CBCS SCHEME

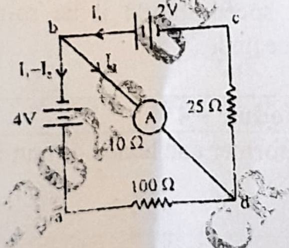
USN

1BESC104B

First Semester B.E./B.Tech. Degree Examination, Dec.2025/Jan.2026
Introduction to Electrical Engineering

Time: 3 hrs. Max. Marks: 100

Note: 1. Answer any FIVE full questions, choosing ONE full question from each module.
2. M : Marks , L: Bloom's level , C: Course outcomes.
3. VTU Formula Hand Book is permitted.

			M	L	C
		Module – 1			
Q.1	a.	List differences between conventional and non-conventional energy sources.	7	L1	CO1
	b.	State Ohm's law and mention its limitations.	6	L2	CO1
	c.	A resistance R is connected in series with a parallel circuit comprising of 20Ω and 48Ω. The total power dissipated in the circuit is 1000W and applied voltage is 250V. Calculate R.	7	L3	CO1
		OR			
Q.2	a.	Draw and explain simple single-line diagram of a power supply system including generation → transmission → distribution.	7	L1	CO1
	b.	State and Explain Kirchhoff's Laws.	6	L2	CO1
	c.	In the network shown in Fig. 2(c) determine the direction and magnitude of current flow in the milli-ammeter A, having internal resistance of 10 Ω.  Fig. 2(c)	7	L3	CO1
		Module – 2			
Q.3	a.	Define: i) Amplitude ii) RMS Value iii) Average Value iv) Form Factor v) Peak Factor with respect to sinusoidally varying quantity.	5	L1	CO2
	b.	Distinguish clearly between ; i) balanced and unbalanced supply ii) balanced and unbalanced load.	8	L2	CO2
	c.	A circuit consisting of a resistance of 25 Ω and a capacitance of 100μF connected in series. A supply of 200V at 50Hz is applied across the circuit. Find Current, power factor and power consumed by the circuit.	7	L3	CO2
		OR			

Q.4	a.	In a three-phase star connection, find the relation between line and phase values of current and voltages.	7	L2	CO2
	b.	Derive an equation for power consumed in R-L-C series circuit.	7	L2	CO2
	c.	A delta connected load consists of a resistance of 10Ω and a capacitance of 100μF in each phase. A supply of 410V at 50Hz is applied to the load. Find the line current, power factor and power consumed by the load.	6	L3	CO2
		Module – 3			
Q.5	a.	Derive the torque equation of a D.C. motor.	7	L3	CO3
	b.	With a neat sketch explain the construction of the various parts of a DC Machine.	8	L2	CO3
	c.	Determine the total torque developed in a 250V, 4 pole DC shunt motor with lap winding accommodated in60 slots, each containing 20 conductors. The armature current is 50A and the flux per pole is 23mWb.	5	L3	CO3
		OR			
Q.6	a.	Derive an EMF equation for DC generator with usual notations.	6	L3	CO3
	b.	Explain the following characteristics of a D.C. Series motor: (i) Torque vs armature current (ii) Speed vs armature current	8	L2	CO3
	c.	The armature of an 8 pole DC generator has 960 conductors and runs at 400rpm. The flux per pole is 40mWb. Calculate the induced emf when the armature is lap wound. At what speed should it be rotated to generate 400V, if the armature is wave connected.	6	L3	CO3
		Module – 4			
Q.7	a.	Derive the emf equation of a transformer and hence obtain the voltage and current transformation ratios.	7	L3	CO4
	b.	Explain the construction and working of 3-phase induction motor.	6	L2	CO4
	c.	A 50kVA, 3300/330 V, single phase transformer has iron loss and full load copper loss of 400W and 600W respectively. Calculate the efficiency at half full load and 0.9 pf.	7	L3	CO4
		OR			
Q.8	a.	Define slip of an induction motor. Derive an expression for effect of slip on the rotor frequency.	7	L3	CO4
	b.	Explain the working principle of single – phase transformer and its necessity in power system.	7	L2	CO4
	c.	A 3 phase, 4pole, 440V, 50Hz induction motor runs with a slip of 4%. Find the rotor speed and frequency of the rotor current.	6	L3	CO4

		Module – 5			
Q.9	a.	What is Earthing? With a neat diagram, explain pipe earthing.	7	L2	CO5
	b.	Define Electric shock. What are the safety precaution to be taken against to avoid electric shock?	7	L2	CO5
	c.	Explain what a "unit" (kWh) means in an electricity bill. Give an example of how it's calculated for a 60W bulb used for 5 hours.	6	L3	CO5
		OR			
Q.10	a.	With neat wiring diagram and truth table explain two way and three way control of lamp.	6	L2	CO5
	b.	What is Fuse? With neat diagram, explain the working principle of fuse.	7	L2	CO5
	c.	Mention the power rating of the following electrical appliances. i) TV ii) Laptops iii) LED Lights iv) Refrigerator Calculate the total power consumed by these four appliances.	7	L3	CO5

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Module – 1

Q1 a) List the differences between conventional and non-conventional energy sources.

Conventional Energy Sources	Non-Conventional Energy Sources
1. Derived from fossil fuels (coal, petroleum, natural gas) and nuclear fuels.	1. Derived from renewable sources like solar, wind, biomass, tidal, geothermal, etc.
2. Exhaustible (limited reserves).	2. Renewable and inexhaustible.
3. Cause high environmental pollution (CO_2, SO_2, global warming).	3. Environment-friendly with minimal pollution.
4. High running cost due to fuel requirement.	4. Low running cost (no fuel cost).
5. Mature and well-established technology.	5. Developing and improving technologies.
6. Large centralized power plants.	6. Can be decentralized (rooftop solar, small wind systems).
7. High maintenance due to mechanical parts and fuel handling.	7. Low maintenance (especially solar PV).
8. Example: Thermal power plant, Nuclear power plant.	8. Example: Solar power plant, Wind power plant.

b) State Ohm's law and mention its limitations.

Ohm's Law: At constant temperature and other physical conditions, the current flowing through a conductor is directly proportional to the potential difference applied across it.

Mathematically,

$$V \propto I$$
$$V = IR$$

Where: **V** = Voltage (Volts), **I** = Current (Amperes), **R** = Resistance (Ohms)

Limitations of Ohm's Law:

1. **Valid only for ohmic conductors**
   It applies only to materials where resistance remains constant (e.g., metals).
2. **Temperature must remain constant**
   If temperature changes, resistance changes, and the law is not strictly valid.
3. **Not applicable to non-linear devices**
   It does not apply to devices like Diodes, Transistors, Thermistors, Electrolytes, Vacuum tubes
4. **Fails at very high electric fields**
   At very high voltages, breakdown may occur and the V–I relationship becomes non-linear.

c) A resistance R is connected in series with a parallel circuit comprising 20Ω and 48Ω. The total power dissipated is 1000W and applied voltage is 250V. Calculate R.

Given:

- Two resistances in parallel: **20 Ω and 48 Ω**
- Series resistance: **R = ?**
- Total Power P=1000 WP = 1000 \, WP=1000W
- Applied Voltage V=250 VV = 250 \, VV=250V

