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B.Tech.
(SEM I) THEORY EXAMINATION 2022-23
Fundamentals of Electrical Engineering

Time: 3 Hours | ***Total Marks: 70***

समयः 03 घण्टे | पूर्णांकः 70

Note:

1. Attempt all Sections. If require any missing data; then choose suitably.
2. The question paper may be answered in Hindi Language, English Language or in the mixed language of Hindi and English, as per convenience.

नोटः 1. सभी प्रश्नो का उत्तर दीजिए। किसी प्रश्न में, आवश्यक डेटा का उल्लेख न होने की स्थिति में उपयुक्त डेटा स्वतः मानकर प्रश्न को हल करें।
2. प्रश्नों का उत्तर देने हेतु सुविधानुसार हिन्दी भाषा, अंग्रेजी भाषा अथवा हिंदी एवं अंग्रेजी की मिश्रित भाषा का प्रयोग किया जा सकता है।

SECTION A

1. Attempt *all* questions in brief. **2 x 7 = 14**

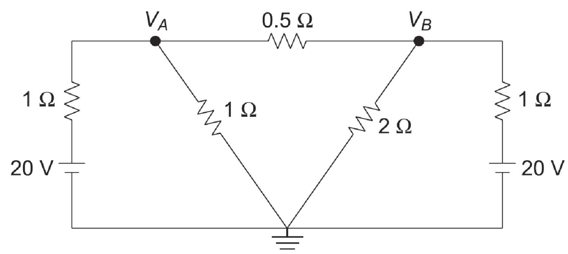
निम्न सभी प्रश्नों का संक्षेप में उत्तर दीजिए।

a.	Describe briefly the following elements with examples: (i) Unilateral & Bilateral (ii) Active & passive
	निम्नलिखित तत्वों का उदाहरण सहित संक्षेप में वर्णन कीजिए (i) एकतरफा और द्विपक्षीय (ii) सक्रिय और निष्क्रिय
b.	Describe the following elements briefly: (i)Independent Ideal Voltage source (ii) Independent Ideal Current source
	निम्नलिखित शब्दों का संक्षेप में वर्णन करें: (i) स्वतंत्र आदर्श वोल्टेज स्रोत (ii) स्वतंत्र आदर्श वर्तमान स्रोत
c.	Determine the RMS value of sinusoidal current $i= I_m \sin\alpha$ in one complete cycle.
	एक पूर्ण चक्र में साइनसोइडल करंट $i= I_m \sin\alpha$ का RMS मान निर्धारित करें।
d.	Draw the phasor diagram of a practical two-winding transformer in no-load condition.
	नो-लोड स्थिति में एक व्यावहारिक two-winding ट्रांसफॉर्मर का फेजर आरेख बनाएं।
e.	Describe briefly the different types of DC machines.
	विभिन्न प्रकार की डीसी मशीनों का संक्षेप में वर्णन कीजिए।
f.	Explain briefly the SFU.
	एसएफयू (SFU) को संक्षेप में समझाइए।
g.	What is the real power consumed by a pure inductor? Discuss with suitable diagrams.
h.	शुद्ध प्रेरक द्वारा उपभोग की जाने वाली वास्तविक शक्ति क्या है? उपयुक्त रेखाचित्रों के साथ विवेचना कीजिए।

SECTION B

2. Attempt any *three* of the following: **7 x 3 = 21**

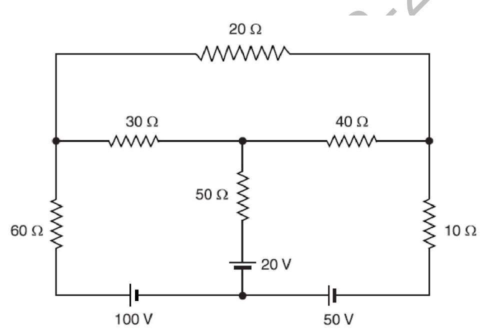
निम्न में से किसी तीन प्रश्नों का उत्तर दीजिए।

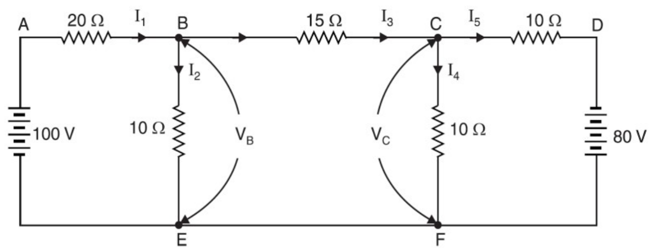
a.	Determine the current by Nodal method, through 2 ohm resistor for the network shown below? नीचे दिखाए गए नेटवर्क के लिए नोडल विधि द्वारा 2 ओम प्रतिरोध में प्रवाहित धारा का निर्धारण करें। 
b.	Derive the equation for resonant frequency in the case of a series RLC circuit. and draw the phasor diagram of resultant Voltage and Current in a series RLC circuit in resonant condition.
	श्रृंखला (series) आरएलसी (RLC) सर्किट में अनुनाद आवृत्ति के लिए समीकरण व्युत्पन्न करें। और अनुनाद की स्थिति में एक श्रृंखला (series) आरएलसी (RLC) सर्किट में परिणामी वोल्टेज और करंट का फेजर आरेख बनाएं।
c.	Describe different types of transformer losses and methods to minimize it.
	ट्रांसफॉर्मर में होने वाली विभिन्न प्रकार की हानियों तथा उन्हें कम करने के उपायों का वर्णन कीजिए।
d.	Derive the EMF equation of the DC generator.
	DC जनित्र का EMF समीकरण व्युत्पन्न कीजिए।
e.	Discuss briefly the types of batteries and explain anyone with the necessary diagram.
	संक्षेप में बैटरी के प्रकारों पर चर्चा करें और किसी एक को आवश्यक आरेख के साथ व्याख्या कीजिए।

SECTION C

3. **Attempt any *one* part of the following:** **7 x 1 = 7**

निम्न में से किसी एक प्रश्न का उत्तर दीजिए।

(a)	Determine the currents in all branches of the circuit as shown in below figure, using Mesh current method? मेश करंट विधि का उपयोग करके, नीचे दिए गए चित्र में सर्किट की सभी शाखाओं में करंट का निर्धारण कीजिए। 
(b)	Determine the currents in the various branches of the circuit shown in Figure by nodal analysis?

	नोडल विश्लेषण द्वारा दिखाए गए सर्किट की विभिन्न शाखाओं में धाराओं का निर्धारण करें? 

