ETE (BEEE)

1. Write notes on -
a) Flux b) Flux density c) MMF, d) Magnetic Field Intensity and e) Reluctance

→ a) Flux - Flux is defined as the number of field lines passing through a given closed surface. It gives the measurement of the total field that passes through a given surface area. It is denoted by Φ. SI unit is weber (Wb). 1 Wb = 10^8 lines of force.

b) Flux density - The flux density is the number of magnetic lines of flux that pass through a certain point on a surface. Flux density is the amount of flux per unit area perpendicular to the field. SI unit is Tesla (T) / (Wb/m^2)

$$B = \frac{\Phi}{A} \left(\frac{Wb}{m^2}\right)$$

c) MMF - It stands for magnetomotive force (mmf): The current flowing in an electric circuit is due to the existence of electromotive force similarly magnetomotive force (MMF) is required ~~magnetic~~ to ~~flux~~ ~~like~~ ~~as~~ ~~magnetic~~ ~~also~~ drive the magnetic flux in the magnetic circuit. The magnetic pressure, which sets up the magnetic flux in a magnetic circuit is called Magnetomotive force. It is denoted by Fm.

$F_m = NI$ (ampere-turns)

d) Magnetic Field Intensity - The magnetic field intensity is the mmf per unit length along the path of the flux. It is also known as magnetic flux intensity and is represented by H

$$H = \frac{mmf}{length} = \frac{NI}{l} \left(\frac{At}{m}\right)$$

e) Reluctance - It is defined as the ratio of magnetomotive force to magnetic flux. It represents the opposition to magnetic flux and depends on the geometry and composition of an object.

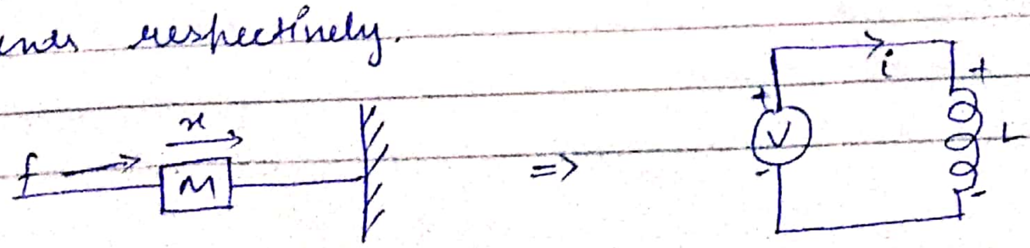
$$S = \frac{F_m}{\phi} \quad , \quad S = \frac{l}{\mu_0 \mu_r A}$$

S is the reluctance in ampere-turns per weber

2. What do you mean by analogous electric circuit? Justify your answer by Force Voltage and Force current analogy.

=> Two systems are said to be analogous to each other if the following two conditions are satisfied.
- The two systems are physically different.
- Differential equation modelling of these two systems are same.

Force Voltage Analogy -
It is also known as Direct Analogy.
In a mechanical system, input and output are force and velocity respectively. While in the electrical network these are voltage and current through the elements respectively.

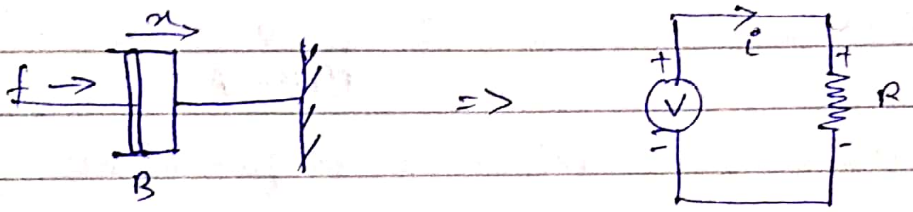


The element 'mass' in the mechanical system corresponds to an inductor in the electrical network

$$f = M\frac{dx^2}{dt} = M\frac{dv}{dt}$$

here, x represents the amount of displacement and v is the velocity

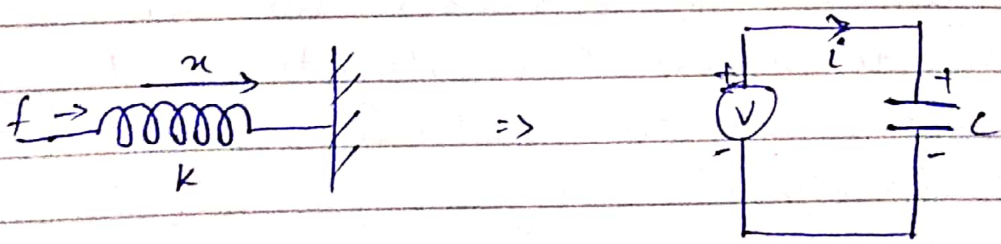
$$V = L\frac{di}{dt}$$



Here, B represents the frictional force constant thus corresponds to resistance in the electrical network

$$f = B\frac{dx}{dt} = Bv$$

$$V = iR$$, v is the voltage.



Here K represents the spring constant, thus it is replaced by a capacitor in the electrical network

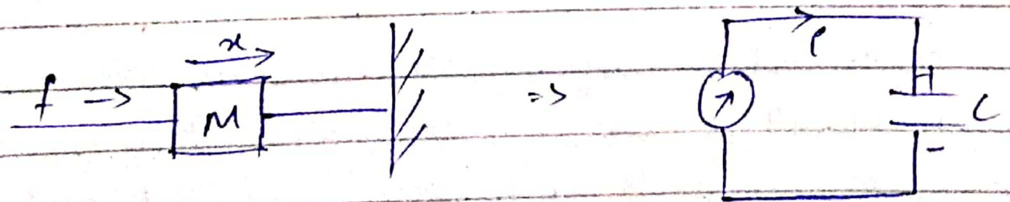
$$f = Kx = K\int v\,dt$$

$$V = \frac{1}{C}\int i\,dt$$

- The elements present in series in mechanical system possess the same velocity. Likewise, the serially connected elements in the electrical network have the same current.
- Each existing mass in the mechanical system corresponds to a separate node in it and represents a separate closed loop in the electrical network
- Also, the number of meshes in the electrical system is equivalent to the number of masses in a mechanical system.
- The elements existing between two masses in the mechanical system represents common elements between two meshes of the electrical system.

Force Current Analogy -

Previously, voltage is regarded as analogous quantity to force. While, in force - current analogy, the current is the analogous quantity in the electrical system to the force in the mechanical system.

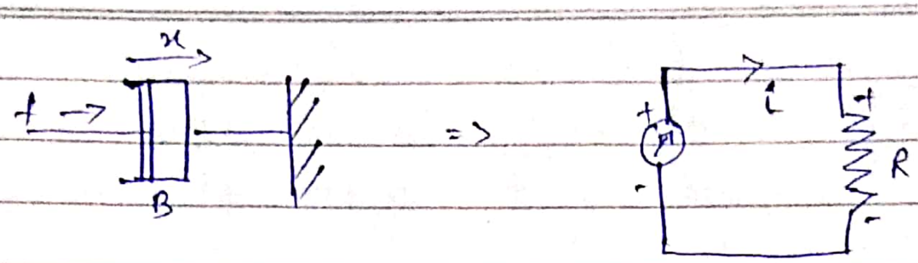


The masses in the mechanical system is replaced by the capacitors in an electrical network.

$$f = M\frac{dx^2}{dt} = M\frac{dv}{dt}$$

where, x represents displacement and v represents velocity

$$i = C\frac{dv}{dt}$$. v is voltage

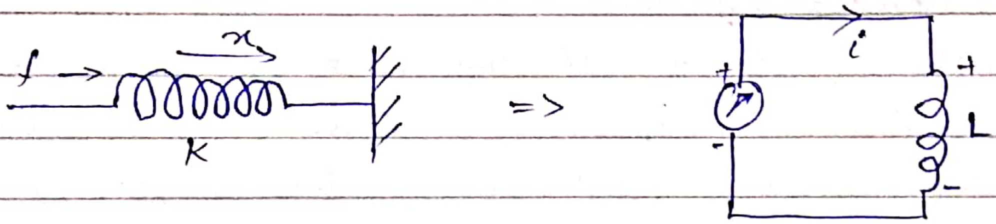


The frictional force B of the damper corresponds to reciprocal of resistance in the electrical network

$$f = B\frac{dx}{dt} = Bv.$$

Thus,

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



Here, the spring constant K of the mechanical system corresponds to the inductor in the electrical network

$$f = Kx = K\int v\,dt.$$

$$i = \frac{1}{L}\int v\,dt.$$

- The parallel combination of masses in the mechanical system have similar force, likewise, the parallel combination of elements in the electrical network has the same voltage across them.
- Each separate mass of the mechanical system corresponds to a separate node in the electrical network.
- So, the number of nodes in the electrical network is equivalent to the number of masses present in the mechanical system.

- Like in force-voltage analogy, here also, the number of components in between two separate masses in the mechanical system is also commonly connected in the electrical network between two separate nodes.

3. A rectangular shaped core is made of mild steel plate 15 mm × 20 mm cross-section. The mean length of magnetic path is 18 cm. The coil has 300 turns and current is 0.7 A. Calculate (a) Magnetic flux (b) Reluctance

⇒ Area of cross-section $= 15 \times 20 \times 10^{-6}\ m^2 = 3 \times 10^{-4}\ m^2$

Length, $l = 18\ cm = 18 \times 10^{-2}\ m$

No. of turns, $N = 300$

Current, $I = 0.7A$.