Rtotal=

$$P = \frac{V^2}{R_{total}}$$

$$R_{total} = \frac{V^2}{P}$$

$$R_{total} = \frac{250^2}{1000}$$

$$R_{total} = \frac{62500}{1000} = 62.5\,\Omega$$

Rp=

$$\frac{1}{R_p} = \frac{1}{20} + \frac{1}{48}$$

$$\frac{1}{R_p} = \frac{48 + 20}{960}$$

$$\frac{1}{R_p} = \frac{68}{960}$$

$$R_p = \frac{960}{68}$$

$$R_p = 14.12\,\Omega$$

Series Resistance R=

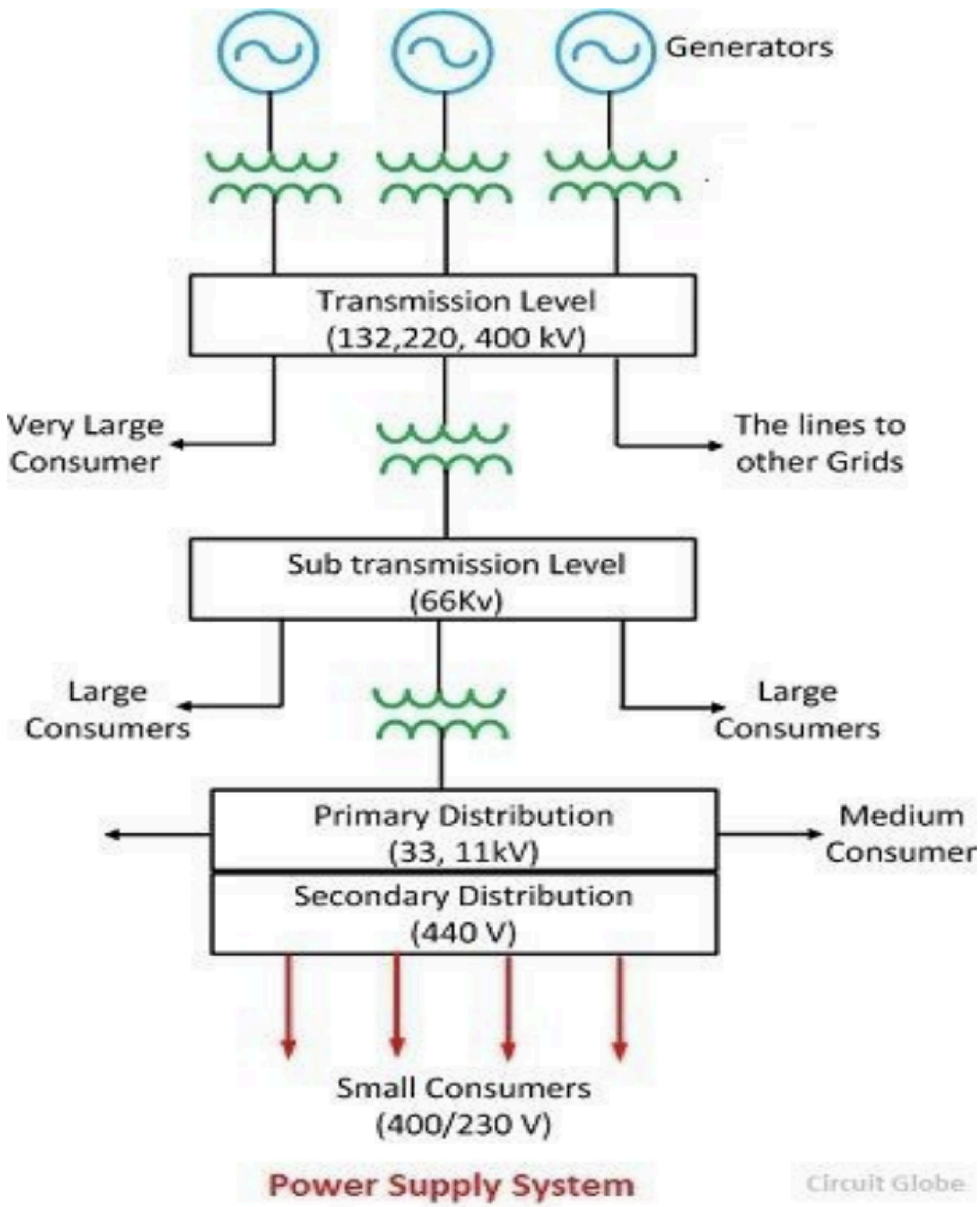
$$R_{total} = R + R_p$$

$$62.5 = R + 14.12$$

$$R = 62.5 - 14.12$$

$$R = 48.38\,\Omega$$

Q2 a) Draw and explain simple single-line diagram of a power supply system including generation → transmission → distribution.



Electrical power transmission and distribution system can be divided into several steps, including:

1. Generation: Electricity is generated at power stations using various sources such as coal, natural gas, nuclear energy, hydroelectricity, wind, or solar energy.
2. Step-up transformers: The voltage of the generated power is stepped up using step-up transformers to reduce energy losses during long-distance transmission.
3. Transmission: High-voltage transmission lines are used to transmit the electricity over long distances from the power station to the substations.
4. Substations: At the substations, the voltage is stepped down using step-down transformers for local distribution.
5. Distribution: Low-voltage distribution lines are used to distribute the electricity to residential, commercial, and industrial consumers.
6. Distribution transformers: At the end of the distribution lines, distribution transformers are used to step down the voltage to the levels suitable for consumer use.
7. Consumption: The electricity is finally consumed by various appliances and devices in homes, businesses, and industries.

Overall, electrical power transmission and distribution system involves the generation, transmission, distribution, and consumption of electricity to meet the needs of the society.

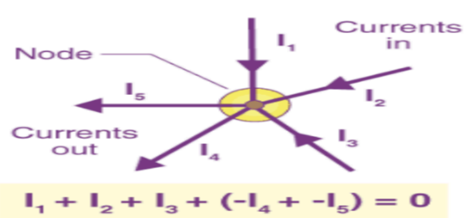
b) State and explain Kirchhoff’s Laws.

Kirchhoff’s Laws are fundamental laws used to analyze electrical circuits. They are:

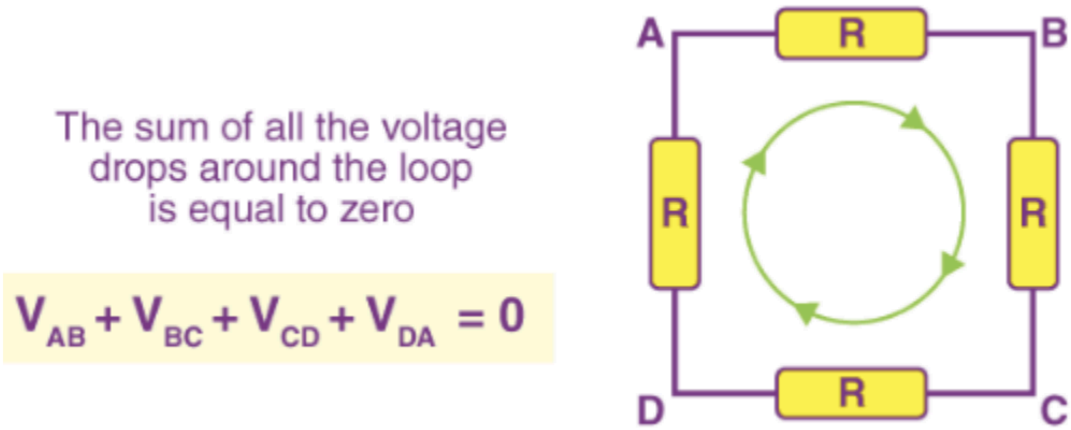
1 Kirchhoff’s Current Law (KCL)

Statement: The algebraic sum of currents at any junction (node) in a circuit is zero.

According to Kirchhoff’s Current Law,The total current entering a junction or a node is equal to the charge leaving the node as no charge is lost.

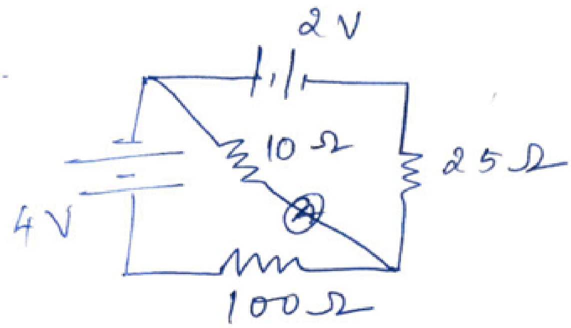


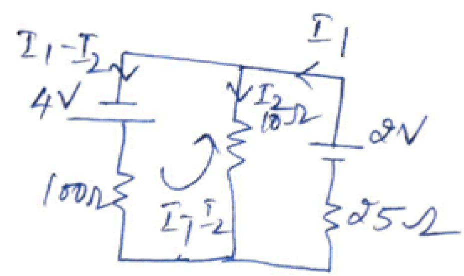
According to Kirchhoff’s Voltage Law,The voltage around a loop equals the sum of every voltage drop in the same loop for any closed network and equals zero.



c) In the given network, determine the direction and magnitude of current flow in the milli-ammeter A (internal resistance 10Ω).

2.C.





$$4 - 100(I_1 - I_2) + 10 I_2 = 0.$$

$$4 - 100 I_1 - 90 I_2 = 0$$

$$100 I_1 + 90 I_2 = 4 \quad - ($$

$$2 - 10 I_2 - 25 I_1 = 0$$

$$25 I_1 + 10 I_2 = 2 \quad - (2)$$

$I_1 = 0.112 A$ $\quad$ $I_2 = -0.08 A.$

Module – 2

Q3 a) Define: i) Amplitude ii) RMS Value iii) Average Value iv) Form Factor v) Peak Factor with respect to sinusoidal quantity.

i) Amplitude (Peak Value): Amplitude is the **maximum value** attained by a sinusoidal quantity during a cycle.

Amplitude=Xm

For example:
If v(t)=325sin(ωt)

Amplitude = **325 V**

ii)RMS Value: The RMS (Root Mean Square) value (also known as effective or virtual value) of of an alternating current (AC) is the value of direct current (DC) when flowing through a circuit or resistor for the specific time period and produces same amount of heat which produced by the alternating current (AC) when flowing through the same circuit or resistor for a specific time. For AC sine wave, RMS values of current and voltage are: IRMS = 0.707 x IM , VRMS = 0.707 VM

iii) Average Value: The mean value of the signal over one complete cycle. It is calculated by integrating the function over one period and dividing by the period, or by using specific formulas for different waveforms.

iv) Form Factor: Form factor is the ratio of RMS value to Average value.

Form Factor=Xrms/Xavg
Form Factor=0.707Xm/0.637Xm
Factor=0.707Xm/0.637Xm =1.11
For pure sine wave, Form Factor = **1.11**

V) Peak factor:

It is the ratio between maximum value and RMS value of an alternating wave.

$$\text{Peak Factor} = \frac{\text{Maximum Value}}{\text{R.M.S Value}}$$

b) Distinguish between: i) Balanced and unbalanced supply ii) Balanced and unbalanced load.

Balanced Supply
A three-phase supply is said to be balanced when:

- All three phase voltages have **equal magnitude**
- Same frequency
- Phase difference of **120°** between them

For example VR=VY=VB

Unbalanced Supply
A supply is unbalanced when:

- Phase voltages are **not equal in magnitude**
- Or phase angles are not exactly 120°
- For Example VR≠VY≠VB

Feature	Balanced Supply	Unbalanced Supply
Voltage magnitude	Equal	Unequal
Phase angle	120° apart	Not exactly 120°
System symmetry	Yes	No

System effect	Stable	Disturbances

Feature	**Balanced Load**	**Unbalanced Load**
Impedance	Equal	Unequal
Current	Equal in all phases	Unequal
Neutral current	Zero	Non-zero
Power distribution	Uniform	Uneven

c) A circuit with 25Ω resistance and 100μF capacitance in series is supplied with 200V, 50Hz. Find current, power factor and power consumed.

