

# BEEE CHEAT SHEET

## A NOTE FROM THE CREATOR:

Unfortunately, not much material was available to be compiled like we did in semiconductor physics. this cheat sheet specifically lacks content from unit 2 and 3.

material guide:

- 1.MCQs
- 2.written short/long Q&A
- 3.complete Beee ppt

it is estimated that u won't find most of the shit here and u will have to end up digging through the ppt in the end, so i have also written keywords in some pts where only images were present (which the search function can't detect)

Not much can be done about numericals..... Jo hai, so hai :(  
also i guess paper will be lengthy

CONCLUSION : SHIT GONNA BE FUCKED UP  
(insert skull emoji here)

P.S. thanks to those who contributed

**SRM INSTITUTE OF SCIENCE AND TECHNOLOGY - RAMAPURAM**  
**DEPARTMENT OF ECE**  
**18EES101J – BASIC ELECTRICAL AND ELECTRONICS ENGINEERING**  
**MULTIPLE CHOICE QUESTION - QUESTION BANK**

(NOTE:

*This question bank has 180 questions*

*Out of which 18 easy questions (blooms level: Remembering, understanding) in each unit  $18 \times 5 = 90$*

*12 moderate questions (blooms level: Applying, Analyzing) in each unit  $12 \times 5 = 60$*

*6 tough questions (blooms level: Evaluating, Creating) in each unit  $6 \times 5 = 30$ )*

## **UNIT 1 - ELECTRICAL CIRCUITS**

### **EASY QUESTIONS**

1) Thevenin resistance is found by \_\_\_\_\_

- A. Shorting all voltage sources
- B. Opening all current sources
- C. Shorting all voltage sources and opening all current sources
- D. Opening all voltage sources and shorting all current sources

ANSWER: C

2) In a star connected system, the current flowing through the line is

- A. Greater than the phase current
- B. Equal to the phase current
- C. Lesser than the phase current
- D. zero

ANSWER: B

3) The 2ohm and 3 ohm resistor are in series the equivalent resistance is

- A. 1.2
- B. 5
- C. 4.2
- D. 1.4

ANSWER: B

4) The internal resistance for the maximum transfer of power should be

- A. equal to load resistance
- B. greater than load resistance
- C. zero
- D. lesser than load resistance

ANSWER: A

5) If the voltage frequency applied to a series RC circuit is increased, then the phase angle will

- A. Increases

- B. reduces
- C. remains the same
- D. zero

ANSWER:A

6) In an RLC circuit above the resonant frequency, the current will

- A. lags the applied voltage
- B. leads the applied voltage
- C. is in phase with the applied voltages
- D. is zero

ANSWER: A

7) The equation for ohms law is

- A.  $V=IR$ ,at contant temperature
- B.  $V=IC$
- C.  $V=IL$
- D.  $V=I/R$

ANSWER: A

8) A 6 kHz sinusoidal voltage is applied to a series  $RC$  circuit. The frequency of the voltage across the resistor is

- A. 6Khz
- B. 12Khz
- C. 13Khz
- D. 14Khz

ANSWER: A

9) In a certain load, the actual power is 150 W and the reactive power is 125 VAR. What is the apparent power?

- A. 19.52W
- B. 195.2W
- C. 375W
- D. 24W

ANSWER: B

10) What is the unit of power?

- A. Watt
- B. Newton
- C. Joule
- D. Henry

ANSWER: A

11) Mesh analysis employs the method of

- A. KVL
- B. KCL
- C. Both KVL and KCL
- D. Neither KVL or KCL

ANSWER: A

12) If there are 10 nodes in a circuit, how many equations do we get?

- A. 10
- B. 9
- C. 8
- D. 7

ANSWER: B

13) Superposition theorem can only be used for circuits

- A. Element resistive
- B. Element passive
- C. Linear bilateral elements
- D. Non-linear elements

ANSWER: C

14) Each phase of a three phase alternator delta connected produces a voltage of 11KV and a current of 1000A at pf 0.9. Find line voltage and line current.

- A. 11KV,1732A
- B. 11KV,1632A
- C. 3.33KV,1732A
- D. 3.33V,1000A

ANSWER: A

15) In a balanced three phase system three voltages differ in \_\_\_\_\_ electrical from each other in a sequence and have equal magnitude.

- A. 240
- B. 120
- C. 360
- D. 0

ANSWER: A

16) For series circuit the equivalent resistance is \_\_\_\_\_ the greatest resistance connected in series circuit.

- A. lesser than
- B. greater than
- C. equal to
- D. not equal to

ANSWER: A

17) The non-linear circuit parameters are ?

- A. Inductance

- B. Capacitance
  - C. Resistance
  - D. Transistor
- ANSWER: A

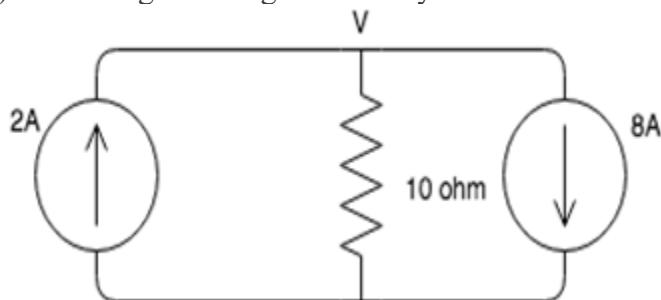
18) In a series  $RC$  circuit, find the RMS voltage where the voltage across resistor is  $12 \text{ V}_{(\text{rms})}$  and voltage across capacitor is  $15 \text{ V}_{(\text{rms})}$ . The rms source voltage is

- A. 3
- B. 27
- C. 19.2
- D. 40

ANSWER: C

### MODERATE QUESTIONS

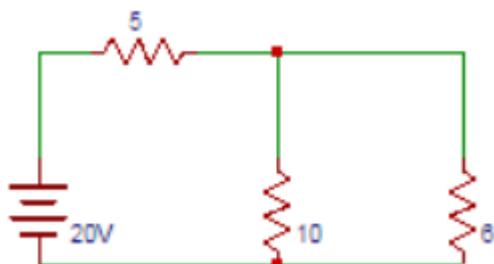
1) The voltage  $V$  using nodal analysis



- A. -60V
- B. 60V
- C. -40V
- D. 40V

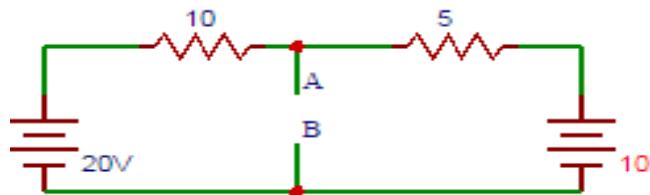
ANSWER: A

2) Find the current flowing between terminals A and B of the circuit shown below.



- A. 1
  - B. 2
  - C. 3
  - D. 4
- ANSWER: D

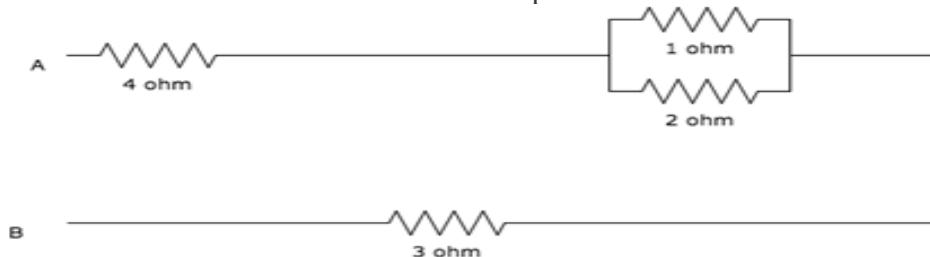
3) Find the current flowing between terminals A and B.



- A. 1
- B. 2
- C. 3
- D. 4

ANSWER: D

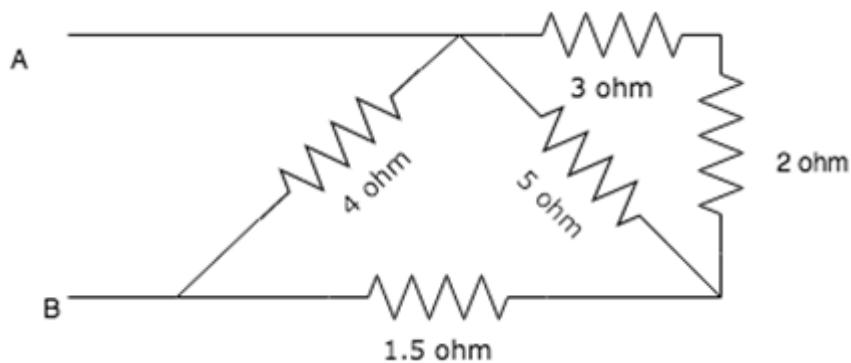
4) Calculate the total resistance between the points A and B.



- A. 7 ohm
- B. 4 ohm
- C. 7.6 ohm
- D. 0.48 ohm

ANSWER: C

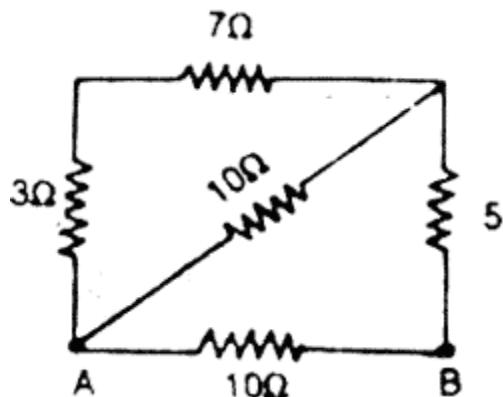
5) Calculate the equivalent resistance between A and B.



- A. 2
- B. 4
- C. 6
- D. 8

ANSWER: B

6) The resistances are connected in series. Find the equivalent resistance



- A. 35
- B. 25
- C. 15
- D. 5

ANSWER: D

7) An electric kettle has a resistance of 30 ohm. What current will flow when it is connected to 240V supply. Also find the power.

- A. 8A, 1.92Kw
- B. 9A, 3Kw
- C. 10A, 4Kw
- D. 12A, 5Kw

ANSWER: A

8) An ideal voltage source has

- A. Zero internal resistance
- B. Open circuit voltage equal to the voltage on full load
- C. Terminal voltage in proportion to current
- D. Terminal voltage in proportion to load

ANSWER: A

9) To find impedance in thevenin's theorem.

- A. All independent current sources are short circuited and independent voltage sources are open circuited
- B. All independent voltage sources are open circuited and all independent current sources are short circuited
- C. All independent voltage and current sources are short circuited
- D. All independent voltage sources are short circuited and all independent current sources are open circuited

ANSWER: A

10) Application of Norton's theorem to a circuit yields

- A. Equivalent current source and impedance in series
- B. Equivalent current source and impedance in parallel
- C. Equivalent impedance
- D. Equivalent current source

ANSWER: A

- 11) What will be the resistance of the wire which has 0.14 mm diameter and specific resistance 9.6 micro ohm-cm is 440 cm long. The resistance of the wire will be

- A. 9.6 ohm
- B. 11.3 ohm
- C. 13.7 ohm
- D. 27.4 ohm

ANSWER: D

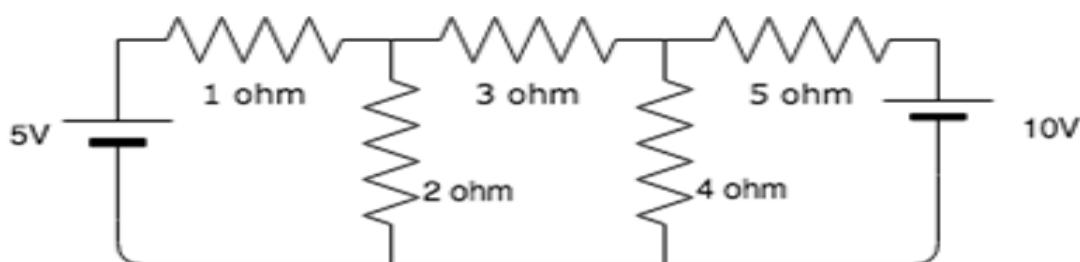
- 12) In Superposition theorem, while considering a source, all other voltage sources are?

- A. open circuited
- B. short circuited
- C. change its position
- D. removed from the circuit

ANSWER: B

### TOUGH QUESTIONS

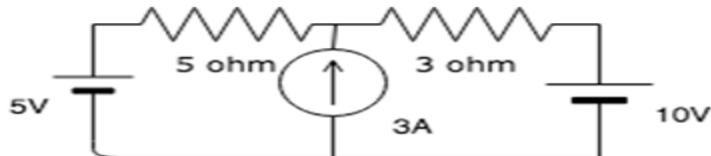
- 1) Find the value of the currents  $I_1$ ,  $I_2$  and  $I_3$  flowing clockwise in the first, second and third mesh respectively.



- A. 1.54A, -0.189A, -1.195A
- B. 2.34A, -3.53A, -2.23A
- C. 4.33A, 0.55A, 6.02A
- D. -1.18A, -1.17A, -1.16A

ANSWER: A

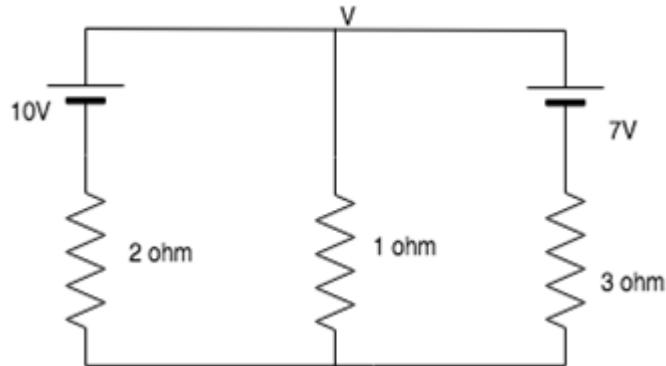
- 2) Calculate the mesh currents  $I_1$  and  $I_2$  flowing in the first and second meshes respectively



- A. 1.75A, 1.25A
- B. 0.5A, 2.5A
- C. 2.3A, 0.3A
- D. 3.2A, 6.5A

ANSWER: A

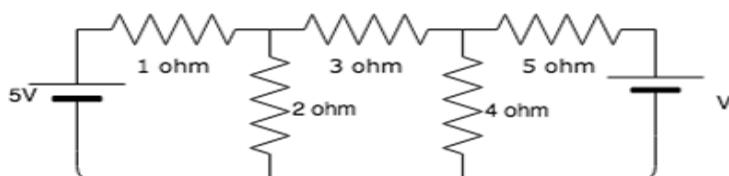
3) Find the node voltage V.



- A. 1V
- B. 2V
- C. 3V
- D. 4V

ANSWER: D

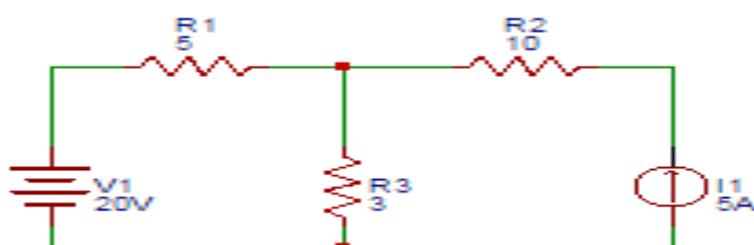
4) Find the value of V if the current in the 3 ohm resistor=0.



- A. 3.5V
- B. 6.5V
- C. 7.5V
- D. 8.5V

ANSWER: B

5) In the circuit shown, find the current through  $4\Omega$  resistor using Superposition theorem.



- A. 4

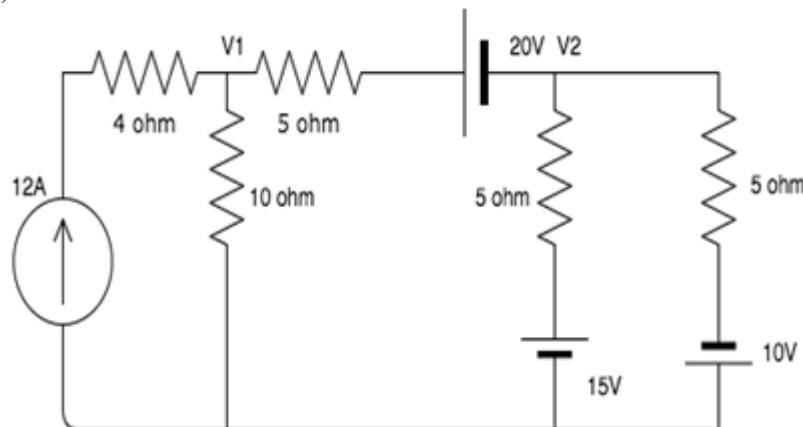
B. 5

C. 6

D. 7

ANSWER: B

6) Find the value of V<sub>1</sub> and V<sub>2</sub>.



A. 87.23V, 29.23V

B. 23.32V, 46.45V

C. 64.28V, 16.42V

D. 56.32V, 78, 87V

ANSWER: C

## UNIT 2 - D.C MACHINES & A.C MACHINES

### EASY QUESTIONS

1. Power factor of Zero indicates

a) Purely resistive element

c) combination of both (A) and (B)

Answer: B

b) Purely inductive element

d) Purely capacitive element

2.No load speed of which of the following motor will be highest

- a)Shunt motor
- b)Cumulatively compound motor
- c)Differentially compound motor
- d)Series motor

Answer: D

3.Which of the following is the most economical method of starting a single phase motor?

- a)Resistance start method
- b)Inductance start method
- c)Capacitance start method
- d)Split phase method

Answer: C

4.Material used for the construction of transformer core is usually

- a)wood
- b)copper
- c)Aluminium
- d)Silicon steel

Answer: D

5.The power factor in resistive circuit is

- a)0.6pf lagging
- b)0.8pf lagging
- c)0.8pf lagging
- d)1

Answer: D

6.DC generator works on the principle of

- a)Fleming 's right hand rule
- b)Fleming's left hand rule
- c)Faraday's law
- d)Lenz's law

Answer: A

7.Two winding of a transformer are -----coupled

- A)Magnetically
- b)Electrically
- c)Both electrically and magnetically
- d)Resistively

Answer: A

8.The synchronous speed of a 4 pole induction motor for 50hz power supply is -----rpm.

- a)1500
- b)1000
- c)750
- d)1440

Answer: A

9.Power factor is the ratio of

- a)Impedance to resistance
- b)Resistance to reactance
- c)Resistance to impedance
- d)Reactance to impedance

Answer: C

10.Form factor is the ratio of

- a)Maximum to RMS Value
- b)Maximum to average value
- c)RMS to average value
- d)RMS to maximum value

Answer: C

11.The unit of magnetic flux density is

- a)Henry/meter
- b)Tesla
- c)Amp/meter
- d)volt/meter

Answer: B

12.The flux is analogous to

- A)Voltage in electric circuit
- c)Power in electric circuit
- b)Current in electric current
- d)Resistance in electric current

Answer: B

13.Which motor is constant speed motor?

- a)DC series motor
- b)DC shunt motor
- c)Dc compound motor
- d)Induction motor

Answer: B

14.The primary winding of a transformer has 110v across it. What is the secondary voltage if the turns ratio is 8?

- a)8.8V
- b)88V
- c)880V
- d)8800V

Answer: C

15.A magnetizing force of 8000A/m is applied to a circular magnetic circuit of mean diameter 30cm by passing a current through a coil wound on the circuit is 750 turned. If the coil is uniformly wound,calculate the current flow in the circuit.

- a)10.05A
- b)9.8A
- c)11A
- d)12A

Answer: A

16.What will be the magnetic potential difference across the air gap of 2cm length in magnetic field of 200 AT/m?

- a)2AT
- b)4AT
- c)6AT
- d)10AT

Answer: B

17.A single -winding single-phase motor has

- a)Low starting torque
- b)zero starting torque
- c)High starting torque
- d)Starting torque equal to full-load torque.

Answer: B

18.A differentially compounded motor under high-over-load conditions behave like a an

- a)Shunt motor
- b)Series motor
- c)Cumulative compound motor
- d) Synchronous motor

Answer: B

### MODERATE QUESTIONS

1. An electric motor with constant power will have a torque speed characteristic in the form of a

- a)Straight line through the origin
- b)Straight line parallel to the speed axis
- c)Circle about the origin
- d)Rectangular hyperbola

Answer: B

2. If load current and flux of DC motor are held constant and voltage applied across it's armature is increase by 5%,then speed of motor will

- a)Increase by about 5%
- b)Reduce by about 5%
- c)Remain unaltered
- d)Depends on other factors

Answer: A

3. The slip of an induction motor normally does not depend on  
a) Rotor speed                  b) Synchronous speed      c) Shaft torque                  d) Core-loss component

Answer: D



Answer: A

5. The dc motor ,which can provide zero speed regulation at full load without any controller,is  
a)Series                            b)Shunt                            c)Cumulative compound    d)Differential compound

Answer: B

6. A Solenoid is wound with a coil of 100 turns. The coil is of length 50cm and is carrying a current of 2A. Determine the magnetic field strength at the line of the solenoid.

- Answer: B

7. If the cross sectional area of a magnetic field increases, but the flux remains the same, the flux density

- Answer: B

O. WU

- m<sup>2</sup>, and a permeability of 4,500 Wb/At × m?  
a)111 At/Wb      b)11.1 At/Wb      c)1.1 At/Wb      d)1 At/Wb

a) PTT A<sub>0</sub> WS      b) PTT A<sub>0</sub> WS      c) PTT A<sub>0</sub> WS      d) PTT A<sub>0</sub> WS

- ANSWER: A

9 A 47 Oh

9. A 17 Ohm resistor and a capacitor with a capacitive reactance of 120 $\Omega$  are in series across an ac source. What is the circuit impedance, Z?

126 1

- Answer: D

10 Tl 11

10. The ability of a material to remain magnetized after removal of the magnetizing force is

known as

- Answer: C

11. The induced voltage across a stationary conductor in a stationary magnetic field is

12. A DC generator is rotated at 50 revolutions/sec .how many times does the dc output voltage reach maximum in each second?



Answer: B

## TOUGH QUESTIONS

1. In a series RC circuit, 12V is measured across the resistor and 15V is measured across the capacitor. The source voltage is

- a)3V b)27V c)19.2V d)12V

Answer: C

2. Each phase of a 3phase star connected alternator produces a voltage of 11000V and current of 1000A at power factor 0.9. find line voltage, line current and total capacity of the alternator.

- a) VL=19053V, IL=1000A, Capacity=29.7MW      b) VL=2000V, IL=1500A, Capacity=25MW  
 c) VL=19053V, IL=1000A, Capacity=29.7MW      d) VL=2500V, IL=500A, Capacity=35MW

Answer: A

3.A DC motor takes an armature current of 110A at 480V. The armature circuit resistance is .2ohm. the machine has 6poles and the armature is lap connected with 864conductors. the flux per pole is 0.05wb . calculate speed and torque developed by the armature.



Answer: C

4. The regulation of dc generator on full load is about

- a) 15 to 20%      b) 20 to 25%      c) 10 to 15%      d) 5 to 10%

Answer: D

5. For a single phase capacitor start induction motor which of the following statements is valid?

- a) The capacitor is used for power factor improvement
  - b) The direction of rotation can be changed by reversing the main winding terminals
  - c) The direction of rotation cannot be changed
  - d) The direction of rotation can be changed by interchanging the supply terminals

Answer: B

6.A DC series motor has linear magnetization and negligible armature resistance, the motor speed is

- a) Directly proportional to  $\sqrt{T}$       b) Inversely proportional to  $\sqrt{T}$       c) Directly proportional to  $T$       d) Inversely proportional to  $\sqrt{T}$

Answer: B

## **UNIT 3 - ELECTRONIC DEVICES**

### **EASY QUESTIONS**

1. The function of choke and starter in a fluorescent lamp circuit is to
  - a) Reduce the power consumed by the fluorescent lamp
  - b) Create a high voltage across the tube during starting
  - c) Help to draw very high current during starting
  - d) Improve the power factor of the fluorescent lamp circuit

Answer: B

2. Moving coil instruments can be used on

- a)DC only      b)sinusoidal AC only      c)All AC waveforms      d)AC and Dc both

Answer: A

3.PMMC Instrument are used for -----quantity measurement

- a)AC      b)Magnetic      c)DC      d)Both AC and DC

Answer: C

4.Moving Parts of instruments are supported in

- a)Bush bearings      b)Ball bearings      c)Roller Bearings      d)Jewelled bearings

Answer: D

5. A single lamp controlled by two -way switches at two places is called

- a)Stair case wiring      b)Corridor wiring      c)Cleat wiring      d)Batter wiring

Answer: A

6. In a moving coil ammeter, the deflecting torque is directly proportional to the

- a)Square of the current to be measured  
b)Current to be measured  
c)Twice the current to be measured  
d)Square root of the current to be measured

Answer: B

7. Which can not reduce the earth resistance?

- a)Pouring water in the earth pit      b)Decreasing plate area  
c)Increasing the depth of the earth pit      d)connecting electrodes in parallel

Answer: B

8. The earth plate made up of

- a)copper      b)aluminium      c)lead      d)iron

Answer: A

9. Good earthing is that which gives

- a)very low resistance      b)High resistance      c)Equal resistance      d)zero resistance

Answer: A

10. The high torque to weight ratio in an analog indicating instrument indicates

- a)High friction loss      b)Low friction loss  
c)Nothing as regards friction loss      d)Copper loss

Answer: B

11. GaAs, LED emits radiation in the

- (a) UV region (b) Blue color  
(c) visible region (d) infra-red region

Answer: D

12. The ripple factor of bridge rectifier is

- (a) 0.482 (b) 0.812 (c) 1.11 (d) 1.21

Answer: A

13. The basic purpose of filter is to

- (a) minimize variations in a.c. input signal (b) suppress harmonics in rectified output
- (c) removes ripples from rectifier output (d) stabilize dc output voltage

Answer: C

14. If  $V_m$  is the peak value of an applied voltage in half wave rectifier with a large capacitor across load, then PIV is

- (a)  $V_m/2$  (b)  $V_m$  (c)  $2V_m$  (d)  $1.414V_m$

Answer: B

15. Junction breakdown of a PN junction occurs

- (a) with forward bias (b) with reverse bias
- (c) because of manufacturing defect (d) None of above

Answer: B

16. In PN junction diode dynamic conductance is directly proportional to

- (a) the applied voltage (b) temperature
- (c) the current (d) the thermal voltage

Answer: C

17. In a full wave rectifier, the current in each of the diodes flows for

- (a) complete cycle of the input signal
- (b) half cycle of the input signal
- (c) less than half of the input signal
- (d) None of above

Answer: A

18. When the PN junction diode is forward biased

- (a) the only current is hole current
- (b) the only current is electron current
- (c) the only current is produced by majority carriers
- (d) the current is produced by both holes and electrons

Answer: C

## MODERATE QUESTIONS

1. For 1N4736 Zener diode has  $Z_z=3.5 \Omega$ . The datasheet gives  $V_{zt}=6.8V$  at  $I_{zt}=37mA$ , What is voltage across zener terminals when the current is 50mA?

- (a) 6.85V (b) 7.85V (c) 8.85V (d) 9.95V

Answer: A

2. A Si PN junction has a reverse saturation current of  $I_0=30\text{nA}$  at room temperature, the junction forward voltage required to produce current of  $0.1\text{mA}$  is  
(a) 0.42V (b) 0.55V (c) 0.80V (d) 0.49V

Answer: A

3. The value of reverse bias resistance for an ideal diode is \_\_\_\_\_  
(a) infinity (b) 0 (c) one (d) none of the above

Answer: A

4. Semiconductor material have \_\_\_\_\_ temp. coefficient  
(a) Positive (b) Negative (c) Both positive and negative (d) None

Answer: B

5. A zener diode works on the principle of  
(a) tunneling of charge carriers across junction  
(b) thermionic emission  
(c) diffusion of charge carriers across junction  
(d) hopping of charge carriers across junction

Answer: C

6. Which one of the following types of indicating instrument is an electrometer?

- a)Electrodynamometer      b)PMMC      c)Electrostatic      d)Moving iron

Answer: C

7. In cleat wiring the porcelain are very easy to erect and fixed at a distance of

- a)4.5cm to 15 cm apart      b)5.5cm to 20 cm apart      c)6.5cm to 25 cm apart      d)7.5cm to 30 cm apart

Answer: A

8. In fluorescent lamp the light output is ----lumens per watt.

- a)70      b)80      c)90      d)95

Answer: A

9. The device used in series with the line wire is

- a)C.B      b)isolator      c)Fuse      d)Both C.B and isolator

Answer: C

10. The earth's potential is always

- a)Zero      b)one      c)Lesser than one      d)Greater than one

Answer: A

11. If the input supply frequency is 50Hz, the output supply frequency of a bridge wave rectifier is \_\_\_\_\_ Hz

- (a) 100 (b) 75 (c) 50 (d) 25

Answer: A

12. A half wave rectifier has an input voltage of 240 V rms if the step down transformer has turns ratio of 8:1, what is the load voltage?

- (a)27.5v (b)86.5v (c)30v (d)42.5V

Answer: D

## TOUGH QUESTIONS

1. Reverse saturation current in silicon PN junction diode nearly doubles for every

- (a) 20°C rise in temperature
  - (b) 50°C rise in temperature
  - (c) 60°C rise in temperature
  - (d) 10°C rise in temperature

Answer: D

2. If, by mistake ac source in a bridge rectifier is connected across the dc terminals it will burn out and hence short diodes

- (a) One (b) Two (c) Three (d) Four

Answer: D

3. A Voltage of 200V produces a deflection of  $90^\circ$  in PMMC spring controlled instrument. If the same instruments provided with gravity control what would be the deflection?

- a) 90°                          b) 45°                          c) 64.2°                          d) 98°

Answer: B

4. In plate earthing, the earth plate made up of copper size

- a)60cm\*60cm\*3.18mm b)70cm\*80cm\*3.18mm c)80cm\*65cm\*3.18mm d)90cm\*60cm\*3.18mm

a) och b)

5. A moving coil instrument gives a full scale detection of 20mA. When a potential difference of 50mV is applied. Calculate the series resistance to measure 500V on scale?

- a)2000ohm b)3000ohm c)3500ohm d)24997.5ohm

Answer: D

6. The applied input ac power to a half wave rectifier is 100 watts. The d.c output power obtained is 40 watts. What is the rectification efficiency?

- (a) 10% (b) 20% (c) 30% (d) 40%

(a) 10% (b)

## UNIT 4 TRANSDUCERS

## EASY QUESTIONS

1. A transducer converting ground movement or velocity to voltage is known as

- a) Geophone  
b) Biegelinse

- c) Hydrophone
- d) Sonar transponder

Answer: A

2. Which is the example of a active transducer?

- a) Strain gauge
- b) Thermistor
- c) LVDT
- d) Thermocouple

Answer:D

3. Which transducer is known as ‘self-generating transducer

- a) Active transducer
- b) Passive transducer
- c) Secondary transducer
- d) Analog transducer

Answer:A

4. What is the relation between scale factor and sensitivity of a transducer?

- a) Scale factor is double of sensitivity
- b) Scale factor is inverse of sensitivity
- c) Sensitivity is inverse of scale factor
- d) Sensitivity is equal to scale factor

Answer: B

5. Which of the following is an analog transducer?

- a) Encoders
- b) Strain gauge
- c) Digital tachometers
- d) Limit switches

Answer:B

6. What is the principle of operation of LVDT?

- a) Mutual inductance
- b) Self-inductance
- c) Permanence
- d) Reluctance

Answer:A

7. Which of the following can be measured using Piezo-electric transducer?

- a) Velocity
- b) Displacement

c) Force

d) Sound

Answer:C

8. Capacitive transducer are used for?

a) Static measurement

b) Dynamic measurement

c) Transient measurement

d) Both static and dynamic

Answer:B

.9. Which of the following is used in photo conductive cell?

a) Selenium

b) Quartz

c) Rochelle salt

d) Lithium sulphate

Answer:A

10. Mechanical transducers sense \_\_\_\_\_

a) electrical changes

b) physical changes

c) chemical changes

d) biological changes

Answer:B

11. Mechanical transducers generate \_\_\_\_\_

a) electrical signals

b) chemical signals

c) physical signals

d) biological signals

Answer:C

12. Electrical transducers generate \_\_\_\_\_

a) biological signals

b) chemical signals

c) physical signals

d) electrical signals

Answer:D

13. The power needs of electrical transducers is \_\_\_\_\_

a) maximum

b) minimum

- c) zero
- d) infinite

Answer:B

14.Electrical transducers are \_\_\_\_\_

- a) small and non-portable
- b) large and non-portable
- c) small and compact
- d) large and portable

Answer:C

15.Potentiometer transducers are used for the measurement of

- A. Pressure
- B. Displacement
- C. Humidity
- D. Both (a) and (b)

Answer:D

16.Thermistor is a transducer. Its temperature coefficient is

- A. Negative
- B. Positive
- C. Zero
- D. Unique

Answer:A

17.Strain gauge is a

- A. Active device and converts mechanical displacement into a change of resistance
- B. Passive device and converts electrical displacement into a change of resistance
- C. Passive device and converts mechanical displacement into a change of resistance
- D. Active device and converts electrical displacement into a change of resistance

Answer:C

18.The linear variable differential transformer transducer is

- A. Inductive transducer
- B. Non-inductive transducer
- C. Capacitive transducer
- D. Resistive transducer

Answer:A

## **MODERATE QUESTIONS**

1. With the increase in the intensity of light, the resistance of a photovoltaic cell

- A. Increases
- B. Decreases
- C. Remains same
- D. Doubled

Answer:B

2. If the displacement is measured with strain gauge then the number of strain gauge normally required are

- A. One
- B. Two
- C. Three
- D. Four

Answer:D

3. LEDs fabricated from the gallium arsenide emit radiation in the

- A. Visible Range
- B. Infrared Region
- C. Ultra violet Region
- D. Ultrasonic Region

Answer:B

4. In light emitting diode, the available light emitting region is

- A. Less than 2.5 mm
- B. From 2.5 to 25 mm
- C. Greater than 25 mm
- D. Greater than 50 mm

Answer:B

5. In liquid crystal displays, the liquid crystal exhibits properties of

- A. Liquid
- B. Solids
- C. Gases
- D. Both (a) and (b)

Answer:D

6. The optical properties of liquid crystals depend on the direction of

- a) Air
- b) Solid
- c) Light
- d) Water

Answer:C

7. LCDs operate from a voltage ranges from

- a) 3 to 15V
- b) 10 to 15V
- c) 10V
- d) 5V

Answer:A

8. LCDs operate from a frequency ranges from

- a) 10Hz to 60Hz
- b) 50Hz to 70Hz
- c) 30Hz to 60Hz
- d) None of the Mentioned

Answer:C

9. What is backplane in LCD?

- a) The ac voltage applied between segment and a common element
- b) The dc voltage applied between segment and a common element
- c) The amount of power consumed

Answer:A

10. In photo emissive transducers, electrons are attracted by \_\_\_\_\_

- a) Cathode
- b) Anode
- c) Grid
- d) Body

Answer:B

11. LDR's are also called \_\_\_\_\_

- a) Photo voltaic cell
- b) Photo resistive cell
- c) Photo emissive cell
- d) All of the mentioned

Answer:B

12. In dark, LDR has

- A. low resistance
- B. high current
- C. high resistance
- D. both A and B

Answer:C

## TOUGH QUESTIONS

31. 1 eV is equal to

- A.  $1.6 \times 10^{-19}$  J
- B.  $2.0 \times 10^{-20}$  J
- C. 3 J
- D. 4 J

Answer:A

32. Solar cell works based on

- (a) Laser technology
- (b) Photo-conduction
- (c) Thermal emission
- (c) Tyndall effect

Answer:B

33. Commonly used photoemissive material is \_\_\_\_\_

- a) gold
- b) opium
- c) tellurium
- d) cesium-antimony

Answer:D

34. Photoconductors are made of \_\_\_\_\_

- a) thick layer of semiconductor
- b) thin layer of semiconductor
- c) capacitive substrate
- d) inductive substrate

Answer:B

35. A device consists of a phototransistor and a led is

- A. Photodiode
- B. Optocoupler
- C. Optoisolator
- D. Photomultiplier

Answer:B

36. A load cell is essentially a

- (a) strain gauge
- (b) thermister
- (c) resistive potentiometer
- (d) inductive transducer

Answer:A

## **UNIT – 5 DIGITAL SYSTEMS**

### **EASY QUESTIONS**

1. Communication is the transfer of meaningful information from
  - (a) source to destination (b) transmitter to receiver
  - (c) sender to receiver (d) above all

ANSWER:D

2. The basic process of information exchange between transmitter and receiver is known as.....  
(a) communication (b) controlling (c) signaling (d) modulating

ANSWER:A

3. The process of converting electrical equivalent of the information to a suitable form is done by....

- (a) transmitter (b) receiver (c) medium (d) above all

ANSWER:A

4. The communication system with wire as conducting medium is known as .....

- (a) wired communication (b) line communication  
(c) guided media communication (d) above all

ANSWER:D

5. The communication system which has no wires as conducting medium is known as.....

- (a) wireless communication (b) radio communication  
(c) unguided communication (d) above all

ANSWER:D

6. Noise is basically a.....

- (a) random signal (b) unwanted electrical signal  
(c) disturbance signal (d) above all

ANSWER:D

7. The process of varying amplitude of sine wave carrier signal according to the instantaneous voltage of sine wave modulating signal is known as ....

- (a) Frequency Modulation (b) Phase modulation  
(c) Amplitude modulation (d) PAM

ANSWER:C

8. The loss of information in AM wave is known as...

- (a) under modulation (b) over modulation  
(c) attenuation (d) rectification

ANSWER:B

9. Each product term of a group,  $a'.b.c'$  and  $a.b$ , represents the \_\_\_\_\_ in that group.

- a) Input  
b) POS  
c) Sum-of-Minterms  
d) Sum of Maxterms

ANSWER:C

10. Each “1” entry in a K-map square represents:

- a) A HIGH for each input truth table condition that produces a HIGH output
- b) A HIGH output on the truth table for all LOW input combinations
- c) A LOW output for all possible HIGH input conditions
- d) A DON’T CARE condition for all possible input truth table combinations

ANSWER:A

11. Which of the following expressions is in the sum-of-products form?

- a)  $(A + B)(C + D)$
- b)  $(A * B)(C * D)$
- c)  $A * B * (CD)$
- d)  $A * B + C * D$

ANSWER:D

12. K-Map of full adder is of ----- variables

A. 2 b. 3 c.4 d.1

ANSWER:B

13. The output of a logic gate is 1 when all its inputs are at logic 1, the gate is either

- (a) A NAND or a NOR
- (b) An AND or an OR
- (c) An OR or an X-OR
- (d) An AND or a NOR

ANSWER:B

14. The output of a logic gate is 1 when all its inputs are at logic 0. The gate is either

- (a) A NAND or a NOR
- (b) An AND or an X-OR
- (c) An OR or a NAND
- (d) An X-OR or an X-NOR

ANSWER:A

15. The most suitable gate to check whether the number of 1’s in a digital word is even or odd is

- (a) X-OR (b) NAND (c) NOR (d) AND, OR and NOT

ANSWER:A

16. The number of rows in the truth table of a 4- input gate is,

- (a) 4 (b) 8 (c) 12 (d) 16

ANSWER:D

17. For checking the parity of a digital word, it is preferable to use

- (a) AND gates (b) NAND gates (c) X-OR gates (d) NOR gates

ANSWER:C

18.  $A+AB+ABC+ABCD+ABCDE\dots =$

- (a) 1 (b) A (c)  $A+AB$  (d)  $AB$

ANSWER:B

## MODERATE QUESTIONS

1. A switching function  $F(a,b,c,d)=a'b'cd+a'bc'd+a'bcd+ab'c'd+ab'cd$

- a.  $\sum m(1,2,4,5,7)$  b.  $\sum m(3,5,7,9,13)$  c.  $\sum m(3,5,7,9,11)$  d.  $\sum m(3,7,9,11,13)$

ANSWER: C

2. The function  $F(a,b,c,d)=\sum m(5,9,11,14)$  is equivalent to

- a.  $a'bc'd+ab'c'd+ab'cd+abcd'$   
b.  $a'b'c'd+ab'c'd'+ab'cd+ab'cd'$   
c.  $a'bc'd+ab'c'd+abcd+ab'cd'$   
d.  $a'bc'd+a'b'c'd+ab'cd+a'bcd'$

ANSWER:A

3. If SOP form of the function  $F= a'bc'd+ab'c'd+abcd+ab'cd'$

- a.  $F=(a+b'+c+d')(a'+b+c+d')(a'+b'+c'+d')(a'+b+c'+d)$   
b.  $F=(a+b'+c+d)(a'+b'+c+d')(a'+b'+c'+d')(a'+b'+c'+d)$   
c.  $F=(a'+b'+c+d')(a'+b+c+d')(a+b'+c'+d')(a'+b+c+d)$   
d.  $F=(a+b'+c+d')(a'+b+c+d')(a'+b'+c'+d')(a'+b+c'+d')$

ANSWER: A

4. If a 3 variable function is represented in POS form as  $\pi M(0, 3, 6, 7)$  then in SOP form it is represented as

- a.  $\sum m(1,2,4,6)$  b.  $\sum m(1,3,4,5)$  c.  $\sum m(1,2,4,5)$  d.  $\sum m(1,2,4,7)$

ANSWER:C

5. Q.96.  $A+B=B+A$ ;  $AB=BA$  represent which laws

- (a) Commutative  
(b) Associative  
(c) Distributive  
(d) Idempotence

ANSWER:A

6. The K-map based Boolean reduction is based on the following Unifying Theorem:  $A + A' = 1$ .

- a) Impact  
b) Non Impact  
c) Force  
d) Complementarity

ANSWER:B

7. The prime implicant which has at least one element that is not present in any other implicant is known as \_\_\_\_\_

- a) Essential Prime Implicant
- b) Implicant
- c) Complement
- d) Prime Complement

ANSWER:A

8. Product-of-Sums expressions can be implemented using \_\_\_\_\_

- a) 2-level OR-AND logic circuits
- b) 2-level NOR logic circuits
- c) 2-level XOR logic circuits
- d) Both 2-level OR-AND and NOR logic circuits

ANSWER:D

9. There are many situations in logic design in which simplification of logic expression is possible in terms of XOR and \_\_\_\_\_ operations.

- a) X-NOR
- b) XOR
- c) NOR
- d) NAND

ANSWER:A

10. These logic gates are widely used in \_\_\_\_\_ design and therefore are available in IC form.

- a) Sampling
- b) Digital
- c) Analog
- d) Systems

ANSWER:B

11. In cellular transmitter system, the carrier generated by frequency synthesizer uses following modulation by the amplified voice signal from microphone

- (a) Frequency modulation (b) Phase modulation
- (c) AM modulation (d) None of above

ANSWER:B

12. The modulation index corresponding to maximum deviation and maximum modulating frequency is called as...

- (a) modulation index (b) deviation ratio
- (c) pre-emphasis factor (d) de- emphasis factor

ANSWER:B

## TOUGH QUESTIONS

1) Reduce the expression  $y=a'b'c'd+a'bc'd+a'bcd+a'bcd'+abc'd'+abc'd+abcd+ab'cd$

- a)  $acd + a'cd + ab'c + a'b'c'$
- b)  $a'c'd + a'bc + abc' + acd$
- c)  $a'c'd + abc + abc' + a'c'd'$
- d)  $ac + a'bc + abc' + acd$

ANSWER : B

2) simplify the function  $f(a,b,c) = \sum m(0,3,4,7)$

- a)  $b'c' + bc$
- b)  $a'b' + bc$
- c)  $a'b' + ab$
- d)  $ab' + bc$

ANSWER: A

3)  $(A + B)(A' * B') = ?$

- a) 1
- b) 0
- c) AB
- d)  $AB'$

ANSWER:B

4. Simplify  $Y = AB' + (A' + B)C$ .

- a)  $AB' + C$
- b)  $AB + AC$
- c)  $A'B + AC'$
- d)  $AB + A$

ANSWER:A

5. The boolean function  $A + BC$  is a reduced form of \_\_\_\_\_

- a)  $AB + BC$
- b)  $(A + B)(A + C)$
- c)  $A'B + AB'C$
- d)  $(A + C)B$

ANSWER:B

6. The canonical sum of product form of the function  $y(A,B) = A + B$  is \_\_\_\_\_

- a)  $AB + BB + A'A$
- b)  $AB + AB' + A'B$
- c)  $BA + BA' + A'B'$
- d)  $AB' + A'B + A'B'$

ANSWER:B



## 1. Define electric current

**Electrical current** is a measure of the amount of electrical charge transferred per unit time. It represents the flow of electrons through a conductive material. The SI unit of electrical current is the ampere, defined as 1 coulomb/second.

## 2. Define Resistance

The **electrical resistance** of an electrical conductor is the opposition to the flow of an electric current through that conductor. The SI unit of electrical resistance is the ohm ( $\Omega$ ).

$$R = \frac{\rho l}{a}$$

Where R = Resistance

$\rho$  = Specific conductivity of the material

l = Length of the conductor

a = Area of the conductor

## 3. State Ohm's law and its limitations?

Ohm's law states that, At constant temperature, in an electrical circuit, the current passing through a conductor, from one terminal point on the conductor to another terminal point on the conductor, is directly proportional to the potential difference (i.e. voltage drop or voltage) across the two terminal points and inversely proportional to the resistance of the conductor between the two terminal points.

$$I = \frac{V}{R}$$

### Limitations:

- i) Not applicable to non metallic conductor
- ii) Not applicable to non linear devices such as Zener diode, Vacuum tubes etc.
- iii) It is not true when temperature changes.

## 4. Define Power

**Electric power** is the rate at which electric energy is transferred by an electric circuit. The SI unit of power is the watt, one joule per second.

$$P = \text{work done per unit time} = P = \frac{QV}{t} = VI$$

where

$Q$  is electric charge in coulombs

$t$  is time in seconds

$I$  is electric current in amperes

$V$  is electric potential or voltage in volts

## 5. Define energy

The work is done by an electric circuit, is known as Electric energy. It is measured in kilo watt hours.

$$\text{Energy} = VIt$$

## 6. Define Linear and Non linear Elements.

In an electric circuit, a **linear** element is an electrical element with a linear relationship between current and voltage. Resistors are the most common example of a linear element; other examples include capacitors, inductors, and transformers.

**Nonlinear** element is one which does not have a linear input – output relation. for example, In a diode, the current is a non-linear function of the voltage. Most semiconductor devices have non-linear characteristics.

## 7. What are active and passive elements?

The **Active elements** rely on a source of energy and usually can inject power into a circuit. Ex. Semiconductor devices, Power sources.

The **passive elements** are those which are capable only of receiving power and either store it or convert it into another form. Ex. Resistors, Inductors, Capacitors, etc.

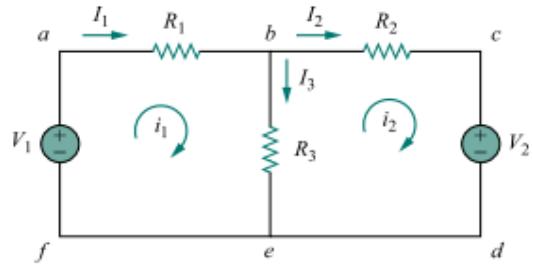
## 8. What is node.

Node - a node is a junction, where two or more circuit elements are connected or joined together. A node is indicated by a dot.

## 9. Differentiate Loop and Mesh.

Loop	Mesh
A loop is a simple closed path	A mesh is also closed path
A "Loop" is a larger one, within containing several "Meshes".	A mesh is a loop which does not contain any other loops within it

In the circuit, paths *abefa* and *bcdeb* are meshes, but path *abcdefa* is not a mesh.



## 10. State Kirchoff's voltage and current law?

**Kirchoff's current law** states that the sum of the currents entering into any point is equal to the sum of the currents leaving that point.

**Kirchoff's voltage law** states that the algebraic sum of the voltages around any closed path in a circuit is always zero.

## 11. Write the steps by step procedure to solve the network by loop analysis and nodal analysis.

### Loop analysis:

Step 1: Identify the mesh currents

Step 2: Determine which mesh currents are known

Step 2: Write equation for each mesh using KVL and that includes the mesh currents

Step 3: Solve the equations

### **Nodal analysis:**

Step 1: Identify the nodes

Step 2: Choose a reference node

Step 3: Identify which node voltages are known if any

Step 4: Identify the BRANCH currents

Step 5: Use KCL to write an equation for each unknown node voltage

Step 6: Solve the equations

## **12. Compare the Series and parallel circuit.**

Series circuit	Parallel circuit
The total effective resistance is the sum of the individual resistance. $R_{eff} = R_1 + R_2 + R_3 \dots$	The reciprocal of the total effective resistance is sum of the reciprocal of individual resistance. $\frac{1}{R_{eff}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
Only one path for the current flow	More than one path for the current to flow
The current flowing through all the resistance will be same and equal to the total current	The current flowing through each resistance is divided according to the value of the resistance
The voltage is divided across each resistance according to the value of the resistance	The voltage across each resistance is same which will be equal to the input voltage

## **13. What is an alternating current?**

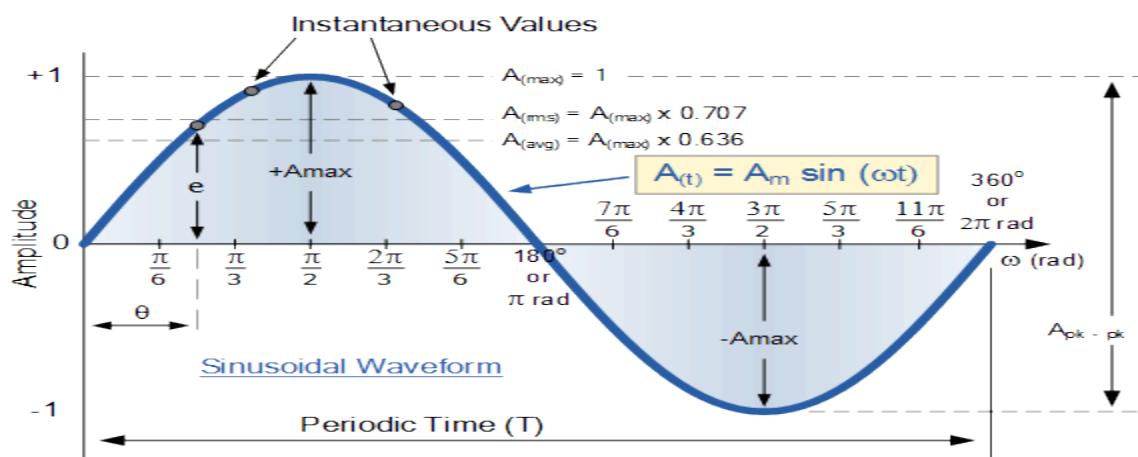
An alternating current or voltage is the one which changes the periodically both in magnitude and direction.

Expression of Ac current and voltage:

$$i = i(t) = I_m \sin(\omega t)$$

$$v = v(t) = V_m \sin(\omega t)$$

### **Illustration:**



#### **14. What is cycle?**

Each repetition of set of a positive negative instantaneous values of an alternating quantity is called a cycle.

#### **15. Define frequency.**

The number of cycle completed by an alternating current per sec is known as its frequency. It is measured in cycle / second. Ie Hertz (Hz).

$$f = \frac{1}{T}$$

Where f = frequency

T = one cycle period or Time taken to complete one cycle.

#### **16. Define instantaneous value**

The value of an alternating quantity at a particular instant is known as its instantaneous value. A(t<sub>1</sub>) is instantaneous value at the instant of t<sub>1</sub>

#### **17. Define Average and RMS value.**

An **Average** or **Mean** value is average of instantaneous value of current for a specific period. The average or mean value of a symmetrical alternating quantity, such as a sine wave, is the average value measured over only half a cycle since over a complete cycle the average value is zero regardless of the peak amplitude.

An **Effective** or **RMS** value of an alternating current is given by that steady current (DC) which when flowing through a given circuit for a given time produces the same amount of heat as produced by alternating current which when flowing through the same circuit for the same time.

RMS value of sinusoidal waveform is  $I_{rms} = \frac{Im}{\sqrt{2}}$

#### **18. Define the expression for form factor and peak factor**

The form factor is defined as the ratio of R.M.S value and Average value

$$\text{Form factor} = \frac{\text{RMS value}}{\text{Average value}}$$

The peak or crest value is defined as the ratio of Maximum or Peak value and R.M.S value

$$\text{Peak factor} = \frac{\text{Maximum value}}{\text{RMS value}}$$

#### **19. Define impedance.**

**Impedance** is defined as opposition of circuit to the flow of an alternating current. It is denoted as by Z and measured in ohms.

$$Z = R + j(X_L - X_C) \quad \Omega \text{ in Rectangular form}$$

$$Z = \sqrt{R^2 + (XL - XC)^2} \text{ in Polar form}$$

$$\text{Angle of } \angle Z = \tan^{-1} \left( \frac{X}{R} \right)$$

## 20. What do you understand by balanced system?

The Three phase system in which three voltages are of same magnitude and frequency and displaced from each other by  $120^\circ$  phase angle is defined as balanced or symmetrical system

## 21. Define Phase sequence.

The sequence in which the voltage in three phase reach their maximum positive value is called phase sequence. Generally the phase sequence is R-Y-B.

## 22. Define power factor.

The numerical value of cosine of the phase angle between voltage and current. It is denoted as  $\cos\varphi$ . It is also defined as the ratio of resistance to the impedance.

$$p.f = \cos \varphi = \frac{R}{Z}$$

It is also defined as ratio of actual power to Apparent power.

$$p.f = \cos \varphi = \frac{KW}{KVA} = \frac{VI \cos \varphi}{VI}$$

## 23. Write down different types of power at AC circuit? and Draw power triangle?

**Real power** is measured in watts (W) and is the power drawn by the electrical resistance of a system doing useful work.

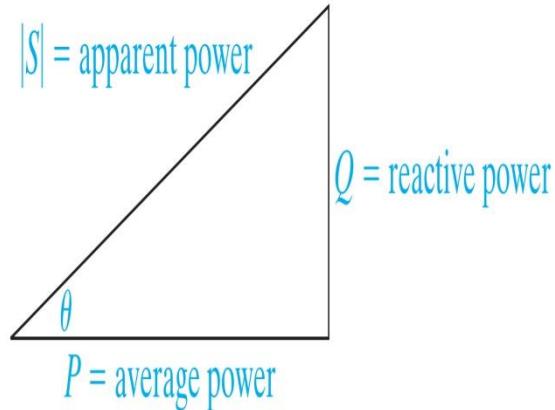
$$P = V_{rms} I_{rms} \cos \varphi$$

**Reactive power** is measured in volt-amperes reactive (VAR). Reactive Power is power stored in and discharged by inductive components.

$$Q = V_{rms} I_{rms} \sin \varphi$$

**Apparent power** is measured in volt-amperes (VA) and is the voltage on an AC system multiplied by all the current that flows in it. It is the vector sum of the active and the reactive power.

$$S = V_{rms} I_{rms}$$



## 24. Give the advantages of 3 phase system.

The three-phase system has the following advantages compared to a single-phase system:

- i. It is more economical as it requires less conductor material compared to a single-phase system.
- ii. A three-phase machine gives more output compared to a single-phase machine of the same size.
- iii. Three-phase motors have uniform torque, whereas most of the single-phase motors have pulsating torque.

- iv. Domestic power and industrial or commercial power can be supplied from the same source.
- v. A three-phase motor produces more torque as compared to a single-phase motor.
- vi. Three-phase induction motors are self-starting, whereas single-phase motors are not self-starting.
- vii. Voltage regulation is better in a three-phase system.

## 25. Write down the voltage and current relation at Star and delta connection.

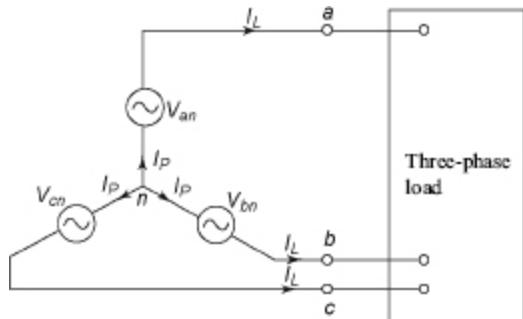
### Star connection :

Phase current:  $I_{1p} = I_{1L}$ ,  $I_{2p} = I_{2L}$ ,  $I_{3p} = I_{3L}$

Line voltage:  $V_L = V_{12} = V_{23} = V_{31}$

$$V_L = V_p / \sqrt{3}$$

Line current:  $I_L = I_{1L} = I_{2L} = I_{3L}$



### Delta connection :

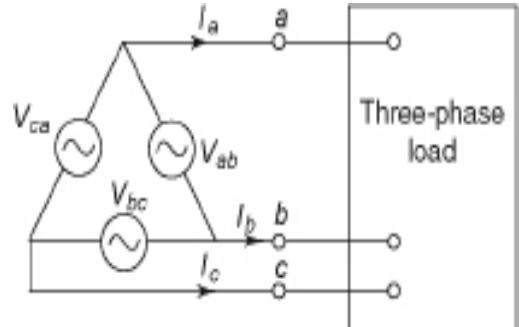
Phase voltage:  $V_{12} = V_{12p}$ ,  $V_{23} = V_{23p}$ ,  $V_{31} = V_{31p}$

Line voltage:

$V_L = V_{12} = V_{23} = V_{31}$  and  $V_p = V_{1p} = V_{2p} = V_{3p}$

Line current:  $I_L = I_{1L} = I_{2L} = I_{3L}$  and  $I_p = I_{12p} = I_{23p} = I_{31p}$

$$I_L = I_p / \sqrt{3}$$



# UNIT-5

## 1. Define Minterm and Maxterm.

- A. A product term containing all the inputs of the functions in either complemented or uncomplemented form is called **MINTERMS**.  
A sum term containing all the inputs of the functions in either complemented or uncomplemented form is called **MAXTERMS**.

## 2. Give the limitations of K-Map.

## 3. Obtain the canonical SOP form of the function $Y(A, B, C, D) = AB + ACD$ .

The image shows a handwritten derivation of the canonical SOP form of the Boolean function  $Y(A, B, C, D) = AB + ACD$ . The steps are as follows:

$$\begin{aligned} Y(A, B, C, D) &= AB + ACD \\ &= AB(C+C') + ACD(B+B') \\ &= ABC + ABC' + ABCD + AB'C'D \\ &= ABC(D+D') + ABC'(D+D') + ABC'D + AB'C'D \\ &\subseteq \cancel{ABC'D} + \cancel{ABCD'} + \cancel{ABC'D} + \cancel{ABC'D} + ABC'D + AB'C'D \\ &= ABC'D + ABC'D' + ABC'D + ABC'D' + AB'C'D \\ & \quad [\text{canonical SOP form}]. \end{aligned}$$

## 4. Simplify the boolean expression using K-Map $F =$

$$AB'C + A'B'C + A'BC + AB'C' + A'B'C'.$$

$$\begin{aligned}
 F &= AB'C + A'B'C + A'BC + AB'C + A'BC \\
 &= 101 + 001 + 011 + 100 + 001 \\
 &\quad \begin{matrix} 5 & 1 & 3 & 4 & 1 & 421 \end{matrix} \\
 F &= \Sigma(5, 8, 13, 1) \\
 \begin{array}{c} A \\ \bar{A} \\ \bar{A} \\ \bar{A} \end{array} &\quad \begin{array}{c} BC\bar{B}\bar{C} \\ 00 \\ 01 \\ 11 \\ 10 \end{array} \quad \begin{array}{c} \bar{B}C \\ 0 \\ 1 \\ 1 \\ 0 \end{array} \quad \begin{array}{c} BC \\ 1 \\ 1 \\ 0 \\ 0 \end{array} \quad \begin{array}{c} \bar{B}\bar{C} \\ 1 \\ 0 \\ 0 \\ 1 \end{array} \\
 \begin{array}{c} 0 \\ 0 \\ 1 \\ 1 \end{array} &\quad \begin{array}{c} 0 \\ 1 \\ 1 \\ 0 \end{array} \quad \begin{array}{c} 1 \\ 1 \\ 0 \\ 0 \end{array} \quad \begin{array}{c} 1 \\ 0 \\ 0 \\ 1 \end{array} \quad \begin{array}{c} 0 \\ 0 \\ 1 \\ 1 \end{array} \\
 \begin{array}{c} 1 \\ 1 \\ 0 \\ 0 \end{array} &\quad \begin{array}{c} 1 \\ 1 \\ 0 \\ 0 \end{array} \quad \begin{array}{c} 1 \\ 0 \\ 0 \\ 1 \end{array} \quad \begin{array}{c} 0 \\ 0 \\ 1 \\ 1 \end{array} \quad \begin{array}{c} 1 \\ 0 \\ 0 \\ 1 \end{array} \\
 &\quad \begin{array}{c} \bar{A}B + \bar{A}C + \bar{B}C \end{array}
 \end{array}$$

5. Simplify  $(A+B)(A'C'+C)(B'+AC)$  using Boolean expression

A.

$$\begin{aligned} (A+B)(\bar{A}C+C) (\bar{B}+AC) &= (A+B)(\bar{A}+C)(\bar{B}(\bar{A}+\bar{C})) \\ &= (\bar{A}\bar{A} + \bar{A}C + \bar{A}B + BC)(\bar{A}B + \bar{B}\bar{C}) \\ &= (0 + \bar{A}C + \bar{A}B + BC)(\bar{A}B + \bar{B}\bar{C}) \\ &= AC\bar{A}B + AC\bar{B}\bar{C} + \bar{A}B \cdot \bar{A}B + \bar{A}B\bar{B}\bar{C} \\ &\quad \bar{B}\bar{C}\bar{A}B + \bar{B}\bar{C} \cdot \bar{B}\bar{C} \\ &= 0 + 0 + \bar{A}B + \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}\bar{C} \\ &\quad + 0 \\ &= \bar{A}B + \bar{A}\bar{B}\bar{C} + \bar{A}\bar{B}\bar{C} \\ &= \bar{A}B + \bar{A}\bar{B}\bar{C} \\ &= \bar{A}B(1 + \bar{C}) \\ &= \bar{A}B. \end{aligned}$$

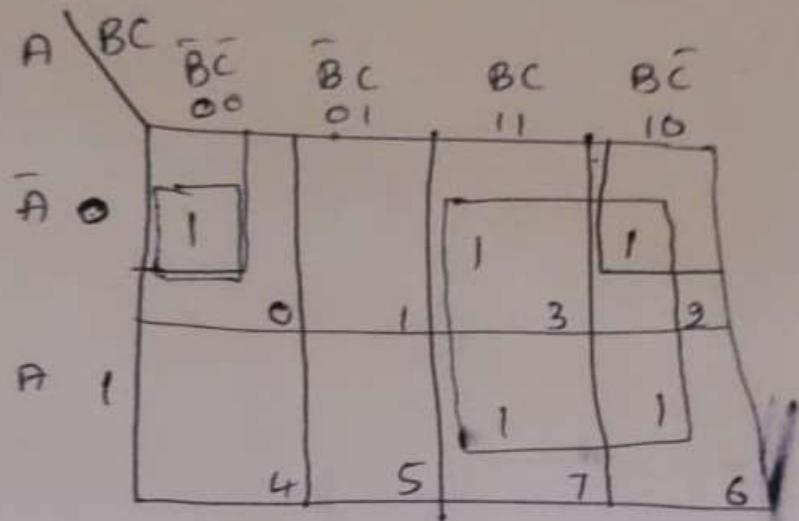
6. Map  $F(A,B,C) = \sum m(0,2,3,6,7)$  Simplify using K-map

A.

6.

$$F(A, B, C) = \Sigma m(0, 2, 3, 6, 7)$$

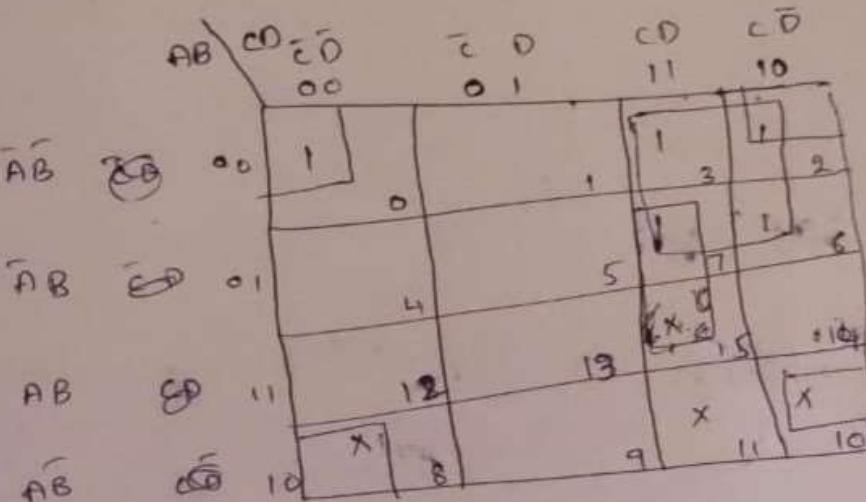
Ans



$$Y = \bar{A}\bar{B}\bar{C} + B \quad Y = \bar{A}\bar{C} + B$$

7. Simplify using K-Map  $F(A, B, C, D) = \Sigma m(0, 2, 3, 6, 7) + d(8, 10, 11, 15)$

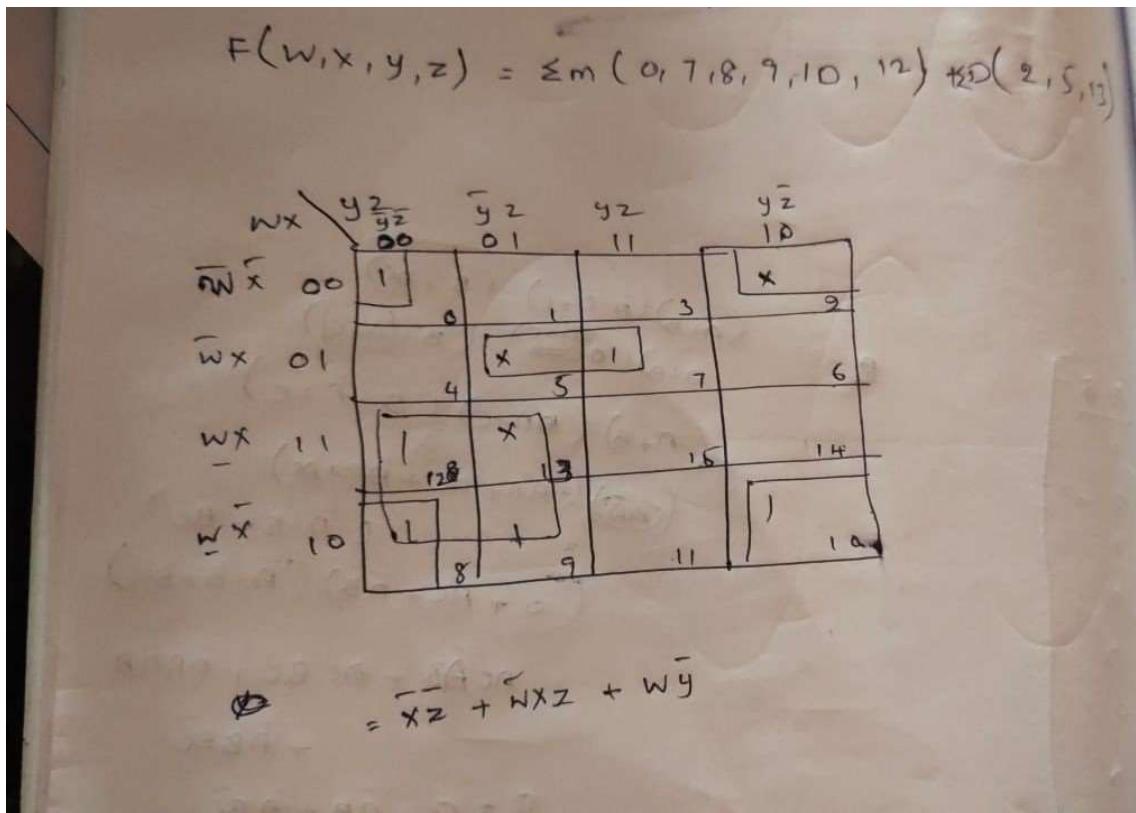
7.  $f(A,B,C,D) = \sum m(0,2,3,6,7) + d(8,10,11,15)$



$$y = \overline{BD} + \overline{AC}$$

8.  $F(w, x, y, z) = \sum m(0, 7, 8, 9, 10, 12) + \sum d(2, 5, 13)$

A.



9. Simplify  $F = (xy + y'z + xz)x$  using Boolean expression.



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$$a(x\bar{y} + \bar{y}z + xz)x$$

$$\bar{x}\bar{y}\cdot x + \bar{y}\bar{x}z + xz\bar{x}$$

$$xy + x\bar{y}z + xz$$

$$x(y + \bar{y}z + xz)$$

$$x[y + z + \bar{y}]$$

$$xy + xz + ux\bar{y}$$

A.

10 . Convert  $(143)_{10}$  to binary form.

10.  $(143)_{10} \rightarrow$  binary form.

$$\begin{array}{r} 2 \overline{)143} \\ 2 \overline{)71} - 1 \\ 2 \overline{)35} - 1 \\ 2 \overline{)17} - 1 \\ 2 \overline{)8} - 1 \\ 2 \overline{)4} - 0 \\ 2 \overline{)2} - 0 \\ 1 - 0 \end{array}$$

$$(143)_{10} = (1000\ 1111)_2$$

11. Convert  $(EC8)_{16}$  to binary form.

11.  $(E\ 08)_{16} \rightarrow$  binary form

8421

A - 10

B - 11

C - 12

D - 13

E - 14

F - 15

14      12      8  
↓      ↓      ↘  
1110    1100    1000

$(1110\ 1100\ 1000)_2$

$\therefore (E\ 08)_{16} = (1110\ 1100\ 1000)_2$

12. Convert  $(220)_{10}$  to hexadecimal form.

12.  $(220)_{10} \rightarrow$  hexa decimal form

16 | 220

13 - 12

13 12

D C

$(220)_{10} \rightarrow (DC)_{16}$

A - 10

B - 11

C - 12

D - 13

E - 14

F - 15

### 13. What is the necessity of modulation?

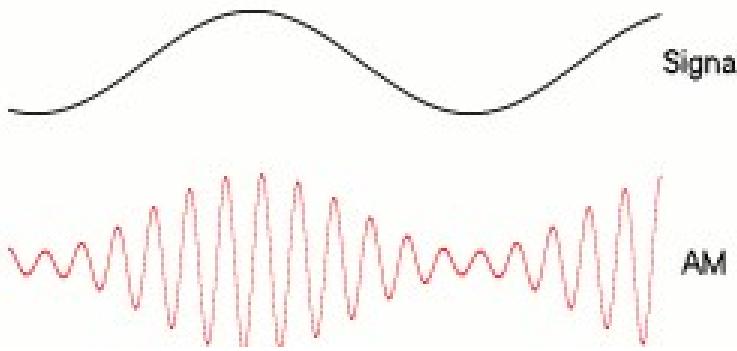
In the modulation process, some parameter of the carrier wave (such as amplitude, frequency or phase) is varied in accordance with the modulating signal. This modulated signal is then transmitted by the transmitter.

It is necessary to modulate the signal because-

1. It avoids mixing of signals. If the base band sound signals are transmitted without using the modulation by more than one transmitter, then all the signals will be in the same frequency range i.e. 0 to 20 kHz. Therefore, all the signals get mixed together and a receiver can not separate them from each other.
2. It increases the range of communication. The frequency of baseband signal is low, and the low frequency signals can not travel long distance when they are transmitted. They get heavily attenuated. The attenuation reduces with increase in frequency of the transmitted signal, and they travel longer distance.

### 14. Define amplitude modulation and draw its waveform.

A. Amplitude modulation (AM) is a modulation technique used in electronic communication, most commonly for transmitting messages with a radio carrier wave. In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to that of the message signal, such as an audio signal.

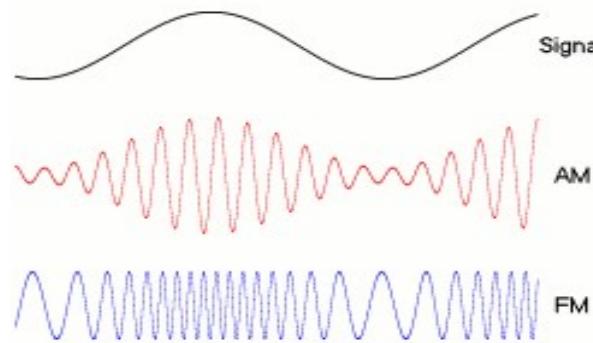


### 15 .Define frequency modulation and draw its waveform

Frequency modulation (FM) is the encoding of information in a carrier wave by varying the instantaneous frequency of the wave. The technology is used in telecommunications, radio broadcasting, signal processing, and computing.

In frequency modulation, such as radio broadcasting, of an audio signal representing voice or music, the instantaneous frequency deviation, i.e. the difference between the frequency of the carrier and its center frequency, has a functional relation to the modulating signal amplitude.

Frequency modulation is widely used for FM radio broadcasting



# **UNIT 4**

1) What is transducer ? Write one example of active & passive transducer

- A. Transducer is defined as a device, which converts energy from one form to another. The energy may be electrical, mechanical, chemical, optical or thermal.  
These are widely used in measurement work because not all quantities that need to be measured can be displayed as easily as others.  
Active Transducer:-Thermocouple , Piezoelectric transducer , Photovoltaic cell , Moving coil generator.  
Passive Transducer:-Resistance , potentiometric device , inductance , capacitance , transformer.

2) Define Primary & secondary transducer & give one example of each.

#### A. Primary transducer

The transducer which converts physical quantity into mechanical displacement is called primary transducer.

- The force detected by the column in first. Hence it is called primary transducer.
  - It is a mechanical device.

### Example:

- Bourdon Tube, Diaphragm

### **Secondary transducer**

The transducer which converts mechanical displacement into electrical output is called secondary transducer.

- Output of primary transducer is converted into useful signal by secondary transducer.
  - It is an electrical device.

### **Example:- LVDT**

**3) Classify each of the following transducers in two different categories:**

i) LVDT ii) Strain Gauge

- A. LVDT : - Passive transducer and Secondary Transducer**      Variable reactance  
**Strain Guage:-passive transducer**                                  variable resistance

#### **4. Write the Advantages & Disadvantages of L.V.D.T.**

#### A. Advantages:

There are some advantages of **linear variable differential transformer** (LVDT) which are given below.

- The LVDT has low power consumption.
  - It has higher sensitive.
  - It has ruggedness.
  - It has wide range.
  - It has low hysteresis.

### **Disadvantages:**

There are some disadvantages of linear variable differential transformer (LVDT) which are given below,

- It has large primary voltage produce distortion in output.
  - Temperature affects the performance.
  - Sensitive to stray magnetic field.

**5) What is piezoelectric effect? Name two piezoelectric materials.**

**Piezoelectric Effect** is the ability of certain materials to generate an electric charge in response to applied mechanical stress.

**Piezoelectric materials are materials that have the ability to generate internal electrical charge from applied mechanical stress.**

- Bone.

- Crystals.
- Certain ceramics.
- DNA.
- Enamel.
- Silk.
- Dentin, and many more

**6) Write the parameter measured by:**

**i) LVDT ii) Piezoelectric Transducer iii) Linear & angular Potentiometer**

**v) Diaphragm**

LVDT can measure displacement, velocity and acceleration which is a **linear variable differential transformer**

Piezoelectricity is the charge created across certain materials when a mechanical stress is applied. **Piezoelectric pressure** sensors exploit this effect

by measuring the voltage across a **piezoelectric** element generated by the **applied pressure**

## Applications of Potentiometer

It is used in many applications such as

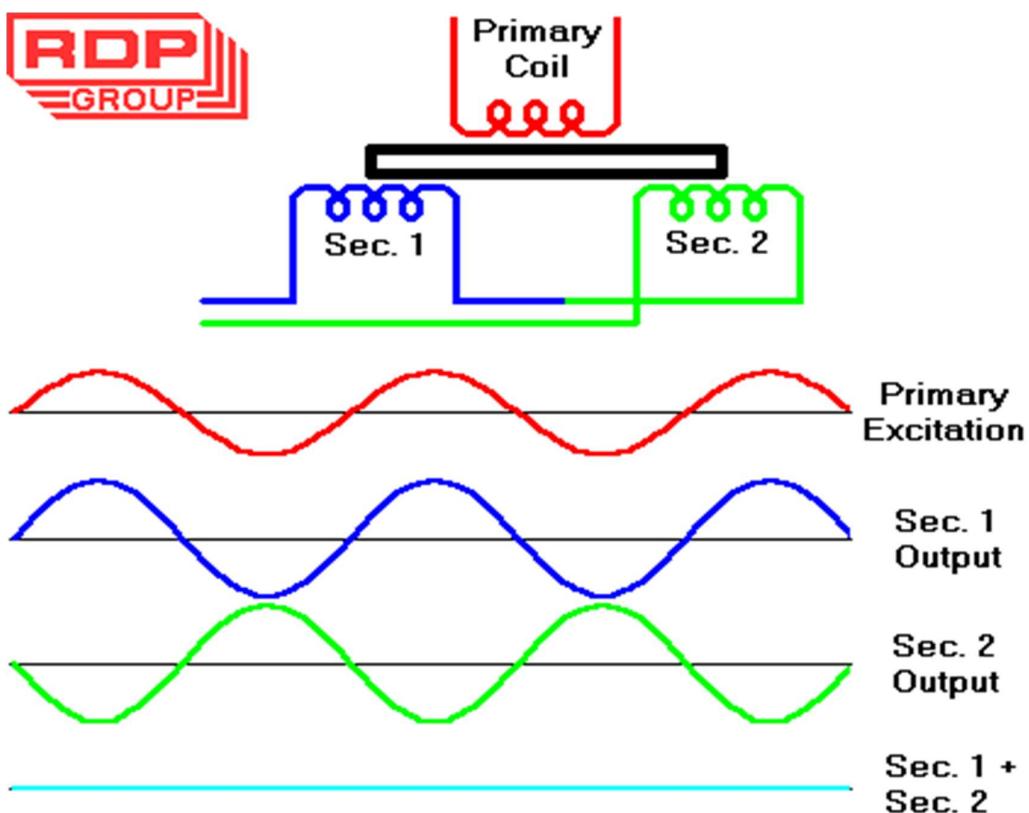
1. Linear displacement measurement
2. Liquid level measurements using floats
3. Rotary displacement measurement
4. Brightness control
5. Volume control

Diaphragm pressure gauges are used to **measure** gases and liquids.

**7) Explain the construction & working of LVDT.**

- **A.** An LVDT transducer comprises a coil former on to which three coils are wound.
- The primary coil is excited with an AC current, the secondary coils are wound such that when a ferrite core is in the central linear position, an equal voltage is induced in to each coil.
- The secondary are connected in opposite so that in the central position the outputs of the secondary cancels each other out.
- The excitation is applied to the primary winding and the armature assists the induction of current in to secondary coils.
- When the core is exactly at the center of the coil then the flux linked to both the secondary winding will be equal. Due to equal flux linkage the secondary induced voltages ( $e_{o1}$  &  $e_{o2}$ ) are equal but they have opposite polarities. Output voltage  $e_o$  is therefore zero. This position is called “null position”
- Now if the core is displaced from its null position toward sec1 then flux linked to sec1 increases and flux linked to sec2 decreases. Therefore  $e_{o1} > e_{o2}$  and the output voltage of LVDT  $e_o$  will be positive

- Similarly if the core is displaced toward sec2 then the  $e_{o2} > e_{o1}$  and the output voltage of LVDT  $e_o$  will be negative.



## 8) Explain the construction & working of piezoelectric type transducer

**A.** same as 16<sup>th</sup> question

## 9) Explain the construction & working of capacitive transducer

**A.** CAPACITIVE TRANSDUCER:

In capacitive transduction transducers the measurand is converted to a change in the capacitance.

- A typical capacitor is comprised of two parallel plates of conducting material separated by an electrical insulating material called a dielectric. The plates and the dielectric may be either flattened or rolled.
- The purpose of the dielectric is to help the two parallel plates maintain their stored electrical charges.
- The relationship between the capacitance and the size of capacitor plate, amount of plate separation, and the dielectric is given by

$$C = \epsilon_0 \epsilon_r A / d$$

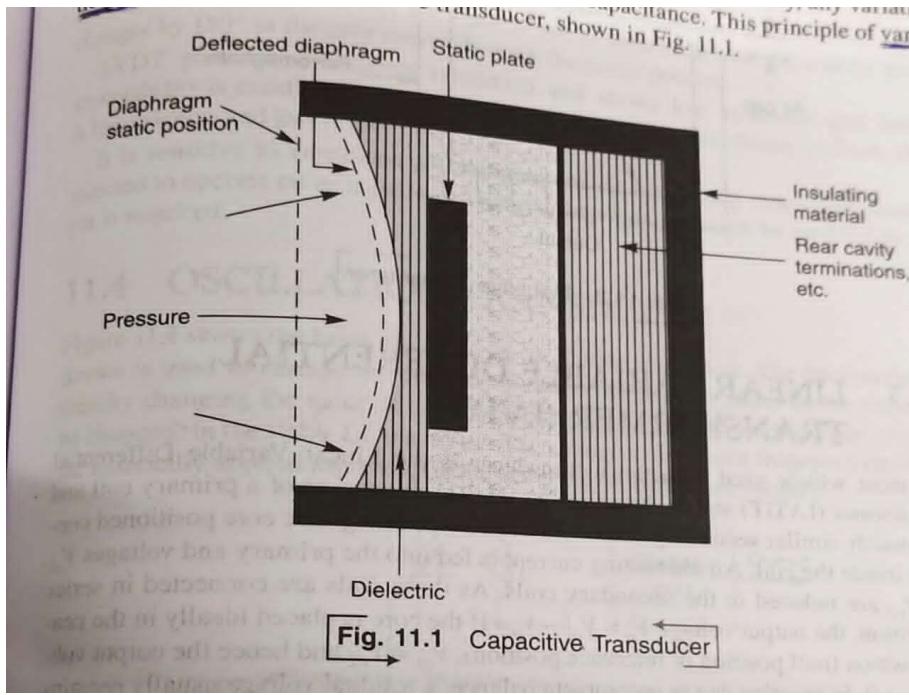
d is the separation distance of plates (m)

C is the capacitance (F, Farad)

$\epsilon_0$  : absolute permittivity of vacuum

$\epsilon_r$  : relative permittivity

A is the effective (overlapping) area of capacitor plates (m<sup>2</sup>)



### 10) Differentiate between passive and active transducers. Give an example of each

Active transducers :

- These transducers do not need any external source of power for their operation. Therefore they are also called as self generating type transducers.
- I. The active transducer are self generating devices which operate under the energy conversion principle.
- II. As the output of active transducers we get an equivalent electrical output signal e.g. temperature or strain to electric potential, without any external source of energy being used.

Passive Transducers :

- I. These transducers need external source of power for their operation. So they are not self generating type transducers.
- II. A DC power supply or an audio frequency generator is used as an external power source.
- III. These transducers produce the output signal in the form of variation in resistance, capacitance, inductance or some other electrical parameter in response to the quantity to be measured.

### 11) Compare and explain static and dynamic characteristics of transducers

**static characteristics** relate to the performance of a **transducer** when the measured quantity is essentially constant.

the **dynamic characteristics** relate to **dynamic** inputs, which **means** that they are dependent on its own parameters as well as the nature of the input signal.

1. **Static Characteristics** – It is the set of criteria which are used for measuring the quantities that are mostly constant or may vary slowly with time, i.e. they remain static without varying. E.g., Precision, Accuracy, Linearity, Repeatability, Sensitivity, Threshold, Resolution, Drift, Range, Stability, and Tolerance.

**2. Dynamic Characteristics** – These set of criteria of the instruments change rapidly with time. E.g., Dynamic error, Speed of response, Fidelity, and measuring lag

### 12) Explain the classification of transducers.

This energy may be electrical, mechanical, chemical, optical or thermal. Transducers may be classified according to their application, method of energy conversion, nature of the output signal, and so on. All these classifications usually result in overlapping areas. A sharp distinction among the types of transducers is difficult.

The transducer that gives electrical energy as output is known as *electrical transducer*. The output electrical signal may be voltage, current, or frequency and production of these signals is based upon resistive, capacitive, inductive effects etc. For measuring non-electrical quantities, a detector is used which usually converts the physical quantity into a displacement, that activates the electrical transducer.

The *displacement transducers*, such as capacitive, oscillation, potentiometric, photoelectric (phototube) and piezoelectric, use the principle of converting a mechanical force into displacement and then into electrical parameters. Here, the mechanical elements used for converting this applied force into displacement are called force-summing devices.

The transducers may also be classified as (i) Active and (ii) Passive transducers. *Active transducers*, also known as self generating type [develop their own voltage or current as the output signal.] The energy required for production of this output signal is obtained from the physical phenomenon being measured.

*Passive transducers*, also known as externally powered transducers, derive the power required for energy conversion from an external power source. However, they may also absorb some energy from the physical phenomenon under study.

### 13) Compare capacitive and inductive transducers

CAPACITIVE	INDUCTIVE
<p><input type="checkbox"/> 1.In capacitive transduction transducers the measurand is converted to a change in the capacitance.</p> <p>2.An electronic counter is a measure of the magnitude of the applied force .</p> <p>3.The capacitive transducer can measure static and dynamic changes.</p> <p>4.The draw back of this transducer is its sensitivity to temperature variations.</p>	<p>1.In inductive transduction, the measurand is converted into a change in the self inductance of a single coil.</p> <p>2.The applied force is measured by the change of inductance in a single coil.</p> <p>3.The inductive transducer enables static and dynamic changes.</p> <p>4.The draw back of that is its sensitivity to temperature variations .</p>

### 14) Elaborate the applications of inductive transducers.

**Inductive transducers** find **application** in proximity sensors which are used for position measurement, dynamic motion measurement, touch pads etc. Particularly **inductive transducer** is used for the detection of type of metal, finding missing parts or counting the number of objects

**15) Explain the working of capacitive transducer with neat schematic.**

SAME AS 9THQUESTION

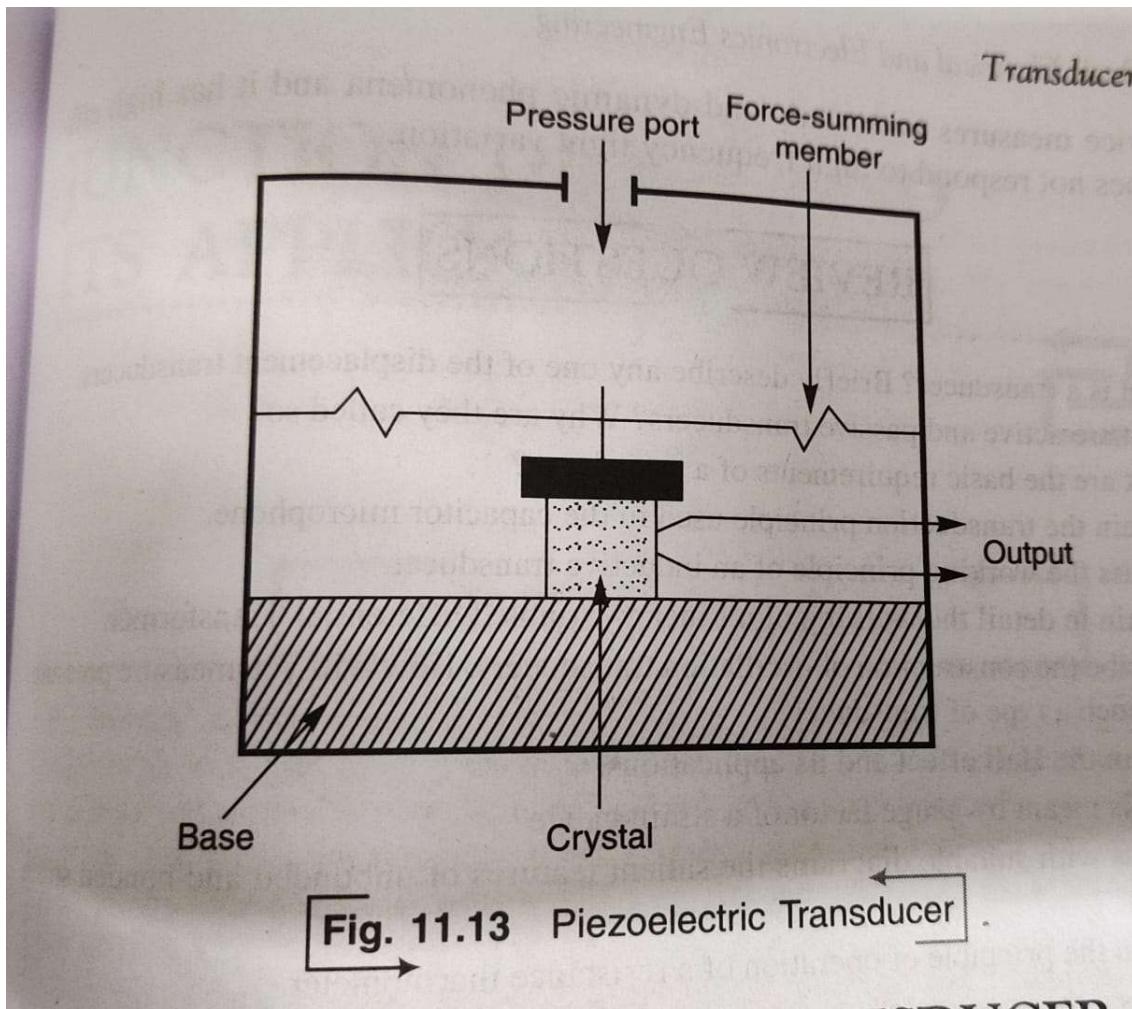
**16) Define Piezoelectric principle and explain the working of piezoelectric transducer.**

## 11.11 PIEZOELECTRIC TRANSDUCER

If the dimensions of asymmetrical crystalline materials, such as quartz, rochelle salt and barium titanite, are changed by the application of a mechanical force, the crystal produces an emf. This property is used in piezoelectric transducers.

