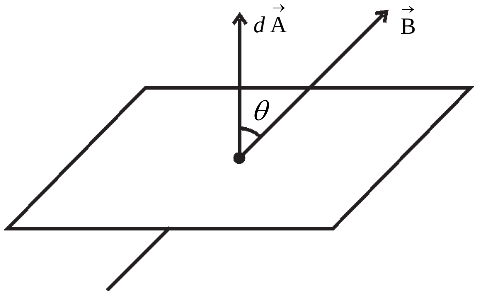
14 Electromagnetic Induction and Alternating Current

Magnetic flux (Φ)

The magnetic flux linked through any surface placed in a magnetic field is the number of magnetic field lines crossing this surface normally.

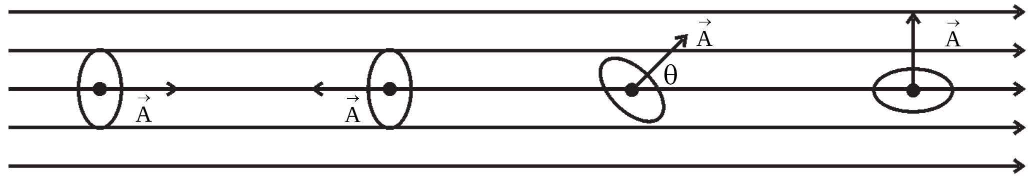


Magnetic flux $\Phi = \oint \vec{B} \cdot d\vec{A}$

$= BA \cos\theta$

where, θ Angle between $\vec{B}$ and $\vec{A}$.

Some cases :



Plane	Perpendicular to $\vec{B}$	Perpendicular to $\vec{B}$	Angle θ with $\vec{B}$	Parallel to $\vec{B}$
θ	0	$\theta = 180°$	$\theta = \theta$	$\theta = 90^{o}$
Magnetic flux	$\Phi = BA$	$\Phi = -BA$	$\Phi = BA\cos\theta$	$\Phi = 0$
Flux (Φ)	Maximum and positive	Maximum and negative		

Unit of Magnetic Flux

SI unit	weber (Wb)
MKS unit	tesla-meter^2
CGS unit	gauss-cm^2, maxwell.

Other units :

$\frac{N\ m}{A}$, $\frac{\text{jule}}{\text{ampere}}$, $\frac{\text{volt - coulumb}}{\text{ampere}}$, volt - second, ohm coulumb, henry - ampere

Dimentional Formula :

$\left[\Phi\right] = \left[M^1 L^2 T^2 A^{-1}\right]$

Equations :

$\Phi = \vec{B} \cdot \vec{A} = BA\cos\theta$

$\vec{B} =$ Magnetic field, $\vec{A} =$ area vector, $\theta =$ Angle between $\vec{A}$ and $\vec{B}$.

If coil having N turns, $\Phi = NBA \cos\theta$

If coil rotating is uniform magnetic field with constant angular speed then magnetic flux linked with coil at time t,

$\Phi = NBA \cos \omega t$.

Magnetic flux linked with current I carrying coil laying in uniform magnetic field.

$\Phi = NBA \cos \omega t$

where, $B = \frac{\mu_0 I}{2\pi a}$ current carrying straight wire having infinite length

$B = \frac{\mu_0 I}{2a}$ current carrying circular loop having radius a

$B = \frac{\mu_0 NI}{l}$ current carrying solenoid having length of l and N turns.

- If surface is spherical then $\Phi = \int \vec{B} \cdot \vec{da}$
- A rectangular loop of length L and breadth b is placed near a very long wire carrying current I, the side of the loop nearer to the wire is at a distance a from the wire, magnetic flux linked with the loop.

$$\Phi = \frac{\mu_0 I b}{2\pi} ln\left[\frac{L+a}{a}\right]$$

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(1) Two coplanar and cocentric coil of radius 100 cm and 1 cm respectively. If 1 A current passing through big coil then magnetic flux linked will small coil is ________. $(\mu_0 = 4\pi \times 10^{-7}\ TmA^{-1})$.

(A) 0.02 Wb (B) 2×10^{-10} maxwell (C) 0.02 maxwell (D) $2 \times 10^{-10}\ Tm^2$

(2) A rectangular loop of length 2 cm and breadth 1 cm is placed near a very long wire current carrying 10 A and in plane of wire. If the side of loop nearer to the wire is at a distance of 2 cm from wire then magnetic flux linked with loop is ________ $G\ cm^2$.

(A) 2×10^{-8} (B) 2 (C) 1.386×10^{-8} (D) 1.386

(3) A circular loop of radii 10 cm having 10 turns placed in uniform magnetic field of 2×10^{-4} G. Initially plane of loop is perpendicular to field. Now it is rotate with uniform angular speed of 2π rad s^{-1}. At which time the flux linked with loop becomes half of maximum time ?

(A) $\frac{1}{2}$ s (B) $\frac{1}{12}$ s (C) $\frac{1}{6}$ s (D) $\frac{1}{4}$ s

(4) Two coil of equal surface area having turns 10 and 20 are lies in a uniform magnetic field with its plane perpendicular to the field. If both coils are rotates with constant angular speed ω_1 and ω_2 respectively. The magnetic flux linked with coils are equal at time t then $\frac{\omega_2}{\omega_1} =$ ________ .

(A) $\frac{1}{3}$ (B) $\frac{1}{6}$ (C) $\frac{1}{4}$ (D) $\frac{2}{3}$

(5) A solenoid of 10 cm length and cross section diameter 5 cm having 1000 turns carrying20 mA current. A circular plane of 2 cm radius is kept near to end of solenoid and its plane perpendicular to axis of solenoid. The magnetic flux associated to circular plane is ...... $H \bullet A$. ($\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1}. $\pi^2 = 10$)

(A) 3.2×10^{-8} (B) 3.2×10^{-7} (C) 3.2×10^{-9} (D) 3.2×10^{-6}

(6) A rectangular plane of length 2 cm and breadth 4 cm is kept horizontally and magnetic field of 0.3 T applied in direction inside at $30°$ with perpendicular upward direction to rectangular plane. Magnetic flux linked with plane is ...... Wb.

(A) 8×10^{-5} (B) 8×10^{-6} (C) 1.2×10^{-4} (D) 12×10^{-6}

Ans. : 1 (C), 2 (D), 3 (C), 4 (B), 5 (B), 6 (C)

Electromagnetic induction and Faraday's law :

Electromagnetic induction : The phenomenon in which electric current is induced in a conductor by varying magnetic field is called electromagnetic induction.

Faraday's law : The magnitude of the induced emf produced in a close circuit (or a coil) is equal to the negative of the time rate of change of magnetic flux linked with it.

- **Equations of induce emf :**

$$\varepsilon = \frac{-d\Phi}{dt}$$

$$\varepsilon = -N\frac{d\Phi}{dt}$$ When N turns

$$= \frac{-N(\Phi_2 - \Phi_1)}{\Delta t}$$ When varing magnetic flux.

$$= \frac{-NA(B_2 - B_1)}{\Delta t}$$ When varing magnetic field.

$$= \frac{-NBA(\cos\theta_2 - \cos\theta_1)}{\Delta t}$$ When changing in θ

- $\Phi = NBA \cos \omega t$ when coil or loop rotate with constant angular speed

$$\therefore \varepsilon = \frac{-d}{dt}(NBA \cos \omega t)$$

Negative sign indicate presence of Lenz's law

- If only area A is changing, then $\varepsilon = -\mathrm{NB}\cos\theta \dfrac{d\mathrm{A}}{dt}$

- If only magnetic field is changing, then $\varepsilon = -\mathrm{NA}\cos\theta \dfrac{d\mathrm{B}}{dt}$

- If only angle θ is changing, then

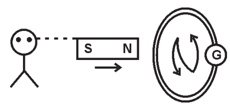
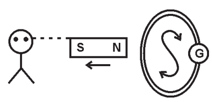
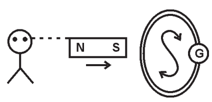
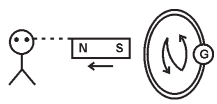
$\varepsilon = -\mathrm{NBA}\dfrac{d}{dt}(\cos\omega t) = +\mathrm{NBA}\ \omega \sin\omega t$ (Induced emf is in form of AC voltage).

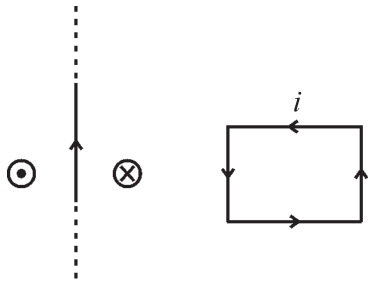
Induced current (I)	**Induced charge (q)**	**Induced power (P)**
$I = \dfrac{\varepsilon}{\mathrm{R}} = \dfrac{-\mathrm{N}}{\mathrm{R}}\dfrac{d\Phi}{dt}$ (R resistance)	$dq = Idt = \dfrac{-\mathrm{N}}{\mathrm{R}}d\Phi$	$P = \dfrac{e^2}{\mathrm{R}} = \dfrac{\mathrm{N}^2}{\mathrm{R}}\left(\dfrac{d\Phi}{dt}\right)^2$

Lenz's force and uses of Lenz's law :

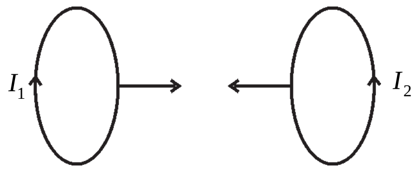
When induced current passing through conducting loop laying in magnetic field it experiance a force. $\vec{\mathrm{F}} = I\vec{l} \times \vec{\mathrm{B}}$, is called Lenz force.

The direction of induced emf or current in a circuit is such as to oppose the cause that produces it. The direction of magnetic field due to induced current is oppose to causes megnetic field.

The various position of relative motion between the magnet and the coil				
Position of magnet				
Direction of induced current	Anticlockwise direction	Clockwise direction	Clockwise direction	Anticlock wise direction
Behaviour of face of the coil	As a north pole	As a south pole	As a south pole	As a north pole
Type of magnetic force developed.	Repulsive force	Attractive force	Repulsive force	Attractive force
Magnetic field linked with the coil and it's progress as viewed from left	Cross (⊗) Increases	Cross (⊗) Decreases	Cross (⊗) Increases	Cross (⊗) Decreases



If the coil move towards I current carrying straight infinite wire or I increasing with time then induced current anticlock wise shown in figure. The coil is move away from wire or current I decreases with time, the induced current in clockwise direction.



Two coils carrying currents I_1 and I_2, placed with their planes parallel and approach each other shown in figure.

(i) If I_1 and I_2 are both clockwise (or anticlockwise) then both I_1 and I_2 will decrease. If the currents I_1 and I_2 are in opposite sense both the currents will increase.

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(7) A conducting circular loop of surface area $5 \times 10^{-3}\ \text{m}^2$ is placed perpendicular to a magnetic field which varies as $\text{B} = (0.10\text{T})\sin\left[\left(100\,\pi\ \text{s}^{-1}\right)t\right]$. Find the charge flowing through any cross section area during the time $t = 0$ to $t = 5\ m\text{s}$. Resistance of loop is $10\ \Omega$.

(A) 5.0 mC (B) 500 mC (C) 5 C (D) 50 μC

(8) A solenoid of diameter 20 cm has 500 turns per unit length. At a centre of this solenoid, a coil of 100 turns is wrapped closely around it. If the current in solenoid changes from zero to 2 A in 1 ms. Calculate the induced emf developed in the coil.

(A) 3.95 μV (B) 3.95 V (C) 3.95×10^{-3} V (D) 39.5 V

(9) A circular loop of diameter 50 cm and 10 turns is placed with its plane perpendicular to uniform magnetic field of 0.4 T. Find an induced emf two condition given below for $t = 0$ to $t = 20\ ms$, when loop is rotated with constant angnlar speed of 100 rads^{-1}.

(i) Loop rotated about an axis, passing through its centre and perpendicular to its plane ....

(ii) Loop rotates about is diameter ....

(A) (0, 7.85) V (B) (0, 0) V (C) (7.85, 0) V (D) (78.5, 78.5) V

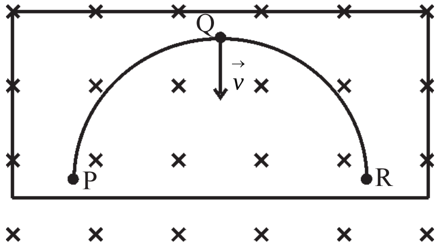
(10) Resistance of conducting coil having 8 turns is $8\,\Omega$. A galvenometer of eight time resistance of coil is connected with coil. If entire system moves in 4 ms in field having magnetic flux 12×10^{-5} wb to 18×10^{-5} wb, then induced current in circuit is ....

(A) 1.6 (B) 1.6×10^{-6} (C) 1.6×10^{-3} (D) 1.6×10^{-4}

(11) A wire in form of a semicircle of radius 5 cm rotates about the diameter with an angular frequency of $10\,\pi$ rad s^{-1} in uniform magnetic field of 2 T. The axis of rotation is perpendicular to the field. If the total resistance of the circuit is $4\,\Omega$, then mean power generated per period of rotation will be ...... W. (Take $\pi^2 = 10$)

(A) 7.81×10^{-3} (B) 7.81×10^{-6} (C) 78.12×10^{-3} (D) 7.81×10^{-5}

(12) A thin semicircular conducting ring of radius 5 cm is free falling vertically in a horizontal magnetic field of 5×10^{-3} T as shown in figure. At the position PQR, the speed of the ring is $20\ \mathrm{cms^{-1}}$ the potential different across P and R point is ...... and point .... having high potential.



(A) O and Q (B) 1×10^{-4} V and R

(C) O and R (D) 1×10^{-4} V and P

(13) A square loop of side a is placed such that its plane is the same as that of a very long wire carrying a current *I*. The centre O of the loop is at a distance x from wire. The loop is given velocity v so that loop moves far away from wire then induced emf in loop will be ...... μV . Take; $a = 2$ cm, $I=1$ A, $\mu_0 = 4\pi \times 10^{-7}$ TmA^{-1}, $v = 50\ \mathrm{cms^{-1}}$, $x = 5$m

(A) 1.6×10^{-3} (B) 1.6×10^{-6} (C) 1.6×10^{-2} (D) 1.6×10^{-6}

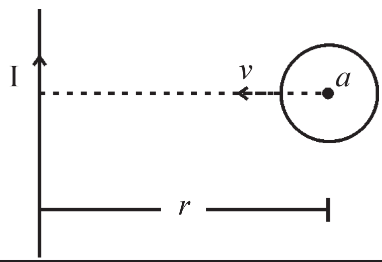
(14) A conducting coil of resistance $225\,\Omega$, 250 turns and area of $1 \times 10^{-2}\ \mathrm{m^2}$ lies with its plane normal to a uniform magnetic field of 0.3 T. If area vactor of coil rotates from 0° to 90° in 500 *ms* then average power produced will be ...... *m*W.

(A) 1 (B) 100 (C) 10 (D) 0.1

(15) A coil having radius 4 cm and 150 turns lies with its area vector make $45°$ angle with magnetic field of intensity $4 \times 10^{-7}\ \dfrac{\text{maxwell}}{\text{cm}^2}$. If a coil rotates in 1.41 s and area vector make angle $135°$ with magnetic field then average induced emf developed is ....

(A) $72\,\pi \times 10^{-3}$V (B) $72\,\pi$ V (C) 301.4 *m*V (D) 301.4 V

(16) As shown in figure, a long wire kept vertically on the plane of paper carries electirc current 2A. A conducting ring having diameter of 4 cm moves towards the wire with velocity of $2\ \mathrm{cm\,s^{-1}}$ with its plane coinciding with the plane of paper. Find the induced emf produced in the ring when it is at a perpendicular distance 2 m from the wire.



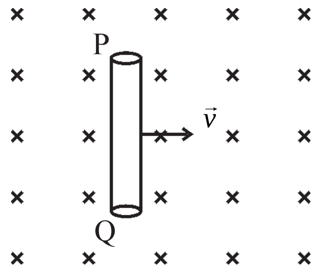
(A) 2.512 V (B) $2.512 \times 10^{-6}\ \mu$V

(C) 2.512 mV (D) 2.512×10^{-6} V

Ans. : 7 (D), 8 (B), 9 (B), 10 (C), 11 (A), 12 (B), 13 (D), 14 (C), 15 (D), 16 (B)

Motional EMF due to translatory motion :

A conducting rod of length l moving with a uniform velocity $\vec{v}$ perpendicular to the uniform magnetic field $\vec{B}$ shown in figure.



Conducting electron experiance a magnetic force in direction from P to Q, so,

end P of rod becomes positive while end Q of rod becomes negative.

An electric field is set up within the rod which is oppose motion of electron.