Current

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

$$I = \frac{200}{40.47}$$

$$I \approx 4.94\ A$$

Power Factor

$$\cos\phi = \frac{R}{Z}$$

$$\cos\phi = \frac{25}{40.47}$$

$$\cos\phi \approx 0.618$$

Since it is capacitive circuit → Leading Power Factor

Power Consumed

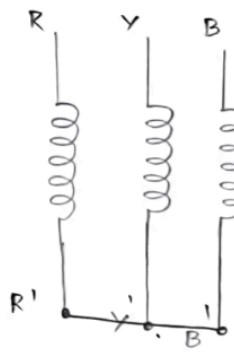
$$P = VI\cos\phi$$

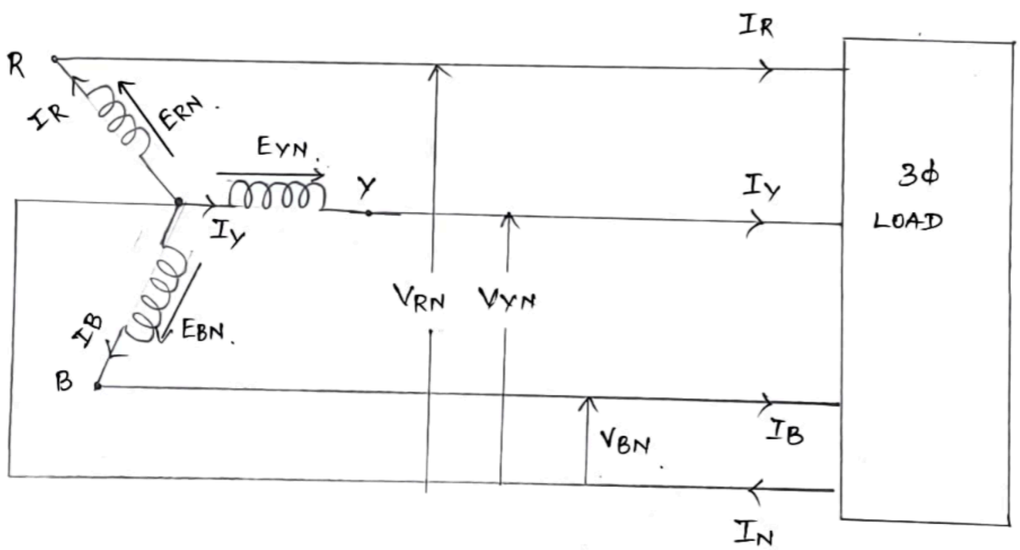
$$P = 200 \times 4.94 \times 0.618$$

$$P \approx 610\ W$$

Q4 a) In a three-phase star connection, find the relation between line and phase values of current and voltages.

STAR CONNECTED 3φ SYSTEM:





Let E_{RN}, E_{YN} and E_{BN} be the rms values of the emfs generated in the 3φ.

Due to impedance drop in the windings, the potential difference is different from the generated emf. ∴ it is preferred to deal with V rather than E.

(iii)

In 3ϕ systems, two set of voltages are of interest.

=> PHASE VOLTAGE
=> LINE VOLTAGE.

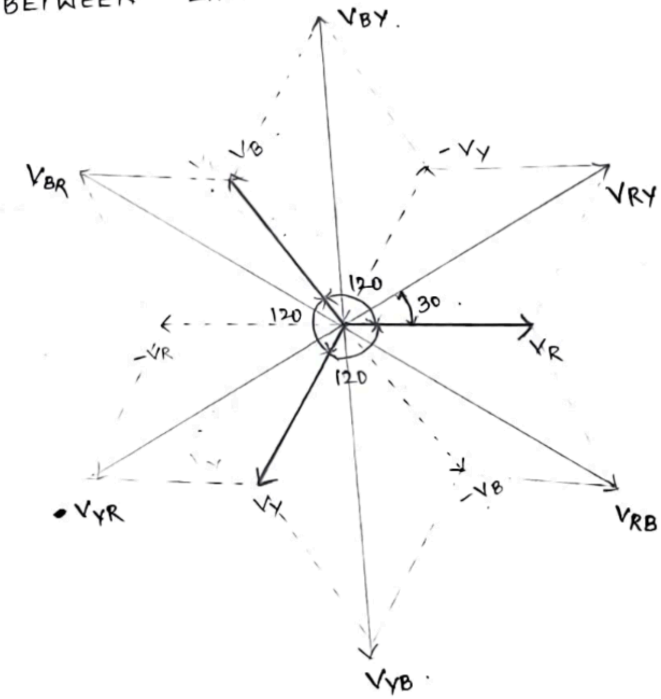
PHASE VOLTAGE :-
The rms value of the voltage drop from any phase (R, Y, B) to neutral N.

V_{RN}, V_{YN}, V_{BN} } phase voltages.

LINE VOLTAGE :
=> Voltage between two lines.

V_{RY}, V_{YB}, V_{BR} } line voltages.

RELATIONSHIP BETWEEN LINE AND PHASE VOLTAGE:



In a balanced system, each phase voltage has sam
magnitude.

Say, $|V_{RN}| = |V_{YN}| = |V_{BN}| = V_{ph}$

$$V_{RN} = V_{ph} \angle 0$$
$$V_{YN} = V_{ph} \angle -120^\circ$$
$$V_{BN} = V_{ph} \angle -240^\circ$$

$$V_{RY} = V_{RN} - V_{YN} = V_{ph} \angle 0 - V_{ph} \angle -120$$
$$= V_{ph} - V_{ph} (\cos 120 - j \sin 120)$$
$$= V_{ph} [1 - (\cos 120 - j \sin 120)]$$
$$= V_{ph} [1 - \cos 120 + j \sin 120]$$
$$= V_{ph} \left[1 + \frac{1}{2} + j \frac{\sqrt{3}}{2}\right]$$

$$\boxed{V_{RY} = \sqrt{3} V_{ph}.}$$

$\boxed{V_{line} = \sqrt{3} V_{phase}}$ => in general.

$$\theta = \tan^{-1} \frac{\sqrt{3}/2}{3/2}$$

$$\boxed{\theta = 30.}$$

For $\curlywedge$ connection, $I_{line} = I_{phase}$.

b) Derive equation for power consumed in R-L-C series circuit.

Three cases of R-L-C series circuit :-

(i) inductive circuit $X_L > X_C$

(ii) capacitive circuit $X_C > X_L$

(iii) purely resistive circuit or resonance $X_L = X_C$.

and circuit eqns

Consider a Series R–L–C Circuit XL> Xc

Let applied voltage:

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

Impedance of circuit:

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

where

$$X_L = \omega L, \quad X_C = \frac{1}{\omega C}$$

Current in the Circuit:

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

Power factor:

$$\cos\phi = \frac{R}{Z}$$

where

$$\tan\phi = \frac{X_L - X_C}{R}$$

Instantaneous Power

Instantaneous voltage:

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

Instantaneous current:

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

Instantaneous power:

$$p = vi$$

$$p = V_m \sin \omega t \times I_m \sin(\omega t - \phi)$$

Using identity:

$$\sin A \sin B = \frac{1}{2}[\cos(A - B) - \cos(A + B)]$$

$$p = \frac{V_m I_m}{2}[\cos \phi - \cos(2\omega t - \phi)]$$

Average Power

Average of $\cos(2\omega t - \phi)$ over one cycle = 0

Therefore,

$$P = \frac{V_m I_m}{2} \cos \phi$$

Since,

$$V = \frac{V_m}{\sqrt{2}}, \quad I = \frac{I_m}{\sqrt{2}}$$

$$\frac{V_m I_m}{2} = VI$$

c) A delta connected load has 10Ω resistance and 100µF capacitance per phase. Supply: 410V, 50Hz. Find line current, power factor and power consumed.

Given:

- Resistance per phase, R=10 ΩR = 10 \ \OmegaR=10 Ω
- Capacitance per phase, C=100µF=100×10−6FC = 100 \mu F = 100 \times 10^{-6} FC=100µF=100×10−6F
- Line voltage, VL=410VV_L = 410 VVL=410V
- Frequency, f=50Hzf = 50 Hzf=50Hz
- Connection: Delta (Δ)

Capacitive Reactance:

$$X_C = \frac{1}{2\pi fC}$$

$$X_C = \frac{1}{2\pi \times 50 \times 100 \times 10^{-6}}$$

$$X_C = \frac{1}{0.0314}$$

$$X_C \approx 31.83\ \Omega$$

Phase Impedance:

$$Z_{ph} = \sqrt{R^2 + X_C^2}$$

$$Z_{ph} = \sqrt{10^2 + 31.83^2}$$

$$Z_{ph} = \sqrt{100 + 1013}$$

$$Z_{ph} = \sqrt{1113}$$

$$Z_{ph} \approx 33.37\ \Omega$$

Phase Voltage

$$V_{ph} = V_L$$

$$V_{ph} = 410V$$

Phase Current & Line Current

$$I_{ph} = \frac{V_{ph}}{Z_{ph}}$$

$$I_{ph} = \frac{410}{33.37}$$

$$I_{ph} \approx 12.29A$$

$$I_L = \sqrt{3}I_{ph}$$

$$I_L = 1.732 \times 12.29$$

$$I_L \approx 21.28A$$

Power Factor

$$\cos\phi = \frac{R}{Z}$$

$$\cos\phi = \frac{10}{33.37}$$

$$\cos\phi \approx 0.30$$

capacitive → Leading Power Factor

Total Power Consumed

$$P = \sqrt{3} V_L I_L \cos\phi$$

$$P = 1.732 \times 410 \times 21.28 \times 0.30$$

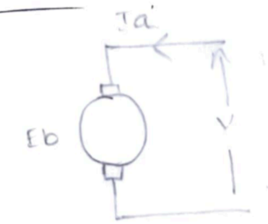
$$P \approx 4530W$$

$$P \approx 4.53\ kW$$

Module 3:

5 a) Derive torque equation of a DC Motor:

Torque Equation of a dc motor :-



$V = E_b + I_a R_a$

Voltage eqn of dc motor

$V = E_b + I_a R_a$ — ①

$\otimes I_a$, $\quad VI_a = E_b I_a + I_a^2 R_a$ — ②

VI_a ↓ elec i/p to arm

$E_b I_a$ ↓ elec equivalent of gross mech power

$I_a^2 R_a$ → cu loss in arm

i.e input = output + losses

$E_b I_a$ - electrical equivalent of gross mech power — ③

Let T be the average electro-magnetic torque developed by armature in Nm (newton metres)

Mechanical power developed by armature

$$P_m = \omega \times T \quad — \text{④}$$

where $\omega = \frac{2\pi N}{60}$

i.e $P_m = \frac{2\pi N}{60} \times T$

Using ③ and ④,

$$E_b I_a = \omega T$$

$$\boxed{T = \frac{E_b I_a}{\omega}} \quad — \text{⑤}$$

w.k.t $E_b = \frac{P\phi N Z}{60 A}$

Sub E_b in ⑤, $T = \frac{P\phi Z N}{60 A} \times \frac{I_a}{2\pi N} \times 60$

$$\boxed{T = \frac{1}{2\pi} \frac{P\phi Z}{A} I_a} \quad — \text{⑥}$$

eqn ⑤ represents the torque eqn of dc motor

Considering eqn ⑥, P, Z and A are constant for given dc machine, ∴ $T = K_t \phi I_a$

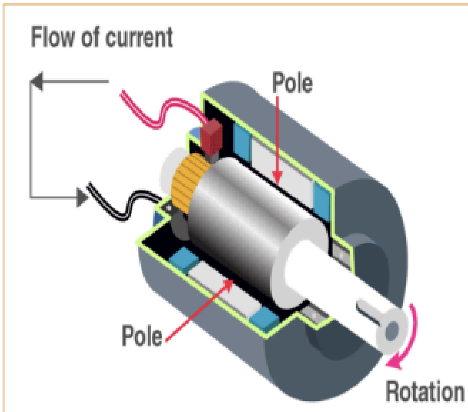
where $K_t = \frac{PZ}{2\pi A}$

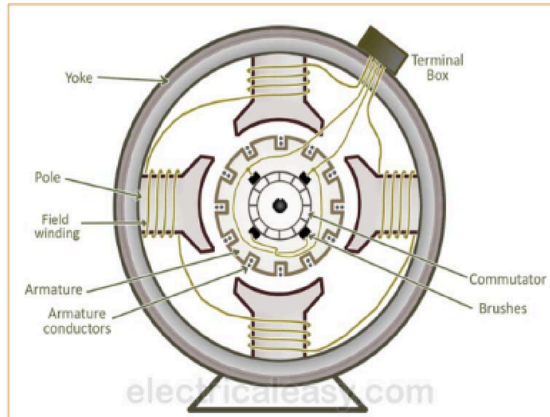
b) With a neat sketch explain the construction of the various parts of DC Machine.

CONSTRUCTION OF A DC GENERATOR

STATOR
Yoke
Poles
Field coils

ROTOR
Armature
Commutator
Brushes





Stator: This is the stationary part of the generator that houses the field magnet. The stator provides the magnetic field required for the generation of the EMF.

Yoke:

Supporting frame and path for magnetic flux

Poles:

Salient poles – pole core – pole shoe – pole carries the field coils

Field coils:

Wound on pole shoes –supported by pole cores.

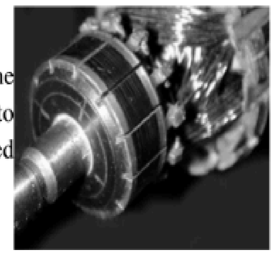
All coils are identical and connected in series so that on excitation alternate N and S poles are created

Armature:

Rotating armature: This is the component that rotates within the magnetic field to generate an electromotive force (EMF). The armature is made up of wire coils that are wound around a rotating shaft. Armature core consists of thin laminations to reduce eddy current loss – slots are provided on the periphery to accommodate windings

Commutator:

This is a rotating component that connects the armature coils to the external circuit. The commutator acts as a switch, reversing the current direction in the armature coils as they pass through the magnetic field. This ensures that a unidirectional current flow is obtained from the generator.



Brush:

These are sliding contacts that connect the external circuit to the commutator. They transfer the current from the armature coils to the external circuit. Two brushes are placed on the commutator - to make electrical connection with moving rotor- to obtain direct voltage from alternating emf obtained in the rotating conductors

c) Determine the total torque developed in a 250 V, 4-pole DC shunt motor with lap winding accommodated in 60 slots, each containing 20 conductors. The armature current is 50 A and the flux per pole is 23 mWb.

$$\text{Torque} = \frac{E_b I_a}{\omega}$$

$$= \frac{P\phi Z N}{60\,A} \times \frac{I_a \times 60}{2\pi N}$$

$$T = \frac{P\phi Z I_a}{2\pi A}$$

$$= \frac{4 \times 23 \times 10^{-3} \times 60 \times 20 \times 50}{2 \times \pi \times 4}$$

$$= 219.63 \text{ Nm}$$

$$\boxed{T \approx 220 \text{ Nm}}$$

6 a) Derive an EMF equation for DC machine with usual notations.

Emf equation of a dc generator :-

Let E_g - the generated emf in armature

ϕ - useful flux per pole (Wb)

Z - total no of conductors in the armature

P - number of poles

A - number of parallel path

A = P .... lap winding

A = 2 .... wave winding

N - speed of armature in r.p.m.

cording to Faraday's law,

e average emf induced in the conductor

$$e = \frac{d\phi}{dt} \quad — \quad (1)$$

Total emf generated = emf per parallel path

$$E_g = \text{emf / conductor} \times \text{no of conductors per parallel path}$$

$d\phi$ - flux cut by conductor in one revolution

$= P\phi$ webers — (2).

dt - time taken to complete one revolution.

$= \frac{60}{N}$ second ... ③

② & ③ in ①,

e = emf / conductor

$= \frac{d\phi}{dt} \Rightarrow \frac{P\phi N}{60}$ — ④.

$E_g = e \times \frac{Z}{A}$

$= \frac{P\phi N Z}{60\,A}$

$$E_g = \frac{\phi Z N}{60} \times \frac{P}{A}$$ — ⑤

emf equation of a dc machine.

6 b)

Explain the following characteristics of a D.C. Series motor:

(i) Torque vs armature current

(ii) Speed vs armature current

(i) Torque vs armature current

In a DC series motor, the field winding is connected in series with the armature. Hence, the same current flows through both armature and field.

Ia = Ise

Because of this, the flux (Φ) depends on armature current.

(i) Torque vs Armature Current Characteristic

Basic Torque Equation

$$T \propto \Phi I_a$$

Flux–Current Relationship

- At **low currents (unsaturated region)**:

$$\Phi \propto I_a$$

- At **high currents (saturated region)**:

$$\Phi \approx \text{constant}$$

Case 1: Unsaturated Region

$$T \propto I_a \times I_a = I_a^2$$

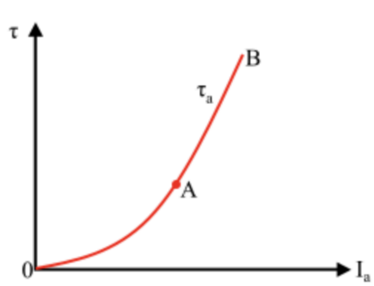
✔ Torque increases **quadratically** with armature current

✔ Produces **very high starting torque**

Case 2: Saturated Region

$$T \propto I_a$$

✔ Torque increases **linearly** with armature current



(ii) Speed vs armature current

(ii) Speed vs Armature Current Characteristic

Speed Equation

$$N \propto \frac{V - I_a(R_a + R_{se})}{\Phi}$$

At Low Load (Small I_a)

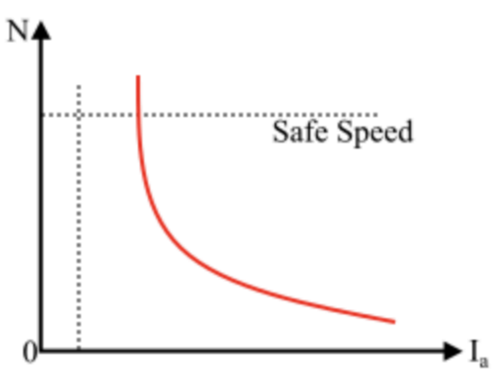
- Flux Φ is **small**
- Speed N becomes **very high**

⚠ **Dangerous condition**

👉 DC series motor **must never be run at no-load**

At Increasing Load

- Armature current I_a increases
- Flux Φ increases
- Speed **decreases rapidly**



6 c) The armature of an 8-pole DC generator has 960 conductors and runs at 400 rpm. The flux per pole is 40 mWb. Calculate the induced e.m.f. when the armature is lap wound. At what speed should it be rotated to generate 400 V, if the armature is wave connected?

6 c) $$E = \frac{P\phi ZN}{60A}$$

i) Lap wound (A=P)

$$= \frac{8 \times 40 \times 10^{-3} \times 960 \times 400}{60 \times 8}$$

$$\boxed{E = 256V} \rightarrow \text{induced EMF}$$

ii) Speed ? if wave winding and E=400V.

