JEPPIAAR

INSTITUTE OF TECHNOLOGY

"Self-Belief | Self Discipline | Self Respect"

QUESTION BANK

Regulation: 2017

Year: I

Semester: 02

Batch: 2019 - 2023

DEPARTMENT OF ELECTRONICS AND COMMUNICATION ENGINEERING

Vision of the Institution

Jeppiaar Institute of Technology aspires to provide technical education in futuristic technologies with the perspective of innovative, industrial and social application for the betterment of humanity.

Mission of the Institution

• To produce competent and disciplined high-quality professionals with the practical skills necessary to excel

as Innovative professionals and entrepreneurs for the benefit of the society.

• To improve the quality of education through excellence in teaching and learning, research, leadership and by Promoting the principles of scientific analysis, and creative thinking.

• To provide excellent infrastructure, serene and stimulating environment that is most conducive to learning.

• To strive for productive partnership between the Industry and the Institute for research and development in the Emerging fields and creating opportunities for employability.

To serve the global community by instilling ethics, values and life skills among the students needed to enrich their lives.

Department Vision

To enhance and impart futuristic and innovative technological education for the excellence of Electronics and Communication Engineering with new ideas and innovation to meet industrial expectation and social needs with ethical and global awareness reinforced by an efficiency through research platform for the advancement of humanity.

Department Mission

M1: To produce competent and high quality professional Engineers in the field of Electronics and Communication Engineering for the benefit of the society globally.

M2: To provide a conducive infrastructure and environment for faculty and students with enhanced laboratories, to create high quality professionals.

M3: To provide Prerequisite Skills in multidisciplinary areas for the needs of Industries, higher education and research establishments and entrepreneurship.

M4: To handle Socio Economic Challenges of Society by Imparting Human Values and Ethical Responsibilities.

PROGRAMME EDUCATIONAL OBJECTIVES

PEO1: To enable graduates to pursue research, or have a successful career in academia or Industries associated with Electronics and Communication Engineering, or as Entrepreneurs.

PEO2: To provide students with strong foundational concepts and also advanced techniques and tools in order to enable them to build solutions or systems of varying complexity.

PEO3: To prepare students to critically analyze existing literature in an area of specialization and ethically develop innovative and research oriented methodologies to solve the Problems identified.

PROGRAM SPECIFIC OBJECTIVES (PSOs)

1. To analyze, design and develop solutions by applying foundational concepts of electronics and communication engineering.

2. To apply design principles and best practices for developing quality products for scientific and Business applications.

3. To adapt to emerging information and communication technologies (ICT) to innovate ideas and solutions to existing/novel problems.

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

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TECHNICAL ENGLISH

Objectives:

The Course prepares second semester engineering and Technology students to:

- Develop strategies and skills to enhance their ability to read and comprehend engineering and technology texts.
- Foster their ability to write convincing job applications and effective reports.
- Develop their speaking skills to make technical presentations, participate in group discussions.
- Strengthen their listening skill which will help them comprehend lectures and talks in their areas of specialization.

UNIT I INTRODUCTION TECHNICAL ENGLISH 12

Listening- Listening to talks mostly of a scientific/technical nature and completing information-gap exercises- **Speaking** –Asking for and giving directions- **Reading** – reading short technical texts from journals- newspapers- **Writing-** purpose statements – extended definitions – issue- writing instructions – checklists-recommendations-**Vocabulary Development**- technical vocabulary **Language Development** –subject verb agreement - compound words.

UNIT II READING AND STUDY SKILLS 12

Listening- Listening to longer technical talks and completing exercises based on them-**Speaking** – describing a process-**Reading** – reading longer technical texts- identifying the various transitions in a text- paragraphing- **Writing-** interpreting charts, graphs- **Vocabulary Development-**vocabulary used in formal letters/emails and reports **Language Development-** impersonal passive voice, numerical adjectives.

UNIT III TECHNICAL WRITING AND GRAMMAR 12

Listening- Listening to classroom lectures/ talks on engineering/technology -**Speaking** – introduction to technical presentations- **Reading** – longer texts both general and technical, practice in speed reading; **Writing**-Describing a process, use of sequence words- **Vocabulary Development-** sequence words- Misspelled words. **Language Development-** embedded sentences

UNIT IV REPORT WRITING 12

Listening- Listening to documentaries and making notes. **Speaking** – mechanics of presentations- **Reading** – reading for detailed comprehension- **Writing-** email etiquette- job application – cover letter –Résumé preparation(via email and hard copy)- analytical essays and issu based essays-**Vocabulary Development**- finding suitable synonyms-paraphrasing-. **Language Development-** clauses- if conditionals.

UNIT V GROUP DISCUSSION AND JOB APPLICATIONS 12

Listening- TED/Ink talks; **Speaking** –participating in a group discussion -**Reading**– reading and understanding technical articles **Writing**– Writing reports- minutes of a meeting- accident and survey **Vocabulary Development- verbal analogies** Language **Development-** reported speech

TOTAL: 60 PERIODS

OUTCOMES:

At the end of the course learners will be able to:

- Read technical texts and write area- specific texts effortlessly.
- Listen and comprehend lectures and talks in their area of specialisation successfully.
- Speak appropriately and effectively in varied formal and informal contexts.
- Write reports and winning job applications.

TEXT BOOKS:

1. Board of editors. **Fluency in English A Course book for Engineering and Technology.** Orient Black swan, Hyderabad: 2016
2. Sudharshana.N.P and Saveetha. C. **English for Technical Communication**. Cambridge University Press: New Delhi, 2016.

REFERENCES

1. Raman, Meenakshi and Sharma, Sangeetha- **Technical Communication Principles and Practice.**Oxford University Press: New Delhi,2014.
2. Kumar, Suresh. E. **Engineering English**. Orient Blackswan: Hyderabad,2015
3. Booth-L. Diana**, Project Work,** Oxford University Press**,** Oxford: 2014.
4. Grussendorf, Marion, **English for Presentations,** Oxford University Press, Oxford: 2007
5. Means, L. Thomas and Elaine Langlois, **English & Communication For Colleges.** Cengage Learning, USA: 2007

Students can be asked to read Tagore, Chetan Bhagat and for supplementary reading.

	UNIT 1: Sharing Information Related To Oneself/Family& Friends
	Listening- Listening to talks mostly of a scientific/technical nature and completing information-gap exercises- **Speaking** –Asking for and giving directions- **Reading** – reading short technical texts from journals- newspapers- **Writing**- purpose statements – extended definitions – issue- writing instructions – checklists-recommendations-**Vocabulary Development**- technical vocabulary **Language Development** –subject verb agreement - compound words.
	PART*A
1.	**Technical Vocabulary 2M BTL1** a. contaminated — i. make easy b. facilitate — ii. unclean c. renowned — iii. Calculate d. estimate — iv. Famous (a.- ii, b- i, c- iv, d- iii) a. narrate — i. requirement b. necessity — ii. cover c. muffle — iii. envious d. jealous — iv. Tell (a-iv ,b- i, c- ii, d- iii.) a. identical — i. joyous b. illegible — ii. complex c. intricate — iii. unreadable d. jubilant — iv. Alike (a-iv ,b- iii, c- ii, d- i) a. gather — i. swoon b. guilty — ii. Accumulate c. faint — iii. flaw d. defect — iv. Ashamed (a-ii ,b- iv, c- i, d- iii.) a. wage — i. definitely b. undoubtedly — ii. pay c. tolerate — iii. Amusement d. recreation — iv. Endure (a-ii ,b- i, c- iv, d- iii.) **Match the words in Column A with their antonyms in Column B** A — B a. whole — i. common b. various — ii.harmful c. useful — iii. part d. rare — iv. Identical (a-iii, b- i, c- ii, d- iv.) a. assist — i. detest b. assent — ii. Proud

c. ashamed iii. hinder
d. admire iv. Dissent (a-iii ,b- iv, c- ii, d- i.)

a. cautious i. welcome
b. banish ii. Forgetful
c. barren iii. polite
d. impudent iv. Fertile (a-iv ,b- i, c- ii, d- iii.)

a. moderation i. conceal
b. rapid ii. Disapprove
c. reveal iii. slow
d. recommend iv. Greed (a-iv ,b- iii, c- i, d- ii.)

3. **Subject-Verb Agreement 2M BTL1**

Fill in the blanks with the correct verb that agrees with the subject. [BTL3]

1. Some of the amazing pictures taken by the contestants ____________ (is/**are)** displayed in the hall.
2. He is one of the successful business men who ______________ (**is**/are) sincere and hard working.
3. The committee ____________ (**have**/has) carefully studied the proposal for providing loan for the needy.
4. The official United Nations website for Peacekeeping_____________
    a. (Contain/**contains)** information on operations around the world.
5. Twenty five kilometers ____________ (**is**/are) a long distance to run every day.
6. The number of unemployed citizens _______________ (**are**/is) more in developing counties.
7. There ____________ (are/**is**) several reasons for implementing the new policy
8. The boy who won the two medals___________________ (are/**is**) a friend of mine
9. The person who is responsible for planning and implementing aims and objectives of the company __________________ (**is**/are) the manager.
10. According to a recent survey, the number of people who opt for purchasing Online.

II. **Choose the correct form of the verb that agrees with the subject.**

(is, are, am, was, were, has, have)

1. The price of the jeans **is** reasonable.

	2. The books borrowed from the library **are** on my desk. 3. Bread and butter **is** our daily food. 4. The quality of the candies **was/is** poor. 5. There **were** ten books in the box. 6. Many a student **were** made the same mistakes. 7. One of the books **has** been missing. 8. Fifty miles is a long distance. 9. The poor **are** suffering. 10. One of the most intelligent students **is** John. 11. She and her friends **are** at the fair. 12. The book or the pen **is** in the drawer. 13. The boy or his friends **run** (run) everyday. 14. His friends or the boy **runs** (run) everyday. 15. The committee **decides** (decide) how to proceed.
4	**IV Compound Words 2M BTL1** **Expand the following Compound Noun** 1. Animal behavior - The behavior of an animal 2. Aluminum extraction - The extraction of aluminum 3. Battery valve - Valve of a battery 4. Boat house - Boat used as a house 5. Butterfly valve - Valve which is in the shape of a butterfly

	6. Calculator memory	- Memory of a calculator
	7. Carbon dioxide	- Dioxide of carbon
	8. Coal gas	- Gas obtained from coal
	9. Computer language	- Language used for computer operation
	10. Computer manual	- Manual for operating the computer
	11. Computer technology	- Technology used in computers
	12. Data input	- Input of data
	13. Disk drive	- Drive of a disk
	14. Flood damage	- Damage caused by flood
	15. Gear mechanism	- Mechanism for operating the gear
	Compound Nouns:	
	1. Inflation rate	Rate of inflation
	2. Information centre	Centre for giving information
	3. Box top	Top of the box
	4. Carbon steel rod	Rod made of carbon steel
	5. Component location	Location of the component
	6. Computer fuel testing	Testing the fuel using the computer
	7. Cylinder walls	Walls of the cylinder
	8. Drinking water	Water for drinking purpose
	9. Engine repair	Repair works related to engine
	10. Engine housing	Housing to protect the engine
	11. Ferrous oxide	Oxide of ferrous
	12. Gear pump	Pump operates by means of gears
	13. Language code	Code which specifies the language
	14. Pare industry	Industry manufacturing paper
	15. Passenger ship	Ship for the purpose of carrying passengers

	16. Radar scan — Scan performed by radar 17. Turret lathe — Lathe having a turret 18. Toy factory — Factory for making toys
5	**Purpose Statement: 2M BTL2** 1. A barometer **is used to** measure atmospheric pressure. 2. Another way of expressing purpose is shown in the following sentences. 3. **The purpose of** painting iron parts **is to protect** them from rust. 4. **The purpose of** a thermostat **is to maintain** temperature at a constant level 5. **The aim of the** test **is to predict** the rise in pressure. ***Use the hint below to make sentences expressing purpose (Use any of the patterns illustrated above)*** 1. **An aerial: receives broadcast signals**. An aerial is used to receive broadcast Signals **2. A feasibility report: makes recommendations on the practicality of a project** A feasibility reports is used to make recommendation on the practicality of a project 3. **Sending telegrams: ensures that the message reaches the address quickly**. Sending telegrams are used to ensure that the messages reached the address quikly. **4. An experiment: demonstrates a principle** An experiment is used to demonstrate a principle **5. Constructing a bypass road: reduces traffic congestion in a city.** Constructing a bye-pass road is used to reduce traffic congestion in a city. **6. A sheet of carbon paper: makes copies while one types.** A sheet of carbon paper is used for making copies while one types **7. A litmus test: identifies acids an alkalies.** A litmus test is used for identifying alkalies. **8. A flow chart: represents a process as a series of steps.** A flowchart is used for representing a process as a series of step. **9. A calculator: calculates with numbers** A calculator is used for calculating numbers **10. A life Boat: rescues people who are in danger at Sea** ALife boat is used for rescuing people who are in danger at Sea **11. A Compass: Finds direction** A compass is used for finding direction

12. **Robot: do Heavy and dangerous jobs**.
    Robot is used for doing heavy and dangerous jobs.
13. **A Satellite: Collects information for communication**
    A satellite is used for collecting information for communication.
14. **A glass bottle : stores acid.**
    A Glass bottles is used for storing acids.
15. **A moderator: slows down the speed of free neutrons**
    A moderator is used to slow down the speed of free neutron.

Extended Definition: 2M BTL2

Example : 1

(Sentence definition) We can define an **SUV** as a vehicle which is usually driven on rough terrain. ***(Illustration)***SUV is an acronym which stands for **s**ports **u**tility **v**ehicle. ***(Description)***The engines of the SUV vehicles supply power to all four wheels, so they are better for cruising sand dunes. ***(Classification)*** SUV vehicles vary in size; some of them can seat 5 passengers, while others can seat 7 passengers. ***(causal analysis)*** SUV vehicles are quite common in Saudi Arabia due to the low cost of petrol and their fantastic performance in the desert.

Example : 2

(Sentence definition)**The periodic table** can be defined as an organized array of all the chemical elements in order of the atomic weight. ***(Illustration)***The elements show a periodic recurrence of certain properties. ***(Chronology)***It was first discovered in 1869 by Dmitry I. Mendeleyev. ***(Description)***Those in the same column or group of the table as usually arranged have similar properties. ***(Chronology)***In the 20th century, when the structure of atoms was understood, the table was seen to precisely reflect increasing order of atomic number. ***(Description)*** Members of the same group in the table have the same number of electrons in the outermost shells of their atoms and form bonds of the same type.

Example : 3

(Sentence definition) Glass is a hard transparent material which is used to make windows, bottles and other objects. ***(Etymology)*** glass is an English word and was first used before the twelfth century. ***(Chronology)***Glass has been used as a decorative object indoors since ancient times. Today, glass is widely used in the construction and telecommunication sectors. ***(Description)*** It is made by cooling molten ingredients such as silica sand with sufficient rapidity to prevent the formation of visible crystals.

Example :4

Appropriate technology is that technology which is affordable within the resources available, is culturally acceptable and is environmentally harmless.

	PART *B
1.	**INSTRUCTION 16M BTL3** **1. To control noise pollution: (May/Jun 2011)** 1. Prohibit noise producing vehicles 2. Avoid using high sounding crackers 3. Don't use loud speakers near schools and hospitals. 4. Use a silencer to absorb noise of the vehicle 5. Establish industrial units away from residential areas 6. Plant trees to absorb noise. 7. Live away from the airport 8. Avoid using high sounding pressure horns 9. Be aware of noise pollution **2. *To reduce unemployment problem:*** 1. Ensure employment to at least one person in a family 2. Increase the number of technical training institutes 3. Give loans to encourage self-employment 4. Give subsidies to encourage the entrepreneurs 5. Employ unemployed graduates for additional government duties like election duties 6. Encourage private sectors to generate employment. 7. Establish more industries in rural areas 8. Train the graduates to start small scale industries **3. *To keep the college campus clean:*** 1. Keep the environment always clean 2. Plant trees in the college campus 3. Conduct awareness classes to make the students to realise the importance of cleanliness. 4. Place more number of dust bins in the campus 5. Impose punishment on these who violate the rules 6. Maintain the vehicles properly 7. Avoid cutting of trees in the name of development 8. Always maintain strict discipline ***4. To maintain a computer / a laptop in good working condition (Jan 2006; May/Jun 2007; Jan 2010)*** 1. Don't touch the cables 2. Avoid touching the open sockets 3. Avoid touching the monitor 4. Always shut down the system when it is not in use. 5. Shut down the system properly. 6. Don't misplace and replace the equipment. 7. Don't handle the equipment roughly. 8. Don't keep your legs on the UPS.

5. *Safety instructions in a chemical engineering lab (Jan 2010)*

1. Don't work in the laboratory barefoot.
2. Don't handle the instruments roughly.
3. Don't wear gold ornaments.
4. Keep all the doors and windows open.
5. Keep your working place neat and tidy.
6. Don't wear loose clothes.
7. Wear apron and gloves while handling the chemicals.
8. Handle all glassware items carefully.
9. Don't drink or eat in lab.
10. Don't taste or sniff chemicals.
11. Identify the safety equipment.
12. Read the chemical safety instructions.

6. *Instructions must be followed by all pedestrians (Road safety)*

1. Walk on the pavement always.
2. Use subways; though it is long.
3. Avoid crossing suddenly.
4. Don't walk on road dividers.
5. Don't ignore traffic signals.
6. Cross the road only at zebra crossing.
7. Make sure that the road is clear, before crossing the road.
8. Avoid using the cell phone while walking along the road.
9. Be familiar with the traffic rules.

7. *Instructions to save petrol (May / Jun 2012)*

1. Keep the engine in good condition
2. Fit the vehicle with an engine that gives high mileage.
3. Don't keep the engine running while the vehicle is not in motion.
4. Inflate the tyres at an optimum level of air pressure.
5. Use the correct engine oil for the proper functioning.
6. Service the vehicle regularly.
7. Avoid clutch driving.
8. Avoid frequent change of gear to save petrol.

8. *Instructions to maintain two/four wheelers in good working condition (May/Jun 2005/2006)*

1. Always maintain the air pressure in the tyre to the recommended levels.
2. Drive only at optimum level of speed depending on the roads.
3. Clean the air-filter regularly since clogged air filters increase fuel consumption.
4. Do not idle the engine not more than 30 seconds to warm it up when starting.
5. Avoid sudden breaks and frequent gear changing.
6. Handle the gear, brake and clutch softly.
7. Service the vehicles regularly for better performance as well as fuel saving

8. Always maintain the lubricants at the required level to ensure running of the engine.
9. Avoid pressure horns.
10. Avoid faulty silencers.

9. *Write eight instructions to preserve environment. (May 2004/2005)*

1. Reduce the usage of plastic
2. Use the eco-friendly papers made out of alternative sources.
3. Use rechargeable batteries for frequent usages to reduce the number of dead batteries
4. Use natural fertilizers and pesticides for agriculture.
5. Don’t cut trees.
6. Plant native and adaptive trees.
7. Turn light off at office as well as at home whenever it is not needed.
8. Treat sewage and industrial effluents before discharging into the water bodies.
9. Conduct awareness programmes for preserving the environment.
10. Encourage rain water harvesting.

10. *Instructions for giving first aid to a victim of a road accident*

1. Check the victim thoroughly whether the victim is breathing or not
2. Take the victim to the side of the road.
3. Try to stop the bleeding by applying pressure on the bleeding side.
4. Give artificial respiration if the victim is struggling for breathe.
5. Don’t crowd round the victim and prevent airflow.
6. Handle the victim carefully.
7. Examine the head, eyes, nose, ears, chest, and abdomen to detect wounds.
8. Ask the victim to move the toes, and fingers to check their movements or function.
9. Take the victim to the hospital

9 **II Checklists 16M BTL2**

1.Checklist for an Interview

	Yes	No
1. Have I taken the ticket?	☐	☐
2. Have I taken the certificates?	☐	☐
3. Have I taken the call letter?	☐	☐
4. Have I taken money?	☐	☐
5. Have I arranged the certificates properly?	☐	☐
6. Have I taken my project report?	☐	☐
7. Have I taken my friends’ contact number?	☐	☐
8. Have I packed the formal wear?	☐	☐

2. Checklist for an Industrial Visit

Yes No

1. Have I taken the ticket? ☐ ☐
2. Have I taken money? ☐ ☐
3. Have I taken the conformation letter? ☐ ☐
4. Have I taken all the documents? ☐ ☐
5. Have I taken my Identity Card? ☐ ☐
6. Have I taken my cell phone and charger? ☐ ☐
7. Have I packed the formal wear? ☐ ☐
8. Have I taken my friends' contact number ☐ ☐

3. Checklist for conducting a two day conference Yes No

1. Have I sent the invitations? ☐ ☐
2. Have I invited the chief guest? ☐ ☐
3. Have I invited the Principal and staffs? ☐ ☐
4. Have I prepared the welcome address? ☐ ☐
5. Have I prepared the agenda? ☐ ☐
6. Have I arranged the conference hall? ☐ ☐
7. Have I arranged enough refreshments? ☐ ☐
8. Have I made the stage ready? ☐ ☐

4. Checklist for organizing a Paper Presentation session Yes No

1. Have I arranged the venue? ☐ ☐
2. Have I finalized the papers? ☐ ☐
3. Have I fixed the judges? ☐ ☐
4. Have I arranged for refreshment and lunch for delegates? ☐ ☐
5. Have I purchased the kits? ☐ ☐
6. Have I prepared the certificates? ☐ ☐
7. Have I prepared the agenda? ☐ ☐
8. Have I prepared the welcome address? ☐ ☐
9. Have I informed the participants? ☐ ☐

5. Checklist for one day Training Programme in Delhi Yes No

1. Have I reserved the tickets? ☐ ☐

	2. Have I taken the money? ☐ ☐ 3. Have I taken the dresses? ☐ ☐ 4. Have I taken the Laptop? ☐ ☐ 5. Have I taken the documents? ☐ ☐ 6. Have I taken the notes for training? ☐ ☐ 7. Have I taken the confirmation letter? ☐ ☐ 8. Have I taken the venue address? ☐ ☐
	Recommendations 16M BTL3 I. Recommendations to preserve our water resources:- 1. It is recommended to observe rain water harvesting by all. 2. It is important to control sand smuggling. 3. It is necessary to construct rain water storage tanks. 4. It is recommended to encourage the people for afforestation. 5. It is essential to conduct awareness programmes. 6. It is advised to plant native and adaptive plants. 7. It is recommended to water gardens and fields early in the morning to avoid evaporation. 8. It is highly recommended to recycle the water. **II. <u>RECOMMENDATIONS</u>** 1. Write a set of eight recommendations to preserve our water resources. Ans: Title : Recommendations to preserve our water resources:- 9. It is recommended to observe rain water harvesting by all. 10. It is important to control sand smuggling. 11. It is necessary to construct rain water storage tanks. 12. It is recommended to encourage the people for a forestation. 13. It is essential to conduct awareness programmes. 14. It is advised to plant native and adaptive plants. 15. It is recommended to water gardens and fields early in the morning to avoid evaporation. 16. It is highly recommended to recycle the water. 2. Power cut is a major problem in southern parts of India and it badly affects small scale industries. Write a set of eight recommendations to ensure continuous power supply to the small scale industries. **(AUC DEC-JAN 2016)** **Ans:** Title : Recommendation to ensure continuous power supply to small scale industries 1. It is recommended that UPS may be installed.

2. It is recommended to create general awareness among public and educate them to save energy resources.
3. It is recommended to introduce feasible solar systems as an alternative source of energy.
4. It is recommended to take adequate measures to implement plants to generate power through pedal power.
5. It is recommended to learn to conserve electricity.
6. It is recommended to use net metering technology which is eco-friendly and economical.
7. It is recommended to tap more alternative sources.
8. It is recommended to generate bio mass power.

3.Write a set of eight recommendations to reduce unemployment problem.

Ans: Title : Eight recommendations to reduce unemployment problem.

1. It is recommended that the government can increase the number of technical training institutes.
2. It is recommended to give loans to encourage self-employment.
3. It is recommended to introduce entrepreneurship courses in the school and college curriculum.
4. It is recommended to give subsidies to encourage the entrepreneurs.
5. It is recommended to start more industries in rural and suburban areas.
6. It is recommended to encourage private sectors to generate employment.
7. It is recommended that the government can ensure employment to at least one person in a family.
8. It is recommended to employ the unemployed graduates for additional government duties like elections duties etc.

4.There are many social problems such as poverty and hunger in India, which need to be solved. Write a set of eight recommendations to solve these problems.
Ans : Title : Eight recommendations to solve social problems such as poverty and hunger in India

1. It is recommended that the government can measures to increase exports.
2. It is recommended to concentrate on the development of the small scale industries.
3. It is recommended to provide loans for small business in rural areas.
4. It is recommended to create livelihood opportunities for the poor and the needy by the state government.
5. It is recommended that the charitable institutions can support the government to eradicate hunger and poverty.
6. It is recommended that the multinational companies can be encouraged to start business for the increase of job opportunities and income.

7. It is recommended that the children suffering from malnutrition can be adopted by social organizations.
8. It is recommended to take necessary steps to monitor whether the deserving people are benefitted of the services provided for them.

5.Write a set of eight Recommendations to make environment clean and less polluted.

Ans : Title : Eight recommendations to make environment clean and less polluted.

1. It is recommended to use renewable resources which can be replenished.
2. It is recommended to start replenish forests for producing raw materials and increasing the area under forest.
3. It is recommended to ban killing or poaching of animals.
4. It is recommended to preserve natural habitat for animals.
5. It is recommended to monitor and survey the maintenance of greenery around by the concerned officials.
6. It is recommended to encourage growing of more trees.
7. It is recommended to stop using plastics and burning of it.
8. It is recommended to use eco-friendly appliances and gadgets.

6.Write a set of eight recommendations for selecting a proper fuel.

Ans : Title : Eight recommendations for selecting a proper fuel.

1. It is recommended to select such a fuel which can burn easily.
2. It is recommended to select the fuel which produces sufficient energy.
3. It is recommended to select the fuel which is available in plenty.
4. It is recommended to select the fuel for which the storage is easy and safe.
5. It is recommended to select such a fuel which does not pollute the air on burning.
6. It is recommended to select a fuel which does not leave behind much residue.
7. It is recommended to select a fuel for which the transportation is easy and safe.
8. It is recommended to select an inexpensive fuel.

	UNIT II READING AND STUDY SKILLS 12
	Listening- Listening to longer technical talks and completing exercises based on them-**Speaking** – describing a process-**Reading** – reading longer technical texts- identifying the various transitions in a text- paragraphing-**Writing**- interpreting charts, graphs- **Vocabulary Development-**vocabulary used in formal letters/emails and reports **Language Development-** impersonal passive voice, numerical adjectives.
	PART*A

Impersonal Passive 2M BTL1

1. **The company had manufactured high powered engines.**

   High powered Engines had been manufactured

2. **One can easily solve this problem.**

   This problem can be solved

3. **Users have maintained this pump themselves.**

   This pump has been maintained

4. **The men are laying roads in many parts of the city.**

   Roads have been laid in many parts of the city.

5. **The Cricket Board men offer to give 1400 transmitters.**

   1400 transmitters have been offered.

6. **They will start production on the new type of reactor soon**.

   New type of reactors production with soon be started.

7. **We pass an electric current across the electrodes**

   An electric current will be passed across the electrode.

8. **The workers are repairing the bridge.**

   The bridge is being repaired .

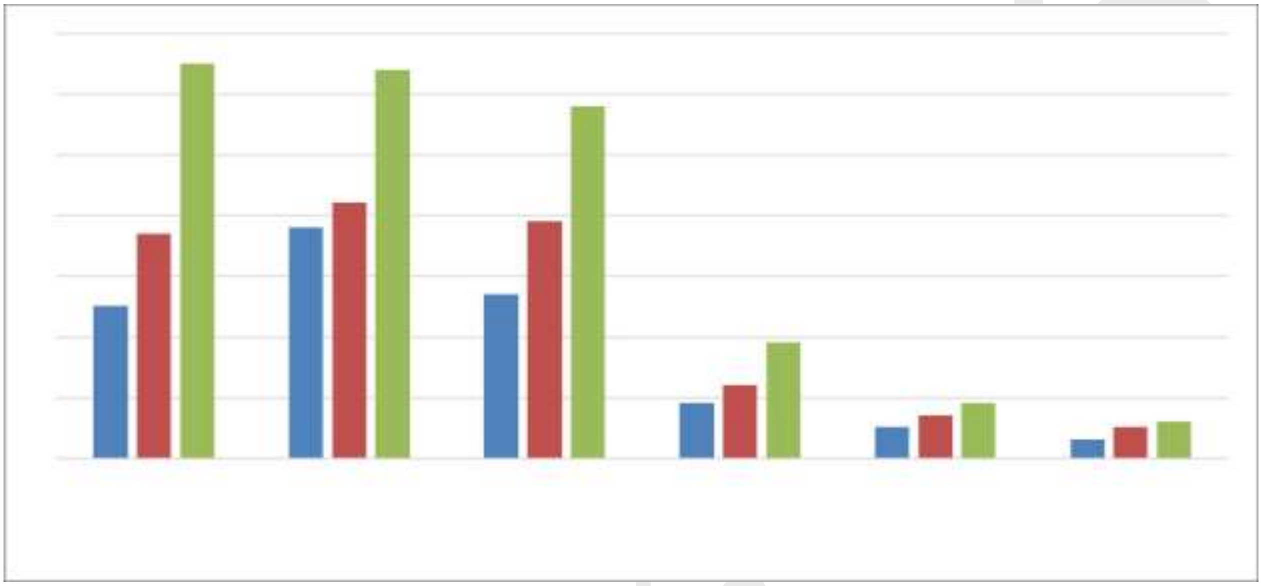
9. **We can cast this metal into very complicated shapes**.

   This metal can been casted into very complicated shapes

	Write the sentence into Passive form 2M BTL1 1. I can answer the question- The question can be answered by me. 2. She would carry the box. – The box would be carried by her. 3. You should open the window – The window should be opened by you. 4. We might play cards. - Cards might be played by us. 5. You ought to wash the car. – The car ought to be washed by you. 6. He must fill in the form. – The form must be filled in by him. 7. They need not buy bread. – Bread need not be bought by them. 8. He could not read the sentence. - The sentence could not be read by him. 9. Will the teacher test our English? - will our English be tested by the teacher? 10. Could jenny lock the door? – Could the door be locked by jenny?
	II Numerical Adjectives. 2M BTL1 **Rewrite the following as numerical expressions** 1. A flask with a capacity of 10 liters- A 10 liter flask 2. A journey of 20 miles- A 20 mile journey 3. A squad of 1000 men- A 1000 men squad 4. A civilization which in 2000 years old- 2000 year old civilization 5. A project of 10 years- A 10 year project. 6. A match lasting five days- A five day Lasting match. 7. At intervals of 10 minutes- A 10 minute interval 8. A DC supply of 240 volts- A 240 volt DC supply 9. A lamp of a power of 60 watts- A 60watts power Lamp. 10. An investment of Rs. 3, 50,000- A 3, 50,000 investment. 11. A book in six volume – a 6 volume book 12. An engine with 100 cc power – a 100 cc power engine 13. A walk of five kilometers – A 5 kilometer walk 14. A drive for 8 hours – A 8 hour drive 15. A committee of 6 members – A 6 member committee 16. A rope with a length of 5 meters – A 5 meter rope

	17. A can with a capacity of 25 liters – A 25 liter tank 18. A training programme for 25 days - A 25 day training programme 19. An auditorium of 1000 capacity – A 1000 capacity auditorium 20. A pen drive with 16 GB storage. – A 16 GB pen drive 21. A lab with 30 computers – A 30 computer lab 22. The pipe is 3 feet long – A 3 foot pipe 23. A colony with 200 houses – A 200 house colony 24. A road measuring 100 feet – A 100 foot road 25. A video running for 40 seconds – A 40 second video.
	Interpreting charts and graphs.16M BTL-4 **Look at the following information and graph about the pass percentage of the students in the plus two examination. Analyze the given data and write a short review of the pass percentage of the student in a paragraph of not more than 120 words:** About John Higher Secondary School This school was started in a village to cater to the needs of the poor people. In 2011, many experienced teachers left the school . After reviewing the low performance of the students in the plus-two examination, the infrastructure facilities were improved and teachers were given adequate training to teach their subjects effectively Besides, the management has started giving special incentives to the teachers who give cent percent results in the examination.

II. The following chart represents the arrival of tourists from different regions. Analyze the given data and write a paragraph:

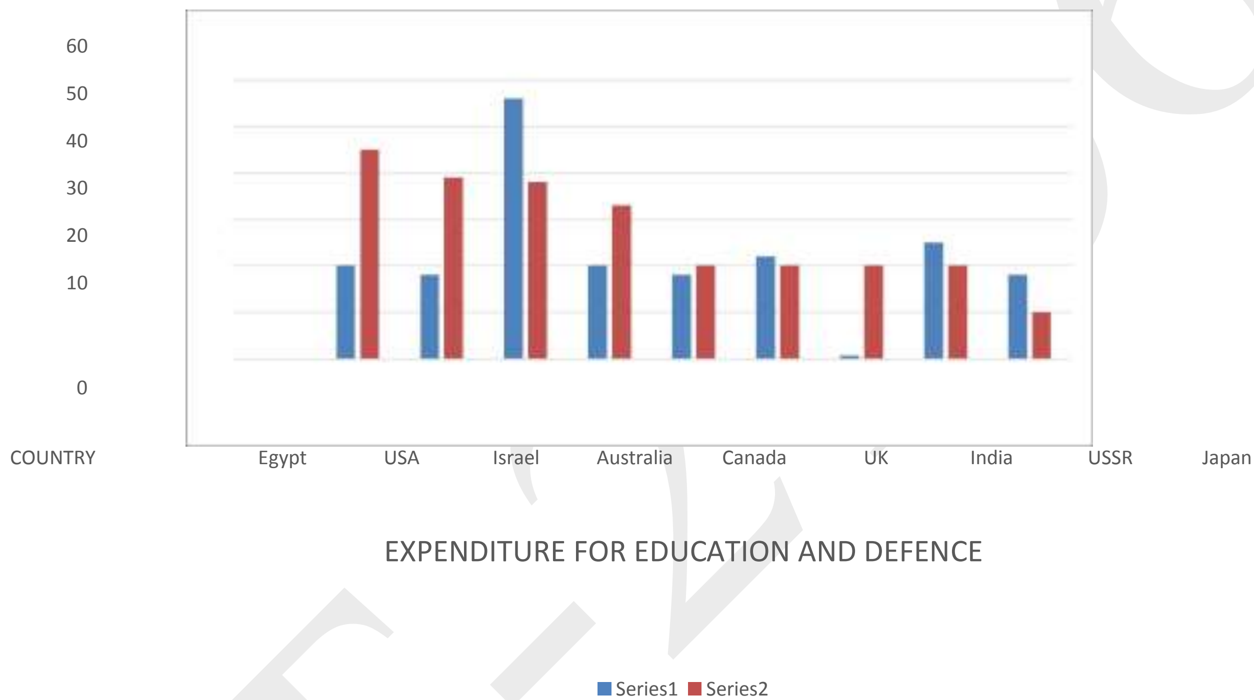


X- axis – Tourists arrival from region of origin

□		2012	2.5	3.8	2.7	0.9	0.5	0.3
□		2013	3.7	4.2	3.9	1.2	0.7	0.5
□		2014	6.5	6.4	5.8	1.9	0.9	0.6

Y-axis- Tourists who visited India in millions

Look at the following bar chart which describes the expenditure on education and defense of the total expenditure incurred by different countries. Write a paragraph presenting the information contain in it using expressions of comparison.


60
50
40
30
20
10
0
COUNTRY
Egypt
USA
Israel
Australia
Canada
UK
India
USSR
Japan
EXPENDITURE FOR EDUCATION AND DEFENCE
Series1
Series2

Unit-III

TECHNICAL WRITING AND GRAMMAR 12

Listening- Listening to classroom lectures/ talks on engineering/technology -**Speaking** – introduction to technical presentations- **Reading** – longer texts both general and technical, practice in speed reading; **Writing**-Describing process, use of sequence words- **Vocabulary Development-** sequence words- Misspelled words. **Language Development-** embedded sentences

PART*A

1. I**. Sequence Words** 2M BTL1

Fill in the blanks with appropriate sequence words.

1. Half an hour passed, but there was no sign of bus. -------------, we decided to go home.
2. The documents will be scrutinized by the bank officials. ------------ they will sanction th loan.
3. To reduce weight, ----------- create rigorous exercise.
4. When air conditioner is used reversed. ---------reverse mechanism, hot air is propelled towarc indoor and cool air towards outdoor.
5. How can you lay two audio tracks --------- in Windows Live Movie Maker?
6. ---------- you buy a new lay out you should decide on what you really need.
7. In the process of making chocolates, firstly the cocoa beans are finely ground. ----------, it mixed with cocoa butter and sugar and then smoothened.
8. Cheese is a concentrated source of many of the nutrients in milk. -----the usual cheese making process, the amount of various nutrients retained depends on the

(a)Then press the "Send" option.

(b) Next type your message and add "smileys" or images, if you want.

(c) To begin with, go to "messages"

(d) After that "Add" the contact number of the recipient.

(a) Then, the tea water is filtered and is served with sugar cubes.

(b) First, water is taken in a kettle and is allowed to boil.

(c) After that, the decoction is allowed to settle down.

(d) Next, tea leaves are added to the boiling water.

(a) First, the clothes and soap powder are put in the respective slots.

	(b) Water is drawn repeatedly as per requirement to wash and rinse. (c) When the start button is pressed the machine starts to draw water from the tap and the operation starts after the tank is full. (d) Finally clothes are dried. (a) The image is charged with electricity. (b) The document for taking photocopy is kept in the machine. (c) Then, an ink powder called toner sticks to the charged parts of the image and is transferred on to paper. (d) Secondly, a bright light reflects the image of the document on to a plate or drum. (a) After you enter your information, click "Sign Up" (b) On here you will need to enter your information. (c) Towards the right side of the screen you will see a "sign up" screen. (d) Go to www.facebook.com.
3.	**Misspelt word 2M BTL3**
	Correct the spelling of the misspelt words. 1. Occasion- occasion 2. Committee- Committee. 3. Tomorrow- tomorrow 4. Charactar- Character. 5. Greatful- Grateful 6. Neessary- Necessary 7. Sychology- Psychology 8. recieve -receive 9. leisue- Leisure. 10. Apetite- Appetite 11. Careulness-Carefulness 12. Exceled- Exceled 13. Prohiited- Prohibited 14. Groupped- grouped 15. Earnned – Earned. 16. Transmited- Transmitted. 17. Aloted – Allotted 18. Refering- Referring 19. Traping – Trapping

	20. Stimuleted- Stimulated
4.	**Embedded Sentences [BTL2]** **Complete the following sentences with appropriate Embedded Clauses** 1. The music, ________________________ gave me a headache. 2. The old lady, _______________________ waited for a taxi. 3. The bus, _________________________ sped down the street. 4. The loaf of bread, ___________________ was spoilt. 5. The singer, _________________________ was the chief guest on our College Day. 6. The child, __________________________ was crying in the super market 7. The airplane,____________________ finally landed at the airport 8. The elderly man, _________struggled to cross the road 9. The astronaut,______________ was received warmly at the airport. 10. The boy, ___________________________ is from our college
	PART *B
	I. Describing a process 16 BMTL-4 1. Describe the process involved in opening a bank account. 2. Describe the process of mending the puncture tube of your two-wheeler. 3. Describe the process involved in making a cup of tea. 4. Describe the process involved in sending an email attachment to your friend. 5. Describe the process involved in becoming successful orator. 6. Describe the process involved in m king a glass of lemon juice **Process:** Explanation in a paragraph or two- Presentation -4 Content – 8 Sentence format- 4
	Reading Comprehension (a) Read the following passage carefully and answer the questions below it: The latest buzz word in the continuing debate about the environment is “sustainable management”-that means using plants and animals for our benefit, but ensuring that enough is left alive to guarantee

	the survival of the species. This sounds good, but is it practical in reality? In spite of years of scientific research, no one really kno s how much damage human beings are doing to their environment. We know that, they are responsible for many problems ranging from global arming to ozone depletion, and there is no doubt that they have a devastating effect on animal and plant life on earth. About 50,000 animal and plant species are becoming extinct every year. All species depend on some way on one another for survival. If you remove one species from this complex web of inter relationships, e have little idea of the repercussions on the ecosystem in general. What makes things more complicated is the fact that unlike global warming - which, if the political will was there, could be reduced by cutting gas emissions -preserving bio diversity- remains a difficult dilemma. There are also questions about whether sustainable management is practical as far as protecting areas of great bio-diversi y such as the world's tropical forest are concerned. In theory, the principle should be to cut a number of trees, but not so many as to completely destroy the forest. Sustainable Management of trees requires controls on the numb r of trees which are cut down as well as investment replacing them. Most tropical forests exist in poor countries which depend on logging to make money. Foremost loggers in these countries, making money means cutting down as ma y trees as Possible in the shortest time. The price of trees remains stable, varyi g by 4-5% annually, whereas the interest rates in most developing countries can create 15% or more in returns. It therefore makes little sense, and certainly no economic sense, to Delay tree felling. One solution could be to insist that wood comes from sustainable managed forests. In theory, consumers would buy only this wood and force logging companies to go "green" or else out of business. Unfortunately, unrestricted logging is more profitable than wood from sustainable managed forests which would cost unto 5 times more to control. Consumers would not be prepared to pay the extra sum just to protect the environment. The sad fact is that there is no practical solution to protect vegetation and wildlife of tropical forests in the future. It is estimated that these forests contain anything form 50-90 percent of all animal and plant species of the earth. In one study of kilometer square area of rain forest in Peru, for example, scientists counted 1300 species of butterfly and 600 species of birds. In the entire USA only 400 species of butterfly and 700 species of birds have been recorded. Sustainable Management represents gigantic experiment. If this doesn't work, we cant move to another planet to escape. It is a case of one planet, one experiment! Complete the following statements choosing from one of the given alternatives

	(i) The extent of the damage being inflicted on our environment....... 1. can be estimated by years of scientific research. 2. is being calculated by scientific research exactly. 3. is impossible to assess despite years of scientific research. 4. is thanks to years of scientific research, on the decrease. (ii) The term "Sustainable Management" means using plants and animals for our own benefit, but....... 1. assuring none are left alive to guarantee the survival of the species. 2. making sure that enough are left alive to guarantee survival of the species.
	The newlyweds agreed to be very ***frugal*** in their shopping because they wanted to save enough money to buy a house. **1. economical** 2. wasteful 3. interested
	Although Alex usually looks ***unkempt,*** he had a very neat appearance at his job interview. 1. orderly 2. handsome **3. messy**
5.	Paragraph writing 16M BTL3

	1. Write two paragraphs comparing the newspaper and the television as media of mass communication. Each of the paragraphs should not exceed 200 words. 2. Write two paragraphs, one describing the benefits of technology the other describing the drawbacks of technology. Each paragraph should not exceed 200 words. 3. Imagine yourself to be in the year 2050 and you are in your early 70's. The fuel position is very bad. Describe how life was fifty years ago when fuel was easily available. Write this in about 170-200 words. 4. Describe in about 170-200 words the utility, function with advantages and disadvantages of a washing machine. 5. Imagine yourself to be living in the year 2050 and you are in your early 70's. The fuel position is very bad. Describe how life was fifty years ago when fuel was easily available. Write this for about 170- 200 words. 6. Write two paragraphs, one describing the advantages and disadvantages of Mass media. 7. Write a paragraph on Population explosion. 8. Write a paragraph on Information Technology in India. Content- 6 Sentence completion 2 Grammar/ spellings 4 Presentation 4 a. The importance of social media in today's world. b. Donate blood and save lives. c. Student's approach to library in the current scenario. d. Going away from nature is happening naturally- Discuss. e. Outdoor and Indoor Games.
6.	
	1. Objective/ Multiple type: 1 per question 2. True or False: 1m/ Question 3. Short note: 2m if any

UNIT IV	REPORT WRITING	12

Listening- Listening to documentaries and making notes. **Speaking** – mechanics of presentations- **Reading** – reading for detailed comprehension- **Writing**- email etiquette- job application – cover letter –Résumé preparation(via email and hard copy)- analytical essays and issue based essays-**Vocabulary Development**-finding suitable synonyms-paraphrasing-. **Language Development-** clauses- if conditionals.

Sr.No	PART* A
1	**Clauses- If conditional** 2M BTL2

1. If he communicates effectively, **he will get selected**.
2. If he had performed well, **he would have passed**
3. If I got up earlier, **I would catch the train**.
4. If the new material had come in time, **we would have transferred the goods**.
5. If you planned well, **you could finish the project**.
6. If I had a net connection, **I would send the email**.
7. If I were you, **I would enjoy the trip**.
8. If you went for a walk every day, **you would maintain your health well**.
9. If people follow traffic rules, **the city can avoid traffic congestion**.
10. If you practised hard, you **would pass** (pass) the exam easily.
11. If the traffic rules are followed, there ---------**will be**----------- (be) very less accidents.
12. If I drop this, it **_______will explode_________** (explode).
13. If I had seen you, I **__would have invited_** (invite) you.
14. If the child goes out in the rain, it ______ (catch) cold. **Ans : will catch**
15. If I were an astronaut, I ______ (visit) the space station. **Ans : would visit**
16. If the boys do not practice, they ______ (lose) in the finals. **Ans : will lose**
17. If there had been good rains, the corps ______ (grow) well. **Ans : would have grown**
18. If I get a new job, ______________________ **Ans : If I get a new job, I will take my family to a holy place for prayer.**
19. __________________ , she would have completed her journey.
Ans : If Rita has joined the crew, she would have completed her journey.

3	PART* B

Ten Quick Tips on Writing a Professional Email 16M BTL3

1. Always fill in the subject line with a topic that means something to your reader. Not "Decals" or "Important!" but "Deadline for New Parking Decals."
2. Put your main point in the opening sentence. Most readers won't stick around for a surprise ending.
3. Never begin a message with a vague "This." ("This needs to be done by 5:00.") Always specify what you're writing about.

4. Don't use ALL CAPITALS (no shouting!), or all lower-case letters either (unless you're e. e. cummings).
5. As a general rule, PLZ avoid textspeak (abbreviations and acronyms): *you* may be ROFLOL (rolling on the floor laughing out loud), but your reader may be left wondering WUWT (what's up with that).
6. Be brief *and* polite. If your message runs longer than two or three short paragraphs, consider (a) reducing the message, or (b) providing an attachment. But in any case, don't snap, growl, or bark.
7. Remember to say "please" and "thank you." And mean it. "Thank you for understanding why afternoon breaks have been eliminated" is prissy and petty. It's *not* polite.
8. Add a signature block with appropriate contact information (in most cases, your name, business address, and phone number, along with a legal disclaimer if required by your company). Do you *need* to clutter the signature block with a clever quotation and artwork? Probably not.
9. Edit and proofread before hitting "send." You may think you're too busy to sweat the small stuff, but unfortunately your reader may think you're a careless dolt.
10. Finally, reply promptly to serious messages. If you need more than 24 hours to collect information or make a decision, send a brief response explaining the delay.

1. **Start with a salutation**

Your email should open by addressing the person you're writing to. Sure, you can get away with leaving out the salutation when you're dashing off an email to your friend, but business-like messages should begin with:

- *Dear Mr Jones,* or *Dear Professor Smith,* (for someone you don't know well, especially if they're a superior)
- *Dear Joe,* or *Dear Mandy,* (if you have a working relationship with the person)

It's fine to use "Hi Joe", "Hello Joe" or just the name followed by a comma ("Joe,") if you know the person well – writing "Dear Joe" to one of your team-mates will look odd!

2. Write in short paragraphs

Get straight to the point – don't waste time waffling. Split your email into two to four short paragraphs, each one dealing with a single idea. Consider using bullet-points for extra clarity, perhaps if you are:

- Listing several questions for the recipient to answer
- Suggesting a number of alternative options
- Explaining the steps that you'll be carrying out

Put a double line break, rather than an indent (tab), between paragraphs.

3. Stick to one topic

If you need to write to someone about several different issues (for example, if you're giving your boss an update on Project X, asking him for a review meeting to discuss a payrise, and telling him that you've got a doctor's appointment on Friday), then don't put them all in the same email. It's hard for people to keep track of different email threads and conversations if topics are jumbled up.

4. Use capitals appropriately

Emails should follow the same rules of punctuation as other writing. Capitals are often misused. In particular, you should:

- Never write a whole sentence (or worse, a whole email) in capitals
- Always capitalise “I” and the first letter of proper nouns (names)
- Capitalise acronymns *(USA, BBC, RSPCA)*
- Always start sentences with a capital letter.

This makes your email easier to read: try retyping one of the emails you’ve received in ALL CAPS or all lower case, and see how much harder it is to follow!

5. Sign off the email

For short internal company emails, you can get away with just putting a double space after your last paragraph then typing your name. If you’re writing a more formal email, though, it’s essential to close it appropriately.

- Use *Yours sincerely,* (when you know the name of your addressee) and *Yours faithfully,* (when you’ve addressed it to “Dear Sir/Madam”) for very formal emails such as job applications.
- Use *Best regards,* or *Kind regards,* in most other situations.
- Even when writing to people you know well, it’s polite to sign off with something such as “All the best,” “Take care,” or “Have a nice day,” before typing your name.

6. Use a sensible email signature

Hopefully this is common sense – but don’t cram your email signature with quotes from your favourite TV show, motivational speaker or witty friend. Do include your name, email address, telephone number and postal address (where appropriate) – obviously, your company may have some guidelines on these.

It makes it easy for your correspondents to find your contact details: they don’t need to root through for the first message you sent them, but can just look in the footer of any of your emails.

Putting it all together

Compare the following two job applications. The content of the emails are identical – but who would you give the job to?

i’ve attached my resume i would be grateful if you could read it and get back to me at your earliest convenience. i have all the experience you are looking for – i’ve worked in a customer-facing environment for three years, i am competent with ms office and i enjoy working as part of a team. thanks for your time

Or

Dear Sir/Madam,

I’ve attached my resume. I would be grateful if you could read it and get back to me at your earliest convenience. I have all the experience you are looking for:

- *I’ve worked in a customer-facing environment for three years*
- *I am competent with MS office*
- *I enjoy working as part of a team*

Thanks for your time.

Yours faithfully,

Joe Bloggs

E-Mail Writing 16M BTL3

1. Send an email to your friend sharing your experience about your College.
2. Send an email to your mother sharing your first weekend experience with your friends.
3. Imagine yourself to be the Team Leader in TCS and send a mail to your team appreciating successful completion of the Project.

Scheme of Marks :
Format – 6M
Key Words – 4M
Presentation- 2M
Content **-** 4M

4. **Letter of Job Application** 16M BTL 4

From

M. Raja,
45, Ragav Apartments,
Rajaji Nagar,
Chennai – 73

To

The Executive Director,
Godrej Company Limited,
455, Greams Road,
Chennai – 600 035

Sir,

Sub: Application for the post of Production Manager – Reg.

Ref: With reference to the advertisement in “The Hindu” dated 18.02.2012

I am a Mechanical Engineering graduate. I have been working in “Prakash Furniture Ltd” as Production Manager for three years. I have managerial skills and inter-personal skills. I have enclosed my resume for your perusal.

Expecting your intimation letter

Thanking you,

Yours faithfully,

(M.Raja)

RESUME

M. Raja
45, Ragav Apartments,
Rajaji Nagar,
Chennai – 73
raja.m@gmail.com

Mobile: 9944488077
E-mail:

OBJECTIVE

To pursue a challenging position in whatever I do and to contribute towards the growth of the organization.

EDUCATIONAL QUALIFICATION:

B.E	-	Mechanical Engineering – 90% ABC Engineering College, Chennai – 13 May 2008
HSC	-	Govt. Higher Secondary School - 85% Chennai – 73 May 2004

EXPERIENCE:

July 2009 – till date	-	Production Manager, Prakash Furniture Ltd, Trichy.
July 2008 – July 2009	-	Junior Production Manager, Rahul Furniture Ltd., Rasipuram, Namakkal. (Dt)

ACHIEVEMENTS:

- University gold medalist at UG Level.
- Won the best project award.
- Presented many papers in conferences and seminars.

RESPONSIBILITIES:

- Sports secretary in 12th std.
- Class representative from 10th std.
- Captain of college football team.

REFERENCES:

1. Dr. V. M. Periasamy,
   Principal,
   BSA Engineering College,
   Nagarkoil.

2. Mr. Ashok Kumar,
   The General Manager,
   Prakash Furniture Ltd.,
   Trichy.

PERSONAL PROFILE:

Name	: M. Raja
Date of Birth	: 12.08.1987
Age	: 29
Gender	: Male
Father's Name	: R. Manikkavasagam
Nationality	: Indian
Religion	: Hindu
Languages Known	: Tamil, English.

DECLARATION

I hereby solemnly declare that all the information made is true to the best of my knowledge and belief.

Thank you,

Yours faithfully,

Place: Chennai
Date: 20.02.12

(M. Raja)

1 .Write a letter of application for the post of an Assistant Engineer to The Human Resource Manager, HRC Communication Ltd., 390, Lake View Road, Santhome, Chennai – 600 004. Attach a separate resume with your letter. **(AU, May/June 2014)**

2.Write a letter of application for the post of Team Leader to The Human Resource Manager, Mayday Motors Ltd., 327, G.T. Naidu Road, Coimbatore. Write the details of your qualification and experience within the application letter. **(AU, May/June 2014)**

3.Write a letter of application for the post of a Junior Engineer to the Divisional Engineer, Mambalam Division, Chennai Telephones, 786, Anna Salai, Chennai – 35. Attach a suitable bio-data with the application.

4. The Chief Engineer of Public Works Department, Kancheepuram, wants to make you a member of the technical committee on Road Developments in Kancheepuram. Write a letter of thanks to him and also enclose your resume with your letter. **(AU, May/June 2013)**

5. Draft a letter of Job Application in response to the following advertisement. Candidates holding a bachelor's / master's degree with a background in engineering are required for work on company for the post of engineer. Applicants' must also possess excellent writing skills and the ability to effectively and CV to Mr.Promod Tiwari, Human Resources Dept., Exclusive software, North Main Street, Chennai – 67. **(AU, May/June2012)**

6.You have come across the following advertisement in the newspaper on 12th June 2014. Write a letter of application and detailed CV to one of the posts selected:

A leading private sector company in India needs the following engineers for the various projects in India **(AU, May/June2015)**

1. CIVIL/MECHANICAL ENGINEERS
2. ELECTRICAL / MANUFACTURING ENGINEERS
3. CHEMICAL ENGINEERS
4. COMPUTER SCIENCE ENGINEERS

1 to 3 years of experience
Should be able to work in a team
Good communication skills

Apply to
The Managing Director,
L and T Ltd.,
Bangalore – 5
Email ID : landtl4@gmail.com

7. You come across the following advertisement

(AU, May/June2015)

Company Name : Way Staffing Location : Thane, Pune Nationality : India Salary : 6.50 – 8.50 lacs Experience : 3 – 8 yrs Education : B.E. / B.Tech • IT • Manufacturing/ Engineering / R&D Posted on : 30th August 2018	Role : Technical Support Engineer Civil Engineer Electrical Engineer Industry : Engineering, Procurement Construction

8. Prepare a detailed CV to be uploaded in the website.

8. Read the following advertisement published in "The Times of India" and write a letter of application. Enclose your resume with the letter of application. **(AU, Nov/Dec, 2014)**

> Job : Software Engineer
> Company : Kamal Info Systems Private Limited
> Location: Hyderabad
> Eligibility : B.E. / B.Tech
> Skills: Capital Markets, Object Oriented Project Planning, Design Patterns in Java, C++
> Send your application with the resume to: The HR Manager, Kamal Info Systems Private Limited, No.14, Greams Road, Hyderabad – 500 002.

Scheme of Marks :
Format – 6M
Presentation- 4M
Content - 6M

	UNIT V **GROUP DISCUSSION AND JOB APPLICATIONS 12**
	Listening- TED/Ink talks; **Speaking** –participating in a group discussion -**Reading**– reading and understanding technical articles **Writing**– Writing reports- minutes of a meeting- accident and survey **Vocabulary Development- verbal analogies Language Development-** reported speech
	PART* A
1	**Reported Speech** 2M BTL 3 1. "I will work hard to get first class" said Lazar (D.S.) Lazar said he would work hard to get first class. (I.S.) 2. "You can do this work" said Nelson to Johnsi (D.S.) Nelson told Johnsi that he could do that work. (I.S.) 3. He says, "I am glad to be here this evening"(D.S.) He says that he is glad to be there that evening. (I.S.) 4. "I'm going to the library now" said David (D.S.) David said that he was going to the library then. (I.S.) 5. "Don't talk in the class" said the teacher to the boys. (D.S.) The teacher advised the boys not to talk in the class. (I.S.) 6. "Please give me something to eat. I am hungry" the old man said to them. (D.S.) The old man requested them to give him something to eat and said that he was hungry (I.S.) 7. Mohan said to Stalin, "Why did you not attend the meeting yesterday"? (D.S.) Mohan asked Stalin why he had not attended the meeting the day before. (I.S.) 8. "How often do you go to the theatre?" said David to John. (D.S.) David asked John how often he went to the theatre. (I.S.) 9. Alas! I have broken my brother's watch" said he. He exclaimed sorrowfully that he had broken his brother's watch. (I.S.) 10. "How beautiful the flower is!" said Kumar. (D.S.) Kumar exclaimed joyfully that the flower was very beautiful. (I.S.) 11. "Won't you help me to caary this box?" said I to my friend. (D.S.) I asked my friend if he would not help me to carry that box. (I.S.) 12. Mohan said to Stalin, "Why did not you attend the meeting yesterday"? (D.S.) Mohan asked Stalin why he had not attended the meeting the day before. (I.S.)

	13. "How often do you go to the theatre?" said David to John. (D.S.) David asked John how often he went to the theatre. (I.S.) 14. Mohamed said to Sultan, "Do you like mangoes?" (D.S.) Mohamed asked Sultan if he liked mangoes. (I.S.) **15. The teacher has said to the pupils, "Sea-water is different from the river water.".** The teacher has told the pupils that sea-water is different from river water. **16. David answered, "The Mines are under the ground".** David answered that the Mines are under the ground. **17. John said to his brother, "The U.N.O. is a world organization".** John told his brother that the U.N.O. is a world organisaiton. **18. The Science teacher told the class, "Ice floats on water.".** The Science teacher told the class that ice floats on water. **19. "I don't know the way. Do you?" he asked.** He said that he didn't know the way and asked her if she did. **20. She said, "Oh! It's a snake. Don't go near it, children."** She exclaimed with disgust that it was a snake and told the children not to go near it. **21. "I the floods get any worse we must leave the house", he said.** (must = will have to) He said that if the floods got any worse they would have to leave the house. **22. "I have just received a letter", he said; "I must go home at once".** He said that he had jus treceived a letter and would have to go home at once. **23.** Angel said, "I brought a pen yesterday". (D.S) Angel said that she had bought a pen the day before. (I.S) **24. John said, "I am going to church". (D.S**) John said that he was going to church. (I.S) **25. He said, "I have been reading a novel". (D.S)** He said that he had been reading a novel. (I.S)

2	**Verbal Analogies: 2M BTL3** **1. Sing : hum :: Talk : ______** a. murmur b. whisper c. **mumble** d. shout **2. Liquid : liter** a**. Weight : kilogram** b. Land : seismometer c. Bushel : corn d. Fame : television **3. If Dawn: Morning, then Dusk: ________** a. **Evening :** b. Night : c. Darkness : d. Fog **4. If Parson lives in Parsonage, then Pioneer lives in _________** a. Cottage : b.**Wagon :** c.Monastery : d. Barracks **5. If Ravens: Croak, then Ducks: __________** a. Talk : b. Gobble : c. Squeak : d. **Quack** **6. If Bears: Growl, then Asses: ______** a. Growl : b. **Bray** : c. Purr : d. Bleat **7. ______ : trail:: grain : grail** a. train : b. path : c. wheat : d. holy **8. particular : fussy :: ______ : subservient** a. meek : b. above : c. cranky : d. uptight **9. ______ : horse :: board : train** a. stable : b. shoe : c. ride : d. mount **10. tureen : ______ :: goblet : wine** **a.** napkin : b. soup : c. spoon : d. pilsner **11. son : nuclear :: ______ : extended** a. father : b. mother : c. cousin : d. daughters **12. coif : hair :: ______ : musical** a. Shower : b. close : c. praise : d. score **13. feta : Greek :: provolone : ______** a. salad : b. Swiss : c. blue : d. Italian **14. moccasin : snake :: ______ : shoe** a. alligator : b. w**aders** : c. asp : d. loafer **15. ______ : zenith :: fear : composure** a. apex : b. **heaven :** c. heights : d. nadir **16. pill : bore :: core : ______** a. **center** : b. mug : c. bar : d. placebo **17. pilfer : steal :: ______ : equip** a. return : b. damage : c. exercise : d. furnish 18. **native : aboriginal :: naïve : ______** a. learned : b. **arid** : c. unsophisticated : d. tribe **19. junket : ______ :: junk : trash** a. trounce : b. trip : c. refuse : d. trinket

	20. _____ : festive :: funeral : somber a. tension : b. soiree : c. eulogy : d. **sari** **21. fetish : fixation :: slight : ______** a. flirt : b. sloth : c. insult : d. confuse **22. hovel : dirty :: hub : ______** a. unseen : b. prideful : c. **busy** : d. shove **23. bog : ______ :: slumber : sleep** a. dream : b. **foray** : c. marsh : d. night **24. ______: segue :: throng : mass** a. **subway :** b. church : c. transition : d. line
	PART * B
3.	**Minutes of a Meeting 16M BTL 3** **1.** Write the minutes of the meeting of organizing a cultural event in the college. Discuss about the budget, responsibilities for organizing functions, Programme, guests and honor, food, stage decoration, logistics, food, publicity. As the secretary, write the minutes of meeting. **2.** Write Minutes of meeting for the class committee meeting held on 19th January 2019. **3.** Write Minutes of meeting for the research meeting over the project with the panel members held on 20th January 2019. **4.** Write Minutes of meeting for the celebration of College day on 24th of march 2018. **5.** Write Minutes of meeting for the meeting between the officer in the Environment Pollution Authority and the Transport Department authority regarding air pollution. **Scheme of Marks :** **Format** – 6M **Presentation-** 4M **Content -** 6M
4.	**Report Writing 16M BTL 4** 1. You are working as a Technical Manager in a Software Company, Hidalco Inc. There was a fire accident in your warehouse which resulted in the damage of goods stored there. Your MD asks you to investigate the cause of the accident and send a report. (2018) 2. Your college administration wants to find what students feel about your college's environment and facilities. As student advisor you have been asked to conduct a survey among students about college infrastructure and environment. Conduct a survey on these topics and submit a report to your Dean.(2018) 3. A company is planning to set up a small shoe unit in a small village 20km from Ranipet. You are asked to prepare a suitable report about the feasibility of starting the factory. Mention the availability of raw materials and labour in your area.

4. Write a survey report on the reading habits of engineering students for submission to your college principal. Also give a set of recommendations for enhancing the reading habits of technical students.
5. You are the Works Manager in Industrial Gases Limited where LPG Cylinders are filled for utilization by the consumers. Write a report about an accident that happened in the LPG section in which three workers were seriously injured.

Scheme of Marks :
Format – 6M
Presentation- 4M
Content - 6M
formal report may include the following points

1. Title Page
2. Executive Summary
3. Abstract
4. Objective
5. Technical details
6. Cost estimation
7. Management Plan
8. Conclusion
9. Recommendations

Title Page
Imagine that you are going to start a language lab in your Institution. Write a detailed proposal about the need for establishing the lab to the General Manager.

A PROPOSAL TO ESTABLISH THE LANGUAGE LAB

SUBMITTED TO
Mr. R. Ravichandran
The General Manager
ABC Group of Institutions
Chennai-28

SUBMITTED BY
Mr. G. Sathiaraj
Department of English
ABC Engineering College
Chennai- 28

DATE
10th April 2013

A. Executive Summary

1. Project Title : Establishing Computer Assisted Language Lab
2. Name & Designation of the Department : Mr. G. Sathiaraj., Asst. Prof
Department of English
ABC Engineering College
Chennai- 28
3. Duration of the Project : 3 Months
4. Amount Required : 20 lakhs

B. Abstract

Communication skills become inevitable in today's survival. Communication skill is expected by every IT firms. Everyone must have a good proficiency in English Language. To meet these expectations, it is proposed to establish a computer assisted language lab in our institution. So, the student could have been provided an independent learning opportunity and acquire the language proficiency.

C. Objective

To establish Computer Assisted language lab to improve and impart the language proficiency of the learning community.

D. Technical plan

It is planned to install 60 students systems with one Teacher control server. 15 different softwares for practice.

E. Cost Estimation

Product Cost per Unit Required Unit Total Cost Remarks

P-IV computer
with 360 GB HD 35000 1 35000
P-IV computer
with 180 GB HD 30000 60 1800000
Head Phones with Mike 500 61 30500
Language Learning Softwares 15 1 each 300000
Split A/C 1.5 ton 25000 2 50000
Total 1946000

F. Management Plan

1. The lab may be taken care by Department of English
2. Lab hours may be included in the Regular Time Table
3. One Technical Assistant may be appointed to assist.
4. One staff may be given in-charge.

G. Recommendations

So, It is recommended to establish a Computer Assisted Language Lab at our institution.

SYLLABUS

MA8251 ` ENGINEERING MATHEMATICS-II L T P C

3 1 0 4

OBJECTIVES:

- To make the student acquire sound knowledge of techniques in solving ordinary differential equations that model engineering problems.
- To acquaint the student with the concepts of vector calculus, needed for problems in all engineering disciplines.
- To develop an understanding of the standard techniques of complex variable theory so as to enable the student to apply them with confidence, in application areas such as heat conduction, elasticity, fluid dynamics and flow the of electric current.
- To make the student appreciate the purpose of using transforms to create a new domain in which it is easier to handle the problem that is being investigated.

UNIT I MATRICES 9+3

Eigenvalues and Eigenvectors of a real matrix - Characteristic equation - Properties of eigenvalues and eigenvectors - Statement and applications of Cayley-Hamilton Theorem - Diagonalization of matrices - Reduction of a quadratic form to canonical form by orthogonal transformation –Nature of quadratic forms.

UNIT II VECTOR CALCULUS 9+3

Gradient, divergence and curl – Directional derivative – Irrotational and solenoidal vector fields – Vector integration – Green's theorem in a plane, Gauss divergence theorem and Stokes' theorem(excluding proofs) – Simple applications involving cubes and rectangular parallelopipeds.

UNIT III ANALYTIC FUNCTIONS 9+3

Functions of a complex variable – Analytic functions: Necessary conditions – Cauchy-Riemann equations and sufficient conditions (excluding proofs) – Harmonic and orthogonal properties of analytic function – Harmonic conjugate – Construction of analytic functions – Conformal mapping: $w = z+k$, kz, $1/z$, z^2, e^z and bilinear transformation.

UNIT IV COMPLEX INTEGRATION 9+3

Complex integration – Statement and applications of Cauchy's integral theorem and Cauchy's integral formula – Taylor's and Laurent's series expansions – Singular points – Residues – Cauchy's residue theorem – Evaluation of real definite integrals as contour integrals around unit circle and semi-circle (excluding poles on the real axis).

UNIT V LAPLACE TRANSFORM **9+3**

Laplace transform – Sufficient condition for existence – Transform of elementary functions – Basic properties – Transforms of derivatives and integrals of functions - Derivatives and integrals of transforms - Transforms of unit step function and impulse functions – Transform of periodic functions. Inverse Laplace transform -Statement of Convolution theorem – Initial and final value theorems – Solution of linear ODE of second order with constant coefficients using Laplace transformation techniques.

TOTAL: 60 PERIODS

TEXT BOOKS:

1. Bali N. P and Manish Goyal, "A Text book of Engineering Mathematics", Eighth Edition, Laxmi Publications Pvt Ltd.,(2011).

2. Grewal. B.S, "Higher Engineering Mathematics", 41 st Edition, Khanna Publications, Delhi, (2011).

REFERENCES:

1. Dass, H.K., and Er. RajnishVerma," Higher Engineering Mathematics", S. Chand Private Ltd., (2011)

2. Glyn James, "Advanced Modern Engineering Mathematics", 3rd Edition, Pearson Education, (2012).

3. Peter V. O'Neil," Advanced Engineering Mathematics", 7th Edition, Cengage learning, (2012).

4. Ramana B.V, "Higher Engineering Mathematics", Tata McGraw Hill Publishing Company, New Delhi, (2008).

Subject Code: MA8251 **Year/Semester:** I /II
Subject Name: ENGINEERING MATHEMATICS-II
Subject Handler: DR. SURESH & MS. J. AROKIA MARY.

	UNIT-I MATRICES
	Eigen values and Eigenvectors of a real matrix – Characteristic equation – Properties of Eigen values and Eigenvectors – Cayley-Hamilton theorem – Diagonalization of matrices – Reduction of a quadratic form to canonical form by orthogonal transformation – Nature of quadratic forms.
Q.No.	**PART-A**
1	**State Cayley Hamilton theorem and give its two uses.** **(NOV/DEC 2015)(MAY/JUNE 2012)** BTL1 Every square matrix satisfies its own characteristic equation. It is used to calculate i. The positive integral powers ii. The inverse of a square matrix.
2	**If $\lambda_1, \lambda_2, \ldots \lambda_n$ are Eigen values of a matrix A then show that $\frac{1}{\lambda_1}, \frac{1}{\lambda_2}, \ldots \frac{1}{\lambda_n}$ are Eigen values of A^{-1}.** BTL2 If λ_i and X_i are corresponding Eigen value and Eigen vector of A where i=1,2...,n. $AX_i =_i X_i A^{-1}(AX_i) = A^{-1}(\lambda_i X_i)$ $\Rightarrow IX_i = \lambda_i A^{-1} X_i$ $\Rightarrow X_i = \lambda_i A^{-1} X_i$ $\Rightarrow A^{-1} Xi = 1/\lambda_i X_i$ $\Rightarrow A^{-1} = 1/\lambda_i$ $\therefore 1/\lambda_i$ is an Eigen values of A^{-1}
3	**If $\lambda_1, \lambda_2, \ldots \lambda n$ are Eigen values of an n x n matrix A then show that $\lambda_1^3, \lambda_2^3 \ldots \lambda_n^3$ are Eigen values of A^3.** BTL2 Let λ be Eigen value of A and let X be Eigen vector of A. $\therefore$ AX = λ X $A^2X = A\lambda X = \lambda(AX) = \lambda(\lambda X) = \lambda^2 X$ $\therefore A^2 = \lambda$

	Similarly, $A^3X = \lambda^3X \Rightarrow A^3 = \lambda^3$ $\therefore \lambda^3$ is an Eigen value of A^3.
4	**If λ is the eigenvalue of the matrix A, then prove that λ^2 is the eigenvalue of A^2.** (APR/MAY 2019) Let λ be Eigen value of A and let X be Eigen vector of A. $\therefore \quad AX = \lambda X$ $A^2X = A\lambda X = \lambda (AX) = \lambda (\lambda X) = \lambda^2 X$ $\therefore A^2 = \lambda$.
5	**Two Eigen values of A=$\begin{pmatrix} 2 & 2 & 1 \\ 1 & 3 & 1 \\ 1 & 2 & 2 \end{pmatrix}$ are equal and are $\frac{1}{5}$ times to the third. Find them.** **(NOV/DEC 2014)** BTL1 Let $\lambda_1, \lambda_2, \lambda_3$ be Eigen values of A. Given $\lambda_1 = \lambda_2 = \frac{1}{5}\lambda_3$ We know sum of Eigen values = sum of diagonal elements $\lambda_1 + \lambda_2 + \lambda_3 = 7$ $\frac{1}{5}\lambda_3 + \frac{1}{5}\lambda_3 + \lambda_3 = 7$ $\frac{7}{5}\lambda_3 = 7$ $\therefore \lambda_3 = 5$ $\therefore \lambda_1 = \lambda_2 = 1$.
5	**Find the Eigen values of A^2 given A=$\begin{pmatrix} 1 & 2 & 3 \\ 0 & 2 & -7 \\ 0 & 0 & 3 \end{pmatrix}$.Also find A^3, A^{-1}, $2A^2$.** BTL1 We know the Eigen values of a triangular matrix are just the diagonal elements. Here given matrix is a upper triangular matrix $\therefore$ Eigen values of A are 1,2,3. We know that "if $\lambda_1, \lambda_2, \ldots \lambda_n$ are Eigen values of a matrix A,then $\lambda_1^m, \lambda_2^m, \ldots \lambda_n^m$ are Eigen values of A^m." $\therefore$ Eigen values of A^2 are 1,4,9. $\therefore$ Eigen values of A^3 are 1,8,27. We know that if $\lambda_1, \lambda_2, \ldots \lambda_n$ are Eigen values of A

	then $k\lambda_1, k\lambda_2, \dots k\lambda_n$ are Eigen values of KA $\therefore$ Eigen values of $2A^2$ are 2,8,18
6	**If A is an orthogonal matrix Show that A^{-1} is also orthogonal.** BTL2 Let A be orthogonal matrix i.e. $A^T = A^{-1}$ Let $A^T = A^{-1} = B$ $B^T = (A^{-1})^T = (A^T)^{-1} = B^{-1}$ Therefore B is orthogonal. i.e. A^{-1} is an orthogonal matrix.
7	**Prove that the product of 2 orthogonal matrices is an orthogonal matrix.** BTL5 Let A be an n^{th} order orthogonal matrix. $\therefore \quad AA' = A'A = I$ Let B be an n^{th} order orthogonal matrix. $BB' = B'B = I$ Now $(AB)(AB)' = ABB'A'$ $= AIA'$ $= AA'$ $= I$ Now $(AB)'(AB) = B'A'AB$ $= B'IB$ $= B'B$ $= I$ Since $(AB)(AB)' = (AB)'(AB) = I.$ AB is orthogonal matrix.
8	**If 1 and 2 are Eigen values of a 2 x2 matrix A, what are the Eigen values of A^2 and A^{-1}.** BTL1 Eigen values of A^2 are 1 and 4 Eigen values of A^{-1} are 1 and $\frac{1}{2}$.
9	**If 2, 3 are the Eigen value of $A = \begin{pmatrix} 2 & 0 & 1 \\ 0 & 2 & 0 \\ b & 0 & 2 \end{pmatrix}$ then find the value of b?** **(NOV/DEC 2013)** BTL1 Given Eigen values are $\lambda_1 = 2, \lambda_3 = 3$ Sum of the Eigen values = Sum of the main diagonal elements

	$\lambda_1+\lambda_2+\lambda_3=6$ $2+3+\lambda_3=6$ $5+\lambda_3=6$ $\lambda_3=1$ Product of the Eigen value $=\lvert A\rvert$ $(2)(3)(1)=8-2b$ $6=8-2b$ $b=1$
10	**If the sum of two Eigen values and trace of a 3 x 3 matrix A are equal, find the value of |A|.** BTL1 Let $\lambda_1,\lambda_2,\lambda_3$ be the Eigen values of A. Then we have $\lambda_1+\lambda_2=$ trace of A $\Rightarrow \lambda_1+\lambda_2=\lambda_1+\lambda_2+\lambda_3 \Rightarrow \lambda_3=0$. Hence |A| = product of Eigen values = $\lambda_1\lambda_2\lambda_3=0$
11	**For a given matrix A of order 3, |A| = 32 and two of its Eigen values are 8 and 2. Find the sum of the Eigen values.** BTL1 Given Eigen value be $\lambda_1=8,\lambda_2=2$. Then (8)(2)(λ_3) = |A| = 32 $\Rightarrow \lambda_3=2$ Let the third Eigen value be $\lambda_3=2$ Hence the sum of the Eigen values = $\lambda_1+\lambda_2+\lambda_3=8+2+2=12$
12	**Find the sum and product of the Eigen values of the square matrix** $A=\begin{pmatrix}8&1&6\\3&5&7\\4&9&2\end{pmatrix}$**.** **(NOV/DEC 2010)** BTL1 Sum of the Eigen values = sum of the main diagonal elements = 8+5+2=15 Product of the Eigen values = $\lvert A\rvert=8(10-63)-1(6-28)+6(27-20)=-360$
13	**Find the sum of the Eigen values of 2A if** $A=\begin{pmatrix}8&-6&2\\-6&7&-4\\2&-4&3\end{pmatrix}$. BTL1 If λ_1, λ_2, λ_3 are the Eigen values of A, then $\lambda_1+\lambda_2+\lambda_3=18$. We know that $2\lambda_1$, $2\lambda_2$, $2\lambda_3$ are the Eigen values of 2A. Therefore the sum of Eigen values of 2A = $2(\lambda_1+\lambda_2+\lambda_3)=2(18)=36$

14	**If the Eigen value of A are 3x3 are 2,3 and 1, then find the Eigen values of adjA. (NOV/DEC 2003)** BTL1 The Eigen values of are 2,3,1 The Eigen value of A^{-1} are $\frac{1}{2},\frac{1}{3},1$ The product of Eigen values are $(2)(3)(1)=\|A\|$ $\therefore \|A\|=6$ We know that $A^{-1}=\frac{1}{\|A\|}adjA$ $adjA=\|A\|A^{-1}$ The Eigen value of adjA are $(6)\left(\frac{1}{2}\right),(6)\left(\frac{1}{3}\right),(6)1$ $\Rightarrow 3,2,6$
	If the eigenvalue of the matrix *A* of the order 3x3 are 2, 3 and 1, then find the determinant of *A*. (APR/ MAY 2019) The Eigen values of are 2,3,1 The product of Eigen values are $(2)(3)(1)=\|A\|$ $\therefore \|A\|=6$.
15	**Find the sum of the squares of the Eigen values of** $A=\begin{pmatrix}3&1&4\\0&2&6\\0&0&5\end{pmatrix}$**.** **(NOV/DEC 2016)** BTL1 A is a triangular matrix. Therefore the Eigen values of A are 3, 2 and 5. The sum of squares of the Eigen values of $A^2 = 3^2 + 2^2 + 5^2 = 9 + 4 + 25 = 38$
16	**Find the Eigen values of 2A – I, given** $A=\begin{pmatrix}-4&1\\3&-2\end{pmatrix}$**.** BTL1 $2\boldsymbol{A}-\boldsymbol{I}=\begin{pmatrix}-8&2\\6&-4\end{pmatrix}-\begin{pmatrix}1&0\\0&1\end{pmatrix}=\begin{pmatrix}-9&2\\6&-5\end{pmatrix}$ The Characteristic equation of 2A - I is given by

	$\lvert 2\boldsymbol{A}-\boldsymbol{I}-\lambda\boldsymbol{I}\rvert = 0 \Rightarrow \begin{vmatrix} -9-\lambda & 2 \\ 6 & -5-\lambda \end{vmatrix} = 0$ $\Rightarrow \lambda^2+14\lambda+33=(\lambda+11)(\lambda+3)=0$ $\Rightarrow \lambda=-3,-11$
17	**Prove that A and A^T have the same Eigen values.** BTL5 $\lvert \boldsymbol{A}^T-\lambda\boldsymbol{I}\rvert=\lvert \boldsymbol{A}^{\mathrm{T}}-(\lambda\boldsymbol{I})^T\rvert=\lvert(\boldsymbol{A}-\lambda\boldsymbol{I})^T\rvert=\lvert\boldsymbol{A}-\lambda\boldsymbol{I}\rvert$. $\Rightarrow$A and A^T have the same characteristic equation and hence they have the same Eigen values.
18	**Prove that Similar matrices have the same characteristic roots.** BTL5 LetA and Bbe two similar matrices, then there exists a matrix P such that $B = P^{-1}AP$. Hence $\lvert\boldsymbol{B}-\lambda\boldsymbol{I}\rvert=\lvert\boldsymbol{P}^{-1}\boldsymbol{AP}-\boldsymbol{P}^{-1}\lambda\boldsymbol{IP}\rvert=\lvert\boldsymbol{P}^{-1}\rvert\lvert\boldsymbol{A}-\lambda\boldsymbol{I}\rvert\lvert\boldsymbol{P}\rvert=\lvert\boldsymbol{A}-\lambda\boldsymbol{I}\rvert\lvert\boldsymbol{PP}^{-1}\rvert$ $=\lvert\boldsymbol{A}-\lambda\boldsymbol{I}\rvert$ i.e., A and B have the same characteristic equation. Therefore, they have the same Characteristic roots.
19	**Is the matrix** $B=\begin{pmatrix}\cos\theta & \sin\theta & 0\\ -\sin\theta & \cos\theta` & 0\\ 0 & 0 & 1\end{pmatrix}$ **orthogonal? Justify.** BTL5 $\mathbf{BB^T}=\begin{bmatrix}\cos\theta & \sin\theta & 0\\ -\sin\theta & \cos\theta & 0\\ 0 & 0 & 1\end{bmatrix}\begin{bmatrix}\cos\theta & -\sin\theta & 0\\ \sin\theta & \cos\theta & 0\\ 0 & 0 & 1\end{bmatrix}=\begin{bmatrix}1&0&0\\0&1&0\\0&0&1\end{bmatrix}=\mathbf{I}$ Similarly, $B^TB = I$. Hence B is orthogonal.
20	**Use Cayley-Hamilton theorem to find** A^4-4A^3-5A^2+A+2I **where** $A=\begin{pmatrix}1&2\\4&3\end{pmatrix}$**.** BTL3 $\lvert\mathbf{A}-\lambda\boldsymbol{I}\rvert=0\Rightarrow\begin{vmatrix}1-\lambda & 2\\ 4 & 3-\lambda\end{vmatrix}=0\Rightarrow\lambda^2-4\lambda-5=0\Rightarrow\boldsymbol{A}^2-4\boldsymbol{A}-5\boldsymbol{I}=0$ **(**By Cayley-Hamilton Theorem) $\Rightarrow\boldsymbol{A}^2(\boldsymbol{A}^2-4\boldsymbol{A}-5\boldsymbol{I})=0\Rightarrow\boldsymbol{A}^4-4\boldsymbol{A}^3-5\boldsymbol{A}^2=0$ $\Rightarrow A^4-4A^3-5A^2+A+2I=0+A+2I=\begin{bmatrix}1&2\\4&3\end{bmatrix}+\begin{bmatrix}2&0\\0&2\end{bmatrix}=\begin{bmatrix}3&2\\4&5\end{bmatrix}$.
21	**Can** $A=\begin{pmatrix}1&0\\0&1\end{pmatrix}$ **be diagonalised? Why?(MAY/JUNE 2016)** BTL1

	Yes. Even if the Eigen values of A are equal, namely 1, 1, it is possible to find two linearly independent Eigen vectors corresponding to the Eigen value 1.
22	**Find the matrix of the quadratic from** $2x^2+2y^2+3z^2+2xy-4xz-4yz$**.** BTL1 The required matrix $A=\begin{bmatrix} coeff\ x^2 & \frac{1}{2}coeff\ xy & \frac{1}{2}coeff\ xz \\ \frac{1}{2}coeff\ yx & coeff\ y^2 & \frac{1}{2}coeff\ yz \\ \frac{1}{2}coeff\ zx & \frac{1}{2}coeff\ zy & coeff\ z^2 \end{bmatrix}$ $A=\begin{pmatrix} 2 & 1 & -2 \\ 1 & 2 & -2 \\ -2 & -2 & 3 \end{pmatrix}$
23	**Find the nature of the quadratic form** $x_1^2+2x_2^2+x_3^2-2x_1x_2+2x_2x_3$. **(MAY/JUNE 2010)** BTL1 $A=\begin{bmatrix} coeffx_1^2 & \frac{1}{2}coeffx_1x_2 & \frac{1}{2}coeffx_1x_3 \\ \frac{1}{2}coeffx_2x_1 & coeffx_2^2 & \frac{1}{2}coeffx_2x_3 \\ \frac{1}{2}coeffx_3x_1 & \frac{1}{2}coeffx_3x_2 & coeffx_3^2 \end{bmatrix}$ $D_1=\begin{vmatrix} 1 & -1 & 0 \\ -1 & 2 & 1 \\ 0 & 1 & 1 \end{vmatrix}=\lvert a_{11}\rvert=1$ $D_2=\begin{vmatrix} 1 & -1 & 0 \\ -1 & 2 & 1 \\ 0 & 1 & 1 \end{vmatrix}=\begin{vmatrix} 1 & -1 \\ -1 & 2 \end{vmatrix}=2-1=1$ $D_3=\lvert A\rvert=1$ The nature positive definite since all are positive values.
24	**Write down the matrix corresponding to the quadratic form** $x^2+y^2+z^2+2zx+4\sqrt{2}yz$ BTL1

	The required matrix $A=\begin{bmatrix} coeff\ x^2 & \frac{1}{2}coeff\ \ xy & \frac{1}{2}coeff\ xz \\ \frac{1}{2}coeff\ \ yx & coeff\ \ y^2 & \frac{1}{2}coeff\ yz \\ \frac{1}{2}coeff\ zx & \frac{1}{2}coeff\ \ zy & coeff\ z^2 \end{bmatrix}$ $A=\begin{pmatrix} 1 & 0 & 1 \\ 0 & 1 & 2\sqrt{2} \\ 1 & 2\sqrt{2} & 1 \end{pmatrix}$
25	**Write down the Quadratic Form corresponding to the matrix** $A=\begin{pmatrix} 2 & 1 & -2 \\ 1 & 2 & -2 \\ -2 & -2 & 3 \end{pmatrix}$**.** BTL1 The Quadratic Form of the matrix is $2x^2+2y^2+3z^2+2xy-4yz-4zx$
26	**Define index and signature of a quadratic form. Find the index and signature of the quadratic form** $x_1^2+2x_2^2-3x_3^2$**.** BTL1 The number (p) of positive terms in the canonical form of a QF is called the index of the QF. The number of positive terms minus the number of negative terms is called the signature of the QF Index = 2 , Signature = 1
27	**Find the constant 'a' and 'b' such that the matrix** $A=\begin{pmatrix} a & 4 \\ 1 & b \end{pmatrix}$ has 3 and -2 as eigen values. BTL1 Give the Eigen values are 3 and -2 Sum of the Eigen value of A are 'a' and 'b' Sum of the Eigen value $a+b=3-2=1$ $\therefore a+b=1$ …………………….(1) Product of the Eigen value $3(-2)=-6$ Product of the Eigen value of A are $\lvert A\rvert=ab-4$

	$\therefore ab-4=-6$ $ab=-2$....................(2) $(1)\Rightarrow \quad b=1-a$ $(2)\Rightarrow \quad ab=-2$ $a(1-a)=-2$ $a^2-a-2=0$ $(a-2)(a+1)=0 \quad \therefore a=2\,\&\,a=-1$ $when\;\; a=2\; then\; b=-1$ $when\;\; a=-1\; then\; b=2$ $\therefore a=2, b=-1\; or\; a=-1, b=2$
28	**Find the Eigen values of 3A+2I , where** $A=\begin{pmatrix}5 & 4\\ 0 & 3\end{pmatrix}$ **.(MAY/JUNE 2007)** BTL1 The Eigen values of A are 5 and 2, The Eigen values of 3A+2I are 3(5)+2 and 3(2)+2 The Eigen values of 3A+2I are 17 and 8
29	**If 3 and 5 are two Eigen values of the matrix** $A=\begin{pmatrix}8 & -6 & 2\\ -6 & 7 & -4\\ 2 & -4 & 3\end{pmatrix}$ **then find its third Eigen value and hence** $\lvert A\rvert$. **(MAY/JUNE 2018 R-17)** BTL1 Given Eigen value be $\lambda_1=3, \lambda_2=5$. Sum of the Eigen values= Trace of A $\lambda_1+\lambda_2+\lambda_3=8+7+3=18$ $\therefore \lambda_3=18-8=10$ Product of the Eigen value $\lvert A\rvert=150$
30	**Show that Eigen values of a null matrix are zero (MAY/JUNE 2018 R-17)** BTL1 Let $A=\begin{pmatrix}0 & 0 & 0\\ 0 & 0 & 0\\ 0 & 0 & 0\end{pmatrix}$ The Characteristic Equation is $\lambda^3=0$ $\therefore \lambda_1=0, \lambda_2=0, \lambda_3=0$

	PART-B
1.	**Find the Eigen values and Eigen vectors of** $\begin{pmatrix} 2 & 2 & 0 \\ 2 & 1 & 1 \\ -7 & 2 & -3 \end{pmatrix}$. **(8M)** BTL1 **Answer : Refer Page No.1.8-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = -4, 1, 3$. **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 1 \\ -3 \\ 13 \end{bmatrix}; X_2 = \begin{bmatrix} 2 \\ -1 \\ -4 \end{bmatrix}; X_3 = \begin{bmatrix} 2 \\ 1 \\ 4 \end{bmatrix}$ **(6M)**
2.	**Find the Eigen values and Eigen vectors of** $\begin{pmatrix} 11 & -4 & -7 \\ 7 & -2 & -5 \\ 10 & -4 & -6 \end{pmatrix}$ **(May/June-2018 R-17) (8M)** BTL1 **Answer : Refer Page No.1.21-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 0, 1, 2$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}; X_2 = \begin{bmatrix} 1 \\ -1 \\ 2 \end{bmatrix}; X_3 = \begin{bmatrix} 2 \\ 1 \\ 2 \end{bmatrix}$ **(6M)**
3.	**Find the Eigen values and Eigen vectors of** $\begin{pmatrix} 1 & 0 & -1 \\ 1 & 2 & 1 \\ 2 & 2 & 3 \end{pmatrix}$ **(DEC/JAN-2016 R-13) (8M)** BTL1 **Answer : Refer Page No.1.10-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 1, 2, 3$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 1 \\ -1 \\ 0 \end{bmatrix}; X_2 = \begin{bmatrix} 2 \\ -1 \\ -2 \end{bmatrix}; X_3 = \begin{bmatrix} 1 \\ -1 \\ 2 \end{bmatrix}$ **(6M)**

4.	**Find the Eigen values and Eigen vectors of** $\begin{pmatrix} 2 & 2 & 1 \\ 1 & 3 & 1 \\ 1 & 2 & 2 \end{pmatrix}$ **(DEC/JAN-2014 R-13) (8M)** BTL1 **Answer : Refer Page No.1.15-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 1,1,5$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}; X_2 = \begin{bmatrix} 0 \\ 1 \\ -2 \end{bmatrix}; X_3 = \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}$ **(6M)**
5.	**Find the Eigen values and Eigen vectors of** $\begin{pmatrix} 6 & -2 & 2 \\ -2 & 3 & -1 \\ 2 & -1 & 3 \end{pmatrix}$ **(APR/MAY-2015 R-13)** **(8M)** BTL1 **Answer : Refer Page No.1.17-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 2,2,8$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 2 \\ -1 \\ 1 \end{bmatrix}; X_2 = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}; X_3 = \begin{bmatrix} 1 \\ 2 \\ 0 \end{bmatrix}$ **(6M)**
6.	**Find the eigenvalues and the eigenvectors of the matrix** $A = \begin{pmatrix} 8 & -6 & 2 \\ -6 & 7 & -4 \\ 2 & -4 & 3 \end{pmatrix}$ **.(APR/MAY 2019)(8M)** BTL3 • The Eigen values are $\lambda = 0,3,15$ **(4 M)** • Eigen vectors $X_1 = \begin{bmatrix} 1 \\ 2 \\ 2 \end{bmatrix}; X_2 = \begin{bmatrix} 2 \\ 1 \\ -2 \end{bmatrix}; X_3 = \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix}$ **(4M)**
7.	**Verify Cayley-Hamilton theorem and hence find the inverse of the matrix** $\begin{pmatrix} 1 & 2 & -1 \\ 3 & -3 & 1 \\ 2 & 1 & -2 \end{pmatrix}$ **(DEC/JAN-2014 R-13) (8M)** BTL3 **Answer : Refer Page No.1.45-Dr.M.CHANDRASEKAR**

	• The Characteristic Equation is $\lambda^3+4\lambda^2-4\lambda-12=0$ **(2 M)** • For Proving $A^3+4A^2-4A-12I=0$ **(3 M)** • $A^{-1}=\frac{1}{12}\begin{pmatrix}5&3&-1\\8&0&-4\\9&3&-9\end{pmatrix}$ **(3 M)**
8.	**Verify Cayley-Hamilton theorem and hence find the inverse of the matrix** $\begin{pmatrix}1&0&3\\2&1&-1\\1&-1&1\end{pmatrix}$ **(DEC/JAN-2015 R-13) (8M)** BTL3 **Answer : Refer Page No.1.47-Dr.M.CHANDRASEKAR** • The Characteristic Equation is $\lambda^3-3\lambda^2-\lambda+9=0$ **(2 M)** • For Proving $A^3\text{-}3A^2-A+9I=0$. **(3 M)** • $A^{-1}=\frac{-1}{9}\begin{pmatrix}0&-3&-3\\-3&-2&7\\-3&1&1\end{pmatrix}$. **(3 M)**
9.	**Using Cayley-Hamilton theorem to find the inverse of the matrix** $\begin{pmatrix}1&2&1\\2&2&1\\1&1&3\end{pmatrix}$ **(May/June-2018 R-17) (8M)** BTL3 **Answer : Refer Page No.1.56-Dr.M.CHANDRASEKAR** • The Characteristic Equation is $\lambda^3-6\lambda^2+5\lambda+5=0$ **(2 M)** • For Proving $A^3\text{-}6A^2+5A+5I=0$ **(3 M)** • $A^{-1}=\frac{-1}{5}\begin{pmatrix}-5&5&0\\5&-2&-1\\0&-1&2\end{pmatrix}$ **(3 M)**
10.	**Use Cayley-Hamilton theorem to find the** A^4 **of the matrix** $\begin{pmatrix}2&-1&1\\0&1&2\\1&0&1\end{pmatrix}$ **(DEC/JAN-2016 R-13) (8M)** BTL3

	Answer : Refer Page No.1.48-Dr.M.CHANDRASEKAR • The Characteristic Equation is $\lambda^3-4\lambda^2+4\lambda+1=0$ **(2 M)** • $A^4=\begin{pmatrix}22&-19&-5\\24&-9&14\\19&-12&3\end{pmatrix}$ **(6 M)**
11.	**Use Cayley-Hamilton theorem to find** $A^8-5A^7+7A^6-3A^5+A^4-5A^3+8A^2-2A+I$ **of** $A=\begin{pmatrix}2&1&1\\0&1&0\\1&1&2\end{pmatrix}$ **(DEC/JAN-2006,APR/MAY 2005) (8M)** BTL3 **Answer : Refer Page No.1.51-Dr.M.CHANDRASEKAR** • The Characteristic Equation is $\lambda^3-5\lambda^2+7\lambda-3=0$ **(2 M)** • For Proving $A^8-5A^7+7A^6-3A^5+A^4-5A^3+8A^2-2A+I=A^2+A+I$ **(3 M)** • $A^8-5A^7+7A^6-3A^5+A^4-5A^3+8A^2-2A+I=\begin{pmatrix}8&5&5\\0&3&0\\5&5&8\end{pmatrix}$ **(3 M)**
12.	**Reduce the quadratic form *2xy-2yz+2xz* into a canonical form by an orthogonal reduction. (APR/MAY 2019)(16M)** BTL3 **Answer : Refer Page No.1.119-Dr.G. BALAJI** • The Eigen values are $\lambda=1,1,-2$ **(4M)** • Eigen vectors $X_1=\begin{bmatrix}1\\2\\-1\end{bmatrix}$, $X_2=\begin{bmatrix}1\\0\\1\end{bmatrix}$, $X_3=\begin{bmatrix}-1\\1\\1\end{bmatrix}$, **(4M)** • $D=\begin{pmatrix}1&0&0\\0&1&0\\0&0&-2\end{pmatrix}$ **(6M)** • Canonical form = $-2y_1^2+y_2^2+y_3^2$. **(2M)**
13.	**Diagonalize** $A=\begin{pmatrix}8&-6&2\\-6&7&-4\\2&-4&3\end{pmatrix}$ **by means of orthogonal transformation.(12M)** BTL1 **Answer : Refer Page No.1.72-Dr.M.CHANDRASEKAR**

	• The Eigen values are $\lambda = 0,3,15$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 1 \\ 2 \\ 2 \end{bmatrix}; X_2 = \begin{bmatrix} 2 \\ 1 \\ -2 \end{bmatrix}; X_3 = \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix}$ **(4M)** • $D = N^T AN = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 15 \end{pmatrix}$ **(6M)**
14.	**Diagonalize** $A = \begin{pmatrix} 3 & 1 & 1 \\ 1 & 3 & -1 \\ 1 & -1 & 3 \end{pmatrix}$ **by means of orthogonal transformation. (12M)** BTL1 **Answer : Refer Page No.1.77-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 1,4,4$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} -1 \\ 1 \\ 1 \end{bmatrix}; X_2 = \begin{bmatrix} 1 \\ 1 \\ 0 \end{bmatrix}; X_3 = \begin{bmatrix} -1 \\ 1 \\ -2 \end{bmatrix}$ **(4M)** • $D = N^T AN = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 4 & 0 \\ 0 & 0 & 4 \end{pmatrix}$ **(6M)**
15.	**Diagonalize** $A = \begin{pmatrix} 6 & -2 & 2 \\ -2 & 3 & -1 \\ 2 & -1 & 3 \end{pmatrix}$ **by means of orthogonal transformation.** BTL1 **(DEC/JAN-2015 R-13) (12M)** **Answer : Refer Page No.1.87-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 2,2,8$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 2 \\ -1 \\ 1 \end{bmatrix}; X_2 = \begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix}; X_3 = \begin{bmatrix} 0 \\ 1 \\ 1 \end{bmatrix}$ **(4M)**

	• $D=N^{T}AN=\begin{pmatrix}8&0&0\\0&2&0\\0&0&2\end{pmatrix}$ **(6M)**
16.	**Reduce the quadratic form** $10x_1^2+2x_2^2+5x_3^2+6x_2x_3-10x_3x_1-4x_1x_2$ **to a canonical form. Discuss its nature.(16M)** BTL1 **Answer : Refer Page No.1.99-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda=0,3,14$ **(2 M)** • Eigen vectors $X_1=\begin{bmatrix}1\\-5\\4\end{bmatrix};X_2=\begin{bmatrix}1\\1\\1\end{bmatrix};X_3=\begin{bmatrix}3\\-1\\-2\end{bmatrix}$ **(4M)** • $D=N^{T}AN=\begin{pmatrix}0&0&0\\0&3&0\\0&0&14\end{pmatrix}$ **(6M)** • Canonical form= $0y_1^2+3y_2^2+14y_3^2$ **.** **(2 M)** • Rank=2, Index=2, Signature=2; Nature = Positive Semi definite. **(2 M)**
17.	**Reduce the quadratic form** $6x_1^2+3x_2^2+3x_3^2-2x_2x_3+4x_3x_1-4x_1x_2$ **to a canonical form. Discuss its nature.(DEC/JAN-2016, JAN-2014 R-13) (16M)** BTL1 **Answer : Refer Page No.1.102-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda=2,2,8$ **(2 M)** • Eigen vectors $X_1=\begin{bmatrix}2\\-1\\1\end{bmatrix};X_2=\begin{bmatrix}1\\2\\0\end{bmatrix};X_3=\begin{bmatrix}2\\-1\\-5\end{bmatrix}$ **(4M)** • $D=N^{T}AN=\begin{pmatrix}2&0&0\\0&2&0\\0&0&8\end{pmatrix}$ **(6M)** • Canonical form= $2y_1^2+2y_2^2+8y_3^2$ **(2 M)** • Rank=3, Index=3, Signature=3; Nature = Positive definite **(2 M)**
18.	**Reduce the quadratic form** $6x_1^2+3x_2^2+3x_3^2-2x_2x_3+4x_3x_1-4x_1x_2$ **to a canonical form by orthogonal reduction. (16M)** BTL1

Answer : Refer Page No.1.104-Dr.M.CHANDRASEKAR

- The Eigen values are $\lambda = 2,3,6$ **(2 M)**
- Eigen vectors $X_1 = \begin{bmatrix} 1 \\ 0 \\ -1 \end{bmatrix}; X_2 = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}; X_3 = \begin{bmatrix} 1 \\ -2 \\ 1 \end{bmatrix}$ **(4M)**
- $D = N^T AN = \begin{pmatrix} 2 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 6 \end{pmatrix}$ **(8M)**
- Canonical form= $2{y_1}^2 + 3{y_2}^2 + 6{y_3}^2$ **(2 M)**

19\. **Reduce the quadratic form** $x^2 + 5y^2 + z^2 + 2xy + 2yz + 6zx$ **to a canonical form through an orthogonal transformation. (DEC/JAN-2015 R-13) (16M)** BTL1

Answer : Refer Page No.1.109-Dr.M.CHANDRASEKAR

- The Eigen values are $\lambda = -2,3,6$ **(2 M)**
- Eigen vectors $X_1 = \begin{bmatrix} -1 \\ 0 \\ 1 \end{bmatrix}; X_2 = \begin{bmatrix} -1 \\ 1 \\ -1 \end{bmatrix}; X_3 = \begin{bmatrix} 1 \\ 2 \\ 1 \end{bmatrix}$ **(4M)**
- $D = N^T AN = \begin{pmatrix} -2 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 6 \end{pmatrix}$ **(8M)**
- Canonical form= $-2{y_1}^2 + 3{y_2}^2 + 6{y_3}^2$ **(2 M)**

20\. **Reduce the quadratic form** $8{x_1}^2 + 7{x_2}^2 + 3{x_3}^2 - 8x_2x_3 + 4x_3x_1 - 12x_1x_2$ **to a canonical form by orthogonal reduction. (16M)** BTL1

Answer : Refer Page No.1.111-Dr.M.CHANDRASEKAR

- The Eigen values are $\lambda = 0,3,15$ **(2 M)**
- Eigen vectors $X_1 = \begin{bmatrix} 1 \\ 2 \\ 2 \end{bmatrix}; X_2 = \begin{bmatrix} 2 \\ 1 \\ -2 \end{bmatrix}; X_3 = \begin{bmatrix} 2 \\ -2 \\ 1 \end{bmatrix}$ **(4M)**

	• $D=N^T AN = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 15 \end{pmatrix}$ **(8M)** • Canonical form= $0y_1^2 + 3y_2^2 + 15y_3^2$ **(2 M)**
21.	**Reduce the quadratic form $2x_1^2 + 5x_2^2 + 3x_3^2 + 4x_1x_2$ to a canonical form by orthogonal reduction. (May/June-2018 R-17) (16M)** BTL1 **Answer : Refer Page No.1.113-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 1, 3, 6$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 2 \\ -1 \\ 0 \end{bmatrix}; X_2 = \begin{bmatrix} 0 \\ 0 \\ 1 \end{bmatrix}; X_3 = \begin{bmatrix} 1 \\ 2 \\ 0 \end{bmatrix}$ **(4M)** • $D=N^T AN = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 3 & 0 \\ 0 & 0 & 6 \end{pmatrix}$ **(8M)** • Canonical form= $1y_1^2 + 3y_2^2 + 6y_3^2$ **(2 M)**
22.	**Reduce the quadratic form $x_1^2 + 2x_2^2 + x_3^2 + 2x_2x_3 - 2x_1x_2$ to a canonical form through orthogonal transformation and hence show that it is positive semi-definite. Also give a non-zero set of values (x_1, x_2, x_3) which makes this quadratic form zero (16M)** BTL1 **Answer : Refer Page No.1.121-Dr.M.CHANDRASEKAR** • The Eigen values are $\lambda = 0, 1, 3$ **(2 M)** • Eigen vectors $X_1 = \begin{bmatrix} 1 \\ 1 \\ -1 \end{bmatrix}; X_2 = \begin{bmatrix} 1 \\ 0 \\ 1 \end{bmatrix} X_3 = \begin{bmatrix} -1 \\ 2 \\ 1 \end{bmatrix}$ **(4M)** • $D=N^T AN = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 3 \end{pmatrix}$ **(6M)** • Canonical form= $0y_1^2 + 1y_2^2 + 3y_3^2$ **(2 M)** • $x_1 = 1, x_2 = 1, x_3 = -1$ which makes Q.F is zero **(1 M)** • For proving Positive Semi definite **(1 M)**

	UNIT-II VECTOR CALCULUS
	Gradient and directional derivative – Divergence and curl – Vector identities – Irrotational and Solenoidal vector fields – Line integral over a plane curve – Surface integral – Area of a curved surface – Volume integral – Green's, Gauss divergence and Stokes theorems – Verification and application in evaluating line, surface and volume integrals.
	PART-A
1	**State Stokes theorem. (DEC/JAN-2015)** BTL1 The surface integral of the normal component of the curl of a vector point function $\vec{F}$ over an open surface 'S' is equal to the line integral of the tangential component of $\vec{F}$ around the closed curve 'C' bounding 'S' $\int_C \overrightarrow{F}.\overrightarrow{dr} = \iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds$
2	**State Gauss divergence theorem. (DEC/JAN-2013) (NOV/DEC-2015)** BTL1 The surface integral of the normal component of a vector function $\vec{F}$ over a closed surface S enclosing volume V is equal to the volume integral of the divergence of $\vec{F}$ taken throughout the volume V $\iint_S \vec{F}.\hat{n}\, ds = \iiint_V \nabla.\vec{F} dv$
3	**State Green's theorem. (DEC/JAN-2009) (NOV/DEC-2010)** BTL1 If $u, v, \frac{\partial u}{\partial y}, \frac{\partial v}{\partial x}$ are continuous and single valued functions in the region R enclosed by the curve C, then $\int_C udx + vdy = \iint_R \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) dxdy$
4	**Find curl $\vec{F}$ if $\vec{F} = xy\vec{i} + yz\vec{j} + zx\vec{k}$.** BTL1 $curl\ \vec{F} = \nabla \times \vec{F}$ $= \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ xy & yz & zx \end{vmatrix} =$ $\vec{i}(0-y) - \vec{j}(z-0) + \vec{k}(0-x)$ $= -y\vec{i} - z\vec{j} - x\vec{k} = -(y\vec{i} + z\vec{j} + x\vec{k})$
5	**Prove that $\vec{F} = yz\vec{i} + zx\vec{j} + xy\vec{k}$ is irrotational.** BTL5

	$$\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ yz & zx & xy \end{vmatrix} = \sum \vec{i}\left[\frac{\partial}{\partial y}(xy) - \frac{\partial}{\partial z}(zx)\right]$$ $= \sum \vec{i}\,[x - x] = 0\vec{i} + 0\vec{j} + 0\vec{k} = \vec{0}$. Hence, $\vec{F}$ is irrotational.
6	**Is the position vector $\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$ irrotational? Justify. (DEC/JAN-2016)** BTL5 $$\nabla \times \vec{r} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x & y & z \end{vmatrix}$$ $$= \vec{i}\left[\frac{\partial}{\partial y}(z) - \frac{\partial}{\partial z}(y)\right] - \vec{j}\left[\frac{\partial}{\partial x}(z) - \frac{\partial}{\partial z}(x)\right] + \vec{k}\left[\frac{\partial}{\partial x}(y) - \frac{\partial}{\partial y}(x)\right]$$ $= 0\vec{i} + 0\vec{j} + 0\vec{k} = \vec{0}$. Hence, $\vec{r}$ is irrotational.
7	**Prove that $3x^2y\vec{i} + (yz - 3xy^2)\vec{j} - \frac{z^2}{2}\vec{k}$ is a solenoidal.** BTL5 $$\nabla.\vec{F} = \frac{\partial}{\partial x}(3x^2y) + \frac{\partial}{\partial y}(yz - 3xy^2) + \frac{\partial}{\partial z}\left(-\frac{z^2}{2}\right)$$ $$= (6xy) + (z - 6xy) + (\frac{-2z}{2}) = 0$$ $\therefore$ $\vec{F}$is Solenoidal.
8	**Show that $\vec{F} = (y^2 - z^2 + 3yz - 2x)\vec{i} + (3xz + 2xy)\vec{j} + (3xy - 2xz + 2z)\vec{k}$ is both solenoidal and irrotational.** BTL2 $$\nabla.\vec{F} = \frac{\partial}{\partial x}(y^2 - z^2 + 3yz - 2x) + \frac{\partial}{\partial y}(3xz + 2xy) + \frac{\partial}{\partial z}(3xy - 2xz + 2z)$$ $$= (-2) + (2x) + (-2x + 2)$$ $$= 0$$ $\therefore$ $\vec{F}$is Solenoidal. $$\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ y^2 - z^2 + 3yz - 2x & 3xz + 2xy & 3xy - 2xz + 2z \end{vmatrix}$$ $$= \vec{i}\left[\frac{\partial}{\partial y}(3xy - 2xz + 2z) - \frac{\partial}{\partial z}(3xz + 2xy)\right]$$ $$-\vec{j}\left[\frac{\partial}{\partial x}(3xy - 2xz + 2z) - \frac{\partial}{\partial z}(y^2 - z^2 + 3yz - 2x)\right]$$ $$+\vec{k}\left[\frac{\partial}{\partial x}(3xz + 2xy) - \frac{\partial}{\partial y}(y^2 - z^2 + 3yz - 2x)\right]$$ $$= [3x - 3x]\vec{i} - [(3y - 2z) - (-2z + 3y)]\vec{j} + [(3z + 2y) - (2y + 3z)]\vec{k}$$

	$$\nabla \times \vec{F} = 0\vec{i} + 0\vec{j} + 0\vec{k} = \vec{0}$$ Hence, $\vec{F}$ is irrotational.
9	**Find α such that $\vec{F} = (3x - 2y + z)\vec{i} + (4x + \alpha y - z)\vec{j} + (x - y + 2z)\vec{k}$ is solenoidal.** BTL1 Given $\nabla.\vec{F} = 0$ $$\frac{\partial}{\partial x}(3x - 2y + z) + \frac{\partial}{\partial y}(4x + \alpha y - z) + \frac{\partial}{\partial z}(x - y + 2z) = 0$$ $$3 + \alpha + 2 = 0$$ $$\alpha + 5 = 0 \therefore \alpha = -5$$
10	**Find the constants a, b, c so that $\vec{F} = (x + 2y + az)\vec{i} + (bx - 3y - z)\vec{j} + (4x + cy + 2z)\vec{k}$ is irrotational. (DEC/JAN-2012) (May/June-2018 R-17)** BTL1 $$\nabla \times \vec{F} = \vec{0}$$ $$\begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x + 2y + az & bx - 3y - z & 4x + cy + 2z \end{vmatrix} = \vec{0}$$ $$\vec{i}[c + 1] - \vec{j}[4 - a] + \vec{k}[b - 2] = 0\vec{i} - 0\vec{j} + 0\vec{k}$$ i.e., $c + 1 = 0, 4 - a = 0, b - 2 = 0$ $$\therefore \boldsymbol{c = -1, a = 4, b = 2}$$
11	**Prove that div $\vec{r} = 3$ and curl $\vec{r} = \vec{0}$.(DEC/JAN-2016) (NOV/DEC-2010)** BTL5 $$\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$$ $$\nabla.\vec{r} = \frac{\partial}{\partial x}(x) + \frac{\partial}{\partial y}(y) + \frac{\partial}{\partial z}(z) = 1 + 1 + 1 = 3$$ $$\nabla \times \vec{r} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x & y & z \end{vmatrix}$$ $$= \vec{i}\left[\frac{\partial}{\partial y}(z) - \frac{\partial}{\partial z}(y)\right] - \vec{j}\left[\frac{\partial}{\partial x}(z) - \frac{\partial}{\partial z}(x)\right] + \vec{k}\left[\frac{\partial}{\partial x}(y) - \frac{\partial}{\partial y}(x)\right]$$ $$= \boldsymbol{0\vec{i} + 0\vec{j} + 0\vec{k} = \vec{0}}$$
12	**Prove that curl (grad $\emptyset$) $= \vec{0}$. (NOV/DEC-2008)** BTL5 $$grad\ \emptyset = \nabla\emptyset$$ $$= \vec{i}\frac{\partial\emptyset}{\partial x} + \vec{j}\frac{\partial\emptyset}{\partial y} + \vec{k}\frac{\partial\emptyset}{\partial z}$$ $$curl\ (grad\ \emptyset) = \nabla \times (\nabla\emptyset)$$

	$$= \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ \frac{\partial \emptyset}{\partial x} & \frac{\partial \emptyset}{\partial y} & \frac{\partial \emptyset}{\partial z} \end{vmatrix}$$ $$= \sum \vec{i}\left[\frac{\partial^2 \emptyset}{\partial y \partial z} - \frac{\partial^2 \emptyset}{\partial z \partial y}\right]$$ $$= \sum \overrightarrow{\vec{i}[0]}\ (Since\ mixed\ partial\ derivatives\ are\ equal)$$ $$= 0\vec{i} + 0\vec{j} + 0\vec{k} = \vec{0}$$
13	**In what direction from $(3, 1, -2)$ is the directional derivative of $\emptyset = x^2y^2z^4$ maximum? Find also the magnitude of this maximum.** BTL1 $\nabla \emptyset = \vec{i}\frac{\partial \emptyset}{\partial x} + \vec{j}\frac{\partial \emptyset}{\partial y} + \vec{k}\frac{\partial \emptyset}{\partial z}$ $= \vec{i}[2xy^2z^4] + \vec{j}[2x^2yz^4] + \vec{k}[4x^2y^2z^3]$ $\nabla \varphi_{(3,1,-2)} = \vec{i}\left[2(3)(1)(16)\right] + \vec{j}\left[2(9)(1)(16)\right] + \vec{k}\left[4(9)(1)(-8)\right]$ $= 96\vec{i} + 288\vec{j} - 288\vec{k}$ $= 96\left(\vec{i} + 3\vec{j} - 3\vec{k}\right)$ The directional derivative is maximum in the direction of $96\left(\vec{i} + 3\vec{j} - 3\vec{k}\right)$ Maximum value is $\lvert\nabla \varphi\rvert = \left\lvert 96\left(\vec{i} + 3\vec{j} - 3\vec{k}\right)\right\rvert$ $= \sqrt{92^2(1+9+9)}$ $= 96\sqrt{19}$
14	**Find the unit vector normal to the surface $x^2 + y^2 = z$ at $(1, -2, 5)$.** BTL1 Given $\phi = x^2 + y^2 - z$ Unit normal vector $\hat{n} = \frac{\nabla \phi}{\lvert\nabla \phi\rvert}$ ………… (1) $\nabla \phi = \vec{i}\frac{\partial \phi}{\partial x} + \vec{j}\frac{\partial \phi}{\partial y} + \vec{k}\frac{\partial \phi}{\partial z}$ $= \vec{i}[2x] + \vec{j}[2y] + \vec{k}[-1]$ $\nabla \phi_{(1,-2,5)} = \vec{i}[2] + \vec{j}[-4] + \vec{k}[-1]$ $= 2\vec{i} - 4\vec{j} - \vec{k}$ $\lvert\nabla \phi\rvert = \sqrt{2^2 + (-4)^2 + (-1)^2}$ $= \sqrt{4 + 16 + 1} = \sqrt{21}$ $\therefore (1) \Rightarrow \hat{n} = \frac{2\vec{i} - 4\vec{j} - \vec{k}}{\sqrt{21}}$

