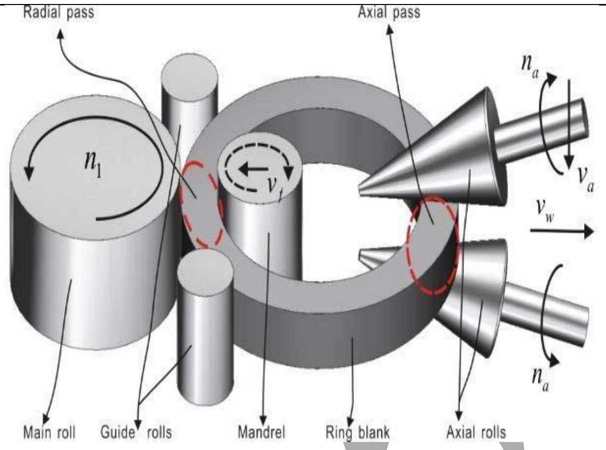
4 **What is shape rolling ? Mention the products of shape rolling and explain production of any one of the products with sketches. (13M)** BTL 4

Answer: Page 3.45 – Dr.Ramachandran

Also known as profile rolling. Metal forming process where structural shapes are passed through rollers to bend or deform the work piece to desired shape while maintaining a constant cross section. (4M)

Structural shapes that can be rolled include: I beams, H beams, T beams, U beams, angle iron, channels, bar stocks and railroad rails. Shape rolling operations are classified into twoparts:1.Ringrolling 2. Thread rolling. (5M)



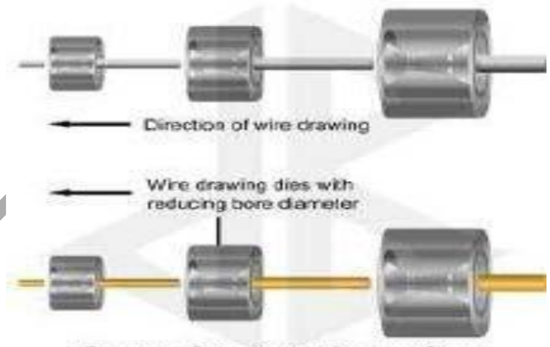


5 **Explain briefly the wire drawing process. (7M)** BTL 1

Answer: Page 3.51– Dr.Ramachandran

This sized point coming out of the die orifice is fixed on the pliers or carriage, which pulls the rod through all the zones of die orifice. That will reduce the diameter of the rod.

The rod is passed through number of dies. Finally the wire is connected to the power reel to get the wire coil. (3M)



(4M)

(ii)Compare press forging and hammer forging(6M) BTL 2

Answer: Page 3.16, 3.24 – Dr.Ramachandran

S.No	PRESS FORGING	HAMMER FORGING
1.	Slow as compared to hammer forging but the reduction in the size of	Fast process. Large number of blows are applied in rapid succession for reduction the size of heavy parts
2.	In press forging there is no restriction of the size of the component	In hammer forging there is a restriction of the component size
3.	The life of the presses and dies is	The life of the hammers and dies is less
4.	Less vibrations and noise	More vibrations and noise
5.	Does not require highly skilled operator	Skilled operator is required for the process

6.	More complicated shapes with better dimensional accuracy can be	Less dimensional accuracy
7.	The distance of the fall cannot be changed	The force of the blow can be varied by changing the distance of the fall

(6M)

6 **How do you compare forged components with cast components**? **(13M)** BTL 2

Answer: Page 3.29 – Dr.Ramachandran

S.NO	FORGED COMPONENTS	CAST COMPONENTS
1.	In forging process, grain flow is continuous and uninterrupted	In casting process, there is no grain flow
2.	Due to improved grain size and true grain flow, forging give greater strength and toughness	Due to no grain flow and weak crystalline structure, casting is weak in withstanding work stresses
3.	Minimum machine finish	More machine finish
4.	Better mechanical properties like strength, toughness, resistance to shock and vibrations	Cast components are brittle and poor resistance to shock and vibrations
5.	Welding of forged parts is easy	Welding of cast parts is difficult
6.	Cracks and blow holes are welded up	Defects like crack and blow holes make the casting weak and unsuitable for use
7.	More accuracy	Less accuracy
8.	Complicated shapes cannot be produced	Complicated shapes can be produced
9.	Used for large parts	Used for small parts
10.	Process is costly because of cost of dies	Casting is less as there are no dies

13M

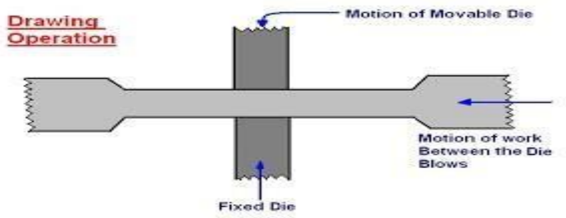
PART * C

1 **Write in detail about the common forging processes. (15M)** BTL2

Answer: Page 3.7 – Dr.Ramachandran

DRAWING

This is the operation in which metal gets elongated with a reduction in the cross sedation area. For this, a force is to be applied in a direction perpendicular to the length axis. (3M)



UPSETTING(3M)

This is applied to increase the cross sectional area of the stock at the expanse of the length. To achieve the length of upsetting force is applied in a direction parallel to the length axis, For example forming of a bolt head.

FLATTING AND SETTING DOWN(3M)

Fullering leaves a corrugated surface on the job. Even after a job is forged into shape with a hammer, the marks of the hammer remains on the upper surface of the job. To remove hammer marks and corrugation and in order to obtain a smooth surface on the job, a flatter or set hammer is used.

SWAGING(3M)

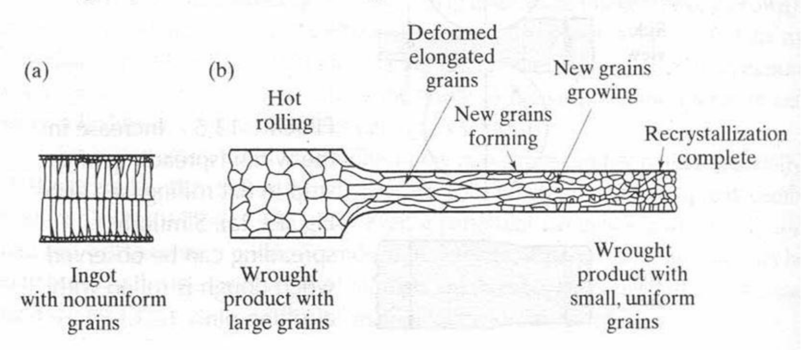
Swaging is done to reduce and finish work for desire size and shape, usually either round or hexagonal. For small jobs top and bottom swage pair is employed, whereas for large work swage block can be used. (3M)

2 **Explain the mechanism of rolling process with clear sketch. Write about some defects associated with rolling (15M)** BTL 4

Answer: Page 3.34 – Dr.Ramachandran

The material to be rolled is drawn by means of friction into the two revolving gap .The compressive forces is applied by the rolls thickness of the material or changes its cross sectional area. Hot rolls are generally rough so that they can bite the work, and cold rolls are ground and polished for good finish In rolling the crystals get elongated in the rolling direction. The peripheral velocity of rolls at entry exceeds that of the strip, which is dragged in if the interface friction is high enough. In the deformation zone the thickness of the strip gets reduced and it elongates. This increases the linear speed of the exit. (5M)

Construction and working (3M)



(3M)

Defects in rolling process

Wavy edges on sheets are the result of roll bending. The strip is thinner along its edges than at its center thus, the edges elongate more than the center.

Zipper Crackers Edge cracks.

Alligatoring : Non uniform bulk deformation of the billet during rolling or by the presence of defects in the original cast material. (4M)

3 **Write a critical note on principle, types, and characteristics and limitations of the extrusion**

process.(15M) BTL 2

Answer: Page 3.56 – Dr.Ramachandran

PRINCIPLE OF EXTRUSION:Heated metal is compressed and forced through a suitable shaped die. Force requirement of cold extrusion is high. Process is high. So, most of the metals are extruded in hot conditions only. During the process, a heated cylindrical billet is placed in the container and it is forced out through a steel die with the help of a ram or a plunger. (4M)

TYPES OF EXTRUSION:

I. Hot extrusion
1. Forward or direct extrusion 2.Backward or indirect extrusion
II. Cold extrusion or Impact extrusion (4M)

CHARACTERISTICS OF EXTRUSION:

As the geometry remains same during the operation,
Extruded parts have the same cross section. (4M)

LIMITATIONS OF EXTRUSION:

Limited complexity of parts
Uniform complexity of parts (3M)

UNIT IV–SHEET METAL PROCESS

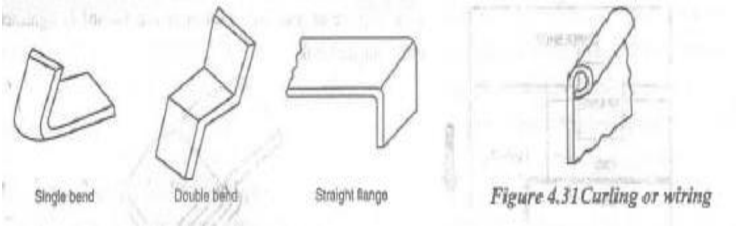
Sheet metal characteristics – shearing, bending and drawing operations – Stretch forming operations – Formability of sheet metal – Test methods –**special forming processes**-Working principle and applications – Hydro forming – Rubber pad forming – Metal spinning– Introduction of Explosive forming, magnetic pulse forming, peen forming, Super plastic forming – Micro forming

PART * A

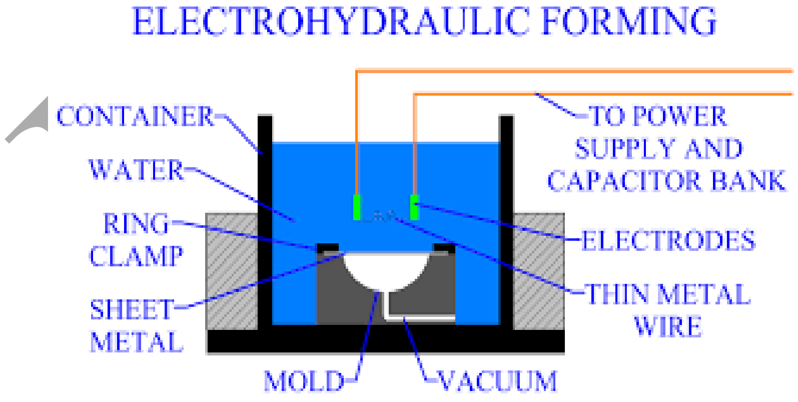
Q.No.	Questions
1.	**Define shear angle. Why is it given in punches and dies.** BTL2 The shearing angle is provided in the die in the case of blanking operations and in the punch in the case of hole punching operations. Most often the shearing angle is provided so that the dimension is roughly equal to or more than the plate thickness.
2	**Define flanging.** BTL2 Flanging metal is the act of swiping sheet metal in a direction contrary to its previous position
3	**What is the principle of magnetic pulse forming?**BTL1 The basic principle is that discharging of a capacitor through coil over a period of micro seconds, the magnetic flux densities of the order of hundreds of kilojoules can be produced.
4	**Explain piercing and blanking.**BTL1 a) Blanking is a process in which the punch operation removes a final product from a larger piece of sheet metal. b) Piercing is process in which punch operation cuts a hole / material by tearing operation from a final piece of sheet metal. Piercing is a blanking operation

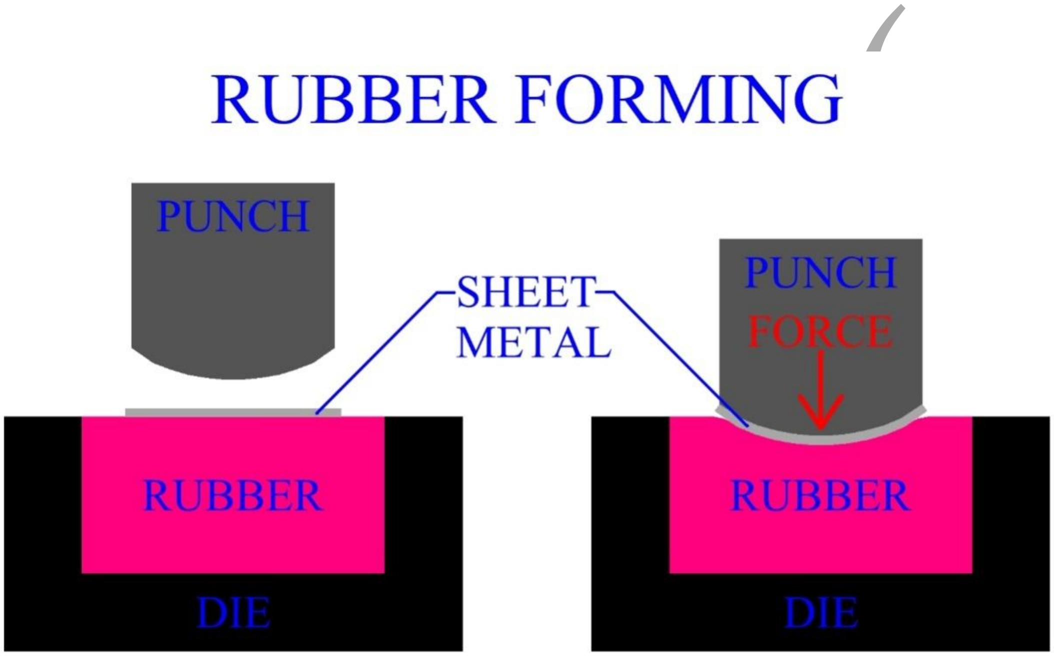
5	**Give the applications of electro hydraulic forming.**BTL2 a) Bulging b) Bending c) Drawing d) Blanking **e)** Piercing
6	**List out advantages of explosive forming.** BTL2 a) Forming process occurs in Small interval of time b) Very high compact densities can be obtained Mixtures of metal can be easily compacted
7	**List out major functions which affect the performance in electromagnetic forming.** BTL2 a) High intensity between the coils Eddy current b) Coil compression Flux concentration
8	**Enumerate the various typical applications of electro magnetic forming process.** BTL2 a) Compression and expansion of circular bar was carried out. b) It is used for instrument gear assembly, embossing and sizing of cups etc.
9	**What is a progressive Die?** BTL1 A progressive die has a series of stations. At each station, an operation is performed on a work piece during a stroke of the press. Between strokes, the piece in the metal strip is transferred to the next station. A finished work piece is made at each stroke of the press.
10	**Define hobbing.** BTL2 It is the process of forming a very smooth, accurate polished shape on punch.
11	**Define squeezing.** BTL2 It is the operation in which the metal is caused to flow to all portions of the die cavity under the action of compressive force.
12	**Define Drawing.** BTL2 Drawing is the process of forming a flat work piece into hollow shape by means of a punch which causes the blank to flow into a die cavity
13	**Define Bending.** BTL2 In this operation material in the form of flat sheet or strip is uniformly strained around a liner axis which lies in the neutral plane perpendicular to the lengthwise direction of sheet or metal.
14	**What is lancing operation that is done on sheet metals?** BTL1 Lancing is a piercing operation in which the workpiece is sheared and bent with one strike of the die. A key part of this process is that there is not reduction of material, only a modification in its geometry. This operation is used to make tabs, vents, and louvers
15	**What are the limitations of explosive forming?** BTL1

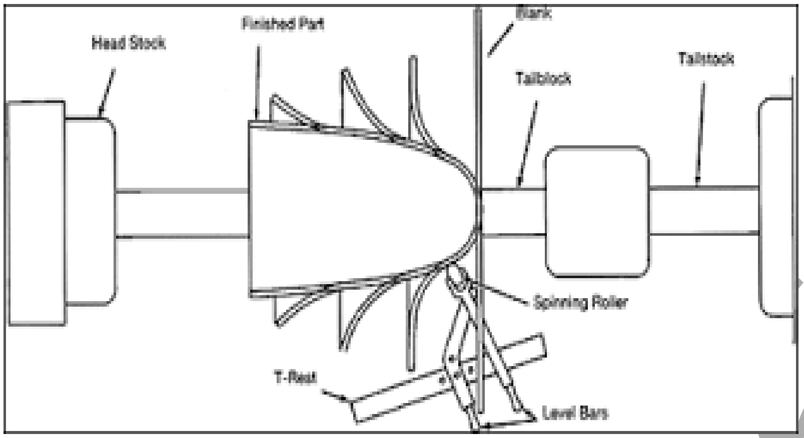
	Itis necessary each time either to lower a die weighing many tons into the water or to evacuate the water from the basin and then refill it; ground tremors and the spillage of water owing to the force of the explosion make explosion forming in buildings difficult and usually make it necessary to carry it out at open-air sites Requies Skilled labours
16	**What are the desirable qualities in metal for maximum streatchability?** BTL1 Fine grain structure and arrangement of atoms in the lattice.
17	**What is shear angle? Why is it given in punches and dies?** BTL1 The surfaces of the punch and of the die are both flat. Because the entire thickness is sheared at the same time, the force increases rapidly during shearing. The location of the regions being sheared at any particular instant can be controlled by bevelling the punch and die surface
18	**What is flanging?** BTL1 Flanging is a process of bending the edges of sheet metals, usually to 90°. In shrink flanging, the flange is subjected to compressive hoop stresses that, if excessive, can cause the flange periphery to wrinkle.
19	**Name any two super plastic materials.** BTL2 The large-grained Fe3Al and Fe Al alloys exhibit all deformation characteristics of conventional fine grain size super plastic alloys.
20	**What are the applications of rubber pad forming process?** BTL1 a) Flanged cylindrical and rectangular cups. b) Spherical domes, c) shells with parallel or tapered walls. **d)** For producing variety of unsymmetrical shapes.
	PART * B
1	**Describe shearing operations in a sheet metal work with a neat sketch.** BTL1
	Answer: Page 4.8 – Dr.Ramachandran a) Principle (2M) b) Types (3M) c) Application (3M) d) Diagram (5M)

2	**Discuss various types of bending operations with its neat sketches**. BTL2
	Answer: Page 4.13 – Dr.Ramachandran a) Principle (2M) b) Types (3M) c) Application (3M) d) Diagram (5M)  *Figure 4.31 Curling or wiring*
3	**How magnetic pulse forming process is carried out on sheet metal?** BTL2
	Answer: Page 4.44 – Dr.Ramachandran a) Diagram (4M) b) Principle (4M) c) Construction (3M) d) Advantages and Disadvantages (2M)