When magnetic force F_m and electric force F_e in equillibrium,

$$F_m = F_e$$

$$\Rightarrow Bev = Ee$$

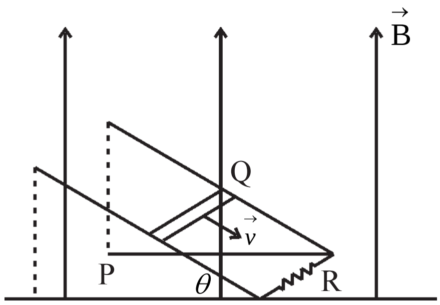
$$\therefore \quad \text{electric field } E = Bv$$

$$\text{induced } emf \ \varepsilon = El = Bvl$$

- If rod is moving by making an angle θ with the direction of magnetic field $\vec{B}$.

$$\text{induced } emf \ \ \varepsilon = Bvl \sin\theta$$

- When conducting rod PQ, length of l and mass of m starts sliding from the top of an inclined plane as shown, it moves with velocity v. Perpendicular to its length but an angle $(90-\theta)$ with the direction of magnetic field $\vec{B}$. Both rails connected with R.



- Induced emf between P and Q, $emf \ \varepsilon = Bv\sin(90-\theta)\, l$

$$\therefore \ \varepsilon = Bvl\cos\theta$$

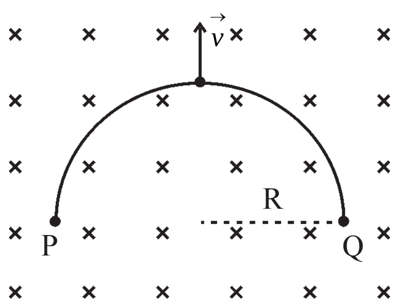
Induced current $I = \dfrac{Bvl\cos\theta}{R}$ (Direction from Q to P)

The rod will move down with constant velocity (terminal velocity)

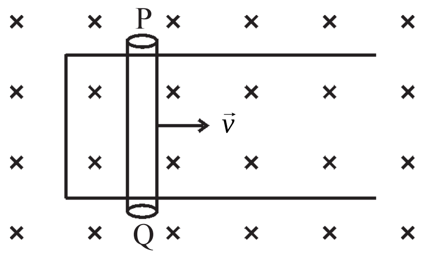
$BIl\cos\theta = mg\sin\theta$ (frictional force zero)

substituting value of I

$$\text{Terminal velocity } V_t = \frac{mgR\sin\theta}{B^2 l^2 \cos^2\theta}$$



When a semi circular conducting rod of radius R is move with a velocity v in a magnetic field $\vec{B}$ as shown in figure the induced emf between end P and Q, $emf \ \varepsilon = 2BvR$



A U shaped conducting frame is placed in a magnetic field B in such a way that the plane of the frame is perpendicular to the field lines. A conducting rod is supported on the parallel arms of the frame perpendicular to them and is given a velocity at time t = 0.

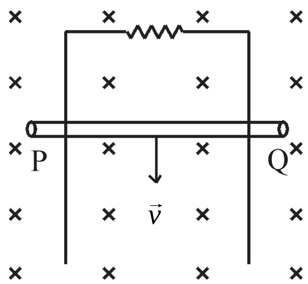
Induced *emf* $\varepsilon = Bvl$

Induced current $I = \frac{\varepsilon}{R} = \frac{Bvl}{R}$ (R is resistant of loop)

The magnetic force acting on rod to opposite direction of its velocity, $F_m = BIl = \frac{B^2l^2v}{R}$

Necessary mechanical power to keep constant velocity of rod PQ, $P_m = F_m v = \frac{B^2l^2v^2}{R}$

Electric power $P_e = I^2R = \frac{B^2l^2v^2}{R}$ Hence, $P_m = P_e$ (Mechanical power = Electric power)



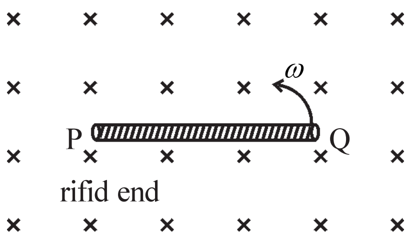
Motion of conducting rod in a vertical plane. If PQ conducting rod length l and mass m is released from rest (at t=0) as shown in figure. Force acting on PQ rod. Weight mg downward direction.

Lenz force $F_m = BIl$ (upward direction)

When rod achieve terminal velocity,

$$mg = BIl = \frac{B^2{v_t}^2l^2}{R} \quad (\text{ R is resistance})$$

$\therefore$ Terminal velocity $\Rightarrow v_t = \frac{mgR}{B^2l^2}$.



When a rod PQ of length l pivoted at one end P is rotated with angular velocity ω in a magnetic field B as shown in figure the induced emf between its end P and Q.

emf $\varepsilon = \frac{1}{2}B\omega l^2$.

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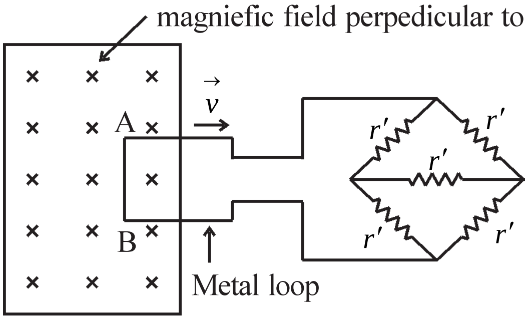
(17) A conducting bar of 5 m length is allowed to fall freely from a 100 m high tower keeping it aligned along east west direction. If rod remain horizontal in its motion then intensity of electric field produced at t = 4s is ...... Vm^{-1}. Take angle of dip 60° and horizontal component of earth's magnetic field if 0.7 G, $g = 10\ ms^{-2}$.

(A) 1.4 (B) 14 (C) 1.4×10^{-3} (D) 0.14

(18) A U shaped conducting frame is placed in uniform magnetic field of intensity 2 T in such a way that the plane of the frame is perpendicular to the filed. A conducting rod having length 10 cm and mass 40 g is supported on the parallel arms of the frame and is given a velocity v_0 at time t = 0 $\left(\vec{v} \perp \vec{B}\right)$. If resistance of rod is 10Ω and velocity v_t at time t = t. If ratio of $\left[\frac{v_t}{v_0}\right] = 0.3679$ then t = ... s.

(A) 0.1 (B) 2.718 (C) 1 (D) 10

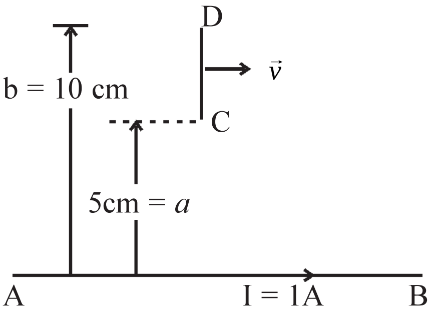
(19) A square metal wire loop of side 10 cm and resistance $2\ \Omega$ is moved with a constant velocity $40 \times 10^{-3}\ \mathrm{ms}^{-1}$ in a uniform magnetic field of induction $B = 2\ \mathrm{Wb\ m}^{-2}$ as shown in figure. The magnetic field is perpendicular to the plane of the loop and directed into the paper. The loop is connected to a network of resistors each of the value $r'\Omega$. what should the value of r' so that a steady current of 1×10^{-3} A flows in the loop.



(A) $3\ \Omega$ (B) $12\ \Omega$

(C) $6\ \Omega$ (D) $8\ \Omega$

(20) A metal rod CD, length of 5 cm moves with a velocity $2\mathrm{ms}^{-1}$ parallel to very long straight current carrying wire AB, as shown in figure. The nearest end of CD rod is at 5 cm from AB wire as shown in figure. The emf induced between the end C and D is .... and D behaves as a ...... electrode. $\left(\mu_0 = 4\pi \times 10^{-7}\ \mathrm{TmA}^{-1}\right)$



(A) 2.77 μV, positive (B) 2.77 mV, positive

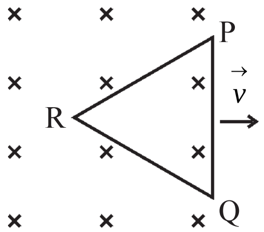
(C) 0.277 μV, negative (D) 2.77 V negative

(21) A metal rod PQ of length 0.3 m slides on parallel rails AB and CD, each rail having resistance of 0.02 Ω cm^{-1}. A resistance $R = 17\ \Omega$ is connected between end of rails A and C. The whole system kept perpendicular to the magnetic field B of 3.5×10^{-4} T. A variable force F is applied to rod PQ, so that it is accelerated and moves x distance apart right side from resistance R and obtain velocity of $2\ \mathrm{ms}^{-1}$. If induced current in loop is 100 μA then distance x ...... cm. (neglect the friction force).

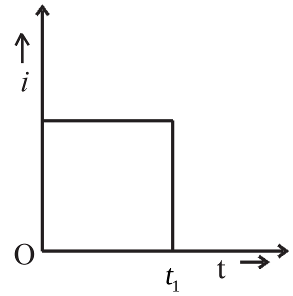
(A) 10 (B) 50 (C) 100 (D) 150

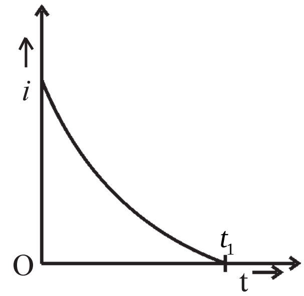
(22) A metal rod PQ of mass m = 50 g. and of negligible resistance slides on two parallel metal rails AB and CD seperated by a distance of 50 cm. The rail have negligible resistance and one side ends are connected by resistance R of 10Ω. The rails and rod are located in a region of uniform magnetic field of 2T and direction in to the plane of loop ACPQ. The rod is given an initial velocity of $4\ ms^{-1}$ to the perpendicular of magnetic field. The distance obtain by rod before it comes to rest after long time is .... (neglect friction force).

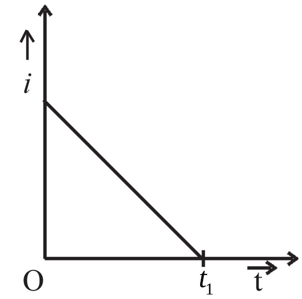
(A) 2 m (B) 4 m (C) Infinite (D) 6 m

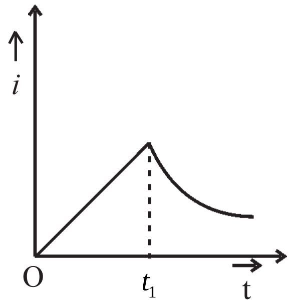
(23) 

An equilateral triangular loop PQR of side, a is at the edge of a uniform magnetic field B at $t = 0$ as shown in figure. It is pulled to the right with a constant velocity v and its edge R leaves the region of magnetic field at $t = t_0$. Which of the graphs represents the variation of induced current I with time ?

(A) 

(B) 

(C) 

(D) 

(24) When a rod of length 1m pivoted at one end is rotated horizontally with constant angular velocity of $5\ rad\ s^{-1}$ at one place. If vertical magnetic field of earth at such place is 0.2 G then 50 μV induce emf developed after ...... rotation is completed by rod.

(A) 0.5 (B) $\frac{1}{2}$ (C) $\frac{3}{4}$ (D) 1

(25) A wire in the form of a circular loop of radius 8 cm lies with its plane normal to a uniform magnetic field of 0.4 T. If the wire is pulled to make a square shape in the same plane in time t = 2 s, the induced emf in the loop will be ....

(A) 4.32×10^{-4} V (B) 8.64×10^{-4} V (C) 4.32 mV (D) 8.64 mV

(26) A square conducting loop of side 40 cm, mass 50 g and resistance $15\ \Omega$ free falls vertically and entering in uniform magnetic field of 2 T to directed perpendicular to the plane of loop. The height d through which the loop fall, so that it attains terminal velosity on entering the region of magnetic field, then d = ... (take g = 10 ms^{-2})

(A) 4 (B) 20.7 (C) 13.8 (D) 6.9

(27) A uniform metal rod is moving with a uniform velocity v parallel to a long straight wire carrying a current I. The rod is perpendicular to the wire with its ends at distance r_1 and r_2 $(\text{with } r_1 < r_2)$ from it. The emf induced in the rod is ....

(A) Zero (B) $\frac{\mu_0 Iv}{2\pi} ln\left(\frac{r_1}{r_2}\right)$ (C) $\frac{\mu_0 Iv}{2\pi} ln\left(\frac{r_2}{r_1}\right)$ (D) $\frac{\mu_0 I v}{4\pi}\left[1-\frac{r_2}{r_1}\right]$

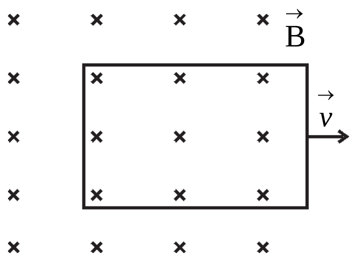
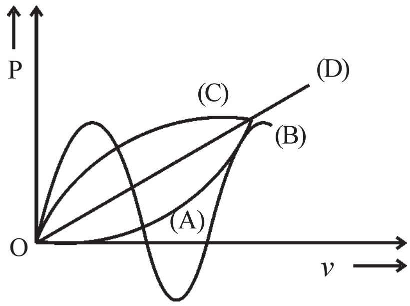
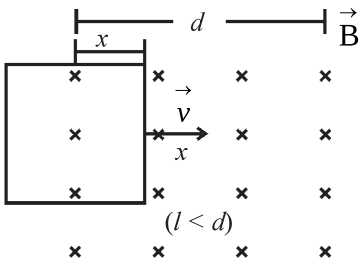
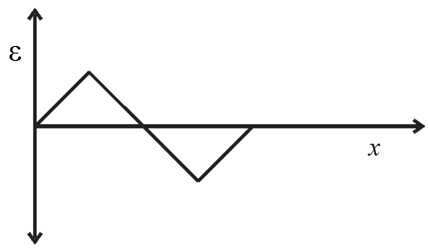
(28) 

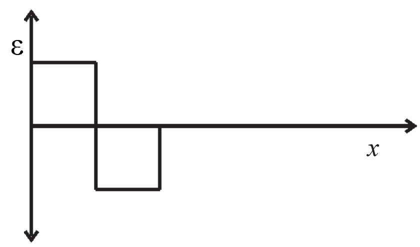
Figure shows a conducting loop being pulled out from a magnetic field with a velocity $\vec{v}$. Which of the four plots shown in bellow figure may represent the power delivered by the pulling agent as a function of the velocity v.

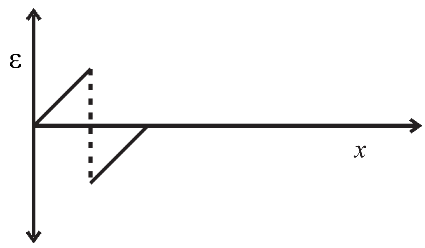


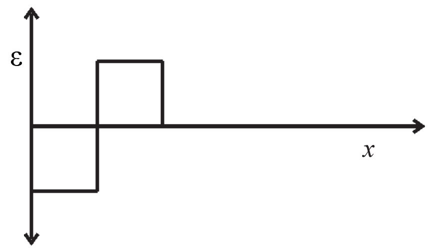
(29) 

A rectangular loop is being pulled at a constant speed v through a region of certain thickness d, in which a uniform magnetic field B is set up. The graph between position x of the right hand edge of the loop and the induced emf ε will be ....

(A) 

(B) 

(C) 

(D) 

(30) A simple pendulum of mass m and conducting wire of length 1 m oscillating under gravity through an angle 30° from its equillibrium position. The earth's magnetic field component perpendicular to simple pendulum is 0.35×10^{-4} T. Maximum potential difference induced across the pendulum is ...... μV (take $g = 10 \text{ ms}^{-2}$)

(A) 57 (B) 114 (C) 28.5 (D) 85.5

Ans. : 17 (C), 18 (D), 19 (C), 20 (C), 21 (C), 22 (A), 23 (C), 24 (D), 25 (B), 26 (D), 27 (C) 28 (A), 29 (D), 30 (A)

Self Inductance :

- Inductance is that property of electrical circuits which oppose any change in the currert in the circuit.
- Inductance is the electro-magnetic analogue of mass (m) in mechanics
- Its symbol is L.

Units of L : $\dfrac{\text{weber}}{\text{amp}} = \dfrac{\text{tesla m}^2}{\text{amp}} = \dfrac{\text{N m}}{(\text{amp})^2}$

$\dfrac{\text{joule}}{(\text{amp})^2} = \dfrac{\text{coulomb volt}}{(\text{amp})^2} = \dfrac{\text{volt sec}}{\text{amp}} = \text{ohm sec}$

But practical unit is henry (H)

Dimensional formula $[\text{L}] = \text{M}^1\text{L}^2\text{T}^{-2}\text{A}^{-2}$

Equation : $\text{L} = \dfrac{N\Phi}{I}$ N = number of turns, Φ = linked magnetic flux per turns

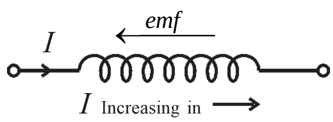
I = current, L = Inductance

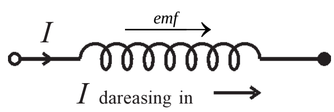
Remember : Magnetic flux $\phi = \oint \text{BA}\cos\theta$.

