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Unit-1
Fundamentals of Electric Circuit

1] Ohm's law
2] Types of sources
3] Ideal and practical sources
4] Source conversion
5] Superposition theorem
6] Series and Parallel combination resistances
7] Kirchoff's law

Ohm's law

* Electric circuit: An interconnection of various elements in which their atleast one closed path in which current can flow as electric circuit.

Active elements: The elements of a circuit which posses energy of their own and can impart its to other element of the circuit are known as active element of circuit.
Ex: Voltage source, current source, generator, OP-AMP

Passive elements: The elements of a circuit which do not posses energy of their own and receive energy from the sources are known as passive elements.
Ex: resistance, capacitance or inductors.

→ If the energy is consumed the circuit element is a pure ~~inductor~~ resistor.

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→ If the energy is stored in magnetic field then a element is a pure inductor.

→ If the energy is stored in a electric field then the element is a pure capacitor.

linear elements: The linear elements shows the linear characteristics of voltage and current its VI characteristics are at all times straight line.
Ex: resistors, inductors, capacitors.

Linear circuit:

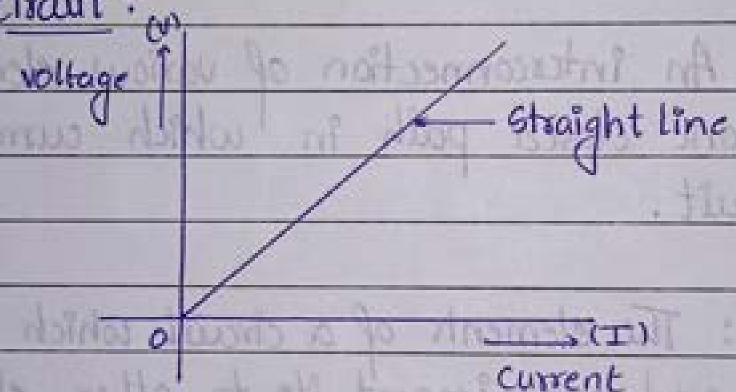

Figure: VI characteristics of linear element.

Non-linear element: The V-I characteristics of non-linear element do not follow the linear pattern i.e. the current passing through it does not change linearly with the linearity change in the voltage across it.
Ex: transistor, diode

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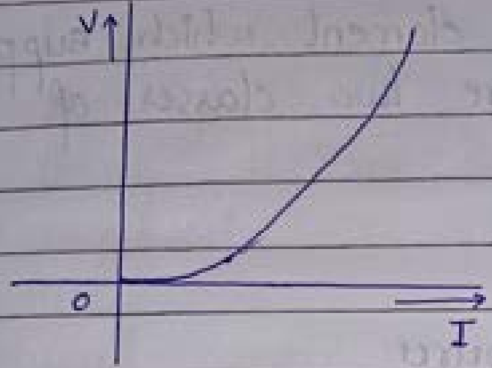
Non-linear circuit:



V-I charateristics of non-linear circuit.

The circuit in which the parameters are R, L and C with voltage in current is known as non-linear circuit.

Ohm's law

Statement of Ohm's law: Ohm's state that the voltage of potential difference across a conducting material is directly proportional to a current flowing through the material

$$\therefore V \propto I$$

$$V = IR$$

$$I = V/R$$

When the current flows through resistive material then heat is generated by the collision of e^-s by other atomic particles the power absorb particles the power absorb by the resistor is converted to heat.

$$P = VI$$

$$= IRI$$

$$\therefore P = I^2R$$

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Types of sources

Source is a basic network element which supplies energy to the networks. Their are two classes of sources

1] Independent sources
2] Dependent sources

Independent voltage source

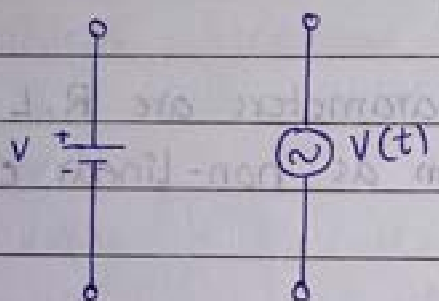

Fig: Symbol for independent voltage source.

Output characteristics of an independent source are not dependent on any network variable such as a current or voltage its characteristics naming time varing.

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An independent voltage source is a two terminal network element that establishes a specified voltage across its terminal the value of this voltage at any instant is independent of the value or direction of the current flows through it. The terminal voltage may be a constant or it may be some specified function of time.

Independent current source

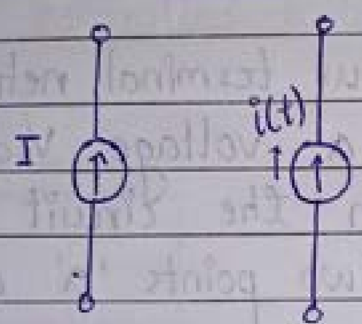

Fig: Symbol for independent current source.

An independent current source is a two terminal network element which produces a specified current the value and direction of this current at any instant is independent of the value or direction of the voltage that appears across the terminals of the source. The output current may be a constant or it may be function of time.

Dependent source

If the voltage current of a source depend upon some other voltage or current then it is called as dependent or controlled source. The controlled variable is voltage or current and controlled source is a voltage source or current source.

Voltage control voltage source (VCVS)

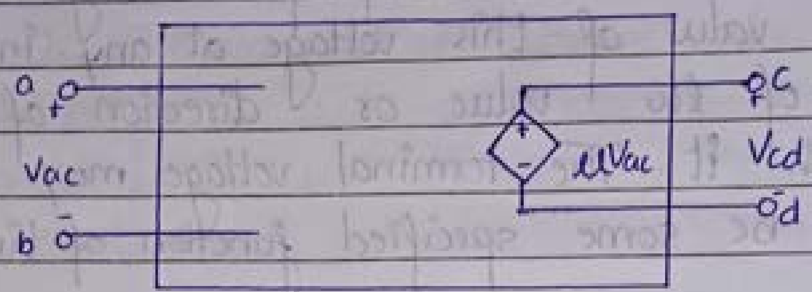

Fig: Symbol for VCVS

A voltage source is a four terminal network component that establishes a voltage V_{cd} between two points c and d in the circuit i.e. proportional to voltage V_{ab} between two points 'a' and 'b' i.e.

$$V_{cd} = \mu V_{ab}$$

Voltage controlled current source (VCCS)

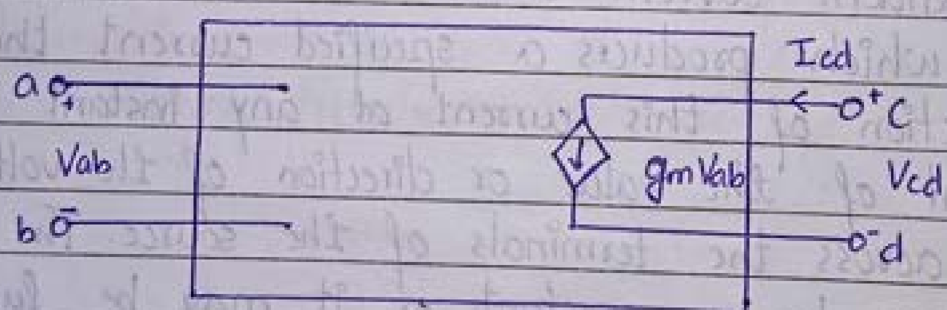

Fig: Symbol for VCCS

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

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

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A voltage controlled current source is a four terminal network component that establishes current I_{cd} in a branch of the circuit i.e. proportional to voltage V_{ab} between two points 'a' and 'b'

$$\therefore I_{cd} = g_m V_{ab}$$

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

Current controlled voltage source (CCVS)

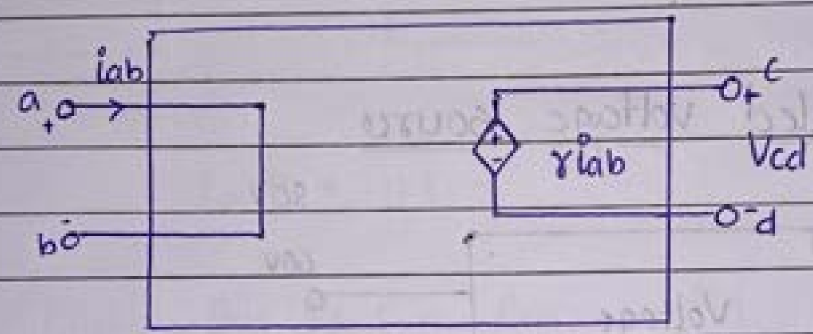


Fig: Symbol for CCVS

A current controlled voltage source is a four terminal network component that establishes the voltage V_{cd} between two points 'c' and 'd' in the circuit i.e. proportional to the current I_{ab} in some branch of circuit.

$$\therefore V_{cd} = \gamma \cdot i_{ab}$$

Voltage V_{cd} depends on the voltage current i_{ab}

Current Controlled Current source (CCCS)

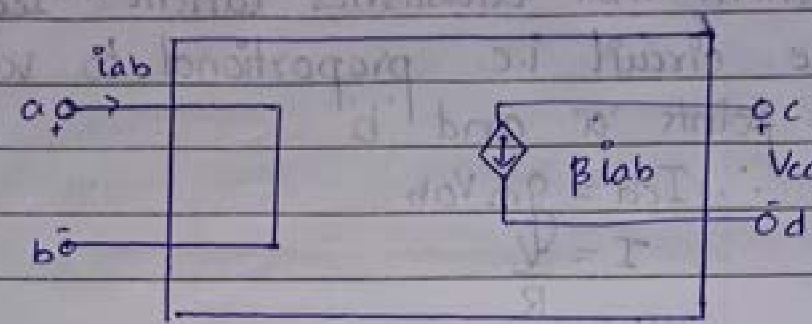
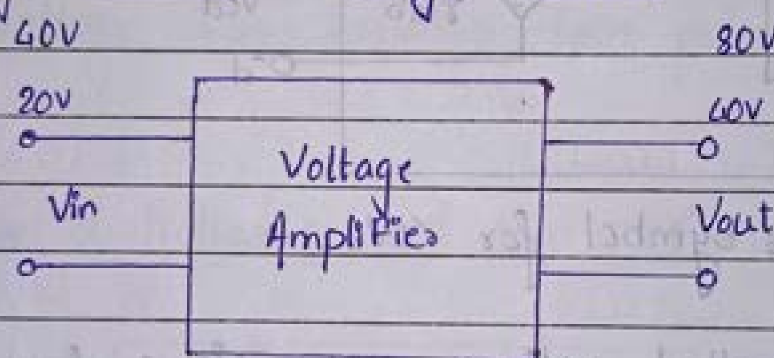


Fig: Symbol for CCCS

$$i_{cd} = \beta i_{ab}$$

Voltage Controlled voltage source

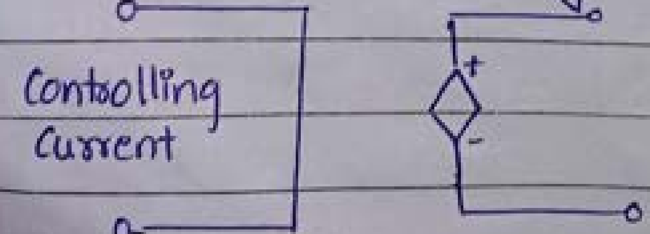


Multiplying factor / Scaling factor = 2

$$V_{out} = \mu V_{in}$$

$$\mu = \frac{V_{out}}{V_{in}} = \frac{Volts}{Volts}$$

Current controlled voltage source



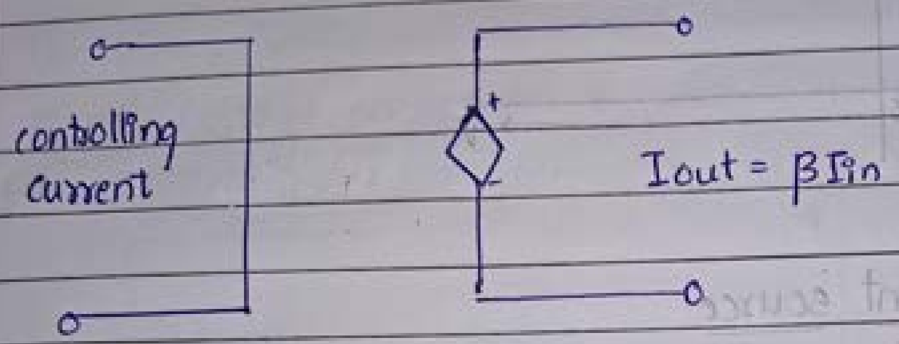
$V_{out} = P \times I_{in}$

Shrikrupa

$$V_{out} = P \times I_{in}$$

$$P = \frac{V_{out}}{I_{in}} = \frac{\text{Volts}}{\text{Ampere}} = \frac{V}{A}$$

Current Controlled Current source

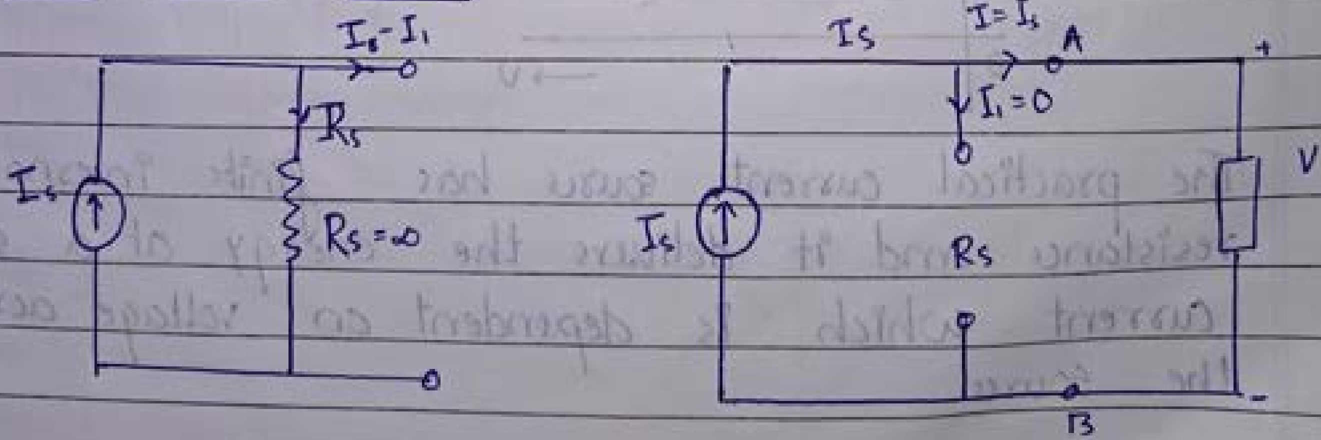


$$I_{out} = \beta I_{in}$$

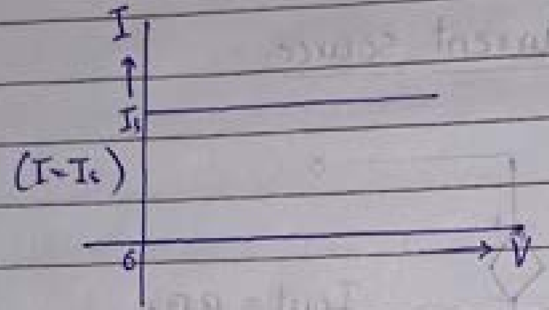
$$\beta = \frac{I_{out}}{I_{in}} = \frac{\text{Amp}}{\text{Amp}}$$

A current source which depends upon the I_{in} is called as current controlled current source. The source is controlled by the I_{in}. ~~The current source is~~

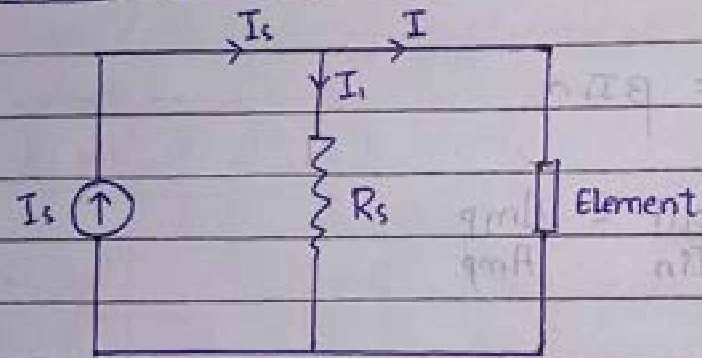
Ideal current source

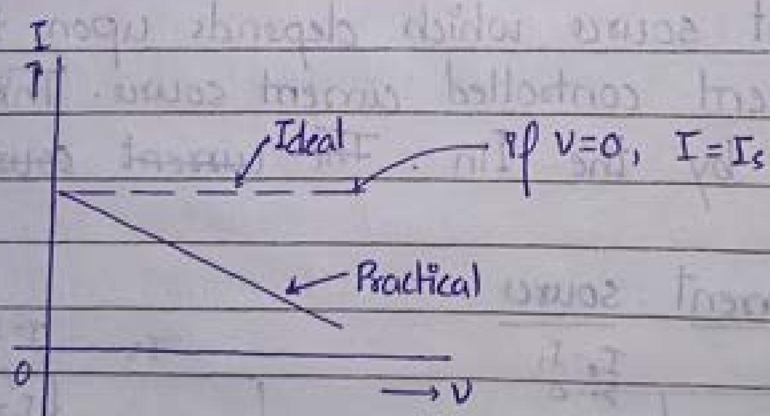


The ideal current source has infinite intanal registance and it desil deliver energy at specified curret which is independent voltage across the source



Practical Current source





The practical current soure has finite internal resistance and it delivers the energy at a specified current which is dependent on voltage acros the source.