4	**Explain peen forming process with a neat sketch.**BTL1
	Answer: Page 4.47 – Dr.Ramachandran e) Diagram (4M) f) Principle (4M) g) Construction (3M) h) Advantages and Disadvantages (2M)
5	**What is super plastic of metal? How this process is carried out on sheet metals?**BTL1
	Answer: Page 4.49 – Dr.Ramachandran

	a) Diagram (4M) b) Principle (3M) c) Construction (3M) d) Application(3M**)**
6	**Explain the Electro hydraulic forming process with neat sketch .**BTL1
	Answer :Page 4.33- Dr.S.Ramachandran a) Diagram (4M) b) Principle (3M) c) Construction (3M) d) Application(3M**)** 

7	**Explain the Rubber pad forming process and neat sketches.**BTL1
	Answer:Page . 4.35- Dr.S.Ramachandran **a)**Diagram (4M) b)Principle (3M) c)Construction (3M) d)Application(3M**)** 
8	**Explain the metal spinning process with a neat sketch .give their applications.**BTL4
	Answer: Page 4.37 – Dr.Ramachandran a) Diagram(4M) b) Principle (3M) c) Construction (3M) d) Application (3M)

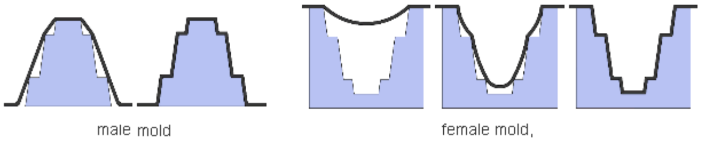
	
	PART * C
1	**Describe various types of drawing operations with its neat sketches.**BTL2
	Answer:Page . 4.19 - Dr.S.Ramachandran a) Diagram (4M) b) Types (4M) c) Principle (4M) d) Application (3M**)**
2	**Explain the Explosive forming process with suitable sketch.**BTL1
	Answer:Page. 4.42- Dr.S.Ramachandran a) Diagram (4M) b) Principle (4M)

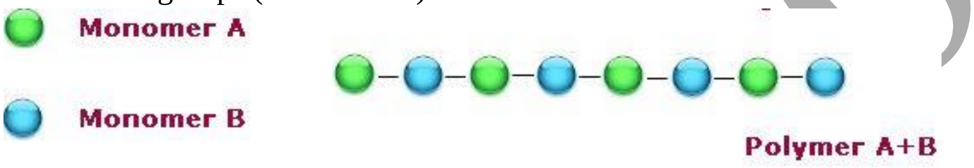
	c) Working (4M) d) Advantage (1M) e) Disadvantage (1M) f) Application (1M)
3	**Explain stretch forming operation with a neat sketch.** BTL2
	Answer: Page.4.23-Dr.Ramachandran a) Diagram (4M) b) Principle (4M) c) Working (4M) d) Advantage (1M) e) Disadvantage (1M) f) Application (1M)

UNIT V – MANUFACTURING OF PLASTIC COMPONENTS

Types of plastics– Characteristics ofthe forming and shapingprocesses–Mouldingof Thermoplastics – Workingprinciplesand typical applications of–Injectionmoulding – Plunger and screw machines – Compression moulding – Transfer moulding– Typical industrial applications–Introduction to Blow moulding – Rotational moulding– Film blowing– Extrusion – Thermoforming–Bondingof Thermoplastics forming – Micro forming

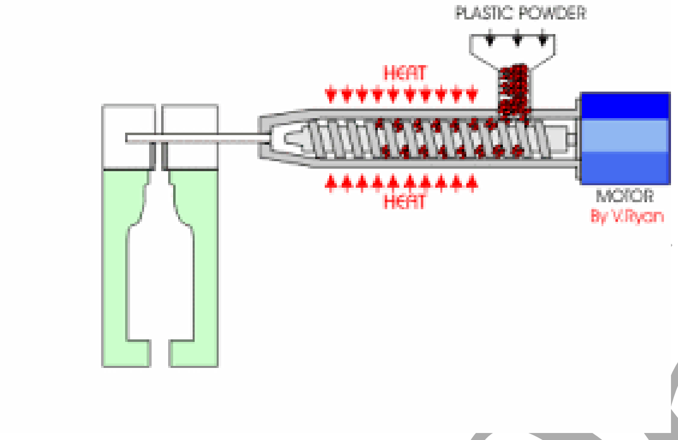
PART * A

Q.No.	Questions
1.	**Define the term polymers.**BTL2 Any of numerous natural and synthetic compounds of usually high molecular weight consisting of up to millions of repeated linked units, each a relatively light and simple molecule.
2	**Define Homopolymer.** BTL2 It is a polymer that is made up of identical monomer**.**
3	**Define positive mould and negative mould in thermoforming. (APRIL/MAY 2016)** BTL1 Depends upon the shape of the product it will be selected. In the positive(male) mould the plastic is stretched over the mould, and then vacuum is applied to draw the plastic down onto the surface of the mould. With a female mould the plastic is drawn down into a cavity by the vaccum. 
4	**What are the uses of fillers?** BTL1 a) It improves the compressive and tensile strengths of the polymer. b) Reduces the cost of the final product**.**
5	**What are the characteristic of thermoplastics?** BTL2 Thermoplastics polymers soften when heated and harden, when cooled. These types of polymers

	are soft and ductile. They have low melting temperature and can be repeatedly moulded and remoulded to the required shapes.
6	**Define the term synthetic resins.** BTL2 A resin having a polymeric structure; especially a resin in the raw state; used chiefly in plastics.
7	**List out few characteristics of polymer.** BTL2 a) High Corrosion resistance. b) Low thermal and electrical properties. Low density. **c)** Light weight
8	**What is film blowing?** BTL1 In this process a heated doughy paste of plastic compound is passed through a series of hot rollers, where it is squeezed into the form of thin sheet of uniform thickness.It is used for making plastic sheets and films.
9	**Define Polyaddition. (APRIL/MAY 2015)** BTL2 Polyaddition are reactions in which the polymer is originated by successive additions of functional groups (monomer A) inside of molecular structures with double bonds (monomer B). 
10	**What are the characteristics of thermoplastics?** BTL1 Thermoplastics (also referred to as thermo-engineering plastics) are high molecular weight polymers that become liquid upon heating and glassy solids on cooling. Bonding between molecules of a polymer could be of varying strength, thus resulting in different types of thermoplastics, i.e., polythenes that have relatively weak attractive forces (van der Waals forces), stronger hydrogen bonds in nylon, and very strong stacked aromatic ring bonds in polystyrene.
11	**Differentiate thermosetting and thermo plastics. (NOV/DEC 2013)** BTL2 a) The main difference between thermoplastics and thermosets is that: b) Thermoplastics can be re-melted and recycled fairly easily c) Thermosets typically are cured and molded into shape and are not recycled as easily
12	**What is rotational moulding of plastics?** BTL1 Rotational moulding (often referred to as Rotamoulding or Rotomoulding) is a process used for producing hollow plastic products. By using additional post-moulding operations, complex components can be produced enabling the process to compete effectively with other moulding and extrusion practices.
13	**Give the list of products produced using blow moulding.** BTL2 Small products may include bottles for water, liquid soap, shampoo, motor oil, and milk, while larger containers include plastic drums, tubs, and storage tanks**.**
14	**What is film blowing? (NOV/DEC 2013)** BTL1 Blown film extrusion is a technology that is the most common method to make plastic films, especially for the packaging industry. The process involves extruding a tube of molten polymer through a die and inflating to several times its initial diameter to form a thin film bubble. This bubble is then collapsed and used as a lay-flat film or can be made into bags. Usually

	polyethylene is used with this process, and other materials can be used as blends with these polymers.
15	**What is parison?** BTL1 A cylindrical tube of resin that is placed within a mold. Positive air pressure forces the parison to fill the mold.
16	**Define the term thermoforming.** BTL2 Thermoforming is a manufacturing process where a plastic sheet is heated to a pliable forming temperature, formed to a specific shape in a mold, and trimmed to create a usable product. The sheet, or "film" when referring to thinner gauges and certain material types, is heated in an oven to a high-enough temperature that it can be stretched into or onto a mold and cooled to a finished shape
17	**What is prepreg ?**BTL1 The term "prepreg" is actually an abbreviation for the phrase pre-impregnated. A prepreg is an FRP reinforcement that is pre-impregnated with a resin. Most often, the resin is an epoxy resin, however other types of resins can be used, including the majority of thermoset and thermoplastic resins.
18	**List the advantage of cold forming of plastics.** BTL2 a) Speed, Net / Near net shape to eliminate or reduce secondary operations, Consistency / dimensional accuracy b) Quality / surface finish c) Material savings & elimination of scrap d) Improvement in mechanical properties, greater strength to weight ratio, unbroken grain flow.
19	**What is lamination process?** BTL1 The process of applying a film of plastic on the surface of any item is known as laminating. When plastic coating is added to any item it becomes tear-proof and waterproof, since the laminating film encapsulates the item completely by being bonded to both its sides.
20	**List any four types of adhesives used in adhesive bonding of plastics. (Nov/Dec 2014)** BTL2 Adhesive bonding has unique applications that require strength, sealing, thermal and electrical insulating, vibration damping, and resistance to corrosion between dissimilar metals. Mechanical fastening involves traditional methods of using various fasteners, especially blots, nuts, adhesive bonding, fusion fastening and rivets. The joining of plastics can be accomplished by various external or internal heat sources, and mechanical.
	PART * B
1	**With a neat sketch explain the process of plasticinjectionmoulding. (13M)** BTL1
	Answer: Page 5.26 – Dr.Ramachandran a)Principle (2M) b)Construction(3M) c)Application (3M) d)Diagram (5M)

2	**Give the sequence of operations in transfer moulding forthermosettingprocess.(13M)** BTL2
	Answer: Page 5.41 – Dr.Ramachandran a) Principle (2M) b) Types (3M) c) Application (3M) e) Diagram (5M)
3	**Illustrate with suitable sketch, the blow moulding process for producing plasticsbeveragebottles.(13M)** BTL2
	Answer: Page 5.46 – Dr.Ramachandran a)Diagram(4M) b)Principle (4M) c)Construction (3M) d)Appplication (2M)

	
4	**Describe the procedure involved inrotational moulding. (13M)** BTL2
	Answer: Page 5.53 – Dr.Ramachandran a)Diagram (4M) b)Principle (4M) c)Construction (3M) d)Advantages and Disadvantages (2M)
5	**Describe in detail about the vaccumformingprocess. (13M)** BTL1
	Answer: Page 5.71 – Dr.Ramachandran a)Diagram (4M) b)Principle (3M) c)Construction (3M)

	d)Application (3M**)**
6	**Describe in detail about the compression mouldingprocess.(13M)** BTL2
	Answer:Page 5.37 Dr.S.Ramachandran a)Diagram (4M) b)Principle (3M) c)Construction (3M) d)Application (3M**)**
7	**llustrate with suitable sketch, the of Bonding pf thermoplastic.(13M)** BTL1

	Answer:Page 5.76- Dr.S.Ramachandran a) Diagram (4M) b) Principle (3M) c) Construction (3M) d) Application (3M**)**
8	**Explain the structure of thermoplastic and thermosetting plastics. Compare thermo and thermosetting plastics. . (13M)** BTL2
	Answer: Page 5.14 – Dr.S.Ramachandran a)Diagram (3M) b)Types (4M) c)Advantages (3M) d)Application (3M) 
	PART * C
1	**D escribe the working principle of film blowing and Thermoforming. (15M)**BTL2
	Answer: Page 5.59 - Dr.S.Ramachandran a)Diagram (4M) b)Types (4M)

c)Principle (4M)

d)Application (3M**)**

2	**Illustrate with suitable sketch, the Micro forming Process. (15M)** BTL1
	Answer:Page 5.86- Dr.S.Ramachandran a)Diagram(4M) b)Principle (4M) c)Working(4M) d)Advantage (1M) e)Disadvantage (1M) f)Application (1M)
3	W**rite down the characteristics of shaping processesforplastics.(15M)** BTL2

Answer: Page 5.17-Dr.S.Ramachandran

a)Characteristics (15M)

S.No	Processes	Characteristics
a)	Injection Moulding	1.High ProductionRate 2.Good dimensionalAccuracy 3.Complex shapes of varioussizes 4.Costlytoolings 5.Eliminatingassembly
b)	Blow Moulding	1. Hollow-thin walled parts 2. Low cost for making container 3. High production rates.
c)	Rotational Moulding	1.Low toolingcost 2.Low productionrates 3.Large hollow shapes of relatively
d)	Extrusion	1.Widetolerance 2.High ProductionRates 3.Low toolingCost 4.Long, Uniform, solid or hollow complex cross sections.
e)	Thermo forming	1.Medium productionrates 2.Shallow or relatively deepcavities 3.Low toolingcost.
f)	Compression moulding	1.Relatively inexpensivetooling 2.Medium productionrates 3.Parts similar to impression dieforging.
g)	Transfer moulding	1.Some scraploss 2.Medium toolCost 3.More complex than compression moulding 4. High productionrates.
h)	Casting	1.Low productionrates 2.Simple or intricate shapes made with flexible moulds

EE 8353 ELECTRICAL DRIVES AND CONTROLS L T P C 3 0 0 3

OBJECTIVES:

- To understand the basic concepts of different types of electrical machines and their performance.
- To study the different methods of starting D.C motors and induction motors.
- To study the conventional and solid-state drives

UNIT 1 INTRODUCTION **8**

Basic Elements – Types of Electric Drives – factors influencing the choice of electrical drives Heating and cooling curves – Loading conditions and classes of duty – Selection of power rating for drive motors with regard to thermal overloading and Load variation factors

UNIT II DRIVE MOTOR CHARACTERISTICS **9**

Mechanical characteristics – Speed-Torque characteristics of various types of load and drive motors – Braking of Electrical motors – DC motors: Shunt, series and compound - single phase and three phase induction motors**.**

UNITIIISTARTINGMETHODS **8**

Types of D.C Motor starters – Typical control circuits for shunt and series motors – Three phase squirrel cage and slip ring induction motors.

UNIT IV CONVENTIONAL AND SOLID STATE SPEED CONTROL OF D.C. DRIVES **10**

Speed control of DC series and shunt motors – Armature and field control, Ward-Leonard control system - Using controlled rectifiers and DC choppers –applications.

UNIT V CONVENTIONAL AND SOLID STATE SPEED CONTROL OF A.C. DRIVES **10**

Speed control of three phase induction motor – Voltage control, voltage / frequency control, slip power recovery scheme – Using inverters and AC voltage regulators – applications.

TOTAL: 45 PERIODS

OUTCOME:

Upon Completion of this subject, the students can able to explain different types of electrical machines and their performance

TEXT BOOKS:

1. Nagrath .I.J. & Kothari .D.P, “Electrical Machines”, Tata McGraw-Hill, 2006
2. VedamSubrahmaniam, “Electric Drives (Concepts and Applications)”, Tata McGraw-Hill, 2010

REFERENCES:

1. Partab. H., “Art and Science and Utilisation of Electrical Energy”, DhanpatRai and Sons, 2017
2. Pillai.S.K “A First Course on Electric Drives”, Wiley Eastern Limited, 2012
3. Singh. M.D., K.B.Khanchandani, “Power Electronics”, Tata McGraw-Hill, 2006.

Subject Name: Electrical Drives and Controls **Subject Handler: Mr.A.Antony Charles**

UNIT I INTRODUCTION

Basic Elements – Types of Electric Drives – factors influencing the choice of electrical drives – heating and cooling curves – Loading conditions and classes of duty – Selection of power rating for drive motors with regard to thermal overloading and Load variation factors

Q.No.	PART*A
1.	**List out the types of electric drives.(NOV/DEC 2016)** BTL1 • Group electric drives, • Individual drives, • Multi motor electric drives.
2	**State the basic elements of an electric drive system.(MAY/JUNE 2014)(MAY/JUNE 2016)**BTL1 • Electrical motors and load • Power modulator • Source • Control unit • Sensing unit
3	**Mention the factors affecting the selection of electrical drives.(NOV/DEC 2015)** BTL1 • Steady state • Acceleration including starting • Deceleration including stopping
4	**Define duty factor.** BTL1 The ratio of ON time (T_{on}) of the drive to total time period (T_{on} + T_{off}) is called duty factor.
5	**Differences between Drive and Electric Drive.** BTL1 Drive:A combination of prime mover, transmission equipment and mechanical working load is called adrive Electric drive**:** An Electric Drive can be defined as an electromechanical device for converting electricalenergy to mechanical energy to impart motion to different machines and mechanisms for various kinds of process control.
6	**How heating occurs in motor drives?(APRIL/MAY 2015)**BTL1 When a machine is switched off from the mains or when the load on the motor is reduced, the machine cools. The curve obtained temperature drop Vs time when the drive is switched off or load on the drive is removed.
7	**Mention the necessity of power rating.** BTL2 Power rating of electric drives for particular operation is important since, following reasons. • Get economy with reliability • To obtain the maximum efficiency on their full load.
8	**List out some examples of prime movers**. BTL2 • I.C Engines • Steam Engine

	• Turbines • Electric Motors.
9	**List the factors affecting the selection of electric drives**.(**APRIL/MAY 2017)** BTL2 • Efficiency • Braking • Load factor • Availability of supply • Effects of supply variations • Economical aspects
10	**Define four – quadrant operation.**BTL2 A motor operate in two modes and braking. In motoring, it converts electrical energy into mechanical energy, which supports its motion. In braking it works as a generator converting mathematical energy into electrical energy and thus, opposes the motion. Motor can provide motoring and braking operations for both forward and reverse directions.
11	**What are the advantages and disadvantages of Group drive (Shaft drive)?** BTL3 **Advantages**: • A single large motor can be used instead of a number of small motors. • The rating of the single motor may be appropriately reduced taking into account the diversity factor of loads. **Disadvantages**: • There is no flexibility; Addition of an extra machine to the main shaft is difficult. • The efficiency of the drive is low, because of the losses occurring in several transmitting mechanisms.
12	**Mention the types of electrical drives.**BTL3 • DC drives • AC drives
13	**Mention the various classes of duty** BTL3 • Continuous duty • Continuous duty, variable loads • Short time loads
14	**What is the three method of operation for electrics drive?**BTL1 • Steady state • Acceleration including starting • Deceleration including stopping
15	**Mention power rating of linear movement in AC motors.**BTL4 Efficiency of load and transmission systemdepend on the type of load. v – Velocity of linear motion, m/s