15	**Find the greatest rate of increase of $\emptyset = xyz^2$ at $(1,0,3)$.** BTL1 $\nabla\emptyset = \vec{i}\frac{\partial\emptyset}{\partial x} + \vec{j}\frac{\partial\emptyset}{\partial y} + \vec{k}\frac{\partial\emptyset}{\partial z}$ $= \vec{i}[yz^2] + \vec{j}[xz^2] + \vec{k}[2xyz]$ $\nabla\emptyset_{(1,0,3)} = 0\vec{i} + 9\vec{j} + 0\vec{k}$ ∴ Greatest rate of increase= $\lvert\nabla\emptyset\rvert = \sqrt{9^2} = 9$
16	**State the physical interpretation of the line integral. $\int_A^B \vec{F}.\vec{dr}$.** BTL1 Physically $\int_A^B \vec{F}.\vec{dr}$ denotes the total work done by the force$\vec{F}$, in displacing a particle from A to B along the curve C.
17	**Define Solenoidal vector function. If $\vec{V} = (x+3y)\vec{i} + (y-2z)\vec{j} + (x+2\lambda z)\vec{k}$ is Solenoidal, find the value of λ.** BTL1 If div$\vec{F}$= 0, then $\vec{F}$ is said to be Solenoidal vector. $\nabla.\vec{F} = 0$. $\nabla.\vec{V} = \frac{\partial}{\partial x}(x+3y) + \frac{\partial}{\partial y}(y-2z) + \frac{\partial}{\partial z}(x+2\lambda z)$ $= 1+1+2\lambda$ $= 2+2\lambda$ $\nabla.\vec{V} = 0$ $2+2\lambda = 0$ $\lambda = -1$
18	**Find grad$(r^n)$where $\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$and $r = \lvert\vec{r}\rvert$.** BTL1 We know that $\frac{\partial r}{\partial x} = \frac{x}{r}, \frac{\partial r}{\partial y} = \frac{y}{r}, \frac{\partial r}{\partial z} = \frac{z}{r}$ $grad\left(r^n\right) = \sum \vec{i}\frac{\partial r^n}{\partial x}$ $= \sum \vec{i}(nr^{n-1})\frac{\partial r}{\partial x}$ $= (nr^{n-2})\vec{r}$
19	**Find grad(r) and grad $(\frac{1}{r})$ where $\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$ and $\vec{r} = \lvert\vec{r}\rvert$.** BTL1

	$\nabla\phi = \Sigma\vec{i}\frac{\partial\phi}{\partial x} = \frac{\Sigma x\vec{i}}{r}$ $= \frac{\vec{r}}{r}$ $grad(\frac{1}{r}) = \Sigma\vec{i}\frac{\partial\left(\frac{1}{r}\right)}{\partial x} = \left(-\frac{1}{r^2}\right)\frac{\Sigma x\vec{i}}{r}$ $= \frac{-\vec{r}}{r^3}$
20	**Find the unit normal to the surface** $x^2 + xy + z^2 = 4\ at\ (1,-1,2)$ **.** BTL1 $\hat{n} = \frac{\nabla\phi}{\lvert\nabla\phi\rvert}$ $\nabla\phi = \Sigma\vec{i}\frac{\partial\phi}{\partial x}$ $Given:$ $x^2 + xy + z^2 = 4\ \ Point(1,-1,2)$ $\nabla\phi = \vec{i} + \vec{j} + 4\vec{k}$ $\lvert\nabla\phi\rvert = \sqrt{1+1+16} = \sqrt{18}$ $\hat{n} = \frac{\vec{i} + \vec{j} + 4\vec{k}}{3\sqrt{2}}$
21	**Prove by Green's theorem that the area bounded by a simple closed curve is** $\frac{1}{2}\int_c (xdy - ydx)$ BTL5 By Green's theorem: $\int_C udx + vdy = \iint_R \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)dxdy$ $u = \frac{-y}{2}, \mathrm{v} = \frac{v}{2} \Rightarrow \frac{\partial u}{\partial y} = \frac{-1}{2}, \frac{\partial v}{\partial x} = \frac{1}{2}$ Given that $\frac{1}{2}\int_C xdy - ydx = \iint_R \left(\frac{1}{2} + \frac{1}{2}\right)dxdy$ $= \iint_R dxdy.$ which a area bounded by a simple closed curve $'c'$

22	**Find** $\nabla\left[\nabla.\left(\left(x^2-yz\right)\vec{i}+\left(y^2-xz\right)\vec{j}+\left(z^2-xy\right)\vec{k}\right)\right]$ **at the point (1,-1,2).** BTL1 $\nabla.\vec{F}=\frac{\partial}{\partial x}(x^2-yz)+\frac{\partial}{\partial y}(y^2-xz)+\frac{\partial}{\partial z}(z^2-xy)$ $=2x+2y+2z$ $\nabla.\vec{F}_{(1,-1,2)}=2-2+4$ $=4$ $Grad(\nabla.\vec{F})=\nabla(\nabla.\vec{F})$ $=\vec{i}\frac{\partial}{\partial x}(2x)+\vec{j}\frac{\partial}{\partial y}(2y)+\vec{k}\frac{\partial}{\partial z}(2z)$ $=2\vec{i}+2\vec{j}+2\vec{k}$
23	**Find the directional directive of** $\phi(x,y,z)=xy^2+yz^2$ **at the point (2,-1,1) in the direction of the vector** $\vec{i}+2\vec{j}+3\vec{k}$ **.(DEC/JAN-2014)** BTL1 Directional derivative(D.D)= $\nabla\phi.\frac{\vec{a}}{\|\vec{a}\|}$ $Given:$ $\phi(x,y,z)=xy^2+z^2y,\quad \vec{a}=\vec{i}+2\vec{j}+3\vec{k}$ $\nabla\phi_{(1,-1,2)}=\vec{i}+2\vec{j}+4\vec{k},\quad \|\vec{a}\|=\sqrt{14}$ $D.D=(\vec{i}+2\vec{j}+4\vec{k}).\frac{(\vec{i}+2\vec{j}+3\vec{k})}{\sqrt{14}}$ $=\frac{17}{\sqrt{14}}.$
24	**If** $\vec{F}$ **is irrotational and C is closed curve then find the value of** $\int_c \vec{F}.d\vec{r}$ **.** BTL1 By Stokes theorem $\int_c \vec{F}.d\vec{r}=\iint_s\left(\nabla\times\vec{F}\right).\hat{n}ds$ $\text{Since }\vec{F}\text{ is irrotational}\therefore\nabla\times\vec{F}=0$ $\int_c \vec{F}.d\vec{r}=\iint_s\left(\nabla\times\vec{F}\right).\hat{n}ds$ $=\iint_s 0.\hat{n}ds$ $=0$
	Prove that $\nabla(\log r)=\frac{\vec{r}}{r^2}$. **(NOV/DEC-2014)**. BTL5

25	we have $\vec{r} = x\vec{i} + y\vec{j} + z\vec{k}$ and $r = \lvert\vec{r}\rvert = \sqrt{x^2+y^2+z^2}$ $r^2 = x^2+y^2+z^2,\ \frac{\partial r}{\partial x} = \frac{x}{r},\ \frac{\partial r}{\partial y} = \frac{y}{r},\ \frac{\partial r}{\partial z} = \frac{z}{r}$ $\nabla(\log r) = \vec{i}\,\frac{\partial(\log r)}{\partial x} + \vec{j}\,\frac{\partial(\log r)}{\partial y} + \vec{k}\,\frac{\partial(\log r)}{\partial z}$ $= \vec{i}\left(\frac{1}{r}\frac{\partial r}{\partial x}\right) + \vec{j}\left(\frac{1}{r}\frac{\partial r}{\partial y}\right) + \vec{k}\left(\frac{1}{r}\frac{\partial r}{\partial z}\right)$ $= \frac{1}{r}\left[\frac{x}{r}\vec{i} + \frac{y}{r}\vec{j} + \frac{z}{r}\vec{k}\right]$ $= \frac{1}{r^2}\left[x\vec{i} + y\vec{j} + z\vec{k}\right] = \frac{\vec{r}}{r^2}$
26	**If** $\vec{F} = (x^3)\vec{i} + (y^3)\vec{j} + (z^3)\vec{k}$ **then find div curl** $\vec{F}$. **(May/June-2018 R-17)** BTL1 $\nabla\times\vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x^3 & y^3 & z^3 \end{vmatrix} = 0$ Therefore **div curl** $\vec{F} = 0$
	PART-B
1.	**Prove that** $\nabla(r^n) = \mathrm{n}r^{n-2}\,\vec{r}.$ **(May/June 2003,2008)** **(8 M)** BTL5 **Answer : Refer Page No.2.5-Dr.M.CHANDRASEKAR** • $\frac{\partial r}{\partial x} = \frac{x}{r},\ \frac{\partial r}{\partial y} = \frac{y}{r},\ \frac{\partial r}{\partial z} = \frac{z}{r}.$ **(2 M)** • $\nabla(r^n) = \vec{i}\left(nr^{n-1}\frac{\partial r}{\partial x}\right) + \vec{j}\left(nr^{n-1}\frac{\partial r}{\partial y}\right) + \vec{k}\left(nr^{n-1}\frac{\partial r}{\partial z}\right)$ **(2 M)** • $\nabla(r^n) = \frac{nr^{n-1}}{r}\left[x\vec{i} + y\vec{j} + z\vec{k}\right] = nr^{n-2}\vec{r}$ **(4M)**
2.	**Prove that** $\mathrm{Curl}\,(\mathrm{Curl}\,\vec{\mathrm{F}}) = \nabla(div\,\vec{\mathrm{F}}) - \nabla^2\,\vec{\mathrm{F}}$**.** **(May/June 2003,2008) (8 M)** BTL5 **Answer : Refer Page No.2.36-Dr.M.CHANDRASEKAR**

	• $\nabla\times(\nabla\times\vec{F})=\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ \partial/\partial x & \partial/\partial y & \partial/\partial z\\ \frac{\partial F_3}{\partial y}-\frac{\partial F_2}{\partial z} & \frac{\partial F_1}{\partial z}-\frac{\partial F_3}{\partial x} & \frac{\partial F_2}{\partial x}-\frac{\partial F_1}{\partial y}\end{vmatrix}$ **(3M)** • $\nabla\times(\nabla\times\vec{F})=\sum\left\{\frac{\partial}{\partial x}(div\,\vec{\mathrm{F}})-\nabla^2\,\vec{\mathrm{F}}_1\right\}\vec{i}$ **(3M)** • For proving $\mathrm{Curl}\,(\mathrm{Curl}\,\vec{\mathrm{F}})=\nabla(div\,\vec{\mathrm{F}})-\nabla^2\,\vec{\mathrm{F}}$ **(2M)**
3.	**Prove that** $\vec{\mathrm{F}}=(y^2\cos x+\mathrm{z}^3)\,\vec{\mathrm{i}}+(2y\sin x-4)\,\vec{j}+3xz^2\,\vec{\mathrm{k}}$ **is irrotational and find its scalar potential. (8 M)** BTL5 **Answer : Refer Page No.2.33-Dr.M.CHANDRASEKAR** • $\nabla\times\vec{F}=\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ \partial/\partial x & \partial/\partial y & \partial/\partial z\\ y^2\cos x+\mathrm{z}^3 & 2y\sin x-4 & 3xz^2\end{vmatrix}=0$ **(2 M)** $\phi_1=y^2\sin x+xz^3+f(y,z)$ • $\phi_2=y^2\sin x-4y+f(x,z)$ **(4M)** $\phi_3=xz^3+f(x,y)$ • $\phi=y^2\sin x+xz^3-4y+c$ **.** **(2M)**
4.	**Prove that** $\vec{\mathrm{F}}=(6xy+\mathrm{z}^3)\,\vec{\mathrm{i}}+(3x^2-z)\,\vec{j}+(3xz^2-\mathrm{y})\,\vec{\mathrm{k}}$ **is irrotational and find its scalar potential.(NOV/DEC 2015,R-13)(8 M)** BTL5 **Answer : Refer Page No.2.32-Dr.M.CHANDRASEKAR** • $\nabla\times\vec{F}=\begin{vmatrix}\vec{i} & \vec{j} & \vec{k}\\ \partial/\partial x & \partial/\partial y & \partial/\partial z\\ (6xy+\mathrm{z}^3) & (3x^2-z) & (3xz^2-\mathrm{y})\end{vmatrix}=0$ **(2 M)** $\phi_1=3x^2y+xz^3+f(y,z)$ • $\phi_2=3x^2y-yz+f(x,z)$ **(4M)** $\phi_3=xz^3-yz+f(x,y)$

	• $\phi = 3x^2 y + xz^3 - yz + c$ **(2M)**
5.	**Prove that** $\vec{F} = (y^2 + 2xz^2)\vec{i} + (2xy - z)\vec{j} + (2zx^2 - y + 2z)\vec{k}$ **is irrotational and find its scalar potential. (8 M)** BTL5 **Answer : Refer Page No.2.47-Dr.M.CHANDRASEKAR** • $\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ (y^2 + 2xz^2) & (2xy - z) & (2zx^2 - y + 2z) \end{vmatrix} = 0$ **(2 M)** $\phi_1 = xy^2 + x^2 z^2 + f(y,z)$ • $\phi_2 = xy^2 - yz + f(x,z)$ **(4M)** $\phi_3 = x^2 z^2 + xy^2 - yz + f(x,y)$ • $\phi = x^2 z^2 + xy^2 - yz + c$ **(2M)**
6.	**Prove that** $\vec{F} = (y+z)\vec{i} + (z+x)\vec{j} + (x+y)\vec{k}$ **is irrotational and find its scalar potential. (8 M)** BTL5 **Answer : Refer Page No.2.46-Dr.M.CHANDRASEKAR** • $\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ (y+z) & (z+x) & (x+y) \end{vmatrix} = 0$ **(2 M)** $\phi_1 = xy + xz + f(y,z)$ • $\phi_2 = xy + yz + f(x,z)$ **(4M)** $\phi_3 = xz + yz + f(x,y)$ • $\phi = xz + xy + yz + c$ **(2M)**
7.	**Evaluate by Green's theorem** $\int_C (xy + x^2)dx + (x^2 + y^2)dy$ **where C is the square formed by** $x = -1, x = 1, y = -1, y = 1$ **(May/June 2016 R-13) (8 M)** BTL1 **Answer : Refer Page No.2.75-Dr.M.CHANDRASEKAR** • $\int_C udx + vdy = \iint_R \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right) dxdy$ **(4M)** $u = xy + x^2, \mathrm{v} = x^2 + y^2 \Rightarrow \frac{\partial u}{\partial y} = x, \frac{\partial v}{\partial x} = 2x$

	• $\int_C (xy+x^2)dx+(x^2+y^2)dy = \int_{-1}^{1}\int_{-1}^{1} x\,dx\,dy$ **(2M)** • $\int_C (xy+x^2)dx+(x^2+y^2)dy = 0$ **(2M)**
8.	**Verify Green's theorem $\int_C (xy+y^2)dx+(x^2)dy$ where C is the closed curve of the region bounded by $y=x$ and $y=x^2$ (May/June 2013 R-13) (8 M)** BTL3 **Answer : Refer Page No.2.78-Dr.M.CHANDRASEKAR** • $\int_C udx+vdy = \iint_R \left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)dxdy$ $u=xy+y^2, \text{v}=x^2 \Rightarrow \frac{\partial u}{\partial y}=x+2y, \frac{\partial v}{\partial x}=2x$ **(2M)** • $\iint_R \left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)dxdy = \int_0^1\int_y^{\sqrt{y}}(x-2y)dx\,dy = \frac{-1}{20}$ **(2M)** • $\int_C (xy+y^2)dx+(x^2)dy = \text{Along OA} + \text{Along AO} = \int_0^1 (x^4+3x^3)dx + \int_1^0 (3x^2)dx$ **(2M)** • $\int_C (xy+y^2)dx+(x^2)dy = \frac{19}{20}-1=\frac{-1}{20}$ **(2M)**
9.	**Verify Green's theorem $\int_C (x^2-xy^3)dx+(\text{y}^2-2\,\text{xy})dy$ where C is the square with vertices (0,0),(2,0),(2,2),(0,2) (May/June 2003) (8 M)** BTL3 **Answer : Refer Page No.2.80-Dr.M.CHANDRASEKAR** • $\int_C udx+vdy = \iint_R \left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)dxdy$ $u=x^2-xy^3, \text{v}=\text{y}^2-2\,\text{xy} \Rightarrow \frac{\partial u}{\partial y}=-3xy^2, \frac{\partial v}{\partial x}=-2y$ **(2M)** • $\iint_R \left(\frac{\partial v}{\partial x}-\frac{\partial u}{\partial y}\right)dxdy = \int_0^2\int_0^2 (3x\,y^2-2y)dx\,dy = 8$ **(2M)**

	• $\int_C (x^2 - xy^3)dx + (y^2 - 2xy)dy = \text{Along OA} + \text{Along AB} + \text{Along BC} + \text{Along CO}$ $= \int_0^2 (x^2)dx + \int_0^2 (y^2 - 4y)dy + \int_2^0 (x^2 - 8x)dx + \int_2^0 (y^2)dy$ **(2M)** • $\int_C (x^2 - xy^3)dx + (y^2 - 2xy)dy = \frac{8}{3} - \frac{16}{3} + \frac{40}{3} - \frac{8}{3} = 8$ **(2M)**
10.	**Evaluate by Green's theorem $\int_C (y - \sin x)dx + (\cos x)dy$ where C is the triangle OAB where $O = (0,0), A = \left(\frac{\pi}{2}, 0\right), B = \left(\frac{\pi}{2}, 1\right)$ (May/June 2015 R-13) (8 M)** BTL3 **Answer : Refer Page No.2.82-Dr.M.CHANDRASEKAR** • $\int_C udx + vdy = \iint_R \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)dxdy$ $u = y - \sin x, v = \cos x \Rightarrow \frac{\partial u}{\partial y} = 1, \frac{\partial v}{\partial x} = -\sin x$ **(4M)** • $\int_C (y - \sin x)dx + (\cos x)dy = \int_0^{\frac{\pi}{2}} \int_0^{\frac{2x}{\pi}} (-\sin x - 1)\, dx\, dy$ **(2M)** • $\int_C (y - \sin x)dx + (\cos x)dy = -\left(\frac{\pi^2 + 8}{4\pi}\right)$ **(2M)**
11.	**Apply Green's theorem to evaluate $\int_C (3x^2 - 8y^2)dx + (4y - 6xy)dy$ where C is the boundary of the region defined by x=0,y=0 and x+y=1 (NOV/DEC 2014 R-13) (8 M)** BTL3 **Answer : Refer Page No.2.83-Dr.M.CHANDRASEKAR** • $\int_C udx + vdy = \iint_R \left(\frac{\partial v}{\partial x} - \frac{\partial u}{\partial y}\right)dxdy$ $u = -8y^2 + 3x^2, v = 4y - 6xy \Rightarrow \frac{\partial u}{\partial y} = -16y, \frac{\partial v}{\partial x} = -6y$ **(4M)** • $\int_C (3x^2 - 8y^2)dx + (4y - 6xy)dy = \int_0^1 \int_0^{1-y} 10y\, dx\, dy$ **(2M)** • $\int_C (3x^2 - 8y^2)dx + (4y - 6xy)dy = \frac{5}{3}$ **(2M)**

12.	**Verify Gauss Divergence theorem** $\vec{F} = xy^2\vec{i} + yz^2\vec{j} + zx^2\vec{k}$ over **the region bounded by** $x=0, x=1, y=0, y=2, z=0, z=3$ **(May/June 2012 R-08)** **(16 M)** BTL3 **Answer : Refer Page No.2.96-Dr.M.CHANDRASEKAR** • $\iint_S \vec{F}.\hat{n}\,ds = \iiint_V \nabla.\vec{F}dv$ **(2M)** • $\nabla.\vec{F} = y^2 + x^2 + z^2$ **(2M)** • $\iiint_V \nabla.\vec{F}dv = \int_0^3\int_0^2\int_0^1 (y^2+x^2+z^2)dxdydz = 28$ **(4M)** • $\iint_S \vec{F}.\hat{n}\,ds = 8+0+18+0+2+0 = 28$ **(8M)**
13.	**Verify Gauss Divergence theorem** $\vec{F} = (x^2-yz)\vec{i} + (y^2-zx)\vec{j} + (z^2-xy)\vec{k}$ over **the rectangular Parallelopiped** $0 \le x \le a,\ 0 \le y \le b,\ 0 \le z \le c$ **(May/June 2009 R-08)** **(16 M)** BTL3 **Answer : Refer Page No.2.99-Dr.M.CHANDRASEKAR** • $\iint_S \vec{F}.\hat{n}\,ds = \iiint_V \nabla.\vec{F}dv$ **(2M)** • $\nabla.\vec{F} = 2x+2y+2z$ **(2M)** • $\iiint_V \nabla.\vec{F}dv = 2\int_0^c\int_0^b\int_0^a (x+y+z)dxdydz = abc(\mathrm{a+b+c})$ **(4M)** • $\iint_S \vec{F}.\hat{n}\,ds = \left(a^2bc - \frac{b^2c^2}{4}\right) + \left(\frac{b^2c^2}{4}\right) + \left(b^2ac - \frac{a^2c^2}{4}\right) + \left(\frac{a^2c^2}{4}\right) + \left(c^2ba - \frac{b^2a^2}{4}\right) + \left(\frac{b^2a^2}{4}\right)$ **(8M)** $\iint_S \vec{F}.\hat{n}\,ds = abc(\mathrm{a+b+c})$
14.	**Verify Gauss Divergence theorem for** $\vec{F} = x^3\vec{i} + y^3\vec{j} + z^3\vec{k}$ over **the cube bounded by** $x=0, x=a, y=0, y=a, z=0, z=a$ **(May/June 2014 R-13) (May/June-2018 R-17)** **(16 M)** BTL3 **Answer : Refer Page No.2.106-Dr.M.CHANDRASEKAR**

	• $\iint_S \vec{F}.\hat{n}\,ds = \iiint_V \nabla.\vec{F}dv$ **(2M)** • $\nabla.\vec{F} = 3y^2 + 3x^2 + 3z^2$ **(2M)** • $\iiint_V \nabla.\vec{F}dv = \int_0^a\int_0^a\int_0^a (3y^2 + 3x^2 + 3z^2)dxdydz = 3a^5$ **(4M)** • $\iint_S \vec{F}.\hat{n}\,ds = a^5 + 0 + a^5 + 0 + a^5 + 0 = 3a^5$ **(8M)**
15.	**Verify Gauss Divergence theorem for** $\vec{F} = 4xz\vec{i} - y^2\vec{j} + zy\vec{k}$ over **the region bounded by** $x = 0, x = 1, y = 0, y = 1, z = 0, z = 1$ **(May/June 2012 R-08) (16 M)** BTL3 **Answer : Refer Page No.2.109-Dr.M.CHANDRASEKAR** • $\iint_S \vec{F}.\hat{n}\,ds = \iiint_V \nabla.\vec{F}dv$ **(2M)** • $\nabla.\vec{F} = 4z - y$ **(2M)** • $\iiint_V \nabla.\vec{F}dv = \int_0^1\int_0^1\int_0^1 (4z - y)dxdydz = \frac{3}{2}$ **(4M)** • $\iint_S \vec{F}.\hat{n}\,ds = 2 + 0 - 1 + 0 + \frac{1}{2} + 0 = \frac{3}{2}$ **(8M)**
16.	**Verify Gauss Divergence theorem for** $\vec{F} = y\vec{i} + x\vec{j} + z^2\vec{k}$ over **the cylindrical region bounded by** $x^2 + y^2 = 9, z = 0$ and $z = 2$ **(Dec/Jan 2015 R-13) (16 M)** BTL3 **Answer : Refer Page No.2.103-Dr.M.CHANDRASEKAR** • $\iint_S \vec{F}.\hat{n}\,ds = \iiint_V \nabla.\vec{F}dv$ **(2M)** • $\nabla.\vec{F} = 2z$ **(2M)** • $\iiint_V \nabla.\vec{F}dv = \int_{-3}^{3}\int_{-\sqrt{9-x^2}}^{\sqrt{9-x^2}}\int_0^2 2z\ dxdydz = 36\pi$ **(4M)** • $\iint_S \vec{F}.\hat{n}\,ds = 0 + 36\pi + 0 = 36\pi$ **(8M)**
17.	**Verify Stokes theorem for** $\vec{F} = (x^2 + y^2)\vec{i} - 2xy\vec{j}$ **taken around the rectangle bounded by** $x = \pm a, y = 0, y = b$ **(May/June 2004) (16 M)** BTL3 **Answer : Refer Page No.2.122-Dr.M.CHANDRASEKAR**

	• $\int_C \overrightarrow{F}.\overrightarrow{dr} = \iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds$ **(2M)** • $\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ (x^2+y^2) & -2xy & 0 \end{vmatrix} = -4y\vec{k}$ **(2M)** • $\iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds = \int_0^b \int_{-a}^{a} (-4\,\mathrm{y})dxdy = -4ab^2$ **(4M)** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = AB+BC+CD+DA = \left(\frac{2a^3}{3}\right) - \left(ab^2\right) - \left(2ab^2 + \frac{2a^3}{3}\right) - \left(ab^2\right) = -4ab^2$ **(8 M)**
18.	**Verify Stokes theorem for** $\vec{\mathrm{F}} = (x^2-y^2)\vec{i} + 2xy\vec{j}$ **taken around the rectangle bounded by** $x=0, x=a, y=0, y=b$ **(May/June 2004) (16 M)** BTL3 **Answer : Refer Page No.2.124-Dr.M.CHANDRASEKAR** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = \iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds$ **(2M)** • $\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ (x^2-y^2) & 2xy & 0 \end{vmatrix} = 4y\vec{k}$ **(2M)** • $\iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds = \int_0^b \int_0^a (4\,\mathrm{y})dxdy = 2ab^2$ **(4M)** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = OA+AB+BC+CO = \left(\frac{a^3}{3}\right) + \left(ab^2\right) + \left(ab^2 - \frac{a^3}{3}\right) + \left(0\right) = 2ab^2$ **(8 M)**
19.	**Verify Stokes theorem for** $\vec{\mathrm{F}} = x^2\vec{i} + xy\vec{j}$ **integrated around the square in z=0 plane whose sides are along the lines** $x=0, x=a, y=0, y=a$ **(May/June 2008) (16 M)** BTL3 **Answer : Refer Page No.2.126-Dr.M.CHANDRASEKAR** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = \iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds$ **(2M)**

	• $\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ x^2 & xy & 0 \end{vmatrix} = y\vec{k}$ **(2M)** • $\iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds = \int_0^a \int_0^a (\mathrm{y}) dxdy = \frac{a^3}{2}$ **(4M)** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = OA + AB + BC + CO = \left(\frac{a^3}{3}\right) + \left(\frac{a^3}{2}\right) + \left(-\frac{a^3}{3}\right) = \left(\frac{a^3}{2}\right)$ **(8 M)**
20.	**Verify Stokes theorem for $\vec{\mathrm{F}} = (y-z+2)\vec{i} + (yz+4)\vec{j} - xz\vec{k}$ where S is the open surface of the cube $x=0, x=2, y=0, y=2, z=0, z=2$ above the xy-plane (May/June 2005) (May/June-2018 R-17) (16 M)** BTL3 **Answer : Refer Page No.2.132-Dr.M.CHANDRASEKAR** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = \iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds$ **(2M)** • $\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ y-z+2 & yz+4 & -xz \end{vmatrix} = -y\vec{i} + (z-1)\vec{j} - \vec{k}$ **(2M)** • $\iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds = (-4)+(4)+(4)+(-4)+(-4) = -4$ **(4M)** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = OA + AC + CB + BO = (4)+(8)+(-8)+(-8) = (-4)$ **(8 M)**
21.	**Using Stokes theorem to Evaluate $\int_C \overrightarrow{F}.\overrightarrow{dr}$ where $\vec{\mathrm{F}} = (y^2)\vec{i} + (\mathrm{x}^2)\vec{j} - (x+z)\vec{k}$ and C is the boundary of the triangle with vertices (0,0,0), (1,0,0) and (1,1,0) (8 M)** BTL3 **Answer : Refer Page No.2.137-Dr.M.CHANDRASEKAR** • $\int_C \overrightarrow{F}.\overrightarrow{dr} = \iint_S (\nabla \times \overrightarrow{F}).\ \hat{n}\, ds$ **(2M)** • $\nabla \times \vec{F} = \begin{vmatrix} \vec{i} & \vec{j} & \vec{k} \\ \partial/\partial x & \partial/\partial y & \partial/\partial z \\ y^2 & x^2 & -(x+z) \end{vmatrix} = \vec{j} + 2(x-y)\vec{k}$ **(2M)**

	• $\iint_S (\nabla\times\overrightarrow{F}).\ \hat{n}\,ds = \int_0^1\int_0^x 2(\mathrm{x}-\mathrm{y})\,dydx = \frac{1}{3}$ **(4M)**
	UNIT-III ANALYTIC FUNCTIONS
	Analytic functions – Necessary and sufficient conditions for analyticity in Cartesian and polar coordinates – Properties – Harmonic conjugates – Construction of analytic function – Conformal mapping – Mapping by $w = z+c, cz, \frac{1}{z}, z^2$ – Bilinear transformation
	PART-A
1.	**Show that the function $f(z)=\bar{z}$ is no where differentiable. (DEC/JAN-2013) (NOV/DEC-2015)** BTL2 Given $w = f(z) = \bar{z}$ $\therefore u+iv = x-iy \Rightarrow u = x, v = -y$ $u_x = 1, v_x = 0$ $u_y = 1, v_y = -1$ $\therefore u_x \neq v_y$ So C-R equations are not satisfied for any x and y. $\therefore f(z)$ is not differentiable anywhere.Hence not analytic anywhere.
2	**Test the analyticity of the function** $w=\sin z$. BTL4 Given $w = \sin z$ $u+iy = \sin(x+iy)$ $= \sin x\cos iy + \cos x\sin(iy)$ $= \sin x\cosh y + i\cos x\sinh y$ $\Rightarrow\ u = \sin x\cosh y\ ;\quad v = \cos x\sinh y$ $\therefore\ u_x = \cos x\cosh y;\quad v_x = -\sin x\sinh y$ $u_y = \sin x\sinh y\ ;\quad v_y = \cos x\cosh y$ $\therefore u_x = v_y,\quad u_y = -\ v_x$ So C-R equations are satisfied forall any x and y and $u_x, ,u_y, v_x, v_y$ are continuous $\therefore f(z)$ is analytic everywhere.
3	**Find the constants a,b,c if $f(z) = x+ay+i(bx+cy)$ is analytic. (DEC/JAN-2014)** BTL1 Let $u+iv = f(z)$ Since $f(z)$ is analytic, u and v satisfy the C-R Equations.

	$u_x = v_y, \quad u_y = -v_x$ $here\, u = x + ay, v = bx + cy$ $u_x = 1, \; v_x = b$ $u_y = a, \; v_y = c$ $\therefore u_x = v_y \Rightarrow c = 1;$ $u_y = -v_x \Rightarrow a = -b$
4	**Show that** $u = 2x - x^3 + 3xy^2$ **is harmonic** BTL2 Given $u = 2x - x^3 + 3xy^2$ $u_x = 2 - 3x^2 + 3y^2; u_y = 6xy$ $u_{xx} = -6x; \qquad u_{yy} = 6x$ $\therefore u_{xx} + u_{yy} = -6x + 6x = 0.$ Therefore u is harmonic
5	**Show that the function** $u = y + e^x \cos y$ **is harmonic.** BTL2 Given $u = y + e^x \cos y$ $u_x = e^x \cos y, \; u_y = 1 + e^x(-\sin y)$ $u_{xx} = e^x \cos y, \; u_{yy} = -e^x \cos y$ $u_{xx} + u_{yy} = e^x \cos y - e^x \cos y = 0$ Therefore u is harmonic
6	**Show that** $x^2 + iy^3$ **is not analytic anywhere.** BTL2 Let $u + iv = x^2 + iy^3$ $\therefore u = x^2, \quad v = y^3$ $u_x = 2x, \; v_x = 0$ $u_y = 0, \; v_y = 3y^2$ $\therefore u_x \neq v_y, \; u_y = -v_x$ $\therefore$ The function is not analytic. But, when $x = 0, y = 0$ the C-R Equations are satisfied.
7	**For the conformal mapping** $f(z) = z^2$, **find the scale factor at** $z = i$. BTL1 Given

	$f(z)=z^2,$ $\therefore f'(z)=2z$ Scale factor at $z=i$ is $\|f'(i)\|=\|2i\|=2$
8	**Find the image of $x=2$ under the transformation** $w=\frac{1}{z}$. BTL1 Given $w=\frac{1}{z}\Rightarrow z=\frac{1}{w}=\frac{\bar{w}}{w\bar{w}}$ $\Rightarrow \quad x+iy=\frac{u-iv}{u^2+v^2}$ $\therefore x=\frac{u}{u^2+v^2}$ $\therefore$ The image of $x=2$ *is* $\frac{u}{u^2+v^2}=2\Rightarrow u^2+v^2-\frac{u}{2}=0$ which is a circle in the w – plane.
9	**Find the image of $x=k$ under the transformation** $w=\frac{1}{z}$**.** BTL1 Given $w=\frac{1}{z}\Rightarrow z=\frac{1}{w}=\frac{\bar{w}}{w\bar{w}}$ $\Rightarrow \quad x+iy=\frac{u-iv}{u^2+v^2}$ $\therefore x=\frac{u}{u^2+v^2}$ $\therefore$ The image of $x=k$ is $\frac{u}{u^2+v^2}=k\Rightarrow u^2+v^2-\frac{u}{k}=0$ which is a circle in the w – plane
10	**Find the image of the circle $\|z\|=2$ under the transformation** $w=3z$ **.(NOV/DEC-2014)** BTL1 Given $w=3z$ $\|w\|=3\|z\|$ $=3\times 2$ $=6$ $\therefore$ The image of the circle $\|z\|=2$ is the circle $\|w\|=6$ in the w-plane. $\therefore \sqrt{u^2+v^2}=6,$ $\Rightarrow u^2+v^2=36,$ which is a circle
11	**Find the image of the circle $\|z\|=2$ under the transformation** $w=z+3+2i$**.** BTL1 Given $w=z+3+2i$

	$u+iv=x+iy+3+2i$ $\therefore\ u=x+3 \Rightarrow\ x=u-3$ $v=y+2 \Rightarrow\ y=v-2$ $\lvert z\rvert=2 \Rightarrow \sqrt{x^2+y^2}=2$ $\Rightarrow\ x^2+y^2=4$ $\Rightarrow (u-3)^2+(v-2)^2=4$
12	**Find the image of the line** $x-y+1=0$ **under the map** $\mathrm{w}=\frac{1}{z}$**.** BTL1 Given $\mathrm{w}=\frac{1}{z} \Rightarrow z=\frac{1}{\mathrm{w}}=\frac{\bar{w}}{w\bar{w}}$ $\Rightarrow\ x+iy=\frac{u-iv}{u^2+v^2}$ $\therefore x=\frac{u}{u^2+v^2}\ , y=\frac{-v}{u^2+v^2}$ The image of the line $x-y+1=0$ is $\frac{u}{u^2+v^2}+\frac{v}{u^2+v^2}+1=0$ $\Rightarrow u^2+v^2+u+v=0$ which is a circle in the $\mathrm{w}-$plane
13	**Findthe fixed points of the transformation** $\mathrm{w}=\frac{6z-9}{z}$**.** BTL1 The given transformation $\mathrm{w}=\frac{6z-9}{z}$. The fixed points are given points by $\mathrm{w}=z$ $\Rightarrow\ z=\frac{6z-9}{z}$ $\Rightarrow\ z^2=6z-9$ $\Rightarrow\ z^2-6z-9=0$ $\Rightarrow\ (z-3)^2=0$ $\Rightarrow\ z=3,3$
14	**Find the fixed points of the mapping** $\mathrm{w}=\frac{3-z}{1+z}$**.** BTL1 The given maps $\mathrm{w}=\frac{3-z}{1+z}$ The fixed points are given by $\mathrm{w}=z$

	$\therefore \quad z=\dfrac{3-z}{1+z} \Rightarrow z+z^2=3-z$ $\Rightarrow z+z^2-3+z=0$ $\Rightarrow z^2+2z-3=0$ $\Rightarrow (z+3)(z-1)=0$ $\Rightarrow z=-3,1$
15	**Find the fixed points of the mapping** $w=\dfrac{2z+6}{z+7}$**. (DEC/JAN-2015)** BTL1 The given map is $w=\dfrac{2z+6}{z+7}$. The fixed points are given by $w=z$ $\therefore \quad z=\dfrac{2z+6}{z+7} \Rightarrow 7z+z^2=2z+6$ $\Rightarrow 7z+z^2-2z+6=0$ $\Rightarrow z^2+5z-6=0$ $\Rightarrow (z+6)(z-1)=0$ $\Rightarrow z=1,-6$
16	**Find the bilinear map which maps points** $\infty, i, 0$ **of the z plane onto** $0, i, \infty$ **of the w-plane.** BTL1 Given $z_1=\infty, z_2=i, z_3=0$ which are mapped onto $w_1=0, w_2=i, w_3=\infty$ Since $z_1=\infty$ & $w_3=\infty$, omitting the factors involving z_1 & w_3 The Bilinear map is, $\dfrac{w-w_1}{w_2-w_1}=\dfrac{z_2-z_3}{z-z_3}$ $\dfrac{w-0}{i-0}=\dfrac{i-0}{z}$ $\Rightarrow w=-\dfrac{1}{z}$
17	**Define the Conformal Mapping**. BTL1 A transformation that preserves angles between every pair of curves through a Point, both in magnitude and sense, is said to be conformal at that point.
18	**State sufficient condition for analytic function. (DEC/JAN-2016)** BTL1 If the partial derivatives u_x, u_y, v_x, and v_y areall continuous in D and $u_x=v_y$, $u_y=-v_x$. Then the function *f(z)*is analytic in a domain D.
19	**Find the constants a, b if $f(z)=x+2ay+i(3x+by)$ is analytic.** BTL1 Given $f(z)=x+2ay+i(3x+by)$ is analytic.

	$\Rightarrow u_x = v_y,\ \ u_y = -v_x$ ....(1) Here $u = x + 2ay$ and $v = 3x + by$ Thus (1) gives $1 = b$ and $2a = -3$ $\Rightarrow a = -\frac{3}{2}$ and $b = -1$
20	**State the Cauchy Riemann equations in polar coordinates satisfied by an analytic Function.** BTL1 Cauchy Riemann equations in polar coordinates are given by $u_r = \frac{1}{r} v_\theta$ and $v_r = -\frac{1}{r} u_\theta$ where u and v are functions of r *and* θ.
21	**Find the critical points of the transformation $w = 1 + \frac{2}{z}$. (NOV/DEC-2016)** BTL1 The critical points of the transformation are obtained by $f'(z) = 2z$ $Hence\ -\frac{2}{z^2} = 0$ $\Rightarrow -\frac{2}{0} = z^2$ $\Rightarrow z = \infty$ is the critical point of the given transformation.
22	**Find the image of the region $x > c$, where $c > 0$ under the transformation $w = \frac{1}{z}$.** BTL1 $w = \frac{1}{z}. \Rightarrow z = \frac{1}{w}$ Let $z = x + iy$ and $w = u + iv$ $x + iy = \frac{1}{u+iv} = \frac{u-iv}{(u+iv)(u-iv)} = \frac{u-iv}{u^2+v^2}$ $\therefore x = \frac{u}{u^2+v^2}$ *and* $y = \frac{-v}{u^2+v^2}$ $x > c \Rightarrow x = \frac{u}{u^2+v^2} > c$ $u > cu^2 + cv^2$ $u^2 + v^2 < \frac{u}{c}$ $u^2 + v^2 - \frac{u}{c} < 0.$ This refers to the inside of the circle center $(\frac{1}{2c}, 0)$ and radius $\frac{1}{2c}$.
23	**Show that an analytic function with constant real part is constant.** BTL2 Let $f(z) = u + iv$ be analytic. $\Rightarrow u_x = v_y$ *and* $u_y = -v_x$ Given that $u = constant. = c(say). \Rightarrow u_x = 0$ *and* $v_y = 0 \Rightarrow u_y = 0$ *and* $-v_x = 0$ $\Rightarrow$v is independent of x and y.$\Rightarrow v$ is constant $\Rightarrow f(z) = u + iv = c + ic$ is a constant.

24	**Find the critical points of the transformation $w^2 = (z-\alpha)(z-\beta)$.(DEC/JAN-2010) (NOV/DEC-2016)** BTL1 Let $w^2 = (z-\alpha)(z-\beta)$. Then, $2w\frac{dw}{dz} = (z-\alpha).1 + (z-\beta).1$ The Critical points of $w = f(z)$ is given by, $\frac{dw}{dz} = 0 \Rightarrow (z-\alpha).1 + (z-\beta).1=0 \quad \Rightarrow z = \frac{\alpha+\beta}{2}$. Also, $\frac{dz}{dw} = 0 \Rightarrow \frac{2w}{(z-\alpha)+(z-\beta)} = 0. \Rightarrow w = 0, (z-\alpha)+(z-\beta) = 0 \Rightarrow z = \alpha,\beta$. The critical points are $z = \alpha,\beta,\frac{\alpha+\beta}{2}$.
25	**Write cross ratio of four points. (NOV/DEC-2018)** BTL1 The cross ratio of four points. $\frac{(w_1-w_2)(w_3-w_4)}{(w_2-w_3)(w_4-w_1)} = \frac{(z_1-z_2)(z_3-z_4)}{(z_2-z_3)(z_4-z_1)}$ is invariant under the bilinear transformation
26	**Verify f(z)= z^3 is analytic or not.** BTL3 Let $f(z) = u + iv = z^3 = (x+iy)^3$ $u + iv = (x^3 - 3xy^2) + i(3x^2y - y^3)$ $u = (x^3 - 3xy^2)$ and $v = (3x^2y - y^3)$ $u_x = (3x^2 - 3y^2)$ *and* $u_y = -6xy$ $v_x = 6xy$ *and* $v_y = (3x^2 - 3y^2)$ $u_x = v_y$ and $u_y = -v_x$. Hence the C-R Equations are satisfied. Therefore f(z)= z^3 is analytic
27	**If $f(z) = u + iv$ is an analytic function , prove that u is a harmonic function.** BTL5 $f(z) = u + iv$ be analytic. $\frac{\partial u}{\partial x} = \frac{\partial v}{\partial y}$; $\quad \frac{\partial u}{\partial y} = \frac{-\partial v}{\partial x}$ … … … … … (1) Now, $\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} = \frac{\partial}{\partial x}\left(\frac{\partial u}{\partial x}\right) + \frac{\partial}{\partial y}\left(\frac{\partial u}{\partial y}\right) = \frac{\partial}{\partial x}\left(\frac{\partial v}{\partial y}\right) + \frac{\partial}{\partial y}\left(\frac{-\partial v}{\partial x}\right)$ (since by (1)) $= \frac{\partial^2 v}{\partial x \partial y} - \frac{\partial^2 v}{\partial y \partial x} = 0$ $\therefore u$ is harmonic
28	**If $f(z) = r^2(\cos 2\theta + i \sin p\theta)$ is an analytic function ,then find the value of p (MAY/JUNE 2018 R-17)** BTL5 C-R Equations are $u_r = \left(\frac{1}{r}\right)v_\theta$, $u_\theta = -rv_r$ $u_r = 2r\cos 2\theta,\ u_\theta = -2r^2 \sin 2\theta$ $v_r = 2r\sin p\theta,\ u_\theta = pr^2 \cos p\theta$ $\Rightarrow p = 2$

29	**Examine whether the function $u = xy^2$ can be real part of an analytic function (MAY/JUNE 2018 R-17)** BTL5 Here $u_{xx} + u_{yy} = 0 - 2x = -2x \neq 0$ It couldn't satisfies harmonic condition. Hence $u = xy^2$ cannot be real part of an analytic function
	PART-B
1.	**If $f(z)$ is an analytic function, Prove that $\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\left\|f(z)\right\|^2 = 4\left\|f'(z)\right\|^2$ (NOV/DEC 2014) (8 M)** BTL5 **Answer : Refer Page No.3.31-Dr.M.CHANDRASEKAR** • C-R Equations are $u_x = v_y$, $u_y = -v_x$ **(2M)** • $\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\left\|f(z)\right\|^2 = 2\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial x}\right)^2 + \left(\frac{\partial u}{\partial y}\right)^2 + \left(\frac{\partial v}{\partial y}\right)^2\right]$ **(4M)** • $\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\left\|f(z)\right\|^2 = 4\left[\left(\frac{\partial u}{\partial x}\right)^2 + \left(\frac{\partial v}{\partial x}\right)^2\right] = 4\left\|f'(z)\right\|^2$ **(2M)**
2.	**If $f(z) = u + iv$ is analytic, Prove that $\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\log\left\|f(z)\right\| = 0$.(MAY/JUNE 2002) (8M)** BTL5 **Answer : Refer Page No.3.33-Dr.M.CHANDRASEKAR** • C-R Equations are $u_x = v_y$, $u_y = -v_x$ **(2M)** • $\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\log\left\|f(z)\right\| = \frac{(u^2+v^2)[u_x^2 + v_x^2 + u_y^2 + v_y^2 + u(u_{xx} + u_{yy}) + v(v_{xx} + v_{yy}) - 2[(uu_x + vv_x)^2 + (uu_y + vv_y)^2]}{(u^2+v^2)^2}$ **(4M)** • Since the function f(z) is analytic, it satisfies C-R equations and hence the function is harmonic. **(2 M)** $\therefore \left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}\right)\log\left\|f(z)\right\| = 0$
3.	**Prove that** $u = x^2 - y^2, v = \frac{-y}{x^2+y^2}$ are harmonic but $u + iv$ **is not regular function.**

	(NOV/DEC 2013) (8 M) BTL5 **Answer : Refer Page No.3.44-Dr.M.CHANDRASEKAR** • For Proving u is harmonic $u_{xx}+u_{yy}=2-2=0$ **(2M)** • For Proving v is harmonic $v_{xx}+v_{yy}=\left(\frac{2y^3-6x^2y}{(x^2+y^2)^3}\right)+\left(-\frac{\left(2y^3-6x^2y\right)}{(x^2+y^2)^3}\right)=0$ **(2 M)** • But $u_x\neq v_y$, $u_y\neq -v_x \Rightarrow f(z)=u+iv$ is not a regular function. **(2 M)**
4.	**If** $f(z)=u+iv$ **is analytic, Prove that** $\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\left\|u\right\|^p=p(p-1)(u^{p-2})\left\|f^{'}(z)\right\|^2$ **(MAY/JUNE 2002) (MAY/JUNE 2018 R-17) (8 M)** BTL5 **Answer : Refer Page No.3.36-Dr.M.CHANDRASEKAR** • C-R Equations are $u_x=v_y$, $u_y=-v_x$ **(2M)** • $\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\left\|u\right\|^p=pu^{p-1}\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+(p-1)pu^{p-2}\left(\left(\frac{\partial u}{\partial x}\right)^2+\left(\frac{\partial u}{\partial y}\right)^2\right)$ **(4M)** • $\left(\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}\right)\left\|u\right\|^p=p(p-1)(u^{p-2})\left\|f^{'}(z)\right\|^2$ **(2M)**
5.	**In a two dimensional flow, the stream function is** $\psi=\tan^{-1}\left(\frac{y}{x}\right)$ **Find the velocityPotential** ϕ **. (NOV/DEC 2016) (8 M)** BTL1 **Answer : Refer Page No.3.50-Dr.M.CHANDRASEKAR** • $\frac{\partial\psi}{\partial x}=\frac{-y}{x^2+y^2}$; $\frac{\partial\psi}{\partial y}=\frac{x}{x^2+y^2}$ **(2M)** • $\phi=\int\left(\frac{\partial\psi}{\partial y}dx-\frac{\partial\psi}{\partial x}dy\right)$ **(2 M)** • $\phi=\log(x^2+y^2)+\mathrm{c}$ **(4M)**
6.	**Show that the function** $u=\frac{1}{2}\log(x^2+y^2)$ **is harmonic and find its harmonic conjugate (MAY/JUNE 2016) (8 M)** BTL2 **Answer : Refer Page No.3.52-Dr.M.CHANDRASEKAR**

	• $\frac{\partial u}{\partial x}=\frac{x}{x^2+y^2}$; $\frac{\partial u}{\partial y}=\frac{y}{x^2+y^2}$ **(2M)** • For Proving u is harmonic $u_{xx}+u_{yy}=\left(\frac{y^2-x^2}{(x^2+y^2)^2}\right)+\left(-\frac{y^2-x^2}{(x^2+y^2)^2}\right)=0$ **(2 M)** • $\text{v}=\tan^{-1}\left(\frac{y}{x}\right)+c$ **(4M)**
7.	**Prove that $e^x[x\cos y-y\sin y]$ can be the real part of an analytic function and determineits harmonic conjugate (NOV/DEC 2013) (8 M)** BTL5 **Answer : Refer Page No.3.55-Dr.M.CHANDRASEKAR** • $\frac{\partial u}{\partial x}=e^x x\cos y+e^x\cos y-e^x y\sin y$ $\frac{\partial u}{\partial y}=-e^x x\sin y-e^x\ \text{y}\cos y-e^x\sin y$ **(2M)** • For Proving u is harmonic $u_{xx}+u_{yy}=\left(e^x x\cos y+2e^x\cos y-e^x y\sin y\right)+\left(-e^x x\cos y-2e^x\cos y+e^x y\sin y\right)=0$ **(2 M)** • $\text{v}=e^x x\sin y+e^x\ \text{y}\cos y+c$ **(4M)**
8.	**Find an analytic function $f(z)=u+iv$ whose real part is $e^x[x\cos y-y\sin y]$ (8 M)** BTL1 **Answer : Refer Page No.3.64-Dr.M.CHANDRASEKAR** • $\frac{\partial u}{\partial x}=e^x x\cos y+e^x\cos y-e^x y\sin y$ $\frac{\partial u}{\partial y}=-e^x x\sin y-e^x\ \text{y}\cos y-e^x\sin y$ **(2M)** • $\frac{\partial u}{\partial x}(\text{z},0)=e^z+ze^z$ $\frac{\partial u}{\partial y}(\text{z},0)=0$ **(2 M)** $f(z)=ze^z+c$ **(4M)**
9.	**Find an analytic function $f(z)=u+iv$ whose real part is $e^{2x}[x\cos 2y-y\sin 2y]$ (8 M)** BTL1

	Answer : Refer Page No.3.66-Dr.M.CHANDRASEKAR • $\frac{\partial u}{\partial x}=2e^{2x}x\cos 2y+e^{2x}\cos 2y-2e^{2x}y\sin 2y$ $\frac{\partial u}{\partial y}=-2e^{2x}x\sin 2y-2e^{2x}\,y\cos 2y-e^{2x}\sin 2y$ **(2M)** • $\frac{\partial u}{\partial x}(z,0)=e^{2z}+2ze^{2z}$ $\frac{\partial u}{\partial y}(z,0)=0$ **(2 M)** • $f(z)=ze^{2z}+c$ **(4M)**
10.	**Find an analytic function $f(z)=u+iv$ if $u-v=e^{x}[\cos y-\sin y]$** **(MAY/JUNE 2018 R-17)(8 M)** BTL1 **Answer : Refer Page No.3.76-Dr.M.CHANDRASEKAR** • $\frac{\partial U}{\partial x}=e^{x}\cos y-e^{x}\sin y$ $\frac{\partial U}{\partial y}=-e^{x}\cos y-e^{x}\sin y$ **(2M)** • $\frac{\partial U}{\partial x}(z,0)=e^{z}$ $\frac{\partial V}{\partial y}(z,0)=-e^{z}$ **(2 M)** • $F(z)=(1+i)f(z)$ $f(z)=e^{z}+c$ **(4M)**
11.	**Prove that the function $v=e^{-x}[x\cos y+y\sin y]$ is harmonic and determine the corresponding analytic function $f(z)=u+iv$** **(8 M)** BTL5 **Answer : Refer Page No.3.69-Dr.M.CHANDRASEKAR** • $\frac{\partial v}{\partial x}=-e^{-x}x\cos y+e^{-x}\cos y-e^{-x}y\sin y$ $\frac{\partial v}{\partial y}=-e^{-x}x\sin y+e^{-x}\,y\cos y+e^{-x}\sin y$ **(2M)**

	For Proving u is harmonic • $v_{xx}+v_{yy}=\left(e^{-x}[(x-2)\cos y+y\sin y]\right)+\left(e^{-x}[(2-x)\cos y-y\sin y]\right)=0$ **(2 M)** • $\frac{\partial v}{\partial x}(z,0)=e^{-z}(1-z)$ $\frac{\partial v}{\partial y}(z,0)=0$ **(2 M)** • $f(z)=ize^{-z}+c$ **(2M)**
12.	**Given that** $u=\dfrac{\sin 2x}{\cosh 2y-\cos 2x}$ **find the analytic function whose real part is u.** **(NOV/DEC 2014)(MAY/JUNE 2006) (8 M)** BTL1 **Answer : Refer Page No.3.71-Dr.M.CHANDRASEKAR** • $\frac{\partial u}{\partial x}(z,0)=-\text{cosec}^2 z$ $\frac{\partial u}{\partial y}(z,0)=0$ **(4M)** • $f(z)=\cot z+c$ **(4M)**
13.	**If** $f(z)=u+iv$ **is analytic, find** $f(z)$ **given that** $u+v=\dfrac{\sin 2x}{\cosh 2y-\cos 2x}$ **(NOV/DEC 2015) (8 M)** BTL1 **Answer : Refer Page No.3.74-Dr.M.CHANDRASEKAR** • $\frac{\partial V}{\partial x}(z,0)=-\text{cosec}^2 z$ $\frac{\partial V}{\partial y}(z,0)=0$ **(4M)** • $f(z)=\left(\frac{1+i}{2}\right)\cot z+c$ **(4M)**
14.	**Find the image of** $\lvert z-3\rvert=3$ **under the mapping** $w=\frac{1}{z}$ **(NOV/DEC 2010) (8 M)** BTL1 **Answer : Refer Page No.3.108-Dr.M.CHANDRASEKAR** • $x=\frac{u}{u^2+v^2}$ & $y=\frac{-v}{u^2+v^2}$ **(4M)**

	• The image of the circle $\lvert z-3\rvert = 3$ is the straight line $u=\frac{1}{6}$ **(4M)**
15.	**Find the image of $\lvert z+i\rvert = 1$ under the mapping $w=\frac{1}{z}$** **(NOV/DEC 2013) (8 M)** BTL1 **Answer : Refer Page No.3.109-Dr.M.CHANDRASEKAR** • $x=\frac{u}{u^2+v^2}$ & $y=\frac{-v}{u^2+v^2}$ **(4M)** • The image of the circle $\lvert z+i\rvert = 1$ is the straight line $v=\frac{1}{2}$ **(4M)**
16.	**Find the image of $1<y<2$ under the mapping $w=\frac{1}{z}$** **(MAY/JUNE 2014) (8 M)** BTL1 **Answer : Refer Page No.3.110-Dr.M.CHANDRASEKAR** • $x=\frac{u}{u^2+v^2}$ & $y=\frac{-v}{u^2+v^2}$ **(4M)** • $1<y<2$ is mapped onto the region between the circles $u^2+v^2+v=0$ and $2(u^2+v^2)+v=0$ **(4M)**
17.	**Find the image of $\lvert z-2i\rvert = 2$ under the mapping $w=\frac{1}{z}$** **(NOV/DEC 2007) (MAY/JUNE 2018 R-17) (8 M)** BTL1 **Answer : Refer Page No.3.112-Dr.M.CHANDRASEKAR** • $x=\frac{u}{u^2+v^2}$ & $y=\frac{-v}{u^2+v^2}$ **(4M)** • The image of the circle $\lvert z-2i\rvert = 2$ is the straight line $v=-\frac{1}{4}$ **(4M)**
18.	**Find the bilinear transformation which maps $-1,-i,1$ in the z-plane $\infty,i,0$ in the w-planerespectively. (8 M)** BTL1 **Answer : Refer Page No.3.132-Dr.M.CHANDRASEKAR** • $\frac{(w-w_1)(w_2-w_3)}{(w-w_3)(w_2-w_1)}=\frac{(z-z_1)(z_2-z_3)}{(z-z_3)(z_2-z_1)}$ **(2M)**

	• $w=\frac{(1-z)}{(1+z)}$ **(6M)**
19.	**Find the bilinear transformation which maps $\infty, i, 0$ onto $0, i, \infty$ respectively. (8 M)** BTL1 **Answer : Refer Page No.3.133-Dr.M.CHANDRASEKAR** • $\frac{(w-w_1)(w_2-w_3)}{(w-w_3)(w_2-w_1)}=\frac{(z-z_1)(z_2-z_3)}{(z-z_3)(z_2-z_1)}$ **(2M)** • $w=\frac{-1}{z}$ **(6M)**
20.	**Find the bilinear transformation which maps $z=1,0,-1$ onto $w=\infty,-1,0$ respectively. (8 M)** BTL1 **Answer : Refer Page No.3.133-Dr.M.CHANDRASEKAR** • $\frac{(w-w_1)(w_2-w_3)}{(w-w_3)(w_2-w_1)}=\frac{(z-z_1)(z_2-z_3)}{(z-z_3)(z_2-z_1)}$ **(2M)** • $w=\frac{z+1}{z-1}$ **(6M)**
21.	**Find the bilinear transformation which maps $-1,0,1$ onto $-1,-i,1$ respectively. Show that under this transformation the upper half of the z-plane maps onto the interior of the unit circle $\|w\|=1$ (MAY/JUNE 2018 R-17) (8 M)** BTL1 **Answer : Refer Page No.3.134-Dr.M.CHANDRASEKAR** • $\frac{(w-w_1)(w_2-w_3)}{(w-w_3)(w_2-w_1)}=\frac{(z-z_1)(z_2-z_3)}{(z-z_3)(z_2-z_1)}$ **(2M)** • $w=\frac{1-iz}{z-i}$ **(2M)** • $x=\frac{2u}{u^2+(v-1)^2}$ & $y=\frac{-(u^2+v^2-1)}{u^2+(v-1)^2}$ **(2M)** • For proving the upper half of the z-plane maps onto the interior of the unit circle $\|w\|\le 1$ **(2M)**
	UNIT IV- COMPLEX INTEGRATION
	Line integral – Cauchy's integral theorem – Cauchy's integral formula – Taylor's and Laurent's series – Singularities – Residues – Residue theorem – Application of residue theorem for evaluation of real integrals – Use of circular contour and semicircular contour.

Q.No.	PART-A
1	**State Cauchy integral theorem. (NOV/DEC 2014)(MAY/JUNE 2016)** BTL1 If a function $f(z)$ is analytic and its derivative $f'(z)$ is continuous at all points inside and on a simple closed curve C, then $\int_C f(z)dz = 0$.
2	**State Cauchy integral formula.** BTL1 If $f(z)$ is analytic inside and on a simple closed curve C in the region R and if 'a' is any point in R then $\int_C \frac{f(z)}{z-a}dz = 2\pi i f(a)$ where the integration around C taken in the positive direction.
3	**State Cauchy integral formula for derivatives. (NOV/DEC 2010)** BTL1 If a function f(z) is analytic within and on a simple closed curve c and 'a' is any point lying in it, then $\int_C \frac{f(z)}{(z-a)^{n+1}}dz = \begin{cases} \frac{2\pi i}{n!} f^n(a) & ;\text{a lies inside c} \\ 0 & ;\text{a lies outside c} \end{cases}$
4	**State Cauchy Residue Theorem (NOV/DEC 2012)** BTL1 If f (z) is analytic at all points inside and on a simple closed curve C except at a Finite number of points $z_1, z_2, z_3, \ldots\ldots\ldots, z_n$ inside C then $\int_C f(z)dz = 2\pi i\left[\text{sum of residues of } f(z)\right]$
5	**Evaluate $\int_C \frac{dz}{z-2}$ where C is the square with vertices (0,0), (1,0), (1,1), (0,1).** BTL5 Given C is the square with vertices (0,0), (1,0), (1,1), (0,1). ie) x=1,y=1. Since $\int_C \frac{dz}{z-2}$. Equating the denominator to zero. $z-2=0, \Rightarrow z=2$. Which lies outside C.
6	**Evaluate $\int_C \frac{3z^2+7z+1}{z-3}dz$ where C is $\lvert z\rvert = 2$.** BTL5 Given $\lvert z\rvert = 2$ that is, $x^2+y^2=2^2$ with center (0,0) and radius 2. Given $\int_C \frac{3z^2+7z+1}{z-3}dz$. Equating the denominator to zero. $(z-3)^2 = 0 \Rightarrow z = 3$ which lies outside C. $\therefore$ By Cauchy's integral formula $\int_C \frac{3z^2+7z+1}{z-3}dz = 0$.

7	**Evaluate** $\int_C \frac{\cos \pi z}{z-1} dz$ **where C is** $\|z\| = 2$. BTL5 Given $\|z\| = 2$ that is, $x^2 + y^2 = 2^2$ with center (0,0) and radius 2. Given $\int_C \frac{\cos \pi z}{z-1} dz$. Equating the denominator to zero. $z-1=0, \Rightarrow z=1$. Which lies inside C. $\therefore$ By Cauchy's integral formula $\int_C \frac{dz}{z-a} = 2\pi i\, f(a)$. $Here\ \ a=1, f(z)=\cos \pi z \Rightarrow f(a)=f(1)=\cos \pi = -1$. $\therefore \int_C \frac{\cos \pi z}{z-1} dz = 2\pi i(-1) = -2\pi i$.
8	**Evaluate** $\int_C \tan z\, dz$ **where C is** $\|z\| = 2$ **(NOV/DEC 2015)** BTL5 Given $\|z\| = 2$ that is, $x^2 + y^2 = 2^2$ with center (0,0) and radius 2. Given $\int_C \tan z\, dz = \int_C \frac{\sin z}{\cos z} dz$. Equating the denominator to zero. Cos z = 0 = $\cos\frac{\pi}{2} \Rightarrow z = \frac{\pi}{2}$ =1.732 . Which lies inside C. $\therefore$ By Cauchy's integral formula $\int_C \frac{dz}{z-a} = 2\pi i\, f(a)$. $Here\ \ a=\frac{\pi}{2}, f(z)=\sin z \Rightarrow f(a)=f(\frac{\pi}{2})=\sin\frac{\pi}{2}=1$. $\therefore \int_C \tan z\, dz = 2\pi i(1) = 2\pi i$
9	**Evaluate the integral** $\int_C \left(z^2+2z\right) dz$ **where C is** $\|z\| = 1$. BTL5 Given $\|z\| = 1$. that is, $x^2 + y^2 = 1$ with centre (0,0)and radius 1. $f(z) = z^2 + 2z$ is a function which is analytic in the region bounded by C Hence by Cauchy's theorem $\int_C \left(z^2+2z\right) dz = 0$.
10	**Find the contour C:** $\|z\| < 1$ **for which** $\int_C \frac{e^z}{(z+1)^2\,(z+1)} dz$ **=0.** BTL1 $\int_C \frac{e^z}{(z+1)^2\,(z+1)} dz$ **=0** when $\|z\| < 1$. [since the points lies outside the contour, then the integral value is 0.]

11	**Evaluate** $\int_C \frac{dz}{(z-3)^2}$ **where C is** $\lvert z\rvert=1$ BTL5 Given $\lvert z\rvert=1$. that is,) $x^2+y^2=1$ with center (0,0) and radius 1. $\int_C \frac{dz}{(z-3)^2}$. Equating the denominator to zero. $(z-3)^2=0 \Rightarrow z=3$ which lies outside C. $\therefore$ By Cauchy's integral formula for derivatives $\int_C \frac{dz}{(z-3)^2}=0$.
12	**Evaluate** $\int_c \frac{e^z dz}{z-2}$ **, where C is the unit circle with centre as origin.** BTL5 **(MAY/JUNE 2009)** $f(z)=\frac{e^z}{z-2}$ z=2 lies outside C. $f(z)$ is analytic inside and on C. $f'(z)$ is continuous in C, By Cauchy's integral theorem $\int_c f(z)dz=0$
13	**Define Taylor's series.** BTL1 If $f(z)$ is analytic inside a circle C with its centre at z = a then, For all z inside c, $f(z)=f(a)+\frac{f'(a)}{1!}(z-a)+\frac{f''(a)}{2!}(z-a)^2+............+\frac{f^n(a)}{n!}(z-a)^n+.......+\infty$.
14	**Define Laurent's series.** BTL1 If C_1 and C_2 are two concentric circles with centre "a" and radii r_1 and r_2 ($r_1<r_2$) and if $f(z)$ is analyticon C_1 and C_2 and in the annulus region between them, then at any point z in R $f(z)=\sum_{n=0}^{\infty} a_n(z-a)^n+\sum_{n=1}^{\infty}\frac{b_n}{(z-a)^n}$, where $a_n=\frac{1}{2\pi i}\int_{C_1}\frac{f(z)}{(z-a)^{n+1}}dz$ *and* $b_n=\frac{1}{2\pi i}\int_{C_2}\frac{f(z)}{(z-a)^{1-n}}dz$ The integrals being taken in the anticlockwise direction.
15	**Define Essential singularity.** BTL1 A singular point z =a is called an essential singular point of $f(z)$ if the Laurent's series of $f(z)$ containing negative powers of z.
16	**Discuss the nature of singularities** $f(z)=e^{\frac{1}{z}}$ **.(NOV/DEC 2015)(MAY/JUNE 2012)** BTL6

	$f(z)=e^{\frac{1}{z}}=1+\frac{\left(\frac{1}{z}\right)}{1!}+\frac{\left(\frac{1}{z}\right)^2}{2!}+\frac{\left(\frac{1}{z}\right)^3}{3!}+....$ $=1+z^{-1}+\frac{z^{-2}}{2!}+\frac{z^{-3}}{3!}+...$ Therefore z =0 is an essential singularity, since the principal part contains negative powers of z.
17	**Define removable singularity.** BTL1 A singular point z=a is called a removable singular point of $f(z)$, if the Laurent's series of $f(z)$ containing positive powers of z.
18	**Find the nature of the singularity $f(z)=\frac{\sin z}{z}$.** BTL1 $f(z)=\frac{\sin z}{z}=\frac{1}{z}\left(z-\frac{z^3}{3!}+\frac{z^5}{5!}+......\right)=1-\frac{z^2}{3!}+\frac{z^4}{5!}$ **-....** There is no negative power of z. Therefore $z=0$ is a removable singularity.
19	**Define isolated singularity with an example.** BTL1 A point $z=z_0$ is said to be isolated singularity of $f(z)$ i) If $f(z)$ is not analytic at $z=z_0$, ii)There exist neighborhoods of $z=z_0$ containing no other singularity Example: $f(z)=\frac{1}{(z-1)(z-2)}$ has two isolated singularity namely z =1 and z =2.
20	**Find the singularities of $f(z)=\frac{z^2+4}{z^2+2z+2}$.** BTL1 Given $f(z)=\frac{z^2+4}{z^2+2z+2}$. [The singularities are poles] The poles of $f(z)$ are given by equating the denominator to zero. $z^2+2z+2=0,\quad z=\frac{-2\pm\sqrt{4-8}}{2}=-1\pm i$. Which is a pole of order 1.
21	**Find the singularities of the function $f(z)=\frac{\cot\pi z}{(z-a)^3}$.** BTL1 Given $f(z)=\frac{\cot\pi z}{(z-a)^3}=\frac{\cos\pi z}{\sin\pi z(z-a)^3}$ $i.e.\sin\pi z(z-a)^3=0 \quad\Rightarrow\quad \sin\pi z=0 \quad (or)(z-a)^3=0$ Now $(z-a)^3=0$ $z=a$ is a pole of order 3 and then $\sin\pi z=0$ $\pi z=n\pi\Rightarrow\quad z=\pm n,\quad n=0,1,2,3.......$ $z=\pm n$ are simple poles.

22	**State nature of the singularities of** $f(z)=\sin\left(\frac{1}{z+1}\right)$**.** Given $f(z)=\sin\left(\frac{1}{z+1}\right)$ $\sin\left(\frac{1}{z+1}\right)=\left(\frac{1}{z+1}\right)-\frac{\left(\frac{1}{z+1}\right)^3}{3!}+\frac{\left(\frac{1}{z+1}\right)^5}{5!}+.......=\left(\frac{1}{z+1}\right)-\frac{1}{3!}\left(\frac{1}{z+1}\right)^3+\frac{1}{5!}\left(\frac{1}{z+1}\right)^5-........$ Z=-1 is an essential singularity.	BTL1
23	**Find the zeros of the function** $f(z)=\tan z$ **and its pole. (NOV/DEC 2016)** Given $f(z)=\tan z=\frac{\sin z}{\cos z}=\frac{P(z)}{Q(z)}$ The poles are given by $\cos z=0$ $z=(2n+1)\frac{\pi}{2}$ *where* $n=0,\pm1,\pm2,\pm3,....$ $\text{Re}s\left[f(z),a\right]=\frac{P(a)}{Q'(a)}$ Now $\frac{P(z)}{Q'(z)}=\frac{\sin z}{-\sin z}=-1$ $\text{Re}s\left[f(z),(2n+1)\frac{\pi}{2}\right]=-1$ *where* $n=0,\pm1,\pm2,\pm3,....$ Hence the residue of each pole is -1	BTL1
24	**Find the zeros of the function** $f(z)=\cot z$ **and it's pole .** Given $f(z)=\cot z=\frac{\cos z}{\sin z}=\frac{P(z)}{Q(z)}$ The poles are given by $\sin z=0$ $z=n\pi$ *where* $n=0,\pm1,\pm2,\pm3,....$ Residue of f(z) at $z=n\pi$ is $\frac{P[n\pi]}{Q'[n\pi]}$ $\frac{P(z)}{Q'(z)}=\frac{\cos z}{\cos z}$ $\frac{P(z)}{Q'(z)}=\frac{\cos(2n+1)\frac{\pi}{2}}{\cos(2n+1)\frac{\pi}{2}}=1$ *where* $n=0,\pm1,\pm2,\pm3,....$	BTL1
25	**Find residue of** $f(z)=\frac{z^2}{(z-1)^2(z+2)}$ **and at its simple pole.**	BTL1

	Given $f(z)=\dfrac{z^2}{(z-1)^2(z+2)}$ The poles of f(z) are given by $(z-1)^2(z+2)=0$ $z=1$ is a pole of order 2 and $z=-2$ is a pole order 1[Simple pole] Residue of f(z) at z=-2: [simple Pole] $\text{Res}\left[f(z)\right]_{z=a}=\lim\limits_{z\to a}(z-a)f(z)$ $\text{Re}\,s\left[f(z)\right]_{z=-2}=\lim\limits_{z\to -2}(z+2)\dfrac{z^2}{(z-1)^2(z+2)}=\lim\limits_{z\to -2}\dfrac{z^2}{(z-1)^2}=\dfrac{4}{9}$
26	**Evaluate** $\int_C \dfrac{3z^2+7z+1}{(z+1)}dz$ **where C is the circle** $\lvert z\rvert=\dfrac{1}{2}$ **(MAY/JUNE 2018 R-17)** BTL3 Here z=-1 lies outside C. Therefore $\begin{cases} f(z) \text{ is analytic inside and on C.} \\ \text{And } f'(z) \text{ is Continuous inside C}\end{cases}$ $\therefore \int_C f(z)dz=0$
27	**If C is the circle** $\lvert z\rvert=3$ and if $g(z_0)=\int_C \dfrac{2z^2-z-2}{(z-z_0)}dz$ then find g(2) **(MAY/JUNE 2018 R-17)** BTL3 $\int_C f(z)dz=2\pi i$ [sum of the residues] Here $z=2$ is a pole order 1[Simple pole] $\left\{\text{Res } f(z)_{at\, z=2}\right\}=\lim\limits_{z\to 2}(z-2)\left[\dfrac{2z^2-z-2}{(z-2)}\right]=4$ $\int_C \dfrac{2z^2-z-2}{(z-2)}dz=8\pi i$
	PART-B
1.	**Use Cauchy's integral formula to evaluate** $\int_C \dfrac{\sin\pi z^2+\cos\pi z^2}{(z-1)(z-2)}dz$ **where C is the circle** $\lvert z\rvert=3$ **(MAY/JUNE 2016) (8 M)** BTL3 **Answer : Refer Page No.4.10-Dr.M.CHANDRASEKAR**

- $\dfrac{\sin \pi z^2 + \cos \pi z^2}{(z-1)(z-2)} = \dfrac{1}{(z-2)} - \dfrac{1}{(z-1)}$ **(2M)**
- $\int_C \dfrac{f(z)}{(z-a)} dz = 2\pi i \, f(a)$ **(2M)**
- $\int_C \dfrac{\sin \pi z^2 + \cos \pi z^2}{(z-1)(z-2)} dz = 4\pi i$ **(4M)**

2\. **Use Cauchy's integral formula to evaluate** $\int_C \dfrac{z+4}{(z^2+2z+5)} dz$ **where C is the circle** $|z+1-i| = 3$ **(NOV/DEC 2006) (NOV/DEC 2014) (8 M)** BTL3

Answer : Refer Page No.4.16-Dr.M.CHANDRASEKAR

- $\dfrac{z+4}{(z^2+2z+5)} = \dfrac{\left(\dfrac{3+2i}{4i}\right)}{z-(-1+2\mathrm{i})} + \dfrac{\left(\dfrac{3-2i}{-4i}\right)}{z-(-1-2\mathrm{i})}$ **(2M)**
- $\int_C \dfrac{f(z)}{(z-a)} dz = 2\pi i \, f(a)$ **(2M)**
- $\int_C \dfrac{z+4}{(z^2+2z+5)} dz = \dfrac{\pi(3+2i)}{2}$ **(4M)**

3\. **Use Cauchy's integral formula to evaluate** $\int_C \dfrac{z}{(z-1)(z-2)} dz$ **where C is the circle** $|z-2| = \dfrac{1}{2}$ **(MAY/JUNE 2015) (8 M)** BTL3

Answer : Refer Page No.4.24-Dr.M.CHANDRASEKAR

- $\int_C \dfrac{f(z)}{(z-a)} dz = 2\pi i \, f(a)$ **(2M)**
- $\int_C \dfrac{z}{(z-1)(z-2)} dz = 4\pi i$ **(6M)**

4\. **Use Cauchy's integral formula to evaluate** $\int_C \dfrac{z+1}{(z-3)(z-1)} dz$ **where C is the circle** $|z| = 2$ **(MAY/JUNE 2016) (8 M)** BTL3

Answer : Refer Page No.4.29-Dr.M.CHANDRASEKAR

	• $\int_C \frac{f(z)}{(z-a)}dz = 2\pi i\ f(a)$ **(2M)** • $\int_C \frac{z+1}{(z-3)(z-1)}dz = -2\pi i$ **(6M)**
5.	**Use Cauchy's integral formula to evaluate** $\int_C \frac{z-1}{(z-2)(z+1)^2}dz$ **where C is the circle** $\lvert z-i\rvert = 2$ **(8 M)** BTL3 **Answer : Refer Page No.4.31-Dr.M.CHANDRASEKAR** • $\int_C \frac{f(z)}{(z-a)^{n+1}}dz = \begin{cases} \frac{2\pi i}{n!} f^n(a) \text{ ; a lies inside c} \\ 0 \text{ ;a lies outside c} \end{cases}$ **(2M)** • $\int_C \frac{z-1}{(z-2)(z+1)^2}dz = -\frac{2\pi i}{9}$ **(6M)**
6.	**Use Cauchy's integral formula to evaluate** $\int_C \frac{z^2}{(z^2+1)^2}dz$ **where C is the circle** $\lvert z-i\rvert = 1$ **(MAY/JUNE 2018 R-17)(8 M)** BTL3 **Answer : Refer Page No.4.30-Dr.M.CHANDRASEKAR** • $\int_C \frac{f(z)}{(z-a)^{n+1}}dz = \begin{cases} \frac{2\pi i}{n!} f^n(a) \text{ ; a lies inside c} \\ 0 \text{ ;a lies outside c} \end{cases}$ **(2M)** • $\int_C \frac{z^2}{(z^2+1)^2}dz = \frac{\pi}{2}$ **(6M)**
7.	**Use Cauchy's integral formula to evaluate** $\int_C \frac{z+1}{(z^2+2z+4)}dz$ **where C is the circle** $\lvert z+1+i\rvert = 2$. **(8 M)** BTL3 **Answer : Refer Page No.4.39-Dr.M.CHANDRASEKAR** • $\int_C \frac{f(z)}{(z-a)}dz = 2\pi i\ f(a)$. **(2M)** • $\int_C \frac{z+1}{(z^2+2z+4)}dz = \pi i$ **(6M)**

8.	**Expand** $\frac{z^2-1}{(z+2)(z+3)}$ **in the appropriate series in the regions** $(i)\,2<\lvert z\rvert<3 \quad (ii)\,\lvert z\rvert>3$ **using Laurent's series. (8 M)** BTL2 **Answer : Refer Page No.4.51-Dr.M.CHANDRASEKAR** • $f(z)=1+\frac{3}{z+2}-\frac{8}{z+3}$ **(2M)** (i) In $2<\lvert z\rvert<3,$ • $f(z)=1+\frac{3}{z}\sum_{n=0}^{\infty}(-1)^n\left(\frac{2}{z}\right)^n-\frac{8}{3}\sum_{n=0}^{\infty}(-1)^n\left(\frac{z}{3}\right)^n$ **(3M)** (ii) In $\lvert z\rvert>3,$ • $f(z)=1+\frac{3}{z}\sum_{n=0}^{\infty}(-1)^n\left(\frac{2}{z}\right)^n-\frac{8}{z}\sum_{n=0}^{\infty}(-1)^n\left(\frac{3}{z}\right)^n$ **(3M)**
9.	**Expand** $f(z)=\frac{7z-2}{z(z-2)(z+1)}$ **in Laurent's series in the regions** $(i)\,2<\lvert z\rvert<3 \quad (ii)\,\lvert z\rvert>3$ **(8 M)** BTL2 **Answer : Refer Page No.4.52-Dr.M.CHANDRASEKAR** • $f(z)=\frac{1}{z}+\frac{2}{z-2}-\frac{3}{z+1}$ **(2M)** (i) In $2<\lvert z\rvert<3,$ • $f(z)=\frac{1}{z}+\sum_{n=0}^{\infty}\left(\frac{2}{z}\right)^{n+1}+3\sum_{n=0}^{\infty}(-1)^{n+1}\left(\frac{1}{z}\right)^{n+1}$ **(3M)** (ii) In $\lvert z\rvert>3,$ • $f(z)=\frac{1}{z}+\sum_{n=0}^{\infty}\left(\frac{2}{z}\right)^{n+1}+3\sum_{n=0}^{\infty}(-1)^{n+1}\left(\frac{1}{z}\right)^{n+1}$ **(3M)**
10.	**Expand** $f(z)=\frac{7z-2}{z(z-2)(z+1)}$ **in Laurent's series in the region** $(i)\lvert z\rvert<2 \quad (ii)\,1<\lvert z+1\rvert<3$ **(MAY/JUNE 2014) (8 M)** BTL2 **Answer : Refer Page No.4.52-Dr.M.CHANDRASEKAR** • $f(z)=\frac{1}{z}+\frac{2}{z-2}-\frac{3}{z+1}$ **(2M)**

(i) In $|z|<2,$

- $$f(z)=\frac{1}{z}-\sum_{n=0}^{\infty}\left(\frac{z}{2}\right)^{n}-3\sum_{n=0}^{\infty}(z)^{n}$$ **(3M)**

(ii) In $1<|z+1|<3,$

- $$f(z)=\frac{-3}{z+1}+\sum_{n=1}^{\infty}\left(\frac{1}{z+1}\right)^{n}-\frac{2}{3}\sum_{n=0}^{\infty}\left(\frac{z+1}{3}\right)^{n}$$ **(3M)**

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11. **Expand** $f(z)=\dfrac{6z+5}{z(z-2)(z+1)}$ **in Laurent's series in the region** $1<|z+1|<3$

(MAY/JUNE 2018 R-17) (8 M) BTL2

Answer : Refer Page No.4.56-Dr.M.CHANDRASEKAR

- $$f(z)=\frac{-5}{2z}+\frac{17}{6(z-2)}-\frac{1}{3(z+1)}$$ **(2M)**

In $1<|z+1|<3,$

- $$f(z)=\frac{-1}{3(z+1)}-\frac{5}{2(z+1)}\sum_{n=0}^{\infty}\left(\frac{1}{z+1}\right)^{n}-\frac{17}{8}\sum_{n=0}^{\infty}\left(\frac{z+1}{3}\right)^{n}$$ **(6M)**

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12. **Expand** $f(z)=\dfrac{1}{(z-1)(z-2)}$ **in Laurent's series in the region** $(i)\ |z|>2 \quad (ii)\ 0<|z-1|<1$

(NOV/DEC 2014) (8 M) BTL2

Answer : Refer Page No.4.57-Dr.M.CHANDRASEKAR

- $$f(z)=\frac{-1}{z-1}+\frac{1}{z-2}$$ **(2M)**

(i) In $|z|>2,$

- $$f(z)=-\sum_{n=0}^{\infty}\left(\frac{1}{z}\right)^{n}+\frac{1}{z}\sum_{n=0}^{\infty}\left(\frac{2}{z}\right)^{n}$$ **(3M)**

(ii) In $0<|z-1|<1,$

- $$f(z)=\frac{-1}{z-1}+\sum_{n=0}^{\infty}(z-1)^{n}$$ **(3M)**

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13. **Use Cauchy's Residue theorem to evaluate** $\displaystyle\int_C \frac{\sin\pi z^2+\cos\pi z^2}{(z-1)^2(z-2)}dz$ **where C is the circle** $|z|=3$ **(NOV/DEC 2015) (8 M)** BTL3

Answer : Refer Page No.4.96-Dr.M.CHANDRASEKAR

	• $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(2M)** • $\left\{\text{Res } f(z)_{at\, z=2}\right\} = 1$ $\left\{\text{Res } f(z)_{at\, z=1}\right\} = -2\pi + 1$ **(4M)** • $\int_C \frac{\sin \pi z^2 + \cos \pi z^2}{(z-1)^2(z-2)} dz = 4\pi i(1-\pi)$ **(2M)**
14.	**Use Cauchy's Residue theorem to evaluate** $\int_C \frac{12z-7}{(z-1)^2(2z+3)} dz$ **where C is the circle** $\|z\| = 2$ **(8 M)** BTL3 **Answer : Refer Page No.4.92-Dr.M.CHANDRASEKAR** • $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(2M)** • $\left\{\text{Res } f(z)_{at\, z=-3/2}\right\} = -4$ $\left\{\text{Res } f(z)_{at\, z=1}\right\} = 4$ **(4M)** • $\int_C \frac{12z-7}{(z-1)^2(2z+3)} dz = 0$ **(2M)**
15.	**Use Cauchy's Residue theorem to evaluate** $\int_C \frac{z^2}{(z+1)^2(z^2+4)} dz$ **where C is the circle** $\|z\| = 3$ **(8 M)** BTL3 **Answer : Refer Page No.4.99-Dr.M.CHANDRASEKAR** • $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(2M)** $\left\{\text{Res } f(z)_{at\, z=-1}\right\} = -\frac{8}{25}$ • $\left\{\text{Res } f(z)_{at\, z=2i}\right\} = \frac{-4}{(1+2i)^2(4i)}$ **(4M)** $\left\{\text{Res } f(z)_{at\, z=-2i}\right\} = \frac{-4}{(1-2i)^2(-4i)}$ • $\int_C \frac{z^2}{(z+1)^2(z^2+4)} dz = 0$ **(2M)**

16.	**Use Cauchy's Residue theorem to evaluate** $\int_C \frac{dz}{(z^2+4)^2}$ **where C is the circle** $\lvert z-i\rvert=2$ **(8 M)** BTL3 **Answer : Refer Page No.4.100-Dr.M.CHANDRASEKAR** • $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(2M)** • $\left\{\text{Res } f(z)_{at\, z=2i}\right\} = \frac{1}{32i}$ $\left\{\text{Res } f(z)_{at\, z=-2i}\right\} = 0$ **(4M)** • $\int_C \frac{dz}{(z^2+4)^2} = \frac{\pi}{16}$ **(2M)**
17.	**Evaluate** $\int_0^{2\pi} \frac{\cos 2\theta}{5+4\cos\theta} d\theta$ **by using Contour integration (MAY/JUNE 2018 R-17) (16M)** BTL5 **Answer : Refer Page No.4.105-Dr.M.CHANDRASEKAR** • $\int_0^{2\pi} \frac{\cos 2\theta}{5+4\cos\theta} d\theta = \frac{1}{4i}\int_C \frac{(z^2+1)dz}{z^2(z+1/2)(z+2)}$ **(4M)** • $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(2M)** $\left\{\text{Res } f(z)_{at\, z=0}\right\} = \frac{-5}{2}$ • $\left\{\text{Res } f(z)_{at\, z=-1/2}\right\} = \frac{17}{6}$ **(8M)** $\left\{\text{Res } f(z)_{at\, z=-2}\right\} = 0$ • $\int_0^{2\pi} \frac{\cos 2\theta}{5+4\cos\theta} d\theta = \frac{\pi}{6}$ **(2M)**
18.	**Prove that** $\int_0^{2\pi} \frac{d\theta}{5+4\sin\theta} = \frac{2\pi}{3}$ **by using Contour integration. (NOV/DEC 2006) (8 M)** BTL5 **Answer : Refer Page No.4.120-Dr.M.CHANDRASEKAR**

	• $\int_0^{2\pi} \frac{d\theta}{5+4\sin\theta} = \int_C \frac{dz}{(z+2i)(2z+i)}$ **(3M)** • $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(1M)** • $\left\{\text{Res } f(z)_{at\, z=-i/2}\right\} = \frac{1}{3i}$ $\left\{\text{Res } f(z)_{at\, z=-2i}\right\} = 0$ **(3M)** • $\int_0^{2\pi} \frac{d\theta}{5+4\sin\theta} = \frac{2\pi}{3}$ **(1M)**
19.	**Evaluate** $\int_0^{2\pi} \frac{d\theta}{13+5\sin\theta}$ **by using Contour integration. (NOV/DEC 2014) (8 M)** BTL5 **Answer : Refer Page No.4.123-Dr.M.CHANDRASEKAR** • $\int_0^{2\pi} \frac{d\theta}{13+5\sin\theta} = \int_C \frac{2dz}{(5z+i)(2+5i)}$ **(3M)** • $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(1M)** • $\left\{\text{Res } f(z)_{at\, z=5i}\right\} = 0$ $\left\{\text{Res } f(z)_{at\, z=-\frac{i}{5}}\right\} = \frac{1}{12i}$ **(3M)** • $\int_0^{2\pi} \frac{d\theta}{13+5\sin\theta} = \frac{\pi}{6}$ **(1M)**
20.	**Evaluate** $\int_{-\infty}^{\infty} \frac{x^2dx}{(x^2+1)(x^2+4)}$ **by using Contour integration. (NOV/DEC 2008) (8 M)** BTL5 **Answer : Refer Page No.4.92-Dr.G.BALAJI** • $\int_{-\infty}^{\infty} \frac{x^2dx}{(x^2+1)(x^2+4)} = \int_C \frac{z^2}{(z^2+1)(z^2+4)}dz$ **(1M)** • $\int_C f(z)dz = 2\pi i$ [sum of the residues] **(1M)**

	• $\left\{\text{Res } f(z)_{at\, z=i}\right\} = \frac{i}{6}$ $\left\{\text{Res } f(z)_{at\, z=2i}\right\} = -\frac{i}{3}$	**(3M)**
	• $\int_{-\infty}^{\infty} \frac{x^2 dx}{(x^2+1)(x^2+4)} = \frac{\pi}{3}$	**(3M)**
21.	**Evaluate** $\int_0^{\infty} \frac{\cos mx}{(x^2+a^2)} dx$ **by using Contour integration. (NOV/DEC 2016) (8 M)**	BTL5
	Answer : Refer Page No.4.101-Dr.G.BALAJI	
	• $\int_0^{\infty} \frac{\cos mx\, dx}{(x^2+a^2)} = R.P\ of\ \int_C \frac{e^{mz}}{(z^2+a^2)} dz$	**(1M)**
	• $\int_C f(z)dz = 2\pi i\ [\text{sum of the residues}]$	**(1M)**
	• $\left\{\text{Res } f(z)_{at\, z=ai}\right\} = \frac{e^{-ma}}{2ai}$	**(3M)**
	• $\int_0^{\infty} \frac{\cos mx}{(x^2+a^2)} dx = \frac{\pi e^{-ma}}{2a}$	**(3M)**

	UNIT V LAPLACETRANSFORMS	
	Existence conditions – Transforms of elementary functions – Transform of unit step function and unit impulse function – Basic properties – Shifting theorems -Transforms of derivatives and integrals – Initial and final value theorems – Inverse transforms – Convolution theorem – Transform of periodic functions – Application to solution of linear second order ordinary differential equations with constantcoefficients.	
	PART * A	
Q.No.	**Questions**	
1.	**State the sufficient condition for the existence of Laplace transforms.** **(OR) State the conditions under which the Laplace Transform of $f(t)$ exisits.** **(APR/MAY 2015, 2017 R-13)** The Laplace transform of $\boldsymbol{f(t)}$ exists if a) $\boldsymbol{f(t)}$ is piecewise continuous in $[\boldsymbol{a}, \boldsymbol{b}]$ where $\boldsymbol{a > 0}$. b) $\boldsymbol{f(t)}$is of exponential order.	BTL1
2.	**Is the linearity property applicable to $L\left[\frac{1-cost}{t}\right]$?Reason out?**	BTL5

	Given, $\boldsymbol{L}\left[\frac{1-cost}{t}\right]=\boldsymbol{L}\left[\frac{1}{t}\right]-\boldsymbol{L}\left[\frac{cos\,t}{t}\right]$by linearity property, provided the result exists. $\boldsymbol{L}\left[\frac{1}{t}\right]$does not exist. Since $\lim_{t\to 0}\frac{1}{t}=\frac{1}{0}=\infty$. $\boldsymbol{L}\left[\frac{cos\,t}{t}\right]$does not exist. Since, $\lim_{t\to 0}\frac{\cos t}{t}=\frac{1}{0}=\infty$. $\therefore$ Linearity property is not applicable to $\boldsymbol{L}\left[\frac{1-cost}{t}\right]$.
3.	**If L[F(t)]=$F(s)$, Prove that $L\left[f\left(\frac{t}{5}\right)\right]=5F(5s)$.** BTL5 $L[f(t)]=\int_0^\infty e^{-st}f(t)dt$ $put\quad \frac{t}{5}=u\Rightarrow 5du=dt$ $L\left[f\left(\frac{t}{5}\right)\right]=\int_0^\infty e^{-(5s)u}f(u)5du$ $=5\int_0^\infty e^{-(5s)u}f(u)du=5F(5s)$
4	**Find the Laplace transform of unit step function.** BTL1 The unit step function is $u_a(t)=\begin{cases}0 & t<a\\ 1 & t>a,\end{cases}\quad a\geq 0$ The Laplace transform $L[f(t)]=\int_0^\infty e^{-st}f(t)dt=\int_a^\infty e^{-st}(1)dt=\left[\frac{e^{-st}}{-s}\right]_a^\infty=-\frac{1}{s}\left[e^{-\infty}-e^{-as}\right]=\frac{e^{-as}}{s}$.
5	**Prove that $L\left(\int_0^t f(t)dt\right)=\frac{F(s)}{s}$ where $L[f(t)]=F(s)$. [DEC 2016 R-13]** BTL5 Let $F(t)=\int_0^t f(t)dt$ $F'(t)=f(t)$ $L[F'(t)]=sL[F(t)]-F(0)=sL[F(t)]-0$ $L[f(t)]=sL[F(t)]=sL[\int_0^t f(t)dt]$ $\therefore L\left(\int_0^t f(t)dt\right)=\frac{F(s)}{s}$
6	**Does $L\left[\frac{\cos at}{t}\right]$ exist?** BTL4 $\underset{t\to 0}{Lt}\frac{f(t)}{t}=\underset{t\to 0}{Lt}\frac{\cos at}{t}=\frac{1}{0}=\infty$ $\therefore L\left[\frac{\cos at}{t}\right]does\quad not\quad exist.$

7	**Obtain the Laplace transform of $sin2t - 2tcos2t$.** BTL3 $L[\sin 2t - 2t\cos 2t] = L[\sin 2t] - 2L[t\cos 2t] = L[\sin 2t] - 2\left(-\frac{d}{ds}L[\cos 2t]\right)$ $= \frac{2}{s^2+4} + 2\frac{d}{ds}\left(\frac{s}{s^2+4}\right) = \frac{2}{s^2+4} + 2\left(\frac{(s^2+4)(1) - s(2s)}{(s^2+4)^2}\right)$ $= \frac{2(s^2+4)+2(4-s^2)}{(s^2+4)^2} = \frac{16}{(s^2+4)^2}.$
8	**Find $L^{-1}\left[\frac{s+2}{s^2+2s+2}\right]$.** BTL4 $L^{-1}\left[\frac{s+2}{s^2+2s+2}\right] = L^{-1}\left[\frac{(s+1)+1}{(s+1)^2+1}\right] \{\because L^{-1}[F(s+a)] = e^{-at}L^{-1}[F(s)]\}$ $= L^{-1}\left[\frac{(s+1)}{(s+1)^2+1}\right] + L^{-1}\left[\frac{1}{(s+1)^2+1}\right]$ $= e^{-t}\left(L^{-1}\left[\frac{s}{s^2+1}\right] + L^{-1}\left[\frac{1}{s^2+1}\right]\right)$ $= e^{-t}(\cos t + \sin t).$
9	**What is the Laplace transform of $f(t), 0 < t < 10$ with $f(t) = f(t+10)$?** BTL3 Given $f(t)$ is a periodic function with period p. $L[f(t)] = \frac{1}{1-e^{-ps}}\int_0^p e^{-st} f(t)dt$ $put \quad p = 10, \quad L[f(t)] = \frac{1}{1-e^{-10s}}\int_0^{10} e^{-st} f(t)dt$
10	**State and Prove Linearity property. [MAY/JUNE 2016]** BTL1 $Statement: \quad L[af(t) \pm bg(t)] = aL[f(t)] \pm bL[g(t)]$ $proof: \quad L[f(t)] = \int_0^\infty e^{-st} f(t)dt$ $L[af(t) \pm bg(t)] = \int_0^\infty e^{-st} L[af(t) \pm bg(t)]dt$ $= \int_0^\infty e^{-st} af(t)dt \pm \int_0^\infty e^{-st} bg(t)dt$ $= a\int_0^\infty e^{-st} f(t)dt \pm b\int_0^\infty e^{-st} g(t)dt$ $= aL[f(t)] \pm bL[g(t)].$

11	**Find** $L^{-1}\left(\frac{S}{S^2+4S+5}\right)$**. [MAY/JUNE 2016]** $L^{-1}\left(\frac{S}{S^2+4S+5}\right)=L^{-1}\left(\frac{(S+2)-2}{(S+2)^2+1}\right)=e^{-2t}L^{-1}\left(\frac{S-2}{S^2+1}\right)$ $=e^{-2t}\left[L^{-1}\left(\frac{S-2}{S^2+1}\right)-2L^{-1}\left(\frac{1}{S^2+1}\right)\right]=e^{-2t}[\cos t-2\sin t].$	BTL3
12	**Find** $L[te^{-3t}\cos 2t]$**.** We know that $L[t\cos at]=\frac{s^2-a^2}{(s^2+a^2)^2}$, $L[te^{-3t}\cos 2t]=\left[\frac{s^2-2^2}{(s^2+2^2)^2}\right]_{s\to s+3}=\frac{(s+3)^2-2^2}{((s+3)^2+2^2)^2}$	BTL3
13	**Find** $\boldsymbol{L^{-1}}\left[\tan^{-1}\left(\frac{1}{s}\right)\right]$**.** *Let* $F(s)=\tan^{-1}\left(\frac{1}{s}\right)$ $F'(s)=\frac{1}{1+\left(1/s\right)^2}\left(\frac{-1}{s^2}\right)=\frac{-1}{s^2+1}$ *By property* $L^{-1}\left[F'(s)\right]=-L^{-1}\left[\frac{1}{s^2+1}\right]=-\sin t$ $\therefore L^{-1}\left[F'(s)\right]=-\sin t;$ $L^{-1}\left[F(s)\right]=\frac{-1}{t}L^{-1}\left[F'(s)\right]$ $\mathrm{L}^{-1}\left[\tan^{-1}\left(\frac{1}{s}\right)\right]=\frac{\sin t}{t}.$	BTL3
14	**Solve using Laplace transform** $\frac{dy}{dt}+y=e^{-t}$ **given that** $\boldsymbol{y(0)=0}$. Taking Laplace transform on both sides, we get $L[y'(t)]+L[y(t)]=L[e^{-t}]$ $sL[y(t)]-y(0)+L[y(t)]=L[e^{-t}]$ $sL[y(t)]-0+L[y(t)]=\frac{1}{s+1}$	BTL3

	$(s+1)L[y(t)] = \frac{1}{s+1}$ $L[y(t)] = \left(\frac{1}{(s+1)^2}\right)$ $\therefore y(t) = L^{-1}\left(\frac{1}{(s+1)^2}\right) = e^{-t}L\left(\frac{1}{s^{2]gh[\ ]}}\right) = e^{-t}t.$ $\{\because L[e^{-at}f(t)] = F(s+a)\}$
15	**Given an example for a function that do not have Laplace transform.** BTL5 Consider $\boldsymbol{f(t) = e^{t^2}}$, since $\underset{t\to\infty}{Lt}\, e^{-st}e^{t^2} = \infty$, hence $\boldsymbol{e^{t^2}}$ is not exponential order. Hence $\boldsymbol{f(t) = e^{t^2}}$ does not have Laplace transform.
16	**Can $\boldsymbol{F(s)} = \frac{s^3}{(s+1)^2}$ be the Laplace transform of some $\boldsymbol{f(t)}$?** BTL5 $\underset{s\to\infty}{Lt}\, F(s) = \underset{s\to\infty}{Lt}\, \frac{s^3}{(s+1)^2} \neq 0$ Hence $\boldsymbol{F(s)}$ cannot be Laplace transform of $\boldsymbol{f(t)}$.
17	**Evaluate $\int_0^t \sin u \cos(t-u)du$ using Laplace Transform.** BTL3 $Let \quad L\left[\int_0^t \sin u \cos(t-u)du\right] = L[\sin t * \cos t]$ $= L[\sin t]L[\cos t] \qquad (by \quad convolution \quad theorem)$ $= \frac{1}{(s^2+1)}\frac{s}{(s^2+1)} = \frac{s}{(s^2+1)^2}.$ $\int_0^t \sin u \cos(t-u)du = L^{-1}\left[\frac{s}{(s^2+1)^2}\right] = \frac{1}{2}L^{-1}\left[\frac{2s}{(s^2+1)^2}\right] = \frac{t}{2}\sin t.$ $\left[\because L^{-1}\left(\frac{2s}{(s^2+1)^2}\right) = t\sin at\right].$
18	**Given an example for a function having Laplace transform but not satisfying the continuity condition.** BTL1 $f(t) = t^{\frac{-1}{2}}$ has Laplace transform even though it does not satisfy the continuity condition. (i.e.) It is not piecewise continuous in $(0,\infty)$ $\quad as\ \underset{t\to 0}{Lt}\, f(t) = \infty.$
19	**Define a Periodic function with example.** BTL1 $\boldsymbol{f(t)}$ for all $\boldsymbol{t}$. The least value of $\boldsymbol{p > 0}$ is called the period of $\boldsymbol{f(t)}$. For example, $\boldsymbol{\sin t}$ and $\boldsymbol{\cos t}$ are periodic functions with period $2\boldsymbol{\pi}$.
20	**If $\boldsymbol{L[f(t)] = F(s)}$, find $\boldsymbol{L[f(at)]}$. [APR/MAY 2018 R-17]** BTL5

	$L[f(at)]=\int_0^\infty e^{-st} f(at)dt$ $put \qquad u=at$ $L[f(at)]=\int_0^\infty e^{-\left(\frac{s}{a}\right)u} f(u)\frac{du}{a}=\frac{1}{a}\int_0^\infty e^{-\left(\frac{s}{a}\right)u} f(u)du=\frac{1}{a}F\left(\frac{s}{a}\right).$
21	**Find the Laplace transform of $\frac{t}{e^t}$. [APR/MAY 2018 R-17]** BTL3 $L\left[\frac{t}{e^t}\right]=L[e^{-t}t]=\left[\frac{1}{s^2}\right]_{s\to s+1}=\frac{1}{(s+1)^2}$.
22	**State Convolution theorem on Laplace Transform. [MAY/JUNE 2017 R-13]** BTL1 The Laplace transform of convolution of two functions is equal to the product of their Laplace transform. (i.e) $L[f(t)*g(t)]=L[f(t)]L[g(t)]$.
23	**Find $L\left[\frac{1}{\sqrt{t}}\right]$. [APR/MAY 2017 R-13]** BTL3 We know that, $L[t^n]=\frac{\Gamma(n+1)}{s^{n+1}}$ $L\left[\frac{1}{\sqrt{t}}\right]=L[t^{-1/2}]$ $=\frac{\Gamma(-1/2+1)}{s^{-1/2+1}}$ $=\frac{\Gamma(1/2)}{s^{1/2}}=\sqrt{\frac{\pi}{s}}.$
24	**Find the Laplace transform $\boldsymbol{sin^3(2t)}$.** BTL3 $L[\sin^3(2t)]=\frac{1}{4}L[3\sin 2t-\sin 6t]$ $=\frac{3}{4}L[\sin 2t]-\frac{1}{4}L[\sin 6t]$ $\{\because \sin^3 t=\frac{1}{4}[3\sin t-\sin 3t]\}$ $=\frac{3}{4}\left(\frac{2}{s^2+4}\right)-\frac{1}{4}\left(\frac{6}{s^2+36}\right)$ $=\frac{6}{4}\left\{\left(\frac{1}{s^2+4}\right)-\left(\frac{1}{s^2+36}\right)\right\}$
25	**Find the Laplace transform of $\boldsymbol{e^{-2t}t^{1/2}}$.** BTL3

	$L(e^{-2t}t^{1/2}) = L[t^{1/2}]_{s\to s+2}$ $\because if \quad L[f(t)] = F(s), \quad then \quad l[e^{-at}f(t)] = F(s)/_{s\to s+2}$ $\left[\dfrac{\Gamma\left(\frac{1}{2}+1\right)}{s^{\frac{3}{2}}}\right]_{s\to s+2} = \left[\dfrac{\frac{1}{2}\Gamma\left(\frac{1}{2}\right)}{s^{\frac{3}{2}}}\right]_{s\to s+2}$ $= \dfrac{\frac{1}{2}\sqrt{\pi}}{(s+2)^{\frac{3}{2}}} \qquad \left(\because \Gamma\left(\frac{1}{2}\right) = \sqrt{\pi}, \quad \Gamma n+1 = n\Gamma n\right).$
26	**Does** $L\left[\dfrac{\cos at}{t}\right]$ **exist?** BTL5 $\underset{t\to 0}{Lt}\dfrac{f(t)}{t} = \underset{t\to 0}{Lt}\dfrac{\cos at}{t} = \dfrac{1}{0} = \infty$ $\therefore L\left[\dfrac{\cos at}{t}\right] does \quad not \quad exist.$
27	**Using Laplace transform, Evaluate** $\int_0^\infty te^{-2t}\sin t dt$**. [APR/MAY 2015 R-13]** BTL3 $\int_0^\infty e^{-2t}f(t)dt = \left[\int_0^\infty e^{-st}f(t)dt\right]_{s=2} = [L[t\sin t]]_{s=2} = \left[-\dfrac{d}{ds}L[\sin t]\right]_{s=2} = -\dfrac{d}{ds}\left(\dfrac{1}{s^2+1}\right) = \dfrac{4}{25}$
	Part*B
1	**Find** **1)** $L[\frac{sinh2t}{t}]$**.** **2)** $L[\frac{e^{-t}sint}{t}]$ **3)** $L[\frac{cosat-cos\,bt}{t}]$**. [APR/MAY 2011,2015, NOV/DEC 2012,2016 R-13] (12M)** BTL3 **Answer: Refer Page No:5.35-Dr. G. Balaji.** 1) $L\left[\dfrac{\sinh 2t}{t}\right] = \int_s^\infty L[\sinh 2t]ds = \int_s^\infty \dfrac{2}{s^2-4}ds = 2\left[\dfrac{1}{2(2)}\log\left(\dfrac{s-2}{s+2}\right)\right]_s^\infty$ $= \dfrac{1}{2}\left[\log\dfrac{s+2}{s-2}\right] = \log\sqrt{s+2/s-2} \qquad (4M)$ 2)

	$L\left[\frac{e^{-t}\sin t}{t}\right]=\left[L\left[\sin t/t\right]\right]_{s\to s+1}$ $=\left[\cot^{-1}s\right]_{s\to(s+1)}=\cot^{-1}(s+1).\quad(3M)$ 3) $L\left[\frac{\cos at-\cos bt}{t}\right]=\int_s^\infty L[\cos at-\cos bt]ds$ $=\int_s^\infty\left[\frac{s}{s^2+a^2}-\frac{s}{s^2+b^2}\right]ds=\frac{1}{2}\left[\log(s^2+a^2)-\log(s^2+b^2)\right]_s^\infty=\frac{1}{2}\log\frac{s^2+b^2}{s^2+a^2}.\quad(5M)$
2	**1) State and prove Initial Value and Final value theorem. [APR/MAY 2017 R-13]** **2) Verify the initial and Final value theorem for $f(t)=1+e^t(\sin t+\cos t)$. [NOV/DEC 2009, MAY/JUNE 2012R-13]** **3) Using the initial value theorem, find $\underset{s\to\infty}{Lt}\, sL[f(t)]$ for the function $f(t)=e^{-t}\cos t$. [NOV/DEC 2016 R-13]** **(16M)** BTL3 **Answer: Refer Page No:5.40-Dr. G. Balaji.** 1) Initial Value theorem Statement: $L[f(t)]=F(s),\quad then\quad \underset{t\to0}{Lt}\, f(t)=\underset{s\to\infty}{Lt}\, sF(s).$ $\Pr oof: We\quad know\quad that\quad L[f'(t)]=sL[f(t)]-f(0)=sF(s)-f(0)$ $=\int_0^\infty e^{-st}f'(t)dt$ $\underset{s\to\infty}{Lt}\left[sF(s)-f(0)\right]=\underset{s\to\infty}{Lt}\int_0^\infty e^{-st}f'(t)dt=\underset{s\to\infty}{Lt}\, sF(s)-f(0)=0$ $hence\quad \underset{t\to0}{Lt}\, f(t)=\underset{s\to\infty}{Lt}\, sF(s).\quad(2M)$ Final Value theorem Statement: $L[f(t)]=F(s),\quad then\quad \underset{t\to\infty}{Lt}\, f(t)=\underset{s\to0}{Lt}\, sF(s).$ $\Pr oof: We\quad know\quad that\quad l[f'(t)]=sL[f(t)]-f(0)=sF(s)-f(0)$ $=\int_0^\infty e^{-st}f'(t)dt$ $\underset{s\to0}{Lt}\left[sF(s)-f(0)\right]=\underset{s\to0}{Lt}\int_0^\infty e^{-st}f'(t)dt=\underset{s\to0}{Lt}\, sF(s)-f(0)=f(\infty)-f(0)$ $hence\quad \underset{t\to\infty}{Lt}\, f(t)=\underset{s\to0}{Lt}\, sF(s).\quad(2M)$ 2) $f(t)=1+e^t(\sin t+\cos t)$ Initial Value theorem state that $L[f(t)]=F(s),\quad then\quad \underset{t\to0}{Lt}\, f(t)=\underset{s\to\infty}{Lt}\, sF(s).$

	$L[f(t)] = L[1+e^{t}(\sin t + \cos t)]$ $= \frac{1}{s} + \frac{1}{(s+1)^2+1} + \frac{s+1}{(s+1)^2+1}$ $LHS \quad = \lim_{t\to 0} f(t) = 2.$ $RHS = \underset{s\to\infty}{Lim}\left[1+\frac{s(s+2)}{(s+1)^2+1}\right] = 2 \qquad (4M)$ $LHS \quad = \quad RHS$ Hence, Initial Value theorem verified. Final Value theorem state that $L[f(t)] = F(s), \quad then \quad \underset{t\to\infty}{Lt} f(t) = \underset{s\to 0}{Lt}\, sF(s).$ $LHS \quad = \lim_{t\to\infty} f(t) = 1.$ $RHS = \underset{s\to 0}{Lim}\left[1+\frac{s(s+2)}{(s+1)^2+1}\right] = 1 \qquad (4M)$ $LHS \quad = \quad RHS$ 3) <u>Initial Value theorem Statement:</u> $L[f(t)] = F(s), \quad then \quad \underset{t\to 0}{Lt} f(t) = \underset{s\to\infty}{Lt}\, sF(s).$ $f(t) = e^{-t}\cos t$ $\lim_{t\to 0} f(t) = 1$ $\lim_{s\to\infty} sF(s) = 1 \qquad (4M)$ Hence proved.
3	**Using convolution theorem find** $L^{-1}\left[\frac{1}{(s+a)(s+b)}\right]$**. [APR/MAY 2011 R-13] (8M)**BTL3 **Answer: Refer Page No:5.77-Dr. G. Balaji.** $L^{-1}\left[\frac{1}{(s+a)(s+b)}\right] = L^{-1}\left[\left(\frac{1}{(s+a)}\right)\left(\frac{1}{(s+b)}\right)\right]$ $= L^{-1}\left(\frac{1}{(s+a)}\right) * L^{-1}\left(\frac{1}{(s+b)}\right)$ $= e^{-at} * e^{-bt} \qquad (3M)$ $= \int_0^t e^{-at}e^{-b(t-u)}du$ $= e^{-bt}\left[\frac{e^{-(a-b)u}}{-(a-b)}\right]_{u=0}^{u=t} \qquad (3M)$ $= \frac{e^{-bt}-e^{-at}}{a-b}. \qquad (2M)$

<u>Note:</u>

Using convolution theorem find $L^{-1}\left[\dfrac{1}{(s+1)(s+2)}\right]$. **[NOV/DEC 2007,2012 R-13] (8M)**

Hint:

In the above problem put $a=2, b=1$.