- Circular loop : $\text{L} = \dfrac{\mu_0 \pi N^2 r}{2}$ N = number of turns, r = radius of coil
- For solenoid : $\text{L} = \dfrac{\mu_0 \text{N}^2\text{A}}{l}$ A = cross section area of solenoid

  N = number of turns, l = length of solenoid
- For Torroid : $\text{L} = \dfrac{\mu_0 \pi \text{N}^2 r}{2}$ r = Axial radius of torroid
- Current carrying square loop, $\text{L} = \dfrac{2\sqrt{2}\,\mu_0 \text{N}^2 a}{\pi}$ a = length of square loop
- For coaxial cylinder : $\text{L} = \dfrac{\mu_0}{2\pi} ln\left[\dfrac{r_2}{r_1}\right]$ $r_2 > r_1$: r_1 and r_2 are radius of cylinder
- Self induscent : $\varepsilon = -\text{L}\dfrac{dI}{dt}$

  Self induced current opposes any change in the current in a circuit.





Energy stored in induction

$\text{U} = \dfrac{1}{2}\text{L}I^2$

Energy stored per unit volume of long solenoid called magnetic energy density

$\rho_B = \dfrac{\text{B}^2}{2\mu_0}$

- **Mutual inductance :**

  If two conducting coils are kept close to eachother and a steady current I passed through one coil, magnetic flux links with the other coil $\Phi = MI$.

  Where, M = mutual inductance of the system formed by two coils.

  If the current flowing through the current carrying coil is changed an *emf* is induced in the second coil.

  $\varepsilon_2 = -M_{21}\dfrac{dI_1}{dt}$ $\qquad$ $\dfrac{dI_1}{dt}$ = time rate of changing current, M = mutual inductance

Note : Units of self inductance and mutual inductance are same.

Equation :

The system of two co-axial solenoid wounding on eachother of length l and having tarns N_1 and N_2.

$$M = \frac{\mu_0 N_1 N_2}{l}A \qquad \text{where A = common cross section area}$$

- The system of two cocentric and co-planner circular loop having radius R and r $(r << R)$

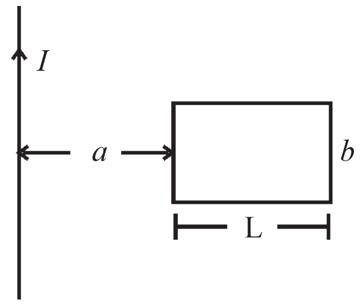
$$M = \frac{\mu_0 \pi r^2}{2R}$$

- The system a small circular coil of radius r at the centre of a large rectangular coil of sides a and b with $a,\ b >> r$.

$$M = \frac{2\mu_0 r^2\sqrt{a^2+b^2}}{ab} \quad a,\ b >> r.$$

- A rectangular loop of length L and width b placed at a distance a from a long straight wire shown in figure.

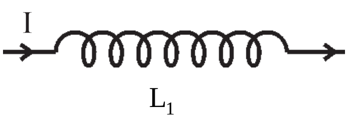
$$M = \frac{\mu_0\ Ib}{2\pi}\ ln\left(\frac{L+a}{L}\right)$$

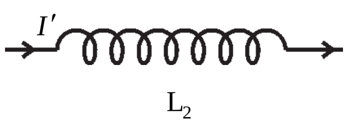


- **Connection of inductor :**

  * Series connection : $L_s = L_1 + L_2$

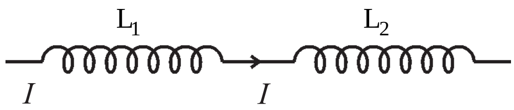
  (when two coil are situated far away to eachother)





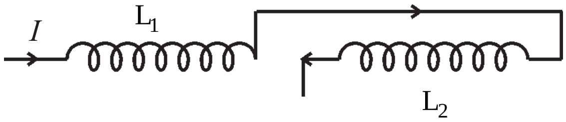
  * When two coils one situated closed to eachother and current passing through both coil in same direction.

$\rightarrow L_s = L_1 + L_2 + 2M$



* When two coils are situated closed to eachother and current passing through both coil in opposite direction

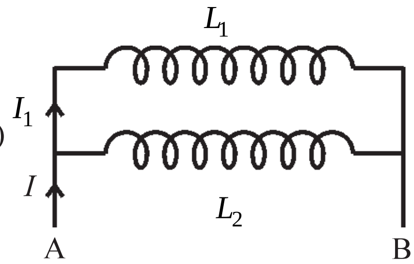
$\rightarrow L_s = L_1 + L_2 - 2M$



- **Parallel connection :**

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} \quad \text{or} \quad L_P = \frac{L_1 L_2}{L_1 + L_2} \qquad (\text{where } M = 0)$$

(Both coils far eway from each other)



* Both coils situated closed to eachother

$$L_P = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$$

- Relation between M, L_1 and L_2

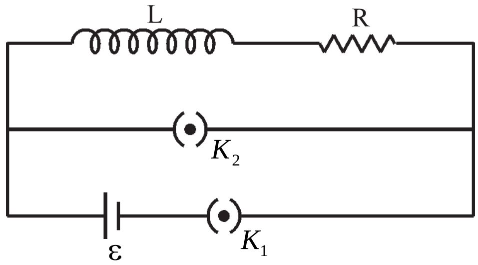
  $M = k\sqrt{L_1 L_2}$

  Where k = co efficient of connection

  $$k = \frac{\text{Magnetic fulx linked with secondary coil}}{\text{magnetic flux linked with primary coil}}$$

  $$0 \le k \le 1$$

- Growth and decay of current in L – R circuit.



Ideal inductor of inductance L and ideal resistor of resistance R connected in series with cell of emf ε shown in figure.

- If switch K_1 is closed at time $t = 0$ with switch K_2 open.

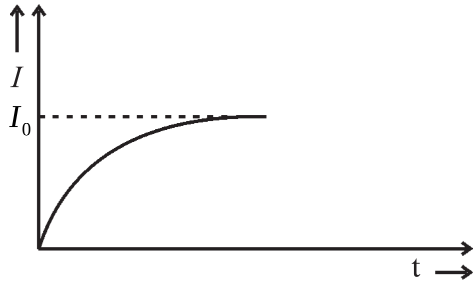
  The current start increasing in inductor with time t is given by

  $\rightarrow I_t = I_0\left(1 - e^{\frac{-t}{\tau}}\right)$ Where $\tau = \frac{L}{R}$ time constant. Its unit is s.

- After a long time $(t = \infty)$ the current attains a steady value $I_0 = \frac{E}{R}$

- At $t = \tau$, $I = I_o\left(1 - \frac{1}{e}\right) = 0.632\ I_0$

  Graph of $I \to t$



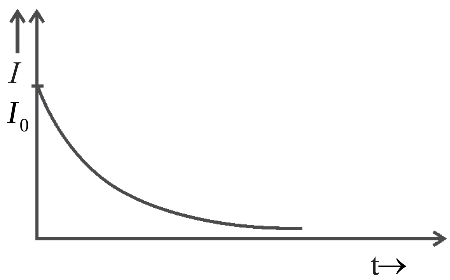
Decay of current

- At time $t = o$, let $I_o = \frac{E}{R}$ be the current in the circuit. If K_2 is closed (with K_1 open) the current decaye as

  $I = I_0 \cdot e^{-\frac{t}{\tau}}$ $\quad\quad \tau = \frac{L}{R}$ time constant

  $t = \tau$,

  $I = \frac{I_o}{e} = 0.368\ I_0$



  Graph of $I \to t$

Note : Here inductance and resistor are ideal means inductor having zero resistance and resistor having zero inductance.

---

(31) A solenoid 1.0 m long and 5 cm diameter has 1000 turns. Another solenoid of 100 turns is tightly would over the first solenoid. When the current in the first solenoid changes from 0 to 5A in 10 ms. The induced emf in the second selonoid will be ...... $\left(\mu_0 = 4\pi \times 10^{-7}\ \text{TmA}^{-1}\right)$

(A) 1.25 *m*V (B) 0.125 *m*V (C) 12.5 *m*V (D) 125 *m*V

(32) An ideal inductor of inductance 5 H and pure resistor of resistance 100 Ω are connected in series to a battery of emf 6 V of negligible internal resistance through a switch. The switch is closed at time $t = 0$. Time is taken for the current to rise to 50% of the maximum .... and after 0.1 s potential different across the inductor will be ....

(A) 34.6 *m*s, 8 *m*V (B) 69.3 *m*s, 80 *m*V (C) 69.3 *m*s, 0.8 *m*V (D) 34.6 *m*s, 0.8 V

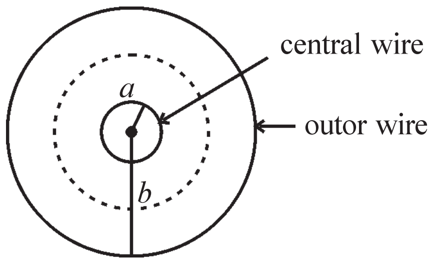
(33) An inductor of inductance 100 *m*H and resistor of resistance 24 Ω are connected to a 18 V DC source when steady current flows in circuit at that time energy stored in inductor and dissipated power in resistor respectively are ...... J and ...... W.

(A) 2.8, 135 (B) 0.14, 6.75 (C) 0.028, 13.5 (D) 1.4, 67.5

(34) An inductor of inductance of 100 mH and resistor of resistance $50\ \Omega$ are connected in series to a 2 V DC battery. After some times the current attains a steady value. The battery is now short circuited the time required for the current to fall of half the steady value is ....

(A) 1.386 s (B) 13.86 s (C) 1.386 ms (D) 13.86 ms

(35) A cross section of co-axial cable having length 100 m and central wire radii of $a = 1$ mm shown in figure is normal to the palne of paper. Current of 2 A is passing through the central wire as well as cylindrical layer of co-axial cable in mutually opposite direction. The magnetic flux linked between area of two wire and self induction of cable are ...... Wb and ...... μH respectively. $\left(\mu_0 = 4\pi \times 10^{-7}\ \text{TmA}^{-1}\right)$



(A) $6.44 \times 10^{-5}, 32.2$ (B) $1.61 \times 10^{-5}, 161$

(C) $6.44 \times 10^{-3}, 3.22$ (D) $1.61 \times 10^{-3}, 0.805$

(36) A solenoid of length 2 m and 2000 turns having diameter is 6 cm. If 2 A steady current passing through solenoid then magnetic energy and density of magnetic energy link with it will be ...... J and ...... Jm^{-3} respectively. $\left(\mu_0 = 4\pi \times 10^{-7}\ \text{TmA}^{-1}\right)$

(A) $28.4 \times 10^{-3}, 5.02$ (B) $14.2 \times 10^{-3}, 2.51$

(C) $7.1 \times 10^{-3}, 1.25$ (D) $1.42 \times 10^{-3}, 0.251$

(37) A square big loop made from thin wire of length 20 m. Another small square loop of length 0.4 cm is kept coplanes and concentric with big loop. If 2A current passing through big loop then mutual inductance of the system will be ....$\left(\mu_0 = 4\pi \times 10^{-7}\ \text{TmA}^{-1}\right)$

(A) 1.44×10^{-7} H (B) 14.43 mH (C) 3.6×10^{-1} mH\` (D) $3.6 \times 10^{-6}\ \mu$H

(38) A conducting small loop of diameter 10 cm and having 10 turns is placed coplaner and concentric with big loop of diameter 10 m. If 2 A current passing through big loop then mutual inductance of the system is ....$\left(\mu_0 = 4\pi \times 10^{-7}\ \text{TmA}^{-1}\ \pi^2 = 10\right)$

(A) 100 mH (B) 1×10^{-3} H (C) 1×10^{-8} H (D) 1×10^{-3} mH

(39) A toroidal ring has cross section radius 4.0 cm and axial diameter 40 cm is having wounding turns 3×10^4. The self inductance of ring will be .... $\left(\mu_0 = 4\pi \times 10^{-7}\ \text{TmA}^{-1}\right)$

(A) 0.57 H (B) 4.52 H (C) 5.1 H (D) 0.452 H

(40) A coil having 100 turns length of 10 cm and radius of cross section area is 2 cm. When 1 Amp current passing through coil linked magnetic flux is 5×10^{-5} Wb. Then stored energy density in coil will be ...... Jm^{-3}.

(A) 0.5 (B) 5 (C) 1.99 (D) 19.9

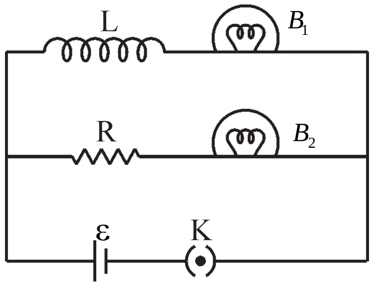
(41) The self inductance of a loop having radius 10 cm and 1000 turns will be ......
.$\left(\mu_0 = 4\pi \times 10^{-7} \text{ TmA}^{-1}, \pi^2 = 10\right)$

(A) 2 mH (B) 0.2 H (C) 20 mH (D) 2 H

(42) Two coils of self inductance L_1 and L_2 are placed closer to each other so that total flux is one coil is completely linked with other. If M is mutual inductance between them, then M = ...

(A) $L_1 L_2$ (B) $\frac{L_1}{L_2}$ (C) $(L_1 L_2)^2$ (D) $\sqrt{L_1 L_2}$

(43) An inductor L, a resistance R and two identical bulbs B_1 and B_2 are connected to a battery through a switch shown in figure gives the correct description of the happening when the switch k is closed ....



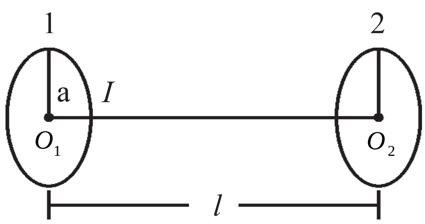
(A) B_1 and B_2 light up together with equal brightness all the times.

(B) B_2 lights up earlier and finally B_1 shines brighter than B_2.

(C) B_1 light up earlier and finally both the bulbs acquire equal brightness.

(D) The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright.

(44) In the fig. two coplaner and coaxial loop of radius 5 cm, their centers aepart 5 m from eachother. The mutual inductance of system when 2 A current passing through one loop is ...... μH .$\left(\mu_0 = 4\pi \times 10^{-7} \text{ TmA}^{-1}, \pi^2 = 10\right)$



(A) 10^{-7} (B) 10^{-5}
(C) 10^{-6} (D) 10^{-3}

(45) If current of L – R, DC circuit in 4 s is 75 % of steady current. Then ratio of $\frac{L}{R}$ = ... s.

(A) 1.44 (B) 2.88 (C) 5.76 (D) 3.84

Ans. : 31 (D), 32 (D), 33 (C), 34 (C), 35 (A), 36 (B), 37 (D), 38 (C), 39 (B), 40 (D), 41 (C) 42 (D), 43 (C), 44 (A), 45 (B)

AC Generater / Dynamo

- **Principle :** Electro magnetic induction

  Construction : A coil consist of large number of turns N of insulated Copper wire wound over a soft iron core.

  - Uniform magnetic field produced by permenent magnetic pole.
  - The coil rotates about its axis with constant angular velocity ω. Area vector is $\vec{A}$.
  - The two ends of coil are connected to slip ring and induced emf produced between two brushes. Which are passed against the slip ring.   where

Magnetic flux at time t, Φ_t = NAB $\cos\omega t$ | ω = angular slip, N = number of turns

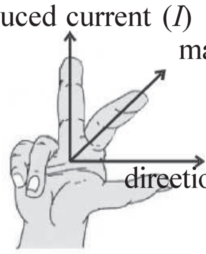
Induced *emf* V = $\frac{-d\Phi_t}{dt}$ = NAB ω $\sin\omega t$ | A = surface area of coil

= $V_m \sin\omega t$ | B = magnetic field

V_m = NAB ω

Voltage V changing with time according to sine function. If at time t = 0 the plane of coil parallel to magnetic field the indus emf given by, $V = Vm \cos\omega t$.

- The direction of the induced emf of the current in the coil is detemine by the Fleming's right hand rule.



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(46) A coil having N turns and surface area A is rotates about it axis with constant angular velocity of $50\frac{\pi}{2}$ rad s^{-1} in uniform magnetic field B. The magnetic flux linked with it at time t is given by Φ_t = NAB $\cos\omega t$. During what minimum time the voltage becomes maximum ?

(A) 2×10^{-3} (B) 2×10^{-2} (C) 2 (D) 2×10^{-1}

(47) If 2 A current passing through an AC generator of 40 W power and terminal voltage is 200 V. Then produced emf ...... V.

(A) 160 (B) 220 (C) 240 (D) 180

(48) In AC generator Induced emf is maximum at time t = 0, The induced emf becomes zero at minimum time t = 50 *m*s. Then angular speed of AC generator is ...... rad s^{-1}.

(A) 10 π (B) 5 π (C) 100 π (D) 50 π

(49) The value of the AC voltage of a generator V = V_m = 4 V at t = 0. At time $t=\frac{1}{2\pi}$ second the voltage V = 3.464 V. The voltage keep decreasing up to zero. The frequency of the generator is ...... H_Z.

(A) 1 (B) 10 (C) 0.5233 (D) 60

(50) A voltage produced in AC dynamo is given by $V = 120\sin(100\pi t)\cos(100\pi t)$. Where t is in second and V is in volt. Maximum voltage and frequency of it will be ...... and ...... respectively.