16	**Compare a multi motor electric drive.Give some examples.(Nov/Dec 2014)** BTL5 In this drive, there are several drives, each of which serves to activate on of the working parts of the driven mechanisms. Metal cutting machine tools, paper making machines, rolling mills, traction drive, Traveling cranes etc.,
17	**Define cooling curve.**(April/May 2017) BTL5 When a machine is switched off from the mains or when the load on the motor is reduced, the machine cools. The curve obtained temperature drop Vs time when the drive is switched off or load on the drive is removed.
18	**State individual electric drive.**(April/May 2015) BTL1 In this drive, each individual machine is driven by a separate motor. • This motor also imparts motion to various other parts of the machine. Single spindle drilling machine, Lathe machines etc.
19	**What are the advantages and disadvantages of individual drive?** BTL6 **Advantages**: • Flexibility of layout • If any failure or maintenance carried out in main motor, corresponding load will be affected or idle. • Efficiency is high because no load losses are less. **Disadvantages**: • Cost is high compared to group drive
20	**State the selection of motor based on load variation (or) Types of mechanical loads**.BTL1 • Continuous or constant loads • Continuous variable loads • Pulsating loads • Impact loads • Short time loads
21	**Give some examples of Electric Drives.**BTL1 • Driving fans, ventilators, compressors and pumps. • Lifting goods by hoists and cranes.
22	**State the some of the advantage of an electric drive system**.BTL1 • Control characteristic can be manipulated as per requirements • Availability of simple and easy speed control methods
23	**Mention the application of electrical drives.**BTL1 • Paper mills • Electric traction • Cement mills • Steel mills
24	**Define cooling time constant.**BTL1 It is defined as the ratio between C and A cooling time constant is denoted as α

	α= C/A
25	**What are the advantages and disadvantages of Group drive (Shaft drive)?**BTL1 **Advantages**: - A single large motor can be used instead of a number of small motors. - The rating of the single motor may be appropriately reduced taking into account the diversity factor of loads. **Disadvantages**: - There is no flexibility; Addition of an extra machine to the main shaft is difficult. - The efficiency of the drive is low, because of the losses occurring in several transmitting mechanisms.
	PART * B
1.	**Explain the factors governing the selection of motors. (13M)** BTL1 **Answer : Page :1.20 - J.Gnanavadivel,J.Karthikeyan** - Transient Operation---------------------------(3M) - A system is said to be in a transient state when a process variable or variables have been changed and the system has not yet reached a steady state. - The time taken for the circuit to change from one steady state to another steady state is called the transient time. - Related with source ---------------------------------(3M) - Need of Cost --------------------------------------- (5M)
2	**Describe in detail the determination of power rating of motors. (13M)** (BTL1) **Answer: Page :1.9-J.Gnanavadivel,J.Karthikeyan** - Continuous duty---------------------------- (3M) - Short time duty --------------------------(3M) - Intermittent periodic duty---------------(7M) Intermittent duty is when a motor or gear motor has a duty cycle that isn't running continuously without any time of break.
3	**Describe about thesimplifications based on which the heating and cooling calculations of an electric motor are made.(13M)** BTL1 **Answer: Page:1.10-J.Gnanavadivel,J.Karthikeyan** - Heat developed-------------------(6M) - Heat dissipated-------------------(7M)

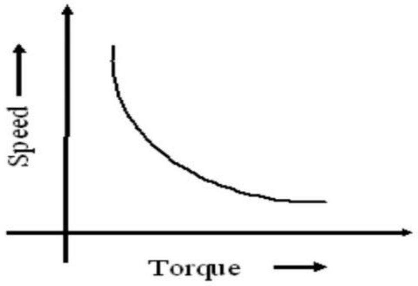
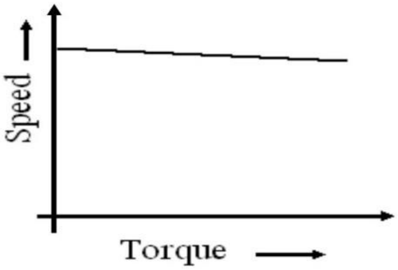
4	**Describe the different types of loading of drives.(APR/MAY 2017)(13M)** BTL1 **Answer: Page :1.23-J.Gnanavadivel,J.Karthikeyan** • Based on load conditions ---------------- (2M) • Based on mode operation ----------------- (3M) • Based on controlling action---------------- (3M) • Based on Number machines------------------(5M)
5	**Give the brief note on classes of duty for an electric motor(13M)** BTL2 **Answer: Page :1.17-J.Gnanavadivel,J.Karthikeyan** • Continuous duty **-------**(3M) • Fluctuating loads ----------- (5M) • Short time and Intermittent duty(5M)
6	**Explain about the torque and power methods for Fluctuating and Intermittent loads.(13M)** BTL2 **Answer: Page:1.29-J.Gnanavadivel,J.Karthikeyan** • Actual variable motor current------------(5M) • Core loss and friction loss--------------- (5M) • Copper loss----------------- (3M)
7	**Explain the Load Equalization.(13M)**BTL2 **Answer: Page :1.30-J.Gnanavadivel,J.Karthikeyan** • Torque Fluctuation---------------(5M) The vibrating force due to the combustion pressure causes torque fluctuationin the crankshaft, which is transmitted to the drive train. • Electric hammer, Steel rolling---------------(3M) • Voltage fluctuation-------------------------- (5M)
8	**Calculate the load rising from 0to 400KW:5min** **Uniform load of 500KW Regenerative power of 400 KW returned to the supply:4 min** **Remains idle for 2 min(13M)** BTL3 **Answer: Page :1.3-J.Gnanavadivel,J.Karthikeyan** • Uniform load =60--------------(5M) • load =5A-----------------------(2M) • Rated power=20 W ------------(3M) • RMS value =50 V ---------------(3M)

	PART *C
	A 100 KW motor ,having rated temperature is 60 C has a full load efficiency of 80% and the maximum efficiency occurs at85% full load.It has a thermal constant of 80 minutes and 65 minutes It is cyclically loaded,120% of full load for one hour and 50% of full load for next hour. Find the temperature rise after 3hrs.(15M) BTL2
1.	**Answer: Page:1.36-J.Gnanavadivel,J.Karthikeyan** • Temperature-25 C------------ (6M) • full load- 10A---------------(2M) • Output power-200 Watts---------(2M) • Full load loss-20------------(2M) • Temperature rise-30C(2M)
2	**Explain the pattern of characteristics under steady state Short time &intermittent time. (15M) (Nov/Dec 2016) BTL3** **Answer: Page:1.27-J.Gnanavadivel,J.Karthikeyan** • Short time & temperature rise intermittent time-(7M) • **Temperature rise-** (3M) • Constant load (3M) • Number of cycles (2M)
3	**Find the rating of a 100KW motor when subjected to a duty cycle of 18 minutes on full load followed by 30 minutes on no load. The heating and cooling time constant of the motor are 90 and 120 minutes respectively. Assume that loss are proportional to square of load current.(15M)** BTL5 **Answer: Page :1.33-J.Gnanavadivel,J.Karthikeyan** Heating and cooling time constant-(6M) Loss-(3M) T1=65.5 °C.(3M) Th1=55.34C
4	**Draw a typical temperature rise –time curve and derive equation for temperature rise in an electric drive(15M)** BTL6 **Answer: Page:1.16-J.Gnanavadivel,J.Karthikeyan** • **Temperature rise** (8M) • **Cooling curves** (6M)

UNIT II DRIVE MOTOR CHARACTERISTICS

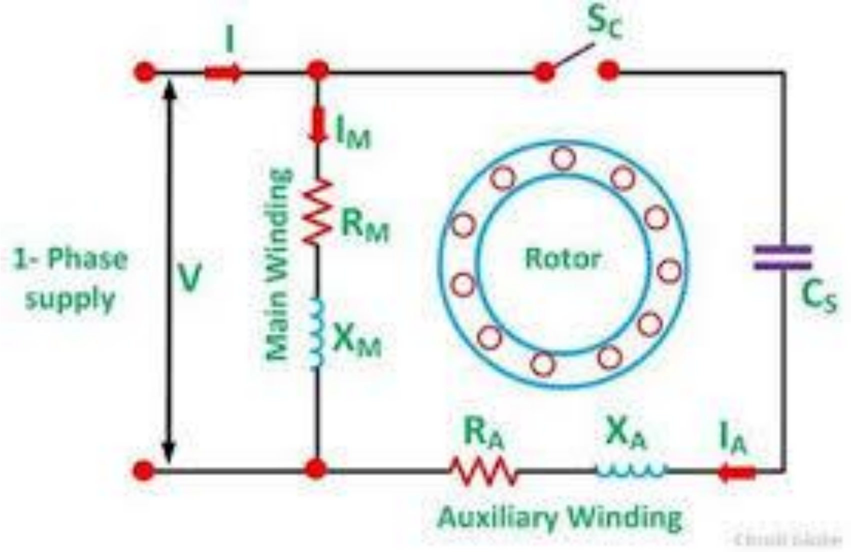
Mechanical characteristics – Speed-Torque characteristics of various types of load and drive motors – Braking of Electrical motors – DC motors: Shunt, series and compound - single phase and three phase induction motors**.**

Q.No.	**PART-A**
1.	**Define back EMF in a D.C. Motor and State its expression.** BTL1 • Armature starts rotating, the main flux gets cut by the armature winding an EMF gets induced in the armature. • This EMF opposes the applied DC voltage and is called back EMF denoted as E_b.
2	**Write the voltage equation of D.C. Motor**. BTL1 • $V=E_b+I_aR_a$. The back EMF is always less than supply voltage ($E_b<V$). • But Ra is very small hence under normal running conditions, the difference between back EMF and supply voltage is very small.
3	**State the various types of D.C. Motors.**BTL1 • Separately excited DC Motor • DC Shunt motor
4	**Define slip.** BTL1 The difference between the synchronous speed (N_S) and actual speed (N) of the rotor is known as slip speed. The percentage of slip is given by % slip s = $[(N_S - N) / N_S] *100$
5	**What is synchronous speed?** BTL1 The speed depends on the supply frequency (f) and the number of poles for which stator winding is wound (P).It is called synchronous speed denoted as N_S and given by $N_S = 120 f / P$ in RPM
6	**What is rotor conductor and end ring?** BTL1 The rotor core is cylindrical and slotted on its periphery. The rotor consists of un insulated copper or aluminum bars called rotor conductors.
7	**Mention the important characteristics of a DC motor.**BTL2 • Torque – Armature current characteristics • Speed – Armature current characteristics • Speed- Torque Characteristics
8	**Why DC motors should not be started without starters? (NOV/DEC 2016)** BTL2 • Under light load or no load as flux is very small, the motor tries to run at dangerously high speed which may damage the motor mechanically. • This can be seen from the speed – armature current and the speed- torque characteristics
9	**State Induction motor as a transformer.** BTL2 • Transformer is a device in which two windings are magnetically coupled and when one winding is excited by AC supply of certain frequency

<table>
<tr><td>10</td><td>Draw the speed torque characteristics of DC shunt and series motors. (MAY/JUNE 2016)BTL2

DC shunt motor

DC series motor</td></tr>
<tr><td>11</td><td>Why a single phase induction motor does not Self start? BTL3
• When a single phase supply is fed to the single phase induction motor. Its stator winding produces a flux which only alternates along one space axis.
• It is not a synchronously revolving field, as in the case of a 2 or 3phase stator winding, fed from 2 or 3 phase supply.</td></tr>
<tr><td>12</td><td>Compare electrical braking and mechanical braking.BTL3
<table><tr><th>Electrical braking</th><th>Mechanical braking</th></tr><tr><td>(i)Frequent Maintenance</td><td>(i)Less maintenance</td></tr><tr><td>(ii)Braking is not smooth</td><td>(ii)Braking is smooth</td></tr></table></td></tr>
<tr><td>13</td><td>Mention the three regions in the speed –torque characteristics of induction motor. BTL4
• Motoring region (0< s<1)
• Generating region(s<0)
• Plugging region (1<s<2)</td></tr>
<tr><td>14</td><td>What are the different types of Electric braking?(APRIL/MAY 2015)(NOV/DEC 2015)BTL4
• Rheostatic or dynamic braking
• Plugging
• Regenerative braking
• D.C. Dynamic braking</td></tr>
<tr><td>15</td><td>Define transformation ratio. BTL4
K = E_2 / E_1(or) k = N_2 / N_1
Where E_1 = Stator EMF per phase in volts
E_2 = Rotor induced EMF per phase in volts at start when motor is at standstill.</td></tr>
<tr><td>16</td><td>Mention the types of Single phase induction motors.BTL5
• Split phase induction motor
• Capacitor start induction motor</td></tr>
<tr><td>17</td><td>State Rheostat or dynamic braking.BTL5
• Dynamic braking of electric motors occurs when the energy stored in the rotating mass is dissipated in an electrical resistance.
• This requires the motor to operate as a generator to convert this stored energy into electrical.</td></tr>
<tr><td>18</td><td>Define Plugging. BTL6</td></tr>
</table>

	It is one method of braking of induction motor. When phase sequence of supply of the motor running at a speed is reversed, by interchanging connections of any two phases of stator.
20	**What is meant by Regenerative Braking?**BTL1 • Regenerative braking occurs when the motor speed exceeds the synchronous speed. • In this case, the induction motor would runs as the induction machine is converting the mechanical power into electrical power, which is delivered back to the electrical system.
21	**What are the advantages of electric braking over other type of braking?(NOV/DEC 2014)** BTL1 • Rheostat or dynamic braking • Plugging • Regenerative braking • D.C. Dynamic braking
22	**List the advantage of squirrel cage I.M.** BTL1 • Cheaper • Light in weight • Rugged in construction • More efficient • Require less maintenance • Can be operated in dirty and explosive environments
23	**Why a three phase induction motor does not Self start?** BTL1 • When a three phase supply is fed to three phase induction motor. Its stator winding produces a flux which only alternates along one space axis. • It is not a synchronously revolving field, as in the case of a 2 or 3phase stator winding, fed from 2 or 3 phase supply.
24	**What are the types of single phase induction motor?** BTL1 • Split phase induction motor • Capacitor start induction run motor • Capacitor start Capacitor run motor • Shaded pole induction motor
25	**Compare Slip ring and Squirrel cage motor.** BTL1 • Construction is complex • High starting torque is added
	PART * B
1.	**Describe the various types of electric braking and discuss the various braking of DC shunt and DC series motor. (13M) (NOV/DEC 2014)BTL1** **Answer: Page :2.45- J.Gnanavadivel,J.Karthikeyan** • Regenerative braking ----------------------------(4M) • Braking is an energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. • Dynamic braking-------------------------- (3M) • Plugging or Reverse current braking------------ (6M)
2	**Write the braking characteristics available for induction motors and explain in details.(13M)BTL1** **Answer: Page:2.56- J.Gnanavadivel, J.Karthikeyan** • DC dynamic braking---------------------- (6M) The motor now works as a generator, producing the braking torque. for the braking operation

	in dynamic braking. • AC dynamic braking----------------------- (7M)
3	**Explain the torque –speed characteristics for the DC motors. (APR/MAY 2015) (13M)BTL1** **Answer: Page:2.31- J.Gnanavadivel, J.Karthikeyan** • Motoring region--------------------- (4M) • The torque-speed curve for the normal MOTORING REGION, where the speed lies between zero and just below synchronous, we must ask what happens if the speed is above the synchronous speed, or is negative. Generating region------------------ (6M) Plugging region--------------------- (3M)
4	**Describe the various torque –slip characteristics for the DC motors.(13M)BTL1** **Answer: Page.:2.28- J.Gnanavadivel, J.Karthikeyan** • Stable operating region------------- (4M) • The solid line is the torque–speed curve of the motor, while the dotted lines • Unstable operating region---------------- (6M) • The concept of stability of induction motor is very important and vital for interview point of view or and motorspeed torque characteristics determines the point of stableoperation of motor • Normal operating region ---------------(3M)
5	**Explain the advantages and disadvantages of electrical braking over mechanical braking.(13M)** BTL2 **Answer: Page:2.38- J.Gnanavadivel, J.Karthikeyan** • Regenerative braking---------------------(4M) • Energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. • Plugging-------------------------- (6M) • A part of energy is returned to the supply consequently the running cost is reduced. • Dynamic braking --------------------------(3M)
6	**Give the various load characteristics of DC Shunt Motor.(APR/MAY 2015) (13M)** BTL2 **Answer: Page:2.29- J.Gnanavadivel, J.Karthikeyan** • Armature resistance------------------------------. (7M) • At the moment a DC motor is started the armature is stationary and there is no counter EMF being generated. • Shunt field winding resistance------------------------------. (6M)
7	**Describe about the operation of Single phase induction induction motor. (13M)** BTL2 **Answer:Page:2.32- J.Gnanavadivel, J.Karthikeyan** • Lacking of starting torque. --------------------------------(6M) • Wound type rotor induction motor addition of external resistance is possible this makes a wide usage like speed control, high starting torque by decreasing • Reduced power factor. ------------------------------(4M) • Less efficiency.-------------------------(3M)

8	**State and explain single-phase induction motors speed torque curve in details. (13M)** BTL3 **Answer: Page.:2.39- J.Gnanavadivel, J.Karthikeyan** • Resistance start----------------(3M) • The phase-angle difference between current in the run winding and current in the start winding of a resistance-start induction-run motor is generally 35 to 40 degrees.-  ------------------(3M) • Single-phase induction motors are not self-starting without an auxiliary stator winding driven by an out of phase current of near 90°. • Capacitor Run ----------------------------(4M) • The capacitor start capacitor run motor has a cage rotor and its stator has two windings known as Main and Auxiliary Windings. • Shaded pole-----------------------------------(3M)
9	**Describe the regenerative braking employed in DC Motors. (13M)** BTL3 **Answer: Page:2.56- J.Gnanavadivel, J.Karthikeyan** • Hoisting mechanism------------------ (6M) • The lifting three-phase induction electric motors are designed for application in the main motion of rope and chain hoists. their brake is electromagnetic with dc supply voltage, **non**-adjustable. • Variable frequency-------------------- (7M) • Variable-frequency drive is a type of adjustable-speed drive used in electro-mechanical drive systems to control ac motor speed and torque by varying motor
10	**Explain the 3Ø induction motor. (13M)** BTL4 **Answer: Page:2.21- J.Gnanavadivel, J.Karthikeyan** • Types (6M) • 1. Squirrel cage induction motor and 2. phase wound induction motor (slip-ring induction motor). • Principle &Operation of motor ---------------(4M) • A motor is an electrical machine which converts electrical energy into mechanical energy. • The principle of working of a DC motor is that "whenever a current carrying conductor is placed in a magnetic field, it experiences a mechanical force". • Advantages &Disadvantages ---------------------------(3M) The primary advantage of the DC motor is that it can develop constant torque over a wide speed application. Power supply is an important consideration in the application of DC motors.

