CBCS SCHEME

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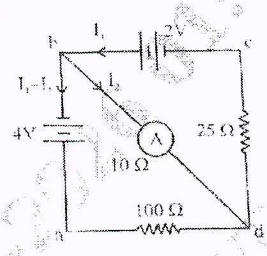
1BESC104B

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.

		Module – 1	M	L	C
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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Question Paper Solution of Introduction to Electrical Engineering (1BESC104B)

December 2025 / January 2026

Q1) a) List differences between conventional and non-conventional energy sources (7M)

Conventional sources	Non-conventional sources
i) Conventional energy such as thermal powers are tapped and used abundantly at present	i) Non-conventional source of energy such as solar energy are not used frequently and in large scale
ii) These uses are practiced for a long time.	ii) Their uses are comparatively more recent
iii) Most of these sources cause pollution when used	iii) Most of these do not cause pollution when used
iv) These sources are limited & exhaustible	iv) These sources are abundant & in exhaustible
v) These sources of energy are non renewable	v) These sources of energy are renewable
vi) They are not replenished continuously. They are formed over a million year	vi) They are replenished continuously by natural processes
vii) They are used extensively at a higher rate than the non-conventional sources	vii) They are not used used as extensively as conventional sources

Q1) b) State Ohm's law & mention its limitations (6M)

- Statement: The temperature remaining constant, the current flowing through any conductor is directly proportional to the potential difference between the two ends of the conductor.

$I \propto V$ when temperature is constant

i.e $I = \frac{V}{R}$

where R is constant, known as the resistance of the conductor

- Ohm's law can be applied to both AC & DC circuits.

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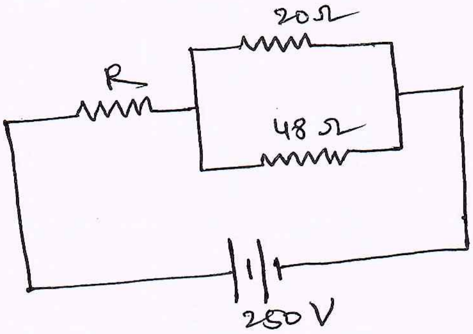
- Limitations of Ohm's law:

i) Ohm's law does not hold good for non metallic conductors such as silicon carbide.

ii) Ohm's law also does not hold good for non-linear devices such as zener diodes, Voltage regulators etc.

iii) Ohm's law does not hold good to arc lamps because of the non-linear characteristics of the arc produced.

Q17 c) A resistance R is connected in series with a parallel circuit comprising of 20 Ω & 48 Ω. The total power dissipated in the circuit is 1000 W & applied voltage is 250V. Calculate R. (7M)



power dissipated,

$$P = \frac{V^2}{R_T} = 1000$$

$$\therefore P = \frac{250^2}{R_T} = 1000$$

$$\therefore R_T = \frac{250^2}{1000} = 62.5\ \Omega$$ where R_T – total resistance

Now $R_T = R + \frac{20 \times 48}{(20+48)}$

Substituting the values we get R as

$$62.5 = R + \frac{960}{68}$$

$$\therefore R = 62.5 - 14.12$$

$$\therefore R = 48.38\ \Omega$$

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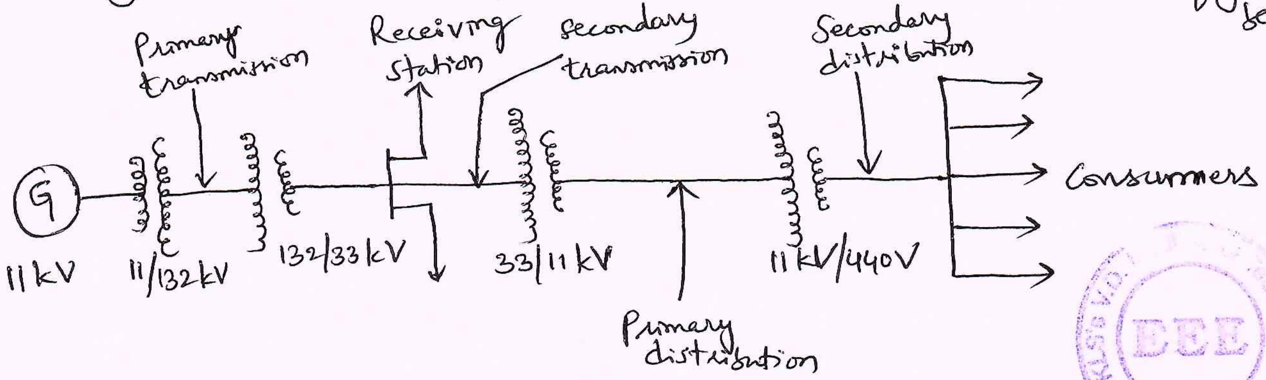
Q27 a) Draw and explain simple single line diagram of a power supply system including generation → transmission → distribution (7 M)

- Single line diagram is the representation of power system using the simple symbols for each component. It is the network which shows the main connections & arrangement of system components along with their data.

- Single line diagram of electrical power system is shown in figure below.



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- Generating station (G):

There electric power is produced by 3-ϕ alternators operating in parallel. The usual generating voltage is 11 kV due to technical considerations.

- Primary transmission:

The electric power produced at 11 kV is stepped up to 132 kV with the help of 3-ϕ step up transformers. Then the electric power at 132 kV is transmitted by 3-phase 3-wire overhead transmission system.

- Secondary transmission:

The primary transmission lines terminate at the Receiving Station (RS). At the RS, the voltage is stepped down to 33 kV using 3-phase stepdown transformer. From the RS, the electric power is transmitted at 33 kV by 3-phase 3-wire over head transmission system to various substation (SS) located at the strategic points in the city.

- Primary distribution:

The secondary ~~distribution~~ transmission lines terminate at the substations where the voltage is further reduced along the road sides of the city.

This 11 kV is generally supplied to the large consumers who were handling their own substation.

- Secondary distribution :

The primary distribution lines is delivered to distribution substation located near the consumers localities & step down the voltage to 440V for secondary distribution.

Here voltages between any two phases is 440 V & between any one phase & neutral is 230V. Therefore secondary distribution system consists of feeders, distributors & service mains.