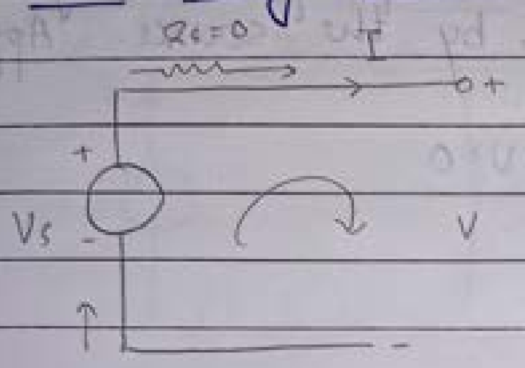
$\therefore\ I_s = I_1 + I$

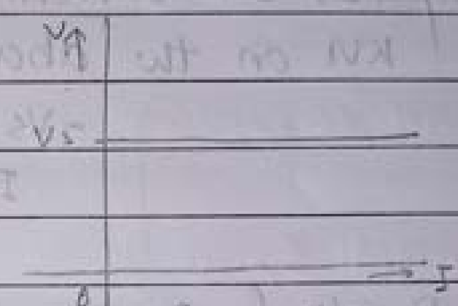
$\therefore\ I = I_s - I_1$

using ohm's law

$$\downarrow I = I_s - \frac{V\uparrow}{R_s}$$

Ideal voltage source



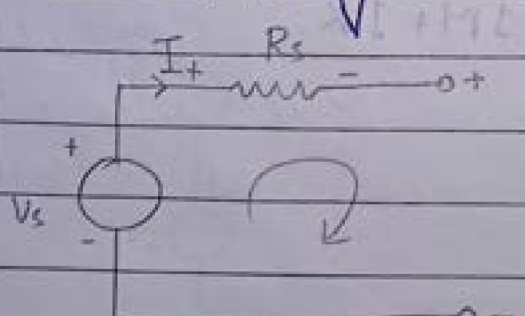


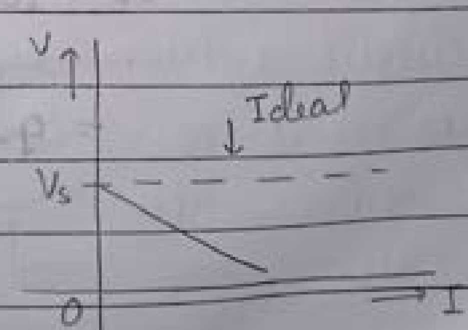
$-V_s + V = 0 \quad \therefore V = V_s$

The ideal voltage source has zero internal resistance. It delivers the energy at a specified voltage which does not depend on the current deliver by the source. Applying KVL on above

The ideal voltage source can draw any amount of current without changing a terminal voltage

Practical voltage source





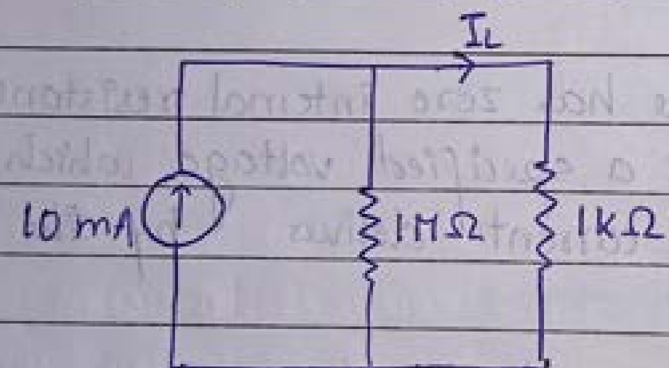
$-V_s + IR_s + V = 0$

$$-V_s + IR_s + V = 0$$
$$IR_s = V_s - V$$
$$V = V_s - IR_s$$
when $I = 0$
$$V = V_s$$

The practical voltage source has a finite internal resistor which delivers a energy at a specific voltage which depends on current delivers by the source. Applying KVL on the above rule.

$$-V_s + IR_s + V = 0$$
$$IR_s = V_s - V$$

Practical Current source



$I_L = ?$

Apply current divider rules

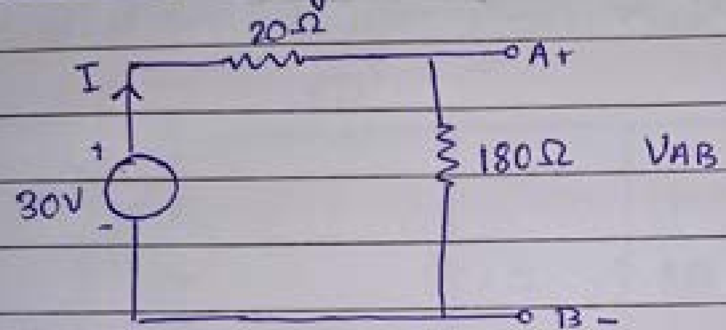
$$I_L = 10m \times \frac{1M}{1M + 1K}$$
$$= 9.990 \text{ mA}$$

For 10 M Ω,

$I_L = 9.999\ mA$

In practical current source the current supplied to the load changes with voltage.

Practical voltage source



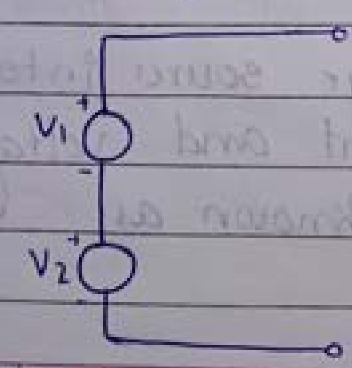
$I = \frac{V}{R} = \frac{30}{1000} = 0.03A$

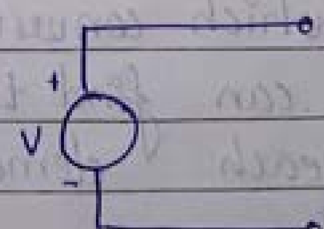
$V_{AB} = V_s - I\,20$

$= 30 - 0.03 \times 20 = 26.4V$

In practical voltage source the voltage across its terminal changes with current.

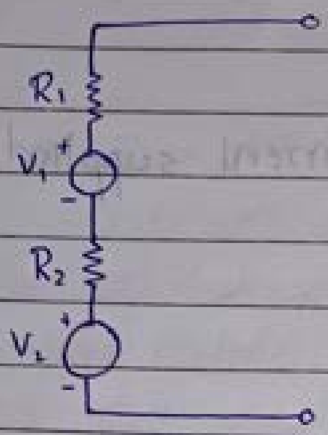
Ideal voltage source

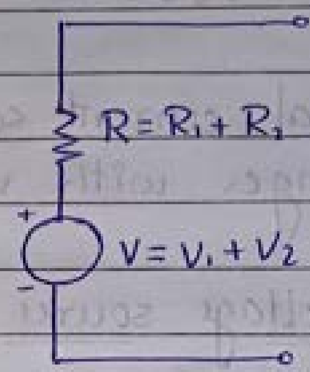




$V = V_1 + V_2$

Practical voltage source





Source conversion

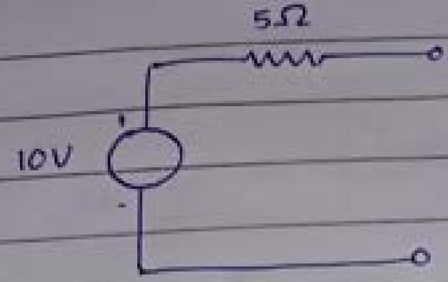
1] Current Source
$R \longrightarrow$ Parallel

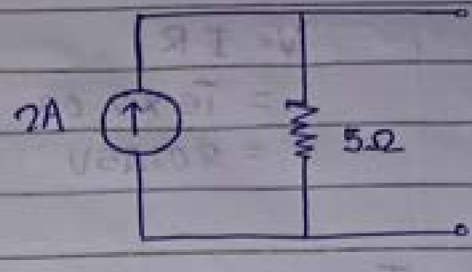
2] Voltage Source
$R \longrightarrow$ Series

3] If current is in same direction = '−'
If current is in $diff^n$ direction = '+'

4] ~~Sa~~ Polarity same = ~~'H'~~ '+'
Polarity $diff^n$ = ~~'N'~~ (−)

5] A circuit which converts voltage source into current source and can find the current and voltage drop across each element is known as source conversion

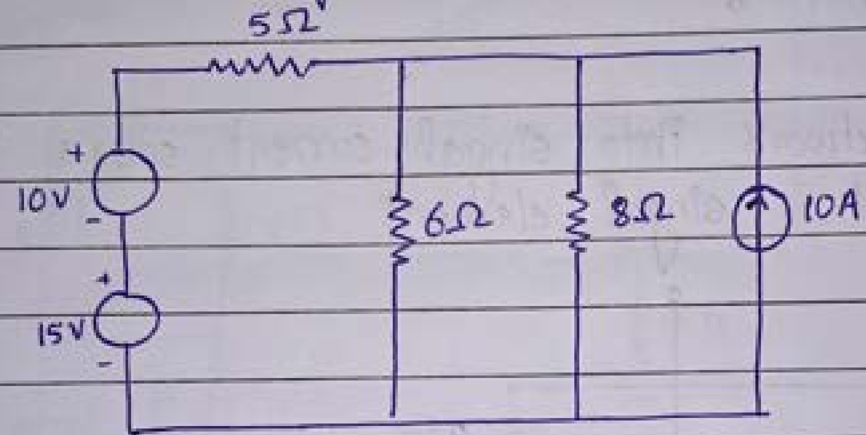


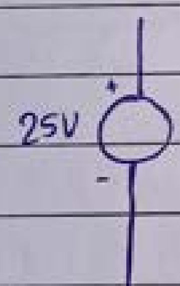


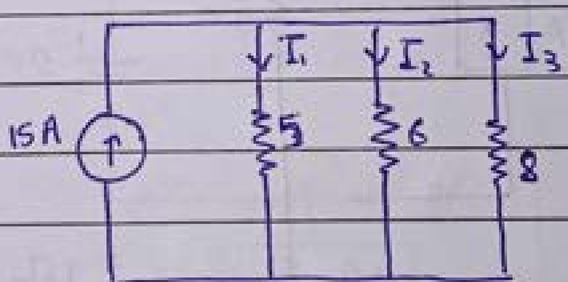
$$I = \frac{V}{R} = \frac{10}{5} = 2A$$

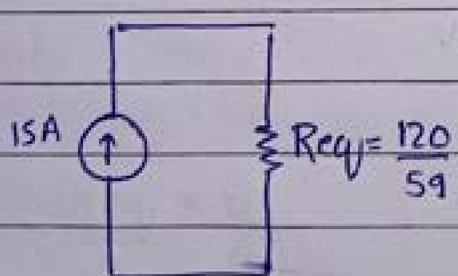
$$V = IR = 2 \times 5 \times 10V$$

Q. Convert the voltage into the current source and find the current and voltage across each.









$$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{eq}} = \frac{1}{5} + \frac{1}{6} + \frac{1}{8}$$

$$\frac{1}{R_{eq}} = \frac{24+20+15}{120} = \frac{59}{120}$$

$$R_{eq} = 2.03\,\Omega$$

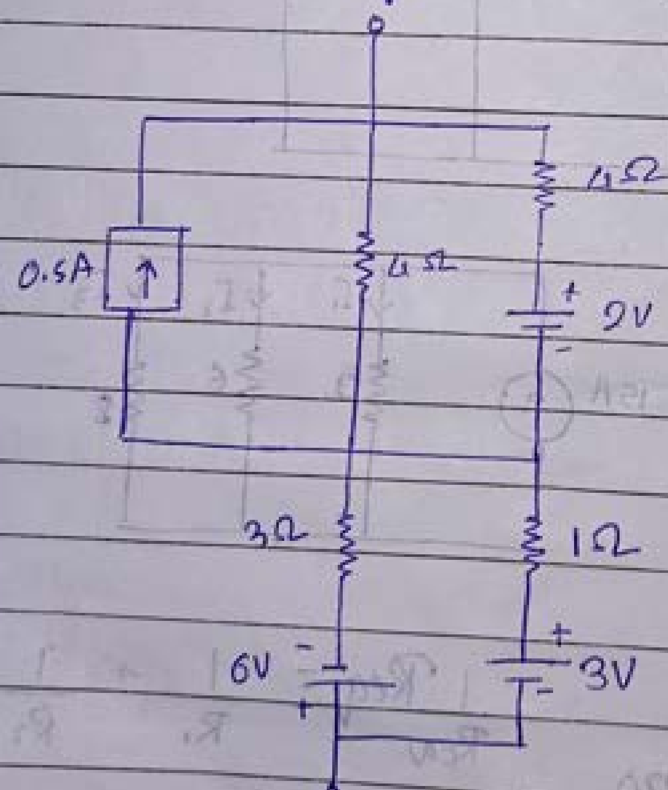
$$V = IR$$
$$= 15 \times 2.03$$
$$= 30.45V$$

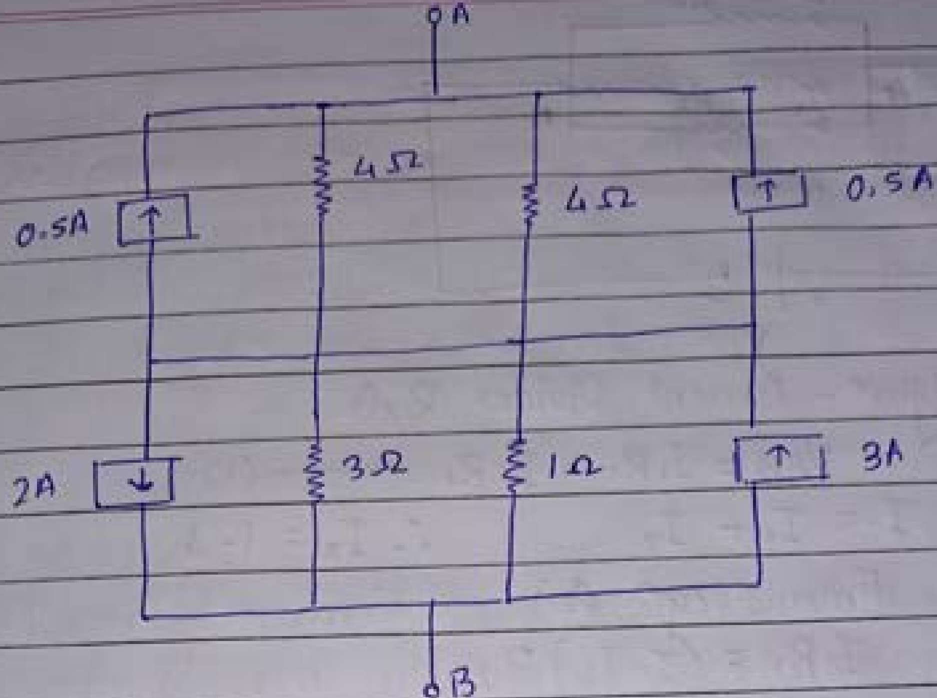
$$I_1 = \frac{V}{R_1} = \frac{30.45}{5} \approx 6.09$$