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4 **Find the Laplace inverse of** $\left[\dfrac{s^2}{(s^2+a^2)^2}\right]$ **using convolution theorem. [NOV/DEC 2011R-13] (8M)**BTL3

Answer: Refer Page No:5.84-Dr. G. Balaji.

$$L^{-1}\left[\frac{s^2}{(s^2+a^2)^2}\right]=L^{-1}\left[\left(\frac{s}{(s^2+a^2)}\right)\left(\frac{s}{(s^2+a^2)}\right)\right]$$

$$=L^{-1}\left(\frac{s}{(s^2+a^2)}\right)*L^{-1}\left(\frac{s}{(s^2+a^2)}\right)$$

$$=\cos at*\cos at \qquad (3M)$$

$$=\int_0^t \cos au\cos a(t-u)du$$

$$=\frac{1}{2}\int_0^t[\cos(au+at-au)+\cos(au-at+au)]du \qquad (2M)$$

$$=\frac{1}{2}\left[[(\cos at)u]+\left[\frac{\sin[2au-at]}{2a}\right]\right]_{u=0}^{u=t}$$

$$=\frac{1}{2}\left[t\cos at+\frac{\sin at}{a}\right]$$

$$L^{-1}\left[\frac{s^2}{(s^2+a^2)^2}\right]=\frac{1}{2a}[\sin at+at\cos at]. \qquad (3M)$$

<u>Note:</u>

Using Convolution theorem, find $L^{-1}\left[\dfrac{s^2}{(s^2+4)^2}\right]$. **[NOV/DEC 2012 R-13] (8M)**

Hint:

In the problem put $a=2$.

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5 **Using convolution theorem find** $L^{-1}\left[\dfrac{s}{(s^2+a^2)^2}\right]$. **[NOV/DEC 2013, APR/MAY 2017 R-13] (8M)**BTL3

	Answer: Refer Page No:5.83-Dr. G. Balaji. $L^{-1}\left[\frac{s}{(s^2+a^2)^2}\right]=L^{-1}\left[\left(\frac{s}{(s^2+a^2)}\right)\left(\frac{1}{(s^2+a^2)}\right)\right]$ $=L^{-1}\left(\frac{s}{(s^2+a^2)}\right)*\frac{1}{a}L^{-1}\left(\frac{a}{(s^2+a^2)}\right)$ $=\cos at*\frac{1}{a}\sin at \qquad (3M)$ $=\frac{1}{a}\int_0^t \cos au\sin a(t-u)du$ $=\frac{1}{2a}\int_0^t [\sin(at-au+au)+\sin(at-au-au)]du \qquad (2M)$ $=\frac{1}{2a}\left[\left[(\sin at)u\right]+\left[\frac{-\cos[a(t-2u)]}{-2a}\right]\right]_0^t$ $=\frac{1}{2a}\left[t\sin at+\frac{\cos at}{2a}-\frac{\cos at}{2a}\right]$ $L^{-1}\left[\frac{s}{(s^2+a^2)^2}\right]=\frac{1}{2a}t\sin at. \qquad (3M)$
6	**Using convolution theorem find** $L^{-1}\left[\frac{s}{(s^2+a^2)(s^2+b^2)}\right]$**. [MAY/JUNE 2016 R-13] (8M)**BTL3 **Answer: Refer Page No:5.81-Dr. G. Balaji.** $L^{-1}\left[\frac{s}{(s^2+a^2)(s^2+b^2)}\right]=L^{-1}\left[\left(\frac{s}{(s^2+a^2)}\right)\left(\frac{1}{(s^2+b^2)}\right)\right]$ $=L^{-1}\left(\frac{s}{(s^2+a^2)}\right)*L^{-1}\left(\frac{1}{(s^2+b^2)}\right)$ $=\cos at*\frac{1}{b}\sin bt \qquad (3M)$ $=\frac{1}{b}\int_0^t \cos au\sin b(t-u)du$ $=\frac{1}{2b}\int_0^t [\sin(au+bt-bu)+\sin(bt-bu-au)]du \qquad (2M)$

	$= \frac{1}{2b}\left[\left[\frac{-\cos[(a-b)u+bt]}{a-b}\right]+\left[\frac{-\cos[bt-(a+b)u]}{-(a+b)}\right]\right]_0^t$ $= \frac{1}{2b}\left[\cos at\left(\frac{1}{a+b}-\frac{1}{a-b}\right)-\cos bt\left(\frac{1}{a+b}-\frac{1}{a-b}\right)\right]$ $L^{-1}\left[\frac{s}{(s^2+a^2)(s^2+b^2)}\right]=\frac{\cos at-\cos bt}{b^2-a^2}.$ $(3M)$ Note: **Using convolution theorem find** $L^{-1}\left[\frac{s}{(s^2+1)(s^2+4)}\right]$**.** [**MAY/JUNE 2015,2016 R-13] (8M)** **Hint:** In the above problem put $a=1, b=2$, **Using convolution theorem find** $L^{-1}\left[\frac{s}{(s^2+4)(s^2+9)}\right]$**.** [**MAY/JUNE 2015,2016 R-13] (8M)** **Hint:** In the above problem put $=2, b=3$.
7	**Find** $L^{-1}\left[\frac{s^2}{(s^2+a^2)(s^2+b^2)}\right]$ **using convolution theorem. [APR/MAY 2014, 2015,2016, NOV/DEC 2014, 2016 R-13] (8M)**BTL3 **Answer: Refer Page No:5.86-Dr. G. Balaji.** $L^{-1}\left[\frac{s^2}{(s^2+a^2)(s^2+b^2)}\right]=L^{-1}\left[\left(\frac{s}{(s^2+a^2)}\right)\left(\frac{s}{(s^2+b^2)}\right)\right]$ $=L^{-1}\left(\frac{s}{(s^2+a^2)}\right)*L^{-1}\left(\frac{s}{(s^2+b^2)}\right)$ $=\cos at*\cos bt$ $(3M)$ $=\int_0^t \cos au\cos b(t-u)du$

	$=\frac{1}{2}\int_0^t[\cos(au+bt-bu)+\cos(au-bt+bu)]du \qquad (2M)$ $=\frac{1}{2}\left[\left[\frac{\sin[(a-b)u+bt}{a-b}\right]+\left[\frac{\sin[(a+b)u-bt}{a+b}\right]\right]_0^t$ $=\frac{1}{2}\left[\sin at\left(\frac{1}{a-b}+\frac{1}{a+b}\right)+\sin bt\left(\frac{1}{a+b}-\frac{1}{a-b}\right)\right]$ $L^{-1}\left[\frac{s^2}{(s^2+a^2)(s^2+b^2)}\right]=\frac{a\sin at-b\sin bt}{a^2-b^2}. \qquad (3M)$ <u>Note:</u> **Find** $L^{-1}\left[\frac{s^2}{(s^2+1)(s^2+4)}\right]$ **using convolution theorem. [APR/MAY 2017 R-13] (8M)** **Hint:** In the above problem put $a=1$ & $b=2$.
8	**Find the Laplace transform of the rectangular wave given by** $f(t)=\begin{cases} k & ,0<t<b \\ -k & ,b<t<2b \end{cases}$. **[APR/MAY 2008, 2015 R-13] (8M)**BTL5 **Answer: Refer Page No:5.92-Dr. G. Balaji.** Given, $f(t)=\begin{cases} k & ,0<t<b \\ -k & ,b<t<2b \end{cases}$. This function is periodic in the interval $(0,2b)$ with period $2b$. $L[f(t)]=\frac{1}{1-e^{-ps}}\int_0^p e^{-st}f(t)dt$ $L[f(t)]=\frac{1}{1-e^{-2bs}}\int_0^{2b} e^{-st}f(t)dt$ $=\frac{1}{1-e^{-2bs}}\left[\int_0^b e^{-st}(k)dt+\int_b^{2b}e^{-st}(-k)dt\right] \qquad (2M)$ $=\frac{k}{1-e^{-2bs}}\left[\left[\frac{e^{-st}}{-s}\right]_0^b-\left[\frac{e^{-st}}{-s}\right]_b^{2b}\right] \qquad (2M)$

	$= \frac{k}{s}\frac{1}{1-e^{-2bs}}\left[1-2e^{-bs}+e^{-2bs}\right]$ $= \frac{k}{s}\frac{\left[1-e^{-bs}\right]^2}{\left(1-e^{-bs}\right)\left(1+e^{-bs}\right)}$ $(2M)$ $= \frac{k}{s}\tanh\left[\frac{bs}{2}\right]$ $(2M)$ Note: **Find the Laplace transform of the rectangular wave given by** $f(t)=\begin{cases} 1 & ,0<t<b \\ -1 & ,b<t<2b \end{cases}$**.** **[APR/MAY 2013, 2014 R-13] (8M)** **Hint:** In the above problem put $k = 1$. **Find the Laplace transform of the rectangular wave given by** $f(t)=\begin{cases} E & ,0<t<a \\ -E & ,a<t<2a \end{cases}$ **for all** $\boldsymbol{f(t+2a)=f(t)}$ **[NOV/DEC 2010 R-13] (8M)** **Hint:** In that above solved problem put $k = E$ and $b = a$.
9	**Find the Laplace transform of a square wave function given by** $f(t)=\begin{cases} E & for \quad 0\le t\le a/2 \\ -E & for \quad a/2\le t\le a \end{cases}$ **and** $\boldsymbol{f(t+a)=f(t)}$. **[NOV/DEC 2011, 2016, MAY/JUNE 2016 R-13] (8M)**BTL5 **Answer: Refer Page No:5.95-Dr. G. Balaji.** $L[f(t)] = \frac{1}{1-e^{-ps}}\int_0^p e^{-st}f(t)dt$ $L[f(t)] = \frac{1}{1-e^{-as}}\int_0^a e^{-st}f(t)dt$ $= \frac{1}{1-e^{-as}}\left[\int_0^{a/2} e^{-st}(E)dt + \int_{a/2}^{a} e^{-st}(-E)dt\right]$ $(2M)$ $= \frac{E}{1-e^{-as}}\left[\left[\frac{e^{-st}}{-s}\right]_0^{a/2} - \left[\frac{e^{-st}}{-s}\right]_{a/2}^{a}\right]$ $(2M)$

$$= \frac{E}{s}\frac{1}{1-e^{-as}}\left[1-2e^{-as/2}+e^{-sa}\right]$$

$$= \frac{E}{s}\frac{\left[1-e^{-as/2}\right]^2}{\left(1-e^{-as/2}\right)\left(1+e^{-as/2}\right)} \qquad (2M)$$

$$= \frac{E}{s}\tanh\left[\frac{as}{4}\right] \qquad (2M)$$

10

Find the Laplace Transform of triangular wave function $\begin{cases} t & , \ 0<t<a \\ 2a-t & , \ a<t<2a \end{cases}$ **with** $\boldsymbol{f(t+2a)=f(t)}$. **[APR/MAY 2000, 2008, 2015, 2016, MAY/JUNE 2006, 2009, 2012, NOV/DEC 2005, 2009, 2014 R-13] (8M)**BTL5

Answer: Refer Page No:5.94-Dr. G. Balaji.

$$L[f(t)] = \frac{1}{1-e^{-2as}}\int_0^{2a} e^{-st} f(t)dt$$

$$= \frac{1}{1-e^{-2as}}\left[\int_0^{a} e^{-st}t\,dt + \int_a^{2a} e^{-st}(2a-t)dt\right] \qquad (2M)$$

$$L[f(t)] = \frac{1}{1-e^{-2as}}\left[\frac{-ae^{-as}}{s} - \frac{e^{-as}}{s^2} + \frac{1}{s^2} + \frac{ae^{-as}}{s} + \frac{e^{-2as}}{s^2} - \frac{e^{-as}}{s^2}\right] \qquad (3M)$$

$$L[f(t)] = \frac{1}{1-e^{-2as}}\left[\frac{1-2e^{-as}+e^{-2as}}{s^2}\right]$$

$$= \frac{1}{s^2}\frac{(1-e^{-as})^2}{(1-e^{-as})(1+e^{-as})}$$

$$= \frac{1}{s^2}\frac{(1-e^{-as})}{(1+e^{-as})}.$$

$$= \frac{1}{s^2}\tanh\left[\frac{as}{2}\right]. \qquad (3M)$$

11

Using Laplace transform technique, solve $\boldsymbol{y''+y'=t^2+2t}$ **, given** $\boldsymbol{y=4, y'=-2}$ **when** $\boldsymbol{t=0}$**. [NOV/DEC 2013, MAY/JUNE 2016 R-13] (8M)**BTL 3

Answer: Refer Page No:5.109-Dr. G. Balaji.

Given: $y''+y'=t^2+2t,\ y=4, y'=-2$ when $t=0$,

	$L[y''(t)]+L[y'(t)]=L[t^2]+2L[t]$ $s^2L[y(t)]-sy(0)-y'(0)+sL[y(t)]-y(0)=\frac{2}{s^3}+2\frac{1}{s^2}$ $(2M)$ $(s^2+s)L[y(t)]=4s+2+\frac{2+2s}{s^3}=\frac{4s^4+2s^3+2+2s}{s^3}$ $L[y(t)]=\frac{4s^4+2s^3+2+2s}{s^3(s^2+s)}$ $L[y(t)]=\frac{4}{s+1}+\frac{2}{s(s+1)}+\frac{2}{s^4}$ $(3M)$ $L[y(t)]=\frac{2}{s}+\frac{2}{s+1}+\frac{2}{s^4}$ $y(t)=2L^{-1}\left[\frac{1}{s}\right]+2L^{-1}\left[\frac{1}{s+1}\right]+2L^{-1}\left[\frac{1}{s^4}\right]$ $y(t)=2+2e^{-t}+\frac{1}{3}t^3.$ $(3M)$
12	**Solve** $\frac{d^2y}{dt^2}+4y=\sin 2t$, **given** $y(0)=3$, **and** $y'(0)=4$. **[MAY/JUNE 2014 R-13] (8M)**BTL 3 **Answer: Refer Page No:5.106-Dr. G. Balaji.** Given: $\frac{d^2y}{dt^2}+4y=\sin 2t, y(0)=3$, and $y'(0)=4$. $L[y''(t)]+4L[y(t)]=L[\sin 2t]$ $[s^2L[y(t)]-sy(0)-y'(0)]+4L[y(t)]=\frac{2}{s^2+4}$ $[s^2+4]L[y(t)]=\frac{2}{s^2+4}+3s+4$ $(3M)$ $L[y(t)]=\frac{2}{(s^2+4)^2}+\frac{3s}{s^2+4}+\frac{4}{s^2+4}$ $y(t)=\frac{2}{8}L^{-1}\left[\frac{(s^2+2^2)-(s^2-2^2)}{(s^2+2^2)^2}\right]+3\cos 2t+\frac{4}{2}\sin 2t.$ $(3M)$ $y(t)=\frac{1}{8}\sin 2t-\frac{1}{4}t\cos 2t+3\cos 2t+2\sin 2t.$ $(2M)$
13	**Solve** $\frac{d^2x}{dt^2}-3\frac{dx}{dt}+2x=2$ **given** $x=0$ **and** $\frac{dx}{dt}=5$ **for** $t=0$ **using Laplace transform method. [APR/MAY 2011, NOV/ DEC 2012 R-13] (8M)**BTL 3 **Answer: Refer Page No:5.100-Dr. G. Balaji.** Given: $\frac{d^2x}{dt^2}-3\frac{dx}{dt}+2x=2$ given $x=0$ and $\frac{dx}{dt}=5$for $t=0$.

	$L[x''(t)]-3L[x'(t)]+2L[x(t)]=L[2]$ $[s^2L[x(t)]-sx(0)-x'(0)]-3[sL[x(t)]-x(0)]+2L[x(t)]=2L[1]$ $[s^2-3s+2]L[x(t)]=\frac{2}{s}+5$ $L[x(t)]=\frac{2+5s}{s(s^2-3s+2)}$ $(2M)$ $L[x(t)]=\frac{1}{s}+\frac{(-7)}{s-1}+\frac{6}{(s-2)}$ $x(t)=L^{-1}\left[\frac{1}{s}\right]-7L^{-1}\left[\frac{1}{s-1}\right]+6L^{-1}\left[\frac{1}{(s-2)}\right]$ $(3M)$ $x(t)=1-7e^t+6e^{2t}$ $(3M)$
14	**Solve using Laplace transform, $x''-2x'+x=e^t$ when $x(0)=2, x'(0)=-1$. [NOV/DEC 2015, APRIL 2017 R-13] (8M).**BTL 3 **Answer: Refer Page No:5.103-Dr. G. Balaji.** Given: $x''(t)-2x'(t)+x(t)=e^t$ $x(0)=2; x'(0)=-1$ $[s^2L[x(t)]-sx(0)-x'(0)]-2[sL[x(t)]-x(0)]+L[x(t)]=L(e^t)$ $L[x(t)](s-1)^2=\frac{1}{s-1}+2s-2-3.$ $(3M)$ $L[x(t)]=\frac{1}{(s-1)^3}+\frac{2(s-1)}{(s-1)^2}-\frac{3}{(s-1)^2}$ $x(t)=L^{-1}\left[\frac{1}{(s-1)^3}\right]+2L^{-1}\left[\frac{1}{(s-1)}\right]-3L^{-1}\left[\frac{1}{(s-1)^2}\right]$ $=e^t\frac{t^2}{2}+2e^t-3e^tt$ $(5M)$
15	**Solve by using L.T$(D^2+9)y=\cos 2t$, given that if $y(0)=1, y\left(\frac{\pi}{2}\right)=-1$. [NOV/DEC 2004, MAY/JUNE 2009, APR/MAY 2015, DEC/JAN 2016 R-13] (8M)**BTL 3 **Answer: Refer Page No: 5.99-Dr. G. Balaji.** Given: $(D^2+9)y=\cos 2t.$ $y''(t)+9y(t)=\cos 2t.$ $L(y''(t))+9L(y(t))=L(\cos 2t).$ $[s^2L[y(t)]-sy(0)-y'(0)]+9L[y(t)]=\frac{s}{s^2+4}.$ $(2M)$ $(s^2+9)L[y(t)]=\frac{s}{s^2+4}+s+k.$

$$L[y(t)] = \frac{s}{(s^2+4)((s^2+9)} + \frac{s+k}{(s^2+9)}.$$

$$L[y(t)] = \frac{1}{5}\frac{s}{s^2+4} + \frac{4}{5}\frac{s}{s^2+9} + \frac{k}{s^2+9} \qquad (2M)$$

$$y(t) = \frac{1}{5}\cos 2t + \frac{4}{5}\cos 3t + \frac{k}{3}\sin 3t. \qquad (2M)$$

$$\because y\left(\frac{\pi}{2}\right) = -1$$

$$\therefore y\left(\frac{\pi}{2}\right) = \frac{1}{5}\cos 2\left(\frac{\pi}{2}\right) + \frac{4}{5}\cos 3\left(\frac{\pi}{2}\right) + \frac{k}{3}\sin 3\left(\frac{\pi}{2}\right) = -1$$

$$k = \frac{12}{5}.$$

$$y(t) = \frac{1}{5}\cos 2t + \frac{4}{5}\cos 3t + \frac{4}{5}\sin 3t. \qquad (2M)$$

16

Find the Laplace transform of theHalf-sine wave rectifier function given by

$$f(t) = \begin{cases} \sin \omega t & for \quad 0 \le t \le \pi/\omega \\ 0 & for \quad \pi/\omega \le t \le 2\pi/\omega \end{cases}$$

. [NOV/DEC 2012, 2016,2019 MAY/JUNE 2017, 2019 R-13] (8M)BTL5

Answer: Refer Page No:5.95-Dr. G. Balaji.

$$L[f(t)] = \frac{1}{1-e^{-ps}}\int_0^p e^{-st} f(t)dt$$

$$L[f(t)] = \frac{1}{1-e^{-as}}\int_0^{2\pi/\omega} e^{-st} f(t)dt$$

$$= \frac{1}{1-e^{-2\pi/\omega s}}\left[\int_0^{\pi/\omega} e^{-st}(\sin \omega t)dt + \int_{\pi/\omega}^{2\pi/\omega} e^{-st}(0)dt\right] \qquad (2M)$$

$$= \frac{1}{1-e^{-2\pi/\omega s}}\left[\frac{e^{-st}}{s^2+\omega^2}[-s\sin \omega t - \omega\cos \omega t\right]_0^{\pi/\omega} \qquad (2M)$$

$$= \frac{1}{1-e^{-2\pi/\omega s}}\left[\frac{e^{-st}\omega + \omega}{s^2+\omega^2}\right]$$

$$= \frac{\omega}{[1-e^{-\pi/\omega s}][[s^2+\omega^2]]} \qquad (2M)$$

PH8253 PHYSICS FOR ELECTRONICS ENGINEERING L T P C
(Common to BME, ME, CC, ECE, EEE, E&I, ICE) **3 0 0 3**

OBJECTIVES:

✓ To understand the essential principles of Physics of semiconductor device and Electron transport properties. Become proficient in magnetic, dielectric and optical properties of materials and nano devices.

UNIT I ELECTRICAL PROPERTIES OF MATERIALS 9

Classical free electron theory - Expression for electrical conductivity – Thermal conductivity, expression - Wiedemann-Franz law – Success and failures - electrons in metals – Particle in a three dimensional box – degenerate states – Fermi- Dirac statistics – Density of energy states – Electron in periodic potential: Bloch thorem – metals and insulators - Energy bands in solids– tight binding approximation - Electron effective mass – concept of hole.

UNIT II SEMICONDUCTOR PHYSICS 9

Intrinsic Semiconductors – Energy band diagram – direct and indirect semiconductors – Carrier concentration in intrinsic semiconductors – extrinsic semiconductors - Carrier concentration in N-type & P-type semiconductors – Carrier transport: Velocity-electric field relations – drift and diffusion transport - Einstein‘s relation – Hall effect and devices – Zener and avalanche breakdown in p-n junctions - Ohmic contacts – tunnel diode - Schottky diode – MOS capacitor - power transistor.

UNIT III MAGNETIC AND DIELECTRIC PROPERTIES OF MATERIALS 9

Magnetism in materials – magnetic field and induction – magnetization - magnetic permeability and susceptibility–types of magnetic materials – microscopic classification of magnetic materials - Ferromagnetism: origin and exchange interaction- saturation magnetization and Curie temperature – Domain Theory. Dielectric materials: Polarization processes – dielectric loss – internal field – Clausius-Mosotti relation- dielectric breakdown – high-k dielectrics.

UNIT IV OPTICAL PROPERTIES OF MATERIALS **9**

Classification of optical materials – carrier generation and recombination processes - Absorption emission and scattering of light in metals, insulators and Semiconductors (concepts only) - photo current in a P- N diode – solar cell –photo detectors - LED – Organic LED – Laser diodes – excitons - quantum confined Stark effect – quantum dot laser.

UNIT V NANOELECTRONIC DEVICES **9**

Introduction - electron density in bulk material – Size dependence of Fermi energy– quantum confinement – quantum structures - Density of states in quantum well, quantum wire and quantum dot structures –Zener-Bloch oscillations – resonant tunneling – quantum interference effects – mesoscopic structures: conductance fluctuations and coherent transport – Coulomb blockade effects - Single electron phenomena and Single electron Transistor – magnetic semiconductors– spintronics - Carbon nanotubes: Properties and applications.

TOTAL :45 PERIODS

OUTCOMES:

At the end of the course, the students will able to

✓ Gain knowledge on classical and quantum electron theories, and energy band structuues,
✓ Acquire knowledge on basics of semiconductor physics and its applications in various devices,
✓ Get knowledge on magnetic and dielectric properties of materials,
✓ Have the necessary understanding on the functioning of optical materials for optoelectronics,
✓ Understand the basics of quantum structures and their applications in spintronics and carbon electronics.

TEXT BOOKS:

1. Kasap, S.O. ―Principles of Electronic Materials and Devices‖, McGraw-Hill Education, 2007.
2. Umesh K Mishra & Jasprit Singh, ―Semiconductor Device Physics and Design‖, Springer, 2008.
3. Wahab, M.A. ―Solid State Physics: Structure and Properties of Materials‖. Narosa Publishing House, 2009.

REFERENCES:

1. Garcia, N. & Damask, A. ―Physics for Computer Science Students‖. Springer-Verlag, 2012.
2. Hanson, G.W. ―Fundamentals of Nanoelectronics‖. Pearson Education, 2009

UNIT I ELECTRICAL PROPERTIES OF MATERIALS

Classical free electron theory - Expression for electrical conductivity – Thermal conductivity, expression - Wiedemann-Franz law – Success and failures - electrons in metals – Particle in a three dimensional box – degenerate states – Fermi- Dirac statistics – Density of energy states – Electron in periodic potential: Bloch theorem – metals and insulators - Energy bands in solids– tight binding approximation - Electron effective mass – concept of hole.

Q. No.	PART – A

1. **List out the properties of metallic conductors.** BTL1(May 2011, Dec 2012)

- Metallic conductors have high electric and thermal conductivities.
- Metallic conductor obey Ohm's law,
- They have low electrical resistivity.
- Resistivity (ρ) α Temperature (T)
- Near absolute zero, ρ tends to zero.
- Resistivity is inversely proportional to Pressure (i.e.) ρ α 1/p

Examples : all metals

2 **Define mean free path.** BTL1(June 2009, June 2012)

The average distance traveled by a free electron between two successive collisions in the presence of an applied field. $\boldsymbol{\lambda = V_d \times \tau_C}$

3 **Define relaxation time and collision time.** BTL1(June 2012)

Relaxation time (τ) : The average time taken by a free electron to reach its equilibrium position from its disturbed position due to the application of an external electric field.

Collision time (τ_c) : The average time taken by a free electron between two successive collisions. $\tau_C = \lambda / V_d$

4 **Define drift velocity of electrons and give its formula.** BTL1(June 2010, June 2011)

The average velocity acquired by free electrons when they are drifted towards the positive terminal of the xternal electric field. Its unit is m/S.

$$\mathbf{V_d = (Ee\tau / m)}$$

5 **What are the differences between Drift velocity and thermal velocity of an electron?** BTL1(June 2010)

S. No.	Drift velocity	Thermal velocity
1.	Drift velocity is the average velocity acquired by the free electron. In the presence of electric field.	Thermal velocity is the velocity of an electron without any external field.
2.	The electrons moving with drift velocity moves in the direction opposite to that of the field direction	The direction of the electrons moving with thermal velocity is random
3.	The velocity is very less (0.5 m/s)	The velocity is very high (10^6 m/s)

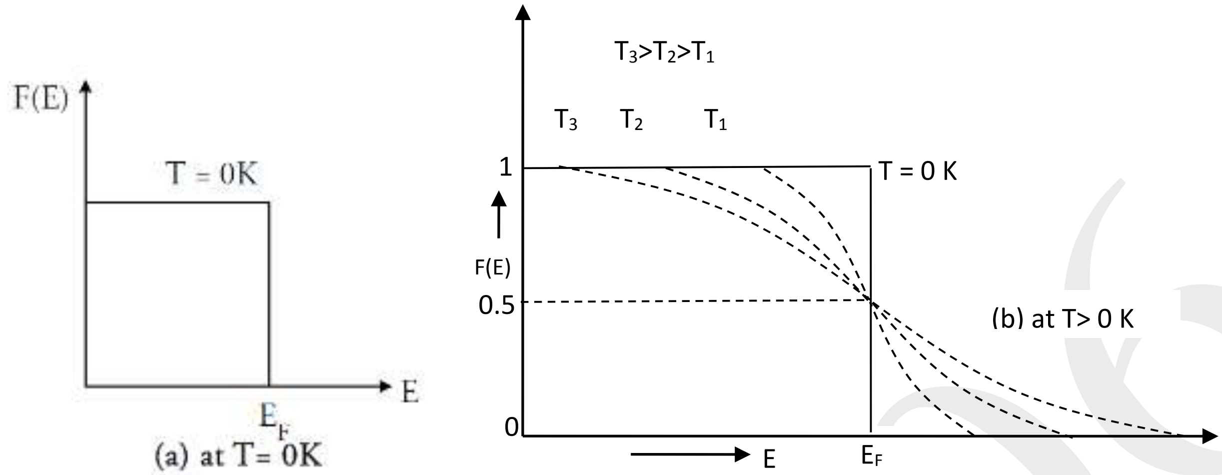
6 **Distinguish electrical (drift) conductivity and thermal conductivity of an electron.**BTL4 (April 2002)

S. No	Electrical (Drift) conductivity	Thermal conductivity
1.	Electrical conductivity is based on the no of free electrons	Thermal conductivity is based on both free electrons and phonons
2.	It is the quantity of electric charge flowing per unit time across unit area in for unit applied electric field.	It is the amount of heat flowing per unit time through the material having unit area of cross-section maintaining unit temperature gradient.

3.	Electrical conductivity takes place from higher potential side to lower potential side	Thermal conductivity takes place from hot end to cold end
4.	Its unit is $\Omega^{-1}m^{-1}$	Its unit is $Wm^{-1}\ k^{-1}$

7	**Define mobility of electrons.** BTL1(June 2011) The drift velocity (V_d) acquired by the free electron per unit electric field (E) applied on it. ItsUnit is $m^2\ V^{-1}\ s^{-1}$.
8	**Define current density.** BTL1 The amount of current flowing per unit area of cross section normal to the direction of flow. Its unit is Am^{-2}. (J=I/A)
9	**Define electrical conductivity (σ).** BTL1(April 2002) The amount of charge conducted per unit time, per unit area per unit electric field strength. It has the unit $\Omega^{-1}m^{-1}$. $$\sigma = \frac{q}{AEt}$$
10	**Define thermal conductivity (K). Give its unit.** BTL1(April 2002) Thermal conductivity of a material is defined as the amount of heat flowing per unit time through the material having unit area of cross-section maintaining unit temperature gradient. Its unit is $Wm^{-1}K^{-1}$ $$K = \frac{Q}{A\frac{dT}{dx}t}$$
11	**Define thermal conductivity (K). Give its unit.** BTL1 The amount of heat flowing per unit time through the material having unit area of cross-section maintaining unit temperature gradient. Its unit is $Wm^{-1}K^{-1}$ $$K = \frac{Q}{A\frac{dT}{dx}t}$$
12	**State Wiedemann – Franz Law.** BTL1(June 2007,2009, Dec 2009, May 2011) The ratio of thermal conductivity (K) to electrical conductivity (σ) of a metal is directly proportional to the absolute temperature (T) of the metal. (i.e) $\frac{K}{\sigma} \propto T$ $\quad ie\ \ \frac{K}{\sigma} = LT$ L = Lorentz number = 1.12 X10^{-8} $W\Omega K^{-2}$ at 293K.
13	**What is Lorentz number? Give the value of Lorenz number and state whether it holds good for all metals and at all temperatures?** BTL4 The ratio between thermal conductivity (K) to the product of electrical conductivity (σ) and absolute temperature (T) of the metal. It is a constant. (i.e) $L = \frac{K}{\sigma T}$; Where, $L = \frac{3}{2}\left(\frac{K_B}{e}\right)^e = 1.12\ \ x\ 10^{-8}\ W\Omega K^{-2}\ at\ 293\ K,$ $where\ K_B\ is\ Boltzman\ constant, e - Charge\ of\ electron$
14	**State the postulates of classical free electron theory or what are the special features of classical free electron theory of metals?** BTL1(June 2009, May 2011) • A metal is composed of atoms in which electrons revolve around the nucleus at its centre. • The free electrons (electron gas) of atoms are free to move about the whole volume of the metal like the molecule of a perfect gas in a container. • In the absence of an electric field, the free electrons move in random directions, making collision with each other or with positive ion core. All the collisions are elastic collisions. • When an external electric filed is applied, the electrons are accelerated towards positive potential with a constant velocity known as drift velocity (V_d). • Free electrons obey Maxwell distribution and kinetic theory of gases
15	**What are the merits of classical free electron theory?** BTL1(June 2005, June 2007, May 2011)

	• Explains the electrical and thermal conductivities of metals. • Used to derive Wiedemann - Franz law. • Explains the optical properties of metals. • Used to verify ohm's law.
16	**Mention the drawbacks of classical free electron theory.** BTL2(May 2011) • The electrical conductivity of semiconductors and insulators cannot be explained by this theory. • Classical theory states that all free electrons absorb the supplied energy, but quantum theory states that only a few electrons absorb the supplied energy. • By Classical theory Lorentz Number ($L = K / \sigma T$) is a constant at all temperatures but by quantum theory it is not constant at low temperatures. • The value of specific heat of a metal is 4.5R but experimental value is only 3R, where R is a universal gas constant. • The susceptibility of a paramagnetic material is inversely proportional to temperature. But experimental results show that it is independent to temperature. This theory cannot be used to explain the Ferro-magnetism. • Photo-electric effect, Compton Effect and black body radiation cannot be explained by this theory.
17	**Mention the important features of quantum free electron theory of metals.** BTL2 • Explains the electrical & thermal conductivity and specific heat capacity of metals. • Can be used to explain photoelectric effect, Compton Effect, Black body radiation
18	**Write Fermi-Dirac distribution function and give its importance.** BTL1(April 2003, Nov.2003, May 2011) Represents the probability of an electron occupying a given energy level at absolute temperature. It is also called as Fermi factor or Fermi distribution (FD) function. It is given by $F(E) = \frac{1}{1+e^{(E-E_F)/KT}}$ Where, E is energy of the level whose occupancy is being considered. E_F is Fermi energy or Fermi level of the system and k is Boltzmann's Constant & T is absolute temperature. The probability value F (E) lies between 0 and 1. • Used to analyse the occupancy of electron in a given energy leave To find Fermi energy levelu
19	**Define Fermi energy level and Fermi energy with their importance.** BTL1(June 2012, June 2010) **Fermi level** The highest energy level of the filled state at 0 K. **Fermi energy** The maximum energy of filled states at 0K. **Importance of Fermi energy** • Gives the information about the filled electrons state and empty states. • At 0 K, below EF electrons filled and above EF it will be empty. • It acts as a reference level which separates the vacant and filled states at 0 K. When the temperature is increased, few electrons gain the thermal energy and they go to higher energy levels.
20	**What is the effect of temperature on Fermi function? (or) How Fermi energy varies with respect to temperature?** BTL1(June 2010, May 2011) $F(E) = \frac{1}{1+e^{(E-E_F)/KT}}$ Where, E_F is called Fermi energy. Case 1: In metals at 0K if $E < E_F$, F (E) = 1, (i.e) 100% chance for occupation of electron in E.

	Case 2: If $E>E_F$, F (E) = 0, (i.e) 0% chance for occupation of electron in E. Case 3: IF T > OK, at E_F, F (E) = ½, (i.e) 50% chance for occupation of electron in E. 
21	**Define density of states with example.** BTL1(Dec 2003) The number of available electron states per unit volume in an energy interval E and E + dE. It is denoted by Z (E). It is given by $$Z(E)\,dE = \frac{\text{Number of energy states available between E and E+dE in a metal piece } (N(E)dE)}{\text{Volume of that metal piece } (V)}$$
22	**Define carrier concentration in metals.** BTL1 The number of free electrons per unit volume. It can be obtained by multiplying density of states and probability of electrons occupancy in the energy band. $$n_c = \int_{Energy\ band} Z(E)dE\ F(E)$$
23	**A uniform silver wire has a resistivity of 1.54 x 10^{-8} Ω m at room temperature, for an electric field along the wire of 1 V cm^{-1}. Compute the average drift velocity of electron assuming that there is 5.8 x 10^{28} conduction electron m^{-3}. Also calculate the mobility. (April 2003)** BTL4 **Given data** Conduction electron concentration n = 5.8 X 10^{28} m^{-3} Resistivity ρ = 1.54 x 10^{-8} Ω m Electric field E = 1 V / cm = $\frac{1}{10^{-2}}$ V / m = 100 V / m **Formula** Mobility $\mu = \frac{\sigma}{ne} = \frac{1}{\rho n e}$ Drift velocity $V_d = \mu E$

	$\mu = \dfrac{1}{1.54\times10^{-8}\times5.8\times10^{28}\times1.6\times10^{-19}} = \mu = 6.9973\times10^{-3}$ $V_d = 6.9973\times10^{-3}\times100$; $V_d = 0.69973$ m/s
24	**The Fermi temperature of a metal is 24,600 K. Calculate the Fermi velocity. (Apr.2003)** BTL4 **Given data** Fermi temperature T_F = 24,600 K We know, Mass of electron m = 9.1 X 10^{-31} Kg **Formula** $E_F = kT_F = \frac{1}{2} m V_F^2$ $V_F^2 = \frac{2kT_F}{m}$; $V_F = \sqrt{\frac{2kT_F}{m}}$ $V_F = \sqrt{\frac{2\times1.38\times10^{-23}\times24600}{9.11\times10^{-31}}} = 0.8633\times10^{6}$ **Answer ;** Fermi velocity $V_F = 0.8633\times10^{6}$ m / S
25	**Use Fermi function to obtain the value of F(E) for E – E_F = 0.01 eV at 200 K.** BTL4 **Given data** E – E_F = 0.01 eV and Temperature T = 200 K We know that eV = 1.6 X 10^{-19} J E – E_F = 0.01 X 1.6 X 10^{-19} J = 1.6 X 10^{-21} J **Formula** $F(E) = \frac{1}{1+e^{(E-E_F)/KT}}$ $F(E) = \frac{1}{1+\exp\left[(1.6\times10^{-21})/(1.38\times10^{-23}\times200)\right]}$ $F(E) = \frac{1}{1+\exp[0.5797]} = \frac{1}{1.7855} = 0.3589$ F (E) = 0.3589; ***Answer***Fermi Function F (E) = 0.3589 No unit
26.	**Comment on effective mass of electron.** BTL1 The mass acquired by a free electron when it accelerated in a periodic potential. It is also called as negative mass behaviour of electron.
27.	**Define energy band.** BTL1

A set of closed spaced energy levels.

28. **Appraise the concept of hole.** BTL1

The electron with the negative effective mass is considered as a new entity having the same positive mass of that of an electron but with positive charge, this new entity is named as hole.

PART – B

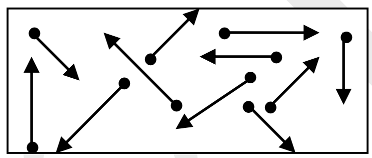
1. **(i) Give the postulates of free electron theory. Derive an expression for electrical conductivity of a metal by using classical free electron theory. (3M+7M)** BTL1

(ii) Compute the electrical conductivity, resistivity and thermal conductivity for a metal with relaxation time 10 $^{-14}$ S at 300 K. Also calculate the Lorentz number using the above result (Density of electrons is 6 X 10^{23} m^{-3}). (6 M) BTL4(Dec 2001, June 2011)

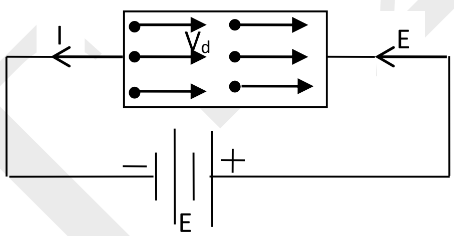
Answer: Page: 1.10 P.MANI

Postulates of CFE

- *A solid metal is composed of atoms and atoms have nucleus around which there are revolving electron.*
- *The valence electrons of an atom are free to move about the whole volume of the metal like the molecule of a perfect gas in a container.*
- *In the absence of an electric field, the free electrons move in random directions making collision with each other or with positive ion core.*



- *When an external electric filed is applied, they begin to move towards the positive potential with a constant velocity known as drift velocity (V_d).*

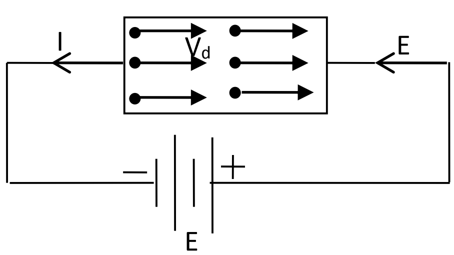


- *The movement of free electrons obeys the classical kinetic theory of gases and the electron velocities in the metal obey Maxwell – Boltzmann statistics.* (3M)

Expression for electrical conductivity (7M)

Answer page:

Electrical Conductivity: The amount charge conducted per unit time through unit cross-sectional area in unit electric field. (1 M)



(1M)

$J = neV_d$

$F = eE$ (1M)

By Newton's second law,

$F = ma \qquad a = \dfrac{eE}{m}$ (1M)

i.e., $a = \dfrac{V_d}{\tau}$; or $V_d = \tau$ a ; $V_d = \tau\left(\dfrac{eE}{m}\right)$; $\dfrac{J}{E} = \dfrac{ne^2\tau}{m}$ (1M)

From Ohm's law, Current density $J = \sigma E$ or $\sigma = \dfrac{J}{E}$ (1M)

Electrical conductivity $\sigma = \dfrac{ne^2\tau}{m}$ (1M)

Thus the electrical conductivity of a metal depends on 'n' and 'τ'.

(ii) Given data

Temperature T = 300 K

Electron concentration n = 6 X 10^{23} m^{-3}

Relaxation time τ = 10^{-14} S

We know, Mass of electron m = 9.1 X 10^{-31} Kg

Charge of electron e = 1.6 X 10^{-19} coulomb

Formula

i) Electrical conductivity $\sigma = \dfrac{ne^2\tau}{m}$ (1 M)

$$\sigma = \frac{6\times10^{28}\times(1.6\times10^{-19})^2\times10^{-14}}{9.1\times10^{-31}}$$

$$= \frac{6\times10^{28}\times2.56\times10^{-38}\times10^{-14}}{9.1\times10^{-31}} = \frac{15.36\times10^{28}\times10^{-52}}{9.1\times10^{-31}}$$

$$= 1.688\times10^{28}\times10^{-52}\times10^{+31} = 1.688\times10^{7}$$

$\sigma = 1.688\times10^{7}\ \Omega^{-1}\ m^{-1}$ (1 M)

ii) Electrical conductivity $\rho = \dfrac{1}{\sigma}$

$$\rho = \frac{1}{1.688\times10^{7}} = 0.5924\times10^{-7} = 5.924\times10^{-8}$$

$\rho = 5.924\times10^{-8}\ \Omega\ m$ (1 M)

iii) Thermal Conductivity $K = \frac{1}{2} n v^2 k \tau$

(Multiplying and dividing by m)

$$K \times \frac{m}{m} = \frac{1}{2} \frac{m v^2 n k \tau}{m}$$

$$K = \frac{3}{2} \frac{kTnk\tau}{m} \qquad \frac{1}{2} m v^2 = \frac{3}{2} kT$$

$$K = \frac{3}{2} \frac{k^2 T n \tau}{m} \qquad \text{(1 M)}$$

$$K = \frac{3 \times 6 \times 10^{28} \times (1.38 \times 10^{-23})^2 \times 300 \times 10^{-14}}{2 \times 9.1 \times 10^{-31}}$$

$$= \frac{10283.76 \times 10^{28} \times 10^{-46} \times 10^{-14}}{18.2 \times 10^{-31}}$$

$$= 565.0418 \times 10 = 56.5042$$

$$\mathrm{K} = 56.5042 \ \mathrm{W\,m^{-1}\,K^{-1}} \qquad \text{(1 M)}$$

iv) Lorentz number $L = \frac{K}{\sigma T}$

$$L = \frac{56.504}{1.688 \times 10^7 \times 300} = 0.1116 \times 10^{-7} = 1.116 \times 10^{-8}$$

$$L = 1.116 \times 10^{-8} \ \mathrm{W\,\Omega\,K^{-2}} \qquad \text{(1 M)}$$

Answers

$\sigma = 1.688 \times 10^7 \ \Omega^{-1}\,\mathrm{m}^{-1}$; $\rho = 5.924 \times 10^{-8} \ \Omega\,\mathrm{m}$

$\mathrm{K} = 56.5042 \ \mathrm{W\,m^{-1}\,K^{-1}}$; $L = 1.116 \times 10^{-8} \ \mathrm{W\,\Omega\,K^{-2}}$

2.

State and prove Wiedemann-Franz law. Why does the Lorentz number determined experimentally does not agree with the value calculated from the classical theory?(14M+2M) BTL2(May 2011)

Answer: Page: 1.10 P.MANI

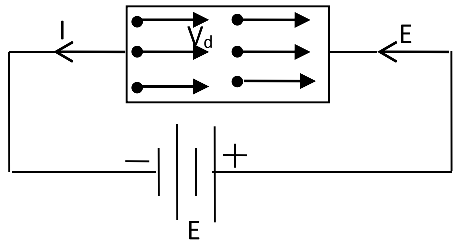
Statement of Wiedemann-Franz law

The ratio of thermal conductivity to electrical conductivity of a metal is directly proportional to the absolute temperature of the metal. This ratio is constant for all metals at a given temperature.

$$\text{i.e.,} \quad \frac{K}{\sigma} \ \alpha \ T \ \text{ or } \ \frac{K}{\sigma} = LT \ \text{(1M)}$$

Derivation of electrical conductivity

Electrical Conductivity: The amount charge conducted per unit time through unit cross-sectional area in unit electric field.



(1M)

$$J = neV_d$$

$$F = eE \qquad (1M)$$

By Newton's second law,

$$F = ma \qquad a = \frac{eE}{m} \qquad (1M)$$

$$\text{i.e., } a = \frac{V_d}{\tau} \qquad \text{or } V_d = \tau\, a \qquad V_d = \tau\left(\frac{eE}{m}\right)$$

$$\frac{J}{E} = \frac{ne^2\tau}{m} \qquad (1M)$$

From Ohm's law, Current density $J = \sigma E$ or $\sigma = \dfrac{J}{E}$

Electrical conductivity $\sigma = \dfrac{ne^2\tau}{m}$ (1M)

Derivation of thermal conductivity

Thermal conductivity: The amount of heat flowing per unit time through the material having unit area of cross-section per unit temperature gradient.

$$\text{i.e., } Q = K\frac{dT}{dx} \quad \text{or} \quad K = \frac{Q}{\frac{dT}{dx}} \qquad (1M)$$

In a uniform metallic rod AB, let us consider two cross-sections A at high temperature T and B at low temperature (T – dT) separated by a distance of mean free path **λ.**

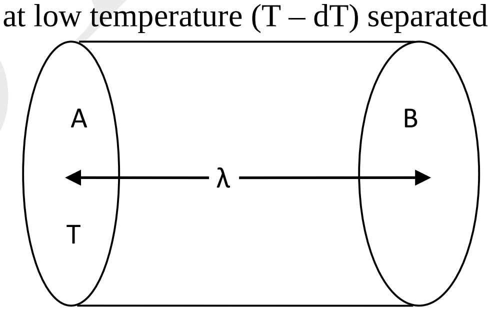


Fig. Conduction of heat in a metallic rod (1M)

	Let n be the free electron density and v be the velocity of free electron. Average kinetic energy of the electron At A = $\frac{3}{2}kT$ Average kinetic energy of an electron At B$=\frac{3}{2}k(T-dT)$ Excess kinetic energy carried by the electron from A to B = $K.E._{\text{Excess}}=\frac{3}{2}kdT$ (1M) Number of electrons crossing unit area per unit time from A to B $=\frac{1}{6}nv$ (1M) Excess energy carried from A to B for unit area in unit time = $=\frac{1}{6}nv\times\frac{3}{2}kdT=\frac{1}{4}nvkdT$ (1M) Similarly, Deficient energy carried from B to A for unit area in unit time $=-\frac{1}{4}nvkdT$ The net amount energy transferred from A to B for unit area in unit time $Q=\frac{1}{2}nvkdT$ (1M) Thermal conductivity is the amount of heat conducted per unit area per unit time = $Q=K\frac{dT}{\lambda}$ $\frac{1}{2}nvkdT=K\frac{dT}{\lambda}$ OR $K=\frac{1}{2}nvk\lambda$ We know for metals $\tau\ v=\lambda$, Therefore $K=\frac{1}{2}nv^2k\tau$ (1M) Thus the classical expression for thermal conductivity depends on ' **v** ' , '**n**' and ' τ ' **Proof of Wiedemann-Franz law** From Classical theory, $\sigma=\frac{ne^2\tau}{m}$ and $K=\frac{1}{2}nv^2k\tau$ (1M) By dividing $\frac{K}{\sigma}=\frac{1}{2}\frac{nv^2k}{e^2}$ or $\frac{K}{\sigma}=\frac{3}{2}\left(\frac{k}{e}\right)^2T$ or $\frac{K}{\sigma}=LT$ or $\frac{K}{\sigma}\ \alpha\ T$ (1M) According to Quantum Physics, the expressions for electrical and thermal conductivity are different when compared to CFE. Therefore Lorentz number are not agree with one another. (2M)
3.	**(i) Obtain Eigen values and Eigen functions of an electron enclosed in a 3-D potential box.(10M)** BTL3 **(ii) Calculate the number of states lying in an energy interval of 0.01 eV above the Fermi level for a crystal of unit volume with Fermi energy E_F = 3.0 eV.**

(i) Answer: Page: 1.23 P.MANI

Energy of the particle (Eigen values) in 3D (5M)

Wave function of the particle (Eigen values) in 3D (5M)

(ii) Solution

Given data

Fermi energy $E_F = 3.0$ eV ; Energy interval $\Delta E = E - E_F = 0.01$ eV

We know, Mass of electron m = 9.1 X 10^{-31} Kg ; Planck's constant h = 6.62 X 10^{-34} J S

We know that eV = 1.6 X 10^{-19} J; Fermi energy in Joule E_F = 3.0 X 1.6 X 10^{-19} J

E_F = 4.8 X 10^{-19} J

Energy interval $\Delta E = E - E_F = 0.01$ eV

$E = \Delta E + E_F$ = (0.01 + 3.0) eV = 3.01 X 1.6 X 10^{-19} J = 4.816 X 10^{-19} J

Formula

Number of states per unit volume lying between E_F and E is given by

$$n = \int_{E_F}^{E} \frac{4\pi}{h^3}(2m)^{3/2} E^{1/2} dE \qquad (2\text{ M})$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} \int_{E_F}^{E} E^{1/2} dE = \frac{4\pi}{h^3}(2m)^{3/2}\left[\frac{E^{3/2}}{3/2}\right]_{E_F}^{E}$$

$$= \frac{4\pi}{h^3}(2m)^{3/2} \times \frac{2}{3}\left[E^{3/2} - E_F^{3/2}\right]$$

$$n = \frac{4\times 3.14\times\left(2\times 9.1\times 10^{-31}\right)^{3/2}}{\left(6.625\times 10^{-34}\right)^3}\times\frac{2}{3}\left[\left(4.816\times 10^{-19}\right)^{3/2} - \left(4.8\times 10^{-19}\right)^{3/2}\right] \qquad (2\text{M})$$

= 3.74 X 10^{55} X (1.108 X 10^{-30}) ; n = 4.14 X 10^{25} m^{-3} (2M)

4.

Develop an expression for the density of states and based on that calculate the carrier concentration in metals. (10M+6M) BTL1(Dec 2005, June 2009, June 2010)

Answer: Page: 1.31 P.MANI

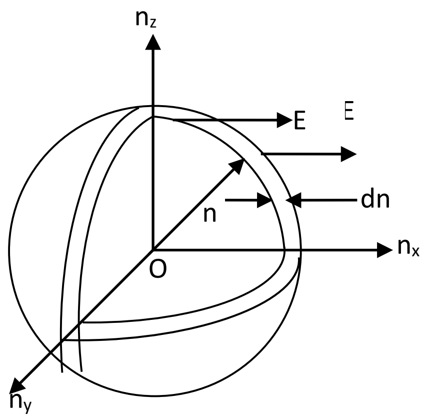
Density of statesderivation

Definition: Density of states is defined as the number of available electron states per unit volume in an energy interval E and E + dE.

$$Z(E)dE = \frac{\text{Number of energy states in energy interval E and } E+dE \text{ in a metal piece N(E) dE}}{\text{Volume of the metal piece}} \quad (2\text{M})$$

Calculation of density of states in three dimensions (derivation)

Let us consider a cubical sample with side 'a' length and volume V. A sphere is constructed with radius 'n' in the space.



(1M)

In this space, unit volume represents one energy state.

$$\text{Number of energy states within a sphere of radius n} = \frac{4}{3}\pi n^3 \quad \text{(1M)}$$

Number of available energy states within one octant of the sphere of radius n corresponding to energy E, $= \frac{1}{8}\left[\frac{4}{3}\pi\,\mathrm{n}^3\right]$ (1M)

Similarly, the number of available energy states within one octant of the sphere of radius n+dn corresponding to energy E+dE $= \frac{1}{8}\left[\frac{4}{3}\pi\,(\mathrm{n}+\mathrm{dn})^3\right]$ (1M)

As a result, the number of available energy states between the shell of radius n and n+dn or between the energy levels E and E+dE,

$$\mathrm{N(E)\ dE} = \frac{1}{8}\left[\frac{4}{3}\pi\,(\mathrm{n}+\mathrm{dn})^3\right] - \frac{1}{8}\left[\frac{4}{3}\pi\,\mathrm{n}^3\right]$$

$$N(E)dE = \frac{1}{8}\left(\frac{4}{3}\pi\right)\left[dn^3 + 3n^2dn + 3ndn^2\right] \quad \text{(1M)}$$

Higher powers of dn is very small, Hence dn^2 and dn^3 can be neglected

i.e., Number of available energy states between the energy interval E and dE

$$N(E)dE = \frac{\pi}{2}\mathrm{n}^2 dn \quad \text{or} \quad N(E)\,dE = \frac{\pi}{2}n\,(ndn) \quad \text{(1M)}$$

According to Particle in a box problem, the energy of an electron in a cubical metal piece of sides a is given by

$$E = \frac{n^2h^2}{8ma^2}$$

Or $n^2 = \frac{8ma^2E}{h^2}$ and $n = \left[\frac{8ma^2E}{h^2}\right]^{1/2}$ (1M)

Differentiating we get , $2ndn = \frac{8ma^2dE}{h^2}$ Or $ndn = \frac{8ma^2dE}{2h^2}$

Substituting $N(E)dE = \frac{\pi}{4}\left[\frac{8ma^2}{h^2}\right]^{3/2} E^{1/2}dE$ (2M)

Pauli's exclusion principle states that two electrons of opposite spins can occupy each state.

$N(E)dE = \frac{4\pi}{h^3}(2m)^{3/2}a^3E^{1/2}dE$; The number of energy per unit volume $Z(E)dE = \frac{4\pi}{h^3}(2m)^{3/2}E^{1/2}dE$ (1M)

Carrier concentration in metal

Carrier concentration is the number of electrons per unit volume in a given energy interval.

i.e., $n_c = \int_{energyband} Z(E)F(E)dE$ (2M)

Substituting the expressions for Z (E) and F (E)

$n_c = \int_{energyband} \frac{4\pi}{h^3}(2m)^{3/2}E^{1/2}dE \times \frac{1}{1+e^{(E-E_F)/KT}}dE$ (2 M)

5.

Starting with the density of energy states obtain the expression for the Fermi energy of an electron at 0 K and hence obtain the expression for the average energy of an electron.(12 M+4M) BTL3

Answer: Page: 1.37 P.MANI

Density of energy states

The number of energy per unit volume $Z(E)dE = \frac{4\pi}{h^3}(2m)^{3/2}E^{1/2}dE$ (2M)

Expression for Fermi energy of electron

Carrier concentration is the number of electrons per unit volume in a given energy interval.

i.e., $n_c = \int_{energyband} Z(E)F(E)dE$ (2M)

Substituting the expressions for Z (E) and F (E)

$n_c = \int_{energyband} \frac{4\pi}{h^3}(2m)^{3/2}E^{1/2}dE \times \frac{1}{1+e^{(E-E_F)/KT}}dE$ (2 M)

For a metal at 0 K, the upper occupied level is E_F and F (E) for all the levels below E_E is 1.i.e., F (E) =1

$n_c = \int_0^{E_F} \frac{4\pi}{h^3}(2m)^{3/2}a^3E^{1/2}dE$ (2M)

i.e., $n_c = \frac{8\pi}{3h^3}(2mE_F)^{3/2}$ (2 M)

Fermi energy E_F at 0 K is given by, $E_{F_0} = \left(\frac{h^2}{2m}\right)\left(\frac{3n_c}{8\pi}\right)^{2/3}$ (2M)

Expression for average energy of an electron

Average energy of an electron at 0K

Eave = Total energy of the electrons at 0K ET / Number of energy states at 0K (N) $E_{ave} = 3/5\ E_{F0}$ (4M)

6.

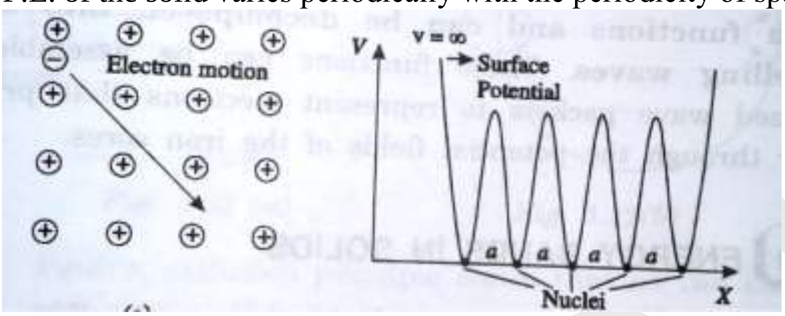
Explain the energy band theory of solids with necessary theory. (or) Describe the behaviour of electron in a periodic potential. (8 M) BTL2

Answer: Page: 1.40 P.MANI

Energy band theory postulates

P.E. of electron within the crystal is periodic due to periodicity of the crystal

P.E. of the solid varies periodically with the periodicity of space lattice ”a” (2M)



(2 M)

Bloch Theory Postulates

The solutions of Schrodinger equations are plane waves modulated by the function $u_k(x)$ which has the same periodicity as the lattice.

$$\frac{\partial^2\psi}{\partial x^2} + \left(\frac{2m}{\hbar^2}\right)[E - V(x)]\psi = 0$$

$$\Psi(x) = e^{\pm ikx} u_k(x)$$

Where, $u_k(x) = u_k(x + a)$

(2M)

These wave functions are called Bloch function,

$$\psi(x+a) = e^{\pm ikx} u_k(x+a) = e^{\pm ikx} \psi(x)$$

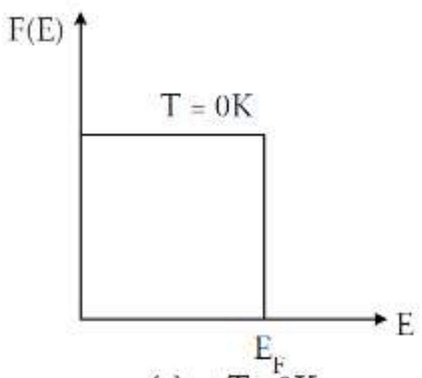
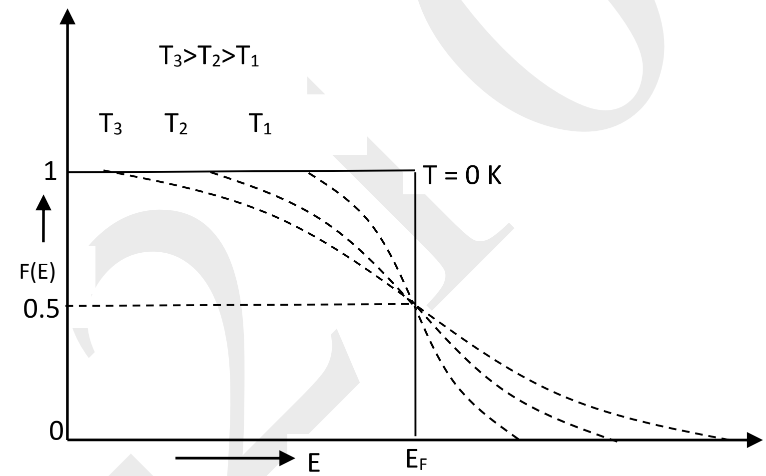
Thus Bloch functions have the property that,

$$\psi(x+a) = \lambda \psi(x)$$

where the constant λ is

$$\lambda = e^{\pm ika}$$

(2M)

8.	**Write an expression for the Fermi energy distribution function F (E) and illustrate its behaviour with change in temperature. Plot F (E) versus E for T= 0 K, and T > 0 K. (2M+8M)(or) What is Fermi function? Describe the variation of Fermi function with respect to temperature.(8M)**BTL2 **Answer: Page: 1.26 P.MANI** Fermi function *Represents the probability of an electron occupying a given energy level at absolute temperature. It is also called as Fermi factor or Fermi distribution (FD) function.* It is given by $F(E) = \frac{1}{1+e^{(E-E_F)/KT}}$ (2M) Variation of Fermi energy with respect to Temperature Case (i) When $E<E_F$, at T = 0K, F(E) = 1 (2M) Case (ii) When $E>E_F$, at T = 0K, F(E) = 0 (2M) Case (iii) When $E=E_F$, at T > 0K, F(E) = 0.5 (2M)  (a) at T= 0K  (2M)
9.	**Explain free electron approximation and tight binding approximation with suitable diagrams.** (**8 M**) BTL2 **Answer Page:1.48 P. MANI** Free electron approximation (4M) Tight binding approximation (4M)
10.	(i) **Discuss the concept of holes formation.(7M**) BTL1 (ii) **Write a short note on effective mass of an electron. (or) What is effective mass? Obtain an expression for effective mass of an electron. (8 M**) BTL3 **(i) Answer: Page: 1.55 P.MANI** Definition of Hole (2M) Concept of hole formation (5M) **(ii) Answer Page: 1.51 P. MANI** Definition (2 M) Derivation (6M)

UNIT-II

Intrinsic Semiconductors – Energy band diagram – direct and indirect semiconductors – Carrier concentration in intrinsic semiconductors – extrinsic semiconductors - Carrier concentration in N-type & P-type semiconductors – Carrier transport: Velocity-electric field relations – drift and diffusion transport - Einstein's relation – Hall effect and devices – Zener and avalanche breakdown in p-n junctions - Ohmic contacts – tunnel diode - Schottky diode – MOS capacitor - power transistor.

Q. No.	PART * A

1. **What are semiconductors? Give example.** BTL1

A solid material which conducts electricity partially.
Act as insulator at 0 K and conductors at high temperature
Atoms are bonded with covalent band
Eg: Si, Ge,

2. **State the properties of semiconductor.** BTL2(May 2003, June 2009, May 2011)

- They are crystalline in nature.
- They have $E_g \approx 1eV$
- They possess negative temperature coefficient of resistance.
- They have four valence electrons.
- At 0 K, semiconducting materials possess filled valence band and empty conduction band.
- Conductivity increases with increase in temperature and impurity.

3. **What are the types of semiconductor?** BTL1

Semiconductor is generally classified on the basics of purity

1) Intrinsic semiconductor and
2) Extrinsic semiconductor

Semiconductor may also classified on the basics of recombination process

1) Elemental / Indirect band gap semiconductors

Compound / Direct band gap semiconductors

4. **What are the types of semiconductor based on impurity?** BTL2

- N-type semiconductors
- P-type semiconductors

5. **Distinguish intrinsic and extrinsic semiconductor.**BTL4(Nov 2003, Dec2003, May 2011)

S. No	Intrinsic semiconductor	Extrinsic semiconductor
1.	Semiconductor in pure form is called as intrinsic semiconductor	Semiconductor doped with impurity is called as extrinsic semiconductor
2.	Here charge carriers are produced only due to thermal agitation	Here charge carriers are produced due to impurities and may also due to thermal agitation
3.	At 0 K, Fermi level exactly lies between conduction band and valance band	At 0K, Fermi level exactly lies closer to conduction band in n- type semiconductor and lies near valance band in the case of p- type semiconductor
4.	They have low electrical conductivity and operating temperature.	They have high electrical conductivity and operating temperature.
5.	Eg . Pure silicon and Germanium	Eg . Si and Ge doped with Al, In, P, As etc.

6. **Distinguish between direct/compound and indirect band gap/elemental semiconductors.** BTL4(April 2002, June 2009, May 2011)

S. No.	Direct band gap / Compound semiconductors	Indirect band gap/ Elemental semiconductors

1.	Here electron-hole recombines directly by emitting a photon.	Here electron-hole recombines directly by emitting a phonon (Heat).
2.	Recombination time of the charge carriers are very less	Recombination time of the charge carriers are more
3.	These are mostly compound semiconductors.	These are mostly elemental semiconductors.
4.	Life time of charge carriers is less	Life time of charge carriers is large
5.	They are used in LED and laser diode fabrication.	They are used in amplification of signals as in the case of diodes and transistors
6.	Example. InP, GaAs, MgO, ZnO	Example . Ge, Si

7. **Distinguish between n – type and p – type extrinsic semiconductors.** BTL4(Nov 2003, Dec 2003, May 2011)

	n – type extrinsic semiconductors	**p – type extrinsic semiconductors**
1.	When pentavalent impurities added to the intrinsic semiconductors, n- type semiconductors are formed	When trivalent impurities added to the intrinsic semiconductors, p- type semiconductors are formed
2.	Majority charge carriers are electrons	Majority charge carriers are holes
3.	Minority charge carriers are holes	Minority charge carriers are electrons
4.	The impurity is called donor impurity	The impurity is called acceptor impurity
5.	Fermi energy decrease with increase of temperature	Fermi energy increases with increase of temperature
6.	The donor energy level is very close to the bottom of the conduction band	The acceptor energy level is very close to the top of the valance band.

8. **Define mobility and electrical conductivity of intrinsic semiconductors?** BTL1

Mobility:

The velocity of a charge carrier produced due to unit field strength $\mu = v_d / E$

Electrical conductivity:

The total electrical conductivity σ_i of the intrinsic semiconductor is the sum of electrical conductivities due to the electrons and holes. $\sigma_i = en_i(\mu_e + \mu_e)$

9. **Define the term carrier concentration in intrinsic semiconductors.** BTL1

The number of electrons in the conduction band per unit volume (n) or the number of holes in the valence band per unit volume (p) of the semiconducting material. It is also known as density of charge carriers.

10. **Define Hall Effect, Hall field, Hall voltage and Hall angle.** BTL1(Nov 2003, May 2005, June 2010)

When a conductor or semiconductor carrying a current (I) is placed in a perpendicular magnetic field (B), a potential difference is produced inside the conductor in a direction normal both the current and the magnetic field. This phenomenon is called Hall Effect and the voltage thus developed is known as Hall voltage. The field induced is known as Hall filed. The angle between applied field and Hall field is known as Hall Angle.

11. **Define hall coefficient.** BTL1

The ratio of the induced electric field to the product of the current density and the applied magnetic field.

$$R_H = \frac{E_H}{J_x B_z}; \qquad R_H = \frac{bV_H}{I_x B_z}; \qquad R_H = -\frac{1}{ne}(N-Type); \quad R_H = +\frac{1}{pe}(P-Type)$$

12.	**Mention four applications of Hall Effect?** BTL4(Nov 2003, May 2005, June 2010) • To identify the nature of semiconductors. • Carrier concentration, Mobility of charge carriers can be measured directly. • Electrical conductivity can be determined. • It can be used to determine whether the solid is metal, insulator or semiconductor • Magnetic field can be measured.
13.	**How can you distinguish p – type and n- type semiconductors using Hall Effect?** BTL4(June 2010, June 2012) The n- type and p-type semiconductors can be distinguished by determining the hall coefficient using Hall Effect. $$R_H = -\frac{1}{ne}(N-type):\ \ R_H = +\frac{1}{pe}(P-type)$$
14.	**What is hall device? List its types.** BTL4 The device which uses hall effect for its applications. • Gauss meter • Electronic meter • Electronic wattmeter
15.	Find the conductivity of intrinsic germanium at 300 K. (Given: $n_i = 2.5 \times 10^{19}\ m^{-3}$) **Solution:** **Given data:** $\mu_e = 0.38\ m^2V^{-1}s^{-1}$ $\mu_e = 0.18\ m^2V^{-1}s^{-1}$ $\sigma_i = en_i(\mu_e + \mu_h)$ $= 2.5 \times 10^{19} \times 1.6 \times 10^{-19}(0.38+0.18)$ $= 2.24\ ohm^{-1}m^{-1}$ Answer: $\sigma_i = 2.24\ ohm^{-1}m^{-1}$
16.	Calculate the intrinsic concentration of charge carriers of germanium at 300 K. The effective masses of electrons and holes are $m_e^* = 0.12m_0$ and $m_h^* = 0.28m_0$ respectively. $E_g = 0.67$ for germanium. **Solution:** **Given data:** T = 300 K ; $m_0 = 9.11\times10^{-31}$; $m_e^* = 0.12m_0 = 1.0932\times10^{-31}$ $m_h^* = 0.28m_0 = 2.5508\times10^{-31}$; $E_g = 0.67$ eV $$n_i = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2}\left(m_e^* m_h^*\right)^{3/4} e^{-E_g/2kT}$$ $$n_i = 2\left(\frac{2\times3.14\times1.38\times10^{-23}\times300}{(6.626\times10^{-34})^2}\right)^{3/2}\times\left(1.0932\times10^{-31}\times2.5508\times10^{-31}\right)^{3/4}.\ e^{\left(\frac{-0.67\times1.6\times10^{-19}}{2\times1.38\times10^{-23}\times300}\right)}$$ $n_i = 4.69\times10^{18}/m^3$

	Answer: $n_i = 4.69 \times 10^{18} / m^3$
17.	**The donor density of a n-type silicon sample is $10^{21} / m^3$. The sample is arranged in a Hall experiment having magnetic field of 0.5 tesla and the current density 300 Ampere/m^2. Find the Hall voltage if the sample is 2 mm wide.** **Given data:** $n_e = 10^{21} / m^3$; B = 0.5 tesla ; $J_x = 300 A/m^2$; t =0.3 mm $R_H = \frac{-1}{n_e e}$ $R_H = \frac{-1}{10^{21} \times 1.6 \times 10^{-19}} = -6.25 \times 10^{-3}\ m^3 C^{-1}$ Hall Voltage $V_H = R_H J_x B t$; $V_H = 6.25 \times 10^{-3} \times 300 \times 0.5 \times 2 \times 10^{-3}$ $V_H = 1.875 \times 10^{-3}$ Volts; $V_H = 1.875$ mV Answer: $V_H = 1.875$ mV
18.	**A n-type semiconductor has Hall coefficient $4 \times 10^{-4} m^3 C^{-1}$. The conductivity is $200 \Omega^{-1} m^{-1}$. Calculate its charge carrier density and electron mobility at room temperature.** **Given data:** $R_H = 4 \times 10^{-4} m^3 C^{-1}$; $\sigma = 200 \Omega^{-1} m^{-1}$ Charge density $n_e = \frac{-1}{R_H e}$ $n_e = \frac{3\pi}{8} \frac{1}{R_H e}$ (Considering the periodic potential in crystals) $n_e = \frac{3 \times 3.14}{8} \times \frac{1}{1.6 \times 10^{-19} \times 4 \times 10^{-4}}$ $n_e = 1.8398 \times 10^{22} / m^3$ Electron mobility $\mu_e = \frac{\sigma_e}{n_e e}$; $\mu_e = \frac{200}{1.8398 \times 10^{22} \times 1.6 \times 10^{-19}}$ $\mu_e = 0.0679 m^{2^{-1}} V s^{-1}$; Answer: $n_e = 1.8398 \times 10^{22} / m^3$ and $\mu_e = 0.0679 m^{2^{-1}} V s^{-1}$
PART * B	
1	**Derive an expression for density of electrons in the conduction band and density of holes in the valence band of an intrinsic semiconductor, hence deduce the expression for intrinsic carrier concentration. (16 M)** BTL2(Dec 2001) **Electron concentration (n):** The number of electrons in the conduction band per unit volume **Hole concentration (p)**: The number of holes in the valence band per unit volume **Carrier concentration (or) Density of electron:** The number of charge carries per unit volume of the material. (1M) **Calculation of Density of Holes in the Valence Band of Intrinsic Semiconductors** Let d_p be the number of holes per unit volume in the valence band between the energy E and E + d E

	$dp = Z(E)(1-F(E))dE$ (1M) The probability of an unoccupied electron state, i.e., presence of a hole. $$1-F(E)=1-\left[\frac{1}{1+e^{(E-E_F)/kT}}\right]$$ Since E is very small when compared to E_F in the valence band, $(E-E_F)$ is a negative quantity and hence $e^{(E-E_F)/\kappa}$ is very small. i.e., $\therefore 1-F(E)=e^{(E-E_F)/kT}$ (1M) E_v, the top level in the valence band is the potential energy of a hole at rest. Hence, $(E_V - E)$ is the kinetic energy of the hole at level below E_V. Density of states in the valence band, $Z(E)dE=\frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v-E)^{1/2}dE$ (1M) $$dp=\frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v-E)e^{(E-E_F)/kT}dE$$ The number of holes in the valence band for the entire range is obtained $p=\int dp=\int_{-\infty}^{E_v}\frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v-E)^{1/2}e^{(E-E_F)/kT}dE$ (1M) To solve the integral in eqn (7), let us assume, $E_v - E = x$; when $E=-\infty$: $E_v+\infty=x$, $\therefore x=\infty$; when $E=E_v$: $x=E_v-E_v$, $\therefore x=0$ $E=-x+E_v$ $\therefore dE=-dx$ Substituting these values in equation, $p=\frac{4\pi}{h^3}(2m_h^*)^{3/2}e^{(E_V-E_F)/kT}\int_0^{\infty}x^{1/2}e^{(-x/kT)}dx$ (1M) Using the gamma function, $$\int_0^{\infty}x^{1/2}e^{(-x/kT)}dx=\frac{(kT)^{3/2}\pi^{1/2}}{2}$$ $p=2\left(\frac{2\pi m_h^*kT}{h^2}\right)^{3/2}e^{(E_V-E_F)/kT}$ (1M) Similarly $n_i=2\left(\frac{2\pi_e^*kT}{h^2}\right)^{3/2}e^{(E_F-E_C)/kT}$ (6M) **INTRINSIC CARRIER CONCENTRATION**

In an intrinsic semiconductor, since the concentration of electrons in the conduction band is equal to the concentration of the holes in the valence band. i.e. $n = p = n_i$, $np = n_i \times n_i = n_i^2$

Substituting the corresponding expressions for n and p,

$$n_i^2 = 2\left(\frac{2\pi_e^* kT}{h^2}\right)^{3/2} e^{(E_F - E_C)/kT} \times 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} e^{(E_V - E_F)/kT} \qquad (1M)$$

where $E_C - E_v = E_g$ is the forbidden energy gap.

$$\therefore n_i = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2} (m_e^* m_h^*)^{3/4} e^{-E_g/2kT} \qquad (2M)$$

2

Obtain an expression for the carrier concentration of holes in the valance band of intrinsic semiconductor. (10 M) BTL2(Dec 2001)

Hole concentration (or) Density of Holes (p): The number of holes in the valence band per unit volume. (1M)

Calculation of Density of Holes in the Valence Band of Intrinsic Semiconductors

Let d_p be the number of holes per unit volume in the valence band between the energy E and E + d E

$$dp = Z(E)(1 - F(E))dE \qquad (1M)$$

The probability of an unoccupied electron state, i.e., presence of a hole.

$$1 - F(E) = 1 - \left[\frac{1}{1 + e^{(E - E_F)/kT}}\right]$$

Since E is very small when compared to E_F in the valence band, $(E - E_F)$ is a negative quantity and hence $e^{(E-E_F)/\kappa}$ is very small.

i.e., $\therefore 1 - F(E) = e^{(E - E_F)/kT}$ (1M)

E_v, the top level in the valence band is the potential energy of a hole at rest. Hence, $(E_V - E)$ is the kinetic energy of the hole at level below E_V.

Density of states in the valence band, $Z(E)dE = \frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v - E)^{1/2} dE$ (1M)

$$dp = \frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v - E)e^{(E-E_F)/kT} dE \qquad (1M)$$

The number of holes in the valence band for the entire range is obtained

$$p = \int dp = \int_{-\infty}^{E_v} \frac{4\pi}{h^3}(2m_h^*)^{3/2}(E_v - E)^{1/2} e^{(E-E_F)/kT} dE \qquad (1M)$$

To solve the integral in eqn (7), let us assume,

	when	when
$E_v - E = x$	$E = -\infty$	$E = E_v$

$$E = -x + E_v \qquad E_v + \infty = x \qquad x = E_v - E_v$$

$$\therefore dE = -dx \qquad \therefore x = \infty \qquad \therefore x = 0 \text{ (1M)}$$

Substituting these values in equation,

$$p = \frac{4\pi}{h^3}(2m_h^*)^{3/2} e^{(E_V - E_F)/kT} \int_0^\infty x^{1/2} e^{(-x/kT)} dx \qquad \text{(1M)}$$

Using the gamma function,

$$\int_0^\infty x^{1/2} e^{(-x/kT)} dx = \frac{(kT)^{3/2} \pi^{1/2}}{2} \qquad \text{(1M)}$$

$$p = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} e^{(E_V - E_F)/kT} \qquad \text{(2M)}$$

3 **Explain extrinsic semiconductors and derive the expression for carrier concentration for n-type and p-type semiconductor. (2 M + 7M+7M)** BTL2(May 2003, Dec 2009, May 2011)

Answer Page: Dr. P. Mani

Extrinsic semiconductor: doped semiconductors are extrinsic semiconductors. Pentavalent doped semiconductors are n-type and trivalent doped semiconductors are p-type semiconductors. (2M)

Carrier concentration in n-type semiconductor (derivation):

Density of electrons per unit volume= $n = 2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2} e^{(E_F - E_C)/kT}$ (1 M)

Equating $$2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2} e^{(E_F - E_C)/kT} = N_d e^{(E_d - E_F)/kT} \qquad \text{(2 M)}$$

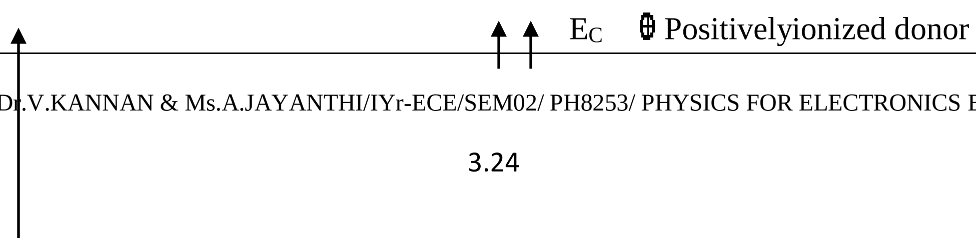
Taking log on both sides, we get

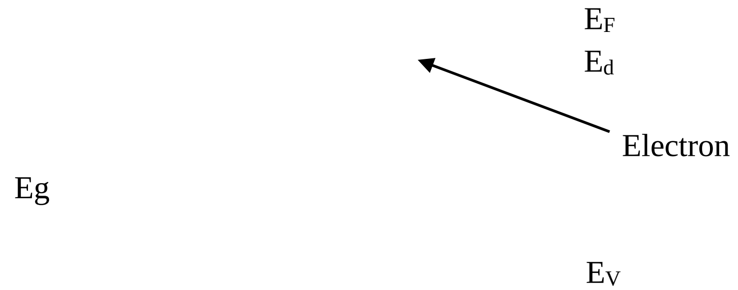
$$\log_e\left[2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}\right] + \frac{E_F - E_C}{kT} = \log_e N_d + \frac{E_d - E_F}{kT}$$

$$E_F = \frac{E_d + E_C}{2} + \frac{kT}{2}\log_e\left[\frac{N_d}{2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2}}\right] \qquad \text{(2M)}$$

Substituting the expression of E_F $$\boxed{n = (2N_d)^{1/2}\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/4} e^{-\Delta E/2kT}} \qquad \text{(1M)}$$

Where $\Delta E = E_C - E_d$ is the ionization energy of the donor





(1M)

Concentration of holes in the valence band of p-type semiconductor (derivation):

Let E_α represent the energy of the acceptor level and $N_\alpha$denote the number of acceptor atoms per unit volume, Density of holes $p = 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} e^{(E_V - E_F)/kT}$ (1M)

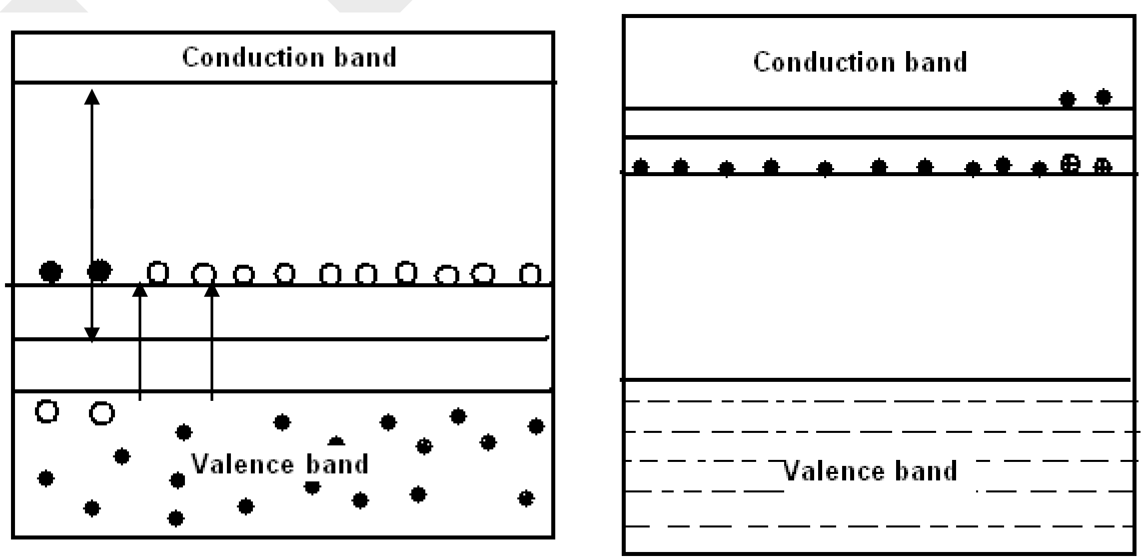
Where E_F is Fermi energy level; E_V is the energy corresponding to the top level of valence band.

Density of ionized Acceptors $N_a F(E_a) = \frac{N_a}{1 + e^{(E_d - E_F)/kT}}$

Density of ionized Acceptors $= N_a e^{(E_d - E_F)/kT}$ (1M)

At equilibrium,= Density of holes in the valence band= Density of ionized acceptors

$$2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} e^{(E_V - E_F)/kT} = N_a e^{(E_d - E_F)/kT} \qquad \text{(1 M)}$$



Taking log on both sides, we have

	$$\log_e 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} + \frac{E_V - E_F}{kT} = \log_e N_a + \frac{E_F - E_a}{kT}$$ Rearranging the expressions, we have $$E_F = \frac{E_a + E_V}{2} - \frac{kT}{2}\log_e\left[\frac{N_a}{2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2}}\right] \quad (2M)$$ Substituting the expression of E_F , If $E_a - E_v = \Delta E$, $$\boxed{p = (2N_a)^{1/2}\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/4} e^{-\Delta E/2kT}} \quad (1M)$$
4	**What is carrier transport? Explain drift transportation in detail. (2M+8M)** BTL1 **Answer Page: 2.35 Dr. P. MANI** **Carrier transport:** • Any motion of free carriers in a semiconductor leads to a current. • This motion can be caused by an electric field due to an externally applied voltage, since the carriers are charged particles. • This transport mechanism is *carrier drift.* • Carriers also move from high density regions to low density region. • This carrier transport mechanism is due to the thermal energy and the associated random motion of the carries. • This transport mechanism *is carrier diffusion*. • The total current equals the sum of the drift and the diffusion current. (2M) **Drift transportation**

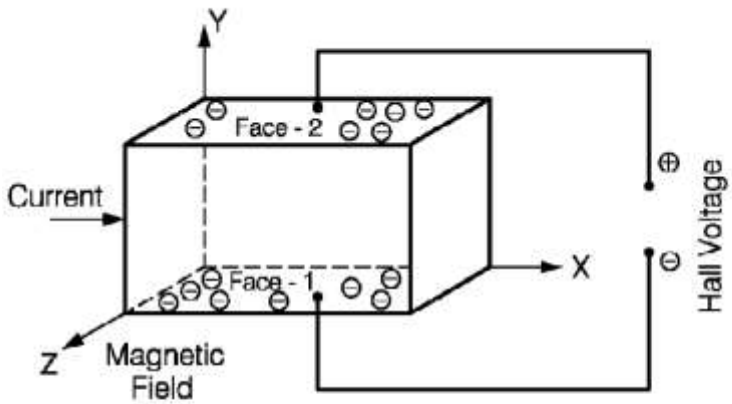
	For electron For Holes $V = -\frac{eE}{m_n}.t$ $V = \frac{eE}{m_n}.t$ Average net velocity of electron Average net velocity of holes $V_{d_n} = -\frac{eE}{m_n}.\tau_c$ $V_{d_p} = \frac{eE}{m_p}.\tau_c$ We know that, We know that, Mobility $\mu_n = \frac{V_{d_n}}{E}$ Mobility $\mu_p = \frac{V_{d_p}}{E}$ $\therefore V_{d_n} = -\mu_n.E$ $\therefore V_{d_p} = \mu_p.E$ (3 M) $J_{nd} = -enV_{dn}$ $J_{pd} = epV_{dp}$ $J_{nd} = +en\mu_n E$ $J_{pd} = ep\,\mu_p E$ **(2M)** $J_{drift} = e(\mu_n n + \mu_p p)E$ We know that, $J_{drift} = \sigma E$ Comparing the above two equation, we get Conductivity, $\sigma = e(\mu_n n + \mu_p p)$ Resistivity $P = \frac{1}{e(\mu_n n + \mu_p p)}$ Resistivity is commonly used to specify doping level. In n-type semiconductor In p-type semiconductor $P_n = \frac{1}{eN_d\mu_n}$ $P_p = \frac{1}{eN_a\mu_p}$ **(3M)**
5	**Write a short notes on (i) Diffusion transport (8 M) (ii) Einstein Relation (6M)** BTL2 **(i) Answer Page: 2.39 Dr. P. MANI**

	In semiconductors, the "flow of carriers" from one region to higher concentration to lower concentration results in a "diffusion current" or carrier diffusion. Ficks law describes diffusion as the flux 'F' is proportional to the gradient in concentration. i.e. Diffusion flux $\propto$ - concentration gradient **(2M)** For electron, For holes, $F_n = -D_n \frac{dn}{dx}$ $F_p = -D_p \frac{dp}{dx}$ $J_{n,\,dif} = e\,Dn\,\frac{dn}{dx}$ $J_{p,\,dif} = -e\,Dp\,\frac{dp}{dx}$ **(2M)** $J_n = en\mu_n E_x + eD_n \frac{dn}{dx}$ $J_p = ep\mu_p E_x - eD_p \frac{dp}{dx}$ $J = J_n + J_p = en\mu_n E_x + ep\mu_p E_x + eD_n \frac{dn}{dx} - eD_p \frac{dp}{dx}$ **(2 M)** **(ii) Answer Page: 2.41 Dr. P. MANI** Einstein derived the relationship between the mobility (μ) and diffusion coefficient (D) using non-uniformly doped semiconductor model $\boxed{\frac{D}{\mu} = \frac{K_B T}{e}}$ **(3M)** In semiconductor, $\boxed{\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{K_B T}{e}}$ **(3 M)**
6	**State and explain Hall effect. With necessary theory and diagram, derive the Hall coefficient. (3 M+ 13M)** BTL2(May 2007, Dec 2009) **Hall Effect:** When a conductor (metal or semiconductor) carrying a current (I) is placed in a magnetic field (B) perpendicular to this current, a potential difference (electric field) is developed inside the

conductor in a direction normal to the directions of both the current and the magnetic field. This phenomenon is known as Hall effect and the voltage thus generated is called Hall voltage. (3 M)

Hall effect in n-type semiconductor

Let us consider a n-type semiconducting material in the form of rectangular slab,



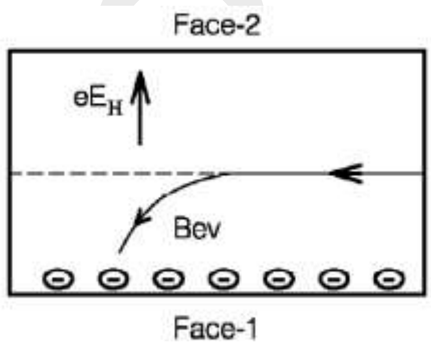
(1M)

Fig. Hall effect

When a magnetic field (B) is applied in Z-direction, the electrons moving with velocity v will experience a downward force.

Downward force experienced by the electrons = Bev (1 M)

This downward force deflects the electrons in downward direction and therefore, there is an accumulation of negatively charged electrons on the bottom face of the slab as shown in fig.



Hall effect in n-type semiconductor (1 M)

This electric field develops a force which is acting in the upward direction on each electron,

Upward force acting on each electron = eE_H (1 M)

At equilibrium, **the downward force Bev will balance the upward force eE_H**

$$\therefore Bev = eE_H \quad \text{or} \quad E_H = Bv \qquad (1\text{ M})$$

The current density (J_x) acting along the X-direction is related to the velocity v as

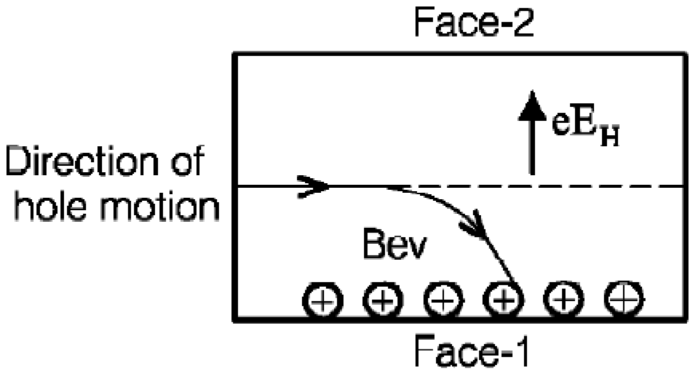
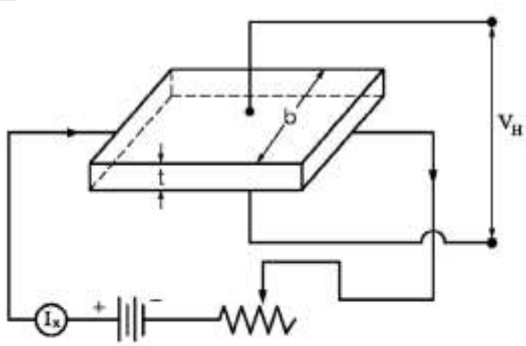
$J_x = -nev$, Where n is the concentration of current carriers (electrons).

$$v = \frac{-J_x}{ne} \text{ ; Substituting v, } E_H = \frac{-BJ_x}{ne} \quad \text{OR} \quad E_H = R_H J_x B \quad \text{OR} \qquad (1\text{ M})$$

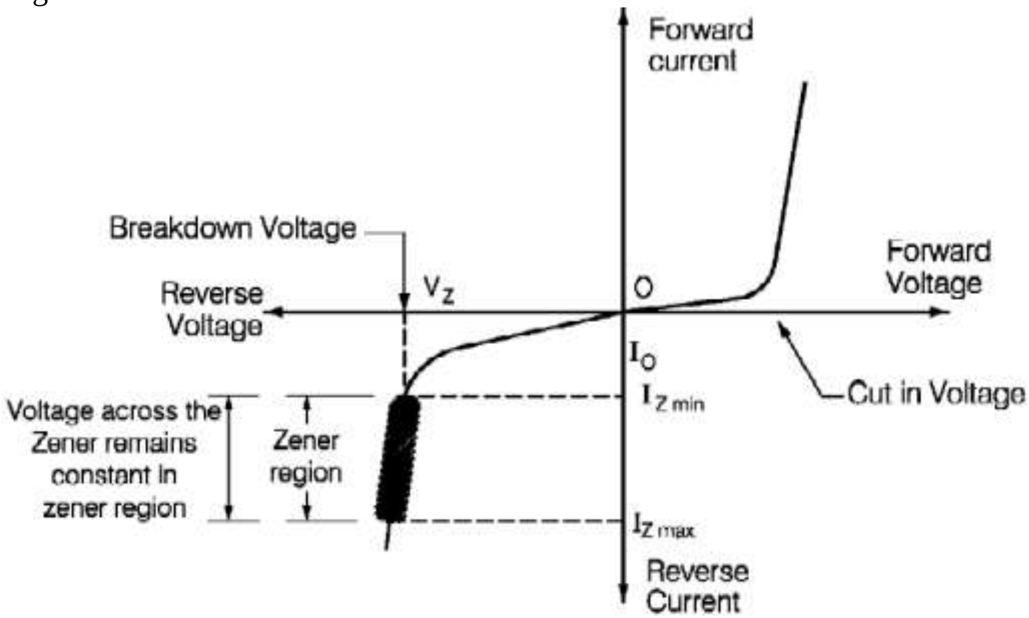
$$\text{or} \quad R_H = \frac{E_H}{J_x B}, \quad \text{where} \quad R_H = -\frac{1}{ne} \qquad (1\text{ M})$$

R_H is a constant and it is known as Hall coefficient.

Hall effect in p-type semiconductor

	Consider a rectangular slab of p-type semiconducting material and the current flow in this case is entirely due to the flow of positive holes from left to right as shown in fig.  (1 M) **Hall effect in p-type semiconductor** Due to applied magnetic field, the holes are accumulated in the bottom of the slab and thus produce a potential difference.Similar to n-type semiconductor, we can write $E_H = R_H J_x B$ (4 M) Where Hall coefficient (R_H) , $R_H = +\frac{1}{pe}$; Where p is the concentration of current carriers (holes). (1 M)
7	**(i) Describe the experiment to determine the Hall Coefficients. List the various Hall devices and explain them. (10 M)** BTL2 **(ii) Find the Hall coefficient and electron mobility of germanium for a given sample of length 1 cm , breadth 5 mm and thickness 1 mm. A current of 5 mA flows from a 1.3 volt supply and develops a Hall voltage of 20 millivolt across the specimen in a magnetic field of 0.45 wb/m^2. (4 M)** BTL4 **(i) Answer Page : 2.48 Dr. P. MANI** Experimental set up  (2 M) Explanation

	$V_H = \frac{R_H I_x B t}{bt}$ $V_H = \frac{R_H I_x B}{b}$ $\boxed{R_H = \frac{V_H b}{I_x B}}$ (2 M) **Hall Devices** Gauss Meter (2 M) Electronic Multiplier (2 M) Electronic Wattmeter (2 M) **(ii) Answer** **Given data:** $I = 5\times10^{-3}\,A$; $V = 1.35$ V ; $l = 1\times10^{-2}$ m ; $b = 5\times10^{-3}$ m; $t = 1\times10^{-3}$ m ; $V_y = 20\times10^{-3}$ V ; H = 0.45 wb/m^2 Resistance $R = \frac{V}{I} = \frac{1.35}{5\times10^{-3}}$ = 270 ohm Resistivity $\rho = \frac{Ra}{l}$ Area $a = b\times t =$ $5\times10^{-3}\times1\times10^{-3} = 5\times10^{-6}$ m^2 $\therefore \rho = \frac{270\times5\times10^{-6}}{1\times10^{-2}}$ = 0.135 ohm m Hall field $E_y = \frac{V_y}{thickness} = \frac{20\times10^{-3}}{1\times10^{-3}}$ = 20 V/m (2 M) Current density $J_x = \frac{Current}{Area} = \frac{5\times10^{-3}}{5\times10^{-6}}$ = 1000 A/ m^2 $\frac{1}{ne} = \frac{E_y}{HJ_x} = \frac{20}{0.45\times1000}$ = 0.044 m^3/C Hall coefficient $R_H = \frac{3\pi}{8}\times\frac{1}{ne}$ = $1.1775\times0.044 = 0.05181$ m^3/C (1 M) Electron mobility $\mu_e = \frac{R_H}{\rho} = \frac{0.05181}{0.135}$ = 0.3838 $m^2V^{-1}s^{-1}$ Answer: $R_H = 0.05181\times10^{-6}\,m^3C^{-1}$ and $\mu_e = 0.3838 m^2V^{-1}s^{-1}$ (1 M)
8.	**Detail the occurrence of zener and avalanche breakdown in p-n – junction. (12 M)** BTL2 **Answer Page: 2.57 D. P. MANI** Occurrence of Zener Breakdown (5 M) Occurrence of avalanche Breakdown (5 M)

	Diagram  (2 M)
9.	**(i) Describe the principle, theory and V-I characteristics of Tunnel diode. (10 M)** BTL2 **(ii) Give its advantages and applications of tunnel diode in engineering field. (4 M)** BTL2 (i) **Answer Page : 2.67 Dr. P. Mani** **P**rinciple : (2 M) Theory (3 M) V-I characteristics Diagram (2 M) Explanation (2 M) (ii) **Answer Page :2.70 Dr. P. Mani** Advantages (2 M) Applications (2 M)
10.	**With a neat sketch, describe the principle, construction and working of a Schottky diode. Compare the V-I characteristics of Schottky diode. (12M+4M)** BTL2, BTL4 **Answer Page : 2.60 Dr. P. Mani** Principle : (2 M) Theory (3 M) V-I characteristics Diagram (2 M) Explanation (2 M) Comparison of V-I characteristics (4 M)
11.	**Explain in detail the operation of MOS capacitor under various gate voltages. (8 M)** BTL2 **Answer Page : 2.71 Dr. P. Mani** Structure (2 M) Principle of operation Below the flat-band voltage (1M) Between the flat-band voltage and threshold voltage (1M) Larger than the threshold voltage (4 M)

UNIT III MAGNETIC AND DIELECTRIC PROPERTIES OF MATERIALS 9 Magnetism in materials – magnetic field and induction – magnetization - magnetic permeability and susceptibility–types of magnetic materials – microscopic classification of magnetic materials - Ferromagnetism: origin and exchange interaction- saturation magnetization and Curie temperature – Domain Theory. Dielectric materials: Polarization processes – dielectric loss – internal field – Clausius-Mosotti relation- dielectric breakdown – high-k dielectrics.	
Q.No.	**PART * A**
1.	**Give Curie-Weiss law and its importance.**BTL1(May 2003) Curie-Weiss law is given by $$\chi_m \propto \frac{1}{T} \quad i.e. \quad \chi_m = \frac{C}{T-\theta}$$ Where C- Curie constant & T-Absolute temperature & θ- Curie temperature Importance: It determines the susceptiplity of magnetic materials in terms of temperatures (i.e.) If the temperature is less than curie temperature; a paramagnetic material becomes diamagnetic and if the temperature is greater than curie temperature, a ferromagnetic material becomes paramagnetic materials.
2	**Define dia, para, ferro, antiferro and ferri magnetic materials. Give examples.** BTL1(June 2009, June 2011) **Dia Magnetic material:** In dia magnetic materials, there are equal numbers of electron spins and randomly oriented hence the net magnetic moment is zero. Susceptibility doesn’t depend on temperature. Eg. Gold, antimony, bismuth, water, hydrogen, alcohol, Si, Ge. **Para Magnetic material:**In para magnetic materials, there are unequal numbers of electron spins and hence there exists a permanent magnetic dipole moment. Susceptibility depends on temperature. Eg. Platinum, chromium, aluminium, Copper Sulphate. **Ferro Magnetic material:**In ferro magnetic materials, there are large numbers of unequal electron spins and hence there exists enormous permanent magnetic dipole moment. They exhibit hysteresis. Susceptibility depends on temperature. Eg. Iron, Nickel, Cobalt, Steel. **Antiferro Magnetic material:**In antiferro magnetic materials, the adjacent magnetic dipoles are aligned antiparallel. Susceptibility depends on temperature. Eg. Iron, Nickel, Cobalt, Steel. **Ferri or Ferrite Magnetic material:**In ferrite magnetic materials, the spin alignment is antiparallel of different magnitudes. Susceptibility depends on temperature. Eg. $Mg^{2+}Fe_2^{3+}O_2^{2-}$, $Mn^{2+}Fe_2^{3+}O_2^{2-}$, $Ni^{2+}Fe_2^{3+}O_2^{2-}$, $Co^{2+}Fe_2^{3+}O_2^{2-}$
3	**What are soft and hard magnetic materials? (or) Compare soft and hardmagnetic materials on the basis of hysteresis loop. Give examples. (or) Discriminate soft and hard magnetic materials.** BTL4

S. No.	Soft Magnetic Materials	Hard Magnetic Materials
1.	They can be easily magnetized and demagnetized	They cannot be easily magnetized or demagnetized.
2.	Movement of domain wall is easy and hence even for a small applied field large magnetization occurs	Moment of domain wall is easy due to the presence impurity and hence large filed is required for magnetization
3.	The hysteresis loop is steep	The hysteresis loop is broad.
4.	Loop area is less and hysteresis loss is minimum	The loop area is maximum and hence the hysteresis loss is maximum
5.	Ex: Iron, Silicon alloys, ferrites &garnets etc	Ex: steel, Tungsten, steel chromium steel, Cu-Ni-Fe (Cunfie), Cu-Ni-Co (Cunico), Al-Ni-Co (Aalnico)
6.	Susceptibility and permeability is very high	Susceptibility and permeability is very low
7.	Retentivity and coercivity are small	Retentivity and coercivity are large
8.	They have low eddy current loss	They have high eddy current loss
9.	These materials are free from irregularities like impurities and strain	These materials are free from irregularities like impurities and strain

4. **What are Ferrites (Ferri magnetic material)?** BTL2

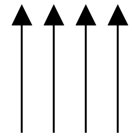
- The uncompensated ferromagnetic materials are called as Ferri magnetic material or ferrites.
- They have the magnetic moments are unequal magnitudes.
- Ferrites are compounds of iron oxides with oxides of other metals.
- Its general formula is given by $X^{2+}Fe_2^{3+}O_4^{2-}$. Where, X^{2+} is a divalent metal ion such as Mg^{2+}, Zn^{2+}, Fe^{2+}, etc.
- Susceptibility is large and positive. ($\chi = C / T \pm \theta$ for $T > T_N$)
- Above curie becomes para, below curie ferro behaviors.

5. **Define magnetic susceptiplity and magnetic permeability. (or) Comment on magnetic susceptiplity and magnetic permeability.** BTL1

Magnetic susceptiplity (χ_m): The ratio between intensity of magnetization (*I*) and magnetic field intensity (*H*) (i.e.,) $\chi_m = I / H$

Magnetic permeability (μ_m); The ratio between Magnetic flux density (B) and magnetic field intensity (H). (i.e.,) $\mu_m = B / H$.

6	**Define residual magnetism (or) Retentivity and Coercive force (or) coercivity with its unit.**BTL1. **Residual magnetism or Retentivity:**The amount of magnetic induction retained in the material after removing the magnetizing field. Unit: Wb m^{-2} **Coercive force (or) coercivity:**The amount of magnetizing field applied in the reverse direction to remove the residual magnetism completely from the material. Unit: Ampere-turn / m.
7.	**Define Curie temperature and Neel temperature.**BTL1 **Curie temperature:** The critical temperature at which a ferromagnetic material changes into a paramagnetic material. **Neel temperature:** The critical temperature at which the antiferro magnetic material changes into paramagnetic material.
8.	**What are the four types of energies involve in the growth of magnetic domains?**BTL1(June 2009) • Exchange Energy (or)Spin Exchange Interaction Energy (or) Interaction Energy • Anisotropy Energy (or) Crystal Anisotropic Energy • Magneto-static energy (or) Magnetic Potential Energy • Magnetostrictive energy (or) Magneto-Elastic energy
9	**Define Hysteresis. (or) What is hysteresis? (or) Appraise the term hysteresis.** BTL1 The lagging of induced magnetic induction (B) behinds the applied magnetizing field (H) is known as hysteresis. i.e. Lagging of B behind H.
10	**Define Bohr Magneton.**BTL1 The orbital magnetic moment and spin magnetic moment of an electron in an atom can be expressed in terms of atomic unit of magnetic moment is called Bohr Magneton. $\mu_B = e\hbar / 2m = 9.27 \times 10^{-24}$ **Am²**
11.	**What is ferromagnetism? Give examples. (or) What are ferromagnetic materials?** BTL1 These materials show spontaneous magnetization. They exhibit permanent magnetic dipole moment even in the absence of magnetic field. There is a strong internal field within the material which makes the atomic magnetic moments align with each other. This phenomenon is ferromagnetism. Examples: Fe, Co, Ni, Steel etc…
12.	**List the properties of ferromagnetic materials.** BTL1 • Relative permeability is very much greater than one. i.e, $\mu_r >> 1$ • They have positive and high value of susceptibility and it depends on temperature. It obeys Curie-Weiss law. • i.e. $\chi = \frac{C}{T-\theta}$ • Due to spin exchange interaction, it exhibits strong magnetization even in the absence of magnetic field. • They have permanent dipole moment. • Ferro magnetic materials consists of small spontaneously magnetized regions called domains. • Ferromagnetic material become paramagnetic material if the temperature is greater than curie temperature. • Magnetic moments of these materials are orderly oriented.

	• i.e.,  • They have hysteresis properties. • Examples: Fe, Co, Ni, Steel etc…
13.	**What are dielectrics? List their uses.**BTL1(Nov 2003) • Dielectric materials are the non-metallic materials in which electric dipoles can be produced permanently or temporarily by applying the electric field. • Examples: Glass, ebonite, mica, rubber, wood, and paper. Vacuum is a perfect insulator but it is not a dielectric. • These are mainly used, to store electrical energy, as insulator and coolant in transformers and as electrical insulators.
14.	**What are the properties of dielectric materials?**BTL1 • They have high resistivity (~10^6 mho cm) and high specific resistance. • In dielectric materials all the electrons are tightly bound to their parent nucleus. • They have negative temperature coefficient of resistance and high insulation resistance. • They have energy gap ~3 Ev
14.	**Define Permittivity.**BTL1 Permittivity is a quantity that represents the dielectric property of a medium. Permittivity of a material indicates how easily dielectric material is polarizable. Its unit is Fm^{-1}. $\varepsilon = \varepsilon_0 \varepsilon_r$
15	**Define dielectric constant or relative permittivity.**BTL1 The ratio of the absolute permittivity of the medium (ε) to the permittivity of free space (ε_o). It is also called as relative permittivity.i.e. $\varepsilon_r = \varepsilon / \varepsilon_o$. It has no unit. For air or vacuum $\varepsilon_r = 1$.
16	**What is Polarization? Name the four types of polarization mechanisms.**BTL1(Dec 2009, June 2010) The process of producing electric dipoles temporarily or permanently in the dielectrics by an external electric filed is called polarization in dielectrics. • Electronic polarization • Ionic polarization • Orientation or Dipolar polarization • Space-charge or Interfacial polarization
17	**Define Polarizability. Name the types of polarizabilities.** BTL2 The ratio of average dipole moment to the electric field applied. Its unit is farad m^2 or Fm^2. • Electronic polarizability • Ionic polarizability • Orientation polarizability

	• Space-Charge polarizability
18.	**What is Polarization Vector**?BTL1 The polarization vector is defined as dipole moment per unit volume of the dielectric material. i.e. $\vec{P} = N \vec{\mu}$ μ is the average dipole moment per molecule, N is the number of molecules per unit volume.
19	**What is electrical susceptibility?** BTL1 The electric susceptibility χ_e is a dimensionless proportionality constant that indicates the degree of polarization of a dielectric material in response to an applied electric field. $\vec{P} \propto \vec{E}$ $\vec{P} = \varepsilon_o \chi_e \vec{E}$ Where χ_e is a scalar constant referred as electrical susceptibility and it is the characteristic of every dielectric.
20	**What is Electronic polarization?**BTL1 Electronic polarization is due to the displacement of positively charged nucleus and negatively charged electrons of an atom in the opposite directions on the application of an electric field. It is independent to temperature. Eg. Inert gases.
21	**What is Ionic polarization?**BTL2(Dec 2009, June 2010) The process of displacement of positive ions (cat-ions) and negative ions (anions) in the opposite direction in a ionic dielectric due to the application of electric field is called Ionic polarization.It is independent to temperature. Eg. Ionic crystals.
22	**What is Orientation polarization?** BTL1 When an external field is applied on the dielectric medium with polar molecules, the dipoles align themselves in the field direction and thereby increase electric dipole moment is called orientation polarization. It is inversely proportional to temperature. Eg. Alcohol, Methane, CH_3Cl.
23	**What is Space-charge polarization?**BTL1 Space-charge polarization occurs due to the accumulation of charges at the electrodes or at the interfaces of multiphase dielectric materials due to the application of electric filed. It is directly proportional to temperature. Eg. Ferrites, Semiconductors.
24	**What is Internal Field or Local Field or Lorenz field?**BTL1 The long–range coulomb field created due to dipoles inside a dielectric is called as internal field or Lorentz local field. This field is responsible for polarization of each atom or molecule in a dielectric. $E_{int}=E+P/ 3\varepsilon_o$ Where, P is the polarization, ε_o is the permittivity of free space
25	**What is dielectric loss and loss tangent?**BTL1 If a dielectric is subjected to AC voltage, electrical energy is absorbed by the dielectric and certain quantity of electrical energy is dissipated in the form of heat energy. This is called as dielectric loss. Generally dielectric loss occurs in both direct and alternating voltages. In a perfect insulator, polarization is complete during each cycle and there is no consumption of energy and the charging current leads to the applied voltage by 90º.

