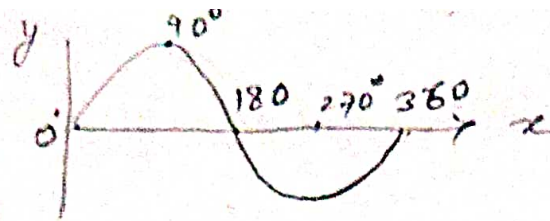


$$y = \sin x$$



$$\sin 0 = 0$$

$$\sin 90 = 1$$

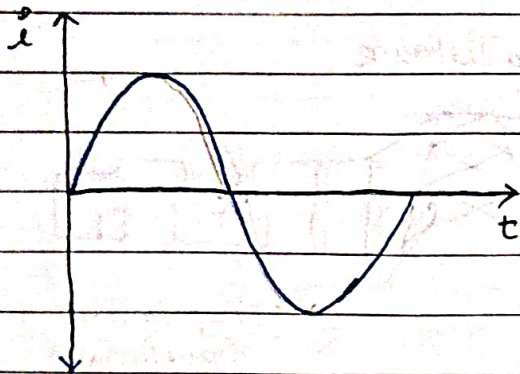
$$\sin 180 = 0$$

$$\text{Date: } \sin 270 = -1$$

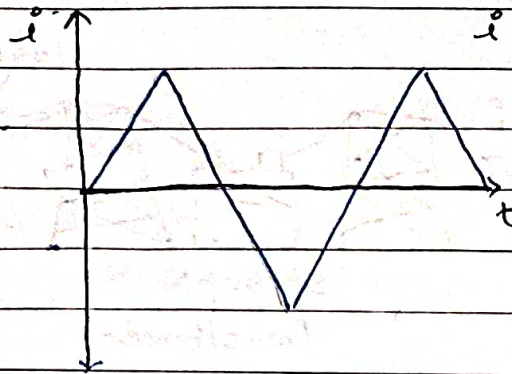
$$\text{Page: } \sin 360 = 0$$

• Alternating Currents (AC)

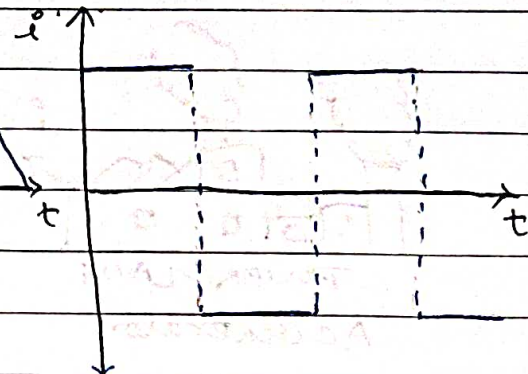
the current which changes its direction after regular interval of time



Sinusoidal AC

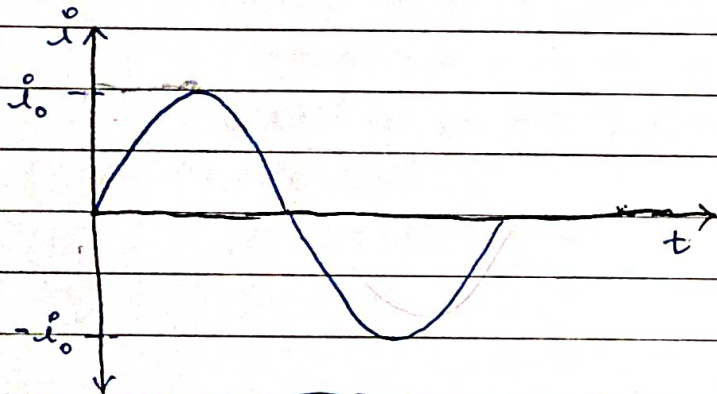


Triangular wave AC

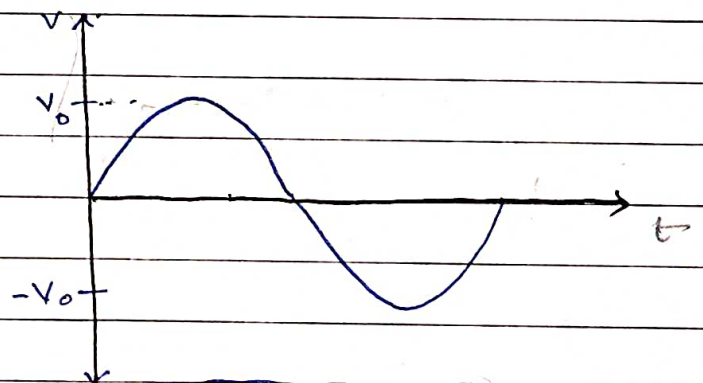


Square wave AC

• Home supply of Alternating current



$$i = i_0 \sin \omega t$$



$$V = V_0 \sin \omega t$$

where i is instantaneous value of current

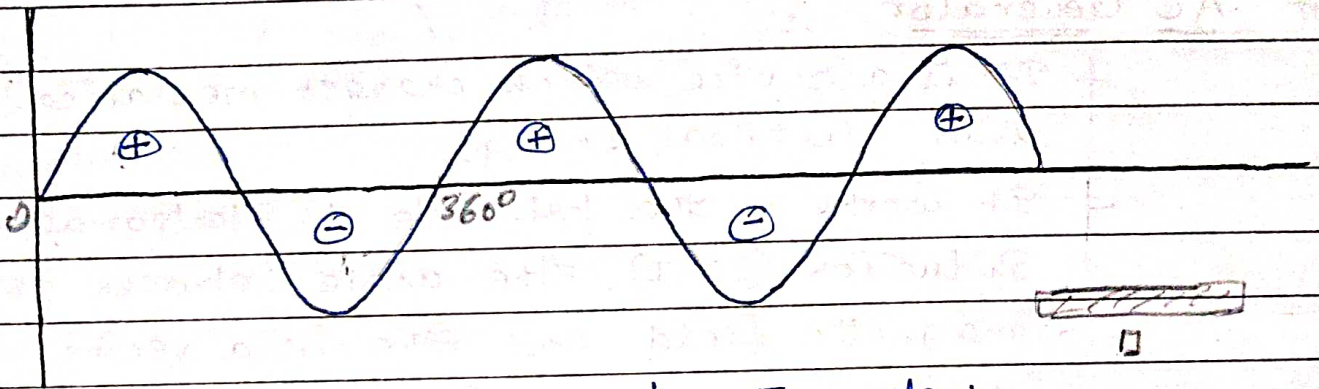
& i_0 = peak value / max^m value

$\omega = 2\pi f$
 Angular frequency
 $\omega = \frac{2\pi}{T}$ frequency (220V, 50Hz)
 $f = 50/\text{sec}$
 Date: _____
 Page: _____

In India $\Rightarrow f = 50 \text{ Hz}$ (1 sec $\rightarrow$ 50 cycles)

In USA $\Rightarrow f = 60 \text{ Hz}$ (110V, 60Hz)

Q:- How many times in Indian home supply, the current its direction in 1 second.



$f = 50 \text{ Hz}$, 1 second = 50 cycles.

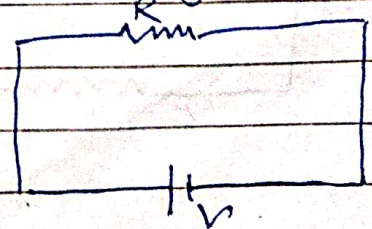
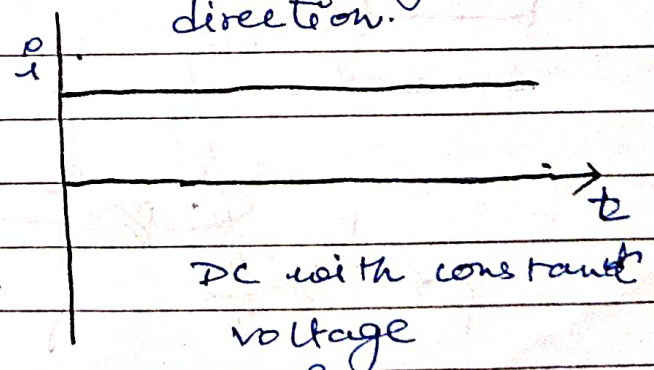
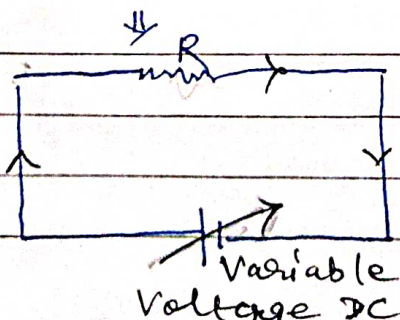
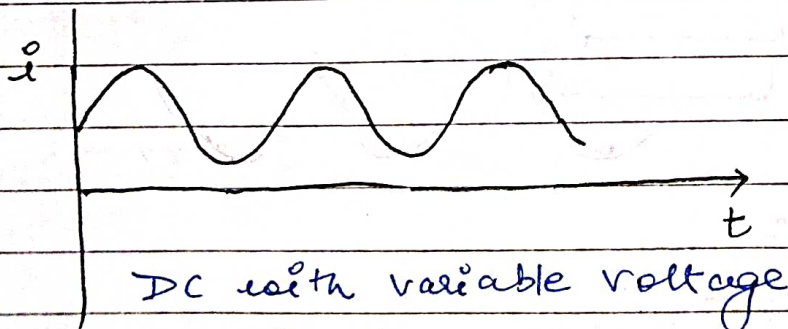
2 revolution $\Rightarrow$ 4 change

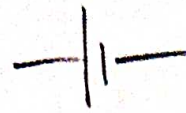
$\therefore$ 1 revolution $\Rightarrow$ 2 change.

$\therefore$ Therefore 100 times direction change

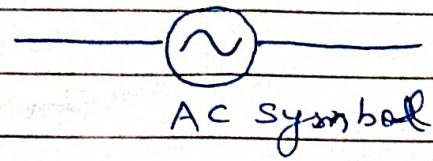
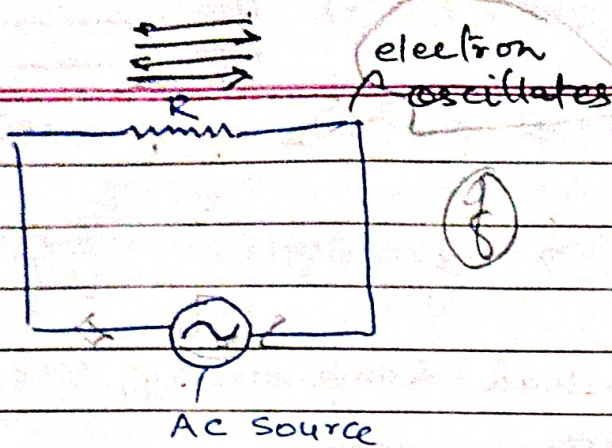
→ Difference b/w AC & DC

DC (Direct current) - doesn't change its direction.





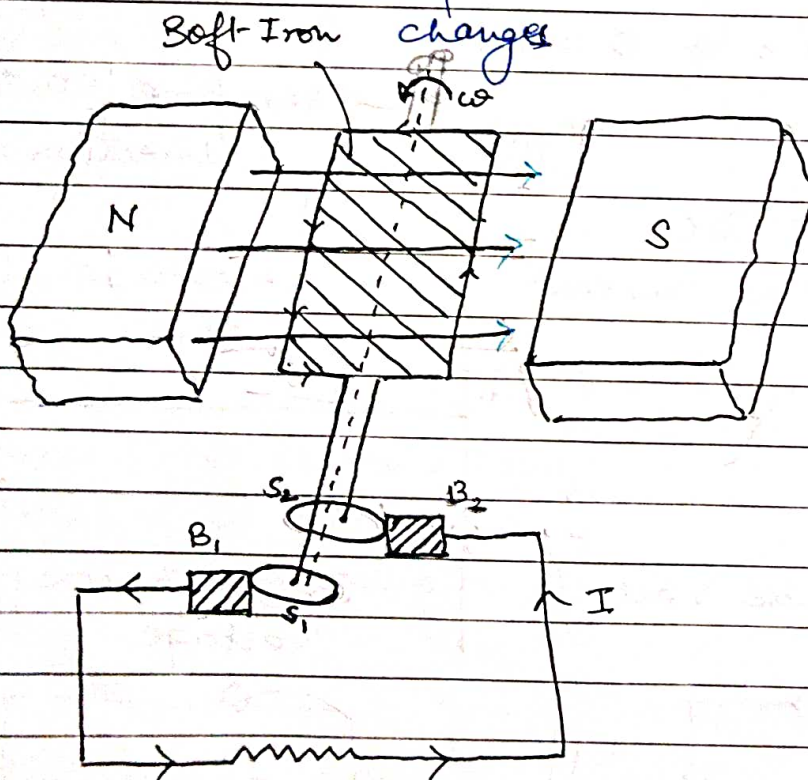
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• AC Generator

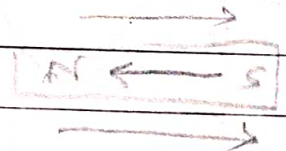
- It is a device which changes mechanical energy into electrical energy.
- It works on the principle of Electromagnetic Induction (EMI). The angle between the magnetic field and the area vector continuously changes

$$\phi = BA \cos \theta \quad \text{changes}$$



$$\phi = B \cdot A$$

Inside Magnet

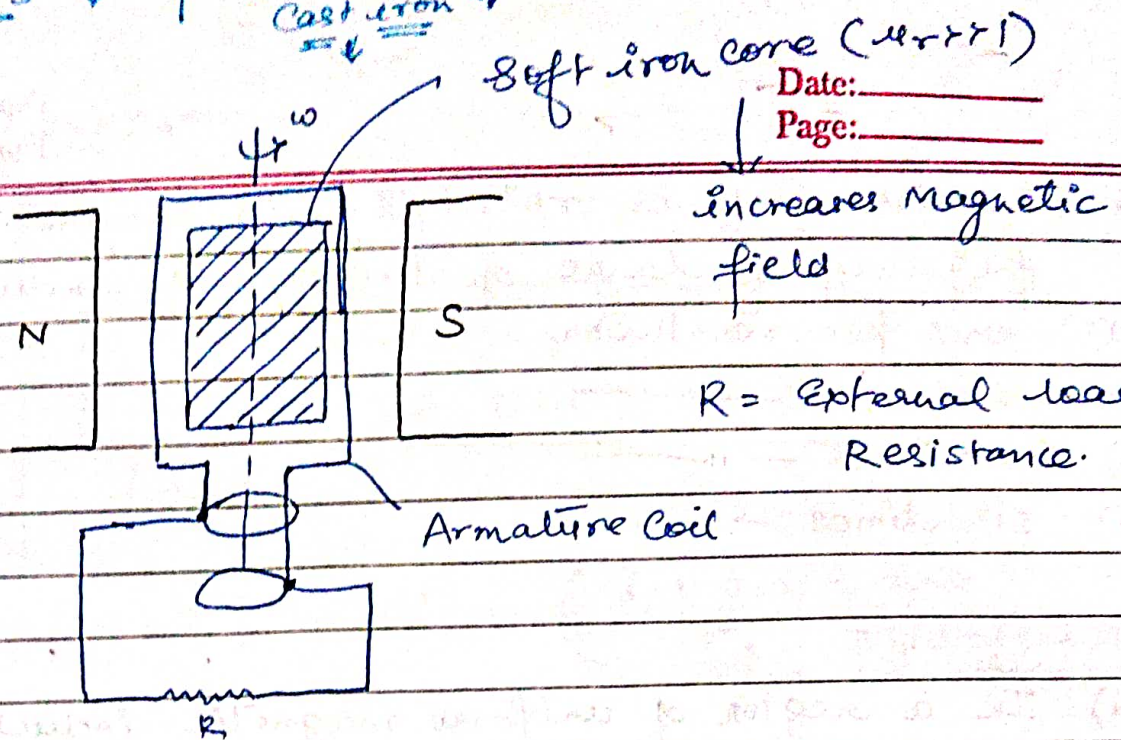


$$\mathcal{E} = - \frac{d\phi}{dt}$$

$$i = \frac{\mathcal{E}}{R}$$

FOS ↓ | Lathe Machine
Cast iron

Construction



Calculation:-

As coil Rotates

$$\omega = \frac{\theta}{t} \Rightarrow \theta = \omega t$$

$$\frac{d}{dt} \cos \omega t = -\sin \omega t (\omega)$$

$$\phi = BA \cos \theta$$

$$\phi = BA \cos \omega t$$

we know $e = -N \frac{d\phi}{dt}$

$$e = -N \times BA (-\sin \omega t) \times \omega$$

$$e = NBA \omega \sin \omega t$$

$$e = e_0 \sin \omega t$$

$$e_0 = NBA \omega$$

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

(max^m value
of induced
emf)

$$i = \frac{e}{R} = \frac{e_0}{R} \sin \omega t$$

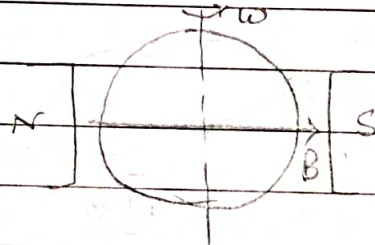
$$i = i_0 \sin \omega t$$

$$i_0 = \frac{NBA \omega}{R}$$

- (Q) A wire loop is rotated in a magnetic field. The frequency of change of direction of induced emf is
- (a) once per revolution (NEET 2013)
- (b) twice — " —
- (c) four times — " —
- (d) six times — " —