The basic circuit of a piezoelectric transducer is shown in Fig. 11.13. Here, a crystal is placed between a solid base and the force-summing member. An externally applied force exerts pressure on the top of the crystal and it produces an emf across the crystal which is proportional to the magnitude of the applied pressure.

As this transducer has a very good high frequency response, it is used in high frequency accelerometers. As it needs no external power source, it is called as self-generating transducer. The main drawbacks are that it cannot measure static conditions and the output voltage is affected by temperature variations of the crystal.



**17) What is the principle of Piezoelectric transducer?**

**Find in 16<sup>th</sup> question**

**18) With a neat schematic explain the working of the following**

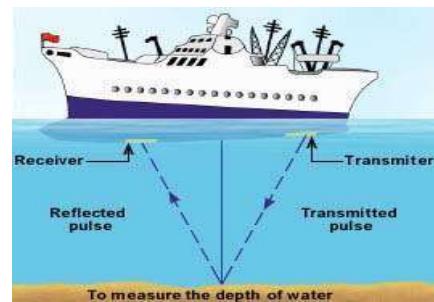
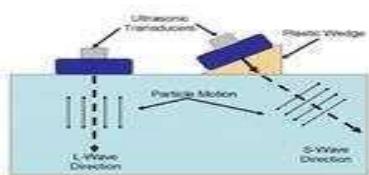
- (i) Mic                  (ii) Speaker                  (iii) Sonar                  (iv) Ultrasonic

- When you speak, sound waves created by your voice carry energy toward the microphone. Remember that sound we can hear is energy carried by vibrations in the air.
  - Inside the microphone, the diaphragm (much smaller than you'd find in a loudspeaker and usually made of very thin plastic) moves back and forth when the sound waves hit it.
  - The coil, attached to the diaphragm, moves back and forth as well.
  - The permanent magnet produces a magnetic field that cuts through the coil. As the coil moves back and forth through the magnetic field, an electric current flows through it.
  - The electric current flows out from the microphone to an amplifier or sound recording device. Hey presto, you've converted your original sound into electricity! By using this current to drive sound recording equipment, you can effectively store the sound forever more. Or you could amplify (boost the size of) the current and then feed it into a loudspeaker, turning the electricity back into much louder sound. That's how PA (personal address) systems, electric guitar amplifiers, and rock concert amplifiers work
  - When things shake about, or vibrate, they make the sounds we can hear in the world around us.
  - At the front of a loudspeaker, there is a fabric, plastic, paper, or lightweight metal **cone** (sometimes called a **diaphragm**) not unlike a drum skin (colored gray in our picture).
  - the inner part is fixed to an iron coil (sometimes called the **voice coil**, colored orange in the diagram) that sits just in front of a permanent magnet (sometimes called the **field magnet**, and colored yellow).
  - When you hook up the loudspeaker to a stereo, electrical signals feed through the speaker cables (red) into the coil.
  - This turns the coil into a temporary magnet or **electromagnet**. As the electricity flows back and forth in the cables, the electromagnet either attracts or repels the permanent magnet.
  - This moves the coil back and forward, pulling and pushing the loudspeaker cone. Like a drum skin vibrating back and forth, the moving cone pumps sounds out into the air.

3. Sonar is a device that is used to detect underwater objects using sound waves. In this system a sound pulse is generated and sent underwater through a transmitter. sound waves are reflected by the underwater object which are received at receiver. The time taken by sound wave to come back is recorded. And by knowing the speed of sound wave in water the distance can be easily calculated by formula.  
 $\text{Distance} = \text{speed} \times \text{time}$

4. The measurement devices using the ultrasonic waves comprise of the two major parts. One part of the device transmits the ultrasonic waves and the other part of the devices receives the ultrasonic waves.

- The devices transmitting and the receiving the ultrasonic waves may be located at the two opposite ends. In some cases the transmitting and the receiving devices are located at the same end and on the same side.
- No matter what the arrangement of the transmitting and the receiving device is, there is a timer that measures the time difference between the sending of the ultrasonic waves and receipt of the ultrasonic waves.
- This time is calibrated against the parameter to be measured. Thus the speed of the ultrasonic waves is an important property based on which the transducers using these waves work.



## 19) Explain the working of LED

- A. Light-emitting diode
- Semiconductor
- Has polarity
- When current flows across a diode, Negative electrons move one way and positive holes move the other way.
- The holes exist at a lower energy level than the free electrons
- Therefore when a free electron falls it loses energy
- This energy is emitted in a form of a photon, which causes light
- The color of the light is determined by the fall of the electron and hence energy level of the photon

## 20) Differentiate LED and LCD

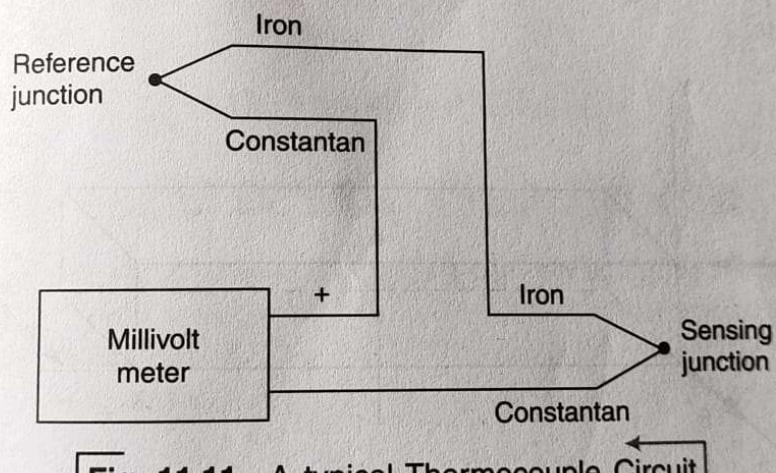
LCD	LED
LCD stands for liquid crystal display.	LED stands for light-emitting diodes.
All LCDs are not a subset of LED TV.	All LEDs are a subset of LCD TV.
LCDs primarily use fluorescent lights.	LEDs use light-emitting diodes.
Fluorescent lights used are usually placed behind the screen.	Light-emitting diodes are usually placed behind the screen or around the edges.
LCDs are usually thicker and lack energy efficiency compared to LEDs.	LEDs are much thinner and are much more energy-efficient

## 21) What is Thermocouple?

## 11.9 THERMOCOUPLE

A thermocouple is a junction between two dissimilar metals or semiconductors that generates a small voltage, typically in the millivolt range, with coefficient of about  $50 \mu\text{V}/^\circ\text{C}$ .

Various thermocouple materials and methods of construction are used depending on the temperature, environment and required sensitivity. A typical thermocouple circuit for temperature measurement is shown in Fig. 11.11. It consists of two junctions, reference and sensing maintained at different temperatures. Each junction is made by welding two dissimilar metals together. The reference junction is maintained at a fixed temperature, usually  $0^\circ\text{C}$  and the output voltage depends upon the temperature of the sensing junction. As only a relatively small output of the order of  $50 \mu\text{V}/^\circ\text{C}$  is obtained, it is necessary to amplify the output for calibration and measurement.



**Fig. 11.11** A typical Thermocouple Circuit

The iron-constantan thermocouple is used for measuring temperatures up to  $760^\circ\text{C}$  and Chromel-Alumel thermocouple is used for temperature measurement up to  $1370^\circ\text{C}$ .

**22) Explain with a neat schematic about Thermistor.**

## 11.8 THERMISTOR

Thermistor or Thermal resistor is a two-terminal semiconductor device whose resistance is temperature sensitive.

The value of such resistors decreases with increase in temperature. Materials employed in the manufacture of the thermistors include oxides of cobalt, nickel, copper, iron, titanium and manganese.

The thermistor has very high temperature coefficient of resistance, of the order of 3 to 5% per  $^{\circ}\text{C}$ , making it an ideal temperature transducer. The temperature coefficient of resistance is normally negative. The resistance at any temperature  $T$ , is given approximately by

$$R_T = R_0 \exp \beta \left( \frac{1}{T} - \frac{1}{T_0} \right)$$

where  $R_T$  = thermistor resistance at temperature  $T$  (K),

$R_0$  = thermistor resistance at temperature  $T_0$  (K), and

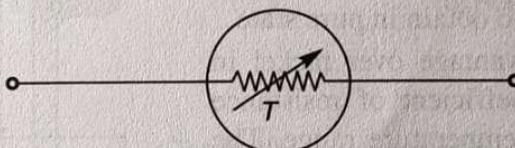
$\beta$  = a constant determined by calibration.

Fig. 11.9 Industrial Platinum Resistance Thermometer

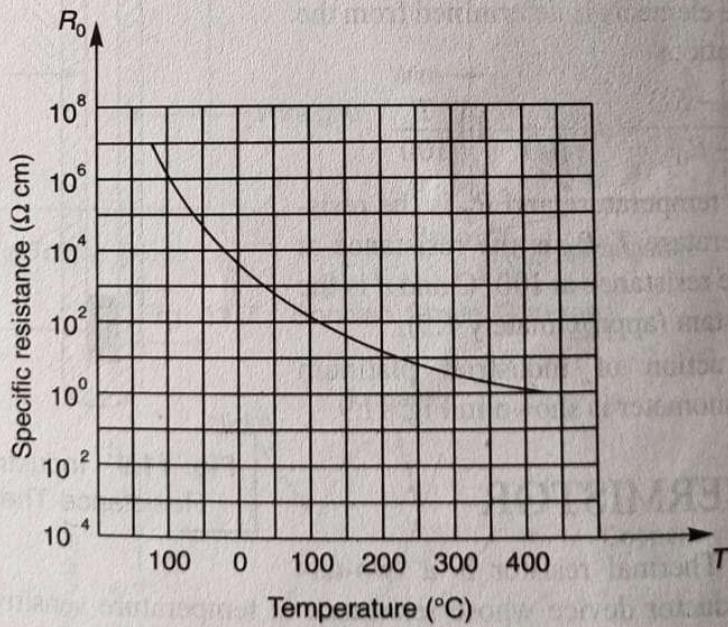
At high temperatures, this equation reduces to

$$R_T = R_0 \exp\left(\frac{\beta}{T}\right)$$

The resistance-temperature characteristic is shown in Fig. 11.10. The curve is non-linear and the drop in resistance from 5000 to 10  $\Omega$  occurs for an increase in temperature from 20 to 100  $^{\circ}\text{C}$ . The temperature of the device can be changed internally or externally. An increase in current through the device will raise its temperature carrying a drop in its terminal resistance. Any externally applied heat source will result in an increase in its body temperature and drop in resistance. This type of action (internal or external) lends itself well to control mechanisms.



(a) Symbol



(b) Characteristics

Fig. 11.10 Symbol and Resistance-temperature Characteristics of Thermistor

### 23) Explain Geiger Muller Tubes, Hall effect

- A. A Geiger counter consists of Geiger-Müller tube, the sensing element which detects radiation. Geiger-Müller tube is filled with an inert gas such as helium, neon or argon at low pressure to which high voltage is applied.

Tube briefly conducts electrical charge when a particle or photon of incident radiation makes the gas conductive by ionization.

## 11.10 HALL EFFECT

When a transverse magnetic field  $B$  is applied to a metal or a semiconductor carrying a current  $I$ , an electric field  $E$  is induced in the direction perpendicular to both  $I$  and  $B$ . This phenomenon is known as the *Hall effect*.

The Hall effect is used to find whether a semiconductor is N or P type and to determine the carrier concentration. The mobility  $\mu$  can also be calculated with simultaneous measurement of the conductivity  $\sigma$ .

### 24) with a neat diagram explain the operation of antenna.

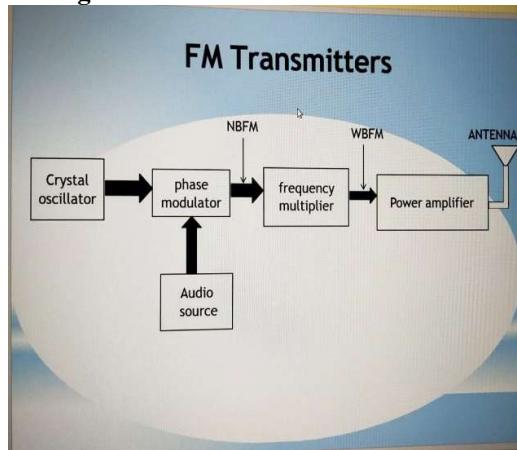
- An antenna is an electrical device which converts electric energy into radio waves, and vice versa. It is usually used with a radio transmitter or radio receiver.
- An antenna is a device for sending or receiving electromagnetic waves.  
Transmitter antenna:-
- A device that converts sound, light, or electrical signals into radio, microwave, or other electrical signals .  
Receiver antenna:-
- An antenna used to convert electromagnetic waves into electrical energy.

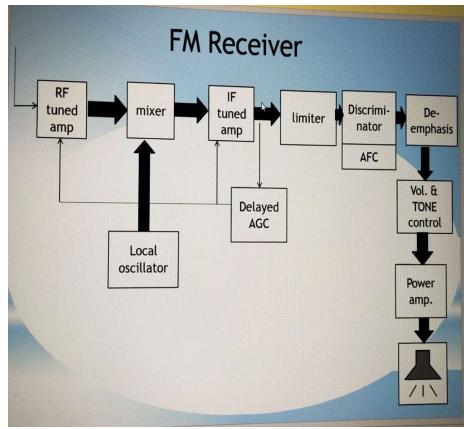


### 25) Explain in a detailed way about transmitter and receiver with a block diagram

The transmitters are those devices which is used to send frequency modulated wave through a band and  
the receivers are the devices which received modulated signal then after demodulation it gives us the original signal.

The FM transmitters and receivers are those devices which is used for sending and receiving FM signal.





Register No.													
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**SRM INSTITUTE OF SCIENCE AND TECHNOLOGY  
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING  
CYCLE TEST – II**

**Program offered/Year/Sem:** B.Tech/I/I

**Date of Exam:** 20.09.2018

**Time:** 100 Minutes

**Max. Marks:** 50

**Part A (5x2=10) Answer All Questions**

**1. What do you mean by fringing effect in magnetic circuit?**

**2 marks**

An air gap is often introduced in the magnetic circuit out of necessity. When crossing an air gap, the magnetic lines of force have a tendency to bulge out. This is because the magnetic lines of force repel each other when they are passing through non-magnetic material. This phenomenon is known as fringing.

**2. Mention any four applications of DC generator.**

DC shunt wound generators are used for lighting purposes.

Used to charge the battery.

Providing excitation to the alternators.

DC series generator is used as a booster in distribution networks.

Over compounded cumulative generators are used in lighting and heavy power supply.

Flat compounded generators are used in offices, hotels, homes, schools, etc.

Differentially compounded generators are mainly used for arc welding purpose.

**3. List out the objectives of earthing.**

Providing path for leakage current (or) Safely discharge the leakage current/fault current

Protecting the equipment/human.

**4. How do we classify measuring instruments?**

Indicating instruments

Integrating instruments

Recording instruments

**5. What is Clamper? Give its applications.**

Shifting the input waveform.

**Applications:** (Any two)

Identify the polarity of the input

Used in testing equipment's, RADARS and SONAR

**Part B (4 x 4 Marks = 16 marks) Answer All Questions**

**6. Discuss the role of starters in a DC motor.**

**2 marks**

The starter protects the armature of dc motor from getting damaged. The electromotive force (emf) induced in the armature winding during starting builds up from zero value to max value to restrict the armature current within the permissible value at full speed.

When a dc motor is at rest the speed of the motor is zero, therefore the back emf is zero.

We know that Back Emf,  $E_b = V - I_a R_a$

Therefore,  $I_a = (V - E_b)/R_a$

Since, the Armature resistance  $R_a$  is very small.

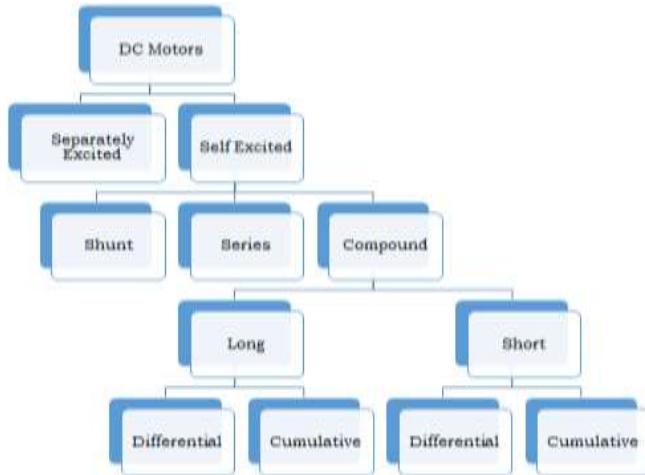
Therefore when the motor is directly connected to the supply lines a heavy current will flow through the armature conductors. This heavy current is very dangerous.

When running back emf oppose the applied voltage and thus a small current flows.

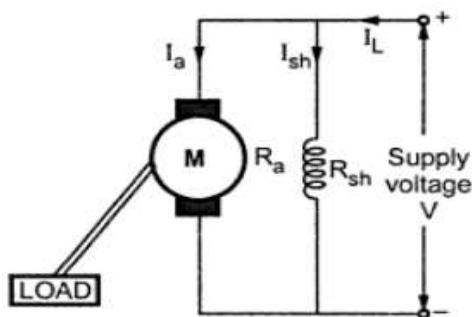
Hence for the protection of the motor from high current during starting period (say 5 to 10 seconds), it is necessary to connect a high resistance in series with the armature of motor at the starting period. The resistance should gradually cut in steps as the motor gains speed and develop back emf.

7. Classify the DC motor and sketch the equivalent electrical circuit of DC shunt and series motor.

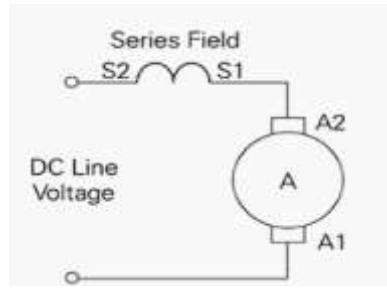
#### **DC motor Classification:**



#### **DC Shunt Motor:**



#### **DC Series Motor:**

**8. Explain the different forces/torques involved in measuring instruments.**

The moving system is subjected to the following three torques:

- i. Deflecting ( or operating) torque;
- ii. Controlling ( or Opposing) torque;
- iii. Damping torque.

Deflecting torque

The deflecting torque is produced by making one of the magnetic, heating, chemical, electrostatic and electromagnetic induction effect of current or voltage and cause the moving system of the instrument to move from its zero position. The method of producing this torque depends upon the type of instrument. This torque is always opposing the deflection torque.

Components of opposing torque is Inertia torque : due to inactive of moving system; the pointer return back to rest.

Control Torque: this torque always present; this torque increase with deflection of moving system; it oppose the operating torque.

Spring Control

Gravity control

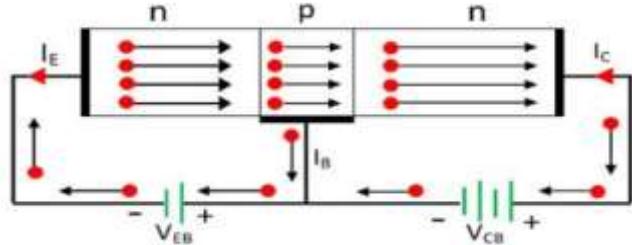
Damping torque – It ensure the deflection reach the final position within the time.

Air friction damping

Eddy Current damping

**9. Illustrate the operation of a NPN transistor with a neat diagram.**

The circuit diagram of the NPN transistor is shown in the figure below. The forward biased is applied across the emitter-base junction, and the reversed biased is applied across the collector-base junction. The forward biased voltage V<sub>EB</sub> is small as compared to the reverse bias voltage V<sub>CB</sub>.



The emitter of the NPN transistor is heavily doped. When the forward bias is applied across the emitter, the majority charge carriers move towards the base. This causes the emitter current  $I_E$ . The electrons enter into the P-type material and combine with the holes.

The base of the NPN transistor is lightly doped. Due to which only a few electrons are combined and remaining constitutes the base current  $I_B$ . This base current enters into the collector region. The reversed bias potential of the collector region applies the high attractive force on the electrons reaching collector junction. Thus attract or collect the electrons at the collector.

The whole of the emitter current is entered into the base. Thus, we can say that the emitter current is the sum of the collector or the base current.

### **Part C (12 x 2 Marks = 24 marks)**

10. a) Two coils A and B are in parallel planes. Coil A has 1500 turns and coil B has 12000 turns in which the Coil A produces 55% of flux that links with coil B. A current of 6 A in coil A produces flux of 0.05 mWb in it, while 6 A current in coil B produces 0.08 mWb flux in it. Calculate the mutual inductance, co-efficient of coupling and reluctance of coils A and B.

**Solution**

**(Each 3 Marks)**

$$L_A = 0.05e^{-3} \times 1500 / 6 = 0.0125 \text{ H}$$

$$L_B = 0.08e^{-3} \times 12000 / 6 = 0.16 \text{ H}$$

$$M = 0.55 \times 0.05e^{-3} \times 12000 / 6 = 0.055 \text{ H}$$

$$K = 0.055 / \sqrt{(0.0125 \times 0.16)} = 1.2298$$

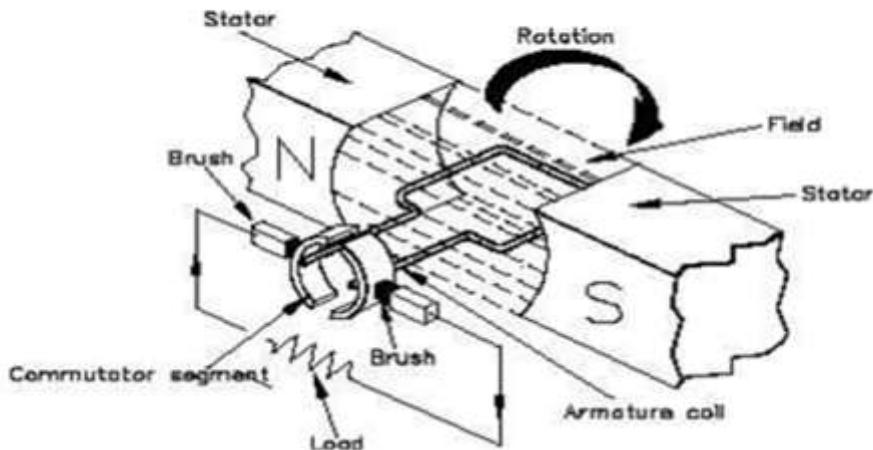
**(OR)**

10. b) Discuss the construction, operating principle of DC generator with neat diagram.

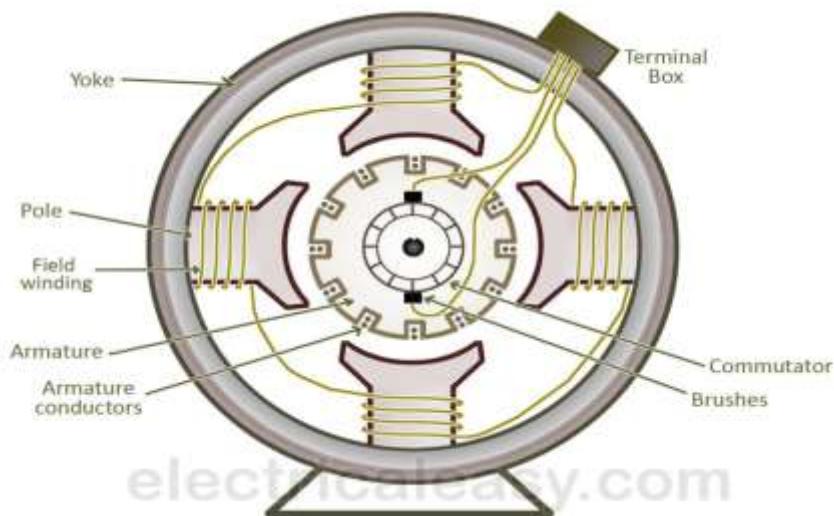
**Neat Diagram + Working principle & Explanation (3+2+7=12M)**

The dc generator is rotating electrical machine which converts mechanical energy into electrical energy. The generator is usually driven by a steam turbine or water turbine which is called as prime mover.

The dc generator operates on the principle based on the Faraday's Law of electromagnetic induction. The generator should have (i) magnetic field (ii) conductors capable of carrying current (iii) movement of conductors in the magnetic field. Necessary magnetic field is produced by field coil. The set of conductors is called the armature.

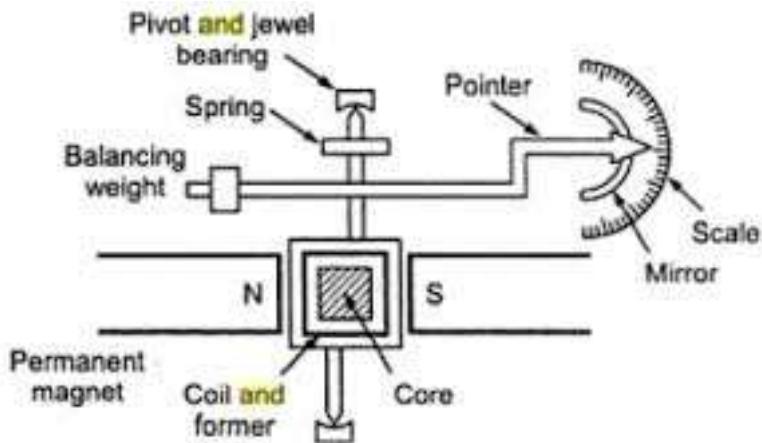


#### Construction:



11. a) Describe the construction, working principle of moving coil instrument with neat sketches.

Neat Diagram + Working principle & Explanation (3+2+7=12M)



### **Working principle**

When a current carrying conductor is placed in a magnetic field, it experiences a force and tends to move in the direction as per Fleming's left hand rule.

Stationary part or magnet system:

made up of materials like alcomax and alnico which provide high field strength

### **Moving coil:**

The moving coil can freely moves between the two permanent magnets.

The coil is wound with many turns of copper wire and is placed on rectangular aluminium which is pivoted on jewelled bearings.

### **Control system**

The spring generally acts as control system for PMMC instruments.

The spring also serves another important function by providing the path to lead current in and out of the coil.

### **Damping system**

The damping force hence torque is provided by movement of aluminium former in the magnetic field created by the permanent magnets.

### **Meter**

Meter of these instruments consists of light weight pointer to have free movement and scale which is linear or uniform and varies with angle.

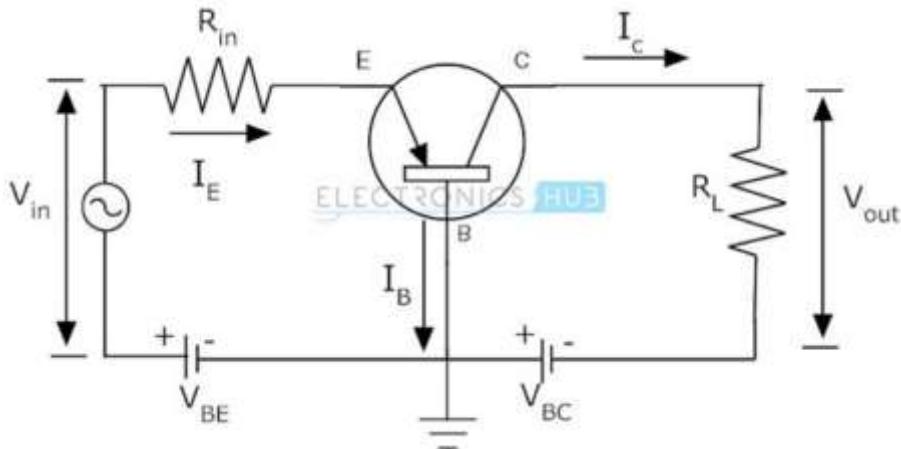
**(OR)**

11. b) Draw and explain the circuit diagram to determine the operating characteristics of CB configuration of BJT.

**Neat Diagram + Explanation**

**(6+6=12M)**

### Common Base Configuration :



### Input characteristics

The input characteristics describe the relationship between input current ( $I_E$ ) and the input voltage ( $V_{BE}$ ).

First, draw a vertical line and horizontal line. The vertical line represents y-axis and horizontal line represents x-axis. The input current or emitter current ( $I_E$ ) is taken along the y-axis (vertical line) and the input voltage ( $V_{BE}$ ) is taken along the x-axis (horizontal line).

To determine the input characteristics, the output voltage  $V_{CB}$  (collector-base voltage) is kept constant at zero volts and the input voltage  $V_{BE}$  is increased from zero volts to different voltage levels. For each voltage level of the input voltage ( $V_{BE}$ ), the input current ( $I_E$ ) is recorded on a paper or in any other form.

A curve is then drawn between input current  $I_E$  and input voltage  $V_{BE}$  at constant output voltage  $V_{CB}$  (0 volts).

### Output characteristics

The output characteristics describe the relationship between output current ( $I_C$ ) and the output voltage ( $V_{CB}$ ).

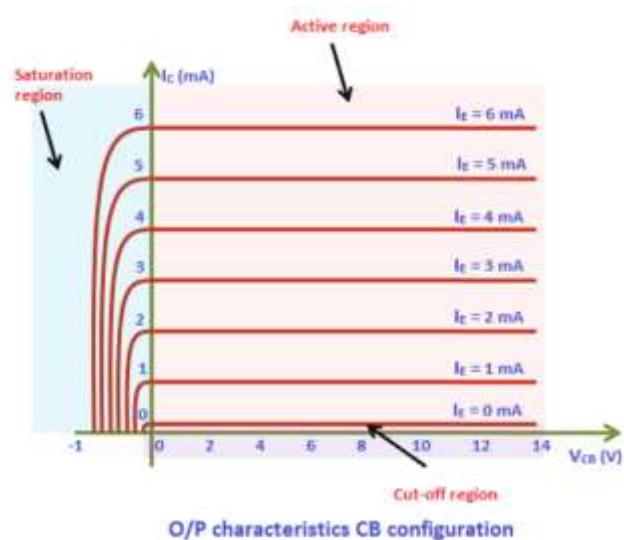
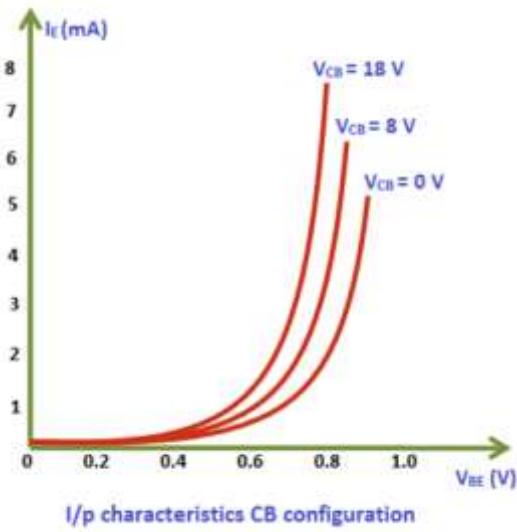
First, draw a vertical line and a horizontal line. The vertical line represents y-axis and horizontal line represents x-axis. The output current or collector current ( $I_C$ ) is taken along the y-axis (vertical line) and the output voltage ( $V_{CB}$ ) is taken along the x-axis (horizontal line).

To determine the output characteristics, the input current or emitter current  $I_E$  is kept constant at zero mA and the output voltage  $V_{CB}$  is increased from zero volts to different voltage levels. For each voltage level of the output voltage  $V_{CB}$ , the output current ( $I_C$ ) is recorded.

## **SET A- Answer key**

A curve is then drawn between output current  $I_C$  and output voltage  $V_{CB}$  at constant input current  $I_E$  (0 mA).

When the emitter current or input current  $I_E$  is equal to 0 mA, the transistor operates in the cut-off region.



Register No.

**SRM INSTITUTE OF SCIENCE AND TECHNOLOGY  
DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING  
CYCLE TEST – II**

**Program offered/Year/Sem: B.Tech/I/I****Date of Exam: 20.09.2018****Time: 100 Minutes****Max. Marks: 50****Part A (5x2=10) Answer All Questions**

- 1. Define the leakage co-efficient of flux..**

**2 marks**

The flux which do not follow the desired path in a magnetic circuit is known as leakage flux.

$$\text{Leakage coefficient, } \lambda = \frac{\text{total flux}}{\text{useful flux}} = \frac{\text{useful flux} + \text{leakage flux}}{\text{useful flux}} = \frac{\phi + \phi_l}{\phi}$$

- 2. What are the characteristics of ideal transformer?**

Zero winding resistance

Infinite permeability of the core

No leakage flux

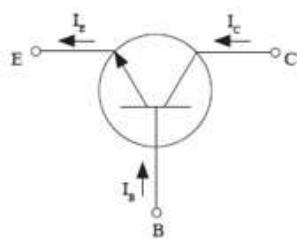
100% efficiency

- 3. Why the single phase induction motor is not self-starting?**

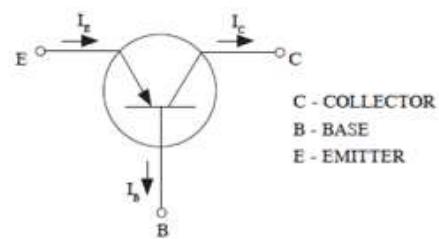
Single phase induction motor has distributed stator winding and a squirrel-cage rotor. When fed from a single-phase supply, its stator winding produces a flux ( or field ) which is only alternating i.e. one which alternates along one space axis only. It is not a synchronously revolving ( or rotating ) flux as in the case of a two or a three phase stator winding fed from a 2 of 3 phase supply. Now, an alternating or pulsating flux acting on a stationary squirrel-cage rotor cannot produce rotation (only a revolving flux can produce rotation). That is why a **single phase motor is not self-starting.**

**2 marks**

- 4. Draw the symbol of NPN and PNP transistor.**



(iii) Symbol of npn transistor



(iv) Symbol of pnp transistor

- 5. What is Clipper? Mention any two applications.**

**2 marks**

A clipper is a type of diode network that has the ability to “clip off” a portion of the input signal without distorting the remaining part of the alternating waveform.

- Speech processing
- Analogue video processing

**Part B (4 x 4 Marks = 16 marks) Answer All Questions**

- 6. Explain the Faraday's laws of electromagnetic Induction? Also derive the self-inductance.**

2 marks

**First Law:** Whenever the flux linking with a coil changes, a static emf is induced in it and as such the emf lasts only for the time the change is taking place. **OR**

When a moving conductor cuts the magnetic field, an emf induced in it which is called as dynamic emf.

**Second Law:** The magnitude of the induced emf is equal to the rate of change of flux linkage. Flux linkage = Flux x Number of turns having units as Wb. turns.

**Self-inductance, L:** Self-inductance of a coil, L is the rate of change of flux linkages with respect to the current in it. Its unit is Henry.

2 marks

$$L = \frac{d\psi}{dT} = N \frac{d\phi}{dT} \text{ Henry}$$

With usual notations

$$\text{Magnetizing force, } H = \frac{NI}{l} \text{ AT/m}$$

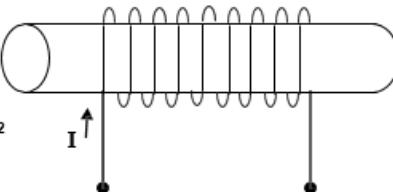
$$\text{Flux density, } B = \mu_0 \mu_r H = \mu_0 \mu_r \left( \frac{NI}{l} \right) \text{ Wb./m}^2$$

$$\text{Magnetic flux, } \phi = \mu_0 \mu_r \left( \frac{NI}{l} \right) a \text{ Wb.}$$

$$\text{Flux linkage} = N \phi = \mu_0 \mu_r \left( \frac{N^2 I}{l} \right) a \text{ Wb. Turns}$$

$$\begin{aligned} \text{Self inductance, } L &= N \frac{d\phi}{dT} = N \frac{\phi}{I} = \frac{\mu_0 \mu_r N^2 a}{l} = \frac{N^2}{(l/a \mu_0 \mu_r)} \\ &= \frac{N^2}{\text{Reluctance}} \end{aligned}$$

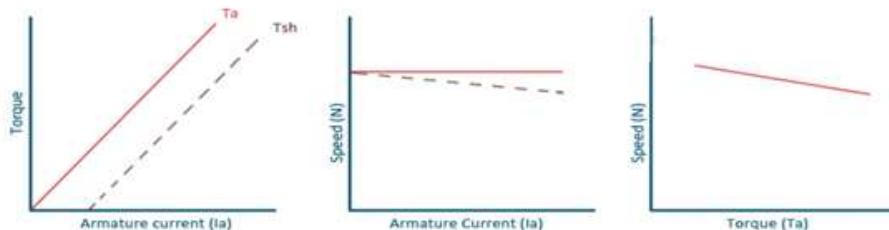
$$\text{Thus self inductance } L = \frac{d\psi}{dT} = N \frac{d\phi}{dT} = \frac{N^2}{\text{Reluctance}}$$



- 7. Discuss the different characteristics of DC shunt motor.**

2 marks

- (i) Torque Vs. Armature Current ( $T_a$ - $I_a$ )  $T_a \propto \phi \cdot I_a$
- (ii) Speed Vs. Armature Current ( $N$ - $I_a$ )  $N \propto E_b/\phi$ ;  $E_b = V - I_a R_a$
- (iii) Speed Vs. Torque ( $N$ - $T_a$ )



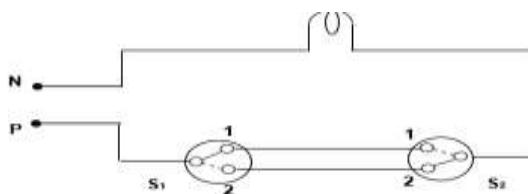
**2 marks**

- 8.** Draw the wiring diagram of the following and explain their working: (i) staircase wiring (ii) corridor wiring.

### Staircase Wiring

**2 marks**

In staircase wiring a single lamp, placed at the middle of the staircase, is controlled by switches at two places, one at the beginning of the staircase and the other at the end of the staircase. For this purpose two-way switches are required. The wiring circuit is shown below.

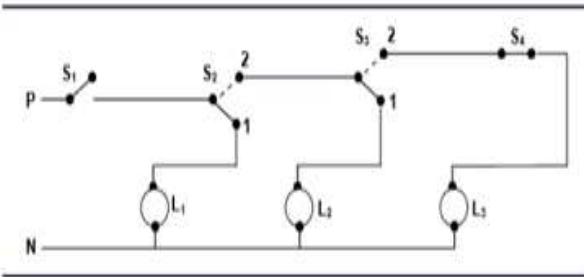


Position of switch $S_1$	Position of switch $S_2$	Condition of lamp
1	1	ON
2	1	OFF
2	2	ON

**2 marks**

### Corridor Wiring

The diagram for corridor wiring is shown below.



### Moving from left to right:

- Enters Closes  $S_1$   $L_1$  ON
- Reaches  $S_2$  Put  $S_2$  to 2  $L_1$  OFF and  $L_2$  ON
- Reaches  $S_3$  Put  $S_3$  to 2  $L_2$  OFF and  $L_3$  ON
- Reaches  $S_4$  Opens  $S_4$   $L_3$  OFF

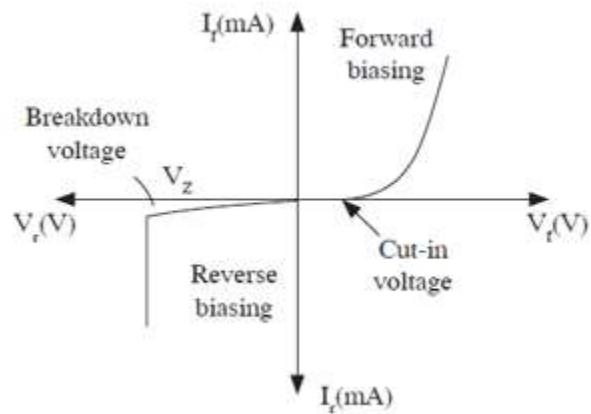
### Moving from right to left:

- Enters Closes  $S_4$   $L_3$  ON
- Reaches  $S_3$  Put  $S_3$  to 1  $L_2$  ON and  $L_3$  OFF
- Reaches  $S_2$  Put  $S_2$  to 1  $L_1$  ON and  $L_2$  OFF
- Leaves Opens  $S_1$   $L_1$  OFF

**2 marks**

- 9.** Explain the operation of Zener diode under forward, reverse bias condition and sketch the V-I characteristics.

The above diagram shows the V-I characteristics of the Zener diode behavior. When the diode is connected in forward bias it acts as a normal diode. When the reverse bias voltage is greater than a predetermined voltage then the Zener breakdown voltage occurs. To get breakdown voltage sharp and distinct doping is controlled and the surface imperfections are avoided. In the V-I characteristics above  $V_z$  is the Zener voltage. And also the knee voltage because at this point the current is very rapid.



2 marks

**Part C (12 x 2 Marks = 24 marks)**

10. a) The number of turns in a coil is 500. When a current of 5 A flows in the coil, the flux in the coil is 0.3 mWb. When this current is reduced to zero in 5 milliseconds, the voltage induced in a coil lying in the vicinity of coil is 225 volts. Find the self-inductance of first and second coil and number of turns in the second coil.

10 a)

$$N_1 = 500$$

$$dI = 5A$$

$$I_1 = 5A$$

$$dt = 5 \text{ msec}$$

$$\phi_1 = 0.3 \text{ mWb.}$$

$$\cancel{M=2} \quad k=0.75$$

$$e_2 = 225V$$

$$L_1 = N_1 \frac{d\phi_1}{dt} = 500 \times \frac{0.3 \times 10^{-3}}{5} = 0.03 \text{ H} \quad \text{--- 3 marks}$$

$$e_2 = M \frac{dI_1}{dt} = M \times \frac{5}{5 \times 10^{-3}} = 225$$

$$M = 225 \text{ mH}$$

--- 3 marks

$$M = k \sqrt{L_1 L_2}$$

$$(225 \times 10^{-3})^2 = 0.75 \sqrt{0.03 \times L_2}$$

$$L_2 = 3 \text{ H.}$$

--- 3 marks

$$K = \frac{\phi_2}{\phi_1} \Rightarrow \phi_2 = K \phi_1 = 0.75 \times 0.3 \times 10^{-3} = 0.225 \times 10^{-3}$$

$$e_2 = N_2 \cdot \frac{d\phi_2}{dt} = N_2 \times \frac{0.225 \times 10^{-3}}{5 \times 10^{-3}}$$

$$225 = N_2 \times \frac{0.225}{5}$$

$$N_2 = 5000.$$

--- 3 marks

(OR)

**10. Explain the construction and working principle of single phase transformer.**

4 marks

**CONSTRUCTION**

A Transformer is a static piece of apparatus by means of which electric power in one circuit is transformed into electric power of same frequency in another circuit. Used to change high voltage low current A.C. into low voltage high current A.C. and vice-versa without changing the frequency. Two coils of wire (called windings) are wound on some type of core material. In some cases the coils of wire are wound on a cylindrical or rectangular cardboard form. In effect, the core material is air and the transformer is called an AIR-CORE TRANSFORMER. Transformers used at low frequencies, such as 60 hertz and 400 hertz, require a core of low-reluctance magnetic material, usually iron. This type of transformer is called an IRON-CORE TRANSFORMER. Most power transformers are of the iron-core type.

6 marks

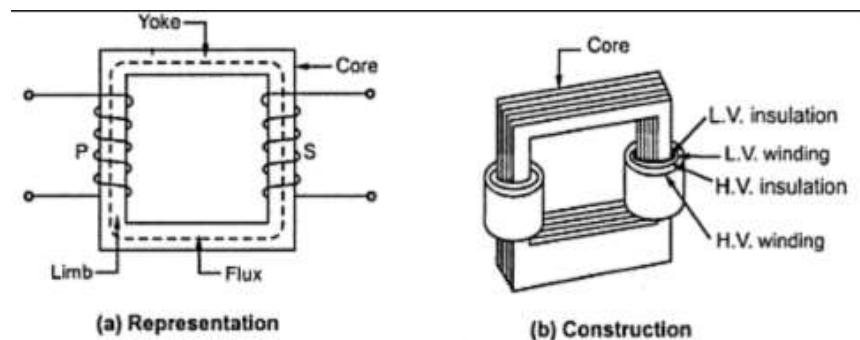
2 marks

2 marks

- **CORE TYPE TRANSFORMER**

2 marks

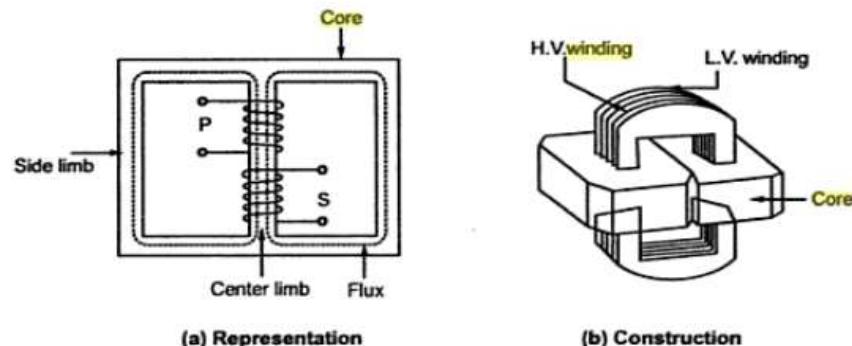
2 marks



(a) Representation

(b) Construction

- **SHELL TYPE TRANSFORMER**



(a) Representation

(b) Construction

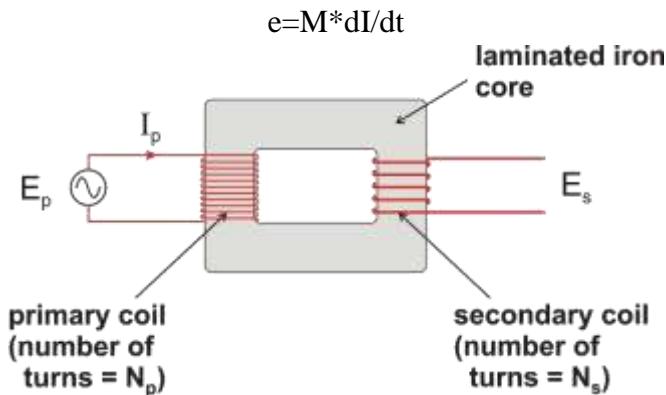
**BASIC WORKING PRINCIPLE OF TRANSFORMER**

6 marks

A transformer can be defined as a static device which helps in the transformation of

electric power in one circuit to electric power of the same frequency in another circuit. The voltage can be raised or lowered in a circuit, but with a proportional increase or decrease in the current ratings.

The main principle of operation of a transformer is mutual inductance between two circuits which is linked by a common magnetic flux. A basic transformer consists of two coils that are electrically separate and inductive, but are magnetically linked through a path of reluctance. The working principle of the transformer can be understood from the figure below.



- 11. What is the necessity of earthing in domestic wiring? Discuss in brief the various methods of earthing with neat sketches.**

**4 marks**

#### Necessity of Earthing

Earthing provides safe discharge of electric current due to leakages and faults to ground. All metallic parts of electrical appliances shall be connected by earth wire made of very good conductor and finally the earth wire is connected to ground. Earthing can be done through G.I. pipe or G.I. plate buried in the ground and surrounded by charcoal and common salt to provide good conductivity. To ensure safety earth resistance should be checked now and then and it is kept at a very low value.

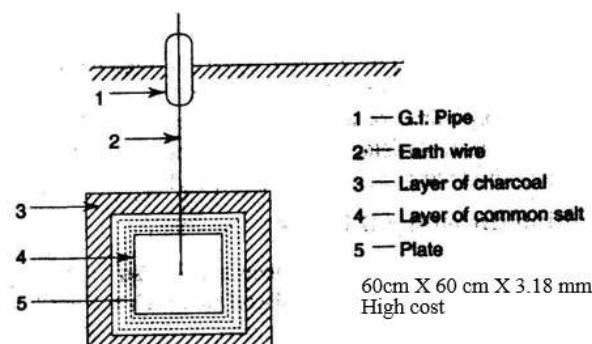
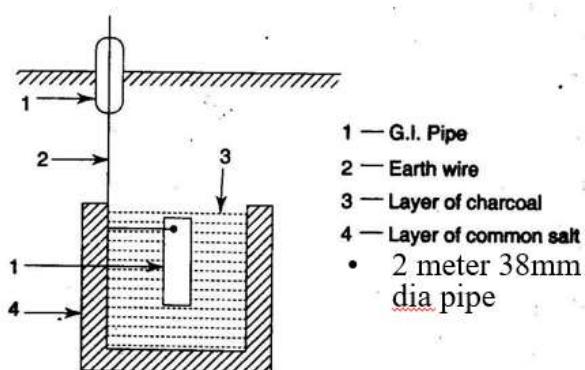
#### Types

##### Earthing through a G.I pipe

(4 marks)

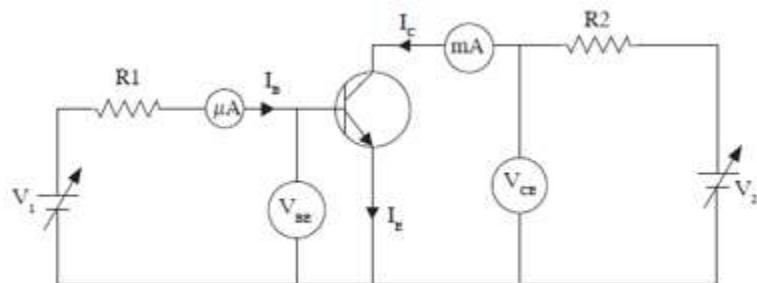
##### Earthing through a plate

4 marks

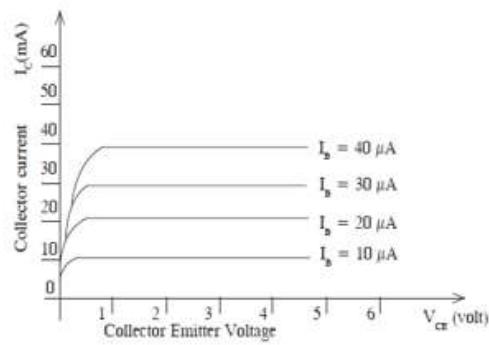
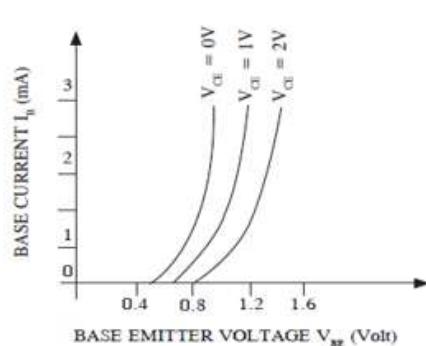


**(OR)**

**11. Draw and explain the circuit diagram to determine the input and output characteristics of CE configuration of BJT.**



**3 diagram+3 Explanation**



**3+3=6**

## UNIT 4

1) What is transducer ? Write one example of active & passive transducer

A) A. Transducer is a device which converts physical measurement to electrical output and vice versa.

Active: thermocouple

Passive: LVDT

2) Define Primary & secondary transducer & give one example of each.

A) Primary: the transducer change the physical input quantities into a mechanical signal.

ex: Bourdon's Tube

secondary : The secondary transducer converts the mechanical signal into an electrical signal. The magnitude of the output signal depends on the input mechanical signal.

ex: LVDT.

3) Classify each of the following transducers in two different categories:

i) LVDT ii) Strain Gauge

4) Write the Advantages & Disadvantages of L.V.D.T

A) advantages:

- low hysteresis
- simple to use
- high range 1.25mm to 250mm
- light in weight
- low power consumption

**Disadvantages:**

- It is sensitive to stray magnetic field but shielding is possible.
- temperature affects the performance of the transducer.

5) What is piezoelectric effect? Name two piezoelectric materials.

A) Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress.

example: quartz, topaz.

6) Write the parameter measured by:

- i) LVDT: displacement, voltage
- ii) Piezoelectric Transducer: pressure, acceleration, strain displacement etc
- iii) Linear & angular Potentiometer : linear and angular displacement
- v) Diaphragm:

7) Explain the construction & working of LVDT.

A) cons:

- one primary coil and 2 secondary coil
- ferro-magnetic core in form of rod or cylindrical
- primary coil is attached to ac excitation

working:

- displacement of core causes voltage in one secondary winding and increases while voltage in other secondary coil decreases

- difference of two voltages appears across the output terminals of the transducers and gives a measure of the physical position of the core and hence the displacement.
- when the core is in centre the total voltage is zero
- By comparing the magnitude and phase of output with input source, the amount and direction of movement of core and hence displacement may be determined

8) Explain the construction & working of piezoelectric type transducer

A) Cons:

**piezoelectric** material, usual quartz, is coated with a thin layer of conducting material such as silver

working: When stress has applied the ions in the material move towards one of the conducting surface while moving away from the other. This results in the generation of charge. This charge is used for calibration of stress. The polarity of the produced charge depends upon the direction of the applied stress. Stress can be applied in two forms as **Compressive stress** and **Tensile stress**

9) Explain the construction & working of capacitive transducer

A) cons: A capacitor consists of two conductors (plates) that are electrically isolated from one another by a dielectric medium.

working:

As the pressure is applied to the diaphragm it bulges in and the distance between the two parallel plates decreases as a result it acts as variable capacitance and it derives a response which can be further converted to different types of outputs using different systems using different types of instruments

10) Differentiate between passive and active transducers. Give an example of each

A)

Active Transducer	Passive Transducer
The active transducer is also called as self generating type transducer.	The passive transducer is also called as externally powered transducer.
The active transducer does not require any auxiliary (external) power supply.	The passive transducer requires auxiliary (external) power supply for transduction.
The signal conversion is simpler.	The signal conversion is more complicated.
The energy required to produce output is obtained from the physical quantity.	They also derive part of the power required for conversion from physical quantity under measurement.

ex: thermocouple

ex: LVDT

11) Compare and explain static and dynamic characteristics of transducers.

A) static characteristics relate to the performance of a transducer when the measured quantity is essentially constant, the dynamic characteristics relate to dynamic inputs, which means that they are dependent on its own parameters as well as the nature of the input signal.

12) Explain the classification of transducers.

A)

1. As active and passive transducer
2. According to transduction principle
3. As analog and digital transducer
4. As primary and secondary transducer
5. As forward transducer and inverse transducer

Mechanical Transducers are those which responds to changes in physical quantities or condition with mechanical quantity. If the physical quantity is converted to an electrical quantity, then the transducers are Electrical Transducers.

13) Compare capacitive and inductive transducers

A) Inductive sensors use a magnetic field to detect objects.

works on principle of electromagnetic induction

Capacitive sensors use an electric field. equation for capacitance of a parallel plate capacitor

$$c = \epsilon a/d$$

14) Elaborate the applications of inductive transducers.

A) Magnetic circuit transducer: Self inductance or mutual inductance of ac-excited coil is varied by changes in the magnetic circuit.

Applications: Pressure, displacement.

Reluctance pickup: Reluctance of the magnetic circuit is varied by changing the position of the iron core of a coil.

Applications: Pressure, displacement, vibration, position.

Differential transformer: The differential voltage of two secondary windings of a transformer is varied by positioning the magnetic core through an externally applied force.

Applications: Pressure, force, displacement, position.

Eddy current gage: Inductance of a coil is varied by the proximity of an eddy current plate.

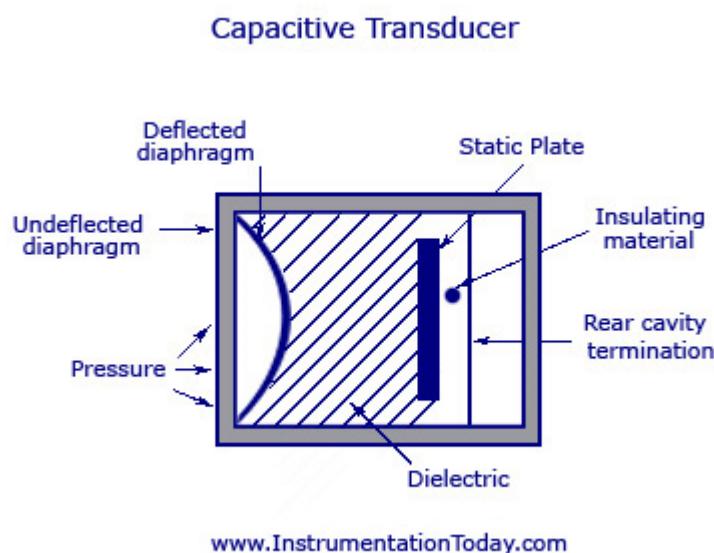
Applications: Displacement, thickness.

Magnetostriction gauge: Magnetic properties are varied by pressure and stress.

Applications: Force, pressure, sound.

15) Explain the working of capacitive transducer with neat schematic.

A) WORKING:



As the pressure is applied to the diaphragm it bulges in and the distance between the two parallel plates decreases as a result it acts as variable capacitance and it derives a response which can be further converted to different types of outputs using different systems using different types of instruments.

16) Define Piezoelectric principle and explain the working of piezoelectric transducer.

A) Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress.

working: When stress has applied the ions in the material move towards one of the conducting surface while moving away from the other. This results in the generation of charge. This charge is used for calibration of stress. The polarity of the produced charge depends upon the direction of the applied stress. Stress can be applied in two forms as **Compressive stress** and **Tensile stress**

17) What is the principle of Piezoelectric transducer?

A) Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress.

18) With a neat schematic explain the working of the following

- (i) Mic: converts sound into small electric current.
- (ii) Speaker
- (iii) Sonar
- (iv) Ultrasonic

19) Explain the working of LED

A) Each time an electron recombines with a positive charge, electric potential energy is converted into electromagnetic energy. • For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material.

20) Differentiate LED and LCD

A) **LED uses the PN-Junction** diode which **emits light** when the **current passing** through it, whereas **LCD uses liquid crystal or plasma** for visible **light emission**.

LED has high resolution LCD has low resolution.

21) What is Thermocouple?

A) When a pair of wires made of different metals are joined together at one end, temperature difference between this end and the other end of the wires produces a voltage between the wires

22) Explain with a neat schematic about Thermistor.



A) *I symbol for a thi*

23) Explain Geiger Muller Tubes, Hall effect

A) Geiger Muller Tubes: detects ionizing radiation used in detection of x-rays

Hall effect: The **Hall effect** is when a magnetic field is applied at right angles to the current flow in a thin film where an electric field is generated, which is mutually perpendicular to the current and the magnetic field and which is directly proportional to the product of the current density and the magnetic induction.

24) with a neat diagram explain the operation of antenna.

25) Explain in a detailed way about transmitter and receiver with a block diagram

## Unit 5

### Digital systems

**1. Define Minterm and Maxterm.**

A) the product term containing all inputs of the function either complemented or uncomplemented form are called minterms.

the sum term containing all inputs of function in either complemented or uncomplemented form are called maxterms

**2. Give the limitations of K-Map.**

A)

- It is not suitable for computer reduction.
- It is not suitable when the number of variables involved exceed four.
- Care must be taken to field in every cell with the relevant entry, such as a 0, 1 (or) don't care terms.

**3. Obtain the canonical SOP form of the function  $Y(A, B, C, D)=AB+ACD$ .**

**4. Simplify the boolean expression using K-Map  $F=AB'C+A'B'C+A'BC+AB'C'+A'B'C'$ .**

**5. Simplify  $(A+B)(A'C'+C)(B'+AC)'$  using Boolean expression**

**6.** Simplify using K-Map  $F(A,B,C) = \Sigma m(0,2,3,6,7)$

**7.** Simplify using K-Map  $F(A,B,C,D) = \Sigma m(0,2,3,6,7) + d(8,10,11,15)$

**8.**  $F(w, x, y, z) = \sum m(0, 7, 8, 9, 10, 12) + \sum d(2, 5, 13)$

**9.** Simplify  $F = (xy + y'z + xz)x$  using Boolean expression.

**10** Convert  $(143)_{10}$  to binary form.

**11.** Convert  $(EC8)_{16}$  to binary form.

**12.** Convert  $(220)_{10}$  to hexadecimal form.

**13.** What is the necessity of modulation?

**14.** Define amplitude modulation and draw its waveform.

**15** Define frequency modulation and draw its waveform

## **UNIT IV TRANSDUCER SHORT QUESTION AND ANSWERS**

### **1) What is instrument?**

It is a device for determining the value or magnitude of a quantity or variable.

### **2) Add $826 \pm 5$ to $628 \pm 3$ .**

$$N1 = 826 \pm 5 (\pm 0.605\%)$$

$$N2 = 628 \pm 3 (\pm 0.477\%)$$

$$\text{Sum} = 1,454 \pm 8 (\pm 0.55\%)$$

### **3) Subtract $628 \pm 3$ from $826 \pm 5$ .**

$$N1 = 826 \pm 5 (\pm 0.605\%) N2 = 628 \pm 3 (\pm 0.477\%)$$

$$\text{Difference} = 198 \pm 8 (\pm 4.04\%)$$

### **4) List three sources of possible errors in instruments.**

1. Gross Error
2. Systematic
3. Random errors.

### **5) Define Instrumental error.**

These are the errors inherent in measuring instrument because of their mechanical structure.

### **6) Define limiting error.**

Components are guaranteed to be within a certain percentage of rated value.

Thus the manufacturer has to specify the deviations from the nominal value of a particular quantity.

### **7) Define probable error.**

It is defined as  $r = \pm 0.6745s$  where  $s$  is standard deviation. Probable error has been used in experimental work to some extent in past, but standard deviation is more convenient in statistical work.

### **8) Define Environmental error**

These are due to conditions in the measuring device, including conditions in the area surrounding the instrument, such as the effects of changes in temperature, humidity.

### **9) Define arithmetic mean.**

The best approximation method will be made when the number of readings would give the best result.

### **10) Define average deviation.**

By definition, average deviation is the sum of absolute values of the value deviations divided by the number of reading.

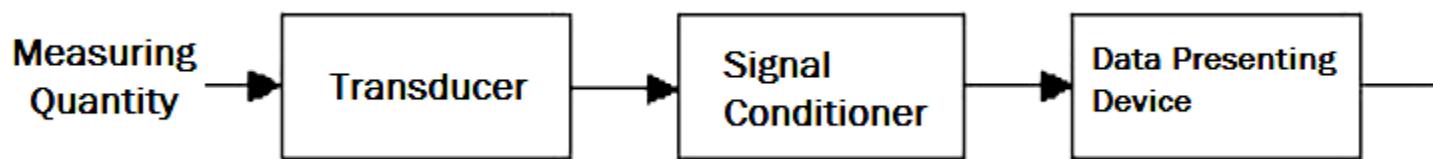
**11) Define units.**

It is necessary to define a physical quantity both in kind and magnitude in order to use this information for further proceedings. The standard measure of each kind of physical quantity is named as the unit.

**12) Define Standards**

The physical embodiment of a unit of measurement is a standard.

For example, the fundamental unit of mass in the international system is the kilogram and defined as the mass of a cubic decimeter of water at its temperature of maximum density of 4°C.

**13) Draw the functional block diagram of a measurement system.****14) Mention the purpose of the measurement.**

- To understand an event or an operation.
- To monitor an event or an operation.
- To control an event or an operation.
- To collect data for future analysis
- To validate an engineer design.

**15) What are the methods of measurement?**

- Direct comparison method
- Indirect comparison method

**16) Define ODDs**

The specification of limiting error is in itself uncertain because the manufacturer himself is not sure about the accuracy because of the presence of random errors.

**17) Classify Standards.**

- International standards
- Primary standards
- Secondary standards
- Working standards

**18) Define transducer and give an example.**

[Transducer](#) is a device which converts one form of energy into electrical energy.

A thermocouple converts heat energy into electrical voltage.

### **19) Classify transducer.**

On the basis of transduction form used:

- As primary and secondary transducers
- As active and passive transducers
- As analog and digital transducers
- As transducers and inverse transducers

### **20) What is primary transducer?**

Bourdon tube acting as a primary transducer senses the pressure and converts the pressure into displacement.

No output is given to the input of the [bourdon tube](#). So it is called primary transducer. Mechanical device can act as a primary transducer.

### **21) What is secondary transducer?**

The output of the Bourdon tube is given to the input of the [LVDT](#).

There are two stages of transduction, firstly the pressure is converted into a displacement by the Bourdon tube then the displacement is converted into analog voltage by LVDT. Here LVDT is called secondary transducer. Electrical device can act as a secondary transducer.

### **22) What is passive transducer?**

In the absence of external power, transducer cannot work and it is called a passive transducer.

Example: capacitive, inductive, resistance transducers.

### **23) What is active transducer?**

In the absence of external power, transducer can work and it is called active transducer.

**Example:**

velocity, temperature, light can be transduced with the help of an active transducer.

### **24) What is analog transducer?**

These transducers convert the input quantity into an analog output which is a continuous function of time.

Thus a strain gauge, an LVDT, a thermocouple or a thermistors may be called analog transducer, as they give an output which is a continuous function of time.

### **25) Give the classification of units.**

1. Absolute units
2. Fundamental and derived units
3. Electromagnetic units
4. Electrostatic units

**26) Define Primary fundamental and auxiliary fundamental units.**

Fundamental units in mechanics are measures of length, mass and time and those are fundamental to most other physical quantities and hence they are called **Primary fundamental units**.

Measures of certain physical quantities in thermal, electrical and illumination fields are also represented by fundamental units and are used only where those disciplines are involved and hence called **auxiliary fundamental units**.

**27) Define unit of mass preserved at International Bureau of weights and measures at Severs near Paris.**

The unit of mass is represented by a material standard: the mass of International prototype kilogram consisting of platinum Iridium hollow cylinder.

**28) Define static calibration.**

It refers to a process in which all the inputs(desired,modifying,interfering) except one are kept at some constant values.

**29) Define Traceability.**

The ability to trace the accuracy of the standard back to its ultimate source in fundamental standards of National Institute of Science and Technology is termed "[Traceability](#)".

**30) What are random errors or residual errors?**

The happenings or disturbances about which we are unaware and lumped together are called random errors or residual errors.

Since these errors remain even after the systematic errors are taken care of,they are called residual errors.

**ALSO READ : [PLC QUESTIONS & ANSWERS](#)**

**31) Give one property of piezo-electric crystal.**

When a force is applied to piezo-electric crystals, they produce an output voltage.

**32) Define an Inverse transducer. Give an example.**

A device which converts an electrical quantity into a non-electrical quantity.

A piezo-electric crystal acts as an inverse transducer because when a voltage is applied across its surfaces, it changes its dimensions causing a mechanical displacement.

**33) List the factors responsible in selection of a transducer.**

1. Operating principle
2. Sensitivity
3. Operating range.
4. Accuracy.

**34) Define static characteristics.**

Static characteristics of a measurement system are, in general, those that must be considered when the system or instrument is used to measure a condition not varying with time.

**35) Mention different types of static characteristics.**

1. Accuracy
2. Sensitivity
3. Reproducibility
4. Drift
5. Static error and
6. Dead zone.

**36) What are dynamic characteristics?**

Many measurements are concerned with rapidly varying quantities and, therefore, for such cases we must examine the dynamic relations which exist between the output and the input .

This is normally done with the help of differential equations. Performance criteria based upon dynamic relations constitute the Dynamic Characteristics.

**37) Mention different types dynamic characteristics?**

- Zero- order transducers
- First – order transducers
- Second-order transducers
- Higher-order transducers

**38) What are the test inputs of the transducer?**

- Impulse input
- Step input
- Ramp input
- Parabolic input

- Sinusoidal input

**39) Define zero order transducer.**

The input- output relationship of a zero- order transducer is given by

$$Y(t) = K r(t)$$

Where  $r(t)$  is the input,  $Y(t)$  is the output and  $K$  is the static sensitivity of the transducer.

Example for zero-order transducer is a [potentiometer](#).

**40) What is mathematical model?**

Mathematical model is defined as the mathematical representation of the system and its process.

**41) What is frequency response of ZOT?**

Frequency response is thus defined as the steady – state output of a transducer when it is excited with sinusoidal input.

The frequency response is represented with the help of two plots namely amplitude ratio versus frequency and phase angle shift versus frequency.

**42) What is damping ratio?**

The damping ratio  $V$  is an important parameter which decides the nature of oscillation in the transducer output.

When  $V = 0$ , the second order system is said to be undamped and the system behaves like an oscillator. When  $V = 1$ , the second order system is said to be critical damped and when  $V > 1$ , the second – order system is said to be over damped.

**43) Define static sensitivity**

Sensitivity should be taken depending on the operating point. The sensitivity is expressed in

$S = \text{output unit} / \text{input unit}$ .

**44) Define linearity.**

Linearity is a measure of the maximum deviation of the plotted transducer response from a specified straight line.

**45) Compare accuracy and precision.**

[Accuracy](#) is the closeness to true value whereas precision is the closeness amongst the readings.

Precision is the degree of closeness with which a given value may be repeatedly measured.

**46) What is Threshold?**

When the input to a transducer is increased from zero, there is a minimum value below which no output can be detected .

This minimum value of the input is defined as the threshold of the transducer.

**47) Define resolution.**

When the input to a transducer is increased slowly from some non-zero arbitrary value, the change in output is not detected at all until a certain input increment is exceeded. This increment is defined as the resolution.

**48) Define hysteresis.**

When the input to a transducer which is initially at rest is increased from zero to full-scale and then decreased back to zero, there may be two output values for the same input.

Hysteresis effects can be minimized by taking readings corresponding to ascending and descending values of the input and then taking their arithmetic average.

**49) What is range and span?**

The range of the transducer is specified as from the lower value of input to higher value of input.

The span of the transducer is specified as the difference between the higher and lower limits of recommended input values.

**50) What is rise time?**

It is defined as time required for the system to rise from 0 to 100 per cent of its final value.

**51) A thermometer has a time constant of 3.5 s. it is quickly taken from a temperature degree celsius to a water bath having temperature 100degree celsius. What temperature will be indicated after 1.5 s?**

$$q = q_0 [ 1 - \exp(-t/\tau)]$$

$$= 100 [ 1 - \exp(-1.5 / 3.5)] = 34.86^\circ\text{C}.$$

**52) A temperature-sensitive transducer is subjected to a sudden temperature change. It takes 10 s for the transducer to reach equilibrium condition (5 times constant). How long will it take for the transducer to read half of the temperature difference?**

Time to reach equilibrium conditions =  $5t = 10\text{s}$ .

Time constant  $t = 10/5 = 2\text{s}$ .

$$q = q_0 [ 1 - \exp(-t/\tau)]$$

$$0.5 = 1 - [\exp(-t / 2)]$$

$$t = 1.39\text{s}.$$

**53) What is potentiometer?**

Basically a resistance potentiometer, or simply a POT, (a resistive potentiometer used for the purposes of voltage division is called a POT) consists of a resistive element provided with a sliding contact.

The POT is a passive transducer.

**54) What are the advantages and disadvantages of potentiometer?**

**Advantages of Potentiometer :**

- Inexpensive
- Useful for measurement of large amplitudes
- Efficiency is very high
- Frequency response of wire wound potentiometers is limited

**Disadvantages of Potentiometer :**

- Require a large force to move

**55) What is gauge factor?**

The gauge factor is unit resistance change per unit strain, which is due to three factors as revealed by the above equation.

**56) What are the different types of strain gauge?**

- Unbonded metal strain gauges
- Bonded metal wire strain gauges
- Bonded metal foil strain gauges
- Vacuum deposited thin metal film strain gauges
- Sputter deposited thin metal strain gauges
- Bonded semiconductor strain gauges
- Diffused metal strain gauges.

**57) What are the factors to be considered for bonded strain gauge?**

- Filament construction
- Material of the filament wire
- Base carrier material or backing material
- Cement used to bond the filament to the carrier
- Lead wire connections.

**58) What is strain?**

It is a ratio of changing length to original length.

**59) What is young's modulus?**

It is a ratio of stress and strain,  $dR/R / \delta l/l$

#### **60) What are resistance thermometers?**

A resistance thermometer consists of a resistive element which is exposed to the temperature to be measured.

If the conductors or metals are used to measure the temperature, they are known as resistance thermometers and if semiconductors are used then they are known as thermistors.

**ALSO READ : [CONTROL SYSTEMS QUESTIONS & ANSWERS](#)**

#### **61) What are the different approximation methods of resistance thermometer?**

- Linear approximation:
- Quadratic approximation

#### **62) What is self-heating error of thermometer?**

Resistance thermometer bridges may be excited with either d.c.or a.c .The direct or rms alternating current through the thermometer is usually in the range of 2 to 20 mA.

This current causes an  $I^2R$  heating which raises the temperature of the thermometer above its surrounding, causing the so called self-heating error.

#### **63) What are the advantages and disadvantages of resistance thermometers (RTD) ?**

##### **Advantages of RTD :**

- They are suitable for measuring large temperature differences and high temperatures.
- They are very accurate which makes them suitable for small temperature measurement.
- Well-designed resistance thermometers have excellent stability
- Unlike thermocouples, they do not need a reference junction and this favors them in many aerospace and industrial applications.

##### **Disadvantages of RTD :**

- Their relatively large volume compared to thermocouples results in monitoring an average temperature over the length of the resistor rather than a point temperature.
- They need auxiliary apparatus and power supply.
- The resistance element is usually more expensive than a thermocouple.
- There are errors due to self-heating and thermoelectric effect of the resistive element and connecting leads (dissimilar metal junctions).

#### **64) What is the principle of hot wire anemometer?**

Othername of resistance variation type transducers is hot wire anemometer. In general [anemometers](#) are devices used for measurement of velocity of flow.

**65) Why dynamic compensation is required for hot wire anemometer?**

It is used avoid the fluctuation, we need dynamic compensation circuits for the hotwire anemometer.

**66) What are the applications of thermistors?**

1. Measurement of power at high frequencies
2. Measurement of thermal conductivity
3. Measurement of level, flow and pressure of liquids
4. Measurement of composition of gases
5. Vacuum measurements
6. Providing time delay.

**67) Mention the features of thermistors.**

1. Compact, rugged and inexpensive
2. Good stability
3. The response time of thermistors can vary from a fraction of a second to minute
4. Self-heating of thermistors is avoided
5. Thermistors can be installed at a distance from their associated measuring circuit

**68) Mention the materials used for thermistors.**

Mixture of metallic oxides such as manganese, nickel, cobalt, copper, iron and uranium.

**69) Mention the applications of strain gauge.**

- Used to measure pressure
- Used to measure torque
- Used to measure acceleration
- Used to measure force

**70) What is inductance transducer?**

Transducers based on the variation of inductance are another group of importance devices used in much application.

In these transducers self-inductance or the mutual of a couple of coils is changed when the quantity to be measured is varied.

**71) Mention three principles of inductance transducer.**

- Change of self-inductance

- Change of mutual inductance
- Production of eddy currents.

## **72) What is LVDT?**

The Linear Variable Differential Transformer (LVDT) is the most common mutual inductance element.

This can be considered to be a versatile transducer element for most of the electromechanical measuring systems with regards to resolution, hysteresis, dynamic response, temperature characteristics, linearity and life.

## **73) What are the advantages and disadvantages of LVDT?**

### **Advantages of LVDT :**

- High range
- Friction and electrical Isolation
- Immunity from external effects
- High input and high sensitivity
- Ruggedness
- Low hysteresis
- Low power consumption

### **Disadvantages of LVDT :**

- Relatively large displacements are required for appreciable differential output
- They are sensitive to stray magnetic fields but shielding is possible
- Many a times, the transducer performance is affected by vibrations
- The receiving instrument must be selected to operate on a.c
- The dynamic response is limited
- Temperature affects the performance of the transducer.

## **74) What are the applications of LVDT?**

- Displacement measurement and LVDT Gage heads
- LVDT pneumatic servo follower
- LVDT Load cells
- LVDT Pressure Transducer

## **75) What is null voltage?**

Ideally the output voltage at the null position should be equal to zero. However, in actual practice there exists a small voltage at the null position.

**76) Explain the principle of Induction Potentiometer?**

The primary is excited with alternating current. This induces a voltage in to the secondary.

The amplitude of this output voltage varies with the mutual inductance between the two coils and this varies with the angle of rotation.

**77) Explain the principle of Variable Reluctance Accelerometer?**

Another common version of the variable reluctance principle.

This is an accelerometer for measurement of acceleration for measurement of acceleration in the range  $\pm 4g$ . Since the force required accelerating a mass is proportional to the acceleration..

**78) What is the need of demodulator in Variable Reluctance Accelerometer?**

To detect motion on both sides of zero, a fairly involved phase- sensitive demodulator would be required.

To eliminate the demodulator the iron core and springs were adjusted so that core was offset to one side by an amount equal to the spring deflection corresponding to 4 g acceleration.

**79) What is the principle of capacitive transducer?**

Many industrial variables like displacement, pressure, level, moisture, thickness etc. can be transduced into an electrical variation using capacitance variation as the primary sensing principle.

**80) What are the desirable features of capacitive transducer?**

- Its force requirements are very small
- As the moving plates have very little mass, design of transducer with fast response characteristics is possible
- There is no physical barrier between moving and stationary parts
- Does not depend on the conductivity of the metal electrode
- Shielded against the effect of external electric stray fields.

**81) What are the different practical capacitance pickups?**

- Equibar differential pressure transducer
- Feedback type capacitance proximity pickup
- Condenser microphone.

**82) What is Microphone?**

It is also a [transducer](#) which converts sound energy into electrical energy.

Example is condenser microphone.

**83) What is the principle of change of capacitance?**

- Change in overlapping area A
- Change in the distance between the plates d
- Change in dielectric constant.

**84) What are the advantages of capacitive transducers?**

- They require only small force to operate
- Have a good frequency response
- Extremely sensitive
- High input impedance

**85) What are the disadvantages of capacitive transducers?**

- The metallic parts of the capacitive transducers must be insulated from each other
- Non-linear behavior
- This leads loading effects
- The cable may be source of loading resulting loss of sensitivity.

**86) What are the uses of capacitive transducer?**

- Can be used for measurement of linear and angular displacement
- Can be used for measurement of force and pressure
- It can be used as pressure transducer
- Measurement of humidity in gases
- Commonly used for measurement of level, density, weight.

**87) What is the value of capacitance for measurement of level of a non-conducting liquid?**

$$C = 2\pi\epsilon_0 [e_1 h_1 + e_2 h_2 / \log(r_2/r_1)]$$

Where,  $h_1$ = height of liquid

$h_2$ = height of cylinder

$e_1$ =relative permittivity of liquid

$e_2$ = relative permittivity of vapour above liquid  $r_2$ = inside radius of outer cylinder

$r_1$ = outer radius of inner cylinder

$\epsilon_0$ = relative permittivity of free space

**88) What is analog transducer?**

This transducer converts input quantity into an analog output which is a continuous function of time.

Thus a strain gauge, LVDT, thermocouple, thermistors, may be called as analog transducer.

**89) What is digital transducer?**

These transducer convert input quantity into an electrical output which is in the form of pulses.

**90) What is piezo electric transducer?**

They convert pressure or force into electrical charge.

These transducers are based upon the natural phenomenon of certain non-metal and di-electric components.

**91) What are the suitable materials for piezo electric transducer?**

Primary quartz, Rochelle salt, ammonium di-hydrogen phosphate (ADP), and ceramics with barium titanate, di-potassium tartrate, potassium di-hydrogen phosphate and lithium sulfate.

**92) What is 'd'coefficient?**

Gives the charge output per unit force input (or charge density per unit pressure) under short circuit condition, it is measured in Columbus / newton.

**93) What is 'g' coefficient?**

G-coefficient representing the generated e.m.f gradient per unit pressure input.

**94) What is 'h' coefficient?**

It is obtained by multiplying the g-coefficient by young's modulus valid for the appropriate crystal orientation of the material, and thus measures the e.m.f gradient per unit mechanical deformation, or  $(V/m) / (m/m)$ .

**95) What are the suitable materials for magneto-strictive transducer?**

Iron , nickel, 68 permalloy and ferroxcube ect .

**96) What is magneto-strictive transducer?**

The permeability can increase or decrease depending upon the material, type of stress , and the magnetic flux density in the sample.

**97) What are the different magneto-strictive transducer?**

- Magneto-strictive load cell
- Magnetostrictive Accelerometer
- Magnetostrictive Phonographic Pickup
- Magnetostrictive Torque Transducer

**98) What are the errors in Magnetostrictive transducer?**

- Hysteresis
- Temperature
- Eddy current
- Input impedance

**99) What are the special features of magneto-strictive transducer?**

- To measure large force
- measure several thousand "g"
- Characteristics depend upon temperature.

**100) What is fiber optic transducer?**

Fiber optic cable consists of outer core and inner cladding.

Data is transmitted in the form of light. It is used for measuring displacement, torsion.

**101) Compare digital transducer with analog.**

Digital transducer gives digital outputs. Analog transducers outputs are continuous functions of time.

If these analog transducers are to be interfaced with digital devices, then one has to use analog to digital converters.

**102) How will u achieve high resolution in digital transducer?**

The number of tracks must be increased and the length of each coded should be reduced, which would require fine brushes.

**103) What are the different digital transducer are available?**

- digital displacement transducer
- shaft angle encoder
- optical encoder
- magnetic encoder

**104) what is piezo electric effect?**

A piezo electric material is one in which an electric potential appears across certain surfaces of a crystal if the dimensions of the crystal are changed by the application of the mechanical force.

**105) What is digitizer?**

Digital encoding transducer or digitizer enables a linear or rotary displacement to be directly converted into digital form without intermediate form of analog to digital (A/D) conversion.

**106) What are the classifications of encoder?**

- Tachometer transducer
- Incremental transducer
- Absolute transducer

**107) What are the input characteristics of the transducer?**

- Type of input and operating range
- Loading effect

**108) What is zero error of the transducer?**

In this case output deviates from the correct value by a constant factor over the entire range of transducer.

**109) What are the different transfer characteristics of the transducer?**

1. Transfer function
2. Error
  - Scale error
  - Zero error
  - Sensitivity error
  - Non-conformity
  - Hysteresis
3. Transducer response

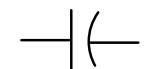
# **BASIC ELECTRICAL AND ELECTRONICS ENGINEERING**

## **Unit-1**

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Associate Professor

# **ELECTRIC CIRCUITS**

Electric circuits are broadly classified as Direct Current (D.C.) circuits and Alternating Current (A.C.) circuits. The following are the various elements that form electric circuits.

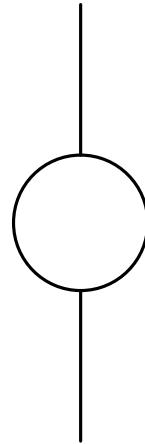
D.C. Circuits		A.C. Circuits	
<u>Elements</u>	<u>Representation</u>	<u>Elements</u>	<u>Representation</u>
Voltage source	 	Voltage source	
Current source		Current source	
Resistor		Resistor	
Inductor			
Capacitor			

We also will classified sources as **Independent** and **Dependent** sources

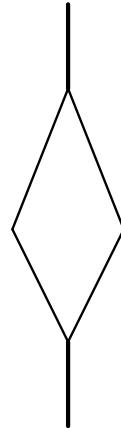
**Independent source** establishes a voltage or a current in a circuit without relying on a voltage or current elsewhere in the circuit

**Dependent sources** establishes a voltage or a current in a circuit whose value depends on the value of a voltage or a current elsewhere in the circuit

We will use circle to represent **Independent source** and diamond shape to represent **Dependent sources**



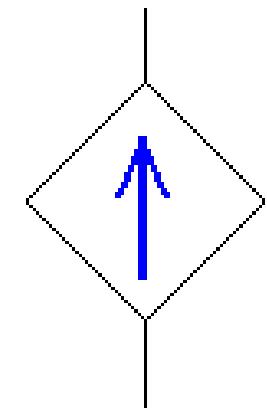
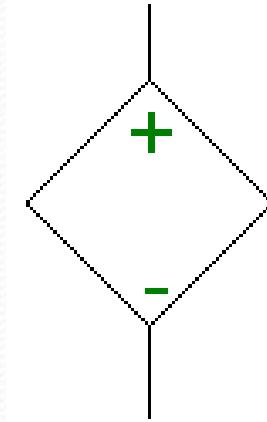
**Independent source**



**Dependent sources**

# Dependent Power Sources

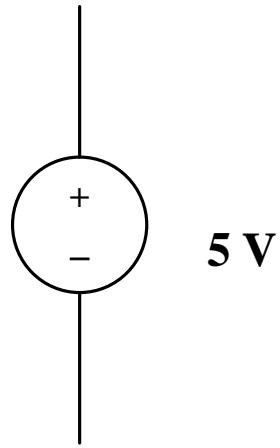
- Voltage controlled voltage source
  - (VCVS)
- Current controlled voltage source
  - (CCVS)
- Voltage controlled current source
  - (VCCS)
- Current controlled current source
  - (CCCS)



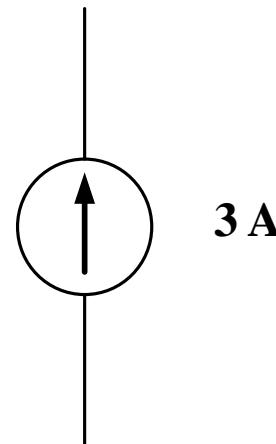
# Summary

- Dependent sources are voltage or current sources whose output is a function of another parameter in the circuit.
  - Voltage controlled voltage source (VCVS)
  - Current controlled current source (CCCS)
  - Voltage controlled current source (VCCS)
  - Current controlled voltage source (CCVS)
- Dependent sources only produce a voltage or current when an independent voltage or current source is in the circuit.
- Dependent sources are treated like independent sources when using nodal or mesh analysis, but not with superposition.

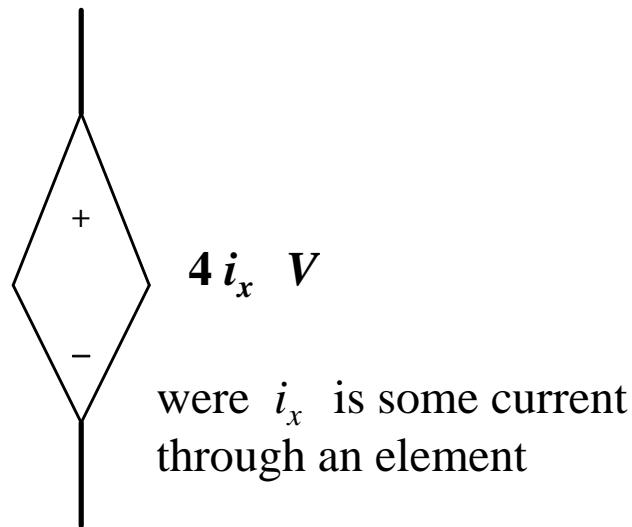
Independent and dependent voltage and current sources can be represented as



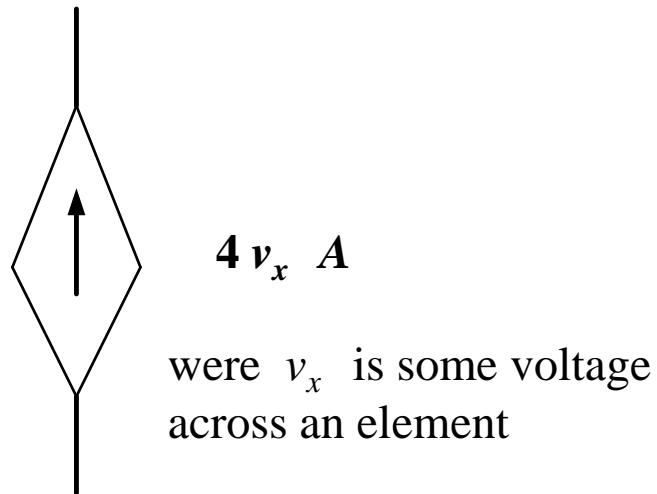
Independent voltage source



Independent current source

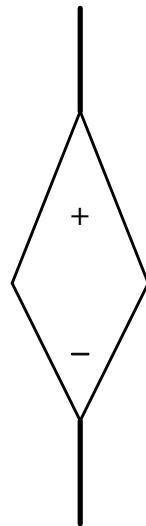


**Dedependent voltage source**  
**Voltage depend on current**



**Dedependent current source**  
**Current depend on voltage**

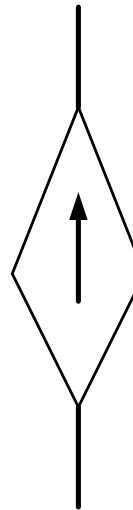
The dependent sources can be also as



$$4 v_x \text{ V}$$

were  $v_x$  is some current through an element

**Dedependent voltage source**  
**Voltage depend on voltage**



$$7 i_x \text{ A}$$

were  $i_x$  is some voltage across an element

**Dedependent current source**  
**Current depend on current**

First we shall discuss about the analysis of DC circuit. The voltage across an element is denoted as  $E$  or  $V$ . The current through the element is  $I$ .

