Printed Pages:03 Sub Code:BEE201

Paper Id: 238164 Roll No.

B.TECH.
(SEM II) 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 KCL and KVL with necessary circuit representation.
आवश्यक सर्किट प्रतिनिधित्व के साथ KCL और KVL का वर्णन करें।

(b) Describe the Active elements and Passive elements with examples.
सक्रिय तत्वों और निष्क्रिय तत्वों का उदाहरण सहित वर्णन करें।

(c) Derive that average power consumed by a pure inductor is zero
व्युत्पन्न कीजिये कि एक शुद्ध इंडक्टर द्वारा खपत की गई औसत शक्ति शून्य है।

(d) Draw the phasor diagram of a practical two winding transformer in no-load condition?
नो-लोड स्थिति में एक व्यावहारिक दो वाइंडिंग ट्रांसफार्मर का फेज़र आरेख बनाएं?

(e) Describe briefly the different types of DC machines?
विभिन्न प्रकार की डीसी मशीनों का संक्षेप में वर्णन करें?

(f) Describe briefly different types of cables?
विभिन्न प्रकार के केबलों का संक्षेप में वर्णन करें?

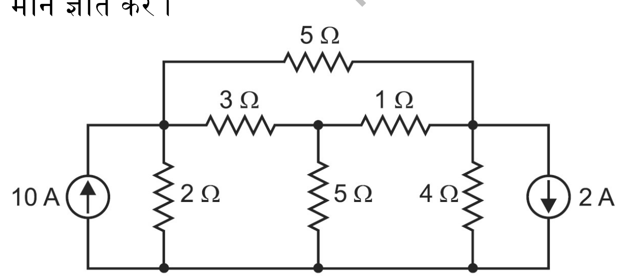
(g) Determine the average value of sinusoidal current $i= I_m \sin\alpha$ in one complete cycle?
एक पूर्ण चक्र में साइनसोइडल धारा $i= I_m \sin\alpha$ का औसत मान निर्धारित करें?

SECTION B

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

निम्न में से किसी तीन प्रश्नों का उत्तर दीजिए।

(a) Use nodal analysis to find the currents in various resistors of the circuit shown below.
नोडल विश्लेषण का उपयोग कर नीचे दिखाए गए सर्किट के विभिन्न प्रतिरोधों में धाराओं का मान ज्ञात करें।



(b) Determine the mathematical expression for instantaneous power and average power in case of R, L and C, elements connected in series across a single phase AC supply of voltage $v=V_m Sin(wt)$? Also draw the instantaneous power waveform?
वोल्टेज $v=V_m Sin(wt)$ की एकल फेज एसी आपूर्ति में श्रृंखला में जुड़े R, L और C तत्व के मामले में तात्कालिक शक्ति और औसत शक्ति के लिए गणितीय अभिव्यक्ति निर्धारित करें। तात्क्षणिक शक्ति का तरंगरूप भी बनाइये।

(c) Describe different types of transformer losses and methods to minimize it?
विभिन्न प्रकार के ट्रांसफार्मर हानियों और इसे कम करने के तरीकों का वर्णन करें।

(d) Derive the torque equation for DC machines.?
डीसी मशीनों के लिए टॉर्क समीकरण प्राप्त करें।

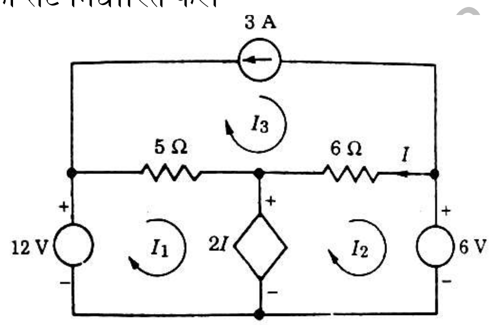
(e) Describe briefly the types of batteries and explain anyone with necessary diagram?
बैटरियों के प्रकारों का संक्षेप में वर्णन करें और आवश्यक चित्र सहित किसी एक को समझाएँ।

SECTION C

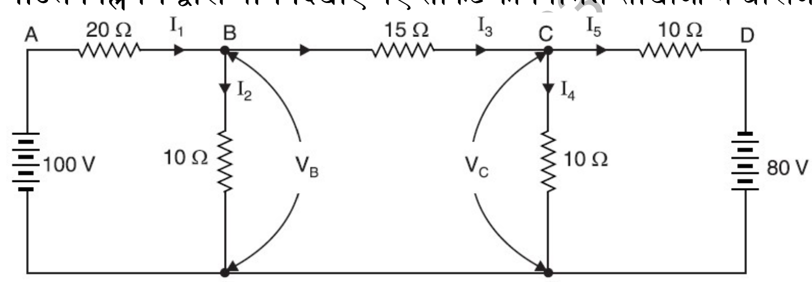
3. Attempt any *one* part of the following: 7 x 1 = 7

निम्न में से किसी एक प्रश्न का उत्तर दीजिए।

(a) Determine the set of Mesh equations that are required to solve the network given in below circuit diagram.
नीचे दिए गए सर्किट आरेख में दिए गए नेटवर्क को हल करने के लिए आवश्यक मेष समीकरणों का सेट निर्धारित करें।



(b) Determine the currents in the various branches of the circuit shown below by nodal analysis.
नोडल विश्लेषण द्वारा नीचे 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 आरेख की सहायता से 3-फेज तारा विन्यास में फेज और लाइन मात्राओं के बीच गणितीय संबंध प्राप्त करें?

(b) Derive the equation for resonant frequency in case of series RLC circuit. Also draw the phasor diagram of resultant Voltage and Current in series RLC circuit in resonant condition.
श्रृंखला RLC सर्किट और समानांतर RLC सर्किट के मामले में अनुनाद आवृत्ति के लिए समीकरण प्राप्त करें। अनुनाद स्थिति में श्रृंखला आरएलसी सर्किट में परिणामी वोल्टेज और करंट का फेजर आरेख 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 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 kVA, एकल-फेज ट्रांसफार्मर में पूर्ण-लोड धारा पर 600 W की आयरन हानि और 1.5 किलोवाट की कॉपर हानि होती है। (i) पूर्ण लोड और 0.8 पश्चगामी pf, और (ii) अर्ध लोड और इकाई pf पर दक्षता की गणना करें।

(b) Draw the complete equivalent circuit model of a real transformer and explain its different parameters?
एक वास्तविक ट्रांसफार्मर का पूर्ण समतुल्य सर्किट मॉडल बनाएं और इसके विभिन्न parameters की व्याख्या करें।

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 विशेषताओं का वर्णन करें।

(b) Describe different types of DC machines with necessary circuit diagrams.
आवश्यक सर्किट आरेखों के साथ विभिन्न प्रकार की डीसी मशीनों का वर्णन करें।

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 Copper, 3 core, armoured XLPE cable and describe the purpose of each layer.
कॉपर, 3 कोर, बख्तरबंद XLPE केबल का विशिष्ट रचनात्मक आरेख बनाएं और प्रत्येक लेयर के उद्देश्य का वर्णन करें।

(b) Describe the working principle of an MCB along with the necessary circuit diagrams?
आवश्यक सर्किट आरेखों के साथ एमसीबी के कार्य सिद्धांत का वर्णन करें?