- (Q) In a region of uniform magnetic induction $B = 10^{-2} \text{ T}$, a circular coil of radius 30 cm and resistance $\pi^2 \Omega$ is rotated about an axis which is perpendicular to the direction of B and which forms a diameter of the coil. If coil rotates at 200 rpm , the amplitude of the Alternating current induced in the coil is (PYQ)

- (a) $4\pi^2 \text{ mA}$
- (b) 30 mA
- (c) 6 mA
- (d) 200 mA



$$200 \text{ rpm}$$

$$\frac{200}{60} = \text{rps}$$

$$B = 10^{-2} \text{ T}$$

$$R = \pi^2 \Omega$$

$$r = 0.3 \text{ m}$$

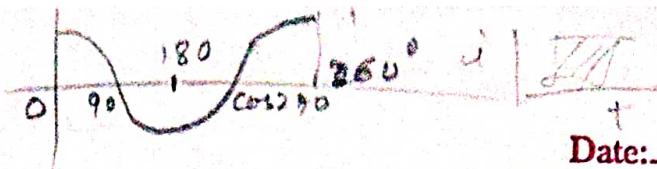
$$f = \frac{200}{60} = \frac{10}{3} \text{ rps} \Rightarrow \omega = 2\pi \left(\frac{10}{3} \right)$$

$$i_0 = \frac{e_0}{R} = \frac{NBA\omega}{R} = \frac{1 \times 10^{-2} \times \pi \times 0.3^2 \times 20\pi}{\pi^2}$$

$$= 10^{-2} \times \frac{9}{100} \times \frac{20}{3} = 6 \times 10^{-3}$$

$$= 6 \text{ mA}$$

* Average current :-



Date: _____
Page: _____

Symbol $\rightarrow i_{av} = \langle i \rangle$

$$i_{av} = \frac{\text{Total charge flow}}{\text{Total time}} = \frac{\int i dt}{\int dt}$$

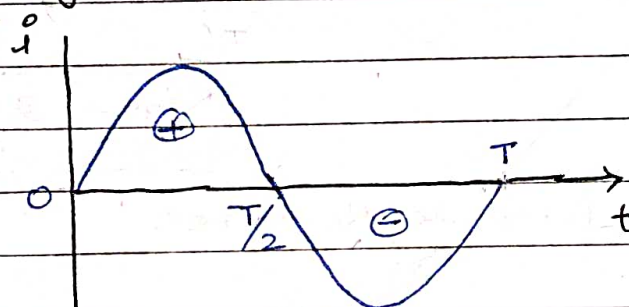
$$i = \frac{dq}{dt}$$

$$\int dq = \int i dt \quad \left(\begin{array}{l} i-t \text{ graph area} \\ = \text{total charge flow} \end{array} \right)$$

$\Downarrow$

$$i_{av} = \frac{\text{Total Area (i-t graph)}}{\text{Total time}}$$

* Average current in sinusoidal AC



$T = \text{Time period of one cycle}$

$$i = i_0 \sin \omega t$$

(a) Full cycle :-

i_{av} in $(0 \text{ to } T \text{ time interval}) \Rightarrow \text{Full cycle}$

$$i_{av} = \langle i \rangle = \langle i_0 \sin \omega t \rangle = i_0 \langle \sin \omega t \rangle = i_0 (0)$$

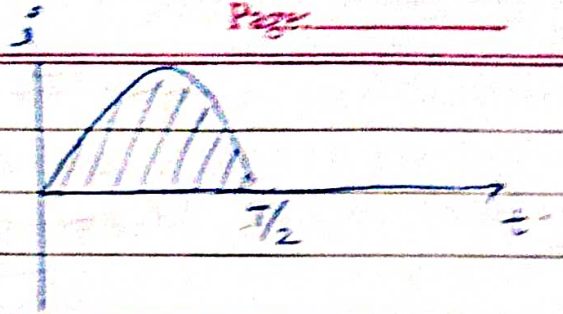
$\therefore i_{av} = 0$ for Full cycle (+ve cancelled by -ve)

$$i_{av} = \frac{\int_0^T i dt}{\int_0^T dt} = \frac{\int_0^T i dt}{T} = 0$$

$$\begin{aligned} i_0 \int_0^T \sin \omega t dt &= i_0 \left[\frac{-\cos \omega t}{\omega} \right]_0^T = -\frac{i_0}{\omega} [\cos \omega t]_0^T \\ &= \frac{i_0}{\omega} [\cos \omega T - \cos 0] = \frac{i_0}{\omega} [\cos 360 - \cos 0] = \frac{i_0}{\omega} [1 - 1] = 0 \end{aligned}$$

(b) Half cycle $(0 \text{ to } \frac{T}{2})$

$$i_{av} = \frac{\int_0^{T/2} i dt}{T/2} = \frac{\int_0^{T/2} (i_0 \sin \omega t) dt}{T/2}$$



$$i_{av} = \frac{2i_0}{\pi}$$

$$\boxed{i_{av} = 0.637 i_0}$$

Calculation $\omega = \frac{2\pi}{T}$

$$i_{av} = \frac{\int_0^{T/2} i_0 \sin \omega t dt}{T/2}$$

$$= \frac{i_0}{\omega} \left[-\cos \omega t \right]_0^{T/2}$$

$$= -\frac{i_0}{\omega} \left[\cos \frac{\omega T}{2} - 1 \right]$$

$$= -\frac{i_0}{\omega} (-2) = \frac{2i_0}{\omega}$$

$$\omega = \frac{2\pi}{T}$$

$$2\pi = \omega T$$

$$i_{av} = \frac{2i_0/\omega}{T/2} = \frac{4i_0}{\omega T} = \frac{2i_0}{2\pi}$$

$$\boxed{i_{av} = \frac{2i_0}{\pi}}$$

Some useful mathematical forms to Remember.

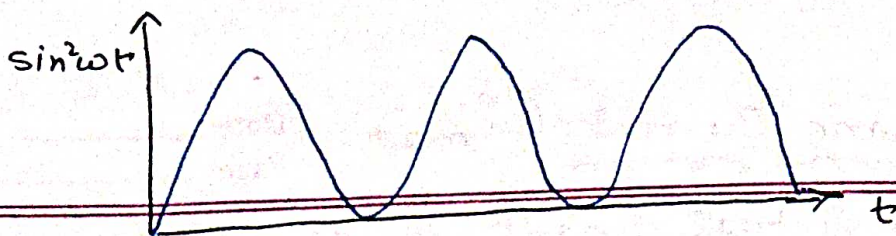
For Full cycle

$$\Rightarrow \langle \sin \omega t \rangle = \langle \cos \omega t \rangle = \langle \sin 2\omega t \rangle = \langle \cos 2\omega t \rangle = 0$$

$$\Rightarrow \langle \sin^2 \omega t \rangle = \langle \cos^2 \omega t \rangle = \frac{1}{2}$$

For Half cycle

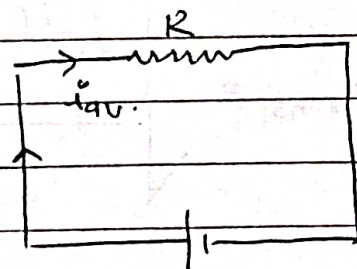
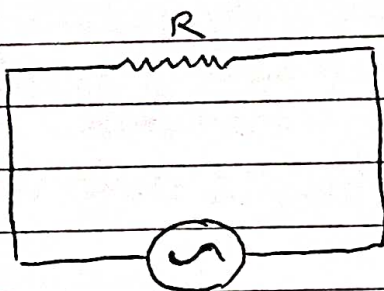
$$\langle \sin \omega t \rangle = \frac{2}{\pi}$$



Date: _____
Page: _____

Derivation of Average current (Based on

It is the constant current which must be flown through an equivalent DC circuit so that same charge flows in both circuits. In a given time.



$$q = \int dq = \int_0^T i dt \quad \text{--- (i)}$$

$$q = i_{av} \times T \quad \text{--- (ii)}$$

equating (i) & (ii)

$$i_{av} = \frac{\int_0^T i dt}{T}$$

* So it can be said that average current is based on concept of conservation of charge flow.

* Root mean Square Current (i_{rms})

Date: _____

Page: _____

- + It is a virtual current or effective current
- + when nothing is mentioned, assume rms current

$$i_{rms} = \sqrt{\frac{\int_0^T i^2 dt}{T}}$$

$$i = i_0 \sin \omega t$$

$$i^2 = i_0^2 \sin^2 \omega t$$

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

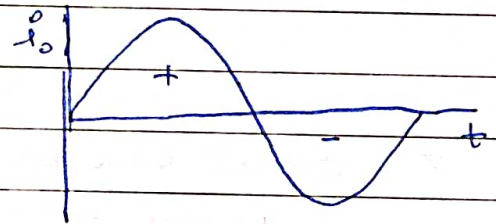
$$i_{rms} = \sqrt{\frac{i_0^2 \int_0^T \sin^2 \omega t dt}{T}}$$

$$\int_0^T \sin^2 \omega t dt = \langle \sin^2 \omega t \rangle T = \frac{1}{2} T$$

$$= \sqrt{i_0^2 \left(\frac{1}{2} \right)}$$

$$i_{rms} = \frac{i_0}{\sqrt{2}} = 0.707 i_0$$

$$\| \text{ } \| \quad V_{rms} = \frac{V_0}{\sqrt{2}} = 0.707 V_0$$



$$* \quad i = i_0 \sin \omega t$$

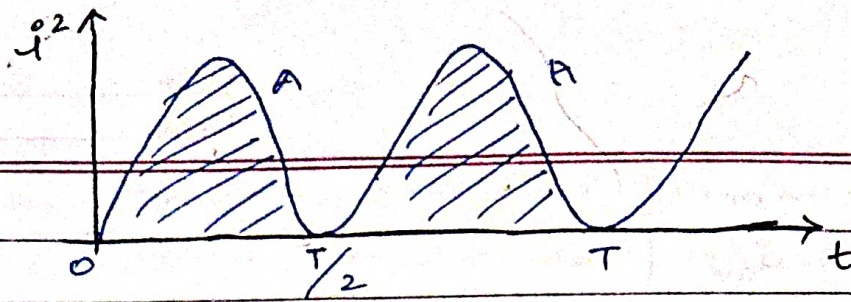
$$V = V_0 \sin \omega t$$

$$\text{RMS value (full cycle)} \Rightarrow i_{rms} = \frac{i_0}{\sqrt{2}}$$

$$V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$* \quad \text{Home supply} \Rightarrow 220V$$

$$V_{rms} = 220V$$



Date: _____
Page: _____

$$i_{rms} \text{ in Full Cycle} \Rightarrow \frac{2A}{T}$$

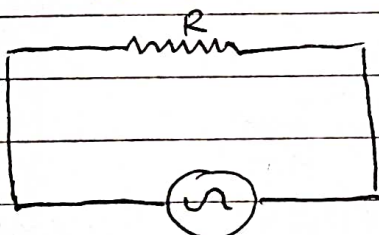
$$i_{rms} \text{ in Half Cycle} \Rightarrow \frac{A}{T/2} = \frac{2A}{T}$$

$i_{rms} = \frac{i_0}{\sqrt{2}}$	$V_{rms} = \frac{V_0}{\sqrt{2}}$
----------------------------------	----------------------------------

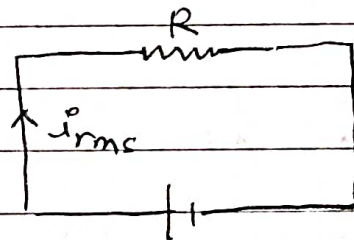
* For full & Half cycle i_{rms} & V_{rms} are same.

• Derivation of RMS value of AC

+ It is the constant current which must be flown through equivalent DC circuit, so that same heat is produced in both circuits in a given time.



$$H = \int_0^T i^2 R dt \quad \text{--- (I)}$$



$$H = i_{rms}^2 R T \quad \text{--- (II)}$$

equating (I) & (II)

$$\int_0^T i^2 R dt = i_{rms}^2 R T$$

$$i_{rms} = \sqrt{\frac{\int_0^T i^2 dt}{T}}$$

* RMS value of current is based on conservation of Heat

* FORM Factor

Date: _____

Page: _____

$$F.F = \frac{i_{rms}}{i_{av}}$$

$$F.F = \frac{i_0/\sqrt{2}}{\frac{2i_0}{\pi}} = 1.11$$

$$i_0 = 10A$$

$$\omega = 200\pi = 2\pi f$$

$$f = 100Hz$$

(Q) For $i = 10 \sin 200\pi t$ amperes
find

(a) Peak value of current

$$\rightarrow i_0 = 10A$$

(b) rms value of current

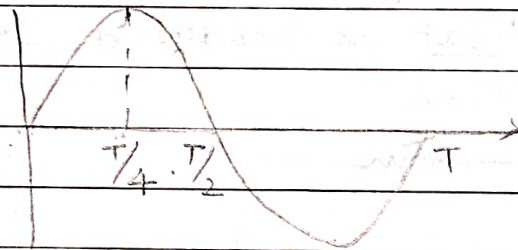
$$\rightarrow i_{rms} = 0.707 \times 10 = 7.07A$$

(c) frequency (f) of AC.

$$\rightarrow \omega = 200\pi$$

$$2\pi f = 200\pi \Rightarrow f = 100Hz$$

(Q) Find time taken by the current to reach its max^m value from zero.



$$t = \frac{T}{4} = \frac{1}{4f}$$

$$= \frac{1}{4 \times 100} = \frac{0.25}{100} = 0.0025s = 2.5 \times 10^{-3}s$$

$$2.5ms$$

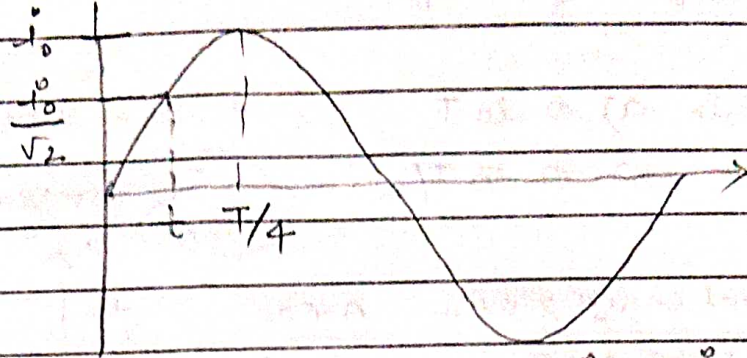
(Q) the time required for the 50Hz sinusoidal source alternating current to reach its rms value from zero is

(a) $\frac{1}{200}$ s

(b) $\frac{1}{400}$ s

(c) $\frac{1}{800}$ s

(d) NOTA.



$$i = i_0 \sin \omega t$$

$$\frac{i_0}{\sqrt{2}} = i_0 \sin \omega t$$

$$\frac{1}{\sqrt{2}} = \sin \omega t$$

$$\sin \frac{\pi}{4} = \sin \omega t$$

$$\omega t = \frac{\pi}{4} \Rightarrow t = \frac{\pi}{4\omega}$$

OR

SHM Concept

$$360^\circ \rightarrow T$$

$$45^\circ \rightarrow t$$

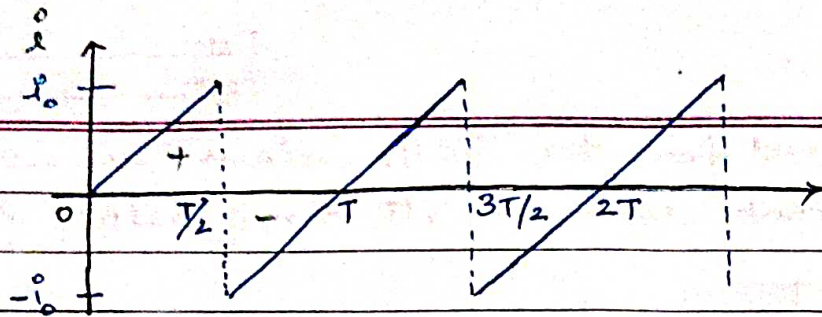
$$t = \frac{45^\circ T}{360^\circ} = \frac{T}{8}$$

$$= \frac{1}{8 \times 50} = \frac{1}{400} \text{ s}$$

$$t = \frac{\pi}{4 \times 2\pi \times 50}$$

$$t = \frac{1}{400} \text{ s}$$

(Q)