Conductor is used to carry current. When a voltage is applied across a conductor, current flows through the conductor. If the applied voltage is increased, the current also increases. The voltage current relationship is shown in Fig. 1.

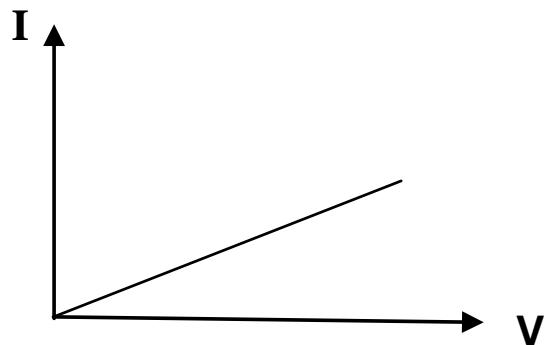


Fig. 1 Voltage – current relationship

It is seen that  $I \propto V$ . Thus we can write

$$I = G V \quad (1)$$

where  $G$  is called the conductance of the conductor.

Very often we are more interested on RESISTANCE, R of the conductor, than the conductance of the conductor. Resistance is the opposing property of the conductor and it is the reciprocal of the conductance, Thus

$$R = \frac{1}{G} \text{ or } G = \frac{1}{R} \quad (2)$$

Therefore

$$I = \frac{V}{R} \quad (3)$$

The above relationship is known as OHM's law. Thus Ohm law can be stated as the current flows through a conductor is the ratio of the voltage across the conductor and its resistance. Ohm's law can also be written as

$$V = RI \quad (4)$$

$$R = \frac{V}{I} \quad (5)$$

The resistance of a conductor is directly proportional to its length, inversely proportional to its area of cross section. It also depends on the material of the conductor. Thus

$$R = \rho \frac{l}{A} \quad (6)$$

where  $\rho$  is called the specific resistance of the material by which the conductor is made of. The unit of the resistance is Ohm and is represented as  $\Omega$ . Resistance of a conductor depends on the temperature also. The power consumed by the resistor is given by

$$P = VI \quad (7)$$

When the voltage is in volt and the current is in ampere, power will be in watt. Alternate expression for power consumed by the resistors are given below.

$$P = R I \times I = I^2 R \quad (8)$$

$$P = V \times \frac{V}{R} = \frac{V^2}{R} \quad (9)$$

## **KIRCHHOFF's LAWS**

**There are two Kirchhoff's laws. The first one is called Kirchhoff's current law, KCL and the second one is Kirchhoff's voltage law, KVL. Kirchhoff's current law deals with the element currents meeting at a junction, which is a meeting point of two or more elements. Kirchhoff's voltage law deals with element voltages in a closed loop also called as closed circuit.**

## Kirchhoff's current law

Kirchhoff's currents law states that the algebraic sum of element current meeting at a junction is zero.

Consider a junction P wherein four elements, carrying currents  $I_1$ ,  $I_2$ ,  $I_3$  and  $I_4$ , are meeting as shown in Fig. 2.

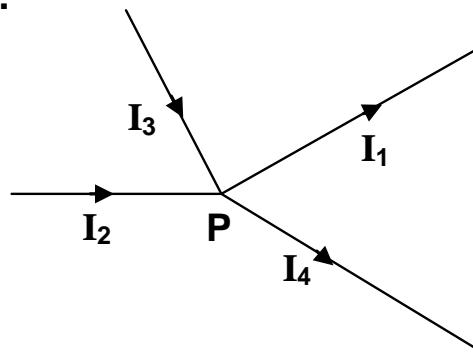


Fig. 2 Currents meeting at a junction

Note that currents  $I_1$  and  $I_4$  are flowing out from the junction while the currents  $I_2$  and  $I_3$  are flowing into the junction. According to KCL,

$$I_1 - I_2 - I_3 + I_4 = 0 \quad (10)$$

The above equation can be rearranged as

$$I_1 + I_4 = I_2 + I_3 \quad (11)$$

From equation (11), KCL can also stated as at a junction, the sum of element currents that flows out is equal to the sum of element currents that flows in.

## Kirchhoff's voltage law

Kirchhoff's voltage law states that the algebraic sum of element voltages around a closed loop is zero.

Consider a closed loop in a circuit wherein four elements with voltages  $V_1$ ,  $V_2$ ,  $V_3$  and  $V_4$ , are present as shown in Fig. 3.

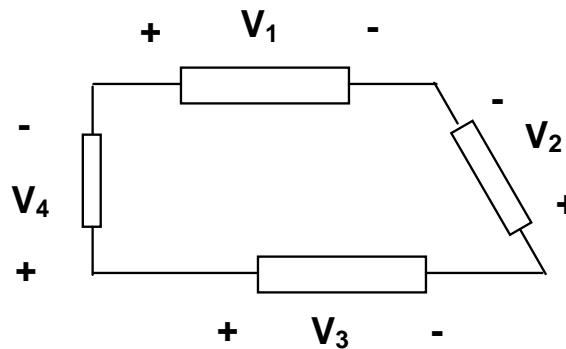


Fig. 3 Voltages in a closed loop

Assigning positive sign for voltage drop and negative sign for voltage rise, when the loop is traced in clockwise direction, according to KVL

$$V_1 - V_2 - V_3 + V_4 = 0 \quad (12)$$

The above equation can be rearranged as

$$V_1 + V_4 = V_2 + V_3 \quad (13)$$

From equation (13), KVL can also stated as, in a closed loop, the sum of voltage drops is equal to the sum of voltage rises in that loop.

## Resistors connected in series

Two resistors are said to be connected in series when there is only one common point between them and no other element is connected in that common point. Resistors connected in series carry same current. Consider three resistors  $R_1$ ,  $R_2$  and  $R_3$  connected in series as shown in Fig. 4. With the supply voltage of  $E$ , voltages across the three resistors are  $V_1$ ,  $V_2$  and  $V_3$ .

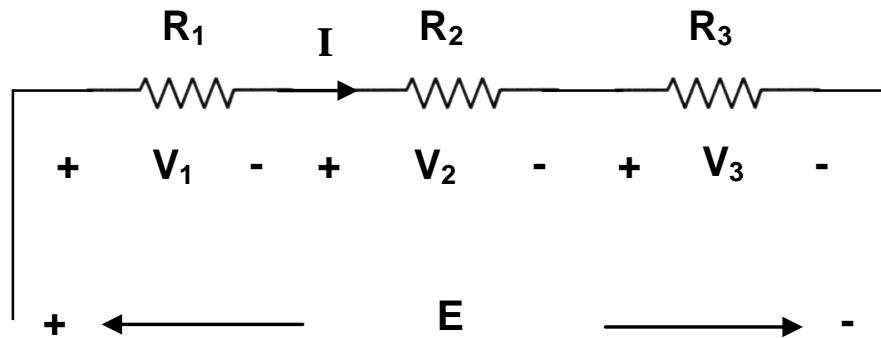


Fig. 4 Resistors connected in series

As per Ohm's law

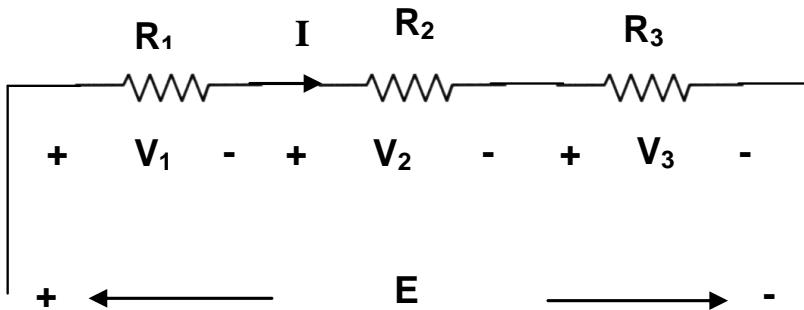
$$V_1 = R_1 I$$

$$V_2 = R_2 I$$

$$V_3 = R_3 I$$

}

(14)



**Fig. 4 Resistors connected in series**

As per Ohm's law

$$V_1 = R_1 I$$

$$V_2 = R_2 I$$

$$V_3 = R_3 I$$

Applying KVL,

$$E = V_1 + V_2 + V_3 \quad (15)$$

$$= (R_1 + R_2 + R_3) I = R_{eq} I \quad (16)$$

Thus for the circuit shown in Fig. 4,

$$E = R_{eq} I \quad (17)$$

where  $E$  is the circuit voltage,  $I$  is the circuit current and  $R_{eq}$  is the equivalent resistance. Here

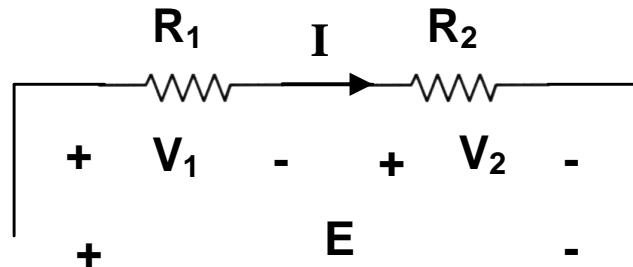
$$R_{eq} = R_1 + R_2 + R_3 \quad (18)$$

This is true when two or more resistors are connected in series. When  $n$  numbers of resistors are connected in series, the equivalent resistor is given by

$$R_{eq} = R_1 + R_2 + \dots + R_n \quad (19)$$

## Voltage division rule

Consider two resistors connected in series. Then



$$V_1 = R_1 I$$

$$V_2 = R_2 I$$

$$E = (R_1 + R_2) I \text{ and hence } I = E / (R_1 + R_2)$$

Total voltage of  $E$  is dropped in two resistors. Voltage across the resistors are given by

$$V_1 = \frac{R_1}{R_1 + R_2} E \quad \text{and} \quad (20)$$

$$V_2 = \frac{R_2}{R_1 + R_2} E \quad (21)$$

## Resistors connected in parallel

Two resistors are said to be connected in parallel when both are connected across same pair of nodes. Voltages across resistors connected in parallel will be equal.

Consider two resistors  $R_1$  and  $R_2$  connected in parallel as shown in Fig. 5.

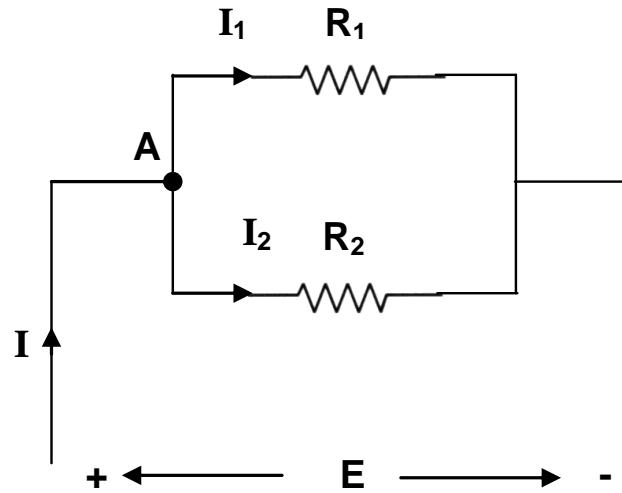
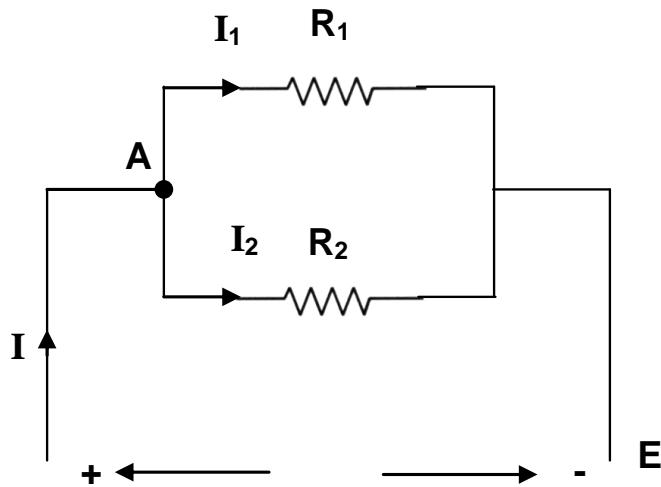


Fig. 5 Resistors connected in parallel

As per Ohm's law,

$$\left. \begin{aligned} I_1 &= \frac{E}{R_1} \\ I_2 &= \frac{E}{R_2} \end{aligned} \right\} \quad (22)$$



As per Ohm's law

$$I_1 = \frac{E}{R_1}$$

$$I_2 = \frac{E}{R_2}$$

Applying KCL at node A

$$I = I_1 + I_2 = E \left( \frac{1}{R_1} + \frac{1}{R_2} \right) = \frac{E}{R_{eq}} \quad (23)$$

Thus for the circuit shown in Fig. 5

$$I = \frac{E}{R_{eq}} \quad (24)$$

where  $E$  is the circuit voltage,  $I$  is the circuit current and  $R_{eq}$  is the equivalent resistance. Here

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \quad (25)$$

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} \quad (25)$$

From the above  $\frac{1}{R_{eq}} = \frac{R_1 + R_2}{R_1 R_2}$

Thus  $R_{eq} = \frac{R_1 R_2}{R_1 + R_2} \quad (26)$

When  $n$  numbers of resistors are connected in parallel, generalizing eq. (25),  $R_{eq}$  can be obtained from

$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \dots + \frac{1}{R_n} \quad (27)$$

## Current division rule

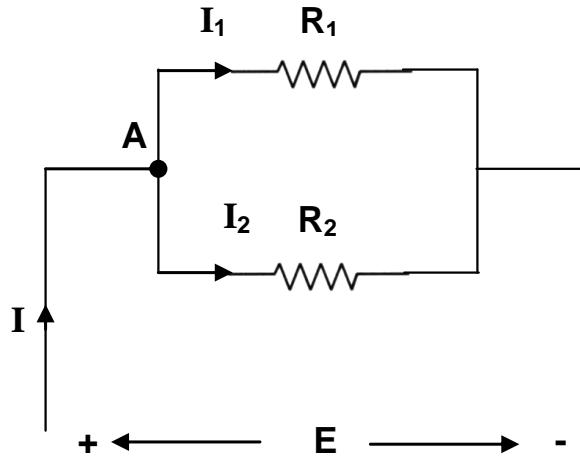


Fig. 5 Resistors connected in parallel

Referring to Fig. 5, it is noticed the total current gets divided as  $I_1$  and  $I_2$ . The branch currents are obtained as follows.

From eq. (23)

$$E = \frac{R_1 R_2}{R_1 + R_2} I \quad (29)$$

Substituting the above in eq. (22)

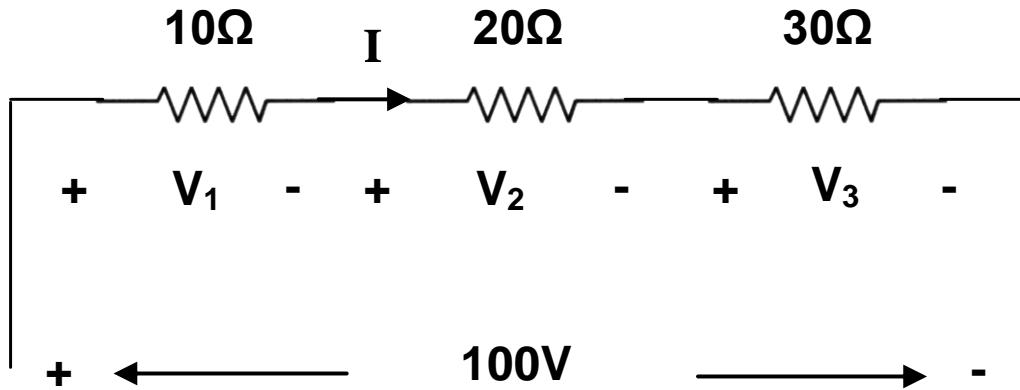
$$\left. \begin{aligned} I_1 &= \frac{R_2}{R_1 + R_2} I \\ I_2 &= \frac{R_1}{R_1 + R_2} I \end{aligned} \right\} \quad (30)$$

## Example 1

Three resistors  $10\Omega$ ,  $20\Omega$  and  $30\Omega$  are connected in series across  $100\text{ V}$  supply.

Find the voltage across each resistor.

## Solution



$$\text{Current } I = 100 / (10 + 20 + 30) = 1.6667 \text{ A}$$

$$\text{Voltage across } 10\Omega = 10 \times 1.6667 = 16.67 \text{ V}$$

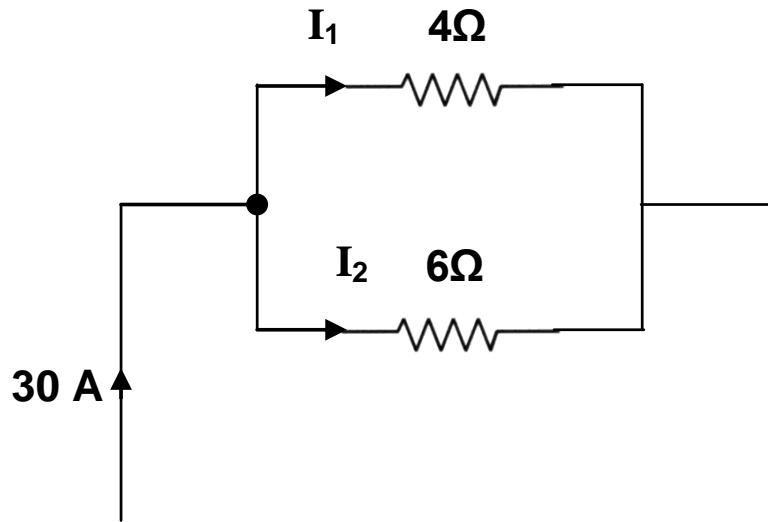
$$\text{Voltage across } 20\Omega = 20 \times 1.6667 = 33.33 \text{ V}$$

$$\text{Voltage across } 30\Omega = 30 \times 1.6667 = 50 \text{ V}$$

## Example 2

Two resistors of  $4\Omega$  and  $6\Omega$  are connected in parallel. If the supply current is 30 A, find the current in each resistor.

### Solution



Using the current division rule

$$\text{Current through } 4\Omega = \frac{6}{4 + 6} \times 30 = 18 \text{ A}$$

$$\text{Current through } 6\Omega = \frac{4}{4 + 6} \times 30 = 12 \text{ A}$$

### Example 3

Four resistors of 2 ohms, 3 ohms, 4 ohms and 5 ohms respectively are connected in parallel. What voltage must be applied to the group in order that the total power of 100 W is absorbed?

### Solution

Let  $R_T$  be the total equivalent resistor. Then

$$\frac{1}{R_T} = \frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{5} = \frac{60 + 40 + 30 + 24}{120} = \frac{154}{120}$$

$$\text{Resistance } R_T = \frac{120}{154} = 0.7792 \Omega$$

Let E be the supply voltage. Then total current taken =  $E / 0.7792$  A

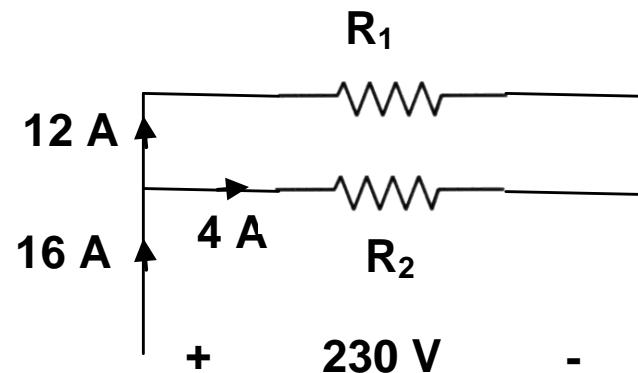
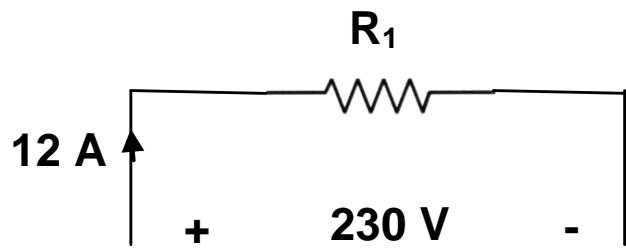
$$\text{Thus } \left(\frac{E}{0.7792}\right)^2 \times 0.7792 = 100 \text{ and hence } E^2 = 100 \times 0.7792 = 77.92$$

$$\text{Required voltage} = \sqrt{77.92} = 8.8272 \text{ V}$$

### Example 4

When a resistor is placed across a 230 V supply, the current is 12 A. What is the value of the resistor that must be placed in parallel, to increase the load to 16 A

### Solution



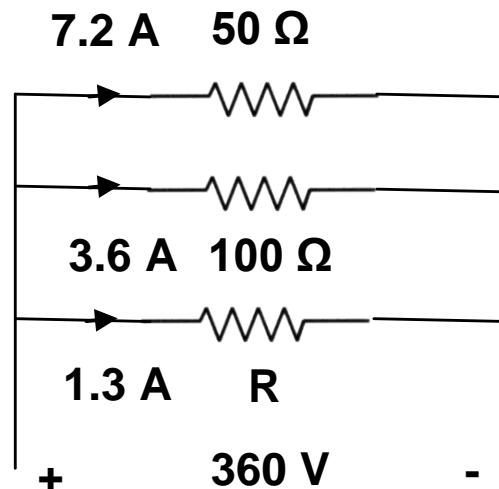
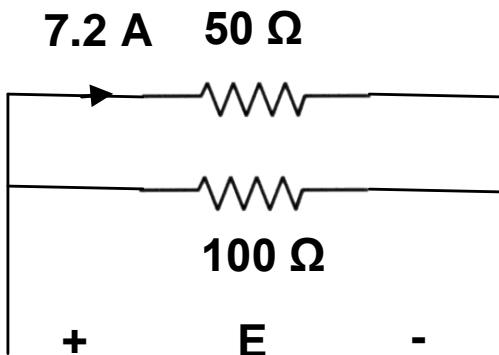
To make the load current 16 A, current through the second resistor =  $16 - 12 = 4$  A

Value of second resistor  $R_2 = 230/4 = 57.5 \Omega$

## Example 5

A  $50\ \Omega$  resistor is in parallel with a  $100\ \Omega$  resistor. The current in  $50\ \Omega$  resistor is  $7.2\ A$ . What is the value of third resistor to be added in parallel to make the line current as  $12.1\ A$ ?

### Solution



$$\text{Supply voltage } E = 50 \times 7.2 = 360\ \text{V}$$

$$\text{Current through } 100\ \Omega = 360/100 = 3.6\ A$$

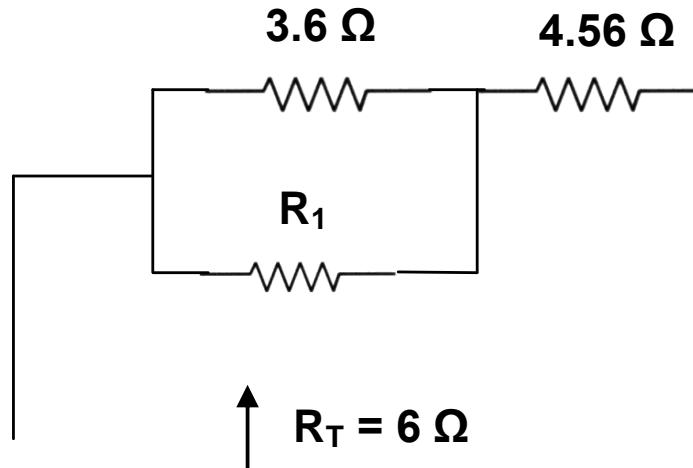
$$\begin{aligned} \text{When the line current is } 12.1\ A, \text{ current through third resistor} &= 12.1 - (7.2 + 3.6) \\ &= 1.3\ A \end{aligned}$$

$$\text{Value of third resistor} = 360/1.3 = 276.9230\ \Omega$$

## Example 6

A resistor of 3.6 ohms is connected in series with another of 4.56 ohms. What resistance must be placed across 3.6 ohms, so that the total resistance of the circuit shall be 6 ohms?

### Solution



$$3.6 \parallel R_1 = 6 - 4.56 = 1.44 \Omega$$

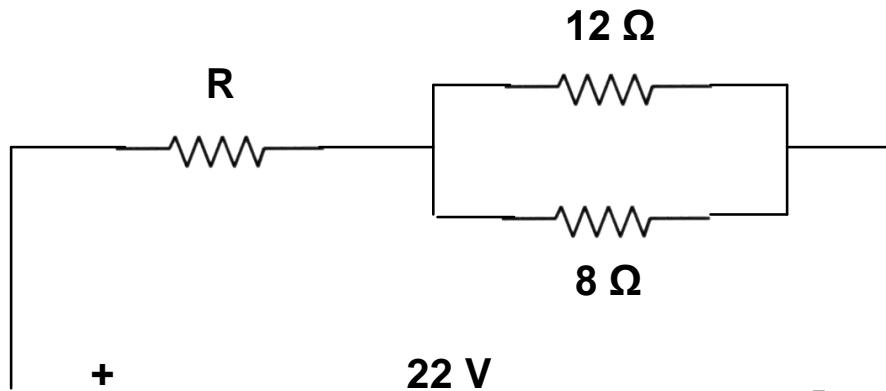
$$\text{Thus } \frac{3.6 \times R_1}{3.6 + R_1} = 0.4; \quad \text{Therefore } \frac{3.6 + R_1}{R_1} = \frac{1}{0.4} = 2.5; \quad \frac{3.6}{R_1} = 1.5$$

$$\text{Required resistance } R_1 = 3.6/1.5 = 2.4 \Omega$$

### Example 7

A resistance  $R$  is connected in series with a parallel circuit comprising two resistors  $12 \Omega$  and  $8 \Omega$  respectively. Total power dissipated in the circuit is  $70 \text{ W}$  when the applied voltage is  $22 \text{ V}$ . Calculate the value of the resistor  $R$ .

### Solution



$$\text{Total current taken} = 70 / 22 = 3.1818 \text{ A}$$

$$\text{Equivalent of } 12 \Omega \parallel 8 \Omega = 96/20 = 4.8 \Omega$$

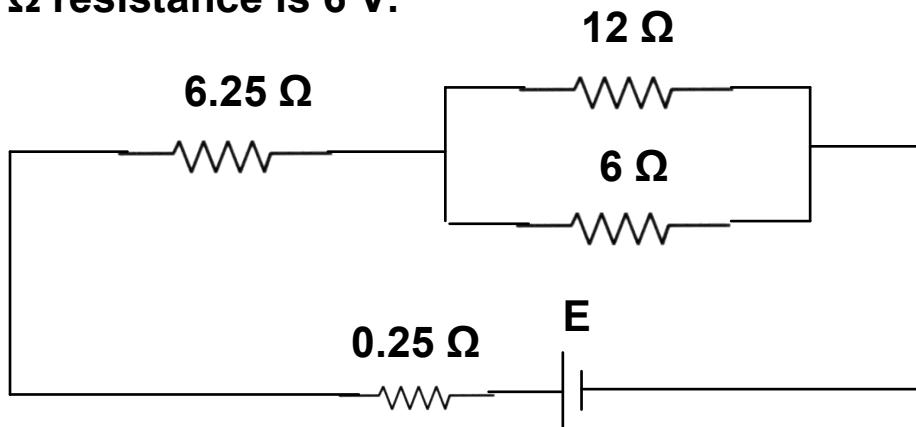
$$\text{Voltage across parallel combination} = 4.8 \times 3.1818 = 15.2726 \text{ V}$$

$$\text{Voltage across resistor } R = 22 - 15.2726 = 6.7274 \text{ V}$$

$$\text{Value of resistor } R = 6.7274/3.1818 = 2.1143 \Omega$$

## Example 8

The resistors  $12 \Omega$  and  $6 \Omega$  are connected in parallel and this combination is connected in series with a  $6.25 \Omega$  resistance and a battery which has an internal resistance of  $0.25 \Omega$ . Determine the emf of the battery if the potential difference across  $6 \Omega$  resistance is  $6 \text{ V}$ .



Voltage across  $6 \Omega = 6 \text{ V}$

## Solution

$$\text{Current in } 6 \Omega = 6/6 = 1 \text{ A}$$

$$\text{Current in } 12 \Omega = 6/12 = 0.5 \text{ A}$$

$$\text{Therefore current in } 25 \Omega = 1.0 + 0.5 = 1.5 \text{ A}$$

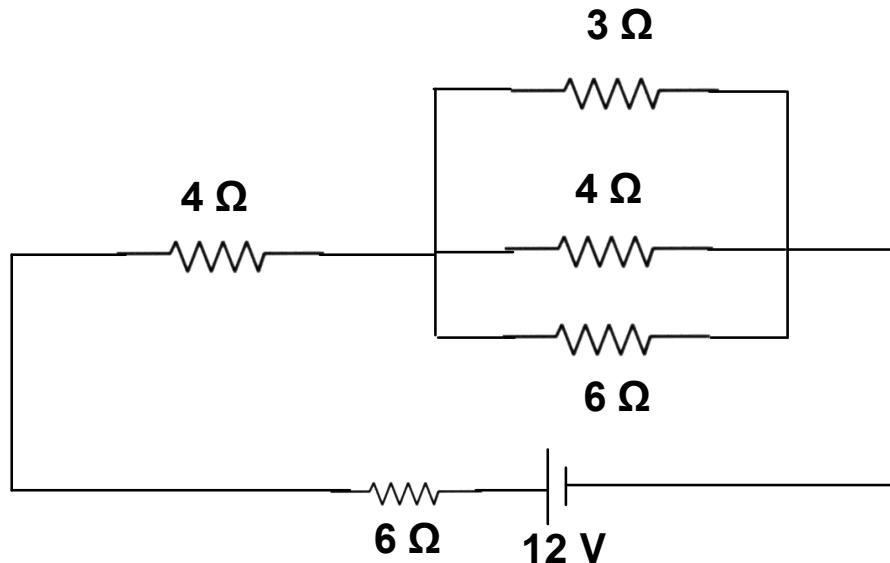
$$\text{Using KVL } E = (0.25 \times 1.5) + (6.25 \times 1.5) + 6 = 15.75 \text{ V}$$

$$\text{Therefore battery emf } E = 15.75 \text{ V}$$

### Example 9

A circuit consist of three resistors  $3\ \Omega$ ,  $4\ \Omega$  and  $6\ \Omega$  in parallel and a fourth resistor of  $4\ \Omega$  in series. A battery of  $12\text{ V}$  and an internal resistance of  $6\ \Omega$  is connected across the circuit. Find the total current in the circuit and the terminal voltage across the battery.

### Solution



$$4\ \Omega \parallel 6\ \Omega = 24/10 = 2.4\ \Omega$$

$$1.4\ \Omega \parallel 3\ \Omega = 7.2/5.4 = 1.3333\ \Omega$$

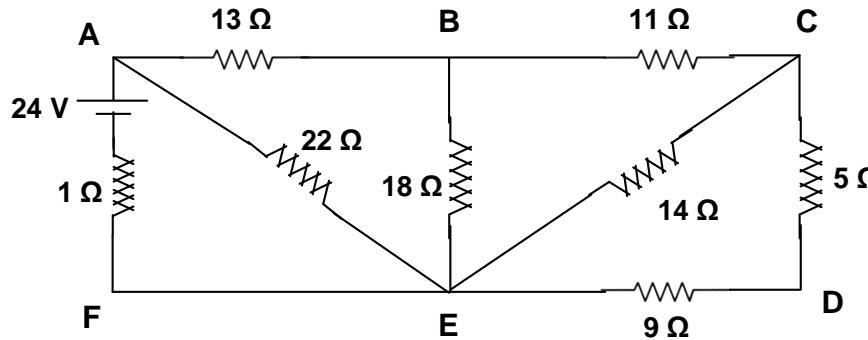
$$\text{Total circuit resistance} = 4 + 6 + 1.3333 = 11.3333\ \Omega$$

$$\text{Circuit current} = 12/11.3333 = 1.0588\text{ A}$$

$$\text{Terminal voltage across the battery} = 12 - (6 \times 1.0588) = 5.6472\text{ V}$$

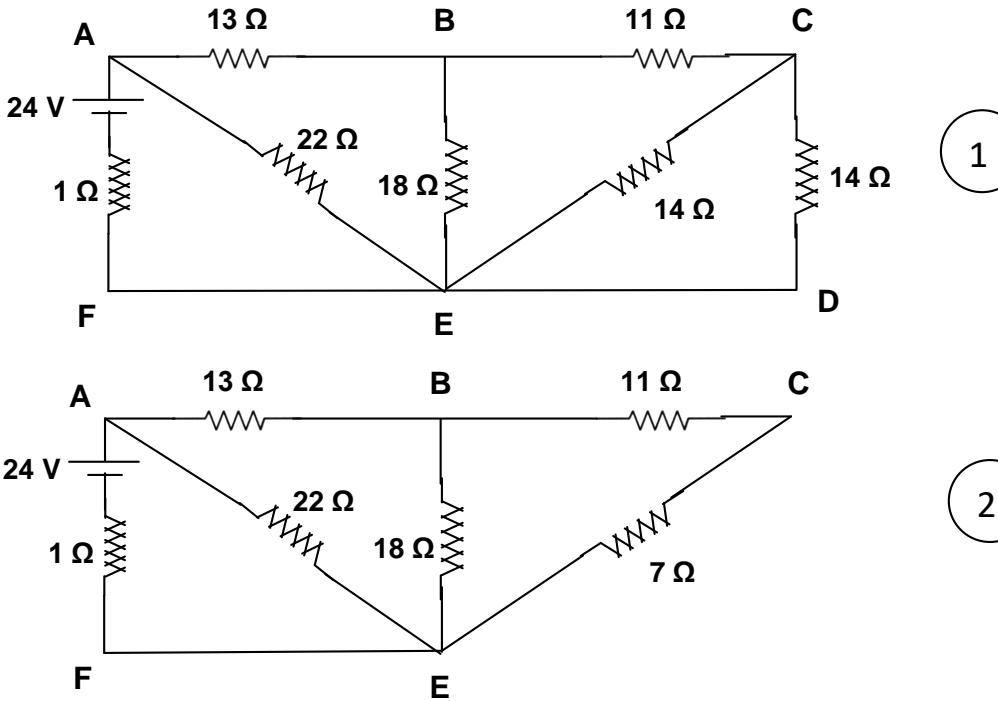
### Example 10

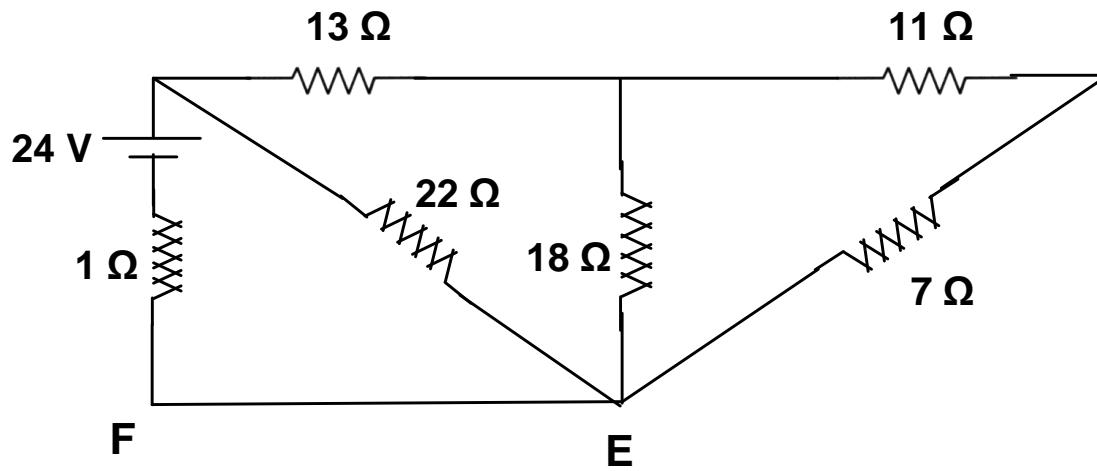
An electrical network is arranged as shown. Find (i) the current in branch AF (ii) the power absorbed in branch BE and (iii) potential difference across the branch CD.



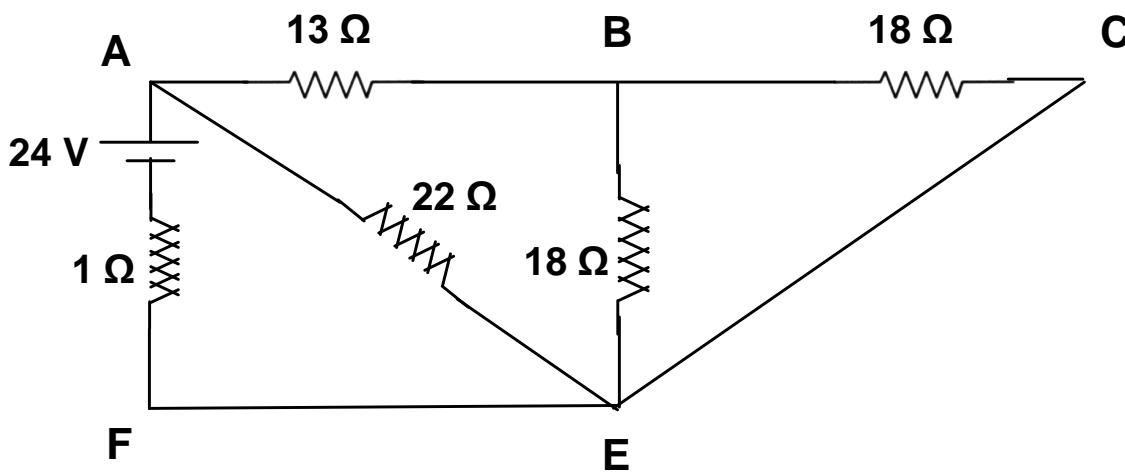
### Solution

Various stages of reduction are shown.

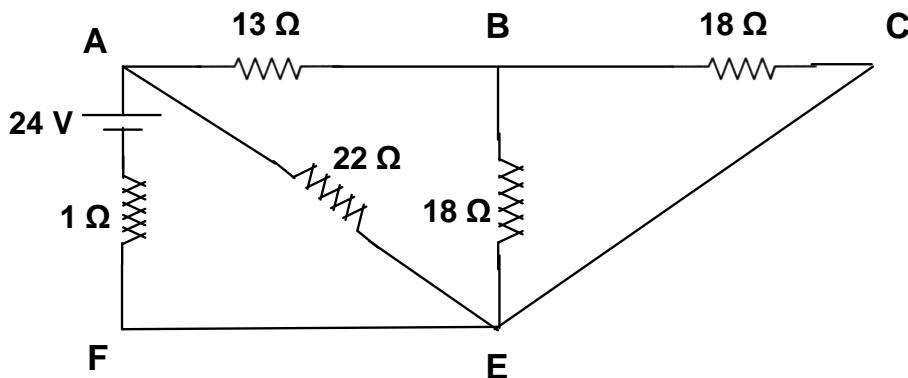




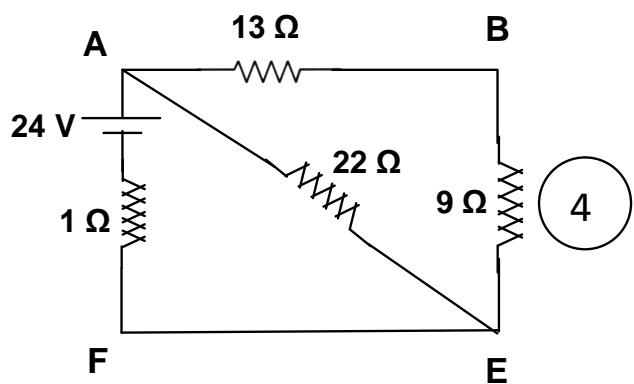
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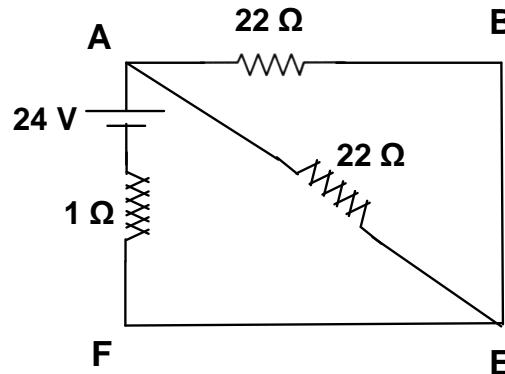
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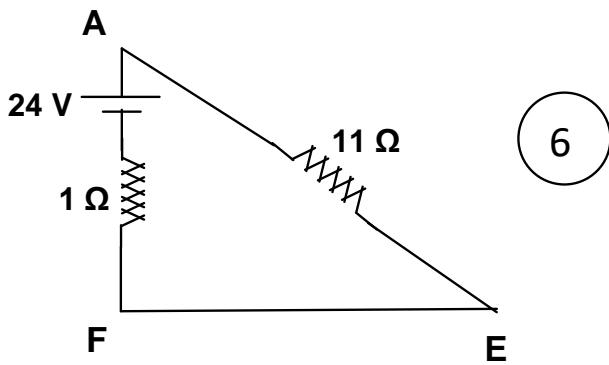
3



4



5



6

**Current in branch AF =  $24/12 = 2$  A from F to A**

**Using current division rule current in  $13\ \Omega$  in Fig. 4= 1 A**

**Referring Fig. 3, current in branch BE = 0.5 A**

**Power absorbed in branch BE =  $0.5^2 \times 18 = 4.5$  W**

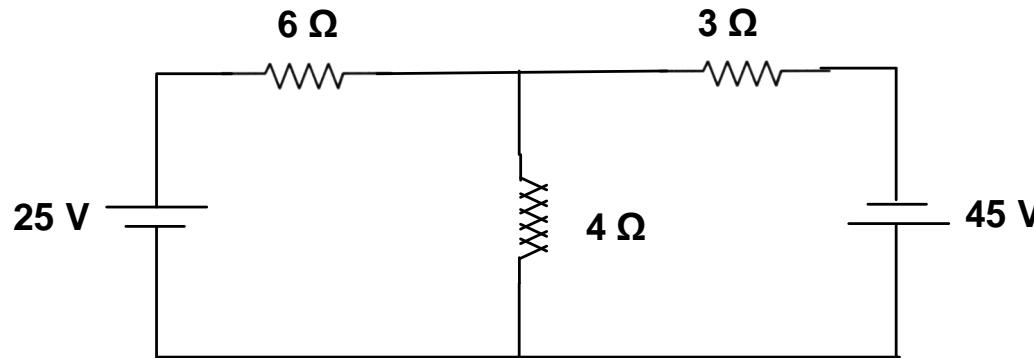
**Voltage across BE =  $0.5 \times 18 = 9$  V**

**Voltage across CE in Fig. 1 =  $\frac{7}{18} \times 9 = 3.5$  V**

**Referring Fig. given in the problem, using voltage division rule, voltage across in  
branch CD =  $\frac{5}{14} \times 3.5 = 1.25$  V**

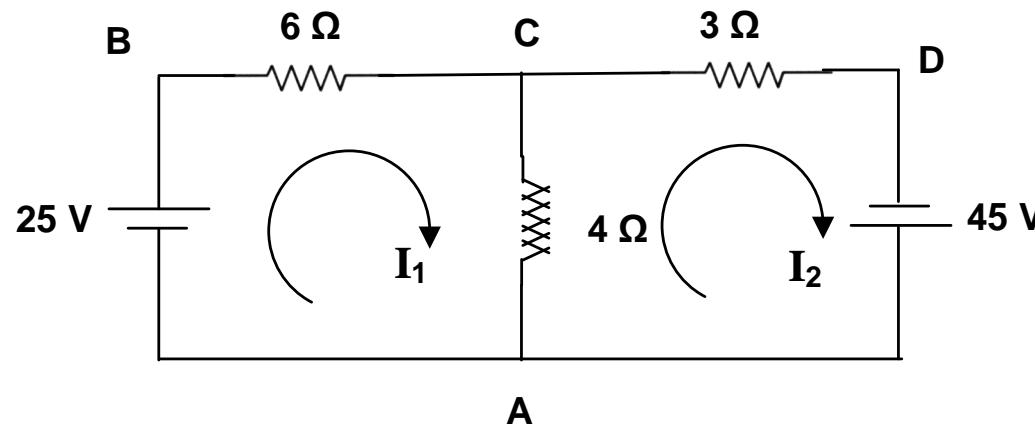
## Example 11

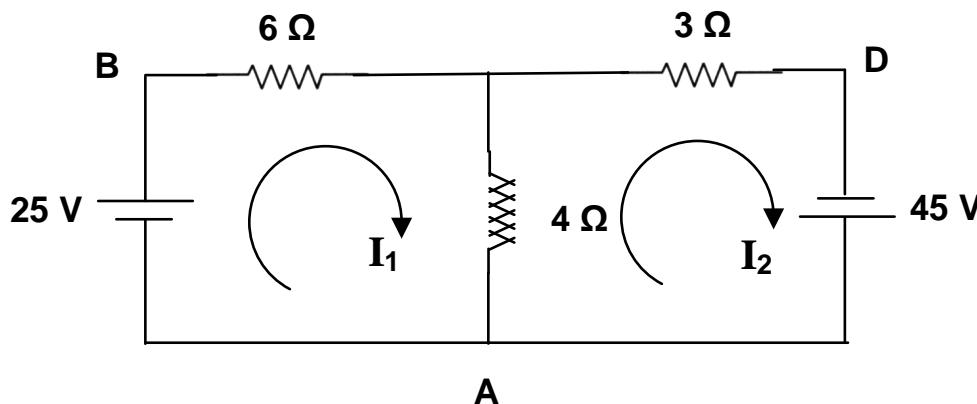
Using Kirchhoff's laws, find the current in various resistors in the circuit shown.



## Solution

Let the loop current be  $I_1$  and  $I_2$





**Considering the loop ABCA, KVL yields**

$$6 I_1 + 4 (I_1 - I_2) - 25 = 0$$

**For the loop CDAC, KVL yields**

$$3 I_2 - 45 + 4 (I_2 - I_1) = 0$$

$$\text{Thus } 10 I_1 - 4 I_2 = 25$$

$$-4 I_1 + 7 I_2 = 45$$

**On solving the above**  $I_1 = 6.574 \text{ A}$ ;  $I_2 = 10.1852 \text{ A}$

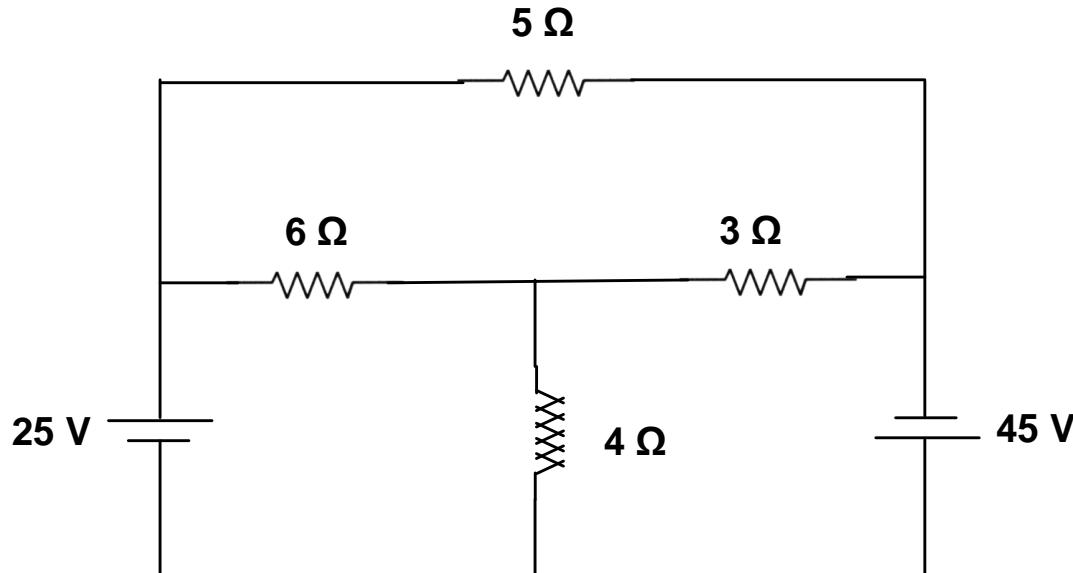
**Current in  $4\Omega$  resistor =  $I_1 - I_2 = 6.574 - 10.1852 = -3.6112 \text{ A}$**

**Thus the current in  $4\Omega$  resistor is  $3.6112 \text{ A}$  from A to C**

**Current in  $6 \Omega$  resistor =  $6.574 \text{ A}$ ; Current in  $3 \Omega$  resistor =  $10.1852 \text{ A}$**

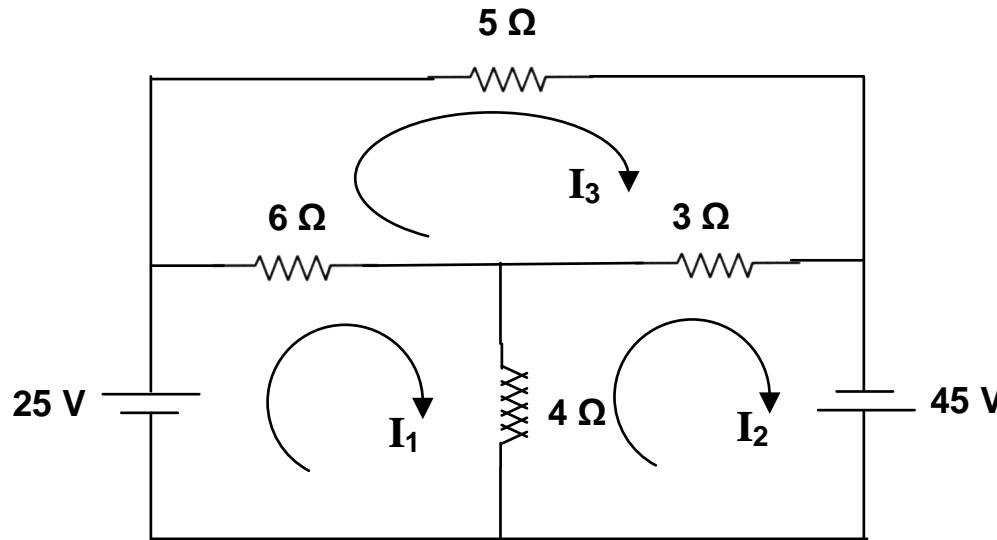
### Example 12

Find the current in  $5\ \Omega$  resistor in the circuit shown.



## Solution

Let the loop current be  $I_1$ ,  $I_2$  and  $I_3$ .



Three loops equations are:

$$6(I_1 - I_3) + 4(I_1 - I_2) - 25 = 0$$

$$4(I_2 - I_1) + 3(I_2 - I_3) - 45 = 0$$

$$5I_3 + 3(I_3 - I_2) + 6(I_3 - I_1) = 0$$

On solving

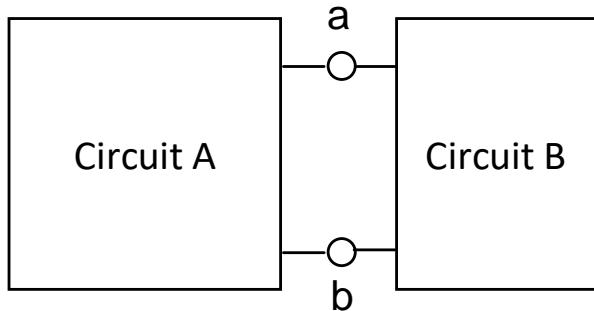
Current in 5 Ω resistor,  $I_3 = 14 \text{ A}$

# *CIRCUIT THEOREMS*

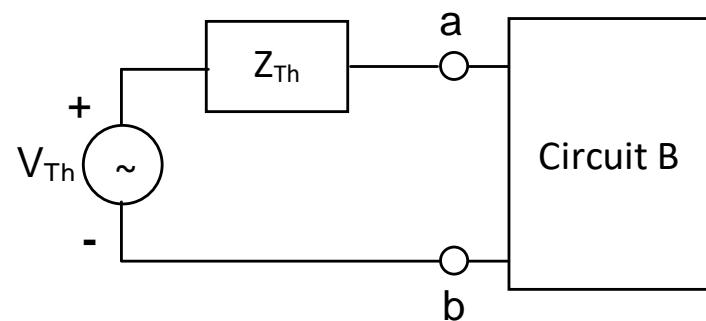
## THEVENIN'S THEOREM

In many practical applications, we may not be interested in getting the complete analysis of the circuit, namely finding the current through all the elements and voltages across all the elements. We **may be interested to know the details of a portion of the circuit; as a special case it may be a single element such as load impedance.** In such a situation it is very convenient to use Thevenin's theorem to get the solution.

Fig. illustrates the Thevenin's equivalent of sub-circuit A.

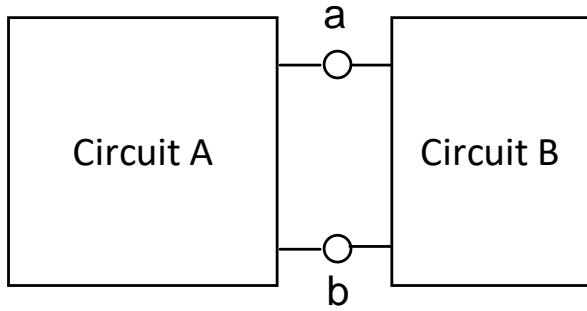


(a)

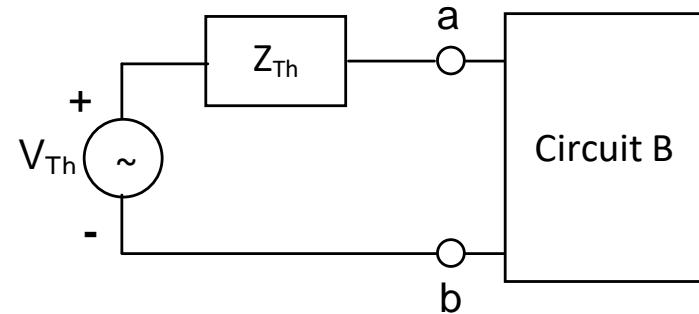


(b)

Fig. Thevenin's equivalent.



(a)



(b)

Fig. Thevenin's equivalent.

In Fig. (a) a circuit partitioned into two parts, namely circuit A and circuit B, is shown. They are connected by a single pair of terminals. In Fig.(b) circuit A is replaced by Thevenin's equivalent circuit, which consists of a voltage source  $V_{Th}$  in series with an impedance  $Z_{Th}$ .

To obtain the Thevenin's equivalent circuit, we need to find Thevenin's voltage  $V_{th}$  and Thevenin's impedance  $Z_{Th}$ . Unique procedure is available to find the Thevenin's voltage  $V_{Th}$ . When we need the Thevenin's voltage of circuit A, measure or calculate the **OPEN CIRCUIT VOLTAGE of circuit A**. This will be the Thevenin's voltage.

Thevenin's impedance can be calculated in three different ways **depending on the nature of voltage and current sources** in the circuit of our interest.

The circuit for which Thevenin's impedance is to be calculated consists of impedances and **one or more independent sources**. That is, **the circuit does not contain any dependent source**. To determine Thevenin's impedance, circuit shown in Fig. (b) is to be used.



Fig. Determining Thevenin's equivalents.

The circuit AA in Fig. (b) is obtained from circuit A by replacing all the independent voltage sources by short circuits and replacing all independent current sources by open circuits. Thus in circuit AA, all the independent sources are set to zero. Then, Thevenin's impedance is the equivalent circuit impedance of circuit AA which can be obtained using reduction techniques.

The methods of finding the Thevenin's impedance depend on the nature of the circuit for which the Thevenin's equivalent is sought for. These methods are summarized below:

Circuit with independent sources only - ANY ONE OF THE FOLLOWING

1. **Make independent sources zeros and use reduction techniques to find  $Z_{Th}$ .**
2. Short circuit terminals a and b and find the short circuit current  $I_{sc}$  flowing from a to b. Then  $Z_{Th} = V_{Th} / I_{sc}$
3. Set all independent sources to zero. Apply 1 V across the open circuited terminals a-b and determine the source current  $I_s$  entering the circuit through a. Then  $Z_{Th} = 1 / I_s$ . Alternatively introduce a current source of 1 A from b to a and determine the voltage  $V_{ab}$ . Then, Thevenin's impedance  $Z_{Th} = V_{ab}$ .

### Example 1

Find the Thevenin's voltage with respect to the load resistor  $R_L$  in circuit shown in Fig.

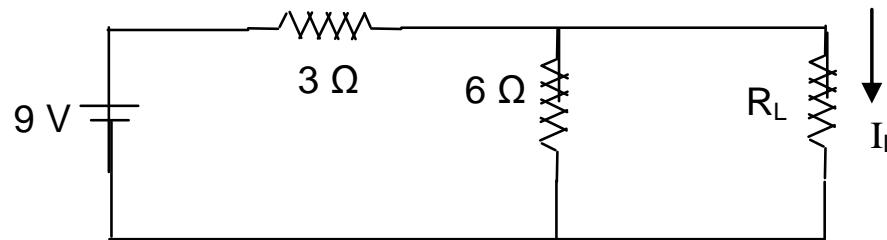
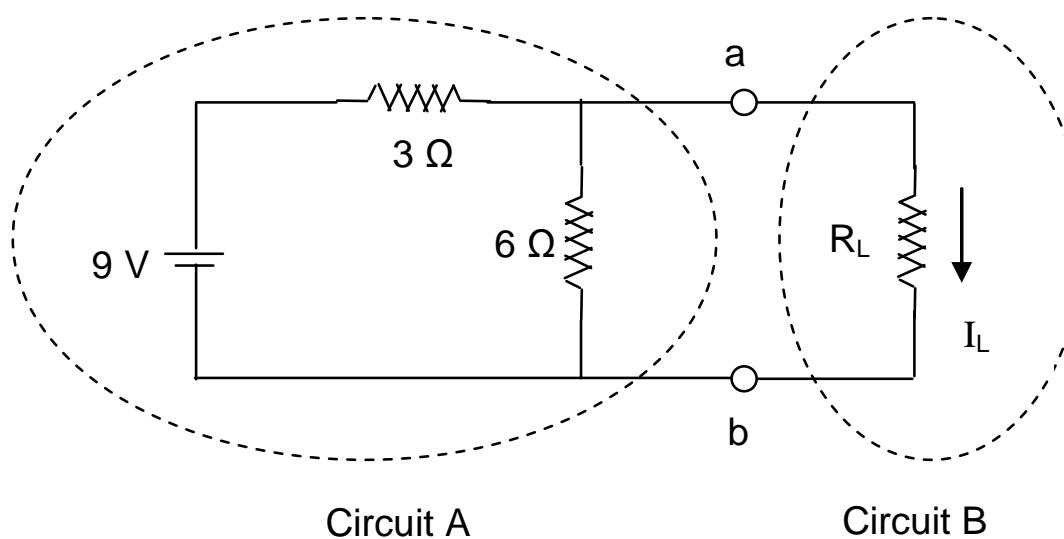
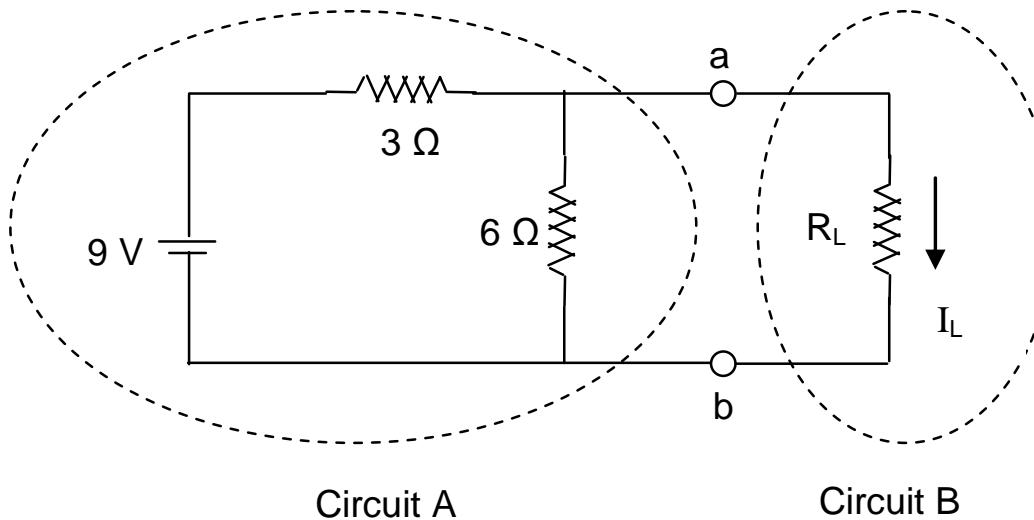


Fig. Circuit for Example1

### Solution

The given circuit can be divided into two circuits as shown in Fig.





Thevenin's voltage of circuit A can be obtained from the circuit shown in Fig.

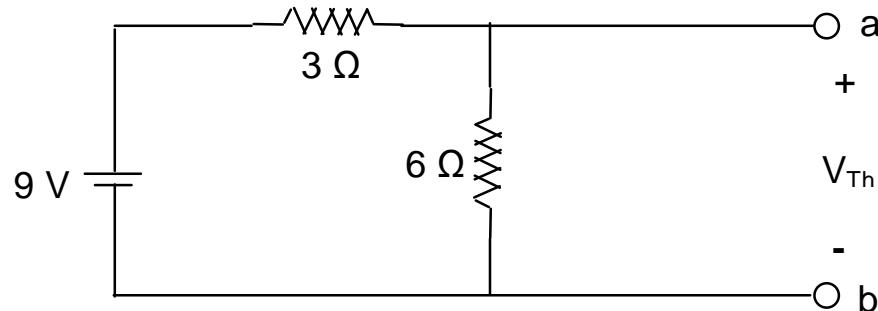


Fig. Circuit.

Using voltage division rule     $V_{Th} = V_{6\Omega} = \frac{6}{9} \times 9 = 6 \text{ V}$

## Example 2

Obtain the Thevenin's equivalent for the circuit shown in Fig.

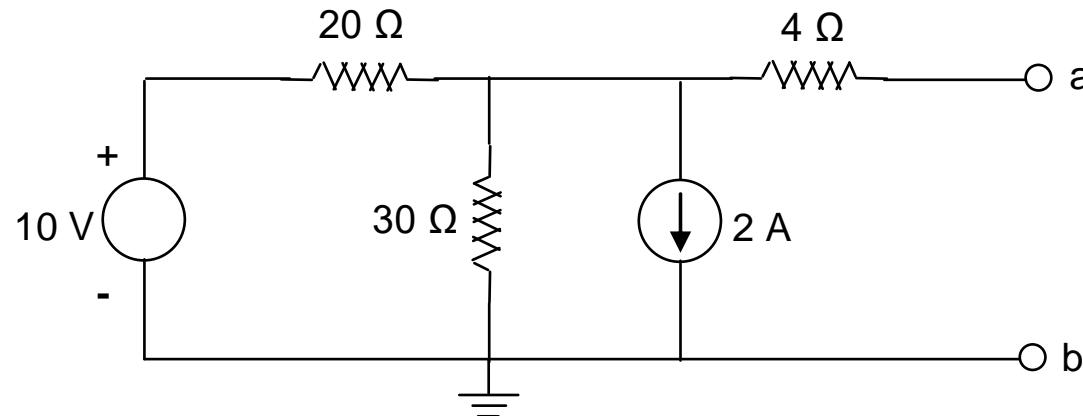


Fig. Circuit for Example 2.

Solution:

Open circuit voltage  $V_{ab}$  is the Thevenin's voltage  $V_{Th}$ .

To find Thevenin's voltage:

Note that there is no current flow in resistor of  $4 \Omega$ . Therefore, voltage  $V_{Th}$  is same as the voltage across  $30 \Omega$  resistor. Then, the node voltage equation is

$$\frac{V_{Th} - 10}{20} + \frac{V_{Th}}{30} + 2 = 0 \quad \text{On solving this, we get } V_{Th} = -18 \text{ V}$$

To find Thevenin's impedance: Since the circuit has only independent sources, it falls under case 1

Reducing the sources to zero, the resulting circuit is shown in Fig.

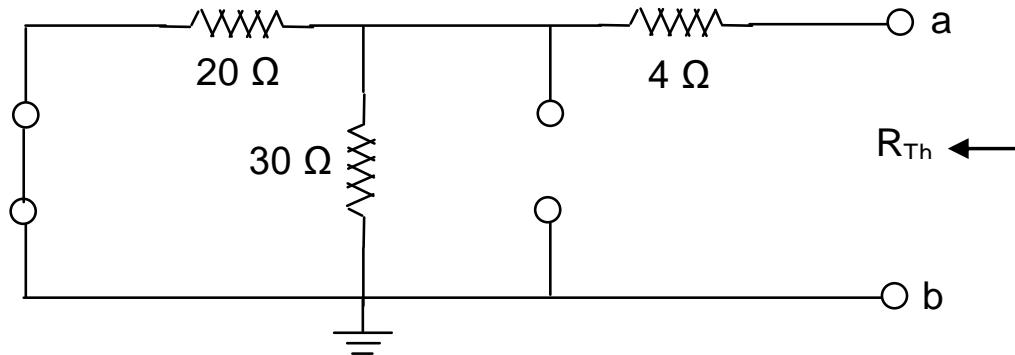


Fig. Circuit - Example 2.

Thus  $R_{Th} = 4 + 20 \parallel 30 = 16 \Omega$  Thevenin's equivalent circuit is shown in Fig.

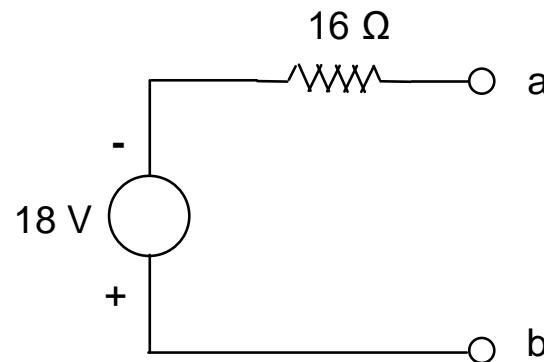
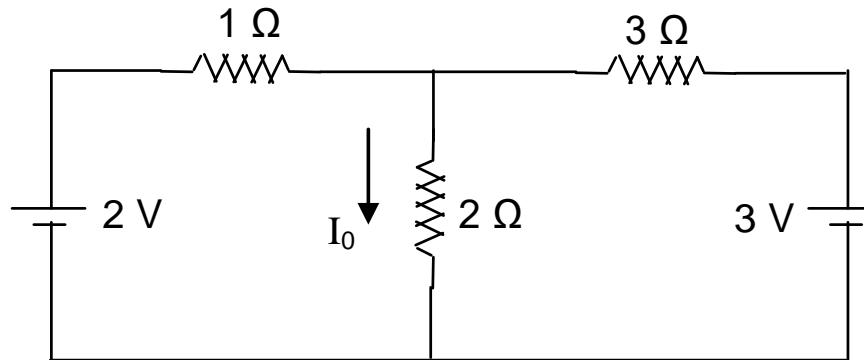


Fig. Thevenin's equivalent circuit – Example 2.

$R_{Th}$  can be obtained by two other methods also

Example 3 Using Thevenin's equivalent circuit, calculate the current  $I_0$  through the  $2\ \Omega$  resistor in the circuit shown below.



Solution: Circuit by which  $V_{Th}$  and  $R_{Th}$  can be calculated are shown in Fig.

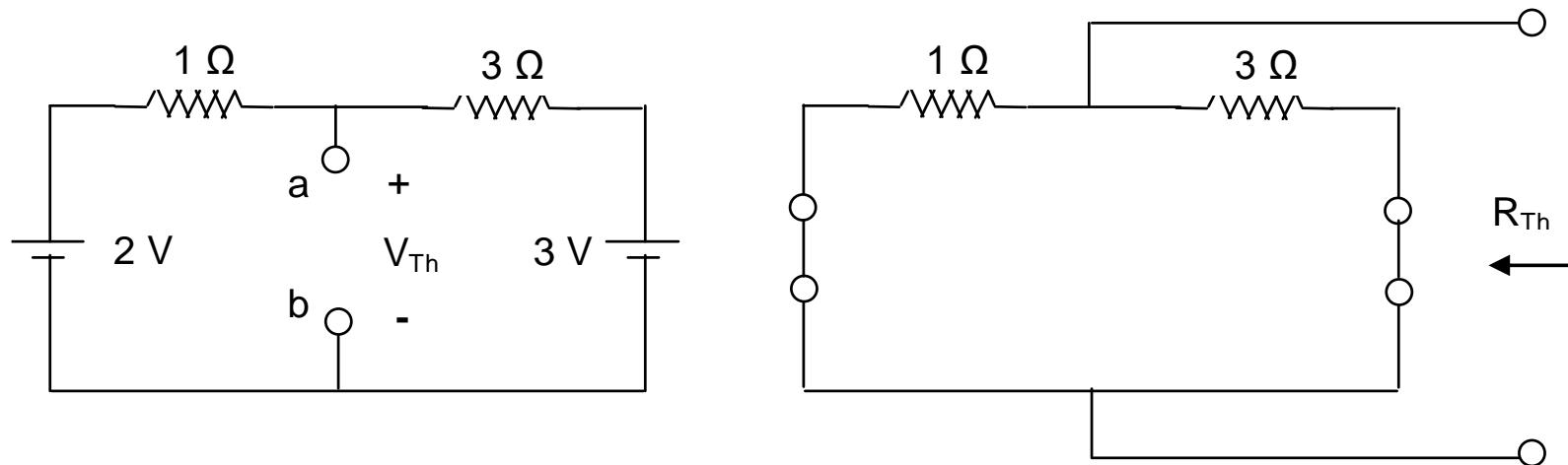
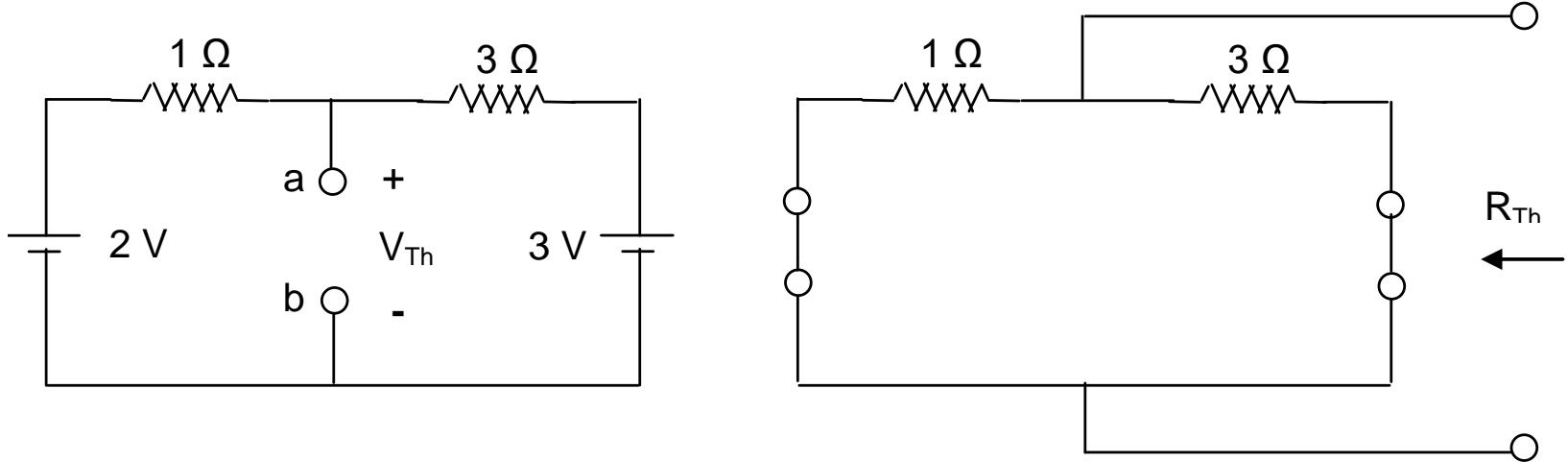


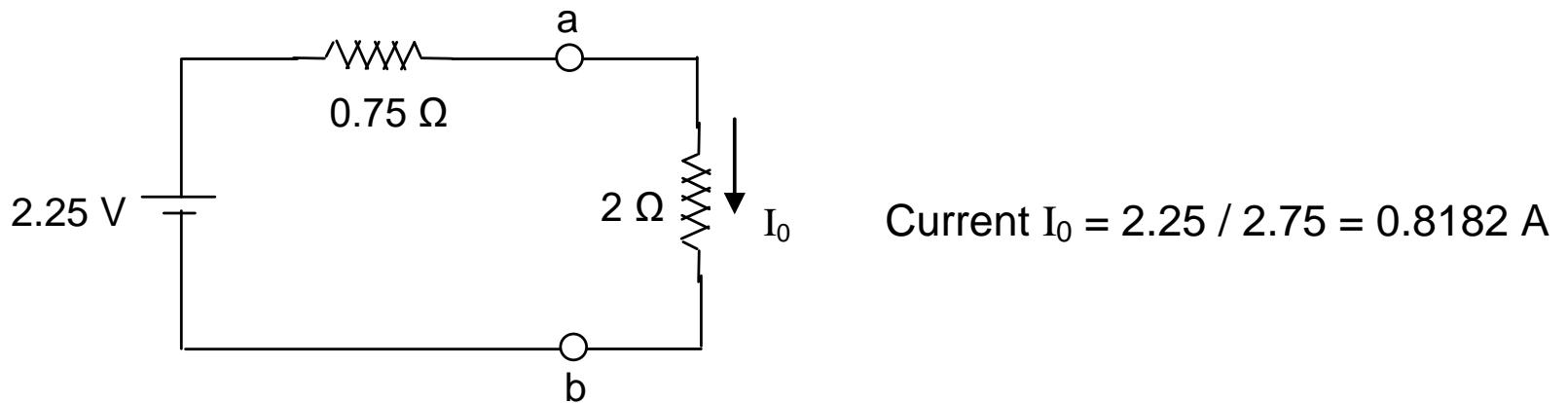
Fig. Circuits for  $V_{Th}$  and  $R_{Th}$  - Example 3.



Knowing the anticlockwise current as 0.25 A

$$-2 - (1 \times 0.25) + V_{Th} = 0. \text{ i.e. } V_{Th} = 2.25 \text{ V; Also } R_{Th} = 1 \parallel 3 = 0.75 \Omega$$

With these Thevenin's equivalent circuit becomes



## NORTON'S THEOREM

Much similar to Thevenin's theorem, Norton's theorem is also used to obtain the equivalent of two terminal sub-circuit.

Fig. illustrates the Norton's equivalent of sub-circuit A.

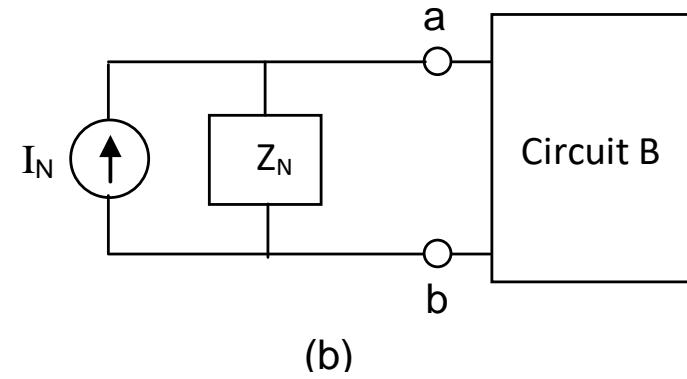
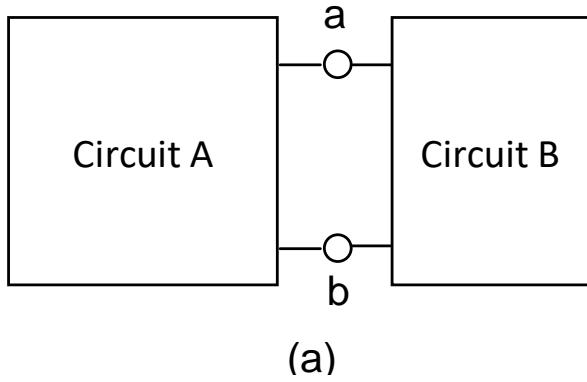
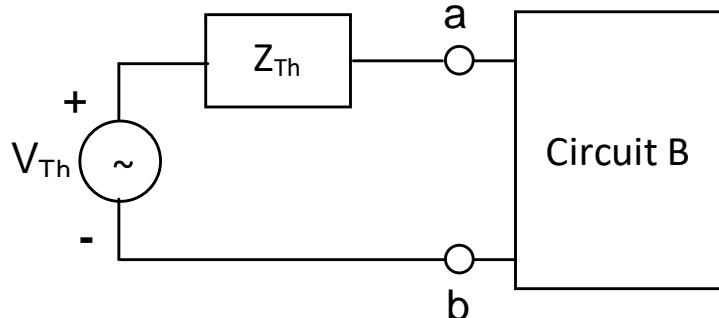


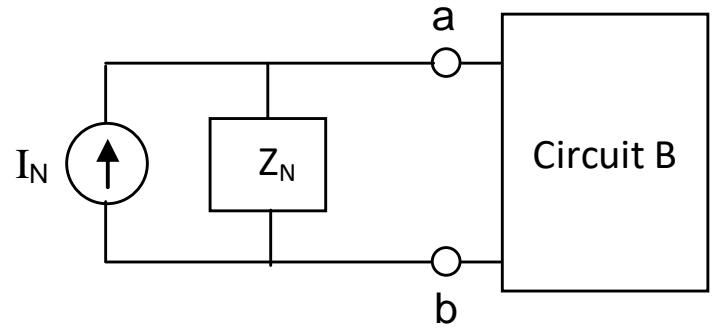
Fig. Norton's equivalent.

In Fig. (a) a circuit partitioned into two parts, namely circuit A and circuit B, is shown. They are connected by a single pair of terminals. In Fig. (b), circuit A is replaced by Norton's equivalent circuit, which consists of a current source  $I_N$  in parallel with an impedance  $Z_N$ .

Looking at the Thevenin's and Norton's equivalents shown in Fig. (a) and (b), it is clear that one can be obtained from the other through source transformation.



(a)



(b)

Fig. Thevenin's and Norton's equivalents.

It is to be noted that

$$Z_N = Z_{Th}$$

$$I_N = \frac{V_{Th}}{Z_{Th}} = \frac{V_{Th}}{Z_N}$$

To obtain Norton's equivalent circuit, we need to find current  $I_N$  and the impedance  $Z_N$ . They can be obtained from Thevenin's voltage and impedance.

Otherwise Norton's current can be obtained by finding the short circuit current as indicated in Fig.

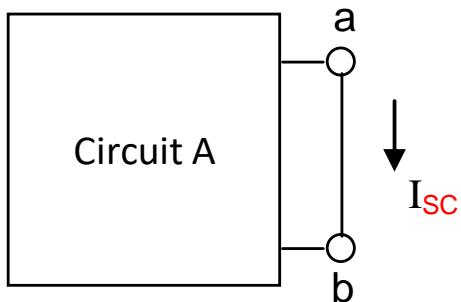


Fig. Getting short circuit current.

It is to be noted that the short circuit current is from terminal *a* to terminal *b* while Norton's current is from terminal *b* to terminal *a*.

The impedance  $Z_N$  can be got exactly same way we got  $Z_{Th}$  as discussed in previous section except that the method indicated under Case 2 is not applicable as it requires the value of  $V_{Th}$ .

## Example 1

Using Norton's theorem, determine the current through the resistor  $R_L$  when  $R_L = 0.7$ ,  $1.2$  and  $1.6 \Omega$  in the circuit shown in Fig.

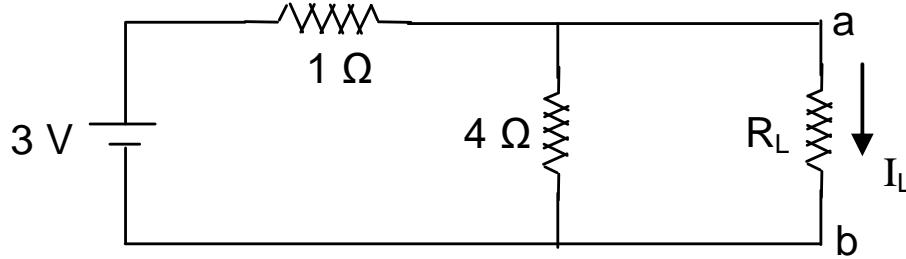


Fig. Circuit for Example 1.

## Solution:

Circuits to determine  $I_{SC}$  and  $R_N$  are shown in Fig. (a) and (b).

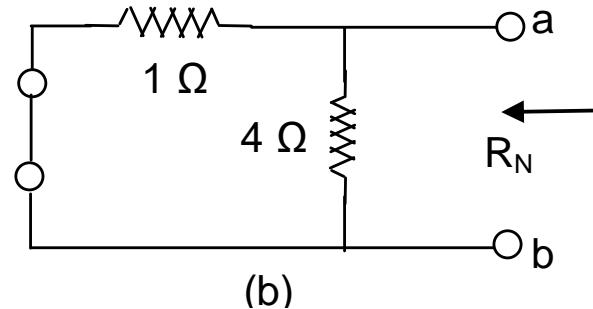
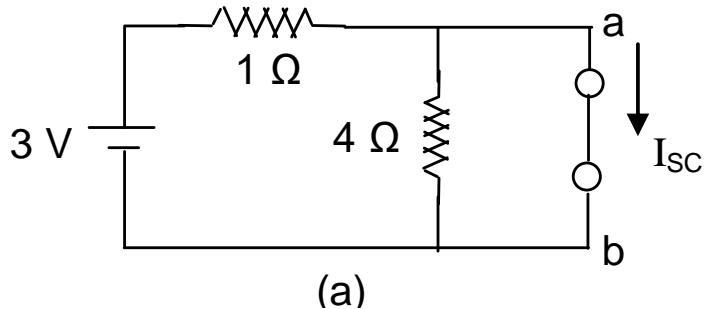
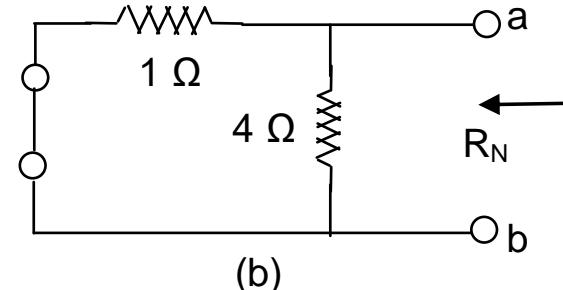
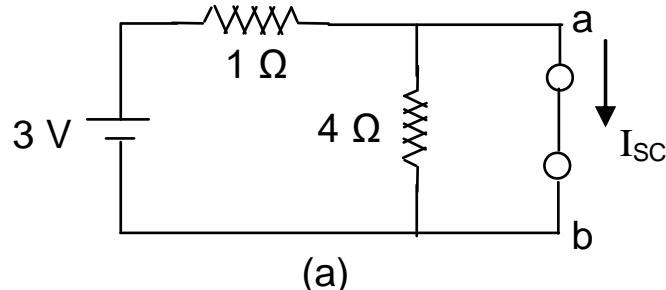


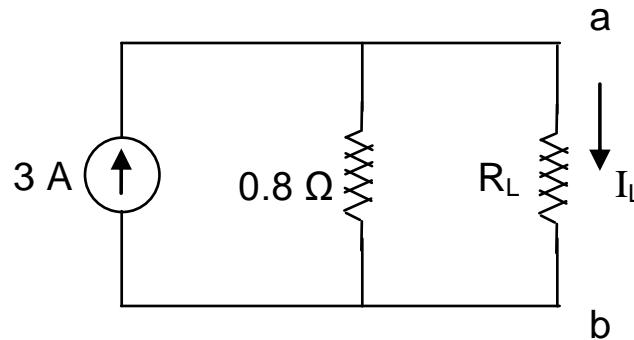
Fig. Short circuit current and Norton's resistance.



It is to be noted that since there is a short circuit parallel to  $4\ \Omega$  no current flows in it.

Norton's current  $I_N = 3\ A$ ; Norton's resistance  $R_N = 1\parallel 4 = 0.8\ \Omega$

Norton's equivalent circuit is shown in Fig.



$R_N$  can be obtained  
by another method  
also.

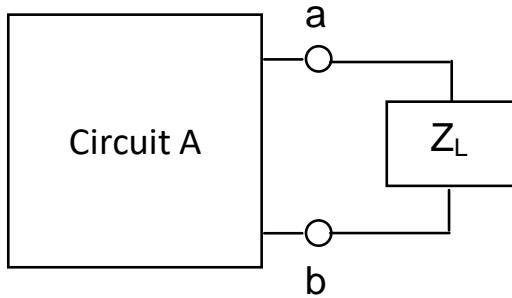
Fig. Norton's equivalent.

When  $R_L = 0.7\ \Omega$ ,  $I_L = (0.8 / 1.5) \times 3 = 1.6\ A$ ; When  $R_L = 1.2\ \Omega$ ,  $I_L = (0.8 / 2) \times 3 = 1.2\ A$

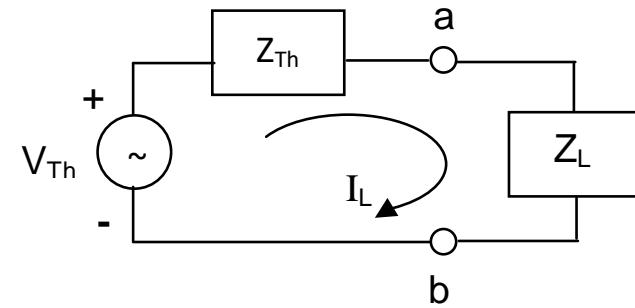
When  $R_L = 1.6\ \Omega$ ,  $I_L = (0.8 / 2.4) \times 3 = 1.0\ A$

## MAXIMUM POWER TRANSFER THEOREM

There are some applications wherein maximum power needs to be transferred to the load connected. Consider a linear ac circuit A, connected to a load of impedance  $Z_L$  as shown in Fig. (a). It is required to transfer maximum real power to the load. The circuit A can be replaced by its Thevenin's equivalent as shown in Fig. (b).



(a)



(b)

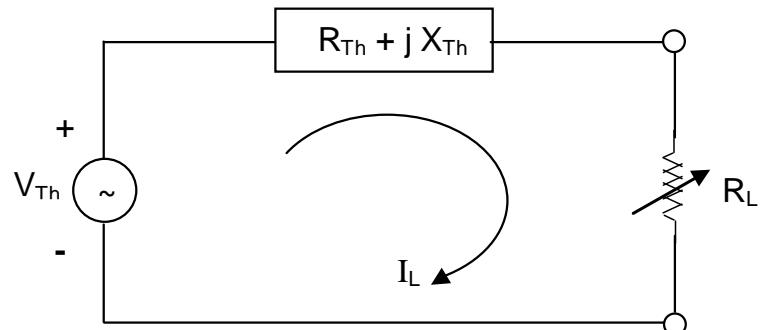
Fig. Maximum power transfer theorem - Illustration.

Let  $Z_{Th} = (R_{Th} + j X_{Th})$  and  $Z_L = (R_L + j X_L)$

The following maximum power transfer theorems determine the values of load impedance  $Z_L$  for which maximum real power is transferred to the load impedance.