	PART * C
1.	**Explain about the various load characteristics of DC Shunt Motor.(15M)** BTL2 **Answer: Page:2.16- J.Gnanavadivel, J.Karthikeyan** • Speed-Armature characteristics------------------. (3M) • Torque-armature characteristics.---------------------(4M) • Speed-Torque characteristics.------------------------------(8M)
2	**Explain anyone method of electrical braking of DC Machines.(NOV/DEC 2014) (15M)**BTL6 **Answer: Page:2.56- J.Gnanavadivel, J.Karthikeyan** • Downward mechanism --(8M) • A dc motor is any of a class of rotary electrical machines that converts direct current electrical .this feature is used to slow down and recharge batteries on hybrid car. • variable frequency ---------------------------------------(7M) • avariable-frequency drive is a type of adjustable-speed drive used in electro-mechanical drive systems to control ac motor speed and torque by varying motor.
3	**Classify the different types of load torques available and sketch few load torques curves of typical loads. (15) (Nov/Dec 2016)**BTL5 **Answer: Page.:2.31- J.Gnanavadivel, J.Karthikeyan** • Motoring region----------------------------(4M) • Energy recovery mechanism which slows a vehicle or object by converting its kinetic energy into a form which can be either used immediately or stored until needed. • Generating region --------------------------------(6M) • A part of energy is returned to the supply consequently the running cost is reduced. • Plugging region---------------------------------- (5M) • Plugging circuit, a reverse torque is developed even when the armature has come to a stop. Circuit interruption is usually controlled by an automatic null-speed device mounted on the motor shaft
4	**Create a torque- slip Characteristics of three phase induction motor. (15M) (April/May 2016)**BTL6 **Answer: Page:2.36- J.Gnanavadivel, J.Karthikeyan** • Stable region------------------------------ (5M) Essential condition that defines a stable operating point is that it is the point where the torque requirement curve crosses the motor capability curve in a region where the motor torque capability is declining as speed increases. • Unstable operating region--------------------- (5M) • Normal operating region--------------------------(5M) • A DC motor is any of a class of rotary electrical machines that converts direct current electrical • Introduction of DC motorsand an electrical grid system to run machinery starting in the 1870s started a new second industrial revolution.

UNIT III STARTING METHODS

Types of D.C Motor starters – Typical control circuits for shunt and series motors – Three phase squirrel cage and slip ring induction motors.

Q.No.	PART-A
1.	**Why we need starters for starting electric motors?(NOV/DEC 2014)** BTL1 • At starting, when the motor is stationary, there is no back EMF ($E_b = 0$) in the armature. • This current will damage the motor.
2.	**What is meant by starting resistance?** BTL1 • To restrict this high starting armature current, a variable resistance is connected in series with the armature at start. • This resistance is called starter or a starting resistance.
3.	**What are the two types of starters used for D.C shunt motors?** BTL1 • Two Point starter • Three point starter • Four Point starter
4.	**List the main parts of three point starter.** BTL1 • L = Line terminal • A = Armature winding • F = Field winding
5.	**What are the disadvantages of three point starter?** BTL1 • The 3 point starter suffers from a serious drawback for motors with a large variation of speed by adjustment of the field rheostat. • To increase the speed of the motor, the field resistance should be increased. Therefore, the current through the shunt field is reduced.
6.	**What is the use of four point starter?** BTL1 • The 4 point starter like in the case of a 3point starter also acts as a protective device that helps in safeguarding the armature of the shunt or compound excited DC motor against the high starting current produced in the absence of back EMF at starting.
7.	**State automatic starter.** BTL2 • Upon pressing ON-push button (start button), current limiting stating resistors get connected in series with armature circuit in DC motor. • Then, some form of automatic control progressively disconnects these resistors until full-line voltage is available to the armature circuit.
8.	**Why DC motors should not be started without starters?**BTL2 • In DC motors starters are used to limit the starting current within about 2 to 3 times the rated current by adding resistance in series with the armature circuit.
9.	**What is the objective of rotor resistance starter?(APRIL/MAY 2015)** BTL2 • Due to addition of resistance in the stator side cause the voltage available to the motor X times the normal voltage. • The starting current drawn by the motor as well as the current drawn from the supply get reduced by X times where as the starting torque developed gets reduced by X_2 times.
10.	**State thebasic principle of increasing rotor resistance in the rotor circuit of a 3-phase induction motor as starting.** BTL3 • Due to addition of resistance in rotor circuit by the stator not only reduces the

	staring current • Addition to that the starting torque developed than those given by DOL starting.
11.	**What are the advantages of Electronic starter?**BTL3 • The moving parts and contacts get completely eliminated. • The arcing problem gets eliminated. • Minimum maintenance is required as there are no moving parts. • The operation is reliable • Starting time also gets reduced.
12.	**What are the various types of reducing starting current of induction motor?(APR/MAY 2015)**BTL4 • Stator resistance starter • Autotransformer starter • Star-delta starter • Rotor resistance starter • Direct on line starter
13.	**State the function of starters.** BTL2 • For large capacity induction motors is to reduce the starting current • Having necessary control devices to limit the starting current
14.	**Define star-delta starter.** BTL1 • This is the cheapest starter of all and hence used very commonly for the induction motors. • It uses triple pole double throw (TPDT) switch. • The switch connects the stator winding in star at start. • Hence per phase voltage get reduced by the factor 1/.3.Due to this reduced voltage, the staring current is limited.
15.	**Define autotransformer starter.**BTL5 • A three phase star connected autotransformer can be used to reduce the voltage applied to the stator. • Such a starter is called as autotransformer starter.
16.	**List the various drawback of three point starter.** BTL5 • In a three-point starter, the no-volt release coil is connected in series with the shunt field circuit so that it carries the shunt field current. • During speed control, speed is varied through field regulator; • The field current may be weakened to such an extent that the no-volt release coil may not be able to keep the starter arm in the ON position. • This may disconnect the motor from the supply when it is not desired. • This drawback is overcome in the four point starter.
17.	**State the function of No Volt Release (NVR) or No Volt Coil (NVC)** BTL3 • The No Volt magnet keeps starter handle at run position against the control spring. • The No-Volt magnet attracts the soft iron bar placed in the handle. • The No-Volt magnet is energized by the .current flowing through the field circuit. • If there is no No-Volt magnet the starter handle is pulled back the off position by the control spring and the motor Point Starter is switched Off.
18.	**What is the function of Over Load Release (OLR) or Over Current magnet (OC)?** BTL1 • When the load on motor increases above the rated limit then the armature takes high current. • When the motor is left unprotected from this high current, then it is damaged, the over

current magnet is used for this protection.
When there is high current due to over load or due to short circuit the over current magnet is energized and attracts soft iron rod H. *As* a result, the soft, iron rod H closes the switch S.

- When the switch S is closed, it short circuits the No-Volt magnet. As a result No Volt magnet is de-energized and release the starter handle to the off position.

19 **What is Soft Starter?** BTL1

- Soft starting an AC motor refers to any one of several starting methods that limit the starting current and torque of the motor.
- The reduced voltage starters, and will be referred to as soft starting.
- The soft starter eliminates unnecessary jerks during the start.
- Gradually, the voltage and the torque increase so that the machinery starts to accelerate the motor by means of thyristor (SCRs)

20. **What are the advantages of soft starter?** BTL1

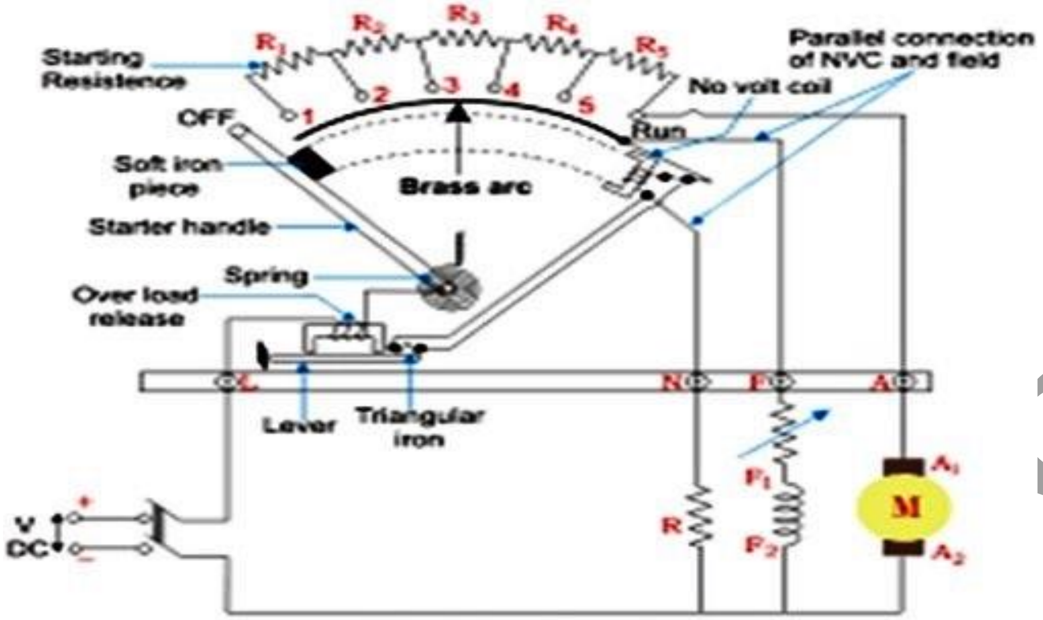
- Reduced wear on mechanical gears, chains and sprockets, and unexpected repair of broken belts and jammed gearboxes.
- Lower inventory of spare mechanical parts and operating costs.
- Increased production rates by reducing machine maintenance downtime.
- Prolonged life of electrical switchgear with lower inrush currents.
- Soft stops on pumping applications reduce piping system stresses and "hammer" effect.

PART-B

1. **How the different types of starters used in cage induction motor with a neat sketch?(13M)**BTL1

Answer: Page :3.1- J.Gnanavadivel,J.Karthikeyan

- Basic function of 2 point starter is to protect dc series motor from high starting current. at the time of starting large armature current is drawn by the motor which is limited by 2 point starter by connection resistance. ----- -------- (3M)
- motor starteris shown in the figure below this no volt trip coil is connected in series with the field winding of the motor.-------------------------(3M)



Four Point Starter

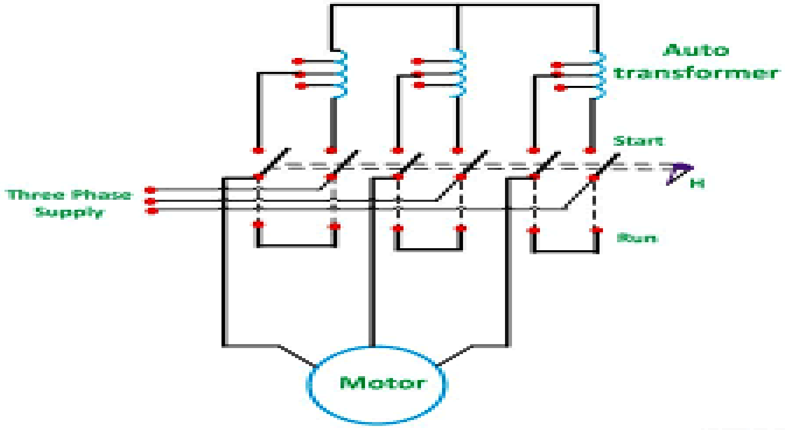
------- (5M)

4 POINT STARTER is a device to start dc motor safely. It provides extra resistance in armature circuit till motor develops rated speed and back EMF. ----- ----------------------------(2M)

2. **Explain starter is necessary for the induction motor?(NOV/DEC 2014) (13M)** BTL1

Answer: Page :3.3- J.Gnanavadivel,J.Karthikeyan

- To limit this starting current we need *a* starter *f*or induction motor.
- As the speed of armature/motor build up, armature induced emf also starts building thus reducing the role resistance offered by the starter, hence requiring it to gradually reduce as the motor picks up full speed.---(6M)



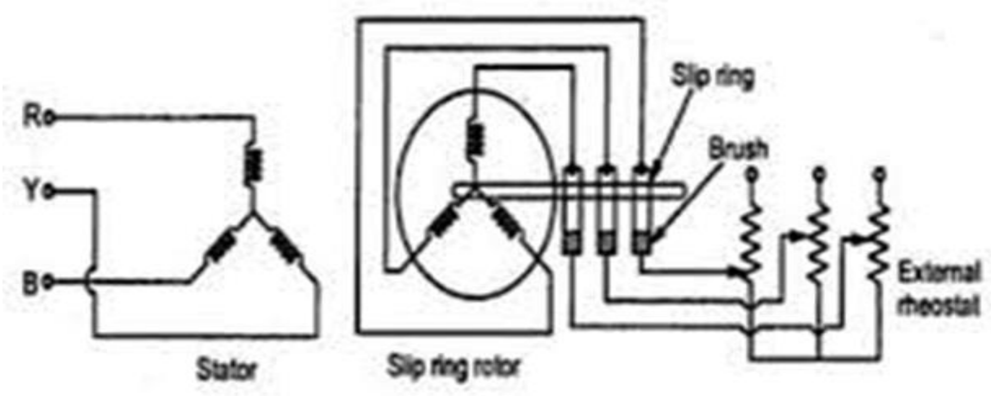
----------------------(5M)

- At the instant of start-up, there are some un-necessary *e*ffect on electrical and the ... in rotor resistance starter the three terminals of the rotor winding.
- It is simple and cheap starter for a 3-phase induction motor. ...
- Isolator is required to isolate the starter from the supply for maintenance. ...
- A three phase motor will give three times the power output when the stator windings. ------(2 M)

3. **Explain about rotor resistance starter.(NOV/DEC 2016) (13M)** BTL1

Answer: Page :3.13- J.Gnanavadivel,J.Karthikeyan

- This starteris used with a wound rotorinduction motor. it uses an external resistance/phase in the

	rotor circuit so that rotor will develop a high value of torque.---------------------(6M)  ----------- (4M) • by correctly selecting the resistors inserted into the rotor circuit, the motor is able to produce maximum torque at a relatively low current from zero to full speed. ------------- (3M)
4.	**Describe the manual auto-transformer starter for three phase induction motor. (13M)** BTL1 **Answer: Page:3.10- J.Gnanavadivel,J.Karthikeyan** • The difference between line and motor current is due to the transformer in the circuit. The lower line current is the reason the autotransformer starter is a very popular type of reduced-voltage starter------------------------------------ (7M)

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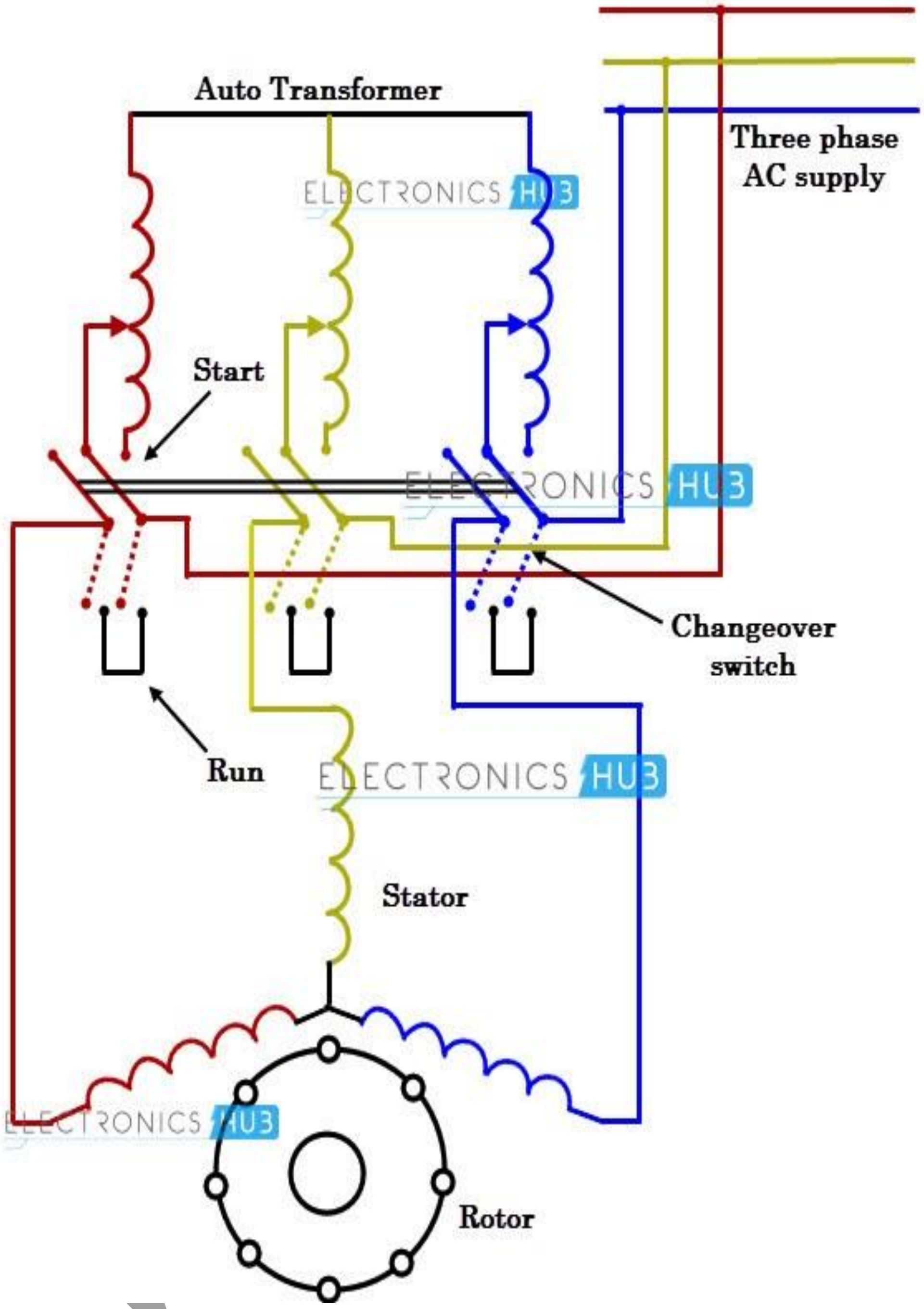
<tr><td></td><td>