(a) Magnetic flux, $\phi = BA = \frac{\mu_0 N I A}{l} = \frac{4\pi \times 10^{-7} \times 300 \times 0.7 \times 3 \times 10^{-4}}{18 \times 10^{-2}}$

$\phi = \frac{\cancel{12}^{2}\pi \times \cancel{210}^{70} \times 10^{-9}}{\cancel{18}_{6}} = \frac{44}{\cancel{7}} \times \cancel{70}^{10} \times 10^{-9} = 4.4 \times 10^{-7}\ Wb$

(b) Reluctance, $S = \frac{l}{\mu_0 A} = \frac{\cancel{18}^{63} \times 10^{-2}}{\cancel{4}_{2}\pi \times 10^{-7} \times \cancel{3} \times 10^{-4}} = \frac{3 \times 10^{9}}{2\pi} = 4.7 \times 10^{8}$

4. A coil of 500 turn having resistance of 20 ohm is wound uniformly on an iron ring of mean circumference of 50 cm with cross section area of 4 cm² is connected to 24 V dc supply, assume relative permeability is 800. Find (i) MMF (ii) Magnetizing force (iii) Total flux.

$\frac{12.6}{10} \times 10^{2}$

⇒ No. of turns, $N = 500$.

Resistance, $R = 20\,\Omega$.

Cross sectional area $= 4\,cm^2 = 4\times10^{-4}\,m^2$

Applied voltage, $V = 24\,V$

Relative permeability $(\mu_r) = 800$

i) MMF

$$I = V/R = \frac{24}{20} = 1.2\,A$$

$$mmf = NI = 500\times1.2 = 600\ At.$$

ii) Magnetizing force

$$H = \frac{mmf}{l} = \frac{600}{50\times10^{-2}} = 1200\ At/m$$

iii) Total flux $(\phi) = \frac{mmf}{S}$

$$\text{Reluctance, } S = \frac{l}{\mu_0 \mu_r A} = \frac{50\times10^{-2}}{4\pi\times10^{-7}\times800\times4\times10^{-4}} = 1.24\times10^{6}\ At/Wb$$

$$\phi = \frac{600}{1.24\times10^{6}} = 483.87\times10^{-6} = 4.83\times10^{-4}\ Wb.$$

5. An iron ring has a cross section area $2\,cm^2$ and a mean diameter of 20 cm. An air gap of 0.4 mm has been cut across the section of the ring. The ring is wound with a coil of 300 turns. The total magnetic flux is 0.20 mWb. The relative permeability of iron is 1000. Determine the current flowing through the coil.

⇒ $\Phi = 0.20\,mWb = 0.20\times10^{-3}\,Wb$

$A = 2\,cm^2 = 2\times10^{-4}\,m^2$

diameter $= 20\,cm = 20\times10^{-2}\,m$.

$$B = \frac{\Phi}{A} = \frac{0.20\times10^{-3}}{2\times10^{-4}} = 0.1\times10 = 1\ Wb/m^2$$

$$\text{AT for iron ring} = H\times l = \frac{B}{\mu_0\mu_r}\times l = \frac{1}{4\pi\times10^{-7}\times1000}\times20\times10^{-2}$$

$$= \frac{5}{\pi}\times10^2 = 1.592\times10^2 = 159.23$$

$$\text{AT for air gap} = H\times l = \frac{B}{\mu_0}\times l = \frac{1}{4\pi\times10^{-7}}\times\frac{0.4}{10}\times10^{-3} = \frac{1}{\pi}\times10^3$$

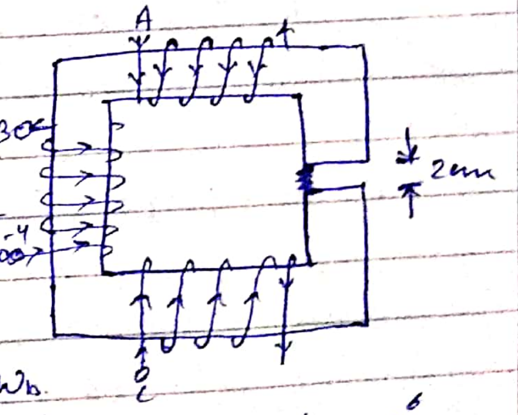
$$= 0.318\times10^3 = 318.47$$

Total AT required $= 159.23 + 318.47$

$300\times I = 477.70$

$\boxed{I = 1.592\ A}$

6. A rectangular iron core with a cut size of 2cm as shown in given figure, details are as follows - mean length of magnetic circuit = 50 cm, cross-section area = 3 cm × 3 cm, Relative permeability = 1000, no. of turns in each coil = 200, current in each coil = 5 A. Calculate flux in air gap.



$\Rightarrow$ Total mmf $= N_A I_A + N_B I_B + N_C I_C$
$= 3(200\times5) = 3000\ At$

$$\text{Reluctance of air gap} = \frac{l}{\mu_0 A} = \frac{2\times10^{-2}}{4\pi\times10^{-7}\times9\times10^{-4}}$$

$$= \frac{1}{18\pi}\times10^9 = 0.01769\times10^9$$

$$= 1.76\times10^7\ At/Wb$$

$$\text{Reluctance of iron core} = \frac{l}{\mu_0\mu_r A} = \frac{48\times10^{-2}}{4\pi\times10^{-7}\times1000\times9\times10^{-4}} = \frac{4\times10^6}{3\pi}$$

$$= 0.4246\times10^6$$

$$= 4.246\times10^5\ At/Wb$$

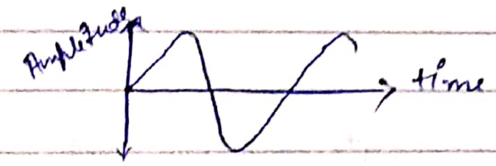
Total reluctance $= 17.6 \times 10^6 + 0.4246 \times 10^6 = 18.0246 \times 10^6 = 1.802 \times 10^7$ At/Wb

Flux in air gap $= \frac{\text{mmf}}{\text{Reluctance}} = \frac{3000}{1.802 \times 10^7} = 1664.81 \times 10^{-7}$

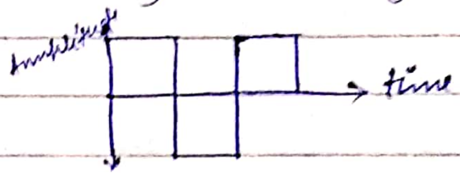
$= 1.664 \times 10^{-4}$ Wb

7. Write notes on - (a) Wave form, (b) Active Power, (c) Peak Factor, (d) Form Factor (e) Average Value.

→ (a) Waveform - It is defined as the graph between magnitude of alternating quantity against time.



Sine wave



Square Wave

(b) Active Power - It is the actual power consumed in any circuit. It is given by product of rms voltage and rms current and cosine angle between voltage and current.

$P = I^2R = VI\cos\phi$ Unit is Watt (W)

(c) Peak Factor - (Crest Factor) - It is defined as the ratio of peak value (crest value or maximum value) to rms value of an alternating quantity.

Peak Factor, $K_p = 1.414$ (for sine wave)

(d) Form Factor - It is defined as the ratio of rms value to average value of an alternating quantity. It is denoted by K_f. $K_f = 1.11$ (for sine wave).

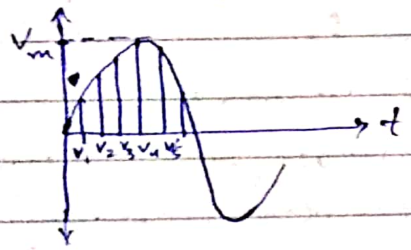
(e) Average Value - The average of all the instantaneous values of an alternating quantity over one complete cycle is called Average value.

$$V_{av} = 0.637 V_m$$

8. Derive the average and rms value for a sinusoidal AC signal by graphical or Analytical method

=> Average Value

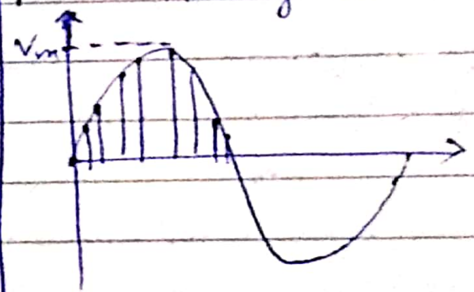
Graphical



$$V_{av} = \frac{\text{Sum of all instantaneous values}}{\text{Total number of value}}$$

$$V_{av} = \frac{V_1 + V_2 + V_3 + \dots + V_n}{n}$$

Analytical



$$V_{av} = \frac{\text{Area under curve}}{\text{Base of curve}}$$

$$V_{av} = \frac{\int_0^\pi V_m \sin\omega t \, d\omega t}{\pi}$$

$$V_{av} = \frac{V_m}{\pi}(-\cos\omega t)_0^\pi$$

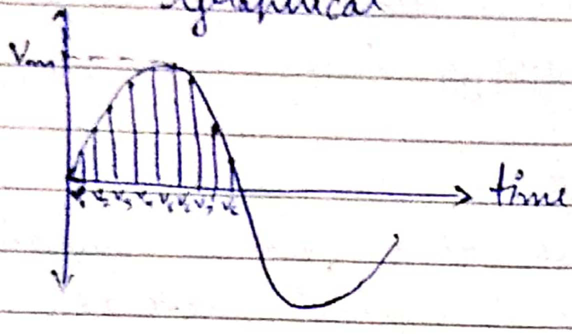
$$V_{av} = -\frac{V_m}{\pi}(\cos\pi - \cos 0)$$

$$V_{av} = \frac{2V_m}{\pi}$$

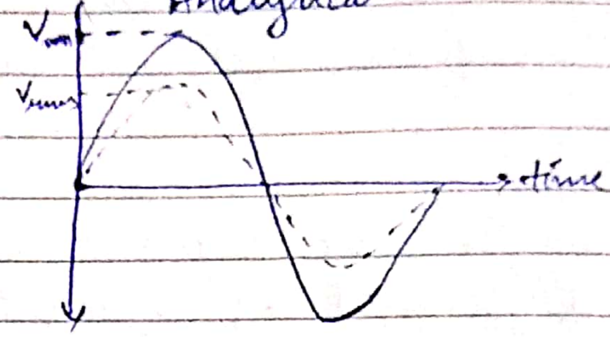
$$\boxed{V_{av} = 0.637 V_m}$$

RMS value

Graphical



Analytical



$$V_{rms} = \sqrt{\frac{\text{Sum of } \cancel{\text{add}} \text{ sq. of all instantaneous}}{\text{Total no. of values}}}$$

$$V_{rms} = \sqrt{\frac{V_1^2 + V_2^2 + \cdots + V_n^2}{n}}$$

$$V_{rms} = \sqrt{\frac{\text{Area under the sq. curve}}{\text{Base of curve}}}$$