4. Attempt any *one* part of the following: 7 x 1 = 7

निम्न में से किसी एक प्रश्न का उत्तर दीजिए।

(a)	Derive the mathematical relationship between phase and line quantities in a 3-phase star configuration with the help of phasor diagram?
	फेजर डायग्राम की मदद से 3-फेज स्टार संरचना में फेज और लाइन राशिओं के बीच गणितीय संबंध को व्युत्पन्न करें?
(b)	Determine the mathematical expression for instantaneous power and average power in the case of R and L elements connected in series across a single phase AC supply of voltage $v = V_m \sin \omega t$. Also draw the instantaneous power waveform.
	एकल फेज एसी वोल्टेज $v = V_m \sin \omega t$ की आपूर्ति में श्रृंखला में जुड़े R और L तत्वों में तात्कालिक शक्ति और औसत शक्ति के बीच गणितीय अभिव्यक्ति निर्धारित करें। तथा तात्कालिक शक्ति का वेवफार्म भी बनाएं।

5. Attempt any *one* part of the following: 7 x 1 = 7

निम्न में से किसी एक प्रश्न का उत्तर दीजिए।

(a)	A 100 kVA, single-phase transformer has an iron loss of 600 W and a copper loss of 1.5 kW at full-load current. Calculate the efficiency at (i) full load and 0.8 lagging pf, and (ii) half load and unity pf
	एक 100 केवीए, एकल- फेज ट्रांसफार्मर में पूर्ण लोड की स्थिति में 600 W का iron loss और 1.5 kW का copper loss होता है। निम्न स्थितियों में दक्षता की गणना कीजिए। (i) पूर्ण लोड और 0.8 lagging pf, और (ii) आधा लोड और unity pf
(b)	Draw the complete equivalent circuit model of a practical transformer and explain its different parameters.
	व्यावहारिक ट्रांसफॉर्मर का पूर्ण समतुल्य परिपथ मॉडल बनाइए तथा इसके विभिन्न प्राचलों (parameters) को समझाइए।

6. Attempt any *one* part of the following: 7 x 1 = 7

निम्न में से किसी एक प्रश्न का उत्तर दीजिए।

(a)	Describe the working principle and slip-torque characteristics of a three-phase Induction motor.
	तीन-फेज इंडक्शन मोटर के कार्य सिद्धांत और स्लिप-टॉर्क (slip-torque) अभिलक्षणों

	का वर्णन कीजिए।
(b)	A six-pole, 2-circwave-connected armature of a DC machine has 300 conductors and runs at 1000 rpm. The emf generated on the open circuit is 400 V. Determine the useful flux per pole.
	एक डीसी (DC) मशीन के six-pole, 2-circwave-connected आर्मेचर में 300 कंडक्टर हैं और यह 1000 RPM पर चलता है। खुले परिपथ पर उत्पन्न विद्युत वाहक बल 400 V है। प्रति पोल उपयोगी फ्लक्स का मान ज्ञात कीजिए।

7. Attempt any *one* part of the following: 7 x 1 = 7

निम्न में से किसी एक प्रश्न का उत्तर दीजिए।

(a)	Draw the typical constructional diagram of a four-core armoured XLPE cable and write down the purpose of its different layers.
	चार-कोर युक्त XLPE केबल का विशिष्ट संरचनात्मक आरेख बनाएं और इसकी विभिन्न परतों (layers) का उद्देश्य लिखें।
(b)	Describe the classification of earthing based on the purpose, with the help of examples.
	उद्देश्य के आधार पर अर्थिंग (earthing) के वर्गीकरण का उदाहरणों की सहायता से वर्णन कीजिए।

B.TECH
(SEM I) THEORY EXAMINATION 2022-23
SOLUTION OF FUNDAMENTALS OF ELECTRICAL ENGINEERING (BEE-101)

Section A

1 (a)

(i) Unilateral and Bilateral elements

Unilateral Element: A unilateral element (**such as a diode or transistor**) conducts current only in one direction.

Bilateral Element: An element that conducts current in both directions and has the same magnitude is referred to as a bilateral element. Examples of such elements are **resistance, inductance, and capacitance.**

(ii) Active and Passive elements

Active elements are the elements of a circuit which possess energy of their own and can impart it to other element of the circuit. **Active elements are of two types : Voltage source (Ex : Battery) and Current source (Ex : Cells).**

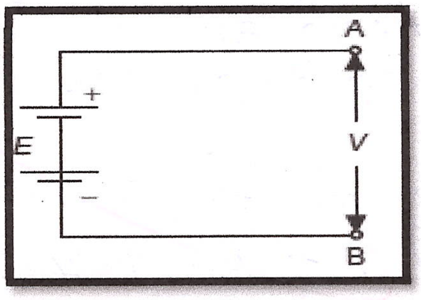
Passive elements: The passive elements of an electric circuit do not possess energy of their own. They receive energy from the sources.

Ex: Resistance, Inductance, Capacitance.

(b)

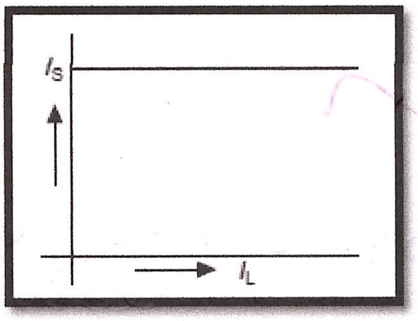
(i) Independent ideal voltage source:

A voltage source that has zero internal resistance is called an ideal voltage source. In such cases, the terminal voltage remains the same, irrespective of the value of load resistance.



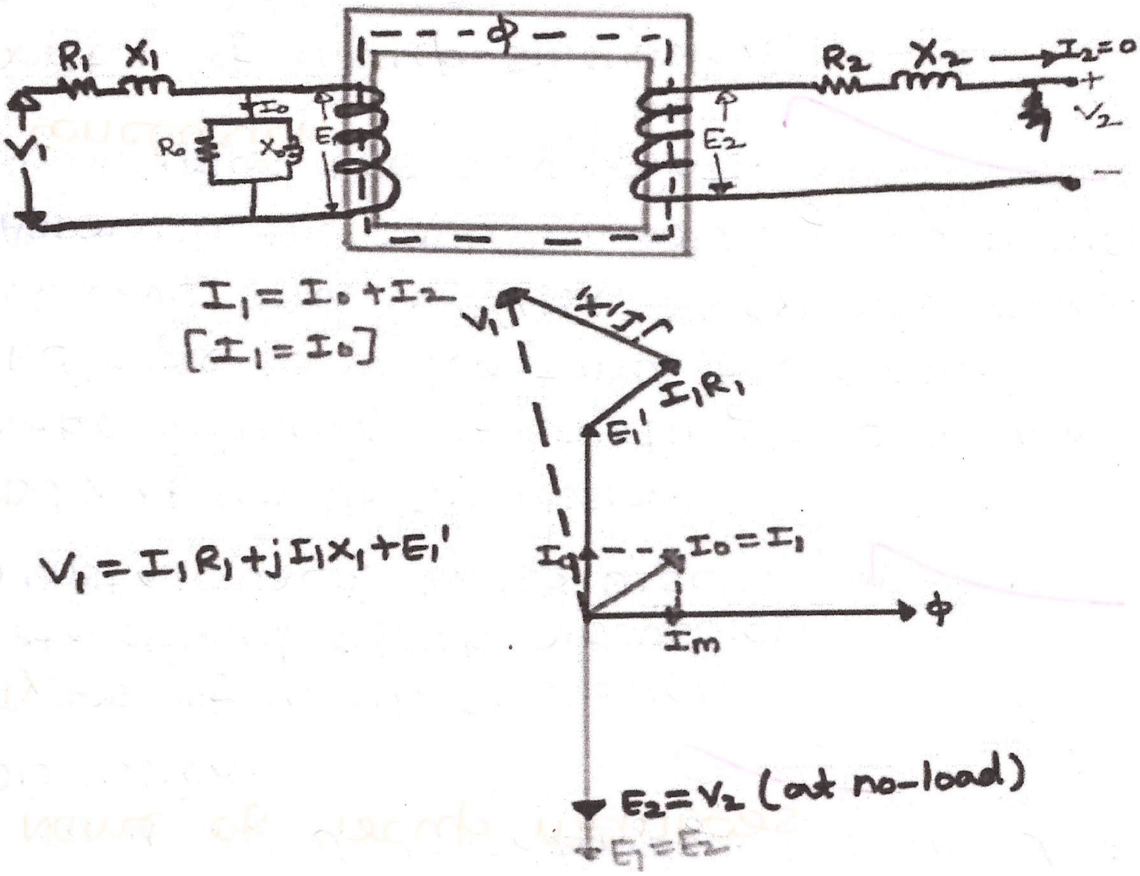
We know, Terminal voltage,
$V = E/(1+R_i/R_L)$
Because $R_i=0$
Terminal voltage, $V= E$

(ii) Independent Ideal Current Source: A current source that supplies a constant current no matter whatever is the load resistance (or impedance) is known as ideal current source. A symbolic representation of such an ideal current source is shown in the figure. The current supplied by the source should remain constant at all values of load resistance.