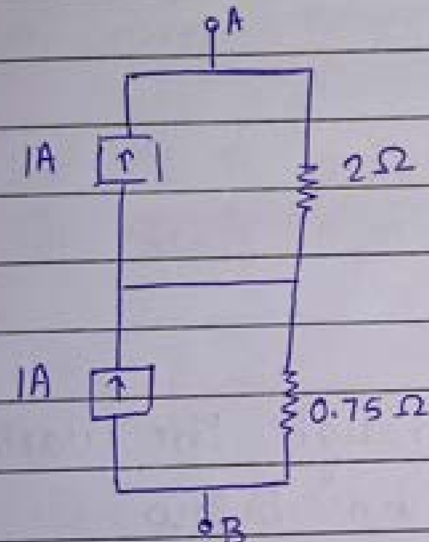
$$I_2 = \frac{V}{R_2} = \frac{30.45}{6} = 5.075$$

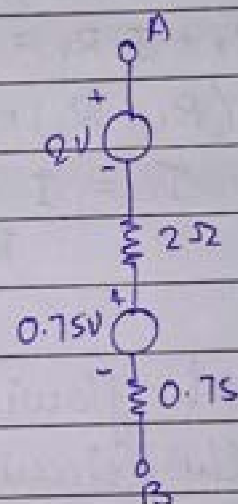
$$I_3 = \frac{V}{R_3} = \frac{30.45}{8} = 3.05625$$

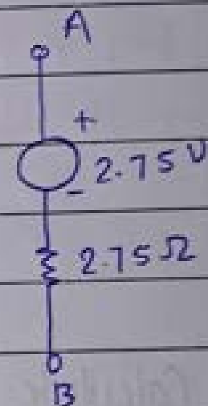
Q. Reduce the network into singal current source in parallel with singal element







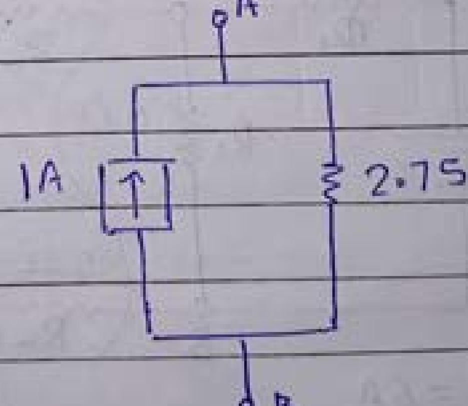




$$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{1}$$

$$\frac{1}{R_{eq}} = \frac{4}{3}$$

$$R_{eq} = \frac{3}{4}$$



$$I = \frac{V}{R} = \frac{2.75}{2.76} = 1A$$

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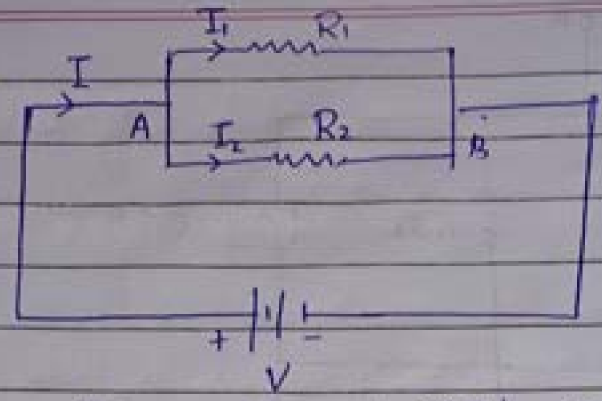


Figure - Current Divider Rule

$$V_{AB} = I_1 R_1 = I_2 R_2 \quad \text{——— (1)}$$

$$I = I_1 + I_2 \qquad \therefore I_2 = I - I_1$$

From eqn (1)

$$I_1 R_1 = (I - I_1) R_2$$

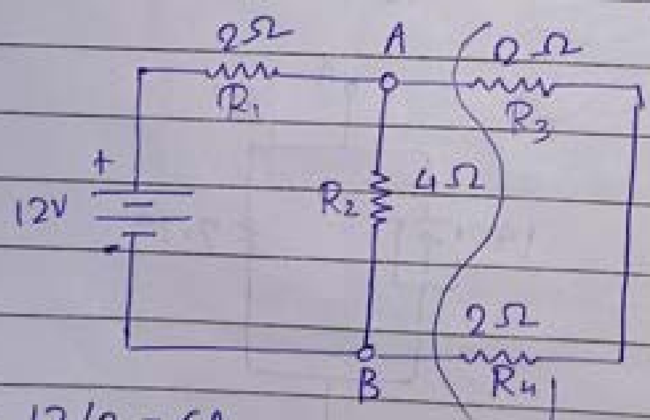
$$I_1 R_1 = I R_2 - I_1 R_2$$

$$I_1 R_1 + I_1 R_2 = I R_2$$

$$I_1 (R_1 + R_2) = I R_2$$

$$I_1 = I \frac{R_2}{R_1 + R_2}$$

Q. Calculate the current flowing through the various resistances in the circuit shown below



$I = \frac{12}{4}$

$V = 12V$

$R = 4\Omega$

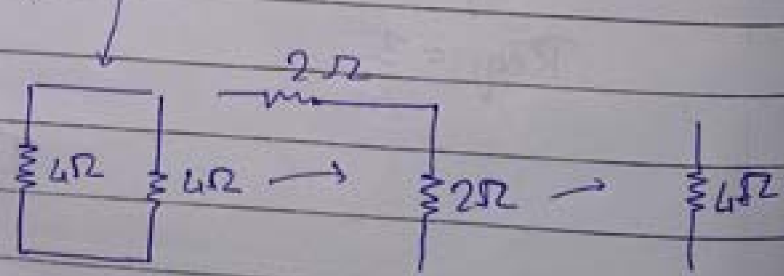
$I = 3A$

$I_1 = 12/2 = 6A$

$I_2 = 3A$

$I_3 = 6A$

$I_4 = 6A$



Kirchoff's law

→ Kirchoff's current law

Kirchoff current law is also known as Kirchoff 1st law or Kirchhoff law of junction.

KCL is based on law of conservasion of charge.

Statement:

The Kirchhoff current law state that the algebaric sum of current meeting at a junction or node in a current is zero.

The KCL is applied at any node of an electric network.

The KCL is expressed mathematically

$$\sum_{j=1}^{n} I_j = 0$$

where, n = no. of branches meeting at a node.

I_j = The current in the j^{th} junction branch

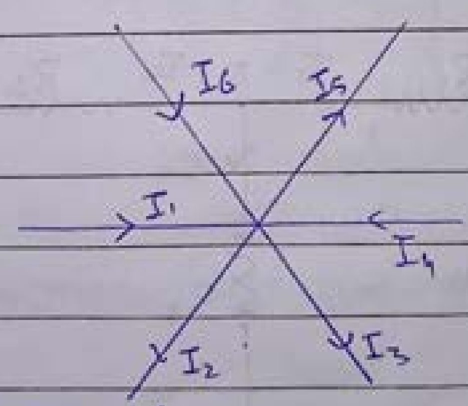


Figure: Applications of KCL

$I_1 + I_6 + I_4 - I_2 - I_5 = 0$

→ Kirchhoff's Voltage law

The Kirchhoff voltage law is also known as Kirchhoff 2nd law.

The KVL is based on law of conservation of energy.

The KVL is applicable to any closed loop in a circuit.

Statement:

The KVL states that any instant of time the algebraic sum of voltages in a close loop is zero.

KVL can be expressed mathematically

$$\sum_{j=1}^{n} V_j = 0$$

where V_j = The voltages of all the branches in a mesh or a loop.

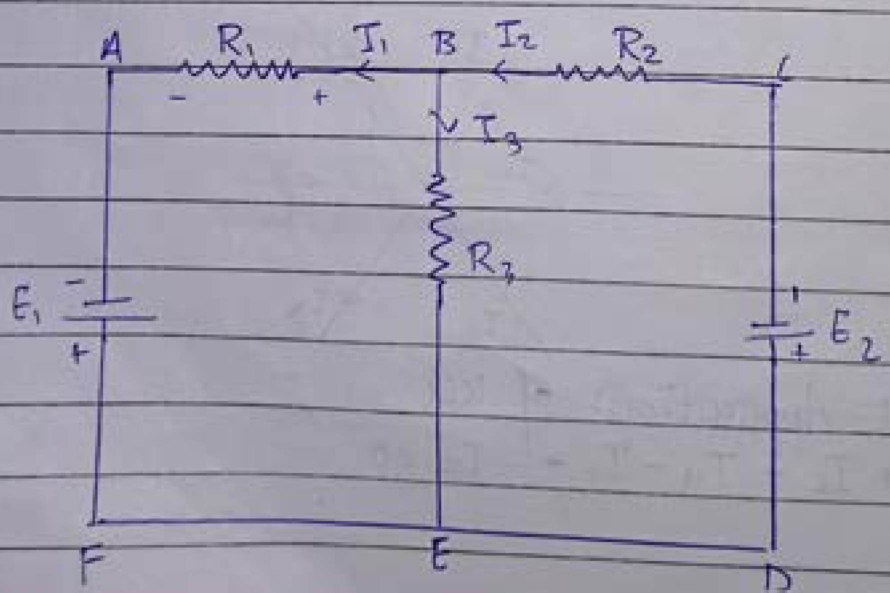


Figure: Circuit for application of KVL mesh ABEFA,

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We get, $-R_1I_1 + R_3I_3 + E_1 = 0$ — (1)

In BCDEF

$$-I_2R_2 - I_3R_3 + E_2 = 0 \quad \text{— (2)}$$

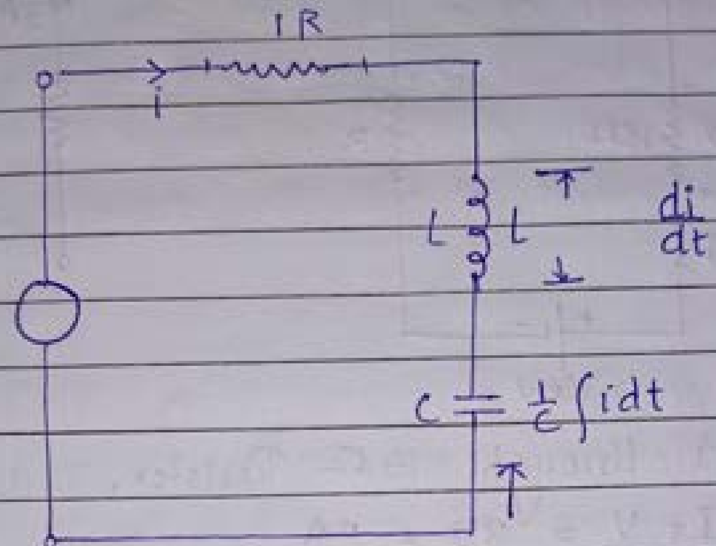


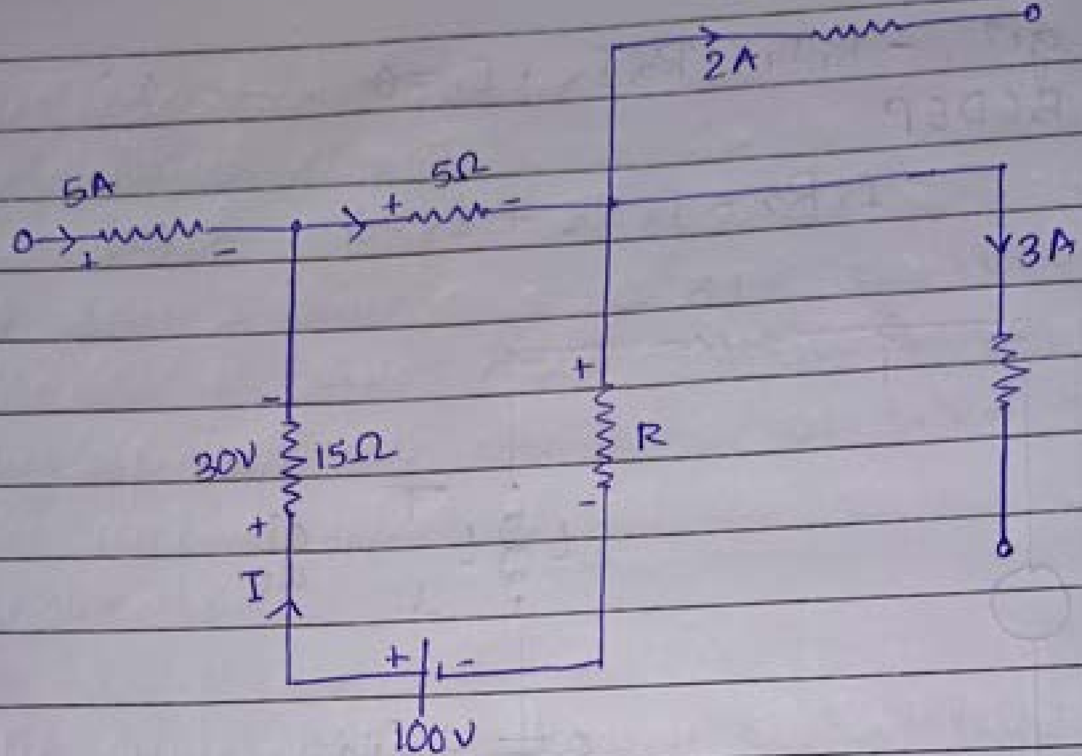
Figure:

Consider a circuit consisting of a resistance, an inductance and a capacitors connected across a voltage source as shown in figure.

Applying KVL, the voltage equation is given

$$e = Ri + L\frac{di}{dt} + \frac{1}{C}\int i\,dt \quad \text{— (3)}$$

Q. The voltage draw across 15Ω resistor is 30Ω adding the polarity indicated, Find the value of R.

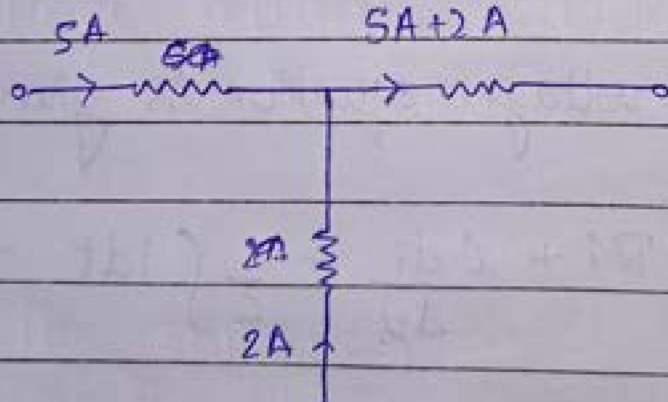


Current through 15Ω Resister,

$$I = \frac{V}{R} = \frac{30}{15} = 2A$$

Current through 5Ω Resister,

$$5A + 2A = 7A$$



Applying KVL at closed path,

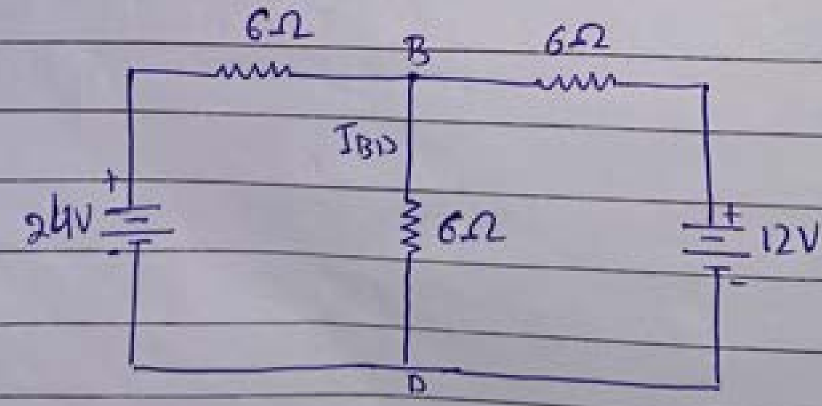
$$-100 + 30 + 7 \times 5 \times 2R = 0$$

Superposition Theorem:

An electrical circuit may contain more than one source of supply. The sources of supply may be of voltage source or a current source. In solving of circuit problems having multiple sources of supply, the effect of each source is calculated separately and the combine effect of all the sources are taken into consideration.

The superposition theorem states that in a linear network containing more than 1 source, the current flowing in any branch is the algebraic sum of current that has been produced by each source taken separately with all the other sources repalced by their respective internal resistances. In case the internal resistance of a source is not provided, the voltage sources built with short circuited and current source is short circuited.