Q2) b) State and explain Kirchoff's Laws (6 M)

- Kirchoff enunciated two laws which enables us to find the currents flowing in an electric circuit and voltages across the various elements of the circuit. These laws form the basis for the study of electrical circuits. The two laws are (i) Current law & (ii) Voltage law

i) Current Law :

The algebraic sum of all the currents meeting at any junction of an electrical circuit is zero.

i.e $\Sigma I = 0$

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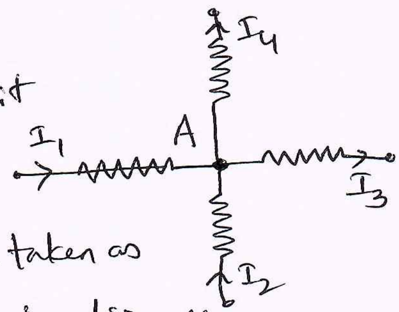


- Fig. shows the junction 'A' of an electric circuit at which four currents I_1, I_2, I_3 & I_4 meet.

- All the currents flowing towards the junction are taken as +ve & all the currents flowing away from the junction are taken as -ve. Then according to Kirchoff's current law

$$I_1 + I_2 - I_3 - I_4 = 0 \Rightarrow I_1 + I_2 = I_3 + I_4$$

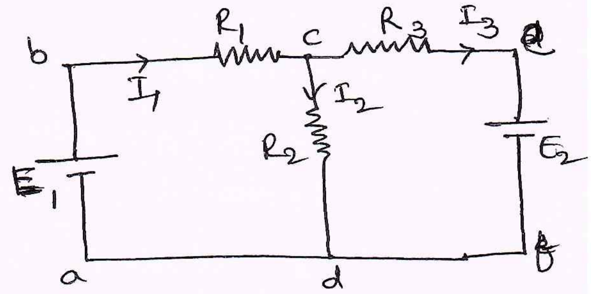
Kirchoff's current law can also be stated as "At any junction of an electric circuit, the sum of all the currents entering the junction is equal to the sum of all the currents leaving the junction."

(ii) Voltage Law :

In any closed electrical circuit, the algebraic sum of all the emfs and the resistive drops is equal to zero.

i.e $\Sigma E + \Sigma IR = 0$

- All the voltage rises are taken as +ve and all the voltage drops are taken as -ve



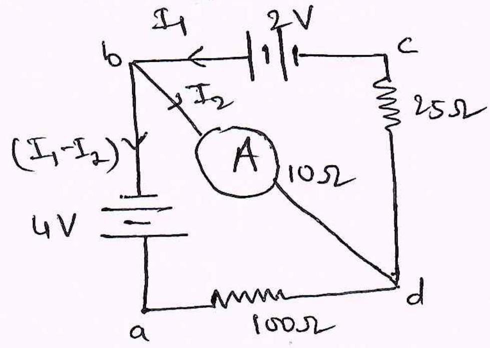
- For loop abcda :

$E_1 - I_1R_1 - I_2R_2 = 0$

For loop dcefd :

$I_2R_2 - I_3R_3 - E_2 = 0$

Q.2) 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 10Ω. (7 M)



For loop abda :

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

$100I_1 - 110I_2 - 4 = 0$ —— ①

For loop bcdb :

$-2 + 25I_1 + 10I_2 = 0$ —— ②

Solving ① & ② we get

$I_2 = 26.7\,mA$

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Q3) a) Define i) Amplitude ii) RMS value iii) Average value iv) Form factor v) Peak factor. with respect to sinusoidally varying quantity. (5M)

i) Amplitude (E_m):

The maximum value of the emf induced in the conductor is called the amplitude.

ii) RMS Value:

The effective value or rms value of an alternating current is equal to that steady current, which produces the same amount of heat as produced by the alternating current, when passed through the same resistance for the same time.

iii) Average Value:

The average value of an alternating current is equal to that steady current which transfers the same amount of charge, as transferred by the alternating current across the same circuit and in the same time.

iv) Form factor (K_f):

The form factor of an alternating quantity represented by the sinusoidal waveform is defined as the ratio of its rms value to its average value.

$$K_f = \text{Form factor} = \frac{\text{rms value}}{\text{average value}} = \frac{I}{I_{av}} = \frac{0.707 I_m}{0.637 I_m} = 1.11$$ for sine wave

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v) Peak factor (K_p):

The peak factor of an alternating quantity, represented by the sinusoidal waveform is defined as the ratio of its maximum value to its rms value.

$$K_p = \frac{\text{max. value}}{\text{rms value}} = \frac{I_m}{0.707 I_m} = 1.414$$ for sine wave

Q3) b) Distinguish clearly between i) balanced and unbalanced supply & ii) balanced and unbalanced load (8 M)

(i)

Balanced supply	Unbalanced supply
a) All the 3 phase voltages are equal in magnitude & separated by 120° phase angle	a) Phase voltages are unequal in magnitude &/or not exactly 120° apart
b) All three phase loads are equal	b) Loads on 3 phases are unequal
c) Neutral current ideally zero	c) It is non-zero
d) Power distribution equal in all phases	d) Unequal power distribution among phases.

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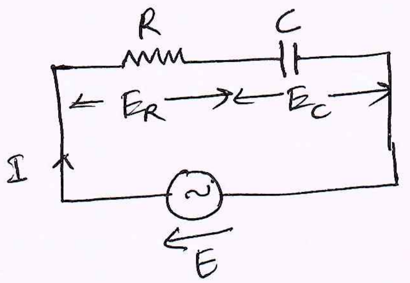
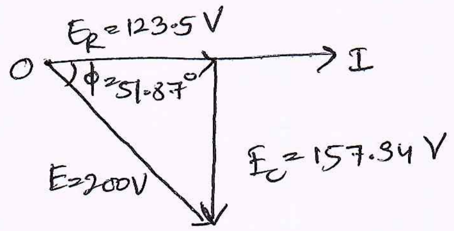
(ii)

Balanced load	Unbalanced load
a) All three phase loads have equal impedance & identical power factor	a) Phase loads have unequal impedance and/or different power factors
b) magnitude of Current is equal in all 3 phases	b) Different magnitudes in each phase
c) Equal voltage drop in each phase	c) Voltage drops are unequal
d) Equal power sharing by all phases	d) Unequal power sharing among phases
e) Produces constant torque in motor loads	e) Produces pulsating torque & possible motor damage