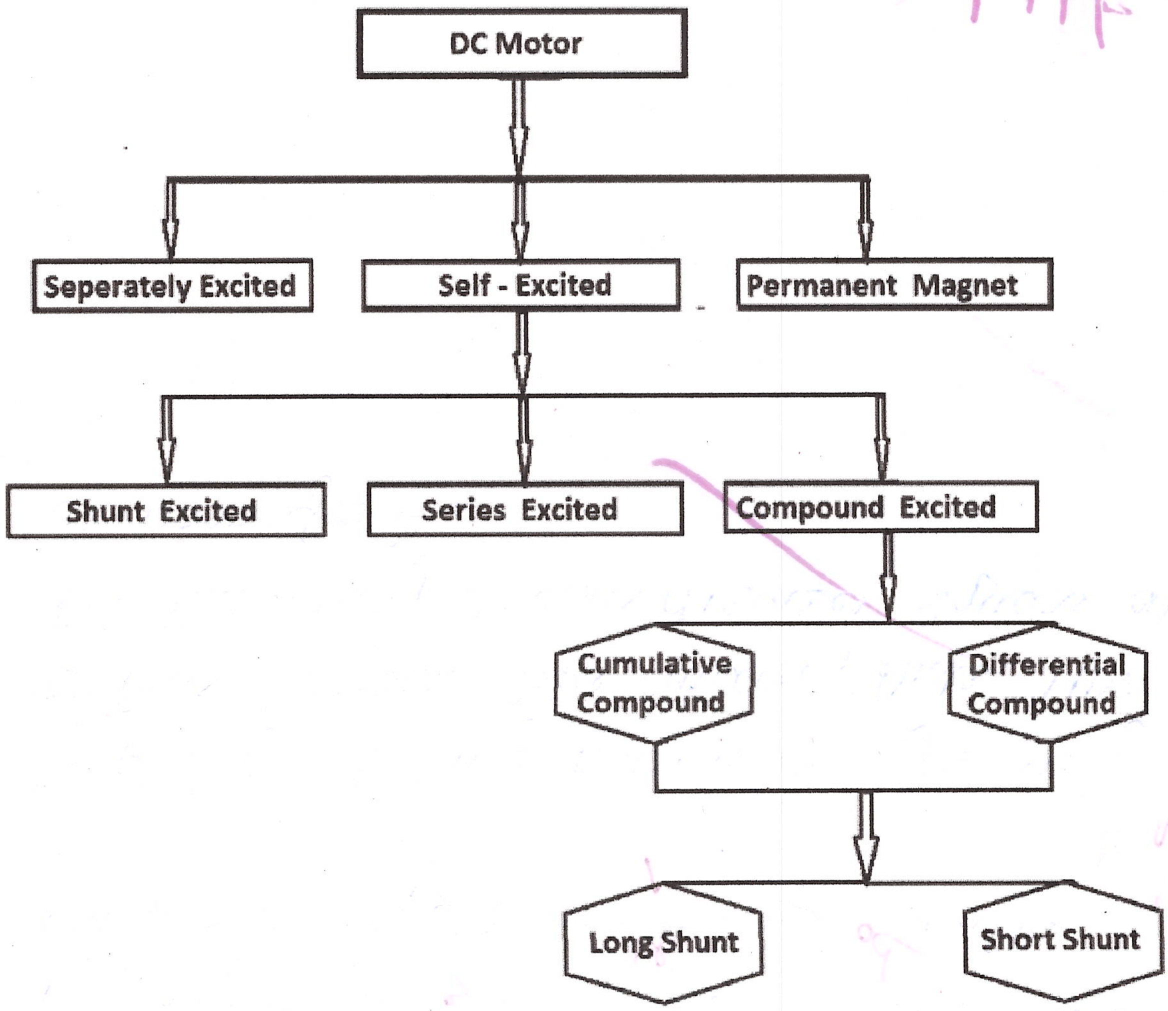


(C) The RMS value of sinusoidal current in one complete cycle is 0.707 I_m

(d) Phasor diagram of Practical two winding transformer at no-load condition



(e) Different types of DC machines



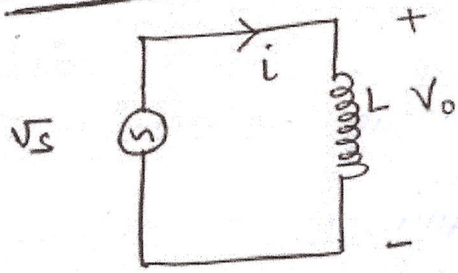
(f) Switch Fuse Unit (SFU)

Switch fuse unit is compact combination, generally metal enclosed of a switch and a fuse. It is very widely used for low and medium voltages. The ratings of switch fuse units are in the range of 30,60,100,200, 400, 600 and 800 amperes.

Switch fuse units are available as 3 pole and 4 pole units. They are developed for making capacities upto 46 kA. They can safely break, depending upon ratings, currents of the order of 3 times the load current. Switch fuse units can be installed on metal-clad switchgear.

(g) Real Power consumed in a purely inductive circuit

Pure inductive Circuit



$V_s = V_m \sin \omega t$ — ①

$V_o = L \frac{di}{dt}$

but $[V_s = V_o]$

so

$$V_s = L \frac{di}{dt}$$

$$V_m \sin \omega t = L \frac{di}{dt}$$

$$di = \frac{V_m}{L} \sin \omega t \, dt$$

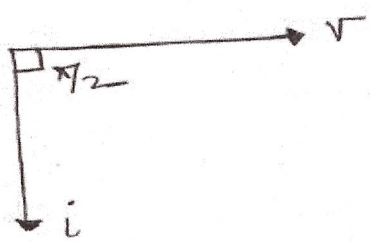
$$i = \int \frac{V_m}{L} \sin \omega t \, dt \qquad ③$$

$$i = \frac{V_m}{\omega L}(-\cos \omega t)$$

$\omega L = X_L \rightarrow$ inductive reactance

$$\left[i = \frac{V_m}{X_L} \sin(\omega t - \pi/2) \right] \quad \text{—— ②}$$

<u>NOTE</u>:→ On comparing eqn ① & ②, eqn current lags the voltage by $\pi/2$.