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

$$V_{rms} = \sqrt{\frac{V_m^2}{2\pi} \int_0^{2\pi} \frac{(1 - \cos 2\omega t)}{2} d\omega t}$$

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

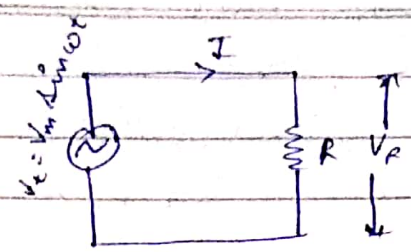
$$V_{rms} = \sqrt{\frac{V_m^2}{4\pi} (2\pi - 0)}$$

$$V_{rms} = \frac{V_m}{\sqrt{2}}$$

$$\boxed{V_{rms} = 0.707 V_m}$$

9. Draw pure resistive circuit diagram, draw its waveform, and phasor diagram also. Derive formula for its active power

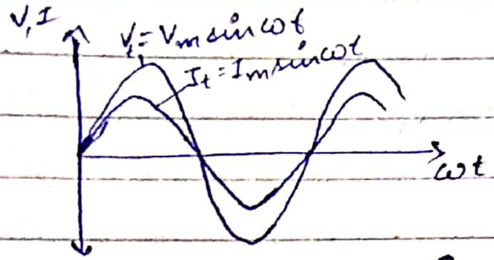
=>

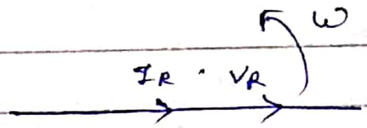


$V_t = V_m \sin\omega t$

$I_t = \frac{V_t}{R} = \frac{V_m \sin\omega t}{R}$

$\boxed{I_t = I_m \sin\omega t}$





$P = VI\cos\phi$.

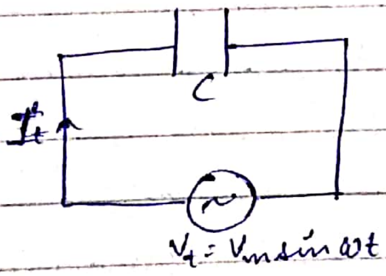
In pure resistive circuit, current and voltage are in same phase i.e., $\phi = 0$.

$P = VI\cos 0^\circ$

$\boxed{P = VI}$

10. With the help of pure capacitive circuit diagram, draw its waveform and phasor diagram also derive its formula for its active power

=>



$q = CV_t$

$q = CV_m \sin\omega t$

$I_t = dq/dt$

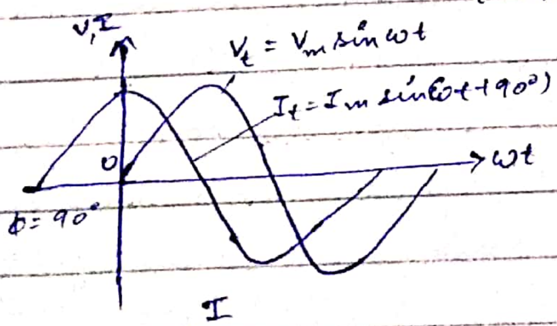
$I_t = \frac{d(CV_m \sin\omega t)}{dt}$

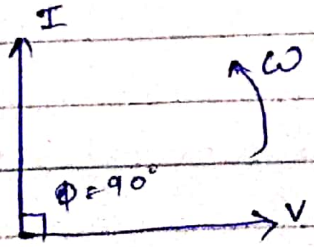
$I_t = \omega C V_m \cos\omega t$

$I_t = \frac{V_m \cos\omega t}{1/\omega C}$

$I_t = \frac{V_m \cos\omega t}{X_c}$

$I_t = I_m \sin(\omega t + 90^\circ)$





Current leads voltage by 90° in purely capacitive circuit.

Active Power, $P = VI\cos\phi$

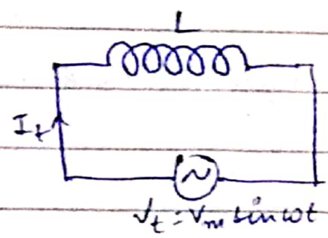
$\because \phi = 90^\circ$

$P = VI\cos 90^\circ$

$$\boxed{P = 0}$$

11 Draw pure inductive circuit diagram, draw its waveform and phasor diagram, also derive formula for its active power.

=>



Due to self inductance of the coil, there will be emf induced in it. This back emf will oppose the instantaneous rise or fall of current through the coil.

$$E = -L\frac{dI}{dt}$$

$$V_t = -E = -\left(-L\frac{dI}{dt}\right)$$

$$V_t = L\frac{dI}{dt}$$

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

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

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

$$I_t = \frac{-V_m}{\omega L}\cos\omega t = -\frac{V_m}{X_L}\cos\omega t = I_m \sin(\omega t - 90^\circ)$$

$$\boxed{I_t = I_m \sin(\omega t - 90^\circ)}$$

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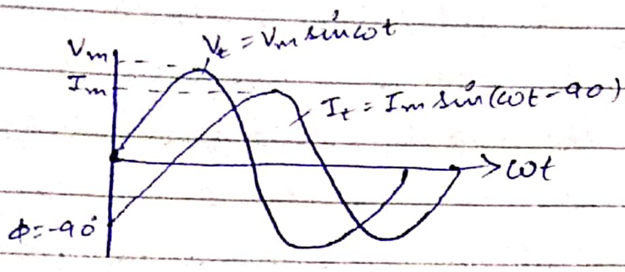
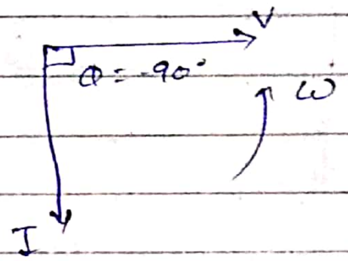
Current lags behind the voltage by 90° in a purely inductive circuit



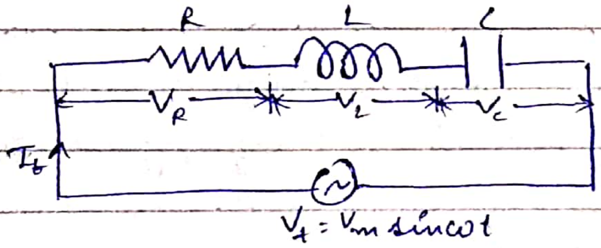


Active Power, $P = VI\cos\phi$

$\phi = 90°$

$\boxed{P = 0}$

12. Derive Resonance frequency and Q factor formula for series resonance LCR circuit. Also, draw its phasor diagram



$V_L = V_C$

$IX_L = IX_C$

$X_L = X_C$

$X_L - X_C = 0$

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

$Z = \sqrt{R^2 + 0}$

$Z = R$

Resonance frequence,

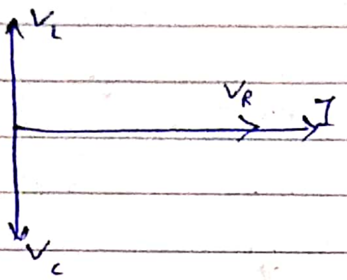
At resonance frequency, $X_L = X_C$

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

$2\pi f_r L = \frac{1}{2\pi f_r C} \Rightarrow f_r = \sqrt{\frac{1}{4\pi^2 LC}}$

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

Phasor Diagram -



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

$$V = \sqrt{V_R^2 + 0}$$

$$\boxed{V = V_R}$$

i.e., the supply voltage will drop across the resistor R

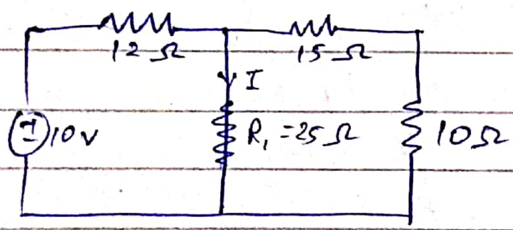
Q - factor -

$$Q\text{-factor} = \frac{V_L}{V_S} = \frac{I X_L}{I R} = \frac{X_L}{R}$$

$$= \frac{\omega_r L}{R} = \frac{2\pi f_r L}{R} = \frac{2\pi L}{R} \cdot \frac{1}{2\pi\sqrt{LC}}$$

$$\boxed{Q\text{-factor} = \frac{1}{R}\sqrt{\frac{L}{C}}}$$

13. Find the current I and voltage V in R_1 using nodal analysis method in circuit of figure below



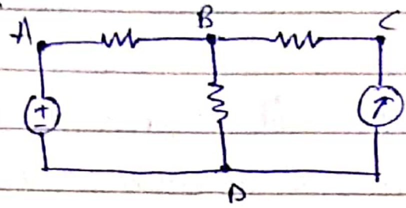
14 Note on - a) Active and Passive circuit
b) Unilateral and Bilateral circuits c) Node and Branch
d) Mesh and loop

a) Active and Passive circuit - Active components are the elements or devices which are capable of providing or delivers energy to the circuit. Examples are Diodes, transistors, SCR, integrated circuits etc.
Passive components are the devices which do not require any external source for the operation and are capable of storing energy in the form of voltage or current in the circuit. Examples are resistor, capacitor and inductor.

b) Unilateral and Bilateral Circuit - A circuit whose characteristics, behaviour ~~is~~ is dependent on the direction of current through various elements is called a unilateral network. Circuit consisting diodes, which allows the flow of current only in one direction is an example of unilateral circuit.