(A) 120 V, 100 Hz (B) 120 V, 50 Hz (C) 60 V, 100 Hz (D) 60 V, 50 Hz

Ans. : 46 (B), 47 (B), 48 (A), 49 (C), 50 (C)

Eddy Currents

Whenever a solid conductor is kept in a region of varying magnetic field the magnetic flux linked with the conductor changes and induced *emf* is produced by induction. As a result circulatory currents are inducced in the plane normal to the direction of flux. These currents are distributed through out the conductr. These are known as Eddy currents. because of their circulatory nature.

Eddy currents were first observed by physicist Foucault.

When a conductor rotates in a uniform magnetic field, then also eddy currents are produced in it.

Disadvantage of Eddy Current :

- The electric energy dissipate in the form of heat energy in metallic plate due to eddy current.
- A metellic plate is allowed to oscillate like a simple pendulum between two pole pices of a strong magnet. The oscillations of the plate is damped is calleel electromagnetic damping.

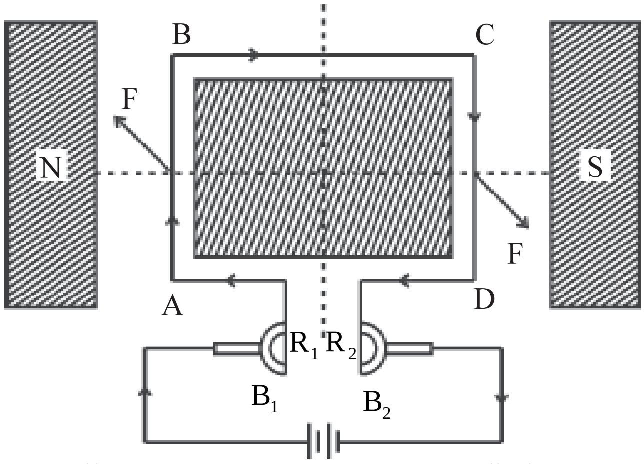
Uses of Eddy Current :

- Eddy currents are undisiarable although it is used in induction Furnace, Speedometer, Electric brakes, Electric power meters.
- To reduce the effect of eddy currents a laminated core instead of a single solid piece of iron is used. Many time ractenguler slots one made metal plate to reduce of Eddy current.

- **DC Moter**

Principle : A current carrying coil placed in the magnetic field experience a torque. The torque rotates the coil.

Construction and Figure :



- ABCD Armature coil — $R_1 R_2$ Slipring comutator

  B_1 and B_2 = carbon brushes — N,S = Strong magnetic poles.

- **Working :**

Force on any arm of the coil is given by $\vec{F} = I\left(\vec{l} \times \vec{B}\right)$, from figure force on AB will be perendicular to plane of the paper and pointing inwords. Force on CD will be equal and opposite. So coil rotates in clockwise seen when viewed from top in figure. The current in AB reverses due to communication keeping the force on AB and CD in such a direction that the coil continues to rotate in the same direction.

- **Back *emf* :**

  Due to the rotation of armature coil in magnetic field a back *emf* is induced in the circuit. It is given by $\varepsilon = E - IR$

  back *emf* $\varepsilon = E - IR$ $\quad \varepsilon$ = Applying DC Voltage

  R = Resistance of armature coil

  $E = NBA\omega \sin \omega t =$ Induced *emf*

  back *emf*, $\varepsilon \alpha \omega$ or

  $\therefore \ \varepsilon = k\omega$ (B, N and A are constant.)

  Current in the DC motor :

$$I = \frac{E - \varepsilon}{R} = \frac{E - k\omega}{R}$$

  When motor is just switched on $\omega = 0$ so e = 0, Hence $I = \frac{E}{R}$ = maximum

  When time starts a large current flows through the motor which may burn it out. Hence a starter is used for starting a DC motor safely.

  Efficiency of DC motor :

$$\text{Efficiency } \eta = \frac{P_{mechanical}}{P_{supplied}} = \frac{P_{out}}{P_{input}} = \frac{e}{E} = \frac{\text{Back } emf}{\text{Supply Voltage}}$$

- **Use of DC Motors :**

  They are used in electric locomotives, electric cars, rolling mills, electric cranes, electric lifts, DC drills, fans and blowers, centrifugal pumps and air compressor etc.

---

(51) Which of the following is not an application of eddy currents ________.

(A) Induction furnace (B) X–ray crystallography

(C) Galvanometer damping (D) Speedometer of automobiles.

(52) The pointer of a dead – beat galvanometer gives a steady deflection because ________.

(A) Its frame is made of abonite.

(B) Its pointer is very light

(C) Its magnet is very strong

(D) Eddy currents are produced in the conducting frame over which the coil is wound.

(53) Eddy currents are produced when ________.

(A) A metal is kept in varying magnetic field.

(B) A metal is kept in the steady magnetic field.

(C) Through a circuler coil currents is passed.

(D) A circular coil is placed in a magnetic field.

(54) When the speed of a DC motor increases the armature current ....

(A) Increases (B) Does not change

(C) Decreases (D) Increases and decreases continously.

(55) Back *emf* 2 V of DC dynamo of rotational velosity is ω_1. If rotational velocity tripple then back *emf* will be ________.

(A) 2 (B) 6 (C) 0.66 (D) 18

(56) A DC generator with fixed field excilation developes as *emf* of 100 V. When oprating at 1500 rpm. At what speed must it rotate to develop 120 V in rpm.

(A) 1200 (B) 800 (C) 750 (D) 1800

(57) The armature of DC motor has $20\ \Omega$ resistance. It draws current of 1.5 ampere, when run by 200 V DC supply. The value of back *emf* induced in it will be ________ V.

(A) 250 (B) 220 (C) 170 (D) 180

(58) An electric motor operates on a 50 V supply and a current of 7 A. If the effeciency of the motor is 30 %. The resistance of the winding of the motor is ________ Ω.

(A) 9.4 (B) 2.9 (C) 5 (D) 8

Ans. : 51 (B), 52 (D), 53 (A), 54 (C), 55 (B), 56 (D), 57 (C), 58 (C)

Assertion - Reason type Question :

Instruction : Read assertion and reason carefully, select proper option from given below.

(a) Both assertion and reason are true and reason explains the assertion.

(b) Both assertion and reason are true but reason does not explain the assertion.

(c) Assertion is true but reason is false.

(d) Assertion is false and reason is true.

(59) **Assertion :** No induced *emf* is developed across the ends of a conductor, if it is moved parallel to a magnetic field.

Reason : No force acts on the free electrons of the conductor.

(A) a (B) b (C) c (D) d

(60) **Assertion :** A rectangular loop and a circular loop are moved with a constant velocity from a region of magnetic field out into a field free region. The field is normal to the loops. Then a constance *emf* will be induced in the circular loop and a time-varying emf will be induced in the rectangular loop.

Reason : The induced *emf* is constant if the magnetic flux changes at a constant rate.

(A) a (B) b (C) c (D) d

(61) **Assertion :** A magnetised iron bar is dropped vertically through a hollow region of a thick cylindrical shell made of Copper. The bar will fall with an acceleration less than g, the acceleration due to gravity.

Reason : The emf induced in the bar causes a retarding force to act on the falling bar.

(A) a (B) b (C) c (D) d

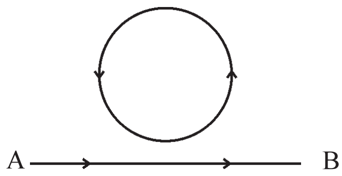
(62) **Assertion :** A coil is connected in series with a bulb and this combination is connected to a d.c. source. If an iron core is inserted in the coil, the brightness of the bulb will increases.

Reason : The reactance offered by the coil to d.c. current is zero

(A) a (B) b (C) c (D) d

(63) **Assertion** : If the current in a straight conductor increases from A to B the diraction of the current induced in the coil will be anticlockwise.

Reason : According to Lenz's law, the direction of the induced current is such that it oppose the change which produces it.



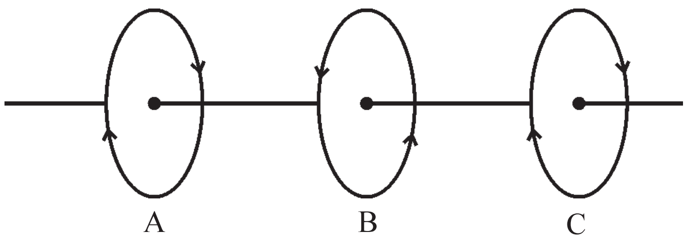
(A) a (B) b
(C) c (D) d

(64) **Assertion** : An emf can be induced between the two ends of a straight Copper wire when it moved through a uniform magnetic field.

Reason : As the straight wire moves through the magnetic field the magnetic flux through the wire changes.

(A) a (B) b (C) c (D) d

(65) **Assertion** : Three identical coils A, B and C are placed with their planes parallel to one another. Coils A and C carry equal currents as showing in figure. If coil A is moved towards B, with coils B and C fixed in position the induced current in B will be in the anticlockwise direction.



Reason : The direction of the induced current is given by Lanz's law.

(A) a (B) b (C) c (D) d

(66) **Assertion** : A coil of metal wire is kept stationary in a non-uniform magnetic field. An emf is induced in the coil.

Reason : Whenever the magnetic flux through a metal coil changes an emf is induced in it.

(A) a (B) b (C) c (D) d

(67) **Assertion** : If a conducting rod moves in X-axis and to parallel to Y-axis in uniform magnetic field B pointing in the positive Z direction the end of rod near to X -axis gets positive charge.

Reason : The free electrons in the rod experiance a force in positive Y direction.

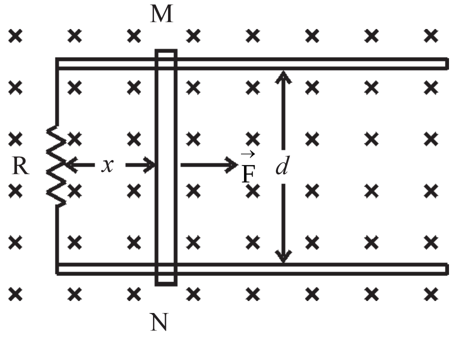
(A) a (B) b (C) c (D) d

Ans. :59 (A), 60 (D), 61 (A), 62 (D), 63 (D), 64 (C), 65 (A), 66 (D), 67 (A)

Comprehension Type Questions :

Paragraph 1 :

Two long parallel horizontal rails, distanse *d* apart and each having a resistance λ per unit lenght, are joined at one end by resistance R. A perfectly conducting rod MN of mass m is free to slide along the rails without friction, shown in figure. There is a uniform magnetic field of induction B normal to the plane of the paper and direction into the paper. A variable force F is applied to the rod MN such that as the rod moves, constant current flows through R.



(68) The magnitude of the induced *emf* in the loop is = ________

(A) $Bvd\left(\frac{2\lambda x}{R}\right)$ (B) $Bvd\left(\frac{R}{2\lambda x}\right)$ (C) Bvd (D) $\frac{1}{2}Bvd$

(69) The current in the loop is I = ________

(A) $\frac{Bvd}{R}$ (B) $\frac{Bvd}{2\lambda x}$ (C) $\frac{2Bvd}{(R+2\lambda x)}$ (D) $\frac{Bvd}{(R+2\lambda x)}$

(70) The velocity of the rod MN is v = ________

(A) $\frac{B^2d^2}{2\lambda m}\left(1+\frac{2\lambda x}{R}\right)$ (B) $\frac{B^2d^2}{R}\left(1-\frac{R}{2\lambda x}\right)$

(C) $\frac{B^2d^2}{2\lambda m}\log e\left(1-\frac{R}{2\lambda x}\right)$ (D) $\frac{B^2d^2}{2\lambda m}\log e\left(1+\frac{2\lambda x}{R}\right)$

Paragraph 2 :

A pair of parallel horizontal conductiog rails of negligible resistance shorted at one end is fixed on a table. The distance between the rail is L. A conducting massless rod of resistance R can slide on the rail without friction. The rod is tide to a massless string which passes over a pully fixed to the edge of the table. A mass m tide to the other end of string, hangs vertically. A constant magnetic field B exists perpendicular to the table. The system is released from rest.

(71) The acceleration of the mass m moving in the downward direction is ________

(A) g (B) $\frac{B^2L^2v}{mR}$ (C) $\left(g-\frac{B^2L^2v}{mR}\right)$ (D) $\left(g+\frac{B^2L^2v}{mR}\right)$

(72) The terminal velocity attained by the rod is = ________

(A) g (B) $\sqrt{gR}$ (C) $\frac{\sqrt{mgR}}{BL}$ (D) $\frac{mgR}{B^2L^2}$

(73) The acceleration of mass m when the velocity of the rod is half of the terminal velocity is ________

(A) g (B) $\frac{g}{2}$ (C) $\frac{g}{3}$ (D) $\frac{g}{4}$

Paragraph 3 :

An infinitesimally small bar magnet of dipole moment M is pointing on X-axis at a distance x from origin O and moving with a speed v in the x-direction. A small closed circular conducting loop of redius a, resistance R and negligible self inductance lies in the yz palne with its centre at x = 0 and its axis coinciding with the x-axis.

(74) The magnitude of magnetic field at a distance x on the axis of the short bar magnet is ________

(A) $\frac{\mu_0 M}{2\pi x}$ (B) $\frac{\mu_0 M}{2\pi x^2}$ (C) $\frac{\mu_0 M}{2\pi x^3}$ (D) $\frac{\mu_0 M}{2\pi x^4}$

(75) If $x = 2a$, the magnetic flux through the loop is ________

(A) $\mu_0 M$ (B) $\frac{\mu_0 M}{2}$ (C) $\frac{\mu_0 M}{4a}$ (D) $\frac{\mu_0 M}{16a}$

(76) If $x = 2a$, then associated magnetic flux ϕ in loop, ________

(A) $\frac{3\mu_0 Mv}{16\,a^2}$ (B) $\frac{3}{32}\frac{\mu_0 Mv}{a^2}$ (C) $\frac{1}{8}\frac{\mu_0 Mv}{a^2}$ (D) $\frac{1}{16}\frac{\mu_0 Mv}{a^2}$

(77) If $x = 2a$ the magnetic moment of the loop is ________

(A) $\frac{3\pi\,\mu_0\ Mv}{32R}$ (B) $\frac{3\pi\,\mu_0\ Mv}{8R}$ (C) $\frac{\pi\mu_0 Mv}{2R}$ (D) $\frac{3\pi\,\mu_0 Mv}{4R}$

Paragraph 4 :

Two co-axial circular coils of radii R and $\frac{R}{100}$ are seperated by a distance $x = \sqrt{3}R$ and carry currents $I_1 = 2I$ and $I_2 = I$ respectively.

(78) The magnetic field at the center of the smaller loop due to current $I_1 = 2I$ in the bigger loop is ________

(A) $\frac{\mu_0 I}{R}$ (B) $\frac{\mu_0 I}{4R}$ (C) $\frac{\mu_0 I}{8R}$ (D) $\frac{\mu_0 I}{3R}$

(79) The magnetic flux (Φ) linked with the smaller loop is ________

(A) $\frac{5\pi\mu_0 IR}{4}\times 10^{-5}$ (B) $\pi\,\mu_0 IR\times 10^{-5}$ (C) $\frac{3\pi\,\mu_0 Ir}{4}\times 10^{-5}$ (D) $\frac{\pi\mu_0 IR}{2}\times 10^{-5}$

(80) The mutual inductance of the pair of coil is ________

(A) $\frac{\Phi}{I}$ (B) $\frac{2\Phi}{I}$ (C) $\frac{\Phi}{2I}$ (D) zero

(81) If M and m are the magnetic moment of the bigger and smaller loops respectively then the ratio $\frac{M}{m}$ is ________

(A) 10^4 (B) 2×10^4 (C) 10^2 (D) 2×10^2

Ans. : 68 (C), 69 (D), 70 (D), 71 (C), 72 (D), 73 (B), 74 (C), 75 (D), 76 (B), 77 (A), 78 (C), 79 (A), 80 (A), 81 (B)

Match the columns :

(82) In column **1** are listed unit's of some quantites. Match their dimantional formula listed in column **2**.

Column-1		Column-2	
(a)	$\frac{\text{newton}}{\text{ampere-meter}}$	(p)	$M^1 L^o T^{-2} A^{-1}$
(b)	henry	(q)	$M^1 L^o T^{-2} A^{-1}$
(c)	weber	(r)	$M^1 L^2 T^{-2} A^{-2}$
(d)	tesla	(s)	$M^1 L^2 T^{-2} A^{-1}$

(A) a – q b – p c – r d – s

(B) a – s b – p c – r d – q

(C) a – r b – q c – p d – s

(D) a – p b – r c – s d – q

(83) In column-1 are listed two inductors of inductance 10 *m*H and 40 *m*H are connected in different types of connection. Equivalent inductance of such connection are listed in column-2. Match column-1 and column-2. Constant of connection k = 0.3.