Power in pure inductive circuit

$$P = vi = V_m \sin \omega t \, I_m \sin(\omega t - \pi/2)$$

$$= -V_m I_m \sin \omega t \cos \omega t$$

$$= -\frac{V_m I_m}{2} (2 \sin \omega t \cos \omega t)$$

$$= -\frac{V_m I_m}{2} \sin 2\omega t$$

$$P_{avg} = \frac{1}{2\pi} \int_0^{2\pi} -\frac{V_m I_m}{2} \sin 2\omega t \, d(\omega t)$$

$\rightarrow 0$ [av. value of complete cycle is zero]

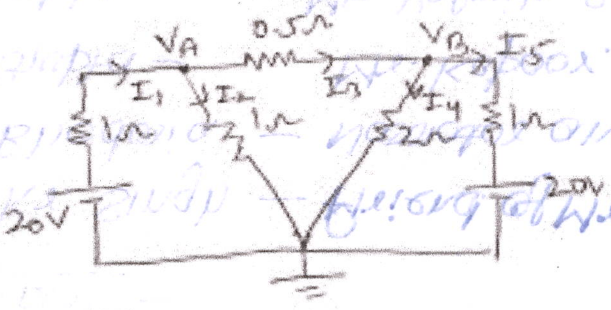
$$\boxed{P_{av} = 0}$$

Hence, the real power consumed in a purely inductive circuit is zero for a complete cycle.

Section B

(a) To calculate current through 2 ohm resistor using nodal method

2(a)



at node (A)

$$I_1 = I_2 + I_3$$

$$\frac{20 - V_A}{1} = \frac{V_A}{1} + \frac{V_A - V_B}{0.5}$$

$$20 - V_A = V_A + 2V_A - 2V_B$$

$$4V_A - 2V_B = 20 \quad \text{—(1)}$$

at node (B)

$$I_3 = I_4 + I_5$$

$$2V_A - 2V_B = \frac{V_B}{2} + \frac{V_B - 20}{1}$$

$$2V_A - 2V_B = \frac{V_B + 2V_B - 40}{2}$$

$$4V_A - 4V_B = 3V_B - 40$$

$$4V_A - 7V_B = -40 \quad \text{—(2)}$$

$$\boxed{V_A = 11V} \quad \boxed{V_B = 12V}$$

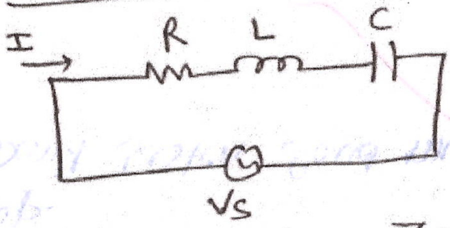
Current across 2Ω resistor

$$I_4 = \frac{V_B}{2} = \frac{12}{2}$$

$$\boxed{I_4 = 6A}$$

(b) Series Resonance

* Series or voltage resonance



$X_L = j\omega L$

$X_C = \frac{1}{j\omega C}$

$Z = R + j(X_L - X_C)$ —— (1)

NOTE: if ω is close to zero then $X_L = 0$ & $X_C = \infty$. if ω increases then $X_L \uparrow$ while $X_C \downarrow$. A point is reached when the imaginary term is zero.

let at $[\omega = \omega_0]$, j'th term $= 0$.

$X_L = X_C$

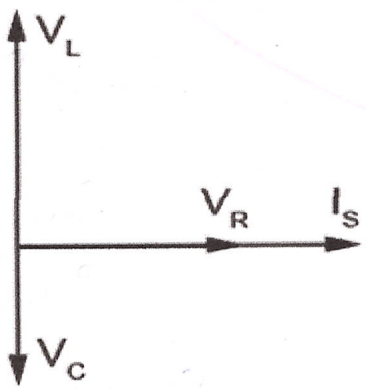
$\omega_0 L = \frac{1}{\omega_0 C}$

$\omega_0^2 = \frac{1}{LC}$

$\left[\omega_0 = \frac{1}{\sqrt{LC}} \text{ rad/sec}\right]$

$2\pi f_r = \frac{1}{\sqrt{LC}}$

$\left[f_r = \frac{1}{2\pi\sqrt{LC}} \text{ Hz}\right]$



Phasor diagram at series resonance condition

$V_L = V_C$ (at resonance)

So $V_s = V_R$

(C) Transformer losses

(1) Core Losses or Iron Losses

Eddy current loss and hysteresis loss depend on the magnetic properties of the material used for the construction of the core. So, these losses are also known as core losses or iron losses.

- **Hysteresis loss in transformer:** The reason is the reversal of magnetization in the transformer core. This loss depends on the volume and grade of the iron, frequency of magnetic reversals and value of flux density. We have the Steinmetz formula:

  $W_h = \eta B_{max}^{1.6} f V$ (watts)

  Where, η = Steinmetz hysteresis constant

  V = volume of the core in m^3

- **Eddy current loss in transformer:** The AC current is supplied to the primary winding which sets up alternating magnetizing flux in the transformer. When this flux flow to a secondary winding, it produces induced emf in it. But some part of this flux also gets linked with other conducting parts such as steel core or iron body or the transformer, which will result in induced emf in those parts, causing small circulating current in them. This current is called as eddy current. Due to the current, some energy will be dissipated in the form of heat.

(2) Copper Loss

The ohmic resistance of the transformer windings creates copper loss. The copper loss for the primary winding is $I_1^2R_1$ and for the secondary winding is $I_2^2R_2$. Where, I_1 and I_2 are current in primary and secondary winding respectively, R1 and R2 are the resistances of primary and secondary winding respectively. We can see that Cu loss is proportional to square of the current, and current depends on the load. So that copper loss in transformer varies with the load

(3) Stray Loss: The reason for the types of loss is the occurrence of the leakage field. When compared with copper and iron losses, the percentage of stray losses are less, so these losses can be neglected.

(4) Dielectric Loss

The oil of the transformer is the reason for this loss. Oil in transformer is an insulating material. When the oil in the transformer gets deteriorates then the transformer's efficiency will be affected.

Methods to reduce the energy loss in transformer:

1. Use of low resistance wire for the winding of the coil.

2. Heat loss due to eddy current can be reduced by the lamination of the iron core.
3. The heat generated can be kept to a minimum by using a magnetic material which has a low hysteresis loss. Hence, soft iron is often chosen for the core material because the magnetic domains within it changes rapidly with low energy loss.

(d) EMF equation of DC Generator

EMF eqn of DC Generator

Let $P \rightarrow$ No. of poles of the machine
$\phi \rightarrow$ flux per pole in Wb.
$Z \rightarrow$ Total no. of armature Conductors.
$N \rightarrow$ speed of armature in RPM.
$A \rightarrow$ No. of parallel paths in armature winding.

In one revolution, flux cut by one conductor

Flux cut by one Conductor $= P\phi$ Wb — (1)

Time taken to complete one revolution

$$t = \frac{60}{N} \text{ sec} \quad \text{— (2)}$$

Therefore, the avg. induced emf in one Conductor

$$e = \frac{P\phi}{60/N} = \frac{P\phi N}{60} \text{ volts} \quad \text{— (3)}$$

Now, The no. of Conductors Connected in series in each parallel path $= Z/A$.

Therefore, the avg. induced emf across each parallel path

$$E_g = \frac{P\phi N}{60} \times \frac{Z}{A} = \frac{P\phi NZ}{60A} \text{ volts} \quad \text{--- (4)}$$

i) In case of DC motor, the induced emf is called back emf (E_b) because it acts opposite to ~~DC~~ supply:

for Lap winding [A=P] $E_g = \frac{\phi NZ}{60}$ ~~volts~~

for Wave winding [A=2] $E_g = \frac{P\phi NZ}{120}$ volts.