	But for commercial dielectric, this phase angle is less than 90º by an angle δ and is called dielectric loss angle. Tan δ is taken as measure of dielectric loss and is known as loss tangent.
26	**Define Dielectric Breakdown and Dielectric strength.**BTL1 When the strength of electric field applied to a dielectric exceeds to a critical value, the dielectric loses its insulating property and becomes a conductor. i.e., very large current flows through it. This phenomenon is called as dielectric breakdown. Dielectric strength is defined as the electric field strength at which dielectric breakdown occurs. It is the breakdown voltage per unit thickness of the material
27	**Mention the various breakdown mechanisms.**BTL4(Dec 2009) 1. Intrinsic breakdowns 2. Avalanche breakdown 3. Thermal breakdown 4. Chemical and electrochemical breakdown 5. Discharge breakdown 6. Defect breakdown
28.	**What are the remedies to avoid dielectric breakdown?**BTL4 To avoid breakdown, the dielectric material should have the following properties: • It must be in pure form. • There should not be any defect. • It should have high dielectric strength to withstand higher voltage. • It should have high resistivity to reduce leakage current. • It should be fire-proof. • It should have low dielectric loss. It should be resistant to oils, liquids, gas fumes, acids and alkalies
31.	**What are the uses of Dielectric Materials?**BTL1 • The dielectric materials has three major applications • It is used as a dielectric medium in capacitors. • It is used as insulating materials in transformers. • Synthetic oils are used as coolant and in high voltage transformers. • Mineral oils are used as transformer oils. • Petroleum oils are used in transformers and circuit breakers. • Miscellaneous oils such as vegetable oils, Vaseline etc are used in the high voltage transformers. • Ceramic materials are used in high frequency capacitors and disc capacitors. • Electrolytic solution of sodium phosphate and ammonium tetra borate are used as wet type and dry type electrolytic capacitors respectively. • Mica is used in discrete capacitors. • Papers filled with synthetic oils are used in power capacitors.
PART-B	

1.

(i) State the origin of magnetic moment. (4 M) BTL2

(ii) How magnetic materials are classified based on magnetic moments? Explain their properties. Give also their characteristics and examples. (16 M) BTL3(May 2011)

(i) Answer Page: 3.1 Dr. P. MANI

- All materials are basically composed of atoms.
- The property of certain magnetic materials is associated with the magnetic property of its constituent atoms.

The magnetic dipole moment of an atom depends on

- The **orbital magnetic moment** due to the orbital motion of electrons around the nucleus and its magnitude is very small.
- The **spin magnetic moment** due to the spin motion of electrons about their own axes.
- The magnetic moment due to the nuclear spin.

The magnetic moment due to the electron spin only is taken into consideration neglecting the orbital and the nuclear magnetic moments because of their small magnitudes. (4M)

(ii) Answer Page: 3.23 Dr. P. MANI

Properties of Dia magnetic materials

i) Relative permeability is always less than one. i.e, $\mu_r < 1$ for these materials.

ii) They have negative value of magnetic susceptibility and it is independent to temperatrure.

iii) Since there is no permanent magnetic dipole moments, they are called as weak magnets.

iv) They are magnetised in a direction opposite to the external magnetizing field.

v) They repel the magnetic lines of forces.

vi) Induced magnetic moment is proportional to the applied magnetic field.

vii)The induced dipoles and magnetization vanishes as soon as the applied field is removed**.**

viii) When temperature is less than critical temperature they become normal material.

Examples; Ge, Si, Ag, Hydrogen, Bi, Niobium etc.. (4 M)

Properties of Para magnetic materials

i) Relative permeability is greater than one. i.e, $\mu_r > 1$ for these materials.

ii)They have positive value of magnetic susceptibility.

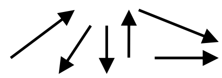
iii) Magnetic susceptibility is inversly proportional to the temperature.

i.e., $\chi \alpha \frac{1}{T} \Rightarrow \chi = \frac{C}{T}$ **(Curie law)**

(or) $\chi = \frac{C}{T-\theta}$ **(Curie-Weiss law)** where C-Curie constant; T-Asolute temperature; θ- Curie temperature

iv) They are magnetised along the direction of the external magnetizing field.

vi) They posses permanent magnetic dipole moments in random directions.



vii) Magnetic lines of forces can penetrate through these materials.

viii) When the temperature is than curie temperature, these materials become diamagnetic nature.

Examples: Alkali metals, Transition metals, Rare earth elements, $CuSo_4$, $MnSo_4$, Pt, Al etc. (4 M)

Properties of ferromagnetic materials

i) Relative permeability is very much greater than one. i.e, $\mu_r = 1$.

ii) They have positive and high susceptibility and it depends on temperature. It obeys **Curie-Weiss law.**

i.e., $\chi = \dfrac{C}{T-\theta}$

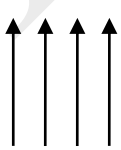
iii) Due to spin exchange interaction, it exhibits strong magnetization even in the absence of magnetic field.

iv) They have permanent dipole moment.

v) Ferro magnetic materials consists of small spontaneously magnetized regions called domains.

vi) Ferromagnetic material become paramagnetic material if the temperature is greater than curie temperature.

vii) Magnetic moments of these materials are orderly oriented.

i.e., 

viii) They have hysteresis properties. Examples: Fe, Co, Ni, etc… (4 M)

Properties of Ferrites orferri-magnetic materials

i) Ferrites possess non-zero magnetic moment.

ii) They exhibit paramagnetic property above Curie temperature and ferromagnetic character below Curie temperature.

iii) The susceptibility of a ferrite is very large and positive. It is temperature dependent

	iv) and it is given by $\chi = \frac{C}{T \pm \theta}$ *for* T > T_N v) They have high permeability and high resistivity **vi)** They have low eddy current losses, low hysteresis losses and low coercivity. (4 M)
2	**(i) Describe about the origin and exchange interaction in ferromagnetism. (6 M)** BTL2 **(ii) Discuss about saturation magnetisation and Curie temperature. (6 M)** BTL2(May 2012) **(i) Answer Page: 3.12 Dr.P. MANI** Origin of ferromagnetism and exchange interaction explanation with diagram (3M +3 M) **(ii) Answer Page: 3.14 Dr. P. MANI** Saturation magnetism and curie temperature definition, explanation with diagram (2M +4 M)
3	**Explain domain theory of ferromagnetism, domain magnetization and different types of energy involved in the process of domain growth in detail. (16 M)** BTL2(June 2010, May 2011) **Principle:**The total energy of a system is minimum at thermal equilibrium. The total internal energy of the domain in a ferromagnetic material is the sum of the following energies. • Magnetostatic energy or magnetic field energy or exchange energy • Crystalline energy or anisotropy energy • Domain wall energy or Bloch wall energy • Magnetostriction or magneto-strive energy. (2M) **(i) Exchange energy** • The energy which makes the adjacent dipoles align themselves in a particular direction • Arises from the interaction of electron spins • Depends upon the interatomic distance. • The energy required in assembling the atomic magnets into single domain and this work done is stored as potential energy. (2M) **(ii) Anisotropy energy** • In ferromagnetic crystals, there are two directions of magnetization namely easy direction and hard direction. • The excess energy required to magnetize a specimenin particular direction over that required to magnetize it along the easy direction (2M) **(iii) Domain wall energy or Block wall energy** • **<u>Domain wall or Bloch wall:</u>** A thin boundary line or region which separates adjacent domains magnetized in different directions • The size of the Bloch walls are about 200 to 300 lattice constant thickness. • In going from one domain to another domain, the electron spin changes gradually as shown in fig. • When the exchange energy is high change occurs abruptly. But, the anisotropy energy is less only when spin changes abruptly.

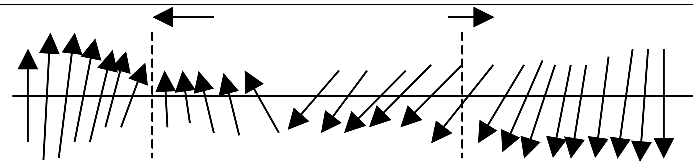


Figure. The change of electron spin in the transition region of Bloch wall (2 M)

(iv) Magnetostriction energy

- **<u>Magnetostriction:</u>**The change in the dimension of a ferromagnetic material when it is magnetized
- The energy involved in this change in dimension is known as magnetostriction energy
- The deformation is different along different crystal directions but it is independent of the direction of the field
- The magnetostriction energy is the energy due to the mechanical stresses generated by domain rotation (2 M)

Domain magnetization

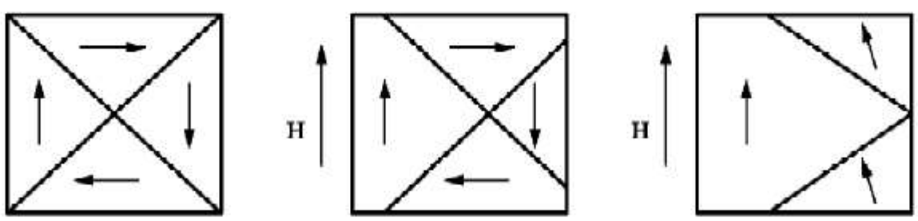
i. By the movement of domain walls.

ii. By rotation of domains.

i. Movement of Domain Walls :

The movement of domain walls takes place in weak magnetic fields.

When a small magnetic field is applied, the domains with magnetisation direction parallel to the field, grow at the expense of others.



Without field With field With field

(a) Random domain alignment(without field) (b) Domain wall movement (with weak field) (c) Domain rotation (with strong field)

ii. Rotation of Domains

If the magnetic field is increased further, domain growth becomes impossible. Rotation of magnetic moment takes place. Finally, completely grown domains and very small domains appear in a direction parallel to the applied field. (3M+ 3M)

4

Define polarization. Describe the different types of polarization mechanisms involved in a dielectric material. (2M+14M) (or) Deduce Langevin-Debye equation (16 M). BTL2(June 2009)

Answer Page:3.53 Dr. P. Mani

Polarization: *The process of producing electric dipoles by an external electric filed (2M)*

<u>Electronic polarization</u>

Electronic polarization is due to the displacement of positively charged nucleus and negatively charged electrons of an atom in the opposite directions on the application of an electric field. This results the creation of dipole moment in the dielectric. Dipole moment (μ) is proportional to the electric field strength (E)

$$\mu \, \alpha \, \mathrm{E}$$

$$\mu = \alpha_e E$$

Where α_e is electronic polarisability

Electronic polarization is independent of temperature. It is proportional to the volume of atoms in the material. Electronic polarization takes place in almost all the dielectrics. Mono – atomic gases exhibit this kind of polarization.

Calculation of Electronic Polarisability (α_e)

(i) Without Electric Field

consider an atom of a dielectric material of nuclear charge Ze, where Z is the atomic number. The electrons of charge (-Ze) are distributed uniformly throughout the sphere of radius R and there is no dipole moment as shown in figure

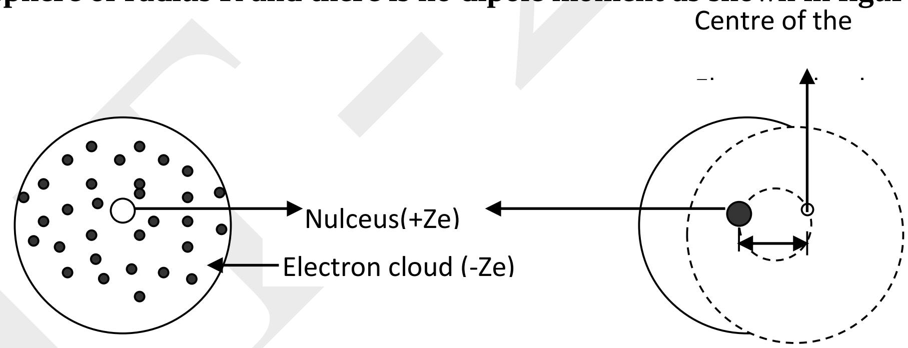


Fig. Atom without field **Fig. Atom with field**

Negative charge density on an atom of radius R is given by

$$\rho = \frac{\text{Total negative charge}}{\text{Volume of the atom}} = \frac{\text{- Ze}}{\frac{4}{3}\pi R^3}$$

$$\rho = -\frac{3}{4}\frac{\text{Ze}}{\pi \text{R}^3} \qquad \text{…..(1)}$$

ii)With Electric Field

When the atom of dielectric is placed in a DC electric field of strength E, two phenomena occur:

(a) Lorentz force due to electric field tends to separate the nucleus and electron cloud from their equilibrium positions.

(b) After separation, an attractive coulomb force arises between the nucleus and the electron cloud, which tries to maintain the original equilibrium position.

Let x be the displacement made by the electron cloud from the positive core as shown in the figure. Since the positive core is heavy, it will not move when compared to electron cloud and x << R, where R is radius of the atom.

Since these two forces are equal and opposite there will be an equilibrium between the nucleus and electron cloud of the atom.

i.e., At equilibrium $F_L = -F_C$ ……(2)

Lorentz force $F_L = \text{Charge} \times \text{Electric field}$

$$F_L = ZeE \quad \text{……(3)}$$

$$\text{Coulomb Force } F_C = \frac{1}{4\pi\varepsilon_0} \frac{\left.\begin{matrix}\text{Total Negative charges enclosed} \\ \text{in the sphere of radius } x(Q_e)\end{matrix}\right\} \times \text{Total Positive carges } (Q_P)}{x^2} \quad \textbf{..(4)}$$

$Q_e = \text{Charge density } (\rho) \times \text{Volume of the sphere of radius x}$

$$= -\frac{4}{3}\frac{Ze}{\pi R^3} \times \frac{4}{3}\pi x^3$$

i.e., $Q_e = -Ze\left(\frac{x^3}{R^3}\right)$ **……(5)**

Total positive charge of an atom present in the sphere of radius x,

$Q_p = +Ze$ ……(6)

Substituting equation (5) and (6) in (4), we get

$$F_C = \frac{1}{4\pi\varepsilon_0} \frac{[+Ze] \times \left[-Ze\left(\frac{x^3}{R^3}\right)\right]}{x^2}$$

$$F_C = -\frac{Z^2e^2x}{4\pi\varepsilon_0 R^3} \quad \text{….(7)}$$

Substituting equation (7) and (3) in (2),

$$ZeE = -\left(-\frac{Z^2e^2x}{4\pi\varepsilon_0 R^3}\right)$$

$$= \left(\frac{Z^2e^2x}{4\pi\varepsilon_0 R^3}\right)$$

$$E = \frac{Zex}{4\pi\varepsilon_0 R^3}$$

$$x = \frac{4\pi\varepsilon_0 R^3 E}{Ze} \qquad \text{.....(8)}$$

Due to the application of electric field the atom gains some dipole moment. From the definition of dipole moment, induced dipole moment (μ_{ind}) is given by:

$$\mu_{ind} = \text{Magnitude of charge} \times \text{Displacement}$$

i.e., $\mu_{ind} = Zex$ **....(9)**

Substituting equation (8) in (9)

$$\mu_{ind} = Ze \times \frac{4\pi\varepsilon_0 R^3 E}{Ze}$$

$$\mu_{ind} = 4\pi\varepsilon_0 R^3 E \qquad \text{.....(10)}$$

Dipole moment in terms of polarisability

$$\mu_{ind} = \alpha_e E \qquad \text{....(11)}$$

From (10) and (11)

The electronic polarizability $\alpha_e = 4\pi\varepsilon_0 R^3$ **.....(12)**

It shows that α_e is directly proportional to the volume of the atom and independent to temperature. (5 M)

Ionic polarization (α_i)

The process of displacement of positive ions (cations) and negative ions (anions) in the opposite direction in a ionic dielectric due to the application of electric field is called Ionic polarization. Examples: NaCl, KCl, KBr

Let us assume that there are one cation and one anion present in the unit cell of NaCl. When an electric field (E) is applied the positive ions displace in the direction of applied electric field through a distance x_1 and the negative ions displace in opposite direction through a distance x_2 as shown in the figure.

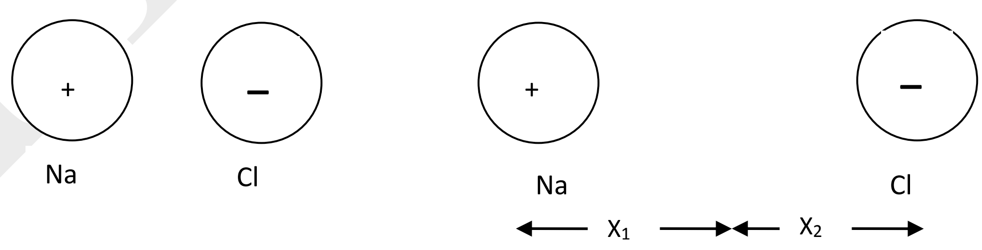


Fig. Without field E Fig. With field E

Hence, the net distance between two ions

$$x = x_1 + x_2 \qquad \text{.......(1)}$$

When the field is applied, the restoring force produced is proportional to the displacement.

For cation

Restoring force, $F \alpha \, x_1$ or $F = \beta_1 x_1$ …..(2)

For anion

Restoring force, $F \alpha \, x_2$ or $F = \beta_2 x_2$ …..(3)

Where β1and ß2 are restoring force constants which depend upon the masses of ions and angular frequency of the molecule in which ions are present.

If m is the mass of cation, M is the mass of anion, and ω_0 is the angular frequency, then

$$\beta_1 = m\omega_0^2 \quad …..(4)$$

$$\beta_2 = M\omega_0^2 \quad …..(5)$$

Substituting (4) in (2), $F = m\omega_0^2 x_1$ …..(6)

We know that force $F = eE$ …..(7)

From (6) and (7),

$$eF = m\omega_0^2 x_1$$

$$x_1 = \frac{eE}{m\omega_0^2} \quad …..(8)$$

Similarly , for the anion, we can write

$$x_2 = \frac{eE}{M\omega_0^2} \quad ….(9)$$

Substituting equations (8) and (9) in (1),

$$x = x_1 + x_2 = \frac{eE}{m\omega_0^2} + \frac{eE}{M\omega_0^2}$$

$$x = \frac{eE}{\omega_0^2}\left(\frac{1}{m} + \frac{1}{M}\right) \quad ….(10)$$

The dipole moment is equal to the product of charges and the net distance between them.

i.e., $\mu = e \times x$ ….(11)

$$\mu = e \times \frac{eE}{\omega_0^2}\left(\frac{1}{m}+\frac{1}{M}\right) = \frac{e^2 E}{\omega_0^2}\left(\frac{1}{m}+\frac{1}{M}\right)$$

$$\mu = \frac{e^2}{\omega_0^2}\left(\frac{1}{m}+\frac{1}{M}\right)\mathrm{E} \qquad \text{….(12)}$$

We know that

$$\mu_i \; \alpha \; E$$

$$\mu_i = \alpha_i \,\mathrm{E} \qquad \text{…..(13)}$$

From equations (12) and (13)

The ionic polarzability $\alpha_i = \frac{e^2}{\omega_0^2}\left(\frac{1}{m}+\frac{1}{M}\right)$ …(14)

***Hence,* Ionic polarisability (α_i) is inversely proportional to the square of angular frequency of the ionic molecule and it is directly proportional to its reduced mass given by $\left(\frac{1}{m}+\frac{1}{M}\right)$. It is independent of temperature**. (5 M)

Orientation polarization

When the dielectric medium consists of polar molecules such as H_2O, HCl and Nitro Benzene, orientation polarization takes place. These molecules have permanent dipole moments even in the absence of an electric field as shown in figure

The orientation of polar molecules with respect to the electric field direction is called orientation polarization.

Explanation: For example CH_3Cl is a polar molecule in which +ve and –ve charges do not coincide. The Cl^- has more electronegativity than hydrogen. Therefore the chlorine atom pulls the bonding electrons strongly than hydrogen. Hence, even in the absence of field, there exists a net dipole moment.

When an electric field, +ve portion align along the filed direction and –ve portion align in the opposite direction of the filed as shown in the figure . This polarization is called orientation or dipolar polarization.

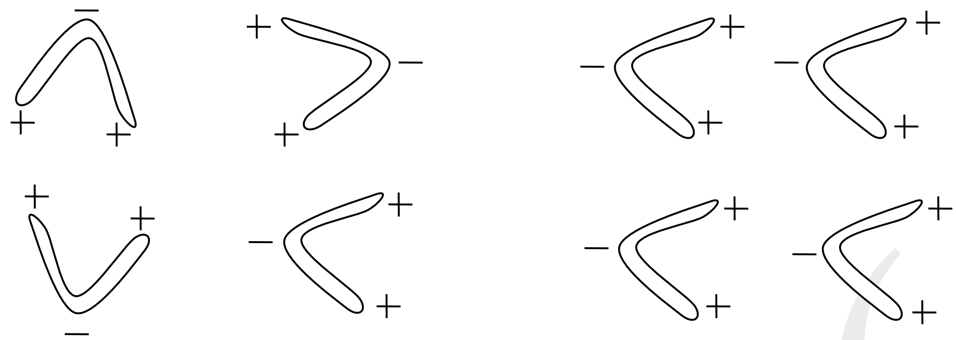


Figure Polar dielectric without field Figure Polar dielectric with field

When the temperature is increased, thermal energy tends to disturb the alignment. Thus this polarization depends on temperature.

From Langevin's theory of paramagnetism,

$$\text{Net intensity of magnetisation} = \frac{N\mu^2 B}{3kT} \qquad \ldots\ldots(1)$$

Since the same principle can be applied to the application of electric field in dielectrics, we may write

$$\text{Orientation Polarisation} = P_o = \frac{N\mu^2 E}{3kT} \qquad \ldots\ldots(2)$$

But, orientation polarization is proportional to applied field (E)

i.e., $P_o \alpha E$

$$P_o = N\alpha_o \vec{E} \qquad \ldots..(3)$$

Comparing (2) and (3) ,

$$\text{Orientational polarizability} \quad \alpha_o = \frac{\mu^2}{3kT} \qquad \ldots..(4)$$

Thus the orientational polarizability is inversely proportional to absolute temperature of the material. *(2M)*

Space-Charge Polarisation

Space-charge polarization occurs due to the accumulation of charges at the electrodes or at the interfaces of multiphase dielectric materials.

Explanation: In the absence of field the charges are orderly arranged as shown in the Fig.. When the electric field is applied at high temperature, the charges get accumulated at the interfaces as

	shown in the Fig., these charges create dipoles. Thus polarization is produced. This polarization is called as space-charge polarization.

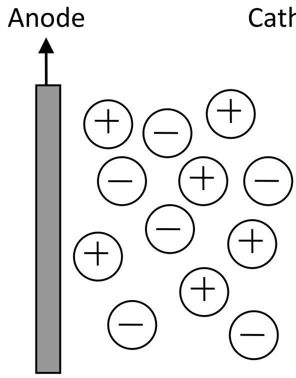


Figure Charges without filed

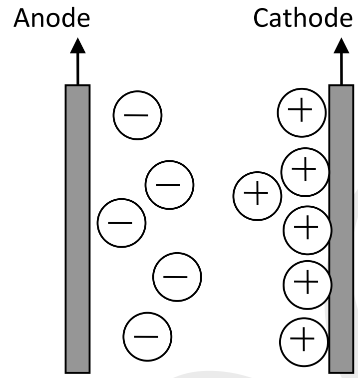


Figure Charges with field

Generally, this type of polarization occurs in ferrites and semiconductors and is very small when compared to other polarization mechanisms.

Total polarization (Langevin-Debye Equation)

The total polarization is the sum of electronic, ionic, orientaional and space–charge polarizations. Since space–charge polarization is very small it is not taken into account. Hence the total polarization is given by

$$P = P_e + P_i + P_o \qquad \ldots\ldots(1)$$

$$\text{or } P = N\,\alpha_e E + N\,\alpha_i E + N\,\alpha_o E$$

$$P = N\,(\alpha_e + \alpha_i + \alpha_o)\,E \qquad \ldots\ldots.(2)$$

Substituting the expressions for α_e , α_i , α_o in (2),

Total polarization, $$P = N\vec{E}\left[4\pi\varepsilon_0 R^3 + \frac{e^2}{\omega_o^2}\left(\frac{1}{m}+\frac{1}{M}\right)+\frac{\mu^2}{3kT}\right] \qquad \ldots.(3)$$

and Total polarizability $$\alpha = 4\pi\varepsilon_0 R^3 + \frac{e^2}{\omega_o^2}\left(\frac{1}{m}+\frac{1}{M}\right)+\frac{\mu^2}{3kT} \qquad \ldots..(4)$$

Equation (3) is known as Langevin – Debye equation. By drawing a plot between P and 1/T, one can determine the orientational polarization and the sum of electronic and ionic polarization.(1 M)

5	**What is meant by Lorentz field in a dielectric and how it is calculated for a cubicstructure? Deduce the Clausius – Mosotti relation. (2M+10M+4M)**BTL2(June 2009, May 2011) **Answer Page: 3.64 Dr. P. Mani** **Internal Field or Local Field** When a dielectric material is subjected to an external electric field, There are two fields are exerted,

(i) Macroscopic field due to external field

(ii) Field due to dipole moment

The long–range coulomb field created due to dipoles inside a dielectric is called as internal field or Lorentz local field. This field is responsible for polarization of each atom or molecule in a solid. (2 M)

Lorentz method to find internal field

Let us assume a dielectric material is placed in between two plates of a parallel plate capacitor as shown in figure 4.10. Consider an imaginary small spherical cavity around an atom inside the dielectric for which the internal field must be calculated at its centre. It is also assumed that the radius of the cavity is large compared to radius of atom.

The internal field (E_i) at the atom site can be considered to be made up of the following four components. E_1,E_2, E_3 and E_4

i.e., $E_i = E_1 + E_2 + E_3 + E_4$ ….(1)

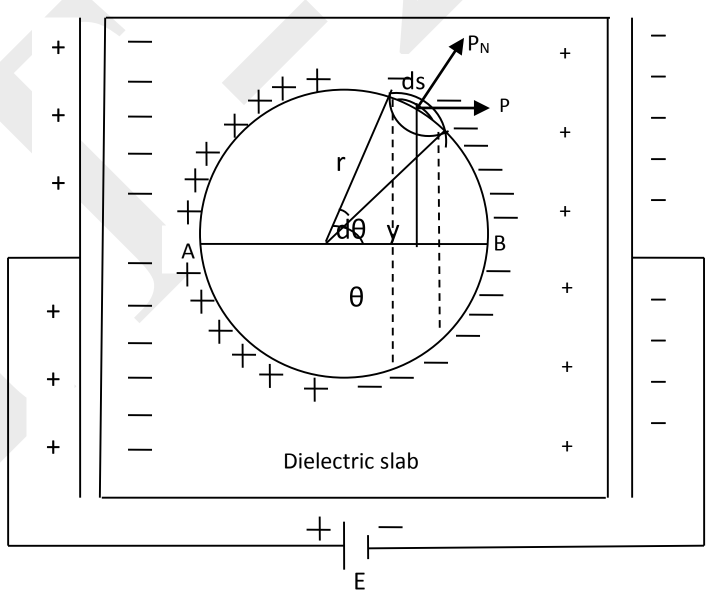
Where

E_1 is the field due to charges on the plates (externally applied)

E_2 is the field due to induced charges on the plane surfaces of the dielectric

E_3 is the field due to induced charges on the surface of the spherical cavity

E_4 is the field due to permanent dipoles of atoms inside the spherical cavity



(2 M)

Figure 4.10 Calculation of Internal field

Macroscopically, we can write $E = E_1 + E_2$ ….(2)

i.e., the field externally applied (E_1) and the field induced on the plane surface of the dielectric (E_2) are considered as a single field(E).

If the dielectric is highly symmetric, then the dipoles present inside the imaginary cavity will cancel out each other.

Therefore, the electric field $E_4 = 0$ ….(3)

From equations (2) and (3), (1) becomes

$$E_i = E + E_3 \quad ….(4) \quad (1\ M)$$

To Find E_3

Let us consider small area ds confined within an angle dɵ at an angle ɵ with the direction of field E on the surface of the spherical cavity and q' is the charge on the area ds.

Polarization is also defined as the surface charges per unit area. Here polarization (P) is parallel to E and P_N is the component of polarization perpendicular to the area ds as shown in figure 4.12.

Therefore $$P_N = P\,Cos\theta = \frac{q'}{ds} \quad ….(5)$$

$$\text{or } q' = P\,Cos\theta\, ds \quad ….(6)$$

From Coulomb laws, the electric field intensity at C due to charge q' can be

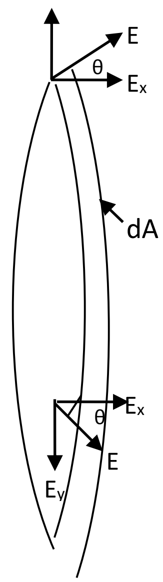
written as

$$E = \frac{q'}{4\pi\varepsilon_0\, r^2} \quad ….(7)$$

Substituting (6) in (7),

$$E = \frac{P\,Cos\theta\, ds}{4\pi\varepsilon_0\, r^2} \quad ….(8) \quad (3\ M)$$

This electric field intensity is along the radius r and can be resolved into two components as shown in figure 4.11



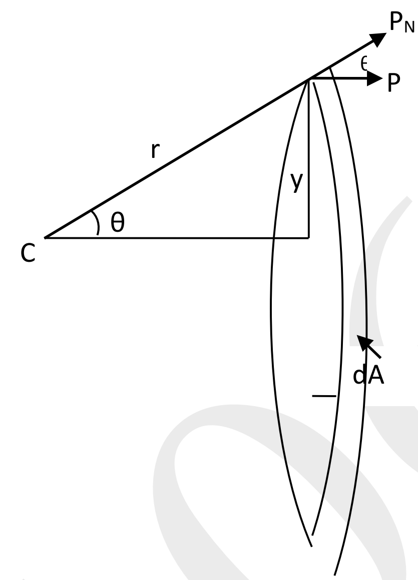


Figure 4.11 components of Intensity Figure 4.12 Components of polarization (1 M)

The component parallel to the field direction,

$$E_x = E\,\mathrm{Cos}\theta \qquad \ldots.(9)$$

Substituting equation (8) in (9), $$\mathrm{E_x} = \frac{P\,Cos^2\theta\,ds}{4\pi\varepsilon_0\,\mathrm{r}^2} \qquad \ldots.(10)$$

The component perpendicular to the field direction,

$$E_y = E\,\mathrm{Sin}\theta \qquad \ldots.(11)$$

Substituting equation (8) in (11), $$\mathrm{E_y} = \frac{P\,Cos\theta\,\mathrm{Sin}\theta\,\mathrm{ds}}{4\pi\varepsilon_0\,\mathrm{r}^2} \qquad \ldots.(12)$$

The perpendicular components are in opposite directions, hence they cancel out each other. For this reason, the parallel components alone are taken into consideration.

If the total surface area of the ring is considered as dA, then

$$\text{Electric field intensity due to elemental ring} = \mathrm{E} = \mathrm{E_x} = \frac{P\,Cos^2\theta\,dA}{4\pi\varepsilon_0\,\mathrm{r}^2} \qquad \ldots.(13)$$

Where, Ring Area $dA = \text{Circumference} \times \text{Thickness}$

$$= 2\pi y \times r\, d\theta$$

$$= 2\pi\, r Sin\theta \times r\, d\theta$$

$$dA = 2\pi\, r^2 Sin\theta\, d\theta \quad \text{….(14)}$$

Substituting equation (14) in equation (13) , we have

$$E = \frac{P\, Cos^2\theta}{4\pi\varepsilon_0\, r^2} \times 2\pi\, r^2 Sin\theta\, d\theta$$

$$E = \frac{P\, Cos^2\theta\, Sin\theta\, d\theta}{2\varepsilon_0} \quad \text{….(15)} \quad \text{(1 M)}$$

The Electric field intensity (E_3) due to charge present in the whole sphere can be obtained by integrating equation (15) within the limits 0 to π.

$$E_3 = \int_0^\pi E = \int_0^\pi \frac{P\, Cos^2\theta\, Sin\theta\, d\theta}{2\varepsilon_0}$$

$$= \frac{P}{2\varepsilon_0} \int_0^\pi Cos^2\theta\, Sin\theta\, d\theta$$

$$= \frac{P}{2\varepsilon_0} \times \frac{2}{3} \qquad \left[Since \int_0^\pi Cos^2\theta\, Sin\theta\, d\theta = \frac{2}{3} \right]$$

$$E_3 = \frac{P}{3\varepsilon_0} \quad \text{….(16)}$$

Substituting equation (16) in equation (4),

$$E_i = E + E_3 = E + \frac{P}{3\varepsilon_0}$$

$$i.e., E_i = E + \frac{P}{3\varepsilon_0} \quad \text{….(17)} \quad \text{(2 M)}$$

Equation (17) shows that the local field E_i is larger than the macroscopic intensity E. Therefore the molecules are more effectively polarized.

Clausius – Mosotti Equation

Let us consider N be the number of molecules per unit volume and α the molecular polarisability. Then

Total polarization, $P = N\alpha E_i$

$$E_i = \frac{P}{N\alpha} \quad .....(1)$$

The displacement vector D can be written as

$$D = \varepsilon E = \varepsilon_0 \varepsilon_r E \quad .....(2)$$

or $\varepsilon E = \varepsilon_0 (1+\chi_e) E \quad [(\varepsilon_r = 1+\chi_e), \chi_e$ -Electrical Susceptibility)]

$$\varepsilon E = \varepsilon_0 E + \varepsilon_0 \chi_e E$$

$$\varepsilon E = \varepsilon_0 E + P \qquad (P = \varepsilon_0 \chi_e E)$$

$$P = \varepsilon E - \varepsilon_0 E = E(\varepsilon - \varepsilon_0)$$

$$E = \frac{P}{(\varepsilon - \varepsilon_0)} \quad .....(3)$$

We know that Lorentz local field,

$$E_i = E + \frac{P}{3\varepsilon_0} \quad .....(4)$$

Substituting the equation (3) in (4),

$$E_i = \frac{P}{(\varepsilon - \varepsilon_0)} + \frac{P}{3\varepsilon_0} = P\left(\frac{1}{(\varepsilon - \varepsilon_0)} + \frac{1}{3\varepsilon_0}\right)$$

$$= P\left(\frac{3\varepsilon_0 + \varepsilon - \varepsilon_0}{(\varepsilon - \varepsilon_0)3\varepsilon_0}\right) = \frac{P}{3\varepsilon_0}\left(\frac{2\varepsilon_0 + \varepsilon}{(\varepsilon - \varepsilon_0)}\right)$$

$$E_i = \frac{P}{3\varepsilon_0}\left(\frac{2\varepsilon_0 + \varepsilon}{(\varepsilon - \varepsilon_0)}\right) \quad ....(5)$$

From equations (5) and (1),

$$\frac{P}{N\alpha} = \frac{P}{3\varepsilon_0}\left(\frac{2\varepsilon_0 + \varepsilon}{(\varepsilon - \varepsilon_0)}\right)$$

$$\frac{N\alpha}{3\varepsilon_0} = \left(\frac{(\varepsilon - \varepsilon_0)}{2\varepsilon_0 + \varepsilon}\right) = \left(\frac{(\varepsilon_0\varepsilon_r - \varepsilon_0)}{2\varepsilon_0 + \varepsilon_0\varepsilon_r}\right) = \left(\frac{\varepsilon_0(\varepsilon_r - 1)}{2\varepsilon_0(2+\varepsilon_r)}\right) \text{ (Since } \varepsilon = \varepsilon_0\varepsilon \text{)}$$

$$\frac{N\alpha}{3\varepsilon_0} = \frac{(\varepsilon_r - 1)}{(\varepsilon_r + 2)} \quad \ldots(6) \quad (4M)$$

Equation (6) is Clausius – mosotti relation. It relates the macroscopic quantity (ε_r) and a microscopic quantity (α).

6

What are the different types of dielectric break down in dielectric medium?Discuss in detail the various types of dielectric breakdown. How it can be avoided? (2M+10M+2M)BTL2(June 2009)

Answer Page: 3.74 Dr. P. Mani

Dielectric Breakdown

When the strength of electric field applied to a dielectric exceeds to a critical value, the dielectric loses its insulating property and becomes a conductor. i.e., very large current flows through it. This phenomenon is called as dielectric breakdown.

Dielectric strength

It is defined as the electric field strength at which dielectric breakdown occurs. It is the breakdown voltage per unit thickness of the material.

$$\text{i.e., Dielectric strength} = \frac{\text{Breakdown voltage}}{\text{Thickness of the dielectric}}$$

There are different mechanisms by which dielectric breakdown takes place. Few important types of dielectric breakdown are as follows

1.Intrinsic breakdown and avalanche breakdown

2. Thermal breakdown

3. Chemical and electrochemical breakdown

4. Discharge breakdown

5. Defect breakdown *(2M)*

<u>Intrinsic breakdown</u>

In a dielectric the charge displacement increases with increasing electric field strength.

When a dielectric is subjected to electrical field, some of the electrons in the valence band go to the conduction band across the energy gap.

They become conduction electrons and thus produce large conduction current.

Therefore a large current flows through the dielectric and is called intrinsic breakdown or Zener breakdown. (1 M)

Avalanche breakdown

When the conduction electrons are accelerated very high velocity, they collide with valence electrons in the covalent bond.

Now the valance electrons on receiving this energy transferred to the conduction band and become conduction electron.

These secondary conduction electrons again dislodge some other valance electrons in the covalent bond and this process continues as a chain reaction. As a result very large current flows through the dielectrics and is called avalanche breakdown.

Characteristics

- They occur at about room temperature or at even low temperature.
- Both breakdowns require large electrical fields.
- They do not depend on the configuration of the electrons and dimension of the sample.
- They occur within a short span of time (microseconds).
- This kind of breakdown occurs in thin samples. (1M)

Thermal breakdown

- When a dielectric material is subjected to an electric field, heat is generated. This heat must be dissipated from the material.
- In some cases, the amount of heat produced will be very high as compared to the heat dissipated.
- Due to excess of heat, the temperature inside the dielectric increases and larger amount of current flows through the material and breakdown occurs.

This type of breakdown is known as thermal breakdown

Characteristics

- It occurs only at high temperatures.
- It requires moderate electric fields.
- It depends upon the size and shape of the dielectric sample.
- The breakdown time is of the order milliseconds. (2M)

Chemical and electrochemical breakdown

It is almost similar to thermal breakdown.When the temperature of a dielectric material increases, mobility of ions increases and hence the electrochemical reaction may take place. This leads to leakage current and finally dielectric breakdown occurs.

Characteristics

- It occurs only at low temperatures.
- It occurs even in the absence of electric field.
- It depends on the concentration of ions and magnitude of leakage current. (2M)

Discharge Breakdown

- Some dielectric material contains occluded gas bubbles as shown in the figure.
- When this type of dielectric is subjected to the electric field, the gas present in the material will easily ionize and thus produce large amount of ionization current.
- This is known as discharge breakdown.

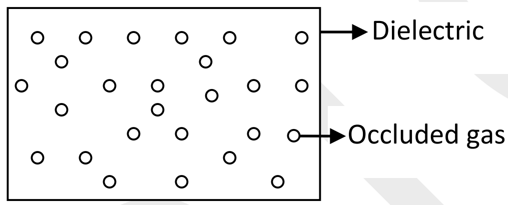


Fig. Discharge breakdown

Characteristics

- It occurs at low voltages.
- It depends upon the frequency of applied voltage.
- It occurs in the dielectric material where there are a large number of occluded gas bubbles. (2 M)

Defect Breakdown

Some dielectric material may have defects such as cracks, porosity and blow holes etc. as shown in the figure. These defects may have moisture or impurities which lead to a current flow. This breakdown is known as defect breakdown.

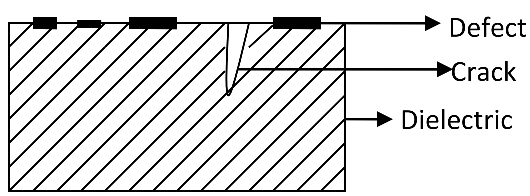


Fig. Defect breakdown (2 M)

Remedies to avoid dielectric breakdown

To avoid breakdown, the dielectric material should have the following properties:

- It must be in pure form.

- There should not be any defect.
- It should have high dielectric strength to withstand higher voltage.
- It should have resistivity to reduce leakage current.
- It should be fire-proof.
- It should have low dielectric.
- It should have sufficient mechanical strength.
- It should be resistant to acids, oils, liquids, gas fumes, and alkalies.
- It should have small thermal expansion to prevent mechanical damage. (2M)

7

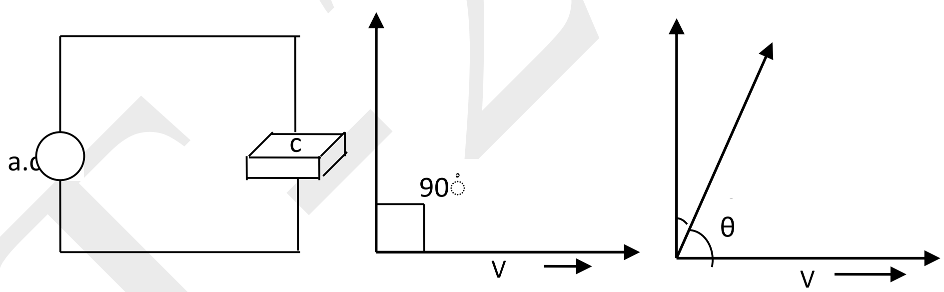
What is dielectric loss? Derive the expression for dielectric power loss. (2M+8M) BTL2

Dielectric Losses

If a dielectric is subjected to AC voltage, electrical energy is absorbed by the dielectric and certain quantity of electrical energy is dissipated in the form of heat energy. This is called as dielectric loss. Generally dielectric loss occurs in both direct and alternating voltages. It is less in direct voltage than that of alternating voltage. (2 M)

Expression for dielectric loss (Loss tangent)

If a perfect insulator like vacuum or purified gas is subjected to an AC voltage as shown in the figure. It does not absorb electrical energy and there is no loss of electrical energy.



Here, the charging current leads the applied voltage by an angle of 90 as shown in figure. polarization of the dielectric is in phase with the voltage.

We know power loss $P_L = VI\,\text{Cos}\theta$ …..(1) (2M)

When $\theta = 90^0$, $P_L = VI\,\text{Cos}\,90^0$

$P_L = 0$ ….(2)

This means that there is no power loss in the perfect insulator.

On the other hand, in a practical dielectric the leakage current leads the voltage by an angle (90-δ). This shows that there is some loss in electrical energy and δ is a measure of the power dissipated in each cycle called as loss angle.

Power loss for this case is $P_L = VI\,\text{Cos}(90 - \delta)$ $(\$\ \theta = 90 - \delta)$

$P_L = VI\,\text{Sin}\delta$ ...(3)$(\$\ \text{Cos}(90 - \delta) = \text{Sin}\delta)$ (2M)

According to Ohm's law, $V = IR$ or $I = \dfrac{V}{R}$ …..(4)

If X_c is the capacitive reactance, then current $I = \dfrac{V}{X_C}$ ……(5)

Frequency in terms of X_c, $f = \dfrac{1}{2\pi X_C C}$ $(\$\ R = X_C)$

$$X_C = \frac{1}{2\pi\ f\ C} \quad \text{….(6)}$$

Substituting (6) in (5), $I = \dfrac{V}{\dfrac{1}{2\pi\ f\ C}} = V 2\pi\ f\ C$

i.e., $I = V 2\pi\ f\ C$ …..(7)

Substituting equation (7) in (3),

Power loss $P_L = 2\pi f C V^2\,\text{Sin}\delta$ …..(8)

Since the loss angle δ is very small

Dielectric power loss, $P_L = 2\pi f C V^2 \tan\delta$ …..(9) (2M)

Here, tan δ is called the power factor of the dielectric.

Generally the power loss varies with frequency. Its value is high in the electrical frequency and low in the optical frequency as shown in the figure 4.16.

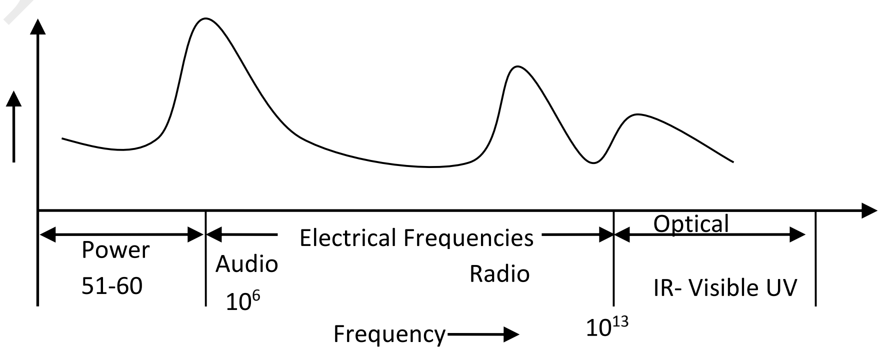


	Figure Variation of power loss with frequency **Factors affecting dielectric loss** Dielectric loss may increase due to the following factors. • High value of the applied voltage • Frequency of applied voltage • Temperature • Humidity (2M)

UNIT IV OPTICAL PROPERTIES OF MATERIALS **9**

Classification of optical materials – carrier generation and recombination processes - Absorption emission and scattering of light in metals, insulators and Semiconductors (concepts only) - photo current in a P- N diode – solar cell –photo detectors - LED – Organic LED – Laser diodes – excitons - quantum confined Stark effect – quantum dot laser.

Q.No	PART * A
1.	**What are Opticalmaterials?**BTL2 The materials which are sensitive to light are known as Optical materials. These optical materials exhibit a variety of optical properties.
2	**What are the types of opticalmaterials?**BTL2 i) Transparent. ii) Translucent. **iii)** Opaque.
3	**Define scattering of light.**BTL2 Process by which the intensity of the waves attenuates as it travels through a medium.
4.	**Define carrier generation and recombination.**BTL2 The carrier generation is the process whereby electrons and holes are created. The recombination is the process whereby electrons and holes are annihilated.
5	**What are the types of carriergeneration?**BTL2 i) Photogeneration. ii) Phonongeneration. **iii)** Impactionization.
6	**What are the types of recombinationprocess?**BTL2 a) Radiative Recombination. b) Shockley-Read-HeadRecombination. **c)** AugerRecombination.
7.	**What is exciton? Mention its types.**BTL2 The combination of an electron in an excited stage (below conduction band) and the associated hole in valence band (electron – hole pair) is known as an exciton. a) Frenkel excitons - strongly bound excitons. **b)** Mott and wannier excitons – weakly boundexcitons.
8.	**Give the basic principle of photodiode.**BTL2 When light is incident on the depletion region of the reverse-biased pn junction, the concentration of minority carriers increases. Therefore, reverse saturation current increases.

9	**What is photodiode?**BTL2 Photo diode is a reverse biased p-n junction diode which responds to light absorption
10	**Give the importance ofexcitons.**BTL4 a) The excitons play an important role in luminescence ofsolids. b) Excitons are unstable and they will separate at hightemperature. c) The excitons can move through the semiconductor and transportenergy **d)** The excitons does not transport any charge as it is electricallyneutral.
11.	**What is solarcell?**BTL2 Solar cell is a p-n junction diode which converts solar energy (light energy) into electrical energy.
12.	**What is photodetector?**BTL2 Photo detector is a semiconductor device which is used to detect the presence of photons. This device is known as photo detector. It converts optical signals into electrical signals**.**
13.	**Specify the types of photodetector?**BTL4 a) Photoemissive. b) Photoconductive. c) Photovoltaic.
14.	**List out the types of photo-voltaic devices?** BTL2 a) PIN photodiode. b) Avalanche photo diode(APD). c) P-N junction photodetector.
15	**What is LED?**BTL2(Jan 2006) LED is a p-n junction diode which emits light when it is forward biased.
16	**What are the disadvantages ofLEDs?**BTL2 **a)** They require highpower. **b)** Their preparation cost is high when compared toLCD
17	**What are the applications used ofLEDs?**BTL2 a) They are used as indicatorlamps. b) Infrared LEDs are used in burglaralarms. c) They are used in image sensing circuits used for picturephone
	PART-B
1	**Describetheopticalabsorptioninmetals,dielectrics(insulators)and semiconductors.(or) Explain the carrier generation and recombination processes in metal, semiconductors and insulators. (16 M)** BTL2 **Answer: Page: 4.5 to 4.11 P.MANI** carrier generation and recombination processes (1 M) Absorption and emission of light in metal (or) conductors(5M)

	Absorption and emission of light in dielectrics (Insulators)(5M) Absorption and emission of light in semiconductors(5M)
2	**Describe the principle, construction and working of a photodiode. Mention its advantages, disadvantages and uses. (16 M)** BTL2 **Answer: Page: 4.18 to 4.20 P.MANI** Principle (2 M) Construction diagram (3 M) Construction description (3 M) Working (4 M) Advantages, disadvantages and uses (4 M)
3	**Discuss the principle, construction and working of solar cell. Mention its advantages, disadvantages and uses. (16 M)** BTL2 **Answer: Page: 4.20 to 4.23 P.MANI** Principle (2 M) Construction diagram (3 M) Construction description (3 M) Working (4 M) Advantages, disadvantages and uses (4 M)
4	**Describe the principle, construction and working of a photo detector. Mention its advantages, disadvantages and uses. (16 M)** BTL2 **Answer: Page: 4.24 to 4.27 P.MANI** Principle (2 M) Construction diagram (3 M) Construction description (3 M) Working (4 M) Advantages, disadvantages and uses (4 M)
5	**Describe the principle, construction and working of a GaAlAs diode laser. (or) Describe the principle, construction and working of a homo-junction diode laser (or) Describe the principle, construction and working of hetero-junction diode laser. Mention its advantages, disadvantages and uses. (16 M)** BTL2(Jan.2009, Jan.2010, Jan.2011) **Answer: Page: 4.31 to 4.35 P.MANI** Principle (2 M) Construction diagram (3 M) Construction description (3 M) Working (4 M) Advantages, disadvantages and uses (4 M)
6	**Describe the principle, construction and working of Light Emitting Diode. Mention its advantages, disadvantages and uses. (or) Explain how p-n junction diode acts as light emitting diode. (16 M)** BTL2(May 2003, Apr 2003) **Answer: Page: 4.27 to 4.31 P.MANI** Principle (2 M) Construction diagram (3 M) Construction description (3 M) Working (4 M) Advantages, disadvantages and uses (4 M)
7	**Describe the principle, construction and working of OLED. Mention its advantages,**

	disadvantages and uses. (16 M) BTL2 **Answer: Page: 4.35 to 4.38 P.MANI** Principle (2 M) Construction diagram (3 M) Construction description (2 M) Working (2 M) Types (3 M) Advantages, disadvantages and uses (4 M)
8	**What is quantum dot? Describe the principle, construction and working of quantum dot laser. Mention its advantages, disadvantages and uses. (16 M) BTL2** **Answer: Page: 4.42 to 4.45 P.MANI** Quantum dot (2 M) Principle (2 M) Construction diagram (3 M) Construction description (3 M) Working (3 M) Advantages, disadvantages and uses (3 M)
9	**Write short noteson (i) Excitons (8 M) (ii) Quantum Confined Stark Effect (QCSE).(4 M)(iii) Quantum dots (4 M)**BTL2 (i) **Answer: Page: 4.15 to 4.18 P.MANI** Definition and explanation of excitons (2 M) Types of excitons Frenkel Exciton (2 M) Motti and Wannier exciton (2 M) Importance of excitons (2 M) (ii) **Answer: Page: 4.39 to 4.40 P.MANI** Definition and explanation of QCSE (2 M) Uses of QCSE (2 M) (iii) **Answer: Page: 4.40 to 4.42 P.MANI** Definition and explanation of quantum dot (2 M) Applications of quantum dot (2 M)

UNIT V NANOELECTRONIC DEVICES **9**	
Introduction - electron density in bulk material – Size dependence of Fermi energy– quantum confinement – quantum structures - Density of states in quantum well, quantum wire and quantum dot structures –Zener-Bloch oscillations – resonant tunneling – quantum interference effects – mesoscopic structures: conductance fluctuations and coherent transport – Coulomb blockade effects - Single electron phenomena and Single electron Transistor – magnetic semiconductors– spintronics - Carbon nanotubes: Properties and applications.	
Q.No.	**PART * A**
2.	**What is meant byTunneling?** BTL1 The phenomenon in which a particle, like an electron, encounters an energy barrier in an electronic structure and suddenly penetrates is known as tunnelling.
2	**What is meant by quantumconfinement?**BTL1 Quantum confinement is a process of reduction of the size of the solid such that the energylevels inside becomes discrete.
3	**Infer the term quantumstructure.**BTL2 When bulk material is reduced in its size, at least one of its dimensions, in the order of few nanometres, then the structure is known as quantum structure
4.	**Define Zener-Blochoscillation.**BTL2 Zener-Bloch oscillation denotes the oscillation of a particle confined in a periodic potential when a constant force is acting on it.
5	**What is resonant tunnelingdiode?**BTL2 Resonant tunnelling diode refers to tunnelling in which the electron transmission coefficient through a structure is sharply peaked about certain energies.
6	**Define quantuminterference.** BTL2 When two or more particles that are space and time independent have an interaction, construction or destructing their wave function is known quantum interference.
7.	**Recall the term Blochoscillations.** BTL2 A particle in a periodic potential with an additional constant force performs osciallations and these oscillations are called Bloch oscillations
8.	**What are Zener – Blochoscillations?**BTL2 The dynamics of quantum particles shows a coherent superposition of Bloch oscillations and Zener tunnelling between the sub-bands which is called as Zener-Bloch oscillation.
9	**DefineMesoscopic**. BTL2 Mesoscopic means intermediate between the macroscopic and microscopic scales.
10	**Define Coulombblockade effect.**BTL2 The resistance to electron transport caused by electrostatic coulomb forces in certain electronic structures, including quantum dots and single electron transistors is called coulomb blockade.
11.	**What is single electronphenomena?**BTL2

	A transistor made from a quantum dot that controls the current from source to drain one electron at a time is called single electron transistor.
12.	**What are magneticsemiconductors?**BTL2 Magnetic semiconductors are semiconducting materials that exhibit both ferromagnetism and semiconductor properties.
13.	**What isspintronics?**BTL2 Spintronics is nano technology which deals with spin dependent properties of on electron instead of charge dependent properties.
14.	**What are the applications ofspintronics?**BTL2 a) Solid state non-volatilememories. b) Quantum information processing and c) Quantumcomputation d) Spin basedtransistors.
PART-B	
1	**ExplaintheelectrondensityinbulkmaterialandsizedependenceofFermi energy. (8 M)**BTL2 **Answer: Page: 5.4 to 5.7 P.MANI** Electron density in bulk materials definition and equation with explanation (4 M) Fermi energy definition and size dependence of Fermi energy equation with explanation (4 M)
2	**Explain quantum confinement and quantum structures in nano materials. (OR) Discussdensityofstatesinquantumwell,quantumwireandquantumdot. (16 M)** BTL2 **Answer: Page: 5.7 to 5.11P.MANI** Definition of quantum confinement and quantum structure (4 M) Definition of quantum well and diagram with equation (4 M) Definition of quantum wire and diagram with equation(4 M) Definition of quantum dot and diagram with equation(4 M)
3	**Writenote(i)Zener–Blochoscillations(ii) Resonanttunnellingand(iii) Quantum interference effect. (5M+5M+6M)** BTL2 **(i) Answer: Page: 5.11 to 5.13P.MANI** Definition of Zener-Bloch oscillation (2 M) Derivation of Zener-Bloch oscillation equation (3 M) **(ii) Answer: Page: 51.4 to 5.16P.MANI** Definition of resonant tunnelling (2 M) Explanation of resonant tunnelling with diagram and equation (3 M) **(iii) Answer: Page: 5.29 to 5.32P.MANI** Definition of quantum interference effect (2 M) Explanation of quantum interference effect with diagram and equation (3 M) Applications of quantum interference effect (1 M)
5	**Explain mesoscopic structure of conductance fluctuations and coherent transport. (14 M)** BTL2 **Answer: Page: 5.4 to 5.7P.MANI** Definition of mesoscopic structure (2 M)

	Explanation of de-Broglie wavelength, Mean free path, diffusion length (6 M) Conductance fluctuations and factors influencing conductance fluctuations (2 M) Definition of coherent transport (2 M) Explanation of coherent transport (2 M)
6	**Describe Coulomb blockade effect and single electron phenomena. (6M +6 M)** BTL2 **Answer: Page:** 5.17 to 5.20**P.MANI** Definition of Blockade effect (2 M) Explanation of Blockade effect with diagram and equation (4 M) Definition of single electron phenomenon (2 M) Explanation of single electron phenomenon with diagram and equation (4 M)
7	**Explain the phenomena of single electron which is used in single electron transistor. (or) Describe the construction and working of single electron transistor. Mention its advantages, disadvantages and uses. (16M)** BTL2 **Answer: Page: 5.20 to 5.24P.MANI** Principle (2 M) Construction diagram (3 M) Construction description (3 M) Working (4 M) Advantages, disadvantages and uses (4 M)
8	**What are magnetic semiconductors? List out the properties and applicationsof magnetic semiconductors. (2M + 4M +4M)** BTL2 **Answer: Page: 5.33 to 5.36P.MANI** Definition of magnetic semiconductors (2 M) Properties of magnetic semiconductors (4 M) Applications of magnetic semiconductors (4 M)
9	**Explain the concept of spintronics and its applications. (12 M) (or) Discuss on spintronics and also on spin based Field Effect Transistor (12M) (or) Write a short note on (i) GMR (6 M) (ii) Spin valve (6M)**BTL2 **Answer: Page: 5.35 to 3.38 P.MANI** Concept of spintronics (4 M) Applications of spintronics (8 M)
10	**What is CNT? Describe the types, structure, properties and applications of CNTs. (15 M)** BTL2(May 2018) **Answer: Page: 5.39 to 5.47 P. MANI** Definition of CNT (2 M) Types of CNT (2 M) Structure of CNT (2 M) Properties of CNT (5 M) Applications of CNT (5 M)

BE 8254 BASIC ELECTRICAL AND INSTRUMENTATION ENGINEERING

L T P C
3 0 0 3

OBJECTIVES:

- Operation of Three phase electrical circuits and power measurement
- Working principles of Electrical Machines
- Working principle of Various measuring instruments

UNIT I AC CIRCUITS AND POWER SYSTEMS (9)

Three phase power supply – Star connection – Delta connection – Balanced and Unbalanced Loads- Power equation – Star Delta Conversion – Three Phase Power Measurement - Transmission & Distribution of electrical energy – Overhead Vs Underground system – Protection of power system – types of tariff – power facto r improvement

UNIT II TRANSFORMER (9)

Introduction - Ideal Transformer – Accounting for Finite Permeability and Core Loss – Circuit Model of Transformer – Per Unit System – Determination of Parameters of Circuit Model of Transformer – Voltage Regulation – Name Plate Rating – Efficiency – Three Phase Transformers - Auto Transformers

UNIT III DC MACHINES (9)

Introduction – Constructional Features– Motoring and generation principle - Emf And Torque equation – Circuit Model – Methods of Excitation and magnetization characteristics – Starting and Speed Control – Universal Motor

UNIT IV AC MACHINES (9)

Principle of operation of three-phase induction motors – Construction –Types – Equivalent circuit, Single phase Induction motors -Construction– Types–starting and speed control methods. Alternator- working principle–Equation of induced EMF – Voltage regulation, Synchronous motors- working principle-starting methods -– Torque equation – Stepper Motors – Brushless DC Motors.

UNIT V MEASUREMENT AND INSTRUMENTATION (9)

Type of Electrical and electronic instruments – Classification- Types of indicating Instruments – Principles of Electrical Instruments –Multimeters, Oscilloscopes- Static and Dynamic Characteristics of Measurement – Errors in Measurement – Transducers - Classification of Transducers: Resistive, Inductive, Capacitive, Thermoelectric, piezoelectric, photoelectric, Hall effect and Mechanical

OUTCOMES:

- Understand the concept of three phase power circuits and measurement.
- Comprehend the concepts in electrical generators, motors and transformers
- Choose appropriate measuring instruments for given application

TEXT BOOKS:

- D P Kothari and I.J Nagrath, ―Basic Electrical and Electronics Engineering‖, McGraw Hill Education (India) Private Limited, Third Reprint ,2016
- Giorgio Rizzoni, ―Principles and Applications of Electrical Engineering‖, McGraw Hill Education (India) Private Limited, 2010
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- Del Toro, Electrical Engineering Fundamentals‖, Pearson Education, New Delhi, 2015.
- Leonard S Borrow, ― Foundations of Electrical Engineering‖, Oxford University Press, 2013
- Rajendra Prasad, Fundamentals of Electrical engineering‖, Prentice Hall of India, 2006.
- Mittle N., ―Basic Electrical Engineering‖, Tata McGraw Hill Edition, 24th reprint 2016
- A.E. Fitzgerald, David E Higginbotham and Arvin Grable, ―Basic Electrical Engineering‖, McGraw Hill Education (India) Private Limited, 2009

UNIT I AC CIRCUITS AND POWER SYSTEMS	
Three phase power supply – Star connection – Delta connection – Balanced and Unbalanced Loads- Power equation – Star Delta Conversion – Three Phase Power Measurement - Transmission & Distribution of electrical energy – Overhead Vs Underground system – Protection of power system – types of tariff – power factor improvement	
PART * A	
Q.No.	**Questions**
1.	**Point out the advantages of 3Φ system over 1Φ system**. (April/May 2019) BTL4 1. Power delivered is constant. In single phase circuit the power delivered is pulsating and objectionable for many applications. 2. For a given frame size a polyphase machine gives a higher output than a single phase machine. 3. Polyphase induction motors are self starting and are more efficient. Single phase motor has no starting torque and requires an auxiliary means for starting. 4. Comparing with single phase motor, three phase induction motor has higher power factor and efficiency. Three phase motors are very robust, relatively cheap, generally smaller, have self-starting properties, provide a steadier output and require little maintenance compared with single phase motors.
2.	**Define power factor.** (April/May 2019) BTL1 The power factor of an AC electrical power system is defined as the ratio of the real power absorbed by the load to the apparent power flowing in the circuit, and is a dimensionless number in the closed interval of −1 to 1.
3.	**Define line voltage and line current.** BTL1 **1.** Line voltage is the voltage measured between any two lines in a three-phase circuit. **2.** Line current is the current through any one line between a three-phase source and load.
4.	**Write the expression for determining reactive and apparent power in a three-phase circuit.** BTL1 The expression for real power is P=VIcosθ. Its unit is KW

The expression for reactive power is P=VIsinθ. Its unit is kVAR. Total power equation is given by P=VI.its unit is kVA.

5. **Differentiate star and delta connected system.** (BTL3)

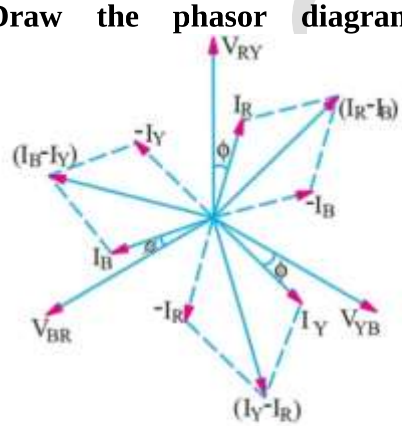
S.NO	STAR CONNECTION	DELTA CONNECTION
1.	Line current is the same as phase current, ie $I_L=I_{ph.}$	Line current is $\sqrt{3}$ X the phase current. $I_L=\sqrt{3}\ I_{ph.}$
2.	Line voltage is $\sqrt{3}$ the phase voltage. $V_L=\sqrt{3}\ V_{ph.}$	Line voltage is the same as phase voltage.
3.	Total power $=\sqrt{3}\ V_L I_L \cos\theta$.	Total power $=\sqrt{3}\ V_L I_L \cos\theta$.
4.	Per phase power= $V_{ph}I_{ph}\cos\theta$.	Per phase power= $V_{ph}I_{ph}\cos\theta$.
5.	Three-phase three-wire and three phase four wire systems are possible.	Three-phase three-wire system is possible.
6.	Line Voltages lead the respective phase voltages by 30^0	Line currents lag the respective phase currents by 30^0

6. **What is balanced and unbalanced system?** BTL2

Balanced load in 3 phase system is a condition where all three phases (lines) carry same magnitude of current, with evenly spaced phase difference. the neutral will carry no current. vector sum of all three phase currents meeting at common neutral point is zero.

Unbalanced load in 3 phase system is a condition where all lines / phases carry different current magnitudes, and sum of these at neutral point is not zero. Load in each phase is different, carrying ts own current. Neutral in this case carries the net unbalanced current.

7. **Draw the phasor diagram of a balanced delta connected load.** BTL6



<table>
<tr><td>8.</td><td>Evaluate the voltage across Y and B in a 3 Φ balanced delta system with voltage across R and Y is 400∠00 V. Assume RYB phase sequence BTL5
The voltage across Y and B in a 3 Φ balanced delta system is 400V. because the voltages in a delta circuit are same.</td></tr>
<tr><td>9.</td><td>A 3Φ 400V supply is given to a balanced star connected load of impedance 8+j6 ohms in each branch. Formulate the line current. BTL6
Solution:
$Vph = V_L/\sqrt{3}$
$= 400/\sqrt{3} = 231V$
$Iph = I_L = Vph/Zph$
$= 231/(8+j6)$
=</td></tr>
<tr><td>10.</td><td>In two wattmeter power measurement method, if one wattmeter reads zero, analyse the power factor of the circuit. BTL3
Reading of one wattmeter will be zero. If we analyse the power factor formula of two-wattmeter method
Now as p.f.=0.5=cos 60°;
Hence θ=60°
$\tan 60° = \sqrt{3} = \frac{\sqrt{3}(W1-W2)}{W1+W2}$
So, $W_1 - W_2 = W_1 + W_2$
So, $2W_2 = 0$
Hence, $W_2 = 0$</td></tr>
<tr><td>11.</td><td>What are the requirements of protection? BTL2
1. Dependability.
2. Security.
3. Select ability.
4. Reliability.</td></tr>
<tr><td>12.</td><td>What are the basic requirements of a circuit breaker? BTL2
1. Fault location and repair
2. Current carrying capacity
3. Maintainance cost
4. Useful life.</td></tr>
<tr><td>13.</td><td>Differentiate between fuse and protective relay. BTL2
<table><tr><th>PARAMETER</th><th>FUSE</th><th>RELAY</th></tr></table></td></tr>
</table>

Working Principle	Fuse works on the electrical and thermal properties of the conducting materials.	Circuit breaker works on the Electromagnetism and switching principle
Reusability	Fuses can be used only once.	Circuit breakers can be used a number of times.
Status indication	It does not give any indication.	It gives an indication of the status
Temperature	They are independent of ambient temperature	Circuit breaker Depends on ambient temperature
Breaking capacity	Breaking capacity of the fuse is low as compared to the circuit breaker.	Breaking capacity is high.

14. **What is the importance of arc resistance? On what factor does it depend?** BTL4

The arc existence depends on the resistance offered for the circuit by the contact medium and it depends on the following factors: Dielectric strength of the medium: The arc resistance increases with increase in dielectric strength of the medium as it offers an opposite force to the electron flow.

15. **Distinguish between recovery voltage and restriking voltage** BTL3

Restriking Voltage: As the arcing current crosses zero, a high frequency transient voltage appears across the contacts of the Circuit Breaker. This Transient voltage is known as Restriking Voltage.

Recovery Voltage: Recovery Voltage is the normal frequency RMS voltage that appears across the contacts of the Circuit Breaker after final arc extinction. It is equal to the system voltage.

16. **Define the term maximum demand.** BTL1

Maximum demand is the highest level of electrical **demand** monitored in a particular period usually for a month period.

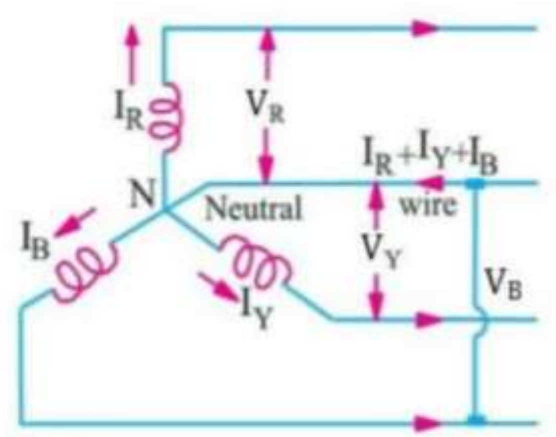
17. **List the objectives of tariff and the factors affecting it.** BTL1 (April/May 2018)

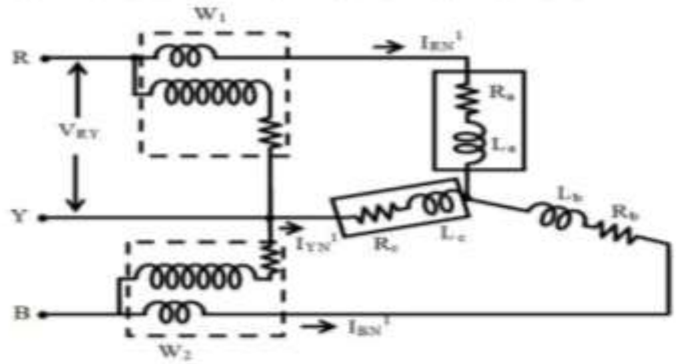
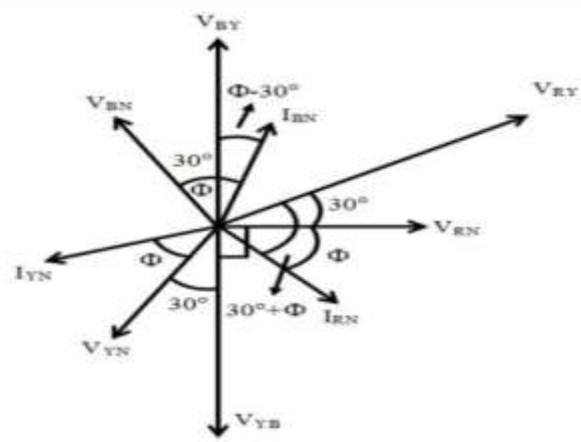
Tariffs may be levied either to raise revenue or to protect domestic industries, but a **tariff** designed primarily to raise revenue also may exercise a strong protective influence, while a **tariff** levied primarily for protection may yield revenue.

Factors affecting:

1. Types of Load
2. Maximum demand
3. The time at which load is required
4. The power factor of the load

	5. The amount of energy used
18.	**What is meant by relay operating time**? BTL1 1. The operating time is the time from when the rated voltage is applied to the coil, until the time when the contacts operate. 2. With Relays that have multiple pairs of contacts, if there are no other conditions, then the operating time is the time required for the slowest pair of contacts to operate. 3. The operating time is given for a coil temperature of 23°C or higher. The bounce time is not included.
19.	**Write the effect of power factor in energy consumption billing.** BTL3 When the **power factor** falls below a set figure, the **electricity** supply companies charge a premium on the kW being consumed, or, charge for the whole supply as kVA. Inductive loads cause the AMPS to lag behind the Volts. Reactive **power** is the vertical or that part of the supply which causes the inductive load.
PART * B	
1.	**A three-phase balanced delta-connected load of 4+j8Ω is connected across a 400V, 3Ø balanced supply. Determine the phase currents and line currents (Phase sequence in RYB).** BTL3 **(13M)** **Answer: Page 1.30-Dr.C.Ramesh babu durai** Taking the line voltage VRY = $V\angle 0^o$ as a reference VRY = $400\angle 0^o$ V, VYB = $400\angle -120^o$ V and ……………..4M VBR = $400\angle -240^o$ V. ………………….4M Impedance per phase = (4+j8) Ω = $8.94\angle 63.4^o$ Ω. …………3M Phase current IR = $(400\angle 0o)/(8.94\angle 63.4o)$= $44.74\angle -63.4^o$ A. ……………..2M
2.	**A positive sequence wye connected source where Van = 120∠90° V, is connected to a delta connected load where ZL = (60+j45) Ω. Determine the line currents. BTL**5 **(13M)** **Answer: Page 1.35-Dr.C.Ramesh babu durai** First the voltages are Van = 120∠90° V, Vbn = 120∠–30° V, and ……….4M Vcn = 120∠–150° V. …………….4M The phase load is ZΔ = 75∠36.87° Ω. ZY = ZΔ/3 = 25∠36.87° Ω Thus, Ia = Van/25∠36.87° = 120∠90°/25∠36.87° = 4.8∠53.13° A. Ib = 120∠–30°/25∠36.87° = 4.8∠–66.87° A……..3M Ic = 120∠–150°/25∠36.87° = 4.8∠173.13° A……..2M
4.	**Explain three phase power measurement by 2 wattmeter method for star and delta connected load and determine the power equation and draw the phasor diagram.** BTL4 **(13M)** (April/May 2019) **BTL-2** **Answer: Page 1.39-Dr.C.Ramesh babu durai**

	Star Connection (Y) In this kind of interconnection, the starting ends or finishing ends (Similar ends) of three coils are connected together to form the neutral point. Or Star Connection is obtained by connecting together similar ends of the three coils, either "Starting" or "finishing". The other ends are joined to the line wires. The common point is called the neutral or Star Point, which is represented by N. (As shown in fig 1) Star Connection is also called Three Phase 4 wires (3-Phase, 4-Wires) system. …5M  -------8M
5.	**Explain the measurement of power in 3 phase circuit using Two wattmeter method. (13M)** BTL4 **Answer: Page 1.40-Dr.C.Ramesh babu durai**

	Measurement of Power in a Three-phase Circuit Two-wattmeter Method of Power Measurement in a Three-phase Circuit  **Connection diagram for two-wattmeter method of power measurement in a three-phase balanced system with star-connected load** The connection diagram for the measurement of power in a three-phase circuit using two wattmeters, is given in Fig. This is irrespective of the circuit connection – star or delta. The **..8M**  **Phasor diagram for two-wattmeter method of power measurement in a three-phase system with balanced star-connected load** **..5M**
6.	**What is tariff? What are its objectives? Discuss in detail about different types of tariffs with its applications (13M)** BTL2 **Answer: Page 1.42-Dr.C.Ramesh babu durai**

Electricity Rates or Tariff

Factors involved in deciding an electricity tariff

- The tariff should be such that the total cost of generation, transmission, and distribution is recovered.
- It should earn a reasonable profit.
- It must be fair and at a reasonable to the consumers.
- It should be simple and easy to apply.
- It should be attractive than a competitor.

Keeping in mind the above factors, various types of tariff have been designed. The most commonly used are given below.

…8M

…………5M

PART * C

1. **i) Compare overhead and underground transmission lines. (8M)** (April/May 2019) (April/May 2018) BTL1

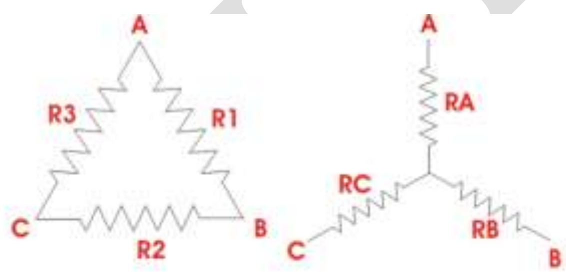
Answer: Page 1.25-Dr.C.Ramesh babu durai

S.no	overhead Cable	Underground Cable
1	The interference from external disturbance like a storm, lightning ice, trees, etc is more.	The interference from external disturbance like a storm, lighting, ice, trees is minimum
2	The overhead cables are less costly as compared with the underground cable.	The underground is more costly as compared with the overhead system for the same voltage.
3	The right of way requirement is more in the case of underground cable.	The right of the way requirement is less the case of underground cable.

4	The possibilities of supply interruption due to lighting and other external influence are more than with overhead cable.	The possibility of supply interruption due to lighting and other external influences cable.
5	The location of the fault in overhead line in easily found.	In the case of underground cable, the fault occurs due to any reasons is not easily located.
6	For long –distance transmission over headline cable can be used.	For the long-distance transmission cable cannot be used due to their long charging current.

ii) Explain about the conversion of star and delta conversion and write its expressions for each conversion. **(7M)** BTL1 (April/May 2018)
Answer: Page 1.25-Dr.C.Ramesh babu durai

1. terminal of three branches is connected to a common point to form a Y like pattern is known as star connection. For simplifying complex network, delta to star or **star to delta transformation** is required.



…….2M

$$R_A = \frac{R_3.R_1}{R_1 + R_2 + R_3}.$$

$$R_B = \frac{R_1.R_2}{R_1 + R_2 + R_3}..$$

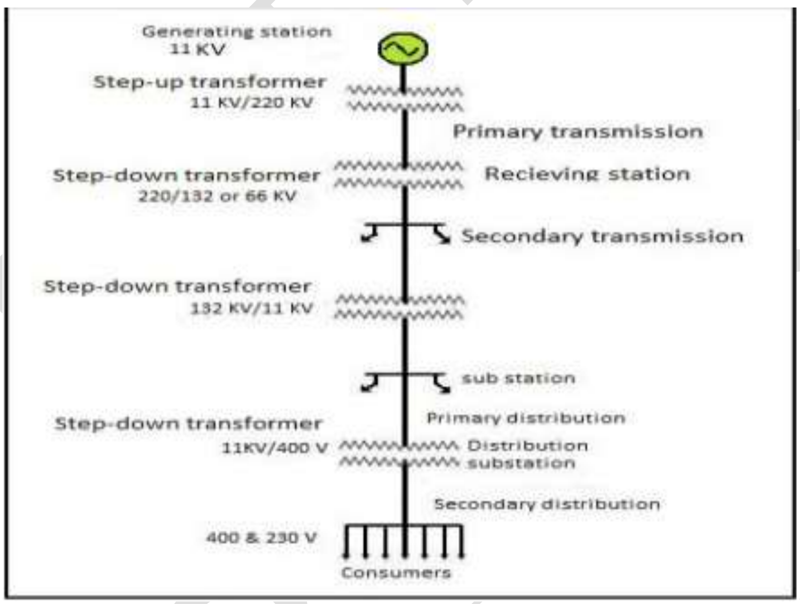
$$R_C = \frac{R_2.R_3}{R_1 + R_2 + R_3}..$$

……………………….3M

2.The replacement of delta or mesh by equivalent star connection is known as **delta – star transformation**

	$R_3 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_A}$ $R_1 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_B}$ $R_2 = \frac{R_A R_B + R_B R_C + R_C R_A}{R_C}$ …..2M
2.	**Explain the measurement of power in 3 phase circuit using one wattmeter method**. **(15M)** BTL1 **Answer: Page 1.25-Dr.C.Ramesh babu durai** **1.** The current coil is connected in any one line and the pressure coil is connected alternatively between this and the other two lines. 2. Balanced 3-wire, 3-phase load circuit the power in each phase is equal. Therefore, the total power of the circuit can be determined by multiplying the power measured in any one phase by three. 3.Total power in balanced load = 3 x Power per Phase = 3 x Wattmeter reading…………10M **Disadvantages of One Wattmeter Method**:This method is not of as much universal application as the two-wattmeter method because it is restricted to fairly balance loads only. Even a slight degree of unbalance in the loading produce a large error in the measurement**……………5M**
3.	**i)What is the need for power factor improvement in electrical circuits? (5M)** BTL1 **Answer: Page 1.34-Dr.C.Ramesh babu durai** 1. Low power factor means lower operating efficiency which results in a need for larger conductors (wires) and increased equipment capacity, as well as causing voltage drops as power losses increase. 2. These equate to higher capital investment, higher expenses, and diminished distribution system performance. Power factor correction does not save much energy (usually less than 1% of load requirements), and even that reduction depends on how low the power factor is to begin with and how heavily loaded inductive devices are in the distribution system.

	3. energy savings are minimal, correcting power factor can bring significant savings in energy bills if the utility imposes a low power factor penalty in their rate structure, as most utilities do for industrial customers. ……..5M **ii)Give the comparison between static capacitors and synchronous condensers. (10M)** BTL1 **Answer: Page 1.35-Dr.C.Ramesh babu durai** **Static capacitor:**The power factor can be improved by connecting capacitors in parallel with the equipment operating at lagging power factor. The capacitor (generally known as static capacitor) draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load. For three-phase loads, the capacitors can be connected in delta or star……………4M Advantages 1. They have low losses 2. They require little maintenance as there are no rotating parts 3. They can be easily installed as they are light and require no foundation 4. They can work under ordinary atmospheric conditions…….1M Disadvantages 1. They have short service life ranging from 8 to 10 years 2. They are easily damaged if the voltage exceeds the rated value 3. Once the capacitors are damaged, their repair is uneconomical………..1M **synchronous condenser:** A synchronous motor takes a leading current when over-excited and, therefore, behaves as a capacitor. An over-excited synchronous motor running on no load is known as synchronous condenser. When such a machine is connected in parallel with the supply, it takes a leading current which partly neutralizes the lagging reactive component of the load. Thus the power factor is improved…..2M Advantages 1. By varying the field excitation, the magnitude of current drawn by the motor can be changed by any amount. This helps in achieving step less †control of power factor 2. The motor windings have high thermal stability to short circuit currents 3. The faults can be removed easily…..1M Disadvantages 1. There are considerable losses in the motor 2. The maintenance cost is high 3. It produces noise 4. Except in sizes above 500 kVA, the cost is greater than that of static capacitors of the same rating………1M

4.	**i) Draw the single line diagram of an AC power system and discuss in detail about Transmission and Distribution of electrical energy. (15M)** (April/May 2018) (April/May 2019) BTL4 **Answer: Page 1.35-Dr.C.Ramesh babu durai** **1.generating station……..2M** **2.Primary Transmission…………..2M** **3.secondary transmission…………3M** **4.primary distribution………….3M** **4.secodary distribution…………..3M** ….2M

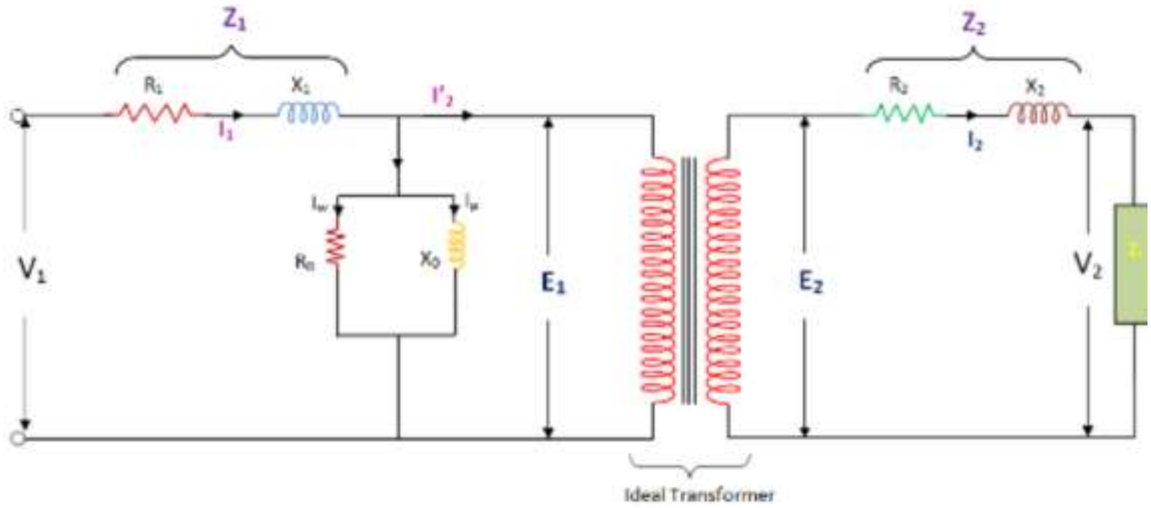
UNIT II TRANSFORMERS
Introduction - Ideal Transformer – Accounting for Finite Permeability and Core Loss – Circuit Model of Transformer – Per Unit System – Determination of Parameters of Circuit Model of Transformer – Voltage Regulation – Name Plate Rating – Efficiency – Three Phase Transformers – Auto Transformers.
PART * A

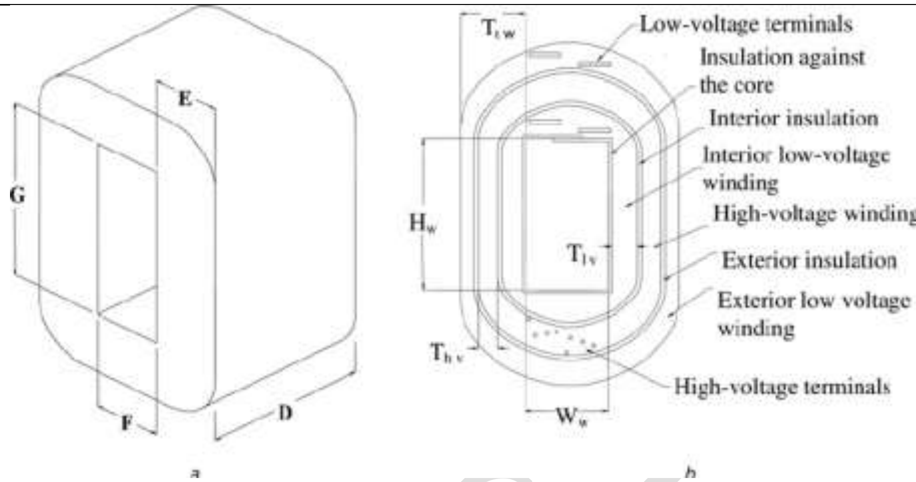
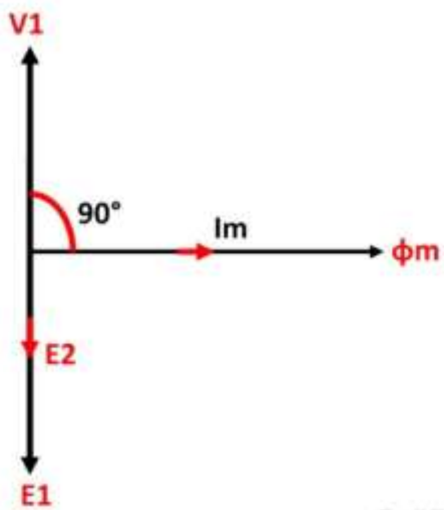
Q.No.	Questions
1.	**What is meant by transformer? Formulate the expression for step up and step-down transformer according to transformation ratio.** BTL6

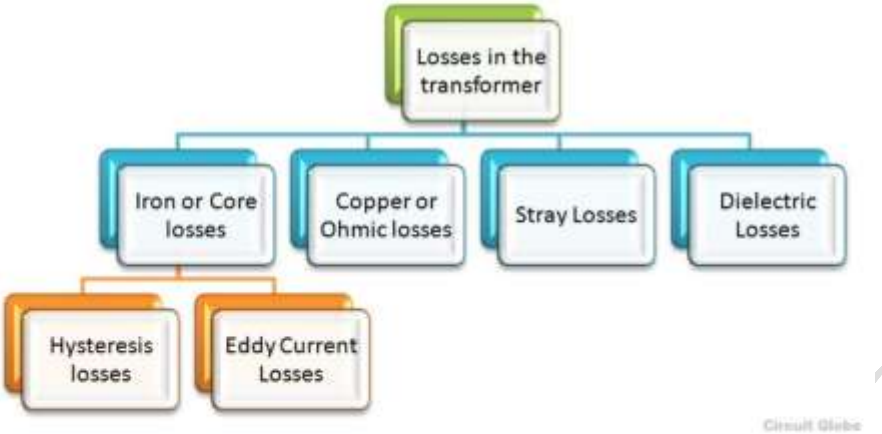
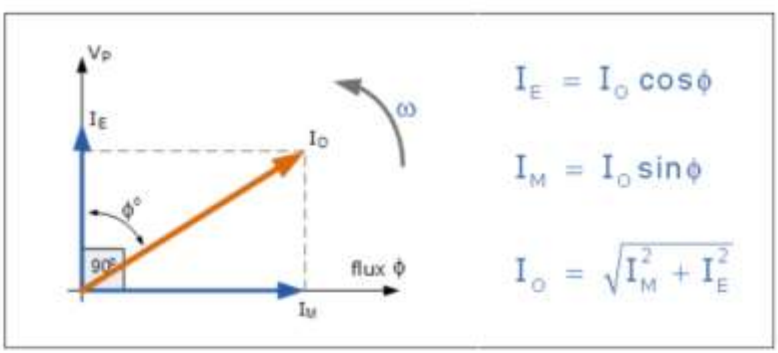
	1. A transformer basically is very simple static (or stationary) electro-magnetic passive electrical device that works on the principle of Faraday's law of induction by converting electrical energy from one value to another. 2. A transformer operates on the principals of "electromagnetic induction", in the form of Mutual Induction. 3. When a transformer is used to "increase" the voltage on its secondary winding with respect to the primary, it is called a Step-up transformer. When it is used to "decrease" the voltage on the secondary winding with respect to the primary it is called a Step-down transformer. 4. K = N2/N1 = E2/E1 = I1/I2.
2.	**Compare the following transformers (i) Core type transformer (ii) Shell type.** BTL5

PARAMETERS	CORE TYPE TRANSFORMER	SHELL TYPE TRANSFORMER
Definition	The winding surrounds the core.	The core surrounds the winding.
Cross Section	Cross-section may be square, cruciform and three stepped	The cross section is rectangular in shape.
Copper Require	More	Less
Flux	The flux is equally distributed on the side limbs of the core.	Central limb carry the whole flux and side limbs carries the half of the flux.
Winding	The primary and secondary winding are placed on the side limbs.	Primary and secondary windings are placed on the central limb

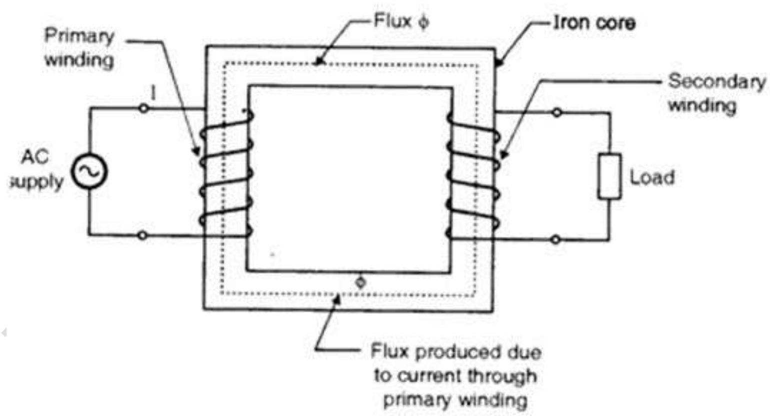
3.	**Draw the circuit diagram of single-phase transformer**. BTL3

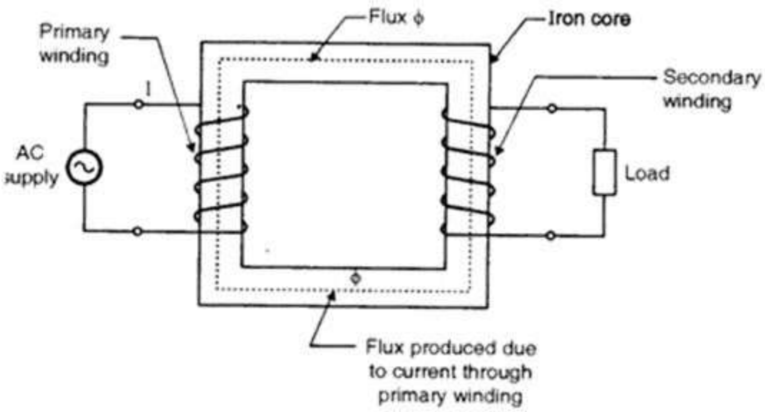
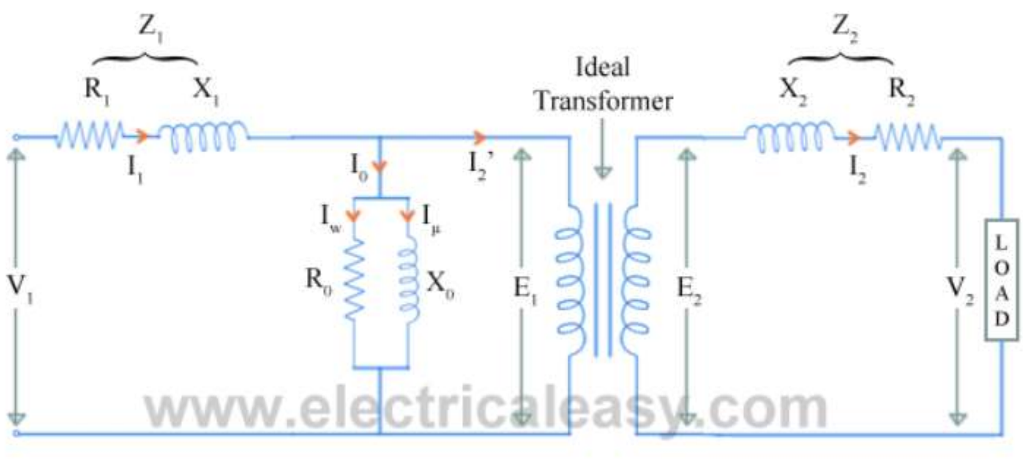
	
4.	**Write down the EMF equation of a transformer relative to the secondary winding.** BTL6 r.m.s value of the induced e.m.f in the primary winding 1. E_1 = (induced e.m.f/turn) x No. of primary turns 2. $E_1 = 4.44\, f\, \Phi_m N1$ (As $\Phi_m = B_m \times A$) 3. $\boldsymbol{E_1 = 4.44\, f\, N1 B_m A}$ r.m.s value of the e.m.f. induced in secondary is, E_2 = (induced e.m.f/turn) x No. of Secondary turns $= 4.44\, f\, \Phi_m N2$ (As $\Phi_m = B_m \times A$) $\Rightarrow \boldsymbol{E_2 = 4.44\, f\, N2\, B_m A}$.the e.m.f/ turn is the same in both primary and secondary windings.
5.	**How do you reduce leakage flux in a transformer?** BTL2 1. **Reducing** the magnetizing current to the minimum. 2. **Reducing** the reluctance of the iron core to the minimum. 3. **Reducing** the number of primary and secondary turn to the minimum. 4. Sectionalizing and interleaving the primary and secondary windings.
6.	**Draw a single-phase shell type transformer and name the parts.** BTL3

	
7.	**The emf per turn for a single-phase 2200/220 V, 50 Hz transformer is 11 V. Calculate the number of primary and secondary turns.** BTL3 Primary turns = 2200/11=200 turns. Secondary turns=220/11=20 turns.
8.	**What is an ideal transformer and draw its phasor diagram?** BTL1 The transformer which is free from all types of losses is known as an ideal transformer. It is an imaginary transformer which has no core loss, no ohmic resistance and no leakage flux. 
9.	**Define voltage regulation of a transformer.** (April/May 2018) BTL1 The voltage regulation of the transformer is the percentage change in the output voltage from no-load to full-load. And since power factor is a determining factor in the secondary voltage, power factor influences voltage regulation. This means the voltage regulation of a transformer is a dynamic, load-dependent number.

	$Voltage\ regulation(\%) = \frac{E_2 - V_2}{V_2} \times 100\%$
10	**List the different losses occurring in a transformer.** (April/May 2018) BTL1 
11	**Why transformer rating is in KVA?** (April/May 2019) BTL2 Copper losses (I^2R) depends on current which passing through **transformer** winding while Iron losses or core losses or Insulation losses depends on Voltage.That's the reason **transformer rating** may be expressed in VA or **kVA**, not in W or kW.
12	**Does transformer draw any current when secondary is open? Why?** BTL2 Transformers basically are two coils that are wound in a core and they work on mutual induction . Even if you open the secondary , that is no current flows in secondary u still will have small no load current I(which is 2–5 % of full load current) as for the working of transformer flux needs to be set up in the core and so primary draws no load current . Also this current is needed to overcome no load losses (hysterisis ,eddy and primary copper losses)
13	**Draw the no-load phasor diagram of a transformer.** BTL3 

<table>
<tr><td>14</td><td>At what condition does a transformer operate at its maximum efficiency. (April/May 2019) BTL4
The Efficiency of the transformer is defined as the ratio of useful power output to the input power, the two being measured in the same unit. Its unit is either in Watts (W) or KW. Transformer efficiency is denoted by Ƞ. Efficiency is maximum in a transformer when Copper losses = Iron losses.</td></tr>
<tr><td>15</td><td>Give the different types of 3 phase transformer connections. BTL2
<table>
<tr><th>Primary Configuration</th><th>Secondary Configuration</th></tr>
<tr><td>Delta (Mesh) △</td><td>Delta (Mesh) △</td></tr>
<tr><td>Delta (Mesh) △</td><td>Star (Wye) Y</td></tr>
<tr><td>Star (Wye) Y</td><td>Delta (Mesh) △</td></tr>
<tr><td>Star (Wye) Y</td><td>Star (Wye) Y</td></tr>
<tr><td>Interconnected Star</td><td>Delta (Mesh) △</td></tr>
<tr><td>Interconnected Star</td><td>Star (Wye) Y</td></tr>
</table></td></tr>
<tr><td>16</td><td>What happen when a DC supply is applied to a Transformer? BTL4
If DC supply is given to the primary of Transformer then DC current flows through primary winding which is constant(time invarient).For production of emf in any winding the current flowing through that must be sinusoidal since e=L*(dI/dt).So in the given case ie, for DC input,no emf produced in primary winding.</td></tr>
<tr><td>17</td><td>List the advantages and applications of auto transformer. BTL1
1. Less costly
2. Compact size
3. Good voltage regulation</td></tr>
<tr><td>18</td><td>In a single-phase transformer, N_p= 350 turns, N_s= 1050 turns, E_p= 400V. Calculate the value of secondary voltage (E_s). BTL5
N2/N1=E2/E1
E2= [1050/350]*400
=1200V.</td></tr>
<tr><td>19</td><td>What is per unit system? BTL2
The ratio of the actual quantity to base quantity is called per unit system.</td></tr>
<tr><td>20</td><td>What is name plate rating? BTL 2
the maximum power-generating capacity of a generator or power-generating facility.</td></tr>
</table>

PART * B	
1.	**Describe the constructional details of different types of 1-phase transformer with neat diagrams. (13M)** BTL1 **Answer: Page 2.1-Dr.C.Ramesh babu durai.** 1. **Definition (2M)** A transformer basically is very simple static (or stationary) electro-magnetic passive electrical device that works on the principle of Faraday's law of induction by converting electrical energy from one value to another. 2. **Diagram(4M)**  3. **Types and explanation(2M)** • shell type • core type 4. **Construction details: (5M)** • **Primary winding**: winding connected to the supply. • **Secondary winding**: connected to the load. • **Transformer core.**
2.	**Draw a general schematic of a single-phase transformer. Describe its working principle and deduce the expression for emf in secondary winding. (13M)** BTL2 **Answer: Page 2.1-Dr.C.Ramesh babu durai.** 1. **Diagram (4M)**

	 2. **Principle of a transformer(2M)** It works on the principle of mutual induction of two coils or Faraday Law's Of Electromagnetic induction. 3. **Emf equation (7M)** $E_1 = 4.44 \text{ f } N1B_m A$ $E_2 = 4.44 \text{ f } N2\ B_m A$
3.	**Develop the equivalent circuit of a single-phase transformer referred to primary and secondary. (13M)** (April/May 2018) (April/May 2019) BTL1 **Answer: Page 2.21-Dr.C.Ramesh babu durai.** 1. Equivalent Circuit diagram of single-phase Transformer. Equivalent circuit diagram of a transformer is basically a diagram which can be resolved into an equivalent circuit in which the resistance and leakage reactance of the transformer are imagined to be external to the winding. **(2M)** 2. **Diagram (3M)**  3. **Equations:(4M)**

<table>
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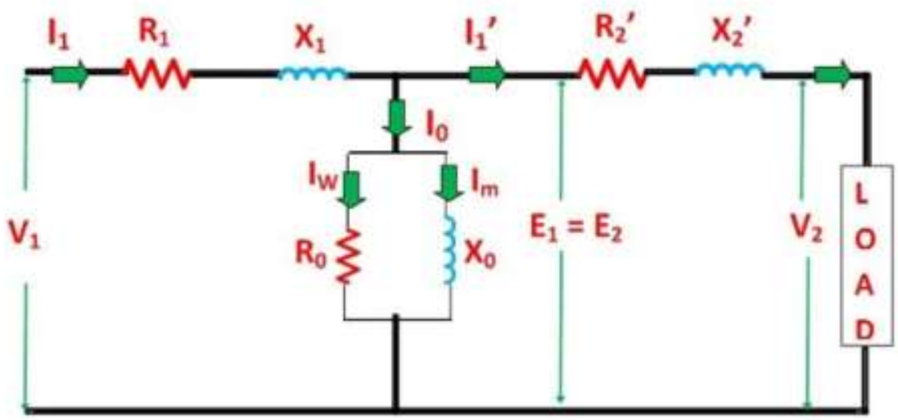
<td>

- $X_o=E_1/I_\mu$
- $R_o=E_1/I_w$
- $E_2'=E_2/K=E_1$
- $V_2'=V_2/K$
- $R_2'=R_2/K^2$
- $X_2'=X_2/K^2$
- $Z_2'=Z_2/K^2$

4. **Equivalent circuit: (4M)**



</td>
</tr>
<tr>
<td>4.</td>
<td>

Derive the equivalent circuit parameter of the transformer by performing OC test. (13M) BTL3

Answer: Page 2.33-Dr.C.Ramesh babu durai

1. The Open circuit test of the transformer is one of the type tests of transformer by which core losses of the transformer are determined. In this test normal voltage is applied on the low voltage side at rated frequency and high voltage side is open condition that means there is no load in the transformer.
2. the reading of wattmeter connected on the low voltage side gives the no load loss or core losses of the transformer and no-load impedance of transformer. **(3M)**
3. Diagram **(2M)**

</td>
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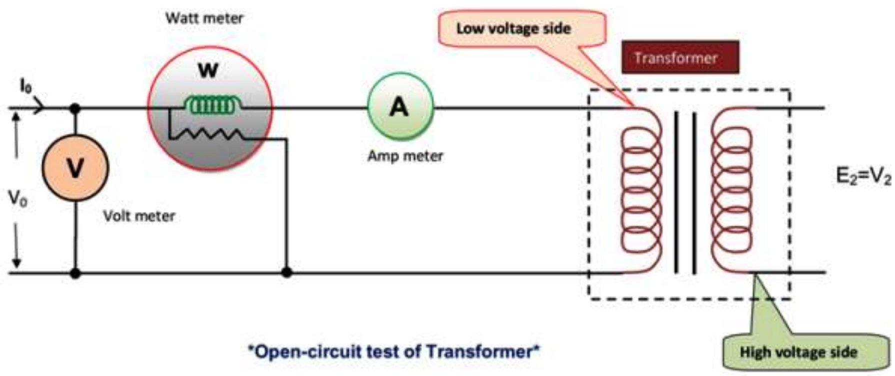
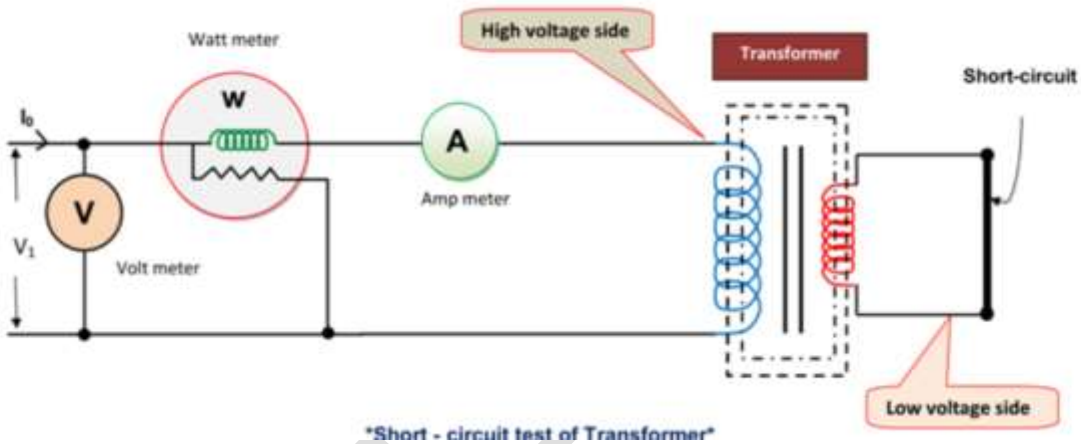
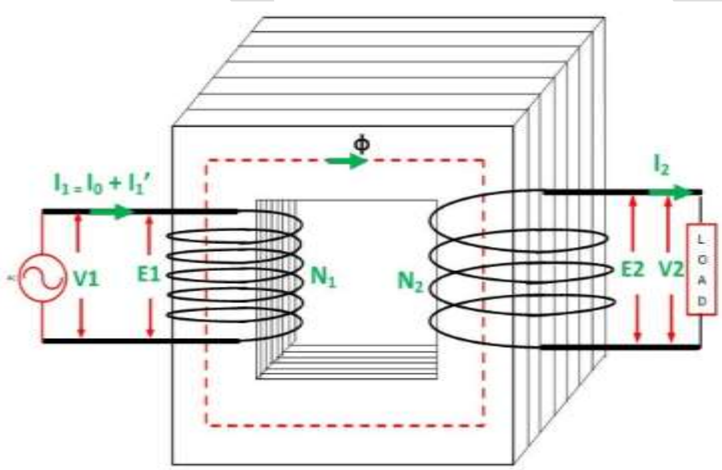
</table>

	 4. **Equivalent circuit parameters: (8M)** • $\mu = I_0 \sin \Phi_0$, $I_w = I_0 \cos\Phi_0$ • $X_0 = V_1/ I\mu$ and $R_0 = V_1 /I_w$ • $Z_0=\sqrt{(R_0^2+ X_0^2)}$ The admittance is the inverse of impedance=$Y_0= 1/Z_0$ The conductance $G_0 = G_0=W/V_1^2$ exciting susceptance, $B_0=\sqrt{(Y_0^2- G_0^2)}$
5.	**Derive the equivalent circuit parameters and thereby find the regulation and efficiency of the transformer by performing SC tests**. **(13M)** BTL6 **Answer: Page 2.34-Dr.C. Ramesh babu durai** **1.** The short circuit test of the transformer is the one of type test by which we can measure the full load cu- loss of the transformer. For testing the short circuit test all meters (i.e ammeter, wattmeter and volt meter) are connected to the high voltage winding and the low voltage winding is short. **2.** the low voltage is applied at high voltage side and the applied voltage is slowly increased with the help of variac until the ammeter gives reading equal to the rated current of the HV side. (3M) **3. Diagram (2M)**

	 4. **Equivalent circuit parameters: (8M)** • $W=I_1^2R_{01}$ • $R_{01}=W/I_1^2$ • $Z_{01}=V_1/I_1$ • $X_{01}=\sqrt{(Z_{01}^2-R_{01}^2)}$
6.	**Draw and explain the phasor diagram for a single-phase transformer supplying a leading power factor load. (13M)** BTL3 **Answer: Page 2.14-Dr.C. Ramesh babu durai** 1. **Diagram (3M)**  2. **Equations related to the loading conditions (3M)** 3. **Phasor diagram for capacitive loads (4M)**

<table>
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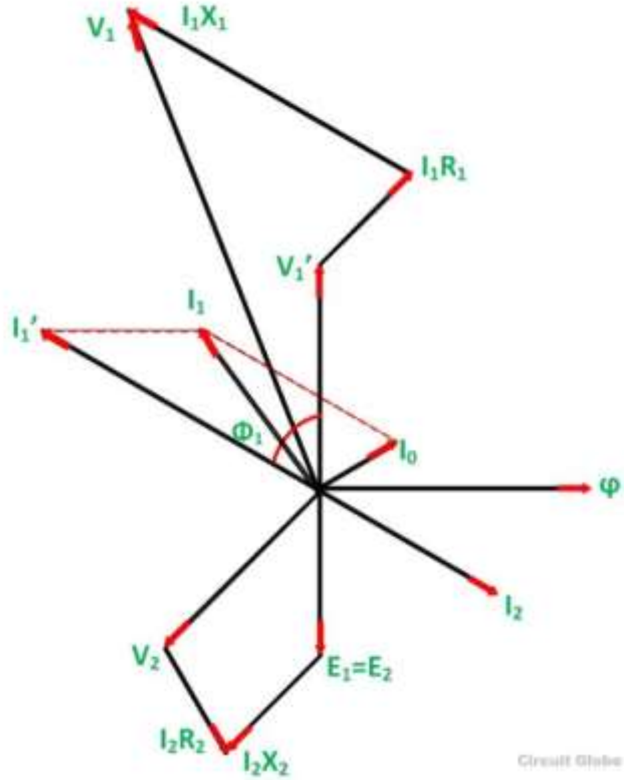
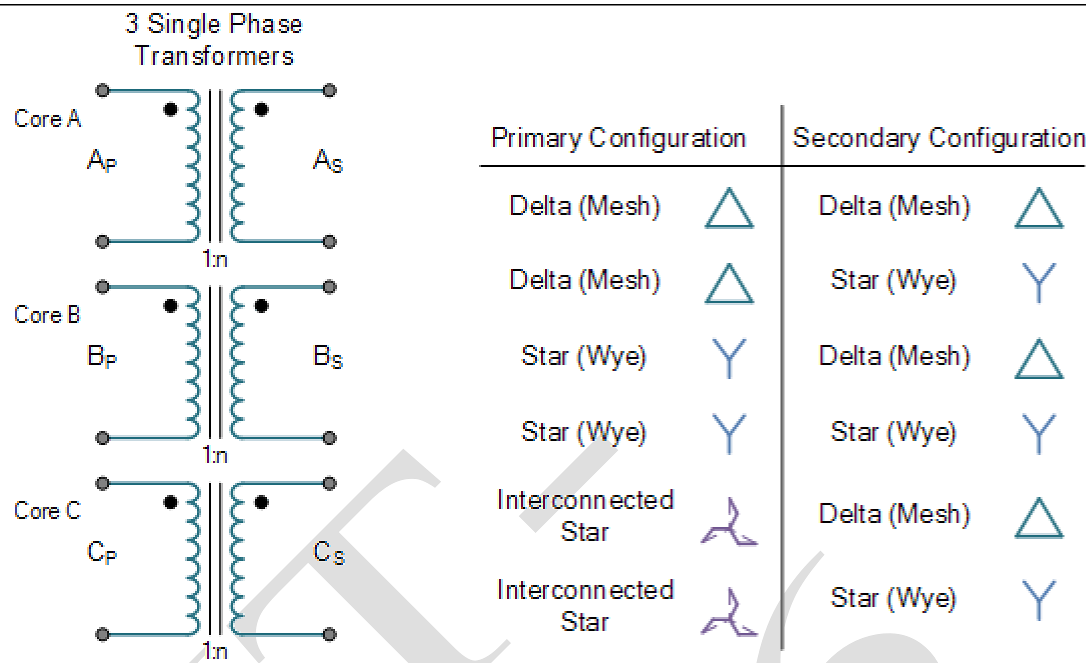
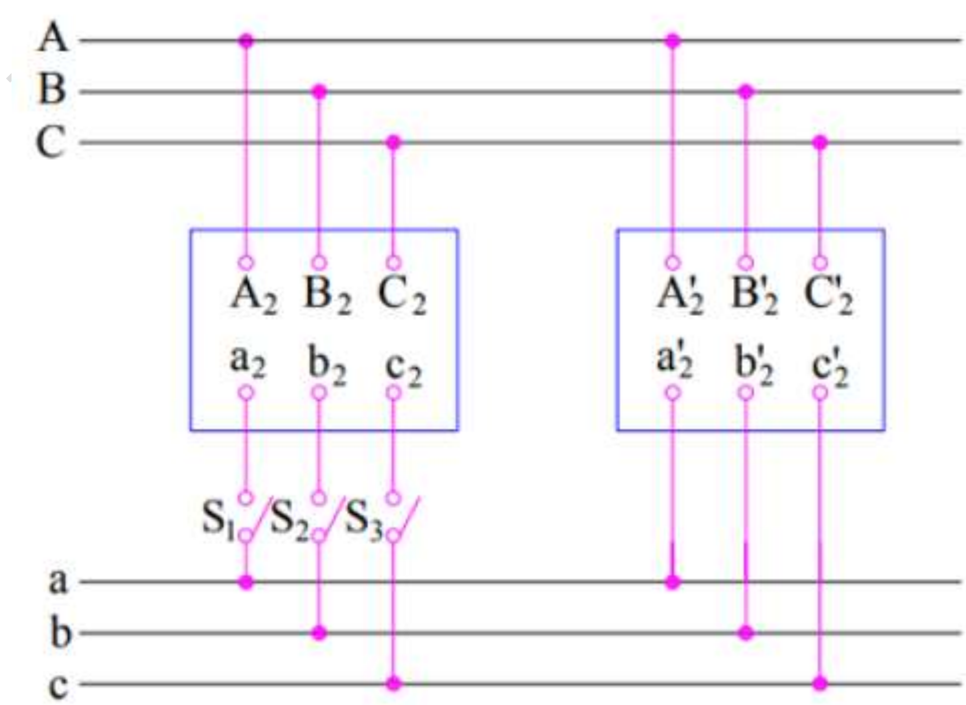


4. Explanation for the phasor diagram (3M)
</td></tr>
<tr><td>7.</td><td>
Describe the various three phase transformer connection and parallel operation of three phase transformer. (13M) BTL1
Answer: Page 2.42-Dr.C. Ramesh babu durai
1. Definition (2M)
Three number of identical single-phase transformers can be suitably connected for use in a three- phase system and such a three- phase transformer is called a bank of three phase transformer. Alternatively, a three-phase transformer can be constructed as a single unit.

