

**4A**

# **ELECTROMAGNETIC INDUCTION**

### **MAGNETIC FLUX**

In analogy with the electric flux  $\phi_E$ , a magnetic flux  $\phi_B$  of the magnetic field for a surface is defined. Imagine dividing a mathematical surface into infinitesimal area elements. The

direction of an area element da at a point on the surface is  $\frac{1}{\sqrt{2}}$  . The contract of the contract o at a point on the surface is perpendicular to the surface at that point. A typical element for a surface is shown in fig. along with the magnetic field B at a point.



The magnetic flux for an infinitesimal area da is given by  $d\phi = \overline{B} \cdot d\overline{a}$ 



The magnetic flux for a surface is proportional to the number of field lines intersecting the surface.

The magnetic flux  $d\phi$  for the area element "da" is

$$
d\phi = \vec{B} \cdot d\vec{a}
$$

If the magnetic field B makes an angle  $\theta$  with the normal to  $\vec{B}$  makes an angle  $\theta$  with the normal to the surface as shown in fig. then the normal component of the field is B cos  $\theta$  and in this case, the magnetic flux is

given by 
$$
\phi = BA \cos \theta
$$
 or  $\phi = \vec{B} \cdot \vec{A}$ 



So, magnetic flux linked with a closed surface may be defined as the product of the surface area and the normal component of the magnetic field acting on that area. It may also defined as the dot or scalar product of magnetic field and surface area. The magnetic flux for a general surface is obtained by integrating (summing) the contributions  $d\phi$  as the area element da ranges over the surface.

Physically it represents total lines of induction passing through a given area.

### **POSITIVEAND NEGATIVE FLUX**

In case of a body present in a field, either uniform or nonuniform. Out ward flux is taken to be positive while inward negative.







uniform field

If the normal drawn on the surface is in the direction of the field, then the flux is taken as positive.

In this case,  $\theta$  is  $0^{\circ}$  or  $\theta$  < 90° then the flux is taken as positive.

If the normal on the surface is opposite to the direction of the field, then  $\theta = 180^{\circ}$ . In this case, the magnetic flux is taken as negative.

### **Magnetic flux density**,  $B = \frac{\phi}{A}$  $=\frac{\Phi}{\dot{\theta}}$

Lines of force are imaginary, but as magnetic flux associ-

ated with elemental area da in a field  $\vec{B}$ , so flux is a real  $\phi_{xy} = (\hat{i}B_H - \hat{j}B_V)$ .  $(\hat{k}A)$ scalar physical quantity

Dimensions :  $[ML^2T^{-2}A^{-1}]$ **Unit** : **SI** : volt  $\times$  sec. It is known as weber (Wb) or  $T.m^2$  (as tesla = Wb/m<sup>2</sup>) **CGS**maxwell (Mx) 1 Wb = 1 V  $\times$  s = 10<sup>8</sup> emu of pot<sup>n</sup>.  $\times$  s = 10<sup>8</sup> Mx [1 volt= $10^8$  emu of potential] Field, then the flux is taken as positive.<br>
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scalar physic

 $\vec{B} = 0$ , then  $\phi_B = 0$ .

But if  $\phi_B = 0$ ,  $\vec{B}$  may or may not be zero.

Because if  $B \neq 0$ , flux for some elements may be positive while for the other negative giving zero net flux, e.g., for a closed surface enclosing a dipole  $\phi_T = 0$  but d $\phi$  and hence  $\vec{r}$  and  $\vec{r$  $\vec{B} \neq 0$ .

### **Example 1 :**

At a given place, horizontal and vertical components of earth's magnetic field  $B_H$  and  $B_V$  are along x and y axes respectively as shown in fig. What is the total flux of earth's magnetic field associated with an area A, if the area A is in (a) x-y plane (b) y-z plane and (c) z-x plane? 1 Wb = 1 V × s = 10° mu of pot<sup>01</sup>, × s = 10° Mx<br>  $\oint_{\text{ZX}} = (iB_{H} - jB_{V}) \cdot (jA) = -1$ <br>  $[1 \text{ vol} = 10^{8} \text{ cm} \text{ or } j\text{ mod } 60^{\circ} \text{ cm} \cdot \text{s}]$ <br> **Special Note :**  $\oint_{\text{B}} = 0$ , then  $\oint_{\text{B}} = 0$ .<br>
Butif  $\oint_{\text{B}} = 0$ ,  $\oint_{\text{B}} =$ axwell (Mx)<br>  $\text{for area } \text{Sin } x \ge \text{plane : } A = 10^8 \text{ mm of } \text{potr}^0. \times s = 10^8 \text{ Mx}$ <br>  $= 10^8 \text{ cm} \text{ or } \text{potential}$ <br>  $= 10^8 \text{ cm} \text{ or } \text{potential}$ <br>
Note:  $\phi_B = \int \vec{B} \cdot d\vec{a}$ <br>  $\vec{B} = 0$ , then  $\phi_B = 0$ .<br>  $\vec{B} = 0$ , then  $\phi_B = 0$ .<br>  $\vec{C} = 0$  a [1 volt=10<sup>8</sup> emu of potential]<br>
Special Note:  $\phi_B = \int \vec{B} \cdot \vec{A}$  [ii<sub>11</sub> - JBy ). (JA) =<br>
Special Note:  $\phi_B = \int \vec{B} \cdot \vec{A}$  [ii<sub>11</sub> - JBy ). (JA) =<br>
So if  $\vec{B} = 0$ , then  $\phi_B = 0$ .<br>
But if  $\phi_B = 0$ ,  $\vec{B}$  may or ma **al Note:**  $\phi_B = \int \vec{B} \cdot d\vec{a}$  Negative sign implies that fliest<br>  $\vec{B} = 0$ , then  $\phi_B = 0$ .<br>  $\phi_B = 0$ ,  $\phi_B = 0$ .<br>  $\phi_B = 0$ ,  $\dot{B}$  may or may not be zero.<br> **ELUX**<br>
See if  $B \ne 0$ , flux for some elements may be positiv

**Sol.** 
$$
\overrightarrow{B} = i\overrightarrow{B}_{H} - j\overrightarrow{B}_{V} = \text{const.}
$$
 and  
 $\phi = \int \vec{B} \cdot d\vec{a} = \vec{B} \cdot \vec{A}$  [as  $\vec{B} = \text{const.}$ ]



A for area in x-y plane:  $\vec{A} = A\hat{k}$ 

for area A in y-z plane:  $\vec{A} = A\hat{i}$ 

 $Z$   $\blacktriangleright$ 

$$
\phi_{yz} = (\hat{i}B_H - \hat{j}B_V) \cdot (\hat{i}A) = B_H A [\because \hat{i} \cdot \hat{i} = 1 \& \hat{j} \cdot \hat{i} = 0]
$$

for area S in z-x plane:  $\vec{A} = A\hat{i}$ 

$$
\phi_{zx} = (\hat{i}B_H - \hat{j}B_V) \cdot (\hat{j}A) = -B_V A
$$

Negative sign implies that flux is directed vertically down.

### **DIFFERENTWAYSWHICH CAN VARYTHE MAGNETIC FLUX**

Magnetic flux in planar area  $\vec{A}$  due to an uniform magnetic

### field B,  $\phi = B A cos \theta$  $\vec{B}$ ,  $\phi = B A cos \theta$

So flux linked with a circuit will change only if field B, area A, orientation  $\theta$  or any combination of these changes.

### **(1) By varying the magnetic field** B  **with time :**  $\vec{r}$  and  $\vec{r$

Due to motion of magnet B will change with time. Or if magnetic field produced due to current carrying loop then due to change in current change in B will occur with time.



Flux changes as B changes



(2) By varying the area of the conducting loop  $\vec{A}$  with time:  $(3)$  Loop entering or leaving a limit reg The second method of inducing a change in flux is to vary the area of the conducting loop with time.

**(a) Change in Shape of the loop :** Consider a square loop of side "a" placed perpendicular to a uniform and steady magnetic field B. Suppose the square loop transforms into a circular loop of the same circumference.



Initial area of the loop  $= a<sup>2</sup>$ 

The initial flux through the loop  $\phi_i = Ba^2$ 

The final radius of the circular loop  $r = \frac{4\pi}{2\pi} = \frac{2\pi}{\pi}$  (8) (8)

The final flux through the loop  $\phi_f = B\pi r^2 = \frac{4Ba^2}{\pi}$ 

The net change in flux  $(\phi_f - \phi_i) = Ba^2 \left(\frac{4}{\pi} - 1\right)$ 

**(b) Rod Translating in a**  $\Pi$  **Circuit :** Consider a U shaped or a  $\Pi$  shaped conducting wire placed with its plane perpendicular to a uniform magnetic field  $\vec{B}$ . .