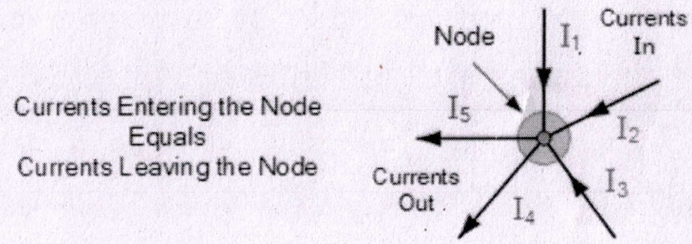
B.TECH.
(SEM II) THEORY EXAMINATION 2022-23
SOLUTION OF FUNDAMENTALS OF ELECTRICAL ENGINEERING

SECTION A

1(a) Kirchhoff's Law is defined based on the usage and application of the law. Kirchhoff's laws are classified into two types:

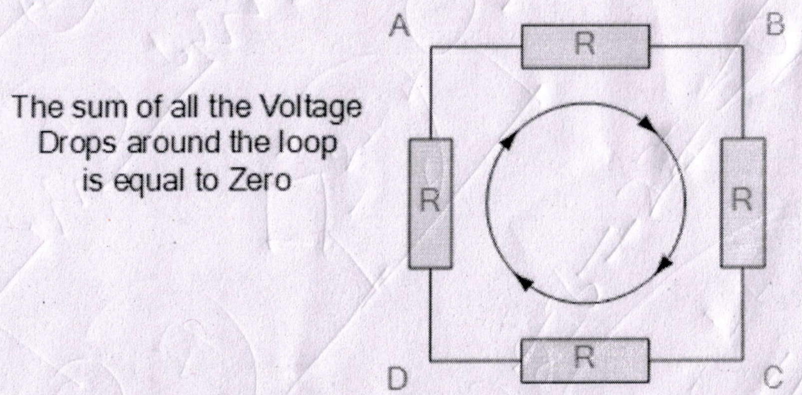
- Kirchhoff's Current Law (KCL)
- Kirchhoff's Voltage Law (KVL)

Kirchhoffs Current Law or KCL, states that the "*total current or charge entering a junction or node is exactly equal to the charge leaving the node as it has no other place to go except to leave, as no charge is lost within the node*". In other words the algebraic sum of ALL the currents entering and leaving a node must be equal to zero, $I_{(exiting)} + I_{(entering)} = 0$. This idea by Kirchhoff is commonly known as the **Conservation of Charge.**



$$I_1 + I_2 + I_3 + (-I_4 + -I_5) = 0$$

Kirchhoff's Voltage Law (KVL): In any closed path (or circuit) in a network, the algebraic sum of the IR product is equal to the EMF in that path.



$$V_{AB} + V_{BC} + V_{CD} + V_{DA} = 0$$

(b) Active elements: An electric circuit element which can supply electric power to the circuit or power gain in the circuit, is known as an **active element** or **active component.**

Some common examples of active circuit elements are energy sources (voltage sources or current sources), generators or alternators, semiconductor devices such as transistors, photodiodes, etc.

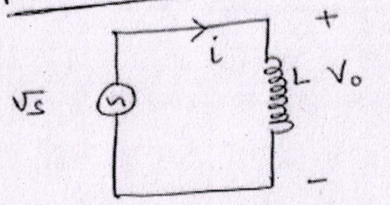
The active elements are the circuit component which are entirely responsible for the flow of electric current in the circuit.

Passive elements: The circuit element which can only absorb electrical energy and dissipates it in the form of heat or stores in either magnetic field or electric field is known as **passive circuit component** or **simply passive component.**

Therefore, a passive component cannot provide electric power or power amplification in an electric circuit. Some common examples of passive circuit components are resistor, inductor, capacitor and transformer, etc.

(c) Average Power Consumed in Purely Inductive Circuit:

Pure inductive Circuit



$V_s = V_m \sin wt$ — ①

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

but $[V_s = V_o]$

so

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

$$V_m \sin wt = L \frac{di}{dt}$$

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

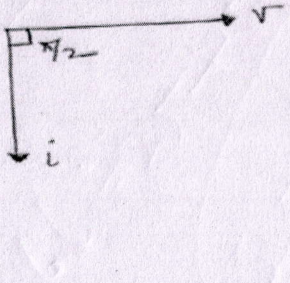
$$i = \int \frac{V_m}{L} \sin wt \, dt \quad ③$$