----------- (6M)</td></tr>
<tr><td>5.</td><td>Explain the different types of starters used in cage induction motor with a neat sketch. (13M) BTL2
Answer: Page :3.7- J.Gnanavadivel,J.Karthikeyan
• DOL, Star Delta, Auto Transformer starter, and latest are Variable Frequency Drive, Soft Starter. These all are used for Squirrel cage motors.--------------------------- (6M)</td></tr>
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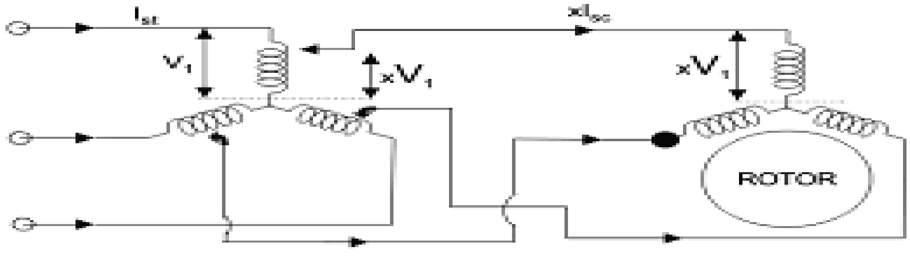


Pertaining to Auto-Transfer Starting

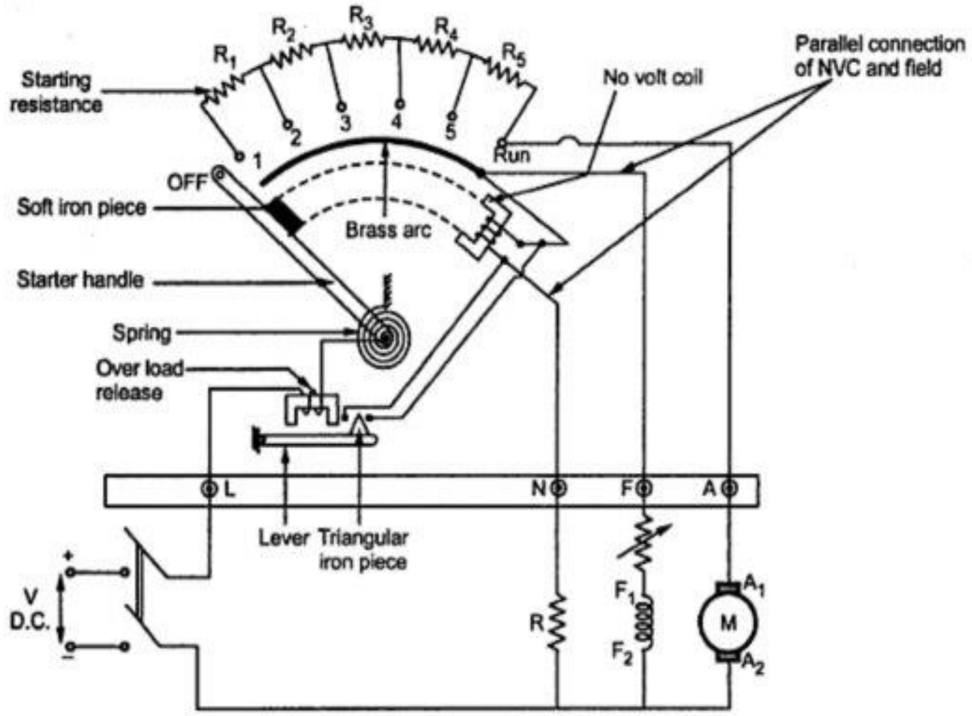
(3M)

- The reduction in back EMF increases the net voltage, since the supply voltage remains constant. (4M)

6 **Draw a neat schematic diagram of a four point starter and explain its working. (13M)** BTL2

Answer: Page :3.6- J.Gnanavadivel,J.Karthikeyan

- Starting of DC Motors. At the moment a DC motor is started the armature is stationary and there is no counter EMF being generated. The only component to limit starting current is the armature resistance, which, in most DC motors is a very low value----------------- (5M)



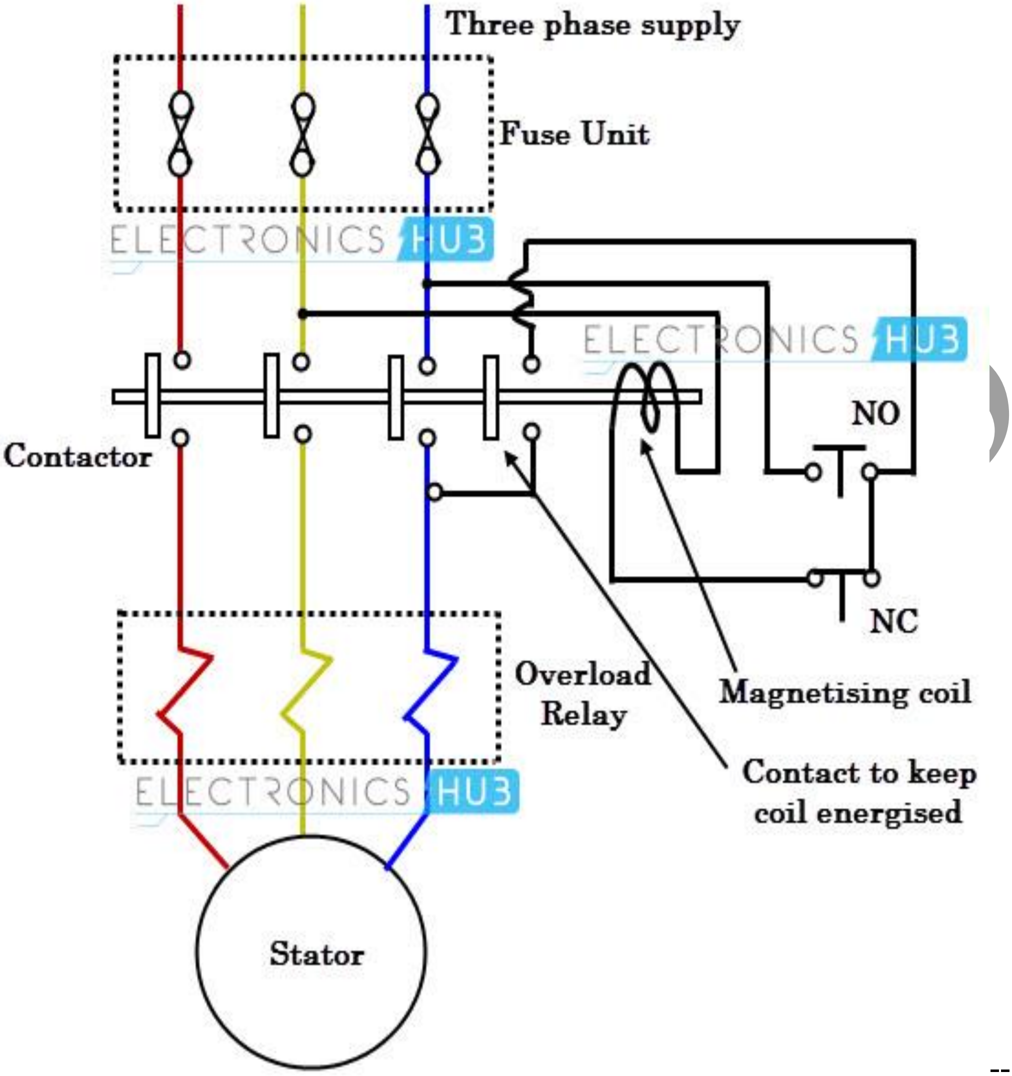
------------ (5M)

- The rotating movement of the starter motor is created through the interaction of two magnetic fields.------------------------------------(3M)

7 **Determine the push-button operated direct-on line starter for three phase induction motor.(13M)** BTL2

Answer: Page :3.7- J.Gnanavadivel,J.Karthikeyan

- Typically, the contactor will be controlled by separate start and stop buttons, and an auxiliary contact on the contactor is used, across the start button, as a hold in contact. ---------(3M)



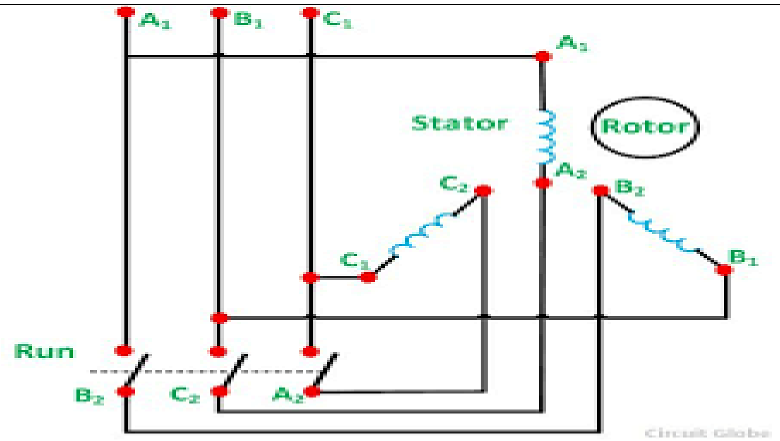
----------(5M)

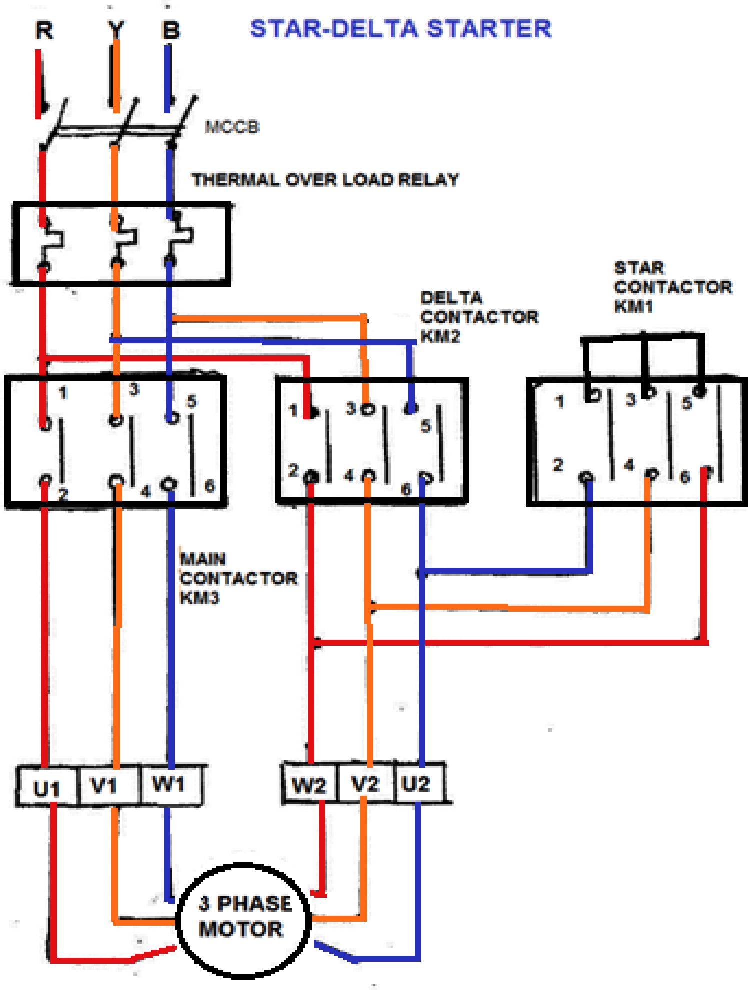
- So this will be inconvenient for the users of the supply line, always experience a voltage drop when starting a motor.
- But if this motor is not a high power---------------------- (5M)

8 **Explain about the star delta starter circuit.(13M)** BTL3

Answer: Page :3.13- J.Gnanavadivel,J.Karthikeyan

- The phase voltage is lower than line voltage in star connection, so the motors or drives connected in star connection runs at lower speed as compared to delta connection.
- Star Connection is preferable in transmission system as the voltage insulation required is less. Delta connection is used in Distribution--------------------------------(5M)

	 ------------- (5M) - Main Different between Star and Delta Connections. In STAR connection, the starting or finishing ends (Similar ends) of three coils are connected together to form the neutral point. - A common wire is taken out from the neutral point which is called Neutral; Line Current is Equal to Phase Current.-------------------------(3M)
9	**Explain the star-delta starting method.(13M)** BTL4 **Answer: Page :3.12- J.Gnanavadivel,J.Karthikeyan** - Starting current is reduced 3-4 times of the direct current due to which voltage drops and hence it causes less losses.--------------- (5M) - Star delta starter circuit comes in circuit first during starting of motor, which reduces voltage 3 times, that is why current also reduces up to 3 times and hence less motor burning is caused.



- ---------------(5M)

- The most commonly used method for starting of a three-phase induction motor is the star-delta method. this method of startingapplies a star delta starter to start an induction motor.
- This starter facilitates the stator winding to run in delta form and in star form for its beginning state. (3M)

10. **Explain DOL,autotransformers,star-delta starters for AC motors.(13M)** BTL4

Answer: Page :3.7- J.Gnanavadivel,J.Karthikeyan

- As the name implies, it switches the motordirectly onto the three phase supply.
- The use of dol startersis restricted up to smaller rating motors, as these startersdo not limit the starting current. --------------------------- (5M)

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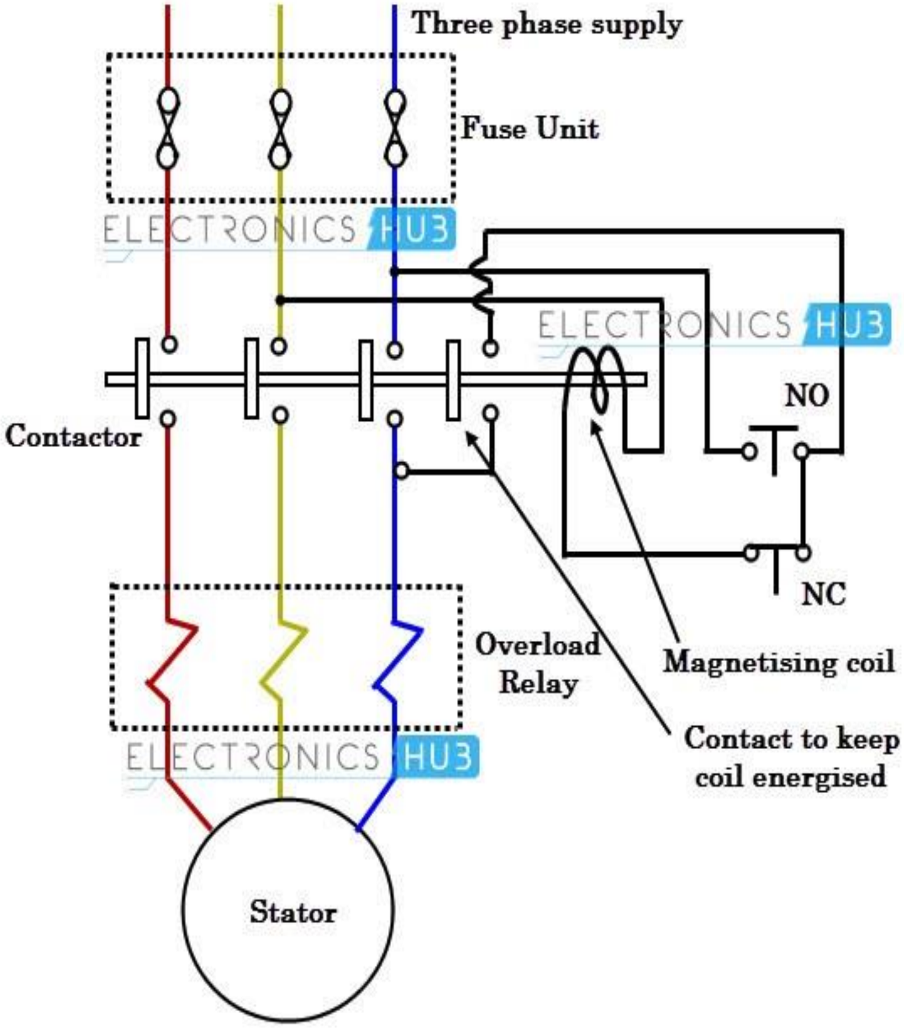

-------------------- (5M)

- The motor is connected through *a* starter across the full supply voltage.
- The three main contacts m and the auxiliary contact a are closed.
- The terminals a theory of Direct on Line Starting of induction motor.
- Let I_{st} be the starting current drawn from the supply mains per phase. -------------------------------- (3M)
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<td>**PART-C**</td>
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<tr>
<td>1.</td>
<td>
Explain the working of three phase slip induction motor using frequency sensing relay.(15M) (Nov/Dec 2014) BTL2
Answer: Page :3.21- J.Gnanavadivel,J.Karthikeyan

- Stator winding can be either star or delta connected depending upon the design. ---------(3M)
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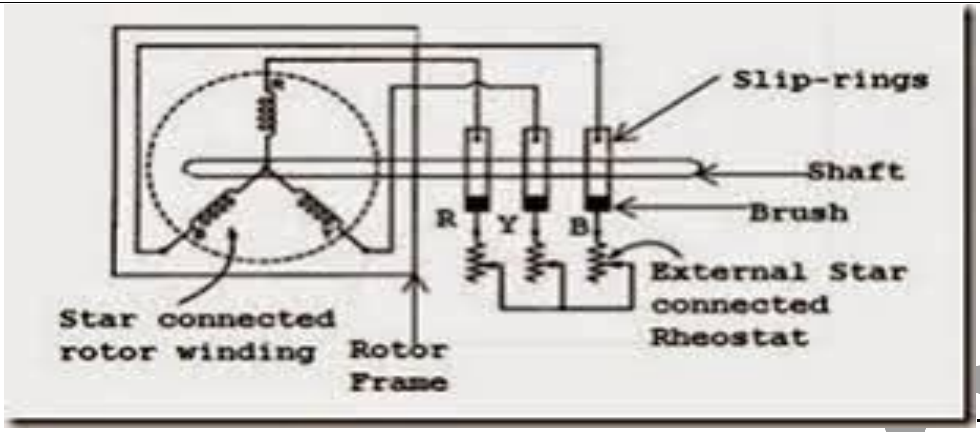


----------(5M)

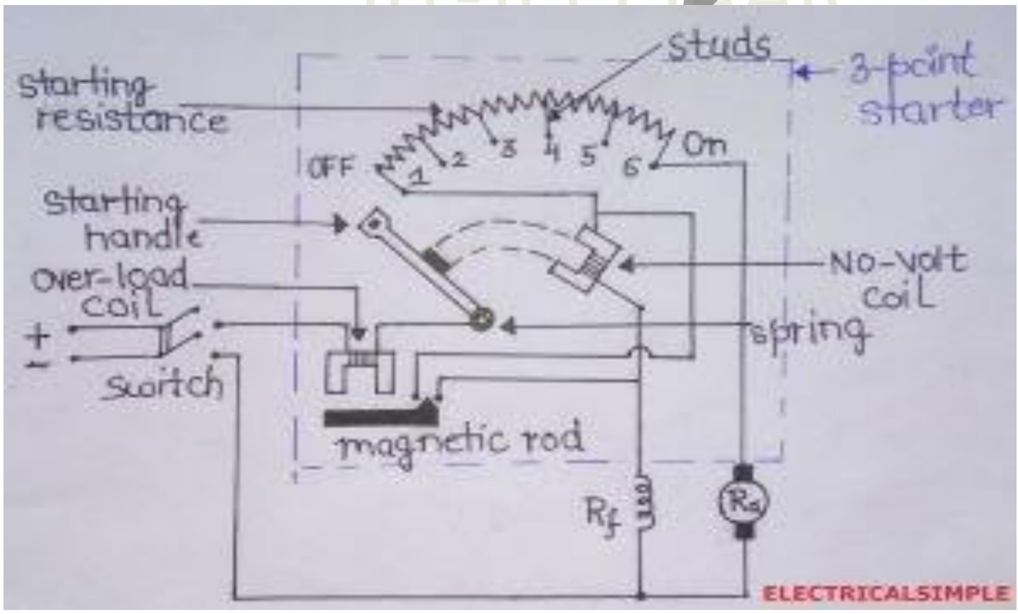
- Induction motors generally will have low starting torque compared to dc series motor. Slip ring induction motor have big advantage of having high starting torque compared to squirrel cage motor. Therefore slip ring induction motors are generally employed where load requires high starting torque or good speed control.--(7M)

2\.