2. Diagrams of 3 phase connections and explanation (4M)
</td></tr>
</table>



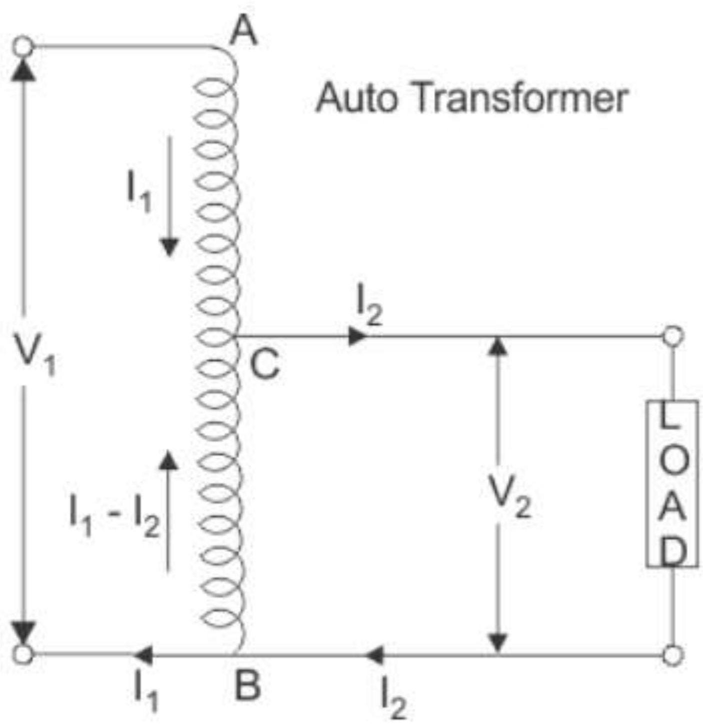
3. Diagram of parallel operation of three-phase transformers and explanation (7M)



8. **What is meant by auto transformer? Explain the principle, construction, working of a auto transformer? (13M)** (April/May 2018) (April/May 2019) BTL4

Answer: Page 2.38-Dr.C. Ramesh babu durai.

1. **Diagram (2M)**



2. **Definition (2M)**
   Auto transformer is kind of electrical transformer where primary and secondary shares same common single winding. So basically, a one winding transformer.
3. **Principle (2M)**

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = a \ (0<V_2<V_1)$$

he ampere-turns provided by the upper half:

$$F_U = (N_1 - N_2)I_1 = \left(1 - \frac{1}{a}\right) N_1 I_1$$

he ampere-turns provided by the lower half:

$$F_L = N_2(I_2 - I_1) = \frac{N_1}{a}(I_2 - I_1)$$

or ampere-turn balance, $F_U = F_L$:

$$\left(1 - \frac{1}{a}\right) N_1 I_1 = \frac{N_1}{a}(I_2 - I_1)$$

4. **Working and construction (3M)**
5. **Advantages and disadvantages (3M)**
6. **Applications (1M)**

9.

i)Describe in detail about per unit system. (8M) BTL1

1. **Definition: (2M)**
   The per unit value of any quantity is defined as the ratio of actual value in any unit and the base or reference value in the same unit. Any quantity is converted into per unit quantity by dividing the numeral value by the chosen base value of the same dimension. The per unit value are dimensionless.
2. **Quantity used in per unit: (3M)**
   - Base voltage = rated voltage of the machine
   - Base current = rated current of the machine
   - Base impedance = base voltage /base current
   - Base power = base voltage x base current
3. **Advantages of using the Per Unit System.(3M)**
   - The parameters of the rotating electrical machines and the transformer lies roughly in the same range of numerical values irrespective of their ratings if expressed in per unit system of their ratings.
   - It relieves the analyst of the need to refer circuit quantities to one or other side of the transformer, making the calculations easy..

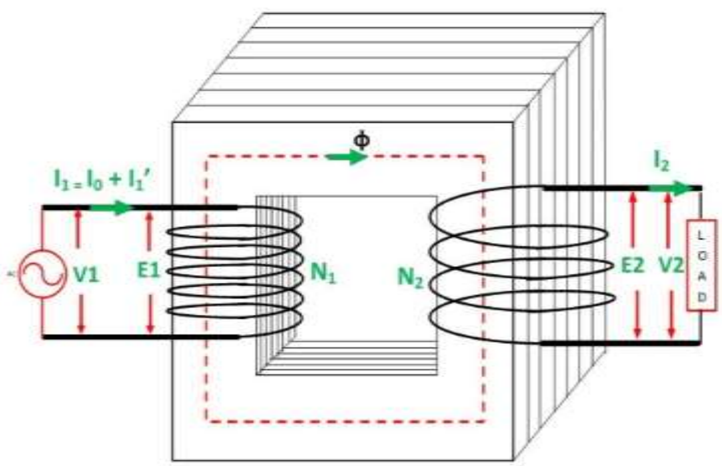
PART * C

1.

Derive the EMF equation of a single-phase transformer with respect to its primary and secondary windings. (15M) BTL6

Answer: Page 2.10-Dr.C. Ramesh babu durai.

1. **Diagram (3M)**



2. **Graph (2M)**

	3. Parameters of the transformer (4M) **4. Form factor (2M)** $=\frac{\text{rms value}}{\text{a verage value}}$ **5. Emf equation (4M)** $E_1 = 4.44\, f\, N1 B_m A$
2.	**The following data were obtained on a 20 kVA, 50 Hz, 2000/200 V distribution transformer:** **OC test with HV open-circuited: 200 V, 4 A and 120 W** **SC test with LV short-circuited: 60 V, 10 A and 300 W** **Estimate all the parameters of the equivalent circuit referred to the HV and LV sides of the transformer. (15M)**BTL2 **Answer: Page 2.61-Dr.C. Ramesh babu durai.** **1. Write the give parameters given. (3M)** **2. Calculate Iw, Iμ. (3M)** Iw= Io cosɵ Iμ =Io sinɵ **3. Calculate Ro, Xo. (3M)** Ro = V1/Iw Xo= V1/ Iμ **4. Calculate Ro2, Xo2. (3M)** Ro2= Wcu/Isc Xo2=Wsc/I^2sc **5. Equivalent circuit diagram.(3M)**
3.	**i)A 40 kVA,3300/240V,50Hz,1Ø transformer has 660 turns on the primary. Determine** **1) The number of turns on the secondary** **2) The Maximum value of flux in the core** **3) The approximate value of primary and secondary full load current. (8M)** BTL3 **1. no of turns:** E_2 = 4.44 f N2Bm A. **(3M)** **2. maximum value of flux:** Ø=Bm*A **(2M)** Bm= flux/ area. **3.primary and secondary full load current: (2M)** • I1= kVA/ E1 • I2= kVA/E2 **ii) Define the term voltage regulation of a transformer and derive the expression for voltage regulation (7M)** BTL1 **Answer: Page 2.52,2.54-Dr.C. Ramesh babu durai.**

	1. definition (3M) 2. formula (1M) 3. derivation(3M)
4.	**The test results obtained on a 1 phase 20 KVA, 2200/220 Volts transformer are:** **OC test: 220 V, 1.1 A, 125 W;** **SC test: 52.7 V, 8.4 A, 287 W** **The transformer is fully loaded. Find the load p.f. for zero voltage regulation. (15M)** BTL5 **Answer: Page 2.61-Dr.C. Ramesh babu durai.** **1. Write the give parameters given. (3M)** **2. Calculate Iw, Iµ. (3M)** Iw= Io cosɵ Iµ =Io sinɵ **3. Calculate Ro, Xo. (3M)** Ro = V1/Iw Xo= V1/ Iµ **4. Calculate Ro2, Xo2. (3M)** Ro2= Wcu/Isc Xo2=Wsc/I^2sc **Equivalent circuit diagram.(3M)**

UNIT-III DC MACHINES	
Introduction - Constructional Features- Motoring and generation principle - Emf And Torque equation- Circuit Model - Methods of Excitation and magnetisation characteristics - Starting and Speed Control- Universal Motor	
PART * A	
Q.No.	**Questions**
1.	**Describe the working principle of operation of a DC generator.** BTL2 According to Faraday's laws of electromagnetic induction, whenever a conductor is placed in a varying magnetic field (Or a conductor is moved in a magnetic field), an emf (electromotive force) gets induced in the conductor. The magnitude of induced emf can be calculated from the emf equation of dc generator.
2.	**How universal motor is different from DC motor?** (April/May 2019) BTL1 There is no difference. A universal motor has its rotor and stator windings connected in series, and it can run on both AC and DC, that is why it's called universal, or sometimes a DC series motor. It is mostly used in home appliances, electric tools and so on. Because it has a high speed.
3.	**Classify the different types of DC generators.** (April/May 2019) BTL 3

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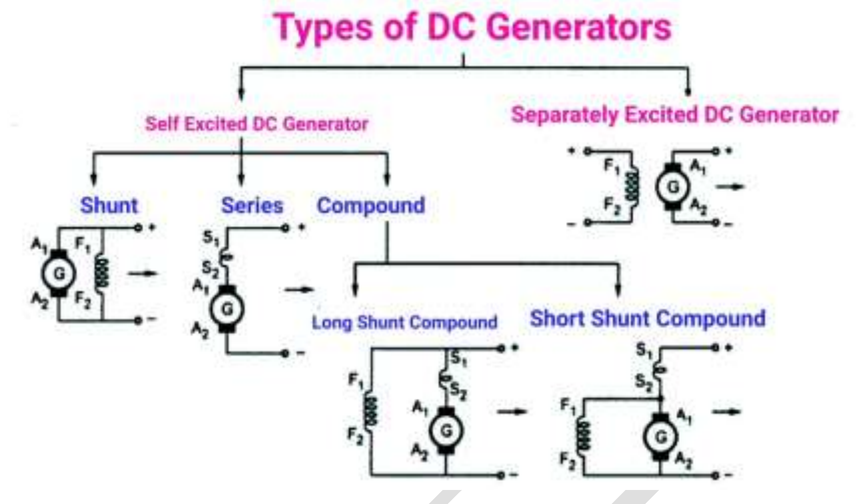
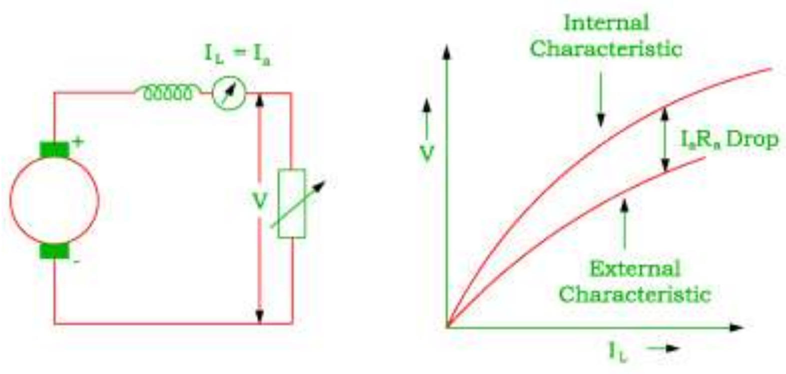
<tr><td></td><td>
</td></tr>
<tr><td>4.</td><td>Sketch the internal and external characteristics of a DC series generator. BTL 3


FIG D : LOAD CHARACTERISTIC OF DC SERIES GENERATOR</td></tr>
<tr><td>5.</td><td>Give the function of commutator in a DC machine. (April/May 2018) BTL 2
The main role of a commutator in a dc motor is to reverse the direction of armature current, in the brush zones, so that the torque will always be unidirectional. In case of dc generator, it is used as a rectifier to convert armature current in dc form.</td></tr>
<tr><td>6.</td><td>What is the function of interpoles? BTL 1
Interpoles are similar to the main field poles and located on the yoke between the main field poles. They have windings in series with the armature winding. Interpoles have the function of reducing the armature reaction effect in the commutating zone. They eliminate the need to shift the brush assembly.</td></tr>
<tr><td>7.</td><td>What is meant by armature reaction in dc machines? BTL4</td></tr>
</table>

	The armature reaction simply shows the effect of armature field on the main field. In other words, the armature reaction represents the impact of the armature flux on the main field flux. The armature field is produced by the armature conductors when current flows through them. And the main field is produced by the magnetic poles.
8.	**Write the conditions which determines if a DC machine is generating or Motoring**. BTL6 1. When supply given to the armature coil then the DC machine acts as a DC motor. 2. When supply is taken from the armature coil then the system is DC generator.
9.	**Write the induced EMF equation when the machine act as DC motor and DC generator.** (April/May 2018) BTL 6 1. When supply given to the armature coil then the DC machine acts as a DC motor. The EMF equation will be equal to back emf. **Eb = PΦNZ / 60A.** 2. When supply is taken from the armature coil then the system is DC generator. The EMF equation will be equal to generated EMF. **Eg = PΦNZ / 60A**
10.	**The starting current of a dc motor is high. Justify.**BTL5 Starting current is high in Dc motor because at the starting time of Dc motor there is not any residual back emf. The armature has very less resistance due to this it need more current at starting time. Hence DC starters are used to limit the starting current of motor.
11.	**The starting torque of a dc series motor more than that of a dc shunt motor of same power rating. Justify.**BTL5 For any dc motor, torque is directly proportional to the flux and armature current. ... Hence torque is directly proportional to the square of armature current. So as current during starting is 1.5 times the rated so starting torque is higher for series motor.
12.	**Analyse on how can the direction of rotation of a DC shunt motor be reversed?** BTL4 The direction of rotation of a DC shunt motor can be reversed by changing the polarity of either the armature coil or the field coil. It can be reversed by simply reversing the armature leads. The same can be done with a shunt motor and a compound motor.
13.	**How can a universal motor be reversed?** BTL1 1. The direction of rotation of a universal motor can be changed by either: (i) Reversing the field connection with respect to those of armature; or (ii) By using two field windings wound on the core in opposite directions so that the one connected in series with armature gives clockwise rotation, while the other in series with the armature gives counterclockwise rotation. 2. The second method, i.e, the two field method is used in applications such as motor operated rheostats and servo systems. This method has somewhat simpler connections than the first method.
14.	**How hysteresis and eddy current losses are minimized?** BTL1

	Hysteresis loss: It can be reduced by using material having least hysteresis loop area. Hence silicon steel or high-grade steel is used for manufacturing of transformer core as it is having very less hysteresis loop area. **Eddy current loss:** 1. In order to reduce the eddy current loss, the resistance of the core should be increased. 2. In devices like transformers, the core is made up of thin sheets of steel, each lamination being insulated from others by a thin layer of varnish. 3. As the laminations are thin, they will have relatively high resistance.
15.	**State any two application of Universal motor**. BTL1 Universal motors have high starting torque, can run at high speed, and are **lightweight** and compact. They are commonly used in **portable** power tools and equipment, as well as many household appliances. They're also relatively easy to control, electromechanically using tapped coils, or electronically.
16.	**What is the significance of back E.M.F. in a DC Motor**? BTL1 1. The presence of back emf makes the d.c. motor a self-regulating machine i.e., it makes the motor to draw as much armature current as is just sufficient to develop the torque required by the load. **2.** therefore, the back emf in a DC motor regulates the flow of armature current i.e., it automatically changes the armature current to meet the load requirement.
17.	**Write the speed equation and List the various methods of speed control in DC series motor.** BTL1 • By varying the supply voltage-voltage control method. • By varying the flux, and by varying the current through field winding- flux control method. • By varying the armature voltage, and by varying the armature resistance-Armature control method.
18.	**Give the necessity of a starter for a dc motor**. BTL2 Starters are used to protect DC motors from damage that can be caused by very high current and torque during startup. They do this by providing external resistance to the motor, which is connected in series to the motor's armature winding and restricts the current to an acceptable level.
19.	**Compare field and armature control methods.** BTL3

	Field controlled DC servomotor	Armature controlled DC servomotor
1.	Field is excited by control voltage	Armature is excited by control voltage
2.	Armature current kept constant	Field current kept constant
3.	Required low power amplifiers are simple to design	Required high power amplifiers
4.	Efficiency is poor	Efficiency is better
5.	It has large time constant	It has small time constant
6.	Cost is low	Cost is high
7.	It is open loop system	It is close loop system

20. **Point out the applications of DC series and shunt motors**. BTL4

d.c. shunt motor	lathes,fans,pumps disc and band saw drive requiring moderate torques.
d.c. series motor	Electric traction, high speed tools
d.c. compound motor	Rolling mills and other loads requiring large momentary toques.

PART * B

1. **Draw and explain the construction and principle of operation of a DC generator (13M)** (April/May 2019) BTL5

Answer: Page 3.3-Dr.C. Ramesh babu durai.

1. Dc generator- principle (3M)

2. Diagram (2M)

3. Construction details:

	4. Stator (4M) • Yoke, • field system -poles, • pole • field winding **5. Rotor(4M)** • Armature, • commutator, • brushes, • bearing
2.	**Explain the armature reaction in a DC generator on no load and on load conditions. Also, briefly explain the methods to overcome the adverse effects of the armature reaction. (13M)** BTL2 **Answer: Refer notes.** **1.** Definition of armature reaction: (3M) **2.** Diagram(2M) **3.** causes of armature reaction(2M) **4.** condition on no load and full load. (4M) **5.** methods to overcome armature reaction (2M)
3.	**Draw and describe the different types of D.C. generators with its winding diagram. (13M)** BTL1 **Answer: Page 3.14-Dr.C. Ramesh babu durai.** **1. Definition of field excitation. (1M)** **2. Types of DC generators (5M)** • Separately excited generator. • Self-excited generator. **3. Self-excited and types (7M)** • Series generator • Shunt generator • Compound generator • Long shunt compound generator • Short shunt compound generator**.**
4.	**i)Derive the emf equation of DC generator. (8M)** BTL6 **Answer: Page 3.13-Dr.C. Ramesh babu durai**

	1. Parameter explanation (4M) **2.** Emf per parallel-path(2M) **3.** Generated emf equation(2M) **ii) The armature of a 4-pole wave wound D.C. shunt generator has 144 slots and 3 conductors per slot. If the armature in rotated with a speed of 1200 rpm in a field of 0.025 weber per pole, Estimate the emf generated**. **(5M)** BTL2 **Answer: Page 3.13-Dr.C. Ramesh babu durai** **1.** Emf generated Eg = θPNZ/60A……(3M) **2.** P=4; N=1200 rpm; θ=0.025 Wb……(2M)
5.	**(i) Discuss in detail about armature reaction. (7M)** BTL 2 **1.** Definition of armature reaction: (3M) **2.** Diagram(2M) **3.** Causes and effects of armature reaction(2M) **(ii) Sketch the characteristics of a DC shunt generator. (6M)** BTL 3 **Answer: Page 3.25-Dr.C. Ramesh babu durai** **1. Circuit diagram..** (2M) **2. Open circuit test (OCC)** (2M) **3. Load characteristics** • Internal characteristics (1M) • External characteristics. (1M)
6.	**i)calculate the flux per pole required for a 4-pole generator with 360 conductors generating 250V at 1000 rpm. When the armature is** **i)Lap connected** **ii)wave connected** **(7M)** BTL5 **Answer: Page 3.70-Dr.C. Ramesh babu durai** **1. armature connected in lap:……(4M)** Eg = θPNZ/60A. = 41.67 mWb. **2. armature is wave connected :……(3M)** Eg = θPNZ/60A. = 20.83 mWb.

	ii) a 8 pole DC shunt generator with 778 wave connected armature conductors and running at 500 rpm. supplying a load of 12.5 ohm resistance at terminal voltage of 250 V. The armature resistance is 0.24ohm and the field resistance is 250ohm.find the armature current, induced emf, flux per pole. **(6M)** BTL3 **Answer: Page 3.70-Dr.C. Ramesh babu durai** **Load current:**$I_L= V/R_L$**:……(1M)** **Shunt field current,**$I_{sh}=V/R_{sh}$**:……(1M)** **Armature current** $Ia= I_L+I_{sh}$. **:……(1M)** **Induced emf** $E_g=V+IaRa$**:……(1M)** **Flux=**(Eg*60*A)/ZNP. **:……(2M)**
7.	**Explain with a neat sketch the principle of operation of a dc motor. (13M)** (April/May 2018) BTL4 **Answer: Page 3.70-Dr.C. Ramesh babu durai** **1.** Definition of DC motor. (2M) **2.** Fleming's left had rule. (3M) **3.** Interaction of two fluxes (3M) **4.** Force experienced by the conductors(2M) **5.** Direction of rotation of conductors(2M)
9.	**Using step by step approach, develop a mathematical expression for torque developed in DC machine**. **(13M)** BTL6 **Answer: Page 3.44-Dr.C. Ramesh babu durai** **1.** Definition of torque (3M) **2.** Armature torque of a motor(5M) **3.** Shaft torque(5M)
	PART * C
1.	**i)Draw a neat diagram showing the salient parts of a DC motor. Explain the function of each in detail**. BTL3 **(10M)** **Answer: refer notes.** **1. Dc motor- principle (3M)** **2. Definition (2M)** **3. Diagram (2M)**

	4. Construction details: **5. Stator (4M)** • Yoke, • field system -poles, • pole • field winding **6. Rotor (4M)** • Armature, • commutator, • brushes, • bearing
2.	**With a neat sketch explain the operation of 4-point starter. What are the advantages of this starter over 3-point starter? (15M)** BTL3 **Answer: Page 3.59-Dr.C. Ramesh babu durai** **1. definition (2M)** **2.diagram (4M)** **3. construction (3M)** **4.operation (3M)** **5. advantages of 4-point starter with respect to 3-point starter (3M)**

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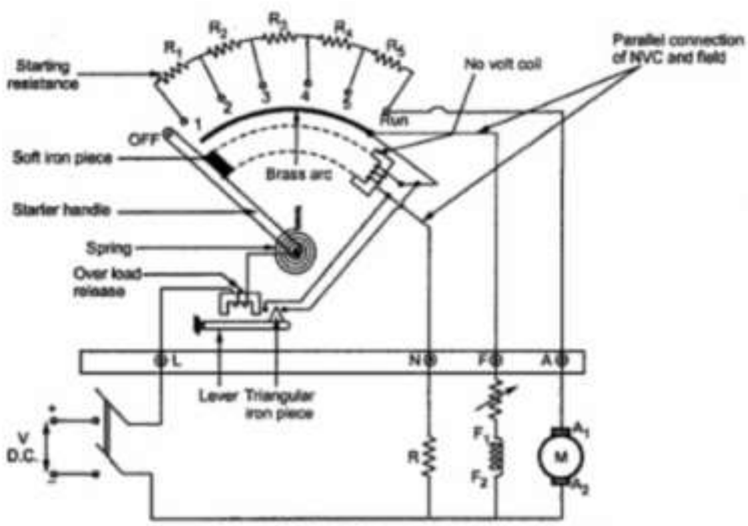

Four Point Starter
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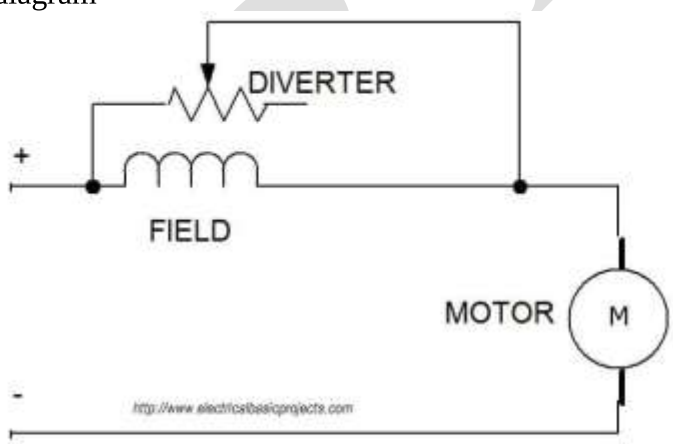
<tr>
<td>3.</td>
<td>
Explain the speed control of a DC series motor by
i) Field diverters method
ii) Variable resistance in series with the motor. (15M) (April/May 2018) (April/May 2019) BTL3

Answer: Page 3.65-Dr.C. Ramesh babu durai

1. definition of flux control(2M)

2. types of flux control methods. (2M)

3. field divertors method(6M)

• diagram


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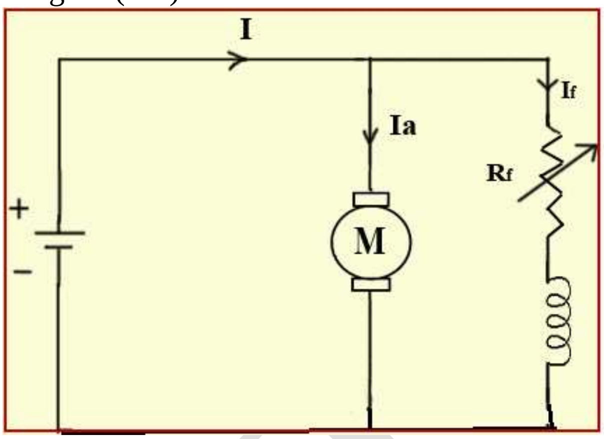
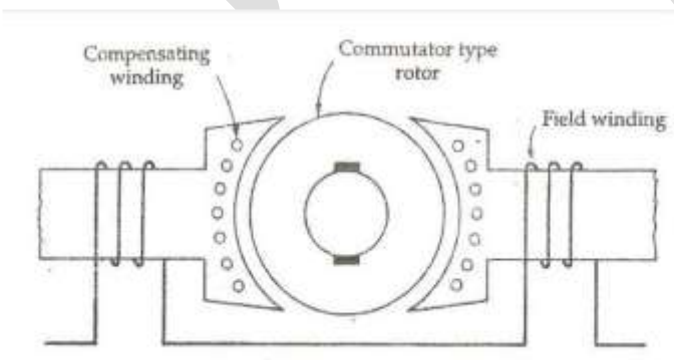
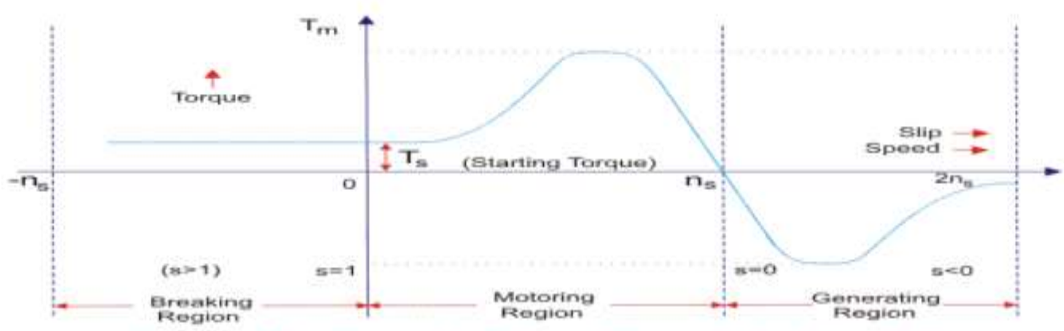
	• explanation 4.variale resistance in series. • Diagram(2M)  • explanation(3M)
4.	**Explain the construction, working principle, characteristics and applications of Universal motor with relevant diagrams** (**15M**) BTL 5 **Answer: Page 4.61-Dr.C. Ramesh babu durai** **1. universal motor-principle(2M)** **2. diagram(2M)**  **3. construction (3M)** **4.operation (3M)** **5. characteristics (3M)** **6.applications. (2M)**

UNIT IV AC MACHINES

Principle of operation of three-phase induction motors – Construction –Types – Equivalent circuit, Single phase Induction motors -Construction– Types–starting and speed control methods. Alternator- working principle–Equation of induced EMF – Voltage regulation, Synchronous motors- working principle-starting methods -– Torque equation – Stepper Motors – Brushless DC Motors.

PART * A

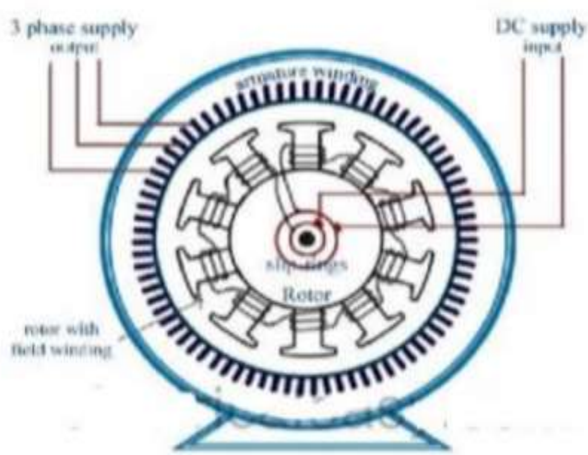
Q.No.	Questions
1.	**Give the advantages and disadvantages of three phase induction motor**. (April/May 2018) BTL 2 **Advantage of an induction motor:** 1. The most important **advantage of an induction motor** is that its construction is quite simple in nature. 2. Due to the absence of Brushes, there are no sparks in the motor. It can also be operated in hazardous conditions. 3. Unlike synchronous motors, a 3 phase induction motor has a high starting torque, good speed regulation and reasonable overload capacity. **4.** An induction motor is a highly efficient machine with full load efficiency varying from 85 to 97 percent. **Disadvantage of an induction motor:** **(1) Squirrel cage induction motor:** 1. Starting torque is not big, it's difficult to meet the needs of starting with a load. 2. High torque is small, often used to drive short-term load of overload, such as crusher mining used, they often stall, thus resulting in motor burning. 3. Starting current is large, increasing the capacity required of supply transformer. **(2) Wound-rotor induction motor** 1. Because of collector ring and brush on the rotor, not only increasing manufacturing costs, but also reducing the reliability of starting and running, sliding contact between the ring and brush is the main reason for such a motor failure.

	2. In order to improve reliability, current conventional winding motors don't to mention brush, so there is energy wasting. 3. Starting torque has increased, comparing conventional winding induction motor with cage induction motor, but still often cannot meet the needs of full start.
2.	**Define the term slip of an 3-phase induction motor.** BTL1 Slip can be defined as the difference between the flux speed (Ns) and the rotor speed (N). SLIP is the difference between the synchronous speed of the magnetic field and the shaft rotating speed and would be some number of RPM or frequency. The slip increases with an increasing load, thus providing a greater torque.
3.	**Draw the slip-torque characteristics of a three-phase induction motor.** BTL3  Torque Slip Curve for Three Phase Induction Motor
4.	**State condition at which starting torque developed in a 3 phase induction motor is maximum.** BTL1 To develop maximum torque at the standstill condition, the rotor resistance must be high and should be equal to X_{20}. But to develop a torque which is maximum at the running condition the rotor resistance must be low.
5.	**Name the test conducted for obtaining the equivalent circuit parameters of 3phase induction motor.** BTL1 No-load and locked rotor test are used to obtain the equivalent circuit parameters of 3phase induction motor.
6.	**List the methods available to control the speed and various starters used for starting a of an induction motor.** BTL1 (April/May 2019)

	Speed of a 3 Phase Induction motor can be controlled by these methods: 1. Stator Voltage control. 2. Rotor resistance control. 3. By changing Pole. 4. Supply Frequency control. **Starters:** 1. D.O.L 2. Star delta stater 3. Auto transformer 4. Soft starters 5. Resistance starter 6. Slip ring motor starting 7. VFD
8.	**Why an induction motor will never run at its synchronous speed?** BTL1 An induction motor always runs at a speed less than synchronous speed because the rotating magnetic field which is produced in the stator will generate flux in the rotor which will make the rotor to rotate, but due to the lagging of flux current in the rotor with flux current in the stator, the rotor will never reach to its rotating magnetic field speed i.e. the synchronous speed.
9.	**Why a single-phase induction motor is not self-starting?** BTL1 In case of single phase motors we have only one winding .Due to which we have a pulsating magnetic field which first increases to maximum value than become zero after that increase in negative cycle to maximum then become Zero .It becomes zero twice in a cycle ,so net torque produced is zero .hence single phase IM are not self-started.
10.	**Compare Brushless DC motor and Stepper motor**. BTL4 The output current can be taken directly from fixed terminals on the stationary armature without using slip rings,brushes,etc.
11.	**What are the principal advantages of rotating field type construction in alternators?** BTL2 1. A stationary armature is more easily insulated for the high voltage for which the alternator is designed.This generated voltage may be as high as 33 kV. 2. The armature windings can be braced better mechanically against high electromagnetic forces due to large short-circuit currents when the armature windings are in the stator. 3. The armature windings, being stationary,are not subjected to vibration and centrifugal forces.

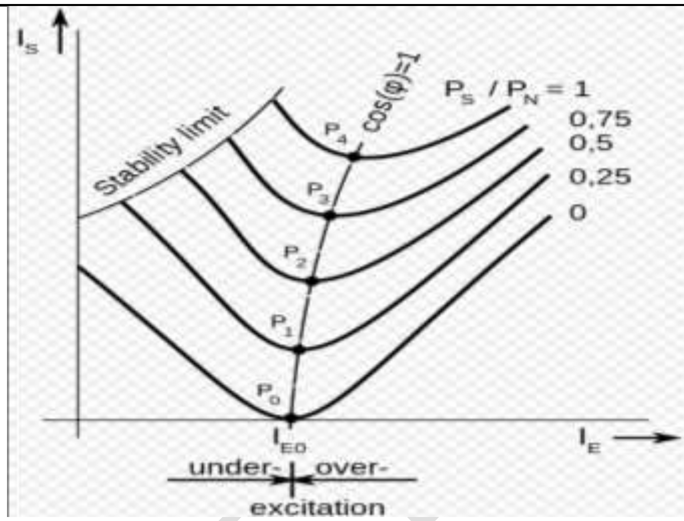
	4. The output current can be taken directly from fixed terminals on the stationary armature without using slip rings,brushes,etc. 5. The rotating field is supplied with direct current.Usually the field voltage is between 100 to 500 volts.
12.	**Classify the different types of alternators and single-Phase induction motor.** BTL3 **Types of alternators:** Alternators can be classified as below Based on rotor 1. Salient pole type 2. Smooth cylindrical type Based on output power 1. Single Phase 2. Three Phase Based on the working principle 1. Revolving armature type 2. Revolving field type Based on the speed on rotation 1. Turbo alternator 2. Low speed alternator Based on coiling 1. Air cooling 2. Hydrogen cooling **Types of single-Phase induction motor:** 1. Split phase induction motor. 2. Capacitor start inductor motor. 3. Capacitor start capacitor run induction motor (two value capacitor method). 4. Permanent split capacitor (PSC) motor . 5. Shaded pole induction motor.
13.	**Write the essential elements for generating EMF in alternators**. BTL6 1. Prime movers 2. Stator 3. rotor 4. exciter.

14.	**What is hunting in a synchronous machine?** BTL3 The phenomenon of oscillation of the rotor about its final equilibrium position is called Hunting. The Hunting process occurs in a synchronous motor as well as in synchronous generators if an abrupt change in load occurs. The steady state or stable operation of a synchronous motor is a condition of equilibrium.
15.	**Write the purpose of damper winding.** BTL6 The primary function of damper winding in a synchronous machine is to prevent the phenomenon called hunting. It acts as a squirrel cage winding and makes the synchronous motor self- starting. The motor starts as an induction motor and approaches near synchronous speed.
16.	**What is synchronous condenser?** BTL5 A synchronous condenser (sometimes called a synchronous capacitor or synchronous compensator) is a DC-excited synchronous motor, whose shaft is not connected to anything but spins freely. Its purpose is not to convert electric power to mechanical power or vice versa, but to adjust conditions on the electric power transmission grid. Its field is controlled by a voltage regulator to either generate or absorb reactive power as needed to adjust the grid's voltage, or to improve power factor.
17.	**Why a synchronous motor is not a self-starting machine?** BTL4 This is because the speed with which rotating magnetic field is rotating is so high that it is unable to rotate the rotor from its initial position, due to the inertia of the rotor. So under any case, whatever may be the starting position of the rotor, synchronous motor is not self-starting.
18.	**Give the various torques associated with synchronous motors.** BTL2 starting torque running torque pull-in torque and pull-out torque
19.	**Alternators rated in kVA and not in kW.** BTL5 There is a component of power used, which is called reactive power, which does not do any work. It is essentially the energy expended by the motor. This reactive component has to be accounted for when we calculate the energy required. This total energy is expressed in KVA.

20.	**Analyse the different methods used to start a synchronous motor.** (April/May 2018) (April/May 2019) BTL4 The various methods to start the synchronous motor are 1. Using pony motors 2. Using damper winding 3. As a slip ring induction motor 4. Using small DC machine coupled to it.
	PART * B	
1.	**(i) Draw and explain the constructional details and operating principles of an alternator. (13M).** (April/May 2019) BTL4 **Answer: Page 4.35- Nagoor Kani**  **…..(3M)** Main parts of the alternator, obviously, consists of stator and rotor. But, the unlike othermachines, in most of the alternators, field exciters are rotating and the armature coil is stationary…..4M Stator:……6M

		Unlike in DC machine stator of an alternator is not meant to serve path for magnetic flux. Instead, the stator is used for holding armature winding. The stator core is made up of lamination of steel alloys or magnetic iron, to minimize the eddy current losses.
	2.	**(i) Derive and show the emf equation of a 3ϕ alternator. (13M)** (April/May 2019) BTL3 **Answer: Page 4.38-Nagoor kani** Let Φ = Flux per pole, in Wb P = Number of poles Ns = Synchronous speed in r.p.m. f = Frequency of induced e.m.f. in Hz Assume full pitch winding for simplicity i.e. this conductor is connected to a conductor which is 180 deg electrical apart. So there two e.m.f.s will try to set up a current in the same direction i.e. the two e.m.f. are helping each other and hence resultant e.m.f. per turn will be twice the e.m.f. induced in a conductor…………5M E.m.f. per turn = 2 x (e.m.f. per conductor)= 2 x (2 f Φ)= 4 f Φ volts Let Tph be the total number of turn per phase connected in series. Assuming concentrated winding, we can say that all are placed in single slot per pole per phase. So induced e.m.f.s in all turns will be in phase as placed in single slot. Hence net e.m.f. per phase will be algebraic sum of the e.m.f.s per turn. Average Eph = Tph x (Average e.m.f. per turn) Average Eph = Tph x 4 f Φ……4M But in a.c. circuits R.M.S. value of an alternating quantity is used for the analysis. The form factor is 1.11 of sinusoidal e.m.f. Kf = (R.M.S.)/Average=1.11

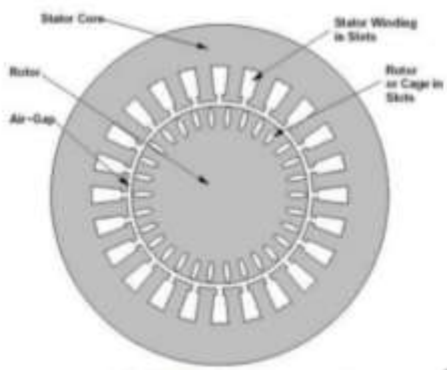
	R.M.S. value of Eph = K x Average value **E = 4.44 x f Φ Tph Volt…..4M**
3.	**Draw and explain the principle of operation of a synchronous motor**. **(13M)** BTL4 **Answer: Page 4.42-Nagoor Kani** • Synchronous motor is a doubly excited machine i.e two electrical inputs are provided to it. • Its stator winding which consists of a 3 phase winding is provided with 3 phase supply and rotor is provided with DC supply. • The 3 phase stator winding carrying 3 phase currents produces 3 phase rotating magnetic flux. The roto r carrying DC supply also produces a constant f lux. • Considering the frequency to be 50 Hz, fro m the above relation we can see that the 3 phase…….5M • rotating flux rotates about 3000 revolution in 1 min or 50 revolutions in 1 sec. • At a particular instant rotor and stator poles might be of same polarity (N-N or S-S) causing repulsive force on rotor and the very next second it will be N-S causing attractive force. ……….3M • But due to inertia of the rotor, it is unable to rotate in any direction due to attractive or repulsive force and remain in standstill condition. Hence it is not self starting……4M
4.	**Discuss ‘V’ and inverted ‘V’ curve of a synchronous motor. (13M)** BTL2 **Answer: Page 4.16-Nagoor kani** In general, over excitation will cause the synchronous motor to operate at a leading power factor, while under excitation will cause the motor to operate at a lagging power factor. The synchronous motor thus possesses a variable-power factor characteristic……9M



….4M

5. **Draw and explain the construction and principle of operation of three phase slip ring induction motor. How is the construction different in squirrel cage induction motor? (13M)** (April/May 2018) BTL3

Answer Page.5.61-Nagoor kani



……4M

- A wound rotor has three phase winding similar to the stator winding.
- The rotor winding terminals are connected to three slip rings which turn with the rotor.
- The slip rings/brushes allow external resistors to be connected in series with the winding.
- The external resistors are mainly used during start up. Under normal running conditions the windings short circuited externally……..4M

Working…………..5M

- Induction motor works on the principle of Faraday's laws of electromagnetic induction.
- When the three supply is given to the stator of an induction motor, rotating magnetic field is produced around the stator.
- This field cuts the rotor conductors; an emf is produced as per Faraday's laws of electromagnetic induction.
- The induced voltage produces currents which circulate in a loop around the conductors.
- Since the current carrying conductors lie in the magnetic field, they experience mechanical force (Torque).
- The force is always acts in a direction to drag the conductor along with the magnetic field.

PART * C

1. **Compare squirrel cage induction motor and slipring induction motor. (15M)** BTL4
Answer Page.5.61-Nagoor kani

Basis For Comparison	Slip Ring Motor	Squirrel Cage motor
Definition	The rotor of the motor is constructed as a slip ring type.	The rotor of the motor is a squirrel cage type.
Rotor	Cylindrical laminated core with parallel slots and each slot consist one bar.	The slots of the rotor are not parallel, but are skewed.
Other name	Phase wound rotor	Cage motor
Construction	Complicated	Simple
Resistance	Added external to the rotor	The rotor bar is permanently shorted at the end of the ring, thus it is not possible to add any external resistance.
Starter	The rotor resistance starter can be used.	Rotor resistance starter can not be used.

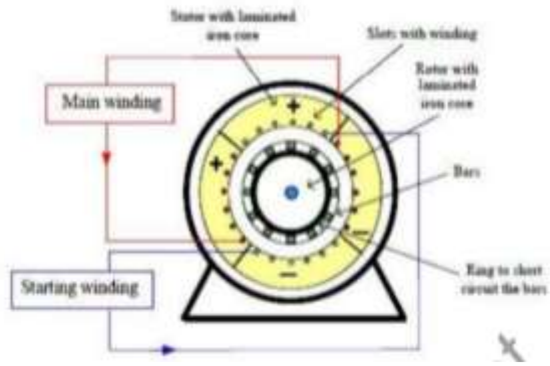
Starting Torque	High	Low
Brushes	Present	Absent
Maintenance	Frequent maintenance required	Less maintenance required
Copper Loss	High	Low
Efficiency	Low	High
Speed Control	Possible	Not Possible
Power Factor	Low	High
Cost	Costly	Cheap
Starting Current	Low	High
Uses	Use in hoist, cranes, elevator where high torque is required.	Use in lathe machines, fan, blower, profiting machines, etc.

2. **Describe the construction, working principle and applications of single-phase induction motor with neat diagrams.** BTL1 **(15M)**

Answer: Page 5.55- Nagoor kani

Stator of Single Phase In duction Motor……..6M

- The single-phase motor stator has a laminated iron core with two windings arranged perpendicularly. One is the main and other is the auxiliary winding or starting winding.



…..3M

Rotor of Single Phase Induction Motor…………6M

- The rotor of single phase induction motor is shown in figure .
- The construction of the rotor of the single phase induction motor is similar to the squirrel cage three phase inductions motor.
- The rotor is cylindrical in shape and has slots all over its periphery.
- The slots are not made parallel to each other but are bit skewed as the skewing prevents magnetic locking of stator and rotor teeth and makes the working of induction motor more smooth and quieter.
- The squirrel cage rotor consists of aluminium, brass or copper bars. These aluminium or copper bars are called rotor conductors and are placed in the slots on the periphery of the rotor.

3

With neat sketches, using the double field revolving field theory, explain why a single-phase induction motor is not self-starting. (15M) BTL5

Answer: Page 5.28 – Nagoor Kani

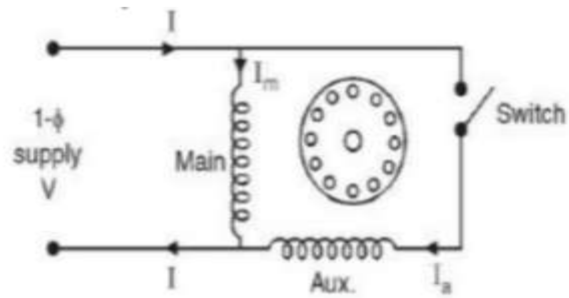
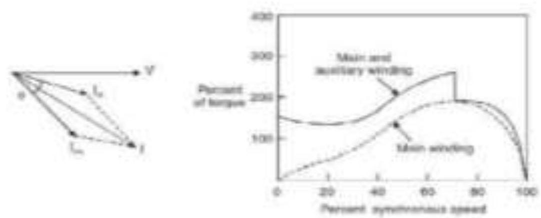
A single-phase ac current supplies the main winding that produces a pulsating magnetic field.

Mathematically, the pulsating field could be divided into two fields, which are rotating in opposite directions.

The interaction between the fields and the current induced in the rotor bars generates opposing torque……………..6M

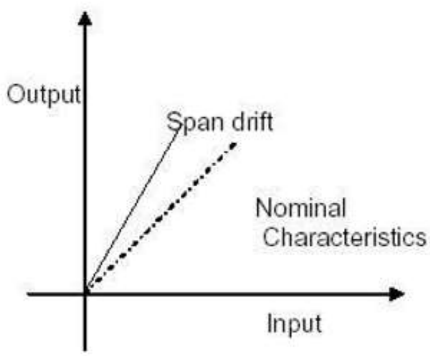
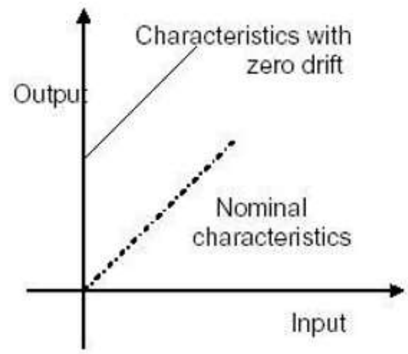
Starting Methods……………….6M

The single-phase IM has no starting torque, but has resultant torque, when it rotates at any other speed, except synchronous speed. It is also known that, in a balanced two-phase IM having two windings, each having equal number of turns and placed at a space angle of 900(electrical), and

	are fed from a balanced two- phase supply, with two voltages equal in magnitude, at an angle of 900, the rotating magnetic fields are produced, as in a three-phase IM. Resistance Split Phase Motor:………3M  

UNIT V MEASUREMENT AND INSTRUMENTATION	
Type of Electrical and electronic instruments – Classification- Types of indicating Instruments – Principles of Electrical Instruments –Multimeters, Oscilloscopes- Static and Dynamic Characteristics of Measurement – Errors in Measurement – Transducers - Classification of Transducers: Resistive, Inductive, Capacitive,Thermoelectric, piezoelectric, photoelectric, Hall effect and Mechanical.	
PART * A	
Q.No.	**Questions**
1.	**Define 'error' in measurement**. (April/May 2018) BTL 2 The measurement error is defined as the difference between the true or actual value and the measured value. The true value is the average of the infinite number of measurements, and the measured value is the precise value**.**
2.	**What is a transducer?** BTL1 (April/May 2019) 1. A transducer is a device that converts energy from one form to another. Usually a transducer converts a signal in one form of energy to a signal in another. 2. Transducers are often employed at the boundaries of automation, measurement, and control systems, where electrical signals are converted to and from other

	physical quantities (energy, force, torque, light, motion, position, etc.). The process of converting one form of energy to another is known as transduction.
3.	**What is piezoelectric effect?** BTL3 **Piezoelectric Principle**. Crystalline materials produce small amounts of electricity when a force is applied that changes their shape in some way. When small amounts of pressure are applied to a quartz crystal, a small voltage is produced from the changing charge created by the moving electrons.
4.	**What are the basic elements of a generalised measurement system?** BTL1 • Primary Sensing Element • Variable Conversion Element • Variable Manipulation Element • Data Processing Element • Data Transmission System • Data Presentation Element
5.	**List any four static characteristics of a measuring system.** BTL1 1. Accuracy 2. Precision 3. Sensitivity 4. Linearity 5. Reproducibility 6. Repeatability 7. Resolution Threshold Drift Stability Tolerance Range or span
6.	**Define the term 'accuracy'.**BTL1 Accuracy is the ability of the instrument to measure the accurate value. In other words, it is the closeness of the measured value to a standard or true value. The accuracy can be obtained by taking the small readings. The small reading reduces the error of the calculation.
7.	**Define the term 'precision'.**BTL2 The reproducibility of the measurement. For example, measure a steady state signal many times. In this case if the values are close together then it has a high degree of precision or repeatability. The values do not have to be the true values just grouped together. Take the average of the measurements and the difference is between it and the true value is accuracy.
8.	**Differentiate zero drift and span drift.** BTL1 **Zero drift:** If the whole calibration gradually shifts due to slippage, permanent set, or due to

	undue warming up of electronic tube circuits, zero drift sets in.  **(Fig) span drift**  **(fig) zero drif** **b) span drift or sensitivity drift** If there is proportional change in the indication all along the upward scale, the drifts is called span drift or sensitivity drift.
9.	**What is measurement and how it is classified?** (April/May 2018) BTL1 1. A unit of measurement is a definite magnitude of a quantity, defined and adopted by convention or by law, that is used as a standard for measurement of the same quantity. Any other value of that quantity can be expressed as a simple multiple of the unit of measurement. For example, length is a physical quantity. 2. Systems of Measurement: there are two main systems of measurement in the world: the Metric (or decimal) system and the US standard system. In each system, there are different units for measuring things like volume and mass.
10.	**Mention the basic requirements of measuring instruments.** BTL4 1. To ensure that the entire collection of measuring instruments of the same type have the required accuracy and to ensure that they are uniform and interchangeable. 2. To make sure that it is possible to evaluate the instrumental measurement errors according to established standards for metrological properties of measuring instruments. 3. To ensure that measuring instruments can be compared with one another according to accuracy.

11.	**What is meant by dynamic characteristics of instruments?** BTL2 **Dynamic characteristics:** The set of criteria defined for the instruments, which are changes rapidly with time, is called dynamic characteristics. The various static characteristics are: i) Speed of response. ii) Measuring lag. iii) Fidelity. iv) Dynamic error.
12.	**Distinguish between active and passive transducer**. BTL3

parameters	**Active Transducer**	**Passive Transducer**
definition	The transducer which generate the output in the form of voltage or current, without any external energy source is known as active transducer.	The passive transducer means the transducer whose internal parameters like capacitance, resistance & inductance changes because of the input signal.
Working Principle	Draw energy from the measurand source.	Take power from the external source which changes the physical properties of transducer.
Design	Simple	Complicated
Output signal	Produces from the signal to be measured.	Output obtains by receiving the signal from the external power source.
Examples	Tachogenerator, Thermocouple, Photovoltaic cell etc.	Thermistor, Differential transformer, Photomultiplier tube, Photovoltaic cell.

13. **List the factors to be considered for selecting a transducer.** BTL6

These are factors which may influence the selection.

1. Operating principle
2. There are operating principles such as resistive, inductive, capacitive, piezoelectric, photo-voltaic, ionization
3. Sensitivity
4. Operating range
5. Accuracy
6. Cross-sensitivity

	7. Error
14.	**Mention the uses of capacitive transducer**. BTL3 1. The capacitive transducers are used to measure humidity in gases. 2. It is used to measure volume, liquid level, density etc. 3. It is used for measurement of linear and angular displacement.
15.	**Define 'gauge factor' of a strain gauge**. BTL6 Gauge factor (GF) or strain factor of a strain gauge is the ratio of relative change in electrical resistance R, to the mechanical strain ε. The gauge factor is defined as: $$GF = \frac{\frac{\Delta R}{R}}{\varepsilon} = \frac{\frac{\Delta \rho}{\rho}}{\varepsilon} + 1 + 2\nu$$
16.	**What is drift?** BTL5 Drift can be defined (VIM) as a slow change in the response of a gauge. Instruments used as comparators for calibration. Short-term drift can be a problem for comparator measurements. The cause is frequently heat build-up in the instrument during the time of measurement.
17.	**What is a primary sensing element?** BTL2 A primary element is a sensor or detector that responds quantitatively to the measured variable and performs the initial measurement operation. A primary element performs the initial conversion of measurement energy.
18.	**Distinguish between reproducibility and repeatability**. BTL4 (April/May 2019) **Repeatability:** **Definition**: It describes closeness of output readings when the same input is applied repetitively over a short period of time. Following should be kept same during repetitive test/measurement. • measurement conditions • instrument • observer • location • conditions of use. **Reproducibility** **Definition**: It describes closeness of output readings for the same input when there are changes in the method of measurement, observer, measuring instrument, location, conditions of use and time of measurement.

	• Both the terms repeatability and reproducibility describe the spread of output readings for the same input. • The spread is known as repeatability if the measurement conditions are constant and known as reproducibility if the measurement conditions vary.
19.	**Define 'static error'. How are static errors classified?** BTL5 Static error is defined as the difference of the measured value and the true value of the quantity. Mathematically we can write an expression of error as, $dA = A_m - A_t$ where, dA is the static error A_m is measured value and A_t is true value. **Types:** 1. Gross error 2. Systematic error 3. Random error
20.	**Compare analog and digital instruments.** BTL4

ANALOG INSTRUMENT	DIGITAL INSTRUMENT
The instrument which gives output that varies continuously as quantity to be measured is known as analog instrument.	The instrument which gives output that varies in discrete steps and only has finite number of values is known as digital instrument
The accuracy of analog instrument is less.	The accuracy of digital instrument is more.
The analog instruments required more power.	The digital instruments required less power
Sensitivity of analog instrument is more.	Sensitivity of digital instrument is less.
The analog instruments are cheap.	The digital instruments are expensive.

PART * B

1.	**List and define the Static characteristics of an instrument. (13M).** (April/May 2018) BTL1 **Answer: Page 4.35- Nagoor Kani**

	Static characteristics: **1 Range** The range of a sensor indicates the limits between which the input can vary. Thus, for example, a thermocouple for the measurement of temperature might have a range of 25-225°C. **….5M** **2 Span** The span is difference between the maximum and minimum values of the input. Thus, the above-mentioned thermocouple will have a span of 200°C. **3 Error** Error is the difference between the result of the measurement and the true value of the quantity being measured. A sensor might give a displacement reading of 29.8 mm, when the actual displacement had been 30 mm, then the error is - 0.2 mm. **4 Accuracy** The accuracy defines the closeness of the agreement between the actual measurement result and a true value of the measurand. It is often expressed as a percentage of the full range output or full–scale deflection. **5 Sensitivity** Sensitivity of a sensor is defined as the ratio of change in output value of a sensor to the per unit change in input value that causes the output change. For example, a general purpose thermocouple may have a sensitivity of 41 µV/°C. **…..7M**
2.	**i)Explain working principle of strain gauge with neat diagram**. (April/May 2019) **(13M)** BTL1

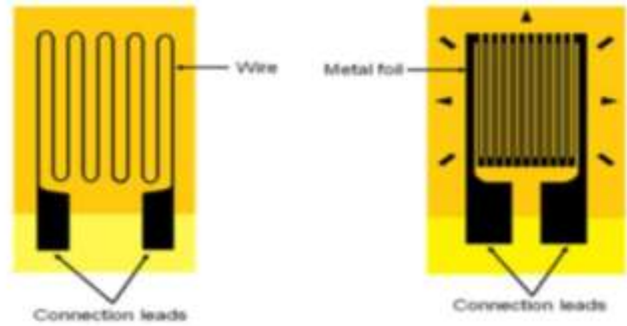
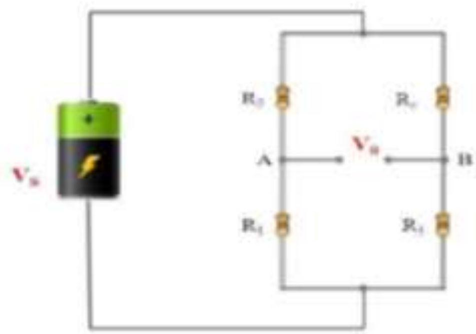


Figure A pattern of resistive foils



……..7M

Applications of strain gauges

Strain gauges are widely used in experimental stress analysis and diagnosis on machines and failure analysis. They are basically used for multi-axial stress fatigue testing, proof testing, residual stress and vibration measurement, torque measurement, bending and deflection measurement, compression and tension measurement and strain measurement.

Strain gauges are primarily used as sensors for machine tools and safety in automotives. In particular, they are employed for force measurement in machine tools, hydraulic or pneumatic press and as impact sensors in aerospace vehicles.

….5M

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Illustrate the working Principle of piezoelectric transducers with neat sketch. (13M) BTL5

Answer: Page 4.14-Nagoor kani

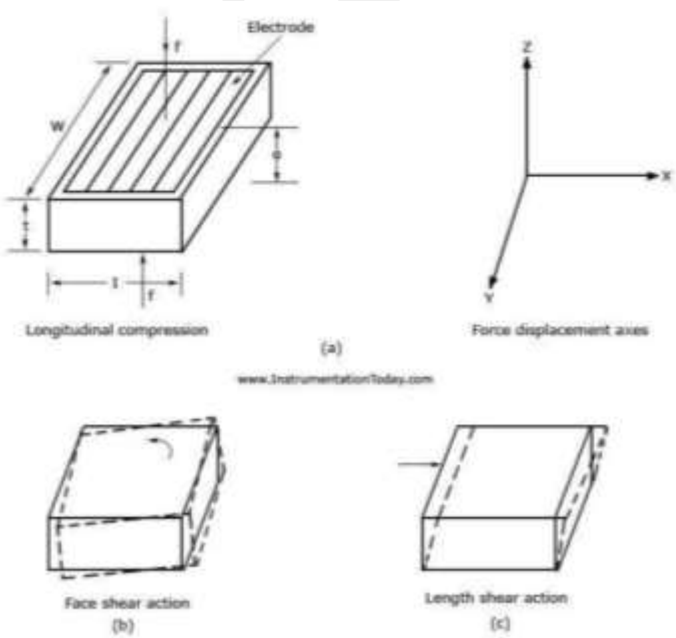
12. Piezo electric transducers

A piezoelectric crystal transducer/sensor is an active sensor and it does not need the help of an external power as it is self-generating.

Piezoelectric Quartz Crystal

A quartz crystal is a piezoelectric material that can generate a voltage proportional to the stress applied upon it. For the application, a natural quartz crystal has to be cut in the shape of a thin plate of rectangular or oval shape of uniform thickness. Each crystal has three sets of axes – Optical axes, three electrical axes OX1, OX2, and OX3 with 120 degree with each other, and three mechanical axes OY1,OY2 and OY3 also at 120 degree with each other. The mechanical axes will be at right angles to the electrical axes.

….6M



Piezoelectric Transducer can measure pressure in the same way a force or an acceleration can be

….7M

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Explain the working principle of LVDT with neat diagram (13M) BTL1

Answer: Page 4.16-Nagoor kani

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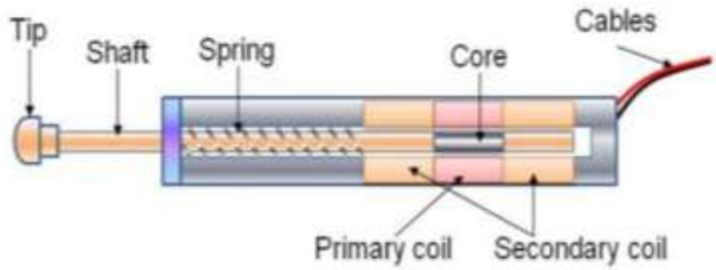
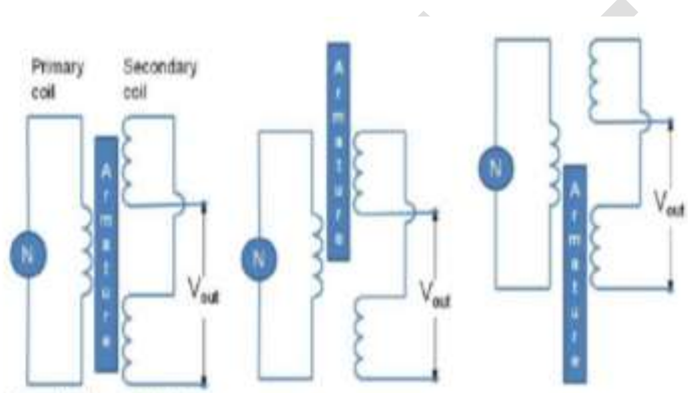
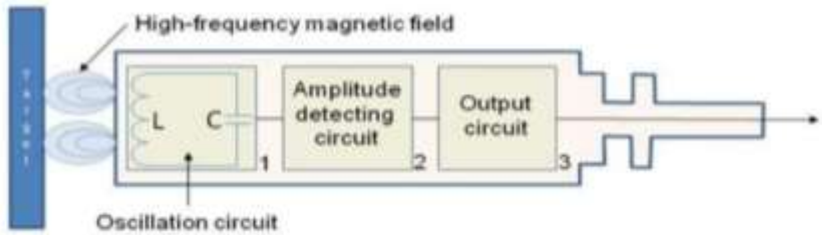
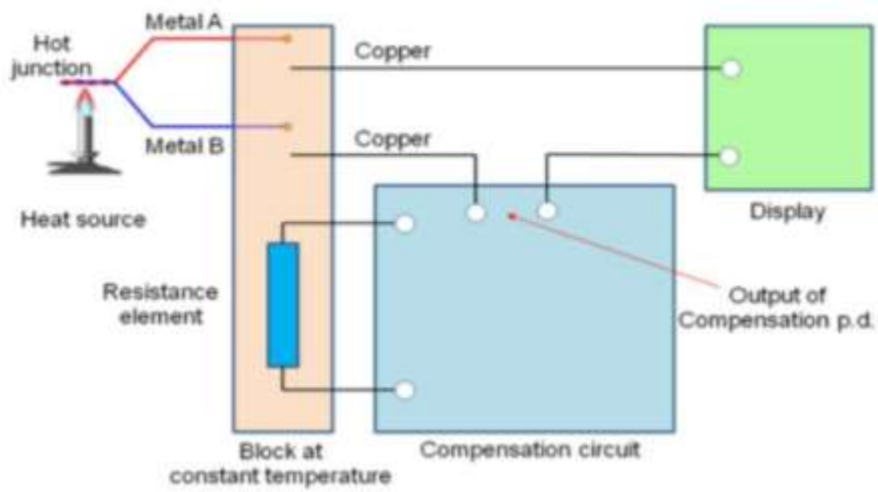
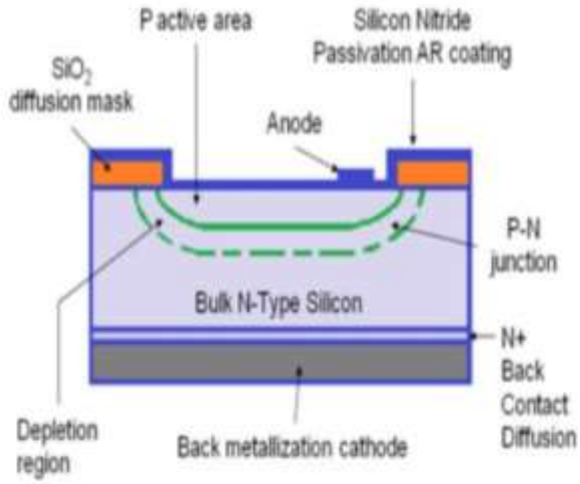
	4. Linear variable differential transformer (LVDT)  Figure Construction of LVDT sensor **…….4M**  Figure Working of LVDT sensor **…….7M**
5.	**Explain the construction and working of Eddy Current Proximity Sensor. (10M)** (April/May 2018) BTL-3 **Answer: Page 5.37-Nagoor kani**

	5. Eddy current proximity sensors  Figure Schematic of Inductive Proximity Sensor Eddy current proximity sensors are used to detect non-magnetic but conductive materials. They comprise of a coil, an oscillator, a detector and a triggering circuit. Figure shows the construction of eddy current proximity switch. When an alternating current is passed thru this coil, an alternative magnetic field is generated. If a metal object comes in the close proximity of the coil, then eddy currents are induced in the object due to the magnetic field. These eddy currents create their own magnetic field which distorts the magnetic field responsible for their generation. As a result, impedance of the coil changes and so the amplitude of alternating current. This can be used to trigger a switch at some pre-determined level of change in current. **….10M**
PART * C	
1.	**Compare the advantage and disadvantages of thermoelectric over electrical Transducers**. **(15M)** BTL3 **Answer Page.5.61-Nagoor kani**

	Thermocouple works on the fact that when a junction of dissimilar metals heated, it produces an electric potential related to temperature. When two wires composed of dissimilar metals are joined at both ends and one of the ends is heated, then there is a continuous current which flows in the thermoelectric circuit. Figure shows the schematic of thermocouple circuit. The net open circuit voltage is a function of junction temperature and composition of two metals. It is given by, $\Delta V_{AB} = \alpha \Delta T$ Where α, the Seebeck coefficient, is the constant of proportionality.  **…10M**
2.	**Sketch and explain the Photo diode transducer principle with an application. (15M)** (April/May 2019) BTL1 **Answer: Page 5.55- Nagoor kani** **Construction…..5M**

	 **Figure Construction of photo diode detector** Figure shows the construction of Photo diode detector. It is constructed from single crystal silicon wafers. It is a p-n junction device. The upper layer is p layer. It is very thin and formed by thermal diffusion or ion implantation of doping material such as boron. Depletion region is narrow and is sandwiched between p layer and bulk n type layer of silicon. Light irradiates at front surface, anode, while the back surface is cathode. The incidence of light on anode generates a flow of electron across the p-n junction which is the measure of light intensity. **……..10M**
3.	**Draw and explain the principal of Hall effect. (15M)** BTL1 **Answer: Page.5.28-Nagoor Kani** **Construction…..5M**

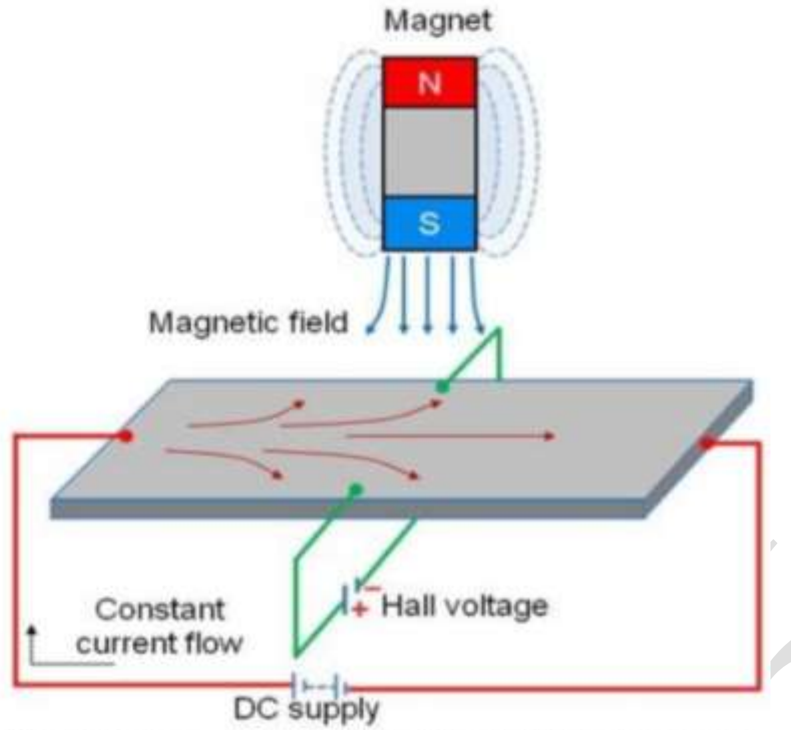


Figure shows the principle of working of Hall effect sensor. **…….10M**

EC8251 **CIRCUIT ANALYSIS** **L T P C**
4 0 0 4

OBJECTIVES:

The student should be made to:

- To introduce the basic concepts of DC & AC circuits behavior
- To study the transient and steady state response of the circuits subjected to step and sinusoidal excitations.
- To introduce different methods of circuit analysis using Network theorems , duality and topology.
-

UNIT I BASIC CIRCUITS ANALYSIS AND NETWORK TOPOLOGY 12

Ohm's Law – Kirchhoff's laws – Mesh current and node voltage method of analysis for D.C and A.C.circuits - Network terminology - Graph of a network - Incidence and reduced incidence matrices – Trees –Cut sets - Fundamental cut sets - Cut set matrix – Tie sets - Link currents and Tie set schedules -Twig voltages and Cut set schedules, Duality and dual networks.

UNIT II NETWORK THEOREMS FOR DC AND AC CIRCUITS 12

Network theorems -Superposition theorem, Thevenin's theorem, Norton's theorem, Reciprocity theorem, Millman's theorem, and Maximum power transfer theorem ,application of Network theorems- Network reduction: voltage and current division, source transformation – star delta conversion.

UNIT III RESONANCE AND COUPLED CIRCUITS 12

Resonance - Series resonance - Parallel resonance - Variation of impedance with frequency –Variation in current through and voltage across L and C with frequency – Bandwidth - Q factor -Selectivity. Self-inductance - Mutual inductance - Dot rule - Coefficient of coupling - Analysis of multilinking coupled circuits - Series, Parallel connection of coupled inductors - Single tuned and double tuned coupled circuits.

UNIT IV TRANSIENT ANALYSIS 12

Natural response-Forced response - Transient response of RC, RL and RLC circuits to excitation by Step Signal, Impulse Signal and exponential sources - Complete response of RC, RL and RLC Circuits to sinusoidal excitation.

UNIT V TWO PORT NETWORKS 12

Two port networks, Z parameters, Y parameters, Transmission (ABCD) parameters, Hybrid (H) Parameters, Interconnection of two port networks, Symmetrical properties of T and π networks.

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TOTAL: 60 PERIODS

OUTCOMES:

At the end of the course, the student should be able to:

- Develop the capacity to analyze electrical circuits, apply the circuit theorems in real time
- Design and understand and evaluate the AC and DC circuits.

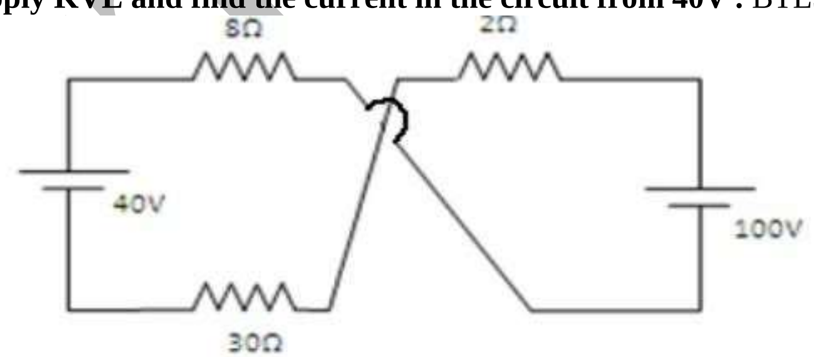
TEXT BOOKS:

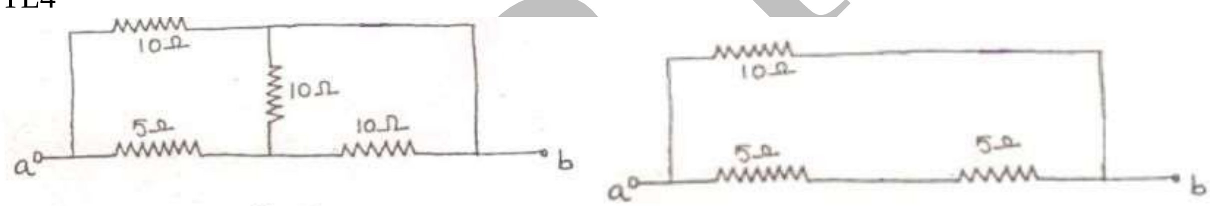
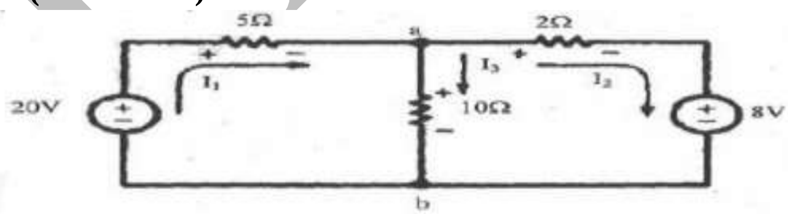
1. William H. Hayt, Jr. Jack E. Kemmerly and Steven M. Durbin, ―Engineering Circuit Analysis‖ , McGraw Hill Science Engineering, Eighth Edition, 11th Reprint 2016.
2. Joseph Edminister and Mahmood Nahvi, ―Electric Circuits‖, Schaum's Outline Series, Tata McGraw Hill Publishing Company, New Delhi, Fifth Edition Reprint 2016.

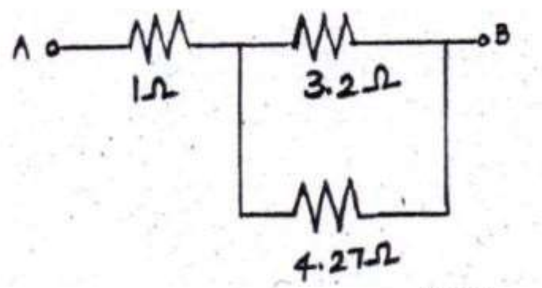
REFERENCES:

1. Charles K. Alexander, Mathew N.O. Sadiku, ―Fundamentals of Electric Circuits‖, Fifth Edition, McGraw Hill, 9th Reprint 2015.
2. A.Bruce Carlson, ―Cicuits: Engineering Concepts and Analysis of Linear Electric Circuits‖, Cengage Learning, India Edition 2nd Indian Reprint 2009.
3. Allan H.Robbins, Wilhelm C.Miller, ―Circuit Analysis Theory and Practice‖, Cengage Learning, Fifth Edition, 1st Indian Reprint 2013.

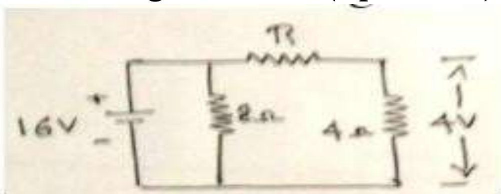
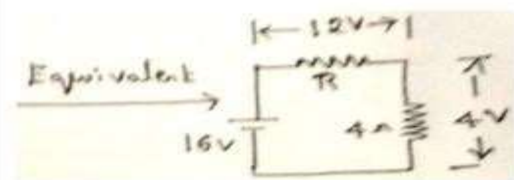
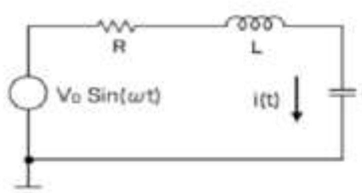
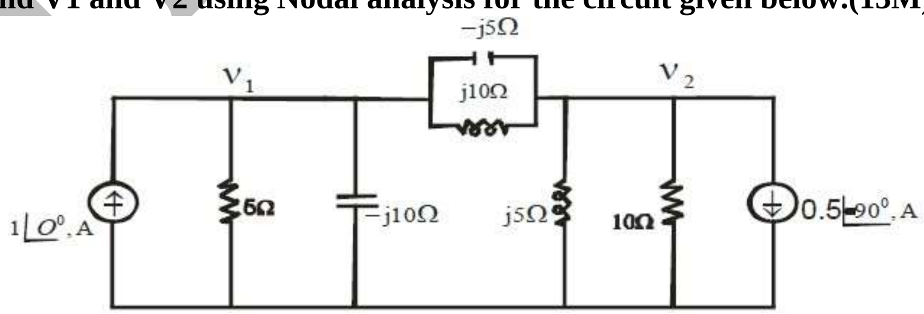
UNIT I - BASIC CIRCUITS ANALYSIS AND NETWORK TOPOLOGY	
Ohm's Law – Kirchhoff's laws – Mesh current and node voltage method of analysis for D.C and A.C.circuits - Network terminology - Graph of a network - Incidence and reduced incidence matrices – Trees –Cut sets - Fundamental cut sets - Cut set matrix – Tie sets - Link currents and Tie set schedules -Twig voltages and Cut set schedules, Duality and dual networks.	
PART * A	
Q.No.	**Questions**
1	**State Ohm's law.**BTL1 Ohm's law states that the current flowing in a conductor is directly proportional to the potential between two ends of a conductor . i.e. $i \alpha v$ $v = iR$
2	**State the Limitation of Ohm's law(JUNE 2013,NOV 2016)** BTL1 Ohm's law doesn't apply to all non-metallic conductors 2. Doesn't apply to nonlinear devices like Zener diode, Voltage regulator, tubes etc.,3. It is not applicable for the metallic conductors which changes with temperature .
3	**Define i) charge ii) electric current iii) power iv) network & v) circuit.** BTL1 **Charge:** Charge is an electrical property of the atomic particles of which matter consists, measured in coulombs(C). **Electric current** is the time rate of change of charge, measured in amperes (A). $i = dq/dt$ A direct current (DC) is a current that remains constant with time. An alternating current (AC) is a current that varies sinusoidally with time **Power** is the time rate of expending or absorbing energy, measured in watts(w).p = p- Power in watts(w);w- energy in joules (J);t - time in seconds (S);(or) p = v i ,v - Voltage in volts(V);i - current in amperes(A). **Network:** The inter connection of two or more simple circuit elements forms an electrical network. Circuit: If the network contains at least one closed path, it is an electric circuit.
4	**State Kirchoff's Current law.(NOV 2015)** BTL1 KCL (Kirchoff's Current Law) states that the algebraic sum of currents entering a node is zero (or)The sum of the currents entering a node is equal to the sum of the currents leaving the node
5	**State Kirchoff'sVoltage law. KVL (NOV 2013)** BTL1 (Kirchoff's Voltage Law) states that the algebraic sum of all voltages around a closed path is zero. (or) Sum of voltage drop = Sum of voltage rise.
6	**The total charge entering a terminal is given by q=5t sin 4πt, mC. Calculate the current at t=0.5 seconds.** BTL4 $i = dq/dt = d(5t \sin 4\pi t)/dt = (5 \sin 4\pi t + 20 \pi t \cos 4\pi t)$ At t = 0.5, $i = 5 \sin 2\pi + 10\pi \cos 2\pi = 0 + 10\pi =$ **342 mA**
7	**Define power and energy. Give the expression for electrical power and energy.** BTL1

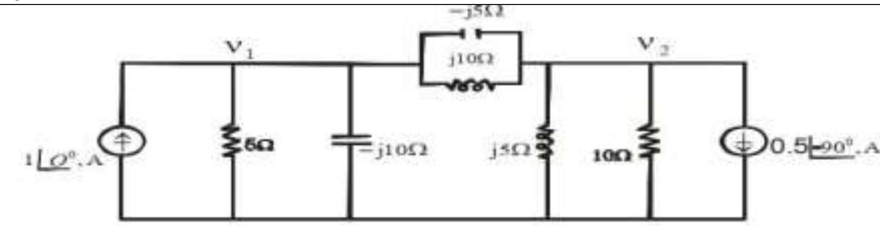
	Power is the rate of doing work and its unit is Watt. The unit of electric power is defined in terms of the joule per second. One joule per second is the work done when one coulomb of electricity is moved through a potential difference of one volt in one second. **P = EI = I2R = E2/R Watts.** **Energy** is the product of power and time. If the power remains constant at Pduring the period of time t seconds, the energy equals Pt Watt-sec or Joules. **Energy W = Pt = EIt = I2Rt = E2t/R J.**
8	**Define: Node (OR) Junction** BTL1 A Node is a point in the network where two or more circuit elements are connected.
9	**Write down the expression of equivalent resistance for ‘n’ - number of resistors in parallel connection.** BTL3 For ‘n’ resistors connected in parallel, the equivalent resistance is given by, $\frac{1}{Req} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3} + ... + \frac{1}{Rn}$
10	**The equivalent resistance of four resistors joined in parallel is 30 Ohms. The current flowing through them are 0.5,0.4,0.6a nd 0.1.Find the value of each resistor.(NOV 2016)** BTL4 Let R1,R2,R3,R4 be the four resistance connected in parallel and currents 0.5,0.4,0.6 ,0.1 flows through them respectively. Total current in the four parallel branch is 0.5+0.4+0.6+0.1=1.6A Total voltage across the parallel combination of four resistance is 30x1.6=48V. Value of R1= 48/0.5 = 96Ω ; Value of R2 = 48/0.4 = 120Ω ; Value of R3 = 48/0.6 = 80Ω and Value of R4 = 48/0.1 = 480Ω
11	**Write the Algorithm for Mesh Analysis.(DEC 2012)** BTL1 Assign mesh currents i1,i2,….in to the n meshes. Apply KVL to each of the n meshes. Solve the resulting in simultaneous equations to get the mesh currents.
12	**Apply KVL and find the current in the circuit from 40V .** BTL5  By applying KVL,40-8I+100-2I-30I=0, Ans: I=5A
13	**Distinguish between a Loop & Mesh of a circuit (DEC 2010)(JUNE 2013)(JUNE 2016)** BTL2 The closed path of a network is called a Loop.An elementary form of a loop which cannot be further divided is called a mesh. In other words Mesh is closed path does not contain any other loop within it.

14	**How are the following affected by change of frequency?a)Resistance b)Inductive reactance. (DEC2010)** BTL3 Resistance will not be affected by change of frequency. Inductive reactance will increase by increasing frequency and vice versa.
15	**Define RMS voltage.(JUNE 2014).** BTL1 The RMS value of an AC is defined as the equivalent steady value of the DC which can produce the equal amount of heat, when flow through the given circuit for an equal time. $$\text{RMSvalue} = \sqrt{\frac{\text{Area under the Square Curve for oneCycle}}{\text{TimePeriod}}}$$ RMS value of an AC voltage, $V_{RMS} = \frac{V_m}{\sqrt{2}} = 0.707V_m$
16	**An electrical appliance consumes 2kWh in 30 mins at 120V. What is the current drawn by the appliance?(NOV 2014)** BTL3 Energy, $W = EIt$,$I = \frac{W}{Et} = \frac{1200 \times 3600}{120 \times 1800} = 20A$
17	**Calculate the equivalent resistance between the terminals "a" and "b" in Fig(NOV 2014)** BTL4  Fig. 1 Resistance between terminals 'a' and 'b' =(10 X 10)/(10 + 10) = 5Ω
18	**Write briefly about resistance in a circuit. (JUNE 2015)** BTL1 The electrical resistance of a circuit component or device is defined as the ratio of the voltage applied to the electric current which flows through it: If the resistance is constant over a considerable range of voltage, then Ohm's law, I = V/R, can be used to predict the behavior of the material. The resistance is measured in units of ohms (Ω).
19	**Obtain the current in each branch of the network shown below using Kirchoff's Current Law. (JUNE 2015)** BTL4  $5I_1 + 10(I_1 - I_2) = 20$ $10(I_2 - I_1) + 20I_2 = -8$ $I_1 = 48A$ $I_2 = 0.91A$
20	**The resistance of two wires is 25Ω when connected in series and 6Ω when connected in parallel. Calculate the resistance of each wire.(JUNE 2016)** BTL4

	$R_1+R_2=25\Omega$, $R_2=25-R_1$------------(1) $R_1R_2/(R_1+R_2) = 6\Omega$,--------------(2) Substitueeqn(1) in eqn(2), $R_1^2-25R_I+150=0$ $R_1=10\Omega, R_2=15\Omega$ (or)$R_1=15\Omega$, $R_2=10\Omega$
21	**Find the equivalent resistance of the circuit shown in fig.(NOV 2015)** BTL3  Equivalent resistance = $1+\frac{2\times27}{2+27}\,\Omega = 83\ \Omega$
22	**Define electric network.** BTL1 A network is an interconnection of elements in various branches at different nodes.
23	**Define Graph of a network.** BTL1 In a network, if the branches are represented by straight line segment and nodes by dots, then the resultant diagrammatic representation is called as a graph.
24	**What is meant by Tree of a network and Twig of a network?** BTL2 The tree of a network connects all the nodes of the network but contains no closed path. Each branch of tree is called as a twig.
25	**Define Planar and Non-Planer graphs.** BTL2 A graph is said to be planar if it can be drawn on a plane surface such that no two branches cross each other. A graph containing cross over is called as non-planer.
26	**List out the properties of a tree.** BTL2 1.It contains all the nodes of the graph. 2.A graph having 'n' nodes will have (n-1) branches in its tree 3.Tree does not have any closed path. 4.There may be many trees for a given graph.
27	**What is a Tie set?** BTL2 Consider a tree of a connected graph. Tie-set is a unique set with respect to this tree containing one chord and all of the tree branches contained in the free path formed between two vertices of the chord.
28	**List out the advantages of Tie-set matrix** BTL2 a) From the tie-set matrix, we can frame the voltage loop equations for each loop b) Tie-set matrix gives the branches currents in terms of loop currents or link currents.
29	**What is a cut-set?** BTL2 Cut-set is the set of elements which if removed divides the graph in to two sub graphs and the graph becomes unconnected.
30	**For a 'n' node network,how many are the chords?** BTL3 If 'b' is the number of branches in a network and n, the number of nodes, then number of chords= b-n+1

31	**What are the terms associated with network graph?** BTL2

	The terms associated with network graphs are branches,link,node,loop,tree,co-tree,tie-set,cut-set.
32	**Define Dual Networks?** BTL2 If the mesh equations of one network have the same form as the nodal equations of another network, then the two networks are called as dual network. The property of duality is a mutual property.
33	**State the dual elements for resistance and Inductance.** BTL1 The dual of resistance is conductance. The dual of inductance is capacitance.
34	**Find R in the given circuit.(April-2017)** BTL3   As per voltage division rule, $\frac{R}{R+4}$ x 16=12 16R=12(4+R) R= $\frac{48}{4}$ = 12Ω
35	**Determine the current i(t) given v(t)=10Cost , L=1H, C = 1μF and R = 1Ω for the given circuit.(April-2017)** BTL4  $L\frac{di}{dt} + \int i(t)dt + i(t) = 10Cost$ Taking Laplace, $SI(S) + I(S)/S + I(S) = 10S/(S^2+1)$ $I(S) = 10S^2/(S^2+1)(S^2+S+1)$
	PART * B
1	**Find V1 and V2 using Nodal analysis for the circuit given below.(13M) (Nov 2017)**BTL4  **Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao**



Apply KCL for node 1,

$$\frac{v1}{5}+\frac{v1}{-j10}+\frac{v1-v2}{-5j}+\frac{v1-v2}{j10}=1$$

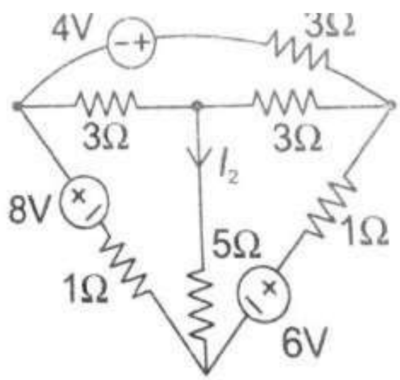
Apply KCL for node 2,

$$\frac{v2-v1}{-5j}+\frac{v2-v1}{10j}+\frac{v2}{5j}+\frac{v2}{10}=-0.5\angle-90$$

Solve and find V_1&V_2

2

(i)Determine the current I_L in the circuit shown in figure below:(JUNE 2016)(7+6 M) BTL4



Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao

Mesh 1

$3*(I_1-I_3)+5*(I_1-I_2)+I_1=8$

$9*I_1-5*I_2-3*I_3=8\rightarrow$eq 1

Mesh 2

$3*(I_2-I_3)+I_2+5+5*(I_2-I_1)=0$

$-5*I_1+9*I2-3*I_3=-5\rightarrow$eq 2

Mesh 3

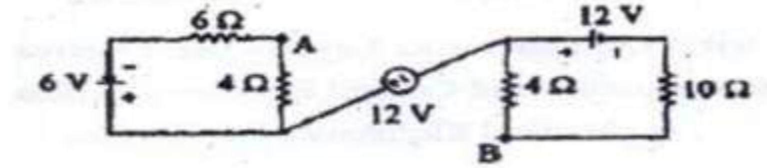
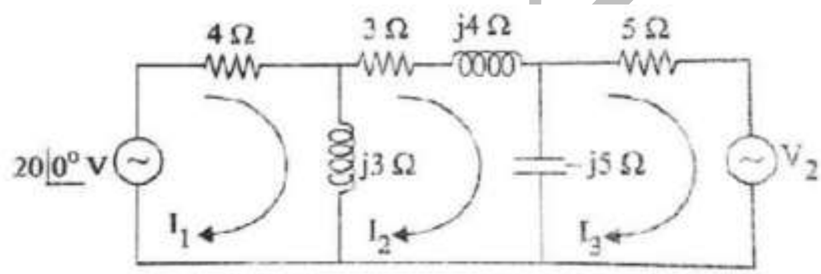
$-4+3*I_3+3*(I_3-I_2)+3*(I_3-I_1)=0$

$-3*I_1-3*I_2+9*I_3=4\rightarrow$eq 3

Solving 1,2,3

I_1=1.88A, I_2=0.95A, I_3=1.39A $I_L=I_1-I_2$=0.93A

ii) **Calculate the voltage across A and B in the circuit shown in figure.(JUNE 2016)** BTL3

	 By Ohm's Law $I_1 = \frac{6}{6+4} = 0.5\ A$ $I_2 = \frac{12}{4+10} = \frac{12}{14}\ A$ $V_{AB} = (I_1 \times 4) - 12 - I_2 \times 4$ $= (0.5\times4) - 12 - \left(\frac{12}{14}\right)\times 4$ $= -13.43V$ $= 13.43V$ with B at negative potential.
3	**(i)For the circuit shown in figure below, determine the value of V_2 such that the current through (3+j4) Ω impedance is zero. (DEC 2012)(13 M)** BTL5  **Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao**

By Inspection

$$\begin{bmatrix} 4+j3 & -j3 & 0 \\ -j3 & 3+j2 & -j5 \\ 0 & -j5 & 5-j5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 20\angle 0^\circ \\ 0 \\ -V_2 \end{bmatrix}$$

The three loop equations are

$(4+j3)\ I_1 - (j3)\ I_2 = 20\angle 0^\circ$

$-(3j)\ I_1 + (3+j2)\ I_2 + j5\ I_3 = 0$

$(j5)\ I_2 + (5-j5)\ I_3 = -V_2$

Since the Current through $(3+j4)\Omega$ is zero

$$I_2 = \frac{\Delta 2}{\Delta} = 0 \qquad i.e. \Delta_2 = 0$$

Where, $$\Delta_2 = \begin{bmatrix} (4+j3) & 20\angle 0^\circ & 0 \\ (-j3) & 0 & j5 \\ 0 & -V_2 & (5-j5) \end{bmatrix} = 0$$

$(4+j3)\ V_2\ (j5) - 20\angle 0^\circ \{(-j3)(5-j5)\} = 0$

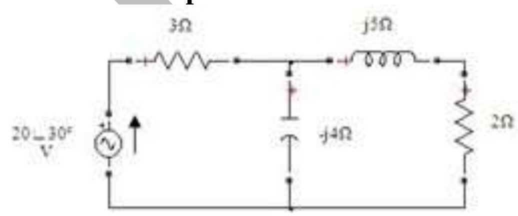
$$V_2 = \frac{20\angle 0^\circ \{(-j3)(5-j5)\}}{(j5)(4+j3)}$$

$$= 20\angle 0^\circ \frac{\{-15-j15\}}{-15+j20}$$

$$= 20\angle 0^\circ \text{X} \ \frac{21.21\angle -135^\circ}{25\angle 126.86^\circ}$$

$$\boxed{V_2 = 16.97\angle\text{-}261.86^\circ \text{V}}$$

(ii) By applying nodal analysis for the circuit shown in Fig, determine the power output of the source and the power in each resistor of the circuit.(JUNE 2013)



Apply KCL

$$\frac{V-20\angle 30}{3}+\frac{V}{-j4}+\frac{V}{2+j5}=0$$

Solving the above expression find V.

$\frac{20\angle 30-V}{3}=I_{3\Omega}$. From $I_{3\Omega}$ find power output of the source & power in 3Ω resistor.

$I_{2\Omega}=\frac{V}{2+j5}$, then find power output at 2Ω resistor

4

i) State and explain Kirchoff's laws. (JUNE 2013)

Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao

Kirchhoff's Current Law (KCL)

KCL states that *the algebraic sum of all currents leaving (or entering) a node is equal to zero.* For example, in Figure 2.9, if we assign a plus (+) sign to the currents *leaving* the node, we must assign a minus (-) sign to the currents *entering* the node. Then by KCL,

$-i_1 - i_2 + i_3 + i_4 = 0$ (2.13)

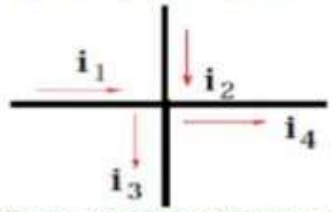


Figure 2.9. Node to illustrate KCL

But if we assign a plus (+) sign to the currents *entering* the node and minus (-) sign to the currents *leaving* the node, then by KCL,

$i_1 + i_2 - i_3 - i_4 = 0$ (2.14)

or

$-i_1 - i_2 + i_3 + i_4 = 0$ (2.15)

We observe that (2.13) and (2.15) are the same; therefore, it does not matter which we choose as plus (+).

Kirchhoff's Voltage Law (KVL)

KVL states that *the algebraic sum of the voltage drops (voltages from + to -) or voltage rises (voltages from - to +) around any closed path (mesh or loop) in a circuit is equal to zero.* For example, in the circuit shown in Figure 2.10, voltages, , , and represent the voltages across devices 1, 2, 3, and 4 respectively, and have the polarities shown.

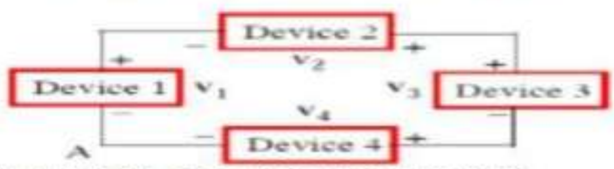


Figure 2.10. Circuit to illustrate KVL

Now, if we assign a (+) sign to the voltage drops, we must assign a (-) sign to the voltage rises. Then, by KVL starting at node and going *clockwise* we obtain:

$-v_1 - v_2 + v_3 + v_4 = 0$ (2.16)

or going *counterclockwise*, we obtain:

$-v_4 - v_3 + v_2 + v_1 = 0$ (2.17)

Alternately, if we assign a (+) sign to the voltage rises, we must assign a (-) sign to the voltage drops. Then, by KVL starting again at node A and going *clockwise* we obtain:

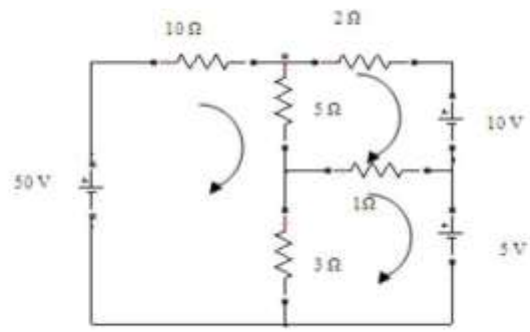
$v_1 + v_2 - v_3 - v_4 = 0$ (2.18)

or going *counterclockwise*, we obtain:

$v_4 + v_3 - v_2 - v_1 = 0$ (2.19)

We observe that expressions (2.16) through (2.19) are the same.

(ii) Using mesh analysis, determine the current through 1Ω resistor in the given circuit .



Loop 1

$50=10*I_1+5*(I_1-I_2)+3*(I_1-I_3)$

$18*I_1-5*I_2-3*I_3=50 \rightarrow$ eq 1

Loop 2

$-10=2*I_2+1*(I_2-I_3)+5*(I_2-I_1)$

$-5*I_1+8*I_2-I_3=-10 \rightarrow$ eq 2

Loop 3

$-5=3*(I_3-I_1)+1*(I_3-I_2)$

$-3*I_1-I_2+4*I_3=-5 \rightarrow$ eq 3

solving eq 1,2,3

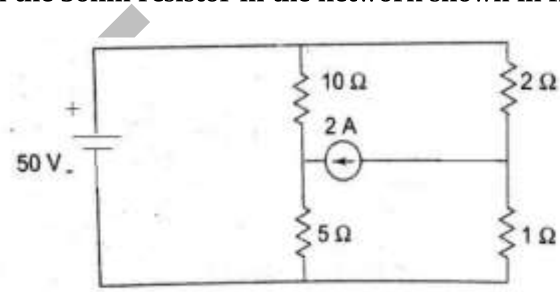
$I_1=3.3A$

$I_2=5A$(counter clockwise)

$I_3=1.47$ A

Current through 1 ohm resistor$=I_2-I_3=3.53A$

5 **(i) Determine the current in the 5ohm resistor in the network shown in fig below.**



Mesh 1

$50=10*(I_1-I_2)+5*(I_1-I_3)$

$15*I_1-10*I_2-5*I_3=50 \rightarrow$ eq 1

Current source common to mesh 1 and 2 => super mesh

$10*(I_2-I_1)+2*I_2+I_3+5*(I_3-I_1)=0$

$-15I_1+12*I2+6*I_3=0 \rightarrow$ eq 2

Eq 1+Eq 2=> $2*I_2+I_3 \rightarrow$ eq 3

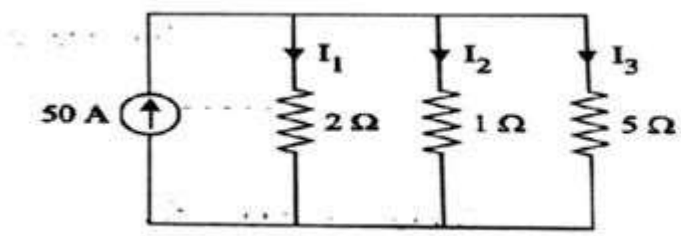
In super mesh I_2-I_3=2→eq 4
Solving eq 1,2
I_2=0.66A
I_3=1.34A

Using in eq 1=> I_1=0.12A

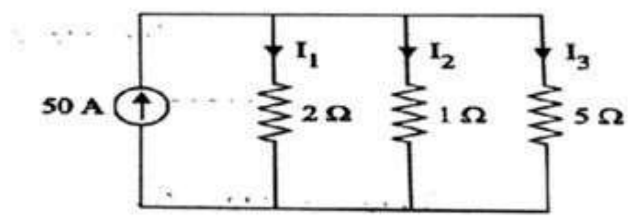
Current through 5 ohm=I_1+I_3=1.46A

6

Determine the current in all the resistors of the circuit shown in fig below.**(13 M)** BTL3



Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao



I=I_1+I_2+I_3
Req=0.59
1 ohm and 5 ohm in parallel= R_{eq1} = 0.83 ohm
2 ohm and 5 ohm in parallel= R_{eq2} = 1.43 ohm
1 ohm and 2 ohm in parallel= R_{eq3} = 0.66 ohm
I_1=I*R_{eq1}/(R_1+R_{eq1})=50*0.83/(2+0.83)=14.67A
I_2=I*R_{eq2}/(R_2+R_{eq2})=50*1.43/(1+1.43)=29.42A
I_3=I*R_{eq3}/(R_3+R_{eq3})=50*0.66/(5+0.66)=5.43A

Answer
Current through resistors: 14.67A,29.42A,5.43A

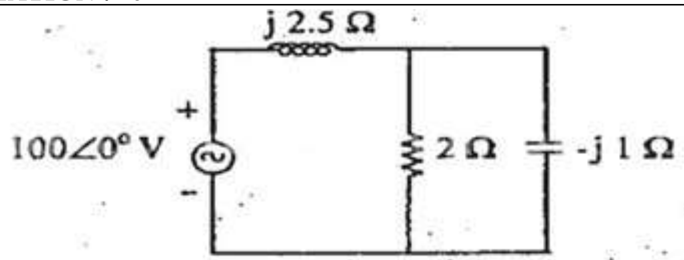
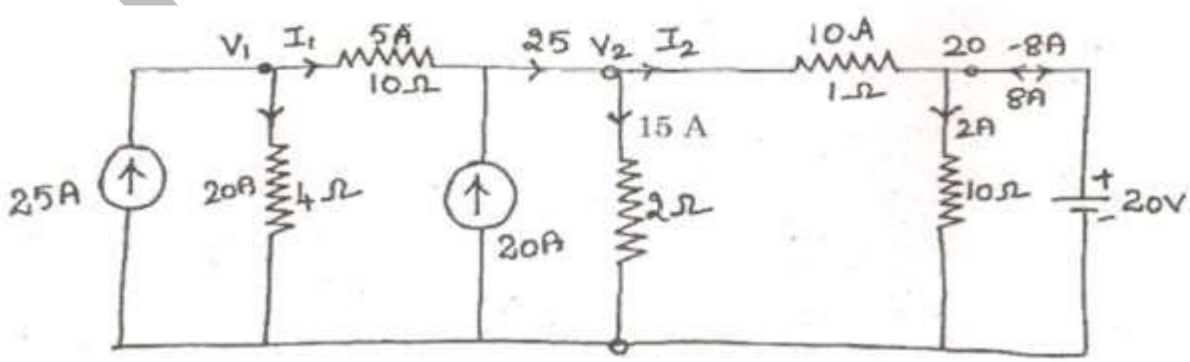
7

For the circuit shown in the below figure, (JUNE 2014)

a. Determine the currents in all the branches

b. Calculate the power and power factor of the source

c. Show that power delivered by the source is equal to the power consumed by the 2Ω resistor.

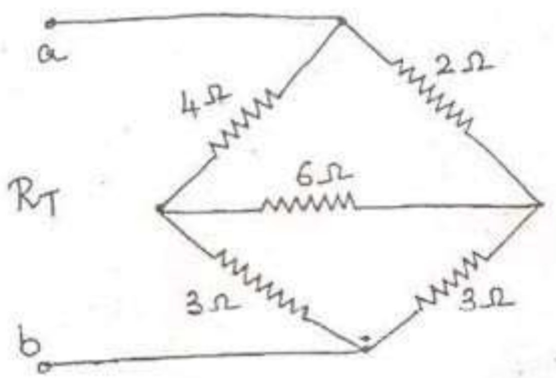
	 (i) $(2+j2.5)I_1 - 2I_2 = 100\angle 0°$ ⟶ (1) $-2I_1 + (2-j1)I_2 = 0$ ⟶ (2) Solving (1) & (2) find I_1 & I_2 (ii) Power, $P_T = V \times I_1 = 100 \times I_1$ We know that $\frac{V}{I_1} = Z\angle\phi$ Power factor = $\cos\phi$ (iii) $P_{2\Omega} = (I_1 - I_2)^2 \times 2 = P_T$
8	**(i) Using nodal analysis, find the node voltages and the currents through all the resistors for the circuit shown in fig. (NOV 2014) (May 2017)(13 M)** BTL4  **Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao**

$$\frac{V_1 - V_2}{10\Omega} + \frac{V_1}{4} = 25 \longrightarrow (1)$$

$$\frac{V_2}{2} + \frac{V_2 - 20}{1} = 20 \longrightarrow (2)$$

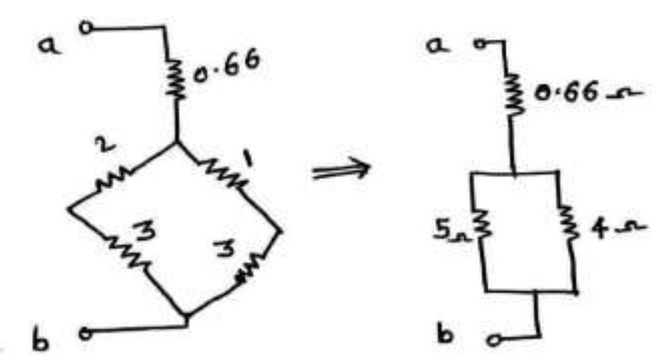
Solving (1) & (2) find V_1 & V_2

(ii) Find the equivalent resistance between the terminals 'a' and 'b' for the network shown in figure.

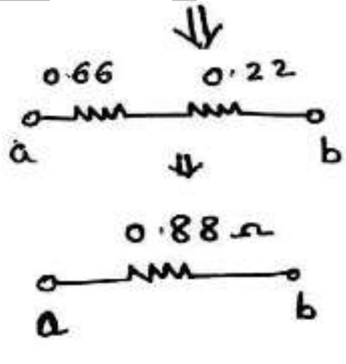


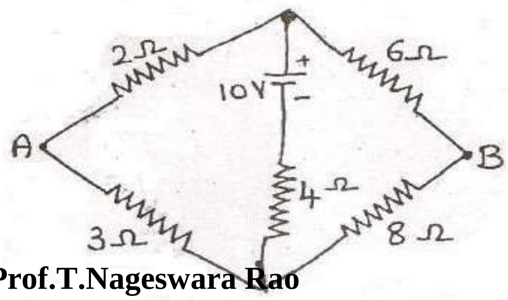
Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao

Converting the upper delta in to star we have,



9	**For the circuit shown in figure find the (i) currents in different branches, (ii) current supplied by the battery, (iii) potential difference between the terminals A & B. (NOV 2014) (13M)** BTL4





Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao

(i) $5I_1 + 4(I_1 - I_2) - 10 = 0$

$9I_1 - 4I_2 = 10 \longrightarrow (1)$

$-4I_1 + 18I_2 = -10 \longrightarrow (2)$

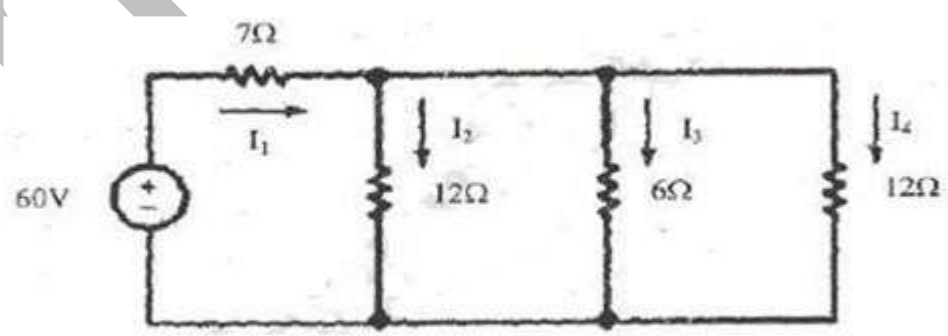
Solving (1) & (2) find branch currents

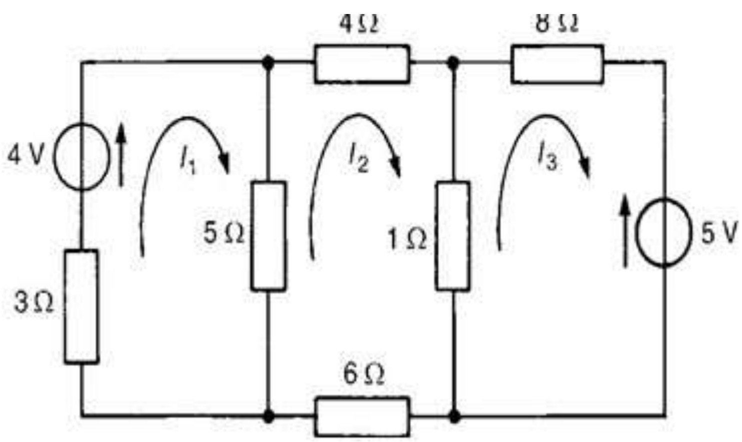
(ii) Equivalent resistance $= 7.68\Omega$

$I_T = \frac{V}{R} = \frac{10}{7.68} = 1.30A$

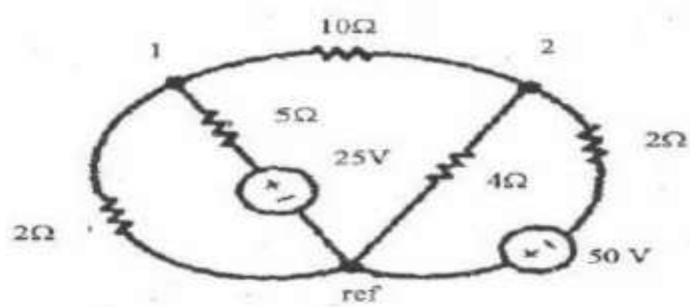
(iii) From I_1 & I_2 find potential drop across 3Ω & 8Ω resistor, then find difference in potential between A & B

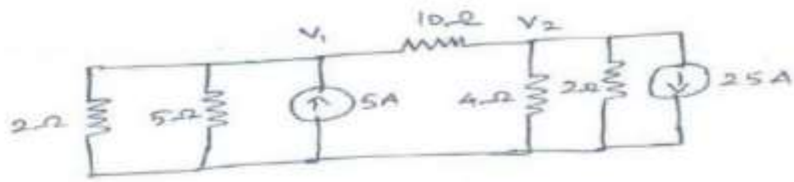
10. **(i) Use branch currents in the network shown below to find the current supplied by the 60V source. Solve the circuit by mesh current method.(JUNE 2015)**



	$7I_1 + 12(I_1 - I_2) - 60 = 0$ $19I_1 - 12I_2 = 60 \longrightarrow (1)$ $-12I_1 + 18I_2 - 6I_3 = 0 \longrightarrow (2)$ $-6I_2 + 18I_3 = 0 \longrightarrow (3)$ Solving (1), (2) & (3) find current supplied by 60V source
	PART – C
1	**Use mesh-current analysis to determine the current flowing in (a) the 5Ω resistance, and (b) the 1Ω resistance of the d.c. circuit shown in Figure. (13M)** BTL 3 **Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao**  The mesh currents I_1, I_2 and I_3 are shown in Figure (7M) Using Kirchhoff's voltage law: For loop 1, $(3 + 5) I_1 - I_2 = 4$...............(1) For loop 2, $(4 + 1 + 6 + 5) I_2 - (5) I_1 - (1) I_3 = 0$ ....(2) For loop 3, $(1 + 8) I_3 - (1) I_2 = -5$...............(3) (6M) Thus $8I_1 - 5I_2 - 4 = 0$ $-5I_1 + 16I_2 - I_3 = 0$ $I_2 + 9I_3 + 5 = 0$

2	Solve the network given below by the node voltage method. **(JUNE 2015)**

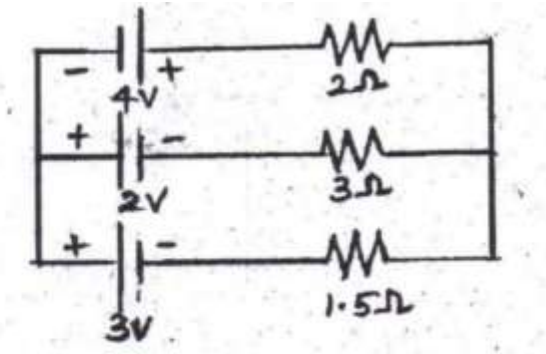




$$\frac{V_1}{5} + \frac{V_1}{2} + \frac{V_1 - V_2}{10} = 5 \longrightarrow (1)$$

$$\frac{V_2 - V_1}{10} + \frac{V_2}{4} + \frac{V_2}{2} + 25 = 0 \longrightarrow (2)$$

Solving (1) & (2) find V_1 & V_2

3	11. Determine the magnitude and direction of the current in the 2v battery in the circuit shown in below figure**.(Nov 2015)**  Solution: In Loop 1: Applying KVL in loop 1 $2I_1 + 3[I_1 - I_2] - 2 - 4 = 0$ $2I_1 + 3I_1 - 3I_2 - 6 = 0$ $\boxed{5I_1 - 3I_2 = 6} \rightarrow (1)$

ii)Determine the power dissipation in the 4 Ω resistor of the given circuit shown in below figure

KVL In Loop 2:

$$1.5I_2 - 3 + 2 + 3[I_2 - I_1] = 0$$

$$1.5I_2 - 1 + 3I_2 - 3I_1 = 0$$

$$\boxed{-3I_1 + 4.5I_2 = 1} \longrightarrow (2)$$

$$\begin{bmatrix} 5 & -3 \\ -3 & 4.5 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 6 \\ 1 \end{bmatrix}$$

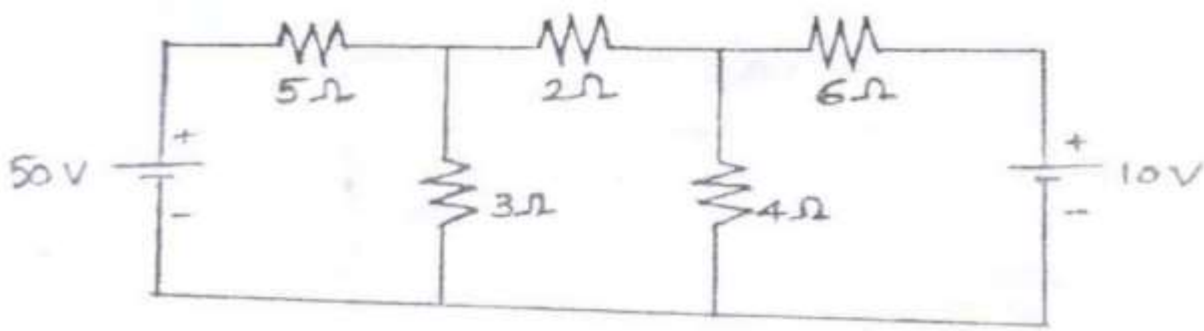
$$\Delta = 22.5 - 9 = 13.5$$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{\begin{bmatrix} 6 & -3 \\ 1 & 4.5 \end{bmatrix}}{13.5} = \frac{27+3}{13.5} = \frac{30}{13.5} = \underline{\underline{2.22\,A}}$$

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{\begin{bmatrix} 5 & 6 \\ -3 & 1 \end{bmatrix}}{13.5} = \frac{5+18}{13.5} = \frac{23}{13.5} = 1.7\,A.$$

$\therefore$ Current through 2V battery is $I_1 - I_2 = 2.22 - 1.7 = \underline{\underline{0.52\,A}}$.