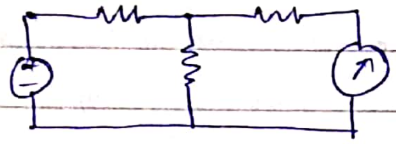
A circuit whose characteristics, behaviour are the same irrespective of the direction of current through various elements of it, is called bilateral network. A network consisting of only resistances is an example of bilateral network.

c) Node and Branch – A node is a point in the circuit where two or more circuit elements (or branches) are connected.



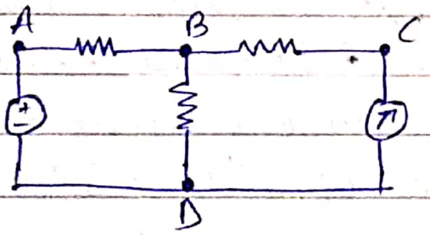
Circuit contains four nodes. A, B, C and D.

A branch represents the single circuit elements like resistor, capacitor, inductor, voltage or current source.



Circuit contains five branches. A voltage source, a current source and three resistors.

d) Mesh and Loop – A mesh is a closed path in the circuit which does not contain any close path inside it.



For example loop 1 (ABDA) and loop 2 (BCDB) does not contain any other closed path within them and are ex of mesh while loop 3 (ABCDA) contains loop 1 and loop 2 within it, so can't be called as mesh.

Any closed path in the circuit is called as a loop.
A loop is a closed path formed by starting at a node, passing through a set of nodes and returning to the starting node without passing through any node more than once.
Loop 1 (ABDA), Loop 2 (BCDB) and Loop 3 (ABCDA)

15 An alternating current is given by $I = 50 \sin 314t$. Find the following -
a) Time period b) The maximum value of current &
c) The instantaneous value when $t = 4\ ms$

=> a) Time period -

$$\omega = 314.$$

$$\frac{2\pi}{T} = 314 \Rightarrow T = \frac{2\times 3.14}{314\times 100} = 0.02\ s = 2ms.$$

b) Maximum value of current, $I_m = 50$.

c) Instantaneous value, $I = 50 \sin (314 \times t)$.

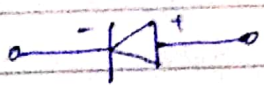
$$t = 4\ ms = 0.04\ s$$

$$I = 50 \sin\left(314 \times \frac{4}{100}\right) = 50 \sin(4\pi)$$

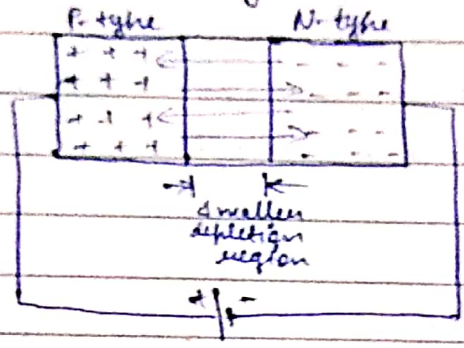
$$I = 50(0) \Rightarrow \boxed{I = 0}$$

17 Define p-n junction diode, explain its forward and reverse biased operation with diagram.

=> A p-n junction diode is formed when a p-type semiconductor is fused to an n-type semiconductor creating a potential barrier voltage across the diode junction.



Forward Biased PN Junction - A P-N junction is said to be forward biased when the p-type region of a junction is connected to the positive terminal of a voltage source and the n-type of region is connected to the voltage source's negative terminal

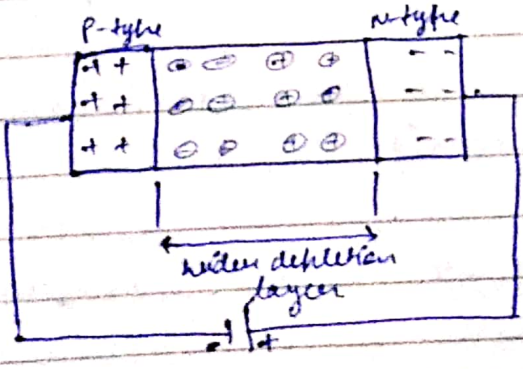


In forward biased condition, due to the attraction of the positive terminal of the source, electrons that participated in covalent bond creation in the p-type material will be attracted towards the terminal. As a result, the number of covalent bonds is broken and electrons are shifted towards the positive terminal. This results in the electrons's concentration in the crystal closer to the terminal to increase and these electrons recombine with holes here. In this way, the number of holes increases in the portion of the p-type region away from the junction and it is reduced in the portion of the p-type region nearer to the terminal. as such holes are shifted from terminal to junction. Due to the higher concentration of holes adjacent to the negative impurity ion layer, the electrons of negative ions come out and recombine with those holes and create new holes in the layer. Consequently, the width of this negative ions layer is reduced and finally this layer vanishes.

Similarly, due to the negative terminal of the source the free electrons in the n-type region will repeal towards the junction where they will find the layer

of positive impurity ions and start recombine with these ions and generate free electrons inside the layer. Consequently, the width of positive impurity ions is reduced and finally it vanishes.
In this way, both layers of ions disappear and there will be no more depletion layer. After the depletion layer disappeared, free electrons from the n-type region can easily drift to the p-type region and holes from the p-type region to the n-type region in the crystal.

Reverse Biased PN Junction - When the positive terminal of a voltage source is connected to the n-type region and the negative terminal of the source is connected to the p-type region. The PN junction is said to be in reversed biased condition.



When there is no voltage applied across the p-n junction the potential developed across the junction is 0.3V for germanium and 0.7V for silicon.
If the reverse biased voltage across the PN junction is increased the barrier potential developed across the PN junction is also increased. Hence the pn junction is widened.

When positive terminal of the source is connected to the n-type region, the free electrons of that region are attracted towards the positive terminal of the source because of that more positive impurity ions are created in the depletion layer which makes the layer of positive impurity ions thicker.
At the same time since the negative terminal of the source is connected to the p-type region of the junction electrons are injected in this region.
Due to positive potential of the n-type region, the electrons are drifted towards the junction and combine with holes adjacent to the layer of positive impurity ions and create more positive impurity ions in the layer. Hence, the thickness of the layer increases.
In this way the overall width of the depletion layer increases along with its barrier potential.

18 Define Transducers. Write its classification and characteristics in detail.

→ Transducer is a device which converts one form of energy into other.
Classification of Transducers:-

a) Primary and secondary Transducers:
Primary Transducer - The transducer consists the mechanical as well as the electrical devices. The mechanical devices of the transducers change the physical input quantities into a mechanical signal

Secondary Transducer - The secondary transducer converts the mechanical signal into an electrical signal. The magnitude of the output signal depends on the input mechanical signal.

b) Analog and Digital Transducers:
Analog Transducer - The analog transducer changes the input quantity into a continuous function. Examples are strain gauge, LVDT, thermocouple...

Digital Transducer - These transducers converts an input quantity into a digital signal or in the form of the pulse. The digital signals work on high or low power.

c) Active and Passive Transducers:
Active Transducer - The transducers which does not require the external power source is known as active transducer. Such type of transducer develops their own voltage or current and hence known as self-generating transducers. (Thermocouple, Photovoltaic cell)

Passive Transducers - The transducer which requires the power from an external supply source is known as passive transducer. They are also known as external power transducer. The capacitive, resistive, and inductive transducers are the examples of passive transducers.

d) Transducer and Inverse-Transducer

Transducer- The device which converts the non-electrical quantity into an electric quantity is known as transducer.

Inverse Transducer - The transducer which converts the electric quantity into a physical quantity. such type of transducers is known as inverse transducer. The transducer has high electrical input and low non-electrical output.

Characteristics of Transducers:-

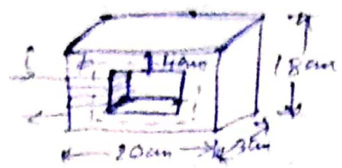
a) Dynamic Range - It is defined as the ratio between largest and smallest amplitude signals that can be translated by a transducer. Larger the Dynamic range implies more sensitive and precise transducer will.

b) Repeatability - A transducer's ability to produce identical output upon stimulation by the same input is termed as repeatability.

c) Noise - All transducers have some random noise in their output. Small signals are largely affected by noise in comparison to larger signals.

d) Hysterisis - This is property wherein a transducer's output is dependent not only on the present input but also on the previous inputs.

e) Sensitivity - The transducer must be sensitive enough to produce detectable output



22 For the rectangular iron core shown has a relative permeability of 1500. If the current in the coil is 1A determine the number of coil turns needed to produce a magnetic flux of 3 mWb in the core

⇒ $\mu_r = 1500$, $I = 1A$, $\Phi = 3\,mWb = 3\times10^{-3}\,Wb$

Area, $A = 4\times3 = 12\times10^{-4}\,m^2$

Mean length, $l = 16+14+16+14 = 60\,cm = 0.6\,m$

$$\Phi = BA$$

$$\Phi = \frac{\mu_0 \mu_r N I A}{l}$$

$$N = \frac{\Phi\times l}{\mu_0\mu_r I A} = \frac{3\times10^{-3}\times 0.6}{4\pi\times10^{-7}\times 1500\times 1\times 12\times10^{-4}}$$

$$N = \frac{1}{4\pi}\times10^{4} = 0.0796\times10^{4}$$

$$\boxed{N \approx 795}$$

23 A capacitor which has an internal resistance of 10 Ω and a capacitance value of 100 μF is connected to a supply voltage given as $V(t) = 100\sin(314t)$. Calculate the current flowing into the capacitor. Also construct a voltage triangle showing the individual voltage drops.