A = 2

$$N = \frac{E \times 60 \times A}{P\phi Z} \Rightarrow \frac{400 \times 60 \times 2}{8 \times 40 \times 10^{-3} \times 960}$$

$$\boxed{N = 156 \text{ rpm}}$$

MODULE-4

7.a Derive EMF equation of transformer and voltage/current transformation ratios.

Let the sinusoidally varying flux be,

$$\phi = \phi_m \sin \omega t \quad \text{— (1)}$$

$$= \phi_m \sin 2\pi f t$$

where ϕ_m - peak or maximum value of flux.

f - frequency of flux.

Let e_1 and e_2 be the instantaneous emf's induced in 1 and 2 with N_1 and N_2 n turns respectively.

$$\therefore \quad e_1 = -N_1 \frac{d\phi}{dt} \quad \text{— (2)}$$

$$= -N_1 \frac{d(\phi_m \sin \omega t)}{dt} \quad \text{— (3)}$$

$$= -N_1 \phi_m (\cos \omega t) \times \omega$$

$$= -\omega N_1 \phi_m \cos \omega t$$

$$= \omega N_1 \phi_m \sin(\omega t - 90)$$

$$\therefore \quad e_1 = 2\pi f N_1 \phi_m \sin(\omega t - 90) \quad \text{— (4)}$$

From ④, the induced emf will be maximum,

if $\sin(\omega t - 90) =$ unity

$$\therefore \; E_{m_1} = 2\pi f N_1 \phi_m \quad — ⑤$$

The rms value $E_1 = \dfrac{E_{m_1}}{\sqrt{2}}$ — ⑥

$$= \frac{2\pi f N_1 \phi_m}{\sqrt{2}}$$

$$E_1 = 4.44 f N_1 \phi_m . \quad — ⑦$$

Similarly, $E_2 = 4.44 f N_2 \phi_m .$

* comparing eqns ① and ④, it is clear that induced emf lags the flux by 90°.

Current Transformer ratio:

Volt - Amperes:

In transformers, the current is transformed in the reverse ratio of voltage

i e $I_1 N_1 = I_2 N_2$

↳ the current in 1° is sufficient to provide mmf $I_1 N_1$ to overcome demagnetising effect of 2° mmf.

$$\therefore \quad \frac{I_2}{I_1} = \frac{N_1}{N_2} = \frac{1}{K}.$$

$$\text{or} \quad \frac{1}{K} = \frac{I_2}{I_1} = \frac{E_1}{E_2}$$

$$\therefore \quad I_1 E_1 = I_2 E_2$$

the i/p VA and o/p VA are identical.

7.b Explain construction and working of 3-phase induction motor.

A 3 Phase induction motor has two main parts:

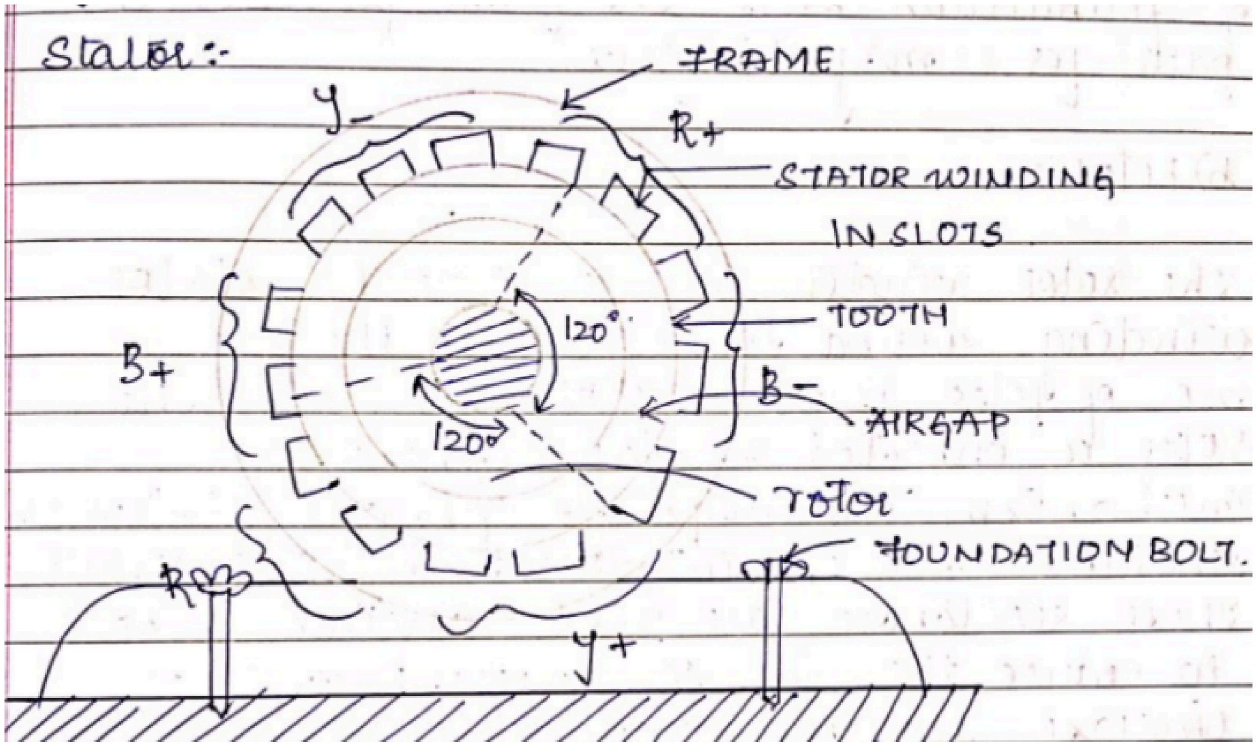
- Stator
- Rotor

By a small air gap ranging from 0.5 mm to 4 mm, the rotor and stator are separated depending on the power rating of the motor. here we will discuss the construction of three phase induction of motor in detail.

Stator of Three Phase Induction Motor

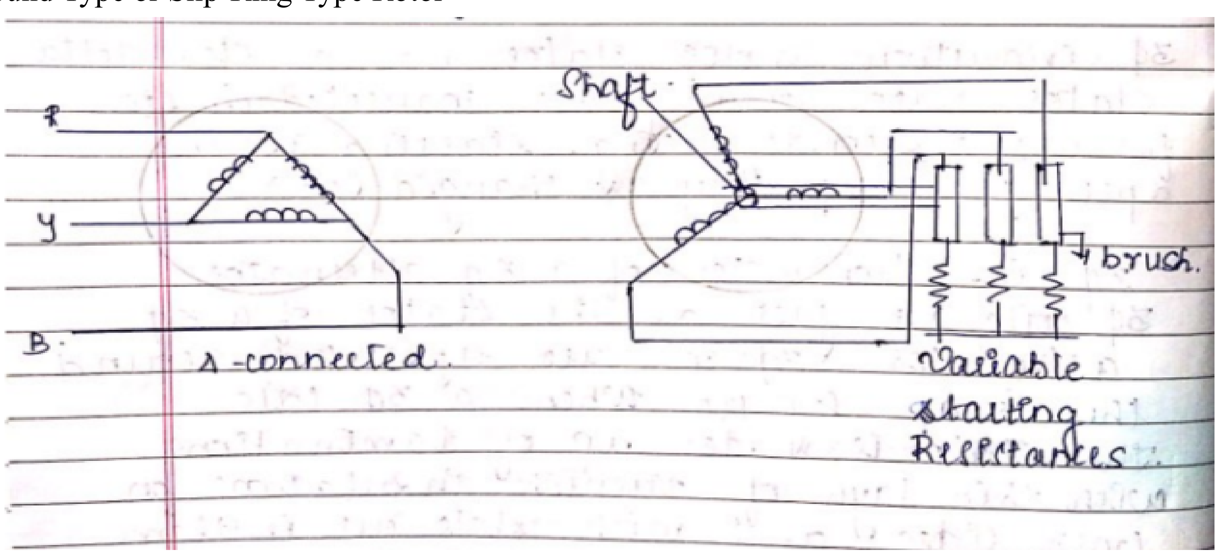
The stationary part of the three phase induction motor is the stator. It is made of a steel frame which encloses a hollow cylindrical core. The core of the three phase induction motor is made of silicon steel lamination of thin layers to minimize the hysteresis losses and eddy current. Evenly spaced slots are given on the inner periphery of the laminated core as shown in the figure. The insulated conductors are kept in these stator slots and are connected properly to form a balanced 3-phase delta or star-connected stator winding.

The 3-phase stator windings are configured with a specific number of poles, depending on the requirement of speed, i.e., the greater the speed of the motor, the lesser the number of poles and vice-versa. When a balanced 3-phase supply is fed to the stator winding, a rotating magnetic flux (RMF) of constant magnitude is produced and this RMF induces currents in the rotor circuit by electromagnetic induction.



Rotor of 3 Phase Induction Motor

The rotor of a three phase induction motor is a laminated core hollow cylindrical, slots are constructed on its outer periphery. On these rotor slots, the rotor windings are placed. Depending upon the winding placement, the rotor of a 3-phase induction motor is of two types:

- Squirrel Cage Type Rotor
- Wound Type or Slip-Ring Type Rotor
- 

Squirrel Cage Type Rotor

The squirrel cage rotor is made of a cylindrical laminated core, Skewed slots are kept on its outer periphery, which are nearly parallel to the shaft axis. An uninsulated aluminum or copper bar (rotor conductor) is placed in each slot. At both ends of the rotor, the rotor bar conductors are connected by heavy end rings made from the same material (see the figure) creating a short-circuit. This is indestructible winding because it is formed by permanently short-circuited winding. This whole arrangement resembles a cage which was once normally used for keeping squirrels hence the name.