Q3) c) A circuit consisting of a resistance of 25 Ω and a capacitance of 100 μF connected in series. A supply of 200 V at 50 Hz is applied across the circuit. Find current, power factor and power consumed by the circuit (7M)





$$X_C = \frac{1}{2\pi f C} = \frac{1}{2 \times \pi \times 50 \times 100 \times 10^{-6}} = 31.85\ \Omega$$

$$Z = \sqrt{R^2 + X_C^2} = \sqrt{25^2 + 31.85^2} = 40.48\ \Omega$$

$$I = \frac{E}{Z} = \frac{200}{40.48} = 4.94\ A$$

$$p.f = \frac{R}{Z} = \frac{25}{40.48} = 0.617 \text{ leading}$$

$$P = EI\cos\phi = 200 \times 4.94 \times 0.617 = 609.59\ W$$

To draw vector diagram we can calculate,

$$E_R = IR = 4.94 \times 25 = 123.5\ V$$

$$E_C = IX_C = 4.94 \times 31.85 = 157.34\ V$$

$$\phi = \tan^{-1}\frac{X_C}{R} = \tan^{-1}\frac{31.85}{25} = 51.87°$$

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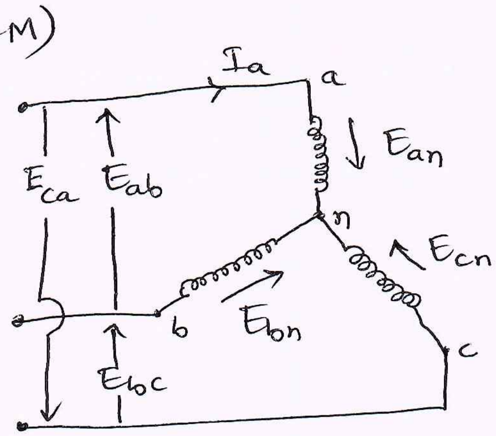
Q4) a) In a 3-phase star connection, find the relation between line & phase values of current & voltages (7M)



- Here E_{an}, E_{bn} & E_{cn} are the phase voltages and each one of them is equal to E_{ph}.
- E_{ab}, E_{bc} & E_{ca} are the line voltages and each of them is equal to E_l.
- Here we observe that currents flowing through the lines are the same as the current flowing through the phases.

Hence line current = phase current i.e. $I_l = I_{ph}$

The line voltage E_{ab} is given by

$$E_{ab} = E_{an} + E_{nb}$$
$$= E_{an} - E_{bn}$$

$$\cos 30^\circ = \frac{E_{ab}/2}{E_{an}}$$

$$\therefore E_{ab} = 2 E_{an} \cos 30^\circ = \sqrt{3} E_{an}$$

$$\therefore E_l = \sqrt{3} E_{ph}$$

line voltage $= \sqrt{3}$ phase voltage

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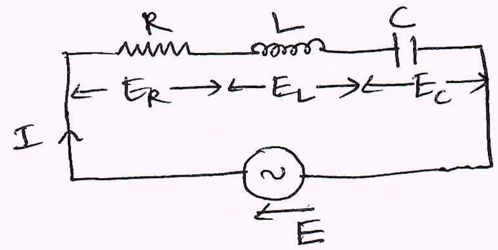
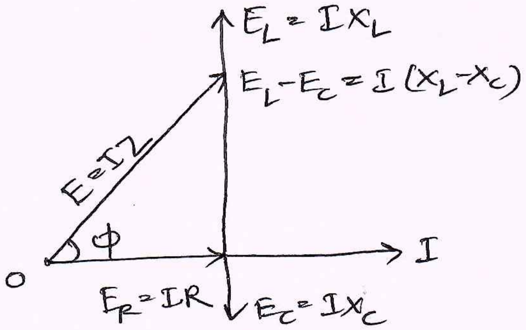
Q4) b) Derive an equation for power consumed in RLC series circuit (7M)



Consider an R-L-C series circuit as shown above, to which an alternating voltage of rms value 'E' is applied due to which, an rms current I flows through the circuit. 3 cases can be discussed.

case 1 : When $X_L > X_C$



We observe from vector diagram that current lags the voltage by an angle ϕ.

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

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

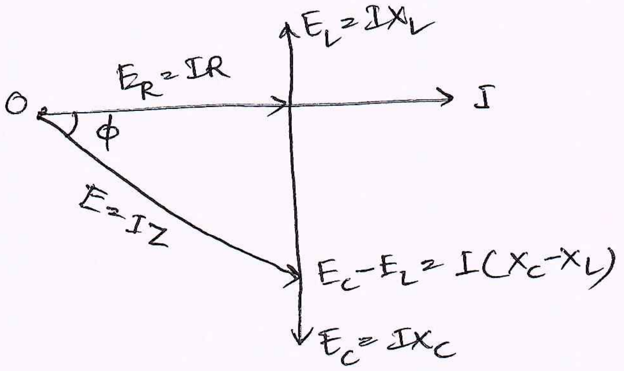
The circuit is similar to an R-L series circuit

If $e = E_m \sin \omega t$

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

Hence $P = EI \cos\phi$

Case 2: When $X_L < X_C$



From vector diagram, it is observed that, the current leads the voltage by an angle ϕ.

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

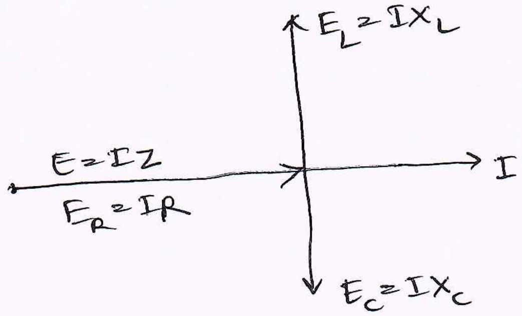
where $Z = \sqrt{R^2 + (X_C - X_L)^2}$

The circuit is similar to an R-C series circuit

If, $e = E_m \sin \omega t$ then $i = I_m \sin(\omega t + \phi)$

Power consumed is given by, $P = EI\cos\phi$

Case 3: When $X_L = X_C$



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When the inductive reactance is equal to capacitive reactance, the vector diagram is given above.

E_L & E_C cancel each other.

The current is in phase with the voltage and the circuit behaves as a pure resistance circuit.