(iv) In DC m/c, Z, P & A are constants so that

$$\boxed{E_g \text{ or } E_b \propto \phi N}$$

ϕ → flux per pole

N → speed of Rotation

(e) Battery or cells are referred to as the parallel combination of electrochemical cells. The major difference between a primary cell and the secondary cell is that primary cells are the ones that cannot be charged but secondary cells are the ones that are rechargeable.

Primary cell

Primary cells have high density and get discharged slowly. Since there is no fluid inside these cells they are also known as dry cells. The internal resistance is high and the chemical reaction is irreversible. Its initial cost is cheap and also primary cells are easy to use.

Secondary cell

Secondary cells have low energy density and are made of molten salts and wet cells. The internal resistance is low and the chemical reaction is reversible. Its initial cost is high and is a little complicated to use when compared to the primary cell.

Difference between Primary Cell and Secondary Cell

Primary Cell	Secondary Cell
Have high energy density and slow in discharge and easy to use	They have smaller energy density
There are no fluids in the cells hence it is also called as dry cells	These are made up of wet cells (flooded and liquid cells) and molten salt (liquid cells with different composition)
It has high internal resistance	It has a low internal resistance
It has an irreversible chemical reaction	It has a reversible chemical reaction
Its design is smaller and lighter	Its design is more complex and heavier
Its initial cost is cheap	Its initial cost is high

Working of Lead Acid Battery

The following chemical reactions takes place at Anode and Cathode during the charging process.

At cathode

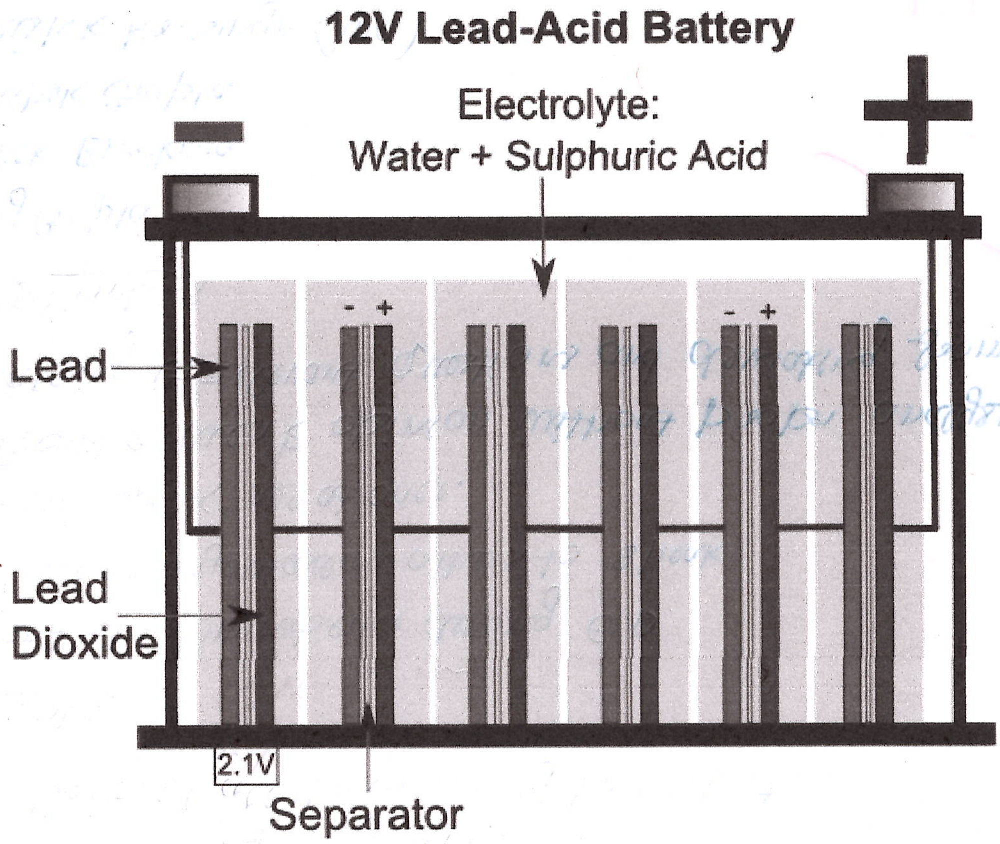
$PbSO_4 + 2e^- \Rightarrow Pb + SO_4^{2-}$

At anode

$PbSO_4 + 2H_2O \Rightarrow PbO_2 + SO_4^{2-} + 4H^- + 2e^-$

Combining above two equation, the overall chemical reaction will be

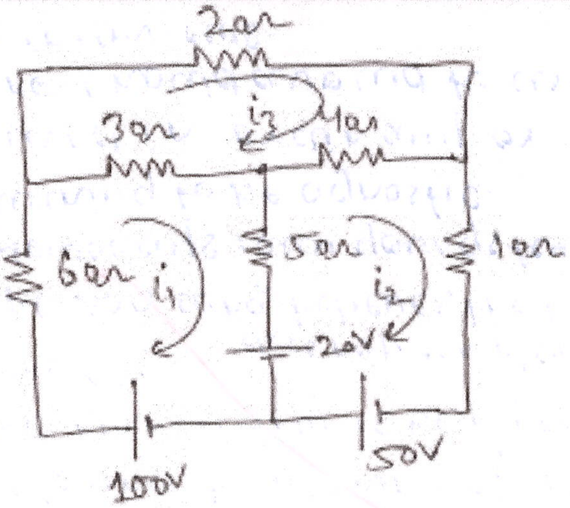
$$2PbSO_4 + 2H_2O \Rightarrow PbO_2 + Pb + 2H_2SO_4$$



Section C

3(a)

3(a)



Mesh (1)

$$60i_1 + 30(i_1 - i_3) + 50(i_1 - i_2) + 20 - 100 = 0$$

$$140i_1 - 50i_2 - 30i_3 = 80 \quad \text{——} (1)$$

Mesh (2)

$$10i_2 - 50 - 20 + 50(i_2 - i_1) + 40(i_2 - i_3) = 0$$

$$-50i_1 + 100i_2 - 40i_3 = 70 \quad \text{——} (2)$$

Mesh (3)

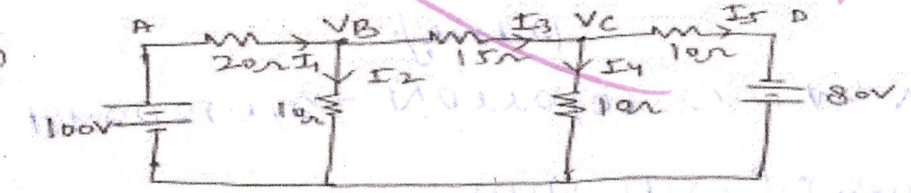
$$20i_3 + 40i_3 - 40i_2 + 30i_3 - 30i_1 = 0$$

$$-30i_1 - 40i_2 + 90i_3 = 0 \quad \text{——} (3)$$

$$\begin{bmatrix} i_1 = 1.649A \\ i_2 = 2.1214A \\ i_3 = 1.4925A \end{bmatrix}$$

3(b)

3(b)