Direction of Current is + − 2V 0.52A 3Ω



KVL in loop 1:

$$5I_1 + 3[I_1 - I_2] - 50 = 0$$

$$8I_1 - 3I_2 = 50 \longrightarrow (1)$$

KVL in loop 2:

$$2I_2 + 4[I_2 - I_3] + 3[I_2 - I_1] = 0$$

$$-3I_1 + 9I_2 - 4I_3 = 0 \longrightarrow (2)$$

KVL in loop 3:

$$6I_3 + 10 + 4[I_3 - I_2] = 0$$

$$-4I_2 + 10I_3 = -10 \longrightarrow (3)$$

$$\begin{bmatrix} 0 & 8 & -3 \\ -3 & 9 & -4 \\ 0 & -4 & 10 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 50 \\ 0 \\ -10 \end{bmatrix}$$

$$\Delta = -8[-30] - 3[12] = 240 - 24 = 216$$

$$\Delta_2 = \begin{bmatrix} 0 & 50 & -3 \\ -3 & 0 & -4 \\ 0 & -10 & 10 \end{bmatrix} = 3[500 - 30] = 3[470] = 1410$$

$$I_2 = \frac{\Delta_2}{\Delta} = \frac{1410}{216} = \underline{6.56\ A}$$

$$\Delta_3 = \begin{bmatrix} 0 & 8 & 50 \\ -3 & 9 & 0 \\ 0 & -4 & -10 \end{bmatrix} = +3[-80 + 200] = -240 + 600 = 360$$

$$I_3 = \frac{\Delta_3}{\Delta} = \frac{360}{216} = \underline{1.67\ A}$$

Current through $4\,\Omega$ is $I_2 - I_3$

$= 6.56 - 1.67$

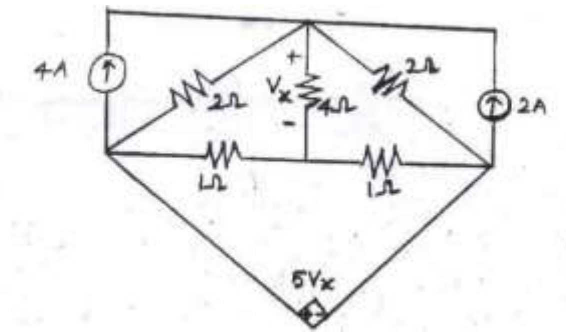
$= \underline{4.89\ A}$

∴ Power Dissipated by $4\,\Omega$ is $= I^2 R$

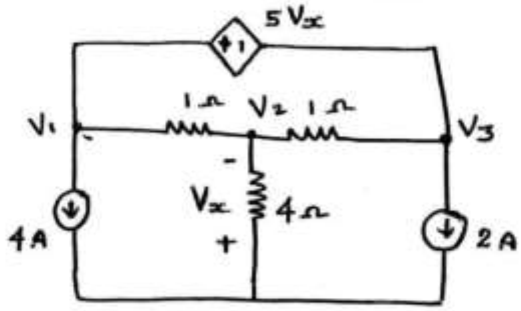
$= (4.89)^2 \times 4$

$= 23.91 \times 4$

Ans. $= \boxed{95.64 \text{ watts}}$

4	Using nodal analysis, find the voltage V_X for the circuit shown in below figure. **(Nov 2015)** 

Redrawing the given Circuit



Applying KCL at node V_2

$$\frac{V_2}{4} + \frac{V_2 - V_3}{1} + \frac{V_2 - V_1}{1} = 0$$

$$V_2 + 4V_2 - V_3 4 + 4V_2 - 4V_1 = 0$$

$$9V_2 - 4V_3 - 4V_1 = 0$$

Also, $\boxed{V_1 - V_3 = 5V_x}$

$$\boxed{V_x = -V_2}$$

$$V_1 - V_3 = -5V_2$$

$$\boxed{V_3 = V_1 + 5V_2}$$

$$\therefore \; 9V_2 - 4V_1 - 4\left[V_1 + 5V_2\right] = 0$$

$$9V_2 - 4V_1 - 4V_1 - 20V_2 = 0$$

$$\boxed{-8V_1 - 11V_2 = 0} \rightarrow (1)$$

Also form node V_1 and V_3 we have,

$$-4 - 2 = \frac{V_1 - V_2}{1} + \frac{V_3 - V_2}{1}$$

$$-6 = V_3 - 2V_2 + V_1$$

$$-6 = V_1 + 5V_2 - 2V_2 + V_1$$

$$\boxed{-6 = 2V_1 + 3V_2} \longrightarrow (2)$$

$$\begin{bmatrix} -8 & -11 \\ 2 & 3 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 0 \\ -6 \end{bmatrix}$$

$$\Delta = -24 + 22 = -2$$

$$\Delta_2 = \begin{bmatrix} -8 & 0 \\ 2 & -6 \end{bmatrix} = 48$$

$$V_2 = \frac{\Delta_2}{\Delta} = \frac{-48}{2} = -24$$

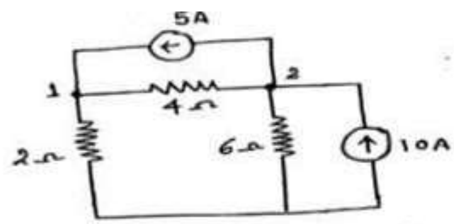
$$V_x = -V_2 = -(-24) = 24V$$

$$\boxed{V_x = 24V}$$

5

Calculate the node voltage of given circuit. (NOV 2016)

Given :



To find : Node Voltages at node-1 and node-2

Solution : Applying KCL at node-1

$$\frac{V_1}{2} + \frac{V_1 - V_2}{4} = 5 \; ; \quad \frac{V_1}{2} + \frac{V_1}{4} - \frac{V_2}{4} = 5 \; ;$$

$$0.5V_1 + 0.25V_1 - 0.25V_2 = 5$$

$$\boxed{0.75V_1 - 0.25V_2 = 5} \longrightarrow (1)$$

Similarly applying KCL at node-2

$$\frac{V_2}{6} + \frac{V_2 - V_1}{4} = 10 - 5 \;;\; \frac{V_2}{6} + \frac{V_2}{4} - \frac{V_1}{4} = 5$$

$$0.17V_2 + 0.25V_2 - 0.25V_1 = 5$$

$$\boxed{-0.25V_1 + 0.42V_2 = 5} \longrightarrow (2)$$

By Cramer's rule

$$\begin{bmatrix} 0.75 & -0.25 \\ -0.25 & 0.42 \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \end{bmatrix} = \begin{bmatrix} 5 \\ 5 \end{bmatrix}$$

$$\Delta = 0.315 - 0.0625 = 0.2525$$

$$\Delta_1 = \begin{bmatrix} 5 & -0.25 \\ 5 & 0.42 \end{bmatrix} = 2.1 + 1.25 = 3.35$$

$$\therefore V_1 = \frac{\Delta_1}{\Delta} = \frac{3.35}{0.2525} = \underline{\underline{13.2\text{ V}}}$$

$$\Delta_2 = \begin{bmatrix} 0.75 & 5 \\ -0.25 & 5 \end{bmatrix} = 3.75 + 1.25 = 5$$

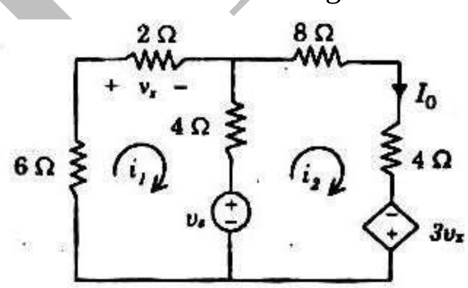
6

$$V_2 = \frac{5}{0.2525} = \underline{\underline{19.8\text{ V}}}$$

Answer : Voltage at node-1 = 13.2V

Voltage at node-2 = 5V

6 Determine the current Io for the given circuit when Vs=12V



To find: I_o i.e, I_2

Applying KVL in loop 1

$6I_1 + 2I_1 + 4[I_1 - I_2] = -12$

$\boxed{12I_1 - 4I_2 = -12}$

Apply KVL in Loop-2

$8I_2 + 4I_2 - 3V_x - 12 + 4[I_2 - I_1] = 0$

But $V_x = 2I_1$

$12I_2 - 3[2I_1] - 12 + 4I_2 - 4I_1 = 0$

$16I_2 - 10I_1 = 12$

$\boxed{-10I_1 + 16I_2 = 12}$

$$\begin{bmatrix} 12 & -4 \\ -10 & 16 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 12 \\ -12 \end{bmatrix}$$

$\Delta = 192 - 140 = 52$

$$\Delta_2 = \begin{bmatrix} 12 & 12 \\ -10 & -12 \end{bmatrix}$$

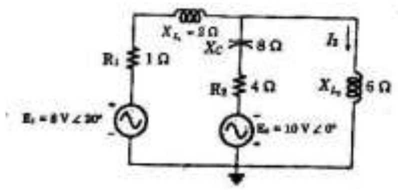
$= -144 + 120$

$= -24$

$I_2 = \frac{\Delta_2}{\Delta} = \frac{-24}{52}$

$I_2 = -0.46\,A$

$\Rightarrow \boxed{I_o = -0.46\,A}$

7	Using mesh analysis for the given circuit, find the current I2 and drop across 1Ω resistor.**(NOV 2016)** 

Applying KVL to Loop 1:

$$I_1 + j2I_1 - j8\left[I_1 - I_2\right] + 4\left[I_1 - I_2\right] = 8\angle 20 + 10\angle 0^\circ$$

$$I_1\left[5 - j6\right] - I_2\left[4 - j8\right] = 7.52 + j2.74 + 10$$

$$I_1\left[5 - j6\right] - I_2\left[4 - j8\right] = 8.52 + j2.74$$

$$\boxed{I_1\left[5 - j6\right] - I_2\left[4 - j8\right] = 8.95\angle 17.83} \longrightarrow (1)$$

Applying KVL to Loop 2:

$$j6I_2 + 10\angle 0^\circ + 4\left[I_2 - I_1\right] - j8\left[I_2 - I_1\right] = 0$$

$$\boxed{-I_1\left[4 - j8\right] + I_2\left[4 - j2\right] = -10\angle 0^\circ} \longrightarrow (2)$$

$$\begin{bmatrix} (5-j6) & -(4-j8) \\ -(4-j8) & (4-j2) \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 8.95\angle 17.83 \\ -10\angle 0^\circ \end{bmatrix}$$

$$\Delta = (5-j6)(4-j2) - \left[(4-j8)(4-j8)\right]$$

$$= 20 - j10 - j24 - 12 - \left[16 - j32 - j32 - 64\right]$$

$$= 8 - j34 - 16 + j32 + j32 + 64 = 56 + j30$$

$$\Delta = 63.53 \angle 28.18$$

$$\Delta_1 = \begin{bmatrix} 8.52 + j2.74 & -(4-j8) \\ -10 & (4-j2) \end{bmatrix}$$

$$= (8.52 + j2.74)(4-j2) - 10(4-j8)$$

$$= 34.08 - j17.04 + j5.48 + 5.48 - 40 + j80$$

$$= -0.44 + j68.44$$

$$I_1 = \frac{\Delta_1}{\Delta} = \frac{-0.44 + j68.44}{63.58\angle 28.18} = \frac{68.44\angle 96.37}{63.58\angle 28.18} = 1.08\angle 62.19 \text{ A}.$$

$$\Delta_2 = \begin{bmatrix} (5-j6) & 8.52 + j2.74 \\ -(4-j8) & -10 \end{bmatrix}$$

$$= -50 + j60 + (4-j6)(8.52 + j2.74)$$

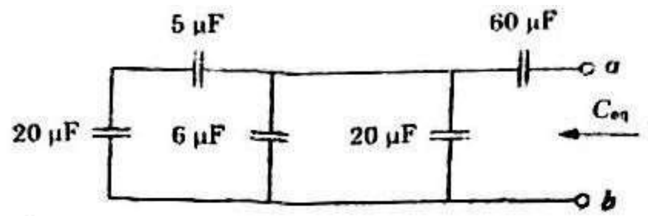
$$= -50 + j60 + 34 + j10.96 - j51.12 + 16.44$$

$$= 0.44 + j19.84$$

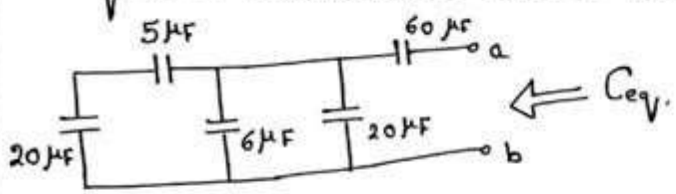
$$I_2 = \frac{\Delta_2}{\Delta} = \frac{0.44 + j19.84}{63.58 \angle 28.18} = \frac{19.84 \angle 88.73}{63.58 \angle 28.18} = 0.312 \angle 60.55 \text{ A}$$

$$\boxed{\text{Drop across } 1\Omega = 1 \times I_2 = 0.312 \angle 60.55 \text{ V}}$$

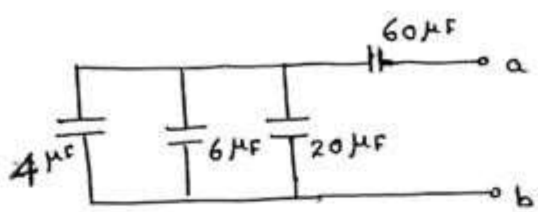
ii) Find the equivalent capacitance C between terminals A and B for the given figure.



Equivalent Capacitance between terminals A and B

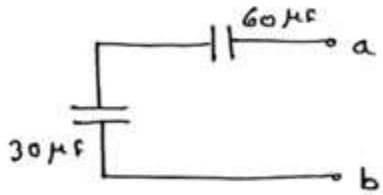


$$20\mu F \text{ and } 5\mu F \text{ are in Series} = \frac{20 \times 5}{20+5} = \frac{100}{25} = 4\mu F$$



4μF, 6μF and 20μF are in Parallel

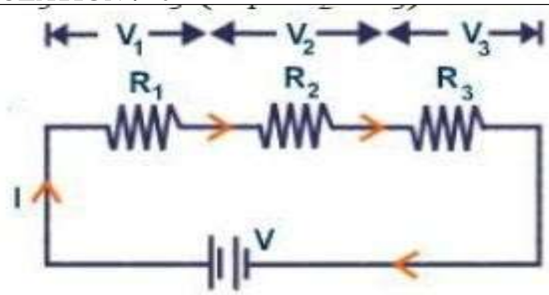
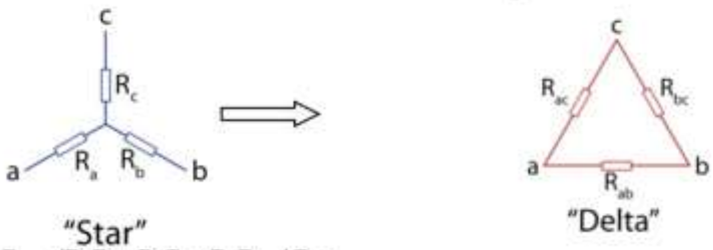
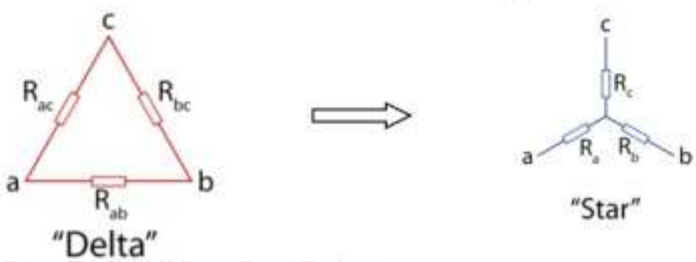
$4+6+20 = 30\,\mu F$



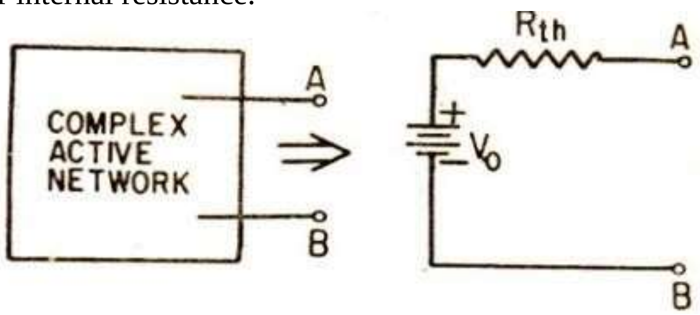
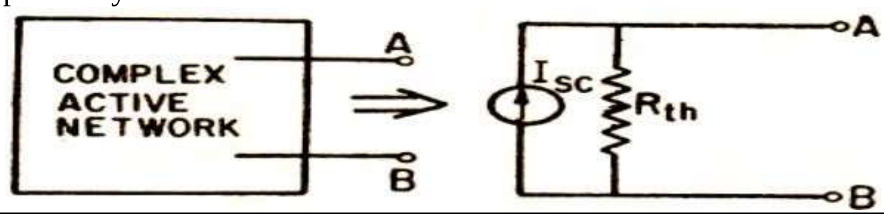
60μF and 30μF are in Series $\frac{60\times30}{60+30} = \frac{180\cancel{0}}{9\cancel{0}} = 20$

$\boxed{\therefore \text{Equivalent Capacitance b/w a-b} = 20\,\mu F}$

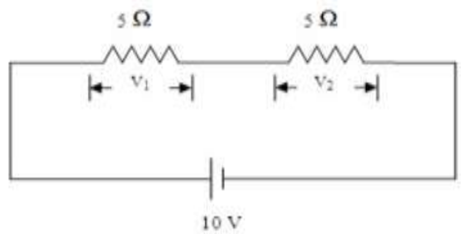
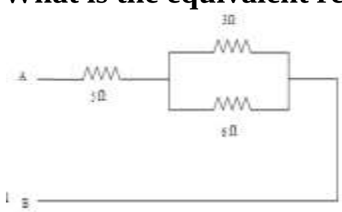
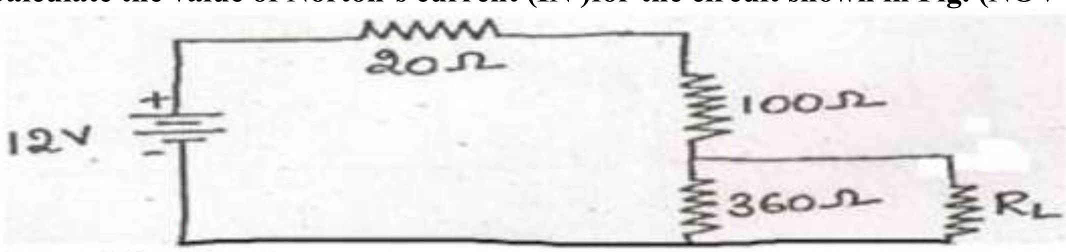
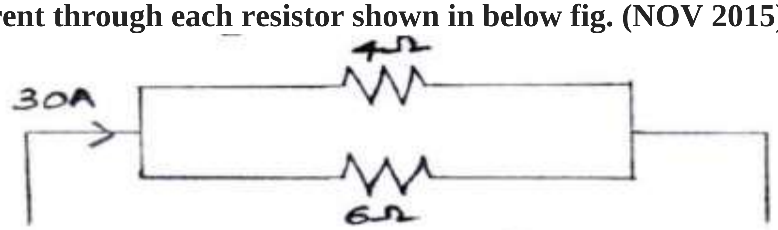
UNIT II - NETWORK THEOREMS FOR DC AND AC CIRCUITS	
Network theorems -Superposition theorem, Thevenin's theorem, Norton's theorem, Reciprocity theorem, Millman's theorem, and Maximum power transfer theorem ,application of Network theorems- Network reduction: voltage and current division, source transformation – star delta conversion.	
PART * A	
Q.No.	**Questions**
1	**Define Lumped circuits.**BTL1 The circuits in which the elements are separated physically like resistors, capacitors and inductors.
2	**State division of current rule for a two branch parallel network.(JUNE 2013,NOV 2013)** BTL3 R1 and R2 are connected in parallel, Let I be the total current, I1 be the current through R1, I2 be the current through R2 Then I1 = I * R2/(R1+R2); I2 = I * R1/(R1+R2)
3	**State division of voltage rule for a circuit with three resistors in series.(JUNE 2103)** BTL4 R1,R2and R3 are connected in series,Let V be the total voltage, V1 be the voltage across R1, V2 be the voltage across R2, V3 be the voltage across RThen, V1=V*R1/(R1+R2+R3),V2=V*R2/(R1+R2+R3) and V3=V*R3/(R1+R2+R3)

	
4	**Write down the formulae for converting Star to Delta.** BTL2  $R_{ab}=(R_aR_b+R_bR_c+R_cR_{a)}$ / R_c; $R_{bc}=(R_aR_b+R_bR_c+R_cR_{a)}$ / R_a; $R_{ca}=(R_aR_b+R_bR_c+RcR_{a)}$ / R_b
5	**Write down the formulae for converting Star to Delta.** BTL2  $R_a = (R_{ac}R_{ab})/(R_{ab}+ R_{bc}+ R_{ca})$; $R_b = (R_{ab}R_{bc})/(R_{ab}+ R_{bc}+ R_{ca})$; $R_c = (R_{ac}R_{bc})/(R_{ab}+ R_{bc}+ R_{ca})$
6	**Define Node and super node.** BTL1 A node is the point of connection of two or more branches. A super node is formed by enclosing a voltage source connected between two nodes.
7	**Define mesh and super mesh.** BTL1 A mesh is a loop, which does not contain any other loops within it. A super mesh results when two meshes have a current source in common.
8	**State Superposition theorem.** BTL1 The superposition theorem states that in any linear bilateral network containing two or more sources, the response in any element is equal to algebraic sum of the responses caused by individual sources acting alone, while the other sources are non-operative; that is, while considering the effect of individual sources, other ideal voltage sources and ideal current sources in the network are replaced by short circuit and open circuit across their terminals.

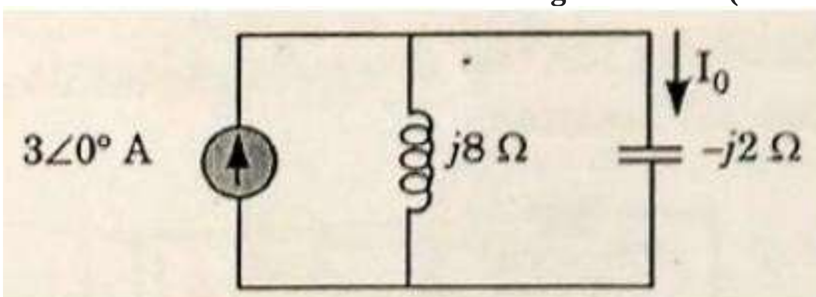
9	**State Thevenin's theorem .** BTL1 Thevenin’s theorem states that any circuit having a number of voltage sources, resistances and open output terminals can be replaced by a simple equivalent circuit consisting of a single voltage sourceVth in series with a resistance (impedance)Rth (Zth.). Where Vthis equal to the open circuit voltage across the two terminals Rth is equal to the equivalent resistance measured between the terminals with all energy sources are replaced by

	their internal resistance. 
10	**What is the limitation of superposition theorem.** BTL1 Super position theorem can be applied for finding the current through or voltage across a particular element in a linear bilateral circuit containing more than two sources. But this theorem cannot be used for the calculation of the power.
11	**State reciprocity theorem.(JUNE 2012,NOV 2013,MAY 2014,JUNE 2016,NOV2016)** BTL1 According to this theorem, In a linear, bilateral network if we apply some input to a circuit which consists of resistors, inductors, capacitors and transformers, the ratio of response in any element to the input is constant even when the position of input and output are interchanged. This is called the Reciprocity Theorem.
12	**State Maximum power transfer theorem. (or) What is the condition for maximum power transfer in DC and AC circuits(JUNE 2013, JUNE 2014, NOV 2014, JUNE 2015,JUNE 2016)** BTL1 According to maximum power transfer theorem, maximum power transfer occurs when RL = RTH, that is, when the load resistance is equal to the thevenin's resistance.
13	**Write the objectives of star delta transformation?(NOV 2013)** BTL1 The star delta transformation is useful in reducing the complexity of a circuit and converts it into simpler equivalent form without altering the current and voltage levels at its network terminals as in the original circuits.
14	**State Norton's theorem.** BTL1 Norton's theorem states that any circuit with voltage sources, resistances (impedances) and open output terminals can be replaced by a single current source Isc in parallel with single resistance Rth(impedance Zth.).Where Isc is equal to the current passing through the short circuit output terminals Rth is equal to the resistance seen into the output terminals with all energy sources are replaced by their internal resistance. 
15	**Where and why maximum power transfer theorem is applied.** BTL3 In a certain applications it is desirable to have a maximum power transfer from source to load. The maximum power transfer to load is possible only if the source and load has matched impedance. Eg: TV/Radio receiver

16	**A 1V Voltage source has an internal resistance of 1Ω, Calculate the Maximum power that can be delivered to any load.** BTL3 Maximum power transferred to the load = $V_s^2 R_L / (R_s + R_L)^2 = ¼ = 0.25$ W.

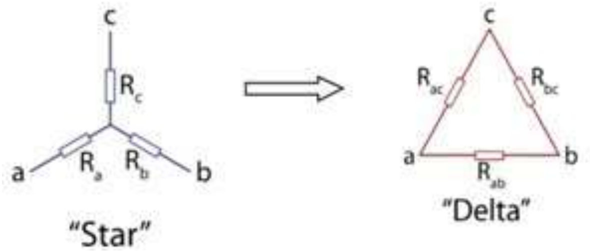
17	**What is source transformation?** BTL1 Source transformation is simplifying a circuit solution, especially with mixed sources, by transforming a voltage into a current source, and vice versa
18	**A 10A current source has a source resistance of 100Ω. What will be the equivalent voltage source?** BTL4 Ans:V=IR=10*100=1000V
19	**Determine the voltages V1 and V2 in the circuit shown in fig.** BTL4  $V_1 = 10 \times \frac{5}{(5+5)} = 5\text{ V}$ $V_2 = 10 \times \frac{5}{(5+5)} = 5\text{ V}$
20	**What is the equivalent resistance across A – B in the network shown in figure?** BTL2  $R_{AB} = 5 + \frac{3\times 6}{3+6} = 7\Omega$
21	**List the applications of Thevenin's theorem. (NOV 2015)** BTL1 It is useful for power system fault current calculation. It is used in transmission line calculation.
22	**Calculate the value of Norton's current (IN)for the circuit shown in Fig. (NOV 2014)** BTL3  $I_N = \frac{12}{120} = 0.1\text{A}$
23	**Two resistors of 4 Ω and 6 Ω are connected in parallel. If the total current is 30A. Find the current through each resistor shown in below fig. (NOV 2015)** BTL4  Current through 4Ω, $I_4 = I_T * \frac{R_6}{R_4 + R_6} = 30\times \frac{6}{6+4} = 18\text{ A}$ Current through 6Ω, $I_6 = I_T * \frac{R_4}{R_4 + R_6} = 30\times \frac{4}{6+4} = 12\text{ A}$

24	**Write briefly about network reduction technique. (JUNE 2015)** BTL1 In network analysis the number of components can be reduced to simplify the network. This can be done by replacing the actual components with other notional components that have the same effect. A particular technique might directly reduce the number of components, for instance by combining impedances in series. On the other hand it might merely change the form into one in

	which the components can be reduced in a later operation.
25	**Is reciprocity theorem applied to the circuit having resistors, capacitors and diodes? Give your reason.** BTL3 No. Reciprocity theorem is applicable only for linear circuits.
26	**A load of 5Ω each is to be converted in to an equivalent delta connected load, Find the resistance to be used.(APRIL 2017)** BTL4 Each resistance in the delta connected load should be 3R, i.e., **15Ω** each.
27	**A load is connected to a network of the terminals to which load is connected,Rth=10Ω and Vth=40V.Calculate the maximum power supplied to the load.(APRIL 2017)** BTL4 For maximum power to be transferred to the load, the value of RL=Rth.i,e., 10Ω Current through the load is 40/(10+10) = 2A. Maximum power to the load is I2R = (2)2 x 10 = **40Watts**
28	**Determine the value of current I0 of the given circuit.(NOV 2016)** BTL4  $I_o = 8j/(8j-2j)\times 3\angle 0^\circ$ $I_o = 4\angle 0^\circ$
	PART * B

1

i)Obtain the expression of equivalent star resistance in terms of delta resistance**.(MAY 2013)**



From the star N/W, equivalent resistance b/w a-b , b-c and c-a is given by,

$R_{a-b} = R_a + R_b$

$R_{b-c} = R_b+R_c$

$R_{c-a} = R_c + R_a$

Similarly from the delta N/W, equivalent resistance b/w a-b , b-c and c-a is given by,

$R_{a-b} = \frac{R_{ab}(R_{ac}+R_{cb})}{R_{ab}+R_{ac}+R_{cb}}$; $R_{b-c} = \frac{R_{bc}(R_{ab}+R_{ca})}{R_{ab}+R_{ac}+R_{cb}}$; $R_{c-a} = \frac{R_{ca}(R_{ab}+R_{bc})}{R_{ab}+R_{ac}+R_{cb}}$;

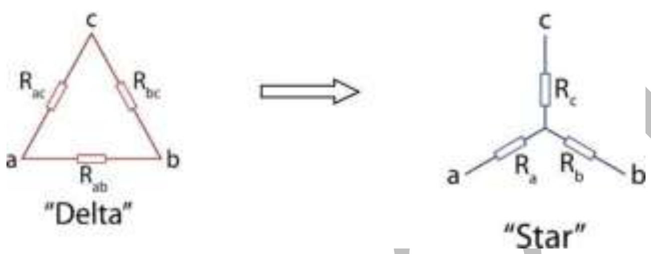
Equating the resistance between the terminals a-b, b-c, c-a in both star and delta N/W, we have,

$R_a + R_b = \frac{R_{ab}(R_{ac}+R_{cb})}{R_{ab}+R_{ac}+R_{cb}}$; $R_b + R_c = \frac{R_{bc}(R_{ab}+R_{ca})}{R_{ab}+R_{ac}+R_{cb}}$; $R_c + R_a = \frac{R_{ca}(R_{ab}+R_{bc})}{R_{ab}+R_{ac}+R_{cb}}$

Knowing the values of star connected N/W the equivalent delta connected N/w can be found out by multiplying and adding above combination of equations and get the delta connected resistance values as follows:

$R_{ab} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_c}$; $R_{ca} = \frac{R_a R_b + R_b R_c + R_c R_a}{R_b}$; $R_{bc} = \frac{R_a R_b + R_b R_c + R_c R_A}{R_a}$

ii)Obtain the expression of equivalent delta resistance in terms of star resistance.



From the delta N/W, equivalent resistance b/w a-b , b-c and c-a is given by,

$R_{a\text{-}b} = \frac{R_{ab}(R_{ac}+R_{cb})}{R_{ab}+R_{ac}+R_{cb}}$; $R_{b\text{-}c} = \frac{R_{bc}(R_{ab}+R_{ca})}{R_{ab}+R_{ac}+R_{cb}}$; $R_{c\text{-}a} = \frac{R_{ca}(R_{ab}+R_{bc})}{R_{ab}+R_{ac}+R_{cb}}$;

Similarly, from the star N/W, equivalent resistance b/w a-b , b-c and c-a is given by,

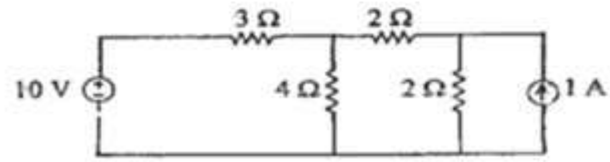
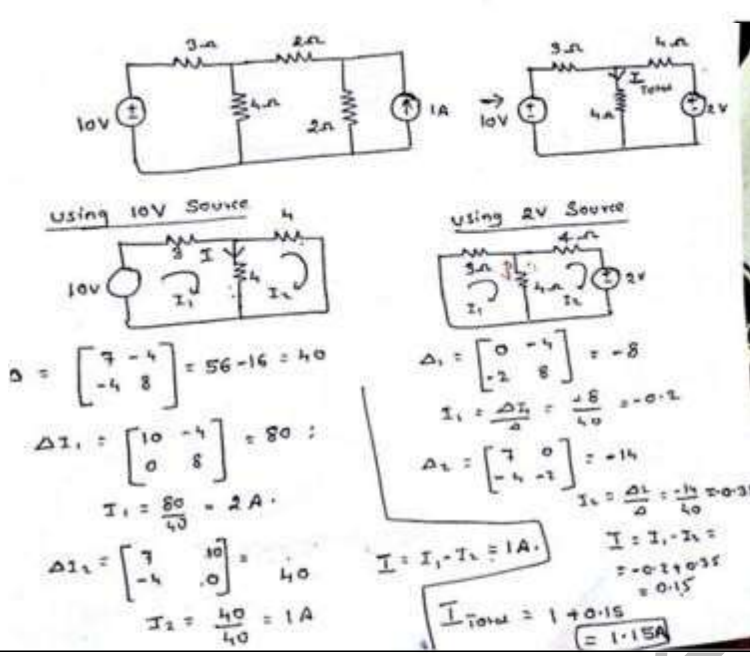
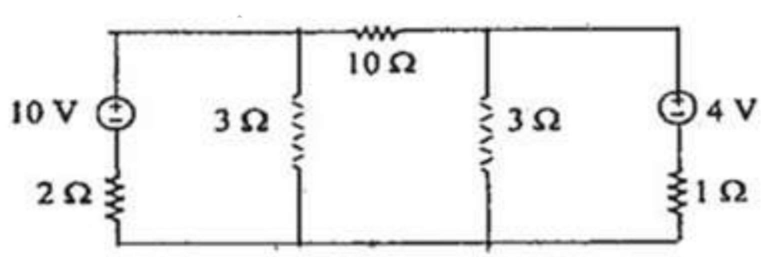
$R_{a\text{-}b} = R_a + R_b$

$R_{b\text{-}c} = R_b + R_c$

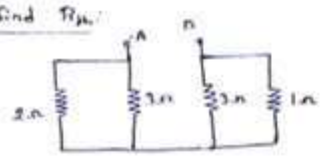
$R_{c\text{-}a} = R_c + R_a$

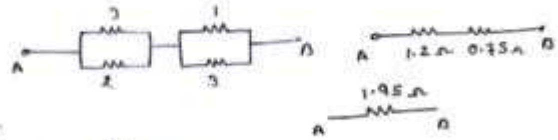
Knowing the values of Delta connected N/W the equivalent Star connected N/w can be found out by adding and multiplying above combination of equations and get the delta connected resistance values as follows:

$R_a = R_{ab} \times R_{ca}$; $R_b = R_{ab} \times R_{bc}$; $R_c = R_{ca} \times R_{bc}$

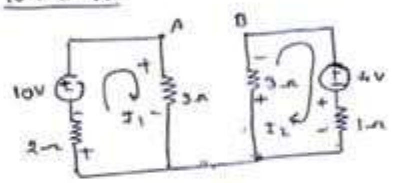
	$R_{ab}+ R_{bc} + R_{ca}$ $R_{ab}+ R_{bc} + R_{ca}$ $R_{ab}+ R_{bc} + R_{ca}$
2	Calculate the current in the 4 Ω resistor using superposition theorem.**(MAY 2014)**  
3	(i) For the circuit shown below (i) using Thevenin's theorem, find the current in the 10 ohm resistor. (**MAY 2014)** 

To find R_{th}:





To find V_{th}:

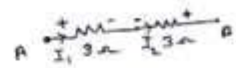


$-3I_2 - 4 - 1I_2 = 0$

$I_2 = -1$

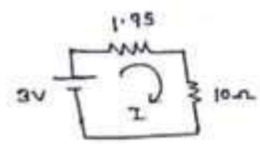
$I_1 = \frac{10}{5} = 2A$;

∴ Voltage Across AB =



$(2\times3 - 1\times3)$

$6 - 3 = 3V.$

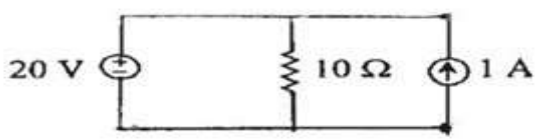


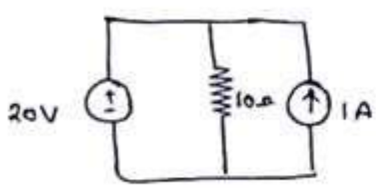
Current through 10Ω is

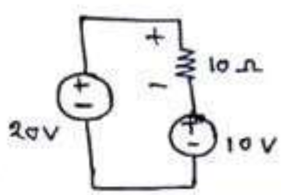
$I = \frac{V}{R} = \frac{3}{11.95} = 0.25A$

$\boxed{\text{Ans } I = 0.25A}$

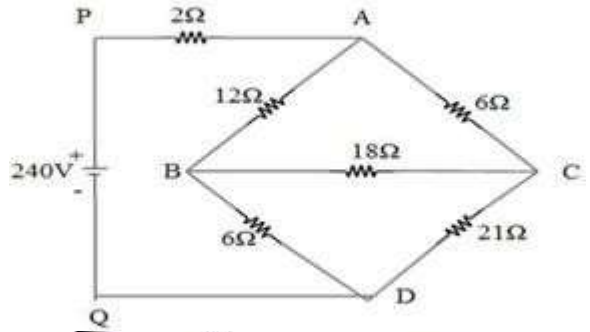
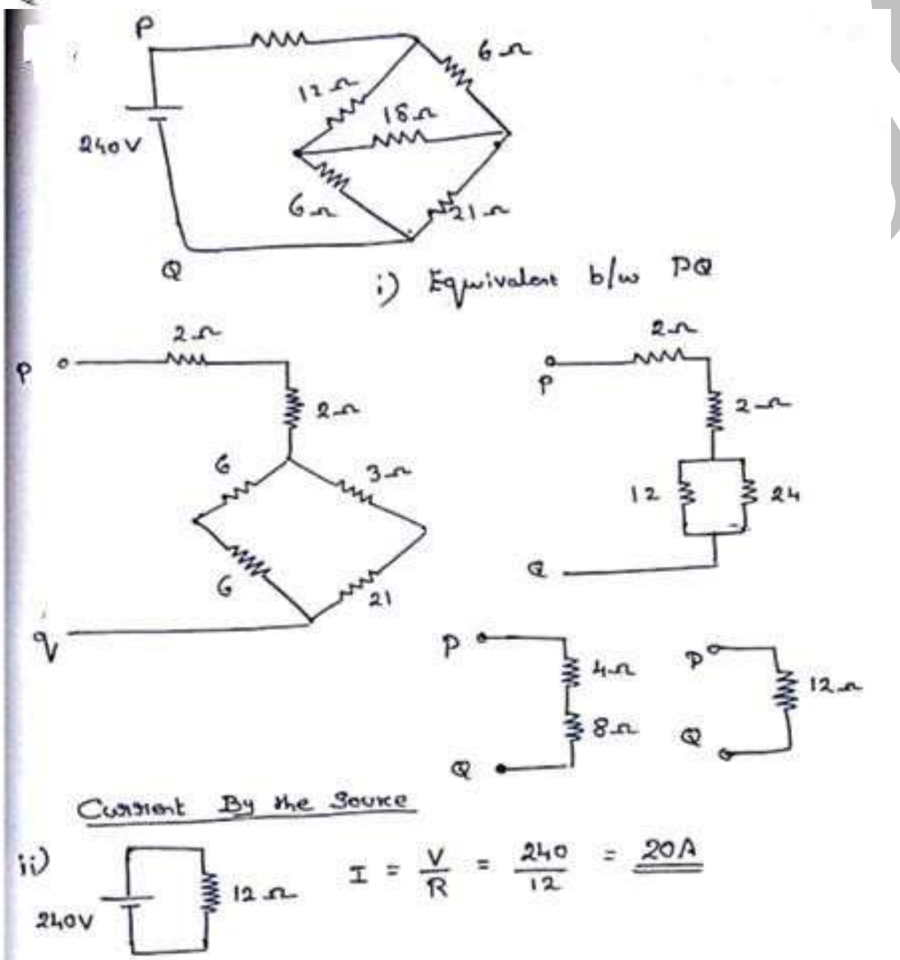
ii) Determine the current through the 20V source in the circuit given below



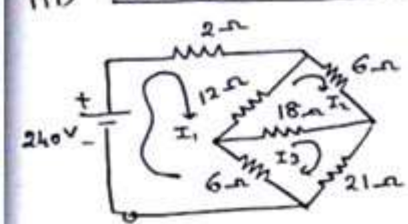




$20 - 10I - 10 = 0$; $\boxed{I = \frac{10}{10} = 1A}$

4	(i)Using star delta transformation, in the following wheat stone bridge circuit of figure, find(i)equivalent resistance between P and Q(ii) the total current and (iii) the current through the 18Ωresistor  

iii) Current through 18Ω



Current through 18Ω resistor $= I_2 - I_3$

$$\begin{bmatrix} 20 & -18 & -6 \\ -18 & 36 & -18 \\ -6 & -18 & 45 \end{bmatrix}$$

$$\Delta = 20[1620-324] + 18[-810-108] - 6[324+216]$$
$$= 25920 - 16524 - 3240$$
$$\boxed{\Delta = 6156}$$

$$\Delta I_3 = \begin{bmatrix} 20 & -18 & 240 \\ -18 & 36 & 0 \\ 6 & -18 & 0 \end{bmatrix} = 240[324-216] = 25920$$

$$\boxed{I_3 = \frac{\Delta I_2}{\Delta} = \frac{25920}{6156} = 4.21\text{ A}}$$

$$\Delta I_2 = \begin{bmatrix} 20 & 240 & -6 \\ -18 & 0 & -18 \\ 6 & 0 & 45 \end{bmatrix} = -240[-810+108]$$
$$= -702(-240)$$
$$= 168480$$

$$\boxed{I_2 = \frac{168480}{\Delta} = 27.36\text{A}}$$

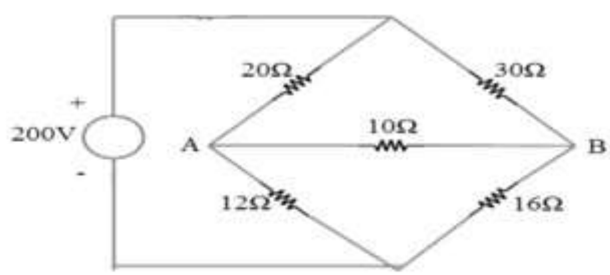
$\therefore$ Current through 18Ω

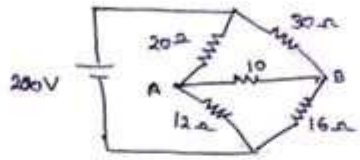
$= I_2 - I_3$

$= 27.36 - 4.21$

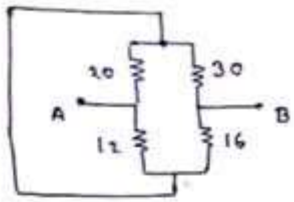
$\boxed{\text{Ans} = 23.15\text{A}}$

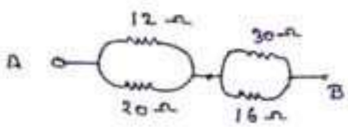
(ii) Find the current through the 10Ω resistor using Thevenin's theorem. (**NOV/DEC 2013)**

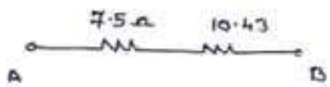


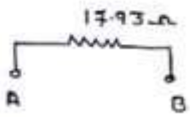


To find R_{th}:



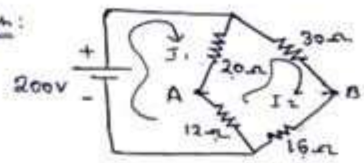






$\boxed{R_{th} = 17.93\,\Omega}$

To find V_{th}:



Open Circuit Voltage across AB is potential drop across $12\Omega + 20\Omega$ (or) $30\Omega + 16\Omega$

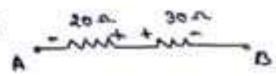
$$\Delta = \begin{bmatrix} 32 & -32 \\ -32 & 78 \end{bmatrix} = 2496 - 1024 = 1472$$

$$\Delta_1 = \begin{bmatrix} 200 & -32 \\ 0 & 78 \end{bmatrix} = 15600 \qquad I_1 = \frac{\Delta_1}{\Delta} = \frac{15600}{1472} = 10.59\text{ A.}$$

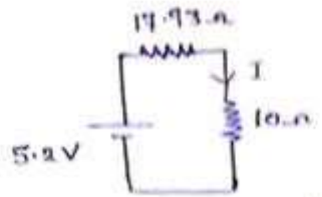
$$\Delta_2 = \begin{bmatrix} 32 & 200 \\ -32 & 0 \end{bmatrix} = 6400 \qquad I_2 = \frac{\Delta_2}{\Delta} = \frac{6400}{1472} = 4.34\text{ A}$$

Current through 20Ω and 12Ω is $I_1 - I_2 = 10.59 - 4.34 = 6.25\text{A}$.

Open Ckt Voltage $= -6.25 \times 20 + 30 \times 4.34 = -125 + 130.2$



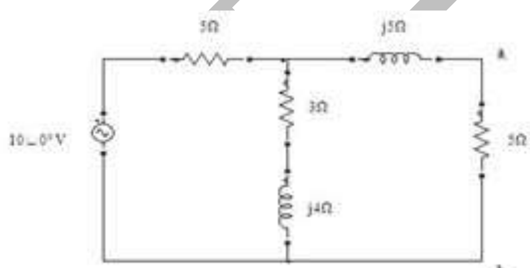
$$\boxed{V_{AB} = 5.2V}$$



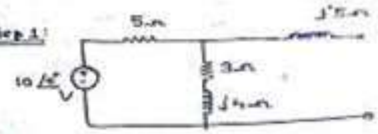
$$I = \frac{V}{R} = \frac{5.2}{27.93} = 0.186$$

$$\boxed{I \text{ through } 10\Omega = 0.186A}$$

5 Find the current through branch a-b of the network shown in fig.using Thevenin's theorem**. (MAY2013)**



Step 1:



Step 2: Obtain the Voltage across open ckt.

Apply KVL $-5I - 3I - j4I + 10 = 0$

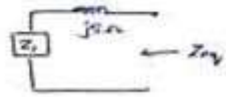
$$-I(8+j4) = -10$$

$$I = \frac{10\angle 0^\circ}{(8+j4)} = \frac{10\angle 0^\circ}{8.94\angle 26.56} = 1.118\angle -26.56^\circ \text{ A}$$

$$V_{TH} = I \times (3+j4) = (1.118\angle -26.56) \times (5\angle +53.13^\circ)$$

$$= 5.59\angle 26.56^\circ \text{ V}$$

$$Z_{eq} = (5) \| (3+j4)$$



$$= 2.5 + j1.25\Omega$$

$$Z_{eq} = 2.5 + j6.25\Omega$$

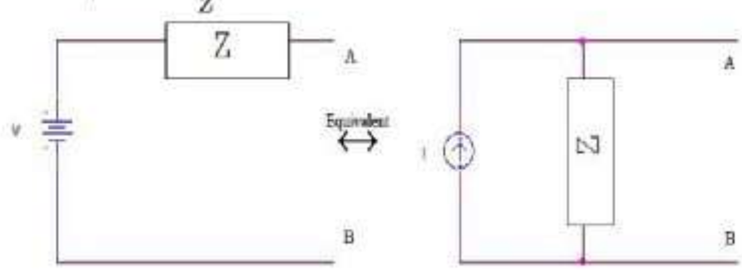
$$I = \frac{V_{TH}}{5 + [Z_{eq}]} = \frac{5.59\angle 26.56}{5 + 2.5 + j6.25} = 0.5725\angle -13.24^\circ \text{ A}$$

6

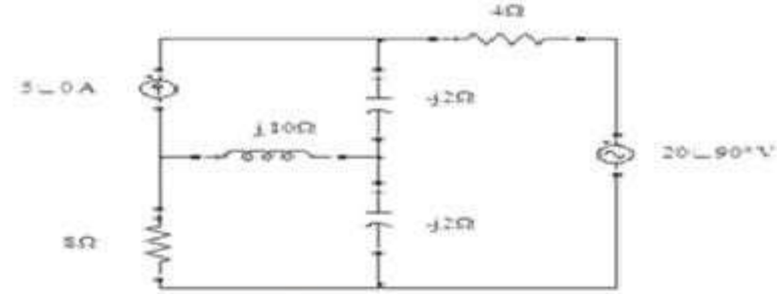
(i) Explain the source transformation technique.

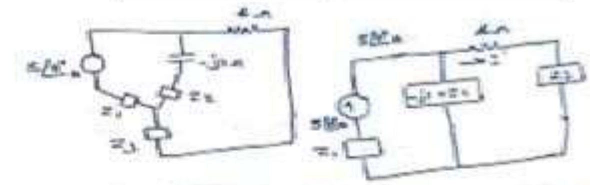
Source transformation is simplifying a circuit solution, especially with mixed sources, by transforming a voltage into a current source, and vice versa. Source transformation is an application of Thévenin's theorem and Norton's theorem. Performing a source transformation consists of using Ohm's law to take an existing voltage source in series with a resistance, and replace it with a current source in parallel with the same resistance.

$$V = I \cdot Z, \qquad I = \frac{V}{Z}$$



(ii) Use the superposition theorem to find the current through 4Ω resistor in the circuit shown in fig. **(MAY 2013)**

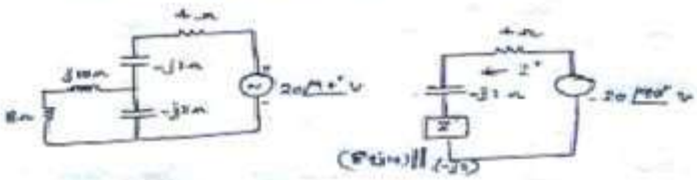




$$I = \frac{5\angle 0° \times 34.595\angle -13.491}{63} = 2.5966\angle -13.961°$$

$$= 2.6x1 - j1.1262\ A$$

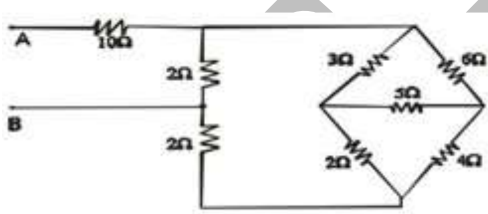
Consider $20\angle 90°$ source open $5\angle 0°$ A source

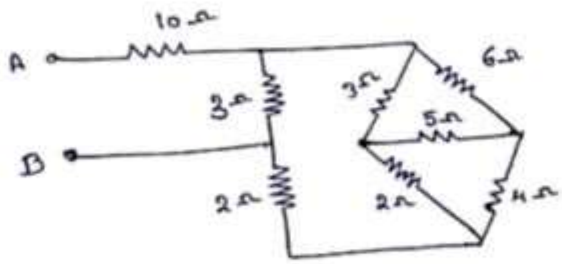


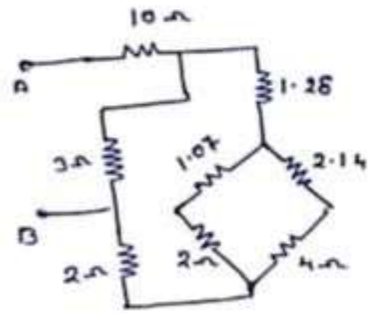
$$I'' = -2.3530 + j2.3530\ A$$

$$I_{4\Omega} = 5 - j3.5294 = 6.12\angle -35.21°\ A$$

7 Find the equivalent resistance between A& B of the circuit shown in the fig.



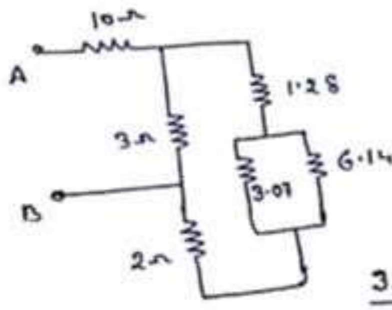




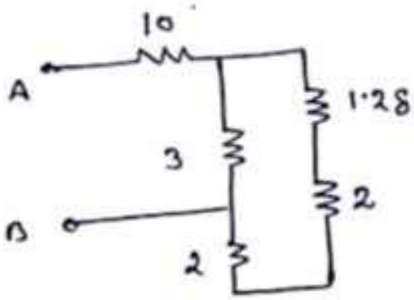
$$\frac{3\times 6}{14} = \frac{18}{14} = 1.28$$

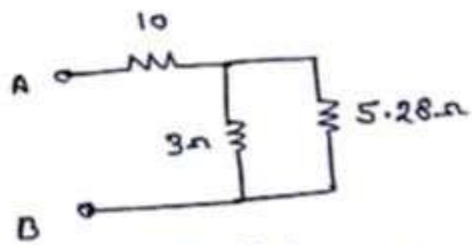
$$\frac{6\times 5}{14} = \frac{30}{14} = 2.14$$

$$\frac{5\times 3}{14} = \frac{15}{14} = 1.07$$

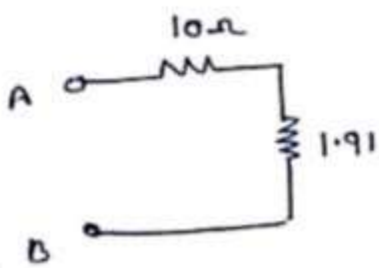


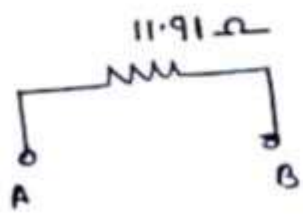
$$\frac{3\times 6.14}{9.14} = 2$$



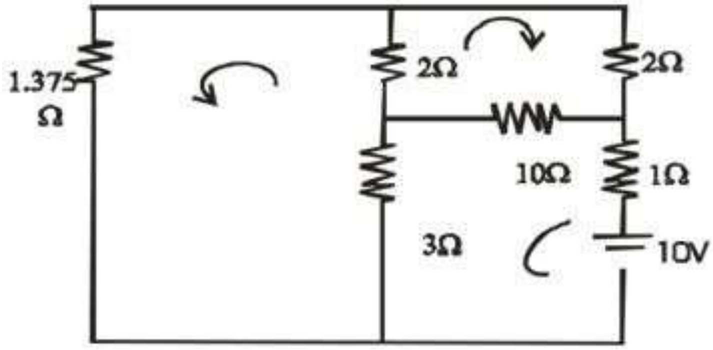


$$\frac{5.28\times 3}{8.28} = 1.91$$





8	i)In the circuit find I_3 and verify the reciprocity theorem.



Step 1: we find I_3.

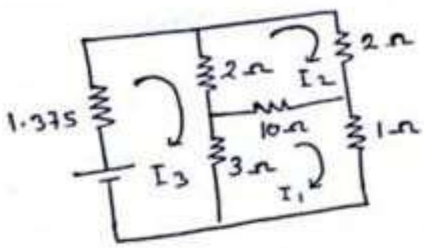
$$\begin{bmatrix} 14 & 10 & -3 \\ 10 & 14 & 2 \\ -3 & 2 & 6.375 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 10 \\ 0 \\ 0 \end{bmatrix}$$

$\Delta = 310$

$I_3 = \frac{\Delta_3}{\Delta} = \frac{620}{310} = 2A \longrightarrow (1)$

Step 2:

Similarly we replace 10V in I_3 loop and find I_1



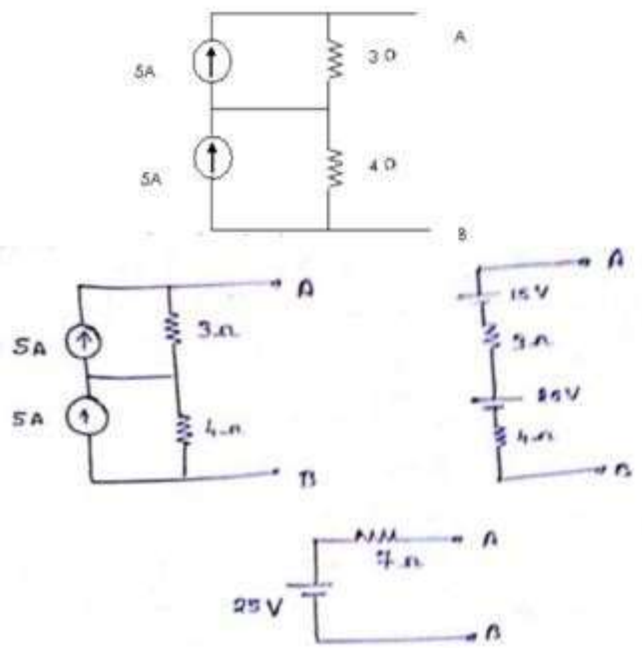
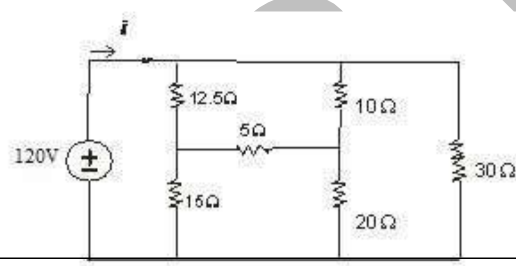
$$\Delta_1 = \begin{bmatrix} 0 & 10 & -3 \\ 0 & 14 & 2 \\ -10 & 2 & 6.375 \end{bmatrix}$$

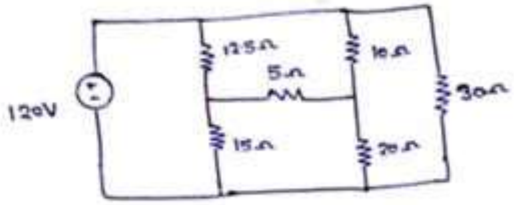
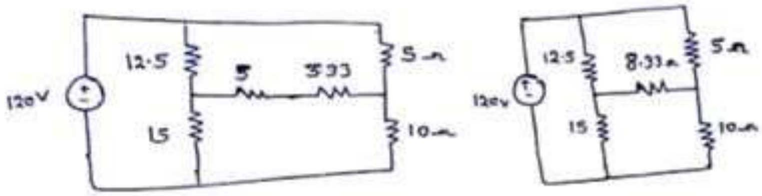
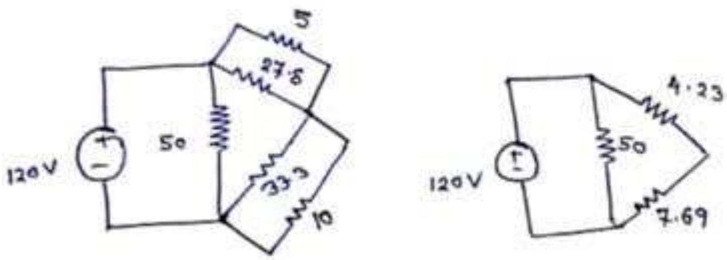
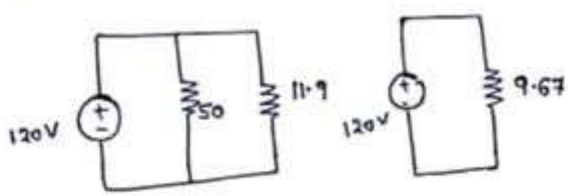
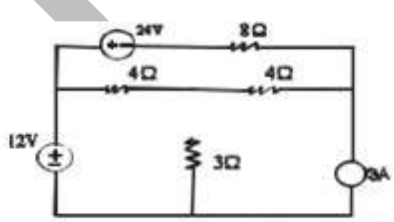
$\Delta_1 = -620$

$I_1 = \frac{\Delta_1}{\Delta} ; = \frac{-620}{310} = -2A \longrightarrow (2)$

From (1) & (2) Reciprocity theorem is Verified.

ii) Convert the circuit show in Fig. to single voltagesource with series resistance

	
9	Obtain the equivalent resistance R_{ab} and then find the current i for Figure given. 

	    $I = \frac{V}{R} = \frac{120}{9.67} = 12.4A.$
10	Use the Superposition theorem to find i for figure given 

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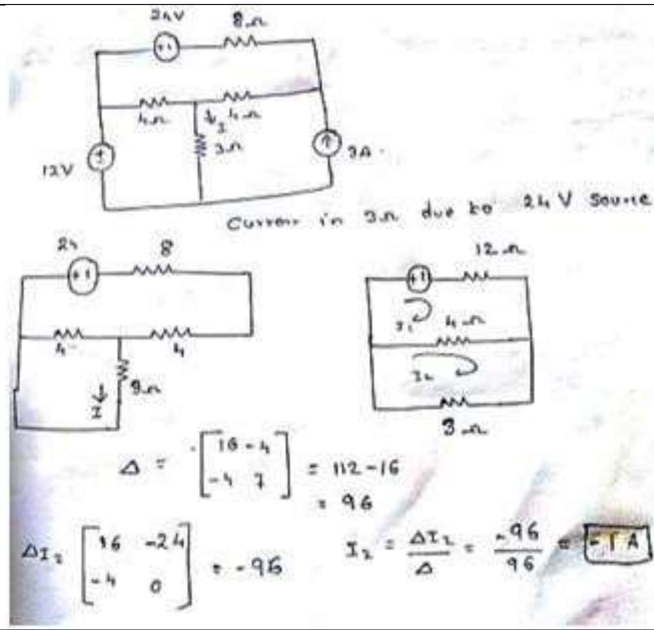
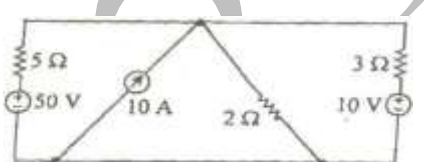
<tr><td></td><td>
</td></tr>
<tr><td></td><td>PART * C</td></tr>
<tr><td>1</td><td>(i) Using source transformation, replace the current source in the circuit shown below by a voltage source and find the current delivered by the 50V voltage source. (DEC 2012)

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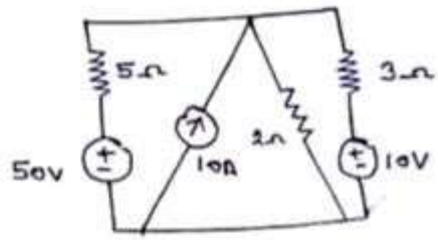
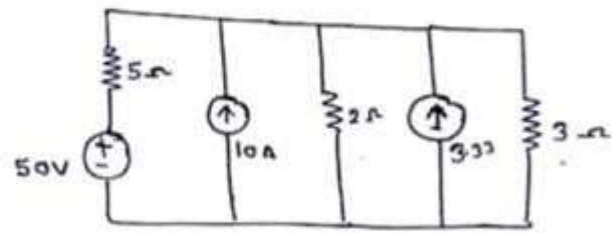
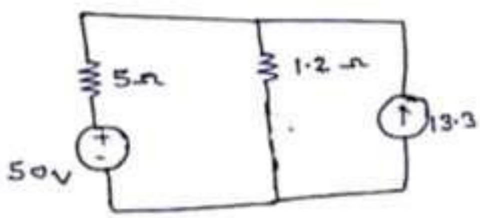
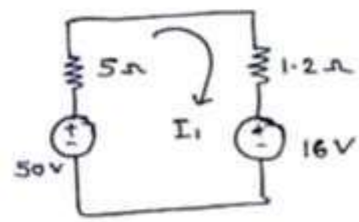






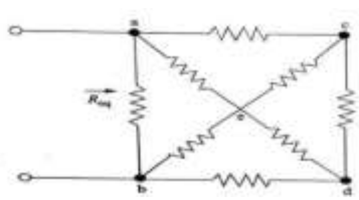


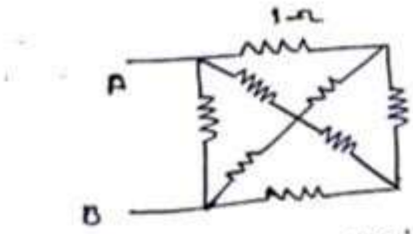
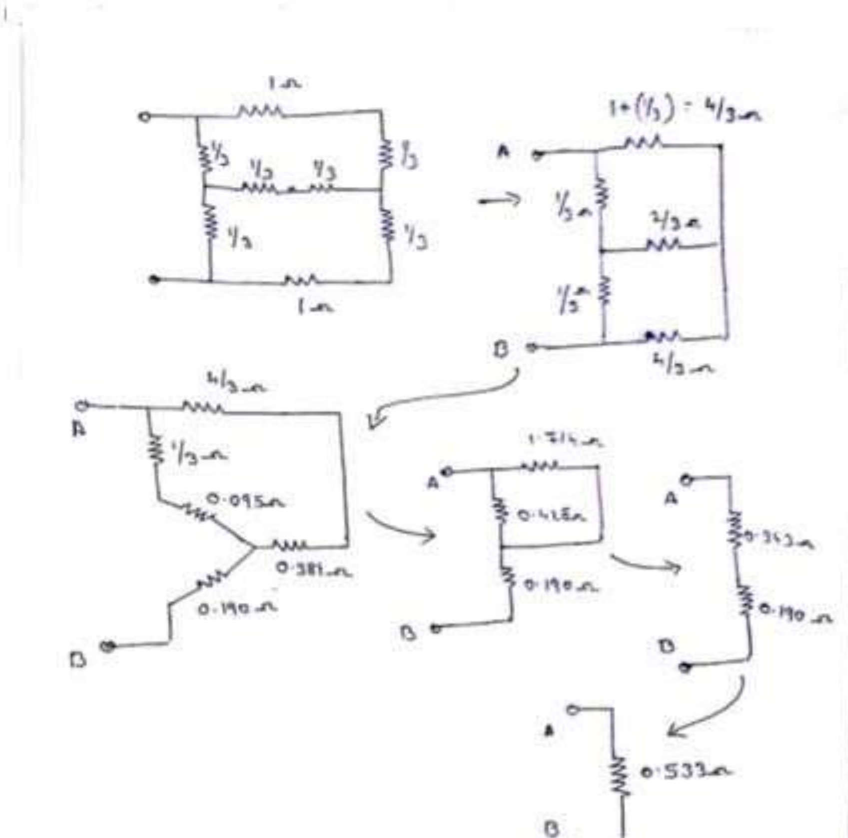
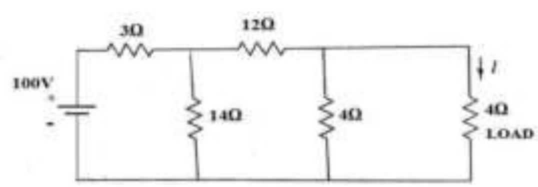
Let the Current Delivered by 50V be I_1

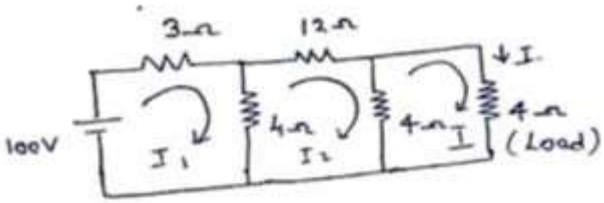
$$50 - 5I_1 - 1.2I_1 - 16 = 0$$

$$34 = 6.2I_1 \; ; \quad I_1 = \frac{34}{6.2} = \boxed{5.48\text{ A}}$$

(iii)Calculate the equivalent resistance R_{ab} when all the resistance values are equal to 1Ω forthecircuit shown below.**(DEC 2012)**



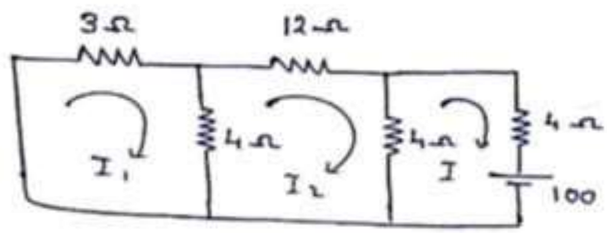
	 All are 1Ω The value of all resistance is 1Ω, the equivalent star for the delta is $R_1 = R_2 = R_3 = \frac{1\times1}{1+1+1} = \frac{1}{3}\,\Omega$ 
2	(i) Verify Reciprocity theorem for the circuit shown below.**(DEC 2012)** 



$$\Delta = \begin{bmatrix} 7 & -4 & 0 \\ -4 & 20 & -4 \\ 0 & -4 & 8 \end{bmatrix} = 7[160+16] + 4[-32]$$
$$= 1232 - 128 = 1104$$

$$\Delta_I = \begin{bmatrix} 7 & -4 & 100 \\ -4 & 20 & 0 \\ 0 & -4 & 8 \end{bmatrix} = 100[16] = 1600$$

$$|I| = \frac{\Delta I}{\Delta} = \frac{1600}{1104} = 1.44$$

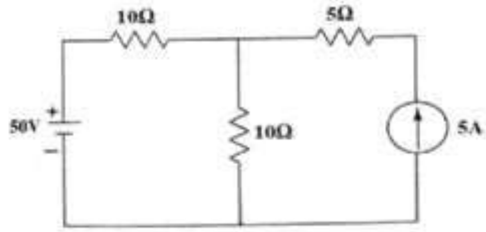


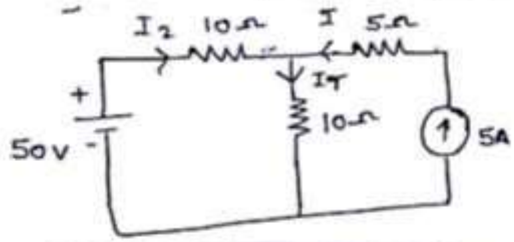
$$\Delta_{I_1} = \begin{bmatrix} 0 & -4 & 0 \\ 0 & 20 & -4 \\ -100 & -4 & 8 \end{bmatrix} = 4[-400] = -1600$$

$$|I_1| = \frac{\Delta I_1}{\Delta} = \left|\frac{-1600}{1104}\right| = \boxed{1.44}$$

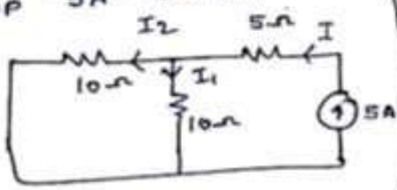
We find $|I| = |I_1|$

4. Find the current through various branches of the circuit shown below, by employing superposition theorem.**(DEC 2012)**





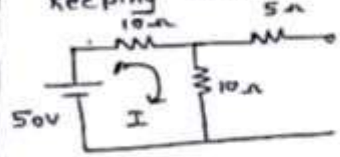
Keeping 5A Source.



$I_1 = \frac{1\cancel{0}}{2\cancel{0}} \times 5 = 2.5A$

$I_2 = 2.5A$

Keeping 50V

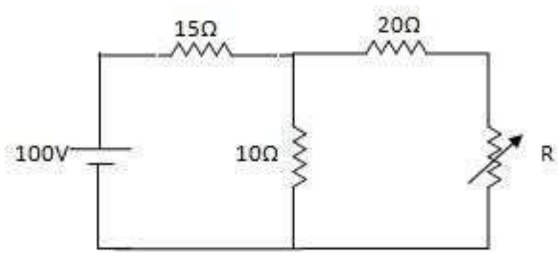


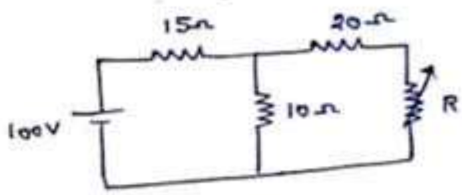
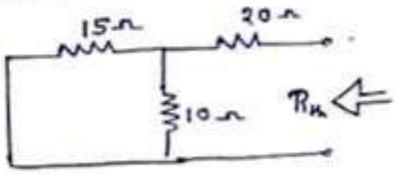
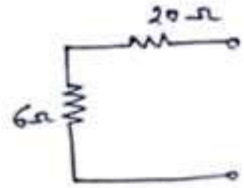
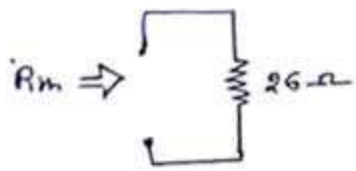
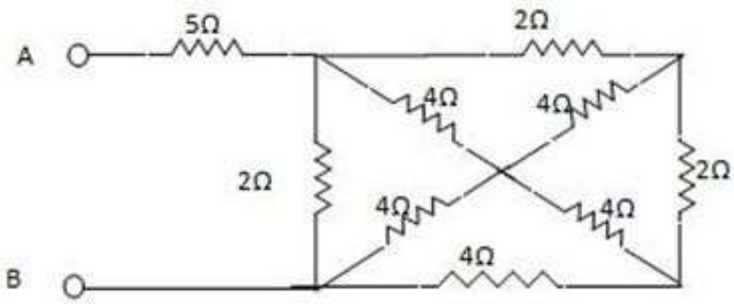
$I = \frac{50}{20} = \frac{5}{2} = 2.5A$

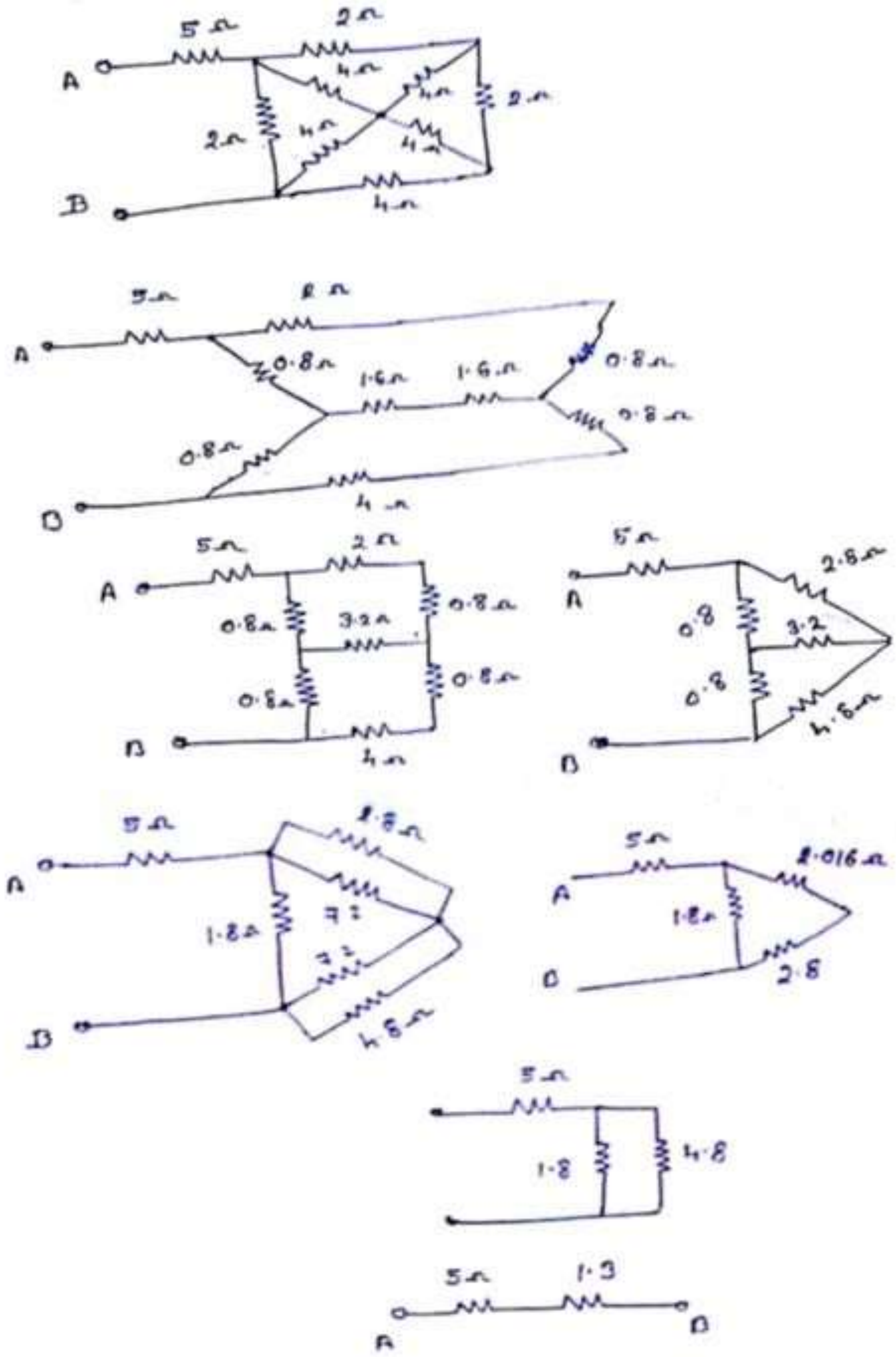
Current $I_T = I + I_2 = 2.5 + 2.5 = 5$

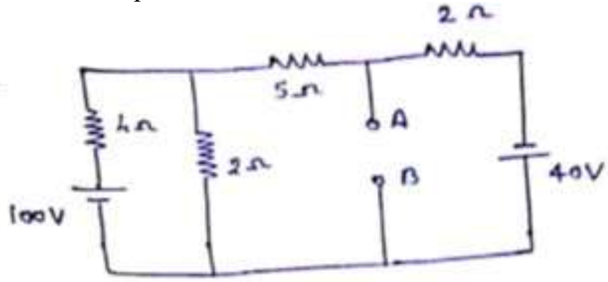
$\boxed{I_T = 5A}$

3 In the circuit shown in fig below, find the value of adjustable resistor R for maximum powertransfer to R.Also calculate the maximum power. **(MAY 2012)**



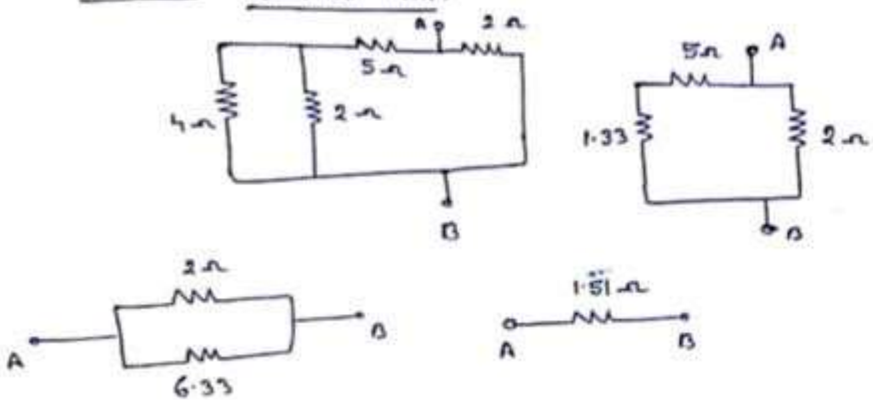
	 For maximum Power Transfer R should be equal to Rth.   $\frac{15\times10}{25} = \frac{150}{25} = 6$ 
4	Use delta – star conversion to find resistance between terminals A and B of the circuit shown in fig.**(MAY 2012)** 


5 Ω
2 Ω
A
B
4 Ω
2 Ω
0.8 Ω
1.6 Ω
3.2 Ω
2.8 Ω
4.8 Ω
7.2
1.8 Ω
2.016 Ω
2.8
1.8
4.8
1.3

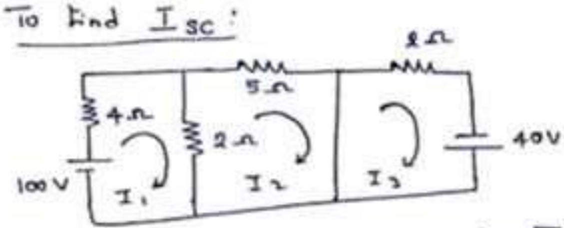
5	Find the Norton's equivalent circuit for the network shown in the figure. 

To find Nortons Equivalent across AB

Step 1: To find R_{th}.



Step 2:
To find I_{sc}:



$$I_{sc} = I_2 - I_3$$
$$= 5.26 - 20$$
$$= -14.74$$

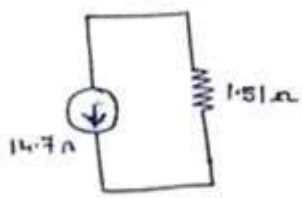
$$\begin{bmatrix} 6 & -2 & 0 \\ -2 & 7 & 0 \\ 0 & 0 & 2 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix} = \begin{bmatrix} 100 \\ 0 \\ 40 \end{bmatrix}$$

$\Delta = 76$; $\Delta_2 = 400$; $\Delta_3 = 1520$

$I_2 = \dfrac{\Delta_2}{\Delta} = 5.26A$

$I_3 = 20A$

Nortons Equivalent



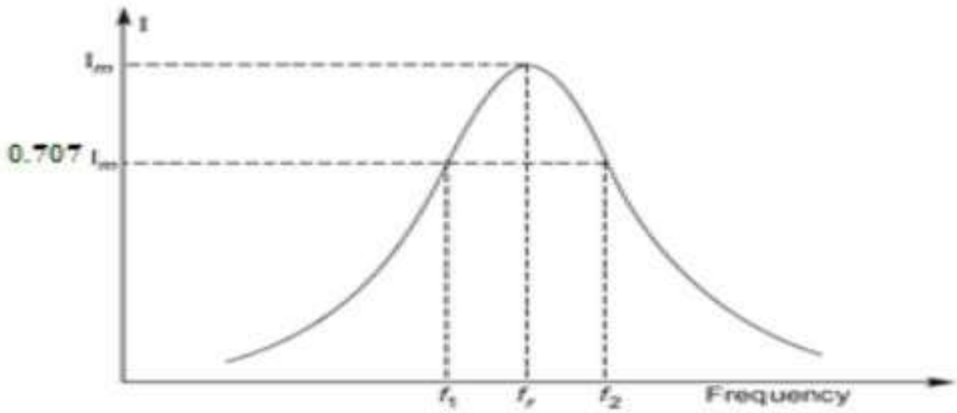
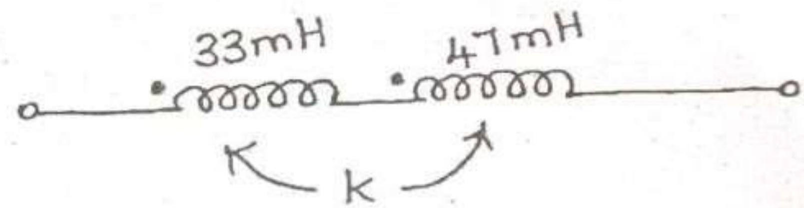
UNIT III - RESONANCE AND COUPLED CIRCUITS
Resonance - Series resonance - Parallel resonance - Variation of impedance with frequency –Variation in current through and voltage across L and C with frequency – Bandwidth - Q factor -Selectivity. Self-inductance - Mutual inductance - Dot rule - Coefficient of coupling - Analysis of multilinking coupled circuits - Series, Parallel connection of coupled inductors - Single tuned and double tuned coupled circuits.
PART * A

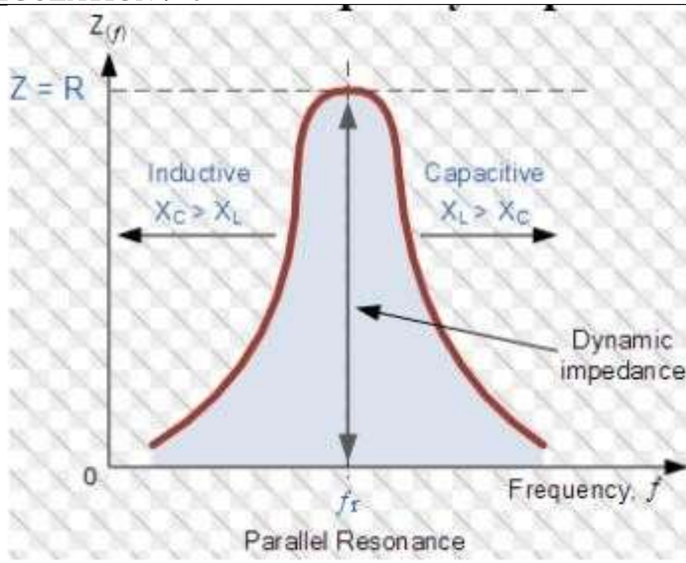
Q.No.	Questions

1.	**Define Impedance.**BTL1 Impedance is defined as the opposition of circuit to flow of alternating current. It is denoted by Z and its unit is ohms.
2	**Define Resonance.** BTL1 Resonance is defined as a phenomenon in which applied voltage and resulting current are in-phase. In other words, an AC circuit is said to be in resonance if it exhibits unity power factor condition, that means applied voltage and resulting current are in phase.
3	**Define Q - factor or Figure of Merit, Q.(MAY 2014)** BTL1 The quality factor, Q of a resonant circuit is the ratio of its resonant frequency to its bandwidth. The Q - factor of a circuit can also be defined as, $Q = 2\pi \times \frac{\text{Maximum energy stored in the circuit}}{\text{Energy dissipated per cycle in the circuit}}$
4	**What are the resonant conditions?** BTL1 (i)The total impedance Z is minimum and is equal to R. (ii) The circuit will be purely resistive circuit.(iii) Power factor of the circuit is unity. iv) Circuit element, Imax= V/R. v)Power at resonance, Pr=I2R
5	**What is a parallel resonance?** BTL1 The parallel circuit is said to be in resonance, when the power factor is unity. This is true when the imaginary part of the total admittance is zero.
6	**Show that in a series RLC circuit, f1f2 = fr2 where fr is the resonant frequency and f1, f2 are the half power frequencies.** BTL4 $\omega_1 = -\frac{R}{2L} + \sqrt{\{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}\}}$, $\omega_2 = \frac{R}{2L} + \sqrt{\{\left(\frac{R}{2L}\right)^2 + \frac{1}{LC}\}}$ $\omega_1\omega_2 = \left(\frac{R}{2L}\right)^2 + \frac{1}{LC} - \left(\frac{R}{2L}\right)^2 = \frac{1}{LC} = \left(\frac{1}{\sqrt{LC}}\right)^2 = \omega_r{}^2$ Hence, $f_1 f_2 = f_r{}^2$
7	**What is the series resonance?** BTL1 The inductive reactance increases as the frequency increases (XL=ωL) but the capacitive reactance decreases with frequency (XC=1/ωc). Thus inductive and capacitive reactance has opposite properties. So, for any LC combination there must be one frequency at which XL=XC. This case of equal and opposite reactance is called **series resonance.**
8	**Define Bandwidth, half power frequencies?(JUNE 2013)** BTL1 The difference between the half power frequencies f1 and f2 at which power is half of its maximum is called **bandwidth** BW = f2-f1 **.**It can be observed that at two frequencies f1 and f2 the power is half of its maximum value. These frequencies are called **half power frequencies.** Out of the two half power frequencies, the frequency f2 is called **upper cut-off frequency** while the frequency f1 is called **lower cut-off frequency.**

9	**What are coupled circuits?** BTL1 The two circuits are said to be coupled circuits if all or part of the electrical energy supplied to one circuit is transferred to the other circuit, without having any electrical connection between them.

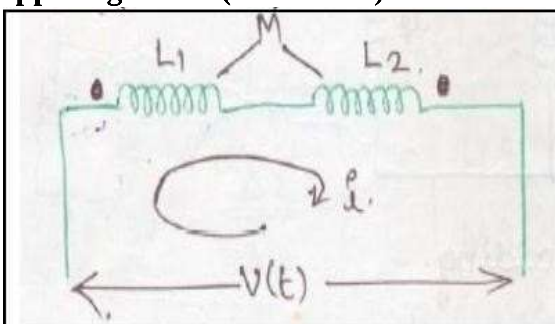
10	**What is meant by Mutual Induction?** BTL1 When two inductors (or coils) are in a close proximity to each other, the magnetic flux caused by current in one coil links with the other coil, thereby inducing voltage in the latter. This phenomenon is known as 'Mutual Induction'.M =N1ϕ12/i= N2ϕ12/i2
11	**Define Mutual Inductance, M.(JUNE 2015)** BTL1 Mutual Inductance is the ability of one inductor to induce a voltage across a neighboring inductor, measured in henrys (H).
12	**Write the total inductance of two coils connected in series aiding and opposing.** BTL2 Series - aiding connection :Leq = L1 + L2 + 2M Series - opposing connection :Leq = L1 + L2 - 2M
13	**Two inductively coupled coils have self - inductances L1 = 50 mH and L2 = 200 mH.If the coefficient of coupling is 0.5 (i) find the value of mutual inductance between the coils, and (ii) what is the maximum possible mutual inductance?** BTL3 (i)M = K $L1L2$ = 0.5 (ii) M is max when K=M = $L1L2$ = 50×10–3 × 200×10–3 =100 mH
14	**Define Coefficient of coupling, K.(JUNE 2012,NOV 20, NOV 2015,JUNE 2016)** BTL1 The fraction of the total flux produced by one coil linking a second coil is called the Coefficient of coupling, K. Thus, K = Φ12 / Φ1 = Φ21/ Φ2 K= M/√L1L2 Since Φ12< Φ1 or Φ21<Φ2.
15	**Two coils connected in series have an equivalent inductance of 0.4H when connected in aiding, and an equivalent inductance of 0.2H when the connection is opposite. Calculate the mutual inductance of the coils.** BTL3 Series aiding,Leq = L1 + L2 + 2M = 0.4----------------- (1) Series opposing,Leq = L1 + L2 - 2M = 0.2------------------ (2) Solving equations (1) and (2),4M = 0.2;**M = 0.05 H**
16	**State dot rule. (JUNE 2015)** BTL2 The sign of the mutual induced voltage depends on direction of the winding of the coil. For convenient, dot conventions are used for purpose of indicating direction of winding. **Rules for dot convention** If a current enters a dot in one coil, then mutually induced voltage is positive at the dotted end. If a current leaves a dot in one coil, then mutually induced voltage is negative at the dotted end.
17	**A coil of resistance 2Ω and an inductance 0.01H is connected in series with a capacitor across 220V mains. Find the value of capacitance such that maximum current flows in the circuit at a frequency of 190 Hz. Also find the maximum current. (NOV 2014)** BTL4 At resonance XL = XC, 2πfL =1/(2πfC), Capacitance, C = 70.16μF At resonance Z = R, Maximum Current, I = V/R = 100A
18	**Define self Inductance.** BTL1 The property of the coil which opposes any change in current passing through it is called self inductance of the coil. L = Nϕ/I
19	**What are the applications of tuned circuit? (JUNE 2013)** BTL1 Tuned circuits are used in communication systems, Radio receivers, in defence and etc.
20	**In a series RLC circuit, if the value of L and C are 100 mH and 0.1 μF, find the resonance frequency in Hz.(JUNE 2016)** BTL3 $f_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{(100mH*0.1\ \mu F)}} = 15935\ \text{Hz.}$
21	**Define quality factor of a series resonant circuit. (NOV 2014)** BTL1 Quality factor is the ratio of resonant frequency to bandwidth.

	$Q_0 = \frac{f_r}{BW}$
22	**Draw the frequency response of RLC series circuit.** BTL3 
23	**Calculate the total inductance of the circuit, if the coefficient of coupling (k) between the two coils is 0.6 as shown in fig. (NOV 2014)** BTL4  $M = K\sqrt{L_1 L_2} = 0.6\sqrt{33 \times 10^{-3} \times 47 \times 10^{-3}} = 0.023H$ $L_{eq} = L_1 + L_2 + 2M = 0.126H$
24	**Write the Significance of Quality factor? (DEC 2013)** BTL1 The relation between bandwidth and quality factor is Q=Resonant frequency/Bandwidth. This indicates a higher value of Q results in a smaller bandwidth and hence greater the selectivity. This indicates the resonant circuit responds to a certain frequency and eliminates all other frequency.
25	**Define Selectivity.(NOV 2015)** BTL1 Selectivity of a resonant circuit is defined as the ratio of bandwidth (BW) to the frequency at resonance (fr) of the circuit.
26	**Draw the frequency response characteristics of parallel resonant circuit.(NOV 2016)** BTL3



27

Determine the equivalent inductance of the circuit comprising two inductors in series opposing mode. (NOV 2016) BTL4



$L_1\frac{di}{dt}$ $-M\frac{di}{dt}$ $+L_2\frac{di}{dt}$ $-M\frac{di}{dt} = V(t)$

$(L_1 + L_2 - 2M)\frac{di}{dt} = V(t)$ -----------(1)

Let L_b be the equivalent inductance of the combination

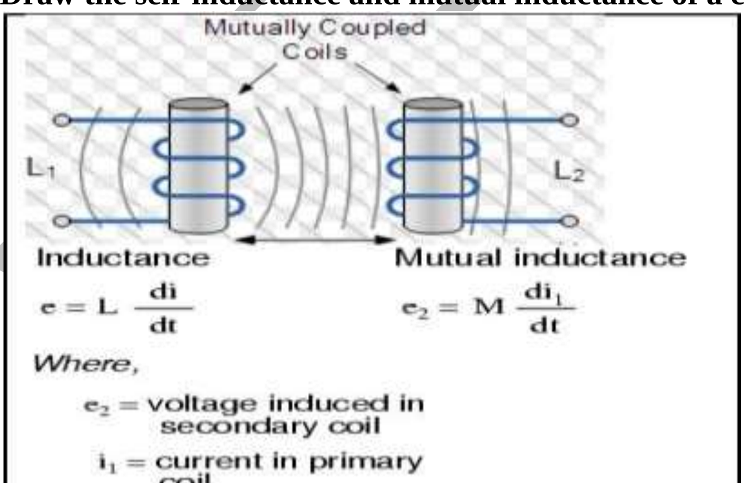
Then $L_b\frac{di}{dt} = V(t)$ -------------------(2)

Equating equation (1) and (2) we get

$L_b = L_1 + L_2 - 2M$

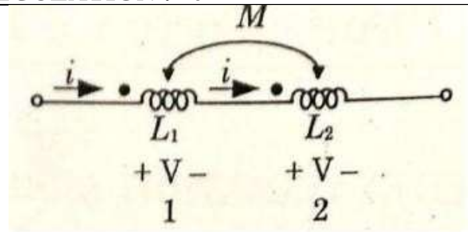
28

Draw the self-inductance and mutual inductance of a coil.(2017) BTL1



29

Given the circuit,What is the equivalent inductance of the system shown below,(April 2017) BTL3



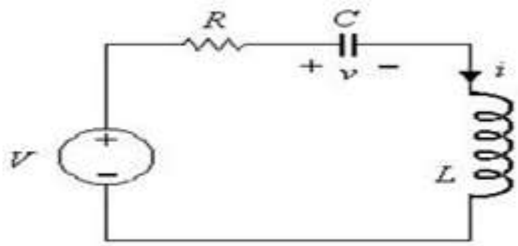
Solution: It's a series aiding circuit $L_{eq} = L_1 + L_2 + 2M$

PART * B

1

Explain in details about the step response of series RLC circuit.[AU-MAY-11][JUN-12].(13M)BTL3

Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao



In series RLC circuit, there are two energy storing element which are L and C, such a circuit give rise to second order differential equation and hence called second order circuit.

Consider a series RLC circuit shown in Figure. The switch is closed at t = 0 and a step voltage of V volts gets applied to circuit.

Apply KVL after switching we get

$$L\frac{di}{dt} + Ri + \frac{1}{C}\int i\,dt = V$$

As 'V' is step i.e., constant, differentiating both sides of above equation gives.

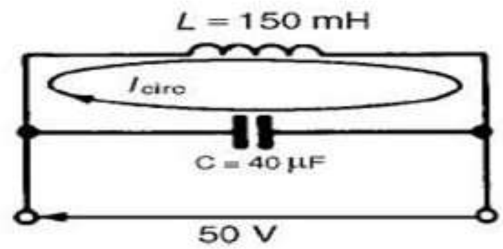
$$\frac{Ld^2i}{dt^2} + \frac{Rdi}{dt} + \frac{1}{C}i = 0$$

$$\frac{d^2i}{dt^2} + \frac{R}{L}\frac{di}{dt} + \frac{1}{CL}i0=$$

2

A pure inductance of 150 mH is connected in parallel with a 40 μF capacitor across a 50 V, variable frequency supply. Determine (a) the resonant frequency of the circuit and (b) the current circulating in the capacitor and inductance at resonance..(13M)BTL3

Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao



Parallel resonant frequency, fr = 1/2π (1/LC-R^2/$L^{2)}$ However, resistance R = 0. Hence,

fr = 1/2π√1/LC
1/2π √ (1/150 * $10^{-3(}$ 40 * $10^{-6)}$
1/2π√$10^{7/}$ 15*4)
10 $^{3/}$ 2π (1/6)
64.97 Hz
Current circulating in L and C at resonance, ICIRC = V/XC
V /1/2πfrC
= 2πfrCV
Hence ICIRC = 2π64.97*40 * 10^{-6} *50= **0.816 A**
Alternatively, ICIRC = V/XL
V/2πfrL
50/2π64.9*0.15
0.817 A

3

Compare the series and parallel resonant circuit.(consider practical parallel resonant circuit) .(10M)BTL3
Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao

Description	Series RLC circuit	Parallel RLC circuit
Impedance at resonance	Minimum	Maximum
Current at resonance	Maximum=$\frac{V}{R}$	Minimum= $\frac{VCR}{L}$
Effective impedance	R	$\frac{L}{CR}$
Power factor at resonance	Unity	Unity
Resonant frequency	$\frac{1}{2\pi\sqrt{LC}}$	$\frac{1}{2\pi\sqrt{\frac{1}{LC}-\frac{R^2}{L^2}}}$
It magnifies	Voltage	Current
Magnification is	$\frac{\omega oL}{R}$	$\frac{\omega oL}{R}$

4	**A series L–R–C circuit has a sinusoidal input voltage of maximum value 12 V. If inductance, L = 20 mH, resistance, R = 80 Ω, and capacitance, C = 400 nF, determine (a) the resonant frequency, (b) the value of the p.d. across the capacitor at the resonant frequency, (c) the**

frequency at which the p.d. across the capacitor is a maximum, and (d) the value of the maximum voltage across the capacitor.[AU-DEC-10].(13M)BTL3

Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao

(a) The resonant frequency.

$$f_r = \frac{1}{2\pi\sqrt{(LC)}} = \frac{1}{2\pi\sqrt{[(20\times10^{-3})(400\times10^{-9})]}}$$
$$= \mathbf{1779.4\ Hz}$$

(b) $V_C = QV$ and $Q = \frac{\omega_r L}{R}\left(\text{or } \frac{1}{\omega_r CR} \text{ or } \frac{1}{R}\sqrt{\frac{L}{C}}\right)$

Hence $Q = \frac{(2\pi 1779.4)(20\times10^{-3})}{80} = 2.80$

Thus $V_C = QV = (2.80)(12) = \mathbf{33.60\ V}$

(c) From equation (28.7), the frequency f at which V_C is a maximum value,

$$f = f_r\sqrt{\left(1-\frac{1}{2Q^2}\right)} = (1779.4)\sqrt{\left(1-\frac{1}{2(2.80)^2}\right)}$$
$$= \mathbf{1721.7\ Hz}$$

(d) From equation (28.9), the maximum value of the p.d. across the capacitor is given by:

$$V_{C_m} = \frac{QV}{\sqrt{\left[1-\left(\frac{1}{2Q}\right)^2\right]}} = \frac{(2.80)(12)}{\sqrt{\left[1-\left(\frac{1}{2(2.80)}\right)^2\right]}} = \mathbf{34.15\ V}$$

5 **A coil of inductance 5 mH and resistance 10 Ω is connected in parallel with a 250 nF capacitor across a 50 V variable-frequency supply. Determine (a) the resonant frequency, (b) the dynamic resistance, (c) the current at resonance, and (d) the circuit Q-factor at resonance..(13M)**BTL3

Answer: Page 1.81-1.86 –Prof.T.Nageswara Rao

	(a) Resonance frequency $$f_r = \frac{1}{2\pi}\sqrt{\left(\frac{1}{LC} - \frac{R^2}{L^2}\right)} \quad \text{from equation (29.3),}$$ $$= \frac{1}{2\pi}\sqrt{\left(\frac{1}{5\times10^{-3}\times250\times10^{-9}} - \frac{10^2}{(5\times10^{-3})^2}\right)}$$ $$= \frac{1}{2\pi}\sqrt{(800\times10^6 - 4\times10^6)} = \frac{1}{2\pi}\sqrt{(796\times10^6)} = \mathbf{4490\ Hz}$$ (b) From equation (29.4), dynamic resistance, $$R_D = \frac{L}{CR} = \frac{5\times10^{-3}}{(250\times10^{-9})(10)} = \mathbf{2000\ \Omega}$$ (c) Current at resonance, $I_r = \frac{V}{R_D} = \frac{50}{2000} = \mathbf{25\ mA}$ (d) Q-factor at resonance, $Q_r = \frac{\omega_r L}{R} = \frac{(2\pi 4490)(5\times10^{-3})}{10} = \mathbf{14.1}$
6	**Derive the relation between coefficient of coupling & the self inductance & mutual inductance.(JUNE 2013) (JUNE 2015)**

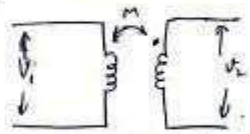
Self Inductance :-

$$L = N\frac{d\phi}{di}$$

Mutual Inductance between two coils N_1, N_2 carrying alternating currents i_1, i_2.

L_1, L_2 - self Inductances ; M - mutual Inductance

$$v_1 = \frac{L\,di_1}{dt} \quad \left(L_1 = \frac{N_1\phi_1}{i_1}\right)$$



v_{m2} - voltage induced in coil 2 due to coil 1.

$$v_{m_2} = M_{12}\frac{di_1}{dt} \quad \left(M_{12} = \frac{N_2\phi_{12}}{i_1}\right)$$

$$|||^{ly} \quad v_{m_1} = M_{21}\frac{di_2}{dt} \quad \left(M_{21} = \frac{N_1\phi_{21}}{i_2}\right)$$

Co-efficient of Coupling :-

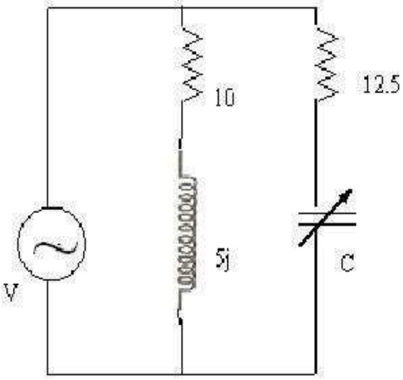
$$k = \frac{\phi_{12}}{\phi_1} = \frac{\phi_{21}}{\phi_2}.$$

$$M^2 = N_1N_2\frac{\phi_{21}\phi_{12}}{i_1 i_2}$$

$$M^2 = k^2 L_1 L_2$$

$$M = k\sqrt{L_1L_2} \quad \therefore k = \frac{M}{\sqrt{L_1L_2}}.$$

7 **Determine the value of capacitance C in order that the circuit resonates at a frequency of 6366Hz**



$$Y = Y_1 + Y_2 = \frac{1}{Z_1} + \frac{1}{Z_2}$$

$$Y = \frac{1}{10+j5} + \frac{1}{12.5 - jX_C}$$

$$= \left[0.08 + \frac{12.5}{156.25 + X_C^2}\right] + j\left[\frac{X_C}{156.25 + X_C^2} - \frac{5}{125}\right]$$

at resonance reactive part = 0.

$$\therefore \frac{X_C}{156.25 + X_C^2} = \frac{5}{125}.$$

$$X_C = 12.5\,\Omega$$

But $X_C = \frac{1}{2\pi f_0 C}$

$$C = \frac{1}{2\pi f_r X_C} \qquad f_r = 6366\,Hz.$$

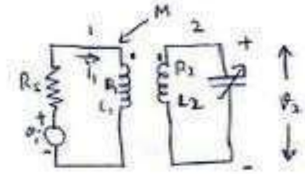
$$C = 2\,\mu F.$$

8	Two coupled coils have self inductances of L_1 = 100 mH and L_2 = 400 mH. The coupling **coefficient is 0.8. Find M. If N_1 is 1000 turns, what is the value of N_2? If a current i_1 = 2sin(500t) .A through the coil-1, find the flux Φ_1 and the mutually induced voltage V_{2M}. (DEC 2012)**

	8(ii). Given $L_1 = 100\,mH$ $L_2 = 400\,mH$ $K = 0.8$ $N_1 = 1000$ turns. $i_1 = 2\sin(500t)\,A$ Soln $M = k\sqrt{L_1 L_2}$ $= 0.8\sqrt{100\times 400} = 160\,mH$ $\frac{L_2}{L_1} = \frac{N_2^2}{N_1^2} = a^2$ $\Rightarrow N_2 = N_1\sqrt{\frac{L_2}{L_1}} = 2000$ turns. Flux produced by current i_1, $\varphi_{11} = L_1 i_1$ $= 100\times10^{-3}\times 2\sin(500t)$ $= 0.2\sin(500t)$ wb Flux produced by i_2 in coil 1 $\varphi_{21} = M i_2$. $i_2 = \frac{I_1}{a} = \sin(500t)$ $\therefore \varphi_{21} = 0.8\sin(500t)$ $\therefore \varphi_1 = \varphi_{11} + \varphi_{21}$ $\boxed{\varphi_1 = \sin(500t)}$ Mutually induced voltage. $V_{2M} = M\frac{di_1}{dt}$ $= 0.8\,(2\cos 500t)\times 500$ $V_{2M} = 800\cos 500t$. V
9	**A RLC series circuit has R=60 Ω, L=160mH and C=160µf. Find the resonant frequency under resonant condition obtain the current, power and the voltage drops across the various elements if the applied voltage is 300V.** (18) (i) $R = 60\,\Omega$; $L = 160\,mH$; $C = 160\,\mu F$; $V = 300V$ $f_r = \frac{1}{2\pi\sqrt{LC}} = 31.47\,Hz$ At resonance $\Rightarrow I_{max} = \frac{V}{R} = 5A$ Voltage across Resistor ; $V_R = I_{max}\times R = 300V$ Voltage across Inductor ; $V_L = I_{max}\cdot X_L = 158.1V$. Voltage across Capacitor ; $V_C = I_{max}\cdot X_C$ $= 5\times\frac{1}{2\pi f_r C}$ $V_C = 158.2V$. $P_{max} = I^2_{max}\times R = 1500W$

10	**Illustrate the amplification factor with respect to frequency and coefficient of coupling of a single tuned circuit in detail. (NOV 2013)**

SINGLE TUNED CIRCUIT :-



$R_s + R_1 + j\omega L_1 = R_s$

$R_s >> R_1 >> j\omega L_1$

mesh equations are $i_1 R_s - j\omega M i_2 = v_i$

on solving $i_2 = \dfrac{j v_i \omega M}{R_s\left(R_2 + j\omega L_2 - \dfrac{j}{\omega C}\right) + \omega^2 M^2}$

$v_0 = i_2 \cdot 1/j\omega C$ (v_0 = output voltage)

voltage amplification factor

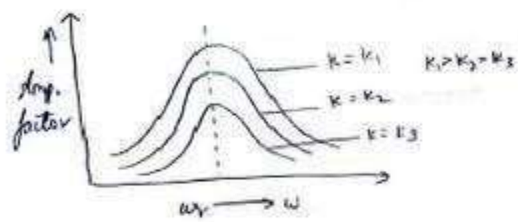
$A = v_0 / v_i = \dfrac{M}{C[R_s R_2 + \omega_r^2 M^2]}$ (on solving)

Max. amplification occurs at $\dfrac{dv_0}{dM} = 0$

$\dfrac{dv_0}{dM} = \dfrac{d}{dM}\left[\dfrac{v_i M}{C[R_s R_2 + \omega_r^2 M^2]}\right]$

$\therefore \quad M = \dfrac{\sqrt{R_s R_2}}{\omega_r}$

$\therefore \quad A_{max} = \dfrac{1}{2\omega_r C\sqrt{R_s R_2}}$



PART * C

1	**With neat illustration and necessary derivations, explain the Linear Transformer.(JUNE 2015)**

A transformer is a static piece of apparatus, having two or more windings or coils arranged on a common magnetic core. The transformer winding to which the supply source is connected is called the *primary*, while the winding connected to load is called the *secondary*. Accordingly, the voltage across the primary is called the primary voltage, and that across the secondary, the secondary voltage. Correspondingly i_1 and i_2 are the currents in the primary and secondary windings. One such transformer is shown in Fig. 10.11(a). In circuit diagrams, ideal transformers are represented by Fig. 10.11(b). The vertical lines betwgen the coils represent the iron core; the currents are assumed such that the mutual inductance is positive. An ideal transformer is characterised by assuming (i) zero power dissipation in the primary and secondary windings, i.e. resistances in the coils are assumed to be zero, (ii) the self inductances of the primary and secondary are extremely large in comparison with the load impedance, and (iii) the coefficient of coupling is equal to unity, i.e. the coils are tightly coupled without having any leakage flux. If the flux produced by the current flowing in a coil

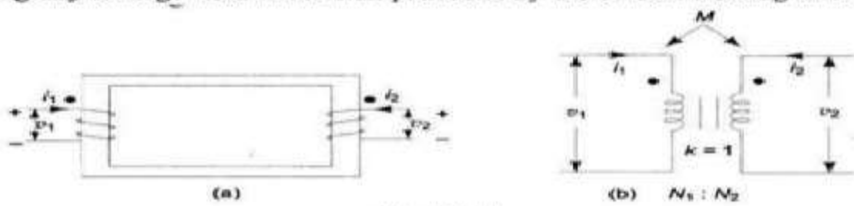


Fig. 10.11

The magnitude of the self induced emf is given by

$$v = L\frac{di}{dt}$$

If the flux linkages of the coil with N turns and current are known, then the self induced emf can be expressed as

$$v = N\frac{d\phi}{dt}$$

$$L\frac{di}{dt} = N\frac{d\phi}{dt}$$

$$L = N\frac{d\phi}{di}$$

$$\phi = \frac{Ni}{\text{reluctance}}$$

$$L = N\frac{d}{di}\left(\frac{Ni}{\text{reluctance}}\right)$$

$$L = \frac{N^2}{\text{reluctance}}$$

$$L \alpha N^2$$

ıbove relation it follows that

$$\frac{L_2}{L_1} = \frac{N_2^2}{N_1^2} = a^2$$

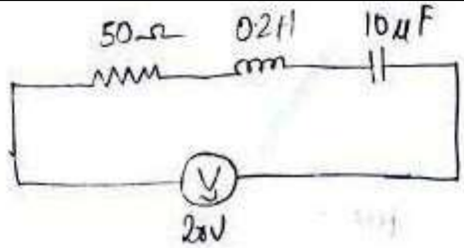
$$\phi_1 = N_1\ \phi;\ \phi_2 = N_2\ \phi$$

Also we have $v_1 = \frac{d\phi_1}{dt}$, and $v_2 = \frac{d\phi_2}{dt}$

so that

$$\frac{v_2}{v_1} = \frac{N_2\frac{d\phi}{dt}}{N_1\frac{d\phi}{dt}} = \frac{N_2}{N_1}$$

2	**A series RLC circuit consists of 50 Ω resistance, 0.2H inductance and 10µF capacitance with the applied voltage of 20V. Determine the resonant frequency, the Q factor, the lower and upper frequency limits and the bandwidth of the circuit.**



Resonant frequency $f_r = \frac{1}{2\pi\sqrt{LC}} = 112.54\,Hz$

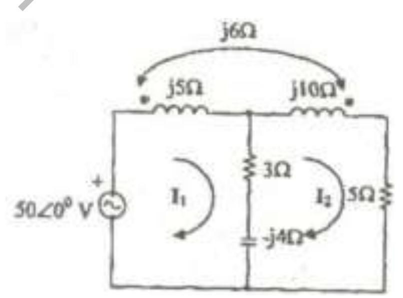
Q factor $= \frac{1}{R}\sqrt{\frac{L}{C}} = 2.8$

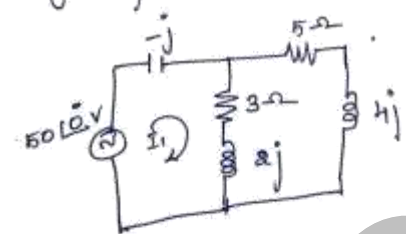
Band width (BW) $= \frac{f_r}{Q} = \frac{112.54}{2.8} = 40.19\,Hz$.