Column-1		Column-2	
(a)	Flux linked with the both inductor in same direction and nearest to eachother. When L_1 and L_2 connected in parallel	(P)	38×10^{-3} H
(b)	Flux linked with the both inductor in opposite direction when L_1 and L_2 connected in series.	(Q)	8×10^{-3} H
(c)	Flux linked with the both inductor in same direction when L_1 and L_2 connected in series	(R)	62×10^{-3} H
(d)	Both inductor connected in parallel and far away from eachother.	(S)	0.8×10^{-3} H
		(T)	5.8×10^{-3} H

(A) a – S, b – P, c – Q, d – R

(B) a – T, b – P, c – R, d – Q

(C) a – R, b – T, c – S, d – Q

(D) a – P, b – T, c – Q, d – R

Ans. : 82 (D), 83 (B)

●

A.C. Current

- **AC GENERATOR :**

Principle : Electro magnetic induction

Construction : A coil having N turns will rotates about it axis which is parallel to its palne and perpendicular to uniform magnetic field is setup.

- The two end of the coil are connected to an external circuit by means of slipring and brushes.
- When the coil rotates in the uniform magnetic field. It cuts the magnetic lines of force and flux linked with the coil changes accorded to $\cos\omega t$ (At time $t = 0, \theta = 0$),

  The emf induced $V = BAN\,\omega \sin \omega t$

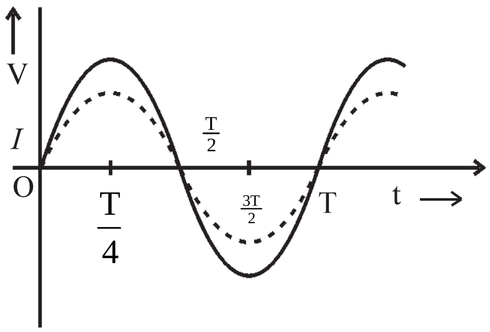
  $$= V_m \sin\omega t$$

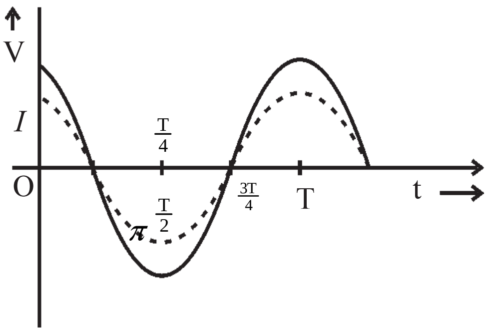
  Current $I = I_m \sin \omega t$

  Where $I_m = \frac{V_m}{R}$

- Hence the induced emf and induced current in the coil varies with time as per the function of sine. Here voltage obtain between brushes is called AC voltage.
- AC voltage or current increases-decreases and its direction change with time according to the function.

Time with referance to periodictime	$V = V_m \sin \omega t$	$I = I_m \sin\omega t$	$V = V_m \cos \omega t$	$I = I_m \cos \omega t$
$t = 0$	$V = 0$	$I = 0$	$V = V_m$	$I = I_m$
$t = \frac{T}{4} = \frac{\pi}{2\omega}$	$V = V_m$	$I = I_m$	$V = 0$	$I = 0$
$t = \frac{T}{2} = \frac{\pi}{\omega}$	$V = 0$	$I = 0$	$V = V_m$	$I = I_m$
$t = \frac{3T}{4} = \frac{3\pi}{2\omega}$	$V = V_m$	$I = I_m$	$V = 0$	$I = 0$
$t = T = \frac{2\pi}{\omega}$	$V = 0$	$I = 0$	$V = V_m$	$I = I_m$





Remember : The average value of AC current and voltage is zero during single periodic time (T).

- **L–C–R series AC circuit :**

An ideal inductor (L) having zero ohmic resistance, a capacitor with capacitance (C) and a resistor (R) with zero inductance are joined in series with the source of A.C voltage called AC series circuit.

For this circuit,

At some time t current passing through the circuit $I(t) = \frac{dQ}{dt}$, the rate of the change of the current $\frac{dI}{dt} = \frac{d^2Q}{dt^2}$

Charge $Q = Idt$

The potential difference between two ends of resistor is $V_R = I_t R$

The potential difference between two ends of inductor $V_L = -L\frac{dI}{dt} = -L\frac{d^2Q}{dt^2}$

Potential different between two ends of capacitor is $V_c = \frac{Q}{C}$

$$V_m \cos \omega t = V_L + V_C + V_R$$

The differential equation of current :

$$\frac{dI}{dt} + \frac{R}{L} I + \frac{1}{LC}\int I\, dt = \frac{V_m}{L}\cos \omega t$$

The differential equation for the charge :

$$\frac{d^2Q}{dt^2} + \frac{R}{L}\frac{dQ}{dt} + \frac{Q}{LC} = \frac{V_m}{L}\cos \omega t$$

- **This differential equation resemble with the equation**

$$\frac{d^2y}{dt^2} + \frac{b}{m}\frac{dy}{dt} + \frac{k}{m}y = \frac{F_o}{m}\sin \omega t\,.$$

Equivalence between the Mechanical and Electrical Quantities :

Number	Mechanical Quantity	Electrical Quantity
(1)	Displacement (y)	Electric change (Q)
(2)	Velocity $\left(\frac{dy}{dt} = v\right)$	Eleatric current $\left(\frac{dQ}{dt} = I\right)$
(3)	Resistive coefficient (b)	Resistance (R)
(4)	Mass (m)	Inductance (L)
(5)	Force constant (k)	Inverse of capacitance $\left(\frac{1}{\text{C}}\right)$
(6)	Angular frequency $\left(\sqrt{\frac{k}{\text{m}}}\right)$	Angular frequency $\left(\sqrt{\frac{1}{\text{LC}}}\right)$
(7)	Periodic Force	Periodic Voltage

- **Complex current for the L–C–R Series Circuit**

Differential equation of complex current :

$$\frac{di}{dt} + \frac{\text{R}}{\text{L}} i + \frac{1}{LC} \int i dt = \frac{\text{V}_\text{m}}{\text{L}} e^{j\omega t}$$

The solution of this equation is called complex current is given by

$$i = I_m \cdot e^{j\omega t}$$

$$\therefore \quad i = \frac{\text{V}_\text{m} e^{j\omega t}}{\text{R} + j\omega\text{L} - \frac{j}{\omega\text{C}}} = \frac{\text{V}_\text{m} e^{j\omega t}}{\text{R} + j\left(\omega\text{L} - \frac{1}{\omega\text{C}}\right)}$$

Above equation resembles with Ohm's law equation $I = \frac{\text{V}}{\text{R}}$.

In the equation, $\text{R} + j\omega\text{L} - \frac{j}{\omega\text{C}} = \text{Z}$

impedance of L-C-R series AC circuit. Its unit is Ohm (Z complex number)

- **Equations of Impedance,**
  - $j\omega\text{L} = \text{Z}_\text{L} =$ Inductive reactance of inductor $|\text{Z}_\text{L}| = \text{X}_\text{L} = \omega\text{L}$.
  - $\frac{-j}{\omega\text{C}} = Z_C =$ Capacitive reactance of the capacitance and it's value $|Z_C| = \text{X}_\text{C} = \frac{1}{\omega\text{C}}$.
- **Ohm's law for complex current, complex voltage and impedance**

$$i = \frac{\text{V}_\text{m} \cdot e^{j\omega t}}{|\text{Z}| \cdot e^{j\delta}} = \frac{\text{V}_\text{m}}{|\text{Z}|} e^{j(\omega t - \delta)}$$

$$= \frac{V_m}{|Z|}\left[\cos(\omega t - \delta) + j\sin(\omega t - \delta)\right]$$

$$\text{Where } |Z| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

Real Current :

$$I = \frac{V_m}{|Z|}\cos(\omega t - \delta)$$

$$\text{Where } I_m = \frac{V_m}{|Z|} = \frac{V_m}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

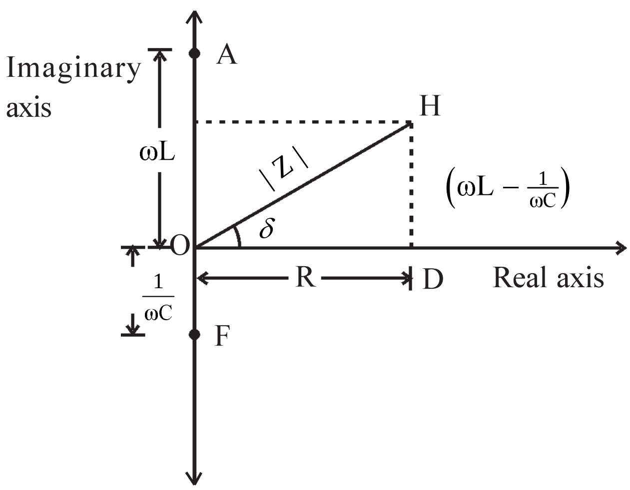
Here δ is phase difference between voltage and current

- **Geomatrical representation of Z.**

Impedance $Z = R + j\omega L - \frac{j}{\omega C}$

In this equation R is real part of complex, $j\omega L$ and $\frac{-j}{\omega C}$ are imagenary part.

Remember : The componants which are connected in circuit, mention them in complex plane and then decide $|Z|$ and phase different for the circuit.



$OD = R$

$OA = \omega L = X_L$

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

$OD = \left(\omega L - \frac{1}{\omega C}\right)$

The impedance $|Z|$ represent by point H.

$$\therefore \; OH = |Z| = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

$$\text{Phase different } \; \delta = \tan^{-1}\left[\frac{\left(\omega L - \frac{1}{\omega C}\right)}{R}\right]$$

Time different $\Delta t = \frac{\delta}{\omega}$ (δ must be in radian unit $\delta^0 = \frac{\delta \times \pi}{180} rad$)

Remember :

Voltage leads the current when δ is in first quadrant. If δ is in fourth quadrant current leads the voltage

To obtained real current equation for the given circuit put the value of magnitude of Z and phase different in the equation $I = \frac{V_m}{|Z|} \cos(\omega t - \delta)$

rms value of current/AC voltage

- *rms* value of AC voltage $V = V m \cos \omega t$ and $V = V m \sin \omega t$ given by

$$V_{rms} = \frac{V_m}{\sqrt{2}} = 0.707 \ V_m$$

Note : voltage of AC source voltage = V_{rms}

- $I = I_m \cos \omega t$ or $I = I_m \sin \omega t$ is given by

$$I_{rms} = \frac{I_m}{\sqrt{2}} = 0.707 \ I_m$$

The average value of AC voltage or current

- The average value AC voltage or current over an interval of one period is zero.

$$\langle V \rangle = \frac{1}{T} \int_0^T V_m \sin \omega t = 0$$

- Average value of $V = V_m \sin \omega t$ on half period of cycle

$$\langle V \rangle = \frac{2}{T} \int_0^{\frac{T}{2}} V_m \sin \omega t \ dt = \frac{2V_m}{\pi} = 0.637 \ V_m$$

$$= 63.7 \ \% \ (V_m)$$

Series Resonance for L–C–R

For a definite angular frequency (ω_0) of the voltage, value of rms current becomes maximum. This is called the series resonance in L–C–R, AC series circuit.

At series resonance,

- Resonance angular frequency $\omega_0 = \frac{1}{\sqrt{LC}} = 2\pi f_0$
- Imaginary part of impendance becomes zero.

i.e. $\left(\omega L - \dfrac{1}{\omega C}\right) = 0$

- Impedance value becomes minimum $|Z| = R$
- I_{rms} becomes maximum and hence

$$I_{rms(\max.)} = \frac{V_{rms}}{|Z|} = \frac{V_{rms}}{R}$$

- Phase differance between V and I becomes zero $(\delta = 0)$.
- Power factor, $\cos\delta = 1$.
- Average power $P = \dfrac{V_m I_m}{2}$ (Hence power loss maximum).

The equation of average power and power factor equation for L–C–R series AC circuit :

Real power $P = \dfrac{V_m I_m}{2}\cos\delta = V_{rms}\ I_{rms}\cos\delta$

Here, $\cos\delta$ = power factor.

$$\cos\delta = \frac{R}{|Z|} = \frac{R}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

Some more quantities for AC voltage/AC current :

Admitance Y : Reciprocal of impedance is Known as admittance $\left(y = \dfrac{1}{Z}\right)$

$$Y = \frac{1}{Z} = \frac{I_m}{V_m} = \frac{I_{rms}}{V_{rms}}$$

It's unit is mho.

- **Susceptance (S) :** The reciprocal of reactance is defined as susceptance

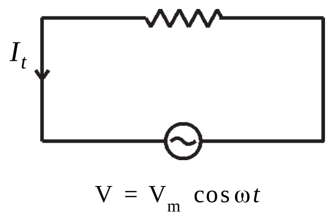
$$S = \frac{1}{X}$$

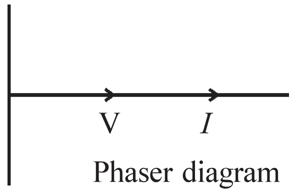
- It is of two types.

(i) Inductive susceptance, $S_L = \dfrac{1}{X_L} = \dfrac{1}{\omega L} = \dfrac{1}{2\pi fL}$ and

(ii) Capacitive susceptance, $S_C = \dfrac{1}{X_c} = \omega C = 2\pi fC$

(1) Resistive circuit (R-circuit)





Phaser diagram

Equation of current $I = I_o \cos\omega t$

Peak value of current $I_m = \frac{V_m}{R}$

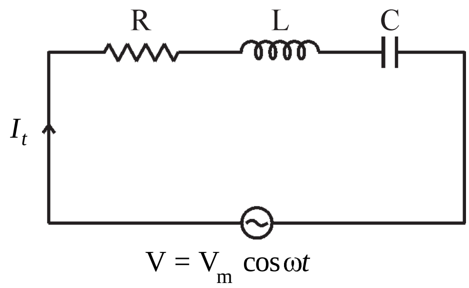
Phase different between voltage and current $\delta = 0$

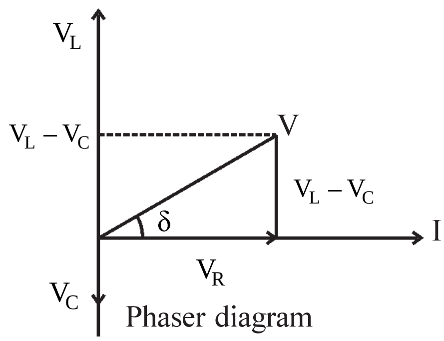
Power factor $\cos\delta = 1$

Power $P = \frac{V_m I_m}{2} = V_{rms}\, I_{rms}$ (maximum power loss)

Time different between voltage and current $\Delta t = \frac{\delta}{\omega} = 0$

(2) L–C–R series circuit





Phaser diagram

(1) Equation of current $I = I_m \cos(\omega t \pm \delta)$ where $I_m = \frac{V_m}{|Z|}$

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

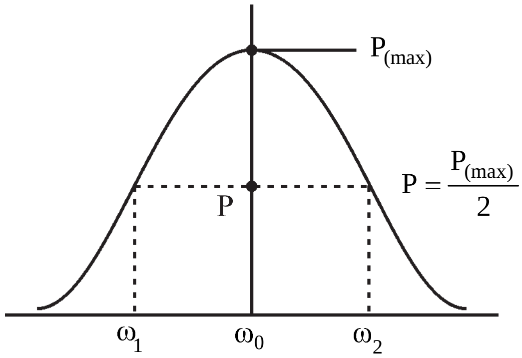
Impedance of circuit : $|Z| = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

Phase difference : $\tan\delta = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} = \frac{\omega L - \frac{1}{\omega C}}{R}$

- If net reactence is inductive circuit behaves as LR circuit.
- If net reactance is capacitive circuit behaves as CR circuit.
- At resonance $X_L = X_C = 0 \Rightarrow X_L = X_C$, this is the condition of resonance.
- Half power frequencies and band width : The frequencies at which the power in the circuit is half of the maximum power (the power at resonance) are called half power frequencies.

- The current in the circuit at half power frequencies

$I = \frac{I_{rms}}{\sqrt{2}} = 0.707\ I_{rms}$.



- There are two half power frequences,

  ω_1 called lower half power frequency, the circuit is capacitive

  ω_2 called upper half power frequency. It is greater than ω_0, at this frequency the circuit is inductive.

- Band width ($\Delta\omega$) : The difference of half power frequencies ω_1 and ω_2 is called band width ($\Delta\omega$) and $\Delta\omega = \omega_2 - \omega_1$.

  For series resonant circuit it can be proved $\Delta\omega = \frac{R}{L}$.