$$i = \frac{V_m}{wL}(-\cos wt)$$

$wL = X_L$ → inductive reactance

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

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



Power in pure inductive circuit

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

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

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

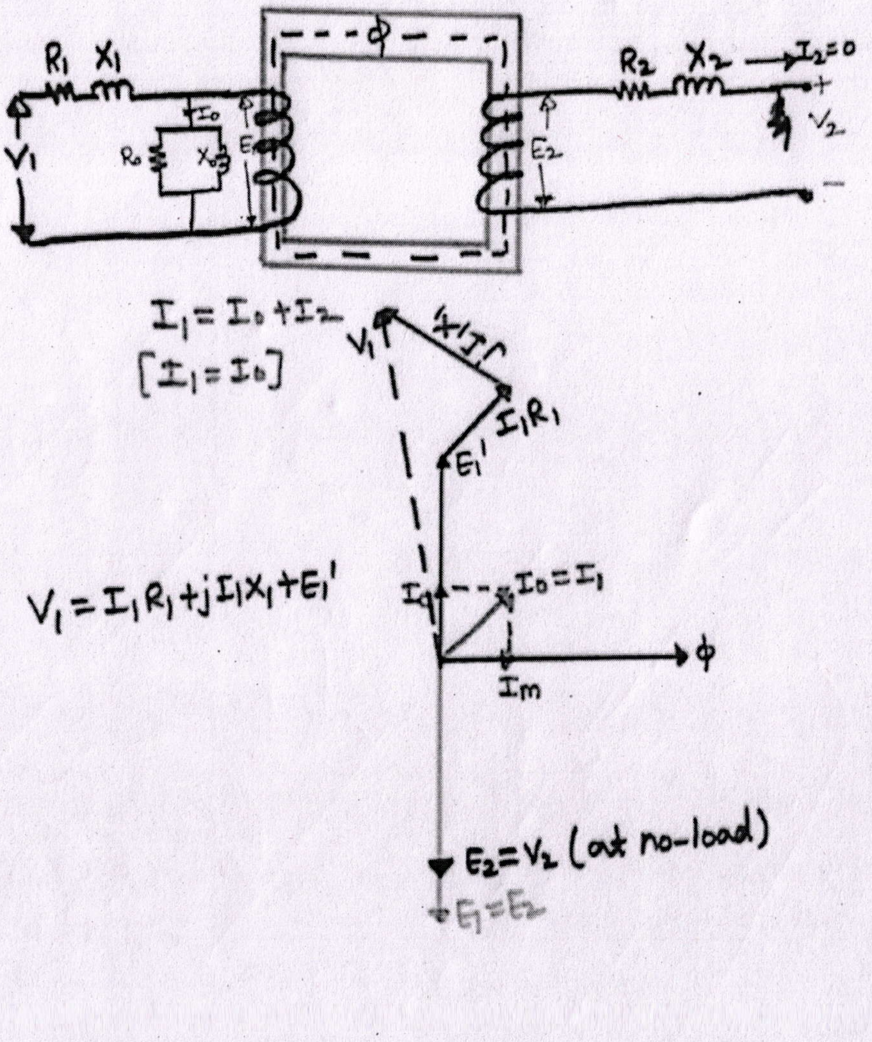
$$= -\frac{V_m I_m}{2}\sin 2\omega t$$

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

$\sin 2\omega t \to 0$ [av. value of complete cycle is zero]

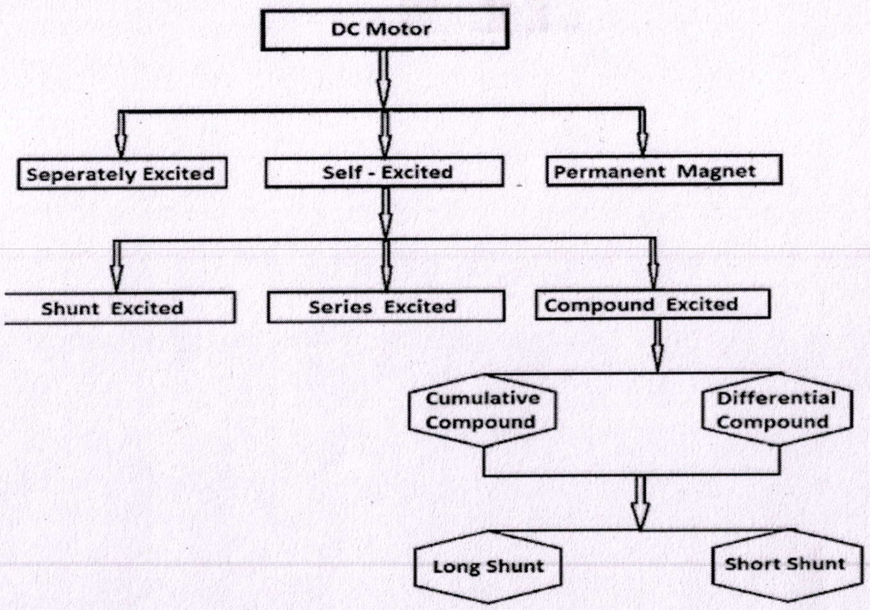
$$\boxed{P_{av} = 0}$$

(d) Phasor diagram of a practical two winding transformer in no-load condition



(e) Different Types of DC Machines

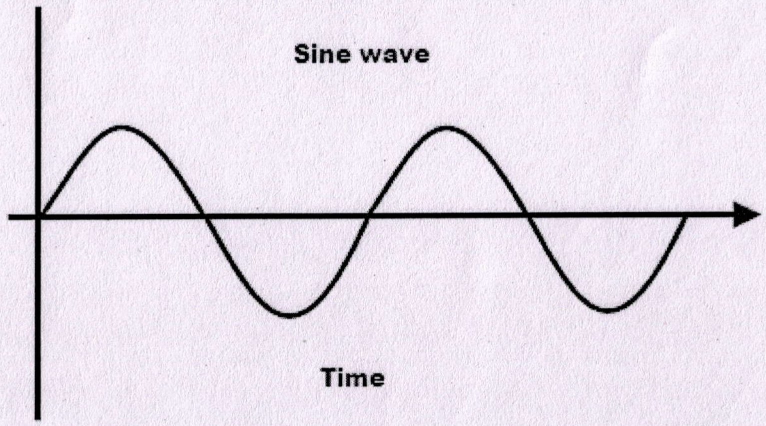
Different types of DC machines



(f) Different types of cables: The cable that is used for the transmission and distribution of electrical power is known as the electrical power cable. It is used for the transmission of high voltages in places where overhead lines are impractical to use. Cables are classified are as follows:

(1) Ribbon Electric Cable
(2) Shielded Cable
(3) Twisted Pair Cable
(4) Coaxial Cable
(5) Fibre Optics Cable

(g) Average value of Sinusoidal Current for one complete cycle:

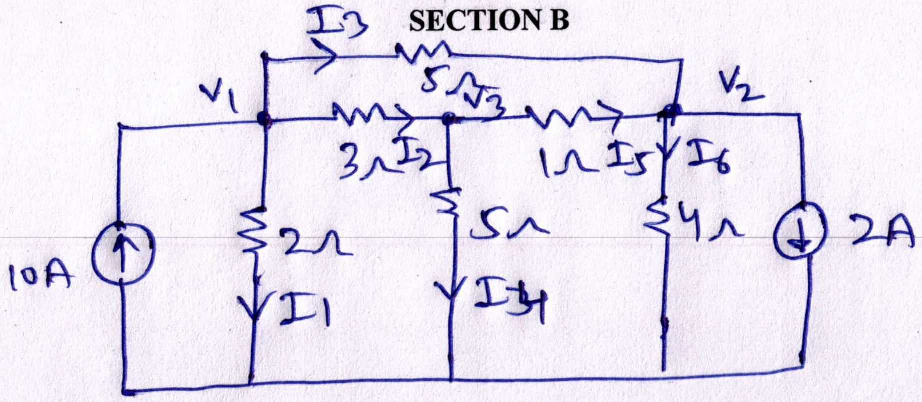


For the complete cycle, the average value is zero. However, the average value is calculate for one half cycle for the pure sinusoidal waveform.