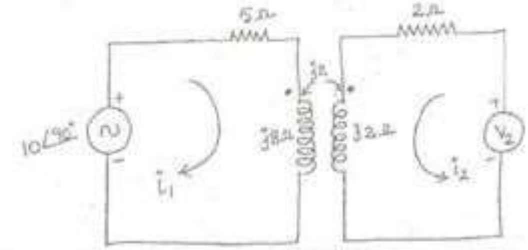
Lower freq Limit (or) Lower half power frequency $f_1 = f_r - \frac{BW}{2} = 92.4\,Hz$

Upper freq. Limit (or) ~~Lower~~ Upper half power frequency $f_2 = f_r + \frac{BW}{2} = 132.6\,Hz$

3	**Obtain a conductively coupled equivalent circuit for the magnetically coupled circuit shown below. (DEC 2012)**



	Mesh Equations Mesh 1 $50 = (3+j)I_1 - (3-4j)I_2 - 6jI_2$ $50 = (3+j)I_1 - (3+2j)I_2 \rightarrow (1)$ Mesh 2 $0 = -(3-4j)I_1 + (8+6j)I_2 - 6jI$ $= -(3+2j)I_1 + (8+6j)I_2 \rightarrow (2)$ Conductively coupled ckt using equ (1) & (2) 
4	**(i) For a magnetically coupled circuit , derive the expression for mutual inductance (M) in terms of L_1 and L_2. (NOV 2014) Refer Question No.1** **(ii) For the coupled circuit shown in fig, find the value of V_2 so that current I_1 =0.**



The mesh equations are.

$$+10j = (5+8j)I_1 + 2jI_2 \rightarrow ①$$

$$V_2 = (2+2j)I_2 + 2jI_1 \rightarrow ②$$

Given $I_1 = 0$

$$① \Rightarrow 10j = 2jI_2$$

$$I_2 = 5\ A.$$

$$② \Rightarrow V_2 = (2+2j)I_2$$

$$= (2+2j) \times 5$$

$$V_2 = 10 + 10j$$

$$= 10\sqrt{2}\angle 45^\circ\ V$$

5

A coil having an inductance of 100mH is magnetically coupled to another coil having an inductance of 900mH. The coefficient of coupling between the coils is 0.45. Calculate the equivalent inductance if the two coils are connected in (1) series opposing and (2) parallel opposing.

(i) $L_1 = 100mH$ $L_2 = 900mH$. $k = 0.45$

Series Opposing :- $M = k\sqrt{L_1L_2} = 0.135$

$$L_{eq} = L_1 + L_2 - 2M = 0.75H$$

Parallel Opposing :-

$$L_{eq} = \frac{L_1L_2 - M^2}{L_1 + L_2 + 2M} = 0.056H$$

6	**With neat illustration describe the parallel resonant circuit and the equivalent parallel network for a series RL combination. Also find the Q-factor of a parallel resonant circuit.(NOV 2014)**

Consider the parallel RLC circuit shown in Fig. 8.16.

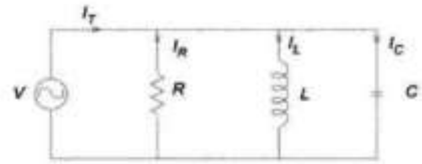


Fig. 8.16

In the circuit shown, the condition for resonance occurs when the susceptance part is zero.

Admittance $Y = G + jB$ (8.22)

$$= \frac{1}{R} + j\omega C + \frac{1}{j\omega L}$$

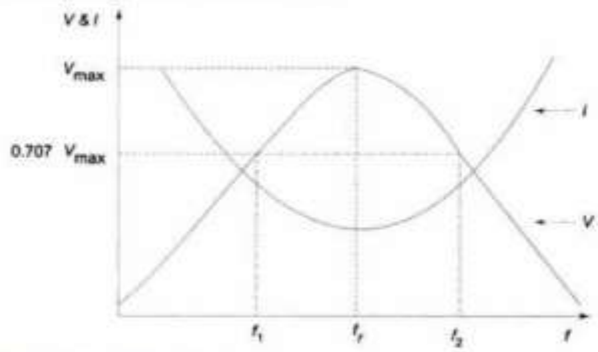
$$= \frac{1}{R} + j\left(\omega C - \frac{1}{\omega L}\right) \quad (8.23)$$

The frequency at which resonance occurs is

$$\omega_r C - \frac{1}{\omega_r L} = 0 \quad (8.24)$$

$$\omega_r = \frac{1}{\sqrt{LC}} \quad (8.25)$$

The voltage and current variation with frequency is shown in Fig. 8.17. At resonant frequency, the current is minimum.



The bandwidth, $BW = f_2 - f_1$

For parallel circuit, to obtain the lower half power frequency,

$$\omega_1 C - \frac{1}{\omega_1 L} = -\frac{1}{R} \quad (8.26)$$

From Eq. 8.26, we have

$$\omega_1^2 + \frac{\omega_1}{RC} - \frac{1}{LC} = 0 \quad (8.27)$$

If we simplify Eq. 8.27, we get

$$\omega_1 = \frac{-1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} \quad (8.28)$$

Similarly, to obtain the upper half power frequency

$$\omega_2 C - \frac{1}{\omega_2 L} = \frac{1}{R} \quad (8.29)$$

From Eq. 8.29, we have

$$\omega_2 = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} \quad (8.30)$$

Bandwidth $\boldsymbol{BW = \omega_2 - \omega_1 = \frac{1}{RC}}$

7

Determine the resonant frequency , bandwidth and quality factor of the coil for the series resonant circuit considering R=10Ω,L=0.1 H and C=10μF. Derive the formula used for bandwidth.(JUNE 2016)

Solution:-

At resonance, $X_L = X_C$

$$\omega L = \frac{1}{\omega C}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$\omega = \frac{1}{\sqrt{0.1\times 0.1\times 10^{-6}}} = 10\times 10^{+3} \text{ rad/sec.}$$

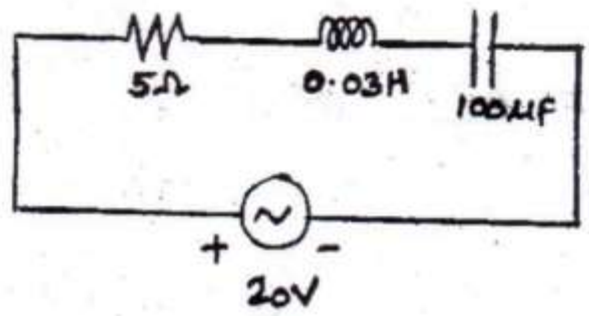
$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi}\cdot\omega = \frac{10\times 10^{+3}}{2\pi} = 1591.54 \text{ Hz}$$

$$\boxed{f_r = 1.591 \text{ kHz}}$$

Quality factor, $Q = \frac{\omega L}{R}$.

$$Q = \frac{10\times 10^{3}\times 0.1}{10} = 100.$$

Bandwidth, $BW = \frac{f_r}{Q} = \frac{1591.54}{100} = 15.915$ Hz

8	**(i) With neat illustration describe the parallel resonant circuit and the equivalent parallel network for a series RL combination.Also find the Q-factor of a parallel resonant circuit.(NOV 2014)** **(ii) for the circuit below, determine the frequency at which circuit resonates. Also find the quality factor, voltage across inductance and voltage across capacitance at resonance (NOV 2015)** 

Solution:- At resonance, $\omega L = \frac{1}{\omega C}$

$$\omega_r = \frac{1}{\sqrt{LC}}$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{0.03 \times 100 \times 10^{-6}}}$$

$$\boxed{f_r = 91.88\ Hz}$$

Quality factor, $Q = \frac{\omega L}{R} = \frac{577.35 \times 0.03}{5} = 3.464.$

$V_L = I . X_L .$

Under Resonance Condition, $I = \frac{V}{R} = \frac{20}{5} = 4\ A.$

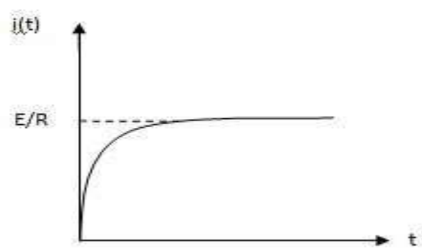
$$V_L = I . X_L = I . \omega L = 4 \times 577.35 \times 0.03$$

$$\boxed{V_L = 69.282\ V}$$

$$V_C = I . X_C = \frac{I}{\omega C} = \frac{4}{577.35 \times 100 \times 10^{-6}} = 69.282\ V.$$

$$\boxed{V_C = 69.282\ V}$$

UNIT IV- TRANSIENT ANALYSIS	
Natural response-Forced response - Transient response of RC, RL and RLC circuits to excitation by Step Signal, Impulse Signal and exponential sources - Complete response of RC, RL and RLC Circuits to sinusoidal excitation.	
PART * A	
Q.No	**Questions**
1.	**Define the term time constant of a RL or RC circuit.(April 2017)** BTL1 In a circuit in which the current is increasing to a final steady value, the time (T) taken to reach 62% of the final value is called the time constant of the circuit.
2	**Define time constant of a decaying circuit.** BTL1 For a decaying circuit, the time constant is defined as the time required to reach 38% of the initial

	value.
3	**Write down the voltage equation of a series RLC transient circuit excited by a dc source, E.** BTL2 Applying KVL to the circuit, the voltage equation becomes, $Ri + L\frac{di}{dt} + \frac{1}{C}\int i dt = E$
4	**Define transient state and transient time.(NOV 2013)** BTL1 In a network containing energy storage elements, with change in excitation, the currents and voltage change from one state to another state. The behavior of the voltage or current when it is changed from one state to another state is called the transient state. The time taken for the circuit to change from one steady state to another steady state is called the transient time.
5	**Draw the current curve of a RL transient connected to a DC source.(April 2017)** BTL3 
6	**Define damping ratio. Give the damping ratio of RLC series circuit.** BTL1 a.Damping Ratio $= \frac{\textit{Value of resistance in the circuit}}{\textit{Resistance for critical damping}}$ b.For RLC series circuit, $\sigma = \frac{R}{2\sqrt{L/C}}$
7	**Give the natural frequency** ωn **and damped frequency β of a series RLCcircuit.** BTL2 Natural frequency $\omega_n = \frac{1}{\sqrt{LC}}$;Damped frequency $\beta = \sqrt{\omega_n^2 - \omega_n^2\sigma^2} = \omega_n\sqrt{1-\sigma^2}$
8	**Write the condition for different cases of damping in a series RLC circuit.** BTL1 If damping ratio, σ = 1, it corresponds to critical damping; σ>1, it corresponds to over damping &σ< 1, it corresponds to under damping.
9	**A DC voltage is applied to a series RL circuit by closing a switch. The voltageacross L is 100 volts at t=0 and drops to .5 volts at t = 0.02 sec.If L = 0.1 H, find the value of R.** BTL4

	$e_{L} = E e^{-Rt/L}$ At $t = 0$, $e_{L} = E e^{-0} = E = 100$ At $t = 0.02$, $e_{L} = 100 E e^{-0.02R/0.1} = E = .5$; $100e^{-0.2R} = .5$ Taking natural logarithm on both sides, $\ln e^{-0.2R} = \ln 0.5$; $-0.2 R = -2$; $R = 10\ \Omega$
10	**Distinguish between natural and forced response.(JUNE 2014)** BTL3 <table><tr><th>Natural Response</th><th>Forced Response</th></tr><tr><td>It is determined by the internal energy stored in the network</td><td>It is determined by the application of external energy source</td></tr><tr><td>Voltage source and current sources are not present.</td><td>Voltage and current sources are present</td></tr></table>
11	**Define Laplace transform.** BTL1 The Laplace transform is an integral transformation of a function f(t) from the time domain into the complex frequency domain, giving F(s).Given a function f(t), its Laplace transform, denoted by F(s) or L[f(t)], is given by L[f(t)] = F(s) = ∫0∞ f(t)e-st dt Where s is a complex variable given by $s = \sigma + j\omega$
12	**Define the term Rise time (tr) & Delay time (td).** BTL1 The time taken by the response to reach 100% of the steady state value for the first time is known as **Rise time.** The time taken by the response to reach 50% of the steady state value for the first time is known as **Delay time.**
13	**A RLC circuit has R=10Ω, L=2H.What value of capacitance will make the circuit critically damped? (JUNE 2013)(NOV2016)** BTL4 (2L R)2=LC 1 ; C=0.08F
14	**Write the purpose of Laplace transformation in the circuit analysis.(NOV 2013)** BTL2 (i)To simplify complex exponential and trigonometric functions into simple algebraic functions. (ii)To simplify differential and integral operations by transforming into simple multiplication and division. (iii)To obtain complete solution including arbitrary constants for differential equations. (iv)To obtain response for any input for a given system, if step and impulse responses are known.
15	**Define transient response.** BTL1 The response or the output of the circuit from the instant of switching to the attainment of steady state is known as transient response.
16	**What is time constant for RL circuit and RC circuit(JUNE 2012, MAY 2014, NOV 2015,JUNE 2016)** BTL1 Time constant of RL circuit ,$\tau = \frac{L}{R}$ Time constant of RC circuit ,$\tau = RC$

17	**Define an ideal transformer.** BTL1

An ideal transformer is a transformer with no losses and having a core with infinite permeability, which results in perfect coupling with no leakage flux.

18 **Find the Time constant of RL circuit having i)R = 10Ω and l = 0.1 mH (JUNE 2013) ii)R=10ohms and L=20mH?(JUNE 2014)** BTL4

i)Time constant = L/R = 10µsec

ii) Time constant = L/R = 2milliseconds

19 **Distinguish Steady State and Transient State(NOV 2015)** BTL3

Steady State	Transient State
A circuit having constant sources is said to be in steady state if the currents and voltages do not change with time. Thus, circuits with currents and voltages having constant amplitude and constant frequency sinusoidal functions are also considered to be in a steady state.	In a network containing energy storage elements, with change in excitation, the currents and voltage change from one state to another state. The behaviour of the voltage or current when it is changed from one state to another state is called the transient state.

20 **Define the frequency response of series RLC circuit. (JUNE 2015)** BTL1

The response of a linear circuit for a sinusoidal excitation as a function of angular frequency ω is known as frequency response of the circuit.

21 **A 50µF capacitor is discharged through a 100KΩ resistor. If the capacitor is initially charged to 400V, determine the initial energy. (NOV 2014)** BTL4

Initial Energy, E = (1/2)CV2 = 4J

22 **Define Inductance?** BTL1

When a time varying current passes through the circuits, varying flux is produced. Because of this change in flux, a voltage is induced in the circuit proportional to time rate of change of flux or current i.e. emf induced α di/dt= Ldi/dt. Where L, the constant of proportionally has to be called as self inductance of the circuits.

23 **Define Capacitance.** BTL1

A capacitor is a circuit element that, like the inductor, stores energy during periods of time and returns the energy during others. In the capacitor, storage takes place in an electric field unlike the inductance where storage is in a magnetic field.

24 **Define Natural response or source free response.(JUNE 2014)** BTL1

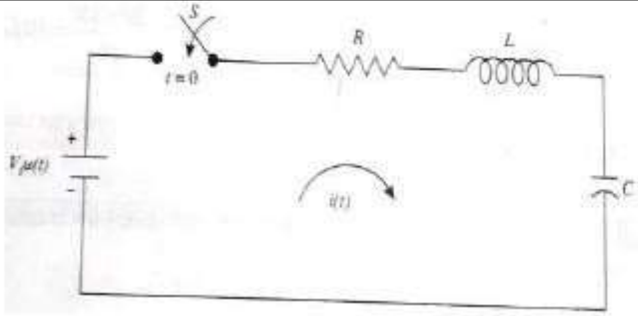
The response of the circuit due to the stored energy in the circuit elements (independent of sources) is called natural response.

25 **Determine the Laplace transform of unit step function U(t) and sinusoidal function Sin(ωt)(NOV2016)** BTL3

Function f(t)	Laplace F(S)
Unit step U(t)	1/S
Sin(ωt)	$\frac{\omega}{S^2+\omega^2}$

PART * B

1 **Explain the solution, methodology of calculating the transient response of RLC series circuit with step input?**



$$L\frac{di(t)}{dt}+Ri(t)+\frac{1}{C}\int_{-\infty}^{0} i(t)dt+\frac{1}{C}\int_{0}^{t} i(t)dt=V_i u(t)$$

Case 1 Overdamped response

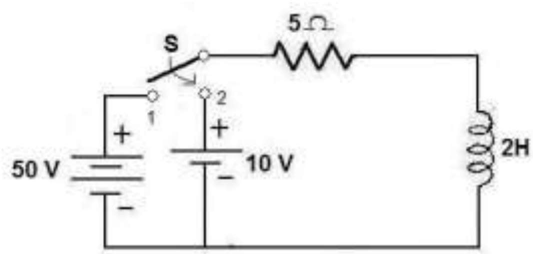
$$\left(\frac{R}{2L}\right)^2 > \frac{1}{LC}$$

Case 2 Critically damped response

Case 3 Underdamped response $\left(\frac{R}{2L}\right)^2 < \frac{1}{LC}$

2

In the circuit shown in figure, switch S is in position 1 for a long time and brought to position 2 at time t=0. Determine the circuit current.



After closing the switch to point 2 applying KVL

$$5i + 2\frac{di}{dt} = 10$$

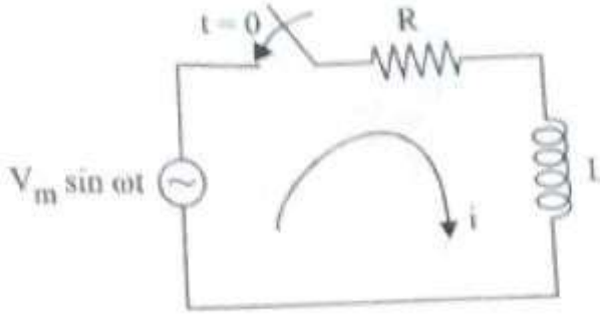
$$I(s) = \frac{2}{s} + \frac{8}{s+2.5}$$

Taking inverse laplace transform on both sides

$$\boxed{i(t) = 2 + 8e^{-2.5t}}$$

3 **Derive the transient current Expression for RL series circuit with input of V_mSinωt. (Nov**

	2015)(13 M) BTL3

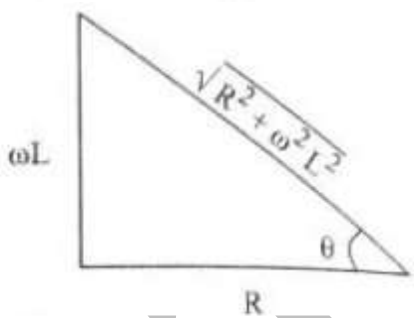


$$Ri + L\frac{di}{dt} = V_m \sin \omega t$$

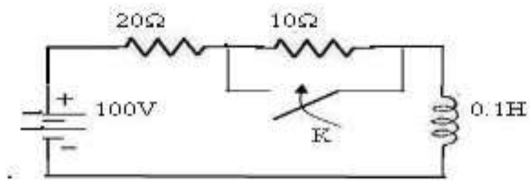
$$\sin\theta = \frac{\omega}{\sqrt{R^2+\omega^2 L^2}}\ ;\ \theta = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

$$\left(\frac{R}{2L}\right)^2 = \frac{1}{LC}$$

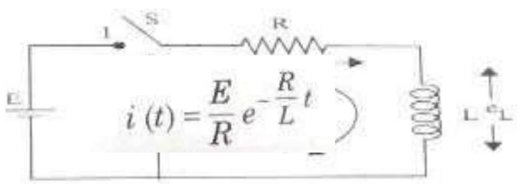
$$\cos\theta = \frac{}{\sqrt{R^2+\omega^2 L^2}}$$

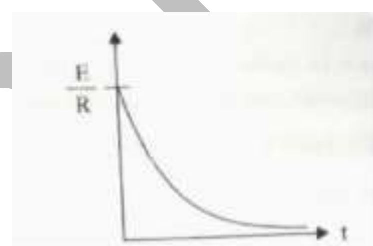


$$i\,(t) = \frac{V_m}{\sqrt{R^2+\omega^2 L^2}}\,[e^{-\frac{R}{L}t}\sin\theta + \sin(\omega t-\theta)]$$

4	**A DC voltage of 100V is applied in the given circuit and the switch K is open. The switch K is closed at t=0. Find the complete expression for the current.**  As soon as the switch is closed at t=0, the mesh equation becomes

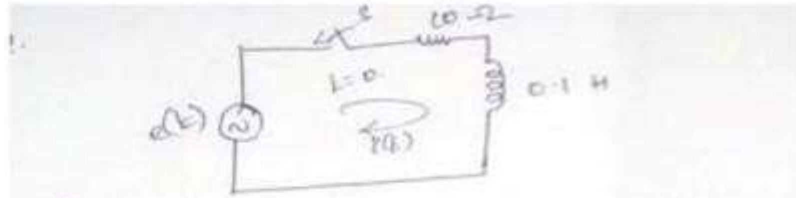
	Energy produced in the capacitor $E_C = \frac{1}{2} CE^2$
6	**Derive an expression for transient current of a RL decay transient excited by a DC source** Applying KVL $o = iR + L\frac{di}{dt}$ (when switch S is in position 2) Taking Laplace transform on both sides $I(s)R + L[sI(s) - i(o)] = 0$ After taking inverse laplace transform we get The exponential decay of current in RL circuit
	PART * C
1	**A RL series circuit excited by a sinusoidal source e(*t*) = 10sin100*t* volts, by closing the switch at *t*=0, take R=10 Ω and *L* = 0.1 H. Determine the current *i(t)* flowing through the RL circuit. (MAY/JUNE 2014)**





$$i(t) = \frac{E}{R} e^{-1} = 0.368 \frac{E}{R}$$

$= 36.8\%$ of the initial value



Given $e(t) = 10 \sin 100t$

By applying KVL,

$$10\, i(t) + 0.1 \frac{d\,i(t)}{dt} = 10 \sin 100t$$

Taking inverse Laplace transform

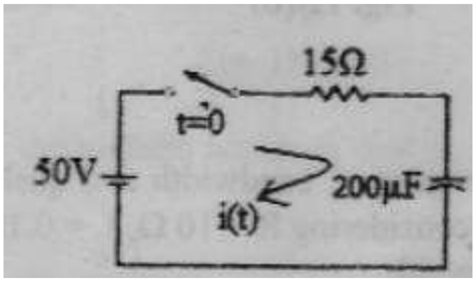
$$i(t) = 0.5 e^{-100t} + \frac{(-1-j)}{4} e^{j100t} + \frac{(-1+j)}{4} e^{-j100t}$$

$$= 0.5 e^{-100t} + -\frac{1}{4}\left[e^{j100t} + e^{-100jt}\right] + \frac{j}{4}\left[e^{-j100t} - e^{j100t}\right]$$

$$= 0.5 e^{-100t} + -\frac{1}{4}\left[2 \cos 100t\right] + \frac{j}{4}\left(-2j \sin 100t\right)$$

$$= 0.5 e^{-100t} + \frac{1}{2}\left[-\cos 100t + \sin 100t\right]$$

$$i(t) = 0.5\left[e^{-100t} + \sin 100t - \cos 100t\right]$$

2	**In a circuit shown in fig, Determine the transient current after switch is closed at time t=0, given that an initial charge of 100 µC is stored in the capacitor. Derive the necessary equations. (May 2016).**  **Steps to solve the problem:** Apply KVL and obtain the differentiointegral equation. Apply laplace transform on both sides to obtain algebraic equation.

Simplify and take inverse laplace transform to obtain the current eqution.

Applying KVL we get

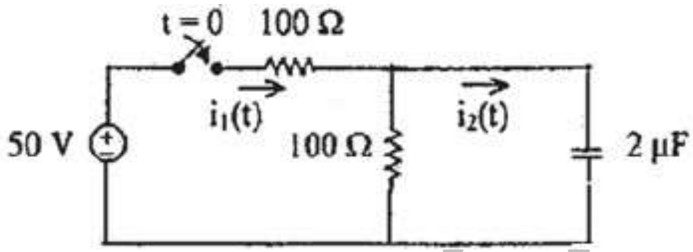
$$iR + \frac{1}{C}\int i\,dt + V_0 = E$$

Taking Inverse laplace transform

$$i(t) = \frac{E + (q_0 / C)}{R} e^{-t/RC}$$

3

In the circuit shown below, the switch is closed at t = 0. Determine the mesh currents $i_1(t)$ and $i_2(t)$. (MAY/JUNE 2014)



Answer: Page: 359 - Rappaport

Apply KVL to Mesh 1,

$$50 - 100\, i_1(t) - 100\,[i_1(t) - i_2(t)] = 0.$$

$$\Rightarrow \quad 200\, i_1(t) - 100\, i_2(t) = 50 \longrightarrow (1)$$

ingL.T

$$200\, I_1(s) - 100\, I_2(s) = 50/s \longrightarrow (1)$$

Apply KVL to Mesh 2,

$$100\,(i_2(t) - i_1(t)) + \frac{1}{2}\int i_2(t)\,dt = 0.$$

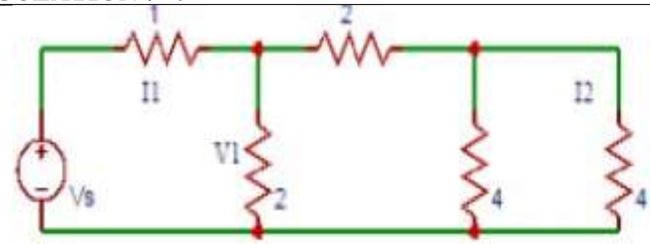
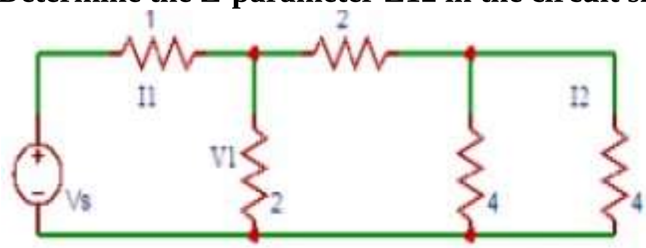
Taking Laplace Transform,

$$100\, I_2(s) - 100\, I_1(s) + 0.5\,\frac{I_2(s)}{s} = 0$$

$$i_1(t) = 0.25\left[1 + e^{-0.01t}\right]$$

$$i_2(t) = 0.5\, e^{-0.01t}.$$

UNIT V - TWO PORT NETWORKS	
Two port networks, Z parameters, Y parameters, Transmission (ABCD) parameters, Hybrid (H) Parameters, Interconnection of two port networks, Symmetrical properties of T and π networks.	
PART * A	
Q.No.	**Questions**
1.	**Define a Port.** BTL1 A port is defined as any pair of terminals in to which energy is supplied, or from which energy is withdrawn, or where the network variables may be measured.
2	**Define a Two port network.** BTL1 A two port network is a network, which has only two pairs of accessible terminals such that one pair represents the input and other represents the output.
3	**Define Z-Parameter?** BTL1 Z-Parameter or open circuited Impedance parameter of a two port network may be defined by expressing the port voltages V1 and V2 in terms of the current I1 and I2.Here V1 and V2 are dependent variables and I1,I2 are independent variables. It is expressed by a pair of governing equation. V1 = Z11I1 + Z12I2 V2 = Z21I1 + Z22I2
4	**Give the condition for reciprocity and symmetrical condition for Z parameter.** BTL3 For a network to be symmetrical A=D. So the relation between Z11 and Z12 for the network is symmetrical is Z11 = Z22. Reciprocity condition of Z parameter is Z12 = Z21.
5	**Calculate the Z –parameter Z11 in the circuit shown below**. BTL4

	 The Z –parameter Z11 is V1/I1, port 2 is open circuited. V1 = (1+1.5)I1 => V1/I1 = 2.5 and on substituting, we get Z11 = 2.5Ω.
6	**Determine the Z-parameter Z12 in the circuit shown in the circuit.** BTL4  The Z-parameter Z12 is V2/I1 |I2=0. On open circuiting port 2 we obtain the equation, V1 = (1.5) I2 => V1/I1 = 1.5. On substituting we get Z12 = 1.5Ω
7	**Define Y Parameter.** BTL1 Y parameter or short circuited admittance parameter of a two port network may be defined by expressing the port currents I1 and I2 in terms of voltages V1 and V2. Here I1 and I2 are dependent variables and V1 and V2 are independent variables. I1 may be considered to be the superposition of two components, one caused by V1 and the other by V2.Its governing equation is given by I1 = Y11V1 + Y12V2 I2 = Y21V1 + Y22V2
8	**Give the condition for reciprocity and symmetrical condition for Y parameter.** BTL3 For a network to be symmetrical A=D. So the relation between Y11 and Y12 for the network is symmetrical is Y11 = Y22. Reciprocity condition of Y parameter is Y12 = Y21.
9	**Define ABCD Parameter.** BTL1 Transmission parameter or ABCD parameters are widely used in transmission line theory and cascade network. Here the input variables V1 and I1 at sending end are expressed in terms of the output variables V2 and I2 at the output or receiving end. It is also called as general parameter or chain parameter. They are defined by a pair of governing equation given by, V1 = AV2 – BI2 I1 = CV2 – DI2
10	**What is the importance of transmission-parameter matrix property?** BTL2 The transmission matrix of a cascade of a two-port network is the product of transmission matrices of the individual two-port networks. This property is used in the design of telephone systems, microwave networks, radars,etc.
11	**Give the condition for reciprocity and symmetrical condition for ABCD parameter.** BTL2 The condition for reciprocity for ABCD is (AD-BC) = 1 The condition for symmetry is A = D

12	**Define hybrid parameters.** BTL1 Hybrid parameter or h parameter describes a two-port network with the voltage of one port and current of other port is taken as dependent variables. Its governing equation is given by

V1 = h11I1 + h12I2
V2 = h21I1 + h22I2

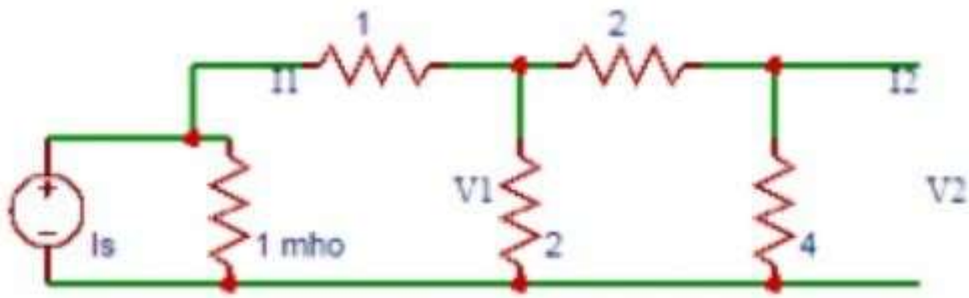
13 **Why h -parameters are extensively used in transistor circuits?** BTL3

In the design of transistor amplifier circuits, one must know the input impedance, output impedance, voltage gain and current gain of the transistor used. In this regard, h parameter suited to transistor circuit as these parameters can be most conveniently measured.

14 **Give the condition for reciprocity and symmetrical condition for h parameter.** BTL3

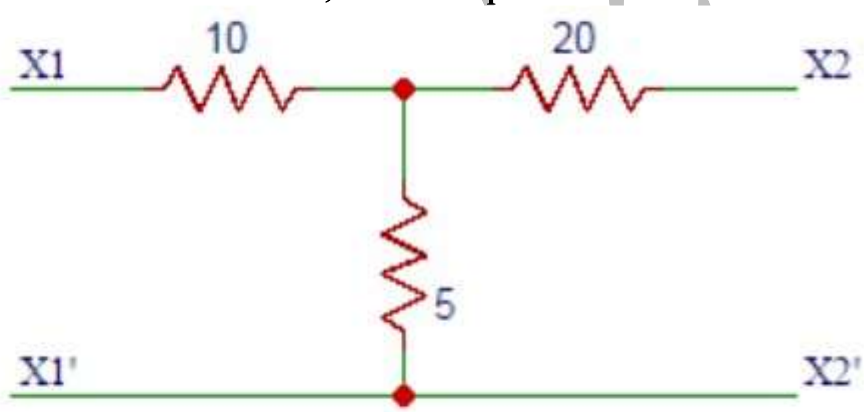
The condition for reciprocity for h parameter is h12 = -h21
The condition for symmetry is (h11h22 – h12h21) = 1

15 **Determine the value of source admittance in the circuit shown below.** BTL4



The Z-parameter Z22 is inverse of the Y-parameter Y22 i.e., Z22 = 1/Y22. We got Y22 = 7/12. So on substituting we get Z22 = 12/7 mho.

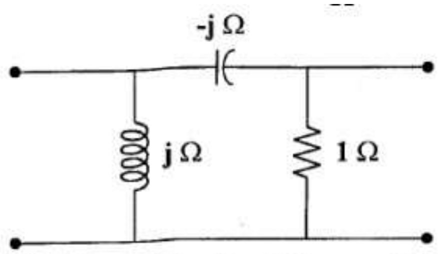
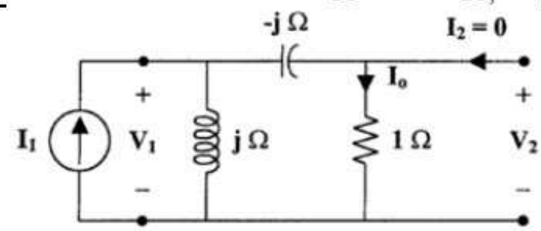
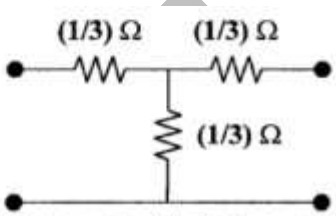
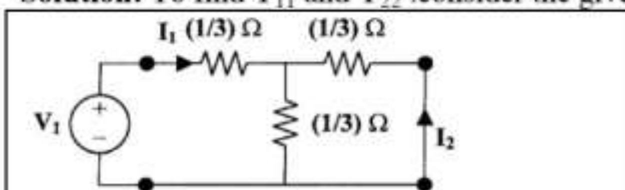
16 **In the circuit shown below, find the Z-parameter Z11** BTL3

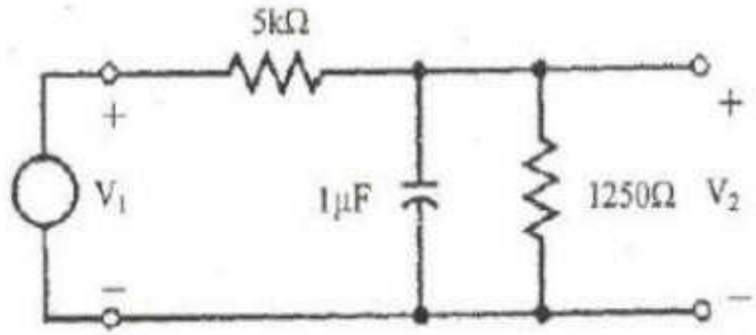


The Z –parameter Z11 is V1/I1, port 2 is open circuited. V1 = (10 + 5)I1 => V1/I1 = 15 and on substituting, we get Z11 = 2.5Ω

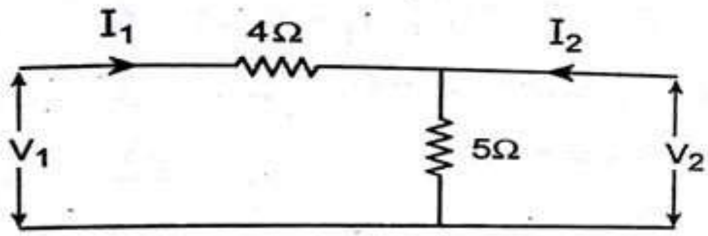
17 **Give the condition for symmetry and reciprocity for various two-port network parameters.** BTL3

Parameter	Condition of Reciprocity	Condition of Symmetry
z	$z_{12} = z_{21}$	$z_{11} = z_{22}$
y	$y_{12} = y_{21}$	$y_{11} = y_{22}$
T (ABCD)	$(AD - BC) = 1$	$A = D$
h	$h_{12} = -h_{21}$	$(h_{11}h_{22} - h_{12}h_{21}) = 1$

18	**Explain briefly about interconnection of two-port networks** .BTL1 When a two port networks are connected in cascade, the parameters of the interconnected network can be conveniently expressed with the help of ABCD parameter. In a similar way,the Z parameter can be used to describe the parameters of series-connected two-port network and Yparameter can be used to describe parameters of parallel connected two-port network. This explains the interconnection of two-port networks.
19	**Write the characteristic impedance of symmetrical T-section.** BTL1 $Z_{OT}^2 = Z_1^2 + Z_1 Z_2$
20	**Determine the Z11 and Z21 for the circuit shown.** BTL3  **Solution:** To find Z_{11} and $Z_{21,}$ consider the given figure,  $z_{11} = \frac{V_1}{I_1} = j \parallel (1-j) = \frac{j(1-j)}{j+1-j} = 1+j$ By current division, $I_o = \frac{j}{j+1-j} I_1 = jI_1$ $V_2 = I_o = jI_1$ $z_{21} = \frac{V_2}{I_1} = j$
21	**Determine Y11 and Y21 for the given circuit.** BTL4  **Solution:** To find Y_{11} and Y_{22} .consider the given figure.  $y_{11} = \frac{I_1}{V_1} = \frac{I_1}{I_1\left(\frac{1}{3} + \left[\frac{(1/3)(1/3)}{(1/3)+(1/3)}\right]\right)} = \frac{1}{\frac{1}{3}+\frac{1}{6}} = 2$ From this we see that $I_1 = 2V_1$, In addition, from current division we get $I_2 = -\frac{(1/3)}{(1/3)+(1/3)} I_1 = -\frac{1}{2} I_1$ $y_{21} = \frac{I_2}{V_1} = \frac{-(1/2)I_1}{(1/2)I_1} = -1$
22	**Find the frequency response V2/V1 for the two port circuit shown below. (JUNE 2015)** BTL4

	 $V_2 = \frac{V_1 \times Z_p}{5000+Z_P}$ $Z_p = \frac{Z_1 Z_2}{Z_1+Z_2} = \frac{1250}{1+0.0012S}$ $\frac{V_2}{V_1} = \frac{1250/(1+0.0012S)}{25s+6250} = \frac{1250}{0.0075S^2+.75S+6250}$
23	**Express Z parameter in terms of h parameter.** BTL3 $Z_{11} = \frac{Y_{22}}{\|Y\|},\ Z_{12} = -\frac{Y_{12}}{\|Y\|},\ Z_{21} = -\frac{Y_{21}}{\|Y\|},\ Z_{22} = \frac{Y_{11}}{\|Y\|}.$
24	**The following equation gives the voltages V1 and V2 at the two ports of a two port network, V1 = 5I1 + 2I2 ; V2 = 2I1 + I2 . A load resistance of 3Ω is connected across port- 2.Calculate the input impedance**. BTL4 $V_1 = 5I_1 + 2I_2$ (i) $V_2 = 2I_1 + I_2$ (ii) At the output, $V_2 = -I_2R_L = -3I_2$ Putting this value in (ii), $-3I_2 = 2I_1 + I_2$ fi $I_2 = -I_1/2$ Putting in (i), $V_1 = 5I_1 + \left(\frac{-I_1}{2}\right) = 4I_1$ ∴ Input impedance, $Z_{in} = \frac{V_1}{I} = 4\Omega$
25	**What is image impedance of a two-port network?** BTL2 Image impedance for a two-port network is the impedance, Zi 1, seen looking into port 1 when port 2 is terminated with the image impedance, Zi 2, for port 2. In general, the image impedances of ports 1 and 2 will not be equal unless the network is symmetrical (or anti-symmetrical) with respect to the ports.

26	**When a two port network is said to be reciprocal?** BTL3 When a voltage V is inserted in port-1 the current I in another port-2 due to the insertion of this voltage is the same as the current at the first port-1 due to the insertion of a voltage V in the

	second port-2, the that two port network is said to be reciprocal.
	PART * B
1	**Find the h–parameters for the network shown.**  *Fig. 13.3.* *Solution :* When the output port is short circuited, $V_2 = 0$. Refer the circuit shown below :

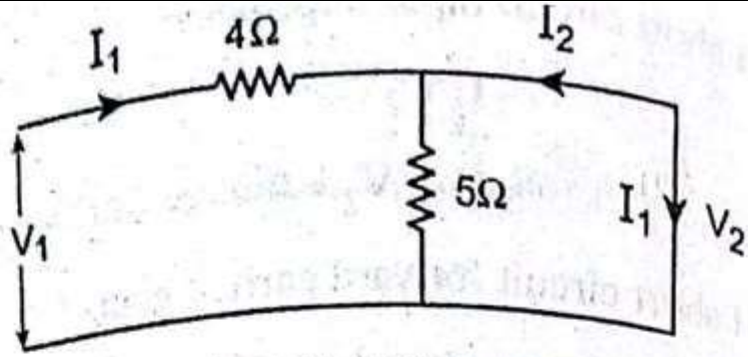


Fig. 13.4.

$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2 = 0}$$

From the circuit,

$$V_1 = I_1 \times 4$$

$$h_{11} = \left.\frac{V_1}{I_1}\right|_{V_2 = 0} = \frac{I_1 \times 4}{I_1} = 4\Omega$$

$$h_{21} = \left.\frac{I_2}{I_1}\right|_{V_2 = 0}$$

But, $I_2 = -I_1$

$$\therefore h_{21} = \left.\frac{-I_1}{I_1}\right|_{V_2=0} = -1.$$

$$h_{12} = \left.\frac{V_1}{V_2}\right|_{I_1=0}$$

and $$h_{22} = \left.\frac{I_2}{V_1}\right|_{I_1=0}$$

In the present case, when $I_1 = 0$,

$V_1 = 5 \times I_2$ and $V_2 = 5 \times I_2$

$$\therefore h_{12} = \left.\frac{5I_2}{5I_2}\right|_{I_1=0} = 1$$

$$\therefore h_{22} = \left.\frac{I_2}{V_2}\right|_{I_1=0}$$

$$= \left.\frac{I_2}{5 \times I_2}\right|_{I_1=0} = 0.2 \text{ mhos}$$

2	The Z – parameters of a two port network are $Z_{11} = 25\Omega$, $Z_{22} = 40\Omega$, $Z_{12} = Z_{21} = 10\Omega$. Find the Y – parameters. *Solution :* $\Delta_z = Z_{11} \cdot Z_{22} - Z_{12} \cdot Z_{21}$ $= 25 \times 40 - 10 \times 10$ $= 1000 - 100$ $\Delta_z = 900$ $Y_{11} = \frac{Z_{22}}{\Delta_z} = \frac{40}{900} = 0.04 \text{ mho}$ $Y_{12} = \frac{-Z_{12}}{\Delta_z} = \frac{-10}{900} = -0.01 \text{ mho}$ $Y_{21} = \frac{-Z_{21}}{\Delta_z} = \frac{-10}{900} = -0.01 \text{ mho}$ $Y_{22} = \frac{Z_{11}}{\Delta_z} = \frac{25}{900} = 0.028 \text{ mho}$

3	**For a two port network, Y – parameters are : Y_{11} = 0.1 mho ; Y_{22} = 0.05 mho, $Y_{12} = Y_{21}$ = –0.02 mho. Calculate the Z-parameters for the same network.** *Solution :* $\Delta_Y = Y_{11} \cdot Y_{22} - Y_{12} \cdot Y_{21}$ $= 0.1 \times 0.05 - 0.02 \times 0.02 = 0.0046$ $Z_{11} = \frac{Y_{22}}{\Delta_Y} = \frac{0.05}{0.0046} = 10.87\ \Omega$ $Z_{12} = \frac{-Y_{12}}{\Delta_Y} = \frac{-(-0.02)}{0.0046} = 4.35\ \Omega$ $Z_{21} = \frac{-Y_{21}}{\Delta_Y} = \frac{-(-0.02)}{0.0046} = 4.35\ \Omega$ $Z_{22} = \frac{Y_{11}}{\Delta_Y} = \frac{0.1}{0.0046} = 21.74\ \Omega$

4

For a two port network, the equations are

$$I_1 = 0.5\,V_1 - 0.2\,V_2$$

$$I_2 = -0.2\,V_1 + V_2.$$

Find the Y–parameters and ABCD parameters. Also find its equivalent π network.

Solution : We know that,

$$I_1 = Y_{11}\,V_1 + Y_{12}\,V_2$$

$$I_2 = Y_{21}\,V_1 + Y_{22}\,V_2.$$

Comparing the given equations with standard equations,

$$Y_{11} = 0.5 \text{ mho}$$

$$Y_{12} = -0.2 \text{ mho}$$

$$Y_{21} = -0.2 \text{ mho}$$

$$Y_{22} = 1 \text{ mho}$$

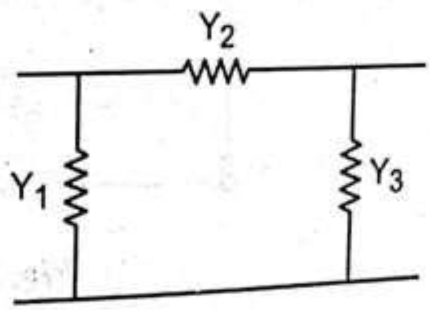


Fig. 13.10.

The equivalent π – network is shown in the figure.

$$Y_2 = -Y_{21} = -Y_{12} = 0.2 \text{ mho}$$

$$Y_1 = Y_{11} + Y_{12} = 0.5 + (-0.2) = 0.3 \text{ mho}$$

$$Y_3 = Y_{22} + Y_{21} = 1 + (-0.2) = 0.8 \text{ mho}$$

To find ABCD parameters :

$$A = 1 + \frac{Y_3}{Y_2} = 1 + \frac{0.8}{0.2} = 5$$

$$B = \frac{1}{Y_2} = \frac{1}{0.2} = 5 \text{ ohms}$$

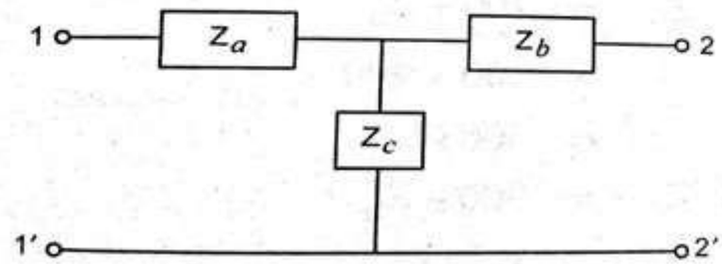
$$C = Y_1 + Y_3 + \frac{Y_1 Y_3}{Y_2}$$

$$= 0.3 + 0.8 + \frac{0.3 \times 0.8}{0.2}$$

$$= 1.1 + 1.2 = 2.3 \text{ mho}$$

$$D = 1 + \frac{Y_1}{Y_2}$$

$$= 1 + \frac{0.3}{0.2} = 2.5$$

5	**A two port network has the following open circuit nd short circuit impedance $Z_{10} = 900\Omega$; $Z_{20} = 1000\ \Omega$ or $Z_{1s} =$ 50 Ω. Find the parameters of the T – equivalent two–port method.** *Solution :* 

$$Z_{10} = Z_a + Z_c$$

$$Z_{10} = 900$$

$$\Rightarrow \quad Z_a + Z_c = 900$$

$$Z_{20} = Z_b + Z_c = 1000$$

Z_{1s} = the impedance between the input terminals when the output terminals are short circuited

$$= Z_a + \frac{Z_b Z_c}{Z_b + Z_c} = 650$$

From equation (*i*) $\quad Z_c = 900 - Z_a$

From equation (*ii*) $\quad Z_b = 1000 - Z_c$

$$Z_b = 1000 - (900 - Z_a) = 100 + Z_a.$$

Substituting the values of Z_b and Z_c in equation (*iii*), we get

$$Z_a + \frac{(100 + Z_a)(900 - Z_a)}{1000} = 650$$

$$\Rightarrow 1000 Z_a + 90000 - 100 Z_a + 900 Z_a - Z_a^2 = 650000$$

$$\Rightarrow Z_a^2 - 1800 Z_a + 56000 = 0$$

$$\Rightarrow Z_a = \frac{1800 \pm \sqrt{(1800)^2 - 4 \times 560000}}{2}$$

$$= \frac{1800 \pm 1000}{2}$$

$$= 1400, 400$$

The acceptable value of Z_a is 400 Ω.

$$\therefore Z_b = 100 + Z_a$$

$$= 100 + 400$$

$$= 500\,\Omega$$

$$\text{and } Z_c = 900 - Z_a$$

$$= 500\Omega$$

PART * C

1	**Find the Y – parameters for the RC lad network shown in fig.**

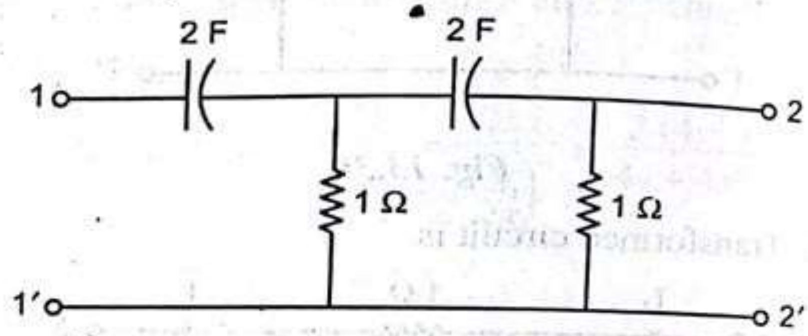
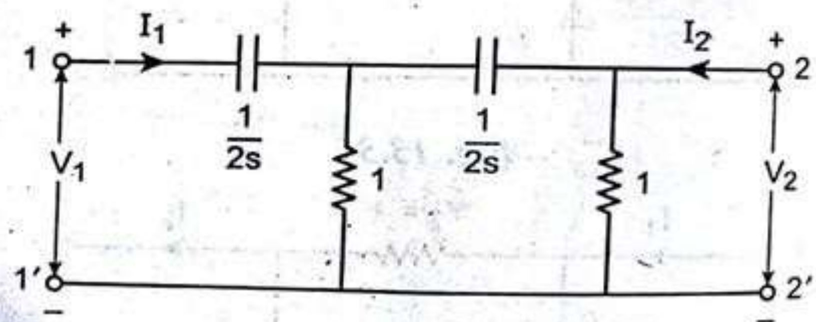


Fig. 13.33.

Solution : Transformed circuit is given by

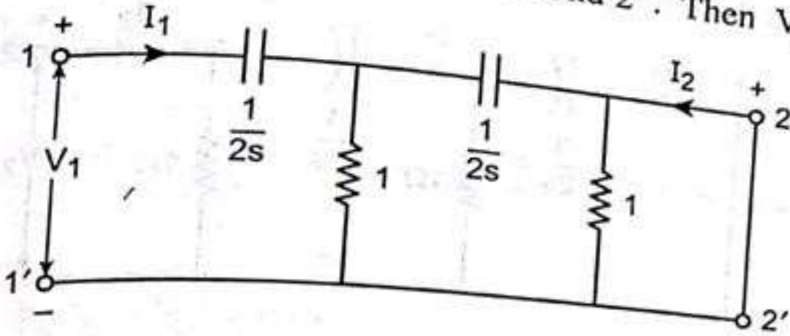


$$I_1 = Y_{11} V_1 + Y_{12} V_2 \; ;$$

$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

To find Y_{11} and Y_{21} :

Short circuit the output port terminal 2 and 2′. Then $V_2 = 0$.



$$V_1 = I_1\left[\frac{1}{2s} + \frac{1 \times \frac{1}{2s}}{1 + \frac{1}{2s}}\right] = I_1 \times \left[\frac{1}{2s} + \frac{1}{2s+1}\right]$$

$$= I_1 \times \left[\frac{2s + 1 + 2s}{2s(2s+1)}\right] = I_1\left[\frac{4s+1}{2s(2s+1)}\right]$$

$$\therefore Y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0} = \frac{2s(2s+1)}{(4s+1)}$$

Also, $$I_2 = -I_1 \times \frac{1}{1 + \frac{1}{2s}}$$

$$\Rightarrow I_2 = -I_1 \times \frac{2s}{2s+1}$$

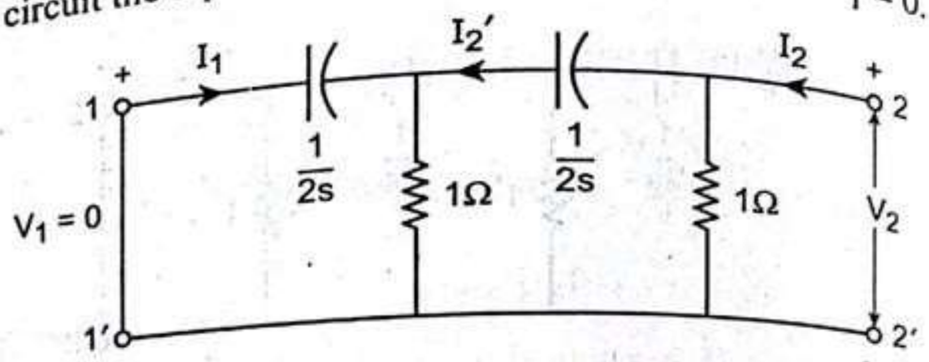
$$\therefore Y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2=0}$$

$$= \frac{-I_1 \times \frac{2s}{(2s+1)}}{I_1 \times \frac{(4s+1)}{2s(2s+1)}}$$

$$= \frac{-(2s)^2}{(4s+1)} = \frac{-4s^2}{(4s+1)}$$

To find Y_{12} and Y_{22} :

Short circuit the input port terminals 1 and 1′. Then $V_1 = 0$.



$$Z_p = \left[\frac{1}{2s+1} + \frac{1}{2s}\right] \text{ in parallel with } 1\Omega$$

$$= \frac{\left[\frac{1}{2s+1} + \frac{1}{2s}\right] \times 1}{\left[\frac{1}{2s+1} + \frac{1}{2s}\right] + 1}$$

$$= \frac{2s + 2s + 1}{(2s+1)(2s) + 2s + 2s + 1}$$

$$= \frac{4s + 1}{4s + 1 + 4s^2 + 2s}$$

$$\frac{V_2}{I_2} = Z_p = \frac{4s+1}{4s^2+6s+1}$$

$$\therefore Y_{22} = \left.\frac{I_2}{V_2}\right|_{V_1 = 0} = \frac{4s^2 + 6s + 1}{4s+1}$$

$$I_2' = I_2 \times \frac{1}{1+\frac{1}{2s}+\frac{1}{2s+1}}$$ [Current division formula]

$$= I_2 \times \frac{2s\,(2s+1)}{2s \times (2s+1) + 4s + 1}$$

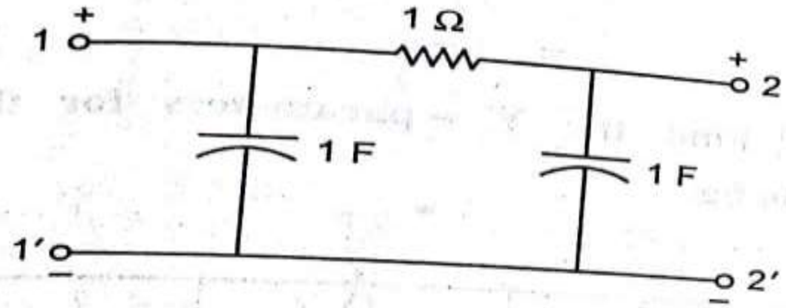
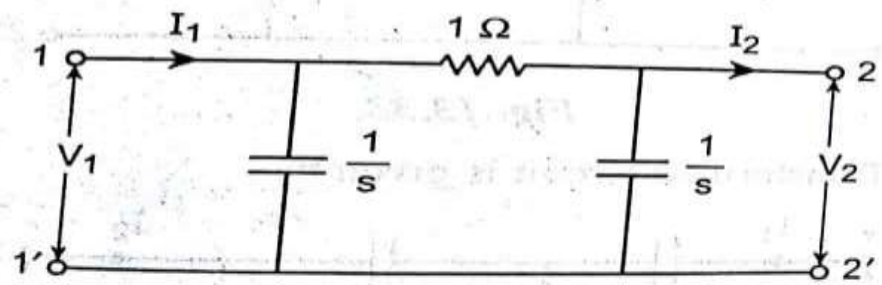
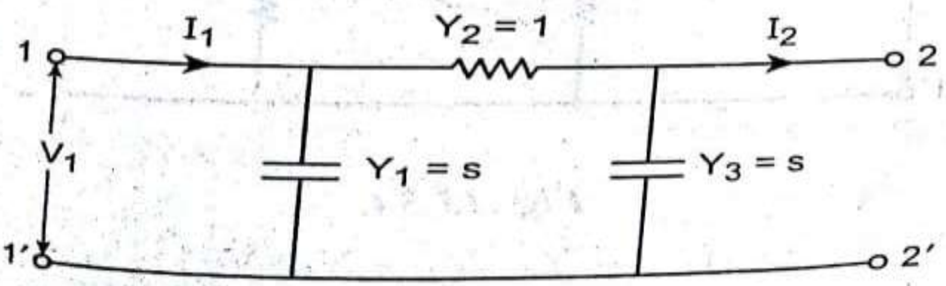
$$I_1 = -I_2' \times \frac{1}{1+\frac{1}{2s}} = -I_2' \times \frac{2s}{(2s+1)}$$ [Current division formula]

$$= -I_2 \times \frac{2s\,(2s+1)}{4s^2+6s+1} \times \frac{2s}{(2s+1)}$$

$$\Rightarrow I_1 = -I_2 \times \frac{4s^2}{4s^2+6s+1}$$

$$\therefore Y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0} = \frac{-I_2 \times \frac{4s^2}{4s^2+6s+1}}{I_2 \times \frac{4s+1}{4s^2+6s+1}}$$

$$Y_{12} = \frac{-4s^2}{4s+1}$$

2	**Example 20** Find the ABCD parameters  *Fig. 13.30.* *lution :* Transformed circuit is  *Fig. 13.31.* 

$$A = 1 + \frac{Y_3}{Y_2} = 1 + s$$

$$B = \frac{1}{Y_2} = \frac{1}{1} = 1 \text{ ohms}$$

$$C = Y_1 + Y_3 + \frac{Y_1 Y_3}{Y_2}$$

$$= s + s + s^2$$

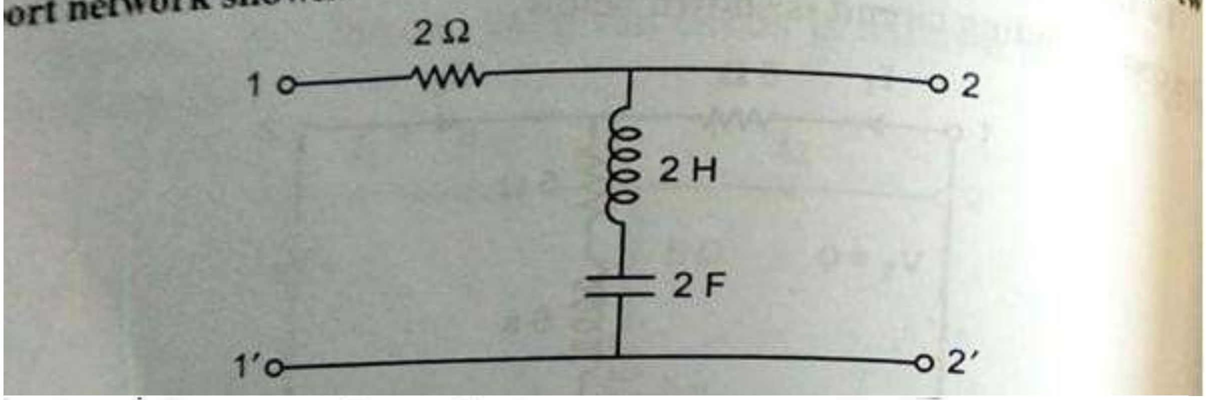
$$C = s^2 + 2s = s(s+2)$$

$$D = 1 + \frac{Y_1}{Y_2}$$

$$= 1 + s$$

3

Determine the admittance parameters of the tw[o-p]ort network shown.



Solution: The transformed circuit of the given network is shown below :

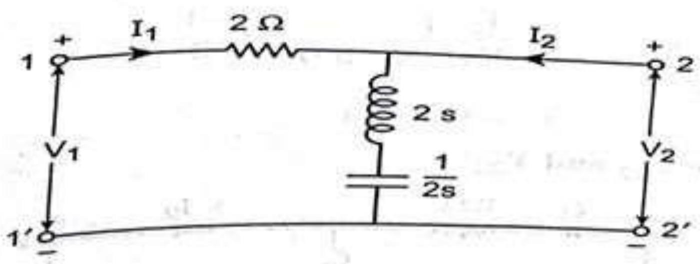


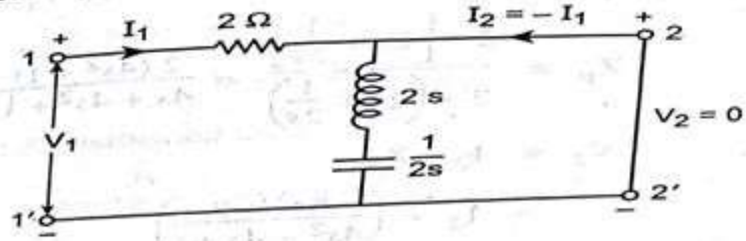
Fig. 13.27.

$$I_1 = Y_{11} V_1 + Y_{12} V_2$$

$$I_2 = Y_{21} V_1 + Y_{22} V_2$$

To calculate Y_{11} and Y_{21} :

Short circuit the output port terminals 2 and 2'. Then $V_2 = 0$.



$$V_1 = I_1 \times 2$$

$$\therefore Y_{11} = \left.\frac{I_1}{V_1}\right|_{V_2=0} = \frac{1}{2} \text{ mho}$$

$$= 0.5 \text{ mho}$$

But $I_2 = -I_1$,

as the current through $2s + \frac{1}{2s}$ is zero.

$$\therefore V_1 = -I_2 \times 2$$

$$\therefore Y_{21} = \left.\frac{I_2}{V_1}\right|_{V_2=0} = \frac{-1}{2}$$

$$= -0.5\text{mho}$$

By current division formula,

$$I_1 = -I_2 \times \frac{\left(2s + \frac{1}{2s}\right)}{2 + 2s + \frac{1}{2s}}$$

$$= -I_2 \times \frac{4s^2 + 1}{4s^2 + 4s + 1}$$

$$\therefore Y_{12} = \left.\frac{I_1}{V_2}\right|_{V_1=0}$$

$$= \frac{-I_2 \times \frac{4s^2+1}{4s^2+4s+1}}{I_2 \times \frac{8s^2+2}{4s^2+4s+1}}$$

$$\Rightarrow Y_{12} = \frac{-(4s^2+1)}{8s^2+2} = \frac{-(4s^2+1)}{2(4s^2+1)}$$

$$= -0.5 \text{ mho}$$

EC8252 ELECTRON DEVICES **L T P C**
3 0 0 3

UNIT I SEMICONDUCTOR DIODE 9

PN junction diode, Current equations, Energy Band diagram, Diffusion and drift current densities, forward and reverse bias characteristics, Transition and Diffusion Capacitances, Switching Characteristics, Breakdown in PN Junction Diodes.

UNIT II BIPOLAR JUNCTION TRANSISTORS 9

NPN -PNP -Operations-Early effect - Current equations – Input and Output characteristics of CE, CB, CC - Hybrid -π model - h-parameter model, Ebers Moll Model- Gummel Poon-model, Multi Emitter Transistor.

UNIT III FIELD EFFECT TRANSISTORS 9

JFETs – Drain and Transfer characteristics, - Current equations - Pinch off voltage and its significance- MOSFET-Characteristics- Threshold voltage -Channel length modulation, D-MOSFET, E-MOSFET- Characteristics – Comparison of MOSFET with JFET.

UNIT IV SPECIAL SEMICONDUCTOR DEVICES 9

Metal-Semiconductor Junction- MESFET, FINFET, PINFET, CNTFET, DUAL GATE MOSFET, Schottky barrier diode-Zener diode-Varactor diode –Tunnel diode- Gallium Arsenide device, LASER diode, LDR.

UNIT V POWER DEVICES AND DISPLAY DEVICES 9

UJT, SCR, Diac, Triac, Power BJT- Power MOSFET- DMOS-VMOS. LED, LCD, Photo transistor, Opto Coupler, Solar cell, CCD.

TOTAL: 45 PERIODS

OUTCOMES:

At the end of the course the students will be able to:

- Explain the V-I characteristic of diode, UJT and SCR
- Describe the equivalence circuits of transistors
- Operate the basic electronic devices such as PN junction diode, Bipolar and Field effect Transistors, Power control devices, LED, LCD and other Opto-electronic devices

TEXT BOOKS:

1. Donald A Neaman, ―Semiconductor Physics and Devices‖, Fourth Edition, Tata Mc GrawHill Inc. 2012.

2. Salivahanan. S, Suresh Kumar. N, Vallavaraj.A, ―Electronic Devices and circuits‖, Third Edition, Tata McGraw- Hill, 2008.

REFERENCES:

1. Robert Boylestad and Louis Nashelsky, ―Electron Devices and Circuit Theory‖ Pearson Prentice Hall, 10th edition, July 2008.

2. R.S.Sedha, ― A Text Book of Applied Electronics‖ S.Chand Publications, 2006.

3. Yang, ―Fundamentals of Semiconductor devices‖, McGraw Hill International Edition, 1978.

Subject Code: EC8252 **Year/Semester: I/02**

Subject Name: Electron Devices **Subject Handler: Mr.V.Yokesh& Ms.A.Parimala**

UNIT I – SEMICONDUCTOR DIODE

PN junction diode, Current equations, Energy Band diagram, Diffusion and drift current densities, forward and reverse bias characteristics, Transition and Diffusion Capacitances, Switching Characteristics, Breakdown in PN Junction Diodes.

PART – A

1. **State mass action law. (May/June 2014, Nov/Dec 2017)** BTL 1

Under thermal equilibrium for any semiconductor, the product of the number of holes and the number of electrons is constant and is independent of the amount of donor and acceptor impurity doping. This relation is known as mass – action law.

$$\boldsymbol{n.p = n_i^2}$$

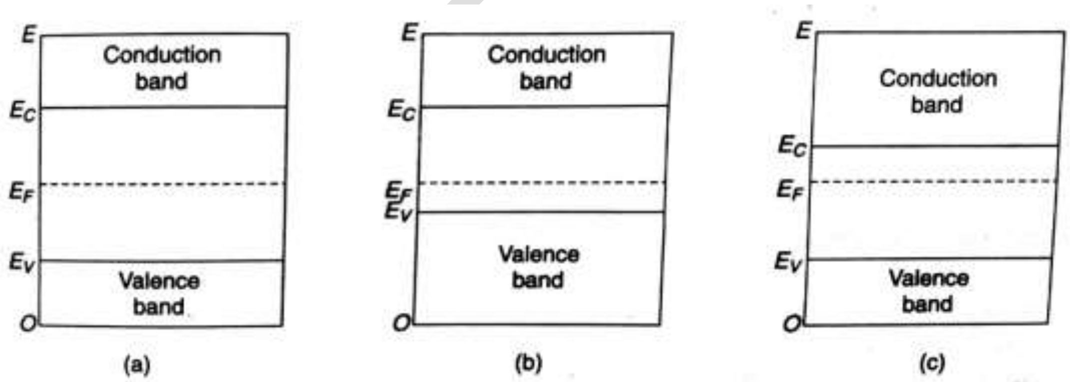
2. **Define Semiconductors.** BTL 1

The materials whose electrical property lies between those of conductors and insulators are known as Semiconductors. Ex: Germanium, Silicon.

It has two types.

1. Intrinsic semiconductor 2. Extrinsic semiconductor.

3. **Energy Band diagrams for intrinsic and extrinsic semiconductors.** BTL 1



4. **Define diffusion current and drift current. (Nov/Dec 2017)** BTL 1

Drift Current: The drift current is defined as the flow electric current due to the motion of the charge carriers under the influence of an external electric field. The drift current is given by

$$I_n = Aqn\mu_o E \qquad (due\ to\ free\ electrons)$$

$$I_p = Aqp\mu_o E \qquad (due\ to\ holes)$$

Diffusion Current: A concentration gradient exists if the number of either electrons or holes is greater in one region of a semiconductor, compared to the rest of the region. The

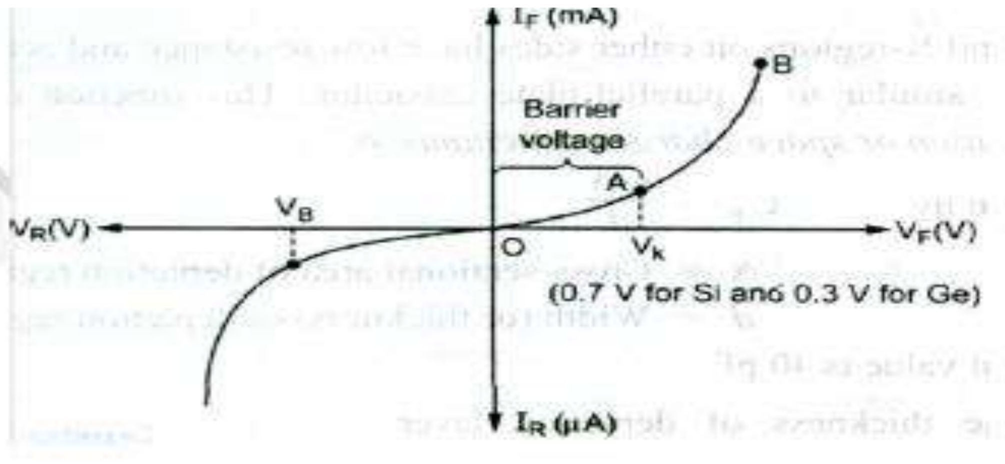
	charge carriers tend to move from the region of higher concentration to that of lower concentration of the same type of charge carriers. The diffusion current is given by, $$I_p = -A.qD_p\frac{dp}{dx} \qquad (due\ to\ holes)$$ $$I_n = A.qD_n\frac{dn}{dx} \qquad (due\ to\ free\ electrons)$$
6.	**Show the expression for drift current density.** BTL 1 $$I_n = Aqn\mu_o E \qquad (due\ to\ free\ electrons)$$ $$I_p = Aqp\mu_o E \qquad (due\ to\ holes)$$
7.	**Distinguish between intrinsic and extrinsic semiconductor.** BTL 2

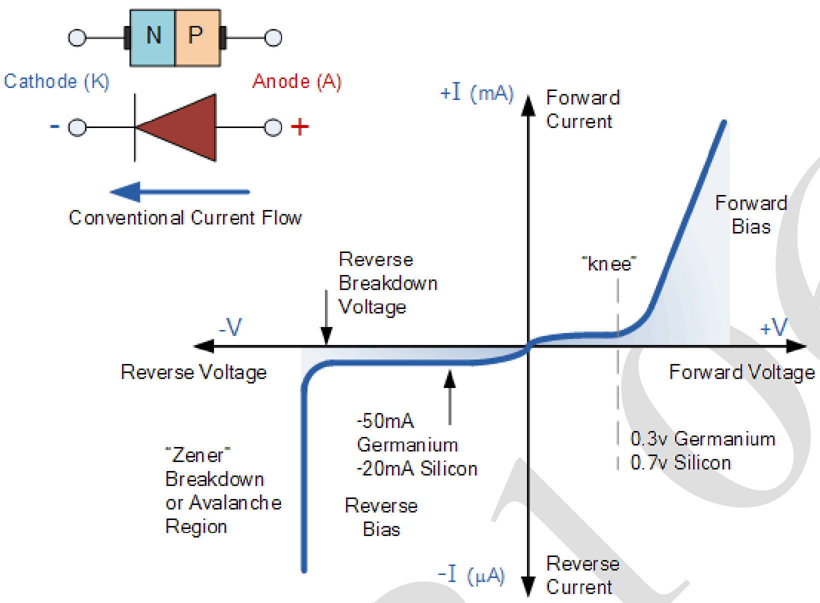
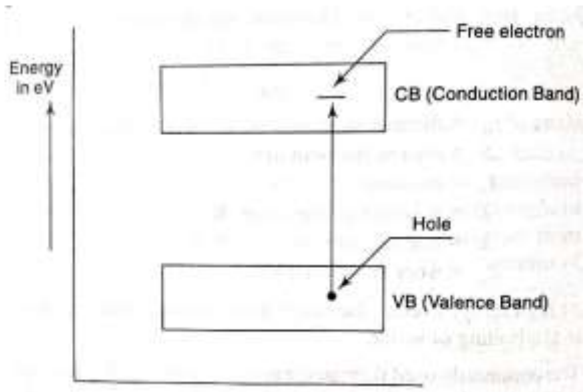
Intrinsic Semiconductor	Extrinsic Semiconductor
It is pure semi – conductor material and no impurity atoms are added to it.	It is prepared by doping a small quantity of impurity atoms of the pure semiconducting materials.
The number of free electrons in the conduction band and the number of holes in the valence band are exactly equal and very small indeed.	The number of free electrons and holes are never equal. There are excess electrons in N – type semi – conductors and excess of holes in p – type semi – conductors.
Its electrical conductivity is a function of temperature alone.	Its electrical conductivity depends upon the temperature as well as on the quantity of impurity atoms doped in the structure.
Its electrical conductivity is low.	Its electrical conductivity is high.
Examples: Crystalline forms of pure silicon and germanium.	*Examples:* Silicon “Si” and germanium “Ge” crystals with impurity atoms of Ab, Sb, P etc. or In B, Al, etc.

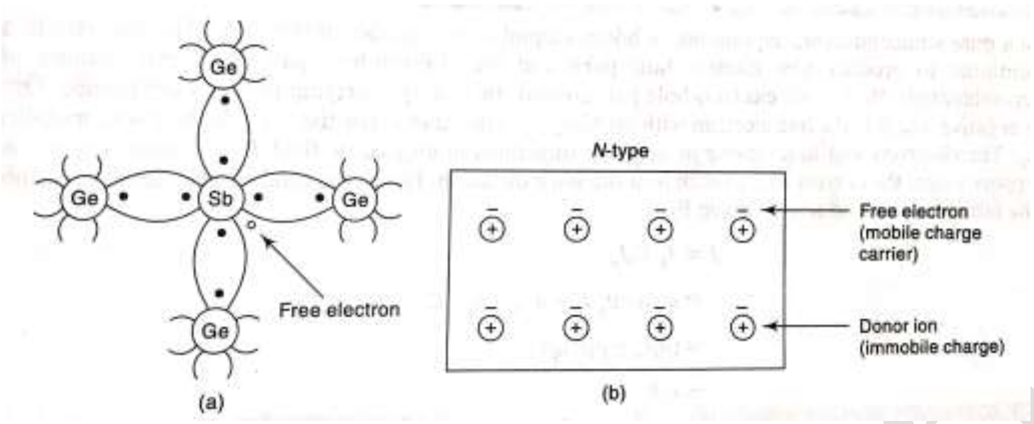
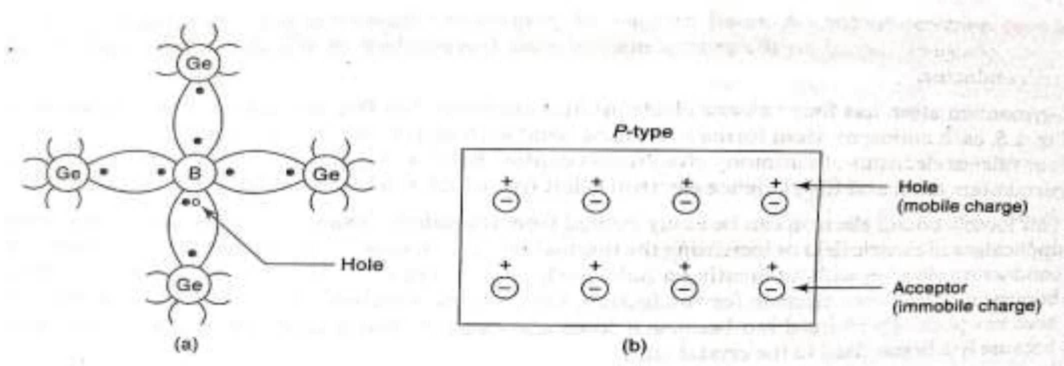
8.	**Write the expression for Depletion Width in PN diode. (May/June 2016)** BTL 2 $$\boldsymbol{W = \left[\frac{2\varepsilon_o\varepsilon_r V_o}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)\right]^{1/2}}$$ $$The\ depletion\ width\ is\ proportional\ to\ (V_o)^{1/2}$$
9.	**Define depletion region in PN junction.** BTL 2 The region around the junction from which the mobile charge carriers (electrons and holes) are depleted is called as depletion region. Since this region has immobile ions, which are electrically charged, the depletion region is also known as space charge region.

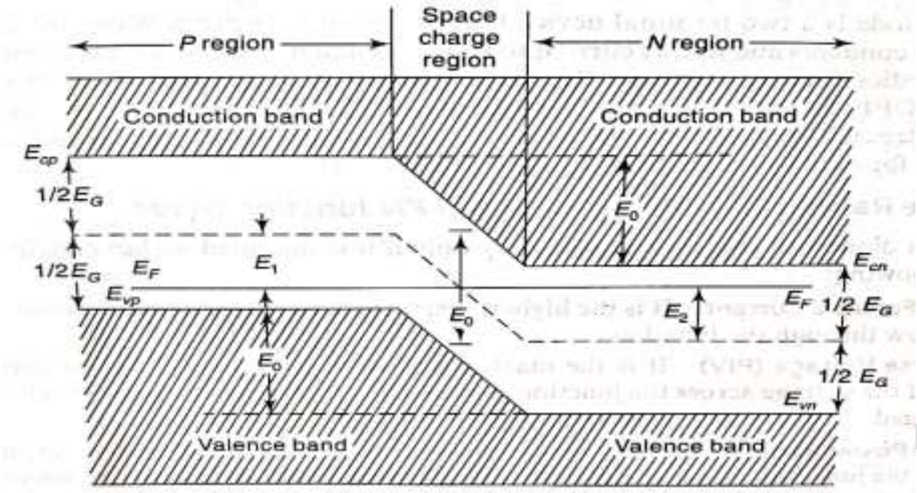
10.	**Define Barrier Potential. (Nov/Dec 2015)** BTL 1 Because of the oppositely charged ions present on both sides of PN junction an electric potential is established across the junction even without any external voltage source which is termed as barrier potential.
11.	**Define Reverse saturation current (I_o) (April/May 2014, April/May 2017)** BTL 1 The minority carriers, electrons in the P – region and holes in the N – region, wander over the junction and flow towards their majority carrier side giving rise to a small reverse current. This current is known as reverse saturation current, I_0. The magnitude of reverse saturation current mainly depends upon junction temperature because the major source of minority carriers is thermally broken covalent bonds.
12.	**What is the total current at the junction of PN junction diode?** BTL 1 The total in the junction is due to the hole current entering the n material and the electron current entering the p material. Total current is given by $I = Ipn(0) + Inp(0)$ Where, I – Total current Ipn(0) - hole current entering the n material Inp(0) - electron current entering the p material
13.	**Express the Diode current equation. (April/May 2018)** BTL 2 The diode current equation relating the voltage V and current I is given by $$\boldsymbol{I = I_o\left[e^{(V/\eta V_T)} - 1\right]}$$ where I – diode current Io – diode reverse saturation current at room temperature V – external voltage applied to the diode η - a constant, 1 for Ge and 2 for Si $V_T = kT/q = T/11600$, thermal voltage K – Boltzmann's constant (1.38066x10^-23 J/K) q – Charge of electron (1.6x10^-19 C) T – Temperature of the diode junction
14.	**Effect of temperature in PN Junction Diode.** BTL 2 The rise in temperature increases the generation of electron – hole pairs in semiconductors and increases their conductivity. As a result, the current through the PN junction diode increases with temperature as given by the diode current equation.

15.	**Define Transition capacitance or Space Charge Capacitance. (Nov/Dec 2018)** BTL 1 Under reverse bias condition, the majority carriers move away from the junction, thereby uncovering more immobile charges. Hence the width of the space – charge layer at the junction increases with reverse voltage. This increase in uncovered charge with applied voltage may be considered a capacitive effect. The parallel layers of oppositely charged immobile ions on the two sides of the junction form the capacitance, C_T which is expressed as $$C_T = \left\|\frac{dQ}{dV}\right\|$$ $$dQ - increase\ in\ charge$$
16.	**Define Diffusion Capacitance. (April/May 2019)** BTL 1 The capacitance that exists in a forward biased junction is called a diffusion or storage capacitance (C_D), whose value is usually much larger than C_T, which exists in a reverse – biased junction. This is also defined as the rate of change of injected charge with applied voltage, i.e., $$C_D = \frac{dQ}{dV}$$ dQ – change in the number of minority carriers stored outside the depletion region dV – When a change in voltage across the diode is applied
17.	**What is recovery time? Give its types.** BTL 1 When a diode has its state changed from one type of bias to other a transient accompanies the diode response, i.e., the diode reaches steady state only after an interval of time " tr" called as recovery time. The recovery time can be divided in to two types such as (i) Forward recovery time (ii) Reverse recovery time
18.	**Define storage time**. BTL 1 The interval time for the stored minority charge to become zero is called storage time. It is represented as t_S.
19.	**Define transition time**. BTL 1 The time when the diode has normally recovered and the diode reverse current reaches reverse saturation current Io is called as transition time. It is represented as tt
20.	**Define PIV**. **(April/May 2017)** BTL 1 Peak inverse voltage is the maximum reverse voltage that can be applied to the PN junction without damage to the junction.

21.	**Draw V-I characteristics of PN diode. (Nov/Dec 2014, Nov/Dec 2016)** BTL 1 
22.	**State the Application of PN diode. (April/May 2015)** BTL 1 • Can be used as rectifier in DC Power Supplies. • In Demodulation or Detector Circuits. • In clamping networks used as DC Restorers • In clipping circuits used for waveform generation. • As switches in digital logic circuits. • In demodulation circuits.
PART – B	
1.	**Recall the quantitative theory of PN diode currents with its switching characteristics and obtain the diode current equation. (13M) (Nov/De 2016, April/May 2017, Nov/Dc 2017, April/May 2018, April/May 2019)** BTL 3 **Ans:** Theory of PN junction diode (4M) Switching characteristics curve (4M) Diode current equation (5M) **Diode current equation** expresses the relationship between the current flowing through the diode as a function of the voltage applied across it. Mathematically it is given as $$I = I_o\left(e^{\frac{qV}{\eta KT}} - 1\right)$$
	Find the expression for PN junction diode forward and reverse currents with suitable diagram and necessary explanation. (13M) (Nov/Dc 2015, April/May 2017, Nov/Dec 2017) BTL 2 **Ans:** PN Junction diode forward bias working principle (4M)

	Reverse bias working principle (4M) Characteristic curves (2M) Zero bias explanation (3M)  • Zero Bias • Reverse Bias • Forward Bias
3.	**i) Show the position of Fermi level in N type and P type semiconductors. (7M)** BTL 1 **Ans:** Fermi level energy diagram (3M) Expression for Fermi level in N type semiconductor (2M) Expression for Fermi level in P type semiconductor (2M) **ii)Write notes on classification of semiconductors. (6M)** BTL 1 **Ans:**  Theory and diagram of Intrinsic semiconductor (3M) Theory and diagram of Extrinsic semiconductor (3M) ***Intrinsic Semiconductor*** Purest form of Semiconductor ***Extrinsic Semiconductor*** This can be achieved by adding small amount of impurity to the intrinsic semiconductor, so that it becomes impure or extrinsic semiconductor. This process of adding impurity is known as doping. *Fig: Creation of Electron – hole pair*

	N – type Semiconductor  ***Fig: N – type Semiconductor: (a) Formation of covalent bonds (b)Charged Carriers*** ***P – type Semiconductor***  ***Fig: P – type Semiconductor: (a) Formation of covalent bonds (b)Charged Carriers***
4.	**Examine the operation of open circuited PN Junction and derive the expression for built in potential barrier with the help of energy band structure. (13M) (Nov/Dc 2014, April/May 2016)** BTL 2 **Ans:** Energy band diagram (4M) Theory for energy band diagram (4M) Derivation of build-in-potential (5M)



Total shift in the energy level E_o is given by

$$E_o = E_1 + E_2 = E_{cp} - E_{cn} = E_{vp} - E_{vn}$$

Contact Difference of Potential

N – type material $E_{cn} - E_F = kTln\frac{N_C}{n_n} = kTln\frac{N_C}{N_D}$

P – type material $E_F - E_{vp} = kTln\frac{N_V}{p_p} = kTln\frac{N_V}{N_A}$

$$\boldsymbol{V_o = \frac{kT}{q} ln\frac{N_D N_A}{n_i^2}}$$

5. **Explain in detail about how temperature affects the VI characteristics of diode. (7M) (April/May 2018)** BTL 1

Ans:

Theory on the impact of temperature (3M)

Expression of diode current w.r.t temperature (4M)

The reverse saturation current I_o is temperature dependent while voltage equivalent of temperature V_T is also temperature dependent. Hence, the diode current involving I_o and V_T is temperature dependent.

$$I_o = KT^m e^{-V_{Go}/\eta V_T}$$

$$K = constant\ independent\ of\ temperature$$

$$m = 2\ for\ Ge\ and\ 1.5\ for\ Si$$

$$V_{Go} = forbidden\ energy\ gap = 0.785\ V\ for\ Ge\ and\ 1.21\ V\ for\ Si$$

The required change in voltage is necessary to keep diode current constant.

$$\frac{dV}{dT} = \frac{V - (V_{Go} + m\eta V_T)}{T}$$

Practically, the value $\frac{dV}{dT}$ is assumed to be -2.5mV/°C for either Ge or Si at room temperature.

$$\frac{dV}{dT} = -2.5\ mV/C$$

Negative sign indicates that $\frac{dV}{dT}$ decreases with increase in temperature.

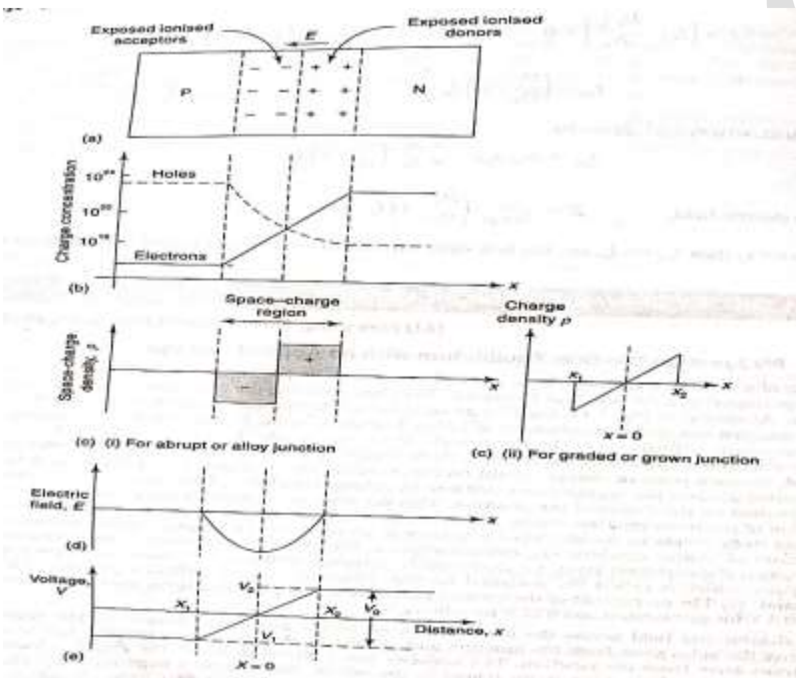
6. **Conclude the theory of PN junction diode and obtain depletion width. (13M) (Nov/Dec 2015)** BTL 1

Ans:

Depletion width diagram (4M)

Theory of PN Junction diode (4M)

Expression for Depletion width (5M)



Calculation of Depletion Width

$$W = \left[\frac{2\varepsilon_o \varepsilon_r V_o}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)\right]^{1/2}$$

7. **Examine the drift and diffusion current densities and obtain the current density for P type and N type. (8M) (April/May 2015, Nov/Dec 2015)** BTL 2

Ans:

Definition for drift current and diffusion current (2M)

Expression for drift current (3M)

Expression for Diffusion current (3M)

Drift Current Densities – 4M

Drift Current Density, J_n due to free electrons is given by

$$J_n = qn\mu_n E\ \ A/cm^2$$

Drift Current Density, J_n due to free holes is given by

$$J_p = qp\mu_p E\ \ A/cm^2$$

	Diffusion Current Densities – 4M The diffusion current density due to holes, J_P, is given by $$J_p = -qD_P\frac{dP}{dx}\ \ A/cm^2$$ The diffusion current density due to free electrons, J_n, is given by $$J_n = qD_n\frac{dn}{dx}\ \ A/cm^2$$ **Total Current** **P – type Semiconductor** $$J_p = qp\mu_pE - qD_P\frac{dP}{dx}$$ **N – type Semiconductor** $$J_n = qn\mu_nE + qD_n\frac{dn}{dx}$$
8.	**Show the expression for transition capacitance and diffusion capacitance of a PN diode. (13M)** BTL 1 **Ans:** Definition for transition and diffusion capacitance (3M) Calculation of transition capacitance (5M) Calculation of diffusion capacitance (5M) ***<u>Transition Capacitance (C_T)</u> – 7M*** Under Reverse bias condition, the majority carriers move away from the junction, thereby uncovering more immobile charges. Hence the width of the space – charge layer at the junction increases with reverse voltage. $$C_T = \left\|\frac{dQ}{dV}\right\|$$ ***Step – graded Junction*** $$W = \left[\frac{2\varepsilon_o\varepsilon_r(V_o - V)}{q}\left(\frac{N_A + N_D}{N_A N_D}\right)\right]^{1/2}$$ ***<u>Diffusion Capacitance (C_D)</u> – 6M*** $$C_D = \left\|\frac{dQ}{dV}\right\|$$ *Calculation of C_D:* $$C_D = \frac{\tau I}{\eta V_T}$$

9.	**Find the conductivity of silicon** (a) in intrinsic condition at a room temperature of 300 K, (b) with donor impurity of 1 in 10^8, (c) with acceptor impurity of 1 in $5*10^7$ and (d) with both the above impurities present simultaneously. Given that n_i for silicon at 300 K is $1.5*10^{10}$ cm^{-3}, μ_n = 1300 $cm^2/V – s$, μ_p = 500 $cm^2/V – s$, number of Si atoms per cm^3 = $5*10^{22}$. **(15M) (April/May 2016, Nov/Dc 2017)** BTL 5 **Ans:** Calculation of donar impurity (4M) Calculation of acceptor impurity (4M) Calculation of conductivity (7M) *(i)* *Intrinsic Condition,* $n = p = n_i$ $$\sigma_i = qn_i(\mu_n + \mu_p)$$ *(ii)* *With Donor impurities* Number of Silicon atoms/cm^3 = $5*10^{22}$ cm^{-3} $$\sigma = nq\mu_n = N_D q\mu_n$$ *(iii)* *With Acceptor impurities* $$\sigma = pq\mu_p = N_A q\mu_P$$ *(iv)* *With both the types of impurities present simultaneously* $$N'_A = N_A - N_D = 5 * 10^{14} cm^{-3}$$ $$\sigma = N'_A q\mu_P$$
10.	**Determine the resistivity** of germanium (a) in intrinsic condition at a room temperature of 300 K, (b) with donor impurity of 1 in 10^7, (c) with acceptor impurity of 1 in 10^8 and (d) with both the above impurities present simultaneously. Given that n_i for silicon at 300 K is $2.5*10^{13}$ cm^{-3}, μ_n = 3800 $cm^2/V – s$, μ_p = 1800 $cm^2/V – s$, number of Germanium atoms per cm^3 = $4.4*10^{22}$. **(15M) (Nov/Dec 2014, May/June 2016)** BTL 5 **Ans:** Calculation of donar impurity (3M) Calculation of acceptor impurity (3M) Calculation of conductivity (5M) Calculation of resistivity (4M) *(i)* *Intrinsic Condition,* $n = p = n_i$ $$\sigma_i = qn_i(\mu_n + \mu_p)$$ $$Resistivity, \rho = \frac{1}{\sigma}\ \Omega - cm$$

	(ii) *With Donor impurities* Number of Silicon atoms/cm^3 = 4.4*10^{22} cm^{-3} $$\sigma = nq\mu_n = N_D q\mu_n$$ *(iii)* *With Acceptor impurities* $$\sigma = pq\mu_p = N_A q\mu_P$$ *(iv)* *With both the types of impurities present simultaneously* $$N_A' = N_A - N_D = 5 * 10^{14} cm^{-3}$$ $$\sigma = N_D' q\mu_n$$

UNIT II - BIPOLAR JUNCTION TRANSISTORS

NPN -PNP -Operations-Early Effect - Current equations – Input and Output characteristics of CE, CB, CC - Hybrid -π model - h-parameter model, Ebers Moll Model- Gummel Poon-model, Multi Emitter Transistor.

PART – A

1. **Why an ordinary transistor is called bipolar?** BTL 1

The operation of the transistor depends on the interaction of both majority and minority carriers. So it is called bipolar device.

2. **Collector region of transistor is larger than emitter. Why?** BTL 2

Collector is made physically larger than emitter and base because collector is to dissipate much power.

3. **BJT is called current controlled device? (April/May 2018)** BTL 2

The output current is controlled by the input current in a transistor. So it is called the current controlled device.

4. **Major Difference between Bipolar and Unipolar Device. (Nov/Dec 2014)** BTL 1

BIPOLAR	UNIPOLAR
The current flowing is controlled by both minority and majority charge carriers	Only the majority charge carriers are responsible for current flow.
Example: BJT	Example: FET

5. **Thermal Runaway in Semiconductors.** BTL 1

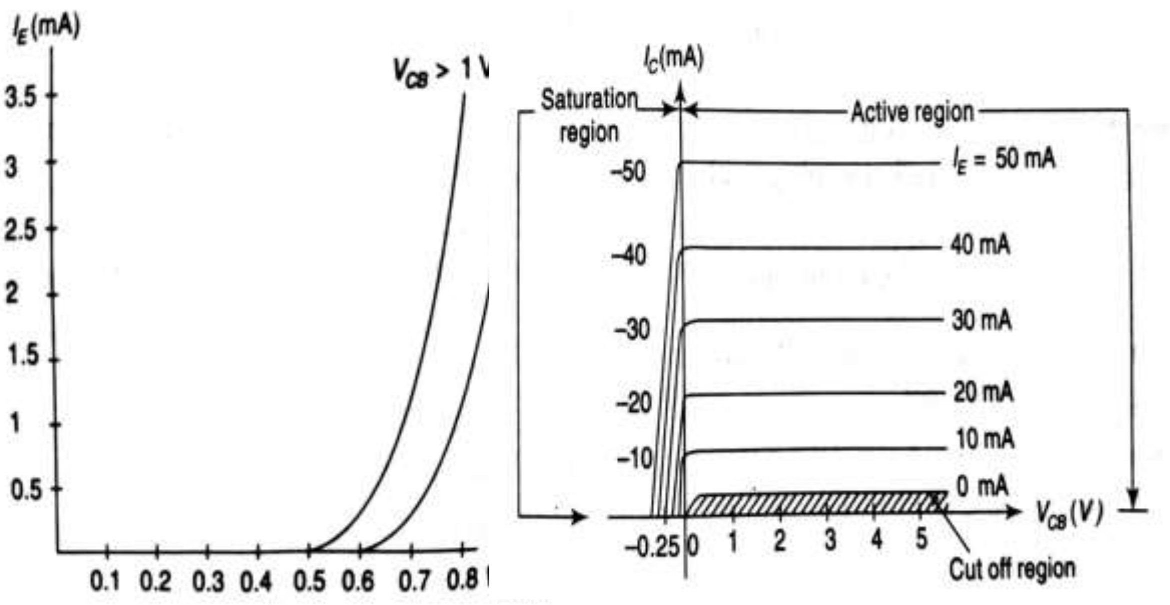
When the reverse bias across the collector – base junction in BJT is increased, there will be an increase in reverse leakage current. This increase in reverse leakage current will further increase the current flowing through a transistor and thus the power dissipation, causing further increase in collector – to – emitter leakage current. This process is cumulative and is termed as thermal runaway.

6. **What is the Need for Biasing? (May/June 2014)** BTL 1

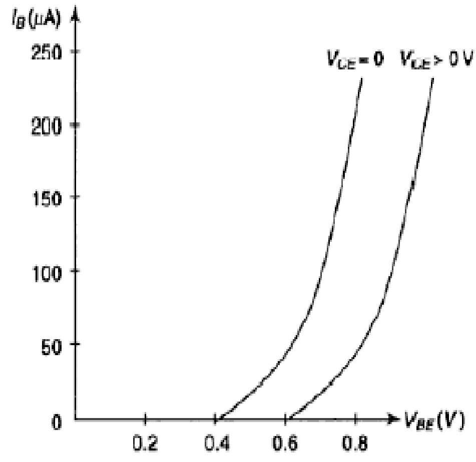
To operate the transistor in active mode, it is required to forward bias the emitter – base junction and the reverse bias the collector – bias junction. By providing proper bias voltage, the transistor can be made to work as an amplifier.

7. **Types of Configuration.** BTL 1

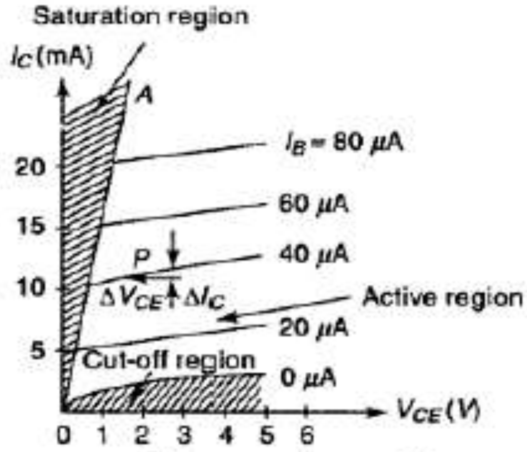
- **Common Base Configuration:** Also called grounded base configuration.
  Input terminal - Emitter
  Output terminal - Collector
  Common terminal – Base

	▪ **Common Emitter Configuration:** Also called grounded base configuration. Input terminal - Base Output terminal - Collector Common terminal – Emitter ▪ **Common Collector Configuration:** Also called grounded base configuration. Input terminal - Base Output terminal - Emitter Common terminal – Collector
8.	**What is Early Effect or Base – width Modulation? (April/May 2017, Nov/Dec 2017, April/May 2018, April/May 2019)** BTL 1 Collector Voltage V_{CC} is made to increase the reverse bias, the space charge width between collector and base tends to increase, with the result that the effective width of the base decreases. This dependency of base – width on collector – to – emitter voltage is known as early effect. This **decrease in base – width has three consequences:** - There is less chance for recombination within the base region. - The charge gradient is increased within the base, and consequently, the current of minority carriers are injected across the emitter junction increases. - For extremely large voltages, the effective base width may be reduced to zero, causing voltage breakdown in transistor. This phenomenon is called **punch – through.**
9.	**Sketch the Characteristics of CB configuration. (May/June 2016)** BTL 1 

10. **Sketch Characteristics of CE configuration.** BTL 1



CE input characteristics



CE output characteristics

11. **Among CE, CB, CC which one is most popular. Why? (Nov/Dec 2017)** BTL 2

CE is most popular among the three because it has high gain compared to base and collector configuration. It has the gain about to 500 that find excellent usage in audio frequency applications.

12. **Compare CE, CB, CC.** BTL 2 **(May/June 2016)**

Property	*CB*	*CE*	*CC*
Input resistance	Low (about 100 Ω)	Moderate (about 750 Ω)	High (about 750 kΩ)
Output resistance	High (about 450 kΩ)	Moderate (about 45 kΩ)	Low (about 25 Ω)
Current gain	1	High	High
Voltage gain	About 150	About 500	Less than 1
Phase shift between input & output voltages	0 or 360°	180°	0 or 360°
Applications	for high frequency circuits	for audio frequency circuits	for impedance matching

13. **Define Current amplification factor. (April/May 2015)** BTL 1

In a transistor amplifier with AC input signal, the ratio of change in output current to be the change in input current is known as the current amplification factor.

	In the CB configuration the current amplification factor, $\alpha = \frac{\Delta I_C}{\Delta I_E}$ In the CE configuration the current amplification factor, $\beta = \frac{\Delta I_C}{\Delta I_B}$ In the CC configuration the current amplification factor, $\gamma = \frac{\Delta I_E}{\Delta I_B}$
14.	**Relationship between α and β. (Nov/Dec 2018)** BTL 1 $\alpha = \frac{\beta}{1+\beta}, \text{or } \frac{1}{\alpha} - \frac{1}{\beta} = 1$
15.	**Relationship between α, β and γ.** BTL 1 $\gamma = \frac{1}{1-\alpha} = (\beta + 1)$
16.	**Define Avalanche Breakdown and Multiplication. (May/June 2016)** BTL 1 When the diode is reverse biased, there is a limit on the voltage that can be applied which is the Avalanche Voltage. Similarly, in the transistor the maximum reverse biasing voltage which may be applied before breakdown between the collector and base terminals with the emitter open is called **Breakdown Voltage (BV_{CBO})**. Breakdown may occur because of Avalanche multiplication of the current I_{CO} that crosses the collector junction. As a result of this multiplication, the current becomes MI_{CO}, where M is the **Avalanche Multiplication.** $M = \frac{1}{1 - \left(\frac{V_{CB}}{BV_{CBO}}\right)^n}$
17.	**Reach – Through or Punch – Through. (Nov/Dec 2018)** BTL 1 According to early effect, the width of the collector – junction transition region increases with increased collector – junction voltage. As the voltage applied across the junction V_{CB} increases the transition region penetrates deeper into the base and will have spread completely across the base to reach the emitter junction, as the base is very thin. Thus, the collector voltage has reached through the base region. This effect is known as **reach – through.**
18.	**Why h parameter model is important for BJT? (May/June 2014, April/May 2019)** BTL 1 It is important because: 1. Its values are used on specification sheets

2. It is one model that may be used to analyse circuit behaviour

3. It may be used to form the basis of a more accurate transistor model

19. **Define Multi emitter transistor** BTL 1

Transistor–transistor logic (**TTL**) is a class of digital circuits built from bipolar junction transistors (BJT) and resistors. It is called *transistor–transistor logic* because both the logic gating function (e.g., AND) and the amplifying function are performed by transistors.

TTL is notable for being a widespread integrated circuit (IC) family used in many applications such as computers, industrial controls, test equipment and instrumentation, consumer electronics, synthesizers, etc.

20. **Give some applications of BJT. (April/May 2015)** BTL 1

The BJT remains a device that excels in some applications, such as discrete circuit design, due to the very wide selection of BJT types available, and because of its high trans conductance and output resistance compared to MOSFETs.

The BJT is also the choice for demanding analog circuits, especially for very-high-frequency applications, such as radio-frequency circuits for wireless systems.

Bipolar transistors can be combined with MOSFETs in an integrated circuit by using a BiCMOS process of wafer fabrication to create circuits that take advantage of the application strengths of both types of transistor.

PART – B

1. **Explain the configurations and the principle of operation of BJT. (13M) (May/June 2016, April/May 2017) BTL 2**

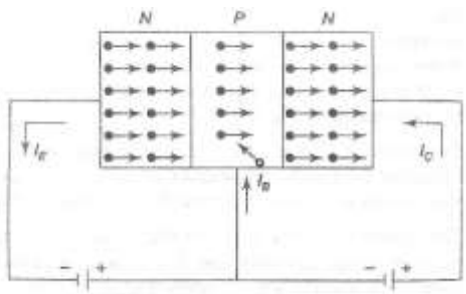
Ans:

Operation of PNP transistor (5M)

Operation on NPN transistor (5M)

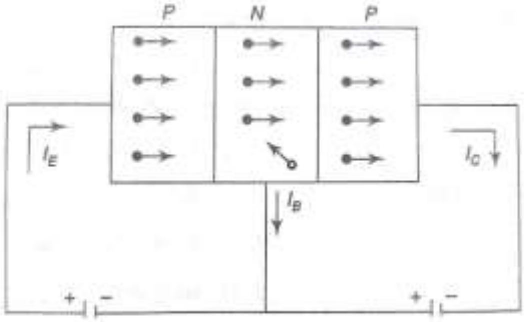
Expression for emitter and bas current (3M)

Operation of an NPN Transistor



$$I_E = I_C + I_B$$

Operation of an PNP Transistor



$$I_E = I_C + I_B$$

2. **Explain the input and output characteristics of a transistor in CB Configuration. (13M) (April/May 2017, Nov/Dec 2017, April/May 2018, April/May 2019) BTL2**

Ans:

Theory of input characteristics (3M)

Input characteristic Curve (2M)

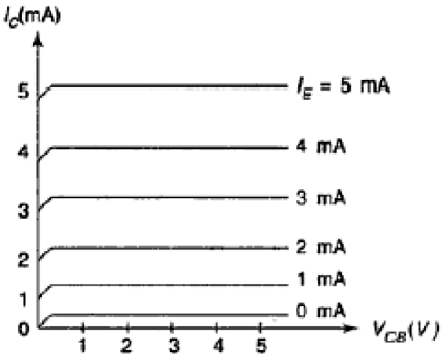
Theory of output charctertics (3M)

Output characteristic Curve (2M)

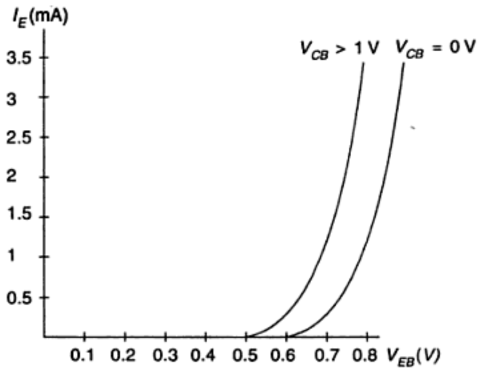
Transistor parameters (3M)

Here base is grounded and it is used as the common terminal for both input and output. It is also called as grounded base configuration. Emitter is used as a input terminal where as collector is the output terminal.