Applying KCL at node (B)

$$I_1 = I_2 + I_3$$

$$\frac{100 - V_B}{20} = \frac{V_B}{10} + \frac{V_B - V_C}{15}$$

$$\frac{100 - V_B}{2\cancel{0}} = \frac{3V_B + 2V_B - 2V_C}{3\cancel{0}}$$

$$300 - 3V_B = 6V_B + 4V_B - 4V_C$$

$$13V_B - 4V_C = 300 \quad \text{———} \; (1)$$

Applying KCL at node (C)

$$I_3 = I_4 + I_5$$

$$\frac{V_B - V_C}{15} = \frac{V_C}{10} + \frac{V_C + 80}{10}$$

$$\frac{V_B - V_C}{15_3} = \frac{V_C + V_C + 80}{10_2}$$

$$2V_B - 2V_C = 6V_C + 240$$

$$2V_B - 8V_C = 240 \quad \text{———} \; (2)$$

Solving eqn (1) & (2)

$$13V_B - 4V_C = 300$$

$$2V_B - 8V_C = 240$$

$$\boxed{V_B = 15V} \quad \boxed{V_C = -26.25V}$$

$$I_1 = \frac{100 - V_B}{20} = \frac{100 - 15}{20} = 4.25A$$

$$I_2 = \frac{V_B}{10} = \frac{15}{10} = 1.5A$$

$$I_3 = 2.75A$$

$$I_4 = -2.625A$$

$$I_5 = 5.375A$$

4(a) **The mathematical relationship between phase and line quantities in a 3-phase star configuration:**

Star Connection (Y)

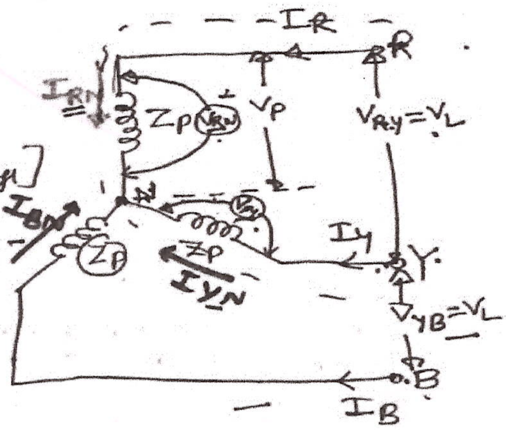
Let $Z_P \rightarrow$ impedance of each phase.

$V_{RN} = V_{YN} = V_{BN} = V_P$ [Magnitude of each phase voltage]

$I_R = I_Y = I_B = I_L$ [Line current]

$I_{RN} = I_{YN} = I_{BN} = I_P$ [phase current]

$V_{RY} = V_{YB} = V_{BR} = V_L$ [Line voltage].



Now

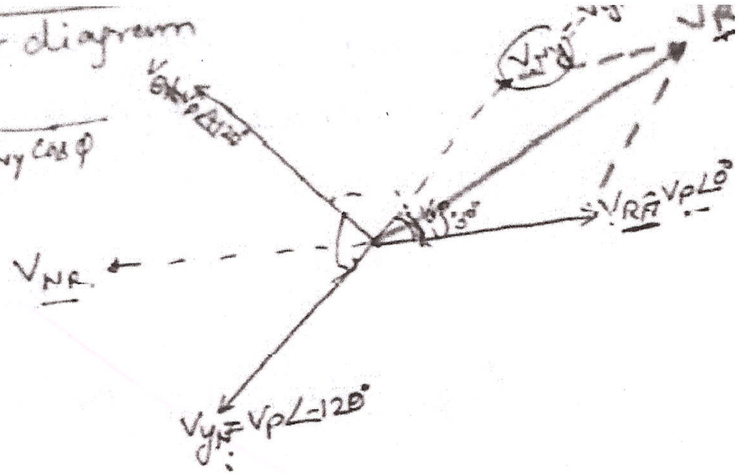
$I_R = I_{RN}$
$I_Y = I_{YN}$
$I_B = I_{BN}$

[Line current = Phase current]

$[I_L = I_P]$

$$\left[\begin{array}{l} V_{RY} = V_{RN} + V_{NY} \\ V_{RY} = V_{RN} - V_{YN} \end{array}\right]$$

Let us draw the phasor diagram



$$V_{RY} = \sqrt{(V_{RN})^2 + (V_{NY})^2 + 2V_{RN}V_{NY}\cos\phi}$$

$$V_{RY} = \sqrt{V_P^2 + V_P^2 + 2V_P^2 \times \cos 60°}$$

$$V_{RY} = \sqrt{3}V_P$$

$$[V_L = \sqrt{3}V_P]$$

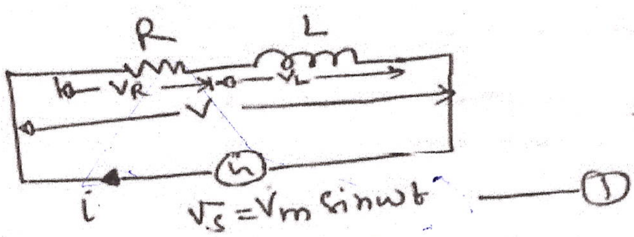
$$P_{3-\phi} = 3V_P I_P \cos\phi$$

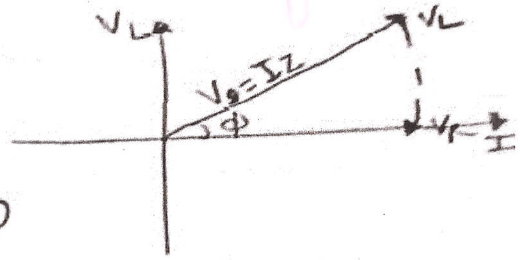
$$= 3\left(\frac{V_L}{\sqrt{3}}\right)(I_L)\cos\phi$$

$$[P_{3-\phi} = \sqrt{3}V_L I_L \cos\phi]$$

4(b) Consider a series RL circuit:

Series RL circuit





$$V = \sqrt{V_R^2 + (V_L)^2} \qquad V = V_R + jV_L$$

$$V = \sqrt{(IR)^2 + (IX_L)^2}$$

$$V = I\sqrt{R^2 + X_L^2}$$

$[V = IZ]$ $\rightarrow$ Impedence of the ckt.

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2+X_L^2}}$$

Magnitude of current

Phase angle

$$\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right) = \tan^{-1}\frac{X_L}{R}$$

$$i = I_{max}\sin(\omega t \pm \phi)$$

from phasor diagram, it is concluded that the current lags the voltage by phase angle (ϕ).

$$\boxed{i = \frac{V_m}{Z}\sin(\omega t - \phi)}$$

Power in RL circuit

$$P_i = vi$$
$$= V_m \sin\omega t \, I_m \sin(\omega t - \phi)$$
$$= \frac{V_m I_m}{2}\left[2\sin\omega t \sin(\omega t - \phi)\right]$$
$$= \frac{V_m I_m}{2}\left[\cos\phi - \cos(2\omega t - \phi)\right]$$
$$= \frac{V_m I_m}{2}\cos\phi - \underbrace{\frac{V_m I_m}{2}\cos(2\omega t - \phi)}$$

Average value of pulsating component 0

$P_{avg} = \frac{1}{2} V_m I_m \cos(2\omega t - \phi)$ is zero

Hence $\left[P_{avg} = \underline{V_r I_r \cos\phi}\right]$

NOTE:→ Since power consumed by inductor of capacitor for 1 cycle is zero.