Squirrel cage rotor conductors are skewed because this offers the following advantages −

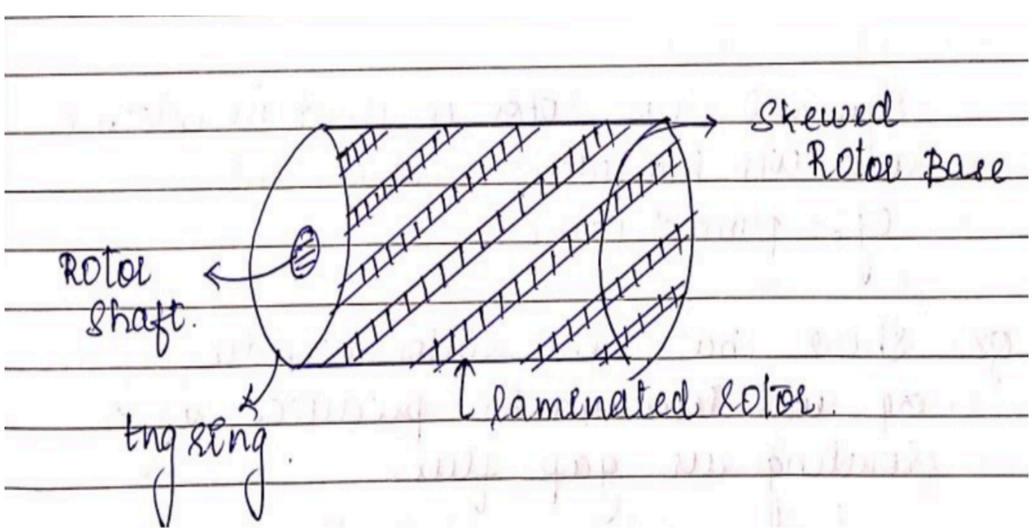
- The noise is reduced during operation.
- More uniform torque is produced.
- The magnetic locking tendency or cogging of the rotor is reduced. Due to magnetic action coggging occurs, in which the rotor and stator teeth lock with each other.

Wound Rotor or Slip Ring Rotor

The slip ring rotor is made of a laminated cylindrical armature core. The slots are constructed on the outer periphery and insulated conductors are placed in the slots. To form a 3-phase double layer distributed winding similar to the stator winding, the rotor conductors are connected. The rotor windings are connected in star form

The external resistors provide the variation of each rotor phase resistance to serve the following two purposes −

- To Reduce the starting current from the supply and increase the starting torque.
- To control the speed of the motor.



7.c

7.c) 50KVA, 3300/330V, $W_i = 400W$ $W_{cu} = 600W$

$x = 0.5$ p.f $= 0.9$

$$\eta = \frac{x \times V_2 I_2 \cos\phi_2}{x \times V_2 I_2 \cos\phi_2 + x^2 W_{cu} + W_i}$$

$$= \frac{0.5 \times 50 \times 10^3 \times 0.9}{0.9 \times 0.5 \times 50 \times 10^3 + 0.5^2 \times 600 + 400}$$

$$= \frac{25000 \times 0.9}{0.9 \times 25000 + 150 + 400}$$

$= 97.61\%$

8.a Define Slip of an Induction motor

Rotor speed and slip:

In induction motor, the rotor field is always less than RMF Ns. $N_r < N_s$

The difference b/w Ns and Nr is called slip and is usually expressed as a percentage of Ns.

i.e $\% S = \frac{N_s - N_r}{N_s} \times 100$.

Effect of Slip on Frequency of an Induction Motor

Frequency of the rotor induced emf :

The frequency of induced voltage (current) due to relative speed b/w rotor winding and magnetic field is given by,

$$\text{Frequency} = \frac{P \times \text{relative speed}}{120}$$

where N = relative speed b/w magnetic field and the winding.

P - no of poles.

For a rotor speed N, the relative speed b/w the rotating flux and rotor is $N_s - N$,

∴ Let f' be the rotor current frequency.

$$f' = \frac{(N_s - N) \times P}{120}$$

$$= \frac{SN_s}{120} \times P \qquad \because f = \frac{N_s P}{120}, \quad \because S = \frac{N_s - N}{N_s}$$

$$\boxed{f' = Sf}$$

i.e rotor current frequency = slip × supply frequency.

8.b Explain the working principle of a single transformer and its necessity

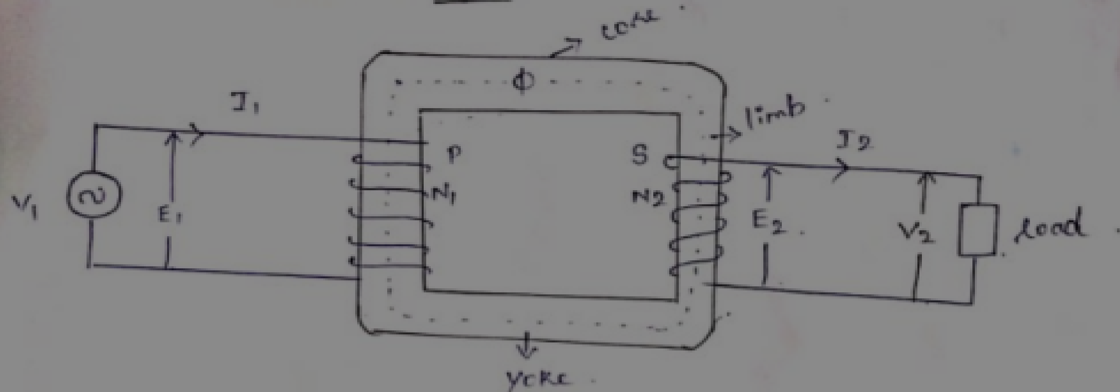
An A.C. device used to change high voltage low current A.C. into low voltage high current A.C. and vice-versa without changing the frequency

In brief,

1. Transfers electric power from one circuit to another
2. It does so without a change of frequency
3. It accomplishes this by electromagnetic induction
4. Where the two electric circuits are in mutual inductive influence of each other.

It is based on principle of MUTUAL INDUCTION. According to which an e.m.f. is induced in a coil when current in the neighbouring coil changes.

FIG 1



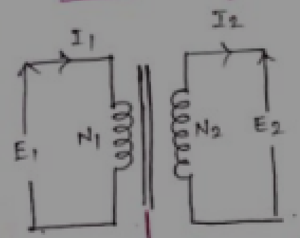
→ The coil connected to supply is called primary (1°)
The coil connected to load is called secondary (2°)

Operation of transformer ① electro-magnetism
② electro-magnetic induction

i.e elec current produces a mag field → ①.
a changing mag field within a coil induces an emf across the ends of the coil. → ②.

* This flux links the secondary coil. and induces voltage in the secondary circuit – mutual inductance.

Circuit Symbol => Refer 1 - when an ... an alternating flux φ is applied to 1°, an alternating flux φ is set up in the core.



↳ iron core

FIG 2.

=> This flux φ links both windings and induces emfs E_1 and E_2 i.e electro-magnetic induction

E_1 - 1° induced emf, N_1 - no of primary turns

E_2 - 2° induced emf. N_2 - no of secondary turns

W.K.T

$$E_1 = -N_1 \frac{d\phi}{dt}$$

$$E_2 = -N_2 \frac{d\phi}{dt}$$

$$\therefore \frac{E_2}{E_1} = \frac{-N_2 \, d\phi/dt}{-N_1 \, d\phi/dt} = \frac{N_2}{N_1}$$

$$\boxed{\frac{E_2}{E_1} = \frac{N_2}{N_1}}$$

* If $N_2 > N_1$ then $E_2 > E_1$ i.e $V_2 > V_1$ - step up transformer

If $N_1 > N_2$, then $E_1 > E_1$ i.e $V_2 < V_1$ - step down transformer

8.c

(8) c. 3ϕ, 4 pole, 440 V, 50 Hz $S = 4\%$

$N_r = S(N_s - 1)$

$= 0.04(1500 - 1)$

$= 59.9$ rpm

$N_s = \frac{120 \times f}{P}$

$= \frac{120 \times 50}{4}$

$= 1500$ rpm

$f_r = S.f$

$= 4\% \times 50$

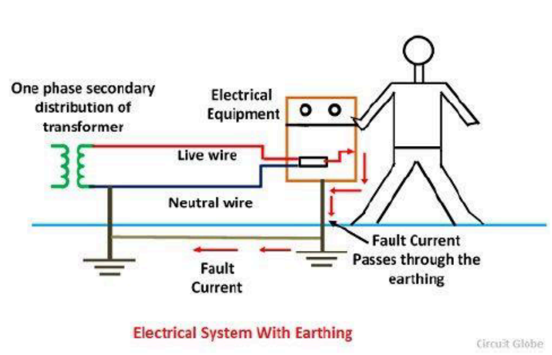
$= 8$ Hz

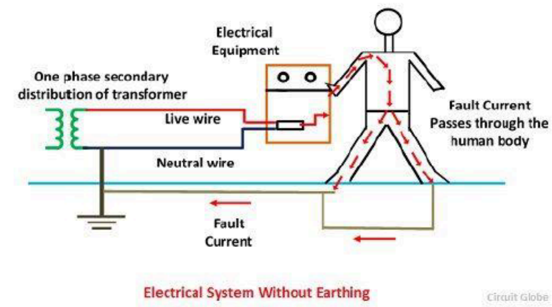
Module 5

9a)

Earthing and Its Importance

- The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing.
- The earthing protects the personnel from the short circuit current.
- The earthing provides the easiest path to the flow of short circuit current even after the failure of the insulation.
- The earthing protects the apparatus and personnel from the high voltage surges and lightning discharge.