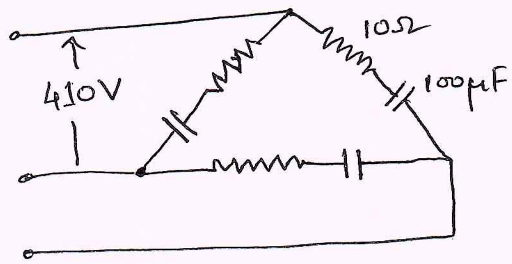
Hence $Z = R$

If $e = E_m \sin \omega t$

then $i = I_m \sin \omega t$

& power consumed is given by $P = EI$

Q4) c) A delta connected load consists of a resistance of 10Ω & a capacitance of 100 μF 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 (6M)



$$X_C = \frac{1}{2\pi f C}$$

$$= \frac{1}{2 \times 3.14 \times 50 \times 100 \times 10^{-6}}$$

$$X_C = 31.85\ \Omega$$

$$Z_{ph} = \sqrt{10^2 + 31.85^2} = 33.38\ \Omega$$

$$V_{ph} = V_l = 410\ V$$

$$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{410}{33.38} = 12.28\ A$$

$$I_l = \sqrt{3}\, I_{ph} = \sqrt{3} \times 12.28$$

$$I_l = 21.27\ A$$

$$P.f = \frac{R}{Z} = \frac{10}{33.38} = 0.3 \text{ leading}$$

$$\text{Power} = \sqrt{3}\, E_l I_l \cos\phi = \sqrt{3} \times 410 \times 21.27 \times 0.3$$

$$P = 45.31\ kW$$

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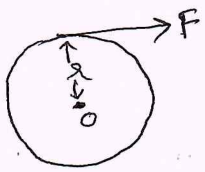
Q5) a) Derive the torque equation of a DC motor. (7M)

- Torque is the turning moment about an axis.
  It is equal to the product of force & the radius at which it acts.



- Consider the armature of the DC motor to have a radius 'r' & let 'F' be the force acting tangential to its surface. The torque exerted by the force on the armature is given by

$$T_a = F \times r \text{ --- } Nm$$

The work done by this force F, in the one revolution is given by

W = Force × distance covered in one revolution

$W = F \times 2\pi r$ --- W-S

The power developed by the armature = Work done in one second

$= F \times 2\pi r \times$ No. of revolutions per second

$= F \times 2\pi r \times \frac{N}{60}$

$= \frac{2\pi N}{60} (F \times r) = \frac{2\pi N T_a}{60}$ --- W

We can also write

$$\frac{2\pi N T_a}{60} = E_b I_a = \frac{\phi Z N P}{60 A} I_a$$

$$\therefore T_a = \frac{1}{2\pi} \phi Z I_a \left(\frac{P}{A}\right) \text{ --- Nm}$$

$$T_a = 0.159 \phi Z I_a \left[\frac{P}{A}\right] \text{ --- Nm}$$

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Q5) b) With a neat sketch explain the construction of the various parts of a DC machine (8M)

- A DC machine mainly consists of two parts i) stationary part & ii) Rotating part.
- The stationary part produces a constant magnetic flux and the rotating part converts the mechanical energy into electrical energy. The stationary & rotating parts are separated by a small air gap.

- The stationary part consists of i) Yoke ii) Main poles along with the pole shoes and pole coils iii) Base plate iv) Lifting eye v) Brush box with brushes vi) Terminal box

- The rotating parts are i) Armature ii) Armature windings. iii) Commutator & iv) Shaft.

- Yoke: Yoke forms the outer cover for the DC generator & is cylindrical in shape. Yoke is made up of cast iron or cast steel.

- Main Poles, Pole shoes and Pole Coils:

The main poles are made of alloy steel of high relative permeability.
The pole core is laminated to reduce eddy currents.
The poles are fixed to the yoke with the help of bolts.
The pole shoes are fixed to the pole core by means of counter sunk screws.
The pole shoes support the field coils, which are former wound and fixed on the pole cores.

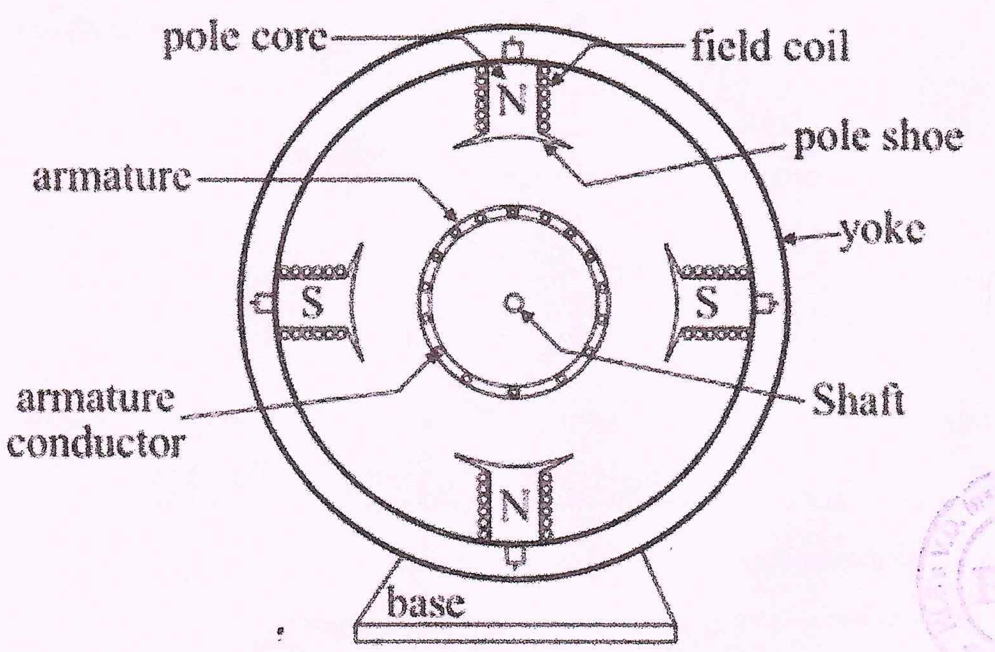

Figure - DC Machine Construction

- Armature:

The armature consists of armature core and armature winding. The armature core is made of silicon steel laminations.
There are slots cut uniformly on the outer periphery of the armature core and armature conductors are placed in these slots as shown in above figure.