Q. Using the superposition theorem find the I_{BD} in the circuit shown below



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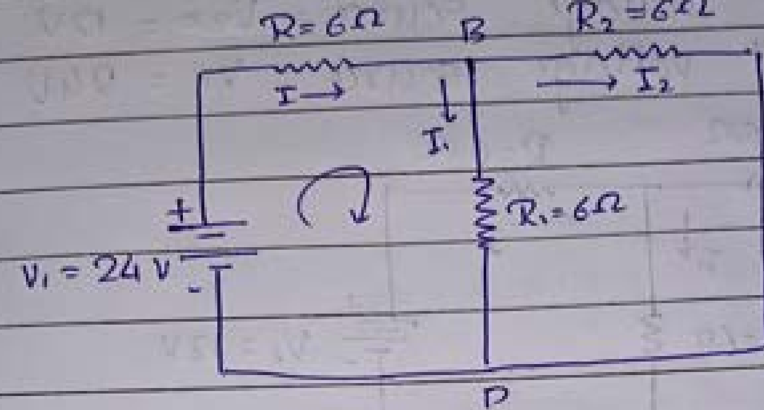
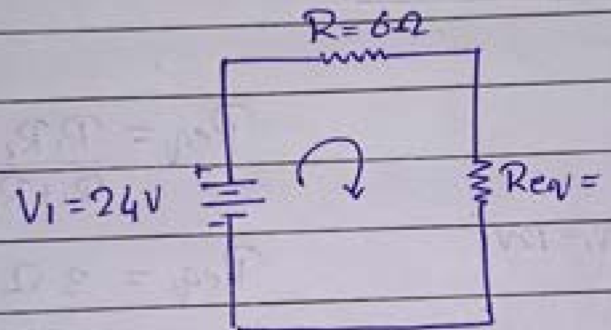
Case - I ⇒

Consider a voltage source given = 24V

Short circuit the voltage source given = 12V

Case-II ⇒





$$R_{eq} = \frac{R_1 R_2}{R_1 + R_2}$$

$$= \frac{6 \times 6}{6+6}$$

$$R_{eq} = 3\Omega$$

∴ The current supplied by the source,

$$I = \frac{V_1}{R + R_{eq}} = \frac{24}{6+3} = \frac{8}{3} \text{ A}$$

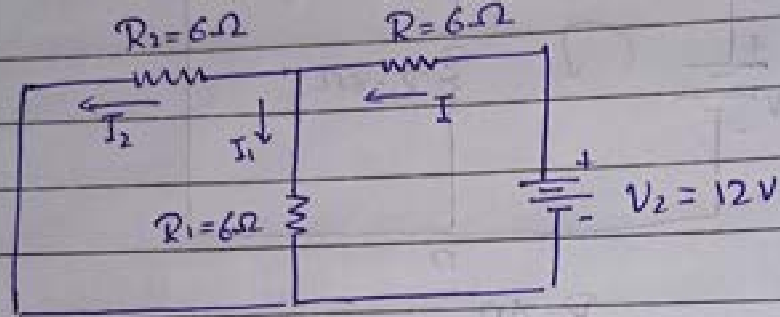
Using current division rule,

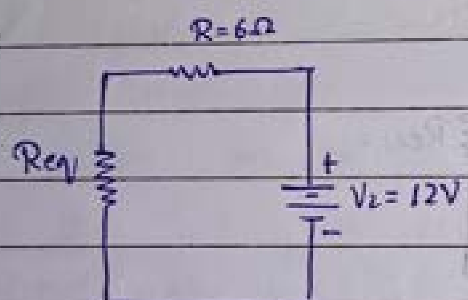
$$I_1 = I \times \frac{R}{R+R_1} = \frac{8}{3} \times \frac{6}{6+6} = \frac{4}{3} A$$

Case - II ⇒

Consider the voltage source = V_2 = 12V

Short circuit voltage source = V_1 = 24V





$$R_{eq} = \frac{R_1 R_2}{R_1+R_2} = \frac{6 \times 6}{6+6}$$

$$R_{eq} = 3\Omega$$

∴ The current supplies by V_2,

$$I = \frac{V_2}{R+R_{eq}} = \frac{12}{6+3} = \frac{4}{3} A$$

∴ Using current division rule,

$$I_1 = I \times \frac{R}{R+R_1}$$

$$= \frac{4}{3} \times \frac{6}{6+6}$$

$$\therefore I_1 = \frac{2}{3} A$$

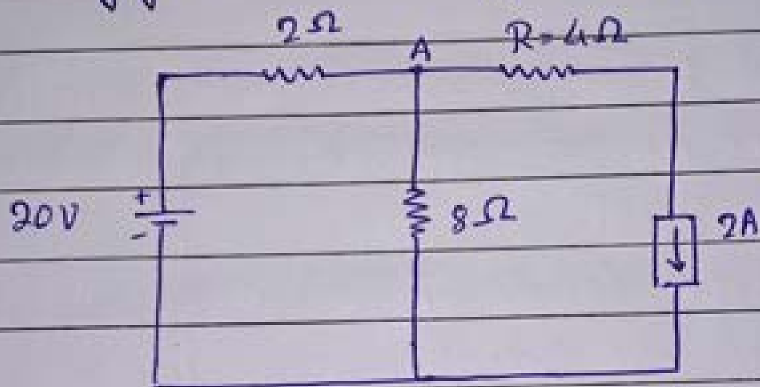
$\therefore$ Current flowing through BD,

I_{BD} = I_1 due to V_1 + I_1 due to V_2

$$= \frac{4}{3} + \frac{2}{3}$$

$$I_{BD} = 2A$$

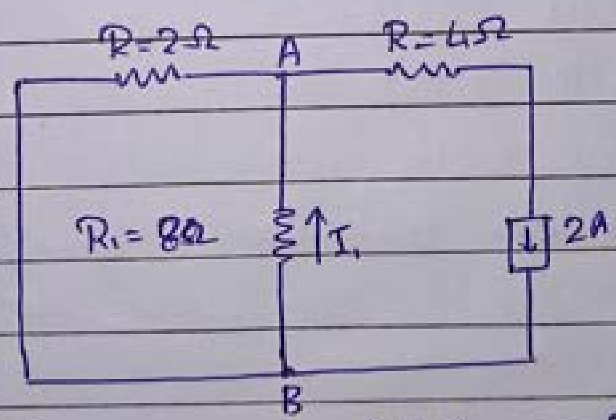
Q. Determine the current to 8Ω resistor in the network shown in figure below using superposition theorem.



Case - I ⇒

Consider a current source

A voltage source is replaced by a short circuit



$\therefore$ Using current division rule,

$$I_1 = I \times \frac{R}{R + R_1} = 2 \times \frac{4}{4+8} = \frac{2}{3}$$

UNIT-2 Magnetic Circuit

→ Types of magnetic material
→ Flux
→ Flux density
→ Flux intensity
→ m.m.f (magnetic motion force)
→ Reluctance
→ Permiability

Magnetic material : The material which gets ~~attracted~~ attracted towards a magnet is known as magnetic material.

Ex: Iron, Cobalt, Nickel etc.

→ Different types of Magnetic material:

1) Dimagnetic material
2) Paramagnetic material
3) Ferromagnetic material
4) Anti-ferromagnetic material
5) ferrimagnetic material

1] Diamagnetic material

Dipole $\longrightarrow$ $\uparrow \; \uparrow \; \uparrow$

- No interaction between the neighbouring dipoles
- No permonent dipoles
- There will be no magnetic moment in the absence of magnetic field.
- In the presence of applied magnetic field, the magnetization produced in the direc^n opposite to applied M.F. (magnetic field)

$$\therefore M \longrightarrow \quad \longleftarrow H$$

$$M = -H$$

$$\frac{M}{H} = -1$$

$$\therefore \chi_m = \frac{M}{H} = -1$$

- Succeptibility is -ve, diamagnetic material
- Eg: copper.
- It does not depends on heat.

2] Paramagnetic Material

Figure: Structures for paramagnetic materials

- In Paramagnetic materials the permanent dipoles are present.
- The interaction between neighbouring atoms are negligible.
- These materials are ~~deeply~~ weakly magnetized in the direction of applied magnetic field.
- Susceptibility is small but +ve
- The relative permiability is greater than unity
- The paramagnetic material depends on the temperature and it is given by Curie's law
- Curie's law Statement:

The magnetization in the paramagnetic material is inversly proportional to the temperature.

$$\therefore X_m \propto \frac{1}{T}$$

$$\therefore \chi_m = \frac{C}{T}$$

where, C = Curie constant
T = Absolute temperature

Example of Paramagnetic material is Aluminium.

3] Ferromagnetic Material:

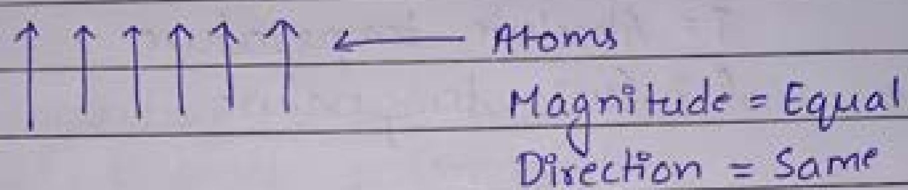


Fig: Stoucture for Ferromagnetic materials

- In ferromagnetic material the permanent dipole moment are present.
- Out of all, the ferromagnetic material is the strongest type.
- The exibit the next spontaneous magnetization they are strongly magnetization in the direction of applied magnetic field.
- The succeptibility is very high.
- The relative permiability is also very high.
- They are also dependent on temperature (T).

It follows the curie's law

$$X_m \propto \frac{1}{T-\theta}$$

$$X_m = \frac{C}{T-\theta}$$

Where,

C = Curie constant
T = Absolute temperature
θ = Curie temperature

- About θ (curie temperature) the ferromagnetic temperature will become paramagnetic material

Ex : Iron, Cobalt, Nickel etc

4] Anti-ferromagnetic material :

Atoms → ↑ ↓ ↑ ↓ ↑ ↓

Magnitude = Equal
Direction = Opposite

Fig : Structure of Anti-ferromagnetic material

- In Antiferromagnetic material the permanent dipole moment are present the interaction between the neighbouring atoms are equal but opposite so the net magnetisation is 0.

- The antiferromagnetic material also depends on temp.

$$X_m \propto \frac{1}{T+\theta}$$

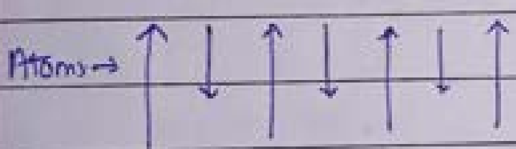
$$X_m = \frac{C}{T+\theta}$$

where,

θ = Neel temperature

The temperature above which certain antiferromagnetic material becomes paramagnetic.

5] Ferrimagnetic materials

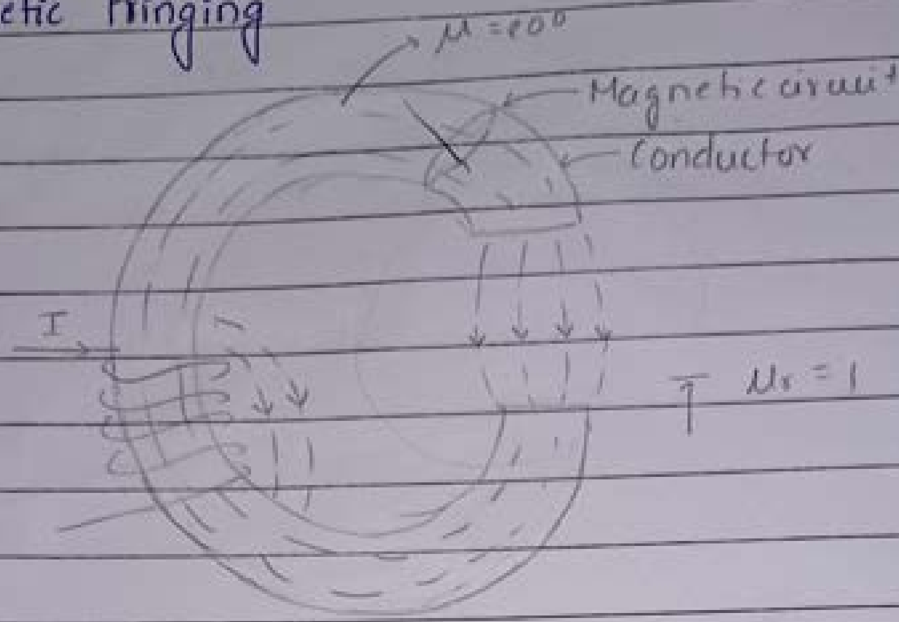


Magnitude = Unequal
Direction = Opposite

Fig: Structure of Ferrimagnetic material

- The ferrimagnetic material the permanent dipoles are present.
- The interaction between the neighbouring atoms are ~~of~~ unequal and opposite (opposing)
- Net magnetization is non-zero.
- These materials are used in magnetic memory.

Magnetic Fringing



Magnetic ~~friction~~ fringing (Bulging) effect in the correction of various lines of process in a specific area.

Whenever a magnetic line of forces travels from one medium to another, then the due to the change in relative permeability of mediums of bulging effect aries in the medium having lower relative permeability.

The magnetic line of forces travelling from one medium to another medium having different lower relative permeability will experience an increased cross sectional area for the flow of magnetic linkage flux and that increase cross-sectional area effect is known as magnetic fringing.

→ Basic effect of Magnetic fringing
- Increase cross-sectional area.
- Reduce magnetic density.

Magnetic leakage Flux

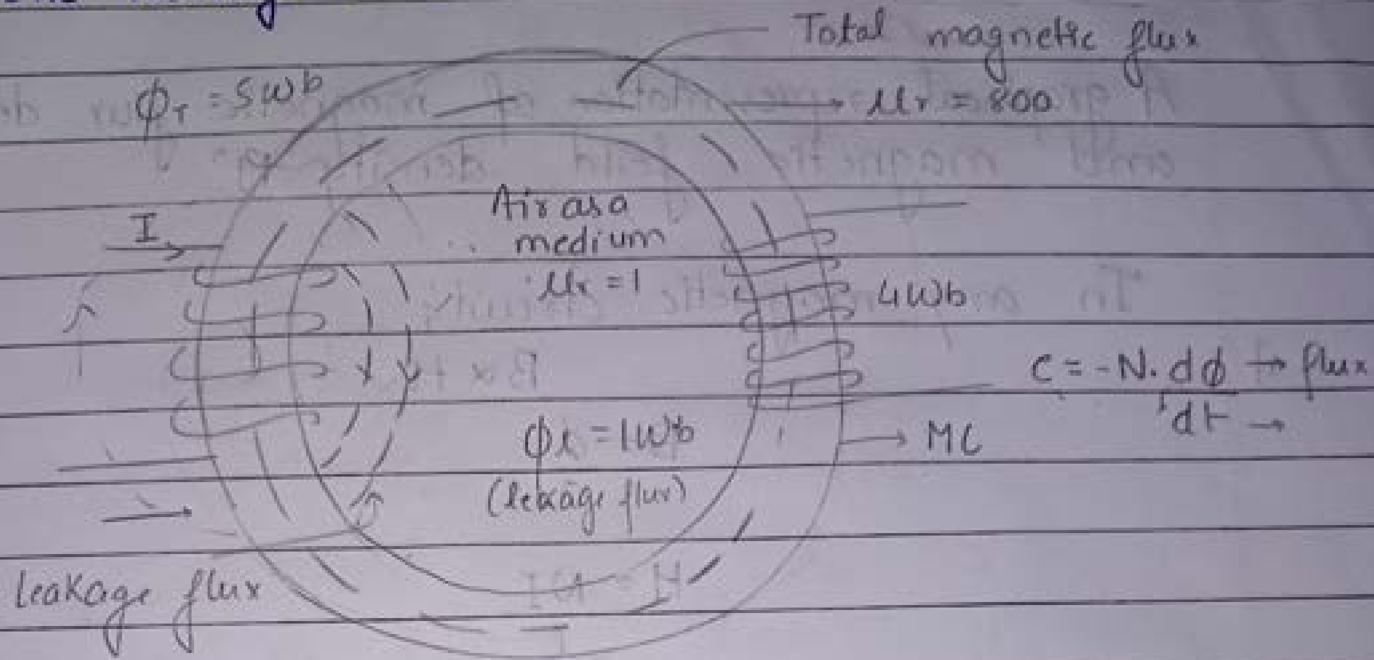


Figure: Magnetic circuit for magnetic flux

Those magnetic flux which does not follow the intendent part are known as ~~Magnetic~~ Leakage Flux.
The total flux is given by: $\phi_T = \phi_L + \phi_u$
where,

ϕ_T = Total Flux
ϕ_L = leakage Flux
ϕ_u = Useful Flux

B-H curve

A graphical representation of magnetic flux density 'B' and magnetic feild density 'H'

In any magnetic circuit,

1] $$B \propto H$$

$$B = \frac{\phi}{a}$$

$$H = \frac{NI}{l}$$

constant

2] $H \propto I\uparrow$

$$B = \mu H$$

$$B = \mu_0 \mu_r H$$

$\therefore \mu = \mu_0 \cdot \mu_r$

$\mu_0 = 4\pi \times 10^{-7}$ and μ_r = relative permeability of medium

Retentivity: The property of magnetic any material to store the residual magnetism inside is known as retentity.