The average value is $\mathbf{I_{avg} = 0.636\ I_m}$

SECTION B

2(a)



at node ①

$$10 = I_1 + I_2 + I_3$$

$$10 = \frac{V_1}{2} + \frac{V_1 - V_3}{3} + \frac{V_1 - V_2}{5}$$

$$10 = \frac{15V_1 + 10V_1 - 10V_3 + 6V_1 - 6V_2}{30}$$

$$300 = 31V_1 - 6V_2 - 10V_3 \quad \text{— ①}$$

at node ②

$$I_5 + I_3 = I_6 + 2$$

$$\frac{V_3 - V_2}{1} + \frac{V_1 - V_2}{5} = \frac{V_2}{4} + 2$$

$$\frac{5V_3 - 5V_2 + V_1 - V_2}{5} = \frac{V_2 + 8}{4}$$

$$\frac{5V_3 - 6V_2 + V_1}{5} = \frac{V_2 + 8}{4}$$

$$20V_3 - 24V_2 + 4V_1 = 5V_2 + 40$$

$$4V_1 - 29V_2 + 20V_3 = 40 \quad \text{— ②}$$

at node ③

$$I_2 = I_4 + I_5$$

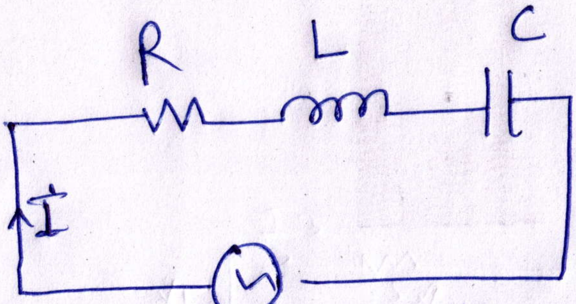
$$\frac{V_1 - V_3}{3} = \frac{V_3}{5} + \frac{V_3 - V_2}{1}$$

$$5V_1 + 15V_2 - 23V_3 = 0 \quad \text{— ③}$$

$V_1 = 12.058V$
$V_2 = 3.8018V$
$V_3 = 5.1009V$

$I_1 = 6.029A$
$I_2 = 2.319A$
$I_3 = 1.649A$
$I_4 = 1.0202A$
$I_5 = 1.299A$

2(b)



$V_s = V_m \sin\omega t$

$$P.f = \cos\phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

$$I = \frac{V}{Z} = \frac{V_m \sin\omega t}{Z}$$

Instantanous Real power dissipated in the ckt.

$$P = I^2 R = \frac{V_m^2 \sin^2\omega t}{Z^2} R$$

<u>Avg. power dissipated</u> :- $P = \dfrac{\int_0^{2\pi/\omega} P\,dt}{\int_0^{2\pi/\omega} dt} = \dfrac{V_m^2 R}{2Z^2 \times 2\pi/\omega} \int_0^{2\pi/\omega} (1 - \cos 2\omega t)\,dt$

$$\boxed{P_{avg} = V_{rms} I_{rms} \cos\phi}$$

<u>Note</u> (i) No power is dissipated when $P=0$
i.e $\cos\phi = 0$, $\phi = \pi/2$
The ckt. is purely inductive/capacitive

(ii) Max. power is dissipated when P is max.
i.e $\cos\phi = 1$
$\phi = 0$ (<u>Resistive</u>)

2(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:

$W_h = \eta B_{max} 1.6 fV$ (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 $I_{12}R_1$ and for the secondary winding is $I_{22}R_2$. 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.

2(d) Torque equation of DC Machine

Torque equation for DC motor

$$P = T\omega$$

$$E_b I_a = T\omega$$

$$E_b I_a = T\frac{2\pi N}{60}$$

we know that $E_b = \frac{P\phi N Z}{60A}$

$$\frac{P\phi \cancel{N} Z}{\cancel{60}A} I_a = T\frac{2\pi \cancel{N}}{\cancel{60}}$$

$$T = \frac{1}{2\pi}\frac{P\phi Z I_a}{A} = 0.16\,\phi I_a \cdot \frac{PZ}{A}$$

2(e) Types of batteries

(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.

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

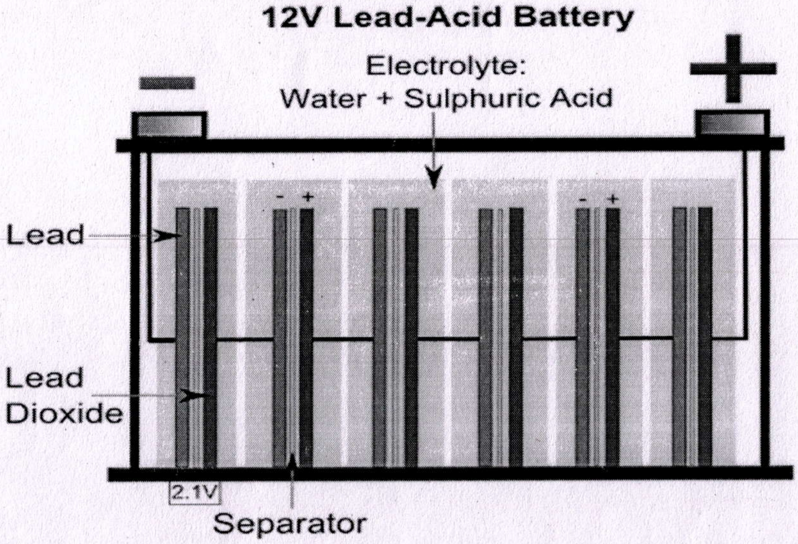
$PbSO_4 + 2H_2O \Rightarrow PbO_2 + SO_4^{2-} + 4H^+ + 2e^-$

Combining above two equation, the overall chemical reaction will be

Difference between Primary Cell and Secondary Cell

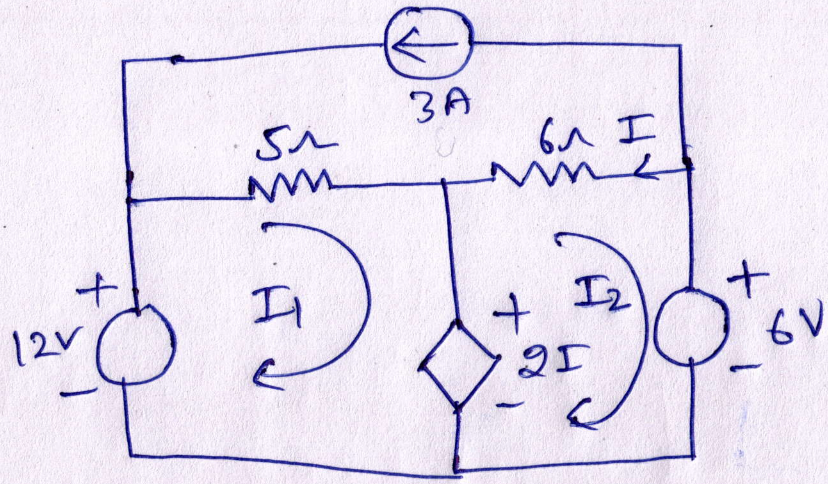
Primary Cell	Secondary Cell
Have high energy density and slow in discharge and easy to use	They have smaller energy density
There are no fluids in the cells hence it is also called as dry cells	These are made up of wet cells (flooded and liquid cells) and molten salt (liquid cells with different composition)
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

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



SECTION C

3(a)



Mesh 1 $\quad 5(I_1+3)+2I=12$ —— (1)