⇒ $X_C = \frac{1}{\omega C} = \frac{1}{314\times100\times10^{-6}} = 31.85\,\Omega$

$Z = \sqrt{R^2+X_C^2} = \sqrt{10^2+(31.85)^2} = 33.4\,\Omega$

$I = \frac{V_s}{Z} = \frac{100}{33.4} = 3A$

$V_R = I\times R = 3\times10 = 30V$

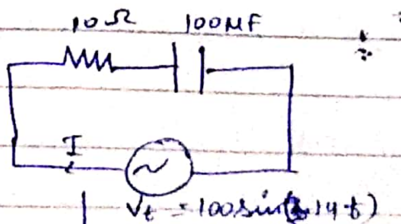
$V_C = I\times X_C = 3\times31.85 = 95.6\,V$

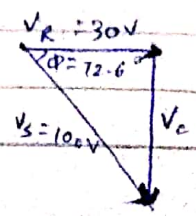
$V_S = \sqrt{V_R^2+V_C^2} = 100\,V$

$\tan\phi = \left(\frac{X_C}{R}\right)$

$\phi = \tan^{-1}\left(\frac{31.85}{10}\right)$

$\boxed{\phi = 72.6°}$





24 What is sensor? What are the criteria to choose sensor? Explain different types of sensors with their function and application.

⇒ A device that detects the changes in electrical or physical or other quantities and thereby produces an output as an acknowledgement of change within the quantity is named as sensor.

Criteria to choose sensor-

a) Range - Difference between maximum and minimum value which can be sensed by the sensor.

b) Sensitivity - Ratio of change in output to a unit change in the input.

c) ~~[illegible]~~ Error - Difference between measured value and true value.

d) Accuracy - It is inversely proportional to error i.e., How close the sensor reading is to the True value.

e) Precision - Ability to give / reproduce accurate value repeatedly.

Types of Sensors -

a) Temperature Sensor - A temperature sensor, as the name suggests, senses the temperature i.e., it measures the changes in the temperature. In temperature sensor, the change in temperature corresponds to change in its physical property like resistance or voltage.

Temperature Sensors ICs (LM35), Thermocouple, RTD. etc.

b) Proximity sensor - A proximity sensor is a non-contact type sensor that detects the presence of an object. Proximity sensors can be implemented using different techniques like Optical (Infrared or Laser), ultrasonic, Hall effect, Capacitive. Some of the applications of Proximity sensors are Mobile Phones, cars (Parking sensors), industries etc.

c) Infrared Sensor - IR sensors are light based sensor that are used in various applications like Proximity and Object Detection. IR sensors are used as proximity sensors in almost all mobile phones. Different applications where IR sensors is implemented are Mobile Phones, Robots, Industrial assembly, automobiles etc.

d) Ultrasonic sensors - Ultrasonic sensors is a ~~device~~ non-contact type device that can be used to measure distance as well as velocity of an object. An ultrasonic sensor works based on the properties of the sound waves with frequency greater than that of the human audible range. Ultrasonic sensor is used in SONAR.

25 A 110 V ac supply is applied to a coil of 1.0 H inductance and 1.0 Ω resistance connected in series with 8.6 μF capacitor. Calculate

a) Impedance b) Current c) Phase angle between current and voltage

d) Power Factor e) Power consumed.

$\Rightarrow$ $V = 110V$, $f = 50Hz$, $L = 1.0H$, $C = 8.6 \times 10^{-6} F$, $R = 1\Omega$.

$\omega = 2\pi f = 100\pi = 314$

$X_L = \omega L = 314 \times 1 = 314$.

$X_C = 1/\omega C = \frac{1}{314 \times 8.6 \times 10^{-6}} = 370.3$.

a) Impedence, $Z = \sqrt{R^2 + (X_C - X_L)^2} = \sqrt{1 + (56.3)^2} = 56.3$

b) Current, $I = \frac{V}{Z} = \frac{1100}{56.3} = \frac{1100}{563} = 1.95A$.

c) Phase angle, $\theta = \tan^{-1}\left(\frac{X_C - X_L}{R}\right) = \tan^{-1}\left(\frac{370.3 - 314}{1}\right)$

$\theta = \tan^{-1}\left(\frac{56.3}{1}\right) \simeq 90°$

d) Power Factor, $\cos\phi = \frac{R}{Z} = \frac{1}{56.3} = 0.0177$.

$\phi = \cos^{-1}(0.0177) \simeq 90°$

e) Power consumed, $P = VI$.

$P = 110 \times 1.95$

26 Define Rectifier explain the working principle of Bridge full wave rectifier with neat diagram. Also write its ripple factor and efficiency formula with their ideal values.

$\Rightarrow$ An electrical device which converts an alternating current into a direct current.

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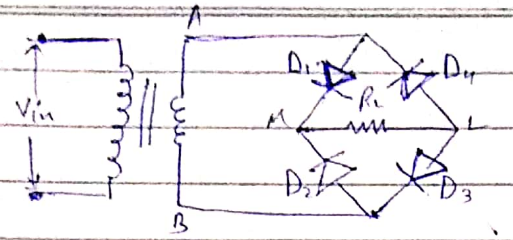
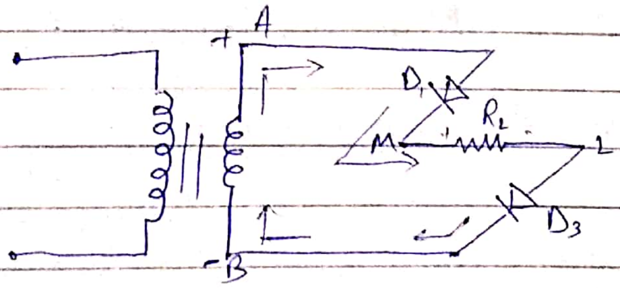
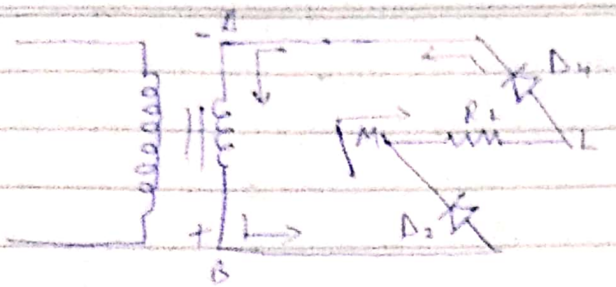
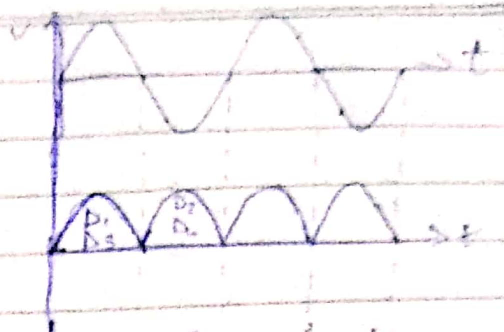


When an AC supply is switched ON, the alternating voltage V_{in} appears across the terminals AB of the secondary winding of the transformer which needs rectification. During the positive half cycle of the secondary voltage, end A becomes positive, and end B becomes negative as shown. The diodes D_1 and D_3 are forward biased and diodes D_2 and D_4 are reversed biased. Therefore, diode D_1 and D_3 conduct and diode D_2 and D_4 do not conduct. The current flows through diode D_1, load resistor R_L (from M to L), diode D_3 and the transformer secondary.



During the negative half cycle, end A becomes negative and end B becomes positive. The diodes D_2 and D_4 are under forward bias and the diodes D_1 and D_3 are reverse bias. Therefore, diode D_2 and D_4 conduct while diodes D_1 and D_3 do not conduct. Thus current flows through the diode D_2, load resistor R_L (from M to L), diode D_4 and the transformer secondary.





The current flows through load resistor R_L in the same direction (M to L) during both the half cycles. Hence, a DC output voltage is obtained across the load resistor.