Flux changes as A changes

A conducting rod is placed on this wire so as to short the two arms of the U as shown in fig. Let the distance between the two arms of the U be  $\ell$ . We now have a closed conducting loop resting in a uniform magnetic field with one of the sides of the loop free to move. Now suppose the rod translates to the right with a speed v. Then with time, the area enclosed by this loop will keep increasing and with it the flux through the loop will also change.

 **(3) Loop entering or leaving a finite region of magnetic field:** sop A win time.<br>
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have a closed loop enter or leave a region of magnetic field :<br>
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(a) Local pentering on Easting through a mini-region of magnetic field :<br>
in flux is to vary<br>
(a) Rectangular loop passing through angnetic field :<br>  $\frac{1}{1}$  and stady magnetic field to creating a loop w **(a) Rectangular loop passing through magnetic field :** Method for creating a loop with a time varying area is to have a closed loop enter or leave a region of magnetic field. Here the actual area of the loop does not change with time. However, the effective area of the loop through which magnetic field lines pass, varies with time.



**(b) Loop rotating in and out of a finite region of magnetic field :** Consider a semicircular loop placed at the edge of a magnetic field. The loop rotates with an angular velocity  $\omega$ about an axis perpendicular to the plane of the paper and passing through O. As the loop rotates, the area immersed in the magnetic field varies with time.



### **the magnetic field vector :**<br> **the magnetic field vector : (4) Effect of time varying angle between the area vector and**

Consider a circular loop placed in an uniform magnetic field

B such that the plane of the loop is initially parallel to  $\overrightarrow{B}$  such that the plane of the loop is initially parallel to the magnetic field. Let us now rotate the loop about its diameter with a constant angular velocity  $\omega$  with time and consequently the flux through the loop also varies ( $\phi = B A cos\theta$ ) Since  $\theta$  varies so  $\phi$  also varies.



**The flux linked with a loop C will not change with time :** If B, A and  $\theta$  does not change with time, then  $\phi = BA \cos \theta = B(N\pi R^2) \cos 0 = N\pi R^2B = \text{const.}$ 







### $\times$  $\mathbf{\hat{x}}$  $C^{-\times}$ v A  $\mathbf{x}$ 0 but  $\frac{d\phi}{dt} = 0$

### **FARADAY'S EXPERIMENTS**

A sensitive galvanometer (G) is connected to the free ends of a coil A, a strong magnet NS is brought near the coil and away from it and the following observations are made. (i) When the magnet with its N-pole facing the coil is moved

towards the coil, the galvanometer shows some deflection while the magnet is in motion showing that an electro current is produced in the coil even though no conventional source of e.m.f. is in the circuit. The current is called the induced current and the e.m.f. responsible for it is called the induced e.m.f.







### **COIL-COIL EXPERIMENTS**

A coil known as primary (P) is connected in series with the source battery (B) and a tap key (K). Another coil called as secondary (S) is placed closed to the primary coil but not perpendicular to one another.



The following observations are made

- (i) When the key is pressed, the galvanometer shows a momentary deflection.
- (ii) When the current becomes steady i.e. key is kept pressed, the deflection is zero.
- (iii) When the key is released, the galvanometer again shows a momentary deflection, but now in the opposite direction. These observations reveal that as long as there is a change in current in P., an e.m.f. is induced in S. This phenomenon in which an e.m.f. is induced in a coil due to a varying current in a neighbouring coil is called mutual induction. It can also be seen that on keeping K pressed i.e. steady current flowing through P, but on moving S away or towards P, the galvanometer shows deflection, in either case in the opposite directions. election, but now in the opposite direction<br>ations reveal that as long as there is a change<br>
ations reveal that as long as there is a change<br>  $\frac{1}{2}$ , an e.m.f. is induced in so. This phenomenon<br>  $\frac{1}{2}$ , an e.m.f. is

These observations show that an e.m.f is induced in the coil, whenever there is a relative motion between the magnet and the coil.

### **FARADAY'S LAWS OF ELECTRO-MAGNETIC INDUCTION**

Whenever there is change in the magnetic flux associated with a circuit, an e.m.f. is induced in the circuit.

The magnitude of the induced e.m.f. (e) is directly proportional to the time rate of change of the magnetic flux through the circuit.

$$
e \propto \frac{\Delta \phi}{\Delta t} \text{ or } e = k \frac{\Delta \phi}{\Delta t}
$$

In the limit  $\Delta t \rightarrow 0$ ,  $e = \frac{d\phi}{dt}$  $d\phi$ dt

 $k =$  const. of proportionality depending upon the system of units used.

In the S.I. system, emf 'e' is measured in volt and  $\frac{d\phi}{dt}$  in  $\frac{d\mathbf{r}}{dt}$  in  $\phi$ .

Wb/sec. In MKS or SI system, these units are so chosen that  $k = 1$ , and 1 Volt = 1 Wb/sec

Induced current or e.m.f. lasts only for the time for which the magnetic flux is changing.

If the coil has N turns, then the emf will be induced in each turn and the emf's of all the turns will be added up. If the turns of coil are very close to each other, the magnetic flux passing through each turn will be same. ion is zero when the magnet<br>parallel to the plane of the coil.<br>ude of current increases.<br>In the limit  $\Delta t \rightarrow 0$ ,  $e = \frac{d\phi}{dt}$ <br> $k =$  const. of proportionality depending upon the system<br>of units used.<br>In the S.I. system, em

t So, the induced emf in the whole coil  $e = N \frac{\Delta \phi}{\Delta t}$  $N\phi$  = number of 'flux linkages' in the coil.

### **LENZ'S LAW**

**The direction of the induced current e.m.f. is given by** Lenz's law : The direction of the induced current is such that it oppose the change in the magnetic flux that causes the induced current or e.m.f. i.e. induced current tries to maintain flux m, emr 'e' is measured in volt and  $\frac{d}{dt}$  in<br>
KS or SI system, these units are so chosen<br>
Volt = 1 Wb/sec<br>
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x is changing.<br>
turns, then the emr will be induced in each<br>
f<sup>r</sup>

On combining Lenz's law with Faraday's laws

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

–ve sign indicating that the induced e.m.f. opposes the change in the magnetic flux. The Lenz's Law is consistent with the law of conservation of energy.

The induced e.m.f. is produced at the cost of mechanical work done by an external agent in the magnet and coil experiment. When the N-pole of the magnet is moved towards the coil, the face of the coil facing the north pole acts like a north pole. (This can be found by Flemings' Right hand Rule). As the magnet is moved towards the coil, the magnetic flux linked with the coil increases.

To oppose this increase in flux, e.m.f. induced in the coil has to be in such a direction as to reduce the increase in flux.



The external agent has to do some work against this force of repulsion between the two N-pole. This is converted into electrical energy as shown in fig.



Similarly if the magnet with its N-pole is moved away from the coil, then the face of the coil acts like a South pole and hence the flux linked with the coil tends to decrease. The induced current or e.m.f. must now be in a direction so as to increase the flux as shown in figure.



The external agent has to do work against this force of attraction between the N and S poles and this is converted into electrical energy. If suppose, on moving the N pole of the magnet towards the coil, a south polarity is induced on the face of the coil, then the magnet would be attracted to the coil, and there would be a continuous increase in magnetic flux linked with the coil leading to a continuous increase in e.m.f. without any expenditure of energy and this would violate the principle of conservation of energy. CUREENT INACHICUIT (USI<br>
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### **INDUCED CURRENTAND INDUCED CHARGE**

If in a coil of N turns the rate of change of magnetic flux be  $(D)$  $\Delta\phi/\Delta t$ , then the induced emf in the circuit is e=– N ( $\Delta\phi/\Delta t$ ). If the coil be closed and the total resistance of its circuit be R, then the induced current in the circuit will be

$$
I = \frac{e}{R} = \frac{N}{R} \frac{\Delta \phi}{\Delta t}.
$$

It is clear from this equation that the induced current in the circuit depends upon the resistance.

### **Whereas the induced emf is independent of resistance.**

The charge flowed through the circuit in time-interval  $\Delta t$  $q = I \times \Delta t$ 

or 
$$
q = \frac{N}{R} \frac{\Delta \phi}{\Delta t} \times \Delta t = \frac{N}{R} \Delta \phi
$$

 $\frac{\text{number of turns} \times \text{change in magnetic flux}}{\text{resis tan ce}}$ 

The induced charge does not depend upon the timeinterval. Whether the change in magnetic flux be rapid or slow, the charge in the circuit will remain the same.

### **FLEMING'S RIGHT HAND RULE**

Fleming's right hand rule gives the direction of the induced e.m.f. and current in a straight conductor moving perpendicular to the direction of magnetic field.