Mesh 2 $\quad 6(I_2+3)+6-2I=0$ —— (2)

$$\boxed{I=-(3+I_2)}$$

$$5(I_1+3)+2\times(-3-I_2)=12$$

$$5I_1+15-6-2I_2=12$$

mesh 1 $\quad 5I_1-2I_2=3 \quad \text{——— (1)}$

for mesh 2

$$6(I_2+3)+6-2(-3-I_2)=0$$

$$6I_2+18+\cancel{6}-\cancel{6}+2I_2=0$$

$$8I_2=-18$$

$$\left[I_2=-9/4A\right]$$

put in (1)

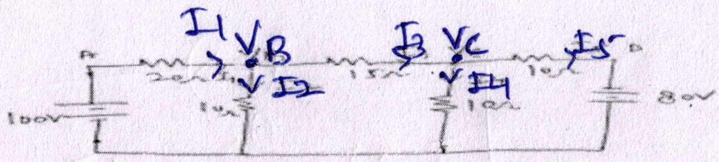
$$5I_1+2\times\frac{9}{4_2}=3$$

$$5I_1=-1.5$$

$$\left[I_1=-1.5/5A\right]$$

3(b)

3(b)



Applying KCL at node (1)

$$I_1=I_2+I_3$$

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

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

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

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

Applying KCL at node (2)

$$I_3=I_4+I_5$$

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

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

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

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

Solving eqn (1) & (2)

$$13V_B-4V_C=300$$

$$2V_B-8V_C=240$$

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

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

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

$$I_3=2.75A$$

$$I_4=-2.625A$$

$$I_5=5.375A$$

$V_B=15V$

$V_C=-26.25V$

$I_1=4.25A, \quad I_2=1.5A$

$I_3=2.75A, \quad I_4=-2.625A$

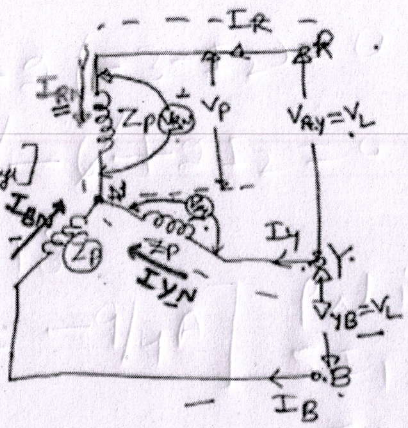
$I_5=5.375A.$

4 (a) The Relation between line and phase voltage in 3-phase star connected circuit:

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

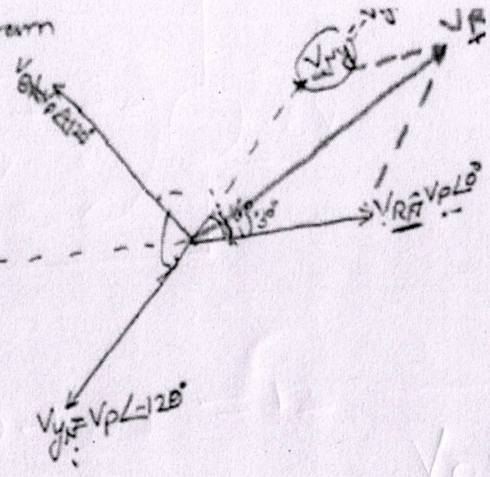
$I_R = I_{RN}$
$I_Y = I_{YN}$
$I_B = I_{BN}$

[Line current = Phase current]

$[I_L = I_P]$

$$\begin{bmatrix} V_{RY} = V_{RN} + V_{NY} \\ V_{RY} = V_{RN} - V_{YN} \end{bmatrix}$$

Let us draw the phasor diagram



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

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

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

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

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

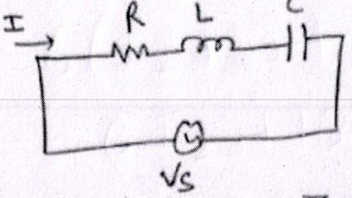
$= 3\left(\frac{V_L}{\sqrt{3}}\right)(I_L)\cos\phi$

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

4(b) Series Resonance:

(b) **Series Resonance**

* Series or voltage resonance



$X_L = j\omega L$

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

$$Z = R + j(X_L - X_C) \quad \text{——} (1)$$

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 $= 0$.

$$X_L = X_C$$

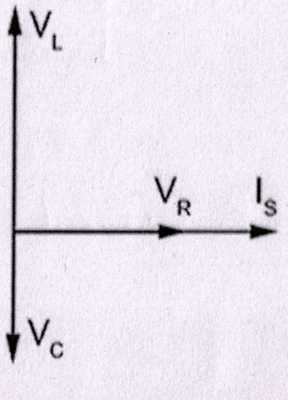
$$\omega_0 L = \frac{1}{\omega_0 C}$$

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

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

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

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



Phasor diagram at series resonance condition

$V_L = V_C$ (at resonance)

So $V_s = V_R$

5(a) VA rating of transformer = 100 X10^3 VA

P_i = 600 W

P_{cu} = 1.5 kW

5(a)

5(a). $Q = 100\times10^3$ VA.

$P_i = 600$W

$P_{CFL} = 1500$W

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

$$\%\eta = \frac{x\,Q\cos\phi}{x\,Q\cos\phi + P_i + x^2 P_{CFL}}\times100$$

$$= \frac{1\times100\times10^3\times0.8}{1\times100\times10^3\times0.8 + 600 + (1)^2\times1500}\times100$$

$$= \frac{80000}{80000+2100}\times100$$

$$= 97.44\%$$

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

$$\%\eta = \frac{0.5\times100\times10^3\times1}{0.5\times100\times10^3 + 600 + (0.5)^2\times1500}\times100$$

$$= \frac{50000}{50000+975}\times100$$

$$= 98.087\%$$

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. R_1 and R_2. These resistances spread uniformly throughout the windings and give rise to copper losses (I_2R). Let us consider that the emf I_1N_1 in the primary winding induces the flux Φl1, the emf I_2N_2 in the secondary windings, and the leakage flux Φ_{l2}. 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 R_1 and R_2, and reactance X_{l1} and X_{l2} in series with the respective windings. However, the induced emfs E_1 and E_2 may vary slightly from the secondary voltages V_1 and V_2 due to the presence of the lumped impedances. This phenomenon is observed due to small voltage drops in the winding resistances R_1 and R_2 and leakage reactance.

The below equation gives the transformer ratio as: $a = (N_1/N_2) = (E_1/E_2) \approx (V_1 / V_2)$.