- **Q factor :**
  - The characteristic of a series resonant circuit is determined by the Quality factor (Q-factor) of the circuit.
  - It defines sharpness of $I_{rms} \to \omega$ curve at resonance. When Q factor is large, the sharpness of resonance curve is more and vise-versa.
  - Q-Factor is also defined as,

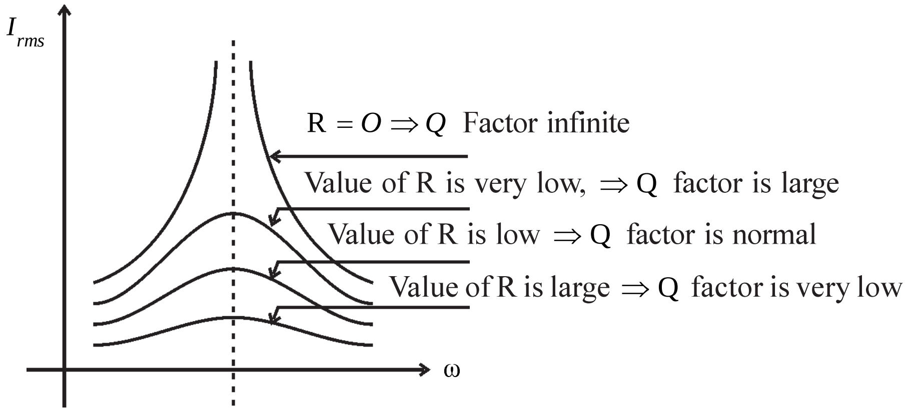
$$\text{Q-facter} = 2\pi \times \frac{\text{Max. energy stored}}{\text{Energy dissipation}}$$

$$= \frac{2\pi}{T} \times \frac{\text{Max. energy stored}}{\text{mean power dissiption}} = \frac{\text{Resonant frequnecy}}{\text{Baund width}}$$

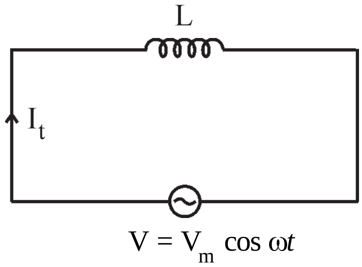
$$= \frac{\omega_o}{\Delta\omega}$$

$$= \frac{V_L}{V_R} = \frac{\omega_0 L}{R} \quad \text{or} \quad \frac{V_C}{V_R} = \frac{1}{\omega_0 CR}$$

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



L-Circuit



(1) Current : $I = I_m \cos\left(\omega t - \frac{\pi}{2}\right)$

(2) Peak current : $I_m = \frac{V_m}{X_L} = \frac{V_m}{\omega L} = \frac{V_m}{2\pi f L}$

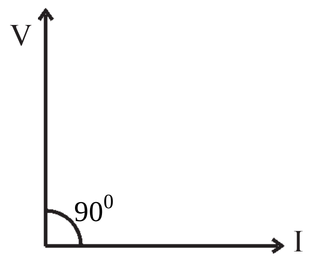
(3) Phase difference between voltage and current $\delta = 90°$ or $\frac{\pi}{2}$

(4) Power factor : $\cos\delta = 0$

(5) Power : $P = 0$

(6) Time difference $\Delta t = \frac{T}{4}$

(7) Phase diagram : Voltage leads the current by $\frac{\pi}{2}$.



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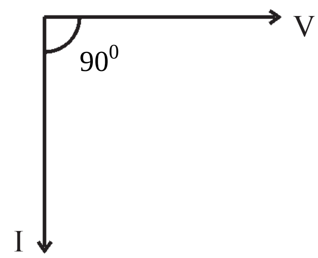
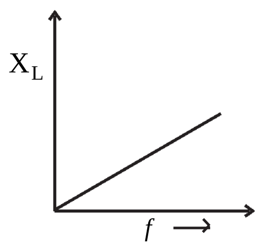


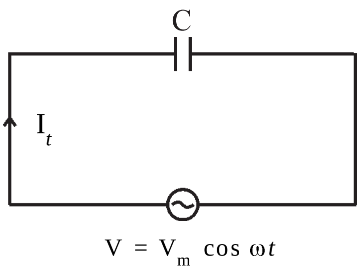
$\therefore X_L = \omega L = 2\pi f L$ (Where $\omega = 2\pi f$)

$\Rightarrow X_L \ \alpha \ f$ (L = constant).



Here inductive reactance increses linearly with increase in frequency, therefore an inductor is called 'low pass filter'.

C-Circuit :



(1) current : $I = I_m \cos\left(\omega t + \frac{\pi}{2}\right)$

(2) Peak current : $I_m = \frac{V_m}{X_c} = V_m \omega C = V_m(2\pi f C)$

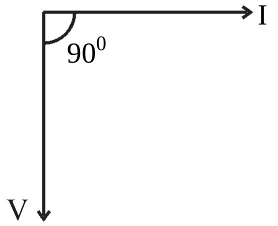
(3) Phase difference between voltage and current : $\delta = 90° \left(or -\frac{\pi}{2}\right)$

(4) Power factor : $\cos\delta = 0$

(5) Power : $P = 0$

(6) Time difference : $\Delta t = \dfrac{T}{4}$

(7) Phase diagram : current leads the voltage by $\dfrac{\pi}{2}$.



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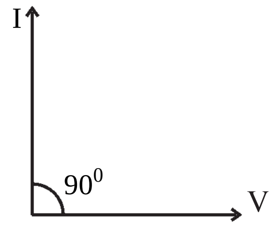
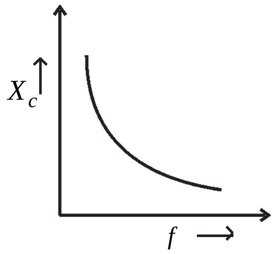


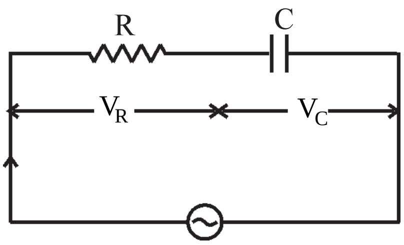
Since, $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi fC}$

$\Rightarrow X_C \ \alpha \dfrac{1}{f} = (C = \text{constant})$



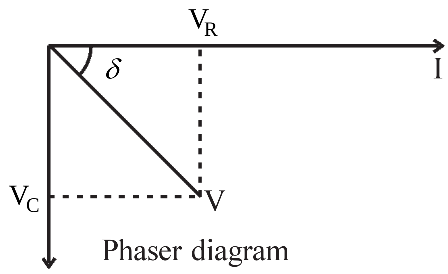
Here capacitives reactance decreases non-linearly with increases in frequency, therefore capacitor is called high pass filter.

RC-Circuit :



$V = V_m \cos \omega t$

$V_R = IR$
$V_C = I\,Xc$



Phaser diagram

(1) Applied voltage : $V = \sqrt{V_R^2 + V_C^2}$

(2) Impedance : $Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\dfrac{1}{\omega C}\right)^2}$

(3) Current : $I = I_m \cos(\omega t + \delta)$

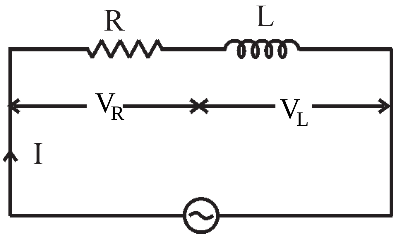
(4) Peak current : $I_m = \dfrac{V_m}{Z} = \dfrac{V_m}{\sqrt{R^2 + X_L^2}} = \dfrac{V_o}{\sqrt{R^2 + \dfrac{1}{4\pi^2 f^2 C^2}}}$

(5) Phase difference : $\delta = \tan^{-1}\dfrac{X_C}{R} = \tan^{-1}\dfrac{1}{\omega CR}$

(6) Power factor : $\cos\delta = \dfrac{R}{\sqrt{R^2 + X_C^2}}$

(7) Current leads the voltage in phase by δ

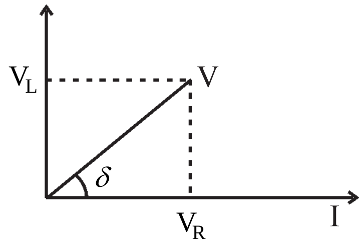
RL-Circuit :



$V = V_m \cos \omega t$

$V_R = IR$

$V_L = IX_L$



Phaser diagram

(1) Applied voltage : $V = \sqrt{V_R^2 + V_L^2}$

(2) Impedance : $|Z| = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \omega^2 L^2} = \sqrt{R^2 + 4\pi^2 f^2 L^2}$

(3) Current : $I = I_m \cos(\omega t - \delta)$

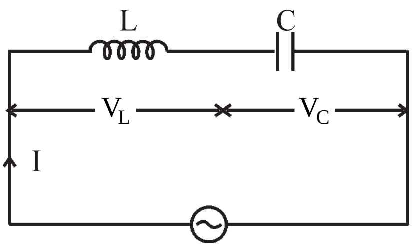
(4) Peak current : $I_m = \dfrac{V_m}{|Z|} = \dfrac{V_m}{\sqrt{R^2 + X_L^2}} = \dfrac{V_m}{\sqrt{R^2 + 4\pi^2 f^2 L^2}}$

(5) Power factor : $\cos\delta = \dfrac{R}{\sqrt{R^2 + X_L^2}}$

(6) Phase different : $\delta = \tan^{-1}\dfrac{X_L}{R} = \tan^{-1}\dfrac{\omega L}{R}$

(7) Voltage leads the current in phase by δ

LC-Circuit :

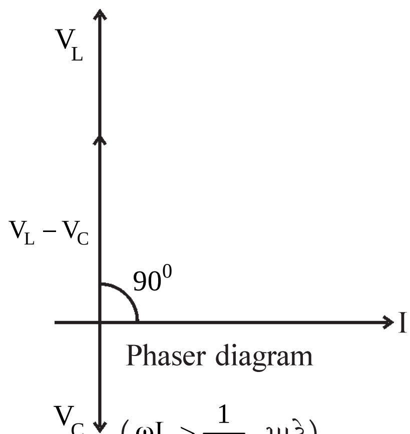


$V = V_m \cos \omega t$

$V_L = IX_L$,

$V = (V_L - V_C)$

$V_C = IX_C$



Phaser diagram

$\left(\omega L > \dfrac{1}{\omega C}\right.$ માટે$\left.\right)$

(1) Applied voltage : $V = V_L - V_C$

(2) Impedance : $|Z| = X_L - X_C = X$

(3) Current : $I = I_m \cos\left(\omega t \pm \dfrac{\pi}{2}\right)$

(4) Peak current : $I_m = \dfrac{V_m}{Z} = \dfrac{V_m}{X_L - X_C} = \dfrac{V_m}{\omega L - \dfrac{1}{\omega C}}$

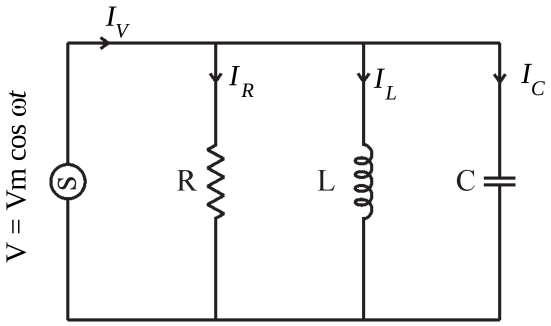
(5) Phase different : $\delta = 90°$

(6) Power factor : $\cos\delta = 0$

(7) If $\omega L > \frac{1}{\omega C}$ the current legs behind the voltage in phase by $\frac{\pi}{2}$.

If $\omega L < \frac{1}{\omega C}$ the voltage legs behind the current in phase by $\frac{\pi}{2}$.

RLC - Parallel circuit :

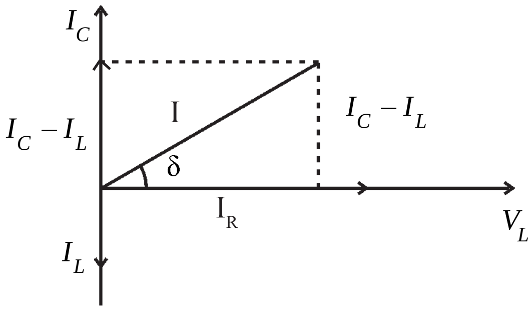


$$I_{t(R)} = \frac{V_m}{R} = V_m G$$

$$I_{t(L)} = \frac{V_m}{X_L} = V_m S_L$$

$$I_{t(C)} = \frac{V_m}{X_C} = V_m S_C$$

Phaser diagram



From phaser diagram, current $I = \sqrt{I_R^2 + (I_C - I_L)^2}$

Phase different $\delta = \tan^{-1}\frac{(I_C - I_L)}{I_R} = \tan^{-1}\frac{S_C - S_L}{G}$

Admiltance (Y) :

$$\frac{V_m}{|z|} = \sqrt{\left(\frac{V_m}{R}\right)^2 + \left(\frac{V_m}{X_L} - \frac{V_m}{X_C}\right)^2}$$

$$\therefore \quad Y = \frac{1}{Z} = \sqrt{\left(\frac{1}{R}\right)^2 + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2} = \sqrt{G^2 + (S_L - S_C)^2}$$

- Resonance :

$$I_C = I_L \Rightarrow I_{min} = I_R$$

$$\Rightarrow \frac{V}{X_C} = \frac{V}{X_L} \Rightarrow S_C - S_L = 0 \Rightarrow \sum S = 0$$

$$Z_{max} = \frac{V}{I_R} = R$$

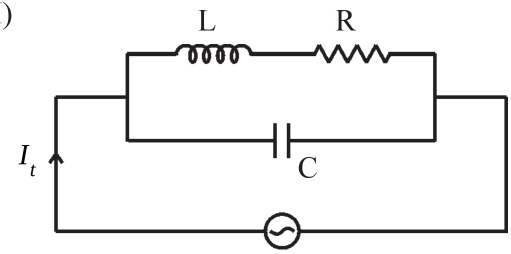
Phase different $\delta = 0$

Power factor $\cos\delta = 1$ (maximum)

Resonance frequency $f = \dfrac{1}{2\pi\sqrt{LC}}$

- **Parallel LC circuit :**

(I)



$V = V_m \cos \omega t$

(1) $Z_{max} = \dfrac{1}{Y_{min}} = \dfrac{L}{CR}$

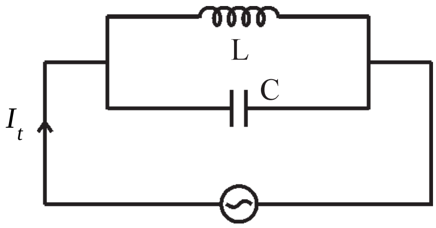
(2) Minimum current of circuit : $I_{min} = V_{max} \times \dfrac{CR}{L}$

(3) Susceptance S : $S_L = S_C \Rightarrow \dfrac{1}{X_L} = \dfrac{1}{X_C} \Rightarrow$ impedence $X = \infty$

(4) Resonant frequency : $\omega_0 = \sqrt{\dfrac{1}{LC} - \dfrac{R^2}{L^2}}$

(5) Q factor $= \dfrac{1}{CR} \dfrac{1}{\sqrt{\dfrac{1}{LC} - \dfrac{R^2}{L^2}}}$

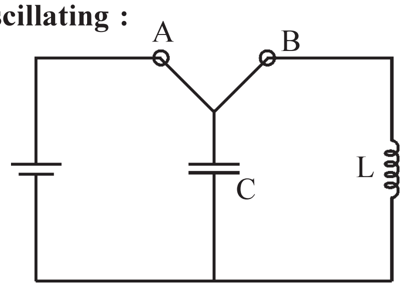
(II) If inductance has no resistance, if R = 0 then circuit becomes parallel LC circuit as shown in figure.



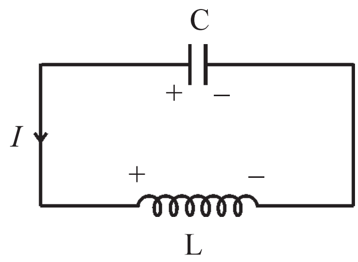
$V = V_m \cos \omega t$

Here condition of resonance : $I_C = I_L \Rightarrow \dfrac{V}{X_C} = \dfrac{V}{X_L} \Rightarrow X_L = X_C$

L–C oscillating :



(a)



(b)

In given circuit when key (A) is closed and key (B) is open the cell charges the capacitor, then on removing key (A) and key (B) closed the charged capacitor connected to L and circuit behaves L-C circuit mention in figure.

Here, resistance of inductor is zero (Ideal Inductor) for this circuit.

Diffrential equation, $\frac{d^2Q}{dt^2} = \frac{-Q}{\text{LC}}$

Angular frequency $\omega_o = \frac{1}{\sqrt{\text{LC}}}$

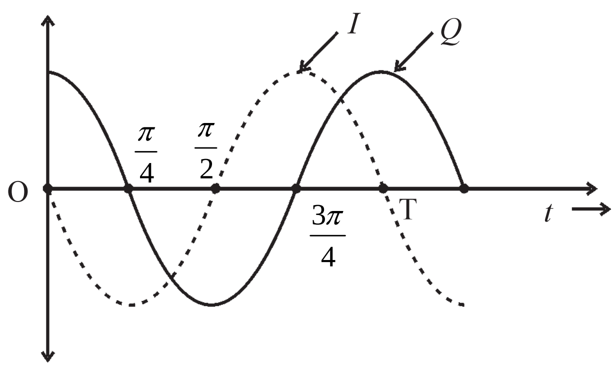
Equation for charge at time t, $Q = Q_o \cos \omega_o t$

Q_o = Charge on C, initially

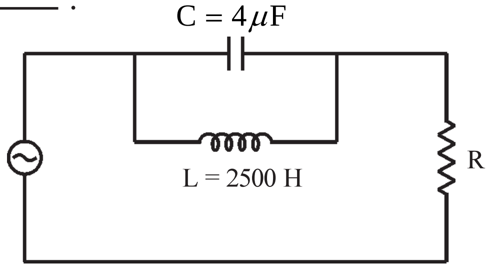
Equation for charge at time t

$$I = -Q_o\, \omega_o \sin \omega_o t$$

- Here charge oscillating within time according to function cosine.
- The electric energy of capacitor reduced to 0 from $\frac{Q^2}{2\text{C}}$ in time $t = 0$ to $t = \frac{\text{T}}{4}$
- The magnetic energy in inductor is increasing from zero to maximum $\frac{1}{2}\text{LI}^2$ in time $t = 0$ to $t = \frac{\text{T}}{4}$
- The current and voltage varing with time shown in below graph.