**Statement :** Stretch out the thumb, fore finger and middle finger of the right hand mutually perpendicular to each other. If the fore finger points in the direction of magnetic field, the thumb in the direction of motion of the conductor, then the middle finger will point out the direction of induced current or induced e.m.f.

### **DETERMINATION OFTHE DIRECTION OFTHE INDUCED CURRENT INA CIRCUIT (USING LENZ'S LAW)**

Lenz's law : "when the magnetic flux through a loop changes, a current is induced in the loop such that the magnetic field due to the induced current opposes the change in the magnetic flux through the loop".

The above rule can be systematically applied as follows to determine the direction of induced currents.

- **(A)** Identify the loop in which the induced current is to be determined.
- **(B)** Determine the direction of the magnetic field in this loop (i.e., in or out of the loop).
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in Euris Line and the control the control telescope of the spin and the control telescope of the spin and the control of the principle of conservation of energy in an a out any expenditure of energy and this<br>
inciple of conservation of energy.<br> **EVALUATE:** Exame as the dimension of charge in fact and the flux through<br>
the rate of charge of magnetic flux be<br>
the rate of charge of magneti **(C)** The direction of flux is the same as the direction of the magnetic field. Determine if the flux through the loop is increasing or decreasing (due to change in area, or change in B).
	- **(D)** Choose the appropriate current in the loop that will oppose the change in flux i.e.,

**a.** If the flux is into the paper and increasing, the flux due to the induced current should be out of the paper.

**b.** If the flux into the paper and decreasing, the flux due to the induced current should be into the paper.

**c.** If the flux is out of the paper and increasing, the flux due to the induced current should be into the paper.

**d.** If the flux is out of the paper and decreasing, the flux due to induced current should be out of the paper.

The above description is the physical interpretation of Lenz's law. We can determine the direction of the induced current mathematically by simply applying Lens' law

 $e_{ind} = -\frac{d\phi_B}{dt}$  with the appropriate sign conventions.  $\phi_B$  is the set of  $\phi_B$ with the appropriate sign conventions.

The Right Hand Sign Convention used is

- Counter clockwise current/emf is +ve
- Clockwise current/emf is –ve
- Magnetic flux out of the paper is +ve



- Magnetic flux into the plane of the paper is –ve
- The rate of change of an increasing positive flux is +ve
- The rate of change of a decreasing positive flux is –ve
- The rate of change of an increasing negative flux is –ve
- The rate of change of a decreasing negative flux is +ve  $\cdot$  S

### **MOTION OFAWIRE INA MAGNETIC FILED**

A wire AC is moving through a magnetic field with constant velocity v at right angles to the direction of the lines of induction B. The direction of its motion is also at right angles to the length L of the wire. Because of this motion, there will be an electromotive force induced in the wire.



Induced potential difference between the ends of the wire  $e = vBL$ 

 $\ell$  in meter, then e will be in volt.

In using this equation, it must be remembered that B, L, and v are considered to be perpendicular to one another.

If they are not, then only those components of all three that are mutually perpendicular are to be considered. In



In a particular case if  $\vec{v}$  and  $\vec{B}$  are mutually perpendicular angle is 30°?

and  $\vec{\ell}$  makes angle  $\theta$  with  $\vec{B}$  and  $\vec{\ell}$  makes angle  $\theta$  with  $\vec{B}$ 

then magnitude of induced e.m.f. is  $e = Bv$  ( $\ell \sin\theta$ )

**Note:** If any one of these  $\vec{v} \parallel \vec{B}$ ,  $\vec{\ell} \parallel \vec{B}$ ,  $\vec{\ell} \parallel \vec{v}$ then induced e.m.f. is zero.

### **Example 2 :**

An artificial satellite with a metal surface has an orbit over the equator. Will the earth's magnetism induce a current in it? Explain.

**Sol.** The satellite will cut vertical component in the equatorial plane is zero. Consequently there will be no change in magnetic flux and hence no current will be induced.

### **Example 3 :**

A conductor of length 10 cm is moved parallel to itself with a speed of 10 m/s at right angles to a uniform magnetic induction  $10^{-4}$  Wb/m<sup>2</sup>. What is the induced e.m.f. in it?

**Sol** Given: 
$$
\ell = 10 \text{ cm} = 0.1 \text{ m}, v = 10 \text{ m/s}
$$
  
\n $B = 10^{-4} \text{ Wb/m}^2$   
\ne.m.f. induced in conductor

 $e = B \ell V = 10^{-4} \times 0.1 \times 10 = 10^{-4} V$ 

### **Example 4 :**

A horizontal telegraph wire 10 m long oriented along the magnetic east-west direction falls freely under gravity to the ground from a height of 10 m. Find the emf induced in the wire at the instant the wire strikes ground.

ive force induced in the wire.<br>
the ground from a height of 10 m. Find the emrinduced in the wire at the instant the wire rest direction falls freely under granches the wire at the instant the wire strikes gound.<br>
Sol. Gi  $(B<sub>H</sub>=2.5\times10^{-5} \text{ Wb/m}^2, g=9.8 \text{ m/s}^2)$ **Sol.** Given :  $u = 0$ ,  $a = -g = -9.8$  m/s<sup>2</sup>,  $s = -10$  m,  $B_H = 2.5 \times 10^{-5}$  Wb/m<sup>2</sup>,  $\ell = 10$  m Let the speed of wire at last moment  $= v$ then  $v^2 = 0 + 2(-9.8) \times (-10) = 196$  [ $v^2 = u^2 + 2 a s$ ]  $\therefore$  v = 14 m/s e.m.f. induced in wire  $e = B_H \ell v = 2.5 \times 10^{-5} \times 10 \times 14 = 3.5 \times 10^{-3}$  Volt

### **Example 5 :**

A wire kept along north-south is allowed to fall freely. Will an induced emf be set up?

**Sol.** No. This is because there will be no change of magnetic flux in this case.

### **Example 6 :**

A metal block and a brick of the same size are allowed to fall freely from the same height above the ground. Which of the two would reach the ground earlier and why?

**Sol.** The brick will reach the ground earlier. This is because the eddy currents produced in the metal block will oppose the motion of the metal block.

### **Example 7 :**

A jet plane is travelling west at the speed of 1800 km/h. What is the voltage difference developed between the ends of the wing 25 m long if the earth's magnetic field at the location has a magnitude of  $5.0 \times 10^{-4}$  Tesla and the dip angle is 30°? th is allowed to fall freely. Will<br>vill be no change of magnetic<br>the same size are allowed to fall<br>t above the ground. Which of<br>und earlier and why?<br>und earlier. This is because the<br>he metal block will oppose the<br>stat at 1 be no change of magnetic<br>
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at the speed of 1800 km/h.<br>
developed between the end

, || B , || v **Sol.** Given that v = 1800 km/h = m/s = 500 m/s = 25 m, B = 5.0 × 10–4 T and = 30° Vertical component of earth's magnetic field B<sup>v</sup> = B sin = 5.0 × 10–4 × sin 30° = 2.5 × 10–4 T

### **MOTIONALe.m.f.**

Suppose the moving rod slides along a stationary U-shaped conductor, forming a complete circuit. Under the action of this field a counterclockwise current is established around this complete circuit.



The moving rod becomes a source of electromotive force. Within it, charge moves from lower to higher potential and in the remainder of the circuit, charge moves from higher to lower potential. We call this a motional electromagnetic force denoted by e, we can write,

 $e = Bv\ell$ 

If R is the resistance of the circuit, then current in the circuit



In the figure shown, we can replace the moving rod ab by a battery of emf Bvl with the positive terminal at a and the negative terminal at b. The resistance r of the rod ab may be treated as the internal resistance of the battery. Hence, the current in the circuit is,

$$
i = \frac{e}{R+r}
$$
 or  $i = \frac{B v \ell}{R+r}$ 

**Induction and energy transfers :** In the figure shown, if you move the conductor ab with a constant velocity v, the current in the circuit is,



$$
i = \frac{B \, v \, \ell}{R} \qquad \qquad (r = 0)
$$

 $\frac{B v \ell}{R}$  (r=0)<br>
etic force  $F_m = i \ell B = \frac{B^2 \ell^2 v}{R}$  acts on the conductor<br>
site direction of velocity. So, to move the conductor<br>
constant velocity v an equal and opposite force F A magnetic force  $F_m = i \ell B = \frac{B}{R}$  acts on the conductor  $\frac{\ell^2 v}{2}$  acts on the conductor