- Armature windings:

The armature conductors are not only insulated from one another but also from the armature slots. The armature conductors are connected together either as a lap winding or a wave winding.

- Commutator:

Commutator converts the alternating emf generated in the armature windings

- Shaft and bearings :

The shaft of the DC generator is rotated by a prime mover, due to which, the armature fixed to it also rotates.

Roller & ball bearings are used in the DC machines.

Q5)c) Determine the total torque developed in a 250 V, 4 pole DC shunt motor with lap winding accomodated in 60 slots, each containing 20 conductors. The armature current is 50A and the flux per pole is 23 mWb. (5M)

$$T_a = 0.159\, \phi Z I_a \left(\frac{P}{A}\right)$$

$$T_a = 0.159 \times 23 \times 10^{-3} \times 60 \times 20 \times \frac{4}{4} \times 50$$

For lap winding $P = A = 4$

$$T_a = 4388.4 \times 10^{-3} \times 50$$

$$T_a = 219.42 \text{ N-m}$$

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OR

[6a] Derive an EMF equation for DC generator with usual notations. [6M]

→ Z = Total no. of armature conductors

ϕ = Useful flux per pole in Webers.

N = Speed of armature in rpm.

P = No. of poles.

A = No. of parallel paths.

The flux cut by conductor in one revolution = $P\phi = d\phi$

Time taken by conductor to make one rev = $\frac{60}{N}$ sec = dt

The EMF induced in one conductor $= \frac{d\phi}{dt} = \frac{P\phi N}{60}$ volts.

The emf induced per parallel path = emf induced per conductor × No. of conductor per llel path.

$$E = \frac{\phi P N}{60} \times \frac{Z}{A} = \frac{P\phi N Z}{60A} \text{ volts.}$$

for lap winding (A = P), $E = \frac{\phi Z N}{60}$ volts.

for wave winding (A = 2), $E = \frac{P\phi N Z}{120}$ volts.

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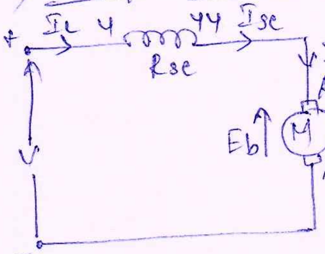
[6b] Explain the following characteristics of a DC series motor.
i) Torque vs armature current ii) Speed vs armature current [8M]

→ i) Torque Vs armature Current : (T_a/I_a)

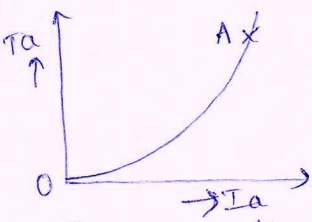


Fig①

* Fig① represents a DC series motor on load. As the load on motor increases, the current through the series field winding also increases & hence flux produced also increases. The torque eqn of a DC motor is given by, $T_a = 0.159\phi Z I_a\left(\frac{P}{A}\right)$

or $T_a \propto \phi I_a$, but $\phi \propto I_a$, ∴ $T_a \propto I_a^2$

But after saturation, the flux remains constant & $T_a \propto I_a$.



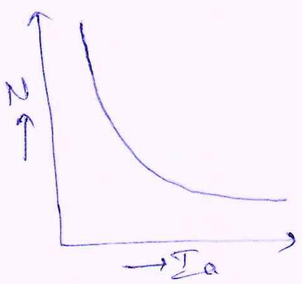
Fig②

* The variation of Ta with respect to Ia is as shown in fig ②.

* Upto saturation i.e. upto point A, $T_a \propto I_a^2$ & hence the curve is a parabola.

After saturation i.e, beyond point A, $T_a \propto I_a$ and hence the curve is a straight line. From the characteristics, we find that the starting torque of a DC series motor is very high.

b) Speed Vs armature current : (N / I_a)



* When load on series motor increases ϕ & I_a increases
* According to back emf eq^n (E_b) $N \propto \frac{1}{\phi}$ but $\phi \propto I_a$

$\therefore N \propto 1/I_a \rightarrow (1)$

* From the characteristics, we observe that, as the load increases, the speed decreases over a wide range. Hence, a D.C. series motor is considered as a variable speed motor.
* At no load, I_a is very small & hence the speed will be dangerously high as per eq^n (1).
* Hence, if a D.C series motor is started without any load on it, the speed is very high & it may run out of the foundation due to the centrifugal forces set up. Hence a D.C series motor should never be started without load.

6 c) The armature of an 8 pole DC generator has 960 conductors & runs at 400 rpm. 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 400 V, if the armature is wave connected. [6M]

Given: $P = 8$, $N = 400$ rpm
$Z = 960$ conductors, $\phi = 40$ mWb
$E = ?$, $N = ?$ when $E = 400V$.

→ When lap connected:

$$E = \frac{\phi Z N P}{60A} = \frac{40 \times 10^{-3} \times 960 \times 400 \times 8}{60 \times 8} = \underline{256 V}.$$

When wave connected:

$$E = \frac{\phi Z N P}{60A} \quad \text{i.e.} \quad 400 = \frac{40 \times 10^{-3} \times 960 \times N \times 8}{60 \times 2}$$

$\therefore N = \underline{156.25}$ rpm

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Module-4

[7a] Derive the emf equation of a transformer and hence obtain the voltage and current transformation ratios. [7M]

→ When an alternating voltage $V_1 = V_m \cdot \sin\omega t$ of rms value $V_1 = V_m/\sqrt{2}$ is applied to the primary winding of the transformer the alternating current flowing through the primary winding produces an alternating flux ϕ.

emf e_1 & e_2 are induced in 1° & 2° winding resply,

$$e_1 = -N_1 \cdot \frac{d\phi}{dt} \rightarrow (1)$$

As the 1° applied voltage is sinusoidal in nature, the current it drives & resulting flux are also sinusoidal.

$$\phi = \phi_m \cdot \sin\omega t \rightarrow (2)$$

Substituting (2) in (1)

$$e_1 = -N_1 \cdot \frac{d}{dt}(\phi_m \sin\omega t)$$

$$= -N_1 \cdot \omega\phi_m \cos\omega t = -2\pi f N_1 \phi_m \cos\omega t = 2\pi f N_1 \phi_m \sin(\omega t - 90°) \rightarrow (3)$$

From (2) & (3), we can find that the induced emf lags the flux by 90°.

$$E_{m1} = 2\pi f N_1 \cdot \phi_m \rightarrow (4)$$

$$E_1 = \frac{E_{m1}}{\sqrt{2}} = \frac{2\pi f N_1 \cdot \phi_m}{\sqrt{2}}$$ The rms value of emf induced in 1° winding.

i.e $\boxed{E_1 = 4.44 f \phi_m N_1}$ → Emf induced in 1° winding.

llly, $\boxed{E_2 = 4.44 f \phi_m N_2}$ → Emf induced in 2° winding.

$$\therefore \frac{E_2}{E_1} = \frac{N_2}{N_1} = K,$$ the transformation ratio.

also $$\frac{E_1}{N_1} = \frac{E_2}{N_2}.$$

∴ The emf induced per turn in both primary and secondary winding is the same.