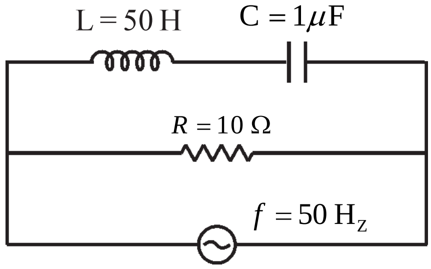


(84) The value of frequency f ________ Hz will be the impedence of given below circuit is maximum value ________ .



(A) 0.628, zero (B) 0.628, infinite (C) 62.8, zero (D) 62.8, infinite

(85) The value of impendence Z for given below circuit at a source voltage frequency of 50 Hz will be ________ Ω.

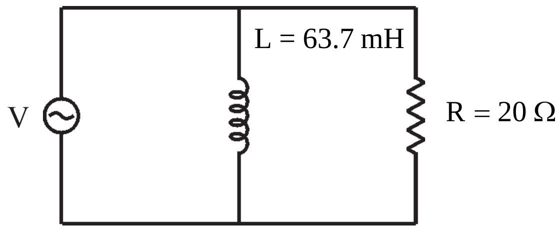


(A) 10 (B) 100 (C) 50 (D) 5

(86) The series combination of $R\ (\Omega)$ and capacitor C (F) is connected to an AC source of V volts and angular frequency ω. If the angular frequency is reduced to $\frac{\omega}{5}$ the current is founded to be reduced to one-half without changing the value of the voltage. Determine the ratio of the capacitive reactance and the resistance.

(A) 1.11 (B) 0.90 (C) 0.77 (D) 1.30

(87) An inductor L and resistor R connected in parallel with an AC source of V = 200 cos 344t shown in circuit below. Hence voltage ________ to current.



(A) lags 45° (B) leads 60° (C) leads 45° (D) lags 60°

(88) A coil of inductance 0.16 H, Resistance $R = 20\,\Omega$ and capacitor of capacitance C are conneeted in L–C–R series circuit. If resonance frequency is 72.70 Hz then capacitor C = ________ and $|Z| =$ ________.

(A) 30 μF, 20 Ω (B) 30 pF, 20 Ω (C) 20 μF, 30 Ω (D) 30 μF, 30 Ω

(89) An Ac voltmeter connected with 50 Hz AC source it read 200 V, maximum voltage during periodic time will be ________.

(A) 28.2 V (B) 2.82 V (C) 282 V (D) 0.282 V

(90) A resistant of 100 Ω resistance and inductor of 14 H inductance are connected in series. If AC current of $\frac{50}{\pi}$ Hz frequency pass through circuit then voltage is ________ to curront.

(A) leads 60° (B) lags 60° (C) leads 45° (D) lags 45°

(91) If $1\,\mu F$ capacitor applying ac voltage of $V = 200 \sin 100t$ (V) then reading of ameter connected in circuit will be ________ mA.

(A) 14.18 (B) 20 (C) 40 (D) 30

(92) Capacitive reactance of $25\,\Omega$ capacitor is $C\mu F$ and it connected in circuit with AC supply of $\frac{400}{\pi}$ Hz frequency the value of capacitance will be ________.

(A) 25 μF (B) 50 μF (C) 400 μF (D) 100 μF

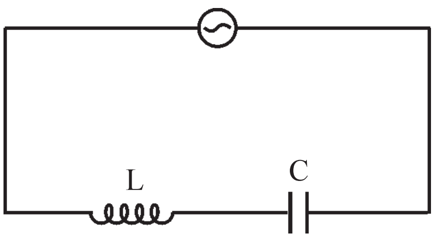
(93) A $200\,\Omega$ resistor and coil of self inductance 1H are connected in series with ac source of $\frac{200}{\pi}$ Hz frequency. The time different between voltage and current will be ________ ms.

(A) 1.37 (B) 1.60 (C) 2.74 (D) 3.20

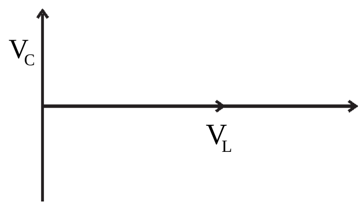
(94) An inductor having negligible resistance and 50 mH self inductance and 500 pF capacitance are connected in AC circuit. The resonance frequency will be ________ .

(A) 31.8 Hz (B) 31.8 kHz (C) 31.8 MHz (D) 31.8 GHz

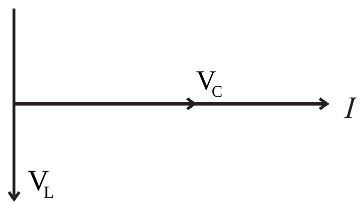
(95) The phaser diagram of circuit given in figure is ________.



(A)



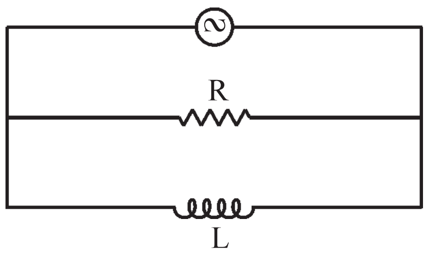
(B)



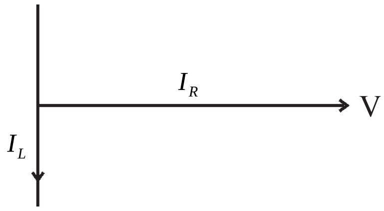
(C)

(D)

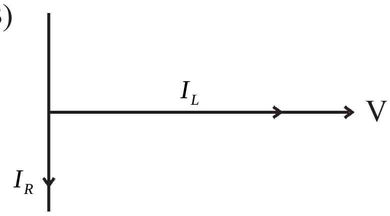
(96) The phase diagram of given circuit is ________.



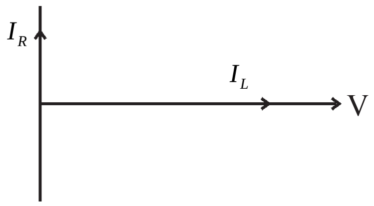
(A)



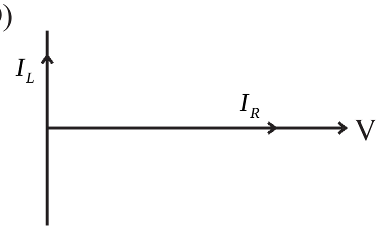
(B)



(C)



(D)



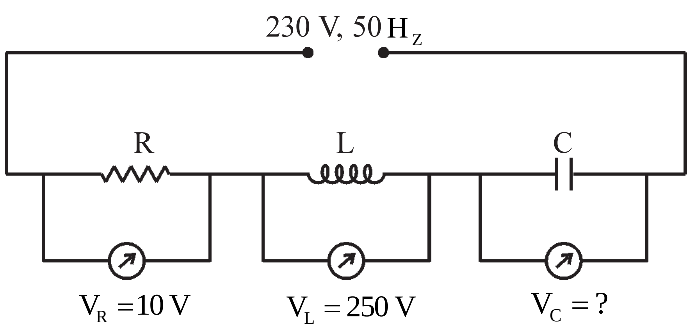
(97) An ideal resistor and ideal inductor are connected in series with 100 V A.C. source. If voltmeter read same reading across resistor or inductor then the reading of it ________ .

(A) 50 V (B) 70.7 V (C) 88.2 V (D) 100 V

(98) L.C.R. circuit having impedence of $110\ \Omega$ and phase different between current and voltage $60°$ is applying AC voltage $V = 200 \sin 100t$ circuit power will be ________ W.

(A) 100 (B) 110 (C) 90.90 (D) 200

(99) A voltmeter reading across capacitor C in mantion below circuit is ________ V.



(A) 15.8 (B) 20.3 (C) 10.3 (D) 18.3

(100) A coil is connected with AC source of 120 V and frequency 50 Hz, current passing through coil is 5A and consumed power is 108 W. Then resistance of circuit will be ________ .

(A) $24\ \Omega$ (B) $10\ \Omega$ (C) $12\ \Omega$ (D) $4.3\ \Omega$

(101) In a serice resonant L–C–R circuit the voltage across R is 10 volt and R = $1\text{k}\,\Omega$ with $C = 2\,\mu F$. The resonant frequency $\omega = 200\ rad\ s^{-1}$. At resonance the voltage across L is ________ .

(A) 250 V (B) 4×10^{-3} V (C) 25 V (D) 40 V

(102) In L.C.R series circuit R = $100\,\Omega$, L = 0.5 H and C = 10×10^{-6} F. If 50 Hz AC supply connected to the circuit the impedence will be ________ Ω.

(A) 1.8765 (B) 18.76 (C) 101.3 (D) 189.9

(103) The resonant frequency of a circuit is *f*. If the capacitance is made 16 times the initial values then the resaonant frequency becomes ________ .

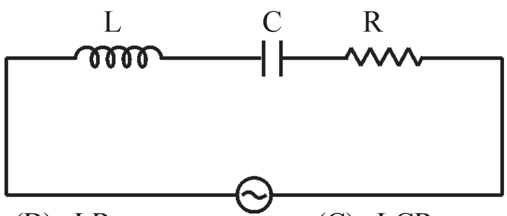
(A) $\frac{f}{2}$ (B) $2f$ (C) $4f$ (D) $\frac{f}{4}$

(104) The resistance of RL AC circuit is $10\,\Omega$ and applied voltage V_m across the circuit at $\omega = 20$ rad s^{-1}. If current in the circuit is $\frac{I_m}{2}$ then value of L will be ________.

(A) 0.5 (B) 0.707 (C) 0.8660 (D) 1.73

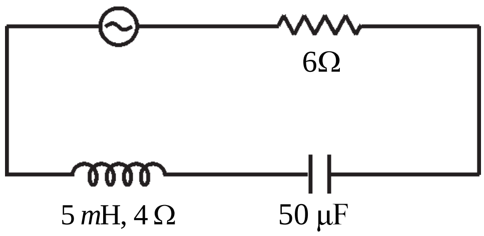
(105) The following series L–C–R circuit when driven by an *emf* source of angular frequency 70 krad s^{-1}, the circuit effectively behave like ________.

$(L = 100\,\mu H,\ C = 1\,\mu F,\ R = 10\,\Omega)$



(A) RC (B) LR (C) LCR (D) LC

(106) In the circuit shown below the AC source has voltage $V = 200\cos\omega t$ volts with $\omega = 2000$ rads^{-1}. The magnitude of the current will be ________ A.



(A) 20 (B) 10 (C) 2 (D) 1

(107) An inductance of $\left(\frac{200}{\pi}\right) mH$, a capacitance of $\left(\frac{10^{-3}}{\pi}\right)$ F and a resistance of $10\,\Omega$ are connected in series with an AC source 220 V, 50Hz. The phase angle of circuit is ________

(A) 90° (B) 60° (C) 30° (D) 45°

(108) The ratio of impedance and resistance for L–C–R series circuit where, $V = 110\sqrt{2}\cos(2000t - 25°)V$ and $I = 10\sqrt{2}\cos(2000t - 20°)$ A will be ________.

(A) 2 (B) 1 (C) infinite (D) $\sqrt{2}$

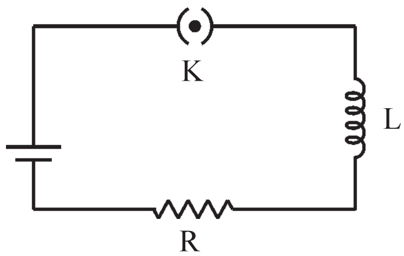
(109) The resistance of $100\ \Omega$ and the coil of inductance of 0.5 H are connected in series with AC source 240 V, 50 Hz. Time different between maximum voltage and maximum current will be ________. (take $V = V_m \sin\omega t$)

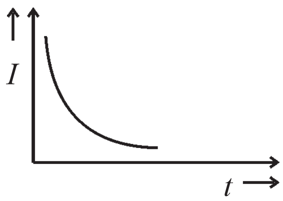
(A) 3.2 *ms* (B) 6.4 *ms* (C) 3.2 s (D) 1.60 *ms*

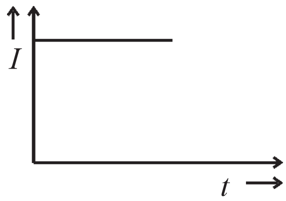
(110) A capacitor of capisitance $100\ \mu F$ and a resistor of resistance $40\ \Omega$ connected in series with AC source 110 V – 60 Hz. The time different between maximum voltage and maximum current ________ (At $t = 0 \Rightarrow V = O\ V$)

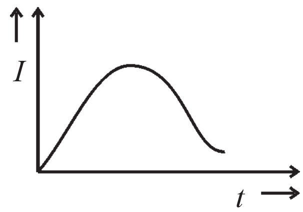
(A) 0.75 ms (B) 2.88 ms (C) 3.10 ms (D) 1.55 ms

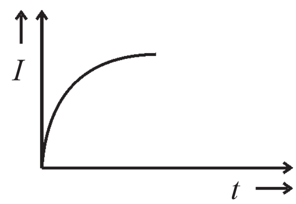
(111) Which one of the following curves is represent the variation of current (I) with time (t) when key close in given circuit.



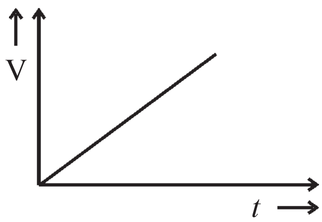
(A)


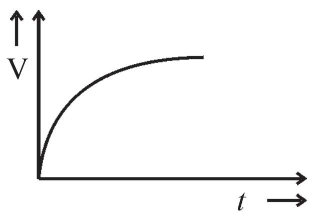
(B)


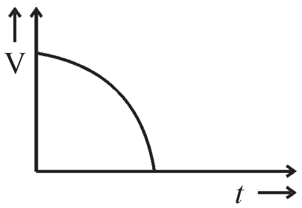
(C)


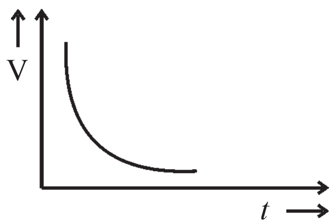
(D)


(112) Which one of the following curves is represent variation of voltage (V) with time (t) w hen key close in circuit of Question No-111.

(A)


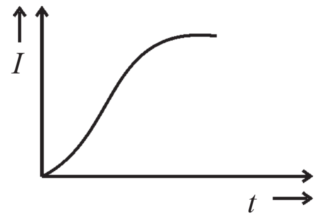
(B)


(C)


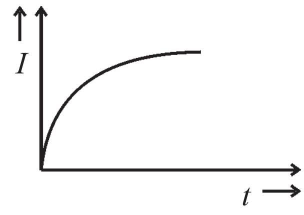
(D)


(113) An AC source of varible frequency f is connected to an LCR series circuit. Which of the graph represent the variation of current (I) in the circuit with frequency (f).

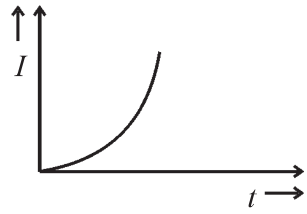
(A)



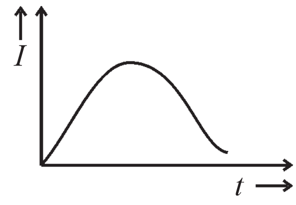
(B)



(C)



(D)



(114) A resister of resistance $R = 10\ \Omega$ and inductor of inductance of L = 25 mH are connected with AC source of 50 Hz frequency. The Q factor of circuit will be ________.

(A) 0.5 (B) 0.393 (C) 0.785 (D) 1

(115) An AC supply of 50 Hz is connected with L–C–R series connection. If L = 2H and phase different between current and voltage is $\frac{\pi}{4}$ rad then C = ________ μF.

(A) 0.5 (B) 5 (C) 2.5 (D) 0.25

(116) A bulb filament having an inductance, is connected first with DC voltage and then AC of same voltage. It will be more shine brightly with ________.

(A) AC (B) Equally both

(C) DC (D) brightly for AC source only

(117) An ameter and AC voltage $V = 4\cos(1000t)$V connected in series with L = 3 mH and $R = 4\ \Omega$ then ameter reading will be ________ A.