Hysteresis law: It is the condition of magnetic flux density B lagging from magnetic feild intensity H in any BH curve.

Cohesive force: The amount of ~~source~~ force provided in negative direction to eliminate or reduce the residual magnetic feild.

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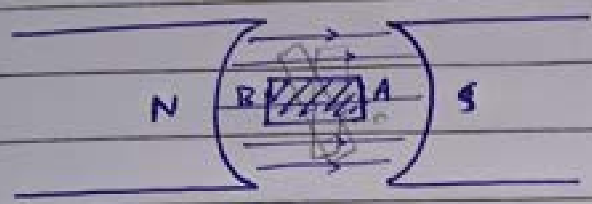
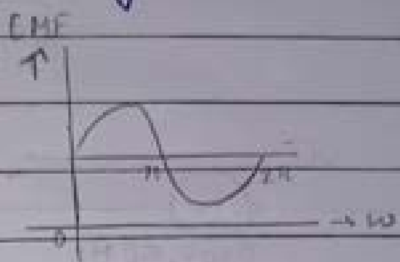
Unit - 3

AC Circuits

→ Generation of singale phase voltage





RLC Circuit with Excitation

- Resistance is the opposition offered by a conductor to the flow of electron

- Current is in phase with voltage source

Reactance

- This is represented by X
- Types of reactance

1) X_L → Inductance

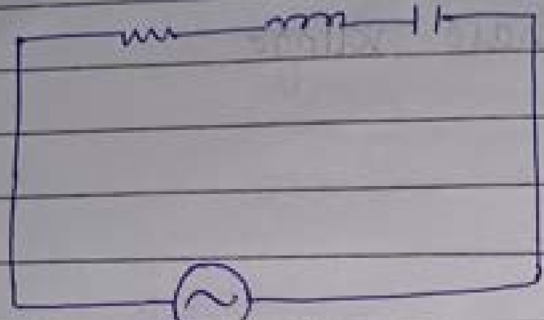
2) X_C → Capacitance

Reactance

X_L — X_C

I 90° V — I 90° L V

Basic RLC circuit



230V, 50 Hz

$X_L =$

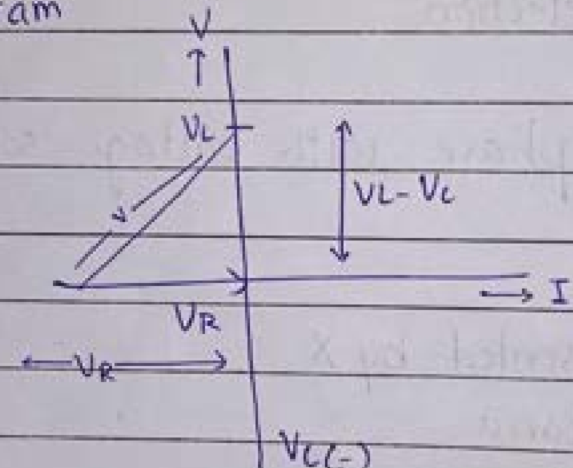
$X_L = \Omega L$ $\qquad X_C = \dfrac{1}{2\pi f C}$

$\Omega = 2\pi f L$

$X_C =$

$\therefore X_L \propto fL$ $\qquad X_C \propto \dfrac{1}{fC}$

Phasor Diagram



In resistor

The voltage adopt across R is in a phase with I

The current I lages the voltage by 90°.

By Pythagorous Theorem

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

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

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

$$\therefore V = I\underbrace{Z}_{\text{Impedence}}$$

* Condition for Phasor diagram

1] In inductive circuit $X_L - X_C = +ve$

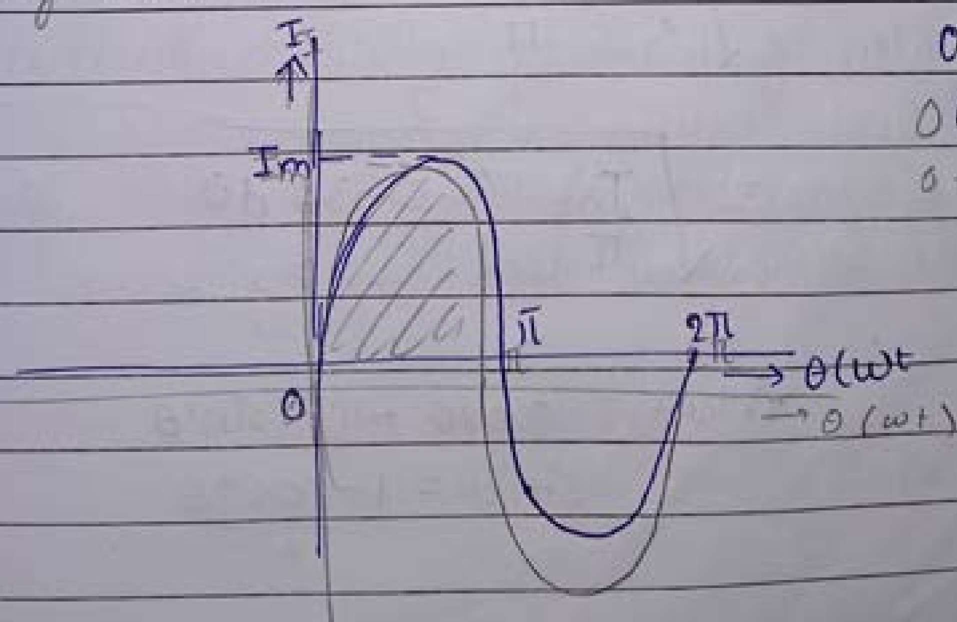
2] In capacitive circuit $X_L - X_C =$ negative

3] In resistive circuit $X_L - X_C =$ zero

* Average and RMS value for sinusoidal wave form

Average value:

$0 - 2\pi =$ cycle



$$\text{Average value} = \frac{\text{Area of half cycle}}{\text{Base length of half cycle}}$$

$$\therefore I_{avg} = \frac{\int_0^{\pi} I \, d\theta}{\pi}$$

Since $i = I_m \sin\theta$

$$= \int_0^{\pi} \frac{I_m \sin\theta}{\pi} \, d\theta$$

$$= \frac{I_m}{\pi} \left[-\cos\theta \right]_0^{\pi}$$

$$= \frac{2 I_m}{\pi}$$

$$= 0.6386 \, I_m$$

Rms $\longrightarrow$

$$I_{rms} = \sqrt{\frac{\int_0^{\pi} i^2 \, d\theta}{\pi}}$$

$$= \sqrt{\int_0^{\pi} \frac{I_m^2 \sin^2\theta}{\pi} \, d\theta}$$

$$= \sqrt{\frac{I_m^2}{\pi} \int_0^{\pi} \sin^2\theta \, d\theta}$$

since $\cos 2\theta = 1 - 2\sin^2\theta$

$$\sin^2\theta = \frac{1 - \cos 2\theta}{2}$$

$$= \sqrt{\frac{I_m^2}{\pi} \int_0^{\pi} \frac{1 - \cos 2\theta}{2} \, d\theta}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \int_0^{\pi} 1 - \cos 2\theta \, d\theta}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \left[\theta - \frac{\sin 2\theta}{2} \right]_0^{\pi}}$$

$$= \sqrt{\frac{I_m^2}{2\pi} \times \pi}$$

$$= \frac{I_m}{\sqrt{2}}$$

$$I_{rms} = 0.707 \, I_m$$

Power in AC circuit:

$$V(t) = V_0 \sin \omega t$$
$$I(t) = I_0 \sin(\omega t + \phi)$$

- In current electricity power is given by $P = V \cdot I$
- In AC circuit Both voltage and current carries with time, ∴ power will also vary with time.

$$P(t) = V(t) \, I(t)$$
$$= V_0 \sin \omega t \cdot I_0 \sin(\omega t + \phi)$$

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$\because$ In AC circuit,

$$V(t) = V_0 \sin \omega t$$
$$I(t) = I_0 \sin(\omega t + \phi)$$

$$P_{avg} = \langle P(t) \rangle$$
$$= \overline{P(t)}$$
$$= \overline{V_0 \sin \omega t \; I_0 \sin(\omega t + \phi)}$$
$$= \overline{I_0 V_0 \sin \omega t \sin(\omega t + \phi)}$$

$V_0 I_0 \sin\omega t(\sin\omega t \cos\phi + \sin\omega t \cos\omega t \sin\phi)$

$$= \overline{V_0 I_0 \left(\sin^2 \omega t \cos\phi + \frac{2 \sin\omega t \cos\omega t \sin\phi}{2}\right)}$$

$$= \overline{V_0 I_0 \left(\sin^2 \omega t \cos\phi + \frac{\sin 2\omega t \cdot \sin\phi}{2}\right)}$$

$\overline{\sin^2 \omega t} = \frac{1}{2}$

$$= \overline{V_0 I_0} \left(\overline{\sin^2 \omega t}\; \overline{\cos\phi} + \frac{\overline{\sin 2\omega t}\; \overline{\sin\phi}}{2}\right)$$

$\overline{\cos\phi} = \cos\phi$

$\overline{\sin 2\omega t} = 0$

$\overline{\sin\omega t} = \overline{\cos\omega t} = 0$

$$= V_0 I_0 \left(\frac{1}{2} \times \cos\phi\right)$$

$$= \frac{V_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}} \cos\phi$$

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

Q. An alternative voltage of $100 \sin 314t$ is applied to a half wave diode rectifier which is in series with a resistance of $20\,\Omega$. What is the RMS value of current drawn from the supply source

For a half wave diode rectifier

$$V_{rms} = \frac{V_m}{2} = 50V$$

Q2 An alternative sinusoidal voltage of $v = 150 \sin 100\pi t$ is applied to a circuit which offers a resistance of 50V to the current in 1 direction and prevents the flow of any current in the opposite direction. Calculate the RMS average value of current and form factors. What is the frequency of the supply.

Solⁿ:

$$V = V_m \sin \omega t$$

$$\omega = 2\pi f$$

The RMS value of the voltage, $V_{rms} = \frac{V_m}{2} = \frac{150}{2} = 75$

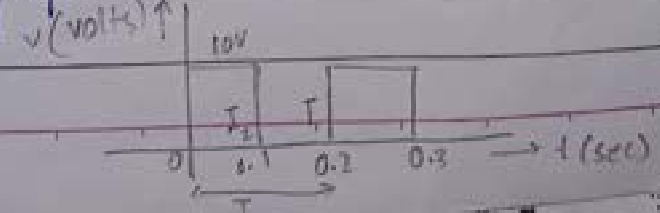
The RMS value of the current, $I_{rms} = \frac{V_{rms}}{R} = \frac{75}{50} = 1.5A$

The average value of the current, $I_{avg} = \frac{V_{avg}}{R}$

$$\therefore V_{avg} = \frac{V_m}{\pi}$$

$$I_{avg} = \frac{V_m}{\pi R} = 0.95A$$

Q3 Calculate the RMS value, average value and form factor of a half rectified square voltage shown in the figure below



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For half rectified ~~red~~ wave the average voltage =

$$V_{avg} = \frac{1}{T}\int_0^{T/2} V\,dt$$

$$= \frac{1}{0.2}\int_0^{0.1} 10\,dt$$

$$= \frac{1}{0.2} \times 10 \times 0.1$$

$$= 5V$$

$$V_{rms} = \sqrt{\frac{1}{T}\int_0^{T/2} V^2\,dt}$$

$$= \sqrt{\frac{1}{0.2} \times 100\,[T]_0^{0.1}}$$

$$= \sqrt{\frac{100 \times 0.1}{0.2}}$$

$$= 5\sqrt{2}$$

$$= 7.071\ V$$

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The form factor of half wave rectifier

$$\therefore K_f = \frac{V_{avg}}{V_{rms}} = \frac{5}{7.07} = 0.70$$

* AC Series - Parallel Circuit

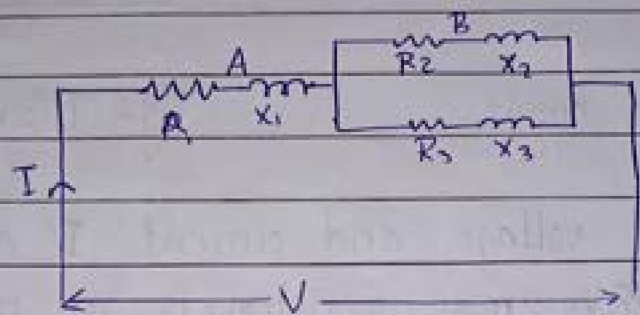
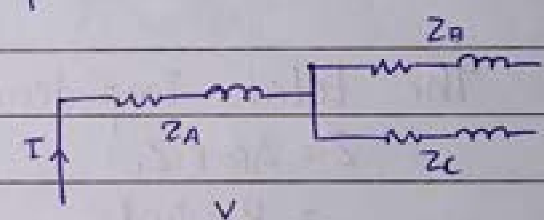


Fig : Series - Parallel Circuit

Q Consider the series - parallel circuit consisting of the 3 branches ABC impedence of branches A branch, B branch C is



$Z_A = R_1 + jX_1$

$Z_B = R_2 + jX_2$

$Z_C = R_3 + jX_3$

$$Z = Z_A + \frac{Z_B \times Z_C}{Z_B + Z_C}$$

I is the total current of the circuit

$$I = \frac{V}{R} \qquad I = \frac{V}{Z} \qquad I_B = I \times \frac{Z_C}{Z_C + Z_B}$$

$$I_C = I \times \frac{Z_B}{Z_B + Z_C}$$

* RL series Circuit

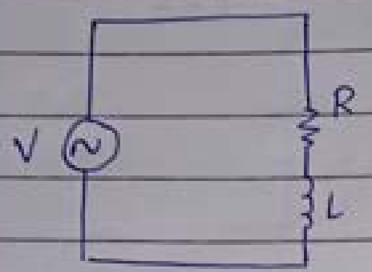


Fig: RL series circuit

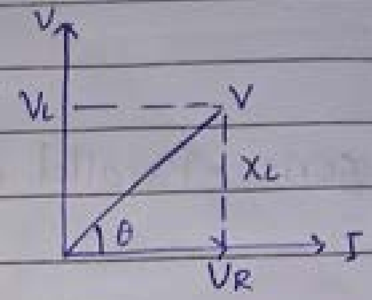


Fig: Phasor diagram

let the applied voltage and current V and R.
The voltage ~~VR~~ V_R across resistance is in phase with current form. The voltage V_L across the inductance leads the current by 90°. The applied voltage V is the resultant of V_R and V_L therefore ~~it~~ leads the current by 'θ' which is less than 90°.