What is the necessity of DC starters? Explain with neat sketches ,the principle and operation of three point starter.(15M)BTL3

Answer: Page :3.4- J.Gnanavadivel,J.Karthikeyan

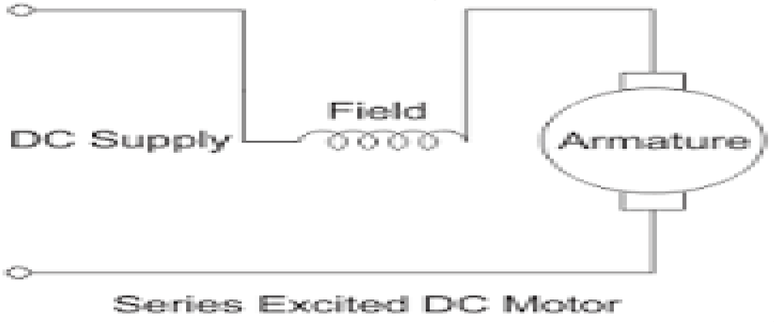
- Fixed spring attached end of the starting resistance is connected to supply through overload release coil. The other end moves against the pull of the spring and makes connections with studs during starting operation of the motor cutting more and more resistance as it passes over each stud in clockwise direction .---(5M)

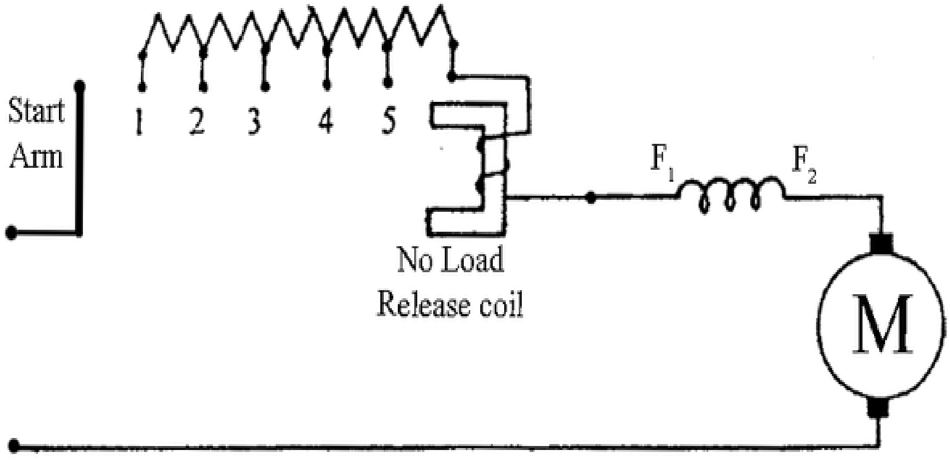


- ---------(5M)

A three-point starter is a device that helps in starting and running the shunt wound motor or compound wound DC motor.

- The back EMF (Eb) plays a crucial role in governing the operation of motors.

	• NVC coil loses its magnetism and leaves the handle the handle than retracts back to OFF position because of spring action. The motor will stop-------------------------------(5M)
3.	**Explain the control circuit for DC series and shunt motor.(NOV/DEC 2016) (15M)**BTL5 **Answer: Page :3.16- J.Gnanavadivel,J.Karthikeyan** • A DC series motor converts electrical energy to mechanical energy. • Its principle of operation is based on a simple electromagnetic law that states that when a magnetic field is created around current carrying conductor and interacts with an external field, rotational motion is generated.---------------------------- (2M)  ---------------- (3M) • A dc series motor converts electrical energy to mechanical energy. its principle of operation is based on a simple electromagnetic law that states that when a magnetic field is created around current carrying conductor and interacts with an external field, rotational motion is generated. • Shunt dc motorsoperate on direct current. As such, the field windings and armature are connected in a parallel combination, and in electrical terminology. --------------(5M) • Induction motor equivalent circuit. ... for the rotor side, the induced emf is affected by the slip.(5M)
4	**Explain the need of starters.(APR/MAY 2015) (15M)** BTL3 **Answer: Page:.3.7- J.Gnanavadivel,J.Karthikeyan** • No back EMF • A starteris a device used to rotate (crank) an internal-combustion engine so as to initiate the engine's operation under its own power. • The powerful electric starter motor does the turning. Its shaft carries a small pinion which engages with a large gear ring around the rim of the engine flywheel. -------(2M) • The starter needs a heavy electric current, which it draws through thick wires from the battery. • Initial rush of excessive current In an electric power system, overcurrent or excess current is a situation where a larger than intended electric current exists through a conductor, leading to excessive generation of heat, and the risk of fire or damage to equipment.-------------------------------(3M) • Five to seven times of full load current



------------ (5M)

- An electrical LOADis an electrical component or portion of a circuit that consumes (active) ... LOADaffects the performance of circuits with respect to output voltages or CURRENTS, such as in sensors, voltage sources, and amplifiers
- The electric starter motor or cranking motor is the most common type used on gasoline engines and small diesel engines. The modern starter motor is either a permanent-magnet or a series-parallel wound direct current electric motor with a starter solenoid (similar to a relay) mounted on it. (5M)

UNIT IV CONVENTIONAL AND SOLID STATE SPEED CONTROL OF D.C. DRIVES

Speed control of DC series and shunt motors – Armature and field control, Ward-Leonard control system- Using controlled rectifiers and DC choppers –applications.

Q.No	PART*A
1.	**What are the various parameters that control speed of DC motors?(NOV/DEC 2014)**BTL1 • Flux in the air gap • Resistance in the armature circuit • Voltage applied to the armature circuit
2	**List the advantages of field control. (APRIL/MAY 2017)** BTL1 • The regulating resistance, which has to carry only a small current • Power wasted in regulating resistance is very small
4	**What will happen due to change in supply voltage on the speed of dc shunt motor?** BTL1 • The reduction of supply voltage to the armature of dc shunt motor causes reduction of back-emf of the motor which in turn reduces the speed the speed is directly proportional to the back emf
5	**Define speed control.** BTL1 • The initial change of drive speed to a value required for performing the specific work process is called as a speed control.
6	**What are the advantages of field control method?(APR/MAY 2016)**BTL1 • Conventional and easy method • Shunt field current I_{sh} is small the power wasted in the field rheostat also small • Independent of load on the motor

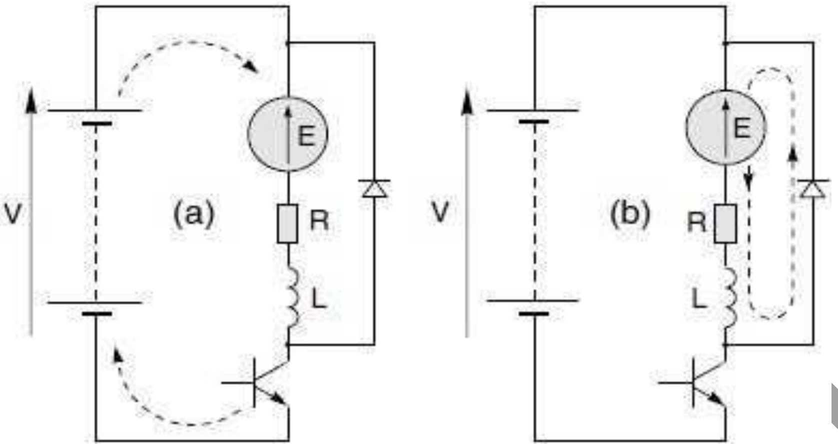
	- Economical and efficient method
7	**What are the disadvantages of field control method?** BTL1 - There is a maximum limit of speed that can be obtained with this method. - It is due to fact that flux per pole is too much weakened commutation becomes poorer.
8	**State the application of ward- Leonard system speed control.(April/May 2015)**BTL2 - This method normally adopted in very sensitive speed control like electric excavators, elevators, coillery winders, main drives in steel mills and paper mills.
9	**What are the advantages of Ward-Leonard speed control?** BTL2 - Wide range of speed control is possible - Full forward and reverse speed can be achieved - Power is automatically regenerated to the ac line through the motor generator set which speed is reduced. - Short time over load capacity is large - The armature current of the motor is smooth
10	**Mention the various types of control in motor.**BTL2 - For armature control method (or) voltage control method the field current is kept constant - For field control (or) flux control the armature current kept constant
11	**What is meant by solid state speed control?** BTL2 - A process which is used to control the speed by using purely semi conducting material. - Power semiconductor devices like thyristors, power Transistors, MOSFET and etc., is called solid state speed control.
12	**Mention the arrangements are available using power semi conducting materials.**BTL3 - Controlled converters - AC voltage regulator - Switch (or)chopper - Inverter - Cyclo converter
13	**What are the advantages of solid state drive methods?** BTL4 - Very fast response - Less losses - Higher efficiency - Pollution free method - Small size maintenance easy and controlled
14	**What are disadvantage of solid state drive methods?** BTL4 - Very difficult to regeneration of power - It contains low power overload capacity - Causes the interference in commutation in communication system due to harmonics in supply
15	**What is meant by dc Chopper?(Nov/Dec 2014)** BTL4 - It is a device which is used to converter fixed dc voltage into variable dc voltage. - This is designed with the help of power Semiconductor devices like Power Transistors, MOSFETS, Thyristors
16	**What are the different types of choppers?(MAY/JUNE 2015)** BTL5 - Class A or First quadrant chopper –Motoring control

	• Class B or Second quadrant chopper – Braking control • Class C or Two quadrant Type A chopper • Class D or Two quadrant Type B chopper • Class E or Four quadrant chopper
17	**What is meant by flux control (or) field control method?** BTL5 • By varying the field flux the speed can be controlled is called flux control. • This method can be used for increasing the speed of the motor is inversely proportional to the field flux
18	**State static Ward – Leonard drive.**BTL6 • Controlled rectifiers are used to get variable dc voltage from an ac source of fixed voltage. • Controlled rectifiers fed dc drives are known as "static Ward – Leonard drive".
19	**Mention the advantage of flux control method**.BTL6 • Convenient and easy method • In this method is independent of load on the motor • Economical and efficient method
20	**What is meant by armature resistance control?(MAY/JUNE 2014)**BTL2 • The armature having controller resistance in series during the speed control. By varying the controller resistance R, the potential drop across the armature is varied. • Hence the speed of the motor also varied. • This method of speed control is applicable for speed less than no load speed.
21	**What is the function of freewheeling diode?** BTL1 • Freewheeling diodes are introduced to maintain the continuous current flow to the load whenever all thyistors are turned off condition.
22	**Mention the output voltage equation for single phase full converter and half converter.**BTL1 • Half converter • $V_0=V_m/2\pi(1+COS\alpha)$ • Full converter • $V_0=2V_m/ \pi COS\alpha$
23	**State the advantages of DC chopper drives?**BTL1 • High efficiency • Flexibility control • Quick response
24	**What are the disadvantages of conventional Ward-Leonard schemes?** BTL1 • Higher initial cost due to use of two additional machines. • Heavy weight and size. • Needs more floor space and proper foundation • Required frequent maintenance. • Higher noise and higher loss.
25	**Mention the drawbacks of rectifier fed dc drives.**BTL1 • Distortion of supply. • Low power factor. • Ripple in motor current

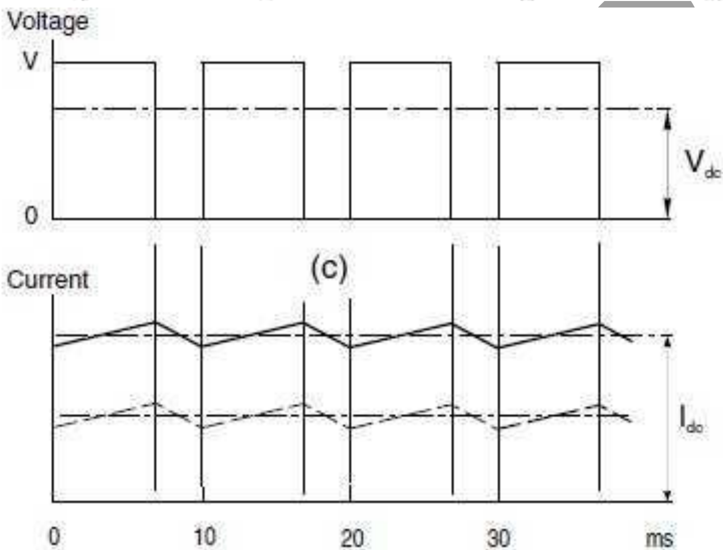
PART* B

1. **Explain the operation of chopper fed DC Series Motor drive. (13M)**BTL1
Answer: Page:4.29- J.Gnanavadivel,J.Karthikeyan

- The principal difference between the thyristor-controlled rectifier and the chopper is that in the former the motor current always flows through the supply.--------------------- (4M)



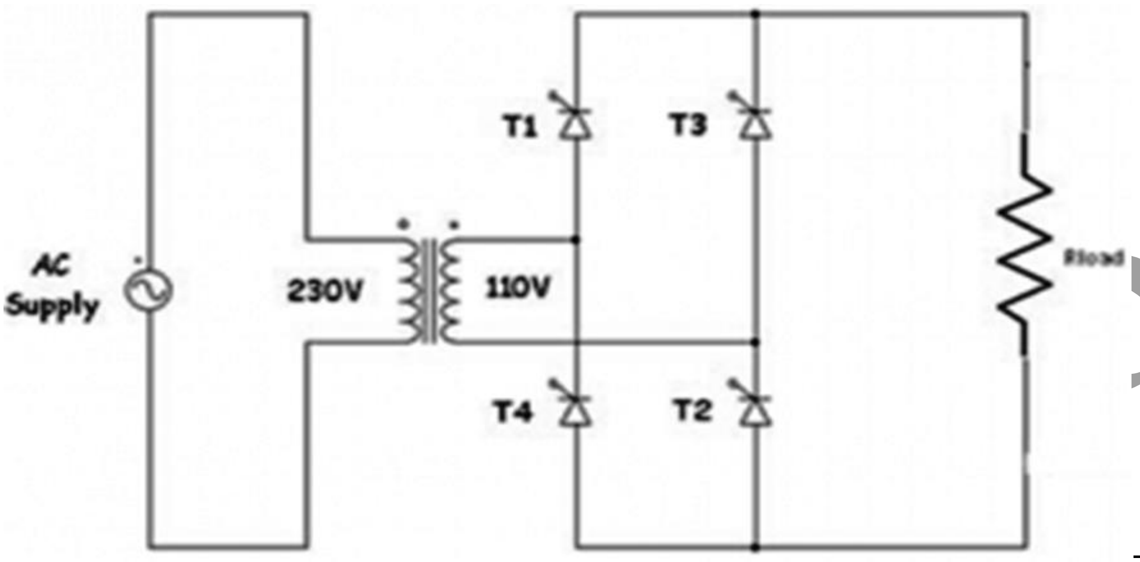
(3M)

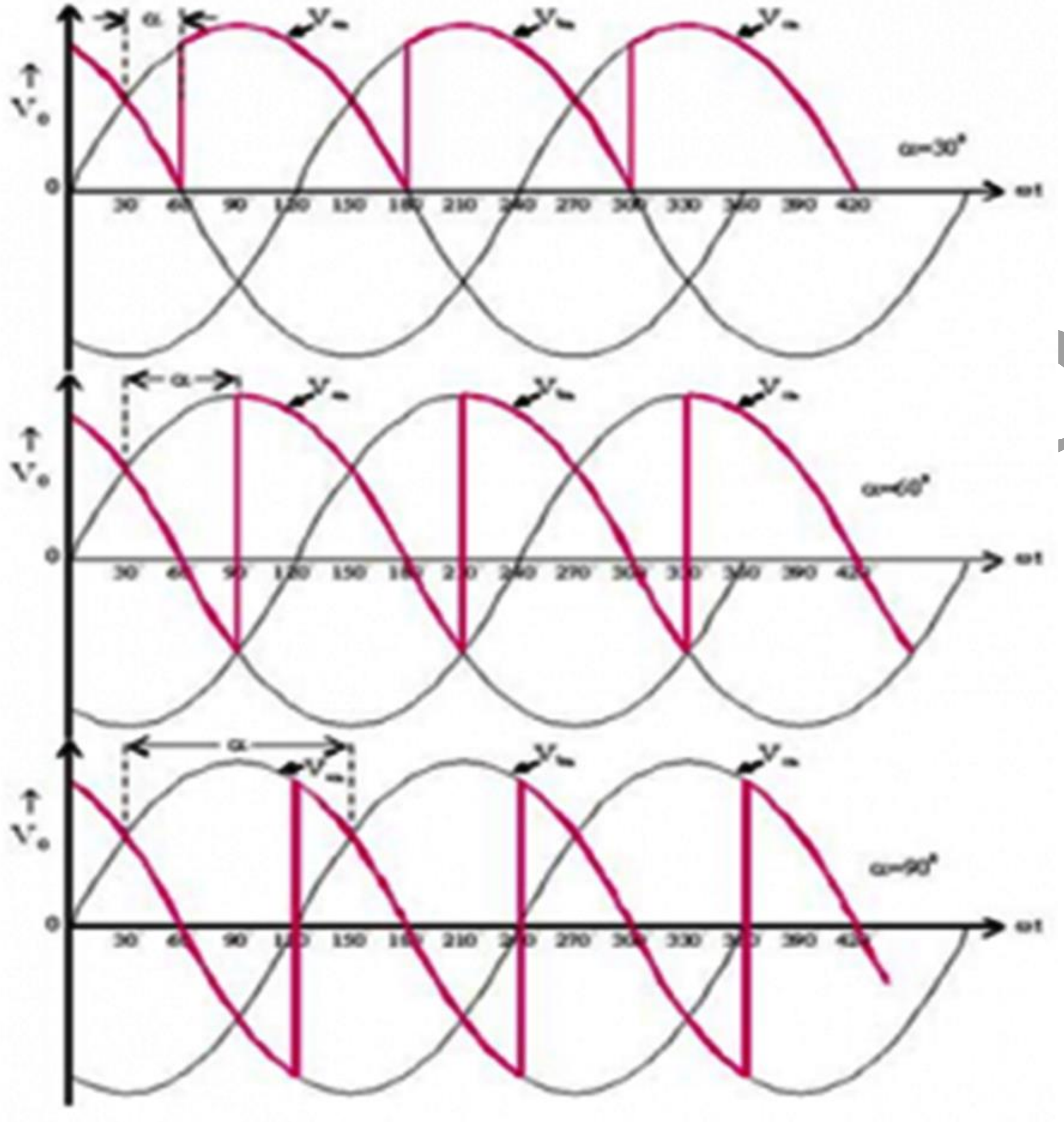


(3M)