Hence, power consumed in the ckt = Power consumed in Resistor.

$$P_{av} = I^2 R = I(IR)$$
$$= \frac{V}{Z} \cdot IR$$
$$= \frac{V}{\cancel{Z}} I \times \cancel{Z} \cos\phi$$
$$P_{av} = VI\cos\phi$$

5(a)

5 (a).
$Q = 100 \times 10^3 VA.$
$P_i = 600W$
$P_{CFL} = 1500W$

(i) $x = 1$, $\cos\phi = 0.8$ (lagging)

$$\%\eta = \frac{x Q \cos\phi}{x Q \cos\phi + P_i + x^2 P_{CFL}} \times 100$$

$$= \frac{1 \times 100 \times 10^3 \times 0.8}{1 \times 100 \times 10^3 \times 0.8 + 600 + (1)^2 \times 1500} \times 100$$

$$= \frac{80000}{80000 + 2100} \times 100$$

$$= 97.44\%.$$

(ii) $x = 0.5$, $\cos\phi = 1$

$$\%\eta = \frac{0.5 \times 100 \times 10^3 \times 1}{0.5 \times 100 \times 10^3 + 600 + (0.5)^2 \times 1500} \times 100$$

$$= \frac{50000}{50000 + 975} \times 100$$

$$= 98.087\%.$$

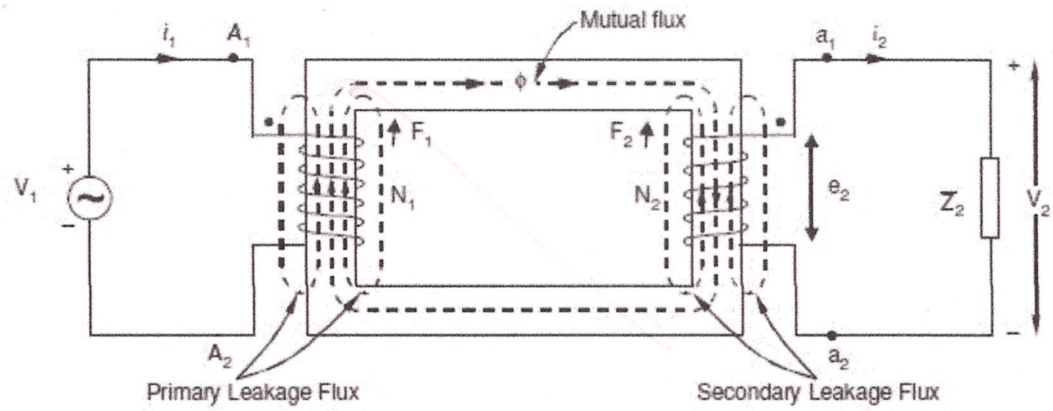
5(b) Practical Transformer and Equivalent Circuits

Transformer windings are made mainly of copper. Although copper is a very good conductor, it still has some internal resistance. Hence, both the primary and the secondary winding of a transformer have finite resistances viz. R1 and R2. These resistances spread uniformly throughout the windings and give rise to copper losses (I2R).

Let us consider that the emf I1N1 in the primary winding induces the flux Φl1, the emf I2N2 in the secondary windings, and the leakage flux Φl2. Both the resistances are regarded as the leakage reactance of the transformer windings. They are series effects at very low (50Hz / 60Hz) operating frequencies. These can be regarded as lumped parameters for ease of calculations.

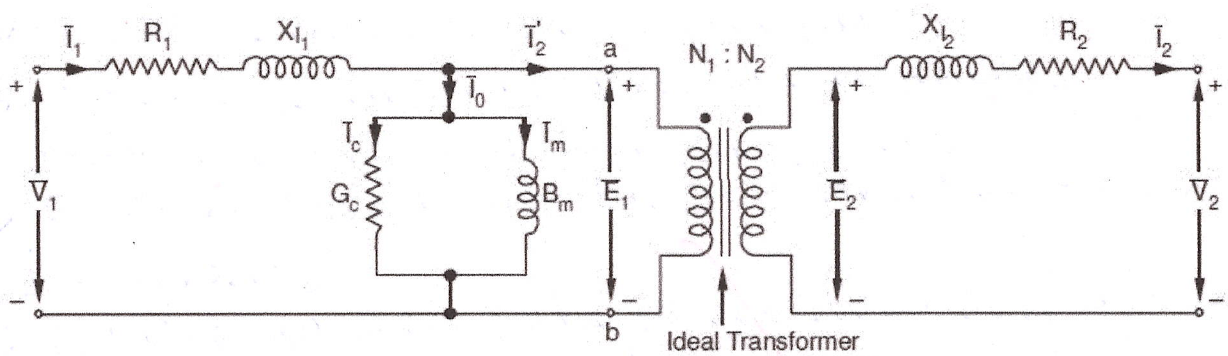
Therefore, the transformer is considered to consist of lumped resistances R1 and R2, and reactance X l1 and X l2 in series with the respective windings. However, the induced emfs E1 and E2 may vary slightly from the secondary voltages V1 and V2 due to the presence of the lumped impedances. This phenomenon is observed due to small voltage drops in the winding resistances R1 and R2 and leakage reactance.

The below equation gives the transformer ratio as:
a= (N1/N2) = (E1/ E2) ≈ (V1 / V2)