Case 1:

Load is a variable resistance  $R_L$



$$\text{Load current } I_L = \frac{V_{Th}}{(R_{Th} + R_L) + jX_{Th}}$$

$$\text{This gives } |I_L| = \frac{|V_{Th}|}{\sqrt{(R_{Th} + R_L)^2 + X_{Th}^2}}$$

$$\text{Real power delivered to the load } P_L = |I_L|^2 R_L = \frac{|V_{Th}|^2 R_L}{(R_{Th} + R_L)^2 + X_{Th}^2}$$

$$\text{This can be written as } P_L = \frac{|V_{Th}|^2}{\frac{R_{Th}^2}{R_L} + 2R_{Th} + R_L + \frac{X_{Th}^2}{R_L}}$$

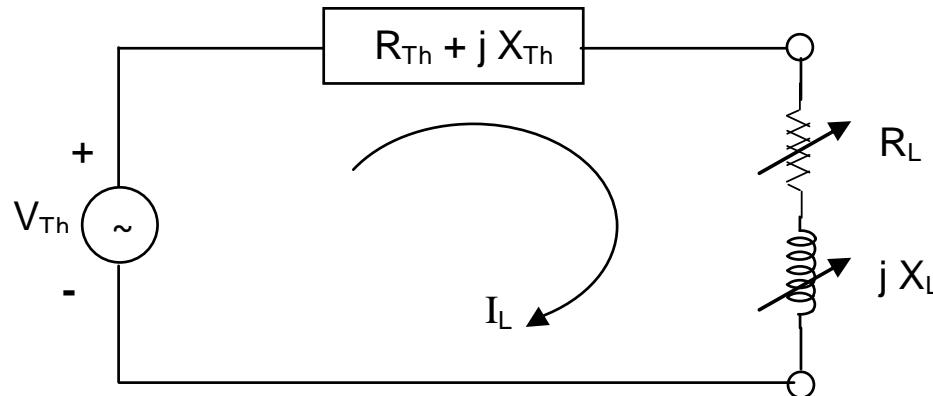
For power  $P_L$  to be maximum,  $\frac{R_{Th}^2}{R_L} + 2R_{Th} + R_L + \frac{X_{Th}^2}{R_L}$  must be minimum. Thus power  $P_L$  will be maximum when

$$\frac{d}{dR_L} \left( \frac{R_{Th}^2}{R_L} + 2R_{Th} + R_L + \frac{X_{Th}^2}{R_L} \right) = 0 \quad \text{i.e. when } -\frac{R_{Th}^2}{R_L^2} + 1 - \frac{X_{Th}^2}{R_L^2} = 0$$

$$\text{i.e. when } R_L^2 = R_{Th}^2 + X_{Th}^2 \quad \text{i.e. when } R_L = \sqrt{R_{Th}^2 + X_{Th}^2} = |Z_{Th}|$$

Using this value of  $R_L$ , the current  $I_L$  and hence maximum power can be computed.

Case 2 In the load impedance,  $R_L$  and  $X_L$  are varied independently as shown.



$$\text{Load current } I_L = \frac{V_{Th}}{(R_{Th} + R_L) + j(X_{Th} + jX_L)} \quad \text{Thus } |I_L| = \frac{|V_{Th}|}{\sqrt{(R_{Th} + R_L)^2 + (X_{Th} + X_L)^2}}$$

$$\text{Real power delivered to the load } P_L = |I_L|^2 R_L = \frac{|V_{Th}|^2 R_L}{(R_{Th} + R_L)^2 + (X_{Th} + X_L)^2}$$

If  $R_L$  in Eq. is held fixed, the value of  $P$  will be maximum when  $(X_{Th} + X_L)^2$  is minimum.

This will occur when  $X_{Th} + X_L = 0$  i.e. when

$$X_L = -X_{Th}$$

Keeping  $X_L = -X_{Th}$  Eq. becomes

$$P_L = \frac{|V_{Th}|^2 R_L}{(R_{Th} + R_L)^2} = \frac{|V_{Th}|^2}{\frac{R_{Th}^2}{R_L} + 2R_{Th} + R_L}$$

For  $P_L$  given by Eq. to become maximum,  $\frac{R_{Th}^2}{R_L} + 2R_{Th} + R_L$  must be minimum. This will

occur when  $\frac{d}{dR_L} \left( \frac{R_{Th}^2}{R_L} + 2R_{Th} + R_L \right) = 0$  i.e. when  $-\frac{R_{Th}^2}{R_L^2} + 1 = 0$  i.e. when

$$R_L = R_{Th}$$

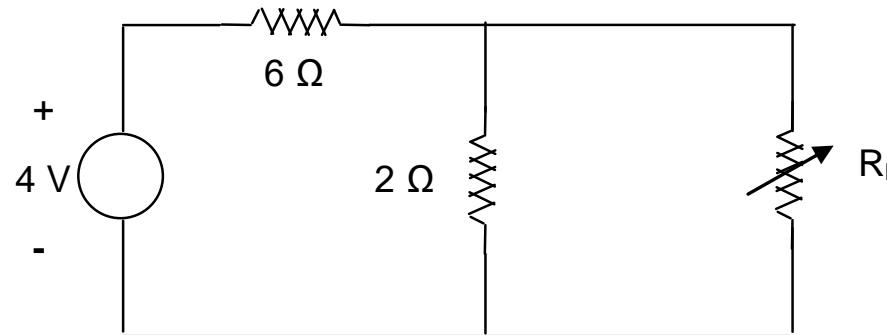
Combining Eqs. and, we can state that real power transferred to the load will be maximum when

$$Z_L = R_{Th} - j X_{Th} = Z_{Th}^*$$

Setting  $R_L = R_{Th}$  and  $X_L = -X_{Th}$  in Eq., maximum real power can be obtained as

$$P_{max} = \frac{|V_{Th}|^2}{4 R_{Th}}$$

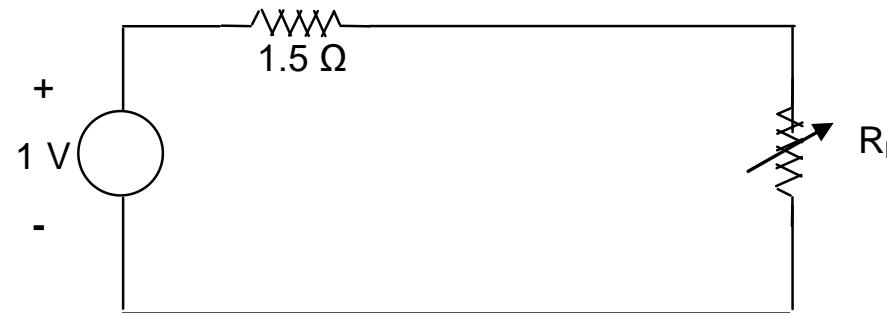
Example 1 Consider the circuit shown below. Determine the value of  $R_L$  when it is dissipating maximum power. Also find the value of maximum power dissipated.



Solution:

As a first step, Thevenin's equivalent across the load resistor is obtained.

$$V_{Th} = \frac{2}{2+6} \times 4 = 1 \text{ V}; \quad R_{Th} = 6 \parallel 2 = 1.5 \Omega \quad \text{Resulting circuit is shown.}$$



For  $P_L$  to be maximum,  $R_L = 1.5 \Omega$ ;      Then circuit current =  $1/3 = 0.3333 \text{ A}$

$$\text{Maximum power dissipated } P_{max} = 0.3333^2 \times 1.5 = 0.16667 \text{ W}$$

## SUPERPOSITION THEOREM

The idea of superposition rests on the linearity property. Superposition theorem is applicable to linear circuits having two or more independent sources.

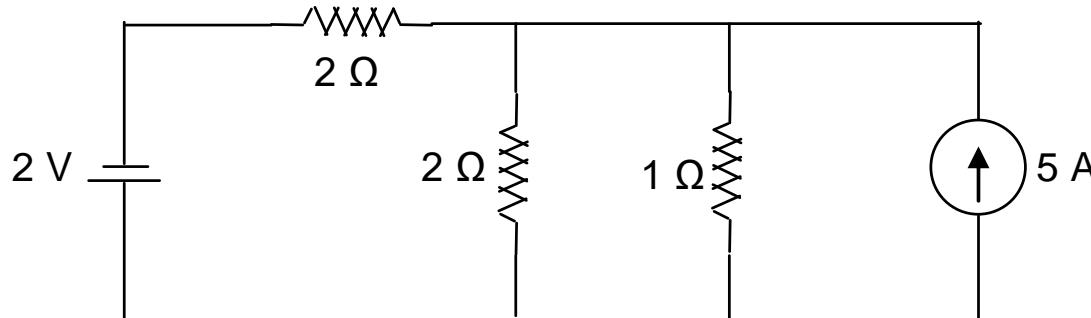
In a linear circuit having two or more independent sources, total response in an element (voltage across the element or current through the element) is equal to the algebraic sum of responses in that element due to each source applied separately while the other sources are reduced to zero.

**To make a current source to zero, it must be open circuited. Similarly, if any voltage source is to be made zero, it must be short circuited.** When this theorem is used in circuit with initial conditions, they are to be treated as sources. Further, dependent sources if any are left intact because they are controlled by circuit variables.

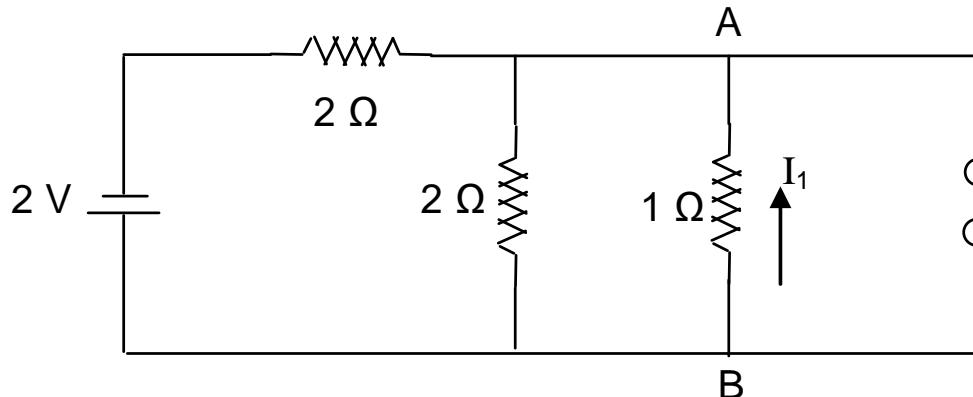
One disadvantage of analyzing a circuit using Superposition theorem is that it involves more calculations. If the circuit has three independent sources, we need to solve three simpler circuits each having only one independent source. However, when the circuit has only one independent source, several short-cut techniques can be readily applied to get the solution.

Major advantage of Superposition theorem is that it can be used to solve ac circuit having more than one source with **different frequencies**. In such case, solution in time frame is obtained corresponding to each source and added up to get the total solution.

Example 1 Calculate the current through the  $1 \Omega$  resistor in the circuit shown below.

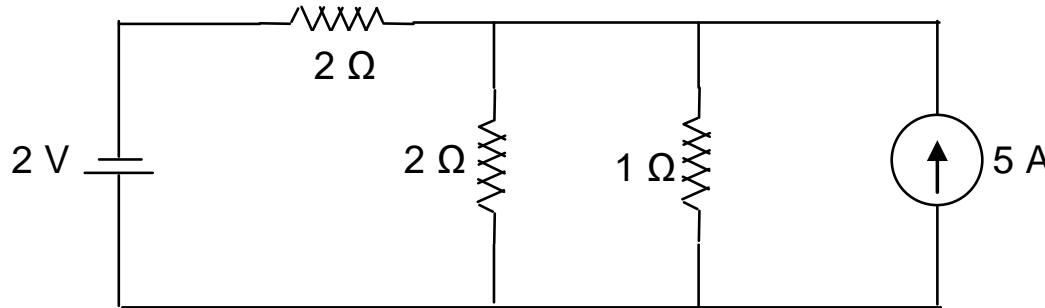


Solution: First calculate current  $I_1$  due to voltage source alone. The current source is open circuited. The resulting circuit is shown below.



$$\text{Total circuit resistance } R_T = 2.6667 \Omega. \quad \text{Circuit current } I_T = \frac{2}{2.6667} = 0.75 \text{ A}$$

$$\text{Current } I_1 = \frac{2}{3} \times 0.75 = 0.5 \text{ A} \text{ from B to A}$$



Now calculate current  $I_2$  due to current source alone. The voltage source is short circuited as shown in Fig.

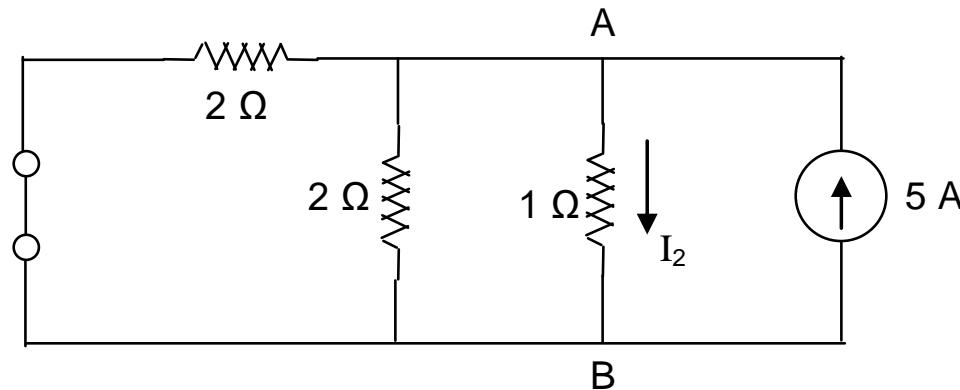


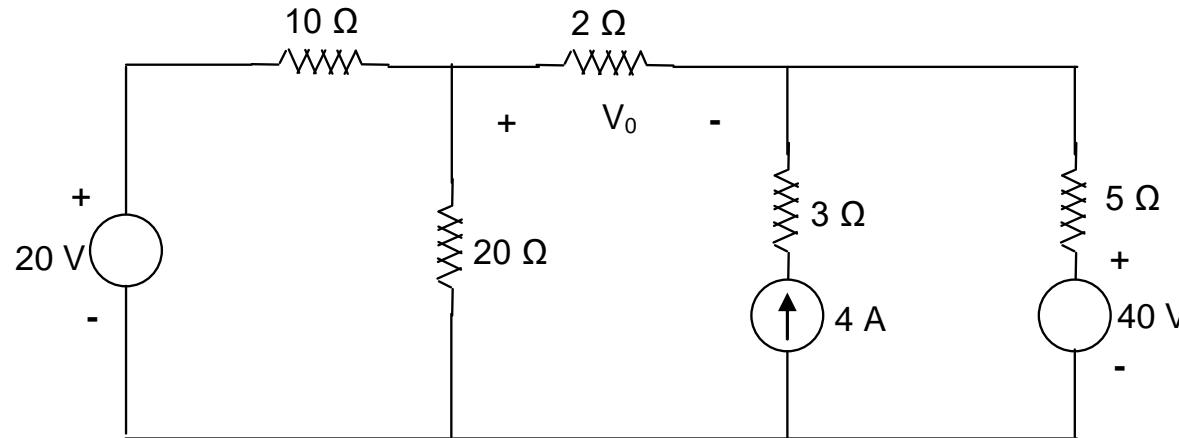
Fig. Circuit - Example 1

Noting that two  $2 \Omega$  resistors are in parallel, current  $I_2 = 2.5 \text{ A}$  from A to B.

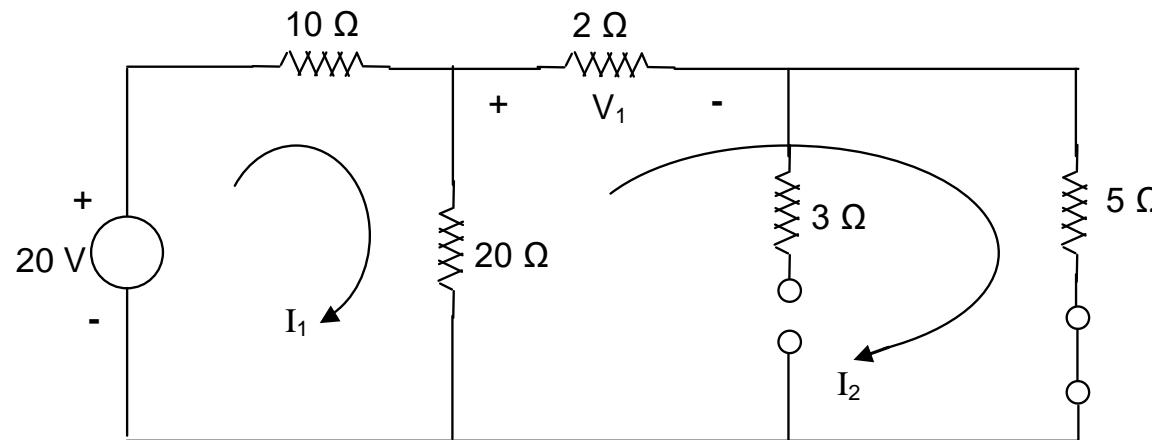
When both the sources are simultaneously present:

Current through  $1 \Omega$  resistor =  $2.5 - 0.5 = 2 \text{ A}$  from A to B.

Example 2 In the circuit shown, find the voltage drop,  $V_0$  across the  $2 \Omega$  resistor using Superposition theorem.



Solution: 20 V source alone present: The circuit will be as shown below.



Mesh current equations:

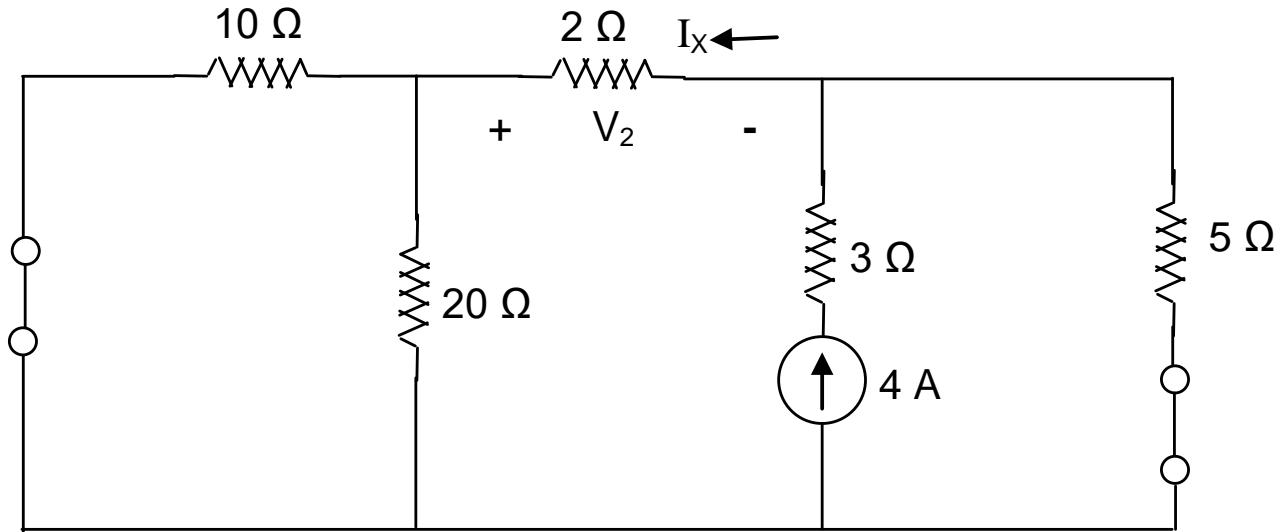
$$\begin{bmatrix} 30 & -20 \\ -20 & 27 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \end{bmatrix} = \begin{bmatrix} 20 \\ 0 \end{bmatrix}$$

On solving,  $I_2 = 0.9756 \text{ A}$

Thus voltage  $V_1 = 2 \times 0.9756 = 1.9512 \text{ V}$

4 A source alone present:

The circuit will be as shown below.



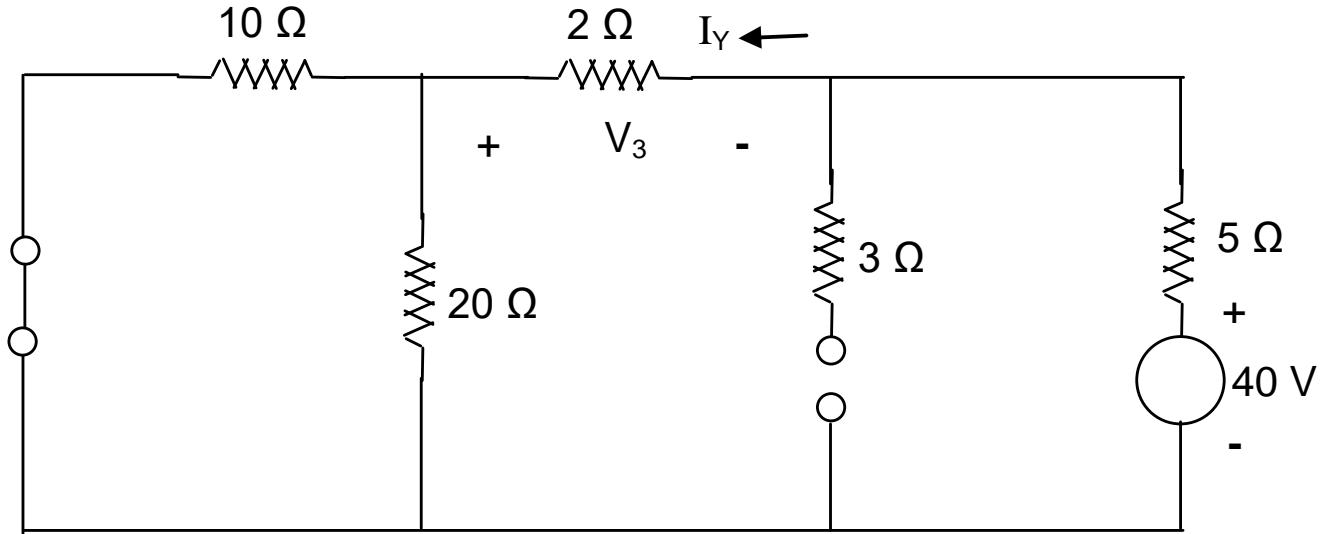
$$2 + 10 \parallel 20 = 8.6667\ \Omega$$

$$\text{Therefore current } I_X = \frac{5}{13.6667} \times 4 = 1.4634\ \text{A}$$

$$\text{Thus voltage } V_2 = -2 \times 1.4634 = -2.9268\ \text{V}$$

40 V source alone present:

Resulting circuit is shown below.



$$\text{Circuit resistance } R_T = 5 + 2 + (10 \parallel 20) = 13.6667\ \Omega$$

$$\text{Current } I_Y = 40 / 13.6667 = 2.9268\ \text{A}; \text{ Thus voltage } V_3 = -2 \times 2.9268 = -5.8537\ \text{V}$$

When all the three sources are simultaneously present,

$$\text{voltage across } 2\ \Omega, \text{ i.e. } V_0 = V_1 + V_2 + V_3 = 1.9512 - 2.9268 - 5.8537 = -6.8293\ \text{V}$$

# BEEE-UNIT 2

<i>D.C Machines &amp; A.C Machines</i>	
<b>18</b>	
<i>Sinusoids, Generation of AC, Average, RMS values, Form and peak factors</i>	<i>Sinusoids, Generation of AC, Average, RMS values, Form and peak factors</i>
<i>Analysis of single phase AC circuit, Real, Reactive, Apparent power, Power factor</i>	<i>Analysis of single phase AC circuit, Real, Reactive, Apparent power, Power factor</i>
<i>Magnetic materials, B-H Characteristics Simple magnetic circuits</i>	<i>Magnetic materials, B-H Characteristics Simple magnetic circuits</i>
<i>Faraday's laws, induced emfs and inductances.</i>	<i>Faraday's laws, induced emfs and inductances.</i>
<i>1 - phase transformers: Construction, types, ideal, practical transformer</i>	<i>1 - phase transformers: Construction, types, ideal, practical transformer</i>
<i>EMF equation, Regulation, Efficiency</i>	<i>EMF equation, Regulation, Efficiency</i>
<i>Problem Solving Session</i>	<i>Problem Solving Session</i>
<i>Lab 4: Transformer Operation, Efficiency</i>	<i>Lab 4: Transformer Operation, Efficiency</i>
<i>Construction, working of DC Generators</i>	<i>Construction, working of DC Generators</i>
<i>Types of DC generators</i>	<i>Types of DC generators</i>
<i>Characteristics of Generators</i>	<i>Characteristics of Generators</i>
<i>Armature reaction, Losses</i>	<i>Armature reaction, Losses</i>
<i>Power stages of DC generators</i>	<i>Power stages of DC generators</i>

# GENERATION OF ALTERNATIVE EMF/

## Sinusoidal emf or Sinusoidal voltage

Consider a coil of  $n$  turns placed in a magnetic field of maximum value  $\phi_m$  Webers [see Fig. 4.1 (a)]. The coil is initially along the reference axis. In this position, the field is perpendicular to the plane of the coil.

Let the coil be rotated in the anticlockwise direction with an angular velocity of  $\omega$  rad/sec.

When the coil is along the reference axis at  $\omega t = 0$ , it is called as zero e.m.f. position. This is because the movement of the coil at this instant  $\omega t = 0$  is along the field.

Let at any instant  $t$  sec. the coil takes a position as shown in Fig. 4.1(b).

At this instant, the coil makes an angle  $\theta = \omega t$  with the reference axis.

At this position, the normal component of the magnetic flux with respect to the plane of the coil is equal to

$$\phi_m \cos \theta \quad (\because \theta = \omega t)$$

The normal component =  $\phi_m \cos \omega t$

Flux linkages ( $\psi$ ) at this instant ( $y$ ) is equal to  $N\phi_m \cos \omega t$ . According to Faraday's law.

The emf induced in the coil at the instant under consideration.

$$\begin{aligned} e &= -\frac{d\psi}{dt} = \frac{-d}{dt} (N\phi_m \cos \omega t) \\ &= -N\phi_m \omega (-\sin \omega t) \\ e &= (N\phi_m \omega) \sin \omega t \end{aligned} \tag{4.1}$$

With the above expression, we can calculate the emf induced at various instants.

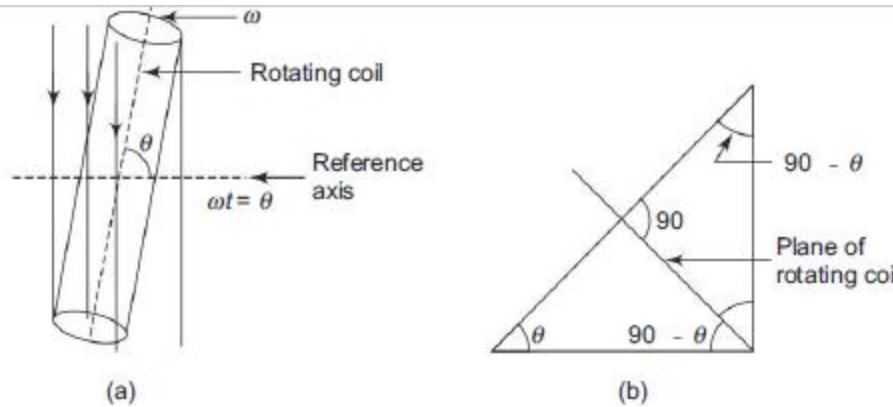


Fig. 4.1

When

$$\begin{aligned} \omega t &= 0 \quad \text{or} \quad 180^\circ \\ &= (N\phi_m \omega) \sin 0 = (N\phi_m \omega) \sin 180^\circ \end{aligned}$$

$$e = 0$$

$$\text{when } \omega t = 90^\circ \quad e = (N\phi_m \omega) \sin 90^\circ$$

$$\text{when } \omega t = 270^\circ \quad e = N\phi_m \omega \sin (270^\circ)$$

$$e = -N\phi_m \omega$$

Let  $N\phi_m \omega = E_m$  denote the maximum value of induced emf then from Eq. (4.1) we can write,

$$\text{Instantaneous emf} \quad e = E_m \sin \omega t \quad (\text{Refer Fig. 4.2}) \quad (4.2)$$

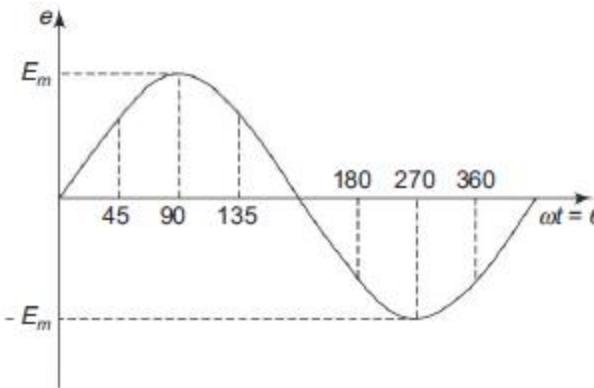


Fig. 4.2 Alternating emf wave for one complete cycle

## 4.2 TERMINOLOGY

**1. Waveform** A waveform is a graph in which the instantaneous value of any quantity is plotted against time. Examples of waveforms are shown in Fig. 4.3.

**2. Alternating Waveform** This is a wave which reverses its direction at regularly recurring intervals, e.g. Fig. 4.3(a).

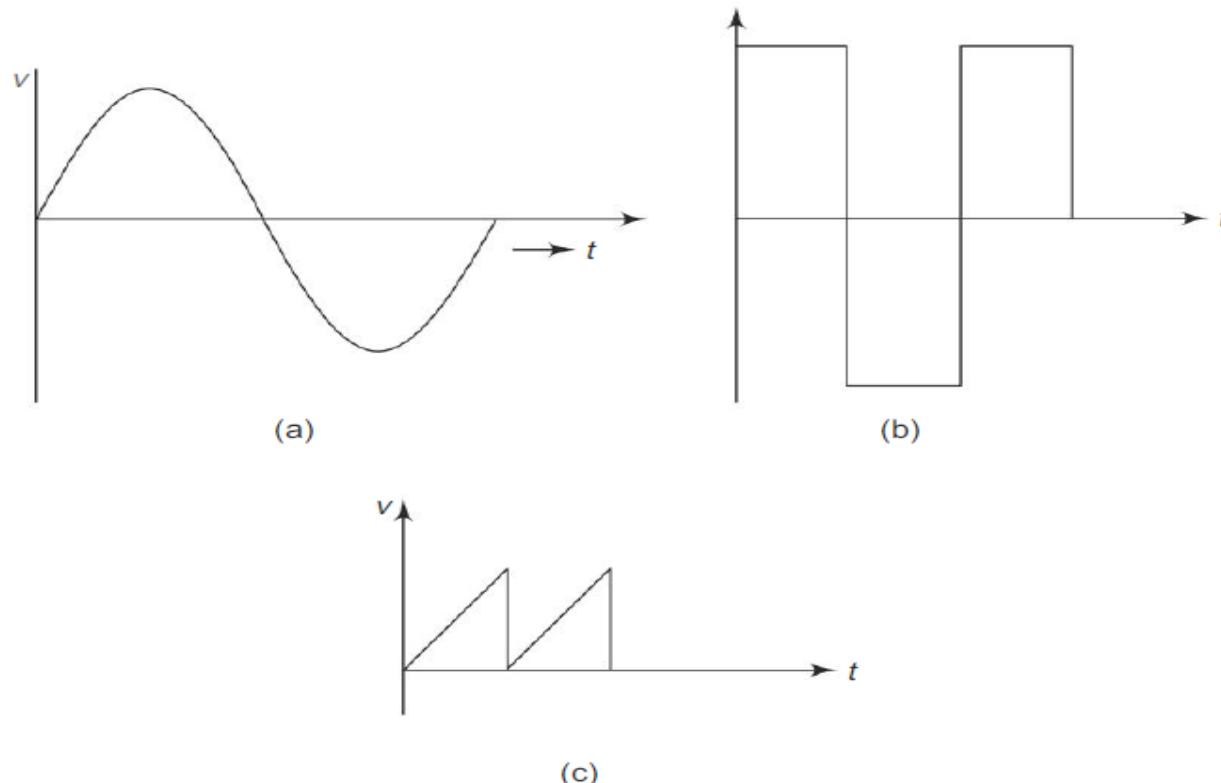


Fig. 4.3 (a) Sinusoidal waveform (b) Rectangular waveform (c) Sawtooth waveform

**3. Periodic Waveform** Periodic waveform is one which repeats itself after definite time intervals.

**4. Sinusoidal and Non-Sinusoidal Waveform**

**Sinusoidal waveform** It is an alternating waveform in which sine law is followed.

**Non-sinusoidal waveform** It is an alternating waveform in which sine law is not followed.

**5. Cycle** One complete set of positive and negative halves constitute a cycle.

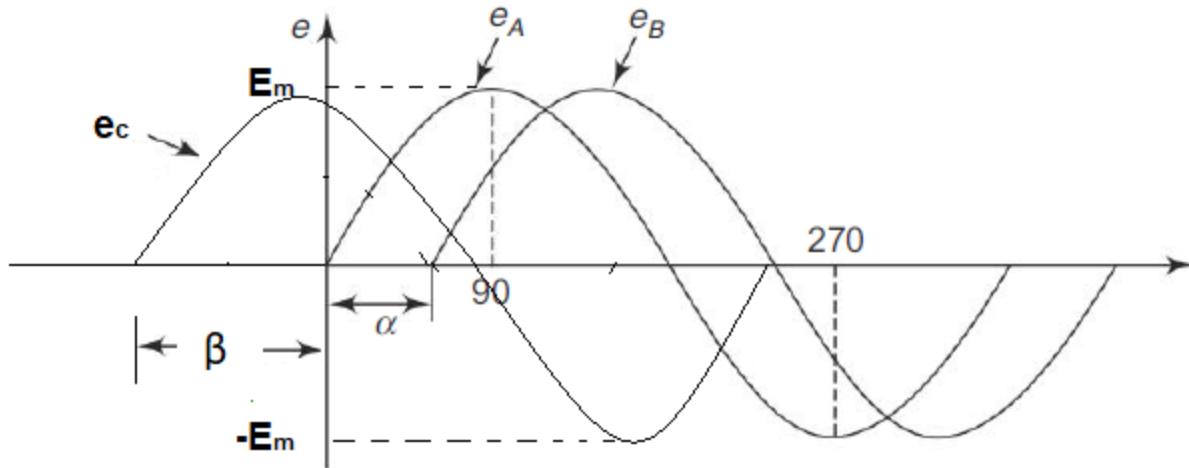
**6. Amplitude** The maximum positive or negative value of an alternating quantity is called the amplitude.

**7. Frequency** The number of cycles per second of an alternating quantity is known as frequency. Unit for frequency is expressed as c/s or Hertz (Hz).

**8. Period (T)** Time period of an alternating quantity is the time taken to complete one cycle. Time period is equal to the reciprocal of frequency. Time period is expressed in secs.

**9. Phase** The phase at any point on a given wave is the time that has elapsed since the quantity has last passed through zero point of reference and passed positively.

**10. Phase Difference** The term is used to compare the phase of two waveforms or alternating quantities.



$$e_A = E_m \sin \omega t$$

**Voltage A is reference**

$$e_B = E_m \sin (\omega t - \alpha)$$

**Voltage B lags voltage A by an angle  $\alpha$**

$$e_C = E_m \sin (\omega t + \beta)$$

**Voltage C leads voltage A by an angle  $\beta$**

# ROOT MEAN SQUARE (RMS) OR EFFECTIVE VALUE

**Definition** Effective or RMS value of an alternating current is defined by that steady value of current (dc) which when flowing in a given circuit for a given time produces the same heat as would be produced by the alternating current flowing in the same circuit for the same time.

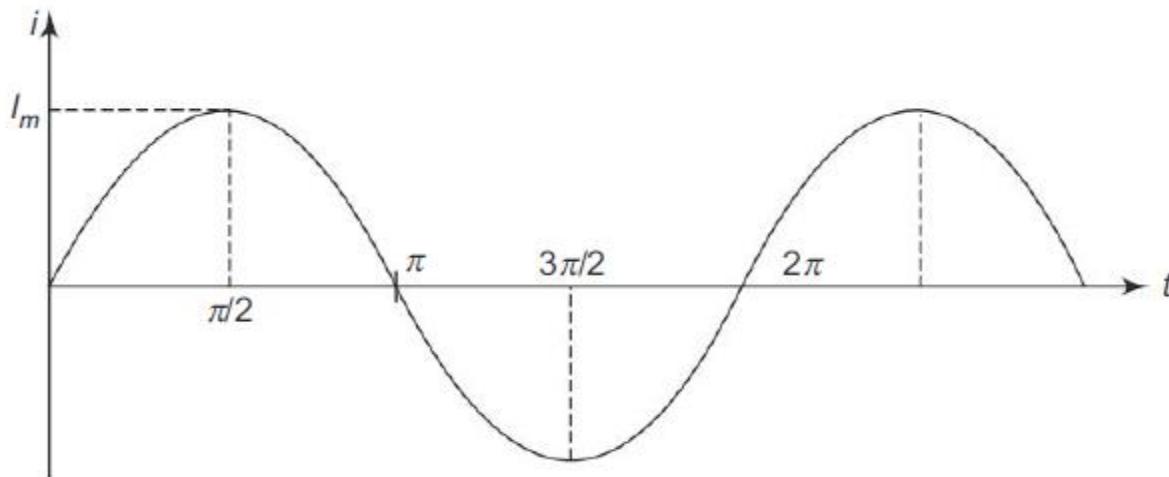
## Method to Obtain the RMS Value for Sinusoidal Currents

Let the alternating current be represented by

$$\begin{aligned} i &= I_m \sin \omega t \\ &= I_m \sin \theta \quad (\theta = \omega t) \\ i^2 &= I_m^2 \sin^2 \theta \end{aligned}$$

Mean square of

$$\begin{aligned} AC &= \int_0^{2\pi} \frac{I_m^2 \sin^2 \theta}{2\pi} d\theta \\ &= \frac{I_m^2}{2\pi} \int_0^{2\pi} \sin^2 \theta d\theta \\ &= \frac{I_m^2}{2\pi} \int_0^{2\pi} \frac{1 - \cos 2\theta}{2} d\theta \end{aligned}$$



$$\begin{aligned}
 &= \frac{I_m^2}{2\pi} \left[ \frac{\theta}{2} - \frac{\sin 2\theta}{4} \right]_0^{2\pi} \\
 &= \frac{I_m^2}{2\pi} \frac{2\pi}{2} = \frac{I_m^2}{2}
 \end{aligned}$$

RMS value of the alternating sinusoidal current is

$$I = \sqrt{\frac{I_m^2}{2}} = \frac{I_m}{\sqrt{2}} = 0.707 I_m$$

$$I_{\text{RMS}} = 0.707 I_m$$

Similarly, For a sinusoidal voltage

$$V_{\text{RMS}} = \frac{V_m}{\sqrt{2}} = 0.707 V_m$$

# AVERAGE VALUE OF AC

average value of AC

**Definition** The average value of an ac is given by that steady current which transfers across a circuit the same charge as would be transferred by the ac across the same circuit in the same time.

## Method to Obtain the Average Value for Sinusoidal Current

Let  $i = I_m \sin \theta$

Since this is a symmetrical wave it has two equal half cycles namely positive and negative halves.

Considering one half cycle for this symmetrical wave the average value is obtained by

$$\begin{aligned}I_{av} &= \frac{1}{\pi} \int_0^{\pi} i d\theta = \frac{1}{\pi} I_m \sin \theta d\theta \\&= \frac{I_m}{\pi} (-\cos \theta) \Big|_0^\pi \\&= \frac{I_m}{\pi} (1 + 1) = \frac{I_m}{\pi} \times 2 \\I_{av} &= \frac{2 I_m}{\pi}\end{aligned}$$

$$I_{av} = 0.637 I_m$$

where  $I_m$  is the maximum value of current.

For a sinusoidal voltage wave,

$$V_{av} = 0.637 V_m.$$

**Form Factor and Peak Factor** The relation between average, RMS and maximum values can be expressed by two factors namely form factor and peak factor. Form factor ( $K_f$ ): Form factor is defined as the ratio of RMS value to the average value.

i.e. Form factor =  $\frac{\text{RMS value}}{\text{Average value}}$

Peak factor or Cost factor) ( $K_p$ ): Peak factor is defined as the ratio of peak value to the R.M.S. value.

i.e. Peak factor =  $\frac{\text{Peak value}}{\text{RMS value}}$

For a sinusoidal wave,

$$\text{Form factor } (K_f) = \frac{0.707 I_m}{0.637 I_m} = 1.11$$

$$\text{Peak factor } (K_p) = \frac{I_m}{I_m/\sqrt{2}} = \sqrt{2} = 1.414.$$

# ANALYSIS OF AC CIRCUIT

1. Real power / True power / Average power/ Power }  $P = VI \cos \Phi$  or  $P = V_{\text{RMS}} I_{\text{RMS}} \cos \Phi$   $P = |V| |I| \cos \Phi$   $P = I^2 R$
- Unit: Watts

Where  $\Phi$  Angle between voltage and current

2. Reactive Power  $Q = VI \sin \Phi$   $Q = V_{\text{RMS}} I_{\text{RMS}} \sin \Phi$
- Unit: VAR

3. Apparent power  $S = VI$   
 $S = \sqrt{P^2 + Q^2}$
- Unit : VA

4. Power Factor =  $\cos \Phi$
- $$= \frac{R}{|Z|}$$
- No Unit

Where  $\Phi$  Angle between voltage and current

$$\text{Where } |Z| = \sqrt{R^2 + (X_L - X_C)^2}$$

# ANALYSIS OF AC CIRCUIT

The response of electric circuits to alternating current can be studied by passing an alternating current through the basic circuit elements resistor ( $R$ ), inductor ( $L$ ) and capacitor ( $C$ ).

## 1 Pure Resistive Circuit

Let the sinusoidal voltage applied across the resistance be

$$v = V_m \sin \omega t$$

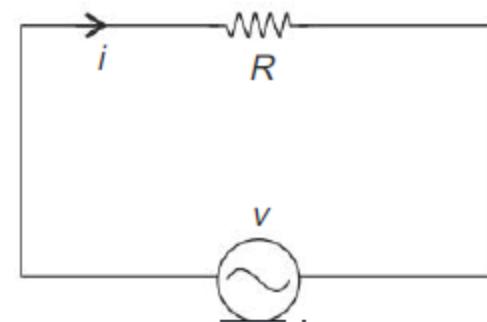
The resulting current has an instantaneous value,  $i$ . By Ohm's law,

$$i = I_m \sin \omega t$$

$$\text{where } I_m = \frac{V_m}{R}$$

### Phasor Representation

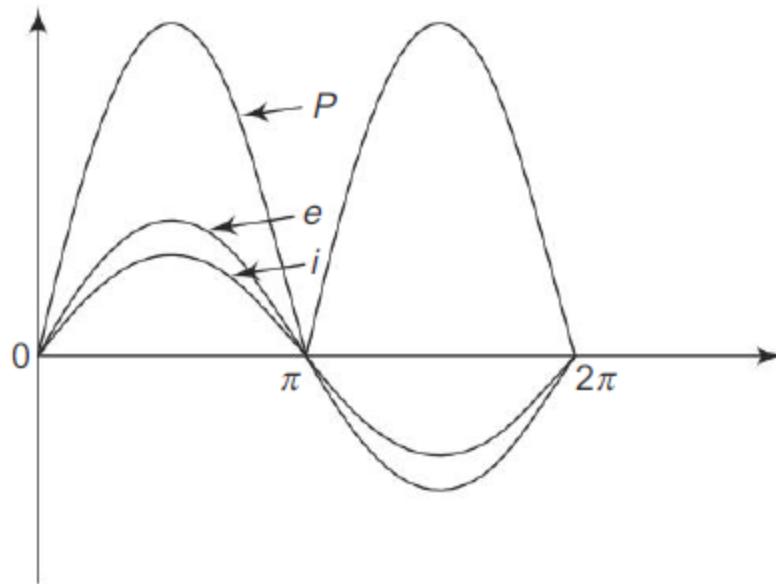
In a pure resistive circuit, there is no phase difference between the voltage applied and the resulting current, i.e. the phase angle  $\phi = 0$ . If the voltage is taken as the reference phasor, the phasor representation for voltage and current in a pure resistive circuit is given in Fig.



$$\xrightarrow{\hspace{1cm}} \quad V = IR$$

$|$

## Waveform Representation



**Power Factor** It is the cosine of the phase angle between voltage and current  
 $\cos \phi = \cos 0 = 1$  (unity)

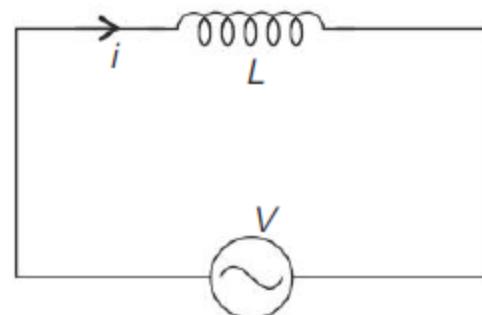
## 2. Pure Inductive Circuit

Consider the circuit of Fig. (4.16). In this circuit, an alternating voltage is applied across a pure inductor of self inductance  $L$  Henry.

Let the applied alternating voltage be

$$v = V_m \sin \omega t$$

We know that the self induced emf always opposes the applied voltage.

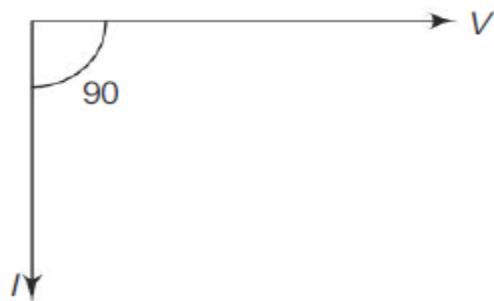


$$v = L \frac{di}{dt}$$

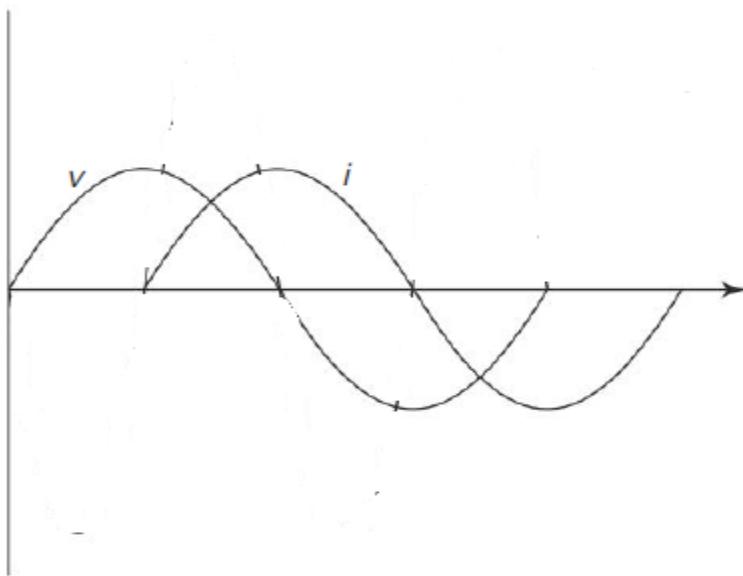
$$\therefore i = \frac{1}{L} \int v dt = I_m \sin(\omega t - \pi/2)$$

we can say that the current through an inductor lags the applied voltage by  $90^\circ$ .

**Phasor Representation** Taking the voltage phasor as reference, the current phasor is shown to lag the voltage by  $90^\circ$  (Fig. 4.18).



**Waveform Representation** The current waveform is lagging behind the voltage waveforms by  $90^\circ$ .



Since  $\phi = 90^\circ$  Real power  $P=0$

The pure inductor does not consume any real power

**Power Factor** In a pure inductor the phase angle between the current and the voltage phasors is  $90^\circ$ .

i.e.  $\phi = 90^\circ$ ;  $\cos \theta = \cos 90^\circ = 0$

Thus the power factor of a pure inductive circuit is zero lagging.

### 3 Pure Capacitive Circuit

Consider the circuit of Fig. 4.19 in which a capacitor of value  $C$  Farad is connected across an alternating voltage source.

Let the sinusoidal voltage applied across the capacitance be

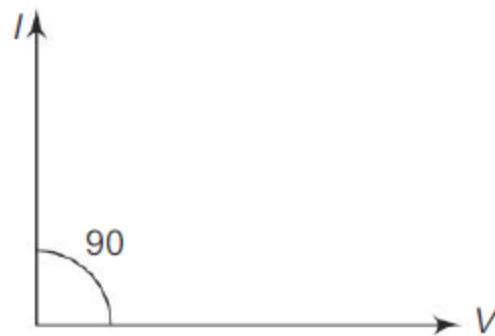
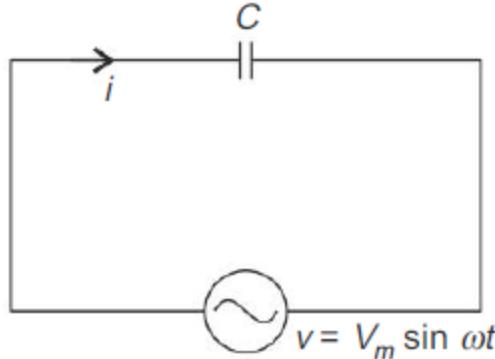
$$v = V_m \sin \omega t$$

The characteristic equation of a capacitor is

$$V = \frac{1}{C} \int i dt$$

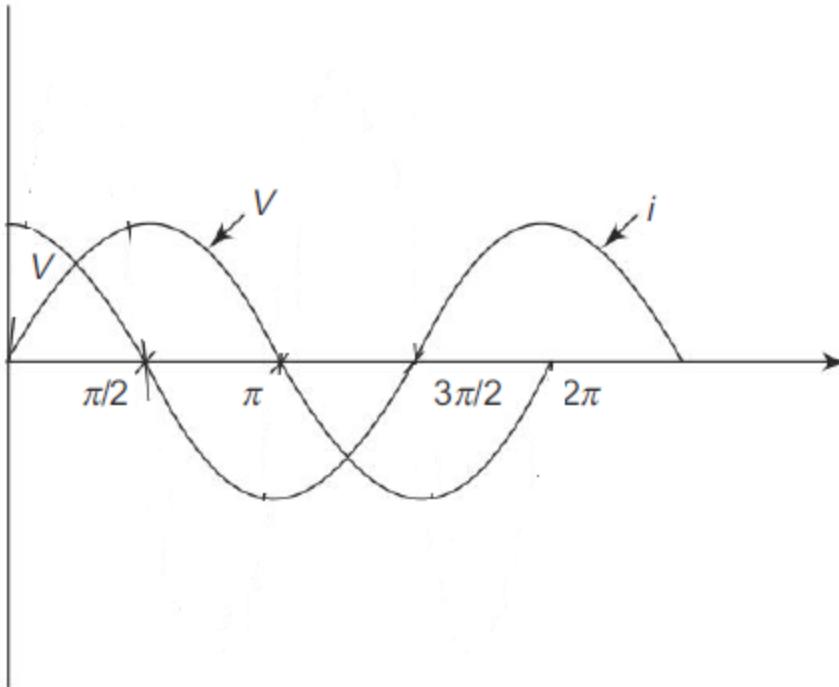
$$i = I_m \sin (\omega t + 90)$$

The current in a pure capacitor leads the applied voltage by an angle of  $90^\circ$ .

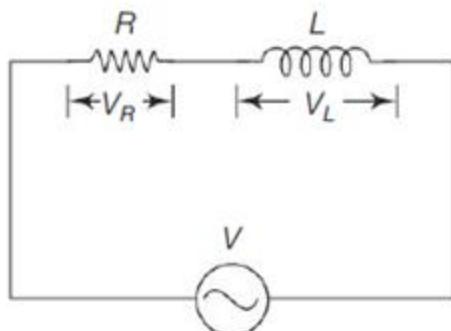


**Phasor Representation** In the phasor representation, voltage phasor is taken as the reference. The current phasor leads an angle of  $90^\circ$

**Waveform Representation** The current waveform is ahead of the voltage waveform by an angle of  $90^\circ$ .



## 4 R-L SERIES CIRCUIT



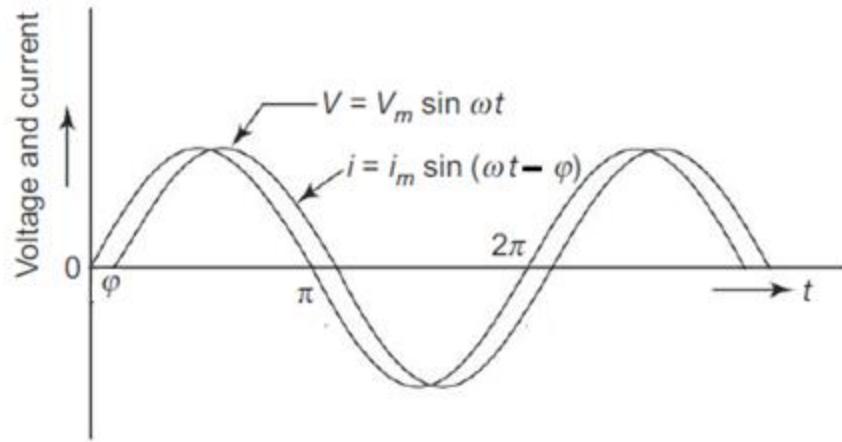
Let  $v = V_m \sin \omega t$  be the applied voltage

then the current equation is

Waveform

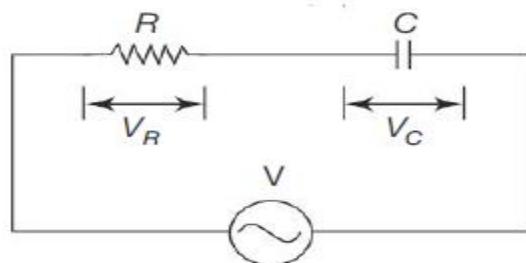
$$i = I_m \sin (\omega t - \phi)$$

Phasor



The current  $I$  lags Voltage  $V$  by an angle  $\varphi$

## 5 R-C SERIES CIRCUIT

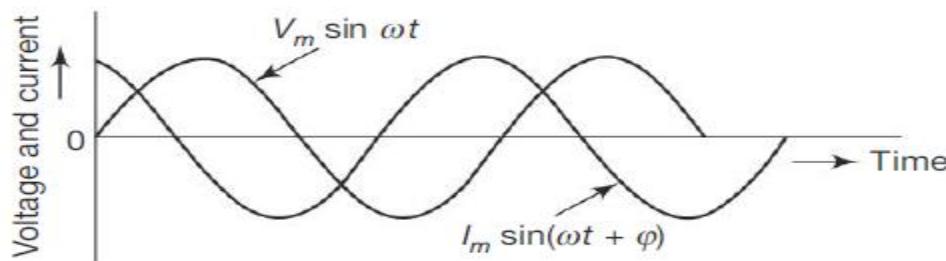


Let

$$v = V_m \sin \omega t \text{ be the applied voltage}$$

Then the current equation is  $i = I_m \sin (\omega t + \phi)$

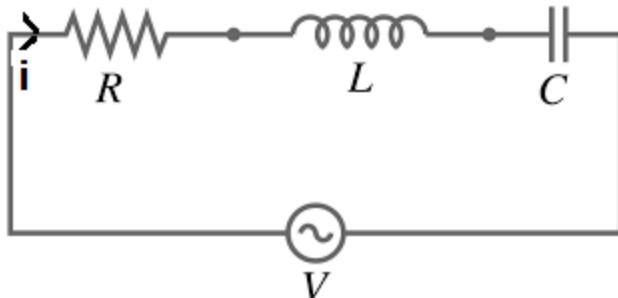
### Waveform



### Phasor



## 6. R-L-C SERIES CIRCUIT



Depends upon the value of  $X_L$  and  $X_C$ , the circuit behaves

If  $X_L > X_C$ , then the circuit behaves as RL circuit

If  $X_L < X_C$ , then the circuit behaves as RC circuit

$$\text{Impedance } Z = R + j X_L - j X_C \quad \text{Unit: } \Omega$$

or

$$Z = R + j(X_L - X_C)$$

Where  $i$  or  $j = \sqrt{-1}$

$$X_L = 2\pi fL \quad \text{Unit: } \Omega$$

$$X_C = \frac{1}{2\pi fC} \quad \text{Unit: } \Omega$$

f-Supply Frequency in Hz

## PROBLEMS

- 1 A voltage  $100 \sin \omega t$  is applied to a 10-ohm resistor. Find the instantaneous current, the **current (rms)** and the average power.

**Solution:** **V Or**  $e = 100 \sin \omega t$

$$R = 10 \text{ ohms}$$

$$i = e/R = 100/10 \sin \omega t = 10 \sin \omega t \text{ A}$$

$$I_{\text{rms}} = I_m / \sqrt{2}$$

$$= 10 / \sqrt{2}$$

$$= 7.07 \text{ A}$$

$$P = VI \cos \phi$$

$$= \frac{100}{\sqrt{2}} \times \frac{10}{\sqrt{2}} \times \cos 0$$

$$= 500 \text{ Watts}$$

2. A voltage  $v = 340 \sin 314t$  is applied to a circuit and the resulting current,  $i = 42.5 \sin 314t$ . Identify and hence find the values of the component. Find the value of power consumed.

Solution:  $v = 340 \sin 314t = \frac{340}{\sqrt{2}} |0| \text{ Volts} = 240 |0| \text{ Volts}$

$$i = 42.5 \sin 314 t = \frac{42.5}{\sqrt{2}} |0| \text{ Amps} = 30 |0| \text{ Amps}$$

From the above voltage and current equations, we find that they are in phase with each other. That is angle between  $V$  and  $I$  is  $0^\circ$ . Hence, the basic component connected in the circuit must be resistor.

Note

$$R = V / I$$

$$= 240.4 / 30$$

$$= 8 \Omega$$

$$V_{\text{rms}} = |V| = V$$

$$P = VI \cos \Phi$$

$$= 240. \times 30 \times \cos 0^\circ$$

$$= 7200 \text{ Watts}$$

$$P = I^2 R$$

$$= 30 \times 30 \times 8$$

$$= 7200 \text{ Watts}$$

**3** In a series circuit containing pure resistance and pure inductance, the current and voltage expressed as  $i(t) = 5 \sin(314t + 2\pi/3)$  and  $V(t) = 20(314t + 5\pi/6)$ .

- (i) What is the impedance of the circuit?
- (ii) What are the values of resistance, inductance and power factor?
- (iii) What is the average power drawn by the circuit?

**Solution**

$$v(t) = 20 \sin(314t + 5\pi/6)$$

$$i(t) = 5 \sin(314t + 2\pi/3)$$

$$\text{Phase angle of voltage} = \frac{5\pi}{6} \text{ radians} = 5 \times \frac{180^\circ}{6} = 150^\circ$$

$$\text{Phase angle of current} = \frac{2\pi}{3} \text{ radians} = 2 \times \frac{180^\circ}{3} = 120^\circ$$

$$V = \frac{20}{\sqrt{2}} \angle 150^\circ \text{ Volts} = 14.14 \angle 150^\circ \text{ Volts}$$

$$I = \frac{5}{\sqrt{2}} \angle 120^\circ \text{ Amps} = \text{Amps}$$

Current lags the voltage by  $150^\circ - 120^\circ = 30^\circ$ .  
Lagging p.f. means that it is an R-L circuit.

$$Z = V / I$$

$$= \frac{14.14 \angle 150^\circ}{3.53 \angle 120^\circ} = 3.46 + j 2 \text{ Ohms}$$
$$= R + j X_L$$

Therefore  $R = 3.46 \text{ Ohms}$

$X_L = 2 \text{ Ohms}$

$$X_L = 2 \text{ Ohms}$$

$$\omega L = 2 \text{ Ohms}$$

$$314L = 2 \text{ Ohms}$$

$$\omega = 314 \text{ rad/s [given]}$$

$$\begin{aligned} L &= 2/314 \\ &= 6.36 \text{ mH} \end{aligned}$$

$$\text{Power Factor} = \cos \phi$$

$$= \cos 30$$

$$= 0.866 \text{ [LAGGING]}$$

$$\text{Average Power } P = VI \cos \phi$$

$$= 14.14 \times 3.53 \times \cos 30$$

$$= 43.22 \text{ Watts}$$

$$P = I^2 R$$

$$= 3.53^2 \times 3.46$$

$$= 43.22 \text{ Watts}$$

4.

Find the circuit constants of a two element series circuit which consumes 700 W with 0.707 leading p.f. The applied voltage is  $V = 141.4 \sin 314 t$ .

### Solution

$$v = 141.4 \sin 314t$$

$$P = 700 \text{ W}, \quad \text{p.f.} = 0.707 \text{ leading}$$

Leading p.f. means  $R-C$  circuit

Max. value of supply voltage = 141.4 V

$$\text{R.M.S. value of supply voltage} = \frac{141.4}{\sqrt{2}} = 99.98 \text{ V}$$

$$\cos \phi = 0.707 \text{ leading}; \quad \text{Power} = VI \cos \phi$$

$$700 = 99.98 \times I \times 0.707; \quad I = 9.9 \text{ A}$$

Impedance  $|Z| = \frac{V}{I} = \frac{99.98}{9.9} = 10.09 \text{ ohms}$

$$\cos \phi = \frac{R}{|Z|} \Rightarrow R = |Z| \cos \phi$$

$$R = 10.09 \times 0.707 = 7.13 \Omega$$

$$X_C = \sqrt{Z^2 - R^2} = \sqrt{10.09^2 - 7.13^2} = 7.13 \text{ ohms}$$

$$\frac{1}{\omega C} = 7.13; \quad \frac{1}{314 \times C} = 7.13 \Rightarrow C = \frac{1}{314 \times 7.13}$$

$$C = 4.466 \times 10^{-4} \text{ F}$$

$$= 446.6 \times 10^{-6} \text{ F}$$

$$C = 446.6 \mu\text{F}$$

**ANOTHER METHOD IN NEXT PAGE**

ANOTHER METHOD

$$v = 141.4 \sin 314t$$

$$P = 700 \text{ W}, \quad \text{p.f.} = 0.707 \text{ leading}$$

Leading p.f. means  $R-C$  circuit

Max. value of supply voltage = 141.4 V

$$\text{R.M.S. value of supply voltage} = \frac{141.4}{\sqrt{2}} = 99.98 \text{ V}; \quad v = 99.98 \angle 0^\circ \text{ V}$$

$$\cos \phi = 0.707 \text{ leading}; \quad \text{Power} = VI \cos \phi$$

$$700 = 99.98 \times I \times 0.707; \quad I = 9.9 \text{ A}; \quad I = 9.9 \angle 45^\circ \text{ A}$$

Impedance

$$Z = v / I$$

Since Current is leading, it is  $+45^\circ$

$$= \frac{99.98 \angle 0^\circ}{9.9 \angle 45^\circ}$$

$$= 7.13 - j 7.13 \text{ Ohms}$$

$$= R - j X_C$$

$$R = 7.13 \Omega \quad X_C = 7.13 \text{ ohms}$$

$$\frac{1}{\omega C} = 7.13; \quad \frac{1}{314 \times C} = 7.13 \Rightarrow C = \frac{1}{314 \times 7.13}$$

$$C = 4.466 \times 10^{-4} \text{ F}$$

$$= 446.6 \times 10^{-6} \text{ F}$$

$$C = 446.6 \mu\text{F}$$

## 3.12 MAGNETIC MATERIALS

diamagnetic  
paramagnetic  
ferromagnetic

Magnetic field is present around a current carrying conductor. It is also exist around magnet. An electron revolving around the nucleus of its atom in its orbit forms a tiny electric current loop. This current loop produces a magnetic field. Most of the substances would exhibit magnetic effects and some of them are magnetically weak. Depending on their magnetic behaviour, substances can be classified into three groups. They are

1. diamagnetic
2. paramagnetic
3. ferromagnetic

The metals and other elements having slight magnetic properties are called diamagnetic materials in which the magnetization is opposite to the applied field. If the magnetization is in the same direction as the applied field, such materials are called as paramagnetic materials. Infact these two materials which have feeble magnetic effects are called non-magnetic materials. Ferro magnetic materials show very strong magnetic effects. The magnetization is in the same direction as the field. Iron, Steel, Nickel and Cobalt are known as ferromagnetic materials.

The metals and other elements having slight magnetic properties are called diamagnetic materials in which the magnetization is opposite to the applied field. If the magnetization is in the same direction as the applied field, such materials are called as paramagnetic materials. Infact these two materials which have feeble magnetic effects are called non-magnetic materials. Ferro magnetic materials show very strong magnetic effects. The magnetization is in the same direction as the field. Iron, Steel, Nickel and Cobalt are known as ferromagnetic materials.

Relative permeability decides the material which belongs to whether diamagnetic, paramagnetic or ferromagnetic. For vacuum,  $\mu_r = 1$ , vacuum is taken as reference medium.

If  $\mu_r < 1$ , the materials are diamagnetic

If  $\mu_r \geq 1$ , the materials are paramagnetic

If  $\mu_r \gg 1$ , the materials are ferromagnetic.

Substances classified according to their relative permeability are tabulated in Table 1.

*Table-I  
Classification of substances according to their relative permeability*

Substance	Magnetic type	Relative permeability ( $\mu_r$ )
Silver	Diamagnetic	0.99998
Copper	Diamagnetic	0.999991
Vacuum	Non-magnetic	1
Aluminium	Paramagnetic	1.00002
Palladium	Paramagnetic	1.0008
Cobalt	Ferromagnetic	250
Nickel	Ferromagnetic	600

### 3.13 MAGNETIZATION CURVE

The ratio between  $B$  and  $H$  may be constant for all values of  $H$ , especially in the case of ferromagnetic materials. The characteristic curve showing the variation of flux density ( $B$ ) with field intensity ( $H$ ) is called **Magnetization Curve**.

magnetization curve

Consider a toroid with ferromagnetic core which has primary and secondary coils. The primary coil is excited by a variable DC power supply which produces the change in field intensity  $H$  and its corresponding effect can be measured by a flux meter at the secondary coil as shown in Fig.3.11(a). The value of  $H$  can be increased or decreased by increasing or decreasing the current through the toroid. Now  $H$  is increased from zero to a certain maximum value and the corresponding value of  $B$  is noted. This is represented as  $oc$  in  $B$ - $H$  curve as shown in Fig.3.11 (b). The point  $c$  is called magnetic saturation.

If  $H$  is reduced to zero gradually,  $B$  will not decrease to zero but has a value  $o.d.$ . This is called **residual** or **remanent** value. In order to bring down the value of  $B$  to zero (i.e. to demagnetize the toroid),  $H$  has to be applied in reverse (negative) direction. When  $H$  is reversed, then  $B$  is reduced to zero at point  $e$ . The field at  $e$  ( $H = -H_e$ ) is called **Coercive force**. The value of  $H$  is further increased in the negative direction, the value of  $B$  is reached in saturation level in negative direction at  $f$ . By taking  $H$  back from its value for negative saturation to its value for positive saturation, a similar curve **fabc** is obtained. It is concluded that  $B$  always lags behind  $H$ . This is called **hysteresis**. The closed loop **cdefabc** is termed as  **$BH$  loop** or **hysteresis loop**.

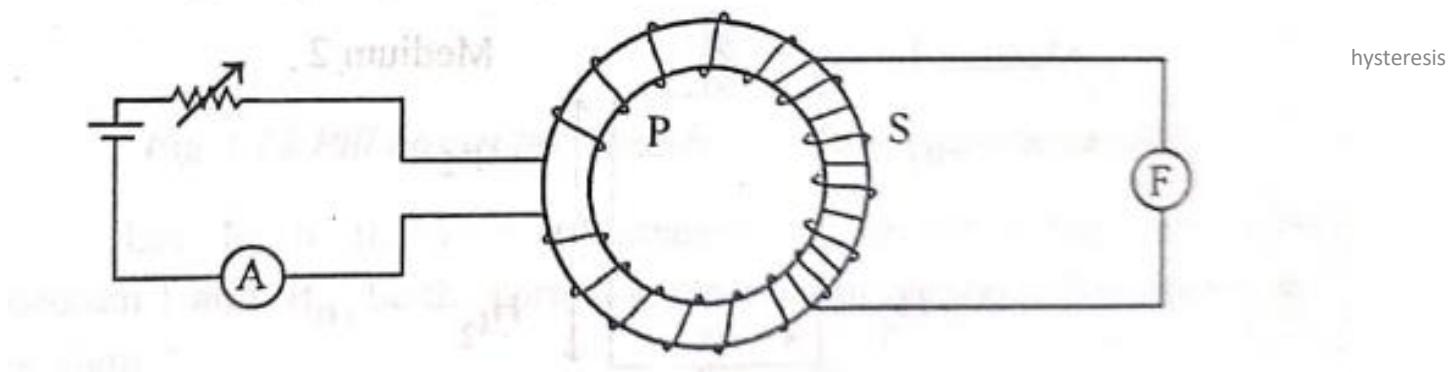
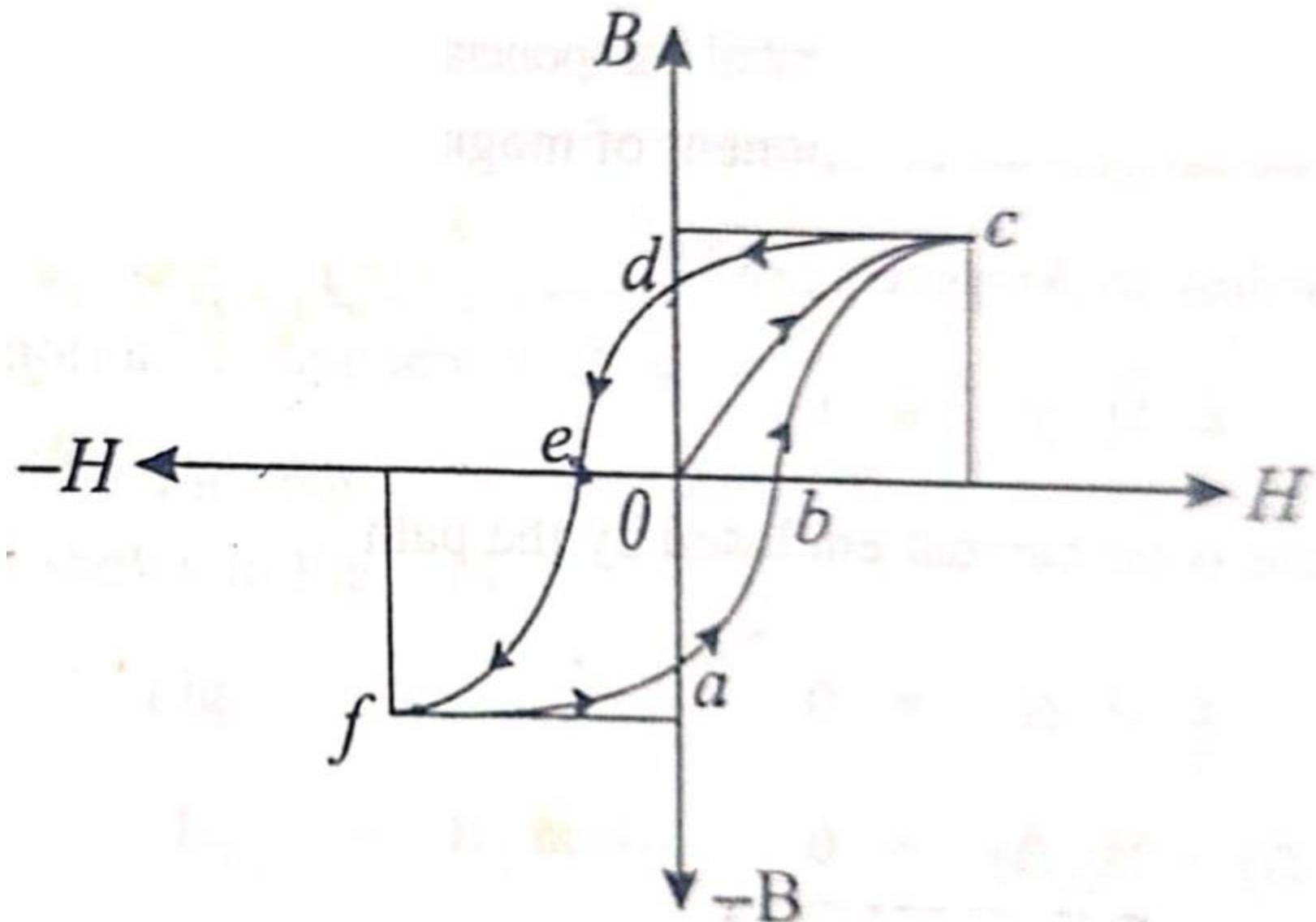


Fig 3.11 (a) Toroidal



# MAGNETIC CIRCUITS

The various terms involved with magnetism are grouped as follows:

## 1. Magnetic Flux [ $\Phi$ ]

The magnetic lines of force produced by a magnet is called magnetic flux.  
Its unit is Weber.       $1 \text{ wb} = 1 \times 10^8$  magnetic lines

## .2 Magnetic Flux Density ( $B$ )

Magnetic flux density is the flux per unit area at right angles to the flux.

$$B = \frac{\phi}{a} \text{ wb/m}^2$$

where  $\phi$ (wb) is the magnetic flux and  $a$  ( $\text{m}^2$ ) is the area of cross section. Its unit is  $\text{wb/m}^2$  or Tesla.

magneto motive force  
magnetic field intensity magnetising force  
permeability

### .3 Magneto Motive Force (F)

MMF is the cause for producing flux in a magnetic circuit. It is obtained as the product of the current ( $I$  amps) flowing through a coil of  $N$  turns. Its unit is Ampere.

Thus,  $F = NI$  Amps.

The term, M.M.F. is normally referred to as Ampere Turns (AT).

### 4 Magnetic Field Intensity (or) Magnetising Force (H)

It is defined as M.M.F. per unit length of the magnetic flux path. It is a measure of the ability of a magnetised body to produce magnetic induction in other magnetic substances. Its unit is Ampere/metre.

With reference to Fig. 2.2  $H = \frac{NI}{l}$

### .5 Permeability ( $\mu$ )

This is the property of the magnetic medium. The flux density ( $B$ ) is proportional to the magnetising force which produces it.

i.e.

$$B \propto H$$

$$B = \mu H$$

$$\mu = B/H$$

where  $\mu$  is the constant of proportionality and is called permeability.

## 6 Relative Permeability ( $\mu_r$ )

The relative permeability of a medium or material is defined as the ratio of the flux density produced in that medium or material to the flux density produced in vacuum by the same magnetising force.

$$\mu_r = \frac{\text{Flux density in the medium}}{\text{Flux density in vacuum}}$$

The absolute permeability of vacuum or free space has the value of  $4\pi \times 10^{-7}$  Henry/m.

The permeability for any other medium is

$$\mu = \mu_r \times \mu_0$$

The relative permeability of vacuum or free space is unity and that of air and other non-magnetic materials is very nearly equal to unity.

## 7 Reluctance (S)

Reluctance is the property of an magnetic circuit by which the setting up of flux is opposed. It is defined as the ratio of the magnetomotive force to the flux.

The unit of reluctance is Amp./Weber and is denoted by  $S$ .

## 8 Permeance (P)

It is the reciprocal of reluctance and is the readiness with which magnetic flux is developed. It is analogous to conductance in an electric circuit. Its unit is weber per Amp.

## MAGNETIC CIRCUIT

Magnetic circuit is the path followed by magnetic flux. Magnetic flux follows a complete loop or circuit coming back to its starting point. In any magnet, magnetic flux leaves its north pole, passing through air, enters the magnet at its south pole and finally reaches point where they start.

## LEAKAGE FLUX

The flux which does not follow the desired path in magnetic circuit is known as *leakage flux*.

Usually, we assume that all the flux lines take the path of the magnetic medium. But, practically, it is impossible to confine all the flux to the iron path only. It is because, to prevent the leakage of flux, there is no perfect magnetic insulator. Even in air, flux is conducted fairly well. Hence, some of the flux leaks through air as shown in Fig. 2.8 and is known as leakage flux. All the magnetic flux which completes the desired magnetic circuit is the *useful flux*.

To account for the leakage flux, the term, “leakage coefficient” is introduced.

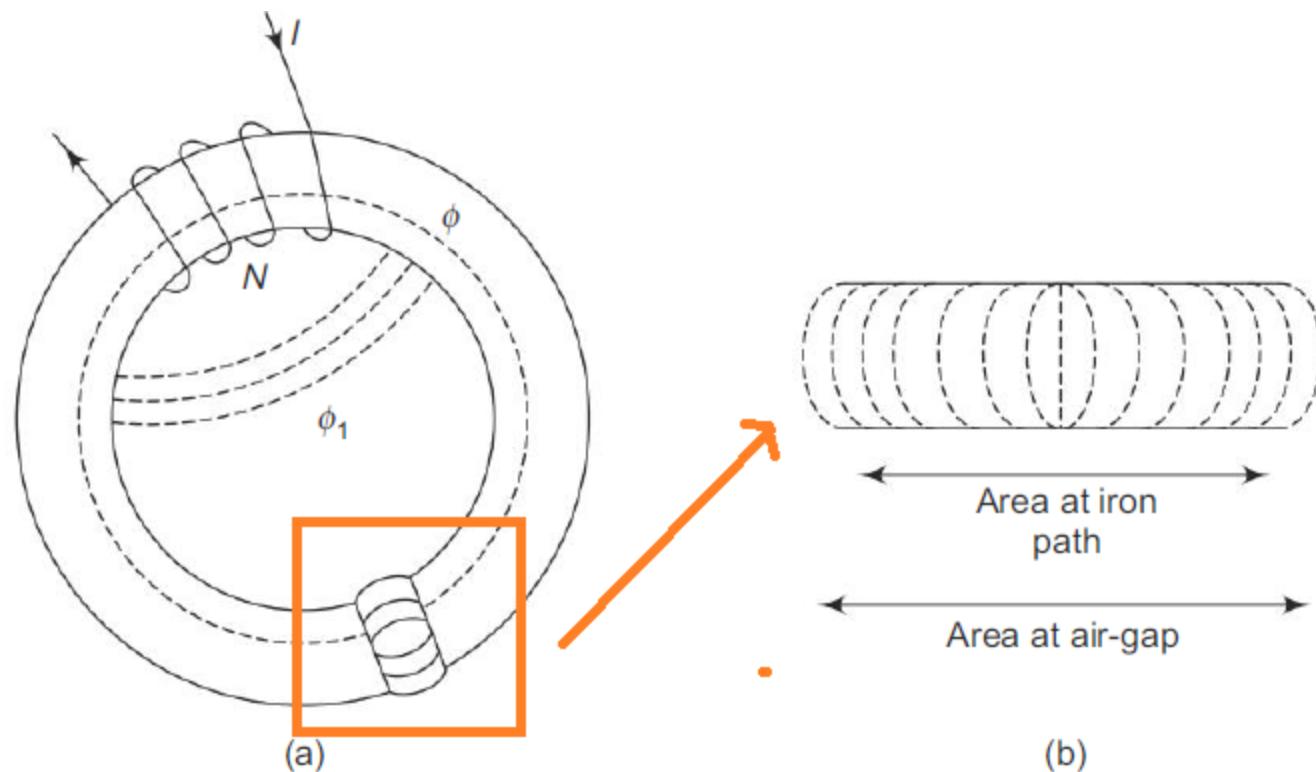
Leakage coefficient is defined as follows and it is defined by  $\lambda$ .

$$\text{Leakage coefficient, } \lambda = \frac{\text{total flux}}{\text{useful flux}} = \frac{\phi + \phi'}{\phi}$$

Usually, leakage factor is greater than unity.

# FRINGING EFFECT

An air gap is often inserted in magnetic circuits out of necessity. When crossing an air gap, the magnetic lines of force have a tendency to bulge out. This is because the magnetic lines of force repel each other when they are passing through a non-magnetic material. This phenomenon is known as *fringing*.



## Analysis of Simple Magnetic Circuit

Consider a circular solenoid or a toroidal iron ring having a magnetic path of  $l$  meters, area of cross-section,  $a \text{ m}^2$  and a coil of turns carrying  $I$  amperes wound anywhere on it as in Fig. 2.3.

$$\text{M.M.F. Produced} = NI \text{ Amps.}$$

According to the definition of  $H$ , the field-strength inside the solenoid is

$$\begin{aligned} H &= \frac{NI}{l} \text{ Amp./metre} \\ &= \frac{NI}{2\pi R_m} \end{aligned}$$

Now

$$B = \mu_0 \mu_r H \quad (\because \mu = B/H)$$

$$B = \frac{\mu_0 \mu_r N I}{l} \text{ wb/m}^2 \dots$$

Total flux produced

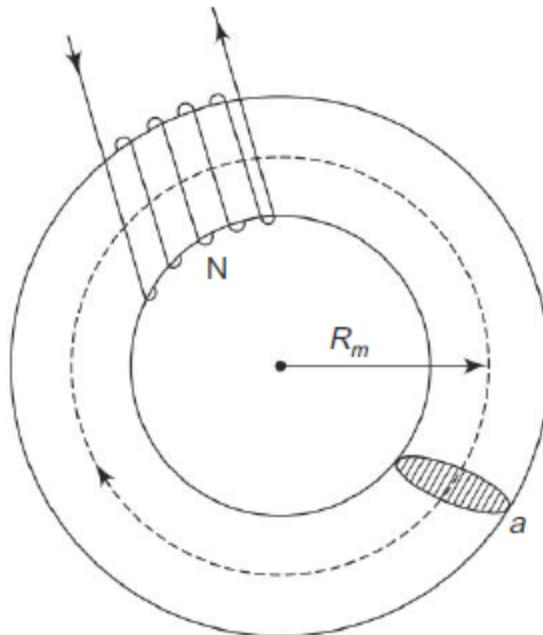
$$\phi = Ba = \frac{\mu_0 \mu_r a N I}{l} \text{ wb}$$

Also,

$$\phi = \frac{NI}{l} = \frac{NI}{\frac{\mu_0 \mu_r a}{S}} \text{ wb}$$

According to the definition of reluctance,

$$S = \frac{NI}{\phi}$$



Thus, the denominator  $\frac{1}{\mu a}$  or  $\frac{1}{\mu_0 \mu_r a}$  is the reluctance of the circuit and is analogous to resistance in electric circuit

$$S = \frac{1}{\mu_0 \mu_r a}$$

$$\text{Flux} = \frac{\text{mmf}}{\text{reluctance}}$$

The above equation is also known as 'Ohm's' law of magnetic circuit' because its resembles a similar expression in electric circuits,

$$\text{Current} = \frac{\text{emf}}{\text{resistance}}$$

Comparison between electric and magnetic circuit

<b>Sl. No.</b>	<b>Magnetic circuit</b>	<b>Electric circuit</b>
1	<b>Magnetic flux, <math>\varphi</math> webers</b>	<b>Electric current, I ampere</b>
2	<b>Magneto motive force, AT</b>	<b>EMF, E volts</b>
3	<b>Reluctance, S AT / Wb</b>	<b>Resistance, R ohm</b>
4	$\varphi = \frac{\text{mmf}}{\text{reluctance}}$	$\text{Current} = \frac{\text{emf}}{\text{resistance}}$

## Problems

- .1 A toroidal air cored coil with 2000 turns has a mean radius of 25 cm, diameter of each turn being 6 cm. If the current in the coil is 10 A, find (a) MMF, (b) flux and (c) flux density.

**Solution:**

$$N = 2000 \text{ turns}; I = 10 \text{ Amps}; R_m = 25 \text{ cm}$$

$$\text{dia. of each turn, } d = 6 \text{ cm.}$$

$$(a) \text{ MMF} = NI = 2000 \times 10 = 20,000 \text{ Amperes}$$

$$(b) \text{ Flux} = \text{MMF}/\text{Reluctance}$$

$$\text{Reluctance} = l/a\mu$$

$$l = 2\pi R_m = 2\pi \times \frac{25}{100} \text{ m} = 1.57 \text{ m}$$

$$a = \frac{\pi d^2}{4} = \frac{\pi}{4} \times (6 \times 10^{-2})^2 = 2.8 \times 10^{-3} \text{ m}^2$$

$$\mu = \mu_0 \mu_r = 4\pi \times 10^{-7} \times 1$$

$$\therefore \text{Reluctance} = \frac{1}{a\mu}$$

$$= \frac{1.57}{2.8 \times 10^{-3} \times 4\pi \times 10^{-7} \times 1}$$

$$= 4.46 \times 10^8 \text{ At/wb}$$

$$\text{Flux} = \frac{\text{mmf}}{\text{Reluctance}} = \frac{20,000}{3.47 \times 10^8}$$

$$= 4.48 \times 10^{-5} \text{ wb}$$

$$\text{Flux density} = \frac{\text{Flux}}{\text{Area of cross section}} = \frac{4.48 \times 10^{-5}}{2.8 \times 10^{-3}}$$

$$= 1.6 \times 10^{-2} \text{ wb/m}^2 \text{ (or) Tesla}$$

**2** The flux produced in the air gap between two electromagnetic poles is  $5 \times 10^{-2}$  wb. If the cross sectional area of the air gap is  $0.2 \text{ m}^2$  find (a) flux density, (b) magnetic field intensity, (c) reluctance, and (d) permeance of the air gap. Find also the mmf dropped in the air gap given the length of the air gap to be 1.2 cm.

**Solution:**

$$\phi = 5 \times 10^{-2} \text{ wb}$$

$$a = 0.2 \text{ m}^2$$

$$l_g = 1.2 \text{ cm} = 0.012 \text{ m}$$

$$\mu_r = 1$$

$$(a) \text{ Flux density } (B) \quad \frac{\phi}{a} = \frac{5 \times 10^{-2}}{0.2} = 0.25 \text{ wb/sq.m}$$

$$(b) \text{ Magnetic field intensity } (H) = \frac{B}{\mu_0 \mu_r}$$

$$= \frac{0.25}{4\pi \times 10^{-7} \times 1}$$

$$= 1.9894 \times 10^5 \text{ A/m}$$

$$(c) \text{ Reluctance } (S) \text{ of the air gap} = \frac{l_g}{a\mu}$$

$$= \frac{0.012}{0.2 \times 4\pi \times 10^{-7} \times 1}$$

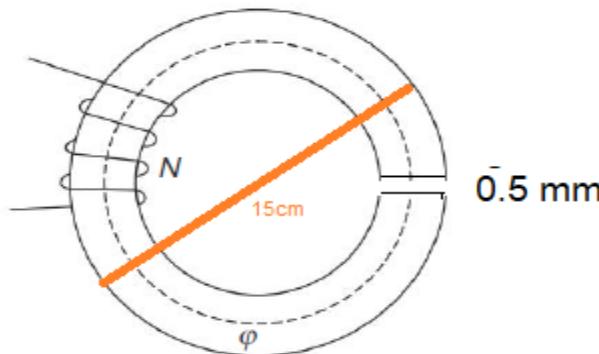
$$= 47746.48 \text{ A/wb}$$

$$(d) \text{ Permeance} = 1/\text{Reluctance} = \frac{1}{47746.48} = 2.0944 \times 10^{-5} \text{ wb/A}$$

$$(e) \text{ mmf in the air gap} = \phi \times \text{Reluctance} = 5 \times 10^{-2} \times 47747 = 2387 \text{ A.}$$

3. A ring has mean diameter of 15 cm, a cross section of  $1.7\text{cm}^2$  and has a radial gap of 0.5 mm in it. It is uniformly wound with 1500 turns of insulated wire and a current of 1 A produces a flux of 0.1 mwb across the gap. Calculate the relative permeability of iron on the assumption that there is no magnetic leakage.

**Solution:**



$$\phi = 0.1 \times 10^{-3} \text{ wb}$$

$$a = 1.7\text{cm}^2 = 1.7 \times 10^{-4} \text{ m}^2$$

Total Reluctance = Reluctance of iron path+Reluctance of air gap

$$S_T = S_i + S_g$$

$$\begin{aligned}\text{Total Reluctance } S_T &= NI / \phi = 1500 \times 1 / 0.1 \times 10^{-3} \\ &= 1,50,00,000 \text{ A/Wb}\end{aligned}$$

$$\text{Reluctance (S) of the air gap } = S_g = \frac{l_g}{a\mu} = \frac{l_g}{a\mu_0\mu_r} \quad \boxed{\mu_r = 1 \text{ for air}}$$

$$= 0.5 \times 10^{-3} / [1.7 \times 10^{-4} \times 4\pi \times 10^{-7} \times 1]$$

$$= 23,40,513.8 \text{ A/Wb}$$

$$\begin{aligned}
 S_i &= S_T - S_g \\
 &= 15000000 - 2340513.8 \\
 &= 1,25,69,486.2 \text{ A/Wb}
 \end{aligned}$$

$$S_i = \frac{l_i}{a\mu} = \frac{l_i}{a\mu_0\mu_r}$$

$$\begin{aligned}
 l_i, \text{ Length of iron path} &= \text{Total length} = l_g \\
 l_i &= (\pi d - l_g)m = (\pi \times 0.15 - 0.005) \\
 &= 0.466 \text{ m}
 \end{aligned}$$

$$\begin{aligned}
 \mu_r &= \frac{l_i}{a\mu_0 S_i} \\
 &= 174
 \end{aligned}$$

4. An iron rod of 1 cm radius is bent to a ring of mean diameter 30 cm and wound with 250 turns of wire. Assume the relative permeability of iron as 800. An air gap of 0.1 cm is cut across the bent ring. Calculate the current required to produce a useful of 20,000 lines if (a) leakage is neglected and (b) leakage factor is 1.1.