 $rac{\sqrt{3}}{\sqrt{2}}$ <br>  $rac{1}{R}$ <br>
2  $\frac{2}{\sqrt{2}}$  acts on the conductor<br>
equal and opposite force F<br>
actor. in opposite direction of velocity. So, to move the conductor with a constant velocity v an equal and opposite force F has to be applied in the conductor. **EDENTIFY**<br>
EDMADVANCED LEARNING<br>
(r = 0)<br>
FOR  $F_m = i \ell B = \frac{B^2 \ell^2 v}{R}$  acts on the conductor<br>
rection of velocity. So, to move the conductor<br>
in the conductor.<br>  $= \frac{B^2 \ell^2 v}{R}$ <br>
fict in the conductor.<br>  $= \frac{B^2 \ell^2 v^2}{$ EXERCISE THE ARRIVANCED LEARNING<br>  $(r=0)$ <br>  $eF_m = i \ell B = \frac{B^2 \ell^2 v}{R}$  acts on the conductor<br>
retion of velocity. So, to move the conductor<br>
velocity v an equal and opposite force F<br>
d in the conductor.<br>  $\frac{B^2 \ell^2 v}{R}$ <br>
wh **EXERCISE AND MADE CONSTRUCTED LEARNING**<br>
(r=0)<br>  $\frac{1}{2}i \ell B = \frac{B^2 \ell^2 v}{R}$  acts on the conductor<br>
nof velocity. So, to move the conductor<br>
conductor.<br>  $\frac{\ell^2 v}{R}$ <br>
Rork is done by the applied force<br>  $\frac{2v^2}{R}$ <br>
ch e (r=0)<br>  $\sum_{m=1}^{N} \ell B = \frac{B^2 \ell^2 v}{R}$  acts on the conductor<br>
on of velocity. So, to move the conductor<br>
elocity v an equal and opposite force F<br>
in the conductor.<br>  $\frac{3^2 \ell^2 v}{R}$ <br>
work is done by the applied force<br>  $\frac{$  $\frac{2}{\sqrt{N}}$ <br>  $\frac{2}{\sqrt{N}}$  acts on the conductor<br>  $\frac{2}{\sqrt{N}}$ , to move the conductor<br>  $\frac{2}{\sqrt{N}}$ <br>
the applied force<br>  $\frac{2}{\sqrt{N}}$ <br>  $\frac$ 

Thus, 
$$
F = F_m = \frac{B^2 \ell^2 v}{R}
$$

The rate at which work is done by the applied force

$$
P_{\text{applied}} = F_v = \frac{B^2 \ell^2 v^2}{R}
$$

and the rate at which energy is dissipated in the circuit

$$
P_{\text{dissipated}} = i^2 R = \left(\frac{B v \ell}{R}\right)^2
$$
;  $R = \frac{B^2 \ell^2 v^2}{R}$ 

This is just equal to the rate at which work is done by the applied force.

### **INDUCED E.M.F. DUETO ROTATION OFA CONDUCTOR ROD INA UNIFORM MAGNETIC FIELD**

Let a conducting rod is rotating in a magnetic field around an axis passing through its one end, normal to its plane.



Length of rod =  $\ell$ Angular velocity of rod =  $\omega$  $\vec{B}$ 

Intensity of magnetic field =  $\vec{B}$ direction of magnetic field is normal to the plane of rod. Consider an small element dx at a distance x from axis of rotation.

Suppose velocity of this small element  $= v$ 

So, according to Lorent's formula induced e.m.f. across this small element  $de = B v. dx$  .....(i)

 $\therefore$  This small element dx is at distance x from O (axis of rotation)

 $\therefore$  Linear velocity of this element dx is  $v = \omega x$ 

substitute of value of v in eq<sup>n</sup> (i) de = B  $\omega$  x dx Every element of conducting rod is normal to magnetic field and moving in perpendicular direction to the field.





So, net induced e.m.f. across conducting rod

**S**0, net induced e.m.f. across conducting rod  
\nSo, net induced e.m.f. across conducting rod  
\n  
\n**INDUCED ELECTRICFIEL**  
\nWhen the magnetic field changes with time (let it increases  
\nwith time) there is an induced electric field in the conductor  
\ncussed by the changing magnetic flux.  
\nor 
$$
e = \frac{1}{2}B \omega \ell^2
$$
;  $e = \frac{1}{2}B \times 2 \pi f \times \ell^2$   
\n[ $f = \text{frequency of rotation}$ ]  
\nor  $e = BA f$   
\n $e \propto B$   
\n $\alpha f$   
\n $\alpha \ell^2$  or A

### **INDUCEDe.m.f. DUETO ROTATION OFA CIRCULAR METAL DISC INA UNIFORM MAGNETIC FIELD**

Let a metallic uniform disc of radius r is rotating about an axis passing through it centre and perpendicular to its plane.

A uniform magnetic field  $\vec{B}$  is perpendicular to plane of disc normally down wards (as shown in fig.)

We can consider this disc is made up of infinite number of rods each having one end at the centre and another end at the circumference of the disc.

Length of each rod = r and rotating with angular frequency  $\overline{F}$  $\omega$ 





So, induced e.m.f. across each rod  $e = \frac{1}{2} B \omega r^2 = B A f$ 

in each rod free electrons are moving with rod in magnetic field B normal to its plane. So, force on electrons is towards away from the centre and hence at centre positive potential develops whereas negative potential at circumference. All the sources of e.m.f. are connected in parallel and hence net e.m.f. will remain  $e = B \Lambda f$ 

### **INDUCED ELECTRIC FIELD**

 $x^2$  with time) there is an induced electric field in the conductor  $\overline{2}$   $\overline{2}$   $\overline{2}$  caused by the changing magnetic flux. **STUDY MATERIAL: PH**<br>
mducting rod<br> **INDUCEDELECTRIC FIELD**<br>
When the magnetic field changes with time (let it in<br>
with time) there is an induced electric field in the cor<br>
caused by the changing magnetic flux.<br>  $2 \pi f \times \ell$ When the magnetic field changes with time (let it increases



It is non-conservative in nature. The line integral of E  $\ddot{a}$ around a closed path is not zero. When a charge q goes once around the loop, the total work done on it by the electric field is equal to q times the emf.

Hence, 
$$
\oint \vec{E} \cdot d\vec{l} = e = -\frac{d\phi}{dt}
$$

This equation is valid only if the path around which we integrate is stationary.

### **Example 8 :**

2

The magnetic field at all points within the cylindrical region whose cross-section is indicated in the figure start increas-

ing at a constant rate  $\alpha \frac{\text{tesla}}{\text{second}}$ . Find the magnitude of

electric field as a function r, the distance from the geometric centre of the region.



Sol. For  $r \leq R$ :

$$
\therefore \quad E\ell = A \left| \frac{dB}{dt} \right|
$$





$$
\therefore E(2\pi r) = (\pi r^2) \alpha \Rightarrow E = \frac{r\alpha}{2} \Rightarrow E \propto r
$$

E-r graph is straight line passing through origin.

$$
At r = R, \quad E = \frac{R\alpha}{2}
$$

### $For r \geq R$ :

$$
\therefore \quad E\ell = A \left| \frac{dB}{dt} \right|
$$



$$
\therefore E(2\pi r) = (\pi R^2) \alpha \Rightarrow E = \frac{\alpha R^2}{2r} \Rightarrow E \propto \frac{1}{r}
$$
 Q.5



### **TRY IT YOURSELF-1**

**Q.1** A conducting rod is moved with a constant velocity v in a magnetic field. A potential difference appears across the two ends



 $\vec{l} \parallel \vec{B}$  (D) none of these

**Q.2** Two coils carrying current in opposite directions are

**EDENTIFY SURFORT SET AN ADVANCED LEARNING**<br> **EDENTIFY SURFORT AND ADVANCED LEARNING**<br>
A conducting rod is moved with a constant velocity v in<br>
a magnetic field. A potential difference appears across<br>
the two ends<br>
(A) if **CONVENTAINMENT TRY IT YOURSELF-1**<br>
ling rod is moved with a constant velocity v in<br>
c field. A potential difference appears across<br>
ads<br>
(B) if  $\vec{v} \parallel \vec{B}$ <br>
(B) none of these<br>
c carrying current in opposite directions **EXECUTE ARY IT YOURSELF-1**<br> **EXECUTE AN ADDITE ARELATE AND CONDUCT AT A CONDUCT CONDUCT A POTENTIFY A CONDUCT AND A potential difference appears across<br>
the two ends<br>
(A) if**  $\vec{v} || \vec{l}$  **(B) if**  $\vec{v} || \vec{B}$ **<br>
(C) if \vec{l** placed co-axially with centres at some finite separation. If they are brought closer to each other then current flowing in them should ,

 $\alpha$  (A) decrease (B) increase

(C) remain constant

 $R\alpha$  h  $\alpha$ **Q.3** A copper bar of length *l* is dropped from a small height 'h' above the Earth's surface. The axis of the bar remains horizontal and magnetic E-W throughout. The horizontal component of the Earth magnetic field is B. Immediately before striking the ground the potential difference between the ends of the bar is **EXTIT YOUKSELF-1**<br>
A conducting rod is moved with a constant velocity v in<br>
a magnetic field. A potential difference appears across<br>
the two ends<br>
(A) if  $\vec{v} || \vec{l}$  (B) if  $\vec{v} || \vec{B}$  (C) none of these<br>
Two coils car