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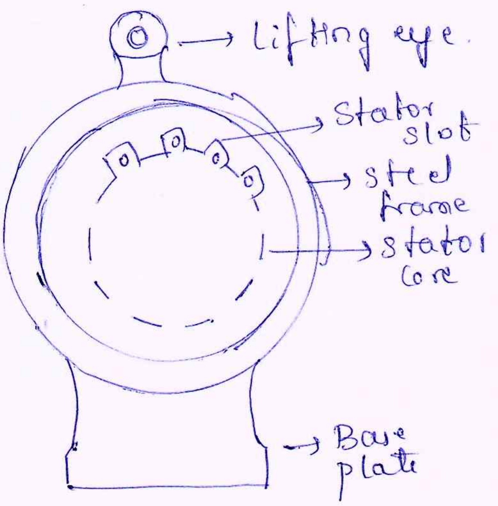
7b]. Explain the construction and working of 3-phase induction motor. [6M]

→ Construction



* 3∅ IM mainly consist of two parts
i) stator ii) Rotor.

* Stator & rotor are seperated by a small air gap of 0.4mm to 4mm depending on the rating of motor.

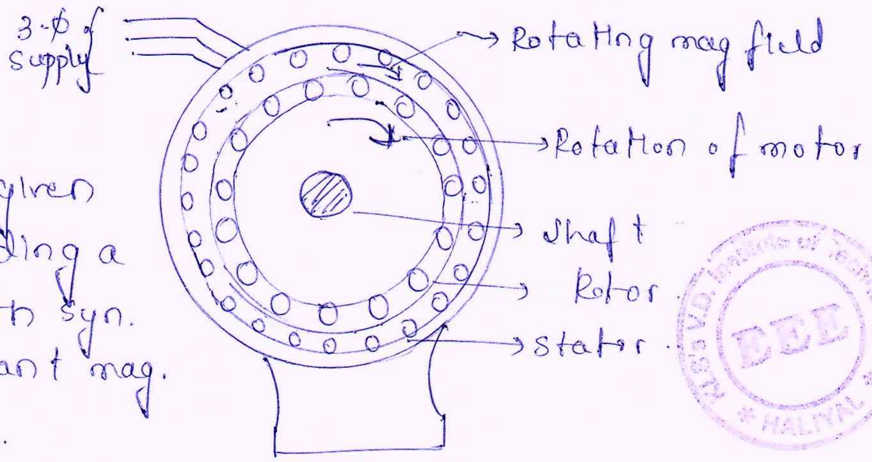
* stator consist of a steel frame & cylindrical core which is madeup of thin laminations of a silicon steel to reduce eddy current & hysterisis losses.

* The winding are wound for definite no. of poles depending on the requirement of speed as given by,

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

* The rotor is the rotating part of the IM & is mounted on the shaft of the motor to which mechanical load can be connected.

Working Principle :



* When a 3-∅ supply is given to the 3-∅ stator winding a rotating mag. field with syn. speed N_s & with constant mag. of 1.5 ∅m is produced.

* This mag. field sweeps across stator conductor & hence an emf is induced in the rotor conductors.

* The speed of the rotor gradually increases & tries to catchup with speed of rotating mag. field, but it fails to reach, because if it catch up with speed of mag. field, relative speed becoms zero.

* Hence, rotor will always rotates at a speed slightly less than the syn. speed.

[7c] A 50 kVA, 3300/330 V, single phase transformer ~~and hence~~ has iron loss and full load copper loss of 400 W & 600 W respectively. Calculate the efficiency at half full load & 0.9 pf. [7M]

→ $\eta = \dfrac{x \times kVA \times 1000 \times p.f}{(x \times kVA \times 1000 \times pf) + W_i + x^2 W_{cu}}$

Given, $x = 1/2$
& $pf = 0.9$
$W_i = 400$
$W_{cu} = 600$

$\eta_{1/2 fl, 0.9pf} = \dfrac{1/2 \times 50 \times 1000 \times 0.9}{(1/2 \times 50 \times 1000 \times 0.9) + 400 + (1/2)^2 \times 600}$

$= 0.976 \Rightarrow 97.6\%$ //

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OR

[8a] Define slip of an induction motor. Derive an expression for effect of slip on the rotor frequency. [7M]

→ The difference between the synchronous speed Ns of the magnetic field & the actual speed of the rotor N is called as the slip speed. ∴ slip speed = Ns − N.

The slip of an induction motor is defined as the ratio of the slip speed to the synchronous speed. i.e $s = \dfrac{N_s - N}{N_s}$

$\%s = \dfrac{N_s - N}{N_s} \times 100$

Effect of slip on the rotor frequency:

- When rotor is stationary, the freq. of the rotor current is the same as the supply freq.
- When IM is rotating, the freq. of the current induced in the rotor conductors is proportional to the slip speed.
- If f' is the freq. of the induced current in rotor.