Date: _____

Page: _____

Find i_{av} in a) 0 to T+ & - Area Cancels $\therefore i_{av} = 0$

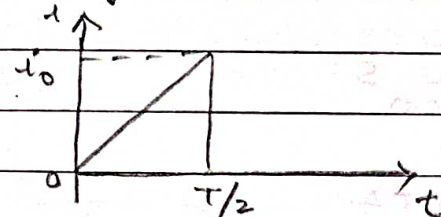
b) 0 to T/2

 ~~$\frac{2 \cdot i_0}{\pi}$~~ Wrong. $\therefore$ not sinusoidal.

$$i_{av} = \frac{\text{Total charge flow}}{\text{Total time}} = \frac{\text{Area}}{\text{Time}}$$

$$= \frac{\frac{1}{2} \times \frac{T}{2} \times i_0}{T/2} = \frac{i_0}{2}$$

$$i_{av} = \frac{i_0}{2}$$



Note:- If graph is linear (straight line)

$$i_{av} = \frac{\text{initial} + \text{final}}{2} = \frac{0 + i_0}{2} = \frac{i_0}{2}$$

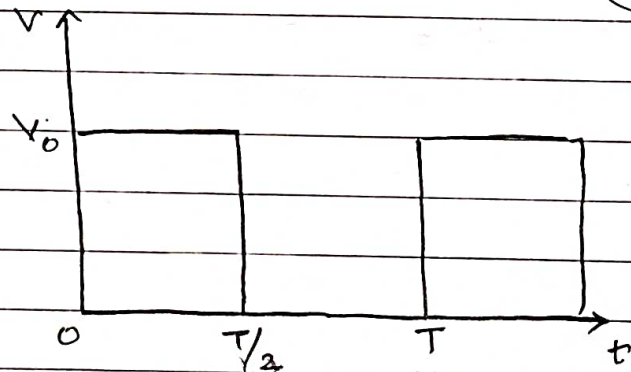
(Q) The r.m.s value of potential difference V is shown in figure is (2011)

(1) $V_0/\sqrt{3}$

(2) V_0

(3) $V_0/\sqrt{2}$

(4) $V_0/2$



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

$$= \sqrt{\frac{V_0^2 \cdot T/2}{T}} = \sqrt{\frac{V_0^2}{2}}$$

$$\therefore V_{rms} = \frac{V_0}{\sqrt{2}}$$

$$N^{\text{th}} = \int_0^T V^2 dt = \int_0^{T/2} V_0^2 dt + \int_{T/2}^T V^2 dt$$

$$\therefore \int_0^T V^2 dt = V_0^2 \frac{T}{2}$$

Date: _____

Page: _____

(Q) which is more dangerous b/w $\bullet$ 220 VDC & 220 VAC

constant

$$V_{rms} = \frac{V_0}{\sqrt{2}} = 220$$

$$V_0 = 220\sqrt{2}$$

$$V_0 \approx 311$$

$\nearrow$ $\nwarrow$ Peak value

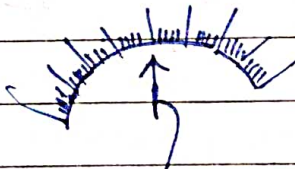
Measurement of AC $\therefore$

Normal Ammeter

$\Downarrow$
Reading = 0

$f = 50 \text{ Hz}$

Due to Inertia
needle will not
move

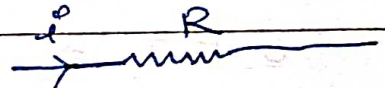


shows $i_{av} = 0$



Hot wire Ammeter

+ works on Heating effect



$$H = \int i^2 R dt \quad +ve \quad \text{always}$$

+ can be used for both
AC & DC

Examples on Average & RMS values.Sin wt & Cos wt(Q.1) For $i = 3 + 4 \sin \omega t$ (a) Find i_{av} 0 to T(b) Find i_{av} 0 to $T/2$ (a) i_{av} in 0 to T

$$i = \underbrace{3}_{\text{DC component}} + \underbrace{4 \sin \omega t}_{\text{AC component}}$$

$$\begin{aligned} \therefore i_{av} &= \langle i \rangle = \langle 3 + 4 \sin \omega t \rangle \\ &= \langle 3 \rangle + \langle 4 \sin \omega t \rangle \\ &= \langle 3 \rangle + 4 \langle \sin \omega t \rangle \\ &= 3 + 4(0) = 3A \end{aligned}$$

(b) i_{av} in 0 to $T/2$

$$\begin{aligned} i_{av} &= \langle i \rangle = \langle 3 \rangle + 4 \langle \sin \omega t \rangle \\ &= 3 + 4 \left(\frac{2}{\pi} \right) = \left(3 + \frac{8}{\pi} \right) A \end{aligned}$$

(Q) For $i = 6 + \pi \sin \omega t$

$$i_{rms} = \sqrt{6^2 + \frac{\pi^2}{2}}$$

(a) Find i_{av} in 0 to $T/2$ (b) Find i_{rms} in 0 to T

$$\begin{aligned} \text{(a)} \quad i_{av} &= \langle i \rangle = \langle 6 \rangle + \langle \pi \sin \omega t \rangle \\ &= 6 + \pi \left(\frac{2}{\pi} \right) \\ &= 8A \end{aligned}$$

$$\begin{aligned} \text{(b)} \quad i_{rms} &= \sqrt{6^2 + \frac{\pi^2}{2}} \\ &= \sqrt{\frac{36 + \pi^2}{2}} = \sqrt{41}A \end{aligned}$$

$$\begin{aligned} \text{(b)} \quad i_{rms} &= \sqrt{\langle i^2 \rangle} = \sqrt{\langle (6 + \pi \sin \omega t)^2 \rangle} \\ &= \sqrt{36 + \pi^2 \sin^2 \omega t + 12\pi \sin \omega t} \\ &= \sqrt{36 + 8} \end{aligned}$$

$$i = 6 + \pi \sin \omega t = 36 + \pi^2 \sin^2 \omega t + 12\pi \sin \omega t$$

Date: _____

Page: _____

$$i_{rms} = \sqrt{\langle 36 \rangle + \pi^2 \langle \sin^2 \omega t \rangle + 12\pi \langle \sin \omega t \rangle}$$

$$= \sqrt{\frac{36 + \pi^2}{2}} = \sqrt{41} \text{ A}$$

(Q) For $i = 3 + 4 \sin \omega t$
Find i_{rms} in 0 to T

$$i_{rms} = \sqrt{\langle i^2 \rangle} = \sqrt{\langle 3^2 + 4^2 \sin^2 \omega t + 24 \sin \omega t \rangle}$$

$$= \sqrt{\langle 9 \rangle + 8 \times \frac{1}{2} + 0} = \sqrt{17} \text{ A}$$

Note:- for $i = a + b \sin \omega t$

$$i_{rms} = \sqrt{a^2 + \frac{b^2}{2}}$$

$$i = 3 + 4 \sin \omega t$$

$$i_{rms} = \sqrt{9 + \frac{16}{2}} = \sqrt{17} \text{ A}$$

(Q) $i = 3 \sin \omega t + 4 \cos \omega t$

(a) i_{av} (0 to T)

(b) i_{rms} (0 to T)

$$\begin{aligned} (a) \quad i &= \langle i \rangle = \langle 3 \sin \omega t \rangle + \langle 4 \cos \omega t \rangle \\ &= 3 \langle \sin \omega t \rangle + 4 \langle \cos \omega t \rangle \\ &= 0 \end{aligned}$$

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

$$\begin{aligned} (b) \quad i_{rms} &= \sqrt{\langle i^2 \rangle} = \sqrt{\langle (3 \sin \omega t + 4 \cos \omega t)^2 \rangle} \\ &= \sqrt{9 \langle \sin^2 \omega t \rangle + 16 \langle \cos^2 \omega t \rangle + \langle 24 \sin \omega t \cos \omega t \rangle} \\ &= \sqrt{9 \langle \sin^2 \omega t \rangle + 16 \langle \cos^2 \omega t \rangle + 12 \langle \sin 2\omega t \rangle} \\ &= \sqrt{\frac{9}{2} + \frac{16}{2} + 0} = \sqrt{\frac{25}{2}} = \frac{5}{\sqrt{2}} \text{ A} \end{aligned}$$

Note if $i = a \sin \omega t + b \cos \omega t$

$$i_{rms} = \sqrt{\frac{a^2 + b^2}{2}}$$

$$i = 3 \sin \omega t + 4 \cos \omega t$$

$$i_{rms} = \sqrt{\frac{9 + 16}{2}}$$

$$= \frac{5}{\sqrt{2}} A$$

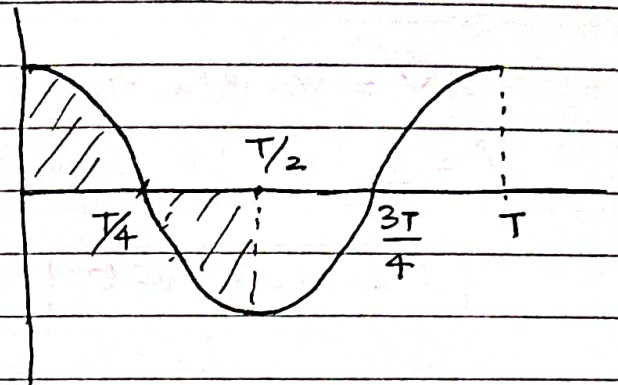
Note

For $\cos \omega t$

$$(a) \begin{cases} \langle \cos \omega t \rangle = 0 \\ \text{for } 0 \text{ to } T/2 \end{cases}$$

$$(b) \quad T/4 \text{ to } 3T/4$$

$$\langle \cos \omega t \rangle = -\frac{2}{\pi}$$



(Q) An Alternating current is given by $I = I_1 \cos \omega t + I_2 \sin \omega t$
The RMS value of current is given by:

$$(a) \quad \frac{I_1 + I_2}{\sqrt{2}}$$

$$(b) \quad \frac{(I_1 + I_2)^2}{2}$$

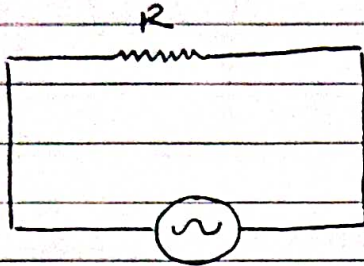
$$(c) \quad \sqrt{\frac{I_1^2 + I_2^2}{2}}$$

$$(d) \quad \sqrt{\frac{I_1^2 + I_2^2}{2}}$$

Date: _____

Page: _____

* AC source connected to Resistor: (Pure Resistive Circuit)



$$V = V_0 \sin \omega t \quad (\text{given})$$

$$i = \frac{V}{R} = \frac{V_0}{R} \sin \omega t$$

$$i = i_0 \sin \omega t$$

$$i_0 = \frac{V_0}{R}$$

$$\frac{i_0}{\sqrt{2}} = \frac{V_0}{\sqrt{2} R}$$

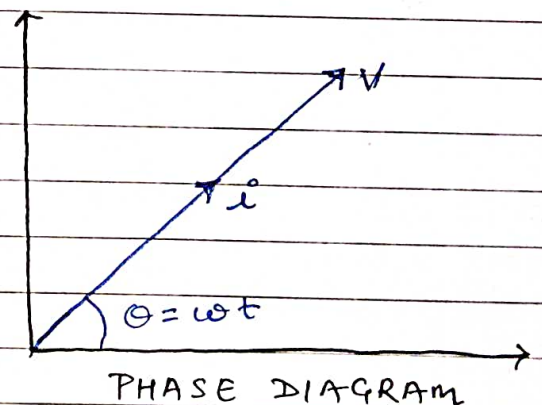
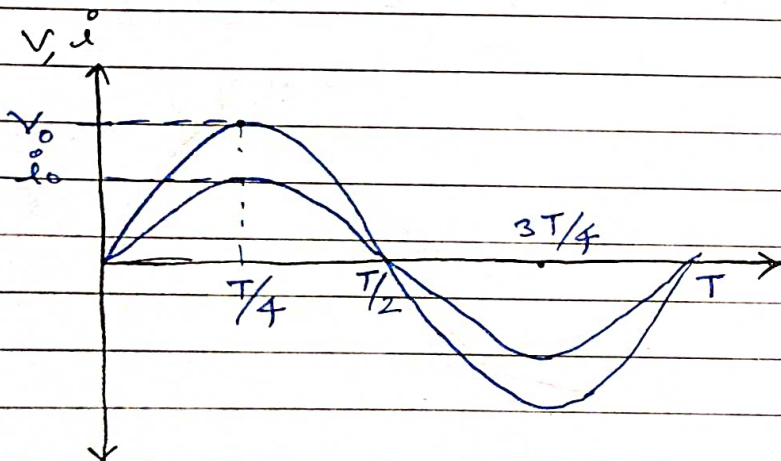
$$i_{\text{rms}} = \frac{V_{\text{rms}}}{R}$$

$$\begin{cases} V = V_0 \sin \omega t \\ i = i_0 \sin \omega t \end{cases}$$

Both V & i are in same phase with each other

⇕

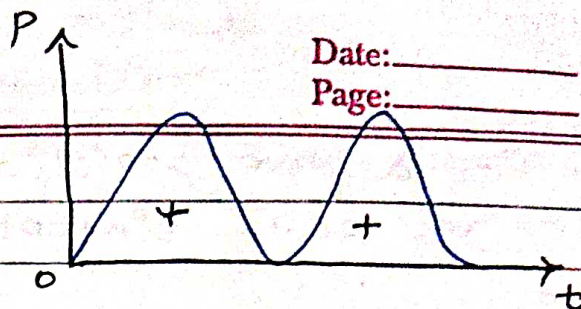
It means both attain their $\text{max}^{\text{m}}/\text{min}^{\text{m}}$ values at same time



Power Consumed

$$V = V_0 \sin \omega t$$

$$i = i_0 \sin \omega t$$



$$P = Vi$$

$$P = V_0 i_0 \sin^2 \omega t$$

↳ Instantaneous
power

$$P_{av} = \langle P \rangle = \langle V_0 i_0 \sin^2 \omega t \rangle$$
$$= V_0 i_0 \langle \sin^2 \omega t \rangle$$

$$P_{av} = \frac{V_0 i_0}{2}$$

OR

$$P_{av} = \frac{i_0^2 R}{2}$$

or

$$P_{av} = \frac{V_0^2}{2R}$$

$$\therefore P_{av} = \frac{V_0 i_0}{2} = \frac{i_0^2 R}{2} = \frac{V_0^2}{2R}$$

$$P_{av} = \frac{V_0}{\sqrt{2}} \times \frac{i_0}{\sqrt{2}}$$

$$P_{av} = V_{rms} \times i_{rms}$$

$$P_{av} = V_{rms} \times i_{rms} = i_{rms}^2 R = \frac{V_{rms}^2}{R}$$

$$\omega = 2\pi f$$

$$f = \frac{\omega}{2\pi} \quad (1/2) \quad \omega = 100 \text{ rad/s}$$

Date: _____

Page: _____

(Q) For a pure resistive circuit, $R = 10 \Omega$
 $V = 20\sqrt{2} \sin 100t$

Find

(a) V_{rms}

$$V_{rms} = V_0 / \sqrt{2} = 20V$$

(b) current at any time t

$$i = \frac{V}{R} = \frac{20\sqrt{2} \sin 100t}{10} = 2\sqrt{2} \sin 100t$$

(c) current in the circuit

$$i_{rms} = i_0 / \sqrt{2} = \frac{2\sqrt{2}}{\sqrt{2}} = 2A$$

(d) P_{av} consumed.