How earthing is done?

- To ensure safety, earthing can be done by connecting the electrical appliance to earthing systems or electrodes placed near the soil or below the ground level.
- The electrode or earthing mat equipped with a flat iron riser is installed under the ground level. It helps to connect all the non-current-carrying metallic parts of the equipment.
- When the overload current is passed through the equipment or when the fault occurs in the system due to the current, the fault current from the equipment flows through the earthing system. The earth mat conductors aid in raising the voltage value equal to the resistance of the earth mat multiplied by a ground fault and helps guard the equipment against overload current or fault current.
- In homes, there shall be three types of wires, live, neutral, and earth. Live and neutral carry electric current from the power station and the earth is connected to the buried metal plate. Electric appliances like refrigerator, iron box, TV are connected to the earth wire while operating. Hence, these devices are protected from the surge or faulty electrical supply. Local earthing is done near the electrical meter of the house.

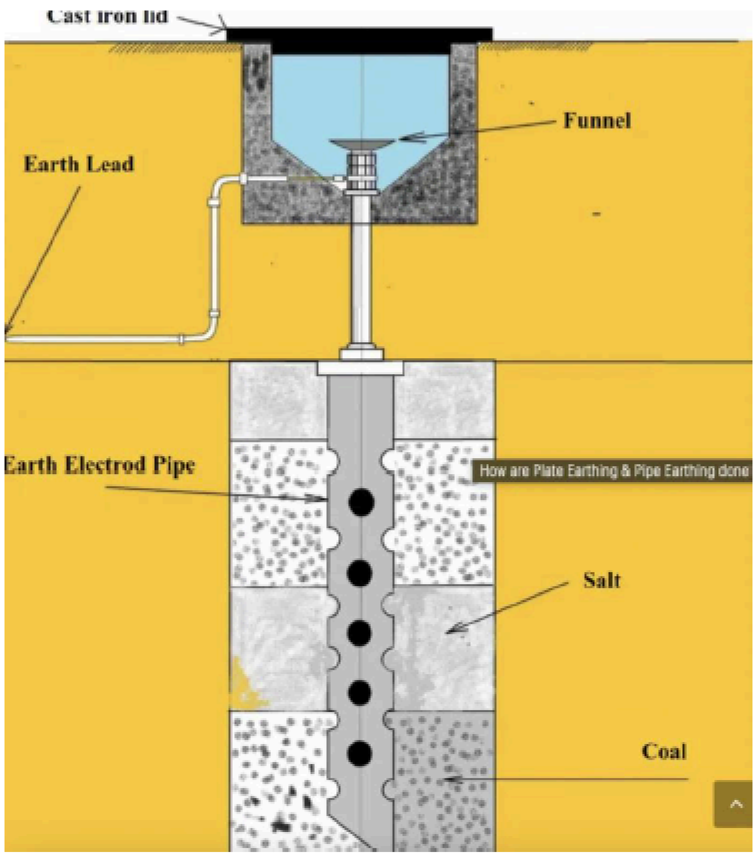
Advantages :

- Earthing is safe and the best method of offering safety. We know that the earth's potential is zero and is treated as Neutral. Since low equipment is connected to earth using low resistance wire, balancing is achieved.
- Metal can be used in electrical installations without looking for its conductivity, proper earthing ensures that metal does not transfer current.
- A sudden surge in voltage or overload does not harm the device and person if proper earthing measures are done.
- It prevents the risk of fire hazards that could otherwise be caused by the current leakage.

Pipe Earthing

- A pit is made 70cm long, 70cm wide and 3.75 meters deep in the ground for Pipe Earthing. a G.I., 38mm in diameter and 2 meters long. The Pipe is used as the earth electrode in that pit.
- The entire surface of that Pipe has 12mm holes. Which are made at a spacing of 7.5 cm. This means the electrode is fitted with a reducing socket with a diameter of 19mm and two such 12.7mm diameter G.I. Pipes are connected.
- A funnel is attached at the top end of the 19mm diameter Pipe. The funnel is used to water the Earthing. An open conductor for the earth lead is connected to the earth electrode through a 12.7mm diameter Pipe.

- The purpose is that the earth lid should not be damaged anywhere.
- Earth is laid around every layer of electrode at an interval of 15-15cm with sandy, sand and coal layer by layer.
- Meaning the pit above the electrode is covered with soil.
- The earth conductor, which is lifted out of a Pipe of 12.7mm diameter, is carried forward 60 cm below the ground, to the place where Earthing is to be done.
- A 30 × 30 cm cement concrete tank is built around the funnel. It is covered with a lid of cast iron.
- This type of Pipe is used for wiring installation of Earthing low and medium voltage.


Cast iron lid
Funnel
Earth Lead
Earth Electrod Pipe
How are Plate Earthing & Pipe Earthing done
Salt
Coal

9b)

Electric Shock

- Electric shock is a jarring, shaking sensation resulting from contact with electric circuits or from the effects of lightning. The victim usually feels that he or she received a sudden blow, if the voltage and resulting current is sufficiently high, the victims may become unconscious. Severe burns may appear on the skin at the place of contact muscular spasm may occur, causing the victim to clasp the apparatus or wire which causes the shock and be unable to turn it loose.
- The amount of current that may pass through the body without danger depends on the individual or current quantity, type, path and length of contact time.
- Body resistance varies from 1000 to 5, 00,000 ohms for unbroken dry skin. Resistance low as 5milliamperes can be dangerous. If the palm of the hand makes contact with the conductor, a current of about12 milli amperes will tend to cause the hand muscles to contract, freezing the body to the conductor. Such a shock mayor may not cause serious damage, depending on the contact time and your physical condition, particularly the condition of your heart. A current of 25milliamperes has been known to be fatal. Due to the physiological and chemical nature of the human body five times more direct current than alternating current is needed to freeze the same body to a conductor. Also 50-hertz (cycles per second) alternating current is about the most dangerous frequency. This is normally used in residential, commercial and industrial power.

- The damage from shock is also proportional to the number of vital organs trans versed, especially the percentage of current that reaches the heart Currents especially 100 and 200 mill amperes are lethal. Ventricular fibrillation of the heart occurs when the current through the body approaches 100miliamperes. Ventricle fibrillation is the unco-ordinated actions of the walls of the hearts ventricles. This in turn causes the loss of the pumping action of the heart. This fibrillation will usually continue some force is used to restore the coordination of the hearts actions.
- Severe burns and unconsciousness are also produced by currents of 200 milli amperes or higher. These currents usually do not cause death if the victim is given immediate attention. The victim will usually respond if rendered resuscitation in the form of artificial respiration. This is due to 20 milli amperes of current clamping the heart muscles which prevents the heart from going in to ventricular fibrillation. When a person is rendered unconscious by a current passing through the body. It is impossible to tell you how much current caused the unconsciousness. Artificial respiration is to be applied immediately if breathing has stopped.

First Aid for Electric Shock

- Intelligent and prompt action of first aider is required in case of electric shock. If the first aider is not cautious, he may also receive severe electric shock or even die along with the casualty. Therefore every employee or workers in the electrical field or those who are having electric supply should make themselves familiar with the instructions given below:
- Removal from contact: When a person gets back a shock and he is in contact with the supply or conductor, first switch off the switch off the switch or main. If the switch or main is not found, cut the cable with the help of axe or plastic handled knife but don't use scissors. If the cable cutting is also not possible in case of LT supply, the first aider should stand on an insulated material which is dry, if available rubber gloves should be worn, if not dry coat, cap, clothing or folded newspaper should be used while removing the casualty victim. In case of HT supply there is greater danger. The casualty may not be in casual contact
- with the wire as the current can pass through the gap causing an arc. The first aider should keep away from the wires and the casualty should be dragged out by means of walking stick, dry rope, dry bamboo stick etc.
- See the victim's clothes and extinguish the spark if smouldering.

9c)

kWh stands for kilowatt-hour.

It is the unit of electrical energy used to calculate your electricity consumption.

- Bulb power = **60 W**
- Time used = **5 hours**
  Electricity bill uses kWh, so first convert W → kW:

60W=60/1000=0.06 kW

So,

- 60 W = 0.06 kW

Energy consumed:

Energy=Power×Time

=0.06 kW×5 hours= 0.30 kWh

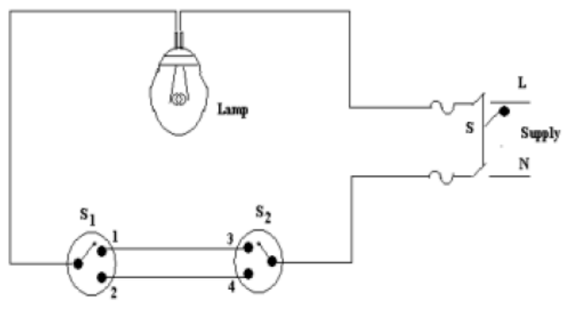
10a)

Two- way and Three- way Control of Lamps:

The domestic lighting circuits are quite simple and they are usually controlled from one point. But in certain cases it might be necessary to control a single lamp from more than one point (Two or Three different points). For example: staircases, long corridors, large halls etc.

(i)Two-way Control of lamp:

Two-way control is usually used for staircase lighting. The lamp can be controlled from two different points: one at the top and the other at the bottom - using two- way switches which strap wires interconnect. They are also used in bedrooms, big halls and large corridors. The circuit is shown in the following figure.