**Solution:**

$$l_g = 0.1 \text{ cm}$$

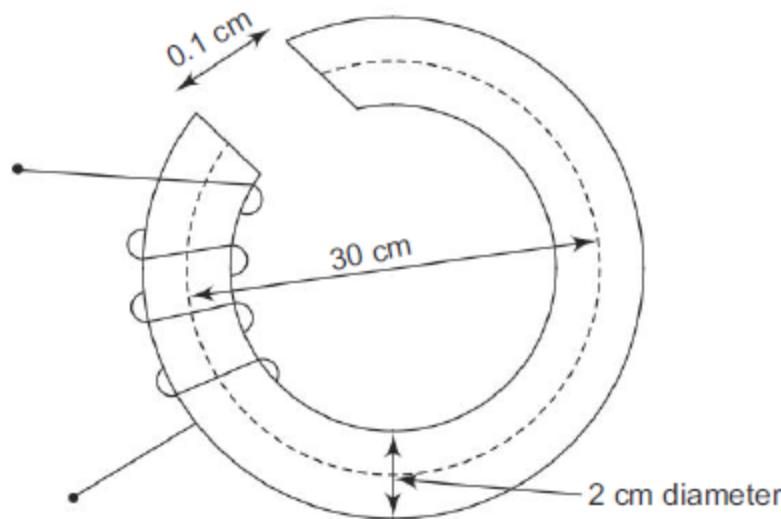
$$\frac{d}{2} = 1 \text{ cm}$$

$$2R_m = 30 \text{ cm}$$

$$N = 250 \text{ turns}$$

$$\mu_r = 800$$

$$\begin{aligned}\phi &= 20,000 \text{ lines} \\ &= 20,000 \times 10^{-8} \text{ wb}\end{aligned}$$



(a) Neglecting leakage:

Total Reluctance = Reluctance of air gap + Reluctance of iron path

$$\text{Reluctance of air gap} = \frac{l_g}{\mu_0 \mu_r a} = \frac{0.001}{(4\pi \times 10^{-7} \times 1 \times \pi \times 1 \times 10^{-4})} \\ = 2533029.59 \text{ A/wh}$$

$l_i$ , Length of iron path = Total length =  $l_g$

$$l_i = (\pi d - l_g)m = (\pi \times 0.3 - 0.001)$$

$$\text{Reluctance of iron path} = \frac{(\pi \times 0.3 - 0.001)}{4\pi \times 10^{-7} \times 800 \times \pi \times 1 \times 10^{-4}} \\ = 2980988.896 \text{ A/wb}$$

Total Reluctance = 5514018.49 A/wb

$$\text{MMF} = \text{Flux} \times \text{Reluctance}$$

$$= 20,000 \times 10^{-8} \times 5514018.49 \text{ A/wb}$$

= 1102.8 Amp. turns

$$\text{Current required} = \frac{1102.8}{\text{No. of turns}} = \frac{1120.8}{250}$$

Current required = 4.41 Amps.

**(b) Including leakage:**

To have a useful flux of 20,000 lines in the air gap, the *MMF* required the air gap position is

$$\begin{aligned} &= \phi \times \text{Reluctance of air gap} \\ &= 20,000 \times 10^{-8} \times 2533039.59 \end{aligned}$$

$$MMF \text{ for air gap} = 506.606 \text{ Amp}$$

For the iron path, the flux has to be more.

$$\begin{aligned} \text{The total flux in iron path} &= \text{Leakage factor} \times \text{Useful flux} \\ &= 1.1 \times 20000 \times 10^{-8} \text{ wb} \end{aligned}$$

$$\begin{aligned} \text{Hence, } MMF \text{ for iron path} &= 1.1 \times 20,000 \times 10^{-8} \text{ Reluctance of iron path} \\ &= 655.82 \text{ Amp.} \end{aligned}$$

$$\text{Total } MMF = 655.82 + 506.606 \text{ A} = 1162.426 \text{ A}$$

$$\text{Current required} = \frac{1162.426}{250} = 4.649 \text{ Amps.}$$

$$\text{Current required} = 4.649 \text{ Amps.}$$

# LAW OF ELECTROMAGNETIC INDUCTION

## 1 Statement of Faraday's Law

Whenever the magnetic flux linking a circuit changes an emf is always induced in it. The magnitude of such an emf is proportional to the rate of change of flux linkages.

## 2 Lenz's Law

The law states that any induced emf will circulate a current in such a direction so as to oppose the cause producing it.

Thus, Lenz's law gives the nature of induced emfs.

## INDUCED EMF

An emf is induced in a coil or conductor whenever there is a change in flux linkages. This change in flux linkages can be brought in the following two ways:

- (i) The conductor is moved in a stationary magnetic field in such a way that there is a magnitude change in flux linkages. This kind of induced emf is known as dynamically induced emf (e.g generator).
- (ii) The conductor is stationary and the magnetic field is moving or changing. This kind of induced emf is known as statically induced emf (e.g. transformer).

## Statically Induced emf

In this case, the conductor is held stationary and the magnetic field varied. It may be self induced or mutually induced.

**Self Induced emf** If a single coil carries a current, a flux will be set up in it. If the current changes the flux will change. The change in flux will induce an emf in the coil. This kind of emf is known as “self induced emf”.

The magnitude of this self-induced emf is  $e = N \frac{d\phi}{dt}$

**Mutually Induced emf** It is the emf induced in one circuit due to change of flux linking it, the flux being produced by current in another circuit.

$$e_2 = N_2 \frac{d\phi_{12}}{dt} \quad \text{Where } \phi_{12} = \text{1 st coil flux linking 2 nd coil}$$

## SELF INDUCTANCE (L)

self inductance

### Definition

Self inductance of a circuit is the flux linkages per unit current in it. Its unit is Henry.

$$\text{By definition, } L = \frac{N \phi}{I} \text{ Henry}$$

## Relationship between Self-Induced emf and Self Inductance

$$e = -L \frac{di}{dt}$$

## MUTUAL INDUCTANCE (M)

mutual inductance

### Definition

Mutual inductance between two circuits is defined as the flux linkages of one circuit per unit current in the other circuit. Its unit is Henry.

$$M = \frac{N_2 \phi_{12}}{I_1} \quad \text{Where } \phi_{12} = \text{1 st coil flux linking 2 nd coil}$$

or 
$$M = \frac{N_1 \phi_{21}}{I_2} \quad \text{Where } \phi_{21} = \text{2 nd coil flux linking 1 st coil}$$

### Relationship between M and Induced emf

mutually induced emf in coil 2 due to change in current of coil 1 is,

$$e_{m,2} = -M \frac{di_1}{dt}$$

Similarly, mutually induced emf in coil 2 due to change in current of coil 2 is,

$$e_{m,1} = -M \frac{di_2}{dt}$$

## COUPLING COEFFICIENT BETWEEN TWO MAGNETICALLY COUPLED CIRCUITS (K)

$$K = \frac{\phi_{12}}{\phi_1} \quad \text{or} \quad K = \frac{\phi_{21}}{\phi_2}$$

Where  $\phi_{12}$  = 1 st coil flux linking 2 nd coil  
Where  $\phi_{21}$  = 2 nd coil flux linking 1 st coil

always  $K \leq 1$ .

Thus, coupling coefficient,  $K = \frac{M}{\sqrt{L_1 L_2}}$

numerical

### Problems

1. The number of turns in a coil is 250. When a current of 2 A flows in this coil, the flux in the coil is 0.3 m wb. When this current is reduced to zero in 2 milliseconds, the voltage induced in a coil lying in the vicinity of coil is 63.75 volts. If **K=0.75**, Find mutual inductance and number of turns in the second coil.

**Solution:**  $N_1 = 250; I_1 = 2 A; \phi_1 = 0.3 \text{ wb}$   
 $dt = 2 \text{ msec}; e_{m2} = 63.75 \text{ V}; K = 0.75$

(a) Self inductance of first coil is

$$\begin{aligned} L_1 &= N_1 \times \frac{\phi_1}{I_1} \\ &= 250 \times \frac{0.3 \times 10^{-3}}{2} \\ &= 37.5 \text{ mH.} \end{aligned}$$

(b) Voltage in the second coil is

$$e_{m2} = M \frac{dI_1}{dt}$$

i.e.

$$63.75 = M \frac{\mathbf{2} \cdot \mathbf{0}}{2 \times 10^{-3}}$$

$$M = 63.75 \times 10^{-3} = 63.75 \text{ mH.}$$

we know that

$$M = K\sqrt{L_1 L_2}$$

i.e.

$$63.75 = 0.75 \sqrt{3.75 \times L_2}$$

$$L_2 = 193 \text{ mH.}$$

(c)  $\phi_{12}$  the flux in the second coil

$$\begin{aligned}\phi_{12} &= k \times \phi_1 \\ &= 0.75 \times 0.3 \times 10^{-3} \\ &= 0.255 \times 10^{-3} \text{ wb}\end{aligned}$$

$$e_2 = N_2 \frac{d\phi_{12}}{dt}$$

$$63.75 = N_2 \frac{0.255 \times 10^{-3}}{2 \times 10^{-3}}$$

$$N_2 = 500 \text{ turns.}$$

**2.**

An air cored toroidal coil has 480 turns, a mean length of 30 cm and a cross-sectional area of  $5 \text{ cm}^2$ . Calculate (a) the inductance of the coil and (b) the average induced emf, if a current of 4 A is reversed in 60 millionseconds.

**Solution:**

$$l = 30 \text{ cm} = 0.3 \text{ m}$$

$$N = 450 \text{ turns}$$

$$a = 5 \text{ cm}^2 = 5 \times 10^{-4} \text{ m}^2 \quad \text{numerical}$$

$$I = 4 \text{ Amps.}$$

$$dt = 60 \text{ m sec}$$

(a)

$$\begin{aligned} L &= \frac{N^2}{(1/\mu_0\mu_r a)} \\ &= \frac{\mu_0\mu_r a N^2}{l} \\ &= \frac{4\pi \times 10^{-6} \times 1 \times 5 \times 10^{-4} \times (480)^2}{0.3} \text{ Henry} \quad (\because \mu_r = 1 \text{ for air}) \\ &= 483 \times 10^{-6} H \end{aligned}$$

(b)  $di = 4 - (-4) = 8 \text{ Amp}$

$$dt = 60 \times 10^{-3} \text{ sec}$$

$$\begin{aligned} \text{Average induced emf } (E) &= L \frac{di}{dt} \\ &= 483 \times 10^{-6} \times \frac{8}{60 \times 10^{-3}} \\ &= 0.064 \text{ V.} \end{aligned}$$

**3** The self inductance of a coil of 500 turns is  $0.25 \text{ H}$ . If 60% of the flux is linked with a second coil of 10500 turns, calculate (a) the mutual inductance between the two coils and (b) emf induced in the second coil when current in the first coil changes at the rate of  $100 \text{ A/sec}$ .

**Solution:**  $L_1 = 0.25 \text{ H}$

$$N_1 = 500 \text{ turns}$$

numerical

$$N_2 = 10500 \text{ turns}$$

$$\phi_{12} = \frac{60}{100} \phi_1; \quad \phi_{12} = 0.6 \phi_1. \quad \text{Where } \phi_{12} = 1^{\text{st}} \text{ coil flux linking } 2^{\text{nd}} \text{ coil}$$

$$\frac{di_1}{dt} = 100 \text{ A/sec}$$

Flux/ampere in the first coil

$$= \frac{\phi_1}{I_1} = \frac{0.25}{500} = \frac{0.25}{500} = 5 \times 10^{-4}$$

Flux linking the second coil  $= \phi_{12} = 0.6 \phi_1$

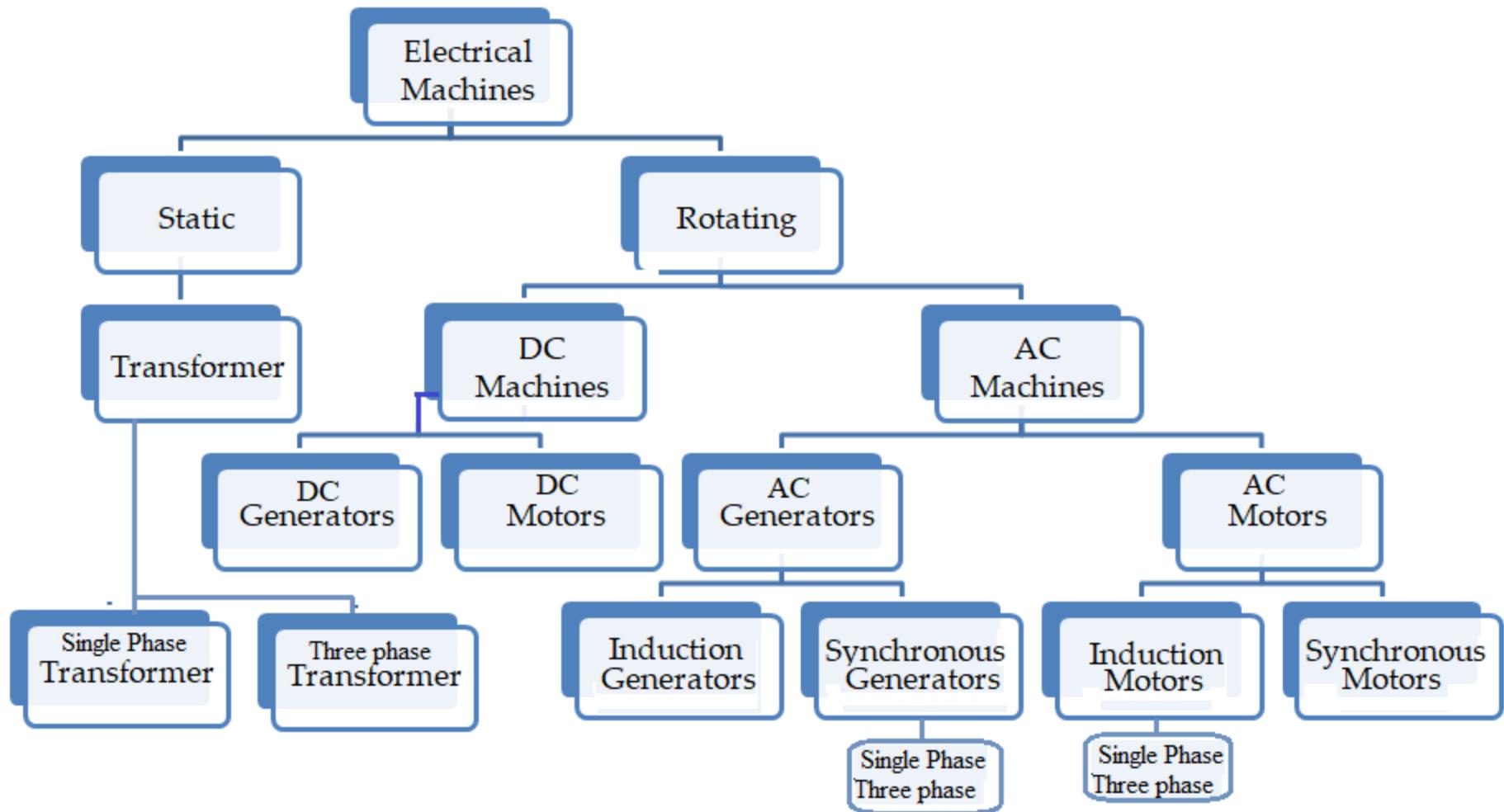
$$\begin{aligned} \frac{\phi_{12}}{I_1} &= 0.6 (\phi_1 / I_1) \\ &= 0.6 \times 5 \times 10^{-4} \\ &= 3 \times 10^{-4} \end{aligned}$$

$$(a) \quad M = N_2 \frac{\phi_{12}}{I_1} = 10500 \times 3 \times 10^{-4} = 3.15 \text{ H}$$

$$(b) \quad e_m = M \frac{di_1}{dt} = 3.15 \times 100 = 315 \text{ V}$$

# **Electrical Machines**

# Classification of Electrical Machines

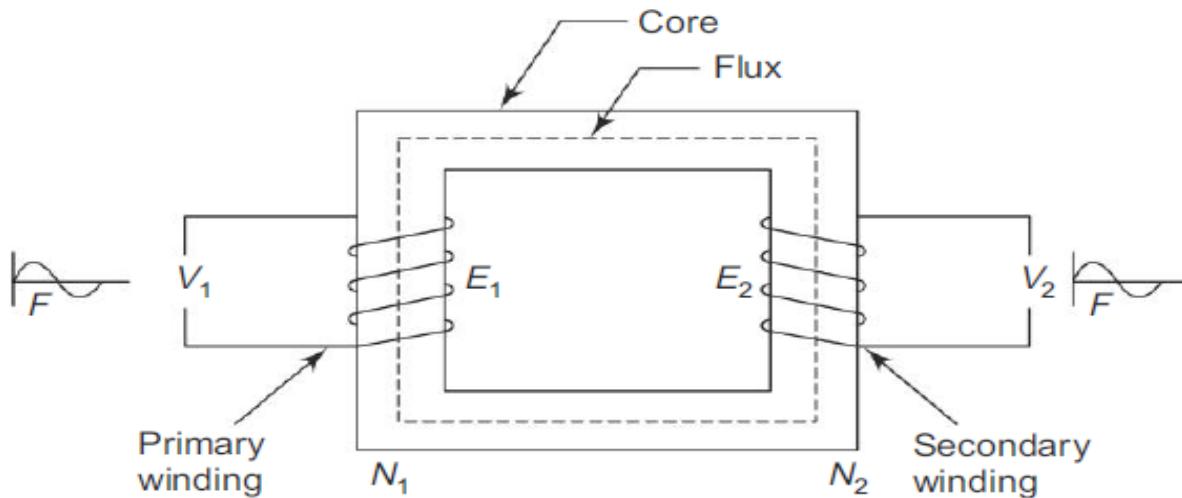


# Single Phase Transformer

## Principle of operation

The transformer works on the principle of electromagnetic induction. In this case, the conductors are stationary and the magnetic flux is varying with respect to time. Thus, the induced emf comes under the classification of statically induced emf.

The transformer is a static piece of apparatus used to transfer electrical energy from one circuit to another. The two circuits are magnetically coupled. One of the circuits is energized by connecting it to a supply at specific voltage magnitude, frequency and waveform. Then, we have a mutually induced voltage available across the second circuit at the same frequency and waveform but with a change in voltage magnitude if desired. These aspects are indicated in Fig.



## Construction

The following are the essential requirements of a transformer:

- (a) A good magnetic core
- (b) Two windings
- (c) A time varying magnetic flux

The transformer core is generally laminated and is made out of a good magnetic material such as transformer steel or silicon steel. Such a material has high relative permeability and **low hysteresis loss**. In order to reduce the **eddy current loss**, the core is made up of laminations of iron. ie, the core is made up of thin sheets of steel, each lamination being insulated from others

## Working

Let us say that a transformer has  $N_1$  turns in its primary winding and  $N_2$  turns in its secondary winding. The primary winding is connected to a sinusoidal voltage of magnitude  $V_1$  at a frequency ' $f$ ' hertz. A working flux of  $\phi$  webers is set up in the magnetic core. This working flux is alternating and sinusoidal as the applied voltage is alternating and sinusoidal. When this flux links the primary and the secondary winding, emfs are induced in them. The emf induced in the primary is the self induced emf and that induced in the secondary is the mutually induced emf. Let the induced voltages in the primary and the secondary be  $E_1$  and  $E_2$  volts respectively. These voltages will have sinusoidal waveform and the same frequency as that of the applied voltage. The currents which flow in the closed primary and the secondary circuits are respectively  $I_1$  and  $I_2$ .

In any transformer,  $K = \frac{N_2}{N_1}$ , defines the transformation ratio.

Three categories of transformer action are possible:

$E_2 < E_1$  (i.e.  $V_2 < V_1$ ) ... step down transformer

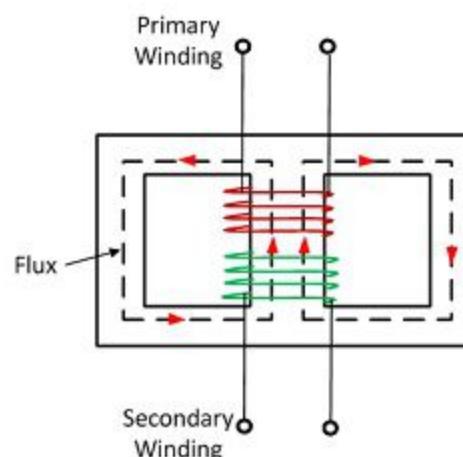
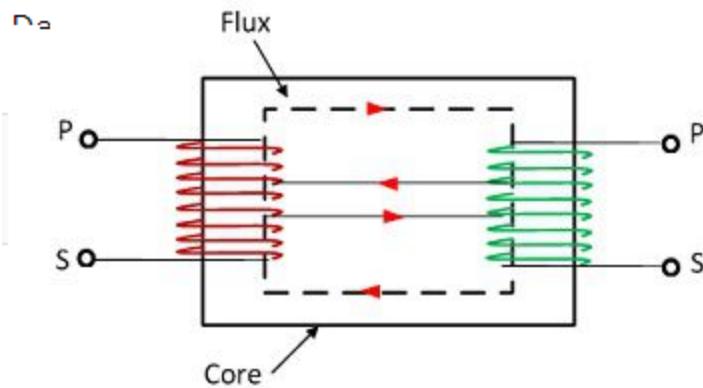
$E_2 > E_1$  (i.e.  $V_2 > V_1$ ) ... Step up transformer

The induced emfs are proportional to the number of turns. In any transformer, the primary ampere turns equals the secondary ampere turns.

i.e. 
$$N_1 I_1 = N_2 I_2$$

Thus, we have 
$$\frac{I_1}{I_2} = \frac{E_2}{E_1} = \frac{V_2}{V_1} = \frac{N_2}{N_1} = K$$

Whenever any load is put on the transformer (connected to secondary winding) the primary of the transmission draws the required amount of current in order to keep the working flux constant. Thus, the transformer works with a perfect static balance.

**Basis for Comparison****Core Type Transformer****Shell Type Transformer**

<b>Winding</b>	In this type, winding surrounds the core	In this type, core surrounds the winding
<b>Limbs</b>	It has two limbs	It has three limbs
<b>Copper requirement</b>	Requires less	Requires more
<b>Lamination</b>	Laminations are usually in the form of alphabet letter L	Laminations are usually in the form of alphabet letter E and L
<b>Flux distribution</b>	Flux is equally distributed on the side limbs	Side limbs carry the half of the flux while the central one carries the whole flux

<b>Windings position</b>	Primary and secondary both windings are wound on the side limbs	Both windings are wound on the central limb
<b>Magnetic circuit</b>	Only one magnetic circuit	There are two magnetic circuits
<b>Types</b>	Cylindrical	Multilayer and Sandwich type
<b>Cooling</b>	Better cooling because more surface is exposed to external atmosphere	Natural cooling is not very effective so fans are used
<b>Repair</b>	Easy to repair because assembly can be dismantled easily	Difficult to repair because both windings are on the same limb
<b>Output</b>	Output is less because of more losses so less efficiency	Output is high because of less losses so efficiency is high in this type
<b>Design</b>	Easy in design and construction	Comparatively complex
<b>Mechanical strength</b>	Low because of non-bracing	Possesses high mechanical strength
<b>Leakage reactance</b>	Leakage reactance is not easily possible	In this type, leakage reactance is highly possible
<b>Heat dissipation</b>	Better heat dissipation from windings	Windings are surrounded by core so heat dissipation is not easy
<b>Application</b>	Used for high voltage application like power transformers,	Used for low voltage application like transformers in an electronic

### 32.6. E.M.F. Equation of a Transformer

Let  
 $N_1$  = No. of turns in primary  
 $N_2$  = No. of turns in secondary  
 $\Phi_m$  = Maximum flux in core in webers  
 $= B_m \times A$   
 $f$  = Frequency of a.c. input in Hz

As shown in Fig. 32.14, flux increases from its zero value to maximum value  $\Phi_m$  in one quarter of the cycle i.e. in  $1/4f$  second.

$$\therefore \text{Average rate of change of flux} = \frac{\Phi_m}{1/4f}$$

$$= 4f\Phi_m \text{ Wb/s or volt}$$

Now, rate of change of flux per turn means induced e.m.f. in volts.

$$\therefore \text{Average e.m.f./turn} = 4f\Phi_m \text{ volt}$$

If flux  $\Phi$  varies *sinusoidally*, then r.m.s. value of induced e.m.f. is obtained by multiplying the average value with form factor.

$$\text{Form factor} = \frac{\text{r.m.s. value}}{\text{average value}} = 1.11$$

$$\therefore \text{r.m.s. value of e.m.f./turn} = 1.11 \times 4f\Phi_m = 4.44f\Phi_m \text{ volt}$$

Now, r.m.s. value of the induced e.m.f. in the whole of primary winding

$$= (\text{induced e.m.f./turn}) \times \text{No. of primary turns}$$

$$E_1 = 4.44fN_1\Phi_m = 4.44fN_1B_mA \quad \dots(i)$$

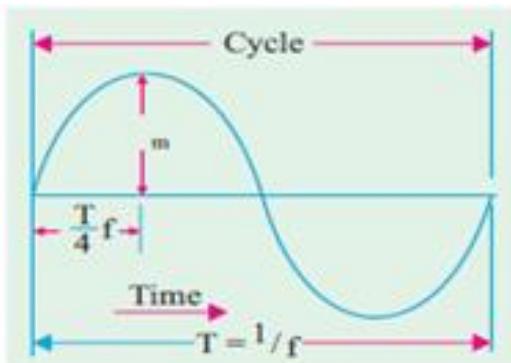


Fig. 32.14

Similarly, r.m.s. value of the e.m.f. induced in secondary is,

$$E_2 = 4.44fN_2\Phi_m = 4.44fN_2B_mA \quad \dots(ii)$$

# DC GENERATOR

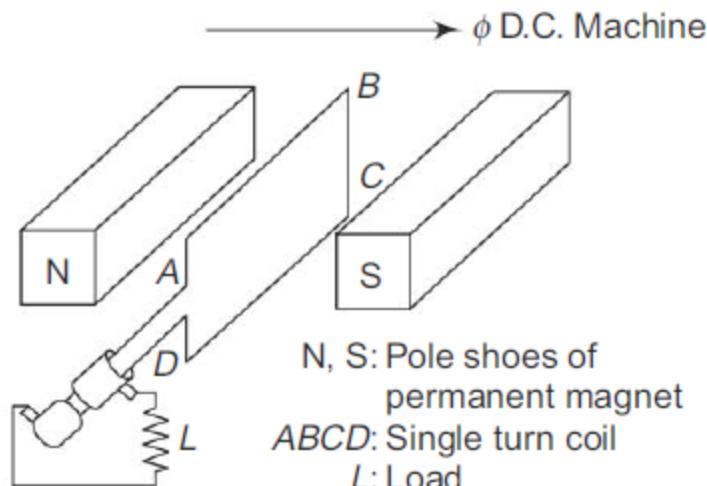
dc generator

## Principle

The generator is a dynamic machine in which mechanical energy is converted into electrical energy. It operates on the principle based on the Faraday's Law of electromagnetic induction. The emf generated is to be classified as dynamically induced emf. The basic requirements for the dynamically induced emf to exist are the following:

- (i) A steady magnetic field
- (ii) A conductor capable of carrying current
- (iii) The conductor to move in the magnetic field

The working principle of a dc generator is illustrated in Fig. 6.1. It shows a steady magnetic field produced by the pole pieces of a magnet N and S. A single turn coil ABCD is placed in the field produced between the pole pieces. The coil is rotated by means of a prime mover. Thus, as per Faraday's law, an emf is induced in the coil. Such an emf is basically alternating. This bidirectional induced emf is made unidirectional using the commutator. Figure 6.2, illustrates the use of commutator.



## Construction

For the satisfactory operation of a dc generator, it should consist of a stator and a rotor.

The stator accommodates the yoke, the main field system and the brushes. The rotor has the armature and the commutator as its main parts. Figure 6.3 shows these parts. Each of these parts is described as follows:

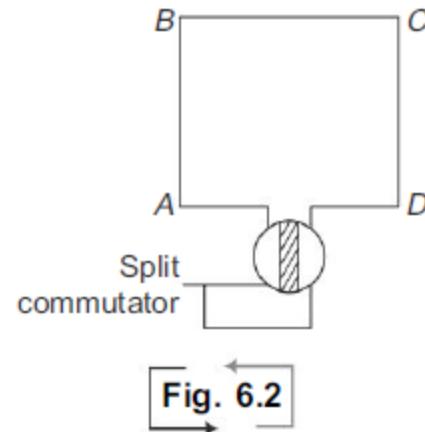
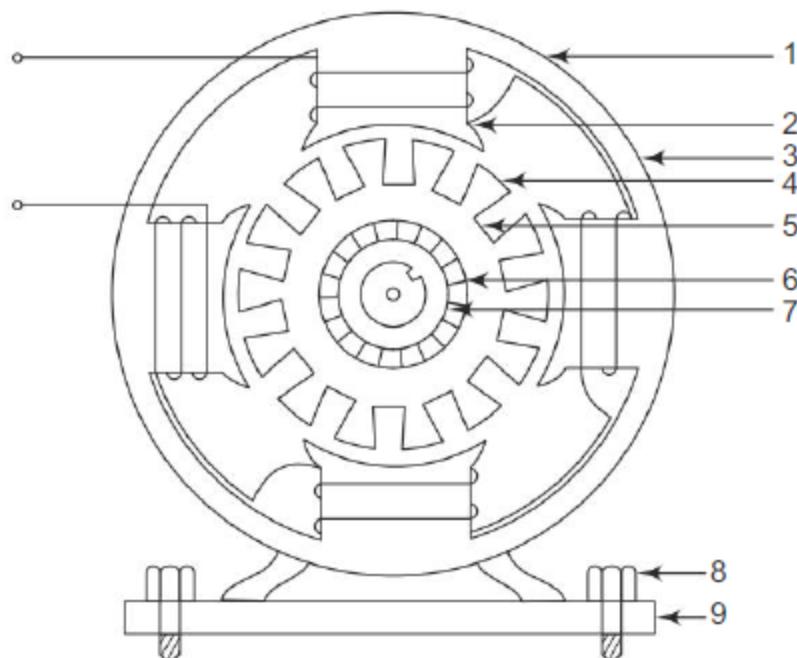


Fig. 6.2

- 1 Yoke or Frame
- 2 Main field pole
- 3 Field winding
- 4 Armature
- 5 Slot
- 6 Commutator
- 7 Shaft
- 8 Foundation bolt
- 9 Bed plate

**Yoke or Frame** It is the outermost solid metal part of the machine. It forms part of magnetic circuit and protects all the inner parts from mechanical damage.

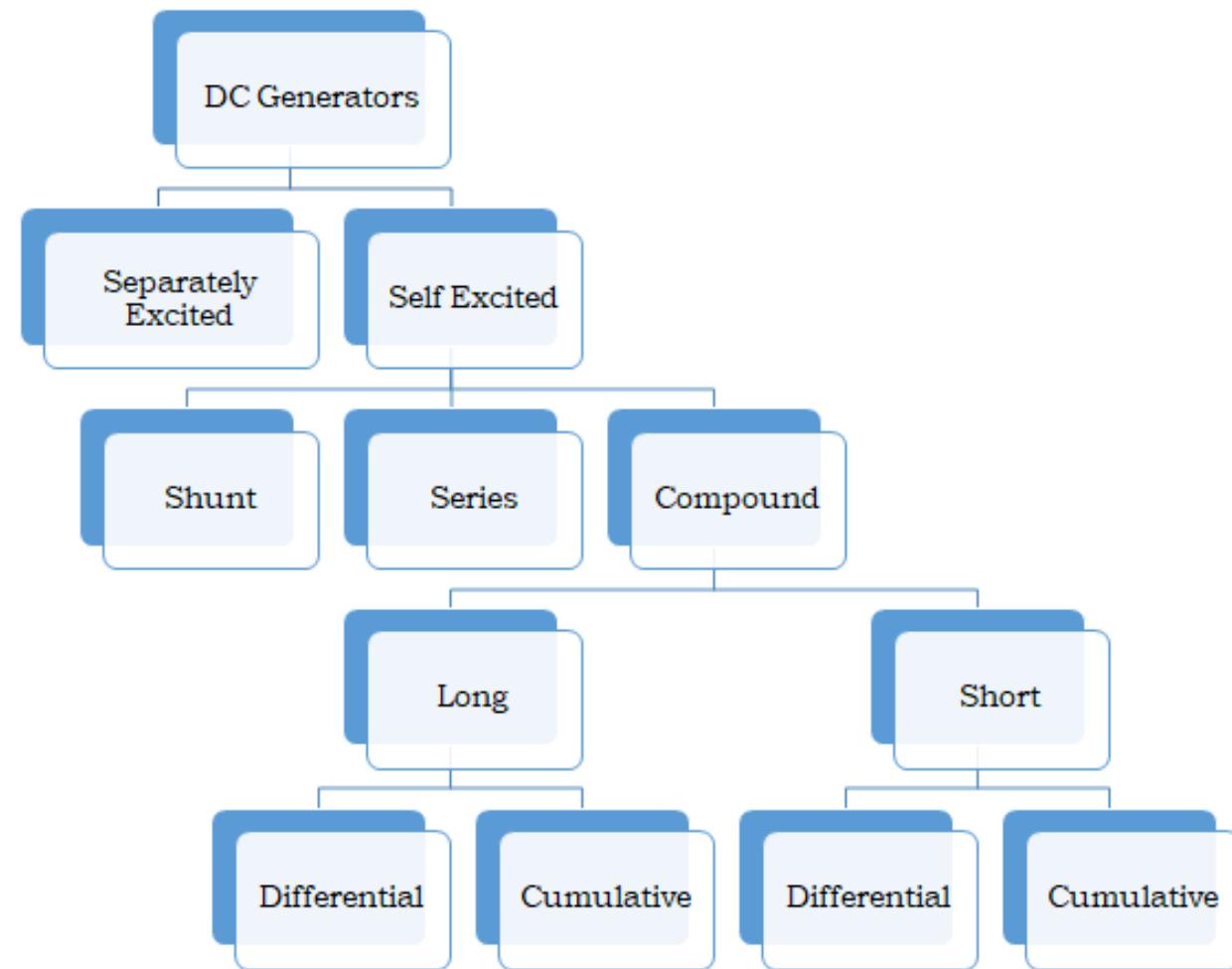
**Field System** This consists of main field poles and field winding. The field poles are made of laminations of a suitable magnetic material. Such a magnetic material has very high relative permeability and very low hysteresis loss. The pole face is in the form of horse shoe so that a uniform flux distribution is obtained in the air gap between the poles and the rotating part. The field winding is placed over the each pole and all these are connected in series. Again the field winding is so arranged on the different poles that when a direct current is passed through this winding, the poles get magnetized to N and S polarities alternately. Thus, the field system is responsible for producing the required working flux in the air gap.

**Brushes** A set of brushes made of carbon or graphic are fixed such that they are always in gentle touch with the revolving armature. The generator is connected to external circuits by means of these brushes. Thus, the brushes are used to tap the generated electrical energy off the rotating part of the generator.

**Armature** The armature of a dc generator is in the form of laminated slotted drum. Slots are provided over the entire periphery of the armature.

**Commutator** The commutator is similar in shape to armature. But, it has less diameter than that of the armature. Required number of segments are provided over the complete periphery of the commutator. There is an electrical insulation between every pair of segments. A minimum of two conductors are connected to each segment. But, at the same time the two conductors making a single coil are connected to different commutator segments. The brushes are so placed that they are always keeping to such with the revolving commutator segments.

# Types of DC Generator



# 1. Separately Excited DC Generator

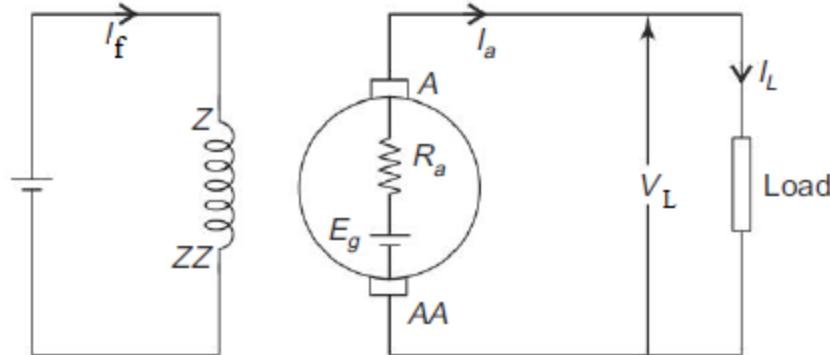
- Armature Current

$$I_a = I_L$$

- Emf Equation

$$E_g = V_L + I_a R_a + V_b$$

$V_b$ =brush drop for pair of brush



## 2. Self Excited DC Generator

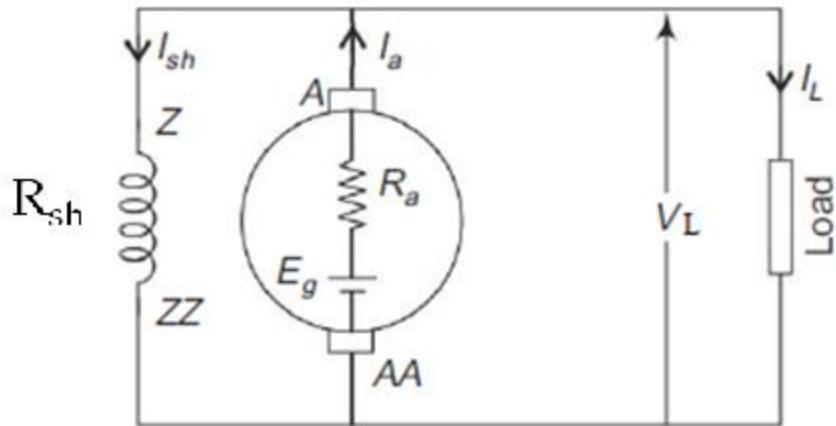
### (i) DC Shunt Generator

- Armature Current

$$I_a = I_L + I_{sh}$$

- Emf Equation

$$E_g = V_L + I_a R_a + V_b$$



## 2. Self Excited DC Generator

### (ii) DC Series Generator

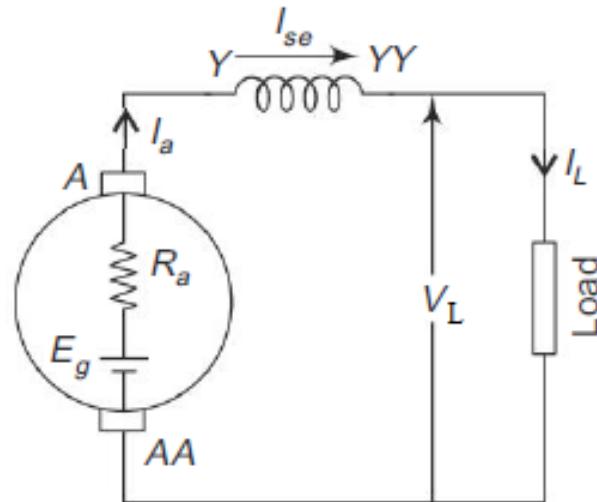
- Armature Current

$$I_a = I_L = I_{se}$$

- Emf Equation

$$E_g = V_L + I_a R_a + I_{se} R_{se} + V_b$$

$$E_g = V_L + I_a (R_a + R_{se}) + V_b$$



## 2. Self Excited DC Generator

### (iii) DC Compound Generator

#### (a) Long Shunt

- Series Field Current

$$I_{se} = I_a$$

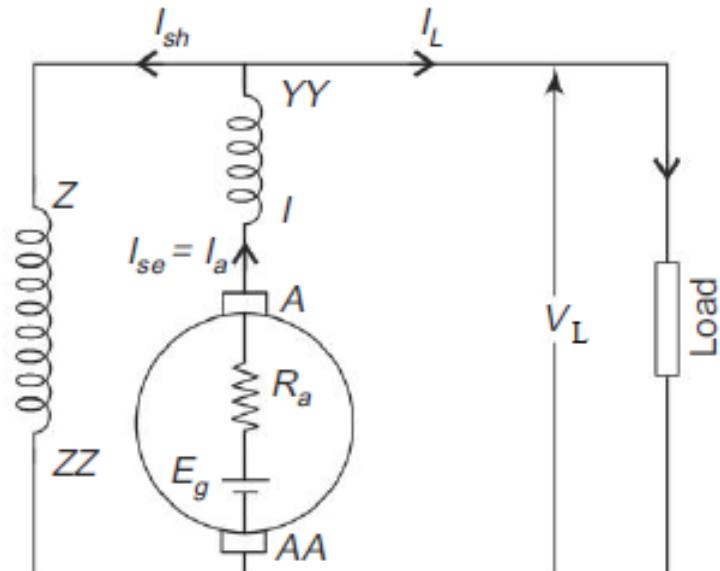
- Armature Current

$$I_a = I_L + I_{sh}$$

- Emf Equation

$$E_g = V_L + I_a R_a + I_{se} R_{se} + V_b$$

$$E_g = V_L + I_a (R_a + R_{se}) + V_b$$



## 2. Self Excited DC Generator

### (iii) DC Compound Generator

#### (b) Short Shunt

- Series Field Current

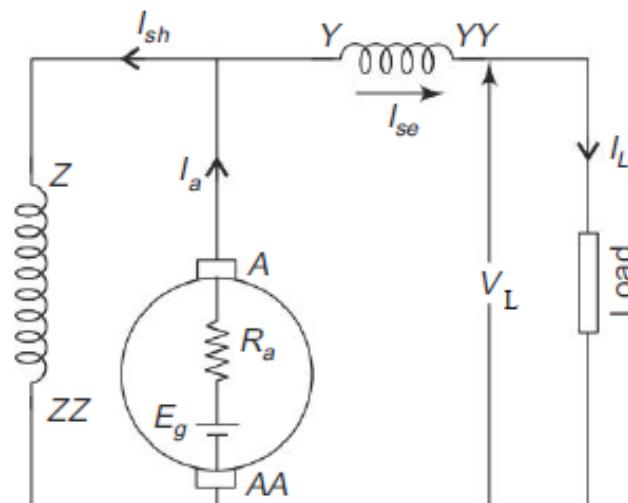
$$I_{se} = I_L$$

- Armature Current

$$I_a = I_L + I_{sh}$$

- Emf Equation

$$E_g = V_L + I_a R_a + I_{se} R_{se} + V_b$$



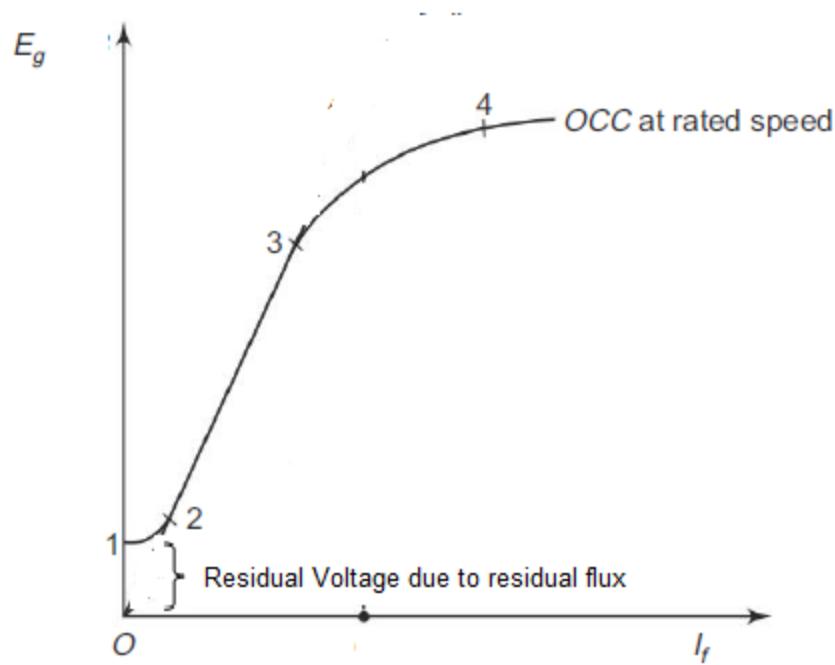
# Characteristics of Generators

- Open Circuit Characteristics ( $I_f, E_{g0}$ )
- Load Characteristics
  - Internal ( $I_a, E_g$ )
  - External ( $V_L, I_L$ )

## Separately Excited DC Generator and DC Shunt Generator- Characteristics

[Both generators have same characteristics]

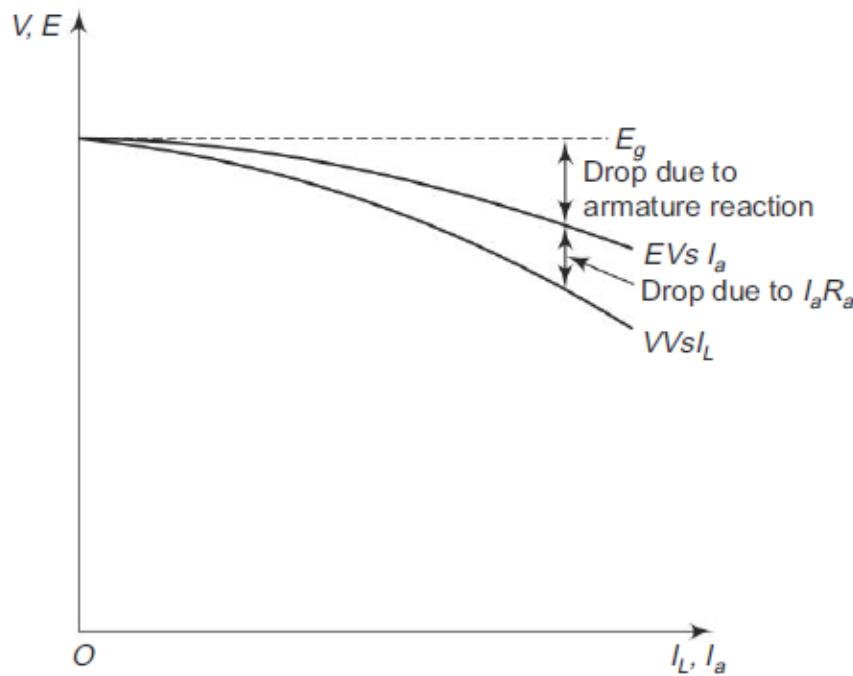
### 1. Open circuit characteristics (OCC) or No-load characteristics or magnetization characteristics. ( $I_f$ , $E_{g0}$ )



By removing the load connected , we obtain the no-load condition. When the generator is run at its rated speed with no-load, the terminal voltage appearing across the armature can be taken as the induced voltage. Thus, it is possible to obtain this open circuit voltage as a function of the field current. By varying the field current, we can obtain the variation in the no-load voltage. The curve thus obtained is known as open circuit characteristics. We can observe that the major portion of this characteristics (2-3) is linear. There are two non-linear portions namely 1-2 and 3-4. Beyond the operating point 4, we say that **saturation has occurred and so there will not be any appreciate increase in the generated voltage even for large increase in field current.** Because of the **residual flux in the magnetic poles there is a small amount of induced voltage even when the field current is zero.**

## 2.Internal ( $I_a$ , $E_g$ ) Characteristics

## 3.External ( $V_L$ , $I_L$ ) Characteristics



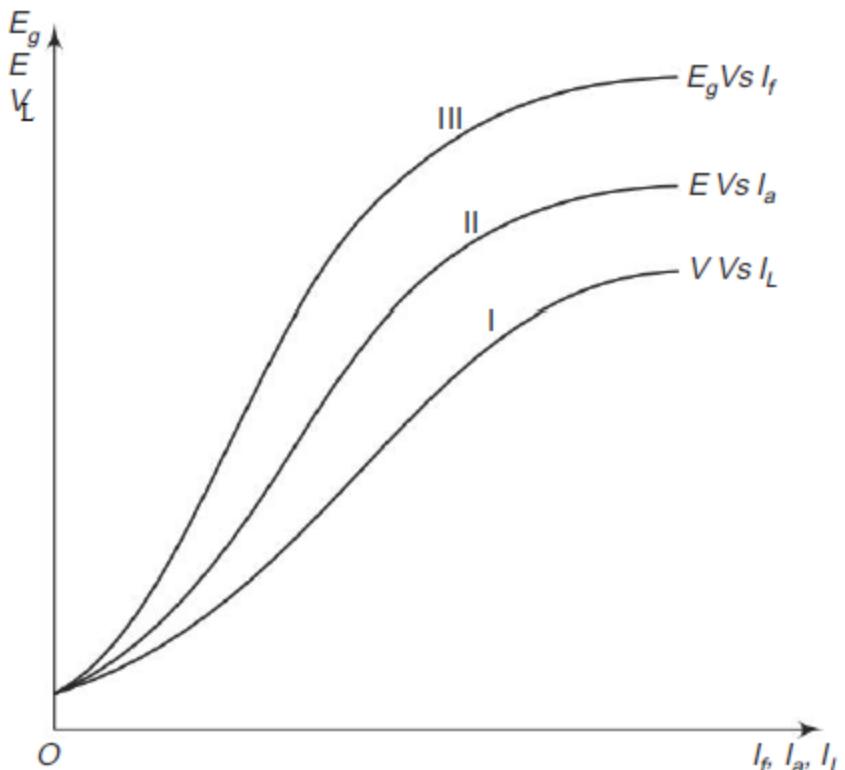
The generators should be made to run at its rated speed. The generator field current should be adjusted so that rated voltage is built up at no-load. Now by varying the load, the terminal voltage  $V$  as a function of load current  $I_L$  can be obtained as shown in Fig

The terminal voltage of the generator decreases on loading. This is because of (i) voltage drop due to armature resistance,  $R_a$  (ii) voltage drop due to armature reaction. So the generated emf and the terminal voltage go on decreasing.

**External characteristics** Variation of load terminal voltage with respect to the load current [i.e.  $V$  vs  $I_L$ ]. These two quantities are external quantities and they can be measured directly. Hence the name external characteristics.

**Internal characteristics** Variation of induced voltage in loaded condition as a function of the armature current [i.e.  $E$  vs  $I_a$ ]. These two quantities are internal quantities for the generation and  $E$  cannot be measured directly, but it can be estimated. Hence the name internal characteristics.

## DC Series Generator- Characteristics [All 3 Characteristics]



The **OCC** of series generator can be obtained with the help of the no load and shape of OCC is similar and same as that for DC shunt generator.

The **load** characteristics is rising characteristics. The difference between curves I and II represents the voltage drop due to internal resistance of the generator, i.e.  $R_a$  ( $R_a + R_{se}$ ) drop. The difference between curves II and III represents the drop due to armature reaction. If the load goes on increasing, then the terminal voltage may become zero because of heavy armature reaction.

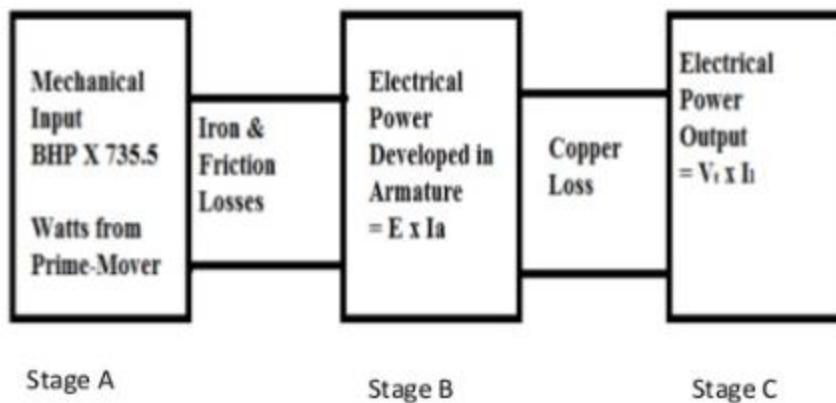
## Armature Reaction

By armature reaction is meant the effect of magnetic field set up by armature current on the distribution of flux under main poles of a generator. The armature magnetic field has two effects :

- (i) *It demagnetises or weakens the main flux* and
- (ii) *It cross-magnetises or distorts it.*

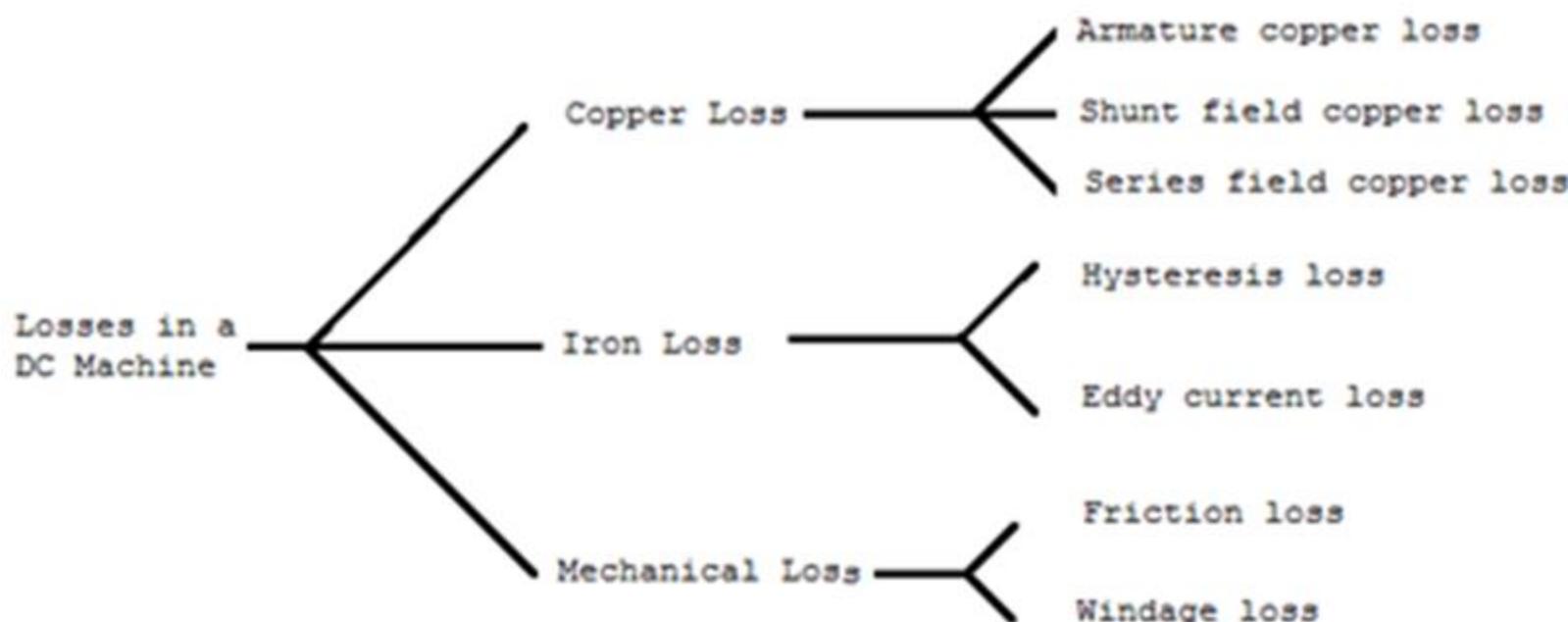
The first effect leads to reduced generated voltage and the second to the sparking at the brushes.

## Power Stages in D.C. Generator



copper loss  
iron loss  
mechanical loss

## Losses in DC Generator



## Applications of DC Generators

### **DC Shunt Generator**

1. Separately excited generators are preferred where the characteristics of dc shunt generators is not upto the expected level.
2. They can be used to excite the field magnets of ac generators.
3. As the drop in voltage is very small, these generators can be used for supplying loads needing constant voltage.
4. They are used as source for battery charging purpose.
5. These generators are used for electroplating and electrolytic purpose.

### **DC Series Generators**

1. They are used for series arc lighting.
2. They are used for series incandescent lighting.
3. They are used as booster, for the purpose of compensating the drop in voltage in the lines on loading.
4. Used for regenerative braking of dc locomotives.

### **Compound Generators**

1. By means of compound generators it is possible to give constant voltage at the line by proper compounding.
2. Differentially compounded generator may be used for welding purposes.
3. They are used to supply power to railway circuits, incandescent lamps, elevator motors, etc.

# DC MOTOR

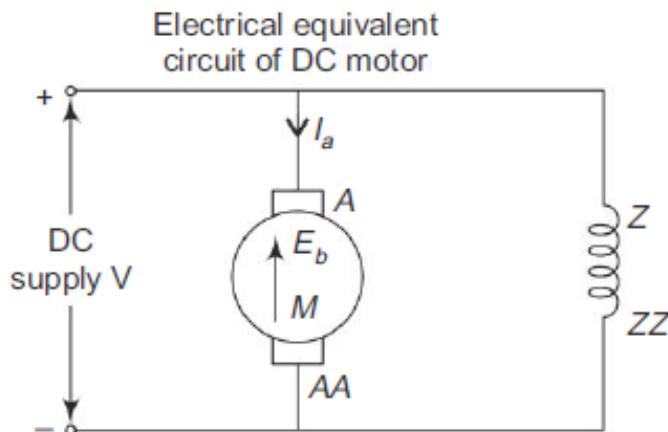
dc motor

## Principle

Whenever a current carrying conductor is kept in a stationary magnetic field an electromagnetic force is produced. This force is exerted on the conductor and hence the conductor is moved away from the field. This is the principle used in d.c. motors.

## Construction

The construction of dc motor is exactly similar to dc generators. The salient parts of a dc motor are yoke or frame, main field system, brushes, armatures and commutator.



## Working

In a dc motor, both the armature and the field windings are connected to a dc supply. Thus, we have current carrying armature conductors placed in a stationary magnetic field. Due to the electromagnetic torque on the armature conductors, the armature starts revolving. Thus, electrical energy is converted into mechanical energy in the armature. When the armature is in motion, we have revolving conductors in a stationary magnetic field. As per Faraday's Law of electromagnetic induction, an emf is induced in the armature conductors. As per Lenz's law, this induced emf opposes the voltage applied to the armature. Hence, it is called the counter or back emf. There also occurs a potential drop in the armature circuit due to its resistance. Thus, the applied voltage has to overcome the back emf in addition to supplying the armature circuit drop and producing the necessary torque for the continuous rotation of the armature.

Figure gives the electrical circuit of a d.c. shunt motor where

$E_b$  = back EMF

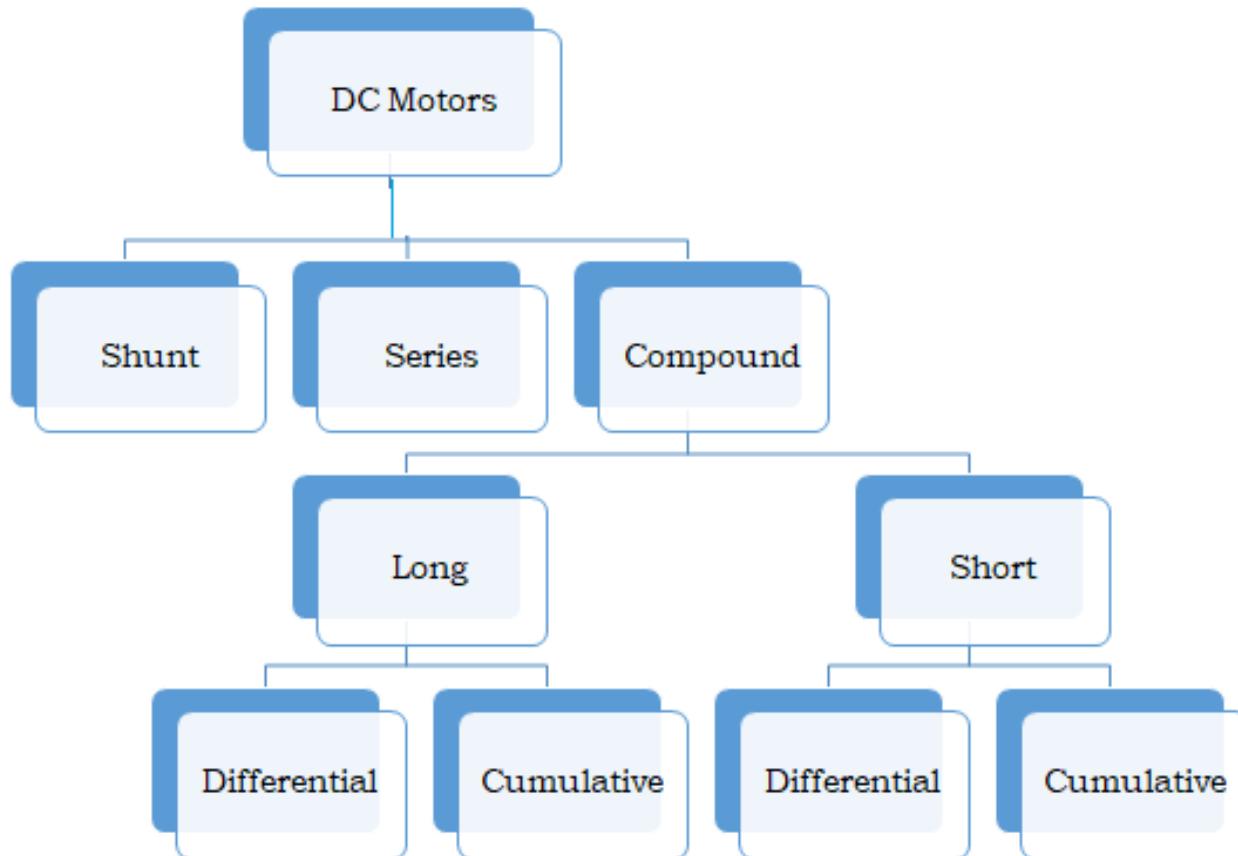
$I_a$  = current flowing in the armature circuit

$R_a$  = resistance of armature circuit

$V$  = applied voltage

Thus, the characteristics equation of a dc motor is  $V = E_b + I_a R_a$ , where  $I_a R_a$  represents the potential drop in the armature circuit.

# Types of Motor



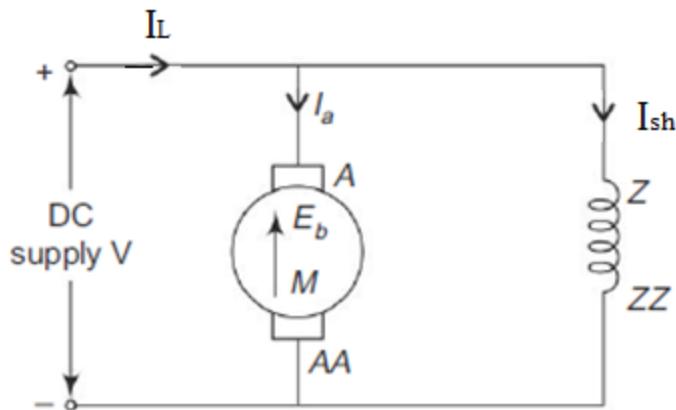
# 1. DC Shunt Motor

- Line Current

$I_L = I_a + I_{sh}$  Where  $I_L$  = Line or supply current

- Emf Equation

$$V = E_b + I_a R_a + V_b$$



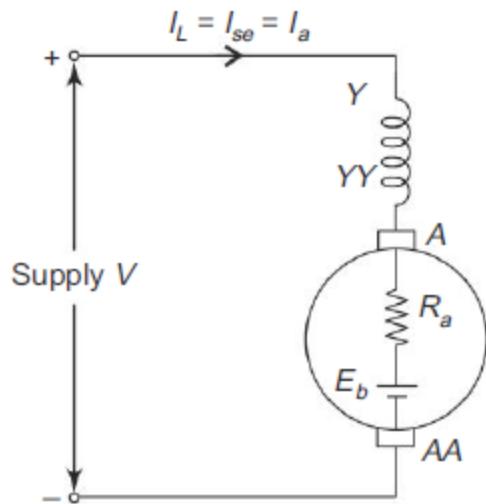
## 2. DC Series Motor

- Line Current

$$I_L = I_a = I_{se}$$

- Emf Equation

$$V = E_b + I_a R_a + I_{se} R_{se} + V_b$$



### 3. DC Compound Motor-Long Shunt

- Line Current

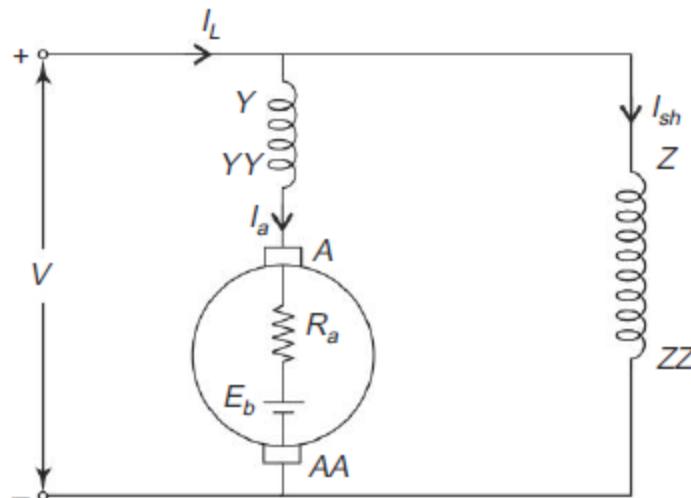
$$I_L = I_a + I_{sh}$$

- Series Field Current

$$I_a = I_{se}$$

- Emf Equation

$$V = E_b + I_a R_a + I_{se} R_{se} + V_b$$



# 4. DC Compound Motor-Short Shunt

- Line Current

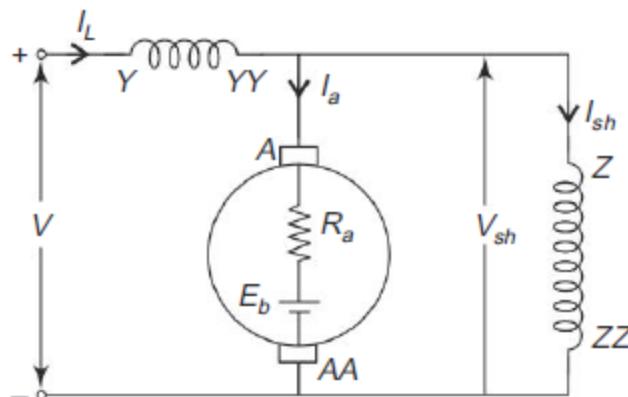
$$I_L = I_a + I_{sh}$$

- Series Field Current

$$I_L = I_{se}$$

- Emf Equation

$$V = E_b + I_a R_a + I_{se} R_{se} + V_b$$



## Torque and Speed Equations DC Motor

Armature Torque  $T_a$  of Motor     $T_a \propto \phi I_a$

Speed Equation               $N \propto \frac{E_b}{\phi}$

## Characteristics of DC Motors

characteristics of dc motors

The characteristics of dc show the relationship between the following quantities.

- (i) Torque and armature current ( $T$  vs  $I_a$ ). It is also known as the electrical characteristic.
- (ii) Speed and armature current ( $N$  vs  $I_a$ ).
- (iii) Speed and armature torque ( $N$  vs  $T_a$ ). It is also known as mechanical characteristics.

The above characteristics can be obtained for all types of motors with the help of torque and speed equations.

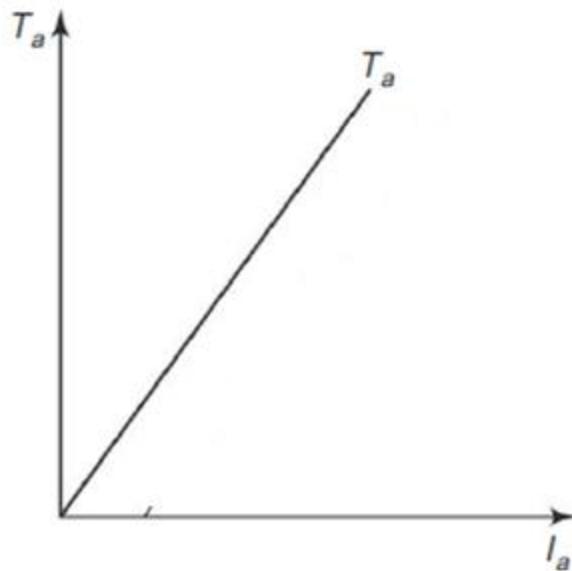
# 1. Characteristics DC Shunt Motor

## (i) $T_a$ Vs $I_a$

(i)  $T_a$  vs  $I_a$  Characteristics The flux,  $\phi$  reduces slightly on heavy loads only. Thus, flux can be considered to remain constant.

$$T_a \propto I_a$$

So,  $T_a$  vs  $I_a$  characteristics is a straight line characteristics as shown in Fig.



# 1. Characteristics DC Shunt Motor

## (ii) N Vs $I_a$

(ii)  $N$  vs  $I_a$  Characteristic

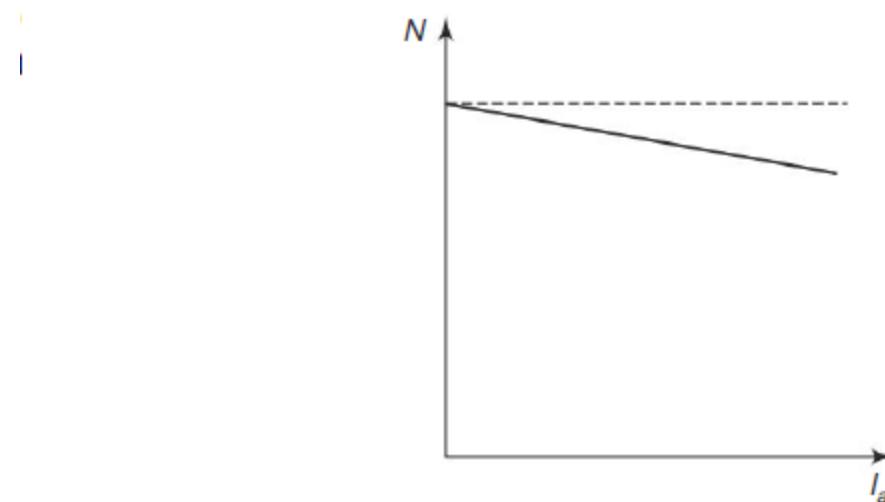
$$N \propto \frac{E_b}{\phi} \quad (1)$$

For shunt motor  $\phi$  is almost constant on load  $\therefore N \propto E_b$

$$N \propto V - I_a R_a \quad (2)$$

As load increases,  $I_a$  increases, but the drop  $I_a R_a$  is very small as  $R_a$  is very small. So there will be a small change in speed from no-load to full load as shown in Fig. The drop in speed from no-load to full-load is 5 to 10% of no-load speed.

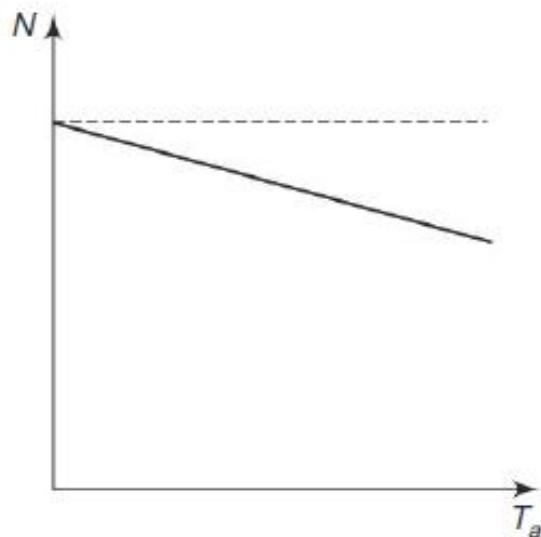
Shunt motor is a constant speed motor



# 1. Characteristics DC Shunt Motor

## (iii) $N$ Vs $T_a$

(iii)  $N$  vs  $T_a$  Characteristics This can be deduced from the above two characteristics and is shown in Fig. 6.24.



## 2. Characteristics DC Series Motor

### (i) $T_a$ Vs $I_a$

(i)  $T_a$  vs  $I_a$  Characteristics

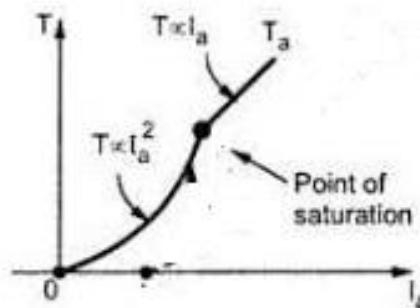
$$T_a \propto I_a;$$

In series motor  $\phi \propto I_{Se}$  and  $I_{Se} = I_a$

At light loads,  $T_a \propto I_a^2$  (prior to saturation of field poles)

At heavy loads,  $T_a \propto I_a$  (after saturation of magnetic poles,  $\phi$  is constant for any value of  $I_a$ )

So,  $T_a$  vs  $I_a$  characteristics is a parabola prior to saturation, and it is a straight line after saturation, as shown in Fig. . On heavy loads, the series motor exerts higher starting torque as  $T_a \propto I_a^2$  prior to saturation.



## 2. Characteristics DC Series Motor

### (ii) $N$ Vs $I_a$

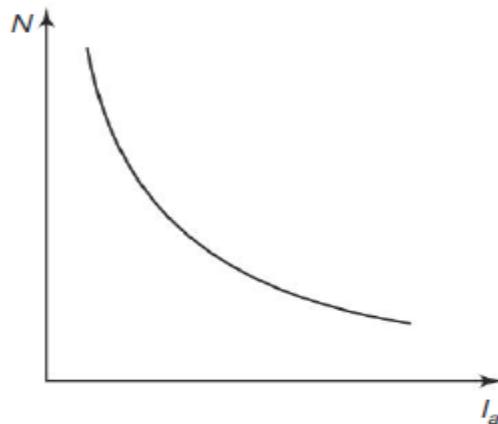
(ii)  $N$  vs  $I_a$  Characteristic

$$N \propto \frac{E_b}{\phi}; \quad (1)$$

$$E_b = V - I_a (R_a + R_{se}) \text{ and } \phi \propto I_{se} (I_{se} = I_a) \quad (2)$$

Change in  $E_b$  is very small with changes in load. So it can be regarded as constant on all loading

$$\therefore N \propto 1/\phi \quad \text{or} \quad N \propto 1/I_a \quad (3)$$

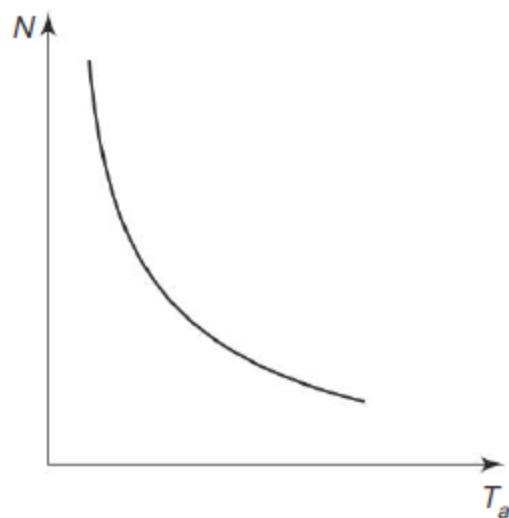


The speed-armature current characteristic is a regular parabola as shown in Fig. 6.26. On light load or no-load, the armature current  $I_a$  is very small, and so the motor will run at dangerously high speeds. So, series motor should always be started with some load on it. Series motor is a variable speed motor.

## 2. Characteristics DC Series Motor

### (iii) $N$ Vs $T_a$

(iii)  $N$  vs  $T_a$  Characteristics From the above two characteristics, this characteristics can be deduced, as shown in Fig. 6.27.



# STARTERS

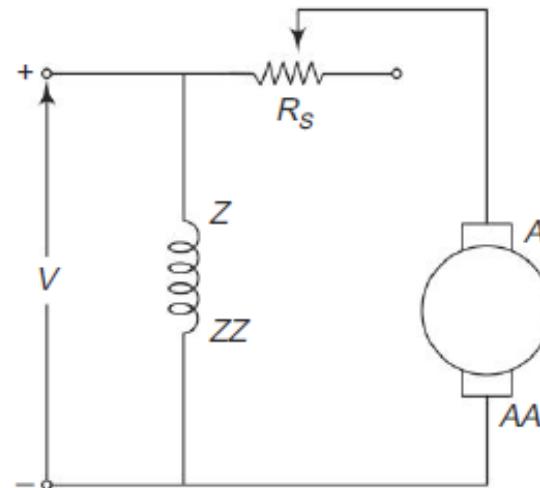
starters

## Starting of D.C. Motors

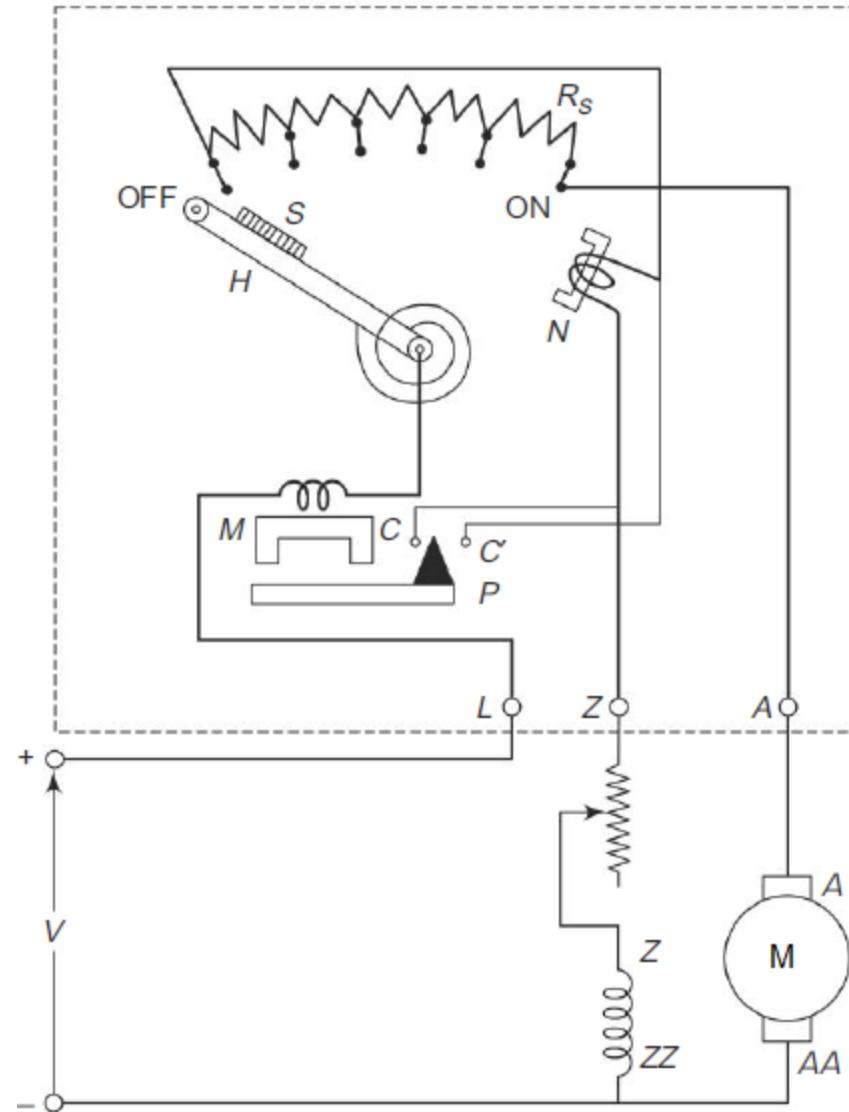
If the motor is directly switched on to the supply, the current drawn by the motor will be many times its full load current. This is because at the moment of switching on, there is no back emf developed by the motor. So, the current drawn by the motor is controlled by its internal resistance which is very small in value. This current is  $I_a = \frac{V}{R_a}$  which is sometimes around 25 to 30 times of full load current of motor. This

starting current will affect the power system supply quality. Specifically, there will be a heavy drop in system voltage momentarily. So, the starting current has to be limited. This can be achieved by connecting a resistance in the armature circuit. Once the motor picks up speed the back emf is developed and so the external resistance can be gradually cut out from the circuit. This is shown in Fig. 6.40. This resistance can be called as starting resistance.

To start the dc motor a device called starter can be used. The main function of the starter is to control the starting current drawn by the motor. The main component of a starter is resistance  $R_s$ . In addition to this they have protective devices like no-voltage release coil and overload release coil. There are 2-point starters meant for starting dc series motors 3-point and 4-point starters which are used for starting dc shunt and compound motors. The construction and working of a 3-point starter alone is discussed here.



## 3-POINT STARTER



## DC 3-point Starter

The components and the internal wiring of a 3-point starter is shown in Fig.

When the starter handle is moved from OFF position to stud (1) of  $R_s$ , the armature circuit of motor is closed through the starting resistance  $R_s$  and the overload release coil [OLR coil], thereby the starting current is controlled. Field circuit of motor is also closed through the voltage coil [NVC]. The motor starts running and back emf develops. Now the starter handle can be moved gradually from one stud to another and finally to ON.

The starter handle should be moved against the restraining force offered by the spring mounted in the starter handle. Once the starter handle comes to ON position, the NVC holds the starter handle firmly, i.e. the electromagnetic attracts the soft iron piece attached to the starter handle.

Whenever supply fails, the NVC gets de-energised and the electromagnetic N is demagnetized. Because of spring “force, the starter” handle comes to OFF position. When the motor is over loaded, electromagnetic force offered by the OLR coil is sufficient to attract the iron strip P. The contacts CC are bridged which results in short circuiting of NVC. So in this case also the electromagnet. “N” is demagnetized and the starter handle comes to OFF position. In this way the motor is protected against failure of supply and against overloading.

# THREE PHASE INDUCTION MOTOR

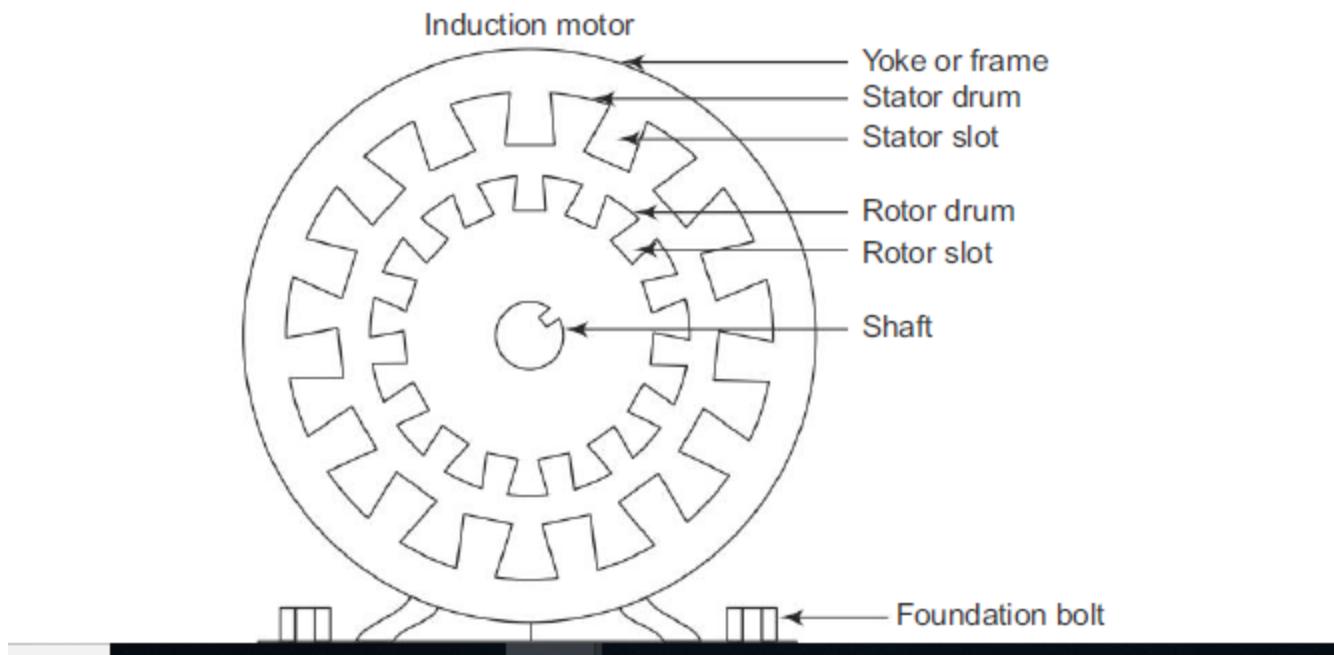
three phase induction motor

## Principle

When a three phase balanced voltage is applied to a three phase balanced winding, a rotating magnetic field is produced. This field has a constant magnitude and rotates in space with a constant speed. If a stationary conductor is placed in this field, an emf will be induced in it. By creating a closed path for the induced current to flow, an electromagnetic torque can be exerted on the conductor. Thus, the conductor is put in rotation.

## Construction

The important parts of a three phase induction motor are schematically represented in Fig. 6.47. Broadly classified, they are stator and rotor. Each of these is described below.



**Stator** This is the stationary part of the motor. It consists of an outer solid circular metal part called the yoke or frame and a laminated cylindrical drum called the stator drum. This drum has number of slots provided over the entire periphery of it. Required numbers of stator conductors are embedded in the slots. These conductors are electrically connected in series and are arranged to form a balanced three phase winding. The stator is wound to give a specific number of poles. The stator winding may be star or delta connected.

**Rotor** This is the rotating part of the induction motor. It is also in the form so slotted cylindrical structure. The air gap between stator and rotor is as minimum as mechanically possible. There are two types of rotors—squirrel cage rotor and slip-ring or wound rotor.

## Working

A three phase balanced voltage is applied across the three phase balanced stator winding. A rotating magnetic field is produced. This magnetic field completes its path through the stator, the air gap and the rotor. In this process, the rotor conductors, which are still stationary, are linked by the time varying stator magnetic field. Therefore, an emf is induced in the rotor conductors. When the rotor circuit forms a closed path, a rotor current is circulated. Thus, the current carrying rotor conductors are placed in the rotating magnetic field. Hence, as per the law of interaction, an electromagnetic force is exerted on the rotor conductors. Thus, the rotor starts revolving.

According to Lenz's law, the nature of the rotor induced current is to oppose the cause producing it. Here the cause is the rotating magnetic field. Hence, the rotor rotates in the same direction as that of the rotating magnetic field.

In practice, the rotor speed never equals the speed of the rotating magnetic field (called the synchronous speed). The difference in the two speeds is called slip. The current drawn by the stator is automatically adjusted whenever the motor is loaded.

## SINGLE PHASE INDUCTION MOTORS

Single phase induction motors are widely used in domestic, industrial and machine tool applications. The capacity of this motor varies from fractional horse power to 5 HP. Fractional horse power motors are used in variety of applications.

### Construction and Non-Self Starting of 1-phase Induction Motor

The construction of 1-phase is similar to 3-phase induction motors. The starter has a single winding. The rotor is squirrel cage type as in 3-phase induction motor. When starter winding is energised with single phase supply an alternating flux is set up, but it is not a revolving field as in 3-phase induction motor. This alternating flux when acting on stationary motor cannot produce rotation. Only a revolving starting. However if the rotor is given an initial start by hand or by other means, then motor may start and run.

To make the single phase induction motors self starting, the following type of 1-phase induction motors were developed.

- (a) Split-phase induction motors
  - (i) Resistance-start motor
  - (ii) Capacitor-start motor

## 1 Split Phase Resistance Start 1-Phase Induction Motor

In addition to the main winding of the motor, an auxiliary winding is also placed in the starter. Both these windings are uniformly distributed in the stator slots. The two windings are displaced by  $90^\circ$  (electrical) in space. The main winding is called running winding and the auxiliary winding is called the starting winding. The arrangement of these two windings in stator is shown in Fig. 6.53. The main winding is

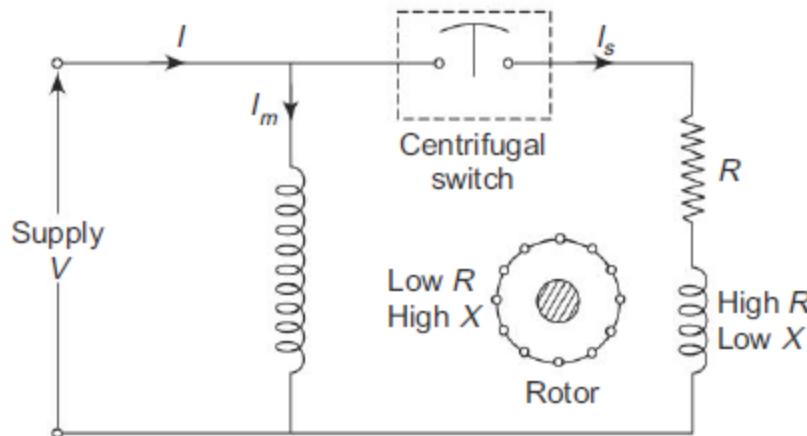
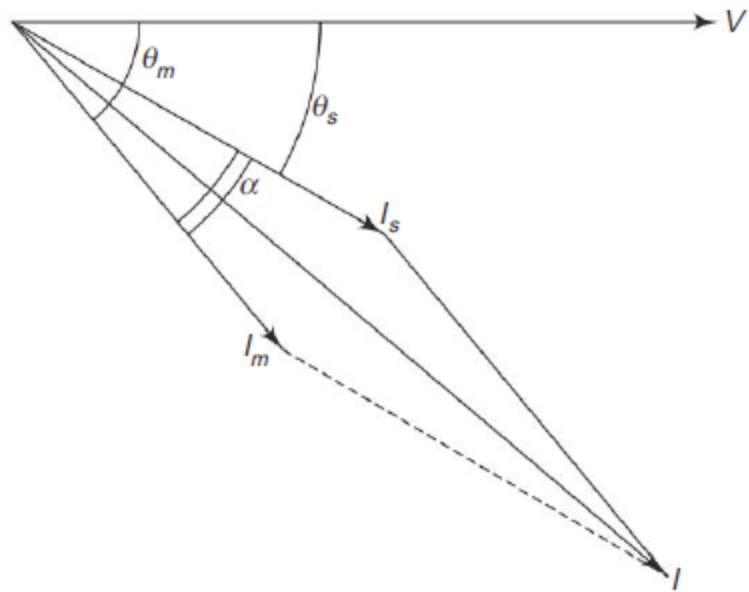


Fig. 6.53

highly inductive and the auxiliary winding should be highly resistive. For this purpose, the auxiliary winding is provided with less number of turns. To make it highly resistive external resistance can be used in the auxiliary winding circuit. A centrifugal switch placed in the auxiliary winding circuit. The switch is in closed condition when the motor is at rest.