$$P_{av} = 20 \times 2 = 40W$$

for purely resistive circuit

$$i = i_0 \sin(\omega t - \phi) \quad (\text{given})$$

$$V = V_0 \sin(\omega t) \quad (\text{given})$$

$\Downarrow$

$$V = V_0 \sin(\omega t - \phi)$$

$$\phi = 0$$

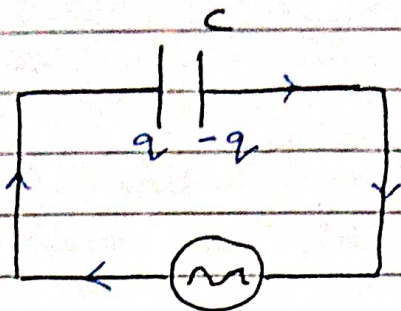
$$V = V_0 \sin(\omega t)$$

$$i = i_0 \sin(\omega t)$$

AC Source connected to Capacitor

Date: _____
Page: _____

(Purely Capacitive Circuit)



$$V = V_0 \sin \omega t \quad (\text{given})$$

$$q = CV = CV_0 \sin \omega t$$

$$q = q_0 \sin \omega t$$

$$i = \frac{dq}{dt} = q_0 (\cos \omega t) (\omega)$$

$$i = q_0 \omega \cos \omega t$$

$$i = CV_0 \omega \cos \omega t$$

$$i = \frac{V_0}{1/\omega C} \sin \left(\omega t + \frac{\pi}{2} \right)$$

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

Capacitive Reactance

(Resistance offered by capacitor to charge flow).

$$i = \frac{V_0}{X_C} \sin \left(\omega t + \frac{\pi}{2} \right)$$

$$\text{Unit} = \Omega \text{ (ohm)}$$

$$\# \quad \left. \begin{array}{l} V = V_0 \sin \omega t \\ q = q_0 \sin \omega t \end{array} \right\} \text{ same phase}$$

$$i = \frac{V_0}{X_C} \sin \left(\omega t + \frac{\pi}{2} \right)$$

$$i = i_0 \sin \left(\omega t + \frac{\pi}{2} \right)$$

$$+ i_0 = V_0 / X_C$$

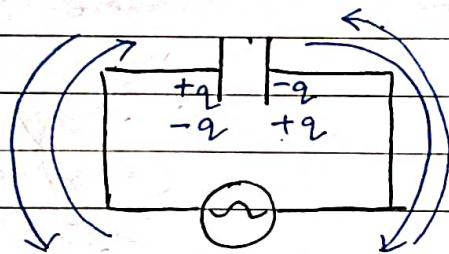
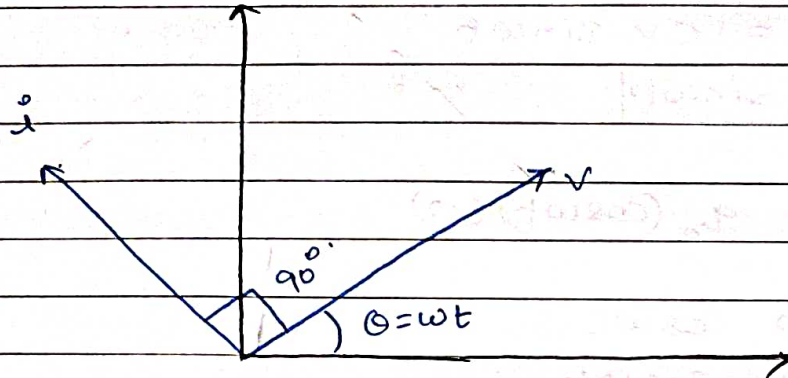
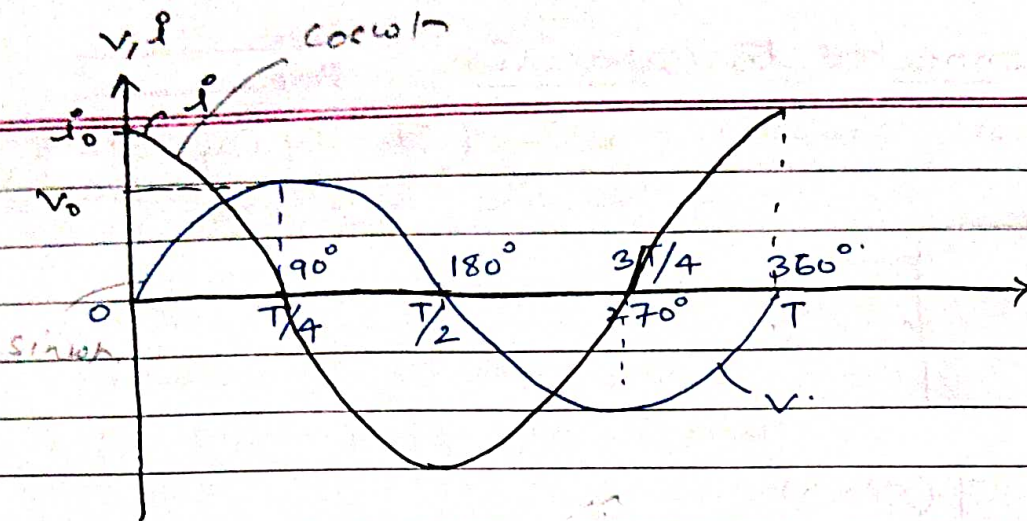
$$+ i_{rms} = \frac{V_{rms}}{X_C}$$

$$+ i \text{ leads } V \text{ by } 90^\circ \text{ or } \frac{\pi}{2} \text{ rad}$$

$$\text{or } V \text{ lags } i \text{ by } 90^\circ \text{ or } \frac{\pi}{2} \text{ rad}$$

V & i don't attain their max/min values at same time

Date: _____
Page: _____



Power consumed:-

$$P = V i$$

$$= V_0 \sin \omega t \cdot i_0 \cos \omega t$$

$$P = \frac{V_0 i_0 \sin 2\omega t}{2}$$

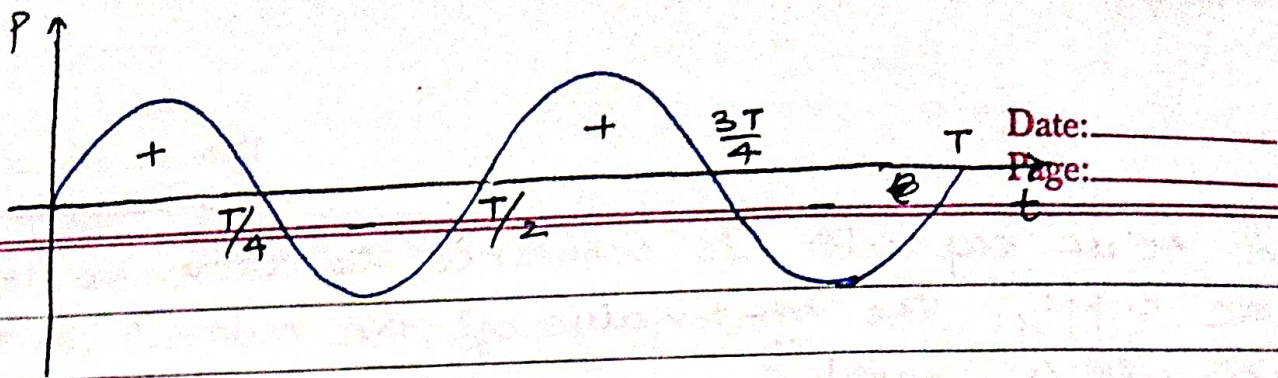
Power has double frequency.

$$\langle \sin 2\omega t \rangle = 0$$

$$P_{av} = \langle P \rangle = \frac{V_0 i_0}{2} \langle \sin 2\omega t \rangle$$

$P_{av} = 0$ for full cycle

$P_{av} = 0$ for Half cycle



(Q) A small signal voltage $V(t) = V_0 \sin \omega t$ is applied across an ideal capacitor C (NEET 2016)

- (a) Current $I(t)$ is in phase with voltage $V(t)$
- (b) Current $I(t)$ leads voltage $V(t)$ by 180°
- (c) Current $I(t)$ lags voltage $V(t)$ by 90°
- (d) Over a full cycle the capacitor C does not consume any energy from the voltage source.

(Q) In an AC circuit, an alternating voltage $e = 200\sqrt{2} \sin(100t)$ volt is connected to capacitor of capacity $1 \mu F$. The rms value of current in the circuit is (2011)

(1) 10 mA

$$V_0 = 200\sqrt{2}, \omega = 100$$

(2) 100 mA

$$V_{rms} = 200 V$$

(3) 200 mA

$$X_c = \frac{1}{\omega C} = \frac{1}{100 \times 10^{-6}} = 10^4 \Omega$$

(4) 20 mA

$$I_{rms} = \frac{V_{rms}}{X_c} = \frac{200}{10^4} = \frac{2}{10^2} \times 1000 = 20 \text{ mA}$$

Date: _____

Page: _____

(Q) A $40\mu\text{F}$ capacitor is connected to 200V , 50Hz AC supply. The rms value of the current in the circuit is, nearly (NEET 2020)

(1) 1.7A

$C = 40\mu\text{F}$

(2) 2.05A

$V_{\text{rms}} = 200\text{V}$

(3) 2.5A

$f = 50\text{Hz}$

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

(4) 25.1A

$$= \frac{1}{2\pi \times 50 \times 40 \times 10^{-6}}$$

$$= \frac{10^3}{2\pi \times 50 \times 40} = \frac{10^3}{4\pi} \Omega$$

$$I_{\text{rms}} = \frac{200 \times 4\pi}{10^3}$$

$$= \frac{4\pi}{5} = \frac{4 \times 3.14}{5} = \frac{12.56}{5} \approx 2.5\text{A}$$

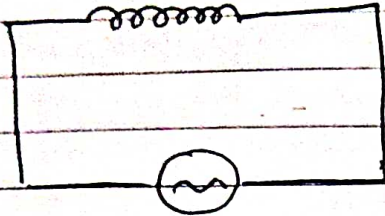
$$X_L = \frac{1}{\omega C}$$

2 AC Source connected to Inductor

Date: _____

Page: _____

(Purely Inductive Circuit)



$$V = V_0 \sin \omega t$$

$$L \frac{di}{dt} = V_0 \sin \omega t$$

$$i = \frac{V_0}{\omega L} \sin \left(\omega t - \frac{\pi}{2} \right)$$

$$= \frac{V_0}{X_L} \sin \left(\omega t - \frac{\pi}{2} \right)$$

$$i = i_0 \sin \left(\omega t - \frac{\pi}{2} \right)$$

i lags V by 90°
or

V leads i by 90°

$$V = V_0 \sin \omega t \text{ (given)}$$

$$i = i_0 \sin \left(\omega t - \frac{\pi}{2} \right)$$

$$= -i_0 \sin \left(\frac{\pi}{2} - \omega t \right)$$

$$= -i_0 \sin (90^\circ - \omega t)$$

$$i = -i_0 \cos \omega t$$

$$\int di = \int \frac{V_0}{L} \sin \omega t dt$$

$$i = \frac{V_0}{L} (-\cos \omega t)$$

$$i = \frac{V_0}{\omega L} \left[\sin \left(\omega t - \frac{\pi}{2} \right) \right]$$

$$i = \frac{V_0}{X_L}$$

$$X_L = \omega L$$

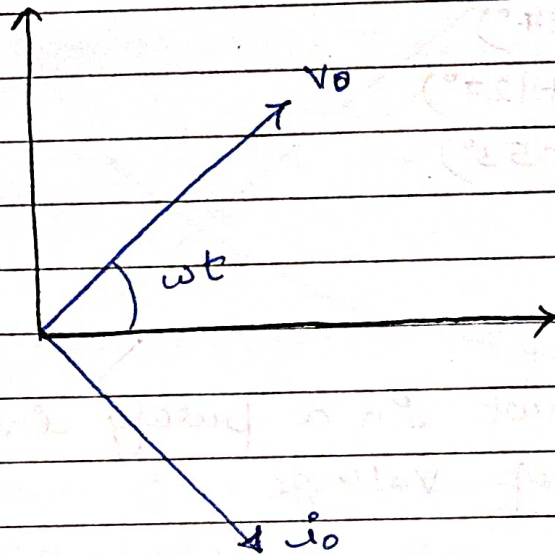
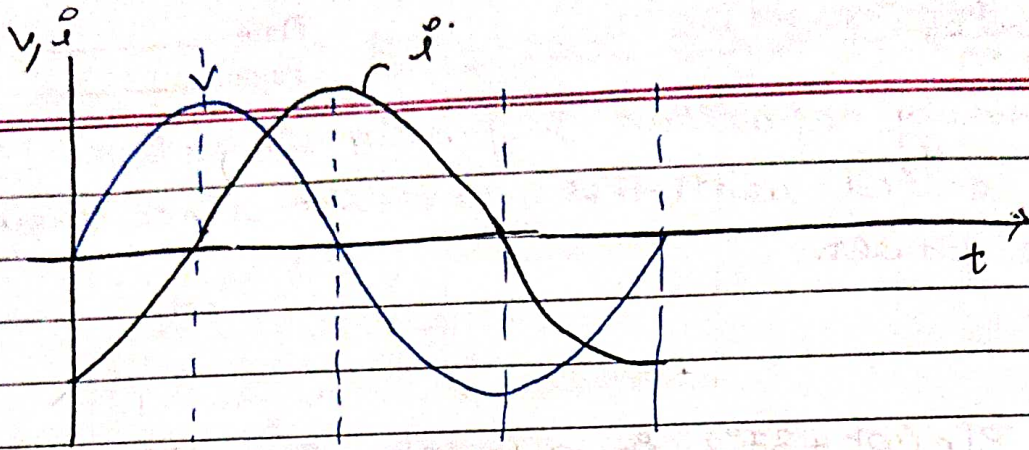
- + Inductive Reactance
- + Resistance offered by the Inductors
- + SI Unit (Ω) ohm

$$V = V_0 \sin \omega t$$

$$L \frac{di}{dt} = V_0 \sin \omega t$$

$$\int di = \frac{V_0}{L} \int \sin \omega t dt$$

$$= \frac{V_0}{L} (-\cos \omega t)$$



Phasor - diagram

Power Consumed :-

$$V = V_0 \sin \omega t$$

$$i = -i_0 \cos \omega t$$

$$P = v i = \frac{-V_0 i_0 \sin 2\omega t}{2}$$

$$\langle \sin 2\omega t \rangle = 0$$

$P_{av} = 0$ for full & Half cycle.

Wattless Currents:-

Date: _____

Page: _____

Current in purely capacitive & purely inductive circuits are called watt-less currents since they consume no power.

(Q) For $V = V_0 \sin(\omega t + 37^\circ)$ in a purely inductive circuit the equation of current is?