Input Characteristics & Output Characteristics



CB output characteristics



CB input characteristics

Transistor Parameters

- Input Impedance (h_{ib})
- Output Admittance (h_{ob})
- Forward Current Gain (h_{fb})
- Reverse Voltage Gain (h_{rb})

3.	**Draw the circuit diagram of a NPN transistor CE configuration and the input and output characteristics. Also define its operating regions. (13M) BTL1 (May/June 2016, April/May 2017, April/May 2018)**

Ans:

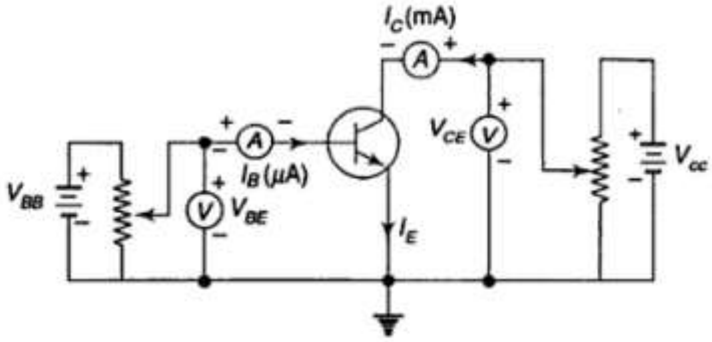
Circuit diagram and explanation (5M)

Input characteristics curve (2M)

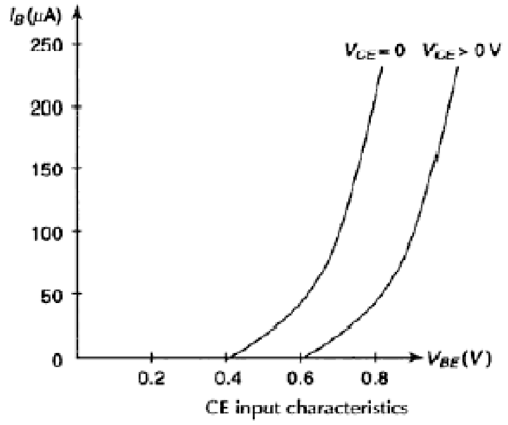
Output characteristic curve (2M)

Transistor parameter equations (4M)

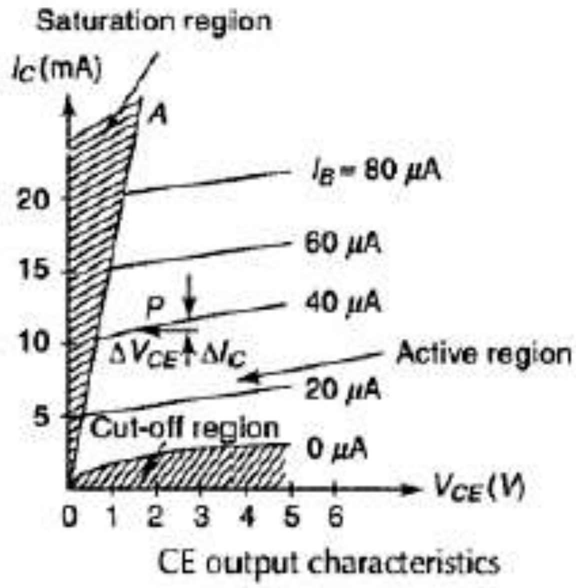
Circuit Diagram



Input Characteristics



Output Characteristics



Regions

Active Region

Saturation Region

Cut – off Region

Transistor Parameters

- Input Impedance (h_{ie})
- Output Admittance (h_{oe})
- Forward Current Gain (h_{fe})
- Reverse Voltage Gain (h_{re})

4. **Explain the input and output characteristics of a transistor in CC Configuration. (8M) BTL2**

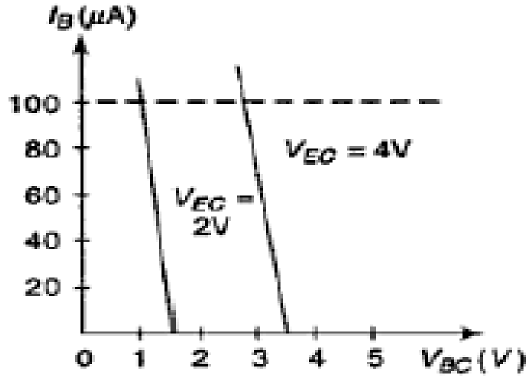
Ans:

Circuit diagram and explanation (4M)

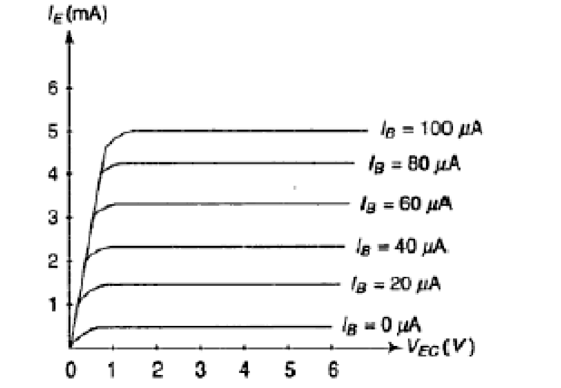
Input characteristics curve (2M)

Output characteristic curve (2M)

Here collector is grounded, and it is used as the common terminal for both input and output. It is also called as grounded collector configuration. Base is used as a input terminal whereas emitter is the output terminal.



CC input characteristics



CC output characteristics

5. **Give the comparison of CE, CB, CC Configuration. (8M) BTL2 (Nov/Dec 2016, Nov/Dc 2018)**

Ans:

Comparison of CB, CE and CC (6M)

Definition for CB, CE, CC (2M)

Property	*CB*	*CE*	*CC*
Input resistance	Low (about 100 Ω)	Moderate (about 750 Ω)	High (about 750 kΩ)
Output resistance	High (about 450 kΩ)	Moderate (about 45 kΩ)	Low (about 25 Ω)
Current gain	1	High	High
Voltage gain	About 150	About 500	Less than 1
Phase shift between input & output voltages	0 or 360°	180°	0 or 360°
Applications	for high frequency circuits	for audio frequency circuits	for impedance matching

6. **Formulate the expression of Gummel Poon-model with neat circuit diagram and obtain the Gummel number. (13M) BTL2 (April/May 2015)**

Ans:

Circuit diagram and explanation (6M)

Gummel plot (3M)

Expression for Gummel Poon model (4M)

The DC and dynamic currents of the transistor in response V_{BE} and V_{CE} can be represented accurately by the BJT model used in circuit simulators such as SPICE. A typical circuit – simulation model or compact model is made of the Ebers – Moll Model along with additional enhancements for high – level injection, parasitic resistances and voltage dependent capacitances that accurately represent the charge storage in the capacitor.

$$I_E = -(I_{pe} + I_{nc})$$

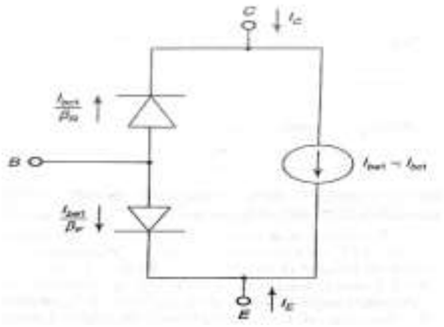


Fig: Gummel – Poon NPN model without early effect and high – level injection

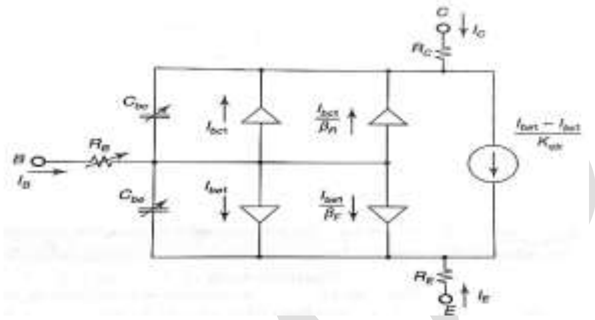


Fig: Gummel – Poon Model with high High – level injection effect & early effect

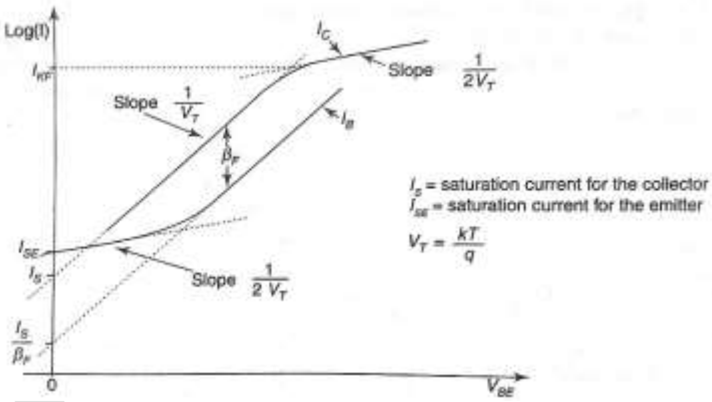


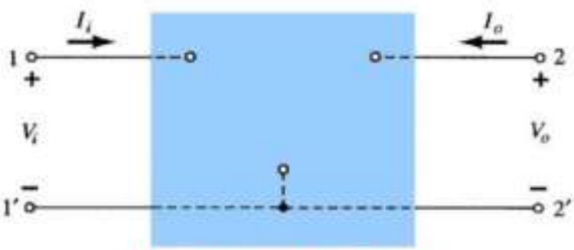
Fig: Gummel plot

7. **Describe hybrid parameters for all three configurations and relations between them.(8M) BTL1**

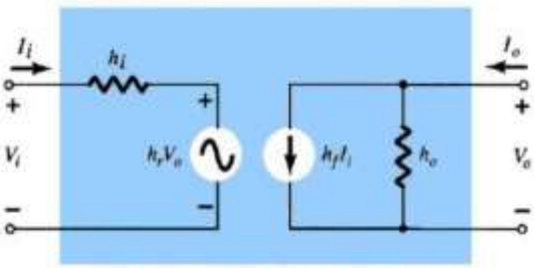
Ans:

Circuit diagram for hybrid model (4M)

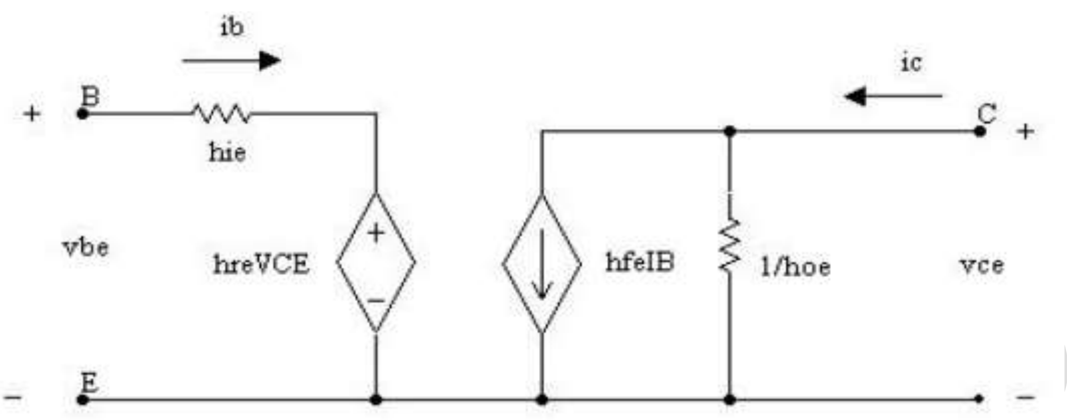
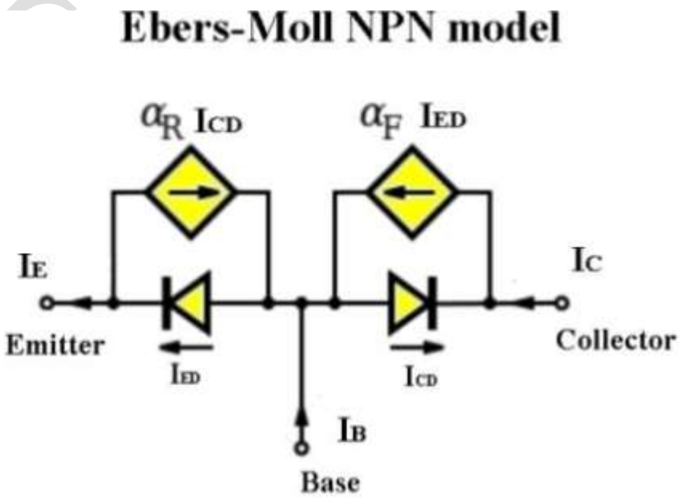
Expression for hybrid parameters (CB, CE, CC) (4M)



Hybrid Equivalent Model



Hybrid Equivalent Circuit

	$$\begin{bmatrix} V_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} h_{11} & h_{12} \\ h_{21} & h_{22} \end{bmatrix} \begin{bmatrix} I_1 \\ V_2 \end{bmatrix}$$ 
8.	**Describe the Eber's Moll model for a NPN transistor. (13M) BTL1 (Nov/Dec 2017, April/May 2018, April/May 2019)** **Ans:** Circuit diagram and explanation (6M) Theory of Eber's moll model (3M) Expression for Eber's moll model (4M) The Ebers-Moll model, or equivalent circuit, is one of the classic models of the bipolar transistor. This particular model is based on the interacting diode junctions and applicable in any of the transistor operating modes.  Expression for Eber moll model $$I_E = I_{E0}(e^{V_{EB}/V_T} - 1) - \alpha_R I_{C0}(e^{V_{CB}/V_T} - 1)$$ $$I_C = -\alpha_F I_{E0}(e^{V_{EB}/V_T} - 1) + I_{C0}(e^{V_{CB}/V_T} - 1)$$

UNIT III - FIELD EFFECT TRANSISTORS

JFETs – Drain and Transfer characteristics - Current equations-Pinch off voltage and its significance-MOSFET- Characteristics- Threshold voltage -Channel length modulation, D-MOSFET, E-MOSFET-Characteristics – Comparison of MOSFET with JFET.

PART – A

1. Define Field effect transistor. (FET). BTL1

FET is a device in which the flow of current through the conducting region is controlled by an electric field. Hence, the name Filed Effect Transistor (FET). As the current conduction is only by majority carriers, FET is said to be a **Unipolar Device**.

2. Why FET is called voltage-controlled device? BTL1 (Nov/Dec 2015)

FET the value of the current depends upon the value of the voltage applied at the gate and drain. So it is *known as voltage controlled device*.

3. Define the term threshold voltage. BTL1 (May/June 2016)

The **threshold voltage**, commonly abbreviated as $\mathbf{V_{TH}}$, of a field-effect transistor (FET) is the value of the gate–source voltage when the conducting channel just begins to connect the source and drain contacts of the transistor, allowing significant current.

The threshold voltage of a junction field-effect transistor is often called **pinch-off voltage** instead, which is somewhat confusing since "pinch off" for an insulated-gate field-effect transistor is used to refer to the channel pinching that leads to current saturation behaviour under high source–drain bias, even though the current is never off. The term "threshold voltage" is unambiguous and refers to the same concept in any field-effect transistor.

4. Mention the Characteristics Parameters of JFET. BTL1 (April/May 2018)

- **Mutual Conductance or Transconductance, g_m**

  It is the slope of transfer characteristic curves, and is defined by

$$g_m = \left(\frac{\partial I_D}{\partial V_{GS}}\right)_{V_{DS}} = \frac{\Delta I_D}{\Delta V_{GS}}, V_{DS} \text{ held constant}$$

  It is the ratio of a small change in the drain current to the corresponding small change in the gate voltage at a constant drain voltage. It has the unit of conductance mho.

- **Drain Resistance, r_d**

  It is the reciprocal of the slope of the drain characteristics and is defined by

$$r_d = \left(\frac{\partial V_{DS}}{\partial I_D}\right)_{V_{GS}} = \frac{\Delta V_{DS}}{\Delta I_D}, V_{GS}\ held\ constant$$

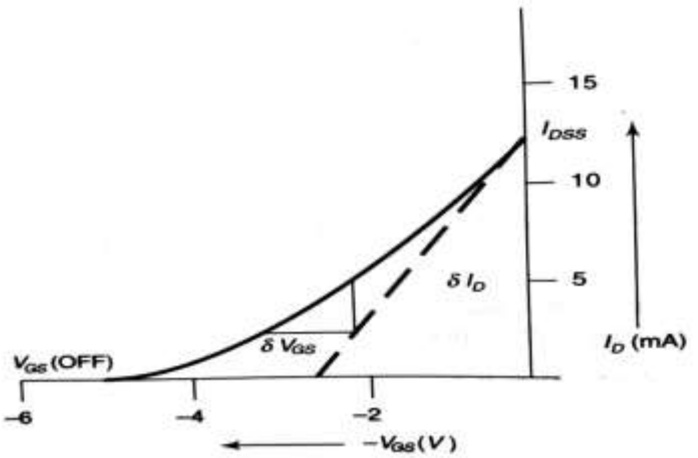
	It is the ratio of a small change in the drain voltage to the corresponding small change in the drain current at a constant gate voltage. It has the unit of resistance in ohms. **The drain resistance at V_{GS} = 0V**. i.e., when the depletion region of the channel are absent, is called as drain – source ON resistance, represented as R_{DS} or $R_{DS(ON)}$ The reciprocal of r_d is called the drain conductance. It is denoted by g_d. **Amplification factor, μ** It is defined by $$\mu = \left(\frac{\partial V_{DS}}{\partial V_{GS}}\right)_{I_D} = -\frac{\Delta V_{DS}}{\Delta V_{GS}}, I_D \text{ held constant}$$ It is the ratio of small change in the drain voltage to the corresponding small change in the gate voltage at a constant drain current. The negative sign shows that when V_{GS} is increased, V_{DS} must be decreased for I_D to remain constant. **Relationship among FET parameters** $$\mu = g_m r_d$$ **Power Dissipation, P_D** Power Dissipation is the product of I_D and V_{DS} $$P_D = V_{DS} I_D$$ **Pinch – Off Voltage** In JFET, the electrons flow through a semiconducting channel between source and drain terminals. By applying a reverse bias voltage to a gate terminal, the channel is made free of charge carriers, i.e., pinched off, so that the electric current is impeded or switched off completely.
5.	**State the Current equation for JFET. BTL2 (Nov/Dec 2018)** $$I_{DS} = I_{DSS}\left(1 - \frac{V_{GS}}{V_P}\right)^2$$
6.	**What is channel length modulation? BTL1 (Nov/Dec 2016, April/May 2017)** One of several short-channel effects in MOSFET scaling, **channel length modulation** (**CLM**) is a shortening of the length of the inverted channel region with increase in drain bias for large drain biases. As the drain voltage increases, its control over the current extends further toward the source, so the uninverted region expands toward the source, shortening the length of the channel region, the effect called *channel-length modulation*.
7.	**Compare JFET with BJT. BTL2 (Nov/Dec 2017, April/May 2017, April/May 2018)**

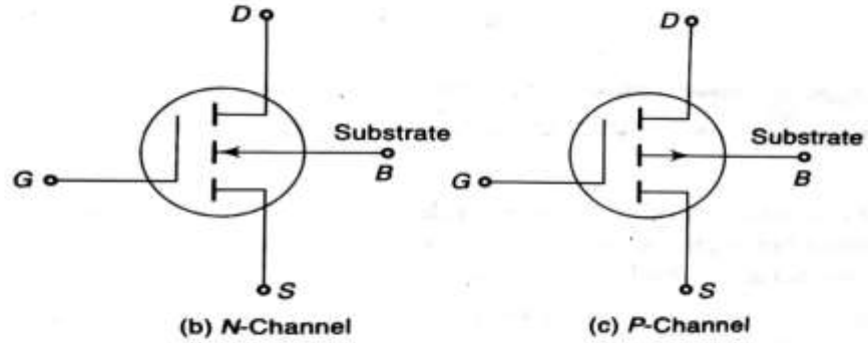
JFET	BJT
Operation depends on the **flow of majority carrier**s - Holes for P – Channel & Electrons for N – Channel - Unipolar Devices.	Operation depends on **both minority and majority current carriers**
Voltage Controlled Device, i.e., voltage at the input terminal controls the output current	**Current Controlled Device**, i.e., input current controls the output current.
Negative temperature coefficient at high current levels, it prevents from thermal breakdown.	**Positive temperature coefficient** at high current levels, which leads to thermal breakdown.
Easier to fabricate and they occupy lesser in space.	Fabrication is quite difficult and occupies a larger space area.
Higher Input impedance & Lower output impedance	Low input impedance

8. Comparison of MOSFET with JFET. BTL2 (Nov/Dec 2014, April/May 2015)

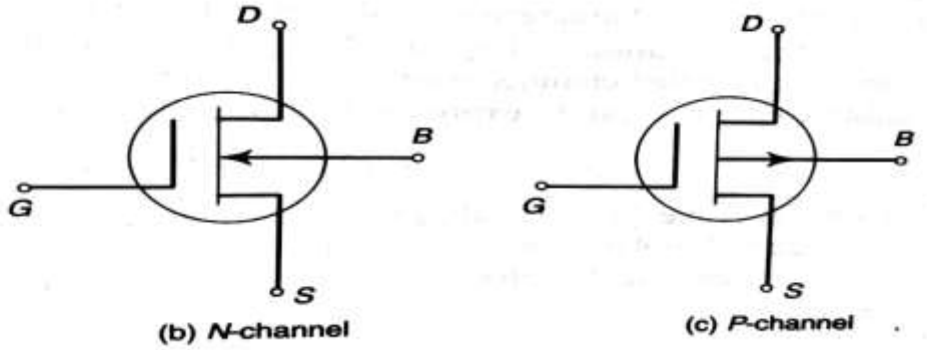
MOSFET	JFET
The transverse electric field induced across an insulating layer deposited on the semiconductor material controls the conductivity of the channel.	The transverse electric field across the reverse biased PN junction controls the conductivity of the channel.
Gate Leakage Current is of the order of 10^{-12}.	Gate Leakage Current is of the order of 10^{-9}
Depletion type MOSFET may be operated in both depletion and enhancement.	JFET's are operated only in the depletion mode
MOSFET are easier to fabricate	JFET are difficult to fabricate compared to MOSFET

9. Draw the transfer characteristics curve for JFET. BTL1

	
10.	**Differentiate between N and P channel FETs. BTL2** 1. In an N channel JFET the current carriers are electrons, whereas the current carriers are holes in a P channel JFET. 2. Mobility of electrons is large in N channel JFET; Mobility of holes is poor in P channel JFET. 3. The input noise is less in N channels JFET than that of P channels JFET. 4. The transconductance is larger in N channel JFET than that of P channel JFET.
11.	**Write some applications of JFET. BTL1 (Nov/Dec 2015, Nov/Dec 2017)** ▪ FET is used as buffer in measuring instruments, receivers it has high input impedance and low output impedance. ▪ FET's are used in RF amplifiers in FM tuners and communication equipment for the low noise level. ▪ Since the input capacitance is low, FET's are used in cascade amplifiers in measuring and test equipment's. ▪ Since the device is voltage controlled, it is used as voltage variable resistor in operational amplifiers and tone controls. ▪ FET's are used in mixer circuits in FM and TV receivers, communication equipment's because inter modulation distortion is low.
12.	**Sketch the graph symbol for N – channel and P – channel MOSFETs. BTL1**



Enhancement MOSFET Circuit Symbol



Depletion MOSFET Circuit Symbols

13. Differentiate between enhancement – type and depletion – type MOSFETs. BTL2 (April/May 2016, April/May 2017)

(i) Gate information of N – channel E – MOSFET is similar to the N – channel D – MOSFET.

(ii) E – MOSFET can be worked only in enhancement mode and hence, this MOSFET is called enhancement MOSFET or E – MOSFET.

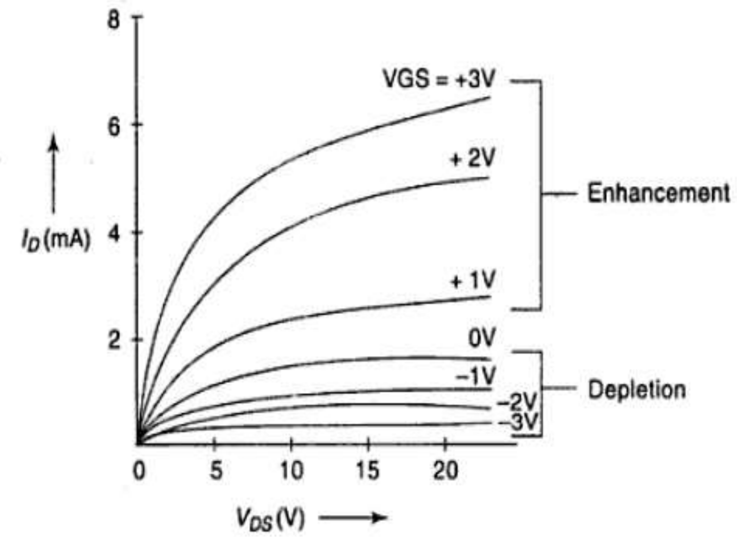
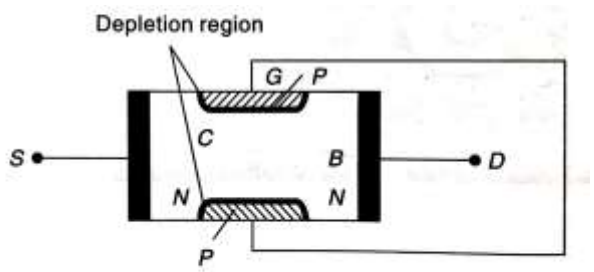
(iii) E – MOSFET ha no conducting channel between the source and the gate terminals whereas D – MOSFET has conducting channel between the source and gate terminals.

14. Compare N channel MOSFET with P channel MOSFET. BTL2 (Nov/Dec 2017)

(i) The P – channel enhancement MOSFET is very popular because it is much easier and cheaper to produce than the N – channel device.

(ii) The hole mobility is nearly 2.5 times than the electron mobility. Thus, a P – channel MOSFET occupies a large area than an N – channel having the same I_D rating.

(iii) The drain resistance of P – channel MOSFET is three times higher than that for an identical N – channel MOSFET.

	(iv) The N – channel MOSFET has the higher packing density which makes it faster in switching applications due to the smaller junction areas and lower inherent capacitances.
15.	**Comparison of N – with P – Channel FETs. BTL2** (i) In an N – channel JFET the current carriers are electrons, whereas the current carriers are holes in a P – channel JFET. (ii) Mobility of electrons is large in N – channel JFET; mobility of holes is poor in P – channel JFET (iii) The input noises in less in N – channel JFET than that of P – channel JFET. (iv) The transconductance is larger in N – channel JFET than that of P – channel JFET.
16.	**Draw the V-I characteristics curve of MOSFET. BTL1** 
PART – B	
1.	**i) Explain the construction and operation and of N channel JFET. (6M) BTL2 (April/May 2017, April/May 2018, April/May 2019)** **Ans:** JFET construction diagram (2M) Characteristic curve (2M) Explanation (2M)  *Fig: JFET Construction*

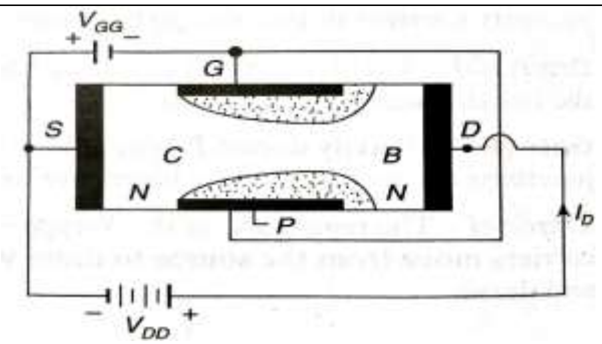


Fig: JFET under applied bias

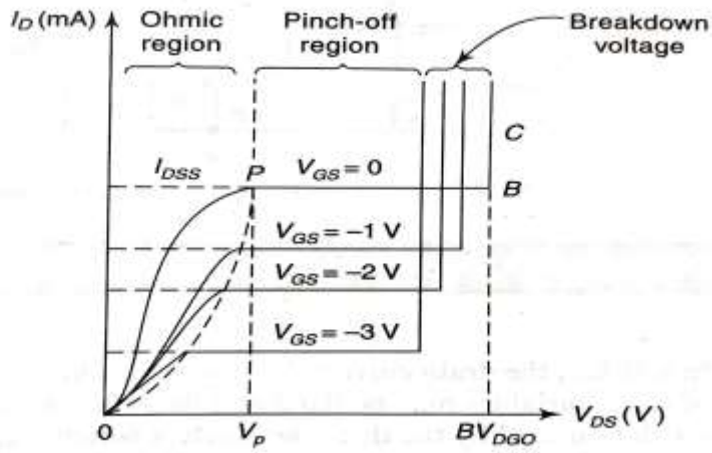


Fig: Drain Characteristics

ii) Derive the FET characteristics parameters from the above characteristics. (7M) BTL2

Ans:

1) Mutual Conductance or Transconductance (g_m) (2M)
2) Drain Resistance (r_d) (1M)
3) Amplification Factor (μ) (1M)
4) Relationship among FET parameters: $\mu = g_m * r_d$ (1M)
5) Power Dissipation (P_D) (1M)
6) Pinch – off Voltage (V_P) (1M)

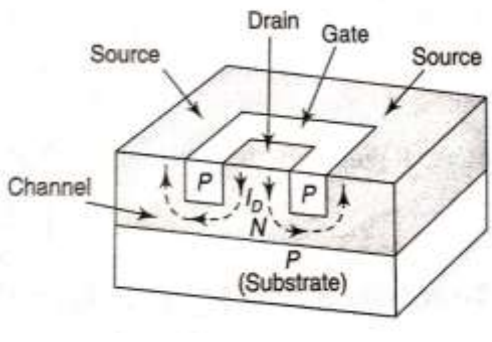
2.	**Define Pinch off Voltage. Sketch the depletion region before and pinch off and derive the Gate to source voltage.(13M) BTL2 (April/May 2019)**

Ans:

Definition for pinch off voltage (2M)

Schematic diagram of FET (4M)

Derivation for Vgs (7M)



The gate reverse voltage that removes all the free charge from the channel is called the Pinch – off voltage V_P.

$$W(x) = a - b(x)$$

$$= \left\{\frac{2\varepsilon}{qN_D}\left[V_o - V(x)\right]\right\}^{\frac{1}{2}}$$

Fig: Single – ended geometry junction FET

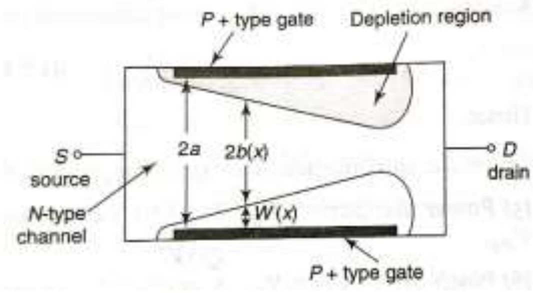


Fig: Detailed Structure of N – channel JFET

$$V_{GS} = \left(1 - \frac{b}{a}\right)^2 V_P$$

3. **Compare JFET with BJT. (4M) BTL2 (Nov/Dc 2017, April/May 2018)**

JFET	BJT
Depends on flow of majority carriers	Depends on both the minority and majority carriers
No junctions & Less Noisy	Bi junctions.
Higher input impedance	Lower input impedance
Voltage Controlled device	Current Controlled device

4. **With the help of a suitable diagram explain the working of different types of MOSFET. (13M) BTL1 (April/May 2017, Nov/Dec 2017, April/May 2018, April/May 2019)**

Ans:

Schematic diagram for Enhancement MOSFET (3M)

Characteristic Curve (2M)

Theory of E-MOSFET (2M)

Schematic diagram/Explanation for Depletion MOSFET (4M)

Characteristic Curve (2M)

Enhancement MOSFET

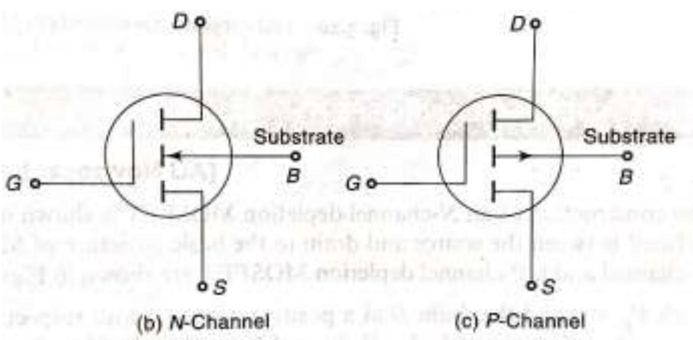


Fig: Circuit symbols for Enhancement MOSFET

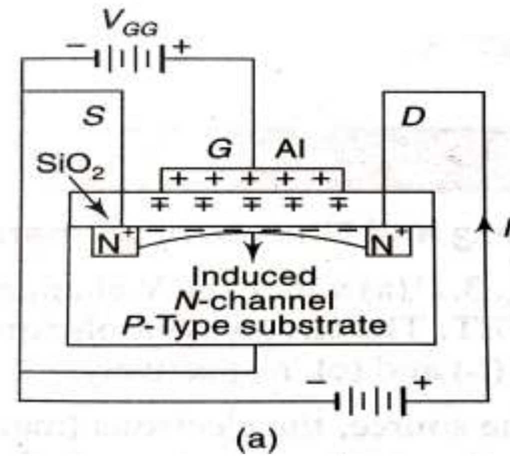


Fig: N – channel Enhancement MOSFET

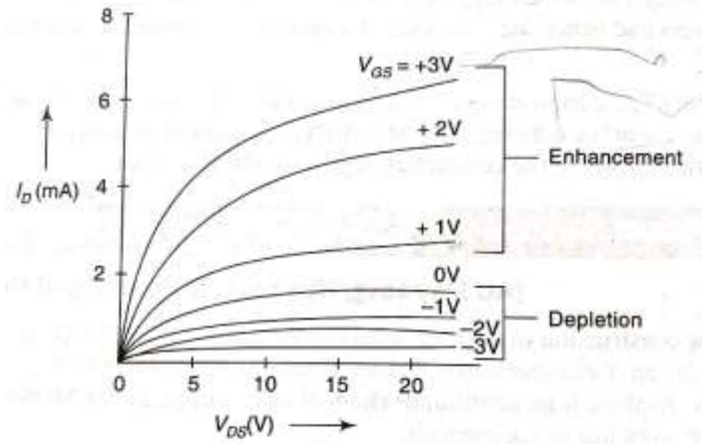


Fig: Volt – ampere characteristics of MOSFET

Depletion MOSFET

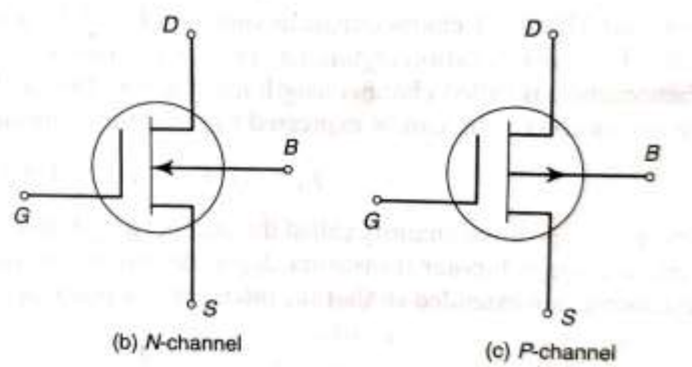
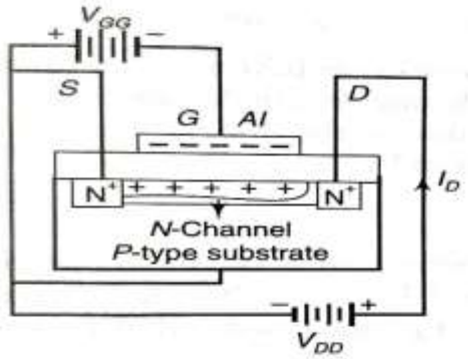
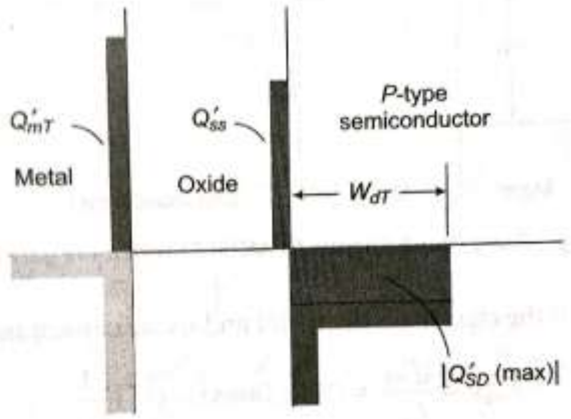
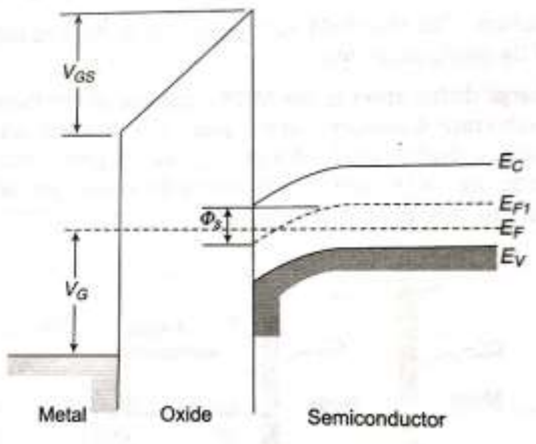
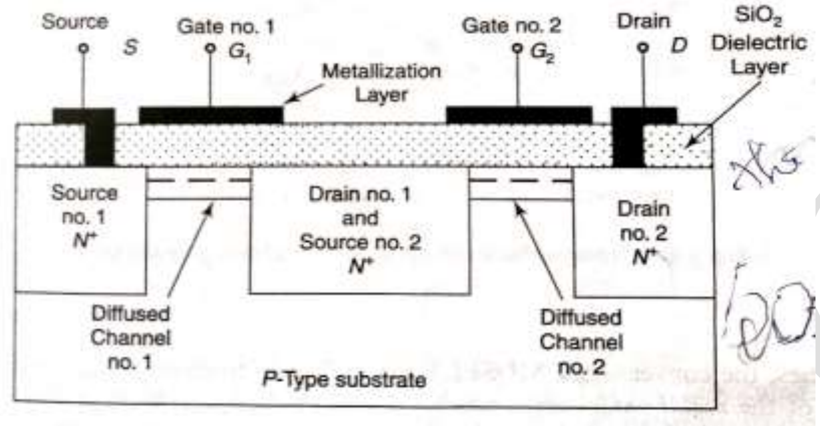
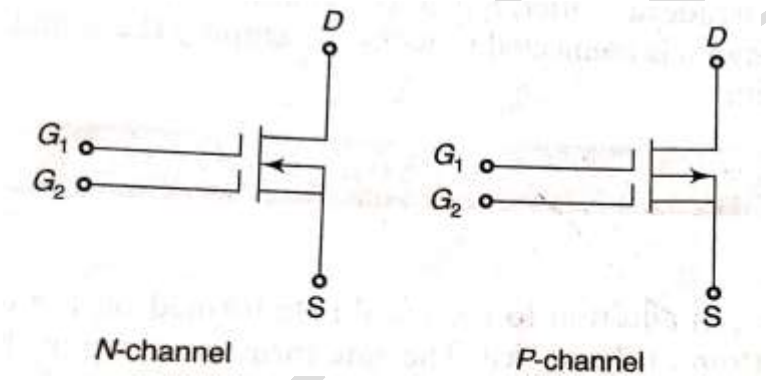
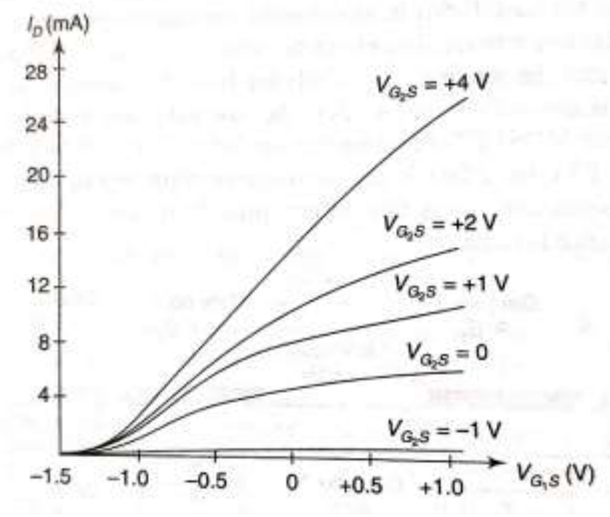


Fig: Circuit symbols for depletion MOSFET

	 *Fig: N – channel depletion MOSFET*
5.	**Derive the expression for threshold voltage in MOSFET. (7M) BTL2 (Nov/Dec 2018)** **Ans:** Charge distribution diagram/Explanation in MOSFET (3M) Energy band diagram (2M) Threshold voltage expression (2M)  *Fig: Charge distribution through MOS capacitor for a P – type substrate*  *Fig: Energy band diagram for MOSFET with a +ve gate bias*
6.	**Explain the construction and operation of Dual – Gate MOSFET. (8M) BTL2**

	Ans: Construction diagram for N and P channel dual gate MOSFET (4M) Explanation/Characteristic Curve (4M)  *Fig: N – Channel dual gate MOSFET*  *Fig: Schematic symbols for N – channel and P – channel MOSFET*  *Fig: Transfer characteristics of N – channel dual gate MOSFET* ***Applications***
7.	**Describe the physical construction, operation and application of FINFET. (8M) BTL2 (Nov/Dec 2015, Nov/Dec 2016)**

Ans:

Construction diagram for FINFET (3M)

Principle of operation (3M)

Applications (2M)

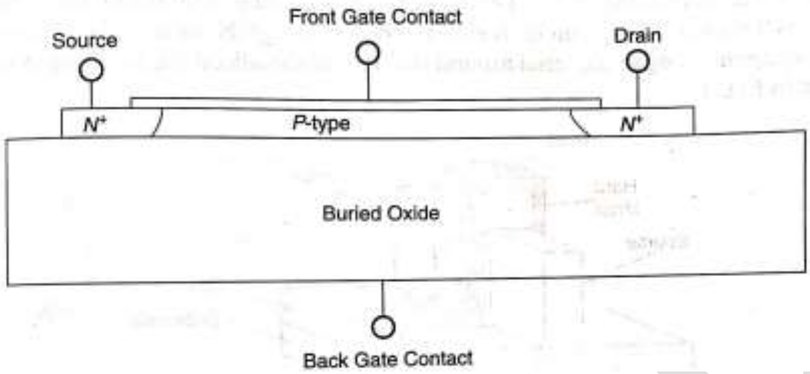


Fig: Back contacted SOI MOSFET Device

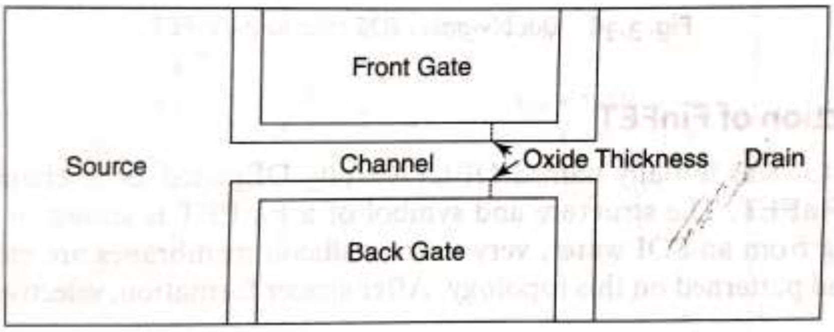
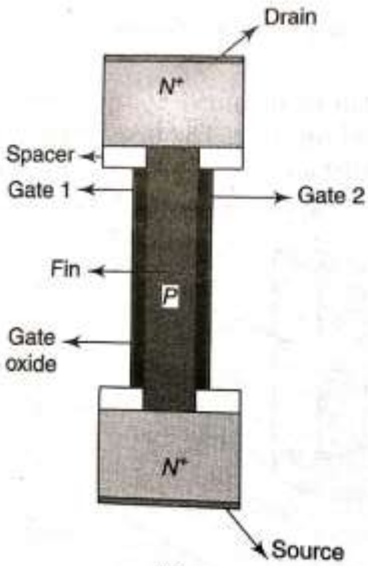


Fig: Cross section of a dual gate MOSFET device



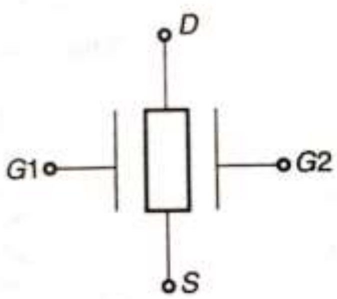
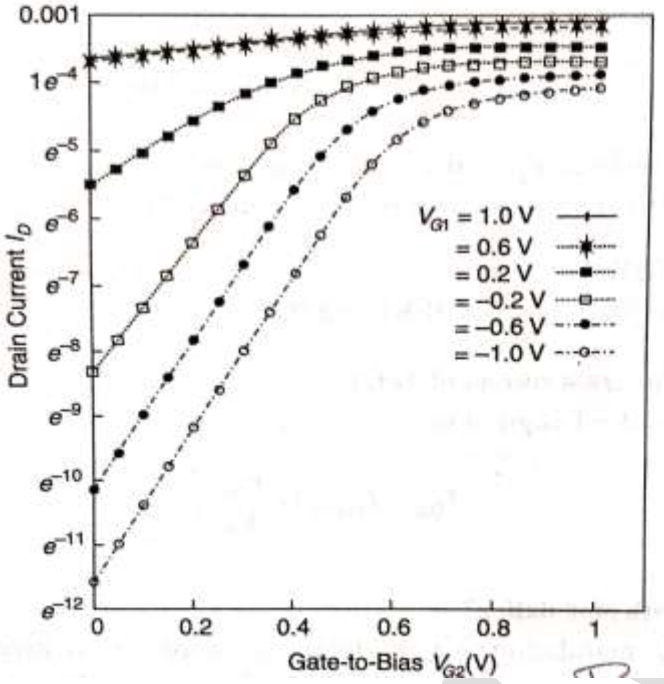
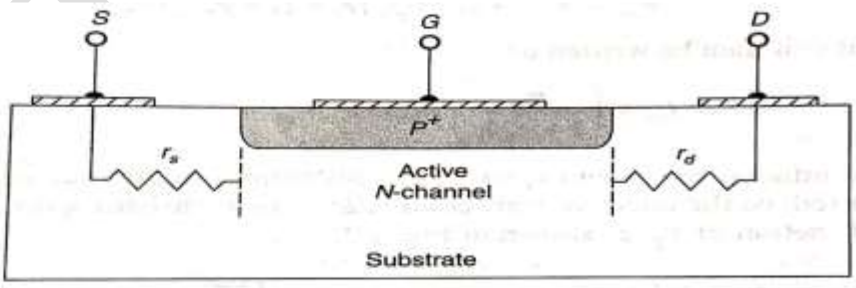
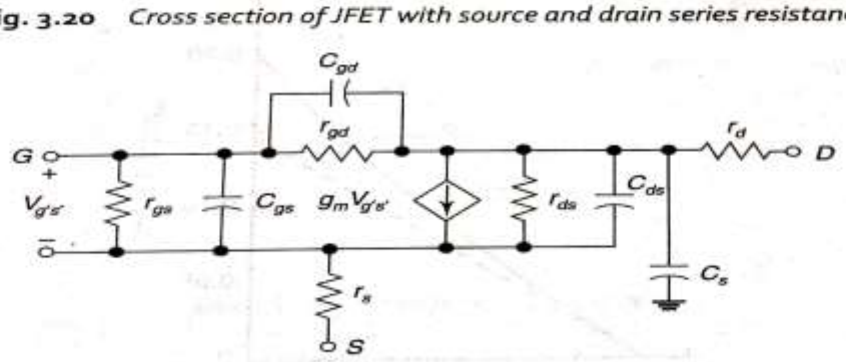


Fig: Schematic Symbol

Fig: Structure of FINFET

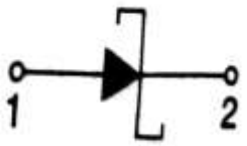
	 *Fig: Characteristics of a FINFET*
8.	**Describe briefly about the small signal equivalent circuit of JFET and its associated parameters with necessary diagrams. (13M) BTL2 (April/May 2017. April/May 2018, Nov/Dec 2018, April/May 2019)** **Ans:** Small signal equivalent circuit of JFET (5M) Expression of parameters (4M) Theory of JFET (4M)  **Fig. 3.20** *Cross section of JFET with source and drain series resistance* 

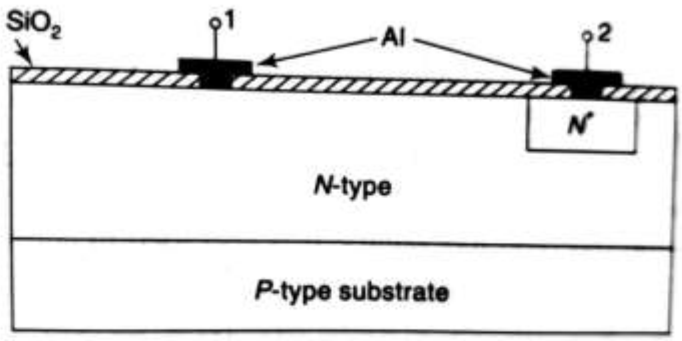
UNIT IV – SPECIAL SEMICONDUCTOR DEVICES	
Metal-Semiconductor Junction- MESFET, FINFET, PINFET, CNTFET, DUAL GATE MOSFET, Schottky barrier diode-Zener diode-Varactor diode –Tunnel diode- Gallium Arsenide device, LASER diode, LDR.	
PART – A	
1.	**Define MESFET. BTL1** MESFET is a modified form of MOSFET in which GaAs epitaxial layer was grown on semi – insulating GaAs substrate. Its operation is similar to PN junction JFET. The use of GaAs rather than silicon in MESFET provides two more significant advantages. i. The electron mobility at room temperature is more than 5 times larger, while the peak electron velocity is about twice that of silicon ii. It is possible to fabricate semi – insulating (SI) GaAs substrate, which eliminates the problem of absorbing microwave power in the substrate due to free carrier absorption and provides better operation at high temperature.
2.	**What do you mean by Metal Semiconductor Contact? BTL1** A metal semiconductor contact is a contact between a metal and a semiconductor which according to the doping level and requirement may act as a rectifying diode or just a simple contact between a semiconductor device and the outside world.
3.	**Define Ohmic Contacts. BTL1 (Nov/Dec 2018)** Ohmic Contact is another type of metal – semiconductor junction. It is formed by applying a metal to a heavily doped semiconductor. Here the current is conducted equally in both directions and there will be a very little voltage drop across the junction. The usage of ohmic contacts is to connect one semiconductor device to another on an IC, or to connect an IC to its external terminals.
4.	**State the features of Gallium Arsenide Devices. BTL1** Gallium Arsenide is a compound semiconductor made of compound of two elements. Gallium having three valence electrons can be combined with arsenic, which has five valence electrons to form the compound GaAs.
5.	**State the Characteristics of GaAs devices. BTL1 (April/May 2019)** • Less than one – micron gate geometry • Less than two – micron metal pitch • ON and OFF devices • Four – inch diameter wafers

	- Up to four layer metal - Suitability for clock rates in the range of 1GHz – 2GHz.
6.	**Mention the salient Features of GaAs Technology. BTL1 (May/June 2016)** - Improved electron mobility over the silicon technology, resulting in very fast electron transit times. - The saturation velocity for GaAs occurs at a lower threshold filled than for silicon. - GaAs devices operate over a wider temperature range (-200^{o}C to +200^{o}C) - Direct band gap allows GaAs to be used as light emitters - Less power dissipation compared to silicon technology.
7.	**Define contact potential in metal semiconductor contact. BTL1** The difference of potential between the work function of metal and the work function of Semiconductor in a metal semiconductor contact is termed as contact potential.
8.	**Mention the Advantages & Disadvantages of MESFET. BTL1 (April/May 2015, Nov/Dec 2018)** **<u>Advantages</u>** MESFET is the higher mobility of the carriers in the channel as compared to the MOSFET. As the depletion region separates the carriers from the surface, their mobility is close to that of bulk material. The higher mobility leads to higher values of current, transconductance and transit frequency of the device. **<u>Disadvantages</u>** Disadvantage of MESFET structure is the presence of Schottky Metal gate. It limits the forward bias voltage on the gate to the turn – on voltage of the Schottky diode. Turn – on voltage is typically 0.7V for GaAs Schottky Diodes. Therefore, the threshold voltage must be lower than this turn – on voltage. As a result, it is more difficult to fabricate circuits containing a large number of enhancement mode MOSFETs
9.	**State the applications of MESFET. BTL1 (Nov/Dec 2016)** i. The higher transit frequency of the MESFET makes it particularly of interest for microwave circuits. ii. MESFET provides a superior microwave amplifier or circuit, the limitation by the diode turn – on is easily tolerated. iii. Extends to low noise preamplifiers and linear amplifiers, oscillators and mixers in communication networks due to some of its outstanding physical properties, such as high cut – off frequency and high electron mobility.
10.	**Comparison of MOSFET and MESFET. BTL2 (April/May 2019)**

MOSFET	MESFET
Gate is controlled through a MOS barrier	Gate control takes place through a Schottky barrier
MOSFETs are usually fabricated in Si	MESFETs are usually fabricated in GaAs
MOSFET is normally in OFF state and there is flow of current only when the channel is inverted by gate bias	MESFET is normally in ON state and negative gate bias is needed to turn the current to OFF state
Both P – channel and N – channel MOSFETs are possible giving rise to CMOS	Typically N – channel MESFET are feasible.
MOSFET is mainly used in integrated circuits, but microwave operation is not yet possible.	MESFET is mainly used in microwave devices but the integration level is not as high as the CMOS devices.

11. Draw the Symbol and Structure of Schottky diode. BTL1





12. Give the applications of Schottky diode. BTL2 (Nov/Dec 2017, April/May 2018)

- It can switch off faster than bipolar diodes
- It is used to rectify very high frequency signals (>10 MHZ)
- It as a switching device in digital computers.
- It is used in clipping and clamping circuits.
- It is used in communication systems such as frequency mixers, modulators and detectors.

13. Compare between Schottky diode and conventional diode. BTL2 (April/May 2017)

PN junction diode	Schottky diode
1. Here the contact is established between two semiconductors	1. Here the contact is established between the semiconductor and metal
2. Current conduction is due to both majority and minority carriers	2. Current conduction is only due to majority carriers

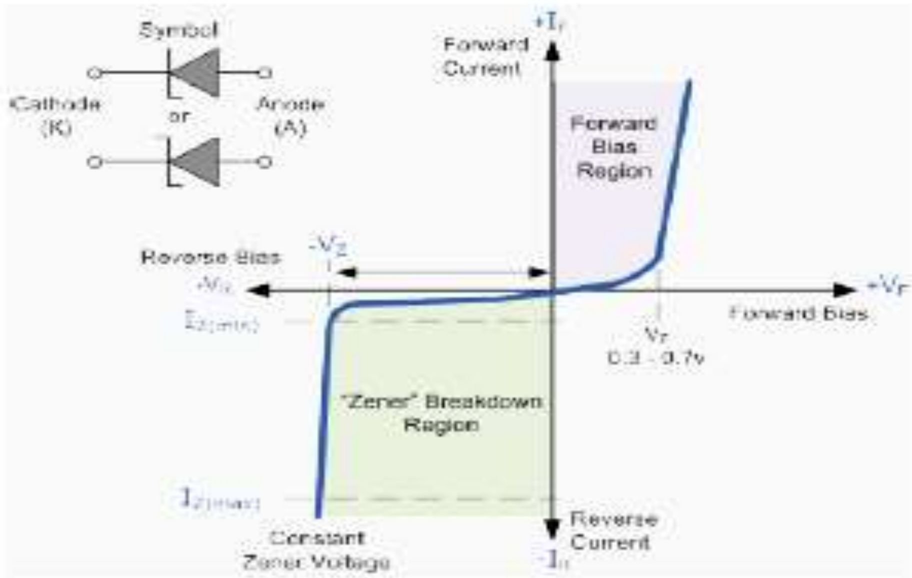
3. Large reverse recovery time	3. Small reverse recovery time
4. Barrier potential is high about 0.7 V	4. Barrier potential is low about 0.25 V
5. Switching speed is less	5. Switching speed is high
6. Cannot operate at high frequency	6. Can operate at very high frequency (> 300MHz)

14. **Why zener diode is often preferred than PN diode. BTL1 (Nov/Dec 2015, April/May 2017)**

When the reverse voltage reaches breakdown voltage in normal PN junction diode the current through the junction and the power dissipated at the junction will high. Such an operation is destructive and the diode gets damaged.

Whereas diode can be designed with adequate power dissipation capabilities to operate in breakdown region. That diode is known as zener diode. It is heavily doped than ordinary diode.

15. **Draw the V-I characteristics curve for zener diode. BTL2 (May/Jun 2016)**



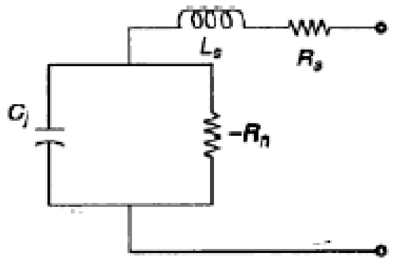
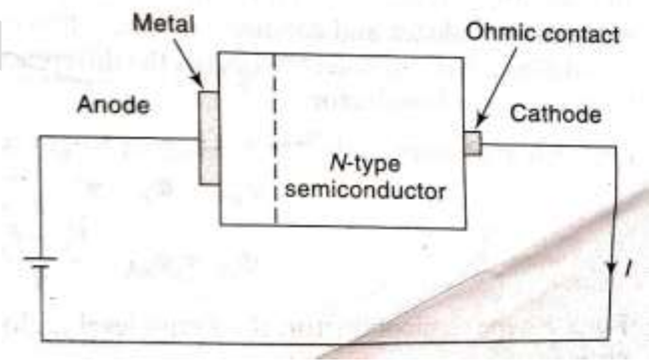
16. **What is zener breakdown? BTL1 (Nov/Dec 2014, Nov/Dec 2015)**

Zener break down takes place when both sides of the junction are very heavily doped and consequently the depletion layer is thin and consequently the depletion layer is tin. When a small value of reverse bias voltage is applied, a very strong electric field is set up across the thin depletion layer. This electric field is enough to break the covalent bonds. Now extremely large number of free charge carriers are produced which constitute the zener current. This process is known as zener break down.

17. **What is avalanche break down? BTL1 (Nov/Dec 2016)**

When bias is applied, thermally generated carriers which are already present in the diode acquire sufficient energy from the applied potential to produce new carriers by removing valence electron from their bonds. These newly generated additional carriers acquire more energy from

	the potential and they strike the lattice and create more number of free electrons and holes. This process goes on as long as bias is increased and the number of free carriers gets multiplied. This process is termed as avalanche multiplication. Thus the break down which occurs in the junction resulting in heavy flow of current is termed as avalanche break down.
18.	**Define Line Regulation and Load Regulation In Zener Diode. BTL1** **Line Regulation:** Line regulation is defined as the change in output voltage for a change in line supply voltage, keeping the load current and temperature constant. Line regulation is given by $$Line\ Regulation = \frac{change\ in\ output\ voltage}{change\ in\ input\ voltage} = \frac{\Delta V_o}{\Delta V_{in}}$$ **Load Regulation:** Load Regulation is defined as a change in regulated output voltage as the load current changes from no load to full load. It is expressed as a percentage of no load voltage or full load voltage $$\%\ Load\ Regulation = \frac{V_{no\ load} - V_{full\ load}}{V_{no\ load}} * 100$$ $$\%\ Load\ Regulation = \frac{V_{no\ load} - V_{full\ load}}{V_{full\ load}} * 100$$
19.	**What is tunneling phenomenon? BTL1 (April/May 2019)** The phenomenon of penetration of the charge carriers directly though the potential barrier instead of climbing over it is called as tunneling.
20.	**Give the application of tunnel diode. BTL2 (Nov/Dec 2018)** • As logic memory storage device • As microwave oscillator • In relaxation oscillator circuit • As an amplifier • As an ultra-high speed switch
21	**Give the advantages and disadvantages of tunnel diode. BTL1 (April/May 2016)** **Advantages** • Low noise • Ease of operation • High speed • Low power **Disadvantages**

	• Voltage range over which it can be operated is 1 V less. • Being a two-terminal device there is no isolation between the input and output circuit.
22	**Draw equivalent circuit of tunnel diode. BTL1**  Equivalent circuit of tunnel diode This is the equivalent circuit of tunnel diode when biased in negative resistance region. • At higher frequencies the series R and L can be ignored. • Hence equivalent circuit can be reduced to parallel combination of junction capacitance and negative resistance.
23	**Expand LASER and LDR. BTL1** LASER: Light Amplification by Stimulated Emission of Radiation LDR: Light Dependent Resistor
	PART – B
1.	**Draw the structure of a metal – semiconductor junction and explain the energy band structure before and after contact. (13M) BTL2** **Ans:** Energy band diagram/Structure (4M) Theory of energy band structure (5M) Relevant Expression (4M) ***Structure of Metal – Semiconductor Junction***  *Fig: Structure of a metal – semiconductor junction* ***Energy Band Diagram***

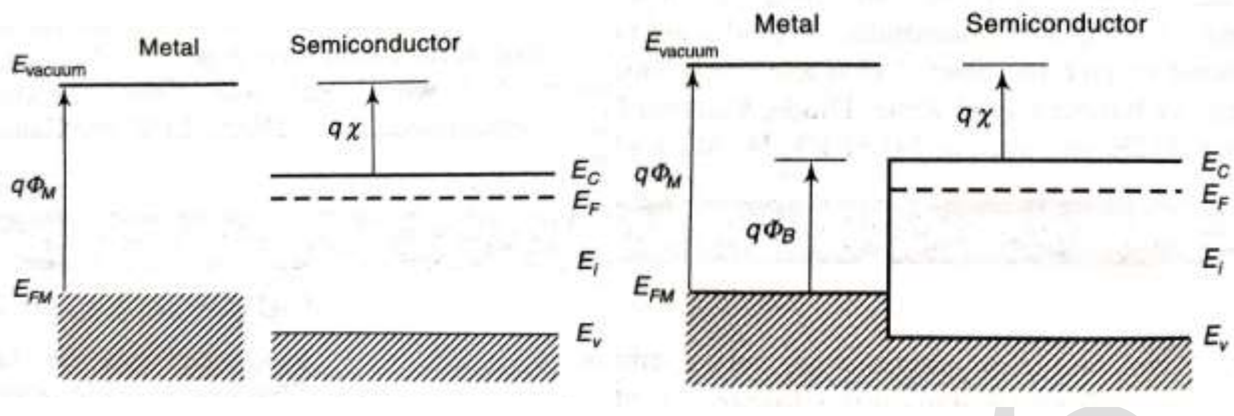


Fig: Energy band diagram of metal and semiconductor (a) before and (b) after contact is made

$$\phi_{IN} = \phi_{BN} - \frac{E_C - E_F}{q} = \phi_{BN} - \frac{kT}{q} ln\frac{N_C}{N_D} \ for\ N - type\ semiconductor$$

$$\phi_{IP} = \phi_{BP} - \frac{E_F - E_V}{q} = \phi_{BP} - \frac{kT}{q} ln\frac{N_V}{N_A} \ for\ P - type\ semiconductor$$

Thermal Equilibrium

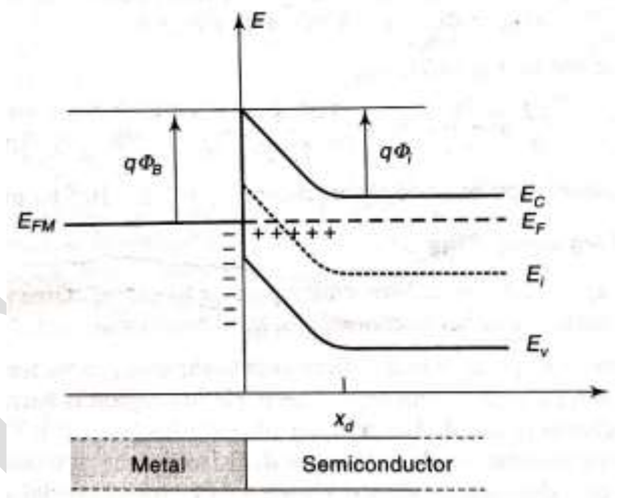


Fig: Energy Band Diagram in thermal Equilibrium

2. **Write Short notes on MESFET. (7M) BTL1 (April/May 2017)**

Ans:

Construction diagram for MESFET (4M)

Principle of operation (3M)

Construction of MESFET

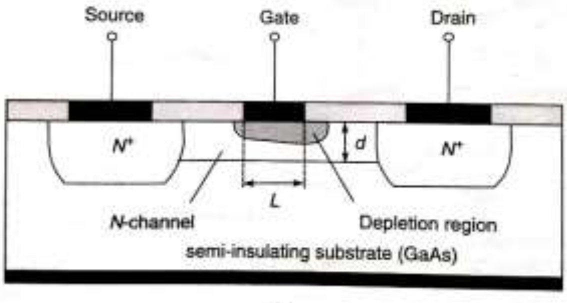


Fig: Depletion type MESFET

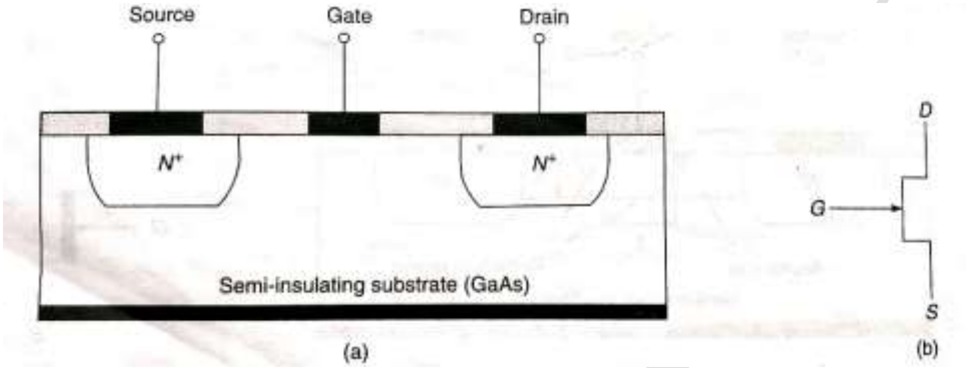


Fig: Enhancement type MESFET (a) Structure (b)Symbol

Operation

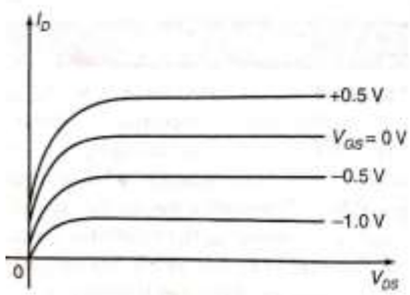


Fig: Drain Characteristics of MESFET

Advantages

- Higher mobility of carriers in the channel as compared to MOSFET
- Higher mobility leads to higher value of current.

Disadvantages

- Presence of Schottky Metal gate.

Applications

3. **(i) Illustrative the V-I characteristic curve and explain the operation of zener diode (13M) BTL2 (Nov/Dec 2017, April/May 2017, April/May 2018, April/May 2019)**

Ans:

Characteristic curve of Zener diode	(5M)
Principle of operation and relevant expression	(5M)
Applications	(3M)

Characteristics of Zener Diode

The sharp increasing current under breakdown conditions are due to the following two mechanism

1) Avalanche Breakdown
2) Zener Breakdown

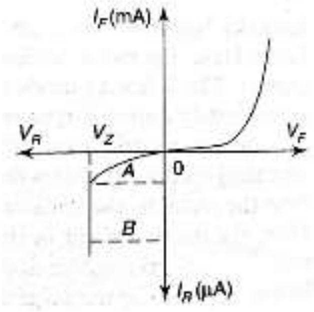


Fig: V – I Characteristics of Zener Diode

Zener Resistances and Zener Diode Ratings

a) Zener Static or DC Resistance (R_Z)

$$R_Z = \frac{V_{ZQ}}{I_{ZQ}}$$

b) Zener Dynamic of AC resistance (r_Z)

$$r_Z = \frac{\Delta V_Z}{\Delta I_Z}$$

Effect of temperature on Zener Diode

$$\boldsymbol{TC = \frac{\Delta V_Z}{V_Z(T_1 - T_0)} * 100\% \ /C}$$

Applications

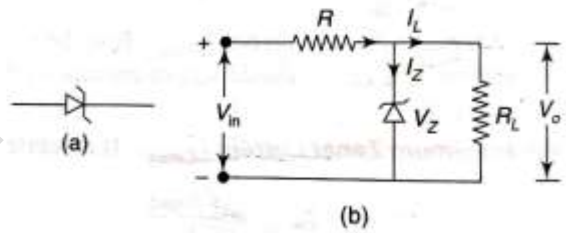


Fig: Zener Diode (a) Circuit Symbol (b) As a Voltage Regulator

4. Illustrate how a zener diode is used in Voltage regulation. (7M) BTL2 (Nov/Dec 2016, Nov/Dec 2017)

Ans:

Circuit diagram for Zener voltage regulator (3M)

Relevant expression for line regulation/load regulation (4M)

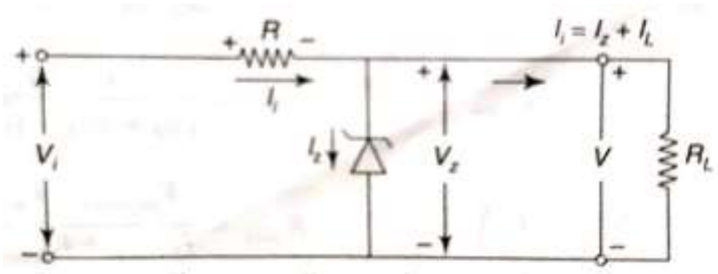
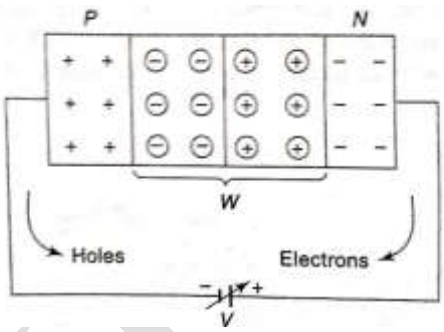
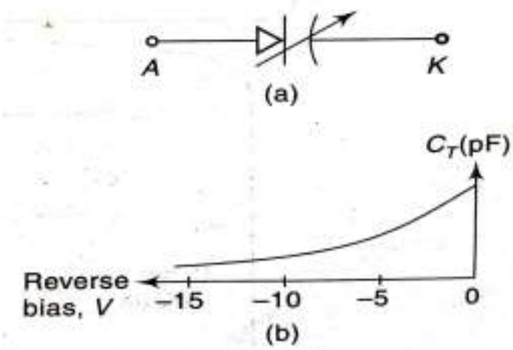
Factors determining the stability

$$\Delta V_o = \frac{\partial V_o}{\partial V_{in}}\Delta V_{in} + \frac{\partial V_o}{\partial I_L}\Delta I_L + \frac{\partial V_o}{\partial T}\Delta T$$

$$\Delta V_o = S_v \Delta V_{in} + R_o \Delta I_L + S_T \Delta T$$

Input regulation factor

Output resistance

	Temperature Coefficient ***Line Regulation*** $$\boldsymbol{Line\ regulation = \frac{Change\ in\ output\ voltage}{change\ in\ input\ voltage} = \frac{\Delta V_o}{\Delta V_{in}}}$$ ***Load Regulation*** $$\%Load\ Regulation = \frac{V_{no\ load} - V_{full\ load}}{V_{no\ load}} * 100$$ ***Zener Diode Shunt Regulator***  *Fig: Zener Voltage Regulator*
5.	**Describe the variable capacitance characteristics of a Varactor diode and analyze its operation in typical circuit. (13M) BTL2 (Nov/Dec 2017, April/May 2017)** **Ans:** Circuit diagram of varactor diode (4M) Theory of operation (4M) Characteristic curve and explanation (5M)   *Fig: Depletion region in a reverse biased PN junction* *Fig: (a) Circuit Symbol* *(b) Characteristics of Varactor Diode*
6.	**Determine the current voltage relationship of a Schottky Barrier diode and discuss its operation. (13M) BTL2 (April/May 2017, Nov/Dec 2017, April/May 2019)** **Ans:** Schematic diagram of Schottky barrier diode (4M) Theory of operation (4M) V-I Characteristic curve and explanation (5M)

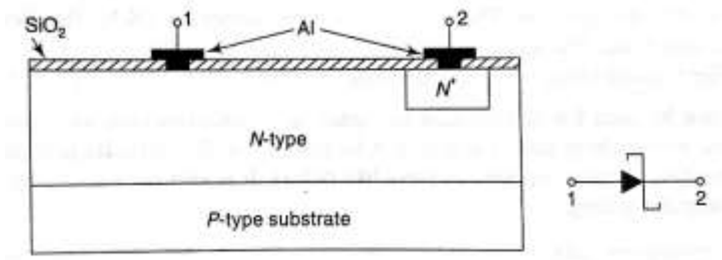


Fig: Schottky Barrier Diode (a) Cross – sectional view (b) Symbol

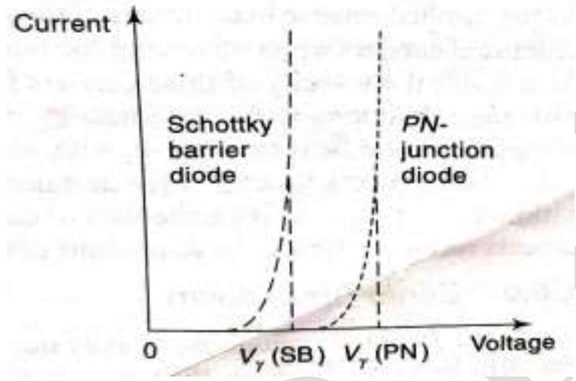


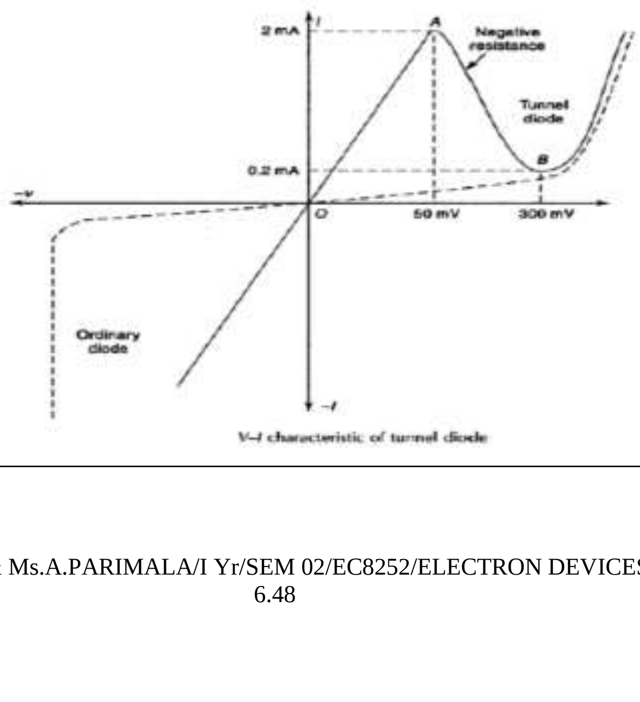
Fig: V – I Characteristics of Schottky barrier diode and PN Diode

7. **Discuss the operation of tunnel diode using energy band diagram and the characteristics of tunnel diode. (13M) BTL2 (April/May 2015, May/June 2016, April/May 2017, Nov/Dec 2017, April/May 2018, April/May 2019)**

Ans:

Ans:

Circuit diagram of Tunnel diode	(2M)
Energy level diagram of tunnel diode and explanation	(4M)
Theory of operation	(3M)
V-I Characteristic curve and explanation	(4M)



V–I characteristic of tunnel diode

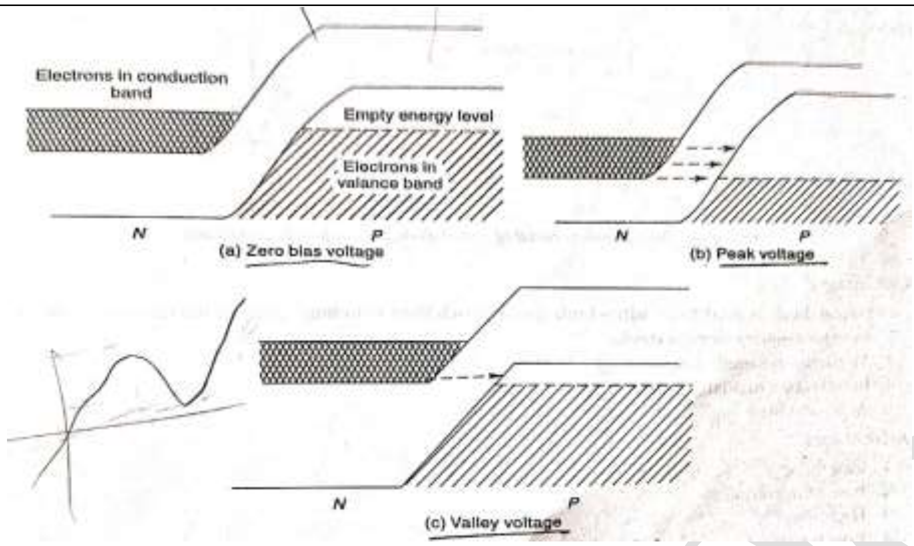


Fig: Energy level diagrams of tunnel diode

Equivalent Circuit

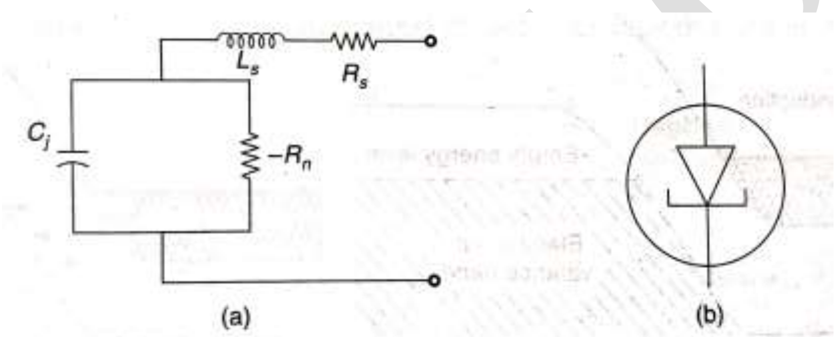


Fig: (a) Equivalent Circuit of Tunnel Diode (a) Symbol of tunnel diode

Applications

Advantages

- Low noise
- Ease of Operation
- High Speed
- Low power

8. **Analyze the construction details and working principle of LASER diode. (8M) BTL2 (April/May 2018)**

Ans:

Ans:

Circuit diagram of LASER diode (2M)

Working principle (2M)

Characteristic curve and explanation (4M)

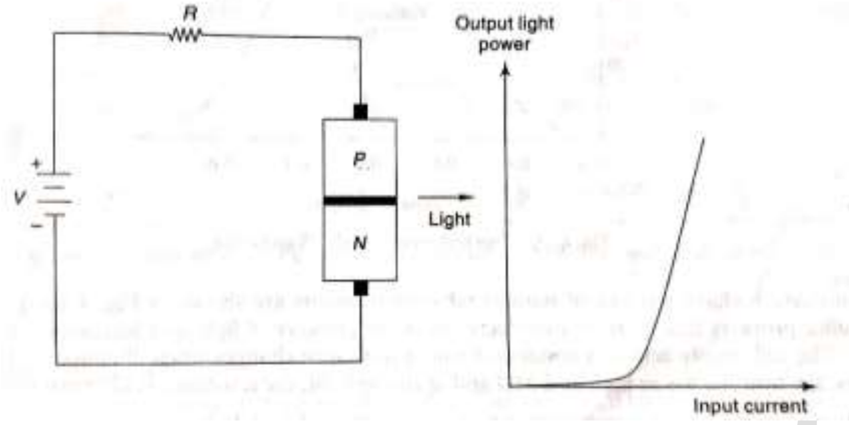


Fig: Structure and Characteristics of Laser Diode

9. **Write short notes on LDR and list out its applications.(7M) BTL1**

Ans:

Ans:

Theory of operation (4M)

Characteristic curve and explanation (3M)

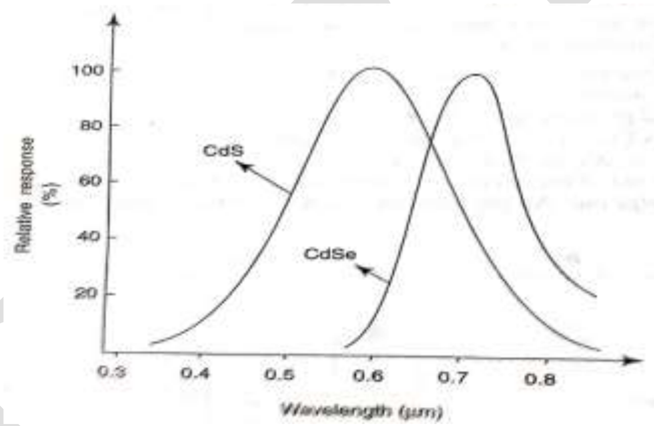


Fig: Spectral responses of CdS and CdSe

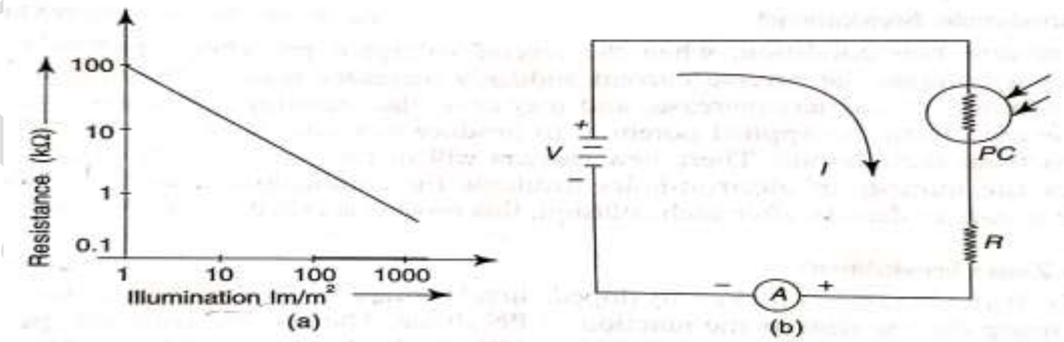


Fig: (a) Illumination characteristics of the photoconductive detector (b) Photoconductive detector connected in a simple circuit.

UNIT V – POWER DEVICES AND DISPLAY DEVICES

UJT, SCR, Diac, Triac, Power BJT- Power MOSFET- DMOS-VMOS. LED, LCD, Photo transistor, Opto Coupler, Solar cell, CCD

PART – A

1. What do you mean by Intrinsic stand- off ratio of an UJT? BTL1 (April/May 2019)

If a voltage V_{BB} is applied between the bases with the emitter terminal open the circuit will behave as a potential divider. Thus the voltage V_{BB} will be divided across R_{B1} and R_{B2}.

$$\eta = \frac{R_{B1}}{R_{B1} + R_{B2}}$$

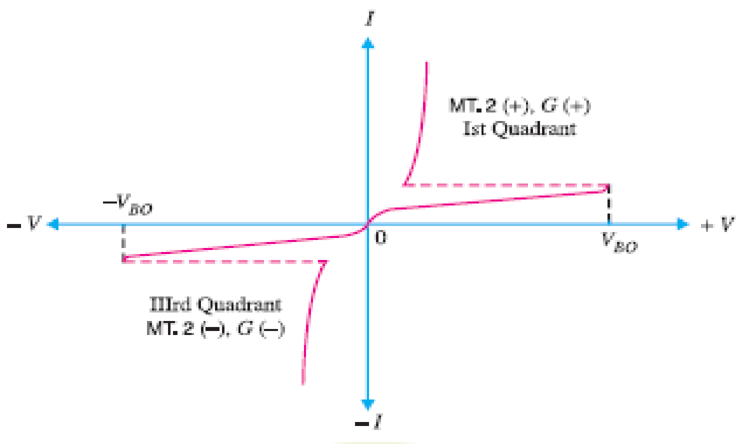
2. Mention the applications of UJT. BTL1 (May/June 2016)

- It is used in timing circuits
- It is used in switching circuits
- It is used in phase control circuits
- It can be used as trigger device for SCR and triac.
- It is used in saw tooth generator.
- It is used for pulse generation

3. What is a TRIAC? Give the symbol and structure of TRIAC. BTL1 (Nov/Dec2017, April/May 2018)

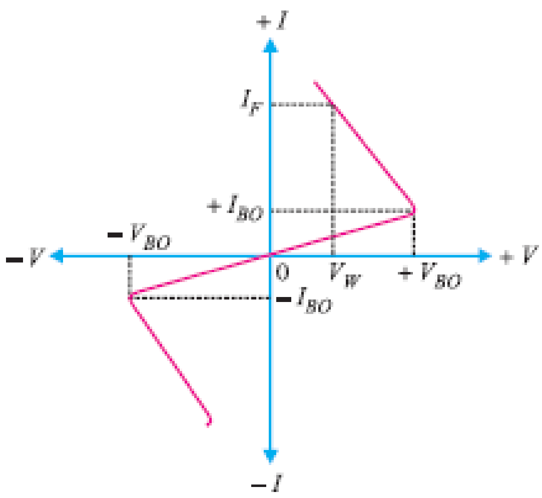
TRIAC is a three terminal bidirectional semiconductor switching device. It can conduct in both the directions for any desired period. In operation it is equivalent to two SCR's connected in antiparallel.

4. Draw the V-I characteristics for TRIAC. BTL1 (April/May 2015)

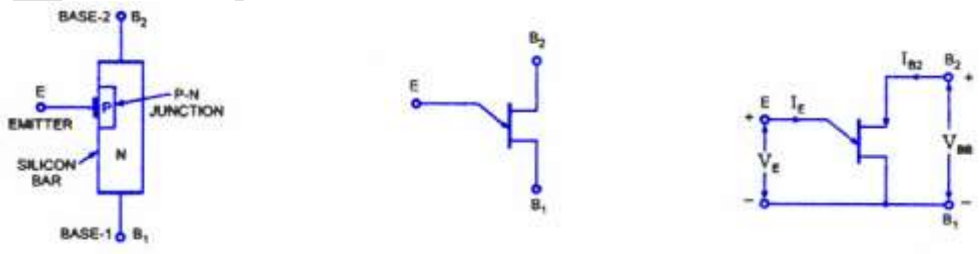


5. Give the application of TRIAC. BTL1

- Heater control

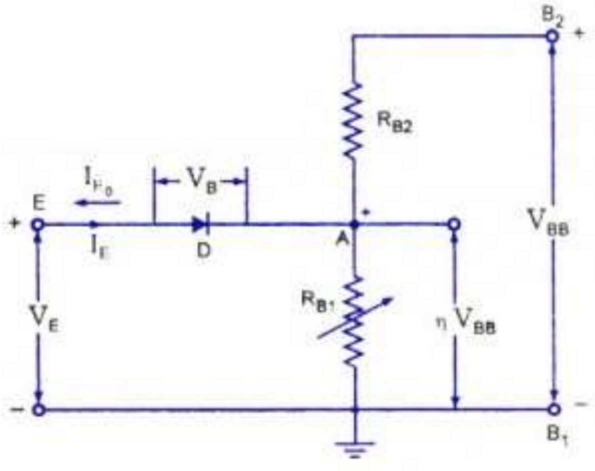
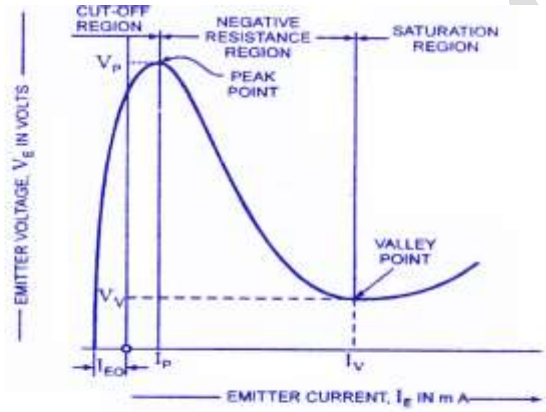
	• Motor speed control • Phase control • Static switches
6.	**What is a DIAC? Give the basic construction and symbol of DIAC. BTL1 (April/May 2017)** DIAC is a two-terminal bidirectional semiconductor switching device. It can conduct in either direction depending upon the polarity of the voltage applied across its main terminals. In operation DIAC is equivalent to two 4-layer diodes connected in antiparallel.
7.	**Draw the V-I curve for DIAC. BTL1** 
8.	**Give some applications of DIAC. BTL1** • To trigger TRIAC • Motor Speed Control • Heat Control • Light dimmer Circuits
9.	**Why SCR cannot be used as a bidirectional switch? BTL1 (Nov/Dec 2015, May/June 2016)** SCR can do conduction only when anode is positive with respect to cathode with proper gate current. Therefore, SCR operates only in one direction and cannot be used as bidirectional switch.
10.	**How turning on of SCR is done? BTL1** • By increasing the voltage across SCR above forward break over voltage. • By applying a small positive voltage at gate. • By rapidly increasing the anode to cathode voltage. • By irradiating SCR with light.
11.	**How turning off of SCR is done? BTL1** • By reversing the polarity of anode to cathode voltage.

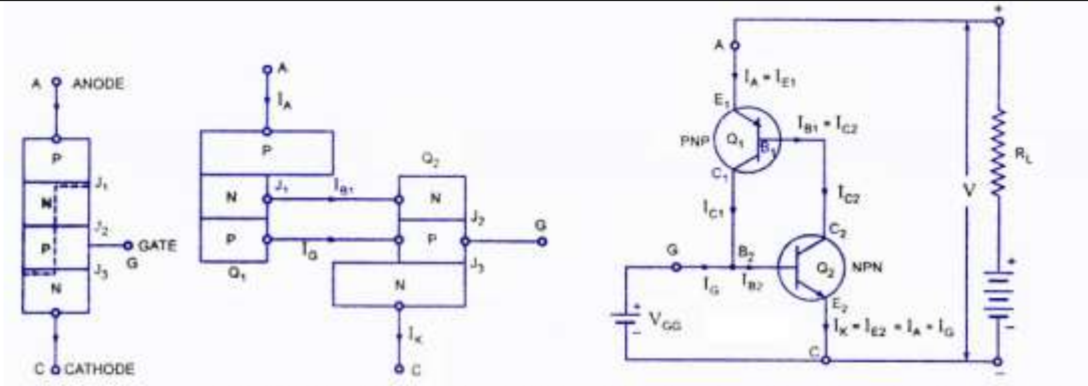
	• By reducing the current through the SCR below holding current. • By interrupting anode current by means of momentarily series or parallel switching
12.	**Define holding current in a SCR. BTL1 (April/May 2015)** Holding current is defined as the minimum value of anode current to keep the SCR ON
13.	**List the advantages of SCR. BTL1** • SCR can handle and control large currents. • Its switching speed is very high • It has no moving parts, therefore it gives noiseless operation. • Its operating efficiency is high
14.	**List the application of SCR. BTL1 (Nov/Dec2014, May/June 2016)** • It can be used as a speed controller in DC and AC motors. • It can be used as an inverter. • It can be used as a converter • It is used in battery chargers. • It is used for phase control and heater control. • It is used in light dimming control circuits
PART – B	
1.	**Draw the basic structure of UJT and explain V-I characteristics of UJT with the help of equivalent circuit. (13M) BTL2 (April/May 2015, Nov/Dec 2016)** **Ans:** Structure/Equivalent circuit of UJT (4M) Principle of operation (5M) V-I characteristics and its explanation (4M) *Basic Structure*



(a) Basic Structure (b) Schematic Symbol (c) Basic Arrangement

Unijunction Transistor

	 Equivalent Circuit of a UJT *V – I Characteristics* 
2.	**Discuss the characteristics and working principle of SCR and list out its applications. (13M) BTL2 (April/May 2017, Nov/Dec 2017, April/May 2018, April/May 2019)** **Ans:** Structure/Equivalent circuit of SCR (3M) Principle of operation (4M) V-I characteristics and its explanation (4M) Applications (2M)



SCR Split-up into Two Transistors *Two Transistor Equivalent Circuit of An SCR*

Two Transistor Model of An SCR

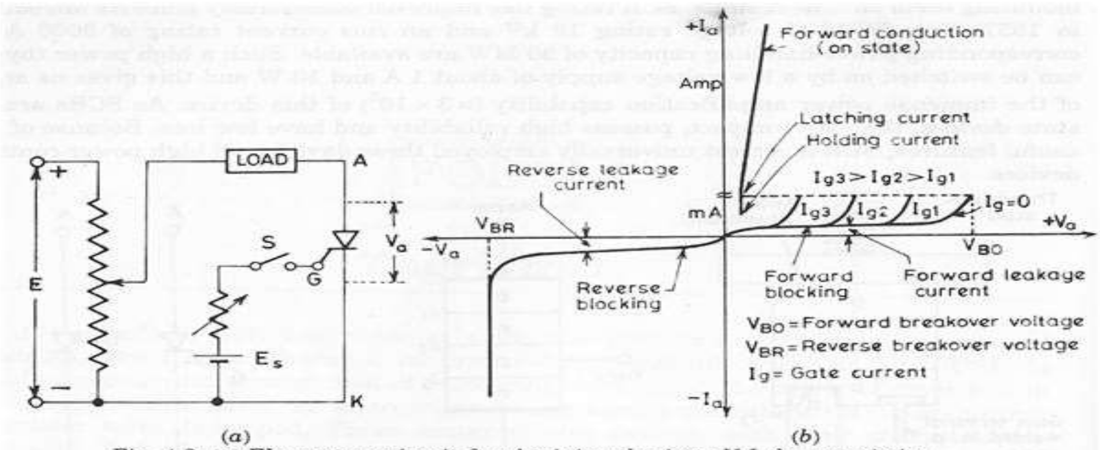


Fig. 4.2. (*a*) Elementary circuit for obtaining thyristor V-I characteristics (*b*) Static V-I characteristics of a thyristor.

3. **Demonstrate the construction, working principle and characteristics of Diac and Triac. (13M) BTL2 (April/May 2018)**

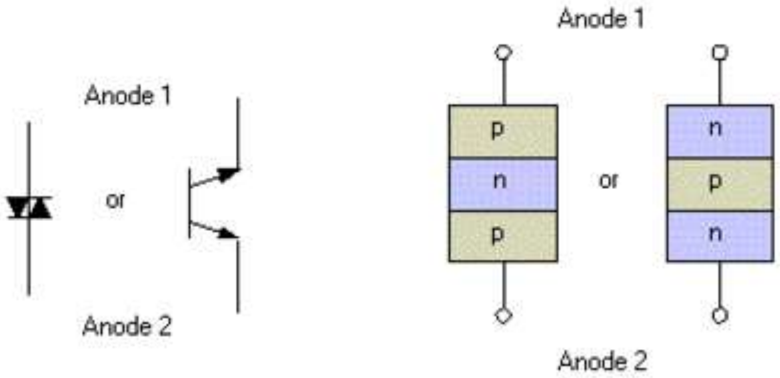
Ans:

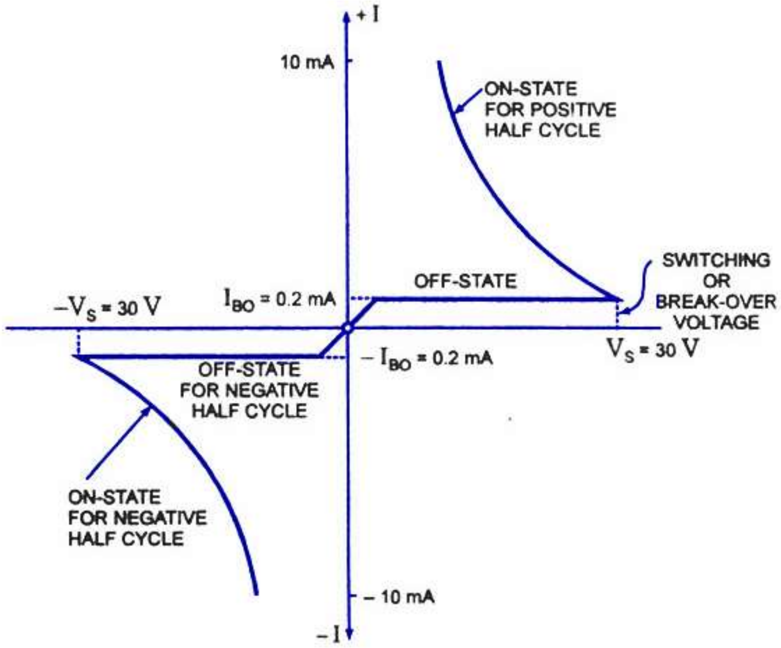
Construction of DIAC/TRIAC (4M)

Principle of operation (5M)

V-I characteristics and its explanation (4M)

DIAC

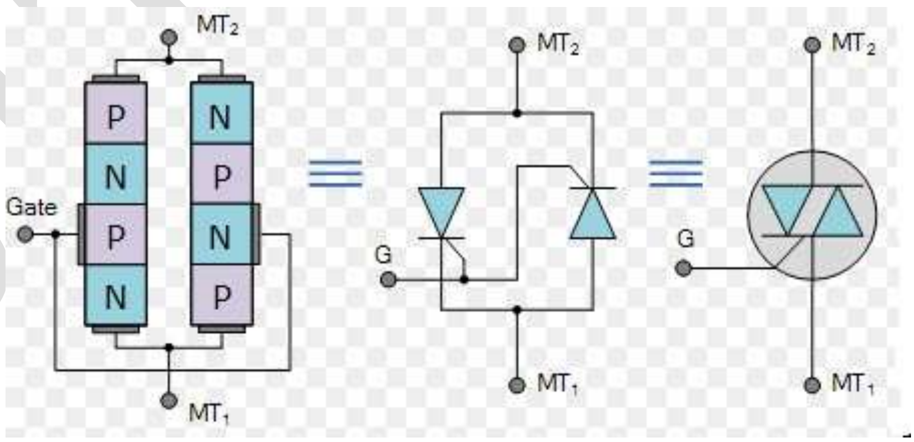




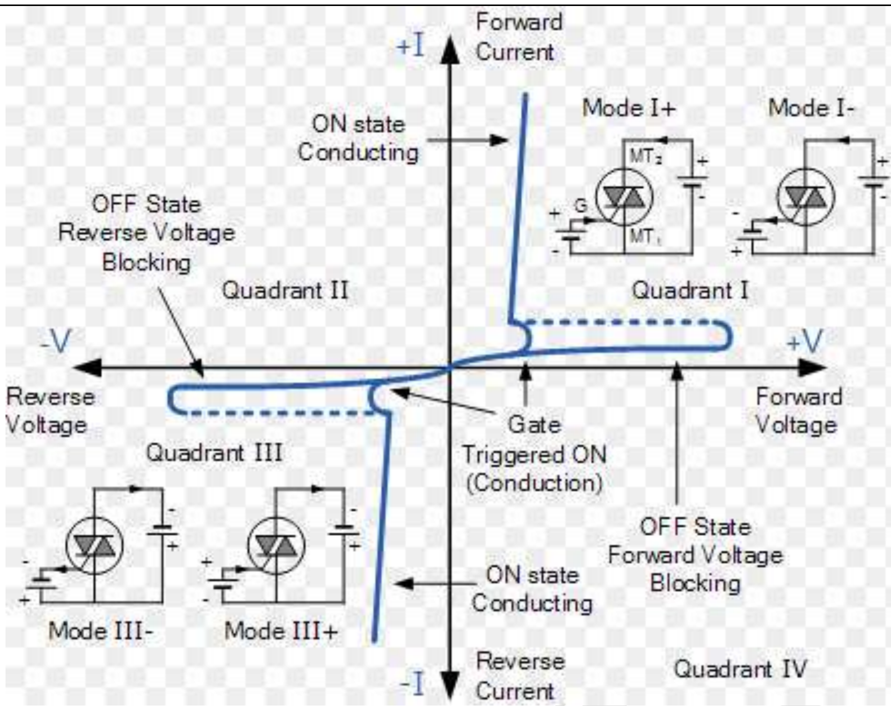
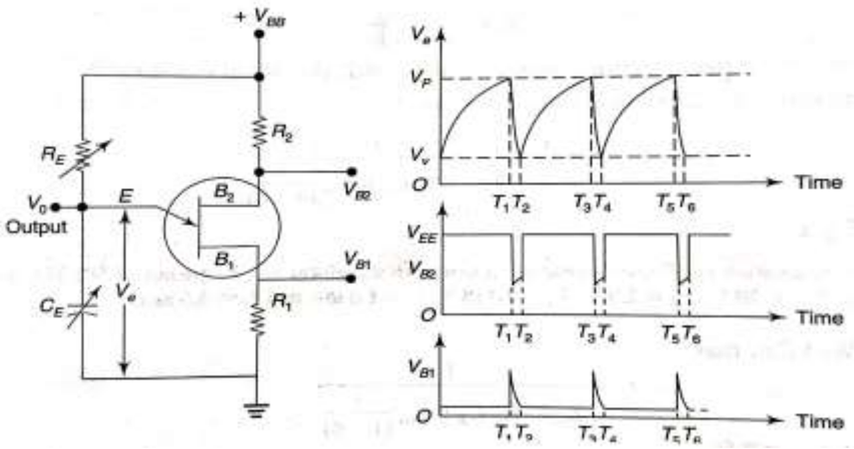
V-I Characteristic of a Diac

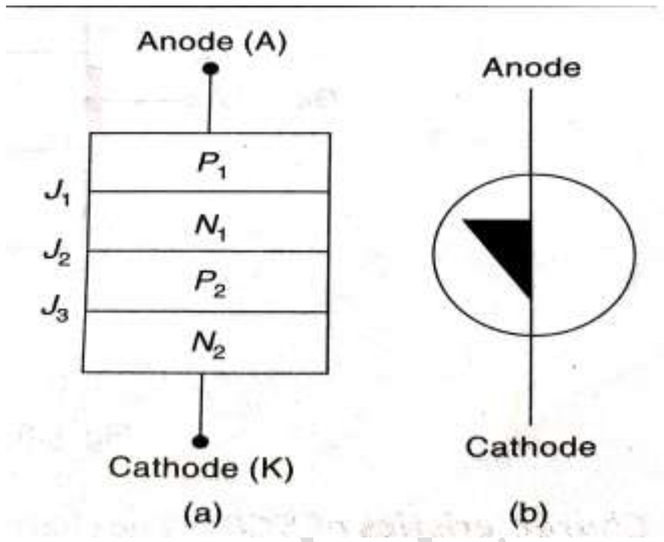
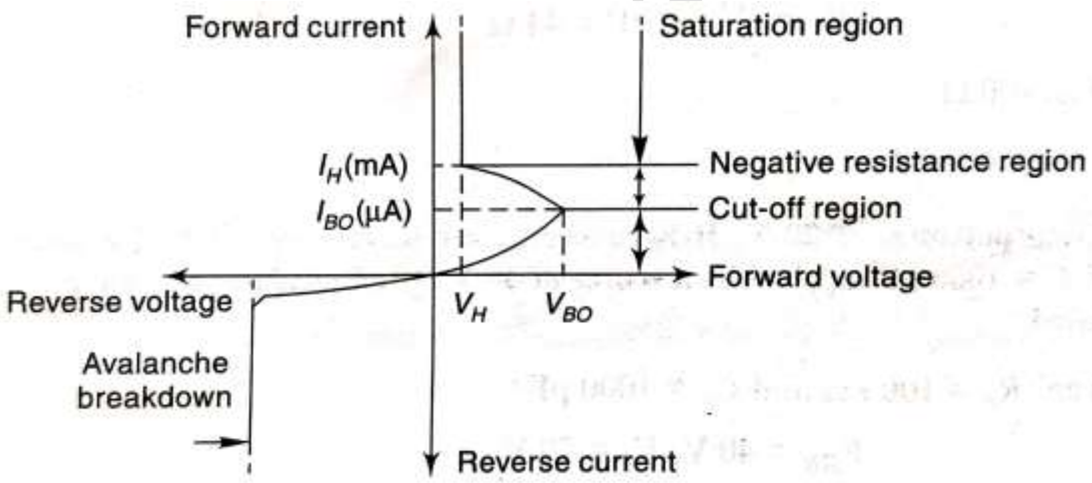
TRIAC

Construction of TRIAC



V – I Characteristics

	
4.	**Determine the operation of UJT relaxation oscillator and R1 value from the conditions for turn-on and turn-off. (8M) BTL2 (Nov/Dec 2015)** **Ans:** Structure/Equivalent circuit of UJT (2M) Principle of operation (2M) Characteristic diagram (2M) Expression for frequency of oscillation (2M)  *Fig: UJT Relaxation Oscillator* ***Frequency of Oscillation*** $$f_o = \frac{1}{T} = \frac{1}{2.303 R_E C_E log_{10} \frac{1}{(1-\eta)}}$$

5.	**Describe the operation of Shockley Diode. (13M) BTL2** **Ans:** Structure/symbol of Shockley diode (4M) Principle of operation (5M) V-I characteristics and its explanation (4M)  *Fig: PNPN Diode (a) Basic Structure (b) Circuit Symbol*  *Fig: Characteristics curve of PNPN Diode*
6.	**Describe with the help of a relevant diagram, the construction of an LED and explain its working. (13M) BTL2 (April/May 2018, April/May 2019)** **Ans:** Structure/symbol of LED (2M) Construction diagram of LED (4M) Principle of operation (5M) Applications (2M)

Light Emitting Diode (LED)

A light-emitting diode (LED) is a semiconductor light source.

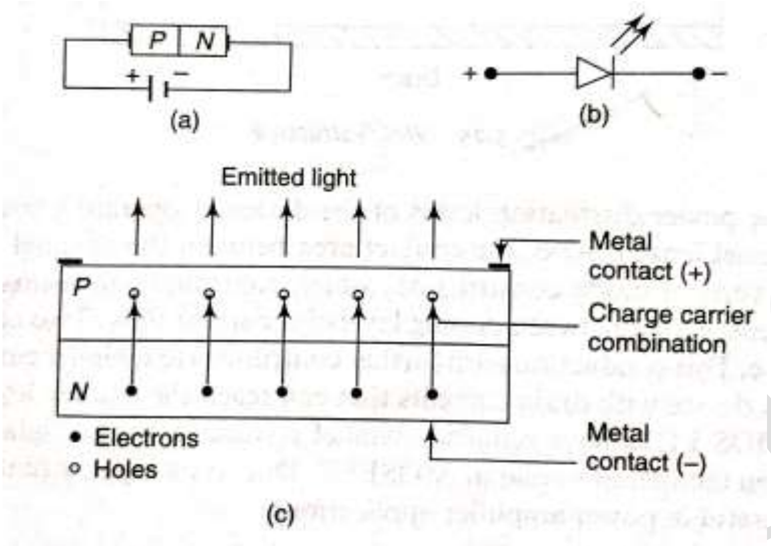


Fig: LED: (a) LED under forward bias (b) Symbol (c) Recombination's and emission of light

Light-emitting diodes are used in applications as diverse as replacements for aviation lighting, automotive lighting (particularly brake lamps, turn signals and indicators) as well as in traffic signals.

7. Describe the operation of principle of an LCD. (8M) BTL2 (April/May 2017)

Ans:

Schematic diagram of LCD (4M)

Principle of operation (4M)

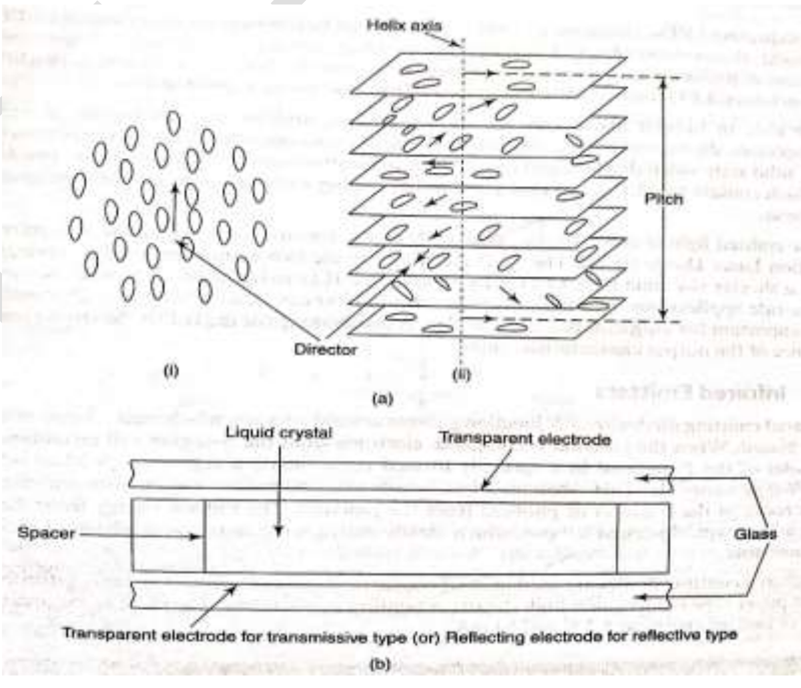


Fig: (a) Schematic arrangement of molecules in liquid crystal (i) Nematic and (ii) Cholesteric

(b) Construction of a dynamic scattering LCD

8.	**Interpret the working of phototransistor & optocoupler. (8M) BTL2 (April/May 2017, Nov/Dec 2017)**

Ans:

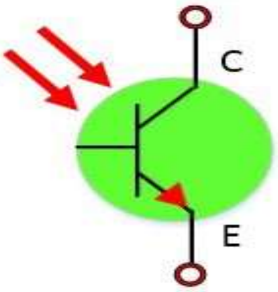
Structure/symbol of phototransistor and optocoupler (2M)

Principle of operation (4M)

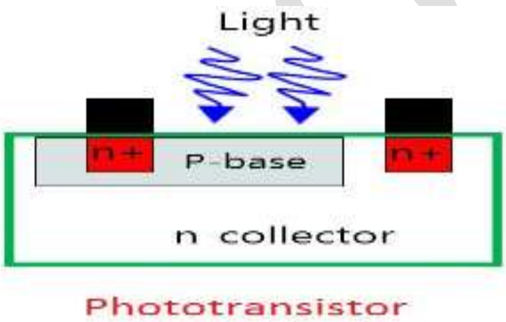
V-I characteristics and its explanation (2M)

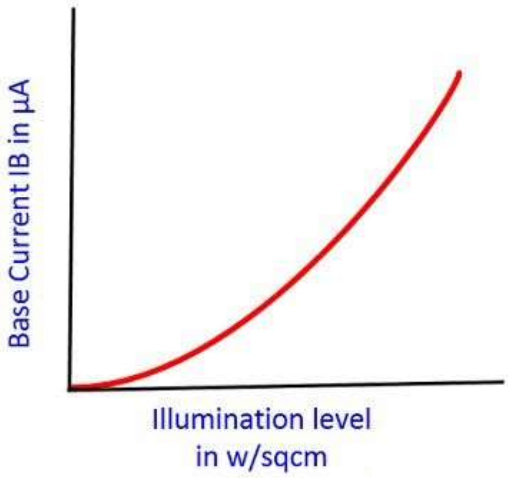
Phototransistor

The phototransistor is a three-layer semiconductor device which has a light-sensitive base region. The base senses the light and converts it into the current which flows between the collector and the emitter region.



Symbol

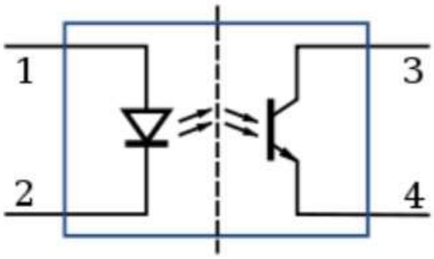




Applications

Some of the areas of application for the phototransistor include punch-card readers, computer logic circuitry, lighting control (highways, etc.), level indication, relays, and counting systems.

Optocoupler

	In electronics, an opto-isolator, also called an optocoupler, photocoupler, or optical isolator, is a component that transfers electrical signals between two isolated circuits by using light.  An opto-isolator contains a source (emitter) of light, almost always a near infrared light-emitting diode (LED), that converts electrical input signal into light, a closed optical channel (also called dielectrical channel), and a photosensor, which detects incoming light and either generates electric energy directly, or modulates electric current flowing from an external power supply.