The 1-phase supply is given to the two windings, which are in parallel across the supply. The currents through the main winding and starting winding are displaced by an angle  $\alpha$  as shown in Fig. 6.54. This angle  $\alpha$  should be kept nearer to  $90^\circ$  by proper design of starting winding. The starting torque developed is proportional to  $\sin \alpha$ . When the motor attains 75% of rated speed, the centrifugal switch is opened and hence starting winding is disconnected from the supply. The starting torque developed is 150 to 200% full load torque of the motor.

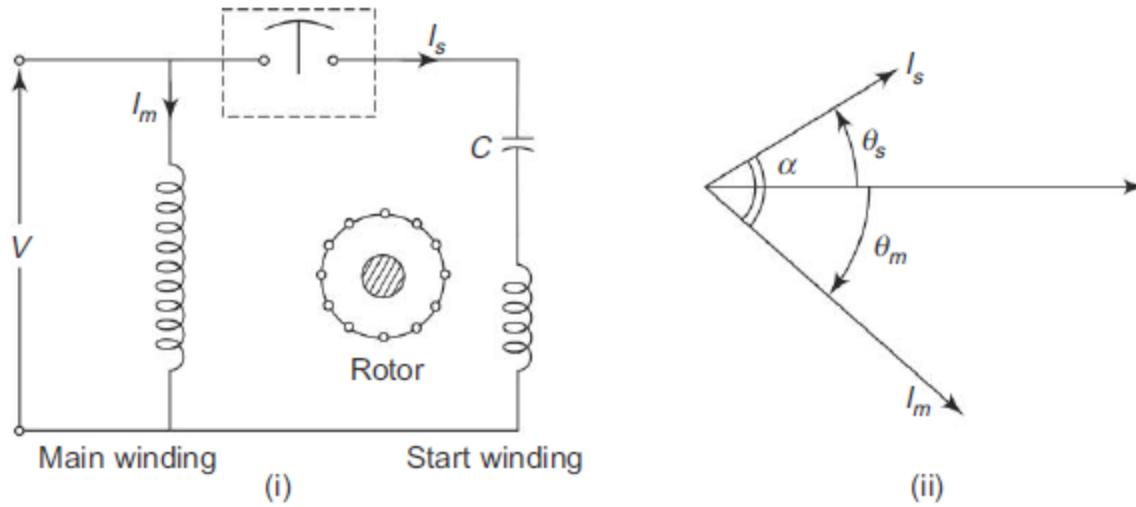
This type of motor is used in oil burns, machine tools, grinders, dish washes, washing machines, airblowers and air compressors.



## 2. Split Phase Capacitor Start Induction Run Single Phase Induction Motor

The single phase supply given to the stator winding, can be split into two phases by connecting a suitable capacitor in series with the starting winding, as shown in Fig. 6.55 (i). The value of capacitance should be such that the phase angle  $\alpha$  between  $I_s$  and  $I_m$  should be nearer to  $90^\circ$ . Then the fluxes due to this current is also displaced by the same angle  $\alpha$ . This causes revolving field. The starting torque developed depends on  $\sin \alpha$ . The starting torque developed is about 300 to 450% of full load torque. This is more as compared to the previous type motor as  $\alpha$  is more here. The value of  $\alpha$  in the previous type motor is around  $40^\circ$  only. When the motor attains 75% of rated speed, the centrifugal switch opens and the starting winding is isolated from the circuit.

This motor is used where high starting torque is needed under loaded condition. They are used for pumps, refrigerations units, air-conditioners, large size washing machines, etc.



## 3-PHASE AC GENERATOR OR ALTERNATOR

An alternator works on the principle of electromagnetic induction. If a conductor is placed in a moving magnetic field an emf is induced in the stationary conductor as per Faraday's first law of electromagnetic induction.

### Construction

The two important parts of AC generators are stator and rotor. The construction of ac generator showing all main parts is given in Fig. 6.56.

**Stator** The stator consists of a cast iron or mild steel frame, which supports the armature core. This frame acts as an enclosure and provides a closed path for the magnetic flux. The armature core is made of laminated sheets. The material for armature core may be special magnetic iron or steel alloys. The inner periphery of

the armature core is slotted, in order to accommodate the armature winding. The armature winding may be single layer or double layer. The 3-phase armature winding should be a balanced one. The number of turns and size of wire should be same for all the 3-phase winding and the 3-phase winding are displaced in space by  $120^\circ$  (electrical) between them. The three ends of three phase winding are connected together to make the starprint, and the other three terminals of the three phase windings are brought out of the generator.

**Rotor** The rotor is like a flywheel having alternate N and S poles on its outer periphery. These electromagnets are magnetised by means of low dc voltage of 125 or 250 V. As rotor and hence the field magnets are rotating, this dc excitation voltage is given through slip rings which are fixed on the frame.

There are two types of rotors used in ac generators.

(i) *Salient or projecting pole type* It is used for engine driven generators, which are run at low and medium speed. The rotor has even number of projecting poles, whose cores are boiled to a heavy magnetic wheel of cast iron. The axial length of rotor is short and the diameter is large.

(ii) *Smooth cylindrical type* It is used for steam turbine driven generators or turbo alternators which are run at high speed. The rotor is made up of cast iron and cylindrical in shape. The outer periphery of the rotor is slotted to receive the field windings. The field windings are wound, such that N and S poles occur alternately. The number of field poles may be two or four. The axial length of rotor is large and its diameter is less.

## Working of Alternator

The field magnets are magnetised by applying 125 volts or 250 volts through slip rings. The field windings are connected such that, alternate N and S poles are provided. The rotor and hence the field magnets are driven by the prime movers (steam driven turbine or engine driven). As the rotor rotates, the armature conductors are cut by the magnetic flux. Hence emf is induced in the armature conductors. As the magnetic poles are alternately N and S pole, the emf acts in one direction and then in the other direction. Hence an alternating emf induced in the stator conductors. The frequency of induced emf depends on the number of N and S poles moving past an armature conductor in one second. The frequency of induced emf is given by,

$$f = \frac{P N}{120}; P \rightarrow \text{No. of magnetic poles}$$

$N \rightarrow$  Speed of rotor in rpm.

The direction of induced emf can be obtained by Fleming's Right hand rule.

# SYNCHRONOUS MOTOR

synchronous motor

Synchronous motor runs only at synchronous speed,  $N_s = \frac{120f}{P}$  on no-load and loaded conditions. It maintains speed while running. The only way to change the speed is by varying the supply frequency. It is not a self starting motor. This motor has to run upto its synchronous speed by some method, and then it can be synchronised.

## Construction

The construction of synchronous motor is same as that of 3-phase ac generator. A synchronous machine may be run as synchronous motor and as synchronous generator.

## Working Principle of Operation

When a 3-phase balanced winding is supplied with a balanced 3-phase supply, a rotating magnetic field of constant magnitude and synchronous speed is produced. Let the motor stator have 2-poles marked as  $N_s$  and  $S_s$  as shown in Fig. 6.57. The stator poles are rotating at synchronous speed. Let us assume that it moves in clockwise direction. The rotor is positioned as shown in Fig. 6.58 initially with reference to the position  $AB$  marked. As like poles repel, the rotor will tend to move in anticlockwise direction. At the end of first half cycle of supply, the rotor poles occupy the position as shown in Fig. 6.58 with respect to the reference plane  $AB$ . Now, because of attractive force between the unlike poles, the rotor will tend to move in the opposite, i.e. clockwise direction. So, with rapid movement of the stator poles, the rotor is subjected to a torque which is also rapidly reversing. But because of the inertia of the rotor, it will not respond to such a rapid reversing torque. So, the rotor remains stationary, which shows that it is not a starting motor.

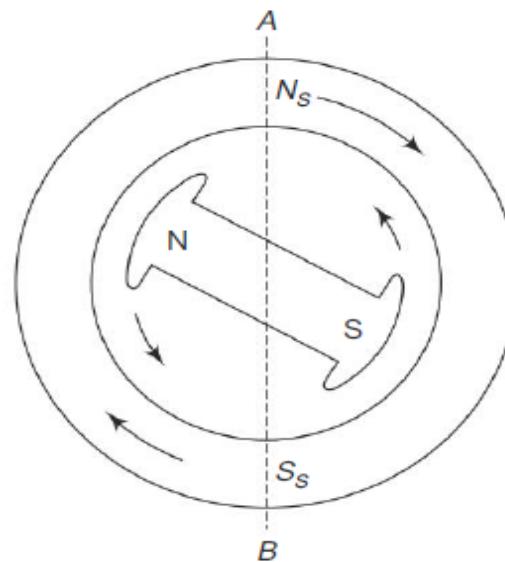
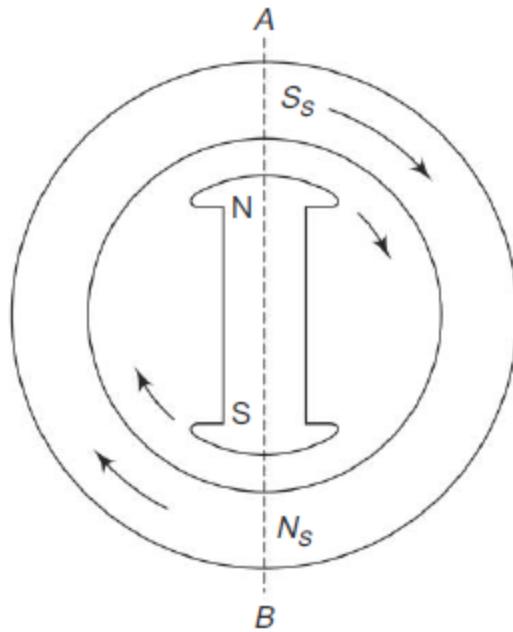
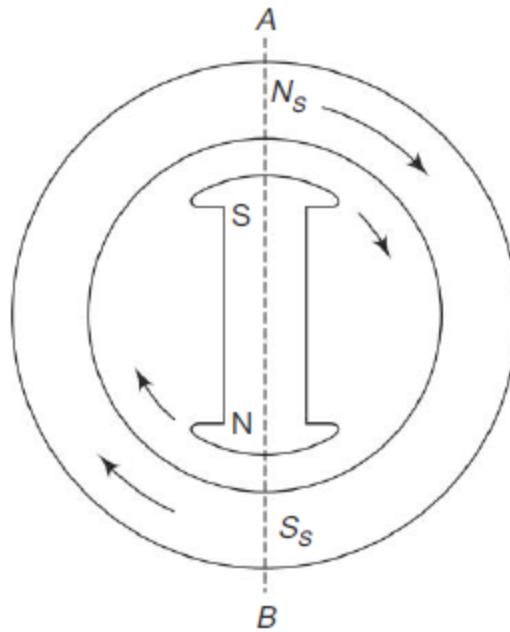


Fig. 6.57



**Fig. 6.58**



**Fig. 6.59**

Now consider the position of the rotor as shown in Fig. 6.59. The stator and rotor poles attract each other. Let the rotor also be rotating in clockwise direction at synchronous speed as that of stator field. So, the stator and rotor poles attract each other, at any instant, which results in unidirectional torque production, in clockwise direction in this case.

## **Synchronous Motor Starting Method**

The methods for starting synchronous motor are:

- (i) A dc motor coupled to the synchronous motor shaft: (discussed above)
- (ii) Using the damper windings as a squirrel cage induction motor.
- (iii) Using the field excited generator as a dc motor [similar to method (i)].

## **Synchronous Motor-application**

- (i) It is used in power house and in major substations to improve the power factor.
- (ii) Used in textile mills, rubber mills, mining and other big industries for power factor improvement purpose and to maintain the facility of system voltage.
- (iii) It is used to drive continuously operating and constant speed equipments like fans, blowers, centrifugal pumps, air comparators, etc.

# BEEE-UNIT 3

Electronic Devices	
18	
Safety measures in electrical systems	Clippers and clampers
Types of wiring, wiring accessories	Problem Solving Session
House wiring for staircase, fluorescent lamp, LED lamp & corridor wiring	Lab 8: Characteristics of semiconductor devices
Basic principles of earthing, Types of earthing. Grounding in DC circuits	BJT construction, operation
Basic principles and classification of instruments	BJT characteristics (CB, CE and CC configurations) and uses
Moving coil and moving iron instruments	JFET construction, operation
Problem Solving Session	JFET characteristics (CS configuration) and uses.
Lab 7: Types of wiring (fluorescent lamp wiring, staircase wiring, godown wiring)	MOSFET construction, operation
Overview of Semiconductors	MOSFET characteristics (CS configuration) and uses
PN junction diode	Problem Solving Session
Zener diode	
Diode circuits: rectifiers, half and full wave	Lab 9: Wave shaping circuits
Bridge type rectifier, filter circuit	

# HOUSE WIRING

- House wiring is to deal with the distribution system within the domestic premises.
- The wiring requirements may vary among the different consumers.
- House wiring is generally done for consumption of electrical energy at 230 V, 1-phase or at 400 V,3-phase.
- In the three phase system, the total load in the house is expected to be divided among the three phases.
- An earth wire is also run connecting all the power plugs from where large quantity of electrical energy is tapped by using electrical appliances like heater, electric iron, hot plate, etc. This chapter deals with the wiring materialsand accessories, different systems of wiring and earthing methods.

# **WIRING MATERIALS AND ACCESSORIES**

- 1. Switches:** A switch is used to make or break the electric circuit.
- 2. Lamp Holders:** A lamp holder is used to hold the lamp for lighting purposes.
- 3. Power point:** Power points (plugs, wall sockets) need to be installed throughout the house in locations where power will be required.
- 4. Main Switch:** This is used at the consumer's premises so that he may have self-control of the entire distribution circuit.

**5.Circuit Breakers:** Domestic Electrical Circuit Breakers provide essential protection to house from electrical hazards. It is essential to use domestic circuit breakers to get protected from electrical overloads and short circuit conditions. The most widely used electrical circuit breakers are Miniature circuit breakers (MCBs) , Residual current circuit breaker (RCCB) and Mounded Case Circuit Breaker (MCCB)

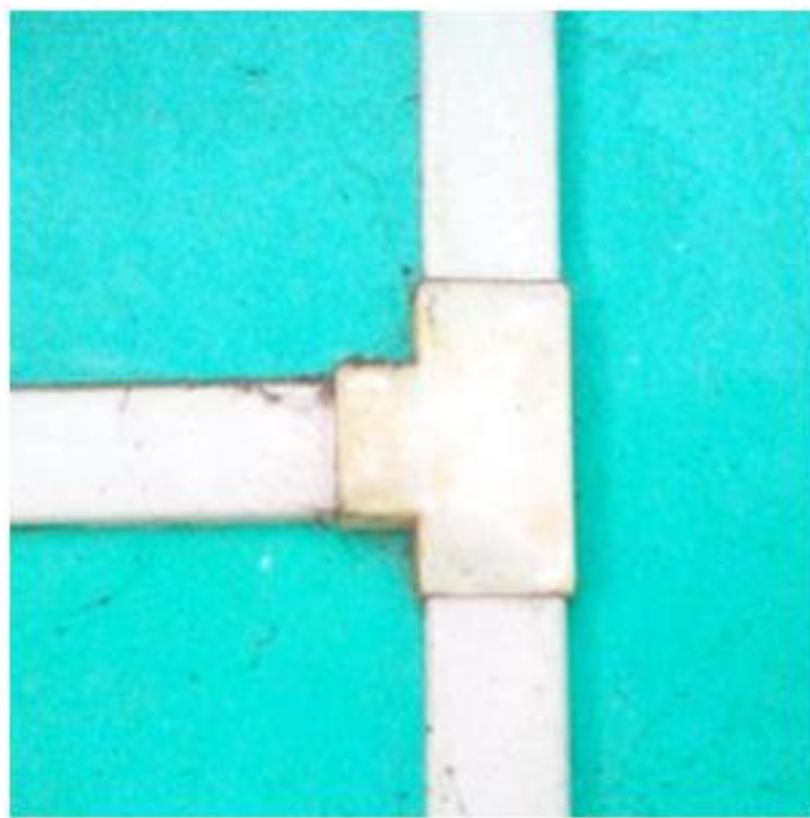
Electrical wiring system is classified into five categories:

1. Cleat wiring
2. Casing wiring
3. Batten wiring
4. Conduit wiring
5. Concealed wiring

**1. Cleat wiring**



**2. Casing wiring**



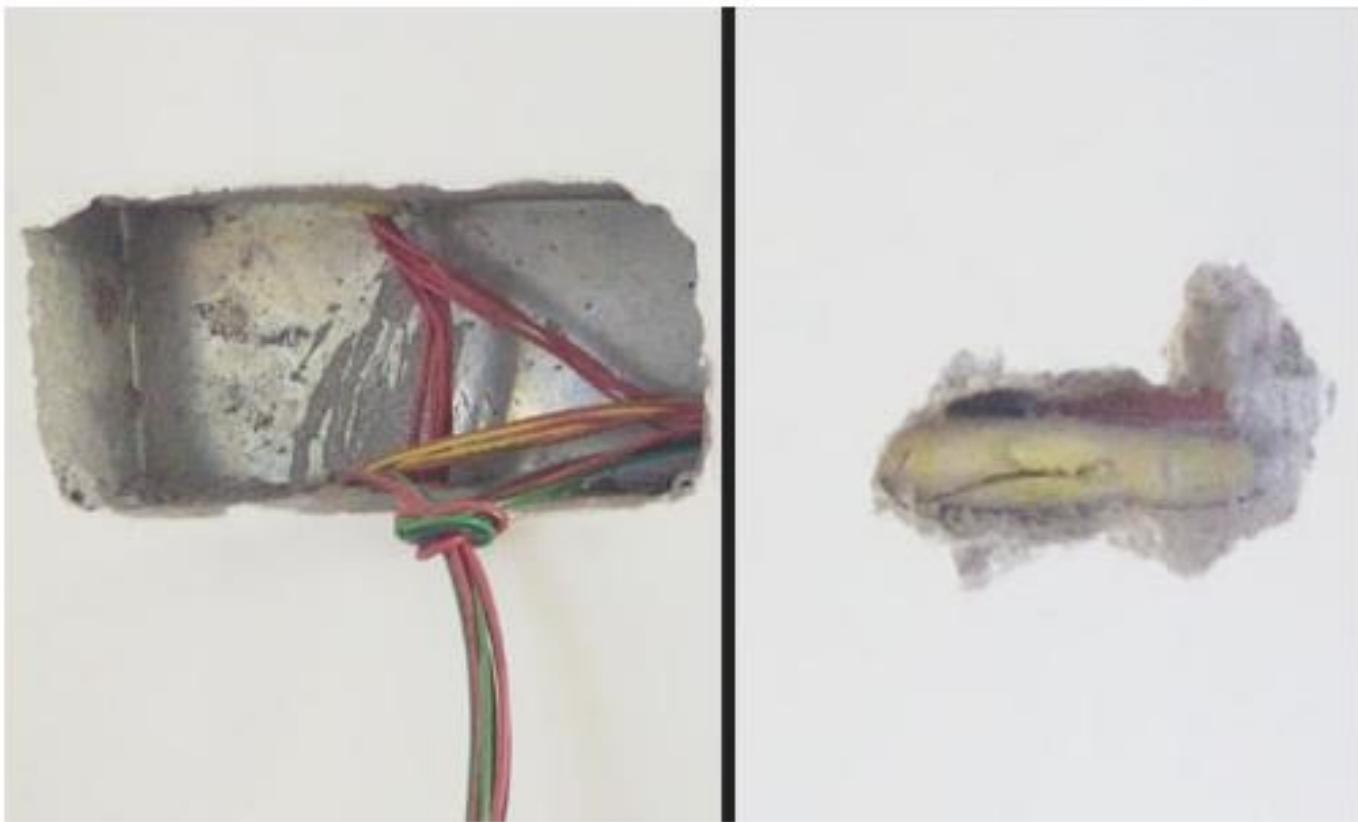
### **3.Batten wiring**



### **4. Conduit wiring**



## **5. Concealed wiring**



## **1-WAY SWITCH**

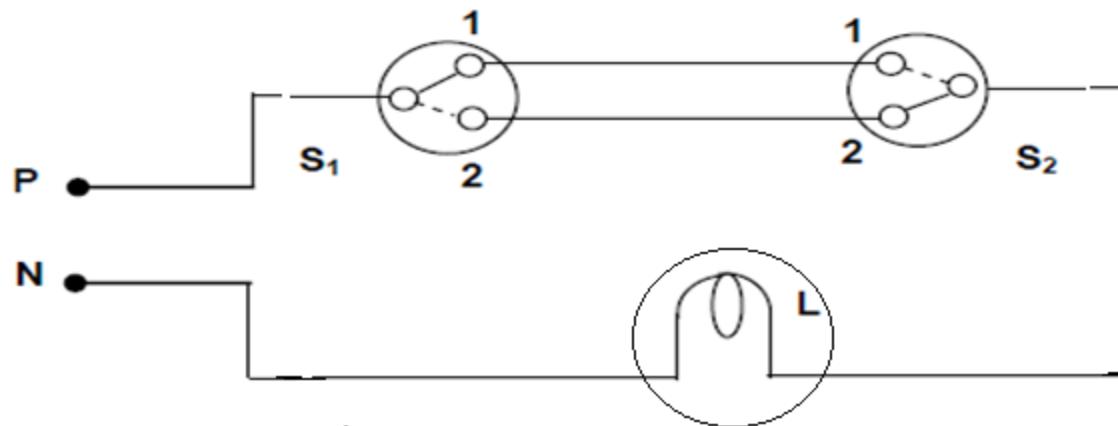


## **2-WAY SWITCH**



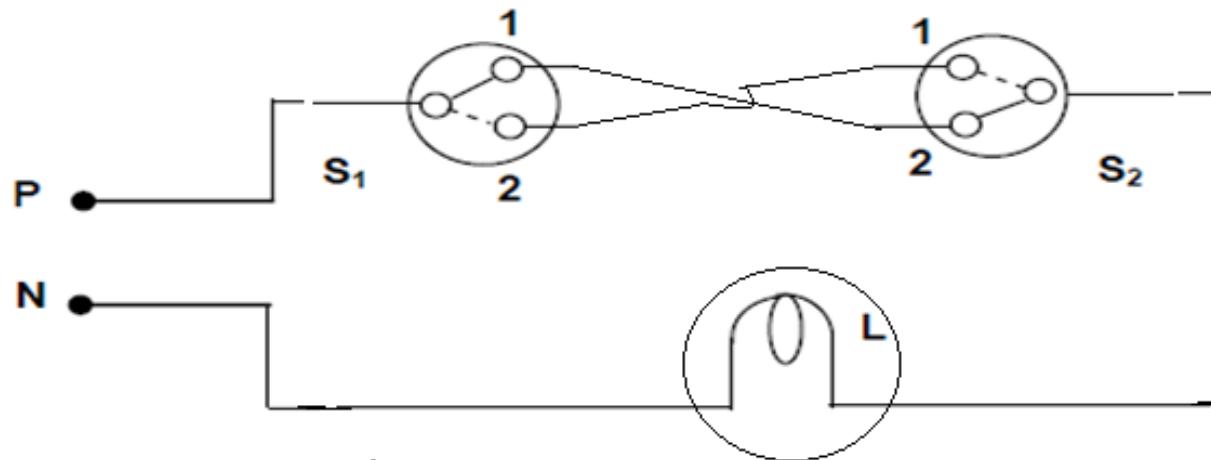
# STAIRCASE WIRING

In staircase wiring a single lamp, placed at the middle of the staircase, is controlled by switches at two places, one at the beginning of the staircase and the other at the end of the staircase. For this purpose two-way switches are required. The wiring circuit is shown below.



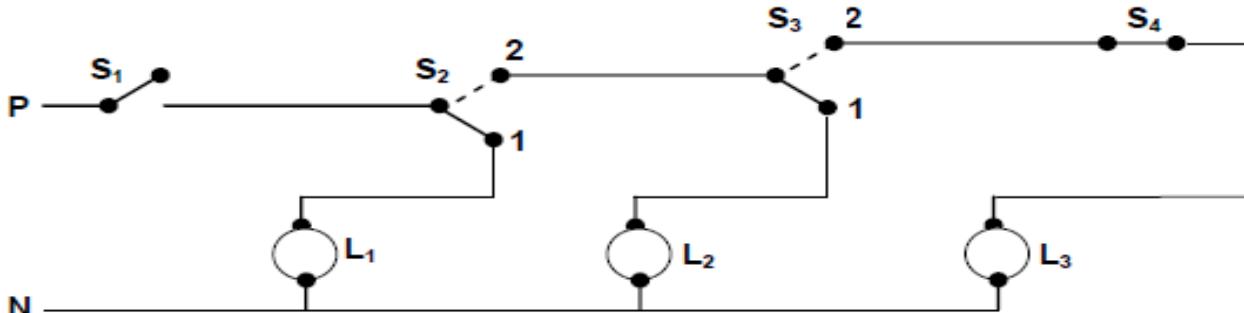
Position of switch $S_1$	Position of switch $S_2$	Condition of lamp
1	1	ON
1	2	OFF
2	1	OFF
2	2	ON

## **STAIRCASE WIRING- Another type of connection**



<b>Position of switch <math>S_1</math></b>	<b>Position of switch <math>S_2</math></b>	<b>Condition of lamp</b>
1	1	<b>OFF</b>
1	2	<b>ON</b>
2	1	<b>ON</b>
2	2	<b>OFF</b>

# CORRIDOR WIRING



Moving from left to right:

Enters      Closes S<sub>1</sub>      L<sub>1</sub> ON

Reaches S<sub>2</sub>      Put S<sub>2</sub> to 2      L<sub>1</sub> OFF and L<sub>2</sub> ON

Reaches S<sub>3</sub>      Put S<sub>3</sub> to 2      L<sub>2</sub> OFF and L<sub>3</sub> ON

Reaches S<sub>4</sub>      Opens S<sub>4</sub>      L<sub>3</sub> OFF

Moving from right to left:

Enters      Closes S<sub>4</sub>      L<sub>3</sub> ON

Reaches S<sub>3</sub>      Put S<sub>3</sub> to 1      L<sub>2</sub> ON and L<sub>3</sub> OFF

Reaches S<sub>2</sub>      Put S<sub>2</sub> to 1      L<sub>1</sub> ON and L<sub>2</sub> OFF

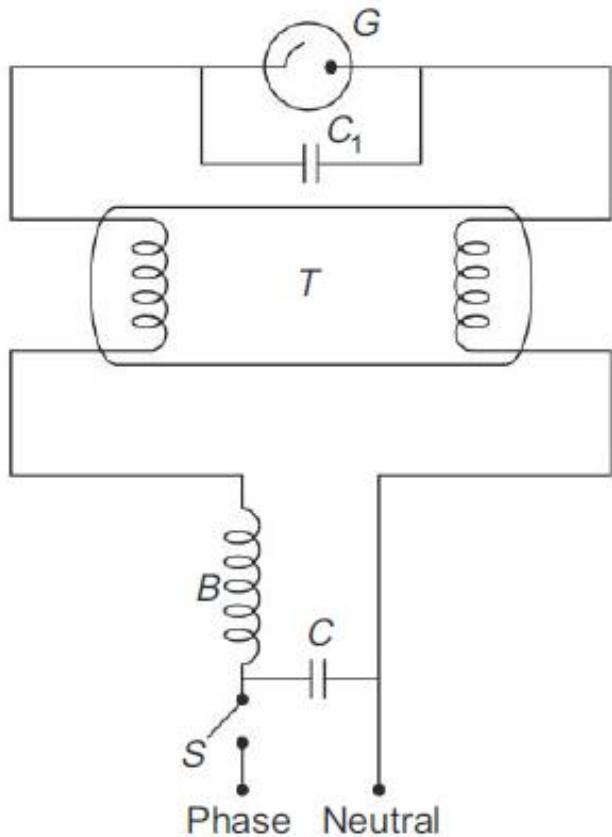
Leaves      Opens S<sub>1</sub>      L<sub>1</sub> OFF

# FLUORESCENT LAMP



A fluorescent lamp or fluorescent tube is a gas-discharge lamp that uses electricity to excite mercury vapor. The excited mercury atoms produce short-wave ultraviolet light that then causes a phosphor to fluoresce, producing visible light. A fluorescent lamp converts electrical power into useful light more efficiently than an incandescent lamp. Lower energy cost typically offsets the higher initial cost of the lamp. The lamp is more costly because it requires a ballast to regulate the flow of current through the lamp.

While larger fluorescent lamps have been mostly used in commercial or institutional buildings, the compact fluorescent lamp is now available in the same popular sizes and is used as an energy-saving alternative in homes.



- $T$  – Fluorescent tube
- $G$  – Glow switch starter
- $B$  – Ballast or choke
- $S$  – Switch
- $C$  – Capacitor for P.F. improvement
- $C_1$  – Capacitor to suppress radio interference

# LED lamp

An LED lamp or LED light bulb is an electric light for use in light fixtures that produces light using one or more light-emitting diodes (LEDs). LED lamps have a **lifespan** many times longer than equivalent incandescent lamps, and are significantly **more efficient** than most fluorescent lamps, with a luminous efficacy of up to 303 lumens per watt. However, LED lamps require an electronic LED driver circuit when operated from mains power lines. Many LEDs use only about **10%** of the energy an incandescent lamp requires.

# Safety Precautions when Working with Electricity

1. Never touch or try repairing any electrical equipment or circuits with wet hands. It increases the conductivity of electric current.
2. Never use equipment with **damaged insulation** or **broken plugs**.
3. If you are working on any electrical socket at your home then always turn off the mains.
4. Always **use insulated tools while working.**(never use aluminium or steel ladder )
5. Electrical hazards include exposed **energized parts** and unguarded electrical equipment which may become **energized unexpectedly** -carries warning signs like “**Shock Risk**”. Always be observant such electrical signs.

6. when working electrical circuit always use appropriate insulated rubber gloves and goggles.
7. Never try repairing energized equipment. Always check that it is de-energized first by using a tester. When an electric tester touches a live or hot wire, the bulb inside the tester lights up showing that an electrical current is flowing through the respective wire.
8. Know the wire code of your country.
9. Always use a circuit breaker or fuse with the appropriate current rating. Circuit breakers and fuses are protection devices that automatically disconnect the live wire when a condition of short circuit or over current occurs. The selection of the appropriate fuse or circuit breaker is essential.

# BASIC PRINCIPLES OF EARTHING

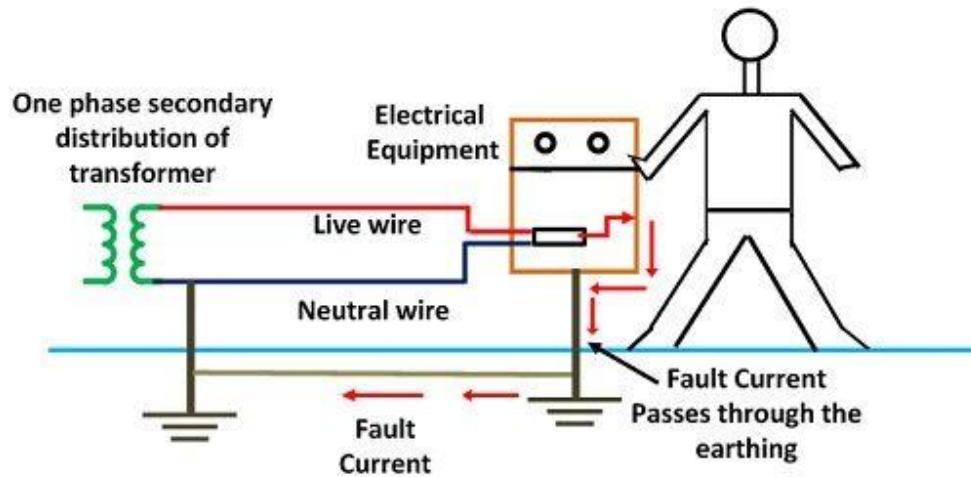
## Earthing and its Necessity

Earthing means generally connected to the mass of the earth. It shall be in such a manner as to ensure at all times an immediate and safe discharge of electric current due to leakages, faults, etc.

All metallic parts of every electrical installation such as conduit, metallic sheathing, armouring of cables, metallic panels, frames, iron clad switches, instrument frames, household appliances, motors, starting gears, transformers, regulators etc, shall be earthed using one continuous bus (barewire). If one earth bus for the entire installation is found impracticable, more than one earthing system shall be introduced. Then, the equipment and appliances shall be divided into sub-groups and connected to the different earth buses.

The earthing conductors, when taken out doors to the earthing point, shall be encased in pipe securely supported and continued up to a point not less than 0.3 m more below ground level. No joints are permitted in an earth bus. Whenever there is a lightning conductor system installed in a building, its earthing shall not be bonded to the earthing of the electrical installation.

Before electric supply lines or apparatus are energized, all earthing system shall be tested for electrical resistance to ensure efficient earthing. It shall not be more than two ohms including the ohmic value of earth electrode.



Electrical System With Earthing

Circuit Globe

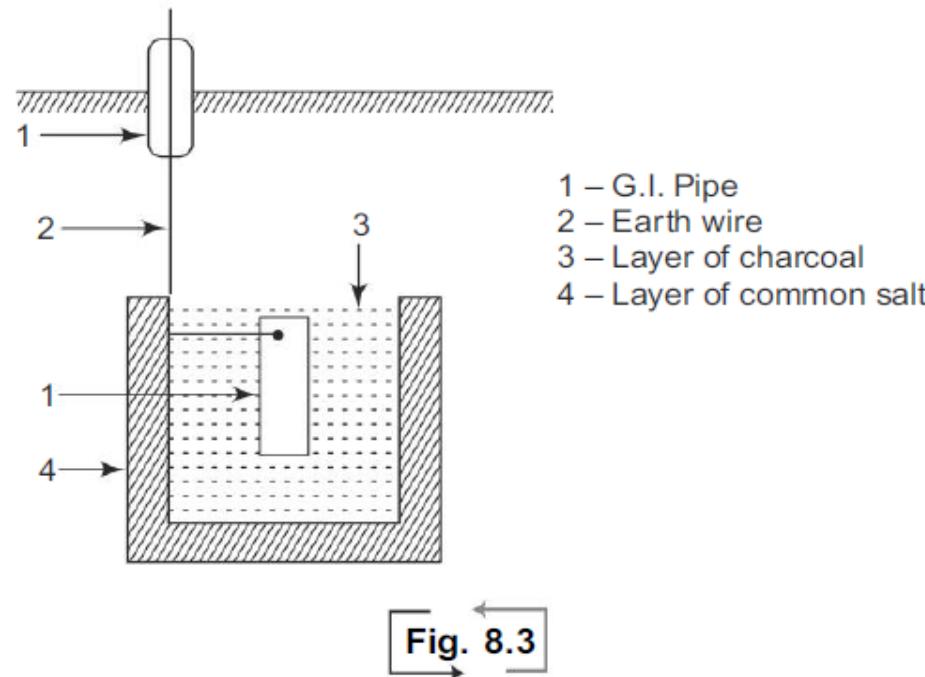


## 1 Earthing through a G.I. Pipe

In this method a G.I. pipe used as an earth electrode. The size of the pipe depends upon the current to be carried and type of soil in which the earth electrode is buried.

earthing through a  
GI pipe

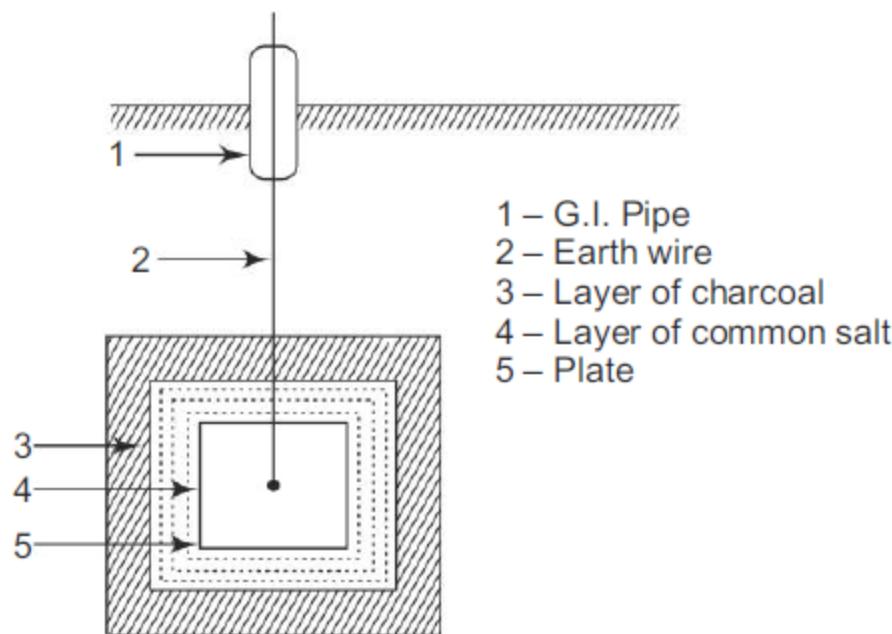
For ordinary soils the length of the G.I. pipe used as an earth electrode is 2 m long and 38 mm in diameter or 1.37 m long and 51 mm in diameter. For dry and



rocky soils the length may be increased to about 2.75 metres and 1.85 metres respectively. The pipe is placed vertically, burying to a depth not less than 2 metres in as moist a place as possible, preferably in close proximity of water tap, water pipe or water drain and at least 0.6 metre away from all building foundations, etc as shown in Fig. 8.3. The pipe shall be completely covered by 80 mm of Charcoal with the layer of common salt 30 mm all around it. The charcoal and salt decreases the earth resistance.

## 2 Earthing through a Plate

A G.I. or copper plate is used as an earth electrode. If a G.I. plate is used it shall be of dimensions  $0.3\text{ m} \times 0.3\text{ m}$  and  $6.35\text{ mm}$  thick and if a copper plate is used it shall be of dimensions  $0.3\text{ m} \times 0.3\text{ m}$  and  $3.2\text{ mm}$  thick. The plate is buried to a depth of not less than  $2\text{ m}$  in as moist a place as possible preferably in close proximity of water tap, water pipe or water drain and at least  $0.6\text{ m}$  away from all building foundations, etc. The plate shall be completely covered by  $80\text{ mm}$  of charcoal with a layer of common salt of  $30\text{ mm}$  all around it, keeping the faces of the vertical as shown in Fig. 8.4.



# CLASSIFICATION OF INSTRUMENTS

Electrical measuring instruments are classified as follows:

- I. Depending on the quantity measured e.g. Voltmeter, Ammeter, Wattmeter, Energymeter, Ohmmeter.
- II. Depending on the different principles used for their working e.g. Moving Iron type, Moving coil type, Dynamometer type, Induction type.
- III. Depending on how the quantity is measured? e.g. Deflecting type, Integrating type, Recording type.

## The different types of torques associated with measuring instruments

### 1. Deflecting Torque

This torque acts on the moving system of the instrument to give the required deflection. It exists as long as the instrument is connected to the supply. The deflecting torque shall ensure a deflection proportional to the magnitude of the quantity being measured.

## 2. Opposing Torque

This torque always opposes the deflecting torque. The moving system attains a steady deflected position when the opposing torque equals the deflecting torque. The components of the opposing torque are inertia torque, control torque and damping torque.

### 2 (a) Inertia Torque

This is due to the inertia of the moving system. The deflecting has to overcome this and make the moving system move from its rest position.

### 2 (b) Control Torque

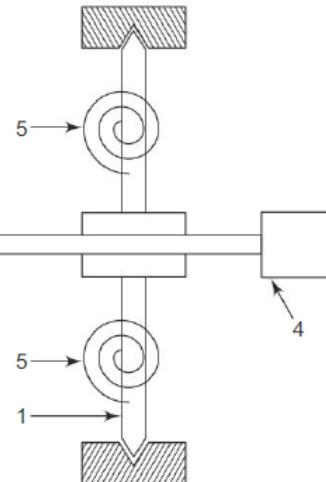
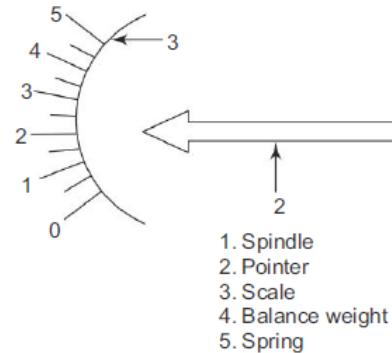
This torque is always present in the instrument whether it is connected to the supply or not. The control torque increases with the deflection of the moving system. It **opposes the deflecting torque**. The moving system is brought to a steady deflected position when the control torque is balanced by the deflecting torque. The control torque is also essential to bring back the moving system to its initial or rest or zero position once the instrument is disconnected from the supply.

The control torque can be produced using spring or gravity:

spring control

**2 (b) (i) Spring control** (Refer Fig.). Two helical springs of rectangular cross section are connected to the spindle of the moving system. With the movement of the pointer, the springs get twisted in the opposite direction. Thus, the required amount of control is affected on the moving system. Also, once the instrument is disconnected from the supply, the pointer (moving system) is brought back to its initial position due to the twisted spring.

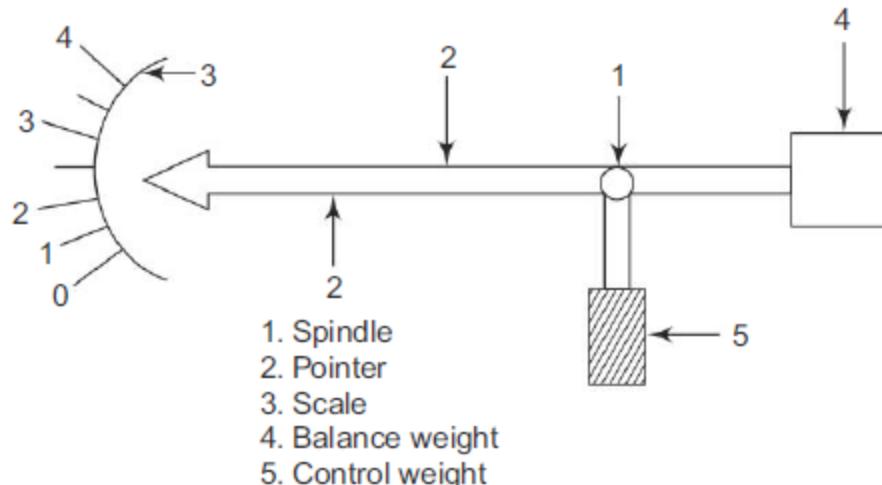
### Spring control



gravity control

### **2 (b) (iii) Gravity control**

(Refer Fig.). In this method, adjustable small weights are added to some part of the moving system. When the pointer deflects, this weight also takes a deflected position. The gravitational force acting on the moving weight produces the required control torque



**2(c) Damping Torque** This torque is produced only when the instrument is in operation. This ensures that the moving system takes just the required time to reach its final deflected position.

moving coil  
moving  
iron

## Electrical measuring instruments

### MOVING COIL INSTRUMENTS

-  PERMANENT MAGNET TYPE
-  DYNAMOMETER TYPE

### MOVING IRON INSTRUMENTS

-  ATTRACTION TYPE
-  REPULSION TYPE

# 1 MOVING COIL INSTRUMENTS

## 1 A. PERMANENT MAGNET MOVING COIL INSTRUMENT [PMMC]

pmmc

**Principle** A current carrying coil is placed in a magnetic field, a force is exerted. It tends to act on the coil and moves it away from the field. This movement of the coil is used to measure current or voltage.

**Construction** (Refer Figs. 7.9 and 7.10). N and S refer to the pole pieces of a permanent magnet. A soft iron core in the form of a cylinder is placed in the space between the poles (C). In the permanent magnetic field is placed a rectangular coil of many turns (*MC*) wound on a former (AF). The former is made of aluminium or copper. To the moving coil is attached the spindle ( $S_p$ ). Two helical springs ( $S_g$ ) are connected to the spindle to give the necessary control torque. A pointer (*p*) attached to the spindle is made to move over a calibrated scale.

**Working** A magnetic field of sufficient density is produced by the permanent magnet. The moving coil carries the current or a current proportional to the voltage to be measured. Hence, an electromagnetic force is produced which tends to act on the moving coil and moves it away from the field. This movement makes the spindle move and so the pointer gives a proportionate deflection.

# PMMC

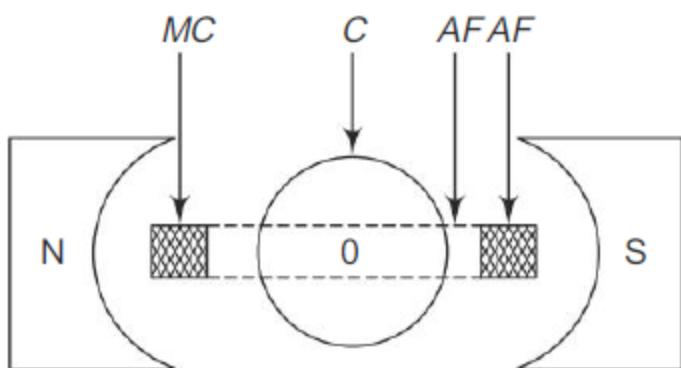


Fig. 7.9

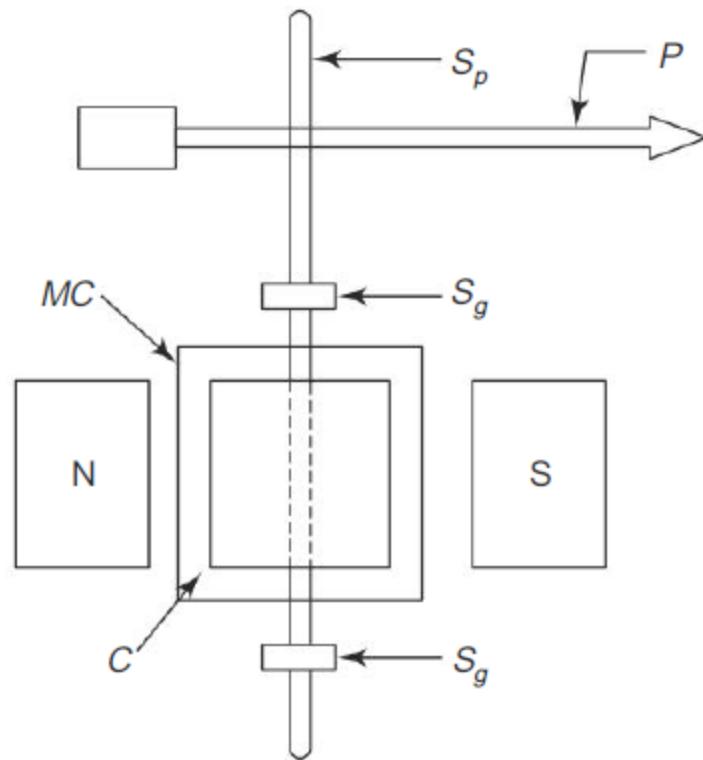


Fig. 7.10

- |                   |  |
|-------------------|--|
| Deflecting torque | ... It is directly proportional to the current or the voltage to be measured. So, the instrument can be used to measure direct current and dc voltage.   |
| Control torque    | ... Spring control   |
| Damping torque    | ... Eddy current damping. When the moving coil made of aluminium former is moved due to the force exerted on it, it cuts the magnetic flux lines produced by the permanent magnet. Hence, eddy currents are induced in the former. |

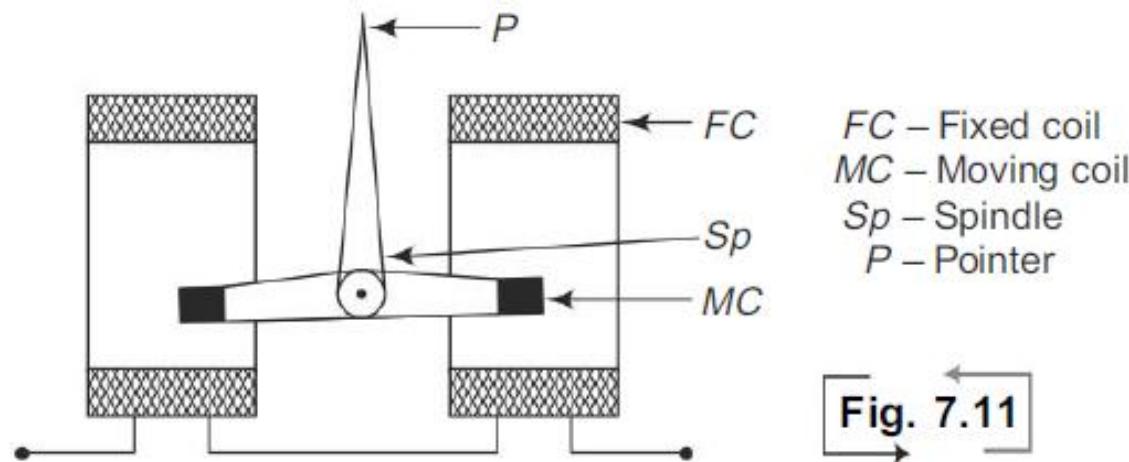
As per Lenz's law, these eddy currents produce the required damping torque opposing the motion of the moving coil.

# 1 B DYNAMOMETER TYPE MOVING COIL INSTRUMENT

dynamometer type  
moving coil  
instrument

**Principle** Working principle of this type of instrument is same as that of permanent magnet moving coil type. But, the difference is that there is no permanent magnet in this instrument. Both the operating fields are produced by the current and/or the voltage to be measured.

**Construction** (Refer Fig. 7.11). The fixed coil (*FC*) is made in two sections. In the space between these two sections, a moving coil (*MC*) is placed. The moving coil is attached to the spindle to which is attached a pointer. The pointer is allowed to move over a calibrated scale. Two helical springs are attached to the spindle to give the required control torque. A piston attached to the spindle is arranged to move inside an air chamber.



**Working** The fixed coil and the moving coil carry currents. Thus, two magnetic field are produced. Hence, an electromagnetic force tends to act on the moving coil and makes it move. This makes the pointer give a proportionate deflection.

### **Deflecting Torque**

- (a) *As voltmeter* The two coils are electrically in series. They carry a current proportional to the voltage to be measured. The deflecting torque is proportional to  $(\text{voltage})^2$ . Hence, the instrument can be used for measuring dc and ac voltages.
- (b) *As ammeter* The two coils are electrically in series. They carry the current to be measured. The deflecting torque is proportional to  $(\text{current})^2$ . Hence, the instrument can be used for measuring dc and ac.
- (c) *As wattmeter* Fixed coils carry the system current. Moving coil carries a current proportional to the system voltage. The design is such that the deflecting torque is proportional to  $VI \cos \phi$ , i.e power to be measured.

Control torque: Spring Control

Damping torque: Air damping

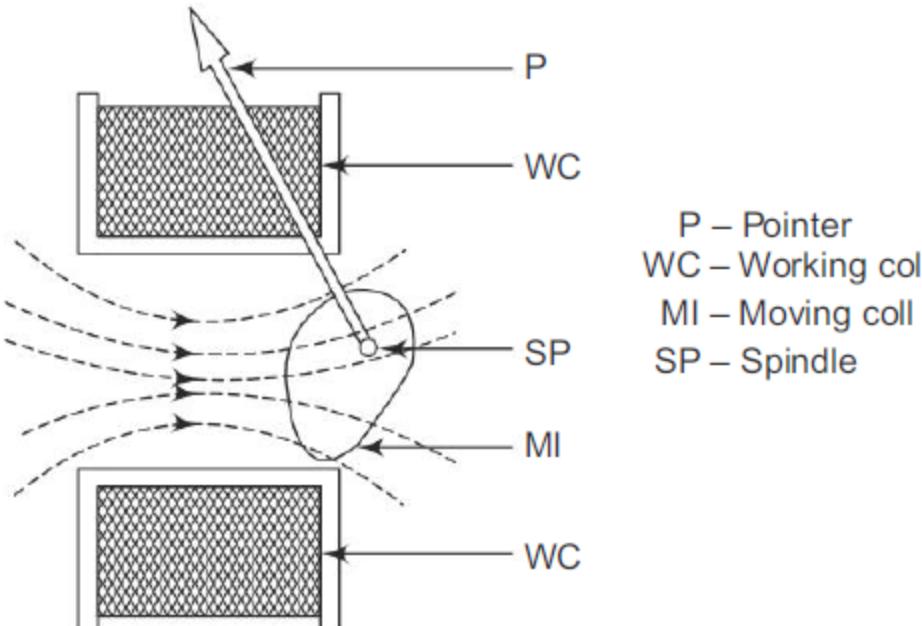
## 2 MOVING IRON INSTRUMENTS

### 2A ATTRACTION TYPE

Moving Iron Instruments are used mainly to measure voltage or current.

**Principle** It is well known that a soft iron piece gets magnetised when it is brought into a magnetic field produced by a permanent magnet. The same phenomenon happens when the soft iron piece is brought near either of the ends of a coil carrying current. The iron piece is attracted towards that portion where the magnetic flux density is more. This movement of the soft iron piece is used to measure the current or voltage which produces the magnetic field.

**Construction** (Refer Fig. 7.7). The instrument consists of a working coil. It carries the current to be measured or a current proportional to the voltage to be measured. A soft iron disc is attached to the spindle. To the spindle, a pointer is also attached. The pointer is made to move over a calibrated scale. The moving iron (soft iron disc) is pivoted such that it is attracted towards the centre of the coil where the magnetic field is maximum.



P – Pointer  
WC – Working col  
MI – Moving coll  
SP – Spindle

Fig. 7.7

**Working** The working coil carries a current which produces a magnetic field. The moving disc is attracted towards the centre of the coil where the flux density is maximum. The spindle is, therefore, moved. Thus, the pointer, attached to the spindle gives a proportional deflection.

**Deflecting Torque** Produced by the current or the voltage to be measured. It is proportional to the square of the current or voltage. Hence, the instrument can be used to measure d.c. or a.c scale is non-uniform.

Control torque: Spring or gravity

Damping: Air friction damping

## 2B REPULSION TYPE MOVING IRON INSTRUMENT

**Principle** Two iron pieces kept with close proximity in a magnetic field get magnetized to the same polarity. Hence, a repulsive force is produced. If one of the two pieces is made movable, the repulsive force will act on it and move it on to one side. This movement is used to measure the current or voltage which produces the magnetic field.

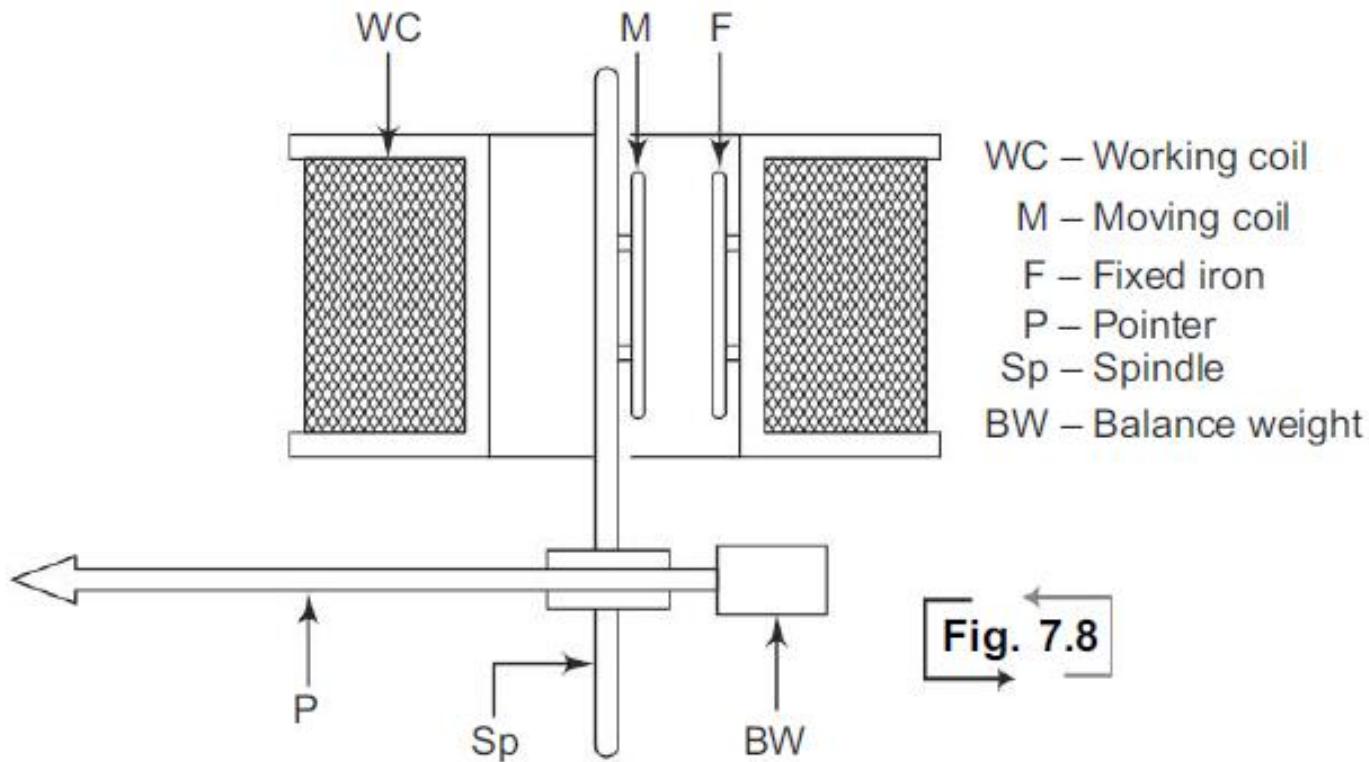
**Construction** (Refer Fig. 7.8). The instrument consists of a working coil which carries a current proportional to voltage or the current to be measured. There are two iron pieces-fixed and moving. The moving iron is connected to the spindle to which is attached a pointer. It is made to move over a calibrated scale.

**Working** When the operating coil carries current, a magnetic field is produced. This field magnetises similarly both the soft iron pieces. Thus, a repulsive force is produced which acts on the moving iron and pushes it away from its rest position. Thus, the spindle moves and hence the pointer gives a proportionate deflection. Whatever be the direction of current in the coil, the two irons are always similarly magnetised.

**Deflecting Torque** Produced by the current or the voltage to be measured it is proportional to the square of the current or voltage. Hence, the instrument can be used for dc and ac.

Control torque: Spring or Gravity

Damping: Pneumatic (i.e air damping)



## NOTE:

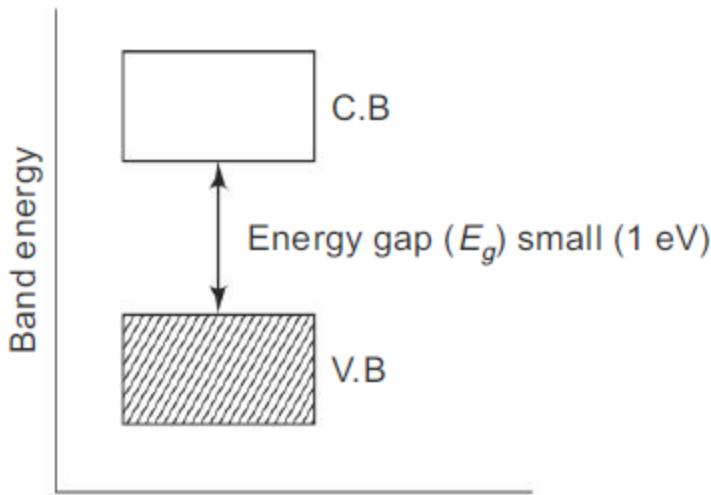
1. MC instruments are used for the measurement of DC Quantities only.
2. MI instruments are used for the measurement of both DC & AC Quantities.

# **OVERVIEW OF SEMICONDUCTORS**

- Depending on their conductivity, materials can be classified into three types as conductors, semiconductors and insulators. Conductor is a good conductor of electricity. Insulator is a poor conductor of electricity. Semiconductor has its conductivity lying between these two extremes.

## **Energy Band of Semiconductor**

In terms of energy band shown in Fig., the valence band is almost filled (partially filled) and conduction band is almost empty.



A comparatively smaller electric field (smaller than required for insulator) is required to push the electrons from the valence band to conduction band. At low temperatures, the valence band is completely filled and the conduction band is completely empty. Therefore a semiconductor virtually behaves as an insulator at low temperature. However even at room temperature some electrons crossover to the conduction band giving conductivity to the semiconductor. As temperature increases, the number of electrons crossing over to the conduction band increases and hence electrical conductivity increases. Hence a semiconductor has negative temperature coefficient of resistance.

## **Classifications of Semiconductors**

**Intrinsic Semiconductor:** A pure semiconductor is called intrinsic semiconductor.

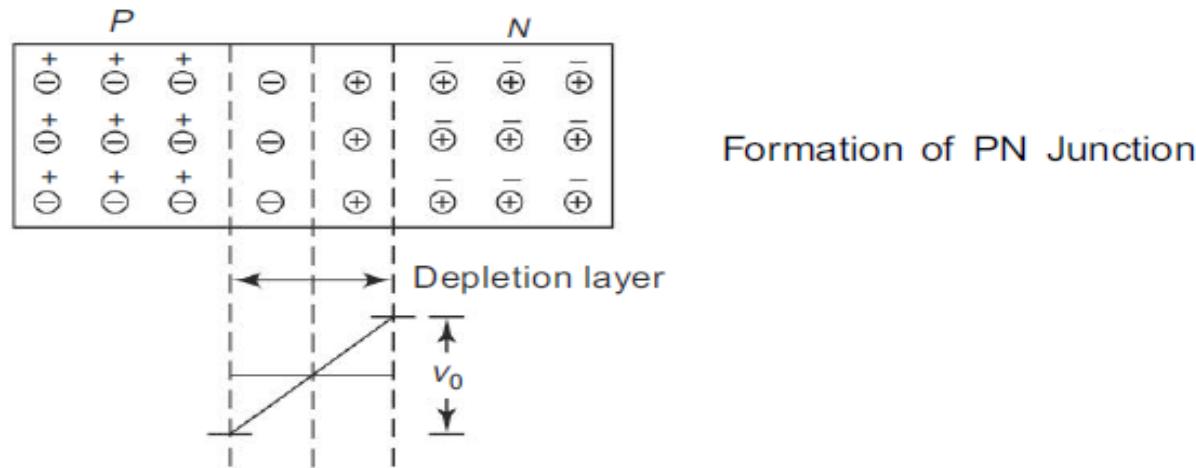
**Extrinsic Semiconductor:** Due to the poor conduction at room temperature, the intrinsic semiconductor, as such, is not useful in the electronic devices. Hence the current conduction capability of the intrinsic semiconductor should be increased. This can be achieved by adding a small amount of impurity to the intrinsic semiconductor, so that it becomes impurity semiconductor or extrinsic semiconductor. This process of adding impurity is known as **doping**.

**N-type Semiconductor**: A small amount of **pentavalent** impurities such as arsenic, antimony or phosphorus is added to the pure semiconductor (germanium or silicon crystal) to get N-type semiconductor. Thus, the addition of pentavalent impurity (antimony) increases the number of electrons in the conduction band thereby increasing the conductivity of N-type semiconductor. As a result of doping, the number of free electrons far exceeds the number of holes in an N-type semiconductor. So electrons are called majority carriers and holes are called minority carriers.

**P-type Semiconductor**: A small amount of trivalent impurities such as aluminium or boron is added to the pure semiconductor to get the P-type semiconductor. The number of holes is very much greater than the number of free electrons in a P-type material, holes are termed as majority carriers and electrons as minority carriers.

## THEORY OF PN JUNCTION DIODE

In a piece of semiconductor material, if one half is doped by P-type impurity and the other half is doped by N-type impurity, a PN junction is formed. The plane dividing the two halves or zones is called PN junction. As shown in Fig., the N-type material has high concentration of free electrons while P-type material has high concentration of holes. Therefore at the junction there is a tendency for the free electrons to diffuse over to the P-side and holes to the N-side. This process is called diffusion.



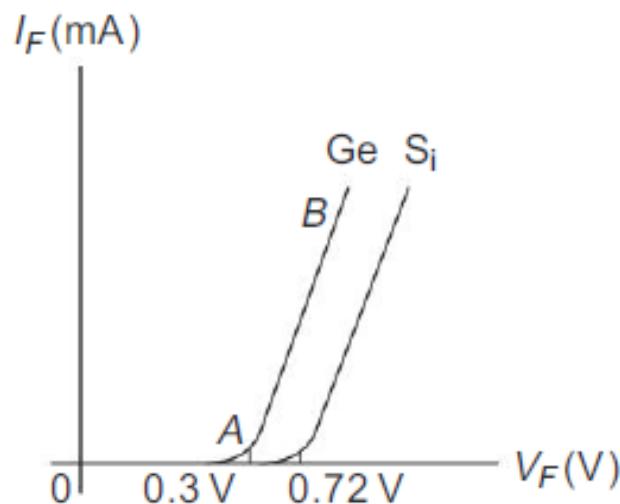
As the free electrons move across the junction from N-type to P-type, the donor ions become positively charged. Hence a positive charge is built. on the N-side of the junction. The free electrons that cross the junction uncover the negative acceptor ions by filling in the holes. Therefore a net negative charge is established on the P-side of the junction. This net negative charge on the P-side prevents further diffusion of electrons into the P-side. Similarly, the net positive charge on the N-side repels the holes crossing from P-side to N-side. Thus a barrier is set up near the junction which prevents further movement of charge carriers, i.e. electrons and holes. This is called potential barrier or junction barrier  $V_0$ .  $V_0$  is 0.3 V for germanium and 0.72 V for silicon. The electrostatic field across the junction caused by the positively charged N-type region tends to drive the holes away from the junction and negatively charged P-type region tends to drive the electrons away from the junction. Thus the junction region is depleted to mobile charge carriers. Hence it is called **depletion layer**.

## **Under Forward Bias Condition**

When positive terminal of the battery is connected to the P-type and negative terminal to the N-type of the PN junction diode, the bias applied is known as forward bias. Under the forward bias condition, the applied positive potential repels the holes in P-type region so that the holes move towards the junction and the applied negative potential repels the electrons in the N-type region and the electrons move towards the junction. Eventually when the applied potential is more than the internal barrier potential, the depletion region and internal potential barrier disappear.

## V-I Characteristics of a Diode under Forward Bias

For  $V_F > V_0$ , the potential barrier at the junction completely disappears and hence, the holes cross the junction from P-type to N-type and the electrons cross the junction in the opposite direction, resulting in relatively large current flow in the external circuit.

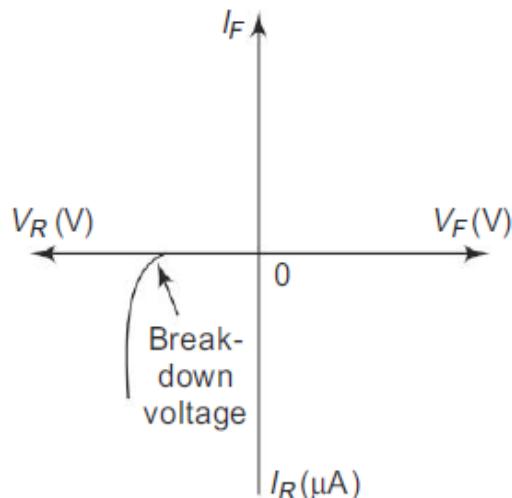


## **Under Reverse Bias Condition**

When the negative terminal of the battery is connected to the P-type and positive terminal of the battery is connected to the N-type of the PN junction, the bias applied is known as reverse bias. Under applied reverse bias, holes which form the majority carriers of the P-side move towards the negative terminal of the battery and electrons which form the majority carrier of the N-side are attracted towards the positive terminal of the battery. Hence the width of the depletion region which is depleted of mobile charge carriers increases. Thus the electric field produced by applied reverse bias, is in the same direction as the electric field of the potential barrier. Hence, the resultant potential barrier is increased, which prevents the flow of majority carriers in both directions. Therefore, theoretically no current should flow in the external circuit. But in practice, a very small current of the order of a few microamperes flows under reverse bias.

## V-I Characteristics of a Diode under Reverse Bias

For large applied reverse bias, the free electrons from the N-type moving towards the positive terminal of the battery acquire sufficient energy to move with high velocity to dislodge valence electrons from semiconductor atoms in the crystal. These newly liberated electrons, in turn, acquire sufficient energy to dislodge other parent electrons. Thus, a large number of free electrons are formed which is commonly called as an avalanche of free electrons. This leads to the breakdown of the junction leading to very large reverse current. The reverse voltage at which the junction breakdown occurs is known as **breakdown voltage**.



## PN DIODE APPLICATIONS

An ideal PN junction diode is a two terminal polarity sensitive device that has zero resistance (diode conducts) when it is forward biased and infinite resistance (diode does not conduct) when reverse biased. Due to this characteristic the diode finds a number of applications as follows.

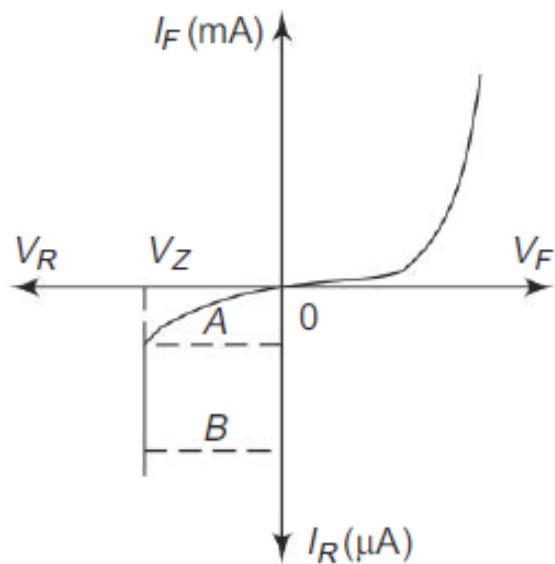
- (i) rectifiers in dc power supplies
- (ii) switch in digital logic circuits used in computers
- (iii) clamping network used as dc restorer in TV receivers and voltage multipliers
- (iv) clipping circuits used as wave shaping circuits used in computers, radars, radio and TV receivers
- (v) demodulation (detector) circuits.

The same PN junction with different doping concentration finds special applications as follows:

- (i) detectors (APD, PIN photo diode) in optical communication circuits
- (ii) Zener diodes in voltage regulators
- (iii) varactor diodes in tuning sections of radio and TV receivers
- (iv) light emitting diodes in digital displays
- (v) LASER diodes in optical communications
- (vi) Tunnel diodes as a relaxation oscillator at microwave frequencies.

## **ZENER DIODE**

Zener diode is heavily doped than the ordinary diode. From the V-I characteristics of the Zener diode, shown in Fig., it is found that the operation of Zener diode is same as that of ordinary PN diode under forward biased condition. Whereas under reverse-baised condition, breakdown of the junction occurs. The breakdown voltage depends upon the amount of doping.



If the diode is heavily doped, depletion layer will be thin and, consequently, breakdown occurs at lower reverse voltage and further, the breakdown voltage is sharp. Whereas a lightly doped diode has a higher breakdown voltage. Thus breakdown voltage can be selected with the amount of doping. The sharp increasing current under breakdown conditions are due to the following two mechanisms.

- (1) Avalanche breakdown
- (2) Zener breakdown.

## **Avalanche Breakdown**

As the applied reverse bias increases, the field across the junction increases correspondingly. Thermally generated carriers while traversing the junction acquire a large amount of kinetic energy from this field. As a result the velocity of these carriers increases. These electrons disrupt covalent bonds by colliding with immobile ions and create new electron-hole pairs. These new carriers again acquire sufficient energy from the field and collide with other immobile ions thereby generating further electron-hole pairs. This process is cumulative in nature and results in generation of avalanche of charge carriers within a short time.

This mechanism of carrier generation is known as Avalanche multiplication. This process results in flow of large amount of current at the same value of reverse bias.

### **Zener Breakdown**

When the P and N regions are heavily doped, direct rupture of covalent bonds takes place because of the strong electric fields, at the junction of PN diode. The new electron-hole pairs so created increase the reverse current in a reverse biased PN diode. The increase in current takes place at a constant value of reverse bias typically below 6 V for heavily doped diodes. As a result of heavy doping of P and N regions, the depletion region width becomes very small and for an applied voltage of 6 V or less, the field across the depletion region becomes very high, of the order of  $10^7$  V/m, making conditions suitable for Zener breakdown. For lightly doped diodes, Zener breakdown voltage becomes high and breakdown is then predominantly by Avalanche multiplication. Though Zener breakdown occurs for lower breakdown voltage and Avalanche breakdown occurs for higher breakdown voltage, such diodes are normally called Zener diodes.

**Applications of Zener diode:** Used as Voltage Regulator or Stabilizer.

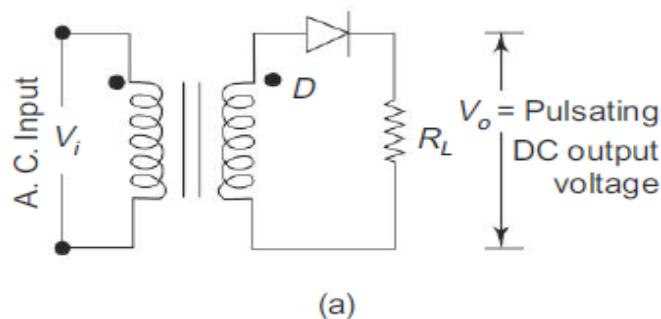
# APPLICATIONS OF PN JUNCTION DIODE

RECTIFIERS, CLIPPERS, CLAMPERS ect..

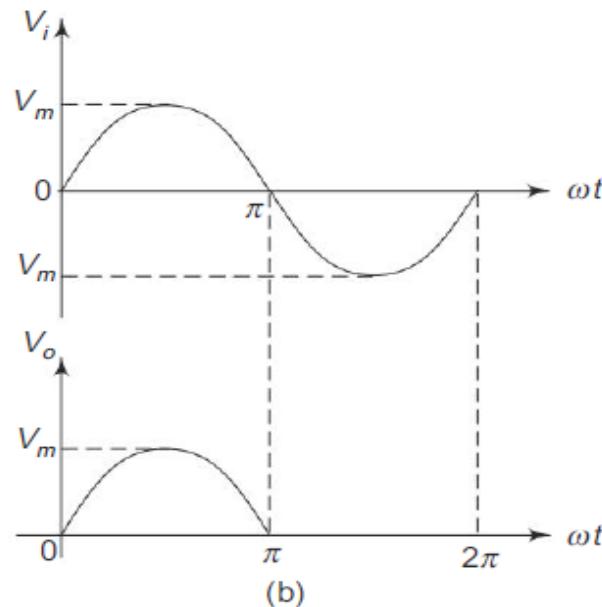
RECTIFIERS-Rectifier is defined as an electronic device used for converting ac voltage into dc voltage

## Half-wave Rectifier

It converts an ac voltage into a pulsating dc voltage using only one half of the applied ac voltage. The rectifying diode conducts during one half of the ac cycle only. Figure shows the basic circuit and waveforms of a half wave rectifier.



(a)



(a) Basic circuit of a Half-wave Rectifier and (b) Input and Output Waveforms of Half-wave Rectifier

Let  $V_i$  be the voltage to the primary of the transformer and given by the equation

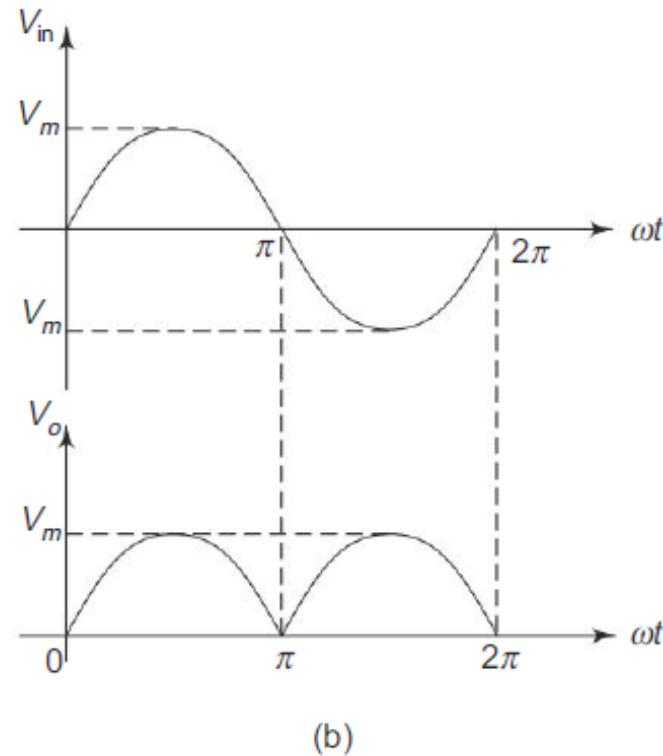
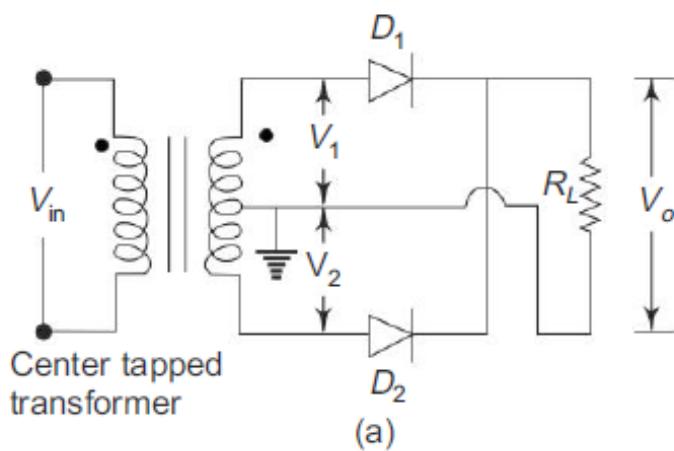
$$V_i = V_m \sin \omega t; V_m \gg V_r$$

where  $V_r$  is the cut-in voltage of the diode. During the positive half-cycle of the input signal, the anode of the diode becomes more positive with respect to the cathode and hence, diode  $D$  conducts. For an ideal diode, the forward voltage drop is zero. So the whole input voltage will appear across the load resistance,  $R_L$ .

During negative half-cycle of the input signal, the anode of the diode becomes negative with respect to the cathode and hence, diode  $D$  does not conduct. For an ideal diode, the impedance offered by the diode is infinity. So the whole input voltage appears across diode  $D$ . Hence, the voltage drop across  $R_L$  is zero.

## Full-wave Rectifier -Center Tapped

It converts an ac voltage into a pulsating dc voltage using both half cycles of the applied ac voltage. It uses two diodes of which one conducts during one half-cycle while the other diode conducts during the other half-cycle of the applied ac voltage. Figure (a) shows the basic circuit and waveforms of full-wave rectifier.

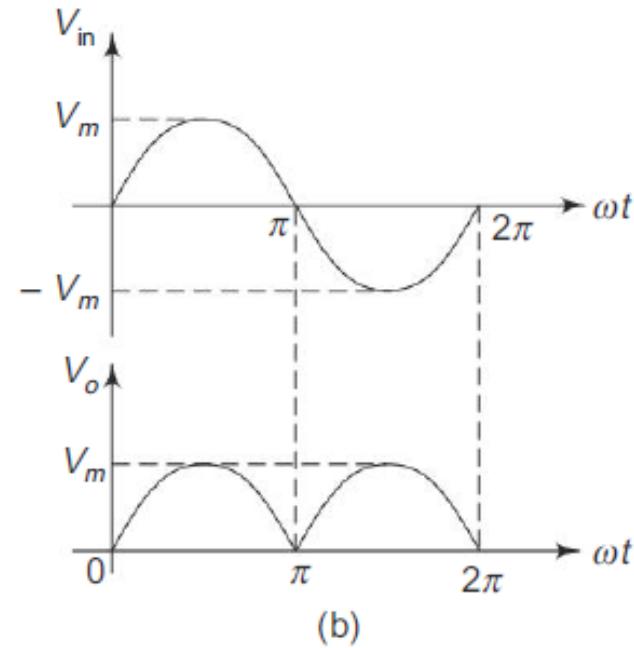
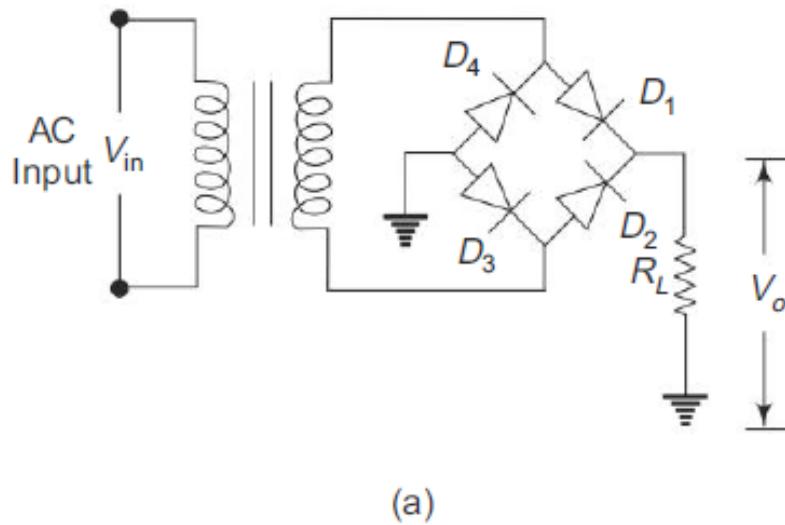


During positive half of the input signal, anode of diode  $D_1$  becomes positive and at the same time the anode of diode  $D_2$  becomes negative. Hence  $D_1$  conducts and  $D_2$  does not conduct. The load current flows through  $D_1$  and the voltage drop across  $R_L$  will be equal to the input voltage.

During the negative half-cycle of the input, the anode of  $D_1$  becomes negative and the anode of  $D_2$  becomes positive. Hence,  $D_1$  does not conduct and  $D_2$  conducts. The load current flows through  $D_2$  and the voltage drop across  $R_L$  will be equal to the input voltage.

## Full-wave Rectifier - Bridge Rectifier

The need for a center tapped transformer in a full-wave rectifier is eliminated in the bridge rectifier. As shown in Fig. the bridge rectifier has four diodes connected to form a bridge. The ac input voltage is applied to diagonally opposite ends of the bridge. The load resistance is connected between the other two ends of the bridge.



For the positive half-cycle of the input ac voltage, diodes  $D_1$  and  $D_3$  conduct, whereas diodes  $D_2$  and  $D_4$  do not conduct. The conducting diodes will be in series through the load resistance  $R_L$ . So the load current flows through  $R_L$ .

During the negative half-cycle of the input ac voltage, diodes  $D_2$  and  $D_4$  conduct, whereas diodes  $D_1$  and  $D_3$  do not conduct. The conducting diode  $D_2$  and  $D_4$  will be in series through the load  $R_L$  and the current flows through  $R_L$  in the same direction as in the previous half-cycle. Thus a bidirectional wave is converted into a unidirectional one.

The average values of output voltage and load current for bridge rectifier are the same as for a center-tapped full wave rectifier. Hence

### ***Advantages of the bridge rectifier***

The bulky center tapped transformer is not required. Transformer utilisation factor is considerably high.

# FILTERS

The output of a rectifier contains dc component as well as ac component. Filters are used to minimise the undesirable ac, i.e. ripple leaving only the dc component to appear at the output.

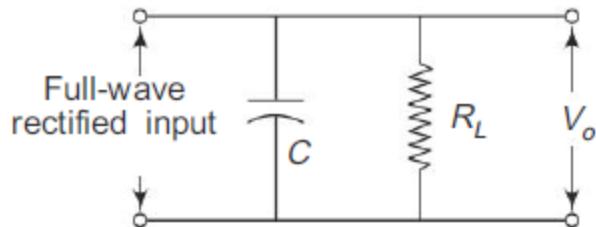
Some important filters are:

- (i) Inductor filter
- (ii) Capacitor filter
- (iii) LC or L-section filter, and
- (iv) CLC or  $\pi$ -type filter

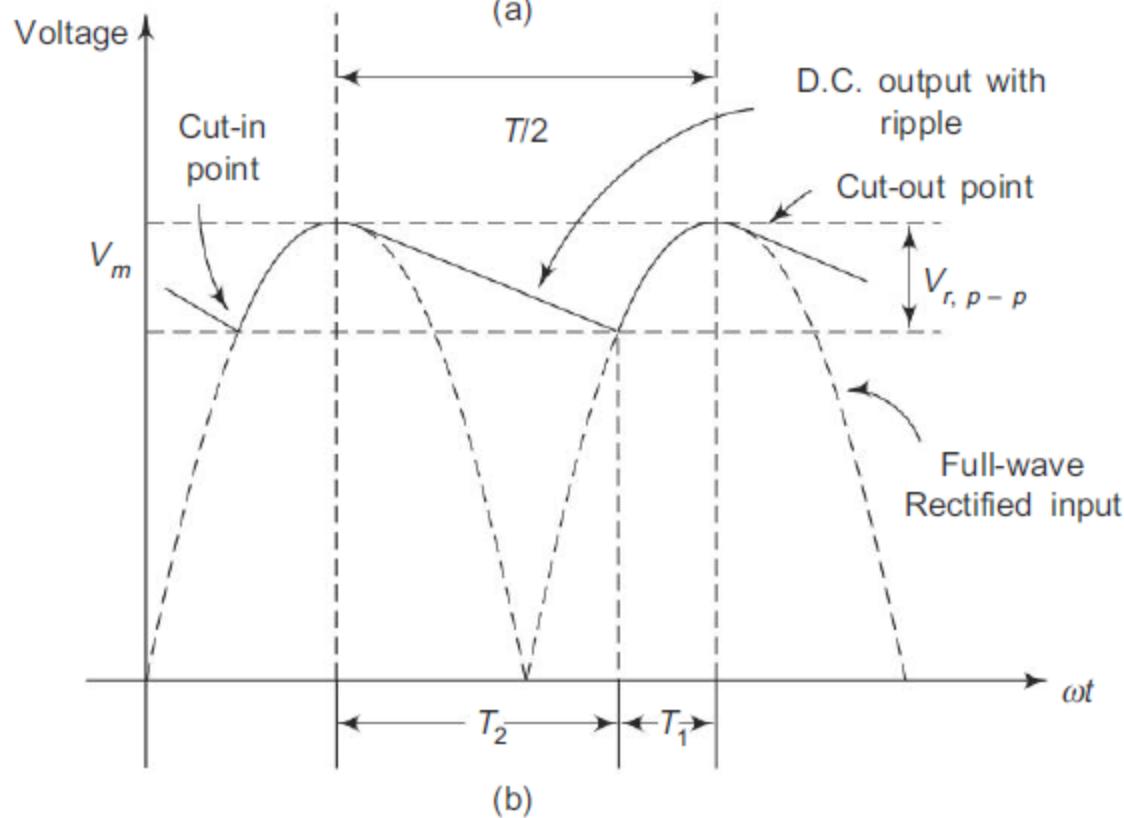
## Capacitor Filter

capacitor filter

An inexpensive filter for light loads is found in the capacitor filter which is connected directly across the load, as shown in Fig. (a). The property of a capacitor is that it allows ac component and blocks the dc component. The operation of a capacitor filter is to short the ripple to ground but leave the dc to appear at the output when it is connected across a pulsating dc voltage.



(a)



(a) Capacitor Filter, (b) Ripple Voltage Triangular Waveform

During the positive half-cycle, the capacitor charges up to the peak value of the transformer secondary voltage,  $V_m$ , and will try to maintain this value as the full-wave input drops to zero. The capacitor will discharge through  $R_L$  slowly until the transformer secondary voltage again increases to a value greater than the capacitor voltage. The diode conducts for a period which depends on the capacitor voltage (equal to the load voltage). The diode will conduct when the transformer secondary voltage becomes more than the ‘cut-in’ voltage of the diode. The diode stops conducting when the transformer voltage becomes less than the diode voltage. This is called cut-out voltage.

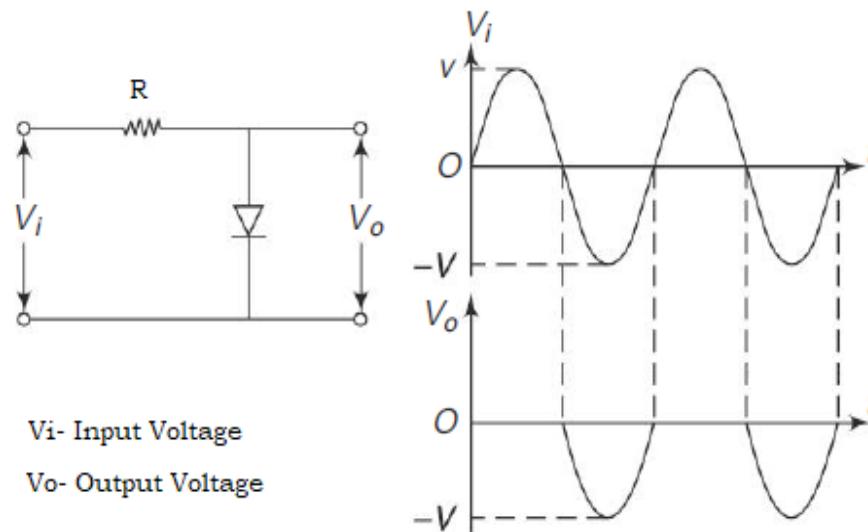
Referring to Fig. (b) with slight approximation, the ripple voltage waveform can be assumed as triangular. From the cut-in point to the cut-out point, whatever charge the capacitor acquires is equal to the charge the capacitor has lost during the period of non-conduction, i.e. from cut-out point to the next cut-in point.