(A) $i = i_0 \sin(\omega t + 37^\circ)$

(B) $i = i_0 \sin(\omega t + 127^\circ)$

(C) $i = i_0 \sin(\omega t - 53^\circ)$ ✓

(D) NOTA

(Q) For $i = i_0 \sin \omega t$ in a purely inductive circuit find the eqn of voltage

(A) $V = V_0 \sin \omega t$

(B) $V = V_0 \sin(\omega t + 90^\circ)$ ✓

(C) $V = V_0 \sin(\omega t - 90^\circ)$

(D) $V = V_0 \sin(\omega t + 180^\circ)$

Variance of Reactance with frequency

Date: _____

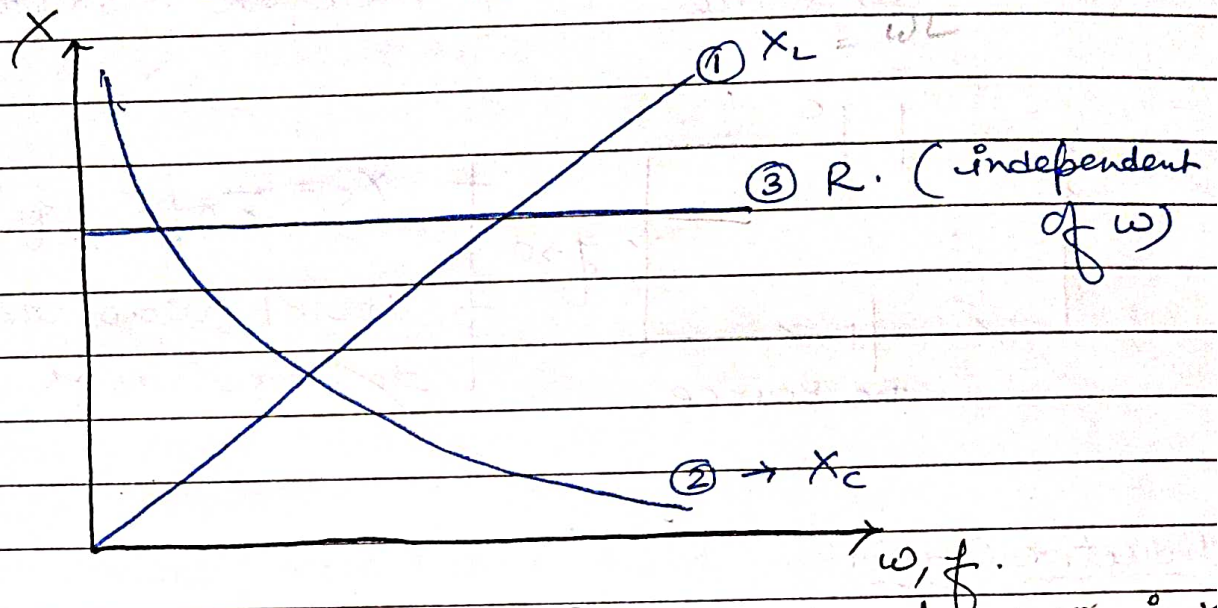
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$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$X_c \propto \frac{1}{\omega} \propto \frac{1}{f}$$

$$X_L = \omega L = 2\pi f L$$

$$X_L \propto \omega \propto f$$



(Q) The reactance of a capacitor of capacitance C is X .
If both the frequency and capacitance be double,
the new reactance will be

PYQ - 200

- (a) X
- (b) $2X$
- (c) $4X$
- (d) $X/4$

$$X_c = \frac{1}{2\pi f C} \quad X'_c = \frac{1}{2\pi 2f 2C}$$

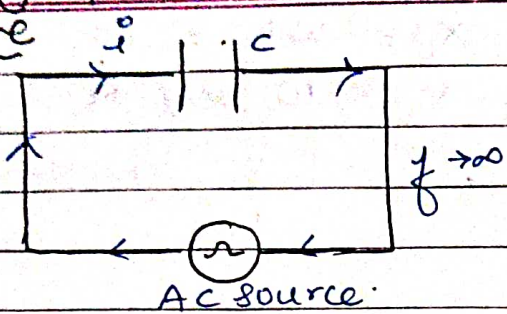
$$X'_c = \frac{X_c}{4}$$

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

High pass & Low pass filter.

Date: _____
Page: _____

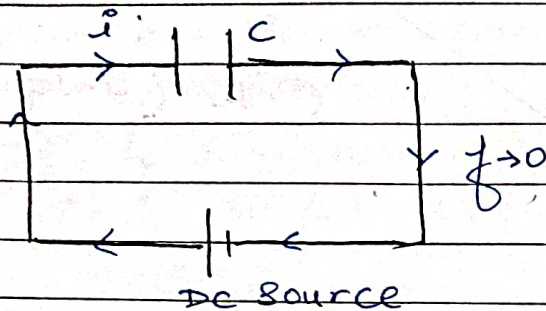
Capacitive Circuit



+ very high f .

+ $X_C = \frac{1}{2\pi f C} \Rightarrow X_C \propto \frac{1}{f}$ $X_C \rightarrow 0$

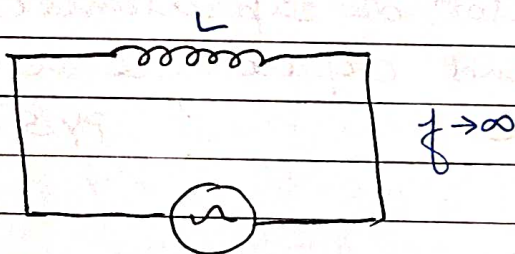
+ Current passes through capacitor.
+ Therefore High pass filter.



+ $X_C = \frac{1}{2\pi f C}$ $f \rightarrow 0$ $X_C \rightarrow \infty$

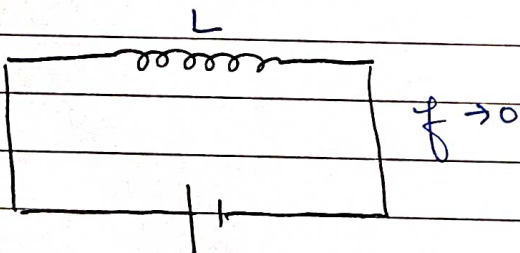
+ doesn't allow the current to pass through DC circuit

Inductive Circuit



+ $X_L = 2\pi f L$; $X_L \propto f$ $X_L \rightarrow \infty$

+ Block high frequency current



+ $X_L = 2\pi f L$; $X_L \rightarrow 0$

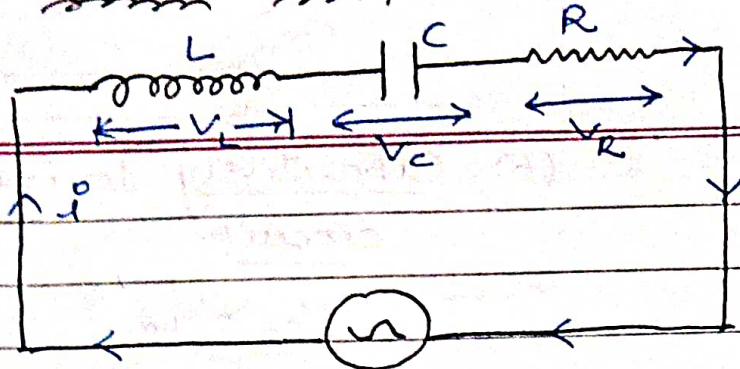
+ allows DC current to pass.

#

$L \Rightarrow$ (Low pass filter)

$C \Rightarrow$ (High pass filter)

Series LCR Circuit:-



Date: _____

Page: _____

+ $i \rightarrow$ same
 $i = i_0 \sin \omega t$ (given)
 V is divided.

+ $V_R = V_{R0} \sin \omega t$
 $V_L = V_{L0} \sin(\omega t + \frac{\pi}{2})$

$V_C = V_{C0} \sin(\omega t - \frac{\pi}{2})$

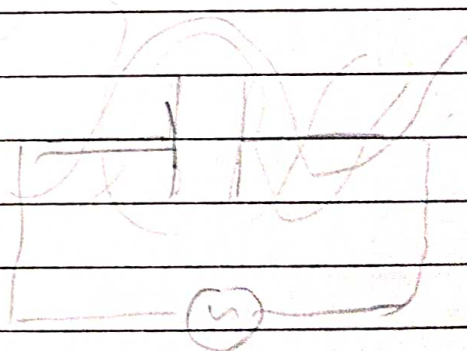
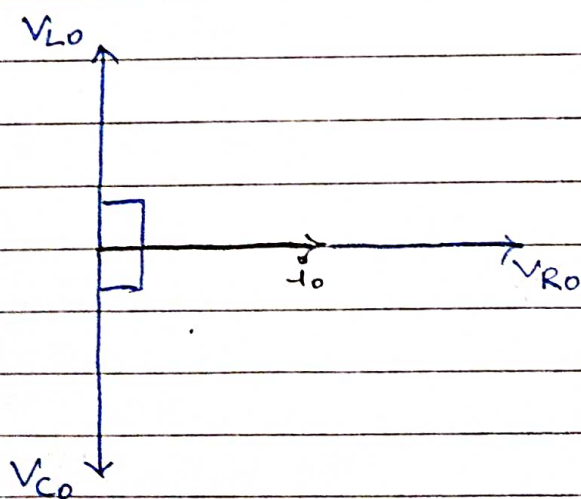
$V = V_R + V_L + V_C$

instantaneous values can be added directly.

$V_0 = V_{L0} + V_{R0} + V_{C0}$

+ Max^m values | rms values can be added vectorially
 $\rightarrow$ Phasor method.

$\vec{V}_0 = \vec{V}_{R0} + \vec{V}_{L0} + \vec{V}_{C0}$

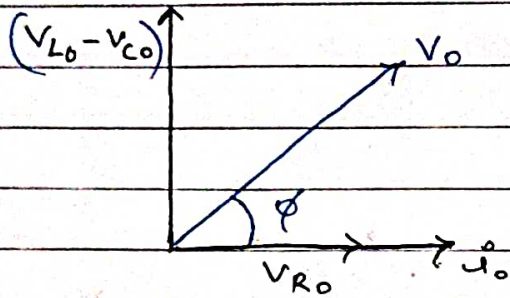


$L > C$

$L < C$ Date: _____
Page: _____

(a) Inductively dominated circuit

$$V_{L0} > V_{C0}$$



$$V_0 = \sqrt{(V_{L0} - V_{C0})^2 + (V_{R0})^2}$$

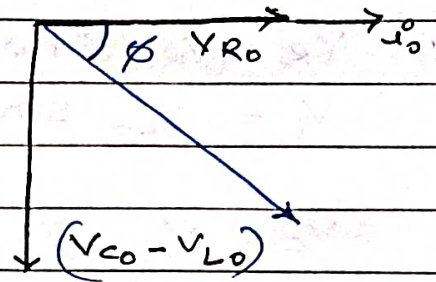
$$\tan \phi = \frac{V_{L0} - V_{C0}}{V_{R0}}$$

$$i = i_0 \sin \omega t$$

$$v = v_0 \sin(\omega t + \phi)$$

(b) Capacitively dominated circuit

$$V_{C0} > V_{L0}$$

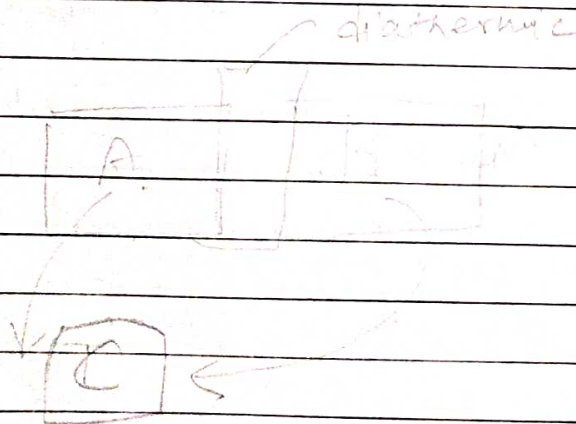


$$V_0 = \sqrt{(V_{C0} - V_{L0})^2 + V_{R0}^2}$$

$$\tan \phi = \frac{V_{C0} - V_{L0}}{V_{R0}}$$

$$i = i_0 \sin \omega t$$

$$v = v_0 \sin(\omega t - \phi)$$



{temperature}

Impedance (Z)

+ the Net Resistance offered by LCR series circuit

Date: _____

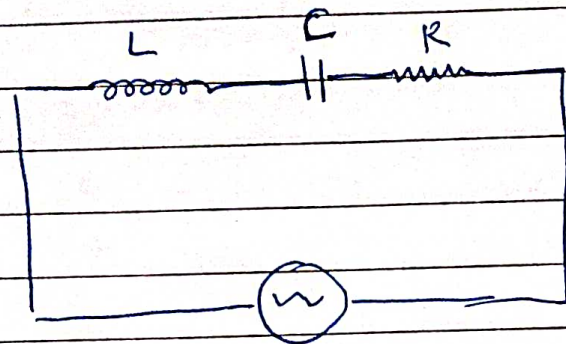
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$$R \rightarrow i_0 = \frac{V_0}{R}$$

$$L \rightarrow i_0 = \frac{V_0}{X_L}$$

$$C \rightarrow i_0 = \frac{V_0}{X_C}$$

$$i_0 = \frac{V_0}{Z} \Rightarrow Z = \frac{V_0}{i_0}$$



$$i_0 = \frac{V_{L_0}}{X_L} = \frac{V_{C_0}}{X_C} = \frac{V_{R_0}}{R}$$

$$V_0 = \sqrt{(V_{L_0}^2 - V_{C_0}^2) + V_{R_0}^2}$$

$$= \sqrt{(i_0 X_L - i_0 X_C)^2 + (i_0 R)^2}$$

$$V_0 = i_0 \sqrt{(X_L - X_C)^2 + R^2}$$

$$\frac{V_0}{i_0} = \sqrt{(X_L - X_C)^2 + R^2}$$

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

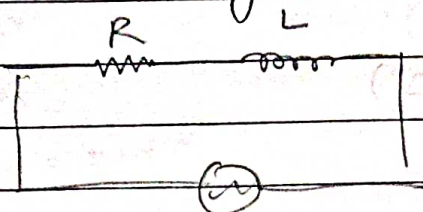
(Q) An AC voltage is applied to a resistance R & an inductor L in series. If R and the inductive reactance are both equal to 3Ω , the phase difference b/w the applied voltage & current in the circuit is (2011)

(1) zero

(2) $\pi/6$

(3) $\pi/4$

(4) $\pi/2$



$$R = 3\Omega$$

$$X_L = 3\Omega$$

$$\tan \phi = \frac{X_L - X_C}{R} = \frac{3}{3}$$

$$(\phi = \pi/4) \text{ Ans}$$

(Q) For $X_L = 10\Omega$, $X_C = 6\Omega$ & $R = 3\Omega$

Find (a) Impedance (Z)

(b) phase angle (ϕ)

(a) 4Ω

(b) 3Ω

(c) 5Ω

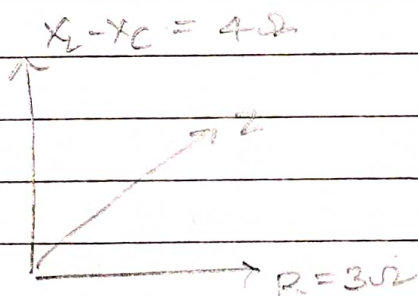
(d) NOTA

(a) 53°

(b) 37°

(c) 45°

(d) 30°



$$Z = \sqrt{4^2 + 3^2} = 5\Omega$$

$$\tan \phi = \frac{X_L - X_C}{R}$$

$$\tan \phi = \frac{4}{3}$$

$$\phi = 53^\circ$$

(Q) The max^m voltages across inductor, capacitor & resistor are 100V, 20V, 60V respectively.

If $i = i_0 \sin \omega t$ then $V = ?$

(A) $V = V_0 \sin(\omega t + 30^\circ)$

$V_{L0} = 100V$

(B) $V = V_0 \sin(\omega t + 53^\circ)$

$V_{C0} = 20V$

(C) $V = V_0 \sin(\omega t - 53^\circ)$

$V_{R0} = 60V$

(D) NOTA.

$$\tan \phi = \frac{100 - 20}{60} = \frac{80}{60} = \frac{4}{3}$$

$\phi = 53$

~~Q~~ (Q) A coil has resistance 30Ω & inductive reactance 20Ω at 50 Hz frequency. If an AC source of $200V$, 100Hz is connected across the coil, the current in the coil will be

(2011)

(1) $20/\sqrt{3} A$

(2) $2.0A$

$X_L = 20\Omega @ 50Hz$

(3) $4.0A$

$X_L \propto f \therefore X_L = 40\Omega @ 100Hz.$

(4) $8.0A$

$$i_{rms} = \frac{V_{rms}}{Z}$$

$$Z = \sqrt{(X_L - X_C)^2 + R^2} = \sqrt{(40 - 20)^2 + (30)^2}$$

$$= \sqrt{1600 + 900}$$

$$= \sqrt{2500}$$

$$= 50\Omega$$

$$i_{rms} = \frac{200}{50} = 4A$$

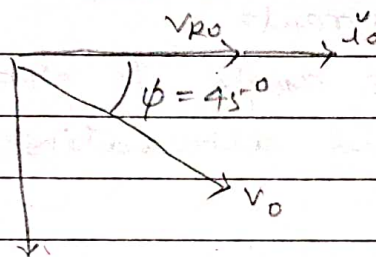
(Q) In a circuit L, C & R are connected in series with alternating voltage source of frequency f . The current leads the voltage by 45° . The value of C is (2005)

(1) $\frac{1}{2\pi f(2\pi fL + R)}$

(2) $\frac{1}{2\pi f(2\pi fL - R)}$

(3) $\frac{1}{\pi f(2\pi fL - R)}$

(4) $\frac{1}{\pi f(2\pi fL + R)}$



capacitance dominated circuit

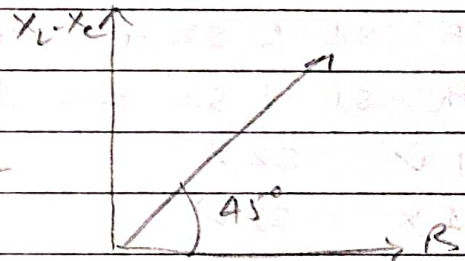
$$\tan \phi = \frac{X_L - X_C}{R} = \frac{X_C - X_L}{R}$$

$$R = X_C - X_L$$

$$X_C = X_L + R$$

$$\frac{1}{2\pi fC} = 2\pi fL + R$$

$$C = \frac{1}{2\pi f(2\pi fL + R)}$$



Date: _____

Page: _____

- (Q) Statement 1:- Capacitor serves as a block for DC & offers easy to AC
Statement 2:- Capacitive reactance is inversely proportional to frequency.