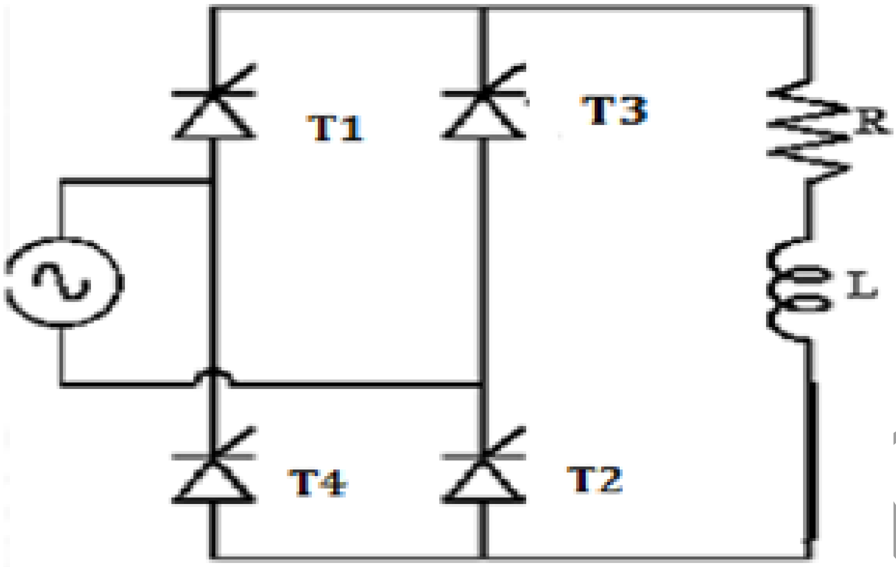
- For the remainder of the cycle the transistor is turned 'off ' and the current freewheels through the diode, as shown by the dotted line.
- When the current is freewheeling through the diode, the armature voltage is clamped at (almost) zero.
- The speed of the motor is determined by the average armature voltage, (V_{dc}), which in turn depends on the proportion of the total cycle time (T) for which the transistor is 'on'. If the on and off times are defined as $T_{on} = kT$ and $T_{off} = (1 - k)T$, where $0 < k < 1$, (3M)

2 **Describe the single phase wave converter operation. (13M) (April/May 2015)** BTL1
Answer: Page: 4.21- J.Gnanavadivel,J.Karthikeyan

	Single Phase Full Wave Controlled Rectifier with 'R' load:  ---- (3M)


α
V_m
V_o
0
30 60 90 120 150 180 210 240 270 300 330 360 390 420
ωt
α=30°
α=60°
α=90°

(2M)

	 (2M) • Induced emf is positive & maintains conducting SCR's T3 & T4 with reverse polarity also. • Thus VL is negative & equal to instantaneous ac supply voltage. Whereas load current continues to be positive. • Thus load acts as source & stored energy in inductance is returned back to ac supply • At wt=α or 2π+α, T3 & T4 are commutated and T1,T2 are turned on---------------------------6M)
3.	**Describe and explain the ward Leonard systems for speed control of DC motors. (13M)**BTL1 **Answer: Page: 4.13- J.Gnanavadivel,J.Karthikeyan** • The direction of rotation of the motor M_1 can be reversed by excitation current of the generator and it can be done with the help of the reversing switch R.S. But the motor-generator set must run in the same direction. (4M) • This speed control system is mainly used in colliery winders, cranes, electric excavators, mine hoists, elevators, steel rolling mills, paper machines, diesel-locomotives, etc. (9M)
4.	**How the speed control of the drive is achieved using Single phase fully controlled rectifier. (13M)** BTL1 **Answer: Page:4.21- J.Gnanavadivel,J.Karthikeyan** • Half converter, semi converter, full converter and dual converter are some of the thyristor circuits(2M)

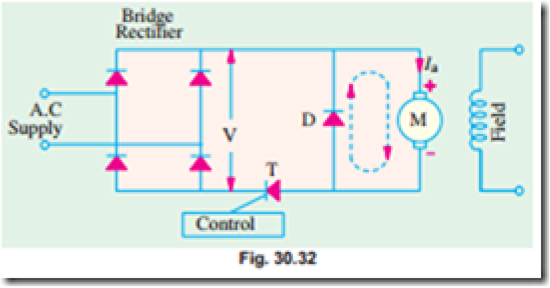


Fig. 30.32

(4M)

- When a is decreased *i.e.*, thyristor is fired earlier, conduction period is increased which increases the mean value of the voltage applied across the motor armature.
- Consequently, motor speed is increased. In short, as a increases, *V* decreases and hence *N* decreases.

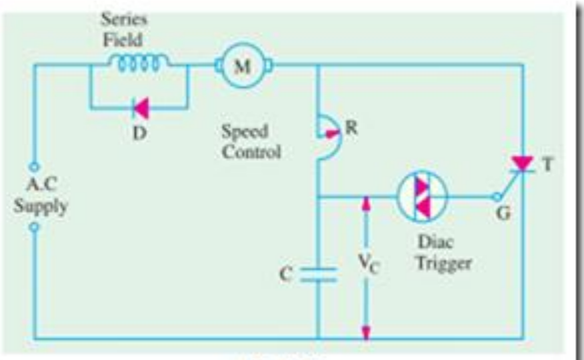


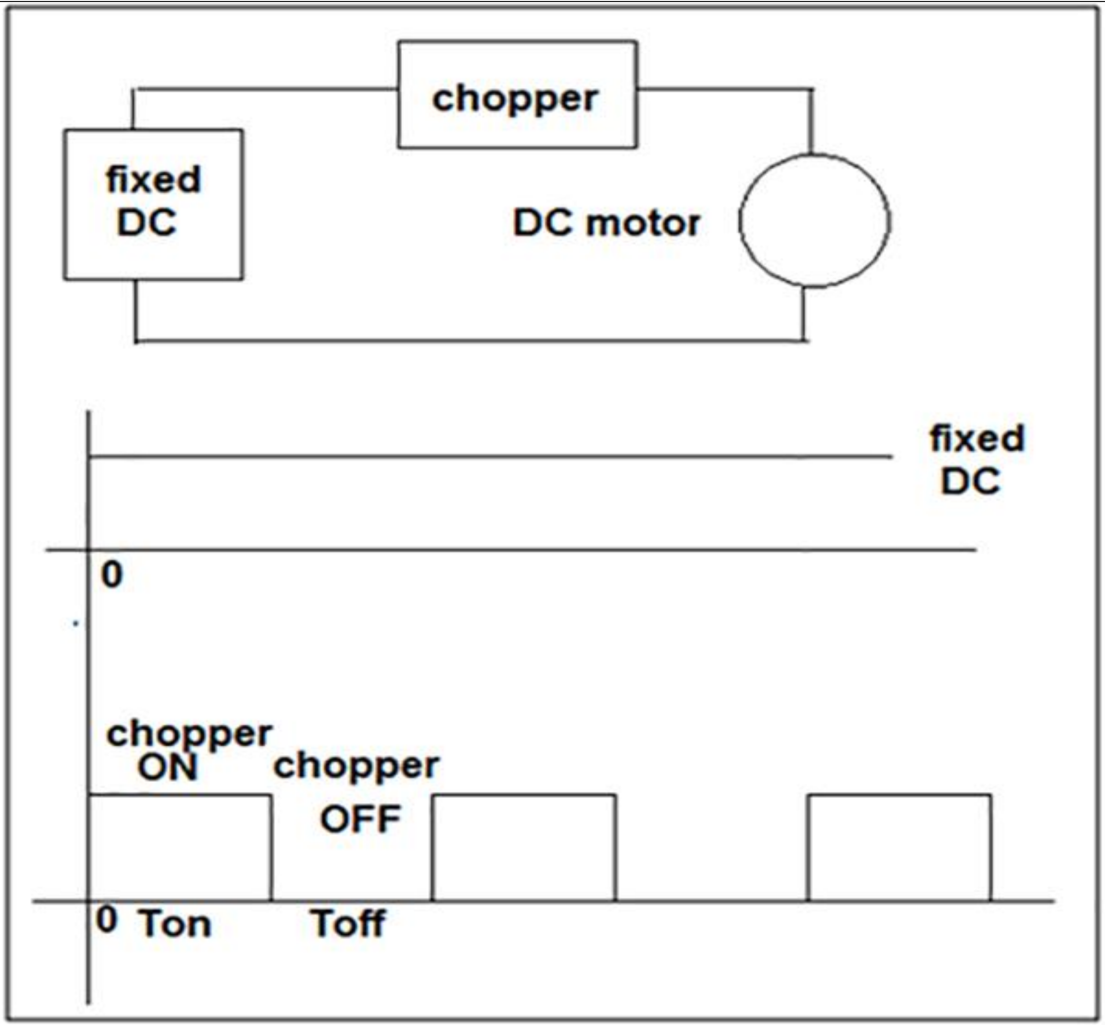
Fig. 30.33

- It further helps to control the motor speed because it is directly proportional to the armature voltage. (7M)

5. **Explain the operation of chopper control methods of speed control DC motors. (13M)** (BTL2)

Answer: Page :4.29- J.Gnanavadivel,J.Karthikeyan

- E-bikes, e-bicycles, e-scooters also runs on DC motor and to vary their speed it is required to control speed of DC motor DC motors are also used in portable sewing machine, drill machine etc, in which speed control of motor is provided for different operation. (2M)

	 $$Vdc = [T_{on} / (T_{on} + T_{off})] \times V_{fixed}$$ But $T_{on} + T_{off} = T_{total}$ So $Vdc = [T_{on} / T_{total}] \times V_{fixed}$(6M) . So the rectified output applied to DC motor is also more – means average voltage applied to motor is more and its speed is moreThus as time period.(7M)
6.	**Describe the first quadrant with help of a suitable diagrams and waveforms. State the relation between input and output voltages.(13M)**(BTL2) **(April/May 2017)** **Answer: Page:4.34- J.Gnanavadivel,J.Karthikeyan** • Chopper circuits, unidirectional power semiconductors are used. If these semiconductor devices are arranged appropriately, a chopper can work in any of the four quadrants.(4M)

- Let us now take a look of these classifications and the characteristics of various classifications.
- This type of chopper is shown in the figure. It is known as first-quadrant chopper or type A chopper. (6M)
- When the chopper is on, $v_0 = V_S$ as a result and the current flows in the direction of the load. (3M)

7 **Explain about two quadrant method of speed control DC shunt motor.(13M)**BTL2**(April/May 2017)**

Answer: Page:4.37- J.Gnanavadivel,J.Karthikeyan

- Flux control method. It is already explained above that the speed of a dc motor is inversely proportional to the flux per pole. ...---------------------- (4M)
- Armature control method. ...
- Voltage Control Method.
- Flux control method. ...
- Variable resistance in series with armature. ...
- Series-parallel control.--------------------------------------(6M)
- Motor armature current is decided by the load. On less load or no load, the armature current drawn by the motor is very small. and on no load as I is small hence flux produced is also very small. ... This is the reason why series motor should never be started on light loads or no load conditions--- (3M)

8 **Discuss the procedure to find Four quadrant chopper.(13M)** (BTL3)

Answer: Page :4.39- J.Gnanavadivel,J.Karthikeyan

- **Four Quadrant Operation of Motors**
  All types of DC-DC converters are capable of operating the motor operation in the first quadrant.
- Some converters are capable of operating in two quadrants and some in all four quadrants.
  Power semiconductor devices (like SCR, MOSFET) used in chopper circuits are unidirectional devices.
- Polarities of output voltage V_O and the direction of output current I_O are restricted.
  Semiconductor devices and passive components, a chopper can operate in any of the four quadrants.
- Based on the number of quadrant a chopper can operate, the chopper circuits can be classified as follows:
- Single Quadrant Chopper:-
  Example: Type-A Chopper, Type-B Chopper
- Two quadrant Chopper:-
  Example: Type-C Chopper, Type-D Chopper
- Four quadrant Chopper;-
  Example: Type-E Chopper
- In some text books these chopper circuits are mentioned as Class-A, Class-B .... Class-E in place

of Type-A, Type-B..... Type-E respectively.
In this Post, we will discuss about the four quadrant operation in detail.
Before proceeding further it is highly recommended to know about the basics, principle of operation, classification of DC-DC Converter Circuits (Choppers). (7M)

- When a motor draws power from supply, the voltage and current are in the same direction.
- Now the motor is said to be in motoring operation, its operation corresponds to first quadrant.
- If there is a possibility of reversing the current direction keeping the voltage polarity same, the motor is said to be operating in second quadrant.
- This happens when regenerative braking is applied on the motor.
- During regeneration operation, reverse power flow will happen. ie, power will fed back to the supply system.
- If the voltage polarity and load current are reversed simultaneously, the motor's operation will be in the opposite direction (but the power is consumed by the load).
- This operation is corresponds to the third quadrant and even now it is said to be in motoring operation (in reverse direction).
- If the voltage polarity is reversed maintaining the current direction from source to load, the power reversed and the operation corresponding to the fourth quadrant.
- Now the motor is said to be in reverse regeneration operation (ie, regeneration in reverse direction). (6M)

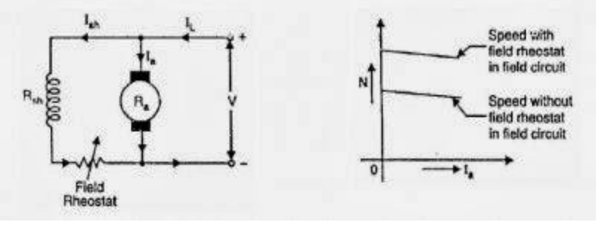
9

Explain with different methods of speed control employed in DC Shunt Motor. (13M) (BTL3)
Answer: Page:4.9- J.Gnanavadivel,J.Karthikeyan

1. Flux Control Method
2. Armature Control Method
3. Voltage Control Method
    - Multiple Voltage Control
    - Ward Leonard System-------------------------------------(6M)

Flux Control Method
Speed is inversely proportional to flux. So by varying flux we can change the speed of the motor.

In this method a variable resistance (known as shunt field rheostat) is placed in series with shunt field winding.



---------------------------------- (4M)

The field rheostat reduces the shunt field current Ish. So the flux also get reduced. There the speed can be

Voltage control method

- There are some disadvantages for flux control method and armature control method such as poor speed regulation and poor efficiency. Voltage control method overcome these problems.