Ripple factor, $\gamma = \frac{I_{ac}}{I_{dc}} = \sqrt{\left(\frac{I_{rms}}{I_{dc}}\right)^2 - 1}$

$I_{rms}/I_{ac} = \frac{I_m}{\sqrt{2}}$

$I_{dc}/I_{avg} = \frac{2I_m}{\pi}$

$\gamma = \sqrt{\left(\frac{I_m/\sqrt{2}}{2I_m/\pi}\right)^2 - 1} = \sqrt{\left(\frac{1/\sqrt{2}}{2/\pi}\right)^2 - 1} = \sqrt{\frac{\pi^2}{8} - 1} = 0.482$

Efficiency $(\eta)\% = \frac{P_{dc}}{P_{ac}} \times 100$ $\qquad P_{dc} = I_{dc}^2 . R_L$

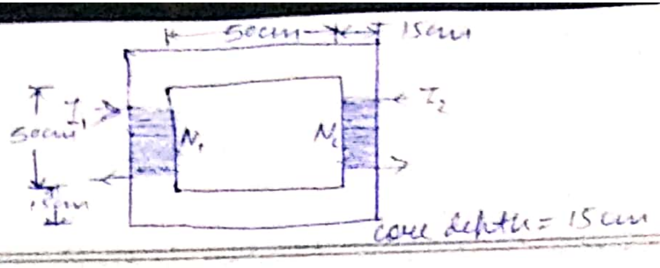
$P_{ac} = (I_{rms})^2 . (r_f + R_L)$

$\eta\% = \frac{I_{dc}^2 . R_L}{(I_{rms})^2 . (r_f + R_L)} \times 100$

$R_L >>> r_f$

$\eta = \frac{I_{dc}^2 . \cancel{R_L}}{(I_{rms})^2 . \cancel{R_L}} \times 100 = \left(\frac{2I_m/\pi}{I_m/\sqrt{2}}\right)^2 \times 100 = \left(\frac{2/\pi}{1/\sqrt{2}}\right)^2 = 0.812 \times 100$

$= 81.2\%$



28 A two legged core is shown in the figure. The winding on the left leg (N_1) has 600 turns and the winding on the right (N_2) has 200 turns. The coils are wound in the directions shown in the figure. If the dimensions are as shown, then what flux will be produced by currents $I_1 = 0.5$ A and $I_2 = 1$ A. Assume $\mu_r = 1000$.

-> Total mmf, $F_m = N_1 I_1 + N_2 I_2 = 600(0.5) + 200(1) = 500$ At

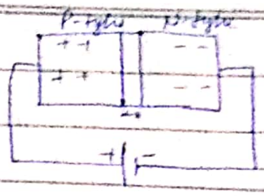
Total reluctance, $S = \frac{l}{\mu_0 \mu_r A} = \frac{2.6}{4\pi \times 10^{-7} \times 10^3 \times 15 \times 15 \times 10^{-4}}$

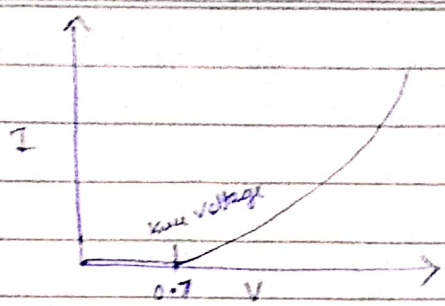
Flux, $\Phi = \frac{F_m}{S} = \frac{5000}{2.6} \times 4\pi \times 10^{-8} \times 15 \times 15 = 543461.538 \times 10^{-8}$
$= 0.00543$ Wb

29 Write notes on - Refer (7)
a) Wave

30 Draw and explain the forward and reverse biased p-n junction VI characteristics curve

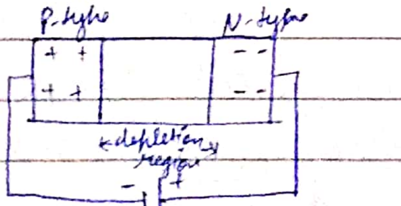
-> Forward bias characteristics -
When the p-section of the diode is connected to positive terminal of a battery and n-section is connected to negative terminal of the battery then junction is said to be forward biased. With increase in bias voltage, the forward current increases slowly in the beginning and then rapidly. At about 0.7V for Si diode, 0.2V for Ge, the current increases suddenly. The value of forward bias voltage, at which the forward current increases rapidly, is called cut in voltage or threshold ~~[illegible]~~ voltage.

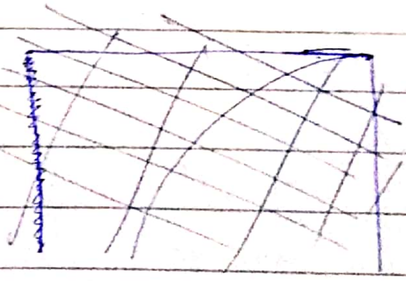


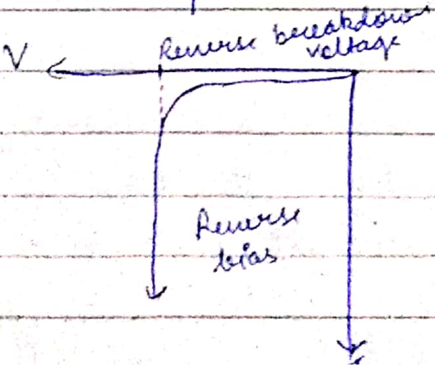


Forward-bias

Reverse-bias Characteristics-
When the p-type section of the diode is connected to negative terminal of high voltage battery and n-section of the diode is connected to ~~negative~~ positive terminal of the same battery then the junction is said to be reverse biased. When reverse bias voltage increases initially there is a very small reverse current flow, which remains almost constant with bias. But when reverse bias voltage increases to sufficiently high value, the reverse current suddenly increases to a large value. This voltage at which breakdown of junction diode occurs is called Zener breakdown voltage or inverse voltage.







31 Differentiate between Sensors and Transducers. What are the criteria to choose sensors?

→

Sensor	Transducer
• Senses the physical changes occurs in the surrounding and converting it into a readable quantity	The transducer is a device which, when actuates transforms the energy from one form to another
• Components - Sensor itself	Sensor and signal conditioning
• Detects the changes and induces the corresponding electrical signals	conversion of one form of energy into another
• Proximity sensor, magnetic sensor, accelerometer sensor	Thermistor, Potentiometer, Thermocouple, etc

Criteria to choose sensor - (Q 24)

32 State Norton's Theorem. List the steps for obtaining Norton's equivalent circuit. Compare Norton's and Thevenin's equivalent circuit.

→ Norton's Theorem - Norton Theorem is an analytical method used to change a complex circuit into a simple equivalent circuit consisting of a single resistance in parallel with a current source. The simplified circuit is known as Norton Equivalent circuit.

Steps to obtain Norton's equivalent circuit:-

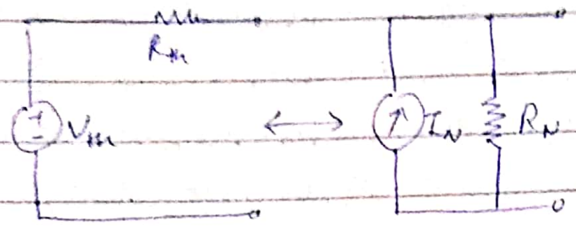
- consider the given circuit and short load terminals after disconnecting the load resistance (or impedence) from output or load terminals.
- Determine the short circuit current I_{sc}, through the shorted terminals by applying any of the circuit reduction techniques like Mesh analysis or Nodal analysis
- Redraw circuit by replacing all the practical sources in the circuit with their internal voltages or simply short circuit voltages sources and open circuit the current sources. And also make sure to open or remove the short circuited terminals of the load
- Calculate the resistance that exists between the load terminals by looking from load terminals. This resistance is equivalent Norton's resistance R_N.
- Insert the resistance in parallel with current source which forms a Norton's equivalent circuit.
- Now, reconnect the load to the Norton's equivalent circuit and calculate the current, voltage and power associated with the load as.

Load current, $I_L = \dfrac{I_N \times R_N}{(R_L + R_N)}$

Load voltage, $V_L = I_L \times R_L$

Power dissipated at load, $P = I_L^2 \times R_L$

Norton and Thevenin Equivalent circuit.



By comparing Thevenin's equivalent circuit, we can observe the Norton's equivalent circuit of a linear network constitute a Norton current source I_N in parallel with a Thevenin's resistance R_{th}.
Therefore, it is possible to perform a source transformation of Thevenin's equivalent circuit to get the Norton's equivalent circuit or vice-versa

$$V_{th} = R_N \times I_N$$
$$R_{th} = R_N$$

33 A solenoid is constructed of sheet steel and its magnetic flux density is to be B = 0.1T when its field strength is H = 100 At/m. Determine the relative permeability of this core also calculate the current required to produce magnetic flux density when the average radius is 0.01 m and the cross-sectional radius is 0.02 m and coil has 500 turns.

$\Rightarrow$ $B = 0.1T$, $H = 100$, $N = 500$, $r = 0.02m$, $l = \pi d = 0.02\pi$

$B = \frac{\Phi}{A} \Rightarrow \Phi = BA = 0.1 \times 3.14 \times 4 \times 10^{-4} = 1.256 \times 10^{-4}$ wb.

$H = \frac{NI}{l} \Rightarrow I = \frac{Hl}{N} = \frac{100 \times 0.02\pi}{500} = 0.01256\,A$

$S = \frac{mmf}{\Phi} \Rightarrow \frac{l}{\mu_0 \mu_r A} = \frac{NI}{1.256 \times 10^{-4}} \Rightarrow \boxed{\mu_r = 796.17}$

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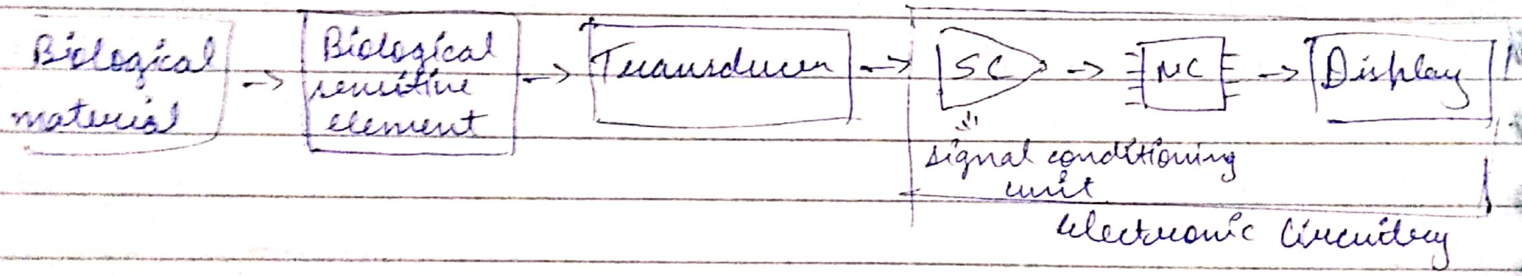
34 What are Biosensors? Describe its main components, working principle and applications in healthcare.