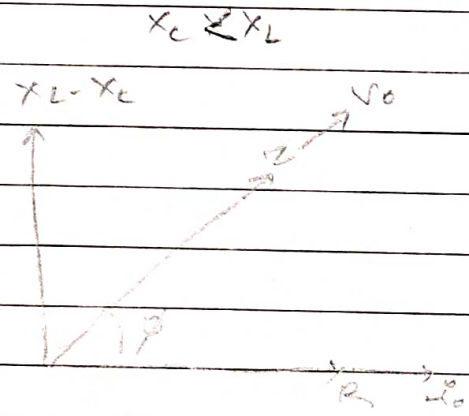
- (1) Both S1 & S2 are correct
(2) Both S1 & S2 are incorrect
(3) S1 ✓ S2 ✗
(4) S1 ✗ S2 ✓

- (Q) Statement 1:- When capacitive reactance is smaller than the inductive reactance in LCR circuit,

~~Statement 2~~ emf leads current

Statement 2 : The phase angle is the angle b/w the alternating emf and alternating current of circuit

- (1) Both S1 & S2 are correct
(2) Both S1 & S2 are incorrect
(3) S1 ✓ S2 ✗
(4) S1 ✗ S2 ✓



(Q) A resistor and capacitor are connected in series with an AC source. If the potential drop, across the capacitor is 15V and across the resistor is 20V, the applied voltage is.

(1) 25V

(2) 40V

(3) 5V

(4) 12V

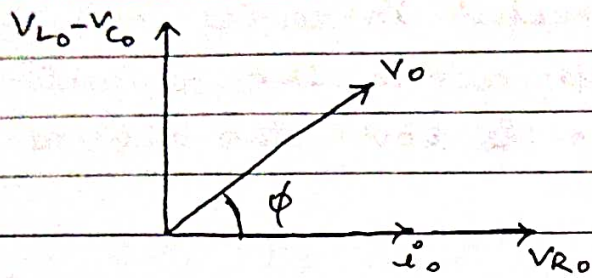
$$V = \sqrt{(V_L - V_C)^2 + R^2}$$

$$= \sqrt{15^2 + 20^2} = \sqrt{225 + 400}$$

$$V = 25V$$

Power consumed in series LCR Circuit

Date: _____
Page: _____



$$i = i_0 \sin \omega t$$

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

$$P = v i$$

$$P_{av} = \frac{V_0 i_0 \cos \phi}{2}$$

or $P_{av} = \underbrace{V_{rms}}_{\text{True power}} \underbrace{i_{rms}}_{\text{Apparent Power}} \underbrace{\cos \phi}_{\text{power factor}}$

$$R \rightarrow \phi = 0^\circ$$

$$P_{av} = \frac{V_0 i_0 \cos \phi}{2}$$

$$P_{av} = \frac{V_0 i_0}{2}$$

L

$$\phi = 90^\circ$$

C

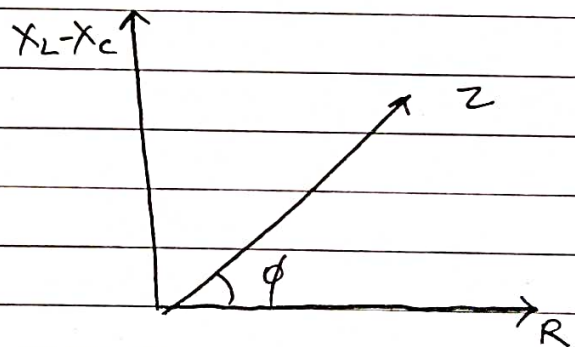
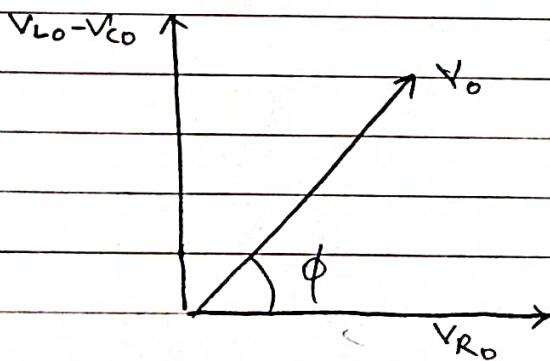
$$\phi = -90^\circ$$

$$\cos \phi = 0$$

$$P_{av} = 0$$

$$\text{True power} = \frac{\text{Apparent Power}}{\text{Power factor}}$$

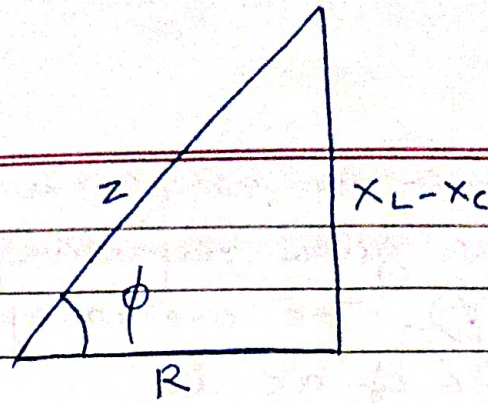
$$\therefore \text{power factor} = \frac{\text{True power}}{\text{Apparent power}}$$



$$\cos \phi = \frac{V_{R_0}}{V_0} = \frac{R}{Z}$$

Impedance Triangle

Date: _____
Page: _____



(Q) which of the following formula is correct for P_{av} in LCR series circuit?

$$P_{av} = \frac{V_0 I_0 \cos \phi}{2}$$

(A) $\frac{I_0^2 R \cos \phi}{2}$ ✗

$$= \frac{(I_0 Z) I_0 \cos \phi}{2} = \frac{I_0^2 Z \cos \phi}{2}$$

(B) $\frac{I_0^2 Z \cos \phi}{2}$ ✓

$$P_{av} = \frac{V_0}{2} \frac{V_0}{Z} \cos \phi$$

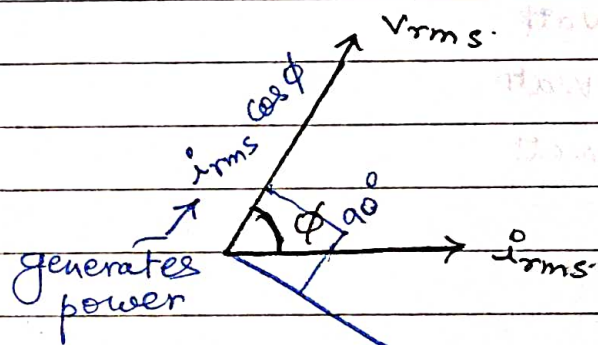
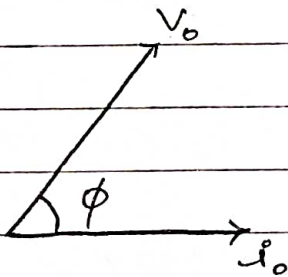
(C) $\frac{V_0^2 \cos \phi}{2R}$ ✗

$$= \frac{V_0^2 \cos \phi}{2Z}$$

(D) $\frac{V_0^2 R}{2Z^2}$ ✗

$$P_{av} = \frac{V_0^2}{2Z} \frac{R}{Z} = \frac{V_0^2 R}{2Z^2}$$

∴ Wattless current in series LCR circuit.



$$I_{rms} \sin \phi = I_{wattless}$$

∴ Purely L & C whole current is wattless ($\because P_{av} = 0$)

Date: _____

Page: _____

(Q) In an ac circuit the em.f (E) and the current (i) at any instant are given respectively by $E = E_0 \sin \omega t$, $i = I_0 \sin(\omega t - \phi)$. The average power in the circuit over one cycle of ac is (2008)

(1) $\frac{E_0 I_0 \cos \phi}{2}$

(2) $E_0 I_0$

(3) $\frac{E_0 I_0}{2}$

(4) $\frac{E_0 I_0 \sin \phi}{2}$

(Q) In an ac circuit, V and I are given by $V = 100 \sin 100t$ (Volts), $I = 100 \sin(100t + \frac{\pi}{3})$ mA. The power dissipated in circuit is

(1) 104 watt

(2) 10 watt

(3) 2.5 watt

(4) 5 watt

$$V_0 = 100 \text{ V}$$

$$I_0 = \frac{100}{1000} = \frac{1}{10} \text{ A}$$

$$\phi = \frac{\pi}{3}$$

$$P_{\text{av}} = \frac{V_0 I_0 \cos \phi}{2} = \frac{100 \times \frac{1}{10} \times \frac{1}{2}}{2}$$

$$= \frac{10}{4} = 2.5 \text{ watt}$$

(Q) The instantaneous value of alternating current and voltage in a circuit are given as

$$i = \frac{1}{\sqrt{2}} \sin(100\pi t) \text{ Ampere, } e = \frac{1}{\sqrt{2}} \sin(100\pi t) \text{ Volt}$$

The average power in the watts consumed in the circuit is

(1) $\frac{1}{4}$

(2) $\frac{\sqrt{3}}{4}$

(3) $\frac{1}{2}$

(4) $\frac{1}{8}$

$$P_{av} = \frac{V_0 I_0 \cos \phi}{2} \quad \phi = 0$$

$$= \frac{1}{\sqrt{2}} \times \frac{1}{\sqrt{2}} \times \frac{1}{2} \times \cos 0^\circ$$

$$= \frac{1}{4}$$

(Q) A coil of inductive reactance 31Ω has a resistance of 8Ω . It is placed in series with a condenser of capacitive reactance 25Ω . The combination is connected to an AC source of 110 Volt. The power factor of the circuit is (2006)

(1) 0.80

(2) 0.33

(3) 0.56

(4) 0.64

$$X_L = 31\Omega$$

$$R = 8\Omega$$

$$X_C = 25\Omega$$

$$\cos \phi = \frac{R}{Z}$$

$$Z = \sqrt{(31-25)^2 + 8^2}$$

$$= \sqrt{36 + 64}$$

$$\Rightarrow Z = 10\Omega$$

$$\text{power factor, } \cos \phi = \frac{8}{10} = 0.8$$

Date: _____

Page: _____

(Q) The potential differences across the resistance, capacitance and inductance are 80V, 40V & 100V respectively in an LCR circuit. The power factor of this circuit is (2016)

(1) 1.0 $V_R = 80V$

(2) 0.4 $V_C = 40V$

(3) 0.5 $V_L = 100V$

(4) 0.8 $V = ?$

$$\cos \phi = \frac{R}{Z} = \frac{V_R}{V_0}$$

$$\begin{aligned} V_0 &= \sqrt{(100 - 40)^2 + 80^2} \\ &= \sqrt{60^2 + 80^2} \\ &= \sqrt{3600 + 6400} \\ &= 100V \end{aligned}$$

$$\cos \phi = \frac{80}{100} = 0.8 \text{ Ans}$$

(Q)

Assertion: A bulb connected in series with a solenoid is connected to AC source. If a soft iron core is introduced in the solenoid, the bulb will glow brighter.

Reason:- On introducing soft iron core in the solenoid, the inductance increases

(1) A ✓ R ✓ R ✓ for A

(2) A ✓ R ✓ R × for A

(3) A ✓ R ×

(4) A × R ✓

$$X_L = \omega L = \omega \frac{\mu_0 N^2 A}{l} \quad \text{--- (1)}$$

$$I_0 = \frac{V_0}{Z} \quad Z = \sqrt{X_L^2 + R^2}$$

$$I_0 \downarrow$$

$$X_L \uparrow$$

↳ dimmer

• Resonance in LCR series circuit

Date: _____
Page: _____

- + Resonance means frequency match
- + current in the circuit at resonance is max^m.

$$I_0 = \frac{V_0}{Z} = \frac{V_0}{\sqrt{(X_L - X_C)^2 + R^2}}$$

max^m
min^m
 $R \neq f(f)$

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

for Z to be min^m $X_L - X_C = 0$

$$X_L = X_C$$

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

$$\boxed{\omega_r = \frac{1}{\sqrt{LC}}}$$

Angular Resonant frequency.
(rad/s)

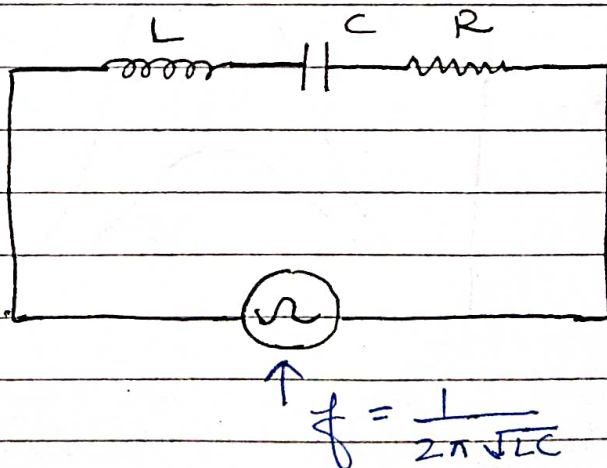
$$2\pi f_r = \frac{1}{\sqrt{LC}}$$

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

resonant frequency. (Hz)

$$\boxed{(I_0)_{\max} = \frac{V_0}{Z_{\min}} = \frac{V_0}{R}}$$

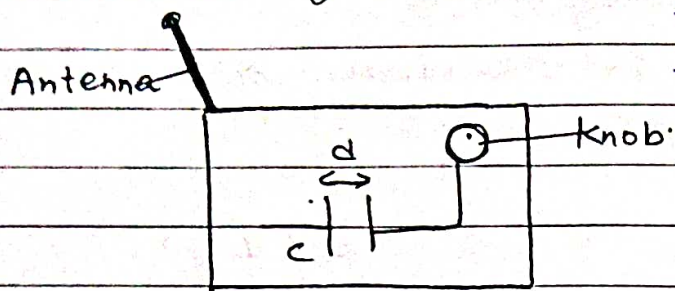
@ Resonant frequency



Example of Radio Tuning

Date: _____

Page: _____



+ FM Radio $\rightarrow 88\text{MHz} - 108\text{MHz}$

+ Knob rotates $\rightarrow d$ changes

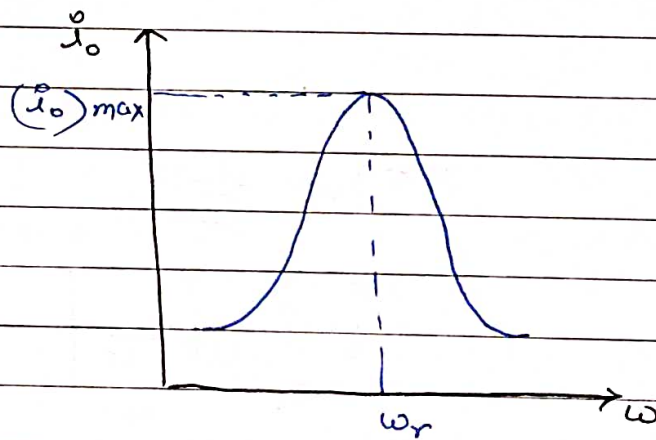
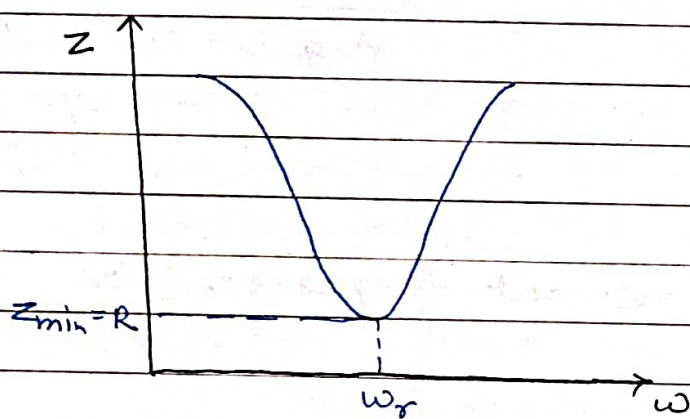
$$C = \frac{A\epsilon_0}{d} \text{ changes}$$

$$\omega_r = \frac{1}{\sqrt{LC}} \rightarrow \text{changes}$$

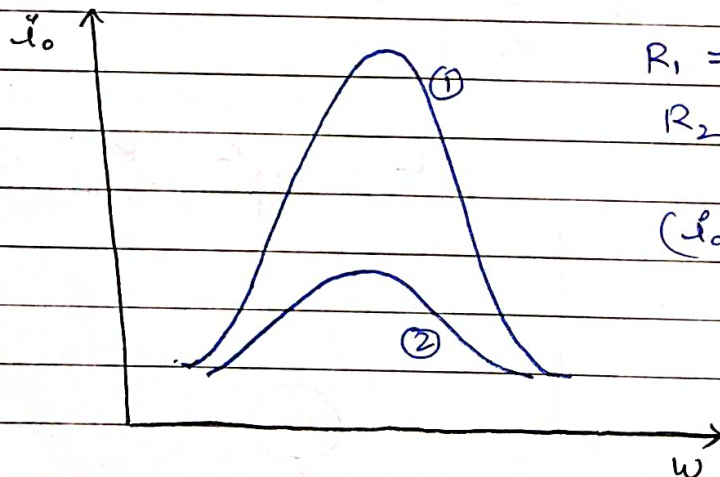
+ External frequency
= Internal Circuit
frequency = ω_r