- = R, F. =  $\frac{Ra}{2}$ <br>  $\Rightarrow$  R =  $\frac{Ra}{2}$ <br>  $\Rightarrow$  E =  $\frac{Ra}{dt}$ <br>  $\Rightarrow$  R =  $\Rightarrow$   $\frac{Ra}{dt}$ <br>  $\Rightarrow$  R =  $\Rightarrow$   $\frac{ln(2)R}{dt}$ <br>  $\Rightarrow$  E =  $\frac{1}{2r}$ <br> component of the Earth magnetic field is B. Immediately<br>before striking the ground the potential difference<br>between the ends of the bar is<br>(A)  $2B/\sqrt{Bh}$  (B)  $B/\sqrt{2gh}$ <br>(C)  $B/gh$  (D)  $2B/gh$ <br>(C)  $B/gh$  (D)  $2B/gh$ <br>or  $B/\sqrt{2gh}$ is straight line passing it<br>rough ongin.<br>
Le  $\frac{R\alpha}{dt}$  is the barr term in the barrier axis of the barr term in the barrier in the barrier<br>
or in the leading of the leading term in the barrier in the barrier of the Eart **Q.4** A uniform circular ring of radius R, mass m has uniformly distributed charge q. The ring is free to rotate about its own axis (which is vertical) without friction. In the space, a uniform magnetic field B, directed vertically downwards, exists in a cylindrical region. Cylindrical region of magnetic field is coaxial with the ring and has radius, greater than R. If induction of magnetic field starts increasing at a constant rate. The angular acceleration of the ring will be :
	- (A) directly proportional to R
	- (B) directly proportional to q
	- (C) directly proportional to m
	- (D) independent of R and m
	- $\frac{\alpha R^2}{\alpha}$   $\Rightarrow$  E  $\alpha$   $\frac{1}{\alpha}$  **Q.5** The bar magnet is oriented so that it lies along the axis of a coil of wire as shown in the diagram. If the magnet is quickly rotated about a vertical axis until the opposite end (south pole) points toward the coil, the direction of the induced current (as seen from the magnet) in the loops of wire in the coil will be –



- (A) without meaning because there will no induced emf or current.
- (B) clockwise if the magnet is rotated clockwise, and vice versa.
- (C) counter-clockwise if the magnet is rotated clockwise, and vice versa.
- (D) the same, whether the magnet is rotated clockwise or counter-clockwise.



**Q.6** The figure shows a conducting bar moving to the right **Q.11** on two conducting rails. To make an induced current *i* in the direction indicated, in what direction would the magnetic field be in the area contained within the conducting rails?

(A) out of the page

- (B) into the page
- (C) to the right
- (D) to the left



**Q.7** A bar magnet with its north (N) and south (S) poles as shown is initially moving to the left, along the axis of and

away from a circular conducting loop. A current I is induced in the loop and acceleration of magnet is a due to this current. As seen from the magnet looking in the direction of the loop.

- (A) I runs clockwise and a points to the left.
- (B) I runs counterclockwise and a points to the right.
- (C) I runs clockwise and a points to the right.
- (D) I runs counterclockwise and a points to the left.
- **Q.8** A rectangular coil of wire rotates about an axis which is perpendicular to a uniform magnetic field at a steady rate. Consider the instant when the plane of the coil is parallel to the magnetic field lines. At that instant the induced electromotive force is,

(A) minimum (B) maximum

(C) zero (D) constant, the same at all times.

**Q.9** A uniform magnetic field *B* is directed out of the page. A metallic wire has the shape of a square frame and is placed in the field as shown. While the shape of the wire is steadily transformed into a circle in the same plane, the current in the frame:  $\bigcirc \bigcirc \bigcirc \bigcirc \bigcirc \bigcirc \bigcirc$ current in the frame:



**Q.10** The four wire loops shown have vertical edge lengths of either L, 2L or 3L. They will move with the same speed

into a region of uniform magnetic field  $\vec{B}$  directed out of the page. Rank them according to the maximum magnitude of the induced emf, greatest to least.



(D) 4 then, 2 and 3 tie and then 1

In a region there exist a magnetic field  $B_0$  along positive x-axis. A metallic wire of length 2a and one side along x-axis and one side parallel of y-axis is rotating about y-axis with a angular velocity  $\omega$ . Then at the instant shown.



(A) Potential difference across PQ is O

(B) Potential difference across PQ is  $\frac{1}{2}B_0 \omega a^2$  $\omega a^2$ 

(C) Potential difference across QR is  $\frac{1}{2}B_0 \omega a^2$  $\omega a^2$ 

(D) Potential difference across QR is  $B_0 \omega a^2$ 

### **ANSWERS**



### **SELF INDUCTION**

Whenever the key in the circuit is closed or opened, the current in the circuit increases or decreases. The variation of current causes a variation in magnetic flux linked with the circuit ( $\therefore \phi \propto I$ ) hence, an induced emf is developed in the circuit. This emf is called induced e.m.f.. Induced emf follows Lenz's law. i.e., induced current always opposes the change in the main current. When the main current is increased (by the rheostat), the induced current flows opposite to the main current and opposes the increases in the main current (fig. A). When the main current is decreased, then the induced current flows is the same direction as the main current and opposes the decrease in the main current (fig. B).



Production of induced e.m.f. in a coil due to the changes in current in the same coil, is called self induction.

According to Lenz's law, direction of induced e.m.f. is opposite to the direction of current where it is increasing. Therefore this e.m.f. is called back e.m.f.

The magnetic flux  $(\phi)$  linked with the coil is directly proportional to the current (I) flowing through it. i.e.  $\phi \propto I$  :  $\phi = L I$ 

The constant L is called self inductance of the coil. L depends on the size and shape of the coil.

The induced e.m.f. 
$$
e = -\frac{d\phi}{dt} = -\frac{d(LI)}{dt} = -L\frac{dI}{dt}
$$
 If n

If 
$$
\frac{dI}{dt} = 1
$$
 then  $e = -L$ 

The self inductance of a coil is equal to the e.m.f. induced in the coil due to the unit rate of change of current in the same coil.

S.I. unit henry (H).

$$
L = \frac{e}{dI/dt} \quad \therefore \quad 1 \text{ henry (H)} = \frac{1 \text{ volt}}{1 \text{ ampere} / \text{sec} \text{ond}}
$$

**MAGNETIC INDUCTION**<br>
gnetic flux ( $\phi$ ) linked with the coil is directly<br>  $\tan L$  is directly<br>  $\tan L$  is called self inductance of the coil.<br>
stant L is called self inductance of the coil.<br>
attack the size and shape of the **1 henry :** The self inductance of a coil is 1 henry, if e.m.f. of 1 volt is induced in the coil, when the current in the coil is changing at the rate of 1 ampere per second. **Relation between henry and weber :**

$$
L = \frac{\phi}{I}
$$
  $\therefore$  1 H =  $\frac{1 \text{ Wb}}{1 \text{ A}} = 1 \text{ Wb A}^{-1}$ 

### **Self-inductance of a plane coil :**

Let current I flowing in a plane coil of radius r.  $N =$  number of turns in the coil.

Magnetic field at the centre of coil, 
$$
B = \frac{\mu_0 NI}{2r}
$$

Magnetic flux per turn of  $\text{coil} = BA$ , cross-sectional area of the coil  $A = \pi r^2$ . .

Total magnetic flux linked with N turns,  $\phi = \frac{\mu_0 N^2 I}{2r}$ 

1 henry : The self inductance of a coil is 1 herry, if e.m.f. of  
\n1 volt is induced in the coil, when the current in the coil is  
\nchanging at the rate of 1 ampere per second.  
\n**Relation between henry and weker :**  
\nL = 
$$
\frac{\phi}{I}
$$
  $\therefore$  1 H =  $\frac{1 \text{ Wb}}{1 \text{ A}} = 1 \text{ Wb A}^{-1}$   
\n**Self-inductance of a plane coil :**  
\nLet current I flowing in a plane coil of radius r.  
\nN = number of turns in the coil.  
\nMagnetic field at the centre of coil,  $B = \frac{\mu_0 NI}{2r}$   
\nMagnetic flux per turn of coil = BA,  
\ncross-sectional area of the coil A =  $\pi r^2$ .  
\nTotal magnetic flux linked with N turns,  $\phi = \frac{\mu_0 N^2 I}{2r}$   
\n $A = \frac{\mu_0 N^2 I}{2r} \times \pi r^2$  or  $\phi = \frac{\mu_0 \pi N^2 r}{2}$   
\n $L = \frac{\mu_0 \pi N^2 r}{2}$   
\nBut  $\phi = L I$   $\therefore$   $L = \frac{\mu_0 \pi N^2 r}{2}$   
\n $L = \frac{\mu_0 N^2 r}{2}$   
\n $L = \frac{\mu_0 \pi N^2 r}{2}$   
\n $L = \frac{\mu_0$ 

### **Example 9 :**

A soft iron core is introduced in an inductor. What is the effect on the self-inductance of the inductor?