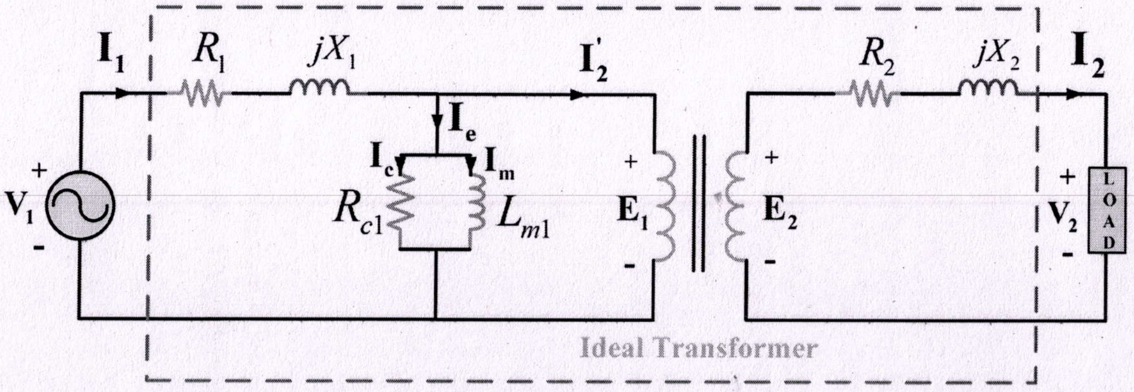


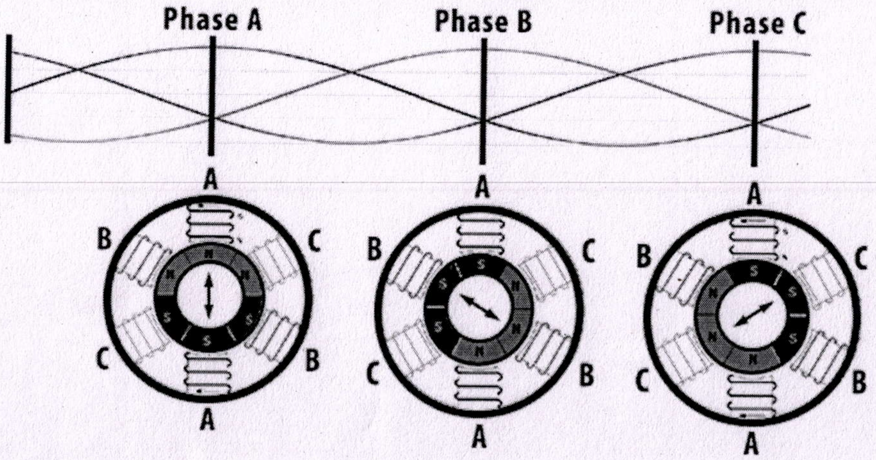
Fig: Equivalent circuit of Transformer

6(a) Working Principle of 3-phase induction Motor

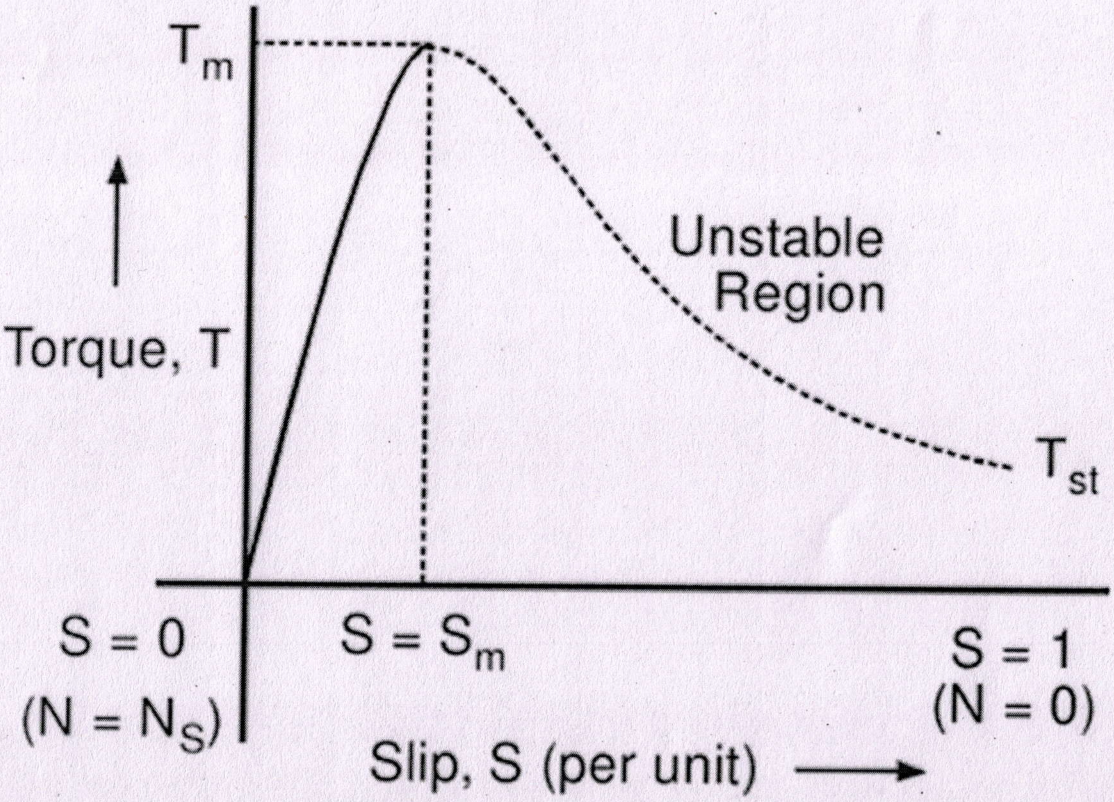
A three phase induction motor has a stator and a rotor. The stator carries a 3-phase winding called as stator winding while the rotor carries a short circuited winding called as rotor winding. The stator winding is fed from 3-phase supply and the rotor winding derives its voltage and power from the stator 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 (Ns).
- 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.

3 PHASE INDUCTION MOTOR



Torque-Slip Characteristics of 3-phase induction motor



6(b) DC Machines and its classification

The magnetic flux in a d.c machine is produced by field coils carrying current. The production of magnetic flux in the device by circulating current in the field winding is called excitation.

There are two types of excitation in D.C machine. Separate excitation, and self-excitation. In self-excitation, the current flowing through the field winding is supplied by the machine itself, and in separate excitation, the field coils are energized by a separate D.C. Source.

The principal types of D.C machine are:

1. **Separately excited DC machine**
2. **Shunt wound or shunt machine.**
3. **Series wound or series machine.**
4. **Compound wound or compound machine.**

1. Separately excited D.C. machine:

When a separate D.C. source is used to energize the field coils it is called as separately excited D.C. machine. The connections showing the separately excited D.C. Machines are given in the figure.