→ A biosensor is an analytical device that detects changes in Biological processes and converts them into an electrical signal. Biosensor is a combination of a Biological sensing element and a transducer, which converts the data into electrical signals.
There is an electronic circuit which consists of a Signal conditioning Unit, a Processor or Micro-controller, and a Display unit.



Working Principle -
Biosensors are operated based on the principle of signal transduction.
The bio-recognition element, essentially bioreceptor, is allowed to interact with a specific analyte. The transducer measures this interaction and outputs a signal. The intensity of the signal output is proportional to the concentration of the analyte. the signal is then amplified and processed by electronic circuit system.
Applications in Healthcare - The use of biosensors for cancer clinical testing may increase speed and flexibility, enable multi-target analysis and automation. Biosensors are used in biochemical labs and clinics to measure glucose levels as well as lactic acid.

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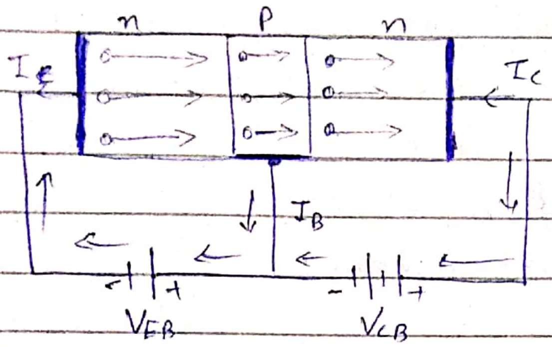
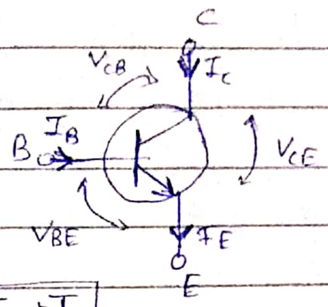
35 Why Transistor is so called Bipolar Junction Transistor and keeping base very thin and light dopped. Explain working of npn and PNP transistor.

→ Transistor are called bipolar because the main flow of current through them takes place in two types of semiconductor material : P and N, as the main current goes from emitter to collector or vice-versa. In other words, two types of charge carriers - electrons and holes comprise this main current through the transistor.

The base region in a transistor is made very thin so that there is a better conduction of majority carriers from emitter to collector through base. Due to it, the base current is quite weak. The collector current is nearly equal to the emitter current. As result of it, the transistor can give good power gain and voltage gain. The base region is doped lightly so that the no. density of majority carriers (electrons in p-n-p and holes in n-p-n) is low. When emitter is forward biased, the majority carriers moves from emitter to collector through base. Since base is thin and lightly doped, only a small (5%) electron-hole combination will take place giving weak base current and remaining majority carriers will be collected by collector giving collector current nearly equal to emitter current.

Working of N-P-N Transistor

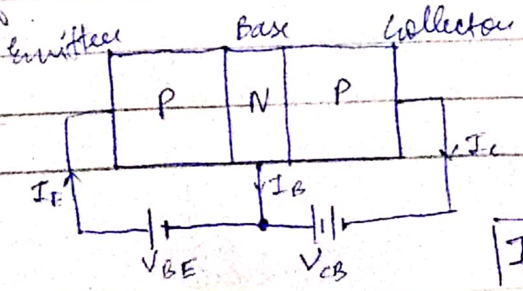


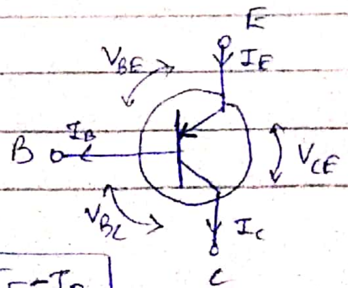


$\boxed{I_E = I_B + I_C}$

The forward biased is applied across the emitter-base junction and reverse biased is applied across the collector-base junction. The forward biased voltage V_{EB} is small as compared to the reverse bias voltage V_{CB}.
The emitter of NPN transistor is heavily doped. When the forward bias is applied across the emitter, the majority charge carriers move towards the base. this causes the emitter current I_E. the electrons enter into P-type material and combine with the holes.
The base of NPN transistor is lightly doped. Due to which only few electrons are combined and remaining constitutes the base current I_B. this base current enters into the collector region. The reverse bias potential of the collector region applies high attractive force on the electrons reaching collector junction. Thus collect the electrons at the collector. The whole of emitter current is entered into the base. Thus we can say that the emitter current is sum of collector or base current.

Working of PNP Transistor





$\boxed{I_C = I_E - I_B}$

The emitter-base junction is connected in forward biased due to which the emitter pushes the holes in the base region these holes constitute the emitter current. When these electrons move into the N-type semiconductor material or base, they combined with the electrons, the base of the transistor is thin and lightly doped. Hence only a few holes combined with the electrons and the remaining are moved towards the collector space charge layer. Hence develops the base current

The collector base region is connected in reverse biased. The holes which collect around the depletion region when coming under the impact of negative polarity collected or attracted by the collector. This develops the collector current. The complete emitter current flows through the collector current I_c

36 same Q12

37 Define significance of three terminals of bipolar junction transistor with neat diagram. Explain common emitter, common base transistor configuration with its current amplification factor and output current equation.

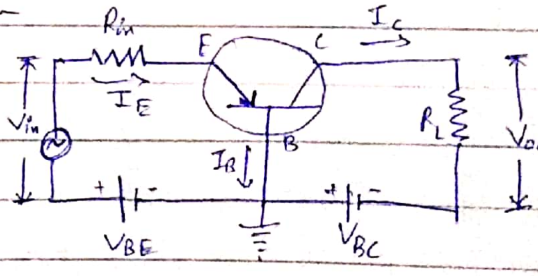
→ Significance of Terminals.

a) Emitter - The section that supplies the large section of majority charge carrier is called emitter. The emitter is always connected in FB with respect to base so it supply majority charge carrier to the base. The emitter base junction injects a large amount of majority charge carrier into the base because it is heavily doped and moderate in size.

b) Collector - the section which collects the major portion of majority charge carriers supplied by the emitter is called a collector. The collector base junction is always in reverse bias. The collector is moderately doped but larger in size so that it can collect most of the charge carrier supplied by emitter.

c) Base - The middle section of the transistor is known as base. The base forms two circuits, the input circuit with the emitter and the output circuit with the collector. The emitter base circuit is in forward biased and offered low resistance to the circuit. The collector base circuit is in reverse bias and offers higher resistance. The base is lightly doped and very thin due to which it offers the majority charge carrier to the base.

Common Base Configuration -



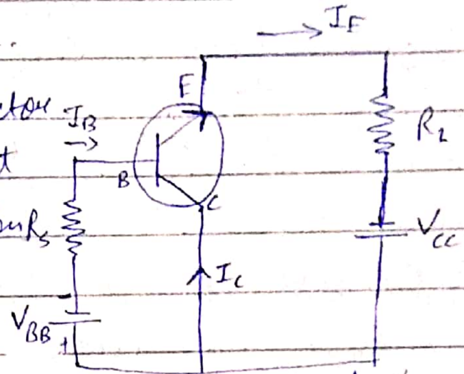
In this configuration we use base as common terminal for both input and output signals.
Here input is applied between base and emitter terminals and corresponding output signal is taken between base and collector terminals with base terminal grounded.
The input current flowing into the emitter terminal must be higher than the base current and collector current to operate transistor, therefore output collector current is less than the input emitter current.
The current gain is generally equal or less than to unity for this configuration

Current amplification factor, $\boxed{\alpha = \frac{I_C\,(\text{output})}{I_E\,(\text{input})}}$

Output current, $I_C = \alpha I_E + I_{leakage}$

$$\boxed{I_C = \alpha I_E + I_{CBO}}$$

Common Collector Configuration -

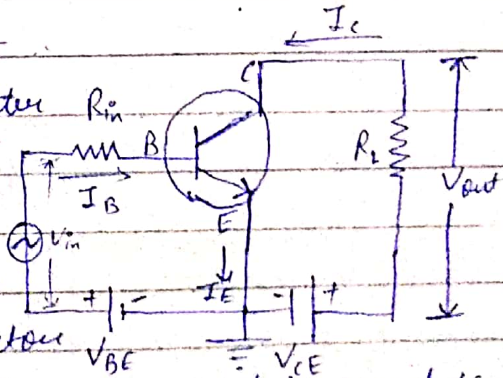


In this configuration we use collector terminal as common for both input and output signals. This configuration is also known as emitter follower configuration because the emitter voltage follows the base voltage. The input signal is applied between the base collector region and the output is taken from the emitter collector region. The emitter current is equal to the sum of collector current and the base current.