Resonance

Graph:-



Resistance Comparison:



$$R_1 = 10\Omega$$

$$R_2 = 100\Omega$$

$$(i_o)_{\max} = \frac{V_o}{R}$$

$$R \downarrow \Rightarrow i_o(\max) \uparrow$$

Bandwidth of a circuit:

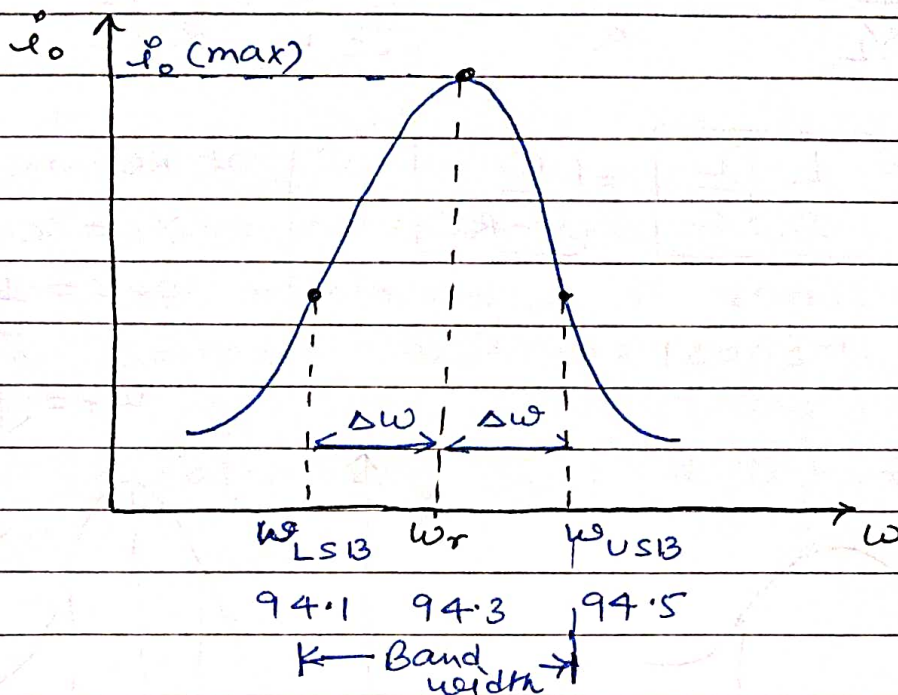
Date: _____
Page: _____

Example * 88 MHz to 108 MHz

frequency Range = Bandwidth.

+ For 94.3 FM
 $\downarrow$
 ω_r

94.1 - 94.5
Band width.



$P \propto i^2$
 $i \uparrow \Rightarrow P \uparrow$
Sound signal $(\uparrow)$

ω_{LSB} = Lower Side Band
 ω_{USB} = Upper Side Band

$$\omega_{LSB} = \omega_r - \Delta\omega$$
$$\omega_{USB} = \omega_r + \Delta\omega$$

$$\therefore \boxed{\text{Band width} = \omega_{USB} - \omega_{LSB} = 2\Delta\omega = \frac{R}{L}}$$

$$X_L = X_C$$

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

Quality factor / sharpness of circuit (Q)

Date: _____

Page: _____

$$Q = \frac{\text{Resonance angular frequency}}{\text{Bandwidth}} = \frac{\omega_r}{2\Delta\omega}$$

+ If Bandwidth $\uparrow \Rightarrow Q \downarrow$

$$Q = \frac{\omega_r}{R/L} = \frac{\omega_r L}{R} = \frac{1}{\sqrt{LC}} \frac{L}{R} = \frac{1}{R} \sqrt{\frac{L}{C}} \quad \omega_r = \frac{1}{\sqrt{LC}}$$

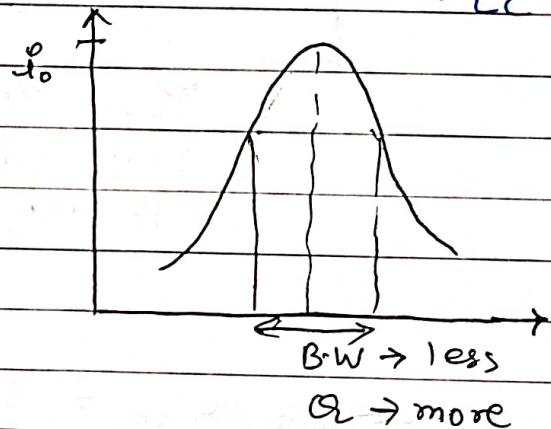
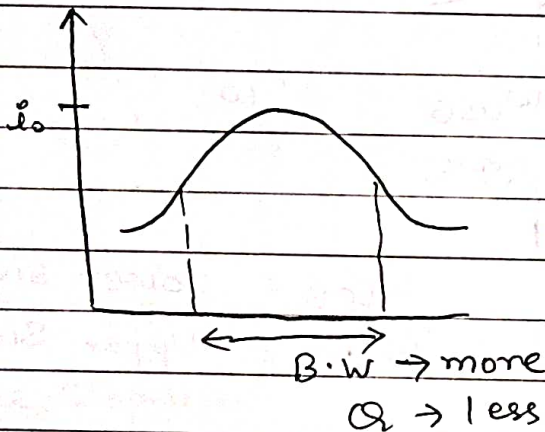
$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{\omega_r R C}$$

at Resonance

$$X_L = X_C$$

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

$$\omega_r = \sqrt{\frac{1}{LC}}$$



(Q) In LCR circuit, the capacitance is changed from C to $4C$. For the same resonant frequency, the inductance should be changed from L to

(1) $2L$

(2) $L/2$

(3) $L/4$ ✓

(4) $4L$

$$\omega = \frac{1}{\sqrt{LC}}$$

$$C \rightarrow 4C$$

$$L \rightarrow L/4$$

(Q) What is the value of inductance L for which the current is maximum in a series LCR circuit with $C = 10 \mu F$ and $\omega = 1000 s^{-1}$ (2007)

(1) $1 mH$

(2) can't be calculated unless R is known

(3) $10 mH$

(4) $100 mH$

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

$$L = \frac{1}{\omega^2 C}$$

$$= \frac{1}{10^6 \times 10 \times 10^{-6}}$$

$$= \frac{1}{10} \times 1000 = 100 mH$$

(Q) The value of Quality factor is: (2000)

(1) $\omega L/C$

(2) ✓ $1/\omega RC$

(3) $\sqrt{LC}$

(4) L/R

Date: _____

Page: _____

(Q) In the circuit shown below, the ac source has voltage $v = 20 \cos \omega t$ volts, with $\omega = 2000 \text{ rad/s}$. The amplitude of the current will be.

$$I_0 = \frac{V_0}{Z} = \frac{20}{Z}$$

(1) 2A

$$R = 10 \Omega$$

(2) 3.3A

$$X_L = \omega L = 2000 \times 5 \times 10^{-3}$$

(3) $2/\sqrt{5}$ A

$$X_C = 10 \Omega$$

(4) $\sqrt{5}$ A

$$X_C = \frac{1}{\omega C} = \frac{1}{2000 \times 50 \times 10^{-6}}$$

$$= \frac{1}{0.1} = 10 \Omega$$

$X_L = X_C \Rightarrow \text{Resonance}$

$$I_0 = \frac{V_0}{R} = \frac{20}{10} = 2 \text{ A}$$

(Q) In the given circuit the reading of voltmeter V_1 and V_2 are 300 volts each. The reading of the voltmeter V_3 and ammeter A are respectively. The source voltage is 220V, 50Hz (2010)

(1) 150V, 2.2A

(2) 200V, 2.2A

(3) 220V, 2.2A

(4) 100V, 2.0A

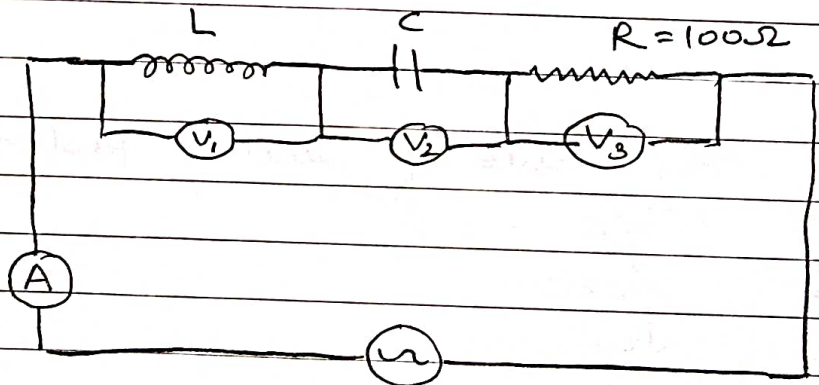
$$V_1 = V_2 = 300 \text{ V}$$

(Resonance)

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

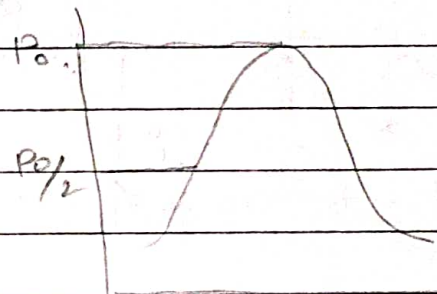
$$V_R = 220 \text{ V}$$

$$I = \frac{V}{Z} = \frac{V}{R} = \frac{220}{100} = 2.2 \text{ A}$$



(Q) A series LCR circuit containing 5 OH Inductor, $80\text{ }\mu\text{F}$ Capacitor and $40\text{ }\Omega$ resistor is connected to 230 V variable frequency AC source. The angular frequencies of the source at which power transferred to the circuit is half the power at the resonant angular frequency are likely to be (NEET 2021)

- (a) 25 rad/s and 75 rad/s
- (b) 50 rad/s and 25 rad/s
- (c) 46 rad/s and 54 rad/s
- (d) 42 rad/s and 58 rad/s



$$BW = \frac{R}{L} = \frac{40}{5} = 8$$

$$\omega_{USB} - \omega_{LSB} = 8$$

$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5 \times 80 \times 10^{-6}}}$$

$$= \frac{1}{\sqrt{400 \times 10^{-6}}} = \frac{1}{20 \times 10^{-3}}$$

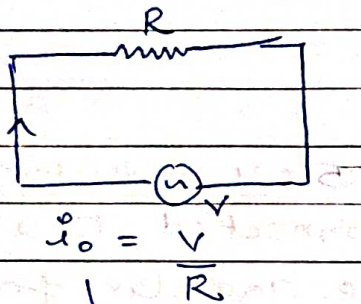
$$= \frac{1000}{20} = 50\text{ rad/s}$$

★ CHOKER COIL:-

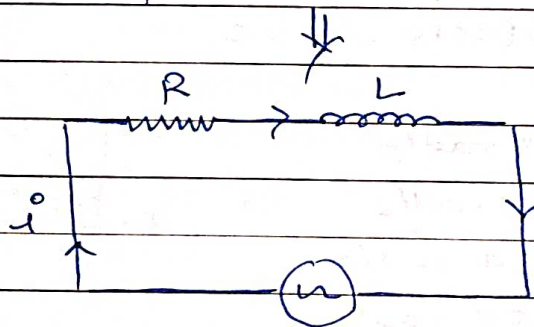
Date: _____

Page: _____

- + It is used to control the current in a circuit without dissipating any power or energy.
- + It is generally inductor but it can also be capacitor



→ If we need to decrease the current without power dissipation



$$i_o = \frac{V_o}{Z}$$

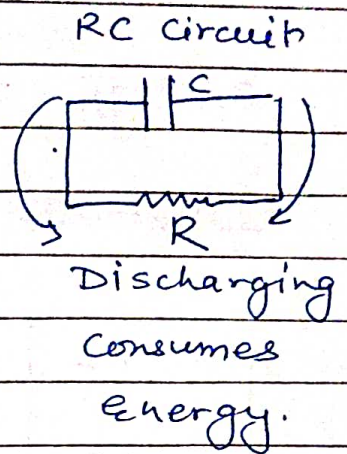
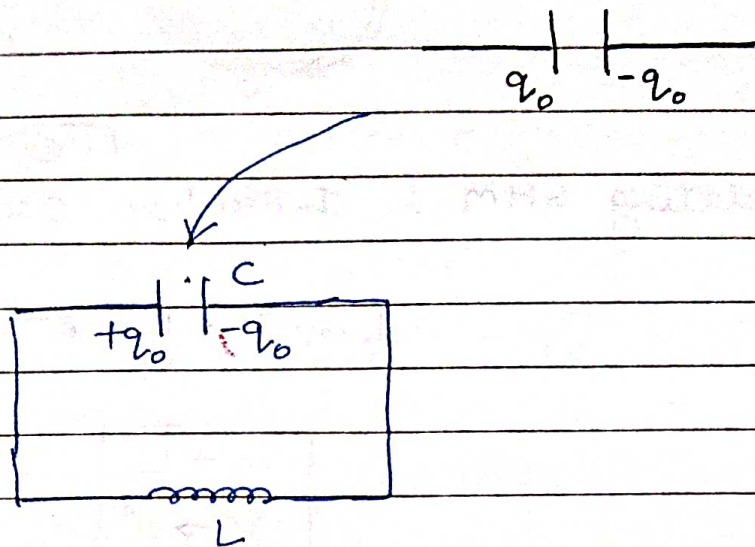
$$i_o = \frac{V_o}{\sqrt{R^2 + X_L^2}}$$

$$Z > R, \therefore i_o \downarrow$$

L-C Oscillations:-

Date: _____
Page: _____

Let a Capacitor fully charged condition.