Practical or Non-Ideal Transformer

Equivalent Circuit of Real Transformer

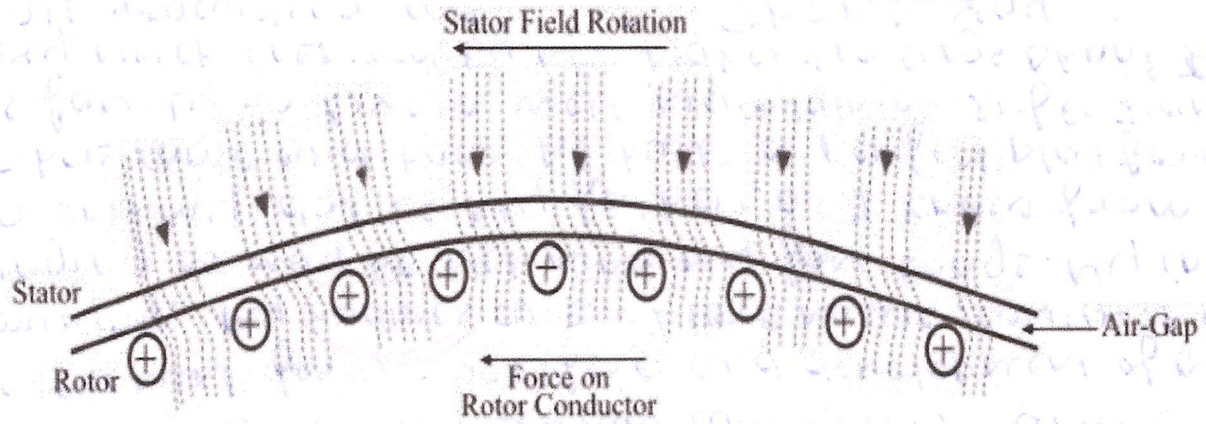


Equivalent Circuit of Transformer

6(a) Working principle of 3-phase induction motor

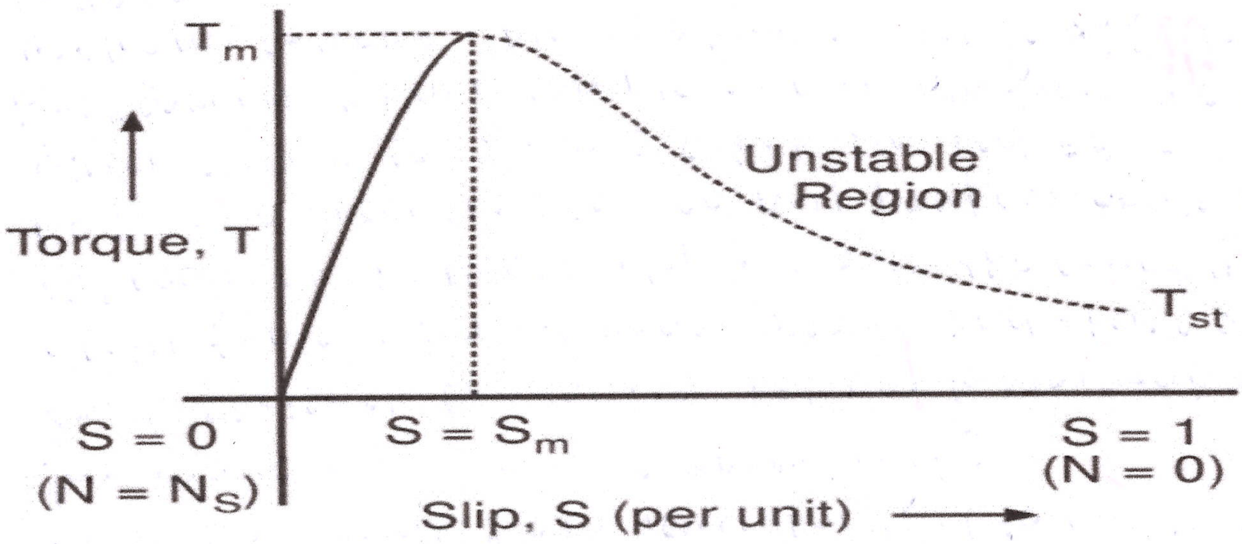
A *three phase induction motor* has a stator and a rotor. The stator carries a 3-phase winding called as *stator winding* while the rotor carries a short circuited winding called as *rotor winding*. The stator winding is fed from 3-phase supply and the rotor winding derives its voltage and power from the stator winding through *electromagnetic induction*. Therefore, the working principle of a 3-phase induction motor is fundamentally based on *electromagnetic induction*.

Consider a portion of a three phase induction motor (see the figure). Therefore, the working of a three phase induction motor can be explained as follows –



- When the stator winding is connected to a balanced three phase supply, a rotating magnetic field (RMF) is setup which rotates around the stator at synchronous speed (N_s).
- The RMF passes through air gap and cuts the rotor conductors, which are stationary at start. Due to relative motion between RMF and the stationary rotor, an EMF is induced in the rotor conductors. Since the rotor circuit is short-circuited, a current starts flowing in the rotor conductors.
- Now, the current carrying rotor conductors are in a magnetic field created by the stator. As a result of this, mechanical force acts on the rotor conductors. The sum of mechanical forces on all the rotor conductors produces a torque which tries to move the rotor in the same direction as the RMF.
- Hence, the induction motor starts to rotate. From, the above discussion, it can be seen that the three phase induction motor is self-starting motor.
- The three induction motor accelerates till the speed reached to a speed just below the synchronous speed.

Torque- Slip Characteristics



6(b)

6(b) $P = 6$.

$A = 2$

$Z = 300$

$N = 1000\ rpm$

$E_g = 400V$.

The Generated emf (E_g)

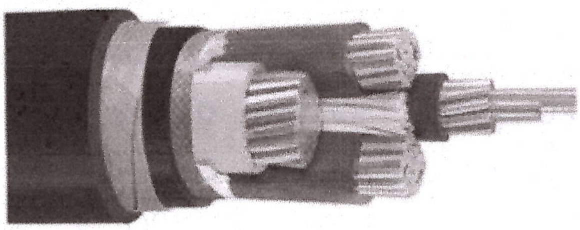
$$E_g = \frac{P\phi N Z}{60A}.$$

[A=2] for wave winding

$$\phi = \frac{400 \times 60 \times 2}{6 \times 1000 \times 300}$$

$$\boxed{\phi = 26.66\ mWb}$$

7(a) Typical Constructional diagram of a four-core armoured XLPE cable:



Purpose of different layers used in construction of cable

1. Core or Conductor: A cable may have one or more core depending upon the type of service for which it is used. The conductors are made up of tinned copper or aluminium and are usually stranded in order to provide flexibility.
2. Insulation: Around the conductor, it is necessary to provide insulation in order to prevent the electrical short circuit.
3. Metallic Sheath: In order to protect cable from moisture, gases, and harmful chemicals, in the soil and atmosphere, a metallic sheath is required.
4. Bedding: over the metallic sheath is applied a layer of bedding which consists of fibrous material like jute or hessian tape.
5. Armoring: Over the bedding, armoring is provided which consists of one or two layers of galvanized steel wire.
6. Serving: In order to protect armoring from atmospheric conditions, a layer of serving is required.

7(b) Earthing is defined as "the process in which the instantaneous discharge of the electrical energy takes place by transferring charges directly to the earth through low resistance wire."

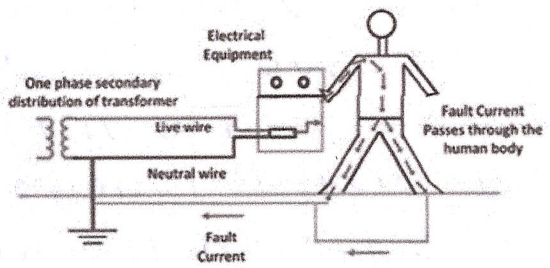
Low resistance earthing wire is chosen to provide the least resistance path for leakage of fault current.

Earthing:

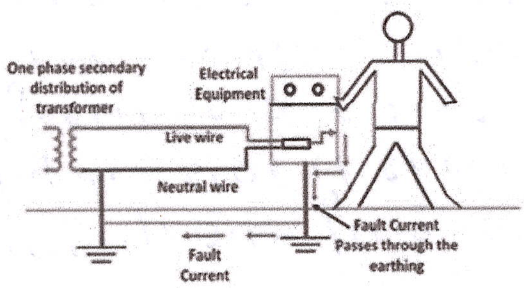
To ensure safety, earthing can be done by connecting the electrical appliance to earthing systems or electrodes placed near the soil or below the ground level.

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.



Electrical System Without Earthing



Electrical System With Earthing

Types of Earthing

There are three types of earthing, they are:

- Pipe earthing
- Plate earthing
- Strip earthing

Pipe earthing is the best and most efficient way of earthing and is also easily affordable. Pipe earthing uses 38mm diameter and 2 meters length pipe vertically embedded in the ground to work as earth electrodes.

In **plate earthing,** an earthing plate made of copper or G.I. is buried into the ground at a depth more than 3 meters from the ground level. This earthing plate is embedded in an alternative layer of coke and salts.

Strip earthing is used in transmission processes. Strip electrodes of cross section not less than 25mm X 1.6mm of copper or 25 mm X 4mm of G.I. or steel are buried in horizontal trenches of a minimum depth of 0.5m.

Advantages of Earthing:

1. Earthing is the 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.
2. Metal can be used in electrical installations without looking for its conductivity, proper earthing ensures that metal does not transfer current.
3. A sudden surge in voltage or overload does not harm the device and person if proper earthing measures are done.
4. It prevents the risk of fire hazards that could otherwise be caused by the current leakage.