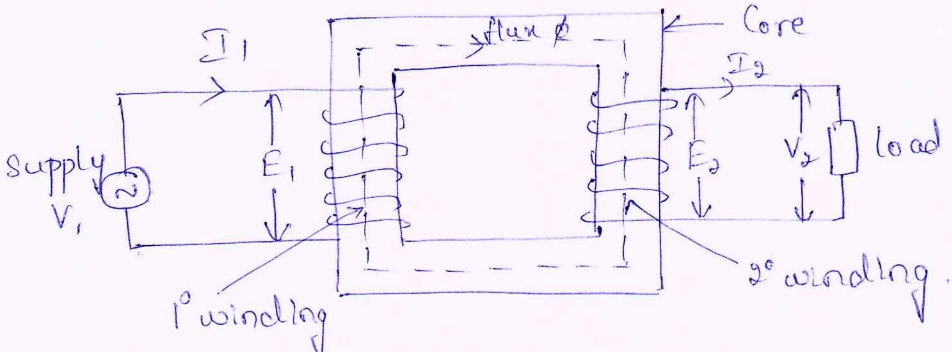
then, $N_s - N = \dfrac{120 f'}{P} \rightarrow (1)$ But $N_s = \dfrac{120 f}{P} \rightarrow (2)$.

from eq^n (1) & (2) we get, $\dfrac{N_s - N}{N_s} = \dfrac{f'}{f} = s$. ∴ $f' = sf$

- The frequency of the rotor current is slip times the freq. of the supply.

[8b] Explain the working principle of single-phase transformer and its necessity in power system. [7M]

→



Working Principle:

- A transformer works on the principle of Mutual Induction between two magnetically coupled coils.
- When a primary winding is connected to an alternating voltage of rms value V_1 volts, an alternating current flows through the 1° winding & sets up an alternating flux ϕ in the material of the core.

$$e_1 = -N_1 \frac{d\phi}{dt} \rightarrow (1) \quad \& \quad e_2 = -N_2 \cdot \frac{d\phi}{dt} \rightarrow (2)$$

, $N_1 \rightarrow$ No. of 1° turns, $N_2 \rightarrow$ No. of 2° turns.

from eqns (1) & (2),

$$\frac{e_2}{e_1} = \frac{N_2}{N_1} = \frac{E_2}{E_1} \Rightarrow \therefore \frac{E_2}{E_1} = \frac{N_2}{N_1} = K \rightarrow (3).$$

K is known as transformation ratio of transformer.

- As the power transferred from the primary winding to the 2° winding is same,

Power i/p to the 1° winding = Power o/p from the 2° winding

i.e $E_1 I_1 = E_2 I_2$

i.e $\frac{E_2}{E_1} = \frac{I_1}{I_2} = K \rightarrow (4)$.

From eqn (3) & (4), $\frac{E_2}{E_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = K \rightarrow (5)$

- The direction of emf E_1 & E_2 induced in the 1° & 2° windings are such that, they always oppose the 1° applied voltage V_1. Necessity : As the transformer is static apparatus, there are no moving parts. Hence there are no mechanical losses, hence efficiency is very high of order 95% to 98%. If transformer is used to increase the voltage it is called step-up transformer, to decrease the voltage, called as step down & if voltage not changed called as one to one transformer.

[8C] A 3 phase, 4 pole, 440V, 50 Hz induction motor runs with a slip of 4%. Find the rotor speed & frequency of the rotor current. [6M]

→ Given: 3ϕ, $P = 4$, $f = 50 Hz$, $S = 4\% = 0.04$, $N = ?$, $f' = ?$

$$N_s = \frac{120f}{P} = \frac{120 \times 50}{4} = 1500 \text{ rpm.}$$

We have, $S = \frac{N_s - N}{N_s} \Rightarrow 0.04 = \frac{1500 - N}{1500} \Rightarrow \boxed{N = 1440 \text{ rpm}}$

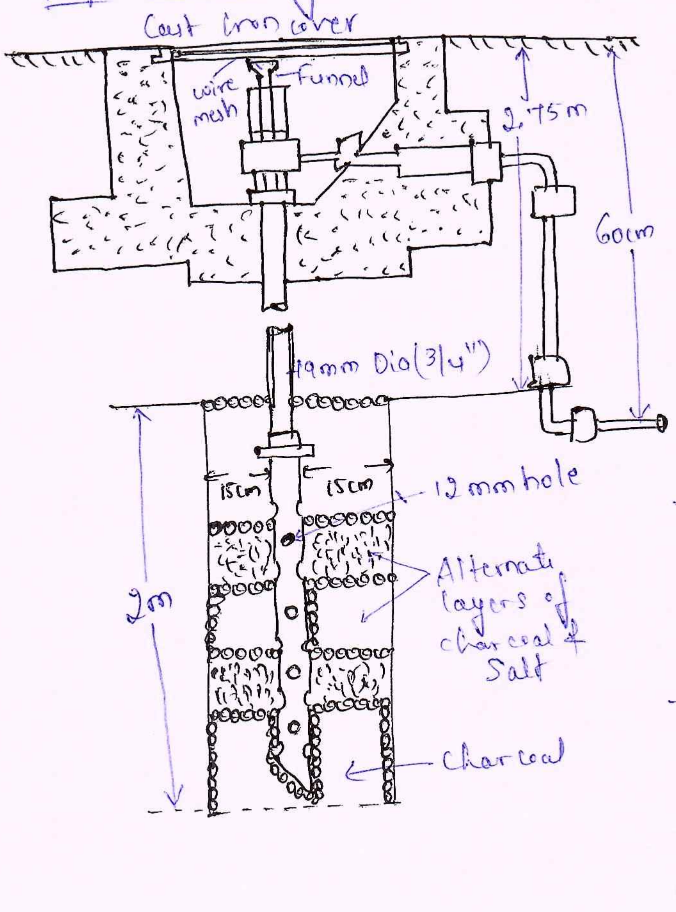
Rotor current freq. $f' = sf = 0.04 \times 50 \Rightarrow \boxed{f' = 2 Hz}$

Module - 5

[9a] What is Earthing? With a neat diagram, explain pipe earthing. [7M]

→ Earthing or grounding is to connect the body of an electrical equipment to the general mass of the earth by a wire of negligible resistance.

Pipe earthing:



- Fig. shows the method of pipe earthing in which a galvanised iron [G.I] pipe of approved length & diameter is used.
- The size of the pipe depends on the diameter of GI pipe should be placed to a depth of 4.75m.
- The pipe must be placed upright & must be placed permanently in a wet ground.
- The pipe at the bottom should be surrounded by broken pieces of coke or charcoal for a distance of about 15cm around the pipe.

- charcoal, if mixed with salt further reduces the resis-tance, therefore, the alternate layers of salt & coal is put as shown in fig.

- During summer, to maintain the moisture content, funnel should be filled with 3 to 4 buckets of water.