Two -way control of lamp

- Switches S_1 and S_2 are two-way switches with a pair of terminals 1&2, and 3&4 respectively.
- When the switch S_1 is in position**1** and switch S_2 is in position **4**, the circuit does not form a closed loop and there is no path for the current to flow and hence the lamp will be **OFF.**
- When S_1 is changed to position **2** the circuit gets completed and hence the lamp glows or is **ON**. N

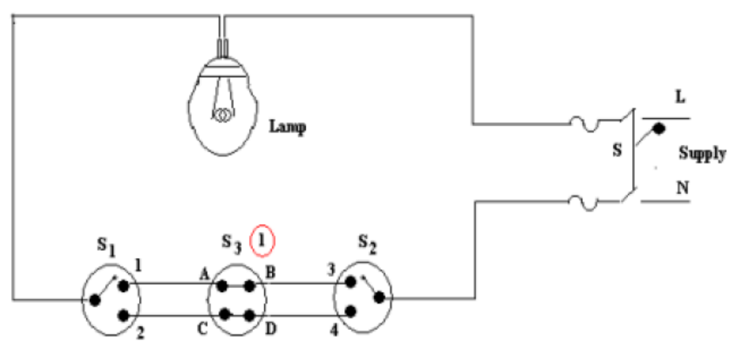
- ow if S_2 is changed to position **3** with S_1 at position **2** the circuit continuity is broken and the lamp is off.
- Thus the lamp can be controlled from two different points.

Position of S1	Position of S2	Condition of lamp
1	3	ON
1	4	OFF
2	3	OFF
2	4	ON

(ii)Three- way Control of lamp:
In case of very long corridors it may be necessary to control the lamp from 3 different points. In such cases, the circuit connection requires two; two-way switches **S_1** and **S_2** and an intermediate switch **S_3**. An intermediate switch is a combination of two, two way switches coupled together. It has 4 terminals ABCD. It can be connected in two ways:
a) Straight connection
b) Cross connection
In case of straight connection, the terminals or points AB and CD are connected as shown in figure 1(a) while in case of cross connection, the terminals AB and CD is connected as shown in figure 1(b).

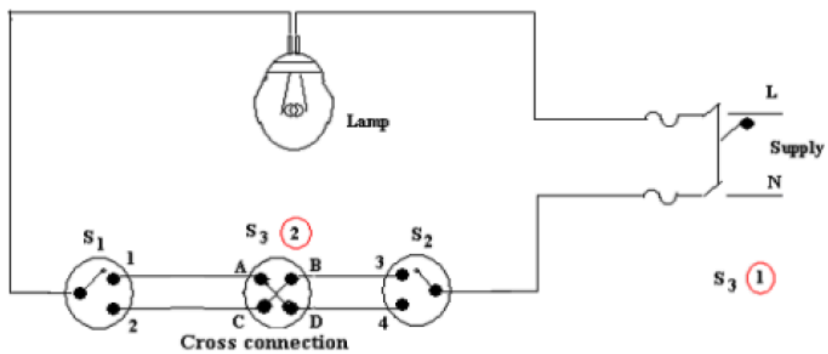
As explained in two ways control the lamp is ON if the circuit is complete and is OFF if the circuit does not form a closed loop.

Three -way control of lamp



Straight connection

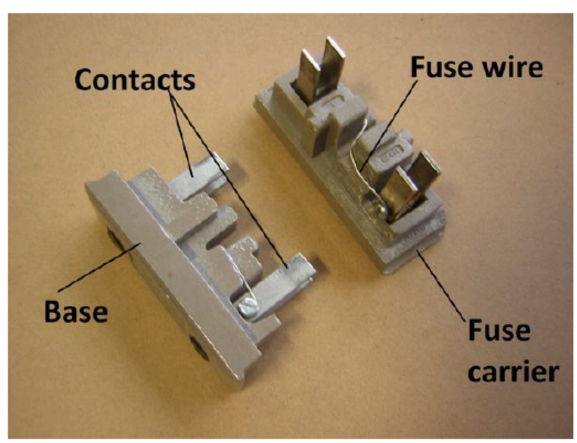
The condition of the lamp depends on the positions of the switches S_1, S_2, and S_3.



10b)

Fuse

- An electrical fuse is a safety device that operates to provide protection against the overflow of current in an electrical circuit. An important component of an electrical fuse is a metal wire or strip that melts when excess current flows through it. It helps to protect the device by stopping or interrupting the current.



Working Principle of Fuse

- To understand the working principle behind an electrical fuse, two critical concepts should be kept in mind Current flows in a loop Heating effect of current. Electric current can flow through a conductor only when the circuit formed is complete. If there is a break in the loop, electric charges cannot flow through. This is also how switches operate. For example, when you put on the light switches at home, the lights come on because you have just completed the circuit allowing charges from the power source to flow through and power your lights. When current passes through a conductor, the different electrical components of the circuit like the devices attached or even the wire itself, offer resistance to the current flow. The work done to overcome this resistance presents itself in the form of heat. This is a simple explanation of the "heating effect" of current.

Principle Of Electrical Fuse

- The primary use of an electric fuse is to protect electrical equipment from excessive current and to prevent short circuits or mismatched loads. Electrical fuses play the role of miniature circuit breakers. Apart from protecting equipment, they are also used as safety measures to prevent any safety hazards to humans.

- The fuse wire in an electrical fuse is selected in such a way that it does not face any damage when the normally stipulated amount of current flows through the circuit. Under normal conditions, the fuse wire is a part of the circuitry, contributing to a complete loop for charges to flow through it. However, when an excessive amount of current flows through the fuse wire, the heating effect of current causes the fuse wire to melt. This is because the fuse wire is chosen such that it has a low melting point. This causes the loop to break thereby stopping the flow of charges in the circuit.

- It is important to select a fuse that is properly specified for the circuit in consideration. For example, if the fuse that is used is underrated, then it will fail even under normal current conditions, unnecessarily breaking the circuit loop. If it is overrated, then it will not break the circuit when required and cause equipment damage and failure and may even present itself as a safety hazard.

Functions of Fuse

In the field of electrical engineering, a fuse is a device that provides overcurrent protection to the functional electrical circuit. Here, we have listed a few major functions of the fuse.

- Acts as a barrier between the electric circuit and the human body
- Prevents device failure due to faulty circuit operation
- Fuse prevents short-circuits
- Prevents overload and blackouts
- Prevents damage that is caused due to mismatched loads
- The markings on the fuse carry information such as the Ampere rating, voltage rating, and interruption rating.

Merits of Fuse

- Fuses are the cheapest form of protection.
- The fuse element change very easily.
- The fuse needs zero maintenance.
- It affords the current limiting effect under short circuit conditions.
- Its operation is completely automatic and requires less time as compared to circuit breakers and no complexity is involved
- Most of the fuses are self-protecting and also they extinguishing the arc.
- When we use the small size of the fuse element impose a current limiting effect under short circuit conditions.
- Its inverse time-current characteristics enable its use for overload protection.
- Fuse has the ability to interrupt enormous short circuits without producing noise, flame or smoke.
- Easy to removable for replacement without any damage to coming into contact with a live part.
- The operation time of fuse can be much smaller than the operation of the circuit breaker. It is the primary protection device, against the short circuits.

De Merits of Fuse

- It is not suitable for overload, at that time fuse blow off replacing of fuse takes time. During this period of lost power the protection of fuse is not reliable, Low breaking capacity.
- Fuse is slow compared to circuit breakers. It is a slow speed.
- Considerable time is required in replacing a fuse after the operations, while the circuit breaker can be used multiple times.
- It can't bear a surge current in the case of motor starting, Fuse has not protected the circuit against under-voltage.
- The fusing elements of the fuse are exposed to air, hence it is oxidized. Therefore the resistance of the element is increased and produced heat when the current passing through it. There is a possibility of renewal by the fuse wire of the wrong size.
- The current time characteristics of a fuse cannot always be correlated with that of the protective device.
- When fuses are connected in series it is difficult to discriminate against the fuse unless the fuse has a significant size difference.
- Fuse does not respond to the high voltage it only cares about current flowing and is not likely to melt and save the house in case of a direct lightning strike. Accurate calibration of fuse wire is impossible, as longer fuse operates earlier than one of shorter length.

10c)

Appliance	Typical Power Rating
LED Light	**10 W**
Laptop	**60 W**
TV (LED)	**100 W**
Refrigerator (Fridge)	**200 W**

Formula:

$$Energy(kWh) = \frac{Power(W)}{1000} \times Time(hours)$$

Let’s assume each appliance is used for **5 hours per day**
(Fridge runs longer, but for simple calculation we take 5 hours)

LED Light (10 W)

$$Energy = \frac{10}{1000} \times 5$$

$$= 0.01 \times 5 = 0.05\,kWh$$

Laptop (60 W)

$$Energy = \frac{60}{1000} \times 5$$

$$= 0.06 \times 5 = 0.30\,kWh$$

TV (100 W)

$$Energy = \frac{100}{1000} \times 5$$

$$= 0.1 \times 5 = 0.50\,kWh$$

Refrigerator (200 W)

$$Energy = \frac{200}{1000} \times 5$$

$$= 0.2 \times 5 = 1.0\,kWh$$

Total Power Used by All Appliances (in 5 hours)

$$Total = 0.05 + 0.30 + 0.50 + 1.0$$

$$= 1.85\,kWh$$

Appliance	Energy Used in 5 hours (kWh)
LED Light	0.05 kWh
Laptop	0.30 kWh
TV	0.50 kWh
Fridge	1.00 kWh
Total	**1.85 kWh**