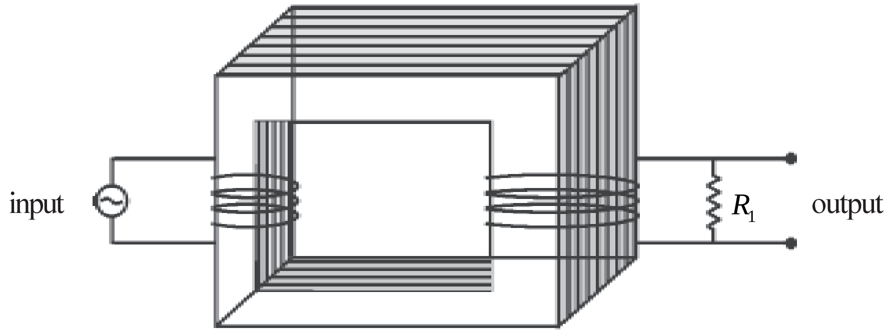
(A) 56×10^{-3} (B) 0.56 (C) 5.6×10^{-3} (D) 5.6

(118) In an AC circuit the direction of current change in 1×10^{-2} s then frequency f of AC current will be ________.

(A) 60 (B) 31.4 (C) 50 (D) 6.28

Ans. : 84 (A), 85 (A), 86 (D), 87 (C), 88 (A), 89 (C), 90 (C), 91 (A), 92 (B), 93 (C), 94 (B), 95 (C), 96 (A), 97 (B), 98 (C), 99 (B), 100 (D), 101 (C), 102 (D), 103 (D), 104 (C), 105 (A), 106 (A), 107 (D), 108 (D), 109 (A), 110 (D), 111 (D), 112 (D), 113 (D), 114 (C), 115 (B), 116 (A), 117 (B), 118 (C)

Transformer :



- A device in which AC voltage can be increased or decreased.
- Principle : Electro magnetic induction.
- It is used only for AC voltage.
- This devices could not change the frequency of AC voltage.

  The coil which is connected with AC source is called primary coil (P) and out put voltage obtain between two ends of coil is called secondary coil (S)
- Both coil connected by magnetic force line.
- The resistance is infinite between primary and secondary coil.

Equations :

$$\frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s} = r$$

For primary coil :

ε_p = Induced *emf*

N_p = Number of tarns

V_p = Applying input voltage

I_p = Current

r = Transformation ratio

For secondary coil,

ε_s = Induced *emf*

N_S = Number of turns

V_s = Output voltage across R_L

I_S = Current

r is transformation ratio

$r > 1$ step-up transformer more out put voltage.

$r < 1$ step-down transformer less out put voltage.

Here phase different between V_S and V_P is π .

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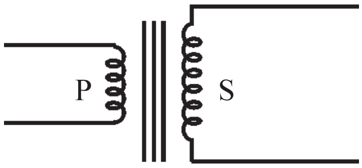
Step-up Transformer

Symbol



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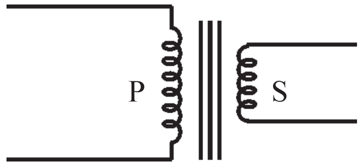
Step-down Transformer

Symbol



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$V_S > V_P$

$N_S > N_P$

$\varepsilon_S > \varepsilon_P$

$I_S < I_P$

$R_S > R_P$

$r > 1$

</td>
<td>

$V_S < V_P$

$N_S < N_P$

$\varepsilon_S < \varepsilon_P$

$I_S > I_P$

$R_S < R_P$

$r < 1$

</td>
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For ideal transformer :

Input power $I_P V_P$ = Output power $I_S V_S$

(P_{in}) = (P_{out})

Efficiency of transformer (η)

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

$$= \frac{V_S I_S}{V_P I_P} \times 100$$

Efficiency of ideal transformer is 100 %.

For practically used transformer,

$$P_{in} = P_{out} + P_{loss}$$

$$\text{Input-Power} = \begin{pmatrix}\text{Output}\\ \text{Power}\end{pmatrix} + \begin{pmatrix}\text{Loss}\\ \text{Power}\end{pmatrix}$$

Here power lost in transformer due to heating of coil, leakage of magnetic flux of eddy current

Uses :

Voltage regulator, Induction furnace, power transmission etc.

---

(119) A step down transformer is used to reduce the main supply of 220 V to 10 V. If the primary draws 5 A and secondary 88 A current, calculate the efficiency of the transformer ________.

(A) 8.8 % (B) 80 % (C) 88 % (D) 8 %

(120) A transformer has an efficiency of 75 %. The power input is 4 kW at 100 V. If the secondary voltage is 200 V, calculate the ratio of current in the primary and secondary. ________.

(A) 7.5 (B) 0.75 (C) 1.5 (D) 2.66

(121) The primary of a transformer has 400 turns while the secondary has 2000 turns. The power output from the secondary at 1000 V is 12 kW. If the resistance of the primary is $0.9\ \Omega$ and that of the secondary is $5\ \Omega$ and the efficiency of the transformer is 90 %, calculate the power loss in the primary coil and is the secondary coil will be ________W and ________W.

(A) 2000, 310 (B) 400, 72 (C) 4000, 720 (D) 800, 144

(122) A transformer is used to step up 6.6 kW, 220 V to 4.4 kV with 80% efficiency. If primary coil have 1000 turns then number of turns and current in secondary coil are ________ and ________.

(A) 2×10^3, 12 A (B) 2×10^4 1.2 A (C) 2×10^4 1.2 A (D) 2×10^3 1.2 A

(123) A 250 V potential different generat by generator of 25 kW is transmit through transmition line of $1\ \Omega$ then power loss will be ________ %

(A) 40 (B) 25 (C) 10 (D) 20

Ans. : 119 (B), 120 (D), 121 (C), 122 (C), 123 (A)

Assertion - Reason type Question :

Instruction : Read assertion and reason carefully, select proper option from given below.

(a) Both assertion and reason are true and reason explains the assertion.

(b) Both assertion and reason are true but reason does not explain the assertion.

(c) Assertion is true but reason is false.

(d) Assertion is false and reason is true.

---

(124) **Assertion :** A variable capaciter is connected in series with a bulb and this combination is connected to an AC source. If the capacitance of the variable capacitor is decreased the brightness of the bulb is reduces.

Reason : The reactance of the capacitor increases if the capacitance is reduced.

(A) a (B) b (C) c (D) d

(125) **Assertion :** A bulb connected in series with coil is connected to AC source. If a soft iron core is introduced in coil, the brightness of bulb will be reduced.

Reason : On introducing soft iron core in the coil the inductance increases.

(A) a (B) b (C) c (D) d

(126) **Assertion :** The alternating current lags behind the emf by phase angle of $\frac{\pi}{2}$, when AC flows through an inductor

Reason : The inductive reactance increases as the frequency of AC source decreases.

(A) a (B) b (C) c (D) d

(127) **Assertion :** A capacitor of suitable capacitance can be used in an AC circuit in place of the choke coil

Reason : A capaciter blocks DC and allows AC only.

(A) a (B) b (C) c (D) d

(128) **Assertion** : An alternating current does not show any magnetic effect.

Reason : Alternating current varies with time.

(A) a (B) b (C) c (D) d

(129) **Assertion** : The division are equally marked on the scale of AC ammeter

Reason : Heat produced is directly proporational to the current.

(A) a (B) b (C) c (D) d

(130) **Assertion** : Average value of AC over a complete cycle is always zero.

Reason : Average value of AC is always defined over half cycle.

(A) a (B) b (C) c (D) d

Ans. :124 (A), 125 (C), 126 (C), 127 (B), 128 (B), 129 (D), 130 (B)

Comprehension Type Questions :

Passage I :

The AC generator which is one of the most important application of the phenomenon of electromagnetic induction converts machenical energy into electrical energy. A rectanguler coil consisting of a large number of turns of copper wire wound over a soft iron core is rotated between the pole of a permanent strong magnet. The magnetic flux through the coil changes continously with time thus producing induced *emf* called AC voltage,

is given by,

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

When a load resistor R is connected across the terminals a current *I* flows through the circuit.

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

(131) In an AC generator, a coil of area A and having N turns rotates in a magnetic field B. The magnetic flux through the coil is ....

(A) Maximum equal to NAB when the plane of the coil is perpendicular to the magnetic field.

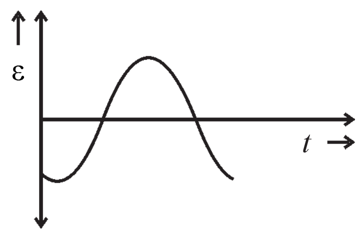
(B) Zero when the plane of the coil is parallel to the field.

(C) $\frac{1}{2}$ NAB when the plane of the coil makes an angle of 60° with the field.

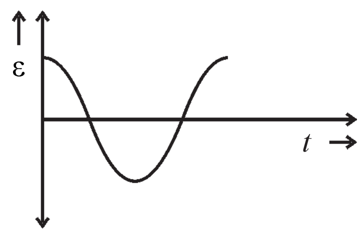
(D) $\frac{1}{4}$ NAB when the plane of the makes an angle of 30° with the field.

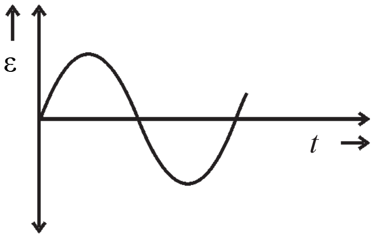
(132) In an AC generator, initially (i.e. at $t = 0$) the plane of the coil is normal to the magnetic field. Which graph shown in figure represents the variation of induced *emf* ε with time.

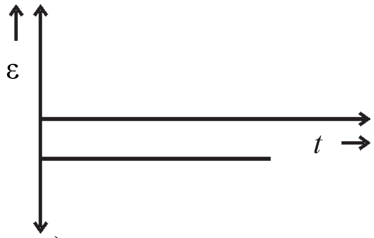
(A)



(B)



(C) 

(D) 

(133) The emf of an AC generator is given by $\varepsilon = 100 \sin\left(100\pi t + \frac{\pi}{3}\right)$ where ε is in volt and t in second.

(A) The peak value of the *emf* is $100\sqrt{2}$ volts.

(B) The frequency of rotation of the armature is 50 Hz.

(C) At start (ie. at $t = 0$) the plane of the armature makes an angle of 60° with the magnetic field.

(D) At start, the plane of the coil is perpendicular of the field.

Passage II :

An L–C–R series circuit with 100 Ω resistance is connected to an AC source of 200 V and angular frequency 300 rad s^{-1}. When only the capacitor is removed, the current leads the voltage by δ. When only the inductor is removed, the current leads the voltage by δ.

(134) The impedance of the L–C–R circuit is ________ Ω.

(A) $200\sqrt{2}$ (B) 100 (C) 200 (D) $100\sqrt{2}$

(135) The current in the circuit is ________ .

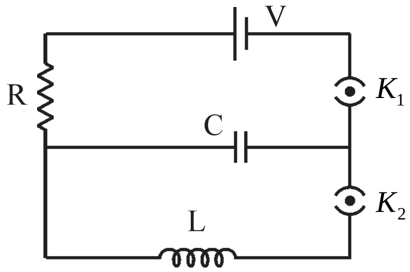
(A) $\sqrt{2}$ A (B) 2 (C) $2\sqrt{2}$ A (D) 1 A

(136) The power dissipated in the circuit is ________ W $(\delta = 60^\circ)$

(A) 200 W (B) 100 W (C) 50 W (D) 800 V

Passage III :

An L–C–R circuit consists of an inductor, a capacitor and a resistor driven by a battery and connected by two switches K_1 and K_2 as shown in figure. At the time $t = 0$ switch K_1 is closed and K_2 is left open. The maximum charge capacitor plate can be hold is q_0. When K_2 is closed and K_1 is open the charge ocillating LC circuit. (Inductor is an ideal inductor)



(137) When switch K_2 is open then circuit behave to as RC circuit and time constant for this circuit $\tau = RC$.

(A) at time $t = \tau$ the charge on the capacitor plates $q = \frac{q_o}{2}$.

(B) at $t = 2\tau$ $q = q_o\left(1 - e^{-2}\right)$.

(C) at $t = 2\tau$ $q = q_o\left(1 - e^{-1}\right)$

(D) work done by the battery is half the energy dissipated in the resistor.

(138) At time $t = 0$ when the charge on the capacitor plates is q_1 switch K_1 is opened and K_2 is closed. The maximum charge the capacitor hold is q_0. choose the correct statement from the following.

(A) $q = q_o \cos\left[\frac{t}{\sqrt{LC}} + \frac{\pi}{2}\right]$ (B) $q = q_o \cos\left[\frac{t}{\sqrt{LC}} - \frac{\pi}{2}\right]$

(C) $q = -LC\frac{d^2q}{dt^2}$ (D) $q = -q\frac{1}{\sqrt{LC}}\frac{d^2q}{dt^2}$

(139) At an instant of time t = 0 when the capacitor has been charged to a voltage V, switch K_1 is opened and K_2 is closed,. Then,

(A) at t = 0, the energy is stored in the magnetic field of the inductor.

(B) at $t > 0$, there is no exchange of energy between the capacitor and the inductor.

(C) at $t > 0$ the current in the circuit flows only in one direction.

(D) the maximum value of the current in the circuit is $\sqrt{\frac{C}{L}}\,V$

Ans. :131 (D), 132 (C), 133 (C), 134 (B), 135 (C), 136 (C), 137 (B), 138 (C), 139 (D)

Match the columns :

(140) An inductor of inductance $L = \frac{100}{\pi}\,mH$ and resistor of resistance $R = 10\,\Omega$ are. connected in series with AC source of $V = 200\sin(100\,\pi t)$. Then match column I and column II.

	Column-1		Column-2
(a)	Maximum value of steady current is ________ A.	(p)	0.02
(b)	Phase different between current and voltage will be ________ degree	(q)	14.14
(c)	Current in circuit at $t = 0$ will be ________ A.	(r)	45
(d)	At ________ s the circuit current becomes first time zero	(s)	30
		(t)	20

(A) a → r b → t c → p d → q
(B) a → p b → q c → r d → t
(C) a → t b → r c → q d → p
(D) a → q b → t c → p d → s

(141) Column-1 is listed type of circuit and Column-2 listed for powerfactor of circuit. Match them eachother :

	Column-1		Column-2
(a)	LCR series AC circuit $\omega L < \frac{1}{\omega C}$.	(p)	0
(b)	LCR series AC circuit at resonace position	(q)	1
(c)	L–R series AC circuit	(r)	ωCR
(d)	Only Capacitive AC circuit	(s)	$\frac{R}{Z}$

(A) a $\rightarrow$ s	b $\rightarrow$ q	c $\rightarrow$ s	d $\rightarrow$ q
(B) a $\rightarrow$ s	b $\rightarrow$ q	c $\rightarrow$ p	d $\rightarrow$ r
(C) a $\rightarrow$ q	b $\rightarrow$ q	c $\rightarrow$ s	d $\rightarrow$ s
(D) a $\rightarrow$ s	b $\rightarrow$ q	c $\rightarrow$ s	d $\rightarrow$ p

(142) For L–C–R series AC circuit column-1 listed variation of component and column-2 listed variation in current. Match column-1 and column-2 :

Column-1		Column-2	
(a)	If R increaes	(p)	I decreaes
(b)	If ω increaes	(q)	I increaes
(c)	If X_L decreaes	(r)	first I increase then decrease
(d)	If Z increaes	(s)	Not sure about it.

(A) a $\rightarrow$ p	b $\rightarrow$ s	c $\rightarrow$ s	d $\rightarrow$ p
(B) a $\rightarrow$ q	b $\rightarrow$ s	c $\rightarrow$ r	d $\rightarrow$ p
(C) a $\rightarrow$ p	b $\rightarrow$ p	c $\rightarrow$ s	d $\rightarrow$ p
(D) a $\rightarrow$ s	b $\rightarrow$ p	c $\rightarrow$ s	d $\rightarrow$ p

(143) A series LCR circuit with $L = 5H$, $C = 80\,\mu F$ and $R = 40\,\Omega$ is connected to a variable frequency 230 V AC source. Column-1 listed quantities and Column-2 listed the value of quantities at resonance frequency. Then match Column-1 and Column-2.

Column-1		Column-2	
(a)	Impedance $\|Z\| - \Omega$	(p)	230 V
(b)	I_{rms} ________ A	(q)	1437.5 V
(c)	V_{Rrms}	(r)	0
(d)	V_{Lrms}	(s)	1206.5 V
(e)	$V_{Lrms} + V_{Crms}$	(t)	5.75
		(u)	80
		(w)	40

(A) a $\rightarrow$ w	b $\rightarrow$ t	c $\rightarrow$ p	d $\rightarrow$ q	e $\rightarrow$ r
(B) a $\rightarrow$ t	b $\rightarrow$ p	c $\rightarrow$ q	d $\rightarrow$ w	e $\rightarrow$ r
(C) a $\rightarrow$ p	b $\rightarrow$ w	c $\rightarrow$ t	d $\rightarrow$ r	e $\rightarrow$ q
(D) a $\rightarrow$ q	b $\rightarrow$ t	c $\rightarrow$ r	d $\rightarrow$ p	e $\rightarrow$ w

Ans. : 140 (C), 141 (D), 142 (A), 143 (A)

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