Current amplification factor, $\boxed{\gamma = \frac{I_E\,(\text{output})}{I_B\,(\text{input})}}$

Output current, $I_C = \gamma I_B + I_{CBO}$

Common Emitter configuration -



In this configuration we use emitter as common terminal for both input and output signals. The input is applied between base-emitter region and the output is taken between collector and emitter terminals. The emitter current is equal to the sum of small base current and large collector current.

Current amplification factor, $\boxed{\beta = \frac{I_C\,(\text{output})}{I_B\,(\text{input})}}$

Output current, $\boxed{I_C = \beta I_B + I_{CEO}}$

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156
600
24649
25549

38. What is resonance circuit. Give equation of series and parallel resonance and define

39 A sinusoidal alternating current of frequency 25 Hz has a maximum value of 100 A. How will it take for the current to attain the value of 20 A!

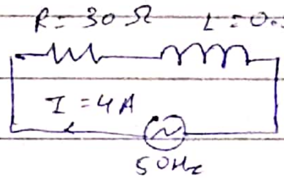
=> $I = I_m \sin \omega t$.

$20 = 100 \sin 2\pi(25)t$

$\frac{1}{5} = \sin 50\pi t$

$0.201 = 157 t \Rightarrow t = 0.00128\,s$.

40. What will be the value of the supply voltage if its frequency is 50 Hz



=> $\omega = 2\pi f = 2\pi(50) = 314$

$X_L = \omega L = 314 \times 0.5 = 157$

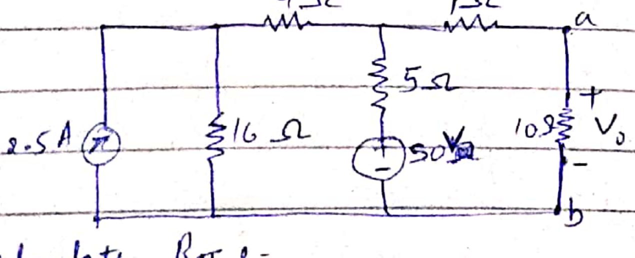
$Z = \sqrt{R^2 + X_L^2} = \sqrt{(30)^2 + (157)^2}$.

$Z = \sqrt{900 + 24649} = \sqrt{25549} = 159.84$

$V = IZ = 4 \times 159.84$

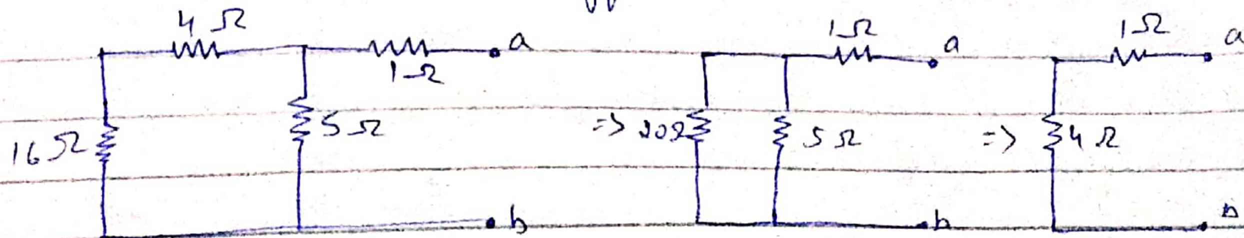
$\boxed{V = 639.36\,V}$

44 Apply Thevenin's Theorem to find V_o in the circuit of



Calculate R_{TH}:-

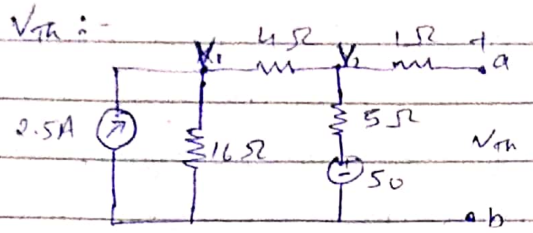
Remove the load and turn off the sources.



20‖5: $\frac{20\times5}{20+5} = \frac{100}{25} = 4$

$\therefore \boxed{R_{TH} = 5\Omega}$

Calculate V_{Th} :-



At node 1,

$$\frac{V_1}{16} + \frac{V_1 - V_2}{4} - 2.5 = 0$$

$$V_1 + 4V_1 - 4V_2 = 40$$

$$5V_1 - 4V_2 = 40 \quad \text{—(i)}$$

At node 2,

$$\frac{V_1 - V_2}{4} + \frac{50 - V_2}{5} = 0$$

$$5V_1 - 5V_2 + 200 - 4V_2 = 0$$

$$5V_1 - 9V_2 = -200 \quad \text{—(ii)}$$

eq (i) − eq (ii)

$$\cancel{5V_1} - 4V_2 = 40$$

$$\underset{(-)}{\cancel{5V_1}} \underset{(+)}{-} 9V_2 = \underset{(+)}{-}200$$

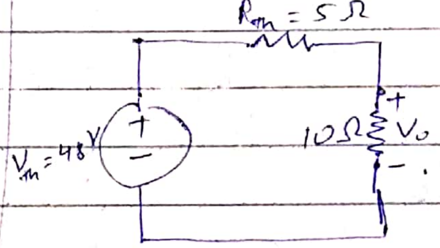
$$5V_2 = 240$$

$$\boxed{V_2 = 48\,V}$$

$$5V_1 = 40 + 4(48) = 40 + 192 = 232$$

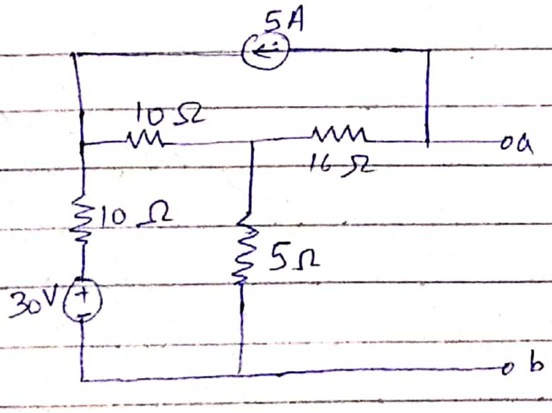
$$\boxed{V_1 = 46.4\,V}$$

$$\boxed{V_{Th} = V_2 = 48\,V}$$

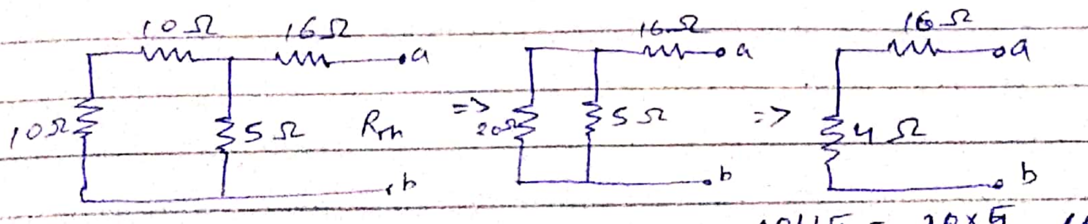


$$V_o = \frac{10(48)}{10+5} = \frac{\cancel{10}^{2} \times \cancel{48}^{16}}{\cancel{15}_{3}} = 32\,V$$

Q 46 Obtain thevenin equivalent at terminals a-b of the circuit shown.



Calculate R_{Th} : Remove load and turn off sources



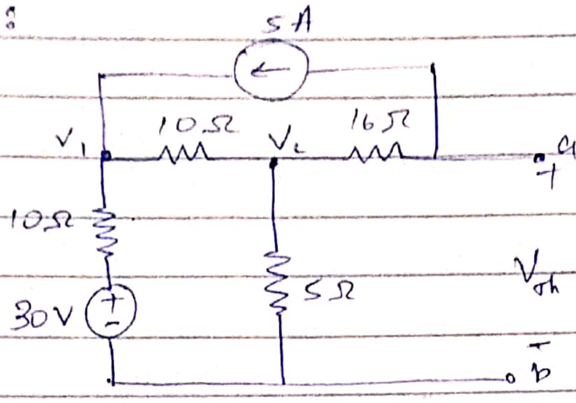
$$\therefore \boxed{R_{Th} = 20\Omega}$$

$$20 \parallel 5 = \frac{20 \times 5}{5 + 20} = \frac{\cancel{100}^{4}}{\cancel{25}} = 4\Omega$$

$2V_1 - V_2 = 54$
$2V_1 - 6V_2 = 60$
$5V_2 = -6$
$V_2 = -1.2$

$2V_1 = 54 - 1.2$
$2V_1 = 52.8$
$V_1 = 26.4$

Calculate V_{Th} :



At node 1,

$$\frac{30 - V_1}{10} + 5 = \frac{V_1 - V_2}{10}$$

$$30 - V_1 + V_2 - V_1 = -50.$$

$$-2V_1 + V_2 = -80 \Rightarrow 2V_1 - V_2 = 80 \quad -(i).$$

At node 2,

$$\frac{V_1 - V_2}{10} + \frac{0 - V_2}{5} = 5$$

$$V_1 - V_2 - 2V_2 = 50.$$

$$V_1 - 3V_2 = 50 \quad -(ii).$$

Solving eq (i) & eq (ii).

$$2V_1 - V_2 = 80.$$
$$2V_1 - 6V_2 = 100$$
$$5V_2 = -20.$$
$$\boxed{V_2 = -4V}$$

$$V_1 = 50 + 3(-4)$$
$$V_1 = 50 - 12.$$
$$\boxed{V_1 = 38V}$$

$$-V_2 + 16 \times 5 + V_{Th} = 0.$$
$$4 + 80 + V_{Th} = 0.$$
$$\boxed{V_{Th} = -84V}$$