The total impedence,

$$Z = Z_R + Z_L$$
$$= R + j\omega L$$
$$Z = R + jX_L$$

The magnitude of impedence,

$$|Z| = \sqrt{R^2 + X_L^2}$$
$$\therefore |Z| = \sqrt{R^2 + \omega^2 L^2}$$

The phase angle impedence,

$$\tan\theta = \frac{X_L}{R}$$

$$\theta = \tan^{-1}\frac{X_L}{R} \qquad \theta = \tan^{-1}\frac{\omega L}{R}$$

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$$Z = |Z| \angle \theta$$
$$= \sqrt{R^2 + \omega^2 L^2} \angle \tan^{-1} \frac{\omega L}{R}$$

* Impedance diagram

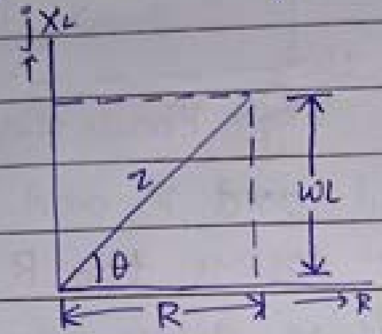

Fig: Impedance diagram

let the applied voltage $V = V_m \cos(\omega t + \theta)$

$$I = \frac{V_m \cos(\omega t + \theta)}{\sqrt{R^2 + \omega^2 L^2}}$$

$$= I_m \cdot \cos(\omega t + \theta)$$

where, $I_m = \dfrac{V_m}{\sqrt{R^2 + \omega^2 L^2}}$

and, $\theta = \tan^{-1} \dfrac{\omega L}{R}$

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* RC series Circuit

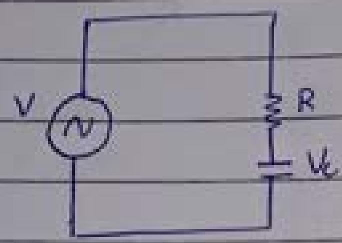

Fig: RC series circuit

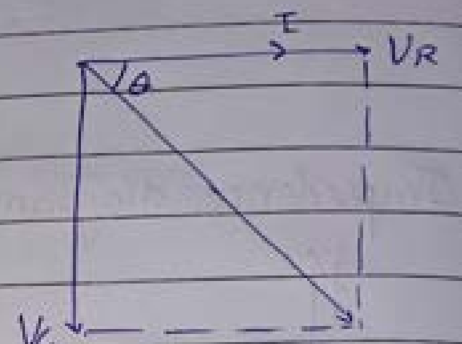

Fig: Phasor diagram

let the applied voltage and current ~~and~~ V and I. The voltage V_R across the resistance across the R is in phase with current I. The voltage across capacitor lack the current by 90°. The applied voltage is the resultant of V_R and V_C and lacks the current by an angle θ less than 90°

$$Z = Z_R + Z_C$$

$$= R - \frac{j}{\omega C}$$

$$\therefore Z = R - jX_C$$

where, $X_C = \frac{1}{\omega C}$

$$|Z| = \sqrt{R^2 + X_C^2}$$

$$= \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$$

$$\theta = \tan^{-1} \frac{X_C}{R}$$

$$\therefore \theta = \tan^{-1} \frac{1}{\omega C R}$$

Impedance Diagram

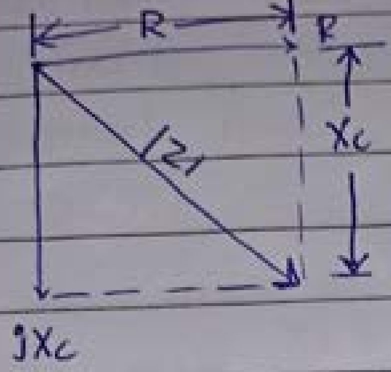

Fig: Impendance diagram

Let $V = V_m \cos(\omega t - \theta)$

$$i = \frac{V_m \cos(\omega t - \theta}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$$

$$= I_m \cos(\omega t - \theta)$$

where, $I_m = \dfrac{V_m}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$

and, $\theta = \tan^{-1} \dfrac{1}{\omega C R}$

* Derivation for Rms value of sinusodial

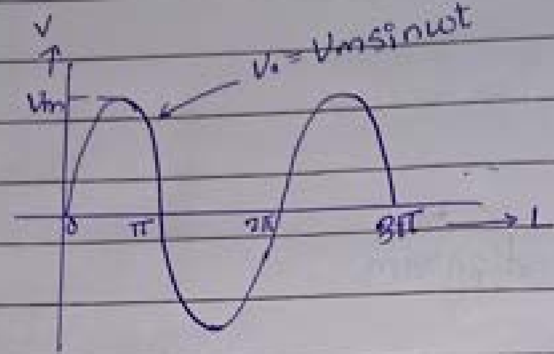

Fig: Sinusodial voltage wave

The instantaneous voltage

$$V = V_m \sin\omega t$$

The Rms voltage value of sinusodial voltage,

$$V_{RMS} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi}[V_m \sin\omega t]^2 \, d\omega t}$$

$$= \sqrt{\frac{V_m^2}{2\pi}\int_0^{2\pi}\sin^2\omega t \, d\omega t}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\int_0^{2\pi}[1-\cos 2\omega t]\, d\omega t}$$

$$= \sqrt{\frac{V_m^2}{4\pi}\left[\omega t - \frac{\sin 2\omega t}{2}\right]_0^{2\pi}}$$

$$= \sqrt{\frac{V_m^2}{2\pi}[2\pi]} = \frac{V_m}{\sqrt{2}} = 0.707 V_m$$

Date / /

Ex: A series circuit consist of $R = 10\Omega$ and $L = 20mH$ the applied voltage $V = 150\cos(500t)$. Calculate voltage across current, voltage across inductance and phase angle of current w.r.t applied voltage

$\omega = 500$

$V = 150\angle 0°$

$X_L = \omega L$

$= 500 \times 20 \times 10^{-3}$

$X_L = 10\Omega$

$Z = R + jX_L$

$= 10 + j10$

$Z = 14.14\angle 45°$

$I = \frac{V}{Z} = \frac{150\angle 0°}{14.14\angle 45°}$

$= 10.6\angle -45°$

$V_R = I \times R = (10.6\angle -45°) \times 10$

$V_R = 106\angle -45°$

$V_L = I \times jX_L$ $10\angle 90°$

$= (10.6\angle -45°) \times j10$

$V_L = 106\angle 45°$

$X_L = \omega L$

<u>Rectangle to Polar</u>

$a + jb = c\angle\theta°$

$c = \sqrt{a^2 + b^2}$

$\theta = \tan^{-1}\left[\frac{b}{a}\right]$

<u>Polar to Rectangle</u>

$c\angle\theta° = a + jb$

$a = c\cos\theta$

$b = c\sin\theta$

Q. Consider an RC circuit $R = 10\,\Omega$ $C = 20\,\mu F$
$V = 50\cos(10000t)$. Calculate $V_R = ?$, $V_c = ?$, $\theta = ?$

Soln:

$V = 50 \angle 0°$

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

$Z = R - jX_c$
$= 10 - jX_c$
$= 10 - j5$
$Z = 11.19 \angle -26.56$

$X_c = \frac{1}{\omega C}$
$= \frac{1000000}{10000 \times 20}$
$= 5$

$I = \frac{V}{Z} = \frac{50 \angle 0°}{11.19 \angle -26.56}$
$= 4.46 \angle 26.56$

$V_R = IR$
$= (4.46 \angle 26.56) \times 10$
$= 44.6 \angle 26.56$

$V_c = I \times -jX_c$
$= (4.46 \angle 26.56) \times (0 - j5)$
$= 5 \angle -90°$
$= 22.3 \angle -63.44°$

Q. Find the circuit element if the applied voltage or current are

$V(t) = 50 \sin(2000t + 65°)$
$I(t) = 8 \sin(2000t + 95°)$

$Z = \frac{V}{I} = \frac{50 \angle 65°}{8 \angle 95°} = 6.25 \angle -30°$

$= 5.4126 - j3.125$
$= -(5.4126$

Q. Find the impedance and circuit element if the applied voltage and currents are

$V(t) = 100 \sin(1000t + 150°)$

$I(t) = 10 \cos(1000t - 140°)$

P to R

$C \angle \theta°$

$a = C\cos\theta°$

$b = C\sin\theta°$

$R = a + jb$

$P = C \angle \theta$

R to P

$C = \sqrt{a^2 + b^2}$

$\theta = \tan^{-1}\left(\frac{b}{a}\right)$

Date / /

Unit 4: Transformer

* **Single Phase transformer:**

The transformer is a electrostatic device which is used to transfer electrical energy (voltage or current) from one circuit to another by the mutual induction of 2 electric circuit without change in frequency which is working under the principle of electromagnetic induction.

It is a static device which transforms the potential or current from 1 level to another, without changing its frequency.

* **Faraday law of electromagnetic induction:**

Whenever their is a relative motion between a set of conductor and uniform magnetic field then emf is induced in the conductor.

The emf induced in the conductor will be directly proportional to amount magnetic flux link with the conductor.

Date / /

* Electrical Machines

Rotating Electrical Machines (REM)
- Motors
- Generators

Static Electrical Machines (SEM)
- Transformer

* Working and Principle of operation of Tranformer

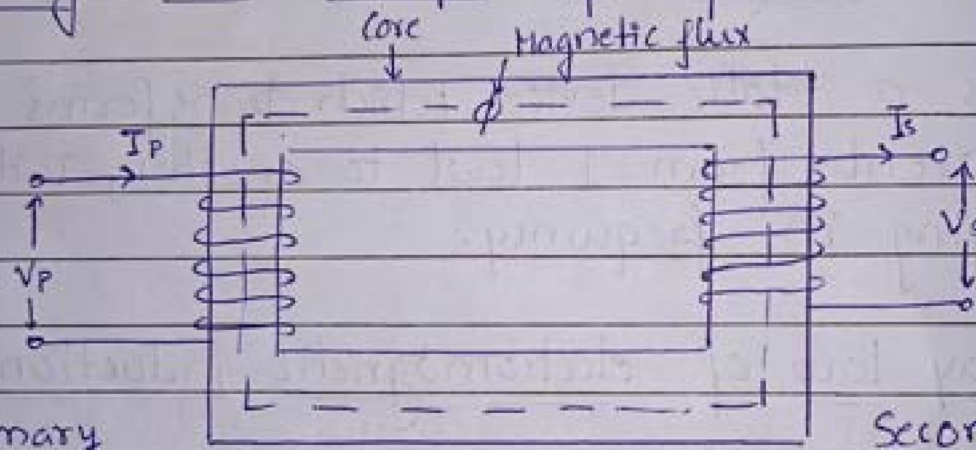

Fig: Single Phase Tranformer

Working

When the primary of the transformer is connected to an AC supply the current flows in the coil and the magnetic field build up. This condition is known as mutual inductance and the flow of is as per the faradays law of electromagnetic induction.

$M = \frac{NI}{l}$ $\quad M \propto I$

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As the current increases from zero to its maximum value, the magnetic field strengthens and is given by $\frac{d\phi}{dt}$

This electromagnet forms the magnetic lines of force and expands outward from the coil froming path of magnetic flux.

The turns of both the windings get linked by this magnetic flux.

The strength of a magnetic field generated in the core depends on the number of turns in the winding and amount of current.

The magnetic flux and current are directly proportion to ~~current~~ each other. $H \propto I$

Principle of Operation

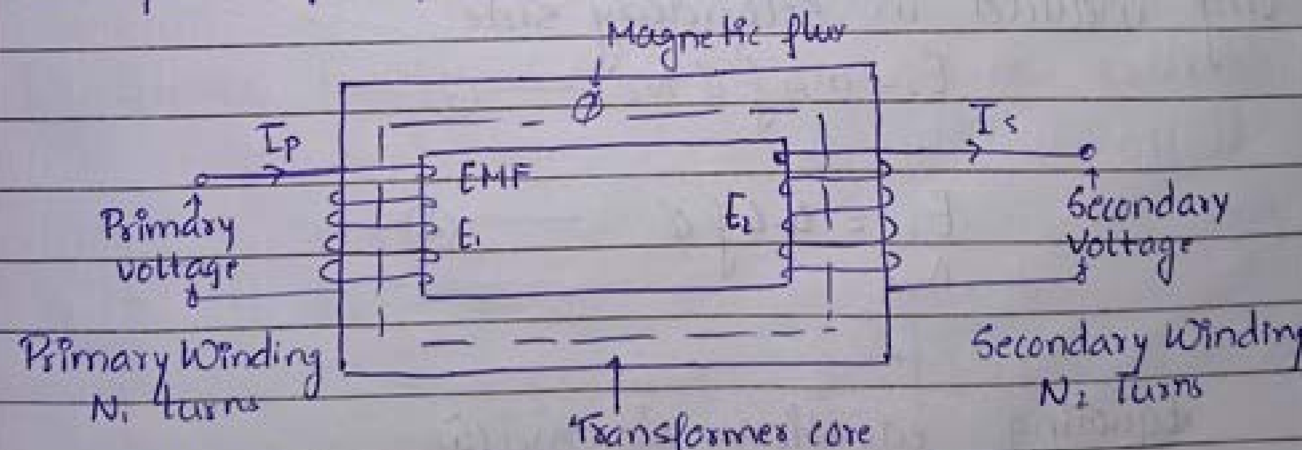

Fig: Single Phase Transformer

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The principle of operation of single phase transformer works on the basis of

1. Faraday's law of electromagnetic induction
2. On the basis of mutual induction

Voltage transformation Ratio ⟶ (K)

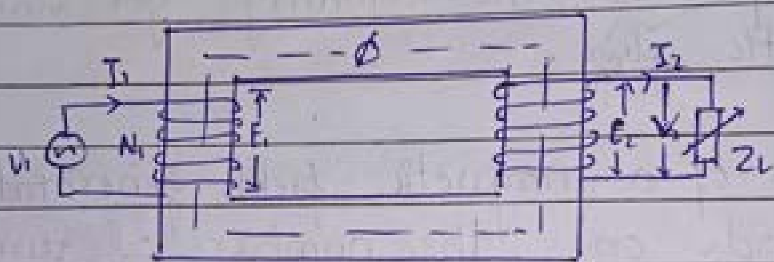


Figure: Core Transformer

Emf induced in primary side, $E_1 = 4.44 f \phi N_1$ —— (1)

$$\frac{E_1}{N_1} = 4.44 f \phi \quad \text{—— (2)}$$

Emf induced in secondary side

$$E_2 = 4.44 f \phi N_2 \quad \text{—— (3)}$$

$$\frac{E_2}{N_2} = 4.44 f \phi \quad \text{—— (4)}$$

Equating equations (2) and (4)

$$\frac{E_1}{N_1} = \frac{E_2}{N_2} \quad \text{—— (5)}$$

Rearranging eq^n ⑤ we get

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

i.e. $K = \frac{N_2}{N_1} = \frac{E_2}{E_1}$ (transformation ratio).

Transformation ratio for current

In an ideal transformer, P at primary side equal to P at secondary side.

Therefore, $V_1 I_1 \cos\phi_1 = V_2 I_2 \cos\phi_2$

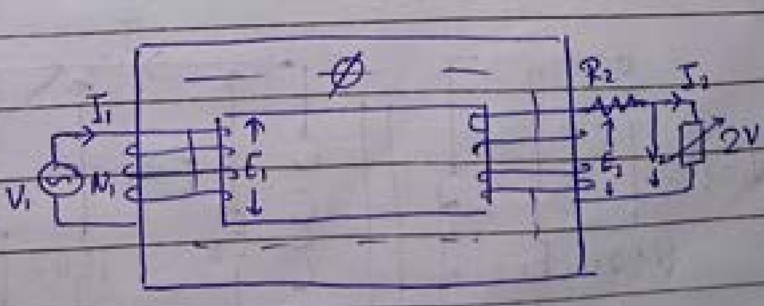
Considering unity Power factor i.e.

$$\cos\phi_1 = \cos\phi_2 = 1$$

$\therefore \; V_1 I_1 = V_2 I_2$

$\therefore \; \frac{V_2}{V_1} = \frac{I_1}{I_2} = K$ (transformation ration).

Difference between induced emf and terminal voltage



When the load is removed $I_2 = 0$, applying KVL in both side,

$$E_2 = V_2 + I_2 R_2$$
$$I_2 = 0$$
$$\therefore E_2 = V_2$$

Turns ratio is reciprocal ~~t~~of transformation ratio

$$\therefore \text{Turns ratio} = \frac{1}{\text{transformation ratio}}$$

The turns ratio for emf $= \dfrac{1}{E_2/E_1} = \dfrac{E_1}{E_2}$

turns ratio for no. of turns $= \dfrac{1}{N_2/N_1} = \dfrac{N_1}{N_2}$

E_1 E_2

Q a] A 1000/100 V, 10 KVA transformer has 60 turns in the secondary. Find no. of turns in primary

b] Full load current in both the winding. Then losses in the current are neglected.