**Sol.** Since soft iron has a large relative permeability therefore the magnetic flux and consequently the self-inductance is considerably increased.

**Self-inductance of a solenoid :**

Let cross-sectional area of solenoid  $= A$ Current flowing through it  $=$  I Length of the solenoid =  $\ell$ 

Then, 
$$
\phi = \text{BAN} = \frac{\mu_0 NI}{\ell}
$$
 AN  $= \frac{\mu_0 N^2 A}{\ell}$  I  
\nBut  $\phi = LI$   $\therefore L = \frac{\mu_0 N^2 A}{\ell}$   
\nIf no iron or similar material is nearby, then the value of self-  
\ninductance depends only on the geometrical factors (length, cross-sectional area, number of turns).

 $\frac{dI}{dt}$  If no iron or similar material is nearby, then the value of selfdt
inductance depends only on the geometrical factors (length,  $\frac{N I}{\ell} AN = \frac{\mu_0 N^2 A}{\ell} I$ <br>
terial is nearby, then the value of self-<br>
ly on the geometrical factors (length,<br>
umber of turns). **EXECUTE ARNING**<br>  $I = \frac{\mu_0 NI}{\ell} AN = \frac{\mu_0 N^2 A}{\ell I}$ <br>
L =  $\frac{\mu_0 N^2 A}{\ell}$ <br>
lar material is nearby, then the value of self-<br>
nds only on the geometrical factors (length,<br>
rea, number of turns). cross-sectional area, number of turns).

1 volt<br>
2011 is directly<br>
2011 is directly<br>
2011 is directly<br>
2011 it.<br>
Then, φ = BAN =  $\frac{\mu_0 N^2}{\ell}$  AN =  $\frac{\mu_0 N^2 A}{\ell}$ <br>
1<br>
1.<br>
But φ = LI ∴ L =  $\frac{\mu_0 N^2 A}{\ell}$ <br>
1<br>
1. If the coil.<br>
1.<br>
1. If the coil is material **Experimental demonstration of self-induction :** Let us consider a solenoid connected in series with a battery through a rheostat and a tap key. An electric lamp L is connected in parallel as shown in fig.



 $=\frac{\mu_0H}{2r}$  with the help of rheostat so that the lamp just glows. Press the tap key and then adjust the current in the circuit

enry : The self inductance of a coil is 1 henry, if e.m.f. of<br>
out is induced in the coil when the curit when the curit of the current in the coil of<br>
lation between henry and weber:<br>  $=\frac{9}{1}$   $\therefore$   $1H = \frac{1 \text{ W}}{1 \text{ A}} =$ For execute the integral of radius r.<br>
For exercise the state and the distribution of radius r.<br>
But  $B = \frac{\mu_0 NI}{2r}$ <br>
Press the tap key and then adjust the current in the circuit<br>
oil,  $B = \frac{\mu_0 NI}{2r}$ <br>
From time the profe Now, when the key is released, the lamp suddenly glows brilliantly for a moment. This is because the induced emf at the time of break is greater than the original emf of the battery. When the key is pressed again, the lamp takes some time to light up properly. This is due to the opposition offered by induced emf to the growth of current.

### $\pi N^2 r$  **Physical significance of self-inductance :**

 $\frac{1}{2}$  Just as mass or inertia is responsible for slowing down the  $\pi N^2 r$  electrical circuit slows down the change in current. change in mechanical motion, the self-inductance in an

2 At the time of  $=\frac{\mu_0 R T T T}{2}$  At the time of 'make' of an electrical circuit, the induced emf opposes the growth of current. Consequently, the current cannot attain its maximum value instantaneously but takes some time to do so. If inductance is large, then this time may be of several minutes. Again, at the time of 'break' of an electrical circuit, the induced emf opposes the decay of current. As an example, the field current in D.C. motor takes quite some time to attain its maximum value. This is due to the large inductance of the coil. Again, when the motor is switched off, an arc is formed at the switch due to large induced emf. So, we conclude that self-inductance plays the same role in an electrical circuit as is played by mass or inertia in mechanical motion. Thus, it is appropriate to describe self-inductance as the 'inertia of electricity'.



 $\ell$ 

### **MUTUAL INDUCTION**

Production of induced e.m.f. in coil due to the changes of current in a neighboring coil, is called mutual induction.



Consider two coil A and B placed near to each other. When current in the coil A changed, there is a change in magnetic flux. As this flux is linked with the coil B, an e.m.f. induced is B. This phenomenon is called mutual induction.

The induced e.m.f. in secondary coil B is proportional to the rate of change of current in primary coil A.

### **Coefficient of mutual induction or mutual inductance :**

Let  $\phi =$  magnetic flux linked with the secondary coil when a current  $I_p$  flows through the primary coil.

Then,  $\phi_s \propto I_p$  or or  $\phi_s = M I_p$ .......[1]  $M = constant$  of proportionality called mutual inductance or coefficient of mutual induction.

If  $I_p = 1$ , then  $M = \phi_s$ .

The mutual inductance of two circuits is equal to the magnetic flux linked with one circuit when a unit current flows through the other. induced e.m.f. in secondary coil B is proportional to<br>
induced e.m.f. in secondary coil B is proportional to<br>
inductance is maximum.<br>
This can be increased ut influctance in the secondary coil when<br>  $\mathbf{B}_s = \text{magnetic flux linked with the second y coil when$ by the mutual inductance is made to the three than induction.<br>
This phenomenon is called mutual induction.<br>
This phenomenon is called mutual induction.<br>
This can be increased to the primary coil B is proportional to<br>
eigh

Differentiating eq<sup>n</sup>. (1) w.r.t. time 't', we get 
$$
\frac{d\phi_s}{dt} = M \frac{dI_p}{dt}
$$
  
The mutual inductance of two circuits is said to be 1 henry

But induced emf in secondary coil  $e = -\frac{d\phi_s}{dt}$  induces an emf dt

$$
\therefore e = -M \frac{dI_p}{dt}. \qquad \text{If } \frac{dI}{dt} = 1 \text{, then } M = e \text{ (numerically).} \qquad \blacksquare
$$

The mutual inductance of two circuits or coils is equal to the induced emf set up in one circuit when the rate of change If of current in the other is unity.



The mutual inductance between two coil is equal to the e.m.f. induced in secondary coil due to the unit rate of change of current in the primary coil.

### **Factors on which mutual inductance depends**

The value of mutual inductance of two coils depends upon (i) Geometry of two coils i.e., size, shape and number of turns ( $N_p$  and  $N_s$ ) of the coils.

(ii) Nature of the material on which the two coils are wound.

(iii) The distance between the two coils. (iv) The relative placement of two coils.

If one coil is perpendicular to the other coil as (fig. A), then the mutual inductance is minimum.

Mutual inductance is maximum for the coils wound on the magnetic material (fig. B). When the entire flux due to the primary is linked with the secondary, then the mutual inductance is maximum.

This can be increased  $\mu$  times when the two coils are closely wound on an iron core (laminated to avoid eddy currents) of permeability µ.

Mutual inductance has intermediate value for the configuration (fig. C).

### **Units of mutual inductance :**

other. When<br>
(iv) The relative placement of two coils.<br>
If one coil is perpendicular to the coil as (fig. A), then<br>
in magnetic<br>
im ampetic the mutual inductance is maximum.<br>
m.f. induced<br>
Mutual inductance is maximum for r to each other. When<br>
If one coil is perpendicular to the other coil as (fig. A),<br>
if one coil is perpendicular to the other coil as (fig. A),<br>
the mutual inductance is minimum.<br>
Mutual inductance is minimum for the coil **CGS :** The unit of M is 'emu of mutual inductance' or 'abhenry'. The mutual inductance of two circuits is said to be 1 emu if a current changing at the rate of 1 emu per second in one circuit induces an emf of 1 emu in the other. **SI:** henry (H). This can be increased  $\mu$  times when the two coils are closely<br>wound on an iron core (laminated to avoid eddy currents)<br>of permeability  $\mu$ .<br>Mutual inductance has intermediate value for the<br>configuration (fig. C).<br>Units

if a current changing at the rate of 1 ampere per second induces an emf of 1 volt in the other. of 1 emu per<br>
nu in the other.<br>
d to be 1 henry<br>
re per second<br>
are lying close<br>
ction<br>
Illy in opposite<br>  $L_1L_2$ <br>  $L_1 + L_2$ <br>  $\frac{L_1L_2}{2}$ In the other.<br>
id to be 1 henry<br>
identical behavior of the second<br>
are lying close<br>
ection<br>
ally in opposite<br>  $\frac{L_1L_2}{L_1 + L_2}$ <br>  $\overline{A_1}$ <br>
induced in coil<br>
Il be induced in

1 henry  $= 10<sup>9</sup>$  emu of mutual inductance.