- The earth wire from GI pipe of 12mm diameter, should be carried in a conduit of GI pipe of dia 12.7mm, at a depth of about 60 cm below the ground.

[9b] Define Electric shock. What are the safety precaution to be taken against to avoid electric shock? [7M]

→ When a person touches the live part of electrical equipment he/she will receive an electrical shock.

* The severity of electric shock depends on voltage of wire & human body resistance.
* Max current human body can withstand for a short time 25msec is 30mA.
* The body resistance is 1 kΩ when the body is wet, if a body is neither wet nor dry its 3kΩ to 5kΩ. & when body is totally dry is 100000Ω.
* Precautions taken against to avoid electric shock:

1) Don't touch victim with bare hands when he is still in contact with electricity.
2) Immediately switch off the supply.
3) If supply is unable to turn off then separate the person from live part of elect. equipment
4) Once a victim is free, check his breathing pulse, if not normal then provide artificial respiration.

[9c] Explain what a "unit" (kWh) means in an electricity bill. Give an ex of how it's calculated for a 60W bulb used for 5 hours. [6M]

[9c] → The electrical energy consumed is expressed as units.

1 unit = 1 kWH.

i.e, 1 kWH is the electrical energy consumed by an electrical appliance of power 1 kW when it is used for one hour.

Example: 60 W bulb used for 5 hours.

Step 1: Convert watts to kilowatts.

$$60\,W = \frac{60}{1000} = 0.06\,kW$$

Step 2: Energy consumed.

$$\text{Energy} = \text{Power} \times \text{Time}$$
$$= 0.06 \times 5$$
$$= 0.30\ kWh.$$

∴ The 60W bulb consumes 0.30 units (kWh) of electricity in 5 hours.

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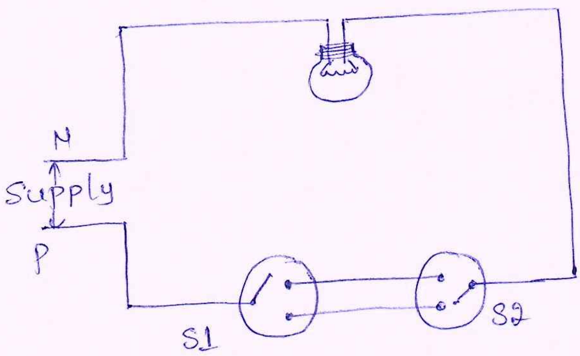
OR

[10a] With neat wiring diagram and truth table explain two way and three way control of lamp. [6M]

→ Two way control of lamp



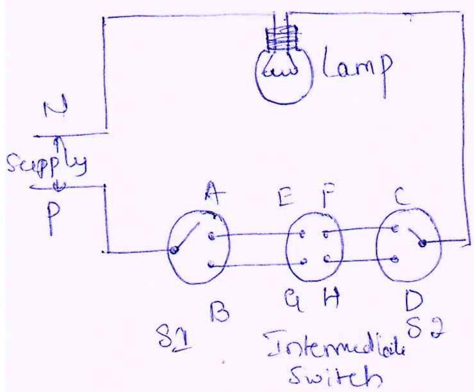
Sl. No.	Position of switch 1	Position of switch 2	Lamp Status
1	A	D	OFF
2	A	C	ON
3	B	C	OFF
4	B	D	ON

- The lamp circuits used for house wiring are quite simple & they are generally controlled from one point such as, room lighting, bathroom lighting etc.
- But in stair case wiring, it is necessary to control the

lamp circuit from two points. i.e one at the top of the stair case & the other at the bottom of the staircase.

- Figure shows a two-way control circuit of a lamp.
- When switch 1 is in position A & the switch 2 is in position D, the lamp circuit is open & the lamp doesn't glow.
- Let us say switch 1 is in downstairs & switch 2 is in upstairs.
- When switch 1 is changed to position B. lamp circuit is closed & hence the lamp glows.
- Table 1 shows the position of switches & the lamp conditions, whether it is ON or OFF.

Three-way Control of lamp:



Sl. No.	Position of S1	Position of Intermediate switch	Position of S2	status of lamp
1	A	EF, GH	C	ON
2	A	EF, GH	D	OFF
3	B	EF, GH	C	OFF
4	B	EF, GH	D	ON
5	A	EH, GF	C	OFF
6	A	EH, GF	D	ON
7	B	EH, GF	C	ON
8	B	EH, GF	D	OFF

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- In a very big corridors, godowns or workshops, it may be necessary to control a lamp from three points.
- In such cases, the circuit connection reqires two, two-way switches & an intermediate switch as shown in fig.
- Table gives positions of the various switches & the condition of the lamp.

[10b] What is fuse ? With neat diagram, explain the working principle of fuse. [7M]

→ A fuse is essentially a small piece of metal connected between two terminals mounted on an insulating base in series with circuit.

- The function of the fuse wire is to carry the normal working current safely without heating, but when the normal working current is exceeded, it should heat up rapidly to the melting point & break the circuit.

- Hence fuse is a simplest protective device used in an electrical circuit against overloading or fault.

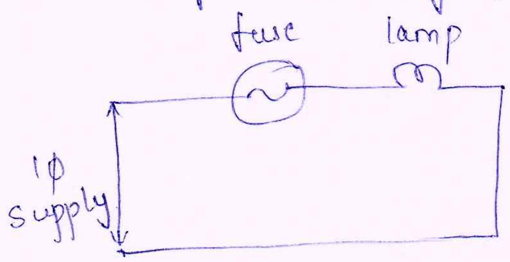
- The heat produced is given by $H = I^2Rt$, hence materia[l] used as fuse wire must have ~~given~~ high resistivity & low melting point so that wire reaches the melting point in the shortest possible time.

- The various materials like tin, lead, zinc, silver, aluminium, copper & their alloys can be used as fuse wire.

- The fusing factor of a fuse is defined as ratio of minimum fusing current to the current rating of fuse element.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Current rating of fusing element}}$$

- The value of the fusing factor is always more than one



[10C] 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. [7M]

→

1) TV = 150 W

2) Laptop = 65 W

3) LED Light = 15 W

4) Refrigerator = 200 W

Total power consumed,

Total Power = 150 + 65 + 15 + 200

= 430 W

= 0.43 kW

∴ Total power consumed by the four appliances = 430 W (or 0.43 kW)

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