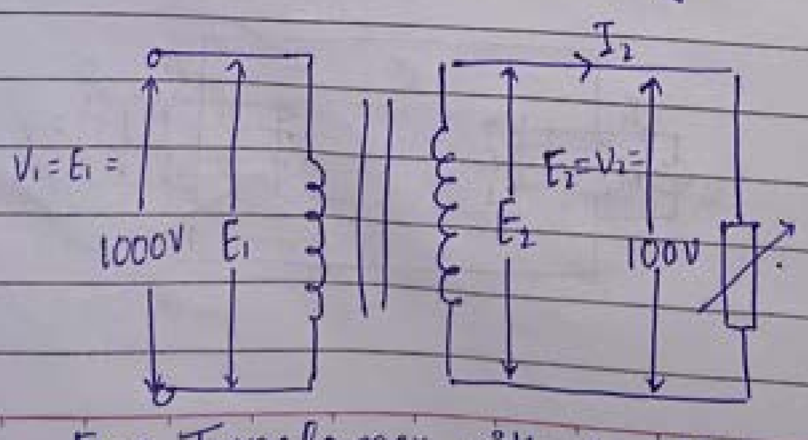


Fig: Transformer with specification

Voltage transformation ratior, $K = \frac{V_2}{V_1} = \frac{100}{1000} = 0.1$

No. of turns in primary, $N_1 = \frac{N_2}{K} = 60$ turns

We know that $V_1 I_1 = V_2 I_2 = 10\,KVA$

The primary full load current, $I_1 = 10\,KVA$

The secondary full load current, $I_2 = 100\,VA$

Q An ideal transformer as a turn ratio of $\frac{N_1\ 400}{N_2\ 30}$ and delivers 20KVA. the The primary is energized by 2000 Volt, 50 Hz supply. Calculate

a] Full load primary and secondary current

b] Induced emf in secondary

c] Maximum flux in the core

Assume transformer is ideal

Soln

$V_1 = 2000V$ $\quad N_1 = 400$

$N_2 = 30$

$f = 50Hz$

$Q = 20KVA = V_2 I_2 = V_1 I_1$

We know that.

$$K = \frac{V_2}{V_1} = \frac{N_2}{N_1} = \frac{I_1}{I_2} = \frac{E_2}{E_1}$$

$$\therefore K = \frac{N_2}{N_1} = \frac{30}{400} = 0.075$$

We know that,

$$Q = V_1 I_1$$

20a

$\therefore$ The full load primary current

$$I_1 = \frac{Q}{V_1}$$

$$I_1 = \frac{20 \times 1000}{2000} = 10A$$

We know that,

$$K = \frac{I_1}{I_2}$$

$$I_2 = \frac{I_1}{K} = 133.33A$$

We know that,

$$K = \frac{E_2}{E_1}$$

$\therefore$ Induced emf in secondary

$$E_2 = K \times E_1$$

$$= K \times V_1$$

$$= 0.075 \times 2000$$

$$= 150V$$

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$\therefore$ The emf in the primary,

$E_1 = 4.44 f \phi m N_1$

$\therefore$ The maximum flux in the core

$$\phi m = \frac{E_1}{4.44 f N_1}$$

$$\phi m = 0.023 \text{ Wb}$$

Q The area of cross section of a step down transformer is 40 cm² & the maximum flux density is 8 Wb/m². Calculate the number of turns in the primary and secondary when the primary is energized with 2000 V, 50 Hz supply and the emf induced in the secondary is 200V assume that the transformer is ideal.

Solⁿ: $A = 40 \text{cm}^2 = 40 \times 10^{-2} \text{m}^2$ $\quad V_1 = 2000V$

$B_m = 8 \text{ Wb/m}^2$ $\quad f = 50 \text{ Hz}$

$B_m =$ $\quad E_2 = 200V$

$\therefore$ The emf induced in primary

$E_1 = 4.44 f \phi m N_1$

But $\phi m = B_m A$

$E_1 = 4.44 f B_m A N_1$

$N_1 = 28.15 \approx 28$ turns

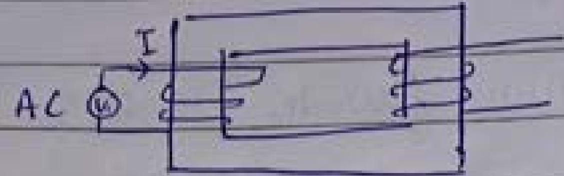
The emf induced in secondary

$N_2 \approx 2.815$

$N_2 = 2$ turns

Shrikrung

Losses in a Transformer



The total power losses in a transformer are classified into 2 types

i) Core loss or Iron loss or magnetic loss
ii) Copper loss or I^2R loss

The iron losses or copper losses are the energies converted into it. heat energy it increase the temperature of transformer and decrease the efficiency

i] Core loss or Iron loss or magnetic loss (P_i)
This consist of 2 parts 1^{st} is eddy current loss and 2^{nd} is hysteresis loss.

Eddy current loss
→ The transformer itself is a shortcut circuit conductor placed in an alternating magnetic field. Therefore, a short circuit current is flowing in the core and desipated as heat. This short circuit current is called eddy current loss. This eddy current loss can be reduced by increasing the resistance of core. To increase resistance

of core, transformer core are laminated.

Formula for eddy current loss:

$$P_e = K_e f^2 B_m^2 t^2 \ W/m^2$$

where,

K_e = constant

f = frequency of the power supply

B_m = maximum flux density

t = thickness of laminated sheet

Hysteresis loss

The magnetic

direction of flux is reversed in very cycle. Due to hysteresis effect, the reversal has some energy loss known as hysteresis loss

Formula for hysteresis loss:

$$P_h = K_h f B_m^{1.6} \ W/m^2$$

where,

K_h = Hysteresis constant

The hysteresis loss may be reduced by choosing appropriate material which has smaller hysteresis constant.

ii) Copper loss (P_c)

The copper losses are due to the resistance of the windings. This is directly proportional to the resistance and square of the current to the windings. Therefore, the total copper losses

$$P_c = I_1^2 r_1 + I_2^2 r_2 \quad \text{——} \; (1)$$

The copper losses are a function of load current therefore, the copper losses are variable w.r.t load current. Hence, the copper losses may be called variable losses

iii) Total losses

The total losses in a transformer is the sum of constant losses and variable losses.

$\therefore$ Total losses in a transformer = Constant losses + variable losses

Effeciency of transformer

The efficiency of transformer is defined as the ratio of the output power to the input power.

$$\therefore \text{efficiency } \eta = \frac{\text{output power}}{\text{input power}} = \frac{\text{output power}}{\text{output power} + \text{Constant losses} + \text{Variable losses}}$$

$$= \frac{\text{Output power}}{\text{output power} + \text{Iron loss} + \text{Variable loss}}$$

$$= \frac{\text{Input power} - \text{constant losses} - \text{Variable losses}}{\text{Input power}}$$

$$= 1 - \frac{\text{losses}}{\text{Input power}}$$

$\therefore$ The percentage efficiency is given by $\% \eta = \frac{\text{Output P} \times 100}{\text{Input P}}$

$$\% \eta = \frac{\text{Input power} - P_i - P_c}{\text{Input Power}} \times 100 \quad \text{—} ②$$

We know that the output power $= V_2 I_2 \cos\phi_2$

The variable losses $P_c = \cancel{V_2^2 R_{02}}\ I_2^2 R_{02}$

let the constant losses, $W_i = P_i$

$\therefore$ the transformer efficiency, $\eta = \frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + \cancel{V_2^2} P_i + I_2^2 R_{02}}$ — ③

Condition for maximum efficiency

To find the condition for maximum efficiency η, differentiate the expression for efficiency w.r.t I_2 and equate to zero.

$$\frac{d\eta}{dI_2} = 0$$

$$\frac{d}{dI_2}\left[\frac{V_2 I_2 \cos\phi_2}{V_2 I_2 \cos\phi_2 + P_i + I_2^2 R_{02}}\right] = 0$$

$\therefore \quad P_i = P_c$ ——— (5)

$\therefore$ the condition for maximum efficiency is
constant losses = variable losses

The load current corresponding to maximum efficiency is given by

$$I_2 = \sqrt{\frac{P_i}{R_{02}}}$$

$30 \times 0.9 \times 10^{-2} m$

Q. A single phase 2500/200V transformer has square core of 30cm side and can carry a maximum of 1 weber/m² flux density. Calculate the number of turns in primary and secondary. The 10% of Iron length is used for insulation of stamping. Assume an ideal transformer.

Soln: Given: Side = 30cm $B = 1$ weber/m^2

$E_1 = 2500V$

$E_2 = 200v$

Area of square $= S^2 = (30\times10^{-2})^2 = (30\times0.9\times10^{-2})^2$

$= (27\times10^{-2})^2$

$= (0.27)^2$

$A = 0.0729$

$\phi_m = B.A$

$\phi_m = 0.0729 \times 1$

$E_1 = 4.44 \times \phi_m \times f \times N_1$

$2500 = 4.44 \times 0.0729 \times 50 \times N_1$

$N_1 = \frac{2500}{16.1838}$

$N_1 = \cancel{15.4.4}\ 154.4$

$N_1 = 154$ turns

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

$\frac{2500}{200} = \frac{155}{N_2}$

$N_2 = \frac{155\times200}{2500}$

$N_2 = 12$ turns

3 Phase induction Motor:

→ Advantages of 3 phase induction motor

1. It is a simple and rugged
2. low cost motor
3. less maintainence is required in motor
4. Reasonably good power factor. and sufficiently high efficieny.
5. self starting motor

→ Disadvantages of 3 phase induction motor

1. Constant speed motor, difficult to change the speed
2. starting torque is inferior to that of DC motor

Slip (s)

1. In the principle of operation the rooter is always trying to reduce the relative speed with rotating stater flux. If it really catches the rotating flux then their is no relative speed. Hence, their is no current and no torque therefore their is always a difference between speed of rotating flux and the roater speed this difference is known as slip.

In other words the difference between the synchronous speed (Ns) and the rooter speed is called a slip.

The percentage of slip is given by $\% \text{ slip}(s) = \frac{N_s - N}{N_s \cancel{\times 40}} \times 100$

Initially during starting, the rooter speed is zero. Therefore, the slip = 1. In an induction motor, the slip varies from 0.1% to 3% as the motor load varies from no-load to full load.

$$\text{Synchronous speed, } N_s = \frac{120 \times f}{P} \quad f \rightarrow \text{frequency}, \; P \rightarrow \text{no. of poles}$$

Frequency of Rotor Current

We know that synchronous speed,

$$N_s = \frac{120f}{P} \quad \text{—— (1)}$$

Let N' be the relative speed between the Rotor and the ~~stator~~ stater rotoring rotating speed

$$N' = \frac{120f'}{P} \quad \text{—— (2)}$$

where, f' = the frequency of rotor current

But the relative speed,

$$N' = N_s - N$$

where, N_s = the synchronous speed and
N = the rotor speed

$$\therefore \quad f' = \frac{N' \times P}{120}$$

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

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

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

where,

$\frac{N_s - N}{N_s} = S \rightarrow$ is the slip of rotor

$$f' = S \times f$$

where,

f = the supply frequency

When the rotor is at stand still.

$\therefore S = 1$

$\therefore f' = f$

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Imp

Q. Find the rating of transformer is in KVA (not in KW)

Soln: The copper loss is equal to $I_1^2 R_{01}$ or $I_2^2 R_{02}$. Similarly the Iron loss is proportional to flux density and in turn proportional to V_1^2 or V_2^2

∴ The total losses are proportional to $V_1^2 I_1^2$ or $V_2^2 I^2$ and independent ~~$V_1^2 = I_1^2$~~ or ~~V_2~~ to power factor

i.e. Total losses $\propto (KVA)^2$

1. It is independent of phase angle this is why the rating of transformer is in KVA and not in KW.

2. The heat generated inside the transformer is proportional to I_1^2 or I_2^2. Hence, the capacity of the transformer is limited by $V_1^2 I_1^2$ or $V_2^2 I_2^2$. This is another reason why the transformer ratings are in KVA

Q. Calculate the slip of 3 phase motor runing at 900 rpm where stater has 6 poles and is operated from 50Hz power supply. Calculate the frequency of the rotor current.

Soln: Given: $N = 900\,rpm$
$f = 50Hz$
$P = 6$

$f' = \frac{5 \times N_s \times P}{120} = \frac{5 \times 1000 \times 6}{120}$

$= 5\,rpm.$

$N_s = 1000\,rpm$

$S = \frac{N_s - N}{N_s} \times 100 = \frac{1000 - 900}{1000} \times 100 = 10\%$

Q A 12 pole 3 phase alternator is driven at a speed of 600 rpm. It supplies power to a 6 pole 3 phase induction motor. Calculate the full load speed of the motor when the slip of motor is 2.5%

Soln. Given: $P = 12$

$N = 600$ rpm

$\%S = 2.5\%$

∴ The alternator supply frequency,

$$f = \frac{NP}{120} = 60\text{Hz}$$

$$N_s = \frac{120f}{P} = \frac{120 \times 60}{6} = 1200 \text{ rpm}$$

$$\text{Slip}(s) = 2.5\% = 0.025$$

Full load speed, $N_r = 1200(1-0.025) = 1170$ rpm

Q A 6 pole 60Hz 3 phase induction motor has a rotor current at a frequency of 3 Hz. Calculate

i] Slip

ii] Speed of rotor

Given: $P = 6$

$F = 60\text{Hz}$

$F' = 3\text{Hz}$

$$S = \frac{N_s - N_r}{N_s} \times 100$$

$$N_s = \frac{120 \times f}{P} = \frac{120 \times 50}{6} = 1000\text{Hz}$$

$$f' = S \times f$$

$$3 = S \times 50$$

$$S = 0.06 = 6\%$$

$$6 = \frac{100 - N}{100} \times 100 \Rightarrow N = 94$$

Synchronous Generator or AC Generator or Alternator

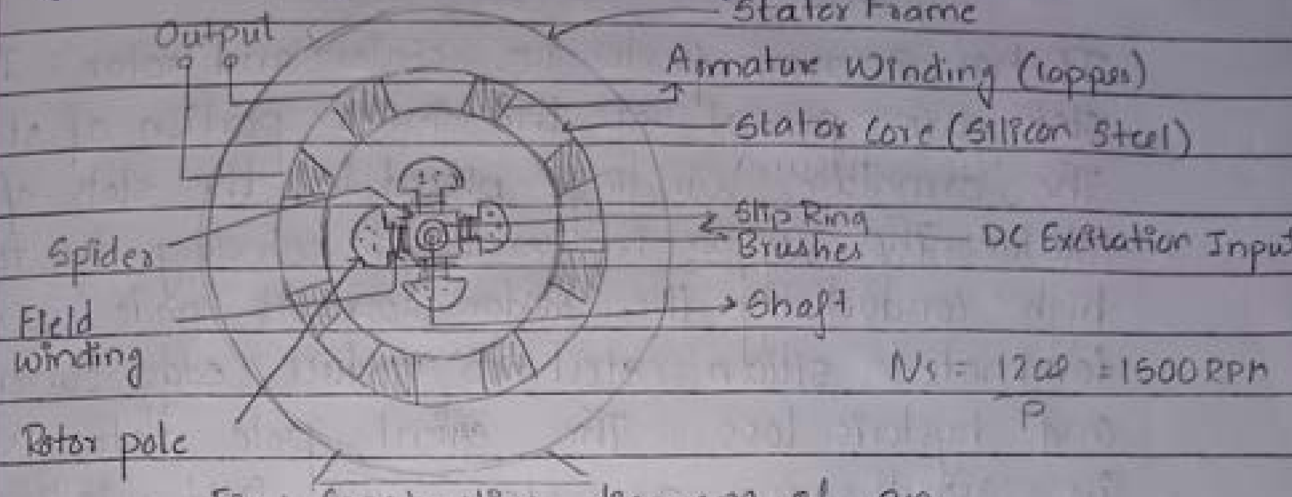


Fig: Construction diagram of an

* Advantages of stationary armature:

1. High voltage can be generated without any insulation problem. As voltage increases current rating decreases

2. No need for slip ring and brushes to bring out the generated power.

3. 2 slip rings are required to feed DC power ~~to~~ through the field winding placed in the rotor.

4. On comparing the size of machines of same power

→ Defination of Altanator

An electrical machine which converts the mechanical energy of ~~time~~ prime mover into an electrical AC energy at particular voltage and frequency range is known as one alternator. An alternator is an important part of any power plant, it is used to generate high voltage AC electrical power.

Constsuction:

It has 2 main parts i.e. stator and rotor. The slots are present at the inner portion of stator. The armature winding placed in the slots of stator. The copper is used for winding due to its high conductivity. the stator core is made up of laminated silicon steel to reduce eddy current and hysteris loss. The salient pole rotor is used in synchronous generator. The field winding is placed around the rotor poles. The rotor is also made up of laminated silicon steel to reduce the electrical losses. The salient pole rotor is designed for low and medium rpm. The spider of cast iron is used with the rotor. The spider provides easy path for magnetic flux. The slip ring and brushes are connected with the rotor.