### **INDUCTANCE IN SERIESAND PARALLEL**

**Two coil are connected in series :** Coils are lying close together (M)

If M = 0, 
$$
L = L_1 + L_2
$$

(a) When current in both is in the same direction

Then  $L = (L_1 + M) + (L_2 + M)$ 

(b) When current flow in two coils are mutually in opposite directions.

$$
L = L_1 + L_2 - 2M
$$

### **Two coils are connected in parallel :**

\n- abnenty. The mutual inductance of two circuits is said to be 1 emu if a current changing at the rate of 1 emu per second in one circuit induces an emf of 1 emu in the other.
\n- **SI**: henry (H).
\n- The mutual inductance of two circuits is said to be 1 henry if a current changing at the rate of 1 ampere per second induces an emf of 1 volt in the other.
\n- 1 henry = 10<sup>9</sup> emu of mutual inductance.
\n- **UCTANCE IN SERIES AND PARALLEL**
\n- **Two coil are connected in series :** Coils are lying close together (M)
\n- If M = 0, 
$$
L = L_1 + L_2 + 2M
$$
\n- (a) When current in both is in the same direction. Then  $L = (L_1 + M) + (L_2 + M)$
\n- (b) When current flow in two coils are mutually in opposite directions.
\n- $L = L_1 + L_2 - 2M$
\n- **Two coils are connected in parallel :**
\n- (a) If M = 0 then  $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$  or  $L = \frac{L_1 L_2}{L_1 + L_2}$
\n- (b) If M ≠ 0 then  $\frac{1}{L} = \frac{1}{(L_1 + M)} + \frac{1}{(L_2 + M)}$
\n- If current in coil 1 changes, an e.m.f. will be induced in coil 2. If current in coil 2 changes, an e.m.f. will be induced in coil 1. That is why the process is called mutual induction.
\n

If current in coil 1 changes, an e.m.f. will be induced in coil 2. If current in coil 2 changes, an e.m.f. will be induced in coil 1. That is why the process is called mutual induction.

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### **COEFFICIENT OF COUPLING OF THE TWO CIRCUITS**

Let us now calculate mutual inductance between two circuit in terms of the self inductance of each circuit alone.

Let us first consider a case when the total flux associated with one coil links with the other, i.e., a case of maximum flux linkage. Consider two coils placed adjacent to each

other, 
$$
M_{12} = \frac{N_2 \phi_{B_2}}{i_1}
$$
 and  $M_{21} = \frac{N_1 \phi_{B_1}}{i_2}$ 

Similarly, 
$$
L_1 = \frac{N_1 \phi_{B_1}}{i_1}
$$
 and  $L_2 = \frac{N_2 \phi_{B_2}}{i_2}$  to the tra

If all the flux of coil 2 links coil 1 and vice-versa then,  $\phi_{\rm B_2} = \phi_{\rm B_1}$ 

$$
M_{12}M_{21} = M^2 = \frac{N_1N_2\phi_{B_1}\phi_{B_2}}{i_1i_2} = L_1L_2
$$
  
( $\because M_{12} = M_{21} = M$ )

this is the maximum possible value of M as the total flux associated with one coil links with the other. In general only a fraction  $K_2$  (<1) of  $\phi_{B_2}$  passes through the coil 1. Similarly a fraction  $K_1$  (<1) of  $\phi_{B_1}$  passes through coil 2. If all the flux of coil 2 links coil 1 and vice-versa then,<br>
the oscillations in an L-C circu<br>
the oscillations in an L-C circu<br>
the oscillations in an L-C circu<br>
M<sub>12</sub>M<sub>21</sub> =  $M^2 = \frac{N_1N_2\Phi_B_1\Phi_B_2}{i_1i_2}$  =  $L_1L_2$ <br>  $\Phi_{B_1} = \Phi_{B_1}$ <br>  $\therefore M_{\text{max}} = \sqrt{L_1 L_2}$ <br>  $\$ 

Hence, 
$$
\Psi_{B_1} = K_2 \Psi_{B_2}
$$
 and  $\Psi_{B_2} = K_1 \Psi_{B_1}$   
\n
$$
\therefore M_{21}M_{12} = M^2 = \frac{N_1 N_2 K_1 K_2 \Phi_{B_1} \Phi_{B_2}}{i_1 i_2} = K_1 K_2 L_1 L_2
$$

or 
$$
M = K \sqrt{L_1 L_2}
$$

of the coils and their relative closeness having value between 0 and 1.

When  $K = 0$ , the coupling of two coils is loose fig. A. When  $K = 1$ , the coupling of two coils is tight fig. B.



Generally, K is always less than 1.

### **LC OSCILLATIONS**

**LECTROMAGNETIC INDUCTION**<br> **EFICIENT OF COUPLING OF THE TWO CIRCUITS**<br>
Let us now calculate mutual inductance between two circuit<br>
in terms of the self inductance of each circuit alone.<br>
Let us first consider a case when **INDUCTION**<br> **ANGOFTHETWOCIRCUITS**<br> **ANGOFTHETWOCIRCUITS**<br> **ANGOFTHETWOCIRCUITS**<br>
LCOSCILLATIONS<br>
LTOSCILLATIONS<br>
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LTOSCILLATIONS<br>
LTOSCILLATI 2 is transferred from the capacitor's electric field to the  $\frac{N_1 \phi_{B_1}}{N_1 \phi_{B_1}}$  oscillations in the circuit persist indefinitely and the energy these idealizations-zero resistance and no radiation, the  $\phi_{\text{B}_{1}}$ **GNETIC INDUCTION**<br>
FCOUPLING OF THE TWO CIRCUITS LC OSCILLATIONS<br>
leulate mutual inductance between two circuit<br>
onsider a case when the total flux associated<br>
limks with the other, i.e., a case of maximum<br>
consider two **THETWOCIRCUITS**<br> **ICOSCILLATIONS**<br>
ICOSCILLATIONS<br>
ICOSCILLA 2  $\omega$   $\omega$  $N_2\Phi_{B_2}$  associated with the circuit is constant. This is analogous COUPLING OF THE TWO CIRCUITS LC OSCILLATIONS<br>
ulate mutual inductance between two circuit<br>
or in the charged capacitor C is shownards in the solen contract alone.<br>
In the charge adducent in the sistem<br>
in sister a case wh the multiplieral modulation of each circuit alone.<br>
the charged capactor C is<br>
the other, i.e., a case of maximum<br>
two coils placed adjacent to each<br>
two coils placed adjacent to each<br>
the strength is dissipated as his wi TIC INDUCTION INCORCUITS LCOSCILLATIONS<br>
termutal inductance of each circuit alone.<br>
E inductance of each circuit alone.<br>
L, the charge and current in the circuit<br>
ler a case when the total flux associated<br>
sight two coil **INDUCTION**<br> **INGOFTHETWOCIRCUITS**<br> **ICOSCILLATIONS**<br> **ICOSCILLATIONS**<br> **ICOSCILLATIONS**<br> **ICOSCILLATIONS**<br> **ICOSCILLATIONS**<br> **ICOSCILLATIONS**<br> **ICOSCILE CONDITY**<br> **ICOSCILE CONDITY**<br> **ICOSCILE CONDITY**<br> **ICOSCILE CONDITY NDUCTION**<br> **NGOFTHETWOCIRCUITS**<br>
LCOSCILLATIONS<br>
tual inductance between two circuit if a charged capacitor C is short-circuited the<br>
tance of each circuit alone.<br>
Let the charge and current in the circuit start<br>
the oth **FFICIENT OF COUPLING OF THE TWO CIRCUITS**<br>
LE US now calculate mutual inductance between two circuit if a charged capacitor C is short-<br>
Let us first consider a case when the total flux associated<br>
the merodic metallic i Find the  $\sinh(k)$  and  $\sinh(k)$  If a charged capacitor C is short-circuited though an inductor L, the charge and current in the circuit start oscillating simple harmonically. If the resistance of the circuit is zero, no energy is dissipated as heat. Assume an idealized situation in which energy is not radiated away from the circuit. With inductor's magnetic field back and forth. The total energy to the transfer of energy in an oscillating mechanical system from potential energy to kinetic energy and back, with constant total energy. Let us now derive an equation for the oscillations in an L-C circuit.