Here Inductance also doesn't consumes energy. The energy oscillates in between them is L-C Oscillation

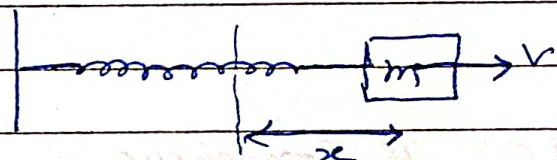
$$E = \frac{1}{2} \frac{q^2}{C} + \frac{1}{2} L i^2$$

$$= \frac{q_0^2}{2C} = \frac{1}{2} L i_0^2$$

when all
energy is in
Capacitor

when all
energy is
in Inductor

where $i_0 = i_{\max}$
 $q_0 = \text{max}^{\text{m}} \text{ charge}$



$$E = \frac{1}{2} m v^2 + \frac{1}{2} K x^2$$

$$E = \frac{1}{2} K A^2 = \frac{1}{2} m v_{\max}^2$$

Extreme position mean position

* $E = \frac{1}{2} Kx^2 + \frac{1}{2} mv^2$ (Mass oscillates) $\omega = \sqrt{\frac{K}{m}}$

Date: _____

Page: _____

$E = \frac{q^2}{2C} + \frac{1}{2} Li^2$ (charge / current oscillates)

$\omega = \frac{1}{\sqrt{LC}}$

Analogy (Relating SHM & Inductor Oscillation)

$\frac{1}{2} Kx^2 \rightarrow \frac{q^2}{2C}$

$\frac{1}{2} mv^2 \rightarrow \frac{1}{2} Li^2$

$K \rightarrow \frac{1}{C}$
$x \rightarrow q$

$m \rightarrow L$
$v \rightarrow i$

$m \rightarrow$ inertia

(opposes motion)

$L \rightarrow$ Electrical Inertia

(opposes change in current) or flux

(Q) A Condenser of capacity C is charged to a potential difference of V_1 . The plates of the condenser are then connected to an ideal ~~cond~~ inductor of inductance L . The current through the inductor when the potential difference across the condenser reduces to V_2 is (2010)

(1) $\left\{ \frac{C(V_1 - V_2)^2}{L} \right\}^{1/2}$

(2) $\frac{C(V_1^2 - V_2^2)}{L}$

(3) $\frac{C(V_1^2 + V_2^2)}{L}$

(4) $\left\{ \frac{C(V_1^2 - V_2^2)}{L} \right\}^{1/2}$

22000V

→ 220V
step down

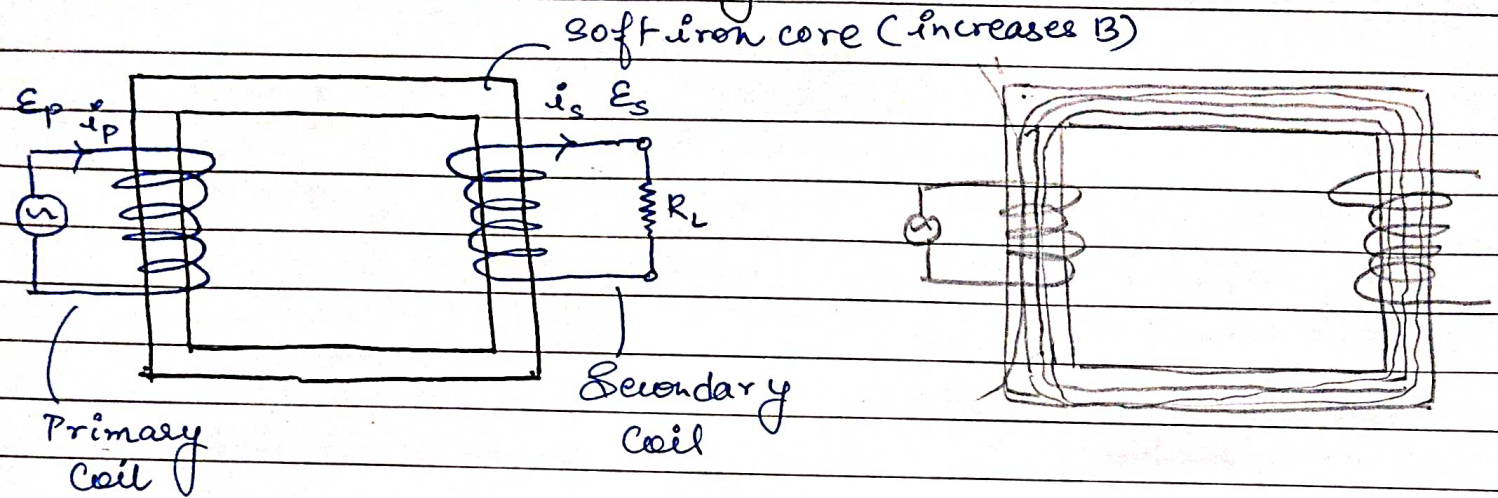
Date: _____

Page: _____

2 TRANSFORMER:-

- + To step up or step down the voltage
- + Based on mutual induction between two coils. whenever there is change in current in primary coil, there is emf induced in secondary coil

Construction & working



E_p & E_s are Primary & secondary emf
 i_p & i_s are ——— " ——— " ——— current
 R_L = Load / Output Resistance

* Transformer work on AC source

✗ for DC source $i = \text{const}$

$\phi = \text{const}$

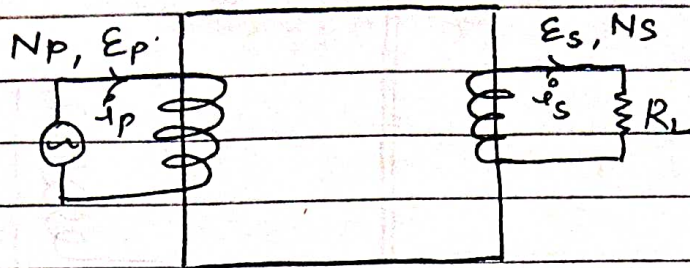
No emf.

7 IDEAL TRANSFORMER.

Date: _____

Page: _____

+ No flux loss & No power loss



N_p & N_s are no. of turns in primary & secondary coils

$$E_p = -N_p \frac{d\phi}{dt} \Rightarrow -\frac{d\phi}{dt} = \frac{E_p}{N_p} \quad \text{--- (I)}$$

$$E_s = -N_s \frac{d\phi}{dt} \Rightarrow -\frac{d\phi}{dt} = \frac{E_s}{N_s} \quad \text{--- (II)}$$

$$\frac{E_p}{N_p} = \frac{E_s}{N_s} \Rightarrow \boxed{\frac{E_p}{E_s} = \frac{N_p}{N_s}} \quad \text{--- (A)}$$

+ No. Power loss, $P_p = P_s$

$$E_p i_p = E_s i_s$$

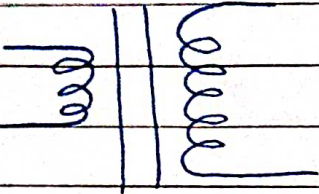
$$\boxed{\frac{E_p}{E_s} = \frac{i_s}{i_p}} \quad \text{--- (B)}$$

from A & B

$$\boxed{\frac{E_p}{E_s} = \frac{N_p}{N_s} = \frac{i_s}{i_p}} \quad *$$

(a) Step-up transformer

$$E_s > E_p$$

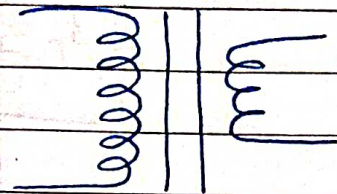


$$N_p < N_s$$

$$i_p > i_s$$

(b) step-down transformer

$$E_s < E_p$$



$$N_p > N_s$$

$$i_p < i_s$$

$$\frac{E_p}{E_s} = \frac{N_p}{N_s} = \frac{i_s}{i_p}$$

* When there is gain in voltage, there is loss in current.

(Q) The primary winding of a transformer has 500 turns whereas its secondary has 5000 turns. The primary is connected to an AC supply 20V, 50 Hz. The secondary will have output of:

(1) 2V, 50Hz

$$N_p = 500$$

$$\frac{E_p}{E_s} = \frac{N_p}{N_s}$$

(2) 2V, 5Hz

$$N_s = 5000$$

$$\frac{E_p}{E_s} = \frac{N_p}{N_s}$$

(3) 200V, 50Hz

$$E_p = 20V$$

$$\frac{20}{E_s} = \frac{500}{5000}$$

(4) 200V, 500Hz

$$E_s = ?$$

$$\frac{20}{E_s} = \frac{500}{5000}$$

$$E_s = 200V$$

$$\# \text{ for } N \quad 500 \xrightarrow{\times 10} 5000$$

$$\therefore \text{ for } E \quad 20 \xrightarrow{\times 10} 200V$$

(Q) A step up transformer operates on a 230V line and supplies a load of 2A. The ratio of primary & secondary winding turns is 1:25. Then the current in the primary is

- (1) 25A
(2) 50A
(3) 15A
(4) 12.5A
- $i_s = 2A$
 $i_p = ?$
- $N_p = 1$
 $N_s = 25$
- $i_s = i_p$
 $i_p = 50A$

(Q) An ideal transformer has 100 turns in the primary and 250 turns in the secondary. The peak value of AC is 28V. The r.m.s secondary voltage is nearest to

- (1) 50V
(2) 70V
(3) 100V
(4) 40V
- $N_p = 100$
 $E_p = 28V$
- $N_s = 250$
 $E_s = 70V$
- $E_s = \frac{N_s}{N_p} E_p = \frac{250}{100} \times 28 = 70V$

(Q) The primary and secondary coils of a transformer have 50 and 1500 turns respectively. If the magnetic flux ϕ linked with the primary coil is given by $\phi = \phi_0 + 4t$, where ϕ is in webers, t is time in seconds & ϕ_0 is a constant, the output voltage across the secondary coil is

- (1) 90V
(2) 120V
(3) 220V
(4) 30V
- $\phi_p = \phi_0 + 4t$
 $E_p = -\frac{d\phi}{dt} = 4V$
- $E_p = 4V$
 $N_p = 50$
- $E_s = ?$
 $N_s = 1500$
- $\frac{E_p}{E_s} = \frac{N_p}{N_s} \Rightarrow \frac{4}{E_s} = \frac{50}{1500} \Rightarrow E_s = 120V$

★ NON-IDEAL TRANSFORMER

$$P_p \neq P_s$$

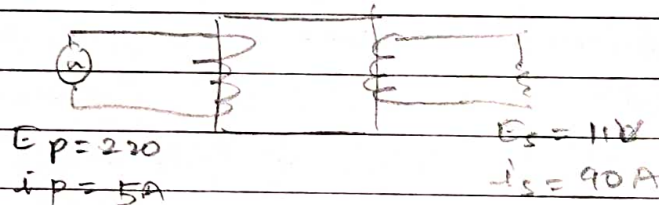
$$P_s < P_p$$

$$\eta = \frac{P_{out}}{P_{in}} \times 100 = \frac{P_s}{P_p} \times 100$$

$$\eta = \frac{E_s i_s}{E_p i_p} \times 100$$

(Q) A transformer is employed to reduce 220V to 11V. The primary draws a current of 5A and the secondary 90A. The efficiency of the transformer is;

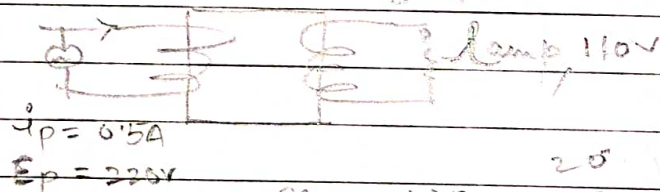
- (1) 20 %
- (2) 40 %
- (3) 70 %
- (4) 90 %



$$\eta = \frac{E_s i_s}{E_p i_p} \times 100 = \frac{11 \times 90}{220 \times 5} \times 100 = 90\%$$

(Q) A transformer is used to light 100W - 110V lamp from 220V mains. If the main current is 0.5A, the efficiency of the transformer is approximately

- (1) 50 %
- (2) 90 %
- (3) 10 %
- (4) 30 %



$$\eta = \frac{P_s}{P_p} \times 100 = \frac{100}{220 \times 0.5} \times 100 = \frac{100}{110} \times 100 = 90.9\% \approx 91\%$$

* Losses in Transformer

Date: _____
Page: _____

(1) Copper loss :- + Due to resistance of windings, heat is produced, ~~to~~ to reduce it, thick wires are used.

$$R = \frac{\rho l}{A}$$

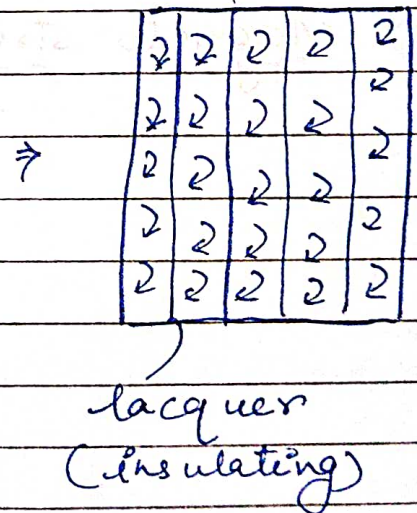
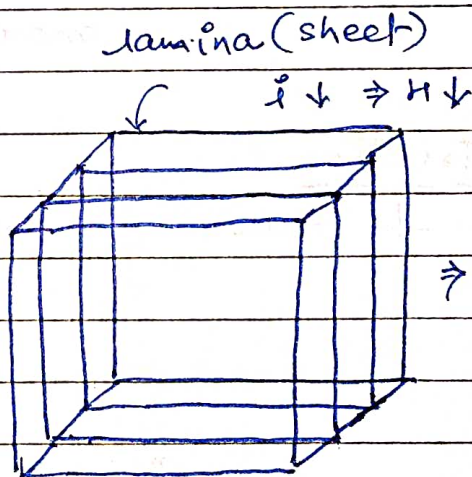
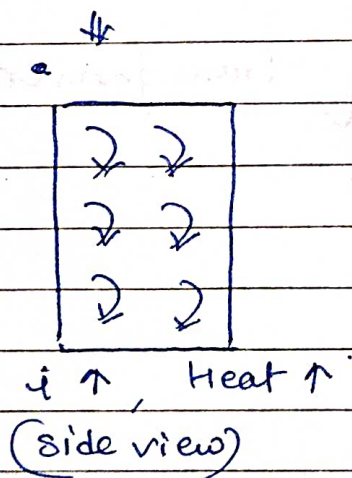
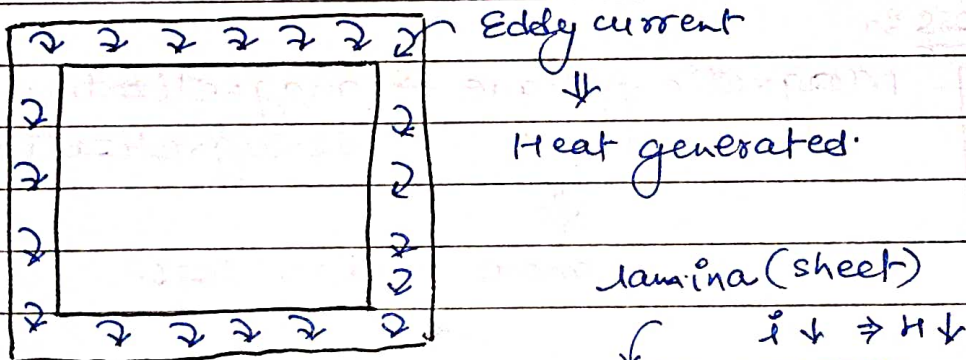
$$A \uparrow \Rightarrow R \downarrow$$

$$H = i^2 R t$$

$$R \downarrow \Rightarrow H \downarrow$$

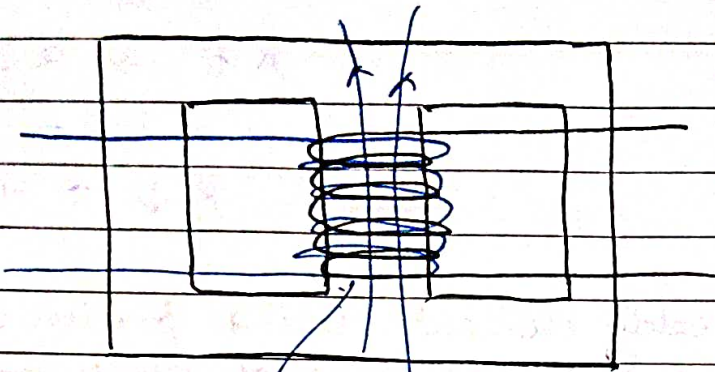
(2) Iron losses :-

+ Due to eddy currents being produced in the soft iron core, heat is produced.
+ to reduce it, laminated core is used.



(3) Flux loss :-

+ to reduce it, both primary & secondary coils are mounted on single vertical pole



coaxial windings

(4) Hysteresis loss :-

+ Magnetic fatigue $\rightarrow$ magnetization & demagnetization

$\downarrow$
more energy loss.

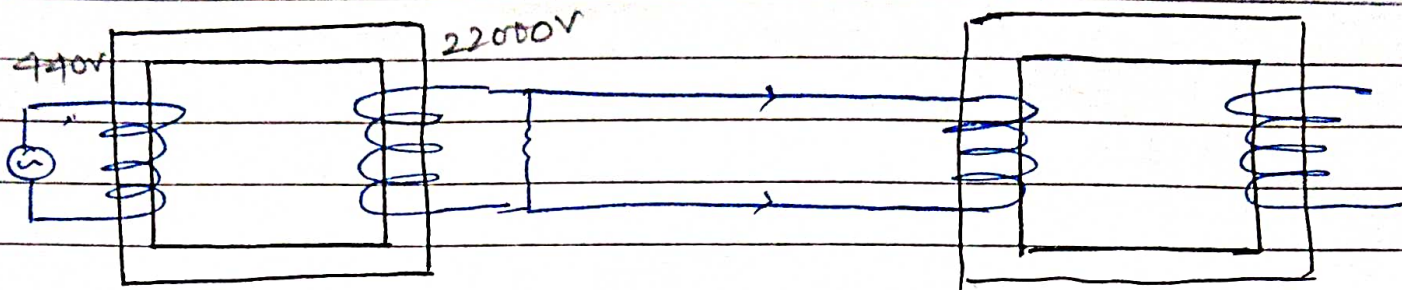
(5) Magnetostriction :-

+ Humming noise of transformer

Long distance Power Transmission ::

Date: _____
Page: _____

$$\text{Power loss} = i^2 R$$



step-up transformer $i \downarrow \Rightarrow P \downarrow$
(Power station)

(Power
loss decreases)

step-down transformer
(Home)