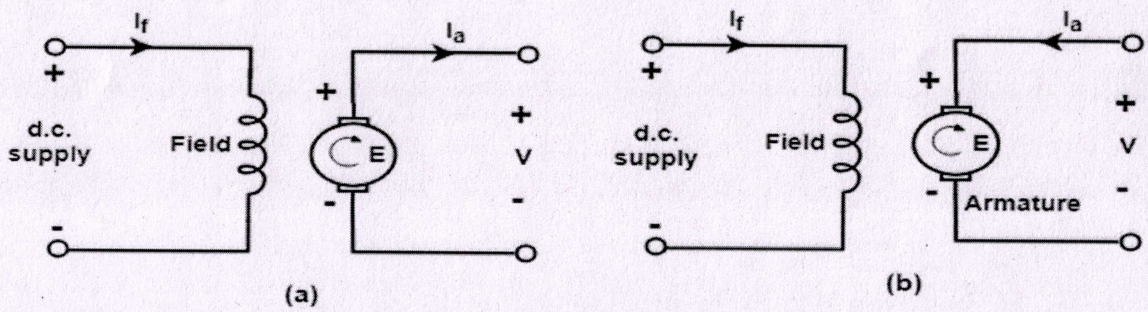
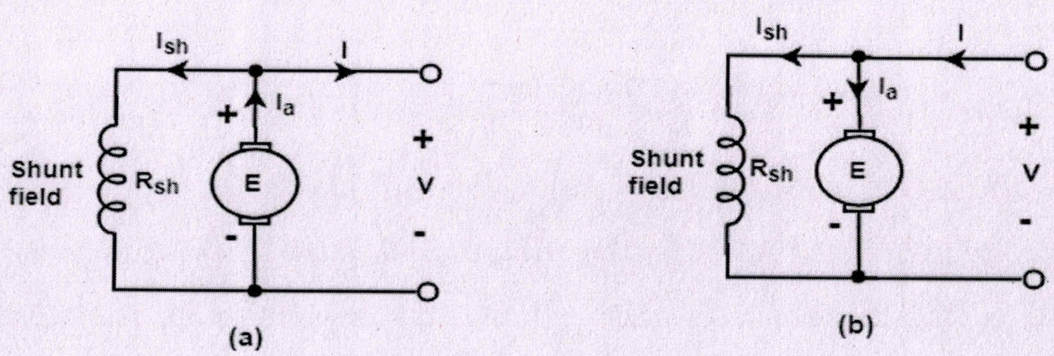


Figure: (a) Separately excited D.C. Generator, (b) Separately excited D.C. Motor.

2. Shunt wound D.C. Machine:

Shunt wound D.C. Machines is the machine in which field coils are connected in parallel with the armature. Since the shunt field receives the full output voltage of a generator or the supply voltage of a motor, it is generally made of a large number of turns of fine wire carrying a small field current.



3. Series wound D.C. Machine:

Series wound D.C. Machines is the machine in which the field coils are connected in series with the armature. The series field winding carries the armature current, and the armature current is large, that is why series field winding consists of few turns of wire of large cross-sectional area.

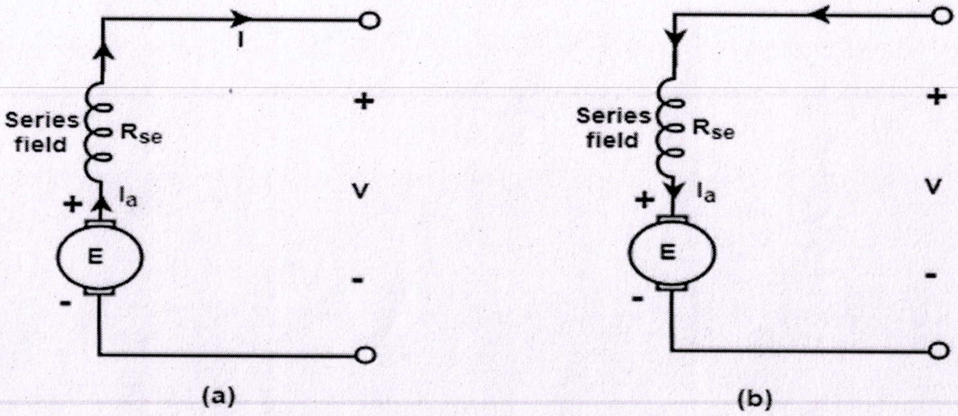


Figure: (a) D.C. series generator (b) D.C. series motor.

4. Compound wound D.C. machine:

A Compound machine is a machine which has both shunt and series fields. Two windings are carried out by each pole of the machine. The series winding has few turns of large cross-sectional area, and the shunt windings have many turns of fine wire.

It can be connected in two ways. If the shunt field is connected in parallel with the armature alone, the machine is called the **short-shunt compound machine** and if the shunt field in parallel with both the armature and series field, the machine is called the **long-shunt compound machine**.

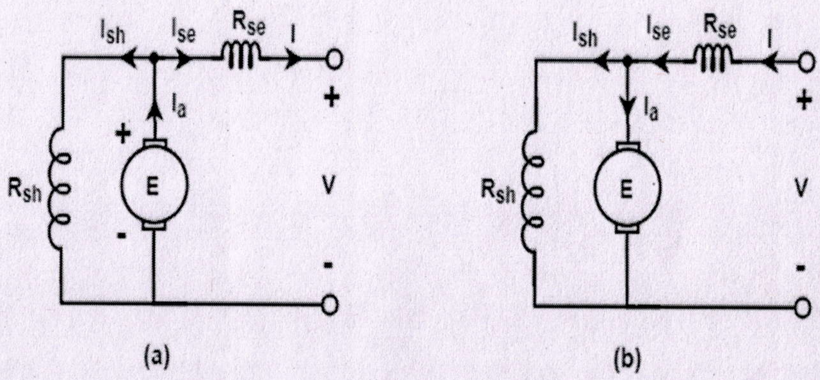


Figure: (a) Short-shunt compound D.C. generator (b) Short-shunt compound D.C. motor.