- In this method, the voltage source supplying the field current is different from that which supplies thearmature.
  This method is used for large size motors since it is very expensive---------------------(3M)

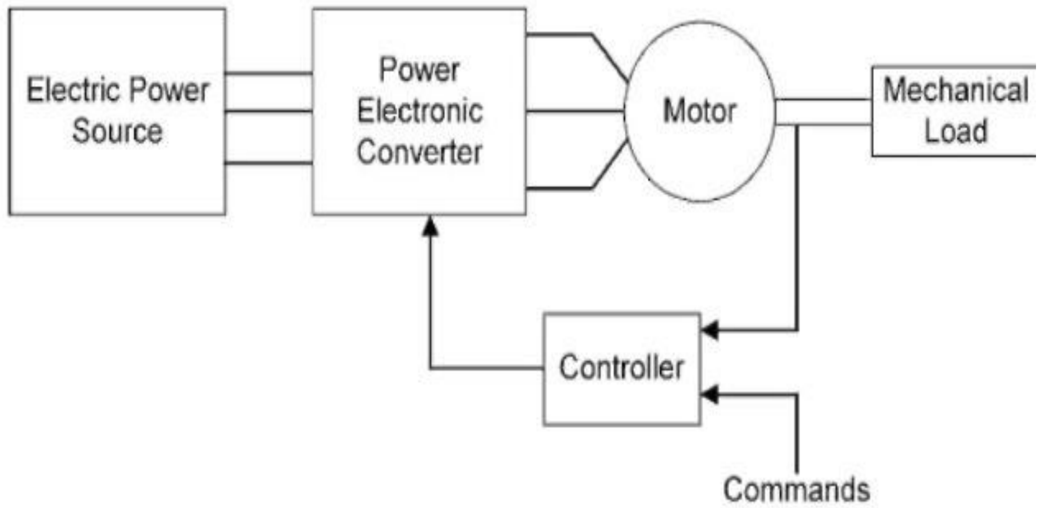
PART* C

1. **Explain in detail the single phase half wave converter drive speed control for DC drive with waveforms.(15M)**BTL4

Answer: Page:4.31- J.Gnanavadivel,J.Karthikeyan

Separately excited DC motor controlled by a single-phase, half-wave controlled rectifier. This rectifier provides speed control for the separately excited DC motor by varying armature voltage and current. The steady state voltage and torque equations for a separately excited DC motor are

$$V_a = R_a I_a + E_a$$



-----------------(5M)

- Speed control can be done by varying Ra, Va, and IF. Varying Ra can only increase the speed. Also, by varying Ra, we increase the losses I2R. IF can only be decreased.
- This is accomplished by putting resistance in the field. Again, this increases the I2R losses. Control of Vf is limited because of saturation. T
- he best method of controlling the speed of the motor is to control Va. Using a thyristor, as shown in Fig. 3.2, the average of Va can be controlled. Figure 3.3 shows the voltage and current for a separately excited DC motor controlled by a single-phase, half-wave, controlled rectifier.
- As seen in Fig. 3.3, a represents the firing angle of the thyristor.
- From these two quantities, we define the conduction angle----------------- (5M)

- Torque at the rated rms current. The rms to average current ratio is also more. The motor current is always discontinuous. The ripple frequency is equal to supply frequency
- The freewheeling diode across the load improves the performance. The speed regulation is very poor. At low speeds the motor receives power in pulses and the motor may chug when the load is high. The speed oscillation is quite high. The supply transformer has premagnetisation due to dc component of the load current. The application of this drive is limited to low powers.
- This inductance also affects the performance of the drive on the line side. The harmonic content

	of the line current is more at lower values of inductance because of possible discontinuous load current. As the inductance increases the harmonic factor decreases. The peak value of current decreases with additional inductance. This improves the commutating capability.------(5M)
2	**Determine the speed control of DC series motor (15M)**BTL3 **Answer: Page :4.5- J.Gnanavadivel,J.Karthikeyan** • By varying the supply voltage. • By varying the flux, and by varying the current through field winding. • By varying the armature voltage, and by varying the armature resistance.----------------(5M) • When supply voltage (V) and armature resistance Ra are kept constant, the Speed is directly proportional to armature current (Ia). ---(5M) • An electronic speed control or ESC is an electronic circuit with the purpose to vary an servo-motor's speed, its direction and possibly also to act as a dynamic brake. ESCs are often used on motors essentially providing an electronically-generated three-phase electric power low voltage source of energy for the motor--- (5M)

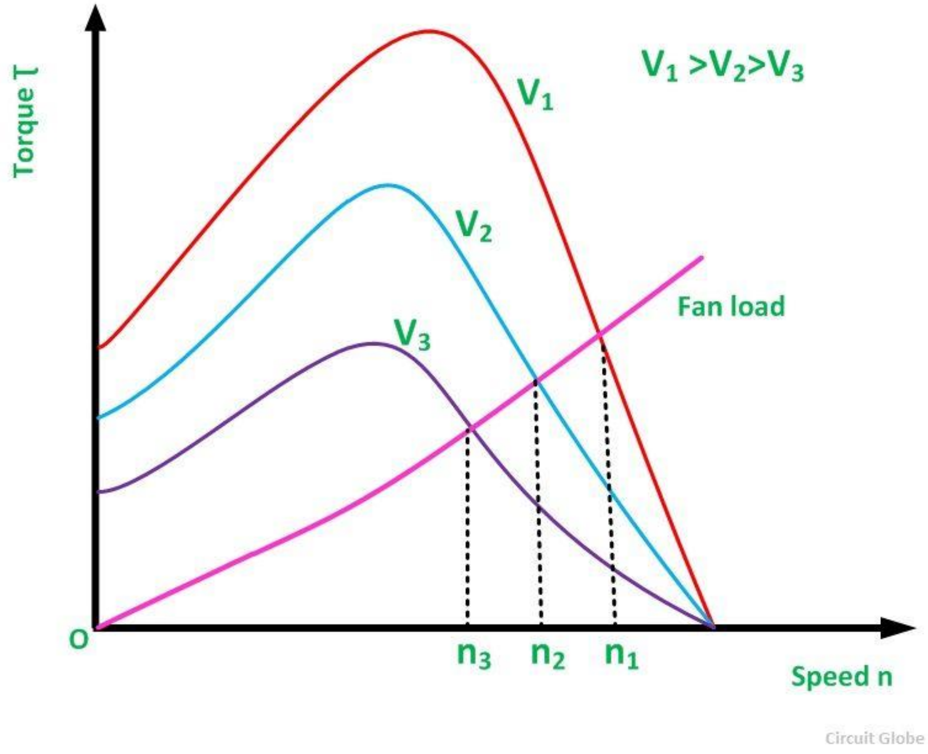
UNIT V CONVENTIONAL AND SOLID STATE SPEED CONTROL OF A.C. DRIVES

Speed control of three phase induction motor – Voltage control, voltage / frequency control, slip power recovery scheme – Using inverters and AC voltage regulators – applications.

Q.No.	PART*A
1.	**What is meant by voltage control in induction motor?** BTL1 • In Induction motor speed can be controlled by varying the stator voltage. • This can be done by using transformer. • This method is called voltage control
2	**What is stator voltage control?** BTL1 • Three phase induction motor speed can be controlled by varying the stator voltage. • This stator voltage can be varied by using ac voltage controller. • This method of speed control of induction motor is called as stator voltage control
3	**What are the various conventional speed control methods used in induction motors?(NOV/DEC 2014).** .BTL1 • Changing applied voltage • Changing the applied frequency • Rotor rheostat control
4	**Mention the advantageof squirrel cage induction motor over a DC motor.(NOV/DEC 2016)**BTL1 • Speed control by changing supply frequency • Speed control by changing no. of poles • Speed control by changing slip
5	**What is Slip-Power recovery system?**BTL1 • The slip power can be recovered to the supply source can be used to supply an additional motor which is mechanically coupled to the main motor. • This type of drive is known as slip-power recovery system
6	**Define V/F control?(Nov/Dec 2014)** BTL1 • When the frequency is reduced the input voltage must be reduced proportionally so as to maintain constant flux. • Otherwise the core will get saturated resulting in excessive iron loss and magnetizing current. • This type of induction motor behavior is similar to the working of dc series motors.

7	**State the main feature of v/f control.** BTL2 • starting current is constant • Maximum torque should be constant
8	**State about stator frequency control.** BTL2 The three phase induction motor speed can be controlled by varying the stator frequency. The variable stator frequency can be obtained by inverters circuit.
9	**What are the advantages of slip-power recovery system?** BTL2 • The slip power from the slip-rings can be recorded and fed back to the supply. • The overall efficiency also improved
10	**What are the advantages of stator voltage control?** BTL2 • Very simple control circuit • More compact and less weight • Quick response and economical method.
11	**What is meant by stator current control?** BTL3 The stator current control means in three phase stator current can be controlled by stator current control. The stator current can be varied by using current source inverter.
12	**What are the disadvantages of stator voltage control?** BTL4 • Input Power factor is low • Operating efficiency is low • Voltage and current waveform are highly distorted due to harmonics, which affects the efficiency of the machine
13	**State ac voltage controller.** BTL4 AC voltage controller is nothing but, which is used to converters fixed ac voltage into variable ac voltage without changing supply frequency
14	**Mentionthe possible methods of speed control available by using inverters.**BTL5 ➢ Variable voltage input (VVI) inverter control ➢ Variable voltage output (VVO) inverter control ➢ Pulse width modulated (PWM) inverter control ➢ Current controlled inverter.
15	**What is meant by PWM inverter control?**BTL5

	The output from inverter is square with some harmonic contents so we have to remove or reducing the harmonic contents by using some voltage control technique called PWM
16	**Mention the classifications of PWM technique?BTL1** • Single pulse width modulation • Multiple pulse PWM modulation • Sinusoidal Pulse PWM
17	**Mention the applications of stator voltage control.BTL2** The application of the stator voltage control method is suitable for torque demand reduced with speed, which points towards its suitability for ,Fan, Pump drives
18	**Mention the applications of AC drives.BTL1** AC drives are used in a number of applications are: • Fans • Blowers • Steel mills • Cranes • Conveyors and • Traction etc.
19	**Mention the advantages of stator voltage control method.BTL1** The advantages of stator voltage control method are: The control circuitry is simple • Compact size • Quick response time
20	**What is meant by soft start?** BTL1 The soft start means, the AC voltage controllers allow a steeples control of supply voltage from zero to rated volt. They are used for soft start of motors.
21	**What is meant by frequency control of induction motor?** BTL1 The frequency control of induction motor means the speed of an induction motor is controlled by Changing the supply frequency, because the speed is directly proportional to supply frequency.
22	**What is meant by stator current control?(NOV/DEC 2015)** (BTL1) The stator current control means in three phase stator current can be controlled by stator current

	control. The stator current can be varied by using current source inverter
23	**What is meant by slip power?** BTL1 The slip power means, the portion of air gap power, which is not converted into mechanical power, it is called slip power. Slip power is nothing but multiplication of slip (S) and air gap power (P_{ag}).
24	**Define sub-synchronous speed operation.(APR/MAY 2014)** BTL1 The sub-synchronous speed operation means, the SRIM speed can be controlled below synchronous speed. That is, the slip power is fed back to the supply.
25	**What is meant by super-synchronous speed operation?** BTL1 The super-synchronous speed operation means, the SRIM speed can be controlled above synchronous speed. That is, the supply is fed back to the rotor side.
	PART* B
1.	**Describe the solid state stator voltage control technique for the speed control of three phase induction motor.(13M)**BTL3 **Answer: Page:5.2- J.Gnanavadivel,J.Karthikeyan** - Stator Voltage Control is a method used to control the speed of an Induction Motor. ---------(4M)  -----------------(5M)

- By varying the supplying voltage, the speed can be controlled.

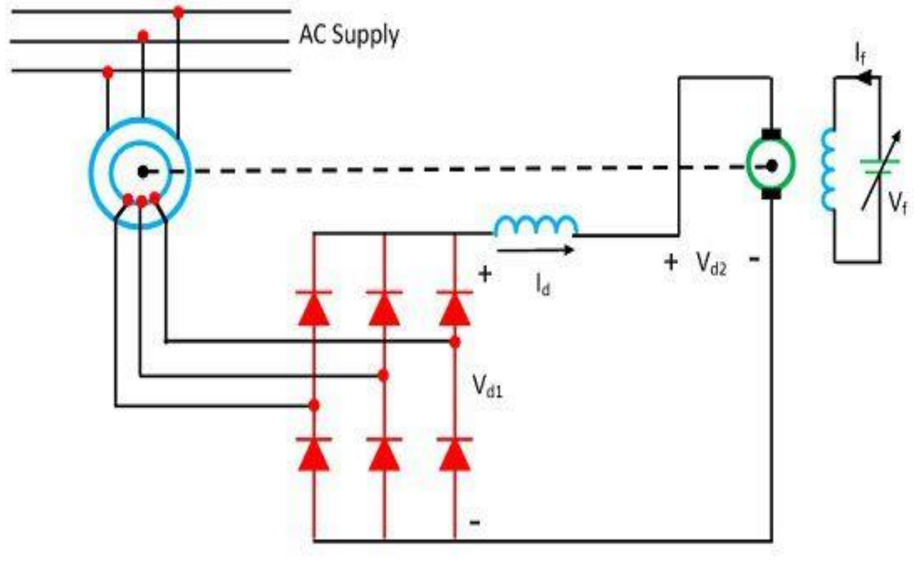
- By connecting an external resistance in the stator circuit of the motor.
- By using an Auto transformer.
- By using a Thyristor voltage controller
- By using a Triac Controller----------------------------(4M)

2

Explain in detail about static Kramer method and static Scherbius method of speed control of three phase induction motor.(13M) BTL3

Answer: Page:5.40- J.Gnanavadivel,J.Karthikeyan

- The static Kramer-drive is the method of controlling the speed of an induction motor by injecting the opposite-phase voltage in the rotor circuit.-------------------------(5M)



Static Kramer Drive Circuit

Circuit Globe

--------------(3M)

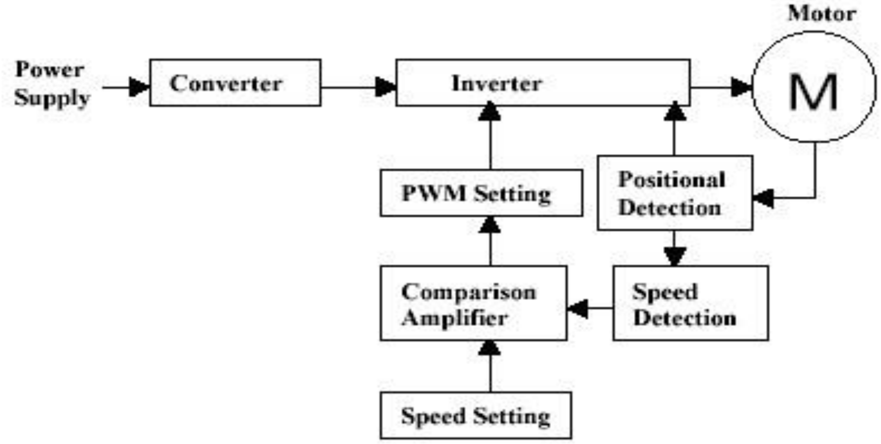
- The current carrying rotor being placed in a magnetic field, experiences a torque and hence begins to rotate.-- (5M)

3

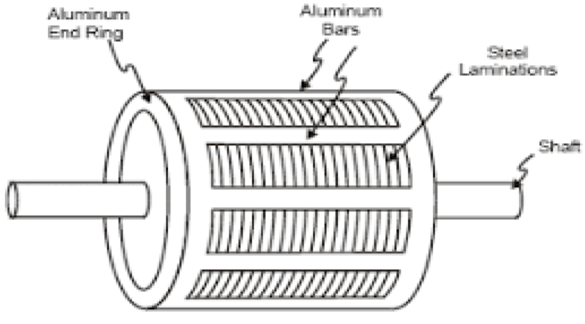
Describe about the operation of three phase induction motors. Hence derive the speed experienced for the cascaded set(13M)BTL3

Answer: Page:5.43- J.Gnanavadivel,J.Karthikeyan

- When the primary winding or stator is connected to a three phase alternating current supply, it establishes a rotating magnetic field which rotates at a synchronous speed.-----------------(3M)
- The direction of rotation of the motor depends on the phase sequence of supply lines, and the order in which these lines are connected to the stator.

	• The synchronous speed, a term given to the speed at which the field produced by primary currents will rotate, is determined by the following expression.------------(5M) • There are mainly two types of Induction Motor: Squirrel Cage Induction Motor andSlip Ring or Wound Rotor Induction Motor. Hence 3 phase synchronous motors are not self-starting. -------------------------(5M)
4	**Write in detail about the various methods of solid state speed control techniques by using inverters.(13M)** BTL6 **Answer: Page:5.17- J.Gnanavadivel,J.Karthikeyan** • AC motors are just not suitable for variable speed operation. Smaller still, standard low-voltage variable frequency drives can now control permanent magnet synchronous motors in addition to induction motors. (4M)  (3M) • A solid state motor speed control is described that is capable of controlling a motor so that it operates quietly, eliminating annoying buzzing noises that would otherwise be generated by the motor's windings. -----------------------------.(6M)
5	**Give the various in detail about Slip power recovery scheme.(NOV/DEC 2016**)**(13M)**BTL2 **Answer: Page:5.33- J.Gnanavadivel,J.Karthikeyan** • The slip power recovery (SPR) drive is an external **system** connected to the rotor circuit in place of the external resistors. ---------------------(4M) • The output of three phase Induction motor is connected to the DC motor by coupling them the mechanical power input--------------------------------- (3M) The phenomenon of this system is same as conventional type but the only difference is this system provides with diode bridge rectifier along with thyristor bridge inverter. This is also known as Sub-synchronous cascade drive.---(6M)
6	**Discuss the method of DC link static scheribus drive(13M)**BTL2

	Answer: Page:5.43- J.Gnanavadivel,J.Karthikeyan • The controlled rectifier works as an inverter and converts the DC power back into AC and feeds it back to the AC source-------------------------------(6M) • The power is fed into the rotor through the slip ring.(4M) • The mechanical power is injected by the shaft and the output power is obtained from the stator and rotor circuit.---------------------------------(3M)
7	**Explain about the operation of CSI fed DC drives(13M)**BTL2 **Answer: Page:5.30- J.Gnanavadivel,J.Karthikeyan** • When the supply is AC, a controlled rectifier is connected between the supply and inverter. When the supply is, DC a chopper is interposed between the supply and inverter.------------------(3M) • The commutation capacitance C_1-C_6 reduces the voltage spikes by reducing the rate of rising and fall of the current. -------------------------------(4M) • A large value of capacitance is required to sufficiently reduce the voltage spikes.-----------(6M)
8	**Mention the necessity speed control schemes of phase induction motors.(13M)** BTL3 **Answer: Page:5.17- J.Gnanavadivel,J.Karthikeyan** • A three phase induction motor is basically a constant speed motor so it's somewhat difficult to control its speed----------------------------- (6M) • It is the part of the motor which will be in a rotation to give mechanical output for a given amount of electrical energy.-------------------------(3M)
9	**Explain the speed control of a three phase induction motor using three phase bridge rectifier.(NOV/DEC 2014) (13M)**BTL4 **Answer: Page:5.27- J.Gnanavadivel,J.Karthikeyan** • There are mainly two types of Induction Motor: Squirrel Cage Induction Motor and Slip Ring or Wound Rotor Induction Motor. This classification is based on the constructional difference between them------------------------------ (4M) • The field windings in the stator of an induction motor set up a rotating magnetic field through the rotor. The relative motion between this field and the rotation of the rotor induces electric current in the conductive bars.

	 *Figure 3-23. Squirrel cage induction motor rotor* --(6M) • A Double Cage Induction motor is that type of motor in which a double cage or two rotor windings or cages are used. -- (3M)
	PART* C
1.	**State the relationship speed control of AC motors by using three phase AC Voltage regulators.(15M)**BTL2. **Answer: Page:5.23- J.Gnanavadivel,J.Karthikeyan** • An alternating current (AC) in one winding creates a time-varying magnetic flux in the core, which induces a voltage in the other windings. -----------------------------------(8M) • A voltage regulator is used to regulate voltage level. When a steady, reliable voltage is needed, then voltage regulator is the preferred device.---------------------------------------(7M)
2	**Explain the power circuit arrangement of three phase variable frequency inverter for the speed control of three phase induction motor and explain its working(15M)** BTL6 **Answer: Page:5.19- J.Gnanavadivel,J.Karthikeyan** • Various automation processes in the industry need control of AC induction motors using AC drives..-----------------------------------(5M) • A simple control panel is wired using an Allen Bradley PLC for demonstration.-------------- (5M) • These allow current to flow in only one direction; the direction shown by the arrow in the diode symbol. ---(5M)