The ripple may be decreased by increasing  $C$  or  $R_L$  (or both) with a resulting increase in dc output voltage.

# CLIPPERS

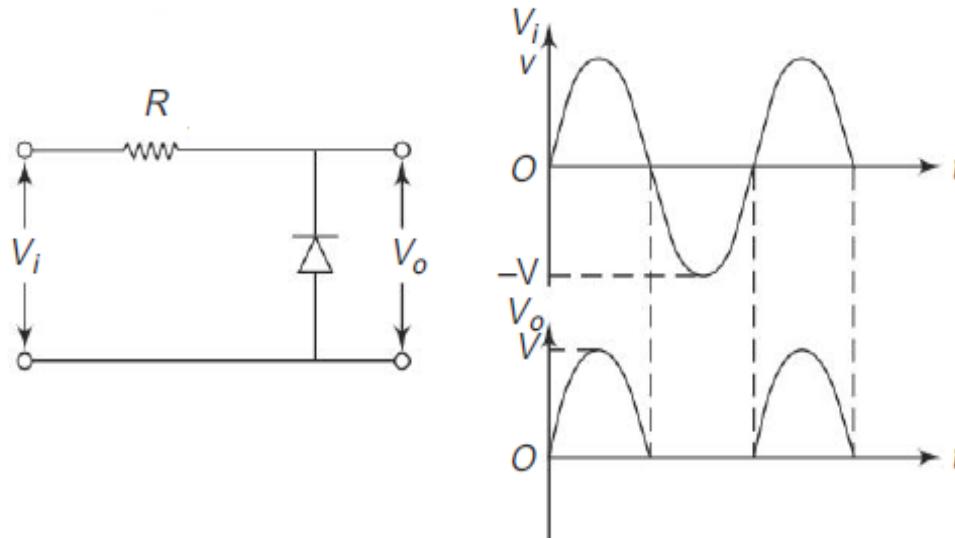
The circuit with which the waveform is shaped by removing (or clipping) a portion of the input signal without distorting the remaining part of the alternating waveform is called a clipper. These circuits find extensive use in radars, digital computers, radio and television receivers etc.

## 1. Positive clipper



When the input voltage is positive, diode conducts and acts as short-circuit and hence there is zero signal at the output, i.e. the positive half cycle is **clipped off**. When the input signal is negative, the diode does not conduct and acts as an open switch, the negative half cycle appears at the output as shown in Fig.

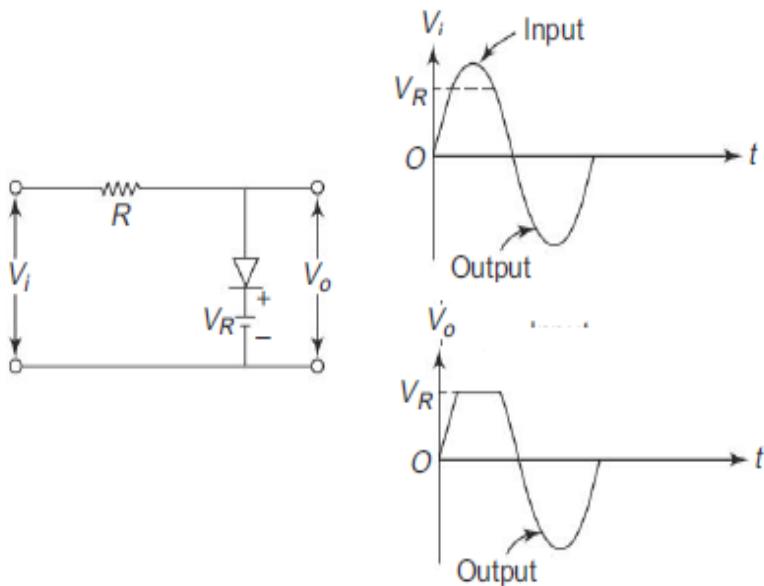
## 2.Negative clipper



When the input signal is positive, the diode does not conduct and acts as an open switch, the positive half cycle appears at the output as shown in Fig.. When the input voltage is negative, diode conducts and acts as short-circuit and hence there is zero signal at the output, i.e. the negative half cycle is **clipped off**.

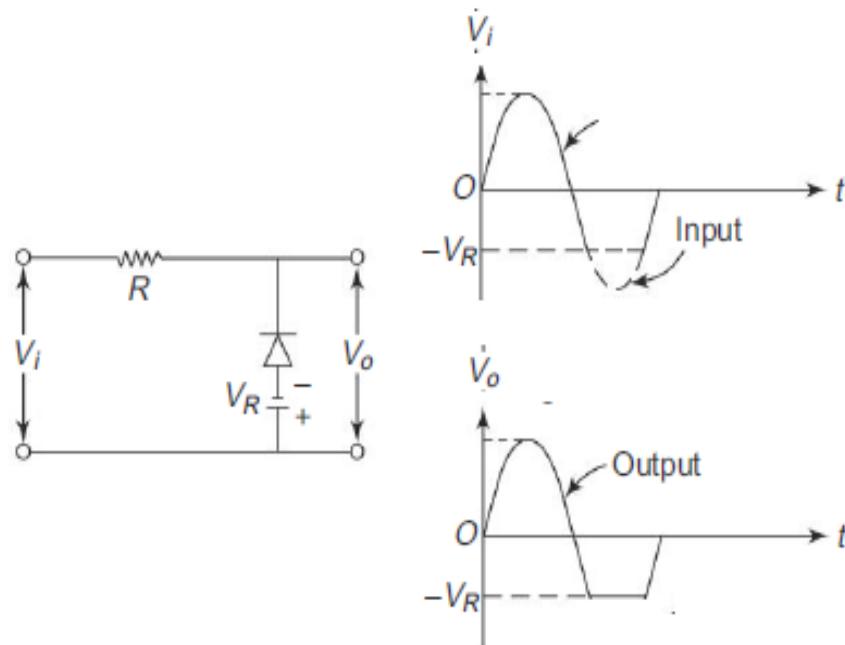
### 3.Biased Positive clipper

In the biased positive clipper as shown in Fig., the diode conducts as long as the input voltage is greater than  $+V_R$  and the output remains at  $+V_R$  until the input voltage becomes less than  $+V_R$ . When the input voltage is less than  $+V_R$ , the diode does not conduct and acts as an open switch. Hence all the input signal having less than  $+V_R$  as well as negative half cycle of the input wave will appear at the output, shown in Fig



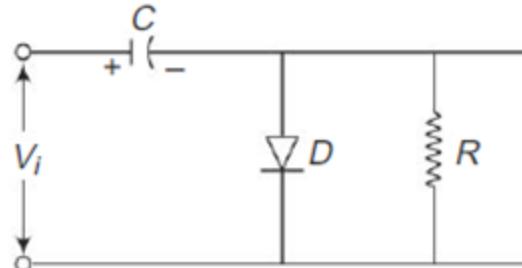
## 4.Biased Negative clipper

In the biased negative clipper shown in Fig. , when the input voltage  $V_i \leq V_R$  the diode conducts and clipping takes place. The clipping level can be shifted up and down by varying the bias voltage ( $-V_R$ ).

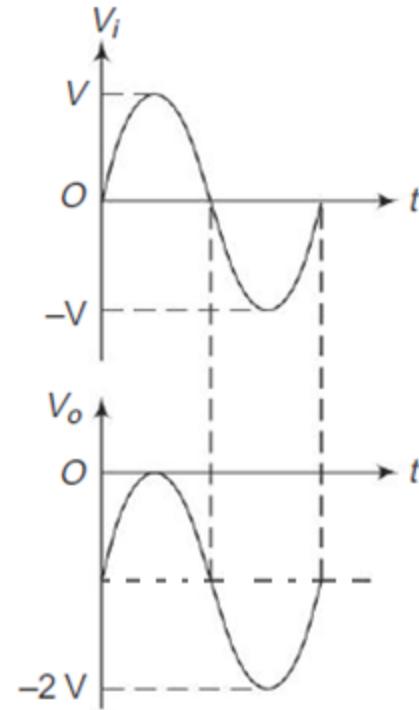


# CLAMPERS

Clamping network shifts (clamps) a signal to a different dc level, i.e. it introduces a dc level to an ac signal. Hence, the clamping network is also known as dc restorer. These circuits find application in television receivers to restore the dc reference signal to the video signal.



Negative Clamper circuit



Consider the clamper circuit shown in Fig. A sine wave with maximum amplitude of  $V$  is given as the input to the network. During the positive half cycle, the diode conducts, i.e. it acts like a short circuit. The capacitor charges to  $V$  volts. During this interval, the output which is taken across the short circuit will be  $V_o = 0$  V. During the negative half cycle, the diode is open. The output voltage can be found out by applying Kirchhoff's law.

$$-V - V - V_o = 0$$

$$\text{Therefore, } V_o = -2 \text{ V}$$

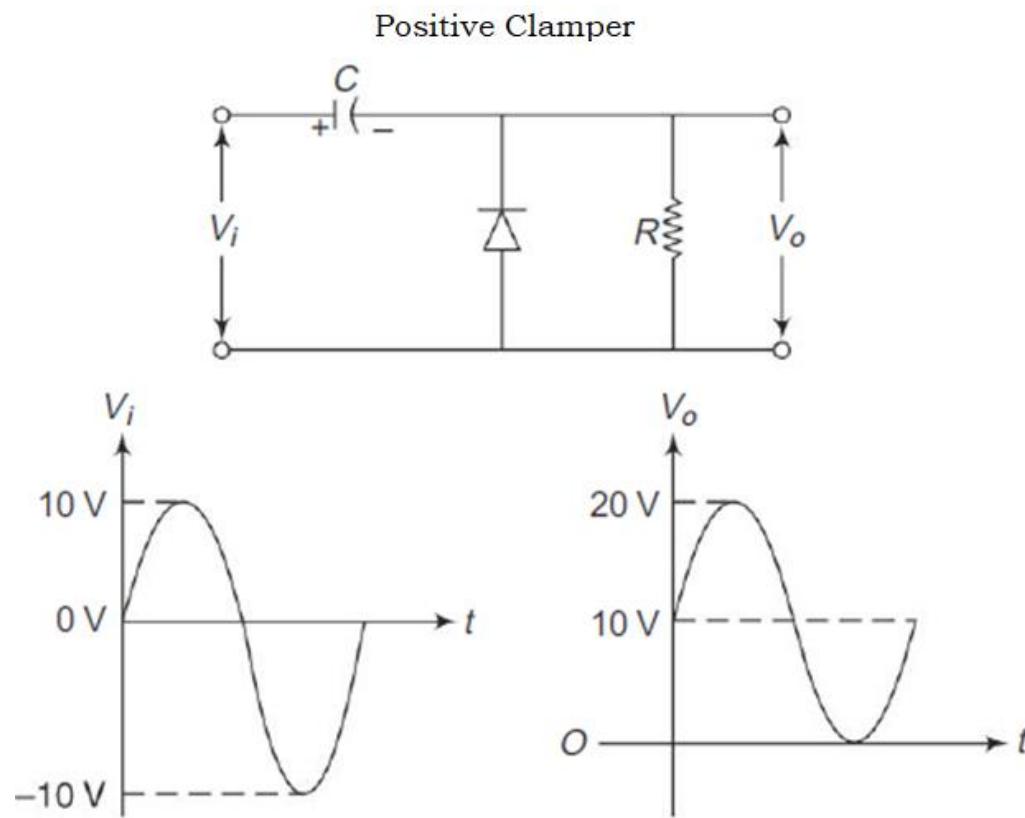
The analysis of the clamper circuit can be done as follows.

Determine the portion of the input signal that forward biases the diode. When the diode is in short circuit condition, the capacitor charges up to a level determined by the voltage across the capacitor in its equivalent open circuit state. During the open circuit condition of the diode, it is assumed that the capacitor will hold on to all its charge and therefore voltage. In the clamper networks, the total swing of the output is equal to the total swing of the input signal. **This is negative clamper.**

**Positive clamper:** Consider the clamper circuit shown in Fig. A sine wave with maximum amplitude of 10 V is given as the input to the network. During the negative half cycle, the diode conducts, i.e. it acts like a short circuit. The capacitor charges to 10 V volts. During this interval, the output which is taken across the short circuit will be  $V_o = 0$  V. During the positive half cycle, the diode is open. The output voltage can be found out by applying Kirchhoff's law.

$$10V + 10V - V_o = 0$$

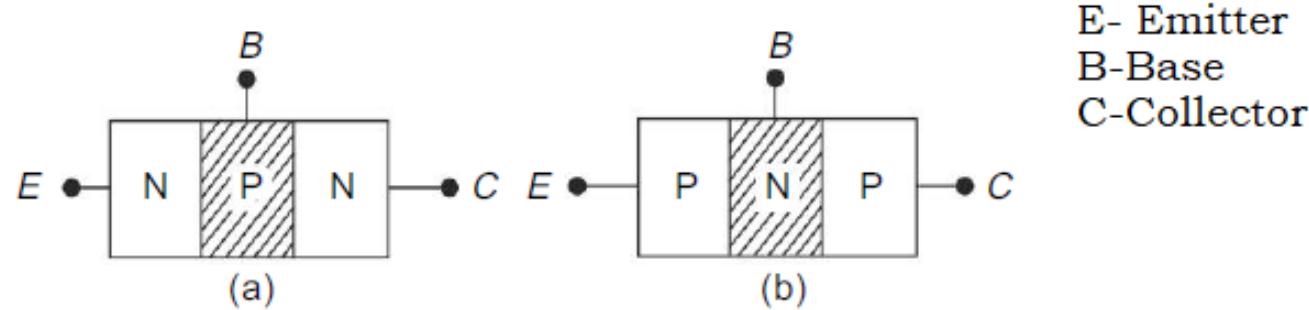
$$\text{Therefore, } V_o = 20 \text{ V}$$



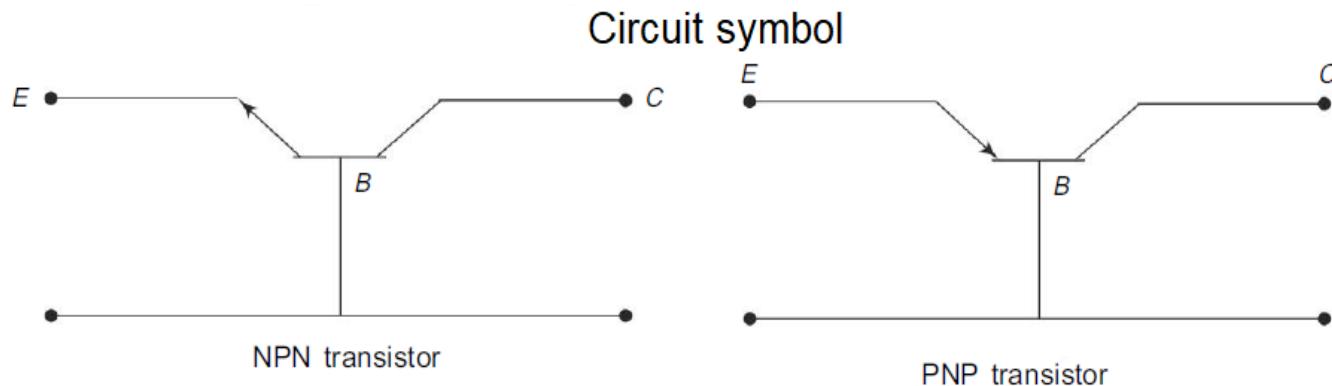
## **BIPOLAR JUNCTION TRANSISTOR [BJT]**

A Bipolar Junction Transistor (BJT) is a three terminal semiconductor device in which the operation depends on the interaction of both majority and minority carriers and hence the name Bipolar. It is used in amplifier and oscillator circuits, and as a switch in digital circuits. It has wide applications in computers, satellites and other modern communication systems.

The BJT consists of a silicon (or germanium) crystal in which a thin layer of N-type Silicon is sandwiched between two layers of P-type silicon. This transistor is referred to as PNP. Alternatively, in a NPN transistor, a layer of P-type material is sandwiched between two layers of N-type material. The two types of the BJT are represented in Fig.

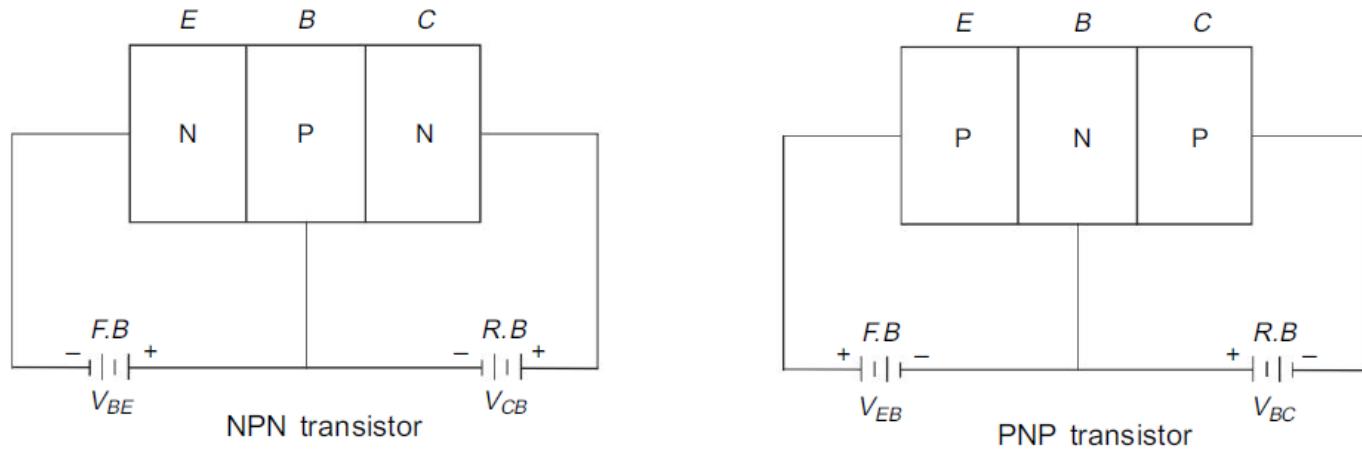


Transistor (a) NPN and (b) PNP



## TRANSISTOR BIASING

Usually the emitter-base junction is forward biased and collector-base junction is reverse biased. Due to the forward bias on the emitter-base junction an emitter current flows through the base into the collector. Though, the collector-base junction is reverse biased, almost the entire emitter current flows through the collector circuit.

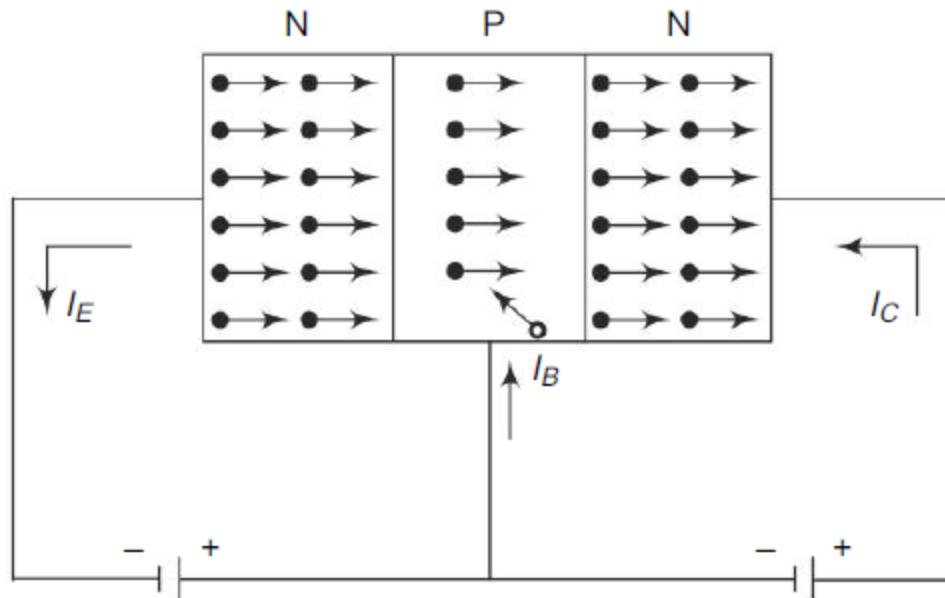


# OPERATION OF NPN TRANSISTOR

npn transistor

As shown in Fig. 13.4, the forward bias applied to the emitter base junction of an NPN transistor causes a lot of electrons from the emitter region to crossover to the base region. As the base is lightly doped with P-type impurity, the number of holes in the base region is very small and hence the number of electrons that combine with holes in the P-type base region is also very small. Hence a few electrons combine with holes to constitute a base current  $I_B$ . The remaining electrons (more than 95%) crossover into the collector region to constitute a collector current  $I_C$ . Thus the base and collector current summed up gives the emitter current, i.e.  $I_E = -(I_C + I_B)$ .

In the external circuit of the NPN bipolar junction transistor, the magnitudes of the emitter current  $I_E$ , the base current  $I_B$  and the collector current  $I_C$  are related by  $I_E = I_C + I_B$ .



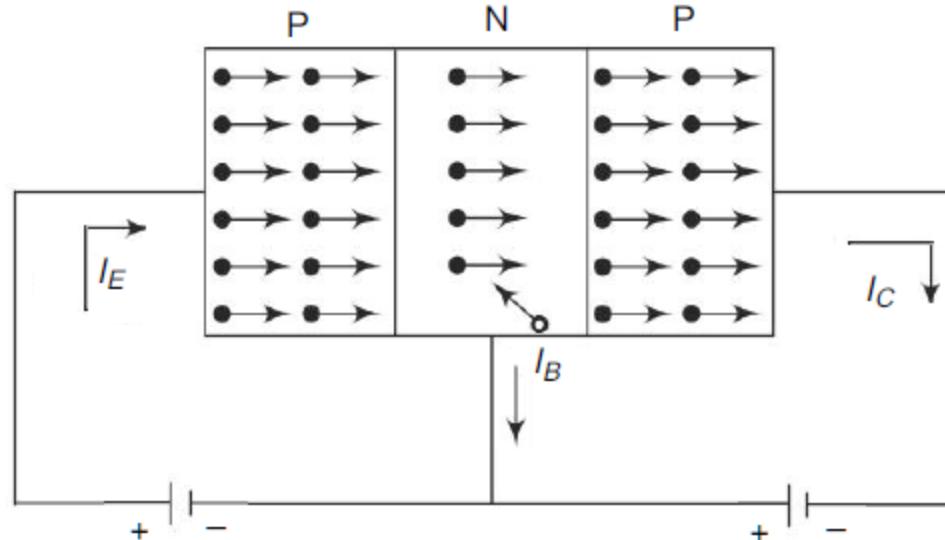
# OPERATION OF PNP TRANSISTOR

As shown in Fig. 13.5, the forward bias applied to the emitter-base junction of a PNP transistor causes a lot of holes from the emitter region to crossover to the base region as the base is lightly doped with N-type impurity. The number of electrons in the base region is very small and hence the number of holes combined with electrons in the N-type base region is also very small. Hence a few holes combined with electrons to constitute a base current  $I_B$ . The remaining holes (more than 95%) crossover into the collector region to constitute a collector current  $I_C$ . Thus the collector and base current when summed up gives the emitter current, i.e.  $I_E = -(I_C + I_B)$ .

In the external circuit of the PNP bipolar junction transistor, the magnitudes of the emitter current  $I_E$ , the base current  $I_B$  and the collector current  $I_C$  are related by

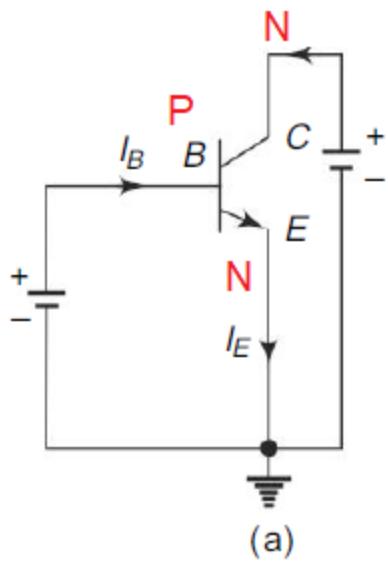
$$I_E = I_C + I_B$$

This equation gives the fundamental relationship between the currents in a bipolar transistor circuit.

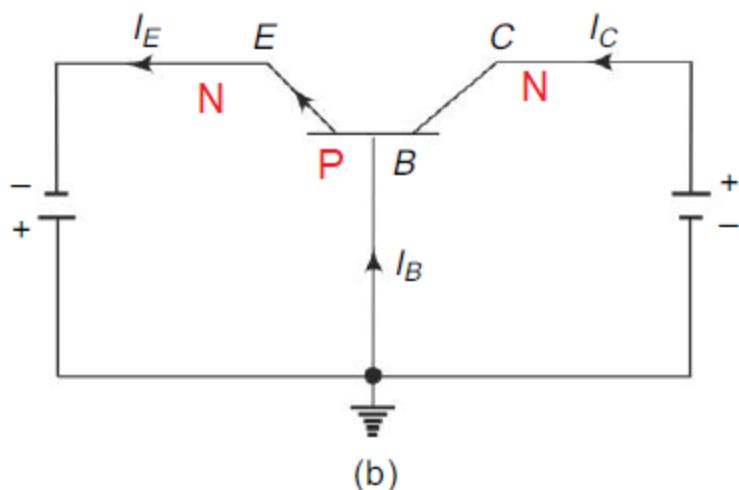


## TYPES OF TRANSISTOR AMPLIFIER CONFIGURATION

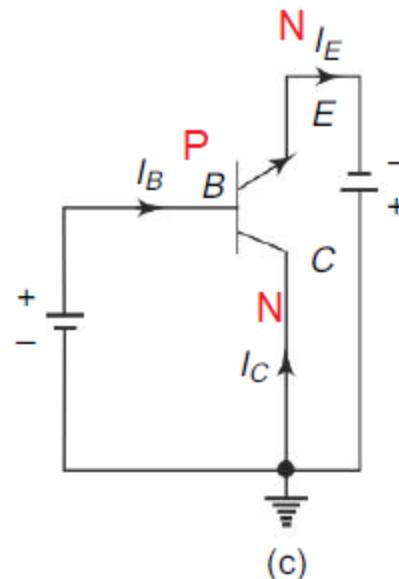
- (i) **CE configuration** This is also called grounded base configuration. In this configuration, emitter is the input terminal, collector is the output terminal and base is the common terminal.
- (ii) **CB configuration** This is also called grounded emitter configuration. In this configuration, base is the input terminal, collector is the output terminal and emitter is the common terminal.
- (iii) **CC configuration** This is also called grounded collector configuration. In this configuration, base is the input terminal, emitter is the output terminal and collector is the common terminal.



(a)



(b)



(c)

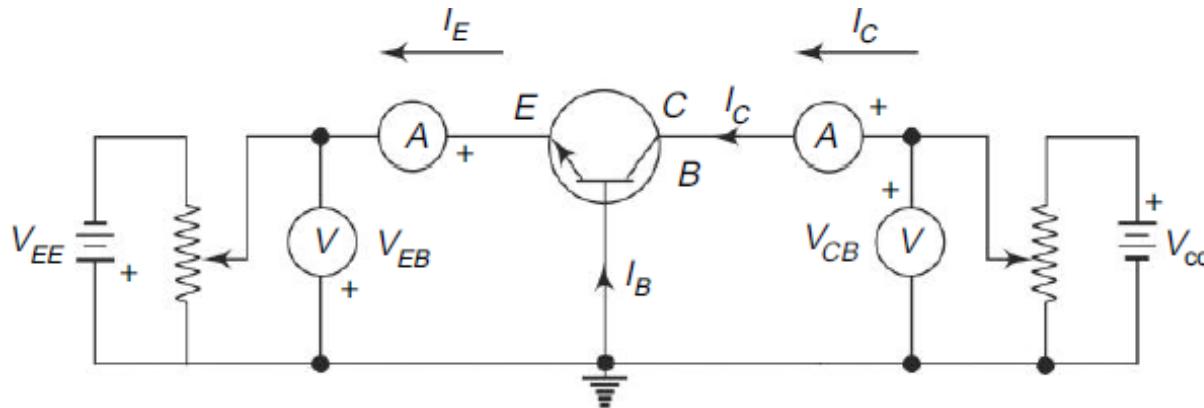
NPN Transistor configuration: (a) common base (b) common emitter and  
(c) common collector

## CB Configuration

The circuit diagram for determining the static characteristics curves of an NPN transistor in the common base configuration is shown in Fig. 13.7.

**Input characteristics** To determine the input characteristics, the collector-base voltage  $V_{CB}$  is kept constant at zero volt and the emitter current  $I_E$  is increased from zero in suitable equal steps by increasing  $V_{EB}$ . This is repeated for higher fixed values of  $V_{CB}$ . A curve is drawn between emitter current  $I_E$  and emitter-base voltage  $V_{EB}$  at constant collector-base voltage  $V_{CB}$ . The input characteristics thus obtained are shown in Fig. 13.8.

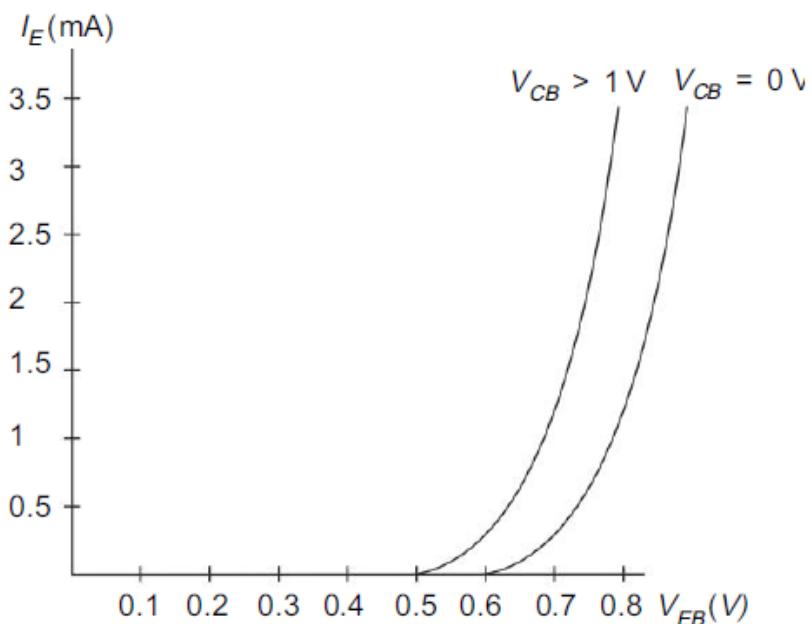
When  $V_{CB}$  is equal to zero and the emitter-base junction is forward biased as shown in the characteristics, the junction behaves as a forward biased diode so that emitter current  $I_E$  increases rapidly with small increase in emitter-base voltage  $V_{EB}$ . When  $V_{CB}$  is increased keeping  $V_{EB}$  constant, the width of the base region will decrease. This effect results in an increase of  $I_E$ . Therefore, the curves shift towards the left as  $V_{CB}$  is increased.



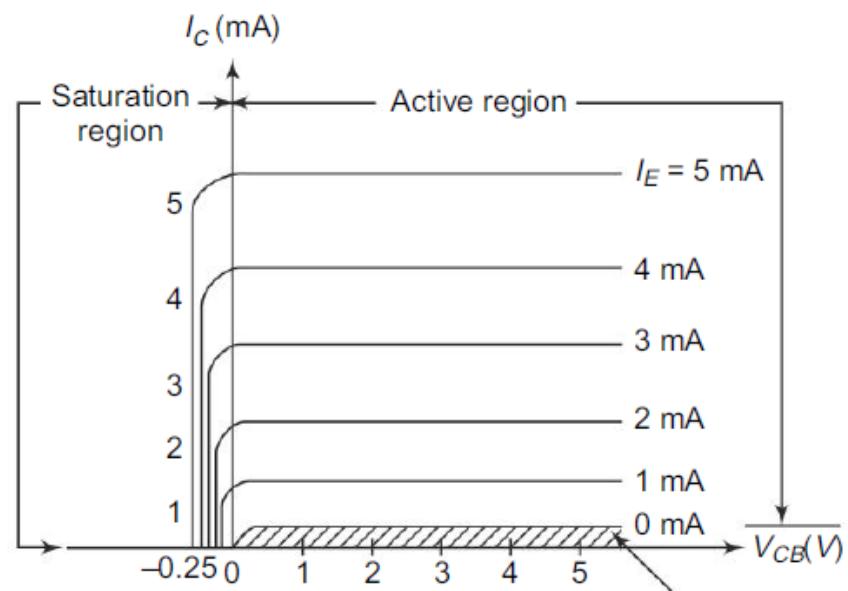
**Fig. 13.7** Circuit to determine CB static characteristics

**Output characteristics** To determine the output characteristics, the emitter current  $I_E$  is kept constant at a suitable value by adjusting the emitter-base voltage  $V_{EB}$ . Then  $V_{CB}$  is increased in suitable equal steps and the collector current  $I_C$  is noted for each value of  $I_E$ . This is repeated for different fixed values of  $I_E$ . Now the curves of  $I_C$  versus  $V_{CB}$  are plotted for constant values of  $I_E$  and the output characteristics thus obtained is shown in Fig. 13.9.

From the characteristics, it is seen that for a constant value of  $I_E$ ,  $I_C$  is independent of  $V_{CB}$  and the curves are parallel to the axis of  $V_{CB}$ . Further,  $I_C$  flows even when  $V_{CB}$  is equal to zero. As the emitter-base junction is forward biased, the majority carriers, i.e. electrons, from the emitter are injected into the base region. Due to the action of the internal potential barrier at the reverse biased collector-base junction, they flow to the collector region and give rise to  $I_C$  even when  $V_{CB}$  is equal to zero.



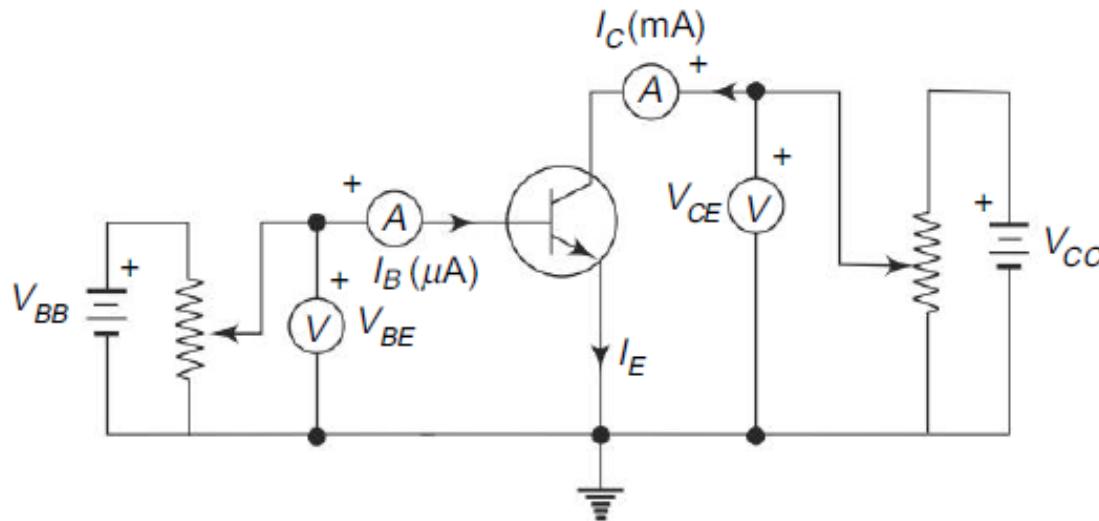
**Fig. 13.8** CB Input characteristics



**Fig. 13.9** CB Output Characteristics

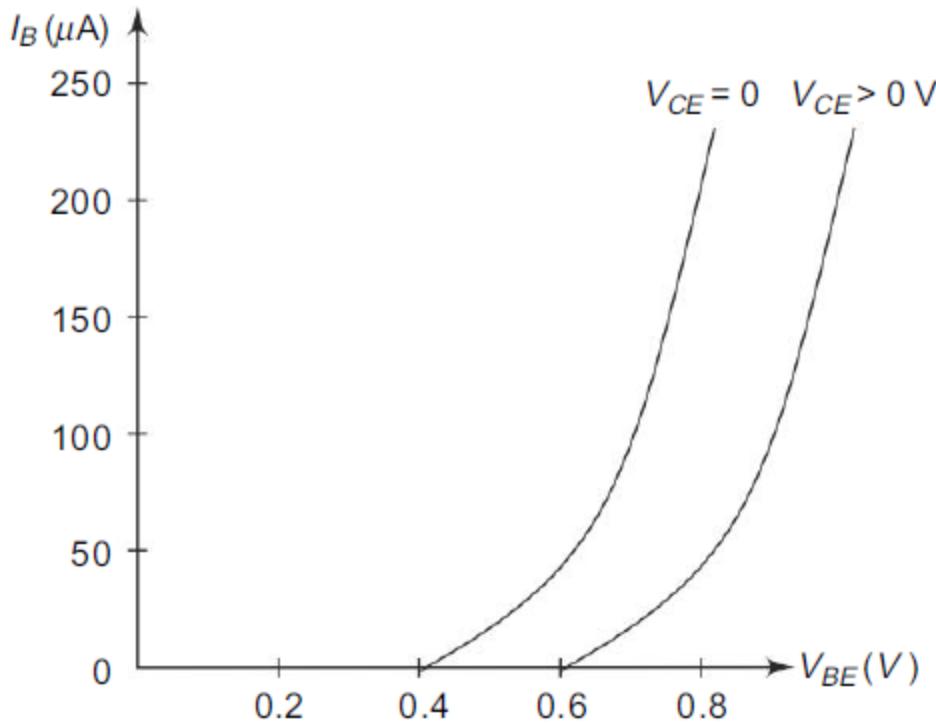
## CE Configuration

**Input characteristics** To determine the input characteristics, the collector to emitter voltage is kept constant at zero volt and base current is increased from zero in equal steps by increasing  $V_{BE}$  in the circuit shown in Fig. 13.10.



**Fig. 13.10** Circuit to determine CE static characteristics

The value of  $V_{BE}$  is noted for each setting of  $I_B$ . This procedure is repeated for higher fixed values of  $V_{CE}$ , and the curves of  $I_B$  vs  $V_{BE}$  are drawn. The input characteristics thus obtained are shown in Fig. 13.11.



**Fig. 13.11** CE input characteristics

When  $V_{CE} = 0$ , the emitter-base junction is forward biased and the junction behaves as a forward biased diode. Hence the input characteristic for  $V_{CE} = 0$  is similar to that of a forward-biased diode. When  $V_{CE}$  is increased, the width of the depletion region at the reverse biased collector-base junction will increase. Hence the effective width of the base will decrease. This effect causes a decrease in the base current  $I_B$ . Hence, to get the same value of  $I_b$  as that for  $V_{CE} = 0$ ,  $V_{BE}$  should be increased. Therefore, the curve shifts to the right as  $V_{CE}$  increases.

**Output characteristics** To determine the output characteristics, the base current  $I_B$  is kept constant at a suitable value by adjusting base-emitter voltage,  $V_{BE}$ . The magnitude of collector-emitter voltage  $V_{CE}$  is increased in suitable equal steps from zero and the collector current  $I_C$  is noted for each setting of  $V_{CE}$ . Now the curves of  $I_C$  versus  $V_{CE}$  are plotted for different constant values of  $I_B$ . The output characteristics thus obtained are shown in Fig. 13.12.

The output characteristics have three regions, namely, saturation region, cutoff region and active region. The region of curves to the left of the line  $OA$  is called the *saturation region* (hatched), and the line  $OA$  is called the saturation line. In this region, both junctions are forward biased and an increase in the base current does not cause a corresponding large change in  $I_C$ . The ratio of  $V_{CE(sat)}$  to  $I_C$  in this region is called saturation resistance.

The region below the curve for  $I_B = 0$  is called the *cut-off region* (hatched). In this region, both junctions are reverse biased. When the operating point for the transistor enters the cut-off region, the transistor is OFF. Hence, the collector current becomes almost zero and the collector voltage almost equals  $V_{CC}$ , the collector supply voltage. The transistor is virtually an open circuit between collector and emitter.

The central region where the curves are uniform in spacing and slope is called the *active region* (unhatched). In this region, emitter-base junction is forward biased and the collector-base junction is reverse biased. If the transistor is to be used as a linear amplifier, it should be operated in the active region.

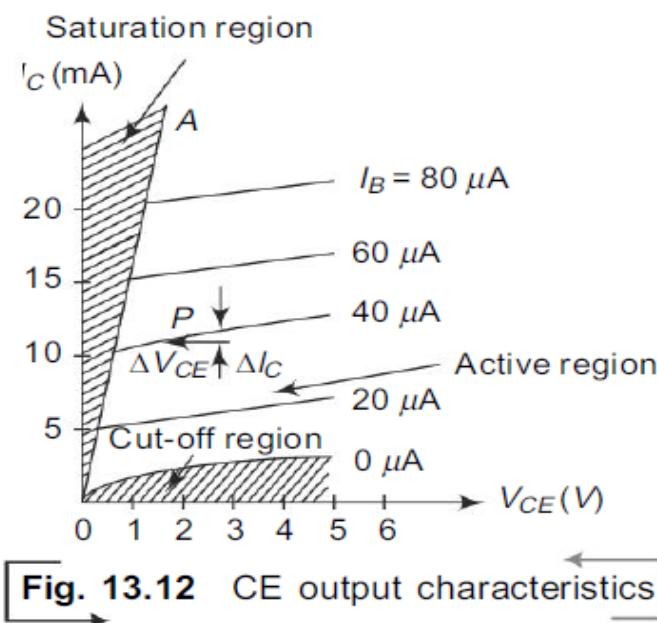


Fig. 13.12 CE output characteristics

# FIELD EFFECT TRANSISTOR

Field effect transistor fet

FET is a device in which the flow of current through the conducting region is controlled by an electric field. Hence the name Field Effect Transistor (FET). As current conduction is only by majority carries, FET is said to be a unipolar device.

Based on the construction, the FET can be classified into two types as Junction FET (JFET) and Metal Oxide Semiconductor FET (MOSFET).

Depending upon the majority carriers, JFET has been classified into two types named as (1) N-channel JFET with electrons as the majority carriers and (2) P-channel JFET with holes as the majority carriers.

## Construction of N-Channel JFET

jfet

source  
drain  
gate

It consists of an N-type bar which is made of silicon. Ohmic contacts, (terminals) made at the two ends of the bar, are called Source and Drain.

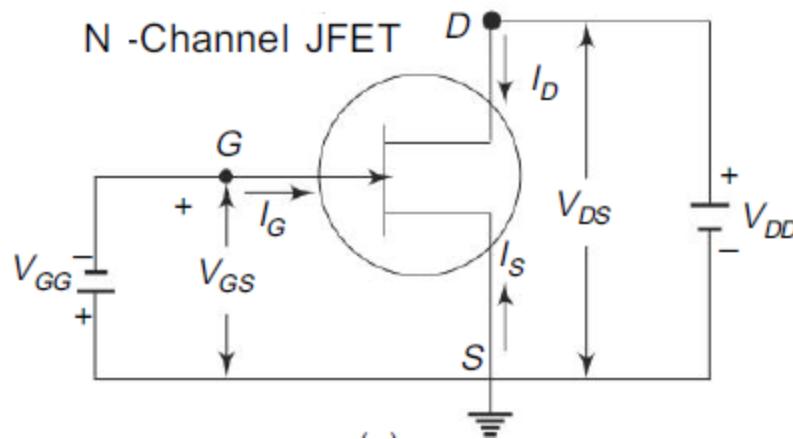
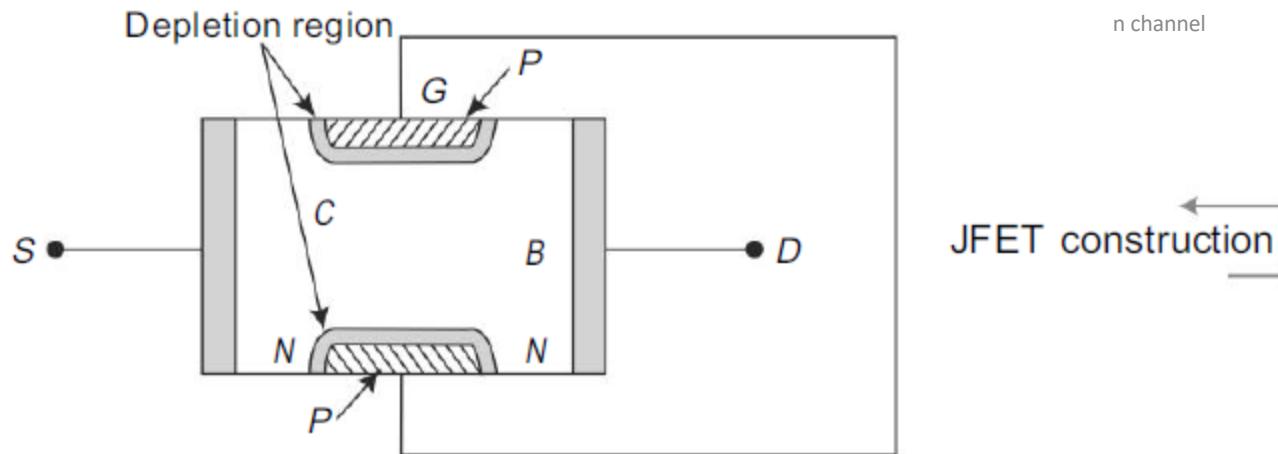
**Source (S)** This terminal is connected to the negative pole of the battery. Electrons which are the majority carriers in the N-type bar enter the bar through this terminal.

**Drain (D)** This terminal is connected to the positive pole of the battery. The majority carriers leave the bar through this terminal.

**Gate (G)** Heavily doped P-Type silicon is diffused on both sides of the N-type silicon bar by which PN junctions are formed. These layers are joined together and the called Gate G.

# Operation of N-channel JFET

1. When  $V_{GS} = 0$  and  $V_{DS} = 0$  When no voltage is applied between drain and source, and gate and source, the thickness of the depletion regions around the PN junction is uniform as shown in Fig.



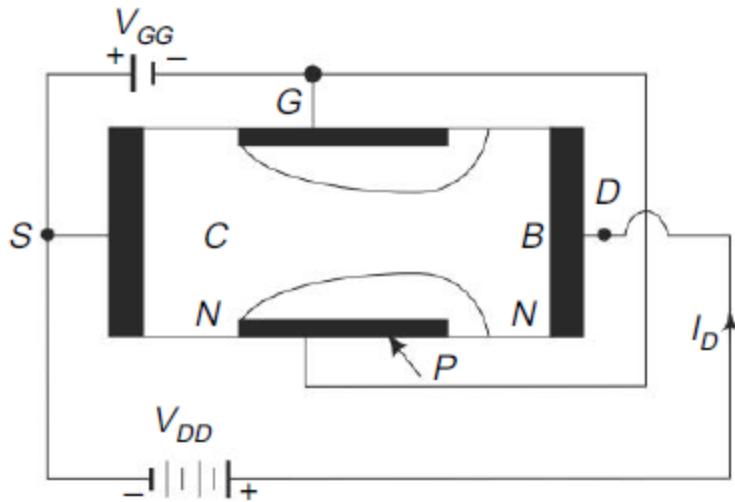
**2. When  $V_{DS} = 0$  and  $V_{GS}$  is decreased from zero**

In this case PN junctions are reverse biased and hence the thickness of the depletion region increases. As  $V_{GS}$  is decreased from zero, the reverse bias voltage across the PN junction is increased and hence the thickness of the depletion region in the channel increases until the two depletion regions make contact with each other. In this condition, the channel is said to be cutoff. The value of  $V_{GS}$  which is required to cutoff the channel is called the cutoff voltage  $V_C$ .

**3. When  $V_{GS} = 0$  and  $V_{PS}$  is increased from zero**

Drain is positive with respect to the source with  $V_{GS}=0$ . Now the majority carriers (electrons) flow through the N-channel from source to drain. Therefore the conventional current  $I_D$  flows from drain to source.

Because the resistance of the channel and the applied voltage  $V_{DS}$ , there is a gradual increase of positive potential along the channel from source to drain. Thus the reverse voltage across the PN junctions increases and hence the thickness of the depletion regions also increases. Therefore the channel is wedge shaped, as shown in Fig. 13.20.



**Fig. 13.20 JFET Under Applied Bias**

As  $V_{DS}$  is increased, the cross-sectional area of the channel will be reduced. At a certain value  $V_P$  of  $V_{DS}$ , the cross-sectional area at  $B$  becomes minimum. At this voltage, the channel is said to be pinched off and the drain voltage  $V_P$  is called the pinch-off voltage.

**4. When  $V_{GS}$  is negative and  $V_{DS}$  is increased** When the gate is maintained at a negative voltage less than the negative cutoff voltage, the reverse voltage across the junction is further increased. Hence for a negative value of  $V_{GS}$ , the curve of  $I_D$  versus  $V_{DS}$  is similar to that for  $V_{GS} = 0$ , but the values of  $V_P$  and  $BV_{DGO}$  are lower, as shown in Fig. 13.21.

From the curves, it is seen that above the pinch-off voltage, at a constant value of  $V_{DS}$ ,  $I_D$  increases with an increase of  $V_{GS}$ . Hence a JFET is suitable for use as a voltage amplifier, similar to a transistor amplifier.

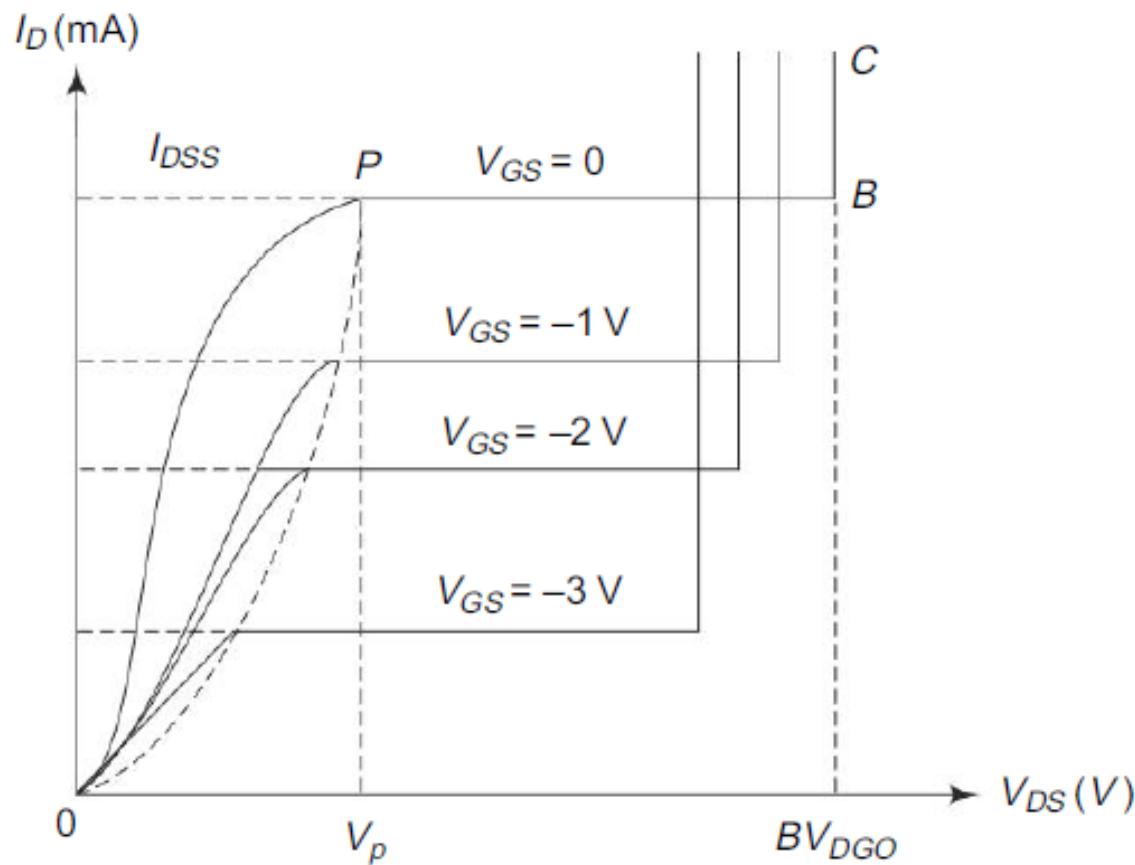


Fig. 13.21 Drain Characteristics

## Comparison of JFET and BJT

1. FET operation depends only on the flow of majority carriers—holes for P-channel FETs and electrons for N-channel FETs. Therefore they are called Unipolar devices. Bipolar transistor (BJT) operation depends on both minority and majority current carriers.
2. FETs are less noisy than BJTs.
3. FETs exhibit a much higher input impedance ( $> 100 \text{ M}\Omega$ ) than BJTs.
4. FETs are much easier to fabricate and are particularly suitable for ICs because they occupy less space than BJTs.
5. FET is normally less sensitive to temperature.
6. FET amplifiers have less voltage gain and produce more signal distortion except for small signal operation.

# Metal Oxide Semiconductor Field Effect Transistor (MOSFET)

mosfet

MOSFET is the common term of the Insulated Gate Field Effect Transistor (IGFET). There are two forms of MOSFET: (i) Enhancement MOSFET and (ii) Depletion MOSFET.

**Principle** By applying a transverse electric field across an insulator, deposited on the semiconducting material, the thickness and hence the resistance of a conducting channel of a semiconducting material can be controlled.

## Enhancement MOSFET

**Construction** The construction of an N-channel Enhancement MOSFET is shown in Fig. 13.23. Two highly doped  $N^+$  regions are diffused in a lightly doped substrate of P-type silicon substrate. One  $N^+$  region is called the source  $S$  and the other one is called the drain  $D$ . They are separated by 1 mil ( $10^{-3}$  inch). A thin insulating layer of  $\text{SiO}_2$  is grown over the surface of the structure and holes are cut into the oxide layer, allowing contact with source and drain. Then a thin layer of metal aluminum is formed over the layer of  $\text{SiO}_2$ . This metal layer covers the entire channel region and it forms the gate  $G$ .

The metal area of the gate, in conjunction with the insulating oxide layer of  $\text{SiO}_2$  and the semiconductor channel forms a parallel plate capacitor. This device is called the insulated gate FET because of the insulating layer of  $\text{SiO}_2$ . This layer gives an extremely high input resistance for the MOSFET.

**Operation** If the substrate is grounded and a positive voltage is applied at the gate, the positive charge on  $G$  induces an equal negative charge on the substrate side between the source and drain regions. Thus an electric field is produced between the source and drain regions. The direction of the electric field is perpendicular to the plates of the capacitor through the oxide. The negative charge of electrons which are minority carriers in the P-type substrate forms an inversion layer. As the positive voltage on the gate increases, the induced negative charge in the semiconductor

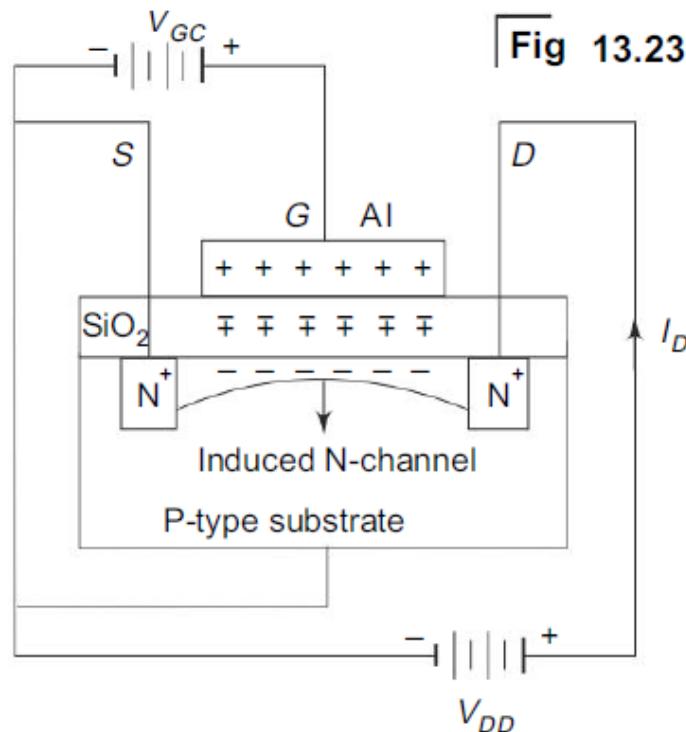


Fig 13.23 N-Channel Enhancement MOSFET

increases. Hence the conductivity increases and current flows from source to drain through the induced channel. Thus the drain current is enhanced by the positive gate voltage as shown in Fig. 13.25.

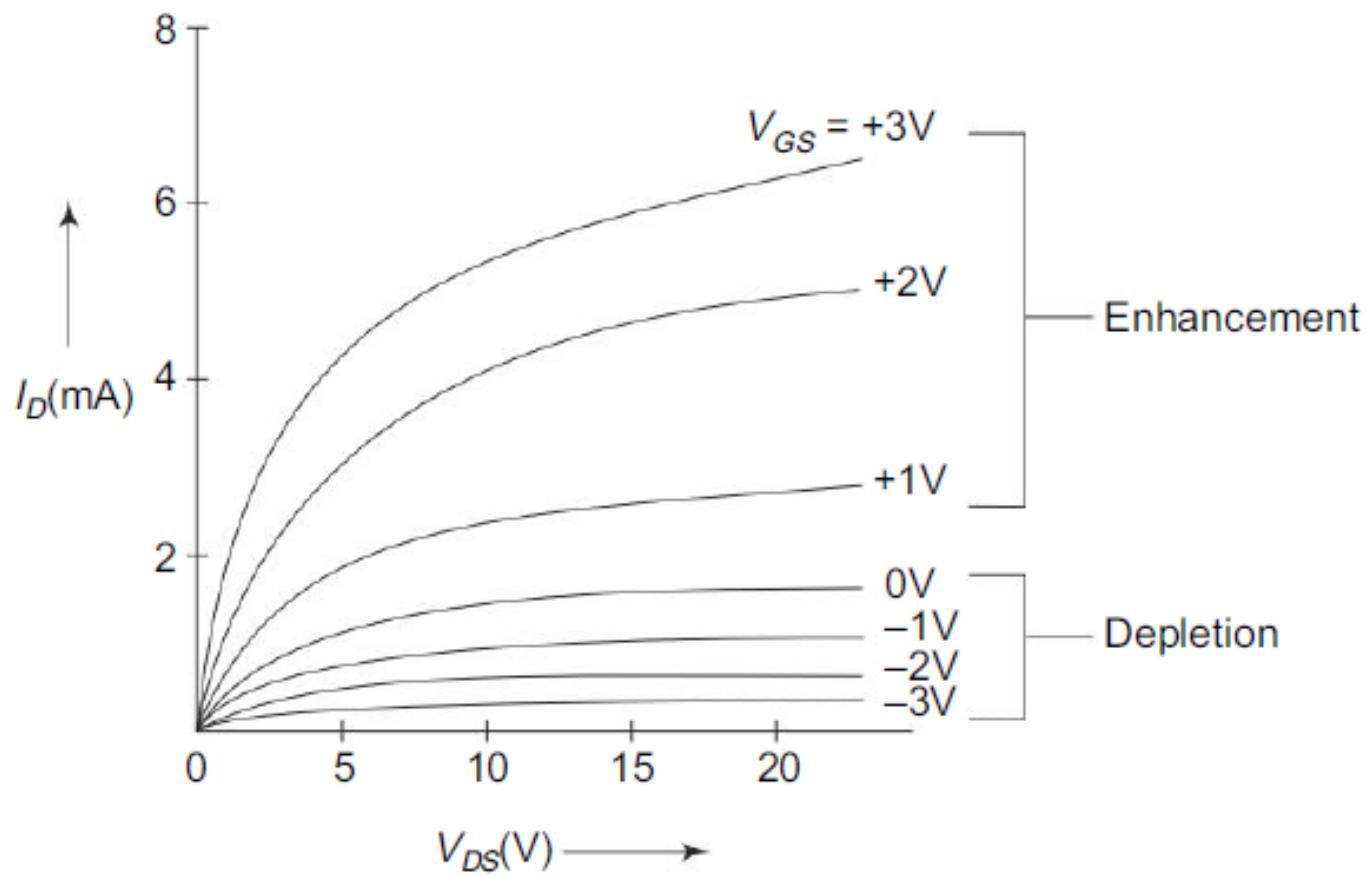


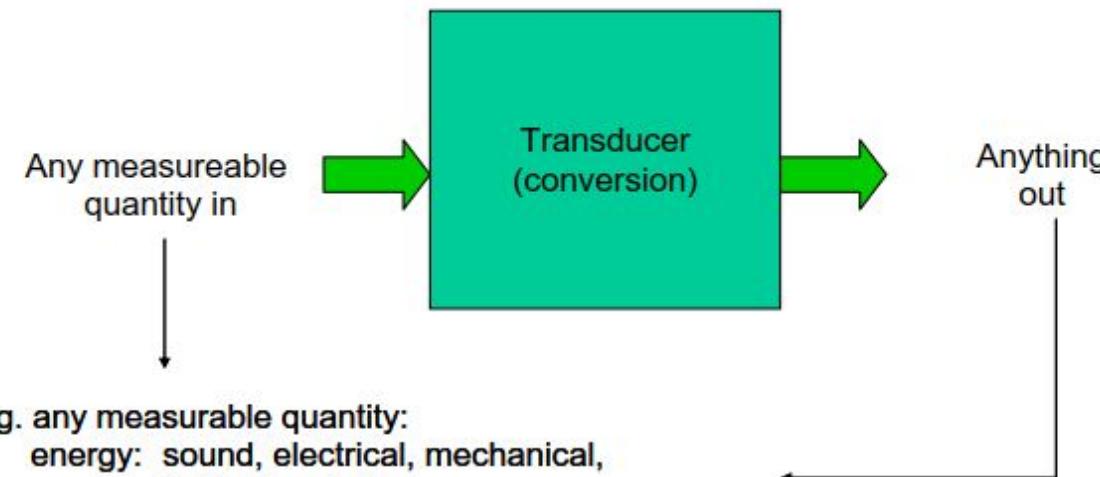
Fig. 13.25 Volt-Ampere Characteristics of MOSFET

# Transducers

# Transducer

**Define :** 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 form.

## Transducers (Briefly)



eg. any measurable quantity:

- energy: sound, electrical, mechanical, light, chemical,
- pressure, level, density, temp, pH, flow, temperature
- position, distance, mass, time
- etc, etc.

# Requirements for Transducer

**Linearity:** Have linear input output characteristics

**Repeatability:** Produce the same result when the same input signal is applied repeatedly under same environmental conditions

**Ruggedness:** Capable of withstanding overload.

**High Signal To Noise Ratio:** Free from the internal and external noise

**Highly Reliable:** Possess minimum error in measurement

**Good Dynamic Response:** Must withstand sudden changes in input

**No Hysteresis:** Produce similar result while input signal is varied from its low value to high value and vice versa.

**Residual Deformation:** No deformation of testing material

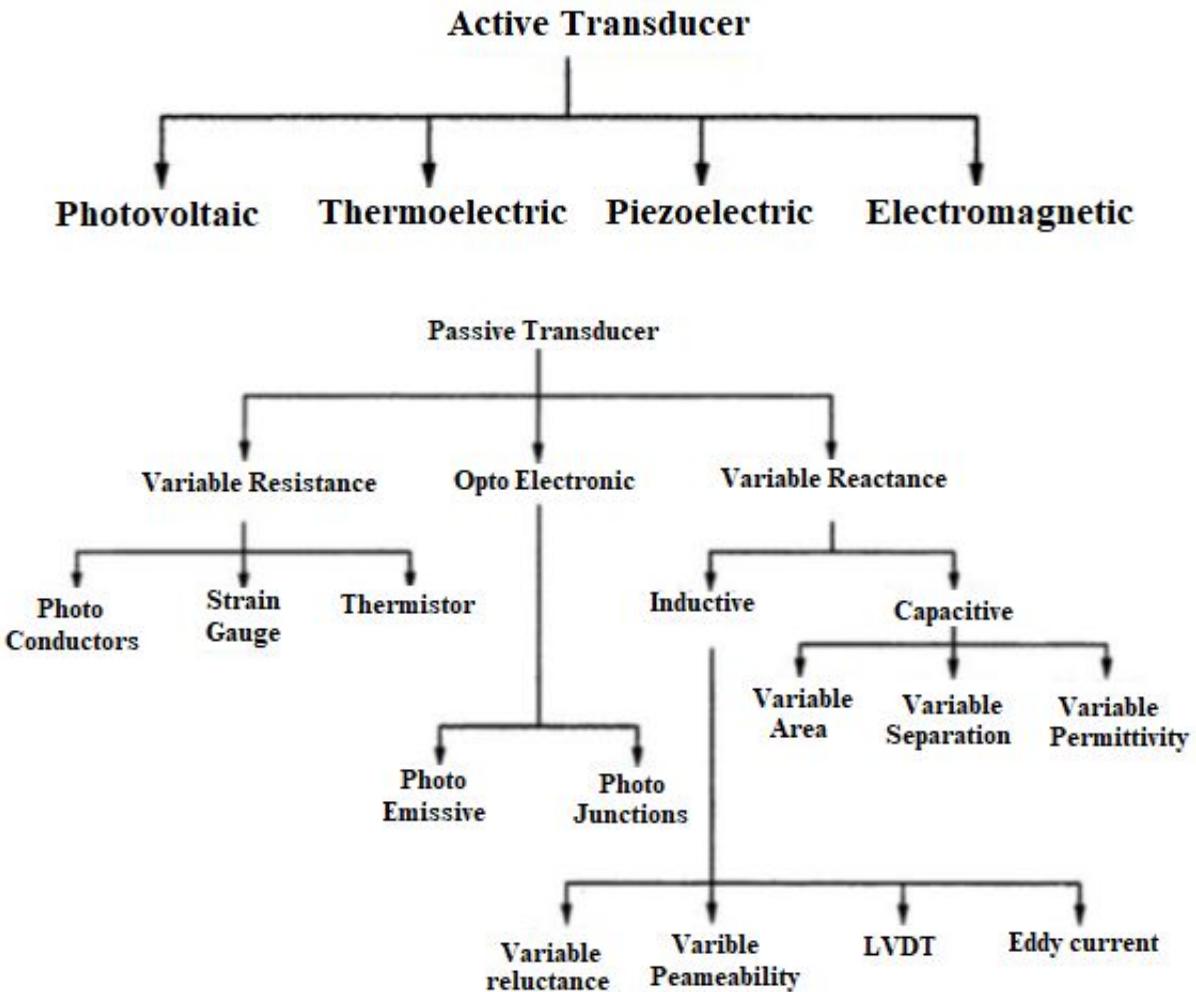
# Classification of Transducer

1. As active and passive transducer
2. According to transduction principle
3. As analog and digital transducer
4. As primary and secondary transducer
5. As forward transducer and inverse transducer

# Active and Passive Transducer

<b>Active Transducer</b>	<b>Passive Transducer</b>
The active transducer is also called as self generating type transducer.	The passive transducer is also called as externally powered transducer.
The active transducer does not require any auxiliary (external) power supply.	The passive transducer requires auxiliary (external) power supply for transduction.
The signal conversion is simpler.	The signal conversion is more complicated.
The energy required to produce output is obtained from the physical quantity.	They also derived part of the power required for conversion from physical quantity under measurement.

# Types of Active Transducer



# Displacement Transducer

**Define :** A Displacement Transducer is an electromechanical device used to convert mechanical motion or vibrations into a variable electric signals.

**Types:**

Capacitive Transducer

Inductive

Variable Inductance

Linear Variable Differential Transformer

# Capacitive Transducer

- A capacitor consists of two conductors (plates) that are electrically isolated from one another by a dielectric medium.
- The principle of operation of capacitive transducers is based upon the equation for capacitance of a parallel plate capacitor as shown below:

$$\text{Capacitance } C = \frac{\epsilon A}{d}$$

A = Overlapping area of plates; d = Distance between two plates;  $\epsilon$  = Permittivity (dielectric constant)

- The capacitive transducers are commonly used for measurement of linear displacement, by employing the following effects.
  1. Change in area of plates.
  2. Change in distance between the two plates.
  3. Change in dielectric between the two plates.

# Capacitive Transducer

## Contd..

### Variable capacitance pressure gauge –

Principle of operation: Distance between two parallel plates is varied by an externally applied force.

Applications: Measurement of Displacement, pressure.

### Capacitor microphone -

Principle of operation: Sound pressure varies the capacitance between a fixed plate and a movable diaphragm.

Applications: Speech, music, noise.

### Dielectric gauge -

Principle of operation: Variation in capacitance by changes in the dielectric.

Applications: Liquid level, thickness.

# Inductive Transducer

- The inductive transducers work on the principle of the electromagnetic induction.
- Inductance of the magnetic material depends on a number of variables
  - The number of turns of the coil on the material,
  - The size of the magnetic material
  - The permeability of the flux path.
  - The change in the air gap



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# Inductive Transducer Contd..

**Magnetic circuit transducer:** Self inductance or mutual inductance of ac-excited coil is varied by changes in the magnetic circuit. **Applications:** Pressure, displacement.

**Reluctance pickup:** Reluctance of the magnetic circuit is varied by changing the position of the iron core of a coil. **Applications:** Pressure, displacement, vibration, position.

**Differential transformer:** The differential voltage of two secondary windings of a transformer is varied by positioning the magnetic core through an externally applied force.

**Applications:** Pressure, force, displacement, position.

**Eddy current gage:** Inductance of a coil is varied by the proximity of an eddy current plate.

**Applications:** Displacement, thickness.

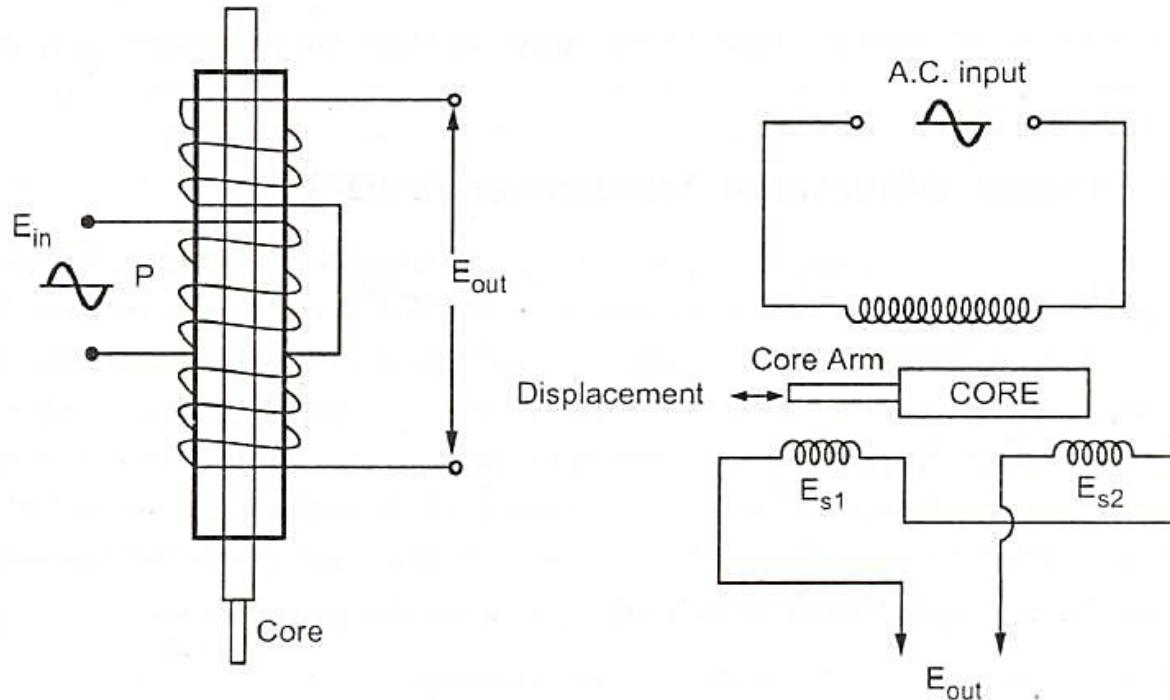
**Magnetostriction gauge:** Magnetic properties are varied by pressure and stress.

**Applications:** Force, pressure, sound.



# Linear Variable-Differential Transformer(LVDT)

The linear variable-differential transformer(LVDT) is the most widely used inductive transducer to translate linear motion into electrical signal



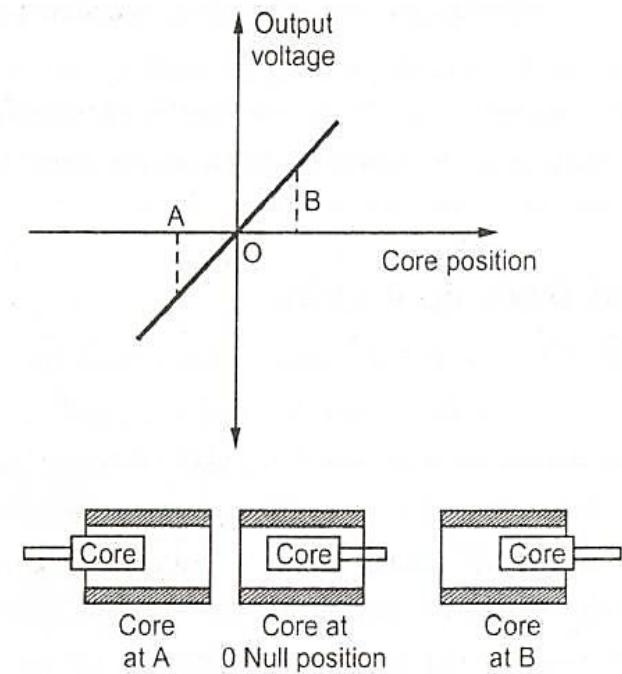
# Construction of LVDT

- Consists of a primary winding and two secondary windings.
- A ferro-magnetic core(armature) in the shape of a rod or cylinder is attached to the transducer sensing which slides freely within the hollow portion of the bobbin.
- An a.c. excitation is applied across the primary winding and the movable core varies the coupling between it and the two secondary windings.
- As the core moves away from the centre position, the coupling to one secondary becomes more and hence its output voltage increases, while the coupling and the output voltage of the other secondary decreases.



# Working Principle of LVDT

- Any physical displacement of the core causes the voltage of one secondary winding to increase while simultaneously, reducing the voltage in the other secondary winding.
- The difference of the two voltages appears across the output terminals of the transducers and gives a measure of the physical position of the core and hence the displacement.
- When the core is in the neutral or zero position, voltages induced in the secondary windings are equal and opposite and the net output is negligible.
- By comparing the magnitude and phase of output with input source, the amount and direction of movement of core and hence displacement may be determined





# Advt, Disadvt and Uses of LVDT

- Advt:**
1. High Range -1.25mm to 250mm.
  2. Low hysteresis
  3. Simple, light in weight and easy to maintain.
  4. Low Power Consumption

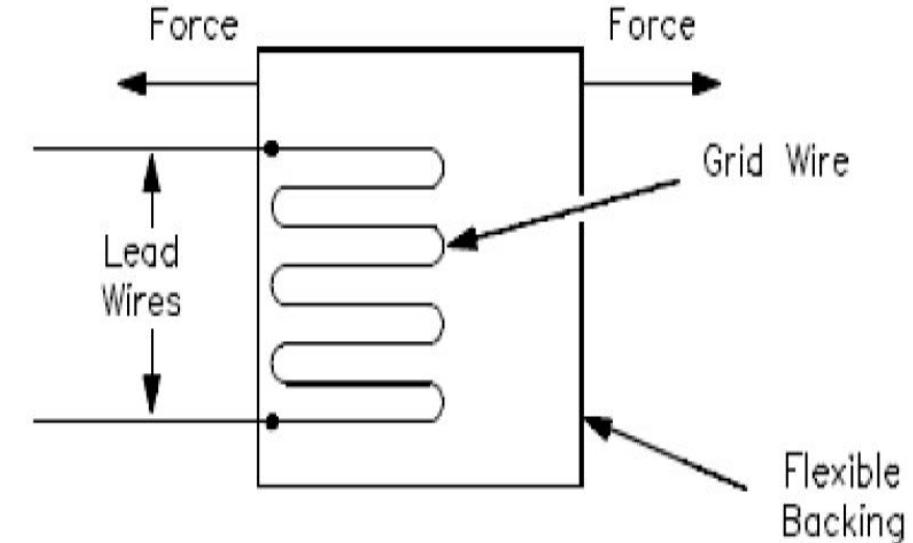
- Disadvt:**
1. They are sensitive to stray magnetic fields but shielding is possible.
  2. Temperature affects the performance of transducer.

- Uses:**
1. The LVDT can be used in all applications where displacements ranging from fraction of a mm to a few cm have to be measured.
  2. Acting as a secondary transducer it can be used as a device to measure force, weight and pressure.



# Strain Gauge

- When the tension is applied to the electrical conductor, its length increases while the cross section area decreases.
- So its resistance changes. This change can be measured to measured.
- Used for the measurement of force, stress and strain.
- A strain gauge is a passive type resistance pressure transducer whose electrical resistance changes when it is stretched or compressed.
- A pressure transducer contains a diaphragm which is deformed by the pressure which can cause a strain gauge to stretch or compress. This deformation of the strain gauge causes the variation in length and cross sectional area due to which its resistance changes.
- The wire filament is attached to a structure under strain and the resistance in the strained wire is measured.

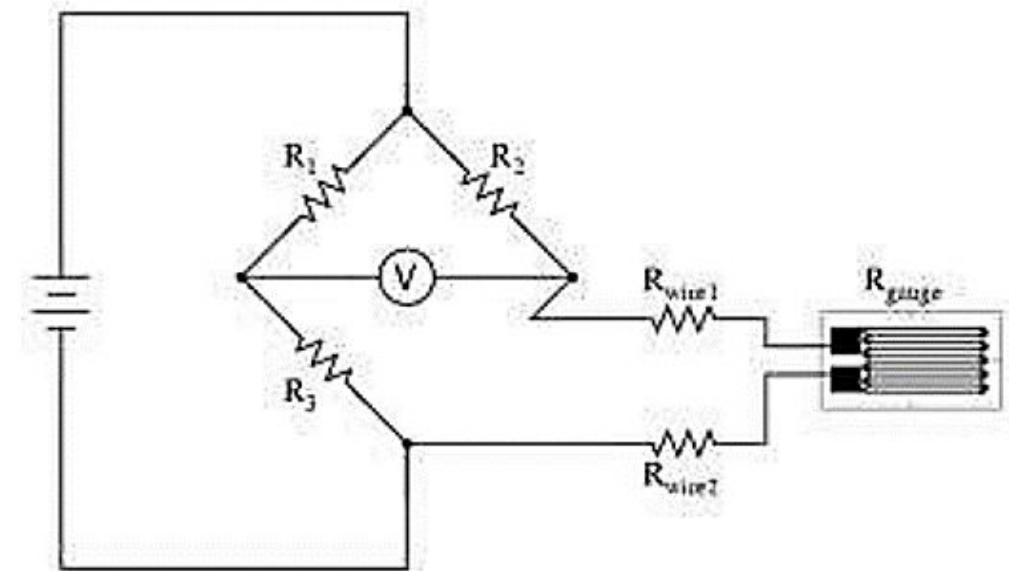




# Strain Gauge

- The strain gauge is connected into a Wheatstone Bridge circuit. The change in resistance is proportional to applied strain and is measured with Wheatstone bridge.
- The sensitivity of a strain gauge is described in terms of a characteristic called the **gauge factor**, defined as unit change in resistance per unit change in length.

$$K = \frac{\Delta R/R}{\Delta l/l}$$





# SRM Advt and Disadvt of Strain Gauge

## Advt

- There is no moving part.
- It is small and inexpensive.

## Disadvt

- It is non-linear.
- It needs to be calibrated.

## Uses :

- Residual stress
- Vibration measurement
- Torque measurement
- Bending and deflection measurement
- Compression and tension measurement
- Strain measurement

# Thermoelectric Transducers

**Define** – Converts Temperature to electrical signal and vice versa

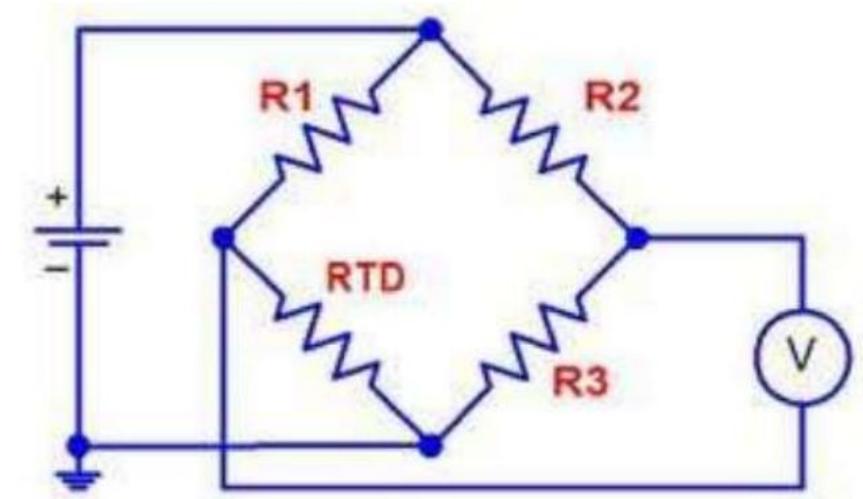
**Types -**

1. **RTD(Resistance Temperature Detector)** -To predict change in electrical resistance of some materials with changing temperature.
2. **Thermocouple** - To convert thermal potential difference into electric potential difference.
3. **Thermistor** - Exhibits a large change in resistance proportional to a small change in temperature.



# RTD

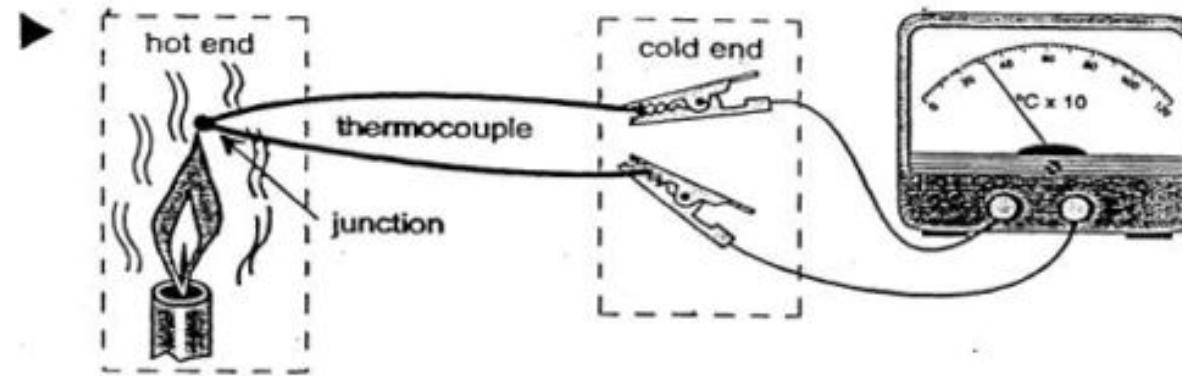
- RTD - Resistance Temperature Detector.
- The change in temperature is detected by the change in resistance of the wire.
- Types:
  1. RTD with positive thermal coefficients of resistivity
  2. RTD with negative thermal coefficients of resistivity
- **Materials:** Platinum (most popular and accurate), Nickel, Copper, Balco (rare), Tungsten (rare)
- RTDs are used for temperature measurements by using them in bridge circuits.
- The change in temperature causes considerable resistance change which gives a voltage drop in accordance with the thermal coefficient of resistance of the wire.





# Thermocouple

A thermocouple is formed by two different metals joined at one point



As the junction temperature increases a small voltage is created in the loop. The voltage produced at the junction of the dissimilar metals is due to a phenomenon called the "Seebeck Effect".

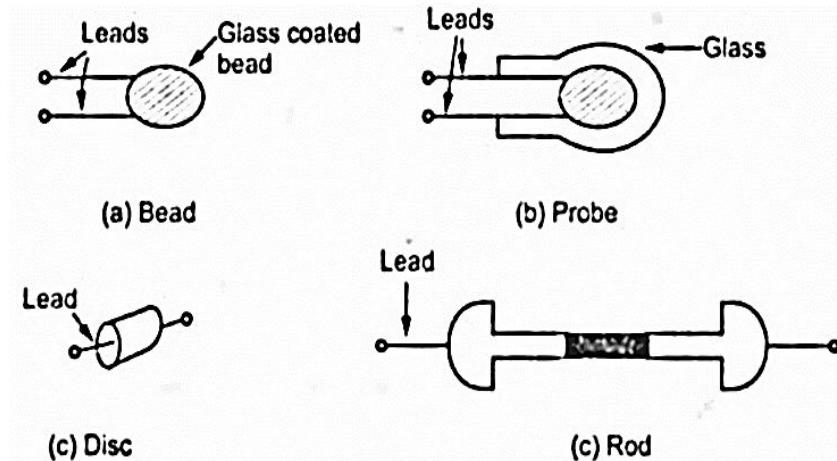
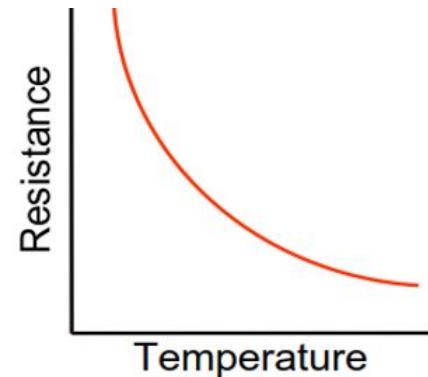
- The higher the temperature at the junction, the greater the voltage produced by that junction.
- The relationship between voltage and temperature is constant and therefore will graph as a linear line.



# Thermistor

- Measures temperature according to change in resistance.
- Made of a sintered semiconductor material.
- Use ceramic or polymer materials
- Available in various shapes like disc, rod, washer, etc.

Semi-conductor thermistors have a Negative Temperature Coefficient (NTC). i.e. as temperature increases, the resistance decreases.



# Photoelectric Transducers

**Define :** Converts light energy to electrical energy and vice versa.

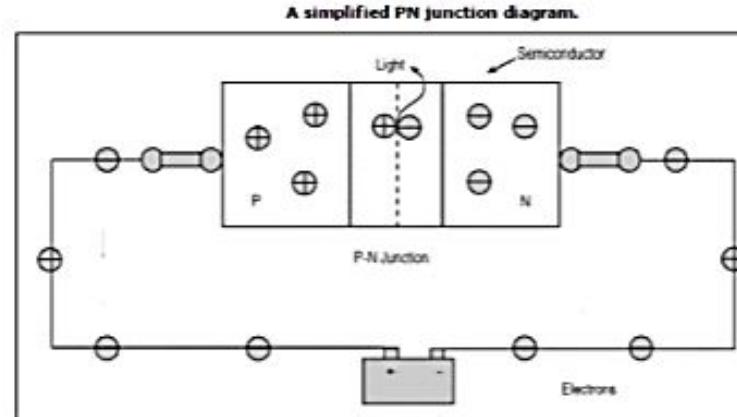
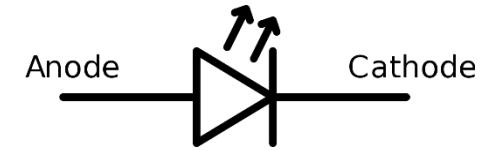
**Types:**

- Laser diode, light-emitting diode - convert electrical power into forms of light.
- Photodiode, photo resistor, phototransistor, photomultiplier tube - converts changing light levels into electrical form.



# Light-Emitting Diode

- LEDs are *semiconductor diodes*, electronic devices that permit current to flow in only one direction.
- The diode is formed by bringing two slightly different materials together to form a *PN junction*.
- In a PN junction, the **P** side contains excess positive charge ("holes," indicating the absence of electrons) while the **N** side contains excess negative charge (**electrons**).



# Light-Emitting Diode

- When sufficient voltage is applied to the chip across the leads of the LED, electrons can move easily in only one direction across the junction between the p and n regions.
- When a voltage is applied and the current starts to flow, electrons in the n region have sufficient energy to move across the junction into the p region.
- Each time an electron recombines with a positive charge, electric potential energy is converted into electromagnetic energy. • For each recombination of a negative and a positive charge, a quantum of electromagnetic energy is emitted in the form of a photon of light with a frequency characteristic of the semi-conductor material.
- LEDs are made from gallium-based crystals that contain one or more additional materials such as phosphorous to produce a distinct color. • Different LED chip technologies emit light in specific regions of the visible light spectrum and produce different intensity levels.
- LEDs are available in red, orange, amber, yellow, green, blue and white.