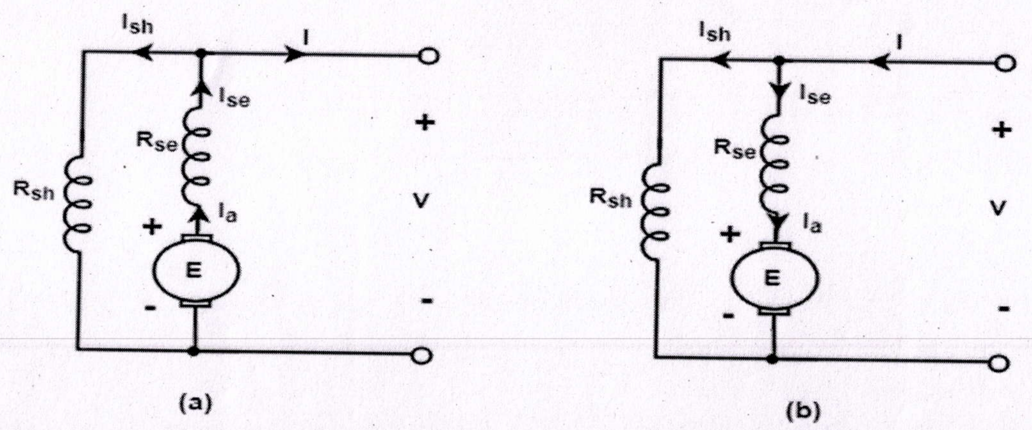
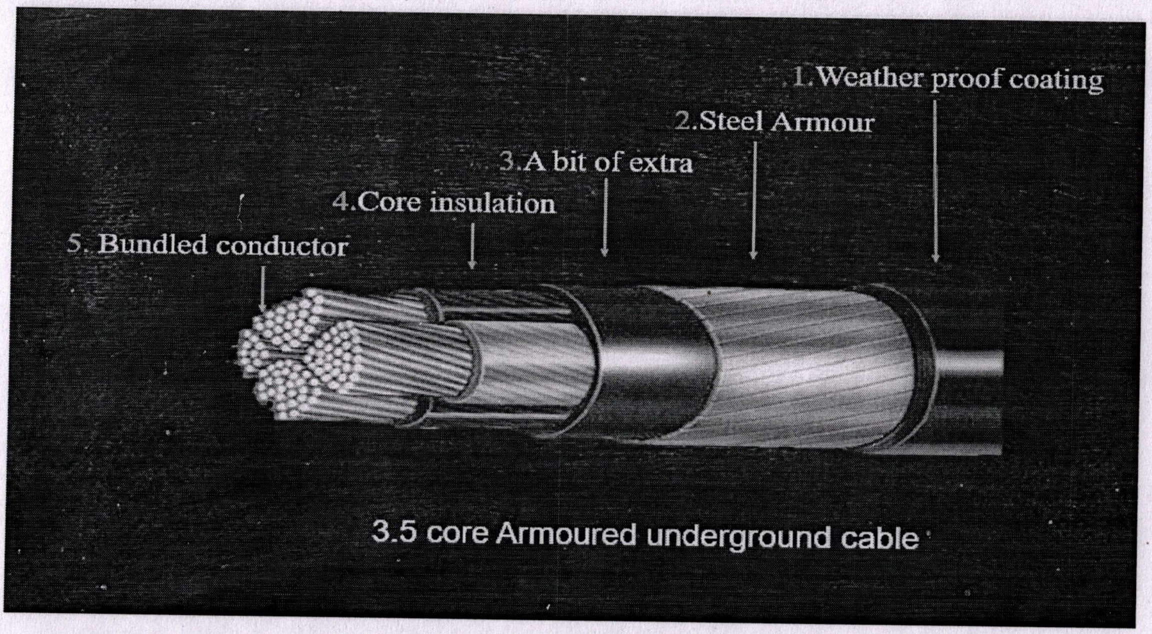


Figure: (a) Long-shunt D.C. generator (b) Long-shunt D.C. motor.

7(a) **3 core armoured cable:**

3 Core Armoured Cable is a large and specific size of Armoured Cable, primarily found within large powered networks whilst also carrying power to a range of different powered devices. Although this cable can be used for domestic uses such as powering outdoor sheds and greenhouses as well as water features and outdoor lights, due to its size, it is commonly found within more industrial installations such as power stations and large construction sites.



Construction:

Conductor: consists of plain stranded copper
Insulation: Cross-linked polyethylene (XLPE) is used in a number of power cables because it has good water resistance and excellent electrical properties.
Bedding: Polyvinyl chloride (PVC) bedding is used to provide a protective boundary between inner and outer layers of the cable.

Armour: Steel wire armour provides mechanical protection, which means the cable can withstand higher stresses, be buried directly and used in external or underground projects
Sheath: a black PVC sheath holds all components of the cable together and provides additional protection from external stresses.

3 Core Armoured Cable Application:

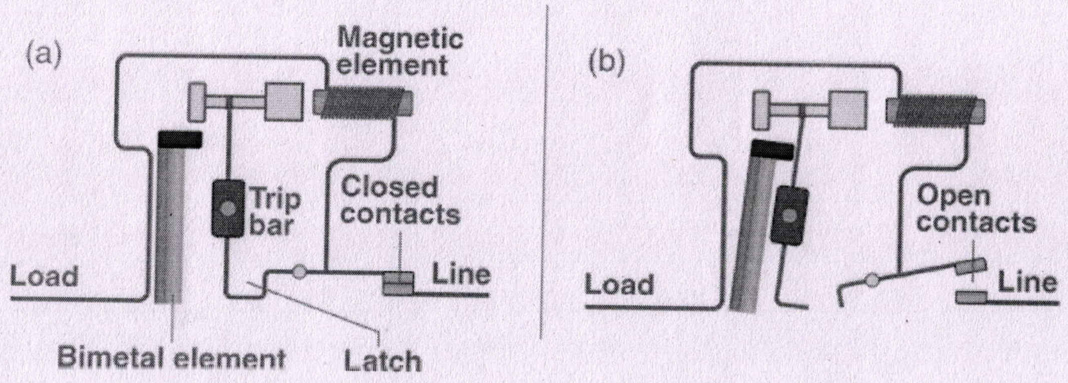
1. The Railway and Transport industry
2. Underneath roads powering buildings
3. Industrial networks such as power plants and factories
4. Within cable ducting in the roofs of warehouses.

7(b) Miniature Circuit Breaker (MCB): MCB is an automatic switch that opens when excessive current flows through the circuit. It can be reclosed without any manual replacement. In the case of a fuse, once it has been operated, it must be replaced or rewired, depending on the type of the MCB. Hence, fuse is known as one of the sacrificial devices. This is the main reason why MCBs are used as an alternative to the fuse in most of the circuits. Also, whenever there is a fault in the circuit, the switches in the MCB automatically shut down and the fault of the device can be easily detected.

Handling MCB is relatively safe, and it quickly restores the supply. MCB – Miniature Circuit Breaker can be reset quickly and does not demand more maintenance costs. MCB works on a bi-metal respective principle that protects against overload current and solenoid short circuit current.

Working Principle:

When the current overflow occurs through MCB – Miniature Circuit Breaker, the bimetallic strip gets heated and deflects by bending. The deflection of the bi-metallic strip releases a latch. The latch causes the MCB to turn off by stopping the current flow in the circuit. This process helps safeguard the appliances or devices from the hazards of overload or overcurrent. To restart the current flow, MCB must be turned ON manually.



In the case of short circuit conditions, the current rises suddenly in an unpredictable way, leading to the electromechanical displacement of the plunger associated with a solenoid. The plunger hits the trip lever, which causes the automatic release of the latch mechanism by opening the circuit breaker contacts.

An MCB is a simple, easily operable device and is maintenance-free too. MCB can be easily replaced. The trip unit is the key part of the MCB – Miniature Circuit Breaker on which the unit operates. The bi-metal present in the MCB circuit protects against overload current, and the electromagnet in the circuit protects against short-circuit current.