DC generator

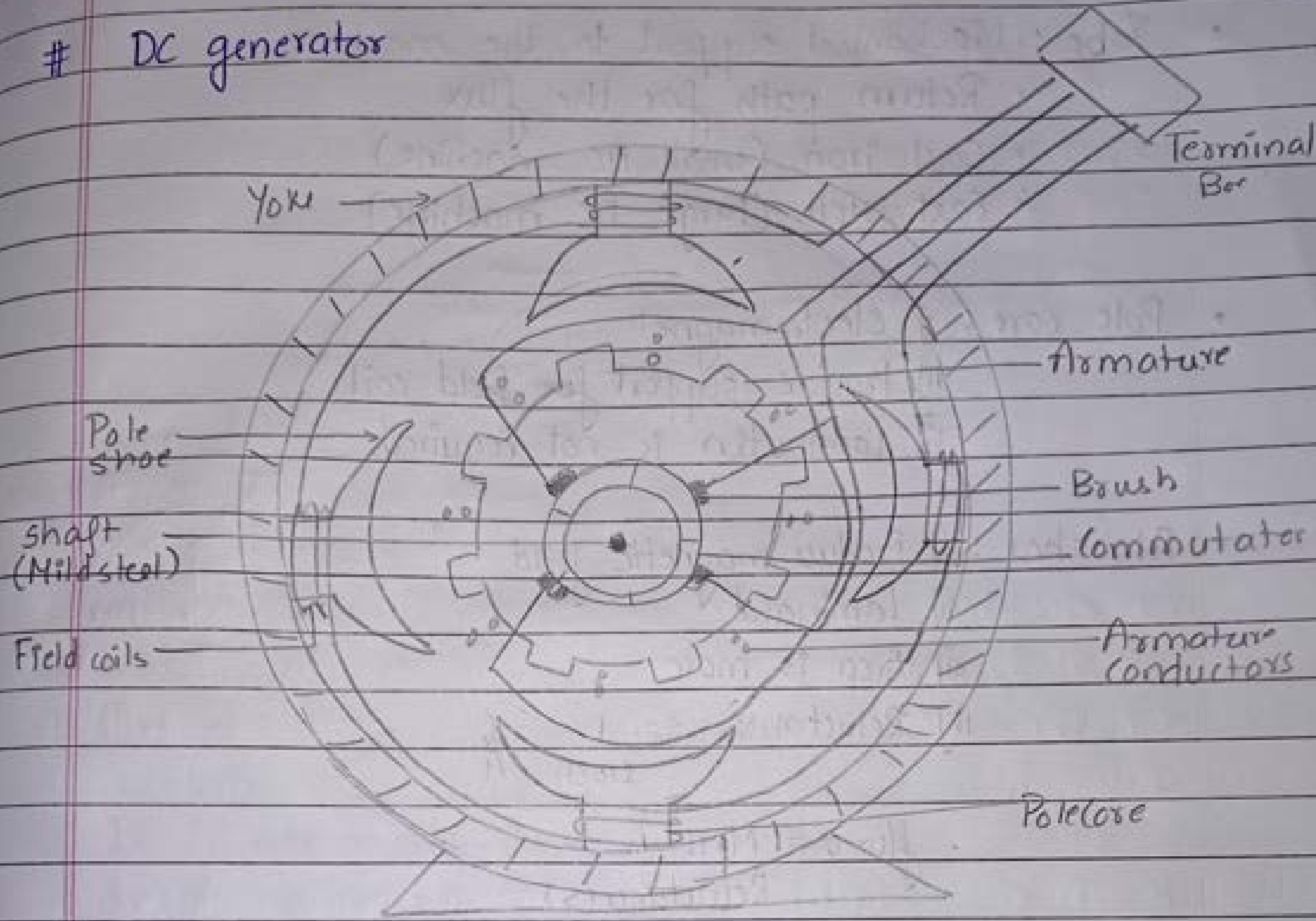


Fig: Constsuction diagram of a DC generator

Essential part of DC generator:

1] Field system

2] Armature

3] Commutator

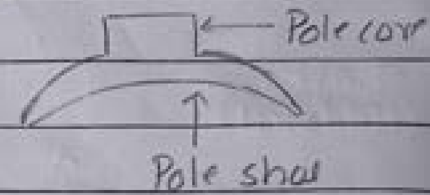
4] Brushes

1] Field System : ~~carry current~~

- Field coil : ① Magnetizing coils
  ⑪ Copper wire
  ⑪ To carry current

- Yoke : • Machanical support to the machine
  - Return path for the flux
  - Cast iron (small DC machine)
  - Cast stell (large DC machine)

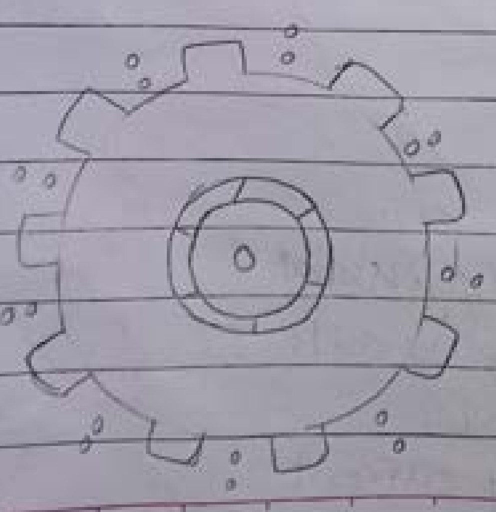
- Pole core : i] electromagnet
  - ii] Provide support for field coil
  - iii] lamination is not required

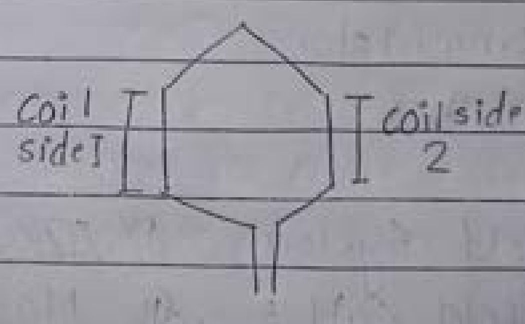


- Pole shoe : i] Produce magnetic field
  - ii] Laminated
  - iii] Area is more
  - iv] Reluctance $S = \frac{1}{\mu_0 \mu_r} \cdot \frac{l}{A}$

$$\text{flux } \phi = \frac{MMF}{\text{Reluctance}(S)}$$

2] Armature : i] It develops emf,
- ii] made up of silicon steel material
- iii] it is laminated to reduce eddy current loss





lap winding

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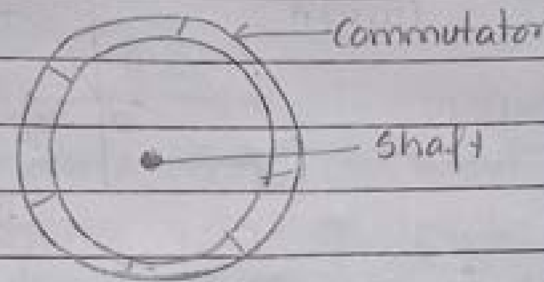
3] Commutator:

i] Convert AC to DC

ii] Alternating current to unidirecting current

iii] Hard, drawn copper

iv] Made up of hard draw copper



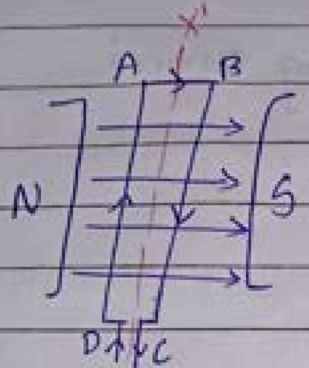
4] Brush:

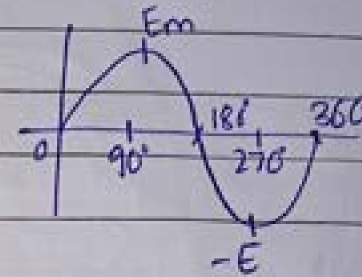
i] To collect the current from commutator and gives to the external load circuit.

ii] It is ~~use~~ made from carbon (for small DC machine) and electrographite (large DC machine)

iii] Disadvantage: Results in voltage drop (upto 2 V generally)

DC Motor.





An electrical motor is a machine which converts electrical energy into mechanical energy. The rotation of the motor is based on the fleming's Left hand rule.

When a current carrying conductor is placed in magnetic field, it experience some mechanical force.

The force 'F' is given by

$$F = B \times \cancel{I}\, i \times l \times \sin\theta \ \text{N}$$

If a rectangular singleton point is placed in a magnetic field then each side of a coil has current in opposite direction to each other.
∴ BC tries to go up and AD tries to go down.

Because of this opposite direction of motion, they form a moment and rotate about x-axis X'

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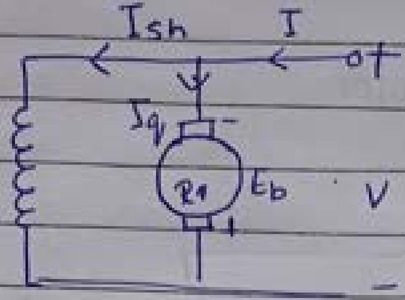
Back or counter EMF $I_{sh} \to$ shunt



When a DC machine is operated as a dc motor, the armature conductor cut the magnetic fields. ∴ according to law of electromagnetic induction, an emf Eb will be generated in the armature conductor.

According to lenz's law, this induced emf is opposite to the applied voltage V. ∴ this induced emf is known as back or counter emf.

$$I = \frac{V}{R} \qquad I_a = \frac{V - E_b}{R_a}$$

where, R_a = armature resistance

$$E_b = \frac{NP\phi Z}{60A}$$

where,

A = number of $\parallel^{el}$ path

Z = total number conductor

P = number of pole

ϕ = flux per pole.

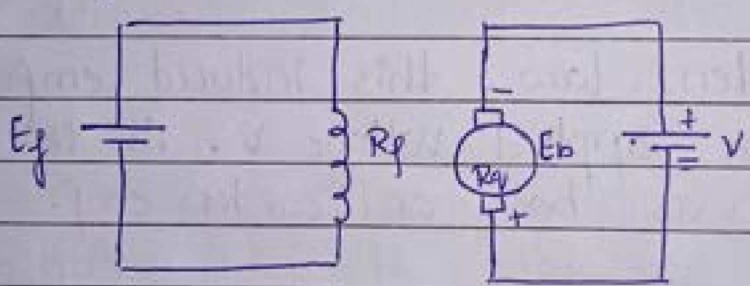
N = speed in rpm.

Types of DC motor

1] Separately excited DC motor
2] Self excited DC motor

- ~~long~~ shunt
- series
- Compound
  - long shunt coumpound DC motor
  - Short shunt compound DC motor

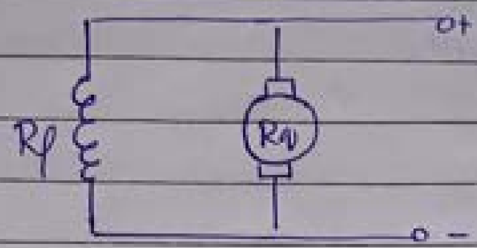
1] Separately excited DC motor



This type of motor have separate independent supplied for armature and field winding.

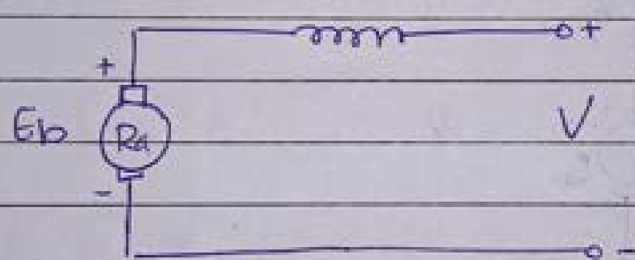
2] Self excited DC motor

In this type of motor instead of using a separate source for exciting the field coil, a part of induced power can be used i] Shunt DC motor



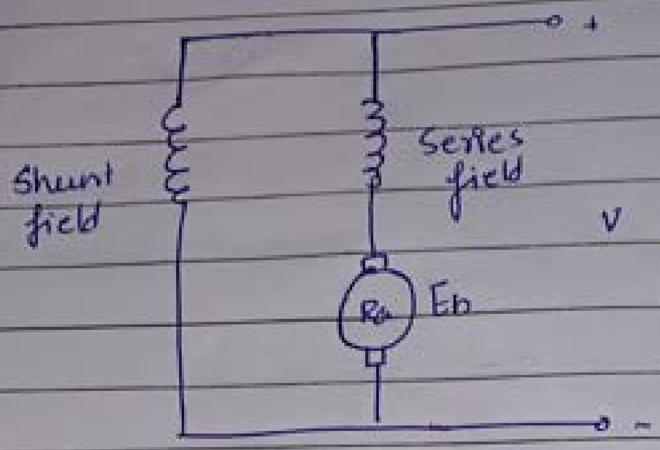
In this type, the field winding is connected to $||^{el}$ armature

ii] DC series motor

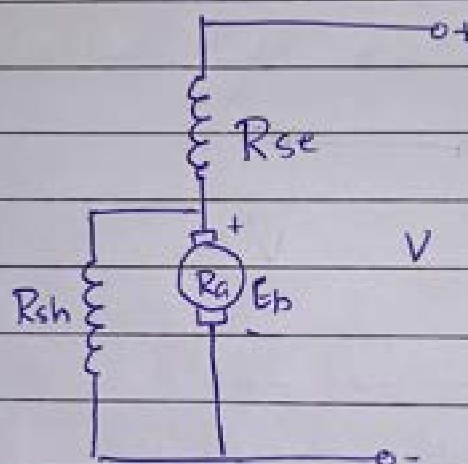


In this type, the field winding is connected ~~to~~ in series with armature

iii] ~~In this~~ Compound DC motor.
In this type, some part of field winding is conneted in series with the armature winding and rest field ~~w~~ winding is conneted in $||^{el}$ with armature winding.



Long shunt



Short shunt

Back emf or counter emf equation of DC motor

According to faraday's law electromagnetic induction,

$$e = \frac{d\phi}{dt}$$

~~that~~ Let each pole have a flux of ϕ

The total change in flux $= P\phi$

where, P = no. of poles

The number of rotation per minute = N rpm

The number of rotation per second = $\frac{N}{60}$ rps

The time taken for 1 complete rotation = $\frac{60}{N}$ sec

$$e = \frac{d\phi}{dt}$$

$$e = \frac{P.\phi}{60/N}$$

$$e = \frac{P\phi N}{60}$$

Let A is the number of paralley path and Z is total number of conductor in the armature ϕ_2. Therefore, the number of conductor in series for parallel path = $\frac{Z}{A}$

$\therefore$ Total induced emf = $\frac{\text{emf per}}{\text{conductor}}$ × number of conductor in ‖el path

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

$$E_b = \frac{NP\phi Z}{60A}$$

For lap winding,

$A = B$

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$$\therefore E_p = \frac{N\phi Z P}{60}$$

For wave winding,

$$A = 2$$

$$\therefore E_b = \frac{N P \phi Z}{120}$$

Application of DC motor

- Electric locomotive for traction purpose.
- Elevators
- Trolley
- Cranes (Normally for high starting torque load)

Applications of shunt

- Lathe machine
- Centrifugal pump
- fans
- Drill machine (Normally for constant speed requirement)

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Applications of compound motor

- Punching machine
- Raciprocating machine (Normally for intermidiate torque load)

Comparison between series, shunt and compound motor

Series motor	Shunt motor	Compound motor
1] Dangerously high speed at no load and low speed at high load.	Sufficiently constant speed	As load increases, speed decreases in case of cumulative compound motor and speed increases in case of ~~dt.~~ differentionally compound motor
2] Very high starting torque	Medium starting torque	High starting torque

3]

Function of field winding to produce flux

$IF \propto IA$

Armature winding in motor carries current from source, in generator winding carries current to load

Emf of AC generator

Let ϕ = flux per wb
A = Number of parallel
Z = number of armature conductor
N = number of revolution per rpm.

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

$d\phi$ = Rate of change of flux
Flux cut in one conductor in one revolution = ϕP

$$d\phi = \phi \cdot P \quad \text{——} \ (2)$$

dt = rate of change of time take to complete one revolution in sec

$$dt = \frac{60}{N} \quad \text{——} \ (3)$$

putting eqn ② and ③ in eqn ①

∴ We get, emf generated per conductor,

$$e = \frac{N\phi P}{60}$$

Conductor per ||^{el} path $= \frac{Z}{A}$

$$\therefore \text{emf} = \frac{N\phi P}{60 \cancel{\times Z/a}} \times \frac{Z}{A}$$