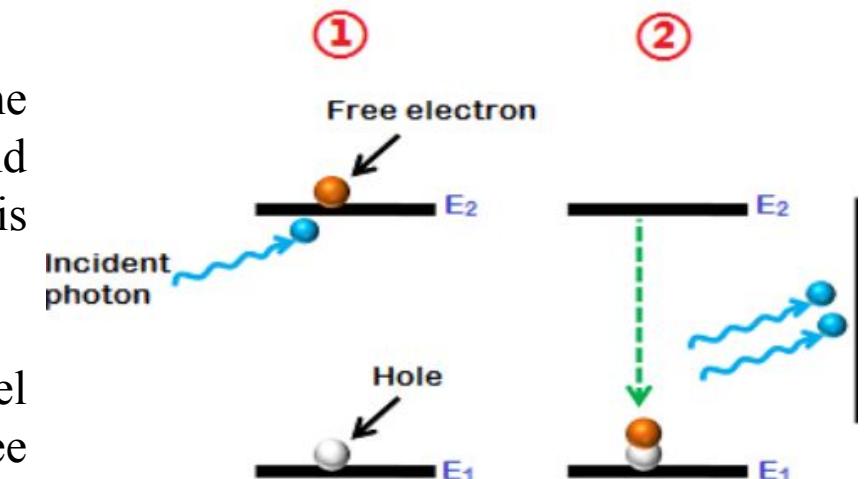
# Laser Diode

- LASER stands for Light Amplification by Stimulated Emission of Radiation.
- A laser diode is an electronic device, which converts electrical energy into light energy to produce high-intensity coherent light.
- Laser diode is very small in size and appearance.
- It is similar to a transistor and has operation like LED but it emit coherent light.
- The material which often used in Laser diode is the gallium Arsenide (GaAs).
- It work on forward biasing.



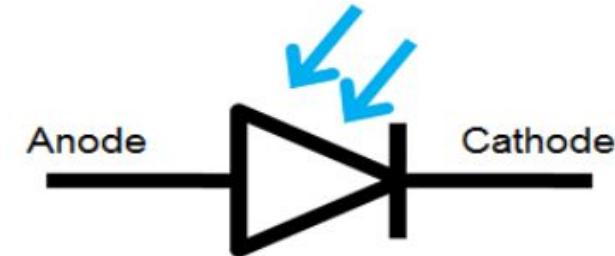
# Laser Diode

- When DC voltage is applied across the laser diode, the free electrons move across the junction region from the n-type material to the p-type material.
- In this process, some electrons will directly interact with the valence electrons and excites them to the higher energy level and releases energy in the form of light. This process of emission is called spontaneous emission.
- The photons generated due to spontaneous emission will travel through the junction region and stimulate the excited electrons (free electrons). As a result, more photons are released.
- This process of light or photons emission is called stimulated emission.



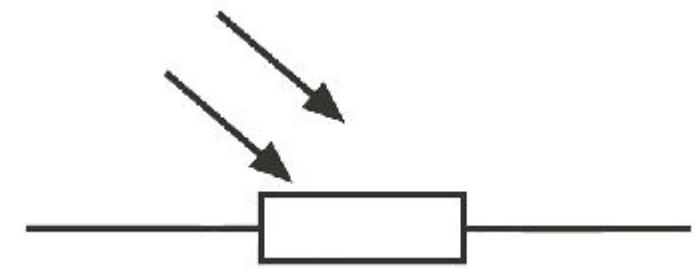
# Photo Diode

- A photodiode is a PN-junction diode that consumes light energy to produce electric current.
- It is also called as photo-detector, a light detector, a photo-sensor.
- A photodiode is one type of light detector, used to convert light into current or voltage based on the mode of operation of the device.
- It comprises of optical filters, built-in lenses and also surface areas.
- These diodes are particularly designed to work in reverse bias condition.
- The working principle of a photodiode is, when a photon of ample energy strikes the diode, it makes a couple of an electron-hole.
- Therefore, holes in the region move toward the anode, and electrons move toward the cathode, and a photocurrent will be generated.



# Photoresistor

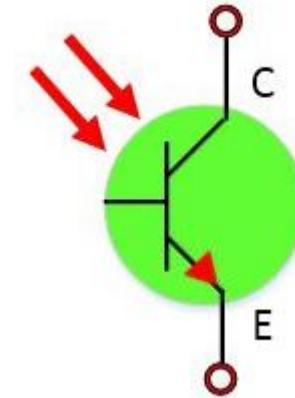
- Photoresistor is a variable resistor whose resistance varies inversely with the intensity of light
- Photoresistors are also known as photoconductive cells or just photocell.
- When light is incident on the photoresistor, photons get absorbed by the semiconductor material.
- The energy from the photon gets absorbed by the electrons.
- When these electrons acquire sufficient energy to break the bond, they jump into the conduction band.
- Due to this, the resistance of the photoresistor decreases. With the decrease in resistance, conductivity increases.
- In the absence of light, the photoresistor can have resistance values in megaohms.
- During the presence of light, its resistance can decrease to a few hundred ohms.





# Phototransistor

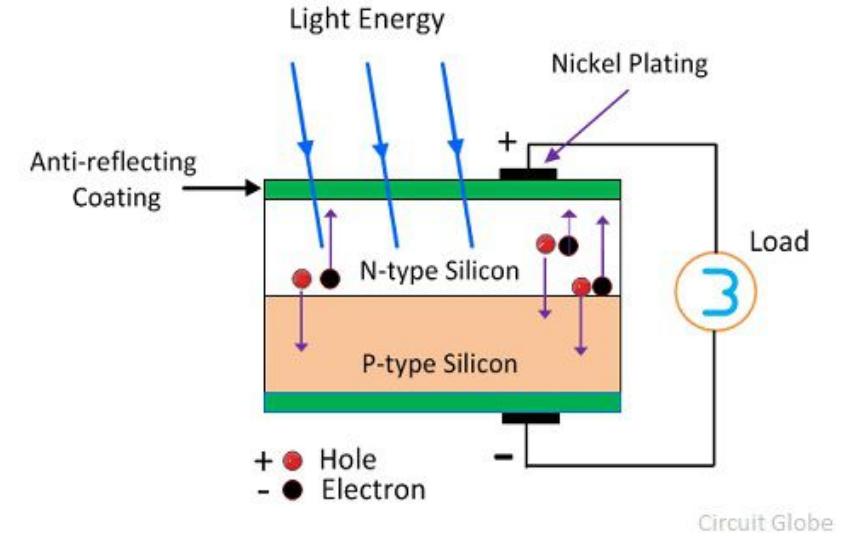
- It is a device to convert light energy into electrical energy.
- The construction of phototransistor is similar to the ordinary transistor, except the base terminal. In phototransistor, the base terminal is not provided, and instead of the base current, the light energy is taken as the input.
- The 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.





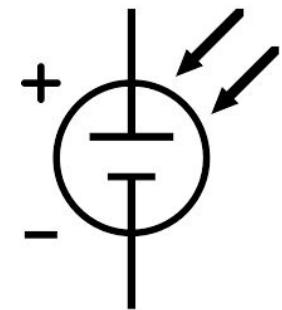
# Photovoltaic or Solar Cell

- The Photovoltaic cell is the semiconductor device that converts the light into electrical energy.
- The voltage induces by the PV cell depends on the intensity of light incident on it.
- The semiconductor materials like arsenide, indium, cadmium, silicon, selenium and gallium are used for making the PV cells.
- Figure shows the constructions of the silicon photovoltaic cell.
- The upper surface of the cell is made of the thin layer of the p-type material so that the light can easily enter into the material.
- The metal rings are placed around p-type and n-type material which acts as their positive and negative output terminals respectively.



# Photovoltaic or Solar Cell

- The multi-crystalline or monocrystalline semiconductor material make the single unit of the PV cell.
  - The mono-crystal cell is cut from the volume of the semiconductor material.
  - The multicell are obtained from the material which has many sides.
- The output voltage and current obtained from the single unit of the cell is very less.
- Many cells together is said to be Solar Panel.



# Chemical Transducer

**Define** – Converts chemical energy into electrical energy and vice versa.

**Types** –

**1) pH probe -**

- A scientific instrument that measures the hydrogen-ion activity in water based solutions, indicating its acidity or basicity expressed as pH.
- The pH meter measures the difference in electrical potential between a pH electrode and a reference electrode, and so the pH meter is sometimes referred to as a "potentiometric pH meter".
- The difference in electrical potential relates to the acidity or pH of the solution.

**2) Electro-galvanic sensor –**

- An electrochemical device which consumes a fuel to produce an electrical output by a chemical reaction.
- One form of electro-galvanic fuel cell based on the oxidation of lead is commonly used to measure the concentration of oxygen gas in underwater diving and medical breathing gases.

# Electroacoustic Transducer

**Define** : convert electrical signals to acoustic (related to hearing) signals or vice versa.

**Types:**

- 1) **Mic** - an instrument whereby sound waves are caused to generate or modulate an electric current usually for the purpose of transmitting or recording sound (such as speech or music).
- 2) **Speaker** - device that converts electric signals to audible sound
- 3) **Sonar** - a system for the detection of objects under water by emitting sound pulses and detecting or measuring their return after being reflected.
- 4) **Ultrasonic** - These transducers send the electrical signals to the object and once the signal strikes the object then it reverts to the transducer. In this process, this transducer measures the distance of the object.
- 5) **Tactile** - A **tactile sensor** is a device that measures information arising from physical interaction with its environment.



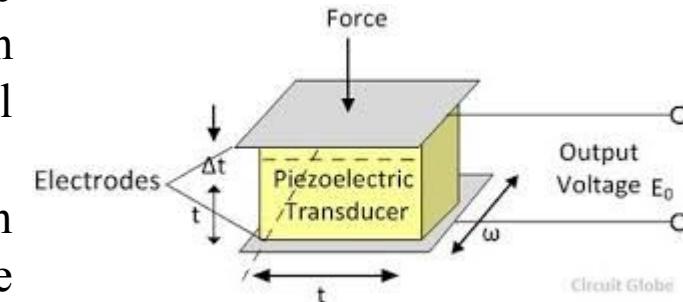
# Electroacoustic Transducer

6) **Geophone** - is a ground motion transducer that has been used by geophysicists and seismologists to convert ground movement into voltage.

7) **Hydrophone** - A hydrophone is a microphone designed to be used underwater for recording or listening to underwater sound.

## 8) Piezoelectric-

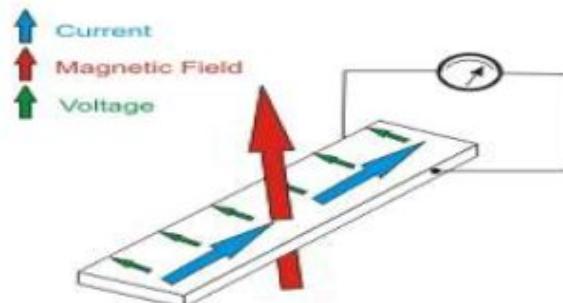
- The Piezoelectric transducer is an electroacoustic transducer used for conversion of pressure or mechanical stress into an alternating electrical force. It is used for measuring the physical quantity like force, pressure, stress
- The piezoelectric transducer uses the piezoelectric material which has a special property, i.e. the material induces voltage when the pressure or stress applied to it.
- The Quartz is the examples of the natural piezoelectric crystals, whereas the Rochelle salts, ammonium dehydration, phosphate, lithium sulphate, dipotassium tartrate are the examples of the man made crystals. The ceramic material is also used for piezoelectric transducer.





# Electromagnetic Transducer

- 1) **Antenna** - Which can convert radio waves (electromagnetic waves) into an electrical signal
- 2) **magnetic cartridge** - A type of transducer used in the playback of analog sound recordings called records on a record player. Commonly called a **turntable**
- 3) **Hall Effect** - The Hall Effect describes a condition if current flow in a conductor being affected by the presence of a magnetic field. If an electric current flows through a conductor in a magnetic field, the magnetic field exerts a transverse force on the moving charge carriers which tends to push them to one side of the conductor. This is most evident in a thin flat conductor. A build up of charge at the sides of the conductors will balance this magnetic influence, producing a measurable voltage between the two sides of the conductor. The presence of this measurable transverse voltage is called the Hall effect after E. H. Hall who discovered it in 1879.



# Radioacoustic Transducer

- 1) **Geiger Muller Tubes** – instrument used for the detection of Ionizing radiation. It is used for the detection of X-rays.
- 2) **Radio Receiver** - receives radio waves (electromagnetic) and converts the information carried by them to a usable form.
- 3) **Radio Transmitter**- Receives the information to be carried and convert that into radio waves (electromagnetic)

# Assignment Topics

- LCD
- Infrared Emitters
- Optocouplers

# End of Session

# BEEE-UNIT 5

<i>Digital Systems</i>	
<b>18</b>	
<i>Number systems, binary codes</i>	<i>Two, Three and Four Variable K-Map</i>
<i>Binary arithmetic</i>	<i>Problem Solving Session</i>
<i>Boolean algebra, laws and theorems</i>	<i>Lab 14: Reduction using Digital Logic Gates</i>
<i>Simplification of Boolean expression</i>	<i>Principles of Communication</i>
<i>Logic Gates and Operations</i>	<i>Block diagram of a Communication System</i>
<i>Simplification of Boolean expression</i>	<i>Amplitude Modulation</i>
<i>Problem Solving Session</i>	<i>Frequency Modulation</i>
<i>Lab 13: Verification of Boolean expression using logic gates</i>	<i>Phase Modulation</i>
<i>SOP and POS Expressions</i>	<i>Demodulation</i>
<i>Standard forms of Boolean expression</i>	<i>Problem Solving Session</i>
<i>Simplify using Boolean Expressions</i>	<i>Lab 15: Demo of Transmission and Reception using MODEM</i>
<i>Minterm and Maxterm</i>	
<i>K-Map Simple Reduction Technique</i>	

## NUMBER SYSTEM

**Definition:** In digital system, the number system is used for representing the information. The number system has different bases and the most common of them are the decimal, binary, octal, and hexadecimal.

### **BASE OR RADIX (r)**

The base or radix of the number system is the total number of the digit used in the number system.

Sl No	Name of the number system	Symbol Used	Base or radix
1	Decimal	0,1,2,3,4,5,6,7,8,9	10
2	Binary	0,1	2
3	Octal	0,1,2,3,4,5,6,7	8
4	Hexadecimal	0,1,2,3,4,5,6,7,8,9, A,B,C,D,E,F	16

## I. Decimal to any number system

### 1. Decimal to Binary

**Problem:**

**Convert  $53.62_{10}$  to binary**

**Sol :**

2	53				$53 = 110101_2$
2	26-1	$110101_2$	0.62x2=1.24		$0.62 = 100\ 111_2$
2	13-0		0.24x2=0.48		
2	6-1		0.48x2=0.96		
2	3-0		0.96x2=1.92		
2	1-1		0.92x2=1.84		
			0.84x2=1.68		
				<b>5 bit after decimal point enough</b>	$53.62=110101.100\ 111_2$
			$100111_2$		

## 2. Decimal to octal

**Problem:**

**Convert  $444.456_{10}$  to octal**

**Sol :**

8	444	674 <sub>8</sub>
8	55-4	0.456x8=3.648-3
8	6-7	0.648x8=5.184-5

↑

0.456x8=3.648-3  
0.648x8=5.184-5  
0.184x8=1.472-1  
0.472x8=3.776-3  
0.776x8=6.208-6

0.35136<sub>8</sub>

↓

5 bit after decimal point enough

$444.456_{10} = 674.35136_8$

## 3. Decimal to hexadecimal

**Problem:**

**Convert  $444.456_{10}$  to hexadecimal**

**Sol :**

16	444	1BC
16	27-12	0.456X16=7.296-7
16	1-11	0.296X16=4.736-4

↑

0.456X16=7.296-7  
0.296X16=4.736-4  
0.736X16=11.776-11

↓

0.74B

$444.456 = 1BC.74B$

A-10  
 B-11  
 C-12  
 D-13  
 E-14  
 F-15

## II. Any number system to Decimal [Use formula]

$$\text{Decimal} = a_n \times r^n + a_{n-1} \times r^{n-1} + \dots + a_1 \times r^1 + a_0 \times r^0 + a_{-1} \times r^{-1} + a_{-2} \times r^{-2} + \dots + a_{-m} \times r^{-m-1}$$

Where: r - base or radix of given number system

$a_n$  - n<sup>th</sup> bit/digit value

$a_0$  - 0<sup>th</sup> bit/digit value (Left immediate bit/digit at decimal point)

$a_{-1}$  - 1<sup>st</sup> bit/digit value (Right immediate bit/digit after decimal point)

### 4. Binary to Decimal

**Problem:**

**Convert  $101111.0101_2$  to decimal**

**Sol :**

$$\text{Decimal} = a_5 \times 2^5 + a_4 \times 2^4 + a_3 \times 2^3 + a_2 \times 2^2 + a_1 \times 2^1 + a_0 \times 2^0 + a_{-1} \times 2^{-1} + a_{-2} \times 2^{-2} + a_{-3} \times 2^{-3} + a_{-4} \times 2^{-4}$$

$$= 1 \times 2^5 + 0 \times 2^4 + 1 \times 2^3 + 1 \times 2^2 + 1 \times 2^1 + 1 \times 2^0 + 0 \times 2^{-1} + 1 \times 2^{-2} + 0 \times 2^{-3} + 1 \times 2^{-4} \quad [\text{Use calci to solve this}]$$

$$= 32 + 0 + 8 + 4 + 2 + 1 + 0 - 0.25 + 0 + 0.0625$$

$$= 47.3125_{10}$$

## **5. Octal to Decimal**

**Problem:**

**Convert 573. 26<sub>8</sub> to decimal**

**Sol :**

$$\text{Decimal} = a_2 \times 8^2 + a_1 \times 8^1 + a_0 \times 8^0 + a_{-1} \times 8^{-1} + a_{-2} \times 8^{-2}$$

$$= 5 \times 8^2 + 7 \times 8^1 + 3 \times 8^0 + 2 \times 8^{-1} + 6 \times 8^{-2}$$

$$= 320 + 56 + 3 + 0.25 + 0.09375$$

$$= 379.34375_{10}$$

## **6. Hexadecimal to Decimal**

A-10

B-11

C-12

D-13

E-14

F-15

**Problem:**

**Convert D2A.5C<sub>16</sub> to decimal**

**Sol :**

$$\text{Decimal} = a_2 \times 16^2 + a_1 \times 16^1 + a_0 \times 16^0 + a_{-1} \times 16^{-1} + a_{-2} \times 16^{-2}$$

$$= 13 \times 16^2 + 2 \times 16^1 + 10 \times 16^0 + 5 \times 16^{-1} + 12 \times 16^{-2}$$

$$= 3370.359375_{10}$$

### III. Other than Decimal conversion

#### 7. Octal to Binary

**Problem:**

**Convert  $365.71_8$  to binary**

**Sol : For each octal digit, write 3 bit binary**

$$\begin{array}{ccccc}
 3 & 6 & 5 . & 7 & 1 \\
 011 & 110 & 101 & 111 & 001 \\
 = & 011110101.111001_2
 \end{array}$$

Oct-Bin
0-000
1-001
2-010
3-011
4-100
5-101
6-110
7-111

#### 8. Binary to Octal

**Problem:**

Convert  $11001111.1101_2$  to Octal

**Sol : Choose 3 bit binary before decimal point and after decimal point.**

**Note: You can add 0, in prefix/suffix if needed**

**011 001 111.110 100**

$$\begin{array}{ccccc}
 3 & 1 & 7 & 6 & 4 \\
 = 317.64_8
 \end{array}$$

## 9. Hexadecimal to Binary

**Problem:**

**Convert  $AB85.2F_{16}$  to binary**

**Sol :** For each hexadecimal digit, write 4 bit binary

<b>A</b>	<b>B</b>	<b>8</b>	<b>5.</b>	<b>2</b>	<b>F</b>	
1010	1011	1000	0101	0010	1111	
$= 1010101110000101.00101111_2$						

Note	
0-0000	8- 1000
1-0001	9- 1001
2-0010	A- 1010
3-0011	B- 1011
4-0100	C- 1100
5-0101	D- 1101
6-0110	E- 1110
7-0111	F-1111

## 10. Binary to Hexadecimal

**Problem:**

**Convert  $110111101.10101111_2$  to Hexadecimal**

**Sol :** Choose 4 bit binary before decimal point and after decimal point

Note: You can add 0 in prefix/suffix, if needed

**0001    1011    1101.    1010    1110**

1              B              D              A              E

$= 1BD.AE_{16}$

## **11. Octal to Hexadecimal [Via Binary]**

Problem:

Convert 7320.12<sub>8</sub> to Hexadecimal

Sol : First convert Octal to Binary, then convert Binary to hexa

$$7320.12 = \underline{111} \underline{011} \underline{010} \underline{000.001} \underline{010}_2$$

$$\begin{array}{cccccc} 1 & 1 & 1 & 0 & 1 & 1 \\ 1 & 1 & 0 & 1 & 0 & 0 \\ \hline E & D & 0 & 2 & 8 & \end{array}$$

$$7320.12_8 = ED0.28_{16}$$

## **12. Hexadecimal to Octal [Via Binary]**

Problem:

Convert EEE.ECE<sub>16</sub> to Octal

Sol : First convert hexa to Binary, then convert Binary to octal

$$EEE.ECE = 111011101110.111011001110_2$$

$$\begin{array}{cccccccccc} 1 & 1 & 1 & 0 & 1 & 1 & 0 & 1 & 1 & 0 \\ 7 & 3 & 5 & 6 & 7 & 3 & 1 & 6 & & \\ \hline & & & & & & & & & \\ 7356.7316_8 & & & & & & & & & \end{array}$$

# Why Binary used in Digital system

- Digital system use binary - the bits 0 and 1 - to store/process data. The circuits in Digital system are made up of **billions of transistors**. A transistor is a tiny switch that is activated by the electronic signals it receives.
- **The digits 1 and 0 used in binary reflect the on and off states of a transistor.**

## SIGNED BINARY NUMBERS

To represent negative numbers, signed number system is used. The four best-known methods of extending the binary numeral system to represent signed numbers are: signed magnitude, **ones' complement**, **two's complement**, and offset binary.

### 1. Signed magnitude / Sign-and-magnitude

In this approach, a number's sign is represented with a sign bit: setting that bit (often the **most significant bit**) to 0 for a positive number and setting it to 1 for a negative number. The remaining bits in the number indicate the magnitude (or absolute value). For example, in an eight-bit byte, only seven bits represent the magnitude, which can range from 0000000 (0) to 1111111 (127). Thus numbers ranging from  $-127_{10}$  to  $+127_{10}$  can be represented once the sign bit (the eighth bit) is added. For example,  $-43_{10}$  encoded in an eight-bit byte is **10101011** while  $43_{10}$  is **00101011**.

### 2. One's Complement

The one's complement form of a negative binary number is the **bitwise NOT** applied to it, i.e. the "complement" of its positive counterpart.

$$43_{10} = \textcolor{red}{00101011}$$

$$\underline{-43_{10}} = 11010100$$

### 3. Two's Complement

In two's complement, negative numbers are represented by the bit pattern which is one greater than the ones' complement of the positive value. ie, one's complement it and add 1.

$$43_{10} = 00101011$$

$$-43_{10} = 11010100 \text{ (one's complement)}$$

$$\begin{array}{r} 1 \\ \hline 11010101 \end{array} \text{ (Two's complement)}$$

$$511_{10} = 011111111$$

$$-511_{10} = 1000010000 \text{ (one's complement)}$$

$$\begin{array}{r} 1 \text{ (Add 1)} \\ \hline 1000000001 \end{array} \text{ (Two's complement)}$$

Note: In our calculator [Casio fx 991 MS], we have 10 bits. So maximum we can use 9 bit only. 10<sup>th</sup> bit is used (MSB) to represent 0 for a positive number. [We can represent only 511 to -512 in our calculator]

## **Binary arithmetic [2's complement arithmetic]**

Perform the following using 2's complement arithmetic. [Use 10 bit]

(i)  $Y = 85 - 42$

(ii)  $Z = 42 - 85$

Sol (i)  $Y = 85 - 42$

$$= 85 + (-42)$$

85 in 10 Bit : 0001010101

42 in 10 Bit : 0000101010

-42 in 1's complement : 1111010101  
   (+)

-42 in 2's complement : 1111010110

$$85 = 0001010101 \quad (+)$$

$$\begin{array}{r} -42 = 1111010110 \\ \hline 10000101011 \end{array}$$

Discard the carry.

$$Y = 0000101011$$

$$\boxed{Y = 43}$$

$$\begin{aligned}\text{Sol (ii)} Z &= 42 - 85 \\ &= 42 + (-85)\end{aligned}$$

42 in 10 Bit : 0000101010

85 in 10 Bit : 0001010101

-85 in 1's complement : 1110101010

1 (+)

$$\begin{array}{r} 0000101010 \\ - 1110101010 \\ \hline \end{array}$$

-85 in 2's complement : 1110101011



$$\begin{array}{r} -85 = 1110101011 \\ (+) \\ 42 = 0000101010 \\ \hline 1110101011 \end{array}$$

Since MSB is 1, it's a negative number.

To know its value, 2's complement it.

$$\begin{array}{r} 0000101010 \\ (+) \\ 1 \\ \hline 0000101011 \end{array}$$

$$Z = -43$$

## **BCD CODES**

Human can understand and use decimal number easily. But Digital system can understand only binary numbers. So, to interface among human and Digital system, BCD codes were developed. There are many types of BCD codes that were introduced by Scientist. **But 8421 code is very much popular and widely used.**

8421 code is a 4 bit BCD code having codes for 0 to 9 (Decimal Numbers). Each decimal digit represents 4 bit binary. It obeys positional weightage principle. It's easy to understand and remember because it's a **normal 4 bit binary number from 0 to 9.**

# BINARY CODES FOR DECIMAL-BCD

## Binary Codes for Decimal digits

The following table shows the various binary codes for decimal digits 0 to 9.

Decimal Digit	8421 Code BCD Code	2421 Code	84-2-1 Code	Excess 3 Code
0	0000	0000	0000	0011
1	0001	0001	0111	0100
2	0010	0010	0110	0101
3	0011	0011	0101	0110
4	0100	0100	0100	0111
5	0101	1011	1011	1000
6	0110	1100	1010	1001
7	0111	1101	1001	1010
8	1000	1110	1000	1011
9	1001	1111	1111	1100

## **BCD CODES**

Express  $7915_{10}$  in BCD and Excess-3

$7915_{10}$  in BCD = 0111 1001 0001 0101

$7915_{10}$  in Excess-3 = 1010 1100 0100 1000

## **BCD Addition**

BCD is a numerical code, and many applications require that arithmetic operations be performed. Addition is the most important operation because the other three operations like subtraction, multiplication and division can be accomplished using addition. The rule for adding two BCD numbers is given below.

1. Add the two numbers, using the rules for binary addition.
2. If a four-bit sum is equal to or less than 9, it is a valid BCD number.
3. If a four-bit sum is greater than 9, or if a carry-out of the group is generated, it is an invalid result. Add 6 ( $0110_2$ ) to the four-bit sum in order to skip the six invalid states and return the code to 8421. If a carry results when 6 is added, simply add the carry to the next four-bit group.

Perform the following using BCD Arithmetic

$$459 + 278$$

Sol:

1	1111		
459 = 0100	0101	1001	
278 = 0010	0111	1000	
<hr/>			
0111	1101	0001	
	0110	0110	
<hr/>			
0111	0011	0111	
7	3	7	

Illegal Code, So add 0110

Legal Code but contains Carry,  
so add 0110

# Boolean Algebra

- Invented by George Boole in 1854
- An algebraic structure defined by a set  $B = \{0, 1\}$ , together with two binary operators (+ and ·) and a unary operator ( $\bar{\cdot}$ )

OR Laws	AND Laws
1. $A + 0 = A$	5. $A \cdot 0 = 0$
2. $A + 1 = 1$	6. $A \cdot 1 = A$
3. $A + A = A$	7. $A \cdot A = A$
4. $A + \bar{A} = 1$	8. $A \cdot \bar{A} = 0$

9. $\overline{\overline{A}} = A$	Involution
10. $A + B = B + A$	11. $AB = BA$ Commutative
12. $(A + B) + C = A + (B + C)$	13. $(AB)C = A(BC)$ Associative
14. $A(B + C) = AB + AC$	15. $A + BC = (A + B)(A + C)$ Distributive
16. $\overline{A + B} = \overline{A} \cdot \overline{B}$	17. $\overline{A \cdot B} = \overline{A} + \overline{B}$ DeMorgan's
18. $A + AB = A$	19. $A(A + B) = A$ Absorption

Prove  $A+A'B = A+B$

Similarly we can prove  $A'+AB = A'+B$

<b>A</b>	<b>B</b>	<b>A'</b>	<b>A'B</b>	<b>A+A'B</b>	<b>A+B</b>
0	0	1	0	0	0
0	1	1	1	1	1
1	0	0	0	1	1
1	1	0	0	1	1

State and prove DeMorgan's Theorem

$$1. \quad \overline{A+B} = \overline{A} \cdot \overline{B}$$

$$2. \quad \overline{A \cdot B} = \overline{A} + \overline{B}$$

<b>A</b>	<b>B</b>	<b>A+B</b>	<b>(A+B)'</b>	<b>A'</b>	<b>B'</b>	<b>A'.B'</b>
0	0	0	1	1	1	1
0	1	1	0	1	0	0
1	0	1	0	0	1	0
1	1	1	0	0	0	0
			LHS			RHS

<b>A</b>	<b>B</b>	<b>A.B</b>	<b>(A.B)'</b>	<b>A'</b>	<b>B'</b>	<b>A'+B'</b>
0	0	0	1	1	1	1
0	1	0	1	1	0	1
1	0	0	1	0	1	1
1	1	1	0	0	0	0
			LHS			RHS

## Simplification of Boolean expressions using Boolean algebra

1. Simplify the following expressions using Boolean algebra

$$Y = A + AB + A B' C$$

Sol:  $Y = A (1 + B + B' C)$

$$= A \cdot 1$$

$$Y = A$$

2. Simplify the following expressions using Boolean algebra

$$Y = (A' + B) C + ABC$$

Sol:  $Y = A'C + BC + ABC$

$$= A'C + BC(1 + A)$$

$$= A'C + BC$$

3. Simplify the following expressions using Boolean algebra

$$Y = AB'C (BD + CDE) + AC'$$

$$= AB'CBD + AB'CCDE + AC'$$

$$= 0 + AB'CDE + AC'$$

$$= A(C' + B'CDE)$$

$$= A(C' + B'DE)$$

$$B'B = 0; CC = C$$

$$C' + CX = C' + X$$

4. Simplify the following expressions using Boolean algebra

$$Y = AB + \overline{AC} + \overline{ABC} (AB+C)$$

Sol: 
$$\begin{aligned} Y &= AB + A' + C' + AB'C \\ &= AB + A' + C' + 0 + AB'C \\ &= AB + A' + C' + AB'C \\ &= AB + A' + C' + AB' \\ &= A[B+B'] + A' + C' \\ &= A + A' + C' \\ &= 1 \end{aligned}$$

$B'B=0; CC=C$   
 $C'+CX=C'+X$   
 $B+B'=1$   
 $A+A'=1;$   
 $1+ \text{ANY}=1$

5. Simplify the following expressions using Boolean algebra

$$Y(A,B,C) = A'B + BC' + BC + AB'C'$$

Sol: 
$$\begin{aligned} Y &= A'B + B[C'+C] + AB'C' \\ &= A'B + B + AB'C' \\ &= B[A'+1] + AB'C' \\ &= B + AB'C' \end{aligned}$$

$$Y = B + AC'$$

$$B + B'X = B + X$$

Where  $X = AC'$

6 Simplify the following expressions using Boolean algebra

$$Y = \overline{\overline{A + B\bar{C}}} + D(\overline{\overline{E + \bar{F}}})$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D(\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D(\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D(\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D(\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D(\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D + (\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D + (\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D + (\overline{\overline{E + \bar{F}}})}}$$

$$Y = \overline{\overline{A + B\bar{C}}} \cdot \overline{\overline{D + E + F}}$$

$$Y = AD' + AE + AF' + BC'D' + BC'E + BC'F'$$

**Simplify the given Boolean expression using Boolean laws and theorems**

SRM-MAY-2019 (3+3)

(1)  $Y = ABC + A\bar{B}C + A\bar{B}\bar{C} + A\bar{B}\bar{C}$ . (2)  $Y = AB + A\bar{B}(\bar{A}\bar{B})$

Sol-1:  $Y = ABC + A\bar{B}C + A\bar{B}\bar{C} + A\bar{B}\bar{C}$

$$Y = ABC + A\bar{B}C + A\bar{B}\bar{C}$$

$$Y = AC(1 + \bar{B}) + A\bar{B}\bar{C}$$

$$Y = AC + A\bar{B}\bar{C} = A(C + \bar{B}\bar{C}) = A(C + B) = AC + AB$$

Sol-1:  $Y = AB + A\bar{B}(\bar{A}\bar{B})$

$$Y = AB + A\bar{B}(\bar{A} + \bar{B})$$

$$Y = AB + A\bar{B}(A + B)$$

$$Y = AB + A\bar{B}A + A\bar{B}B = AB + A\bar{B} = A$$

## **LOGIC GATES**

Name	Graphic symbol	Algebraic function	Truth table															
AND		$F = x \cdot y$	<table border="1"><thead><tr><th>x</th><th>y</th><th>F</th></tr></thead><tbody><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>0</td></tr><tr><td>1</td><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></tbody></table>	x	y	F	0	0	0	0	1	0	1	0	0	1	1	1
x	y	F																
0	0	0																
0	1	0																
1	0	0																
1	1	1																
OR		$F = x + y$	<table border="1"><thead><tr><th>x</th><th>y</th><th>F</th></tr></thead><tbody><tr><td>0</td><td>0</td><td>0</td></tr><tr><td>0</td><td>1</td><td>1</td></tr><tr><td>1</td><td>0</td><td>1</td></tr><tr><td>1</td><td>1</td><td>1</td></tr></tbody></table>	x	y	F	0	0	0	0	1	1	1	0	1	1	1	1
x	y	F																
0	0	0																
0	1	1																
1	0	1																
1	1	1																
Inverter		$F = x'$	<table border="1"><thead><tr><th>x</th><th>F</th></tr></thead><tbody><tr><td>0</td><td>1</td></tr><tr><td>1</td><td>0</td></tr></tbody></table>	x	F	0	1	1	0									
x	F																	
0	1																	
1	0																	
Buffer		$F = x$	<table border="1"><thead><tr><th>x</th><th>F</th></tr></thead><tbody><tr><td>0</td><td>0</td></tr><tr><td>1</td><td>1</td></tr></tbody></table>	x	F	0	0	1	1									
x	F																	
0	0																	
1	1																	

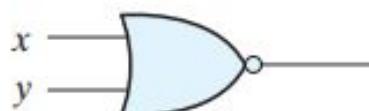
NAND



$$F = (xy)'$$

$x$	$y$	$F$
0	0	1
0	1	1
1	0	1
1	1	0

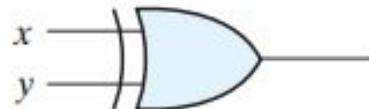
NOR



$$F = (x + y)'$$

$x$	$y$	$F$
0	0	1
0	1	0
1	0	0
1	1	0

Exclusive-OR  
(XOR)



$$\begin{aligned} F &= xy' + x'y \\ &= x \oplus y \end{aligned}$$

$x$	$y$	$F$
0	0	0
0	1	1
1	0	1
1	1	0

Exclusive-NOR  
or  
equivalence



$$\begin{aligned} F &= xy + x'y' \\ &= (x \oplus y)' \end{aligned}$$

$x$	$y$	$F$
0	0	1
0	1	0
1	0	0
1	1	1

## SUM OF PRODUCTS [SOP] AND PRODUCT OF SUMS [POS]

Logical functions (Boolean expression) are generally expressed in terms of logical variables (inputs) in following forms. (Each input variable can have the value, either 0 or 1 only)

- **SUM OF PRODUCTS [SOP]** Ex:  $AB' + BC + C'D$
- **PRODUCT OF SUMS [POS]** Ex:  $(A' + B') (B' + C) (C' + D)$

### MINTERMS

A **product** term containing all the inputs of the functions in either complemented or uncomplemented form is called **MINTERMS**.

Let us consider 3 variable (input) function. It has  $2^3$  all possible combinations. [A 'n' variable (input) function has  $2^n$  all possible combinations]. Let the inputs are A, B, C and output is Y.

## TRUTH TABLE

	Inputs				Output
	A	B	C	MINTERMS	Y
0	0	0	0	$A'B'C'$	0
1	0	0	1	$A'B'C$	0
2	0	1	0	$A'BC'$	1
3	0	1	1	$A'BC$	1
4	1	0	0	$AB'C'$	1
5	1	0	1	$AB'C$	0
6	1	1	0	$ABC'$	1
7	1	1	1	$ABC$	0

- In minterms, 0 are assigned with bar letter and 1 are assigned with unbar letter.
- Within the row, all are multiplied (Product)
- Choose only the output 1.
- Add the minterms which having 1 output.
- In this example, we get  $Y = A'BC' + A'BC + AB'C' + ABC'$ . This expression is called **canonical SOP form**. [Standard SOP form]
- Each input is assigned with it equivalent decimal value. In the truth table, only the output  $Y = 1$  is chosen, its corresponding input's decimal values are stated as below.

$$Y = \sum m (2,3,4,6)$$

## MAXTERMS

A sum term containing all the inputs of the functions in either complemented or uncomplemented form is called **MAXTERMS**. Let us consider the same truth table.

	Inputs			MAXTERMS	Output
	A	B	C		Y
0	0	0	0	(A+B+C)	0
1	0	0	1	(A+B+C')	0
2	0	1	0	(A+B'+C)	1
3	0	1	1	(A+B'+C')	1
4	1	0	0	(A'+B+C)	1
5	1	0	1	(A'+B+C')	0
6	1	1	0	(A'+B'+C)	1
7	1	1	1	(A'+B'+C')	0

- In maxterms, 1 are assigned with bar letter and 0 are assigned with unbar letter.
- Within the row, all are summed (Added)
- Choose only the output 0.
- Product the maxterms which having 0 output.
- In this example, we get  $Y = (A+B+C) (A+B+C') (A'+B+C') (A'+B'+C')$ . This expression is called **canonical POS form**. [Standard POS form]
- Each input is assigned with it equivalent decimal value. In the truth table, only the output  $Y=0$  is chosen, its corresponding input's decimal values are stated as below.

$$Y = \prod M(0,1,5,7)$$

1. For the Boolean function given below, obtain the (i) canonical SOP form (ii) canonical POS form.

$$Y(A,B,C) = A + B'C$$

$$= AXX + XB'C$$

$$= AB'C' + AB'C + ABC' + ABC + A'B'C + AB'C$$

[Remove the common term; Since  $A+A=A$  ]

$$Y = AB'C' + AB'C + ABC' + ABC + A'B'C \text{ [Canonical SOP form]}$$

$$100 \quad 101 \quad 110 \quad 111 \quad 001$$

$$(m_4 \ m_5 \ m_6 \ m_7 \ m_1)$$

$$Y = \sum m (1,4,5,6,7)$$

$Y = \prod M (0,2,3)$  [ Minterms and Maxterms are complement with each other]

$$\begin{array}{ccc} M_0 & M_2 & M_3 \\ 000 & 010 & 011 \end{array}$$

$$Y = (A+B+C) (A+B'+C) (A+B'+C') \text{ [Canonical POS form]}$$

# Karnaugh maps/ K-map

If the number of input variables is more than 2, its very difficult to minimize the Boolean function by Boolean algebra. **Karnaugh maps/ K map** overcomes this difficulty.

## Karnaugh maps/ K map

- A visual way to simplify logic expressions
- It gives the most simplified form of the expression
- K-Maps are a graphical technique used to simplify a logic equation.
- K-Maps can be used for any number of input variables, BUT are only practical for **two, three, and four variables**

## General Structure of K-Map

Two variable (Inputs- A,B)

<b>A</b>	<b>B</b>
0	0
1	1
0	1

Three variable (Inputs- A,B,C)

<b>A</b>	<b>BC</b>
0	00 01 11 10
1	0 1 3 2
0	4 5 7 6

Four variable (Inputs- A,B,C,D)

<b>AB</b>	<b>CD</b>
00	00 1 11 10
01	0 1 3 2
11	4 5 7 6
10	12 13 15 14
00	8 9 11 10

## Procedure to minimize Boolean expression by K-map:

1. We have to check, number of variables (Inputs).

(i) If the maximum number in the Boolean expression is  $\leq 3$ , it is 2 variable function.

(ii) If the maximum number in the Boolean expression is  $\leq 7$ , it is 3 variable function.

(iii) If the maximum number in the Boolean expression is  $\leq 15$ , it is 4 variable function.

Note: Some times, in the question itself, inputs will be given. Ex:

$$Y(A,B,C) = \sum(0,4,5,7)$$

2. Check the given question is Minterms or Maxterms. If  $\Sigma$  is given, it is Minterms. In K-map, for the given decimal location, we have to enter 1. In remaining location, we have to enter 0.

If  $\Pi$  is given, it is Maxterms. In K-map, for the given decimal location, we have to enter 0. In remaining location, we have to enter 0.

3. Draw the K-map and fill it. (use step 1 & 2)

#### 4 (a) Solution Procedure for SOP method

- (i) We have box **ALL** the 1.
- (ii) Larger the box, smaller the equation. Since all are minimization problem, we have chose larger box.
- (iii) The number of 1's inside the box must be  $2^n$ . [ie we have to try boxing **16**, if not possible we have to try boxing **8**, if not possible we have to try boxing **4**, if not possible we have to try boxing **2**, if not possible we have to box **1**]

- (iv) The shape of the box must be square or rectangular. ie



- (v) For each box, we have to find **unchanged** input.

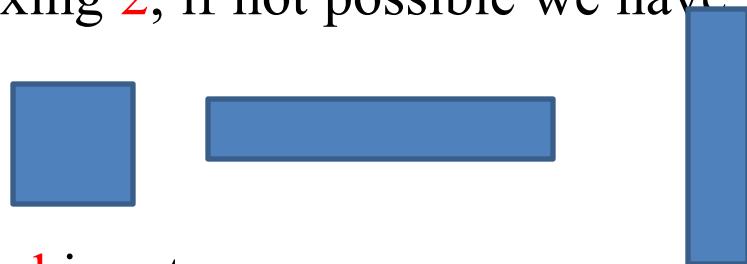
For that, we have see K-map from **right to left**, then **bottom to top**. The unchanged input within the box should be **product**. The product of one box should be sum with next box.[In input, 0 are assigned with bar letter and 1 are assigned with unbar letter]

- (vi) Overlapping is allowed to make larger box.

#### 4 (b) Solution Procedure for POS method

- (i) We have box **ALL** the 0.
- (ii) Larger the box, smaller the equation. Since all are minimization problem, we have chose larger box.
- (iii) The number of 0's inside the box must be  $2^n$ . [ie we have to try boxing **16**, if not possible we have to try boxing **8**, if not possible we have to try boxing **4**, if not possible we have to try boxing **2**, if not possible we have to box **1**]

- (iv) The shape of the box must be square or rectangular. ie



- (v) For each box, we have to find **unchanged** inputs.

For that, we have see K-map from **right to left**, then **bottom to top**. The unchanged input within the box should be **summed**. The sum of one box should be product with next box.[In input, 1 are assigned with bar letter and 0 are assigned with unbar letter]

- (vi) Overlapping is allowed to make larger box.

# K-MAP-SOP METHOD

- 1 Simply the following Boolean expression

$$Y(A,B,C) = \sum m(1,2,3,6,7)$$

## Method 1: Boolean Algebra

Binary of minterms: 001, 010, 011, 110, 111

$$Y = A'B'C + A'BC' + A'BC + ABC' + ABC$$

$$Y = A'B'C + A'B[C' + C] + AB[C' + C]$$

$$Y = A'B'C + A'B + AB$$

$$Y = A'B'C + B[A + A']$$

$$Y = A'B'C + B$$

$$\boxed{Y = A'C + B}$$

$$B + B'X = B + X$$

- 1 Simply the following Boolean expression

$$Y(A,B,C) = \sum m(1,2,3,6,7)$$

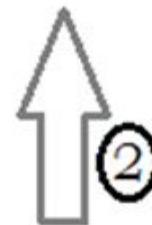
### Method 2: K-MAP

Three variable (Inputs- A,B,C)

		BC		B'C'	B'C	BC	BC'
		A	00	01	11	10	
A'	0	0	1	1	1	1	2
	1	0	0	5	1	7	6



$$Y = B + A'C$$



- 2 Simplify the following Boolean expression

$$Y(A,B,C) = \sum m(0,1,2,3,6)$$

		<b>BC</b>	B'C'	B'C	BC	BC'
		00	01	11	10	
<b>A</b>	0	1 0	1 1	1 3	1 2	
	1				1 6	

$$Y = A' + BC'$$

# Three-Variable K-Map : Examples

$$f = \sum(0,4) = \bar{B} \bar{C}$$

		BC				
		00	01	11	10	
A		0	1	0	0	0
1	0	1	0	0	0	0

$$f = \sum(4,5) = A \bar{B}$$

		BC				
		00	01	11	10	
A		0	0	0	0	0
1	0	1	1	0	0	0

$$f = \sum(0,1,4,5) = \bar{B}$$

		BC				
		00	01	11	10	
A		0	1	1	0	0
1	0	1	1	0	0	0

$$f = \sum(0,1,2,3) = \bar{A}$$

		BC				
		00	01	11	10	
A		0	1	1	1	1
1	0	0	0	0	0	0

$$f = \sum(0,4) = \bar{A} C$$

		BC				
		00	01	11	10	
A		0	0	1	1	0
1	0	0	0	0	0	0

$$f = \sum(4,6) = A \bar{C}$$

		BC				
		00	01	11	10	
A		0	0	0	0	0
1	0	1	0	0	1	0

$$f = \sum(0,2) = \bar{A} \bar{C}$$

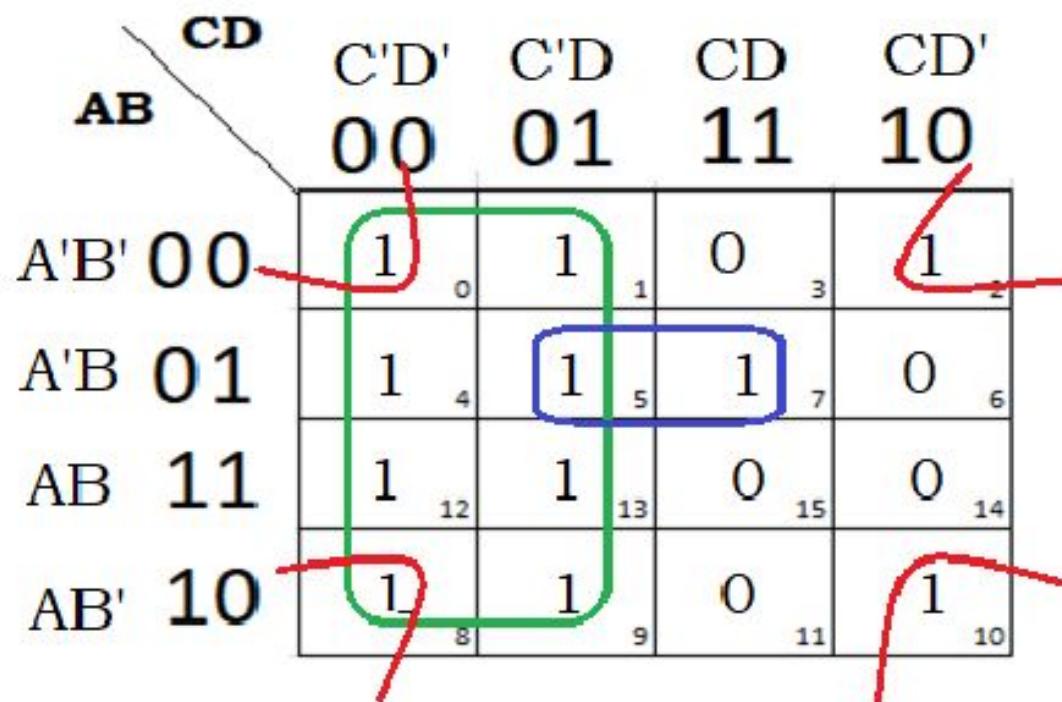
		BC				
		00	01	11	10	
A		0	1	0	0	1
1	0	0	0	0	0	0

$$f = \sum(0,2,4,6) = \bar{C}$$

		BC				
		00	01	11	10	
A		0	1	0	0	1
1	0	1	0	0	1	1

**3.** Simply the following Boolean expression  
and implement it using logic gates

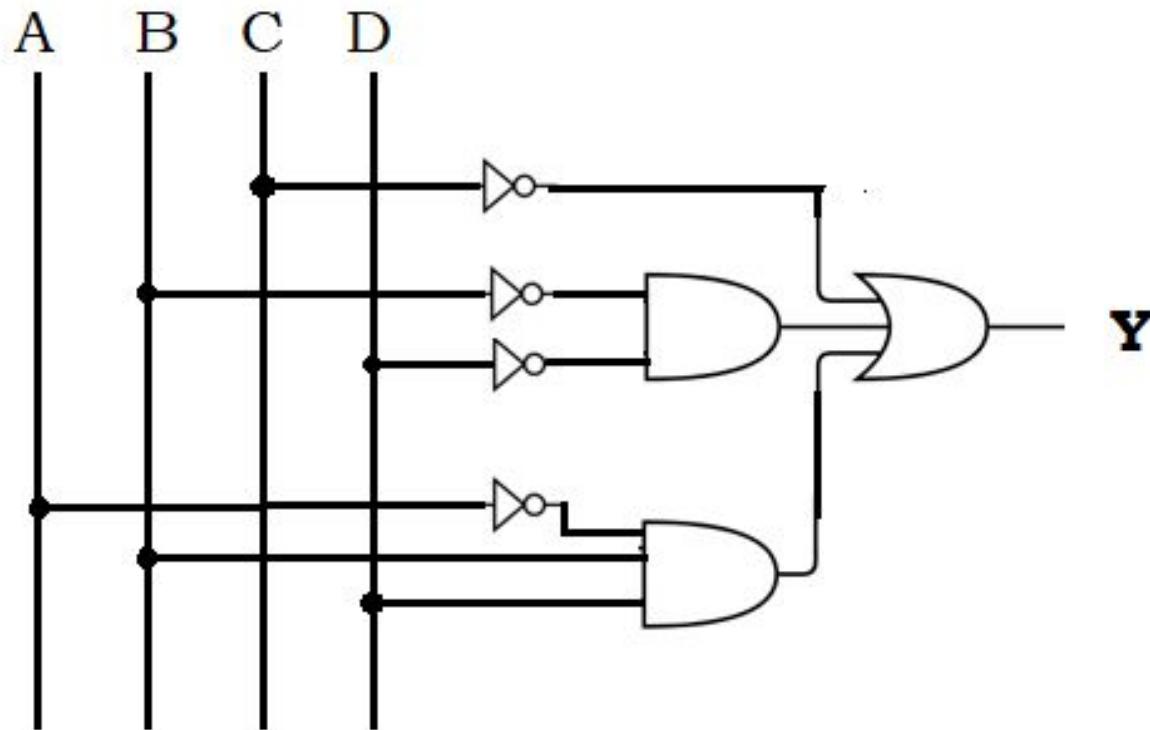
$$Y(A,B,C,D) = \sum m(0,1,2,4,5,7,8,9,10,12,13)$$



$$Y = C' + B'D' + A'BD$$

## Implementation

$$Y = C' + B'D' + A'BD$$



# Four-Variable K-Maps Examples

	CD	00	01	11	10
AB	00	1	0	0	0
00	01	0	0	0	0
11	0	0	0	0	0
10	1	0	0	0	0

$$f = \sum(0,8) = \bar{B} \cdot \bar{C} \cdot \bar{D}$$

	CD	00	01	11	10
AB	00	0	0	0	0
01	0	1	0	0	0
11	0	1	0	0	0
10	0	0	0	0	0

$$f = \sum(5,13) = B \cdot \bar{C} \cdot D$$

	CD	00	01	11	10
AB	00	0	0	0	0
01	0	0	0	0	0
11	0	1	1	0	0
10	0	0	0	0	0

$$f = \sum(13,15) = A \cdot B \cdot D$$

	CD	00	01	11	10
AB	00	0	0	0	0
01	1	0	0	1	0
11	0	0	0	0	0
10	0	0	0	0	0

$$f = \sum(4,6) = \bar{A} \cdot B \cdot \bar{D}$$

	CD	00	01	11	10
AB	00	0	0	1	1
01	0	0	1	1	0
11	0	0	0	0	0
10	0	0	0	0	0

$$f = \sum(2,3,6,7) = \bar{A} \cdot C$$

	CD	00	01	11	10
AB	00	0	0	0	0
01	1	0	0	1	0
11	1	0	0	0	1
10	0	0	0	0	0

$$f = \sum(4,6,12,14) = B \cdot \bar{D}$$

	CD	00	01	11	10
AB	00	0	0	1	1
01	0	0	0	0	0
11	0	0	0	0	0
10	0	0	1	1	0

$$f = \sum(2,3,10,11) = \bar{B} \cdot C$$

	CD	00	01	11	10
AB	00	1	0	0	1
01	0	0	0	0	0
11	0	0	0	0	0
10	1	0	0	0	1

$$f = \sum(0,2,8,10) = \bar{B} \cdot \bar{D}$$

# Four-Variable K-Maps Examples

	CD	00	01	11	10
AB	00	0	0	0	0
00	1	1	1	1	
01	0	0	1	0	
11	0	0	1	0	
10	0	0	1	0	

$$f = \sum(4, 5, 6, 7) = \overline{A} \bullet B$$

	CD	00	01	11	10
AB	00	0	0	1	0
01	0	0	1	0	
11	0	0	1	0	
10	0	0	1	0	

$$f = \sum(3, 7, 11, 15) = C \bullet D$$

	CD	00	01	11	10
AB	00	0	0	0	1
01	0	0	0	1	
11	0	0	0	1	
10	0	0	0	1	

$$f = \sum(2, 6, 10, 14)$$

$$f = C \overline{D}$$

	CD	00	01	11	10
AB	00	0	0	0	0
01	0	0	0	0	
11	1	1	1	1	
10	0	0	0	0	

$$f = \sum(12, 13, 14, 15) = AB$$

	CD	00	01	11	10
AB	00	0	1	1	0
01	0	1	1	0	
11	0	1	1	0	
10	0	1	1	0	

$$f = \sum(1, 3, 5, 7, 9, 11, 13, 15)$$

$$f = D$$

	CD	00	01	11	10
AB	00	1	0	0	1
01	1	0	0	1	
11	1	0	0	1	
10	1	0	0	1	

$$f = \sum(0, 2, 4, 6, 8, 10, 12, 14)$$

$$f = \overline{D}$$

	CD	00	01	11	10
AB	00	0	0	0	0
01	1	1	1	1	
11	1	1	1	1	
10	0	0	0	0	

$$f = \sum(4, 5, 6, 7, 12, 13, 14, 15)$$

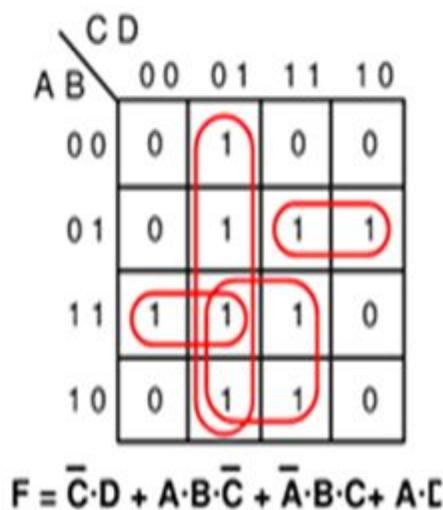
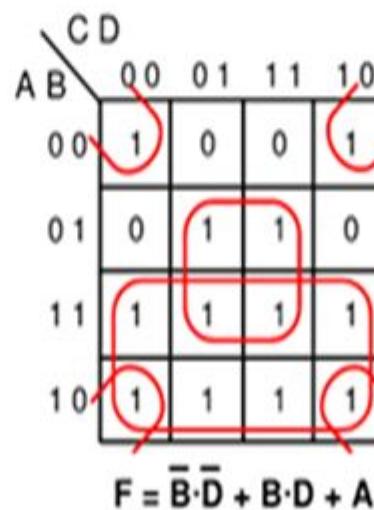
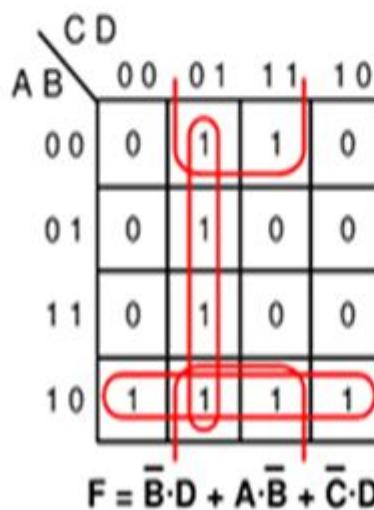
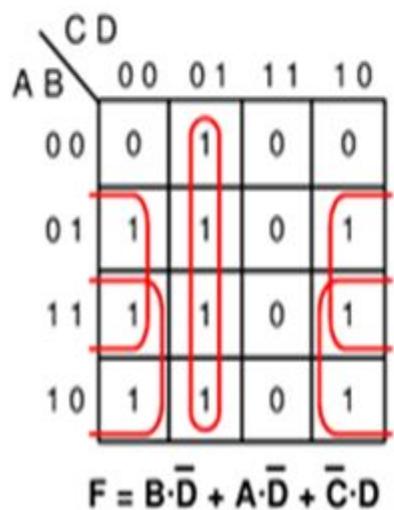
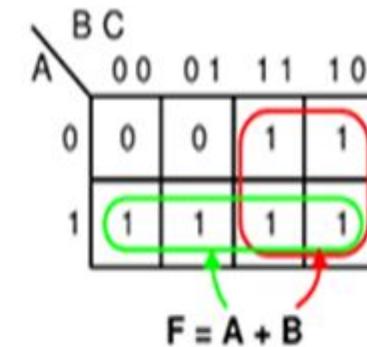
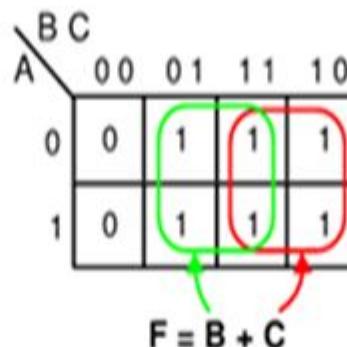
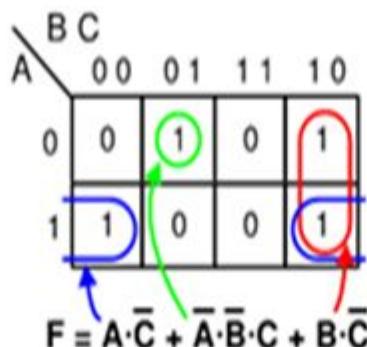
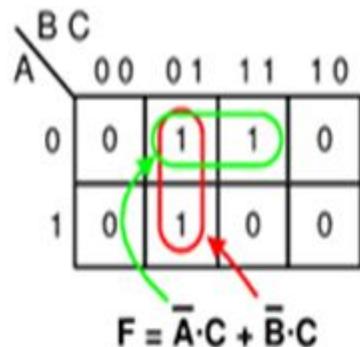
$$f = B$$

	CD	00	01	11	10
AB	00	1	1	1	1
01	0	0	0	0	
11	0	0	0	0	
10	1	1	1	1	

$$f = \sum(0, 1, 2, 3, 8, 9, 10, 11)$$

$$f = \overline{B}$$

# 3,4-Variable K-Maps Examples



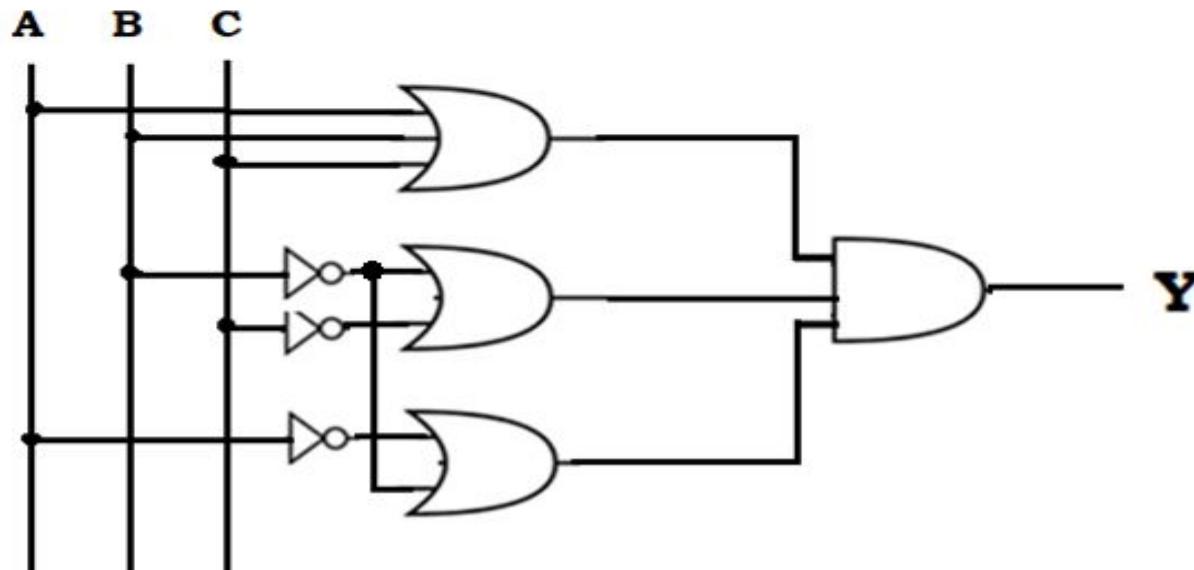
# K-MAP-POS METHOD

- Simply the following Boolean expression by POS method and implement it using logic gates

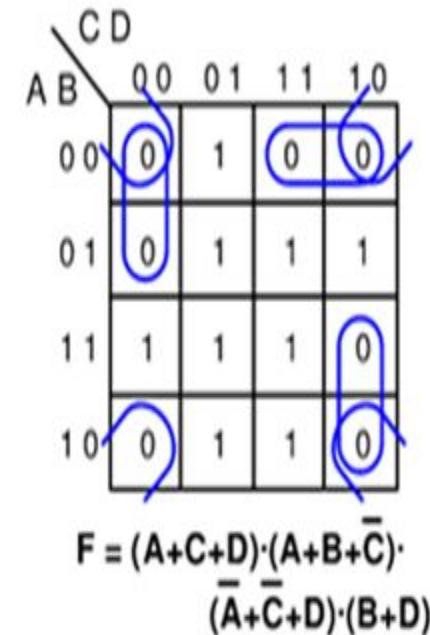
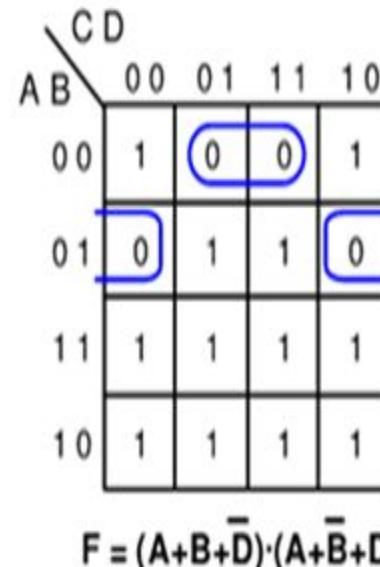
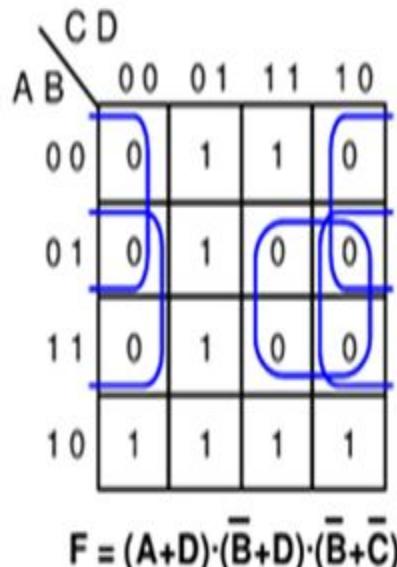
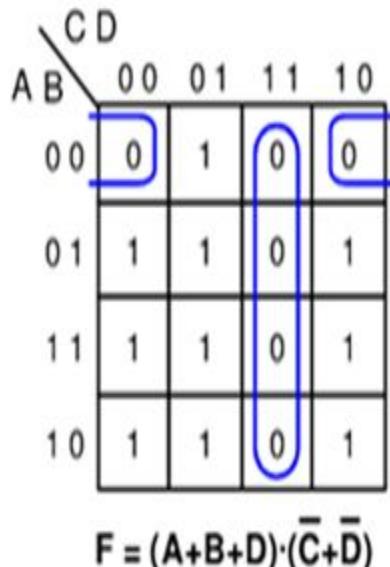
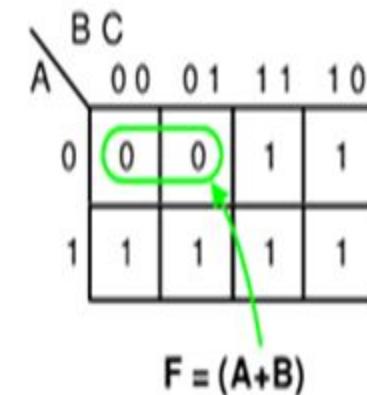
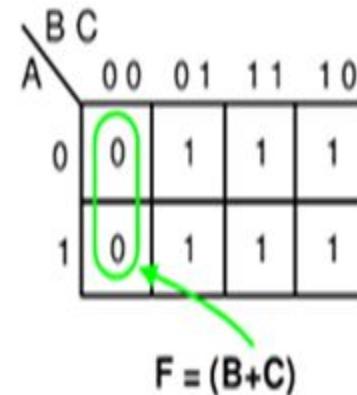
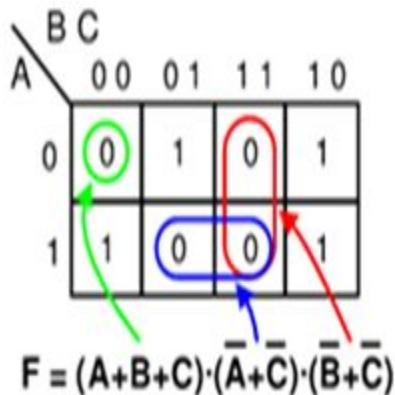
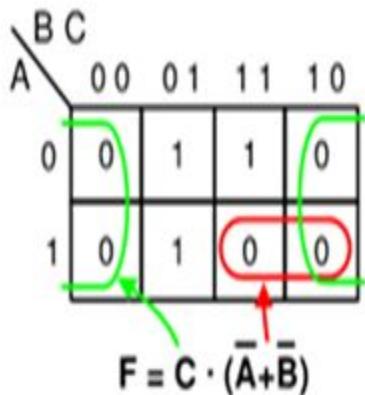
$$Y(A,B,C) = \prod m(0,3,6,7)$$

		BC	BC'	B'C'	B'C
		00	01	11	10
A		0	1	0	1
A'	0	0	1	0	1
	1	1	1	0	0

$$Y = (A+B+C) \cdot (B'+C') \cdot (A'+B')$$



# 3,4-Variable K-Maps Examples [POS]

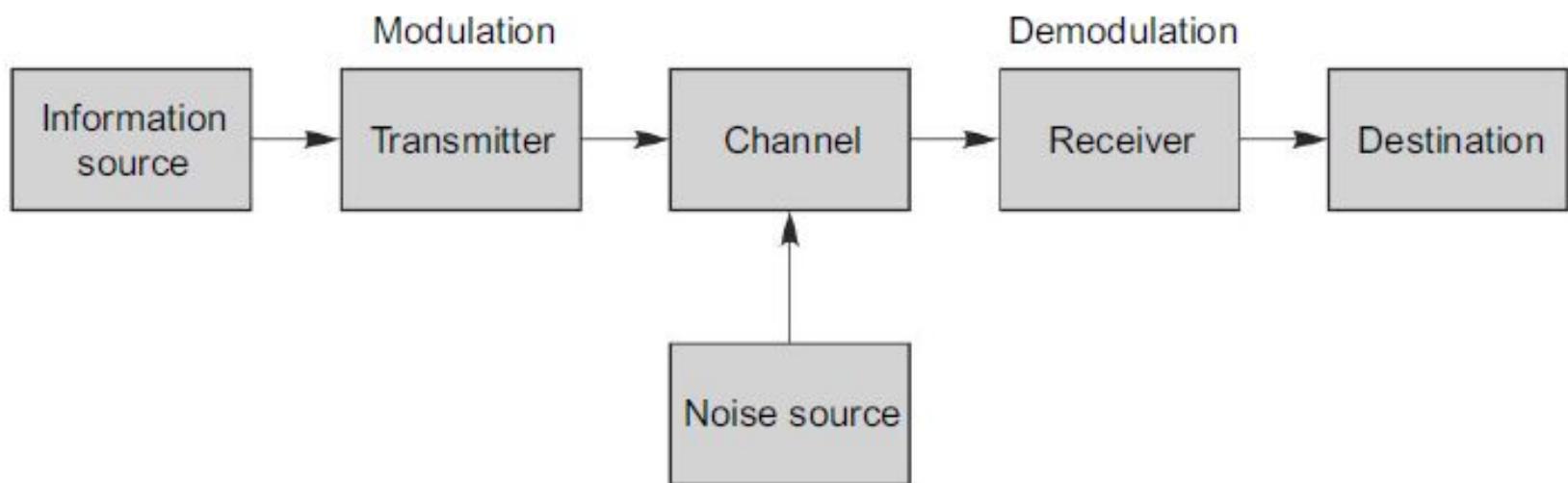


# COMMUNICATION SYSTEMS

Communication is a process of transfer of information bearing signals from one place to another. The equipment that transmits the information is the transmitter and the equipment that receives the information is the receiver. Channel is the medium through which the signal travels from the transmitter to the receiver. Telegraphy, telephony, facsimile, radio broadcast, TV transmission and computer communication are a few examples of communication services.

## **Block Diagram of Communication System**

The basic function of a communication system is to communicate a message. The block diagram of a communication system is shown



The information to be transmitted is given by the information source. In most of the cases, the information will be non-electrical in nature. For example, audio signals in speech transmission and picture signals in television transmission. This information in the original form is converted into a corresponding electrical variation known as the message signal by using a transmitter. This message signal cannot be directly transmitted due to various reasons. Hence this message signal is superimposed on a high frequency carrier signal before transmission. This process is referred to as **modulation**.

After modulation, the modulated carrier is amplified by using power amplifiers in the transmitter and fed to the transmitting antenna. Channel is a medium through which the signal travels from the transmitter to the receiver. There are various types of channels, such as the atmosphere for radio broadcasting, wires for line telegraphy and telephony and optical fibers for optical communication.

As the signal gets propagated through the channel, it is attenuated by various mechanisms and affected by noise from the external source. Noise is an unwanted signal that interferes with the reception, of wanted signal. Noise is usually of random nature and in the design of communication system, careful attention should be paid to minimize the effect of noise on the reception of wanted signals.

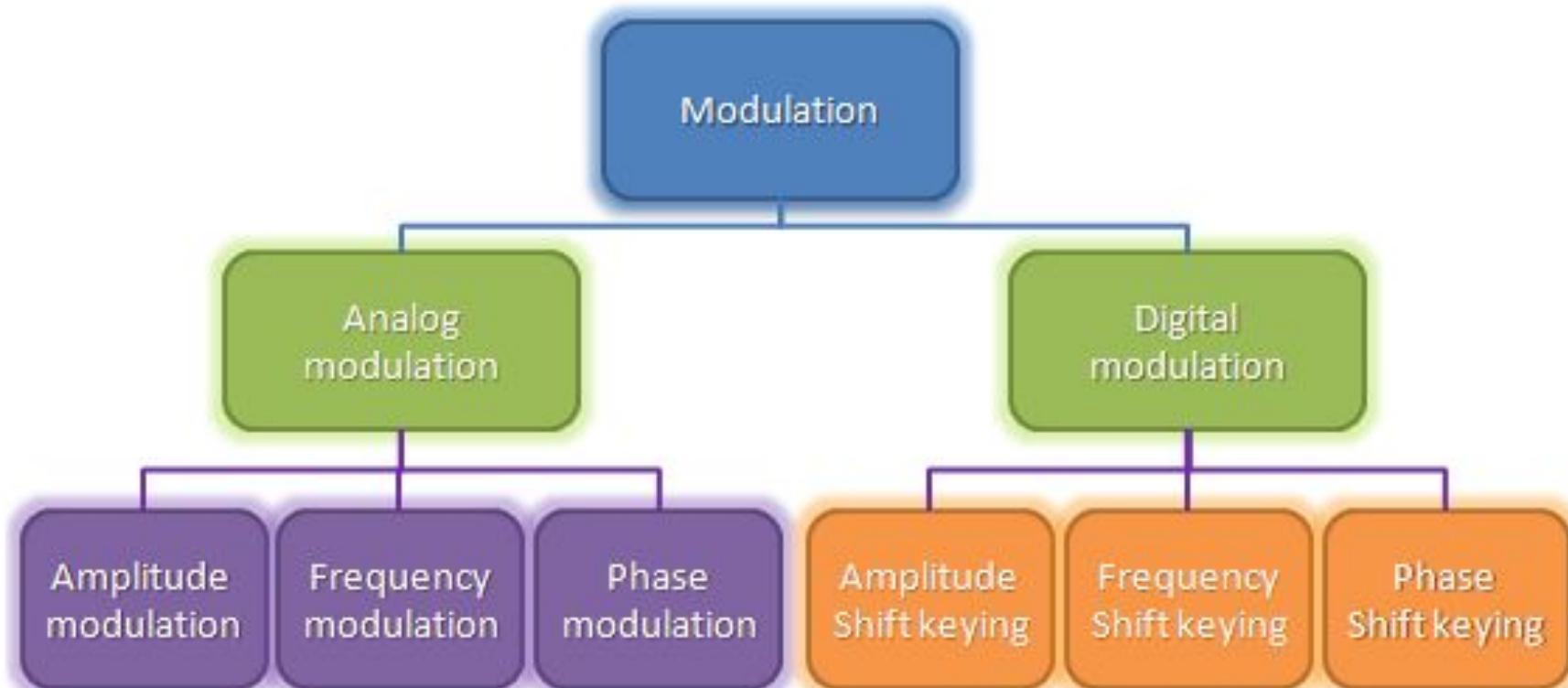
At the receiving end, a weak modulated carrier that is transmitted from the transmitter is received. As the received signal power will be very small, it is first of all amplified to increase the power level and the process of **demodulation** is done to recover the original message signal from the modulated carrier. The recovered message signal is further amplified to drive the output transducer such as a loud speaker or a TV receiver.

## Electromagnetic Spectrum for Various Communication Services

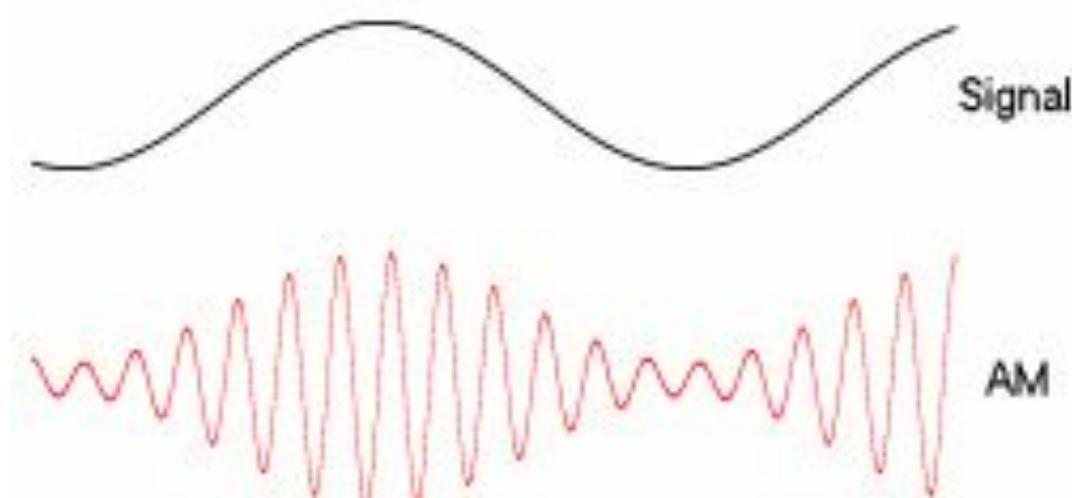
<i>Classification</i>	<i>Frequency Range</i>	<i>Wavelength</i>	<i>Uses</i>
Very Low Frequencies (V.L.F.)	10–30 kHz	30–10 km	Long distance point to point communications
Low Frequencies (L.F.)	30–300 kHz	10–1 km	Long distance point to point communication, Marine, Navigation, Power Line Carrier communication and Broadcast
Medium Frequencies (M.F.)	300–3000 kHz	1000–100 metres	Power Line Carrier communication, Broadcast, Marine communications, Navigation and harbour telephone
High Frequencies (H.F.)	3–30 MHz	100–10 metres	Moderate and long range communication of all types, Broadcast
Very High Frequencies (V.H.F.)	30–300 MHz	10–1 metres	Short distance communications, TV and FM broadcast, Data communication, Mobile and Navigation systems
Ultra High Frequencies (U.H.F.)	300–3000 MHz	1–0.1 metres	Short distance communications, TV broadcast, Radar, Mobile, Navigation and Microwave relay systems
Super High Frequencies (S.H.F.)	3–30 GHz	10–1 cms	Radar, Microwave relay and navigation systems
Extremely High Frequencies (E.H.F.)	30–300 GHz	1–0.1 cm	Radar, Satellite, Mobile, Microwave relay and navigations

## BASIC PRINCIPLES OF MODULATION

Modulation is the process of changing some parameter of a high frequency carrier signal in accordance with the instantaneous variations of the message signal. The carrier signal has a constant amplitude and frequency. The function of a carrier signal is to carry the message signal and hence the name. The message or modulating signals are low frequency audio signals which contain the information to be transmitted. Generally message signal ranges from 20 Hz to 20 kHz.



**Amplitude modulation (AM)** is a modulation technique used in electronic communication, most commonly for transmitting messages with a radio carrier wave. In amplitude modulation, the amplitude (signal strength) of the carrier wave is varied in proportion to that of the message signal, such as an audio signal.



In amplitude modulation, the amplitude or *strength* of the carrier oscillations is varied. For example, in AM radio communication, a continuous wave radio-frequency signal (a sinusoidal carrier wave) has its amplitude modulated by an audio waveform before transmission. The audio waveform modifies the amplitude of the carrier wave and determines the envelope of the waveform. In the frequency domain, amplitude modulation produces a signal with power concentrated at the carrier frequency and two adjacent sidebands. Each sideband is equal in bandwidth to that of the modulating signal, and is a mirror image of the other. Standard AM is thus sometimes called "double-sideband amplitude modulation" (DSBAM). Single-sideband amplitude modulation.

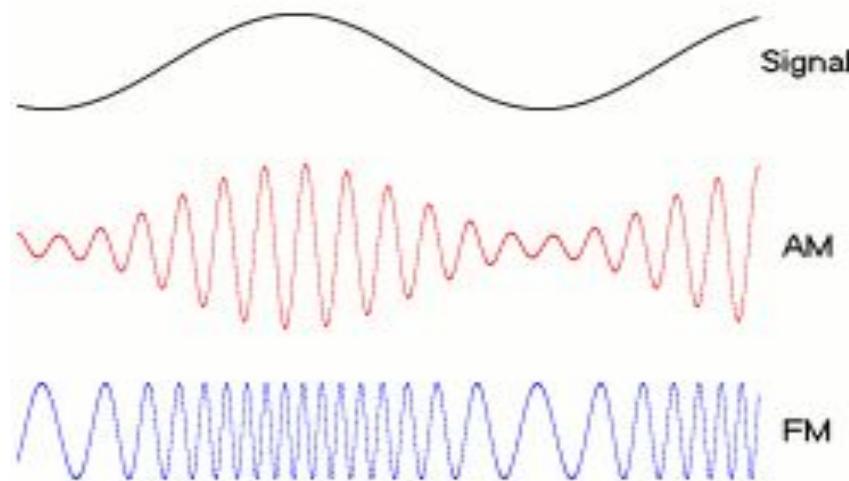
A disadvantage of all amplitude modulation techniques, not only standard AM, is that the receiver amplifies and detects noise and electromagnetic interference in equal proportion to the signal. AM broadcast is not favored for music and high fidelity broadcasting, but rather for voice communications and broadcasts (sports, news, talk radio etc.).

AM is also inefficient in power usage; at least two-thirds of the power is concentrated in the carrier signal.

**Frequency modulation (FM)** is the encoding of information in a carrier wave by varying the instantaneous frequency of the wave. The technology is used in telecommunications, radio broadcasting, signal processing, and computing.

In frequency modulation, such as radio broadcasting, of an audio signal representing voice or music, the instantaneous frequency deviation, i.e. the difference between the frequency of the carrier and its center frequency, has a functional relation to the modulating signal amplitude.

Frequency modulation is widely used for FM radio broadcasting.



It is also used in telemetry, radar, seismic prospecting, and monitoring newborns for seizures via EEG, two-way radio systems, sound synthesis, magnetic tape-recording systems and some video-transmission systems. In radio transmission, an advantage of frequency modulation is that it has a larger signal-to-noise ratio and therefore rejects radio frequency interference better than an equal power amplitude modulation (AM) signal. For this reason, most music is broadcast over FM radio.

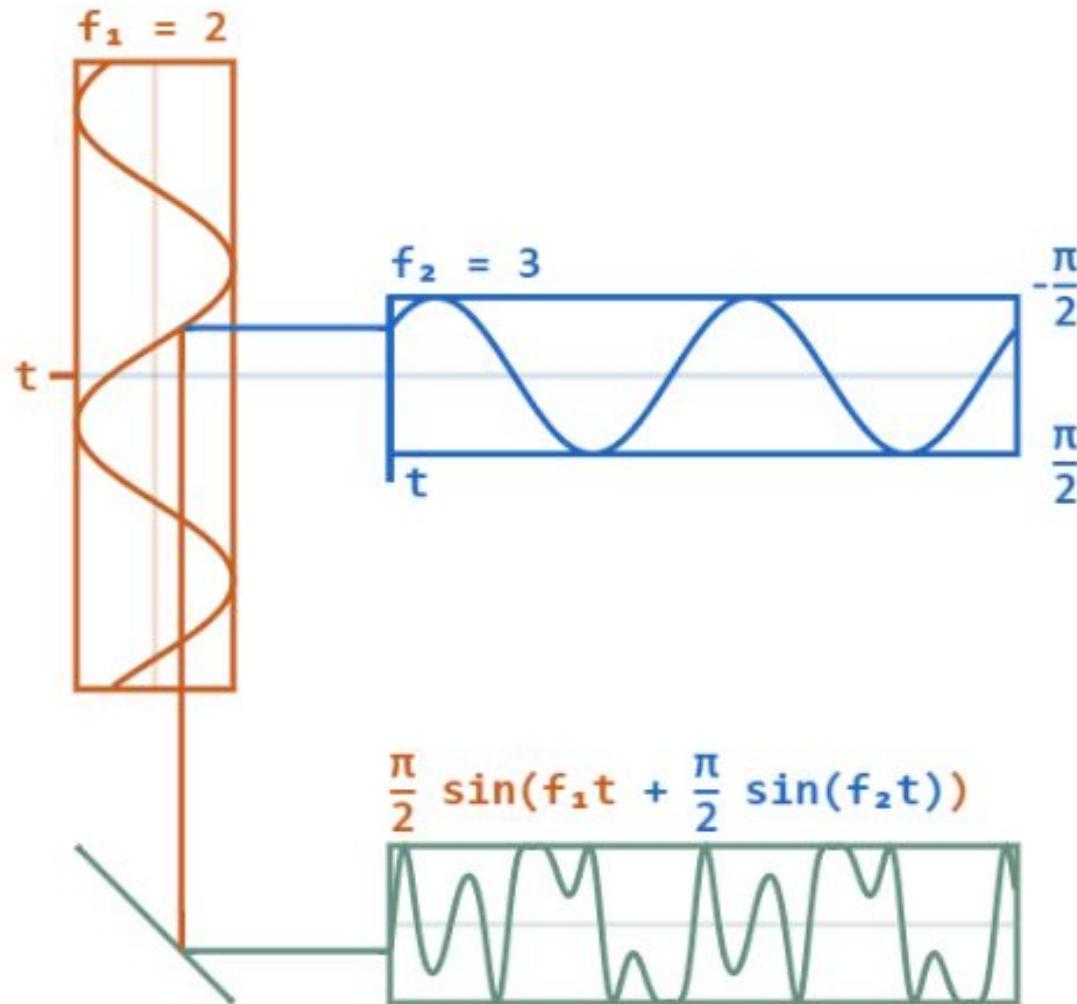
Frequency modulation and phase modulation are the two complementary principal methods of angle modulation; phase modulation is often used as an intermediate step to achieve frequency modulation. These methods contrast with amplitude modulation, in which the amplitude of the carrier wave varies, while the frequency and phase remain constant.

**Phase modulation (PM)** is a modulation pattern for conditioning communication signals for transmission. It encodes a message signal as variations in the instantaneous phase of a carrier wave. Phase modulation is one of the two principal forms of angle modulation, together with frequency modulation.

The phase of a carrier signal is modulated to follow the changing signal level (amplitude) of the message signal. The peak amplitude and the frequency of the carrier signal are maintained constant, but as the amplitude of the message signal changes, the phase of the carrier changes correspondingly.

Phase modulation is widely used for transmitting radio waves and is an integral part of many digital transmission coding schemes that underlie a wide range of technologies like Wi-Fi, GSM and satellite television.

PM is used for signal and waveform generation in digital synthesizers, such as the Yamaha DX7, to implement FM synthesis. A related type of sound synthesis called phase distortion is used in the Casio CZ synthesizers.



The modulating wave (blue) is modulating the carrier wave (red), resulting the PM signal (green).  $g(t) = \frac{\pi}{2} \sin(2 \cdot 2\pi t) + \frac{\pi}{2} \sin(3 \cdot 2\pi t)$

**Demodulation** is extracting the original information-bearing signal from a carrier wave. A **demodulator** is an electronic circuit that is used to recover the information content from the modulated carrier wave. There are many types of modulation so there are many types of demodulators. The signal output from a demodulator may represent, images or binary data.

There are several ways of demodulation depending on how parameters of the base-band signal such as amplitude, frequency or phase are transmitted in the carrier signal. For example, for a signal modulated with a linear modulation like AM , we can use a synchronous detector. On the other hand, for a signal modulated with an angular modulation, we must use an FM demodulator or a PM demodulator. Different kinds of circuits perform these functions.

Many techniques such as carrier recovery, clock recovery, bit slip, frame synchronization, rake receiver, pulse compression, Received Signal Strength Indication, error detection and correction, etc., are only performed by demodulators, although any specific demodulator may perform only some or none of these techniques.

## AM demodulators:

An AM signal encodes the information into the carrier wave by varying its amplitude in direct sympathy with the analogue signal to be sent. There are two methods used to demodulate AM signals:

1. The envelope detector is a very simple method of demodulation that does not require a coherent demodulator. It consists of an envelope detector that can be a rectifier (anything that will pass current in one direction only) or other non-linear component that enhances one half of the received signal over the other and a low-pass filter. The rectifier may be in the form of a single diode or may be more complex. Many natural substances exhibit this rectification behavior, which is why it was the earliest modulation and demodulation technique used in radio. The filter is usually an RC low-pass type but the filter function can sometimes be achieved by relying on the limited frequency response of the circuitry following the rectifier. The crystal set exploits the simplicity of AM modulation to produce a receiver with very few parts, using the crystal as the rectifier and the limited frequency response of the headphones as the filter.

2. The product detector multiplies the incoming signal by the signal of a local oscillator with the same frequency and phase as the carrier of the incoming signal. After filtering, the original audio signal will result.

## **FM demodulators:**

- The quadrature detector, which phase shifts the signal by 90 degrees and multiplies it with the unshifted version. One of the terms that drops out from this operation is the original information signal, which is selected and amplified.
- The signal is fed into a PLL and the error signal is used as the demodulated signal.
- The most common is a Foster-Seeley discriminator. This is composed of an electronic filter which decreases the amplitude of some frequencies relative to others, followed by an AM demodulator. If the filter response changes linearly with frequency, the final analog output will be proportional to the input frequency, as desired.
- A variant of the Foster-Seeley discriminator called the ratio detector
- Another method uses two AM demodulators, one tuned to the high end of the band and the other to the low end, and feed the outputs into a difference amplifier.  
Using a digital signal processor, as used in software-defined radio.