Refer figure (a) : The capacitor is charged to a potential difference V such that charge on capacitor  $q_0 = CV$ Here  $q_0$  is the maximum charge on the capacitor.

At time  $t = 0$ , it is connected to an inductor through a switch S. At time  $t = 0$ , switch S is closed.

Refer figure (b) : When the switch is closed, the capacitor



starts discharging. Let at time t charge on the capacitor is  $q \, (< q_0)$  and since, it is further decreasing there is a current i in the circuit in the direction shown in figure. (b)<br>
discharging. Let at time t charge on the capacitor is<br>  $\omega$ ) and since, it is further decreasing there is a current<br>
considerable in the direction shown in figure.<br>
the contential difference across capacitor = potent S<br>
S<br>
S<br>
(a) (b)<br>
s discharging. Let at time t charge on the capacitor is<br>
q<sub>0</sub>) and since, it is further decreasing there is a current<br>
he circuit in the direction shown in figure.<br>
potential difference across capacitor S (a) (b)<br>
s discharging. Let at time t charge on the capacitor is<br>
q<sub>0</sub>) and since, it is further decreasing there is a current<br>
he circuit in the direction shown in figure.<br>
potential difference across capacitor = poten (b)<br>
ime t charge on the capacitor is<br>
her decreasing there is a current<br>
ion shown in figure.<br>
across capacitor = potential<br>  $\frac{q}{C} = L\left(\frac{di}{dt}\right)$  ...(i)<br>
easing,<br>  $= -\frac{d^2q}{dt^2}$ <br>
...(ii)<br>
...(ii)<br>
on of simple harmon

The potential difference across capacitor = potential difference across inductor,

or 
$$
V_b - V_a = V_c - V_d
$$
 :  $\frac{q}{C} = L\left(\frac{di}{dt}\right)$  ...(i)

Now, as the charge is decreasing,

$$
i = \left(\frac{-dq}{dt}\right)
$$
 or  $\frac{di}{dt} = -\frac{d^2q}{dt^2}$ 

Substituting in equation (i), we get

$$
\frac{q}{C} = -L\left(\frac{d^2q}{dt^2}\right) \text{ or } \frac{d^2q}{dt^2} = -\left(\frac{1}{LC}\right)q \qquad ...(ii)
$$

This is the standard equation of simple harmonic motion

$$
\begin{aligned}\n& q_0 \text{ and since, it is further decreasing there is a current} \\
& \text{the circuit in the direction shown in figure.} \\
& \text{potential difference across capacitor} = \text{potential} \\
\text{ference across inductor,} \\
& V_b - V_a = V_c - V_d \quad \therefore \quad \frac{q}{C} = L\left(\frac{di}{dt}\right) \qquad ...(i) \\
& \text{with } V_b - V_a = V_c - V_d \quad \therefore \quad \frac{q}{C} = L\left(\frac{di}{dt}\right) \qquad ...(ii) \\
& \text{with } V_b = V_a \text{ and } V_b = V_b \text{ and } V_b = V
$$

The general solution of equation (ii), is

$$
q = q_0 \cos{(\omega t \pm \phi)}
$$

In our case  $\phi = 0$  as  $q = q_0$  at  $t = 0$ . Thus, we can say that charge in the circuit oscillates with angular frequency given by equation (iii). Thus,



In L-C oscillations, q, i and 
$$
\frac{di}{dt}
$$
 all oscillate harmonically

w i t h s a m e a n g u c w c w c w c w c w c u e n c u e n difference

between q and i or between i and  $\frac{di}{dt}$  is  $\pi/2$ .

Their amplitudes are  $q_0$ ,  $q_0$  and  $\omega^2 q_0$  respectively. So

$$
q = q_0 \cos \omega t, \text{ then } i = \frac{dq}{dt} = -q_0 \omega \sin \omega t
$$

$$
\frac{di}{dt} = -q_0 \omega^2 \cos \omega t
$$

Similarly potential energy across capacitor ( $\rm U_C$  ) and across inductor  $(U_L)$  also oscillate with double the frequency 2 $\omega$ .

### **Example 10 :**

Consider the circuit shown in figure. Suppose the switch which has been connected to point a for a long time is suddenly thrown to b at  $t = 0$ .



Find the following quantities:

(a) the frequency of oscillation of the LC circuit.

(b) the maximum charge that appears on the capacitor.

- (c) the maximum current in the inductor.
- **Sol.** (a) The (angular) frequency of oscillation of the LC circuit

is given by 
$$
\omega = 2\pi f = 1/\sqrt{LC}
$$

 $f = \frac{1}{\sqrt{1 - \frac{1}{n}}}$   $\phi_B = BA$ 

- (b) The maximum charge stored in the capacitor before the switch is thrown to b is  $Q = CE$
- (c) The energy stored in the capacitor before the switch is

$$
t
$$
 
$$
U_E = \frac{1}{2}CE^2
$$

On the other hand, the magnetic energy stored in the

inductor is  $U_L = \frac{1}{2}LI^2$ 

Thus, when the current is at its maximum, all the energy originally stored in the capacitor is now in the inductor: Example the three than the capacitor is now in the inductor:<br>  $2 = \frac{1}{2} L I_0^2$ <br>  $2 = \sqrt{L} I_0^2$ <br>  $2 = \sqrt{L} I_1^2$ <br>  $2 = \frac{1}{2} L I_2^2$ <br>  $2 = \frac{1}{2} L I_0^2$ <br>  $2 = \frac{1}{2} L I_0^2$ <br>  $2 = \frac{1}{2} L I_1^2$ <br>  $2 = \frac{1}{2} L I_0^2$ <br>  $2 = \frac{1}{2} L I_$ Therefore, the frequency is  $f = \frac{1}{2\pi\sqrt{LC}}$  (b)  $\frac{1}{2\pi\sqrt{LC}}$  (c)  $\frac{1}{2\pi\sqrt$ 

$$
\frac{1}{2}CE^2 = \frac{1}{2}LI_0^2
$$

This implies a maximum current

 $0 = E \sqrt{\frac{C}{I}}$  $\mathbf C$ L

### **GENERATOR**

One of the most important applications of Faraday's law of induction is to generators and motors. A generator converts mechanical energy into electric energy, while a motor converts electrical energy into mechanical energy.





### **Figure (a) A simple generator. (b) The rotating loop as seen from above.**

2 Let the species of the switch is<br>
a for a long time is<br>  $\frac{1}{2\pi\sqrt{LC}}$ <br>  $\frac{1}{2\sqrt{LC}}$ <br>  $\frac{1}{2\sqrt{LC$ **Example generator.**<br>
In the inductor:<br>
The containing loop assesses from<br>
the methanical of the LC circuit.<br>
Tigure (a) is a simple illustration of a gy<br>
of oscillation of the LC circuit<br>
for an N-turn loop rotating in a Example illustration of the number of the section<br>
in the maximum charge that appears on the capacitor.<br>
Tigure (a) is a simple illustratic<br>
the (angular) frequency of oscillation of the LC circuit assumed to be uniform. Example the maximum current in the inductor.<br>
Let  $\sin \theta = 2\pi I$  and  $\sin \theta = 2\pi I$ <br>  $\sin \theta = 2\pi I$ <br> Figure (a) is a simple illustration of a generator. It consists of an N-turn loop rotating in a magnetic field which is assumed to be uniform. The magnetic flux varies with time, thereby inducing an emf. From figure (b), we see that the magnetic flux through the loop may be written as **Example 18**<br> **Example generator.**<br>
The rotating loop as seen from above.<br>
is a simple illustration of a generator. It consists<br>
um loop rotating in a magnetic field which is<br>
obe uniform. The magnetic flux varies with ti Figure (a) A simple generator.<br>
(b) The rotating loop as seen from above.<br>
re (a) is a simple illustration of a generator. It consists<br>
n N-turn loop rotating in a magnetic field which is<br>
need to be uniform. The magnetic (b) The rotating loop as seen from above.<br>
re (a) is a simple illustration of a generator. It consists<br>
n N-turn loop rotating in a magnetic field which is<br>
med to be uniform. The magnetic flux varies with time,<br>
by induc 9) is a simple illustration of a generator. It consists<br>
turn loop rotating in a magnetic field which is<br>
to be uniform. The magnetic flux varies with time,<br>
nducing an emf. From figure (b), we see that the<br>
flux through igure (a) A simple generator.<br>
(b) The rotating loop as seen from above.<br>
(a) is a simple illustration of a generator. It consists<br>
N-turn loop rotating in a magnetic field which is<br>
ed to be uniform. The magnetic flux va

$$
\phi_{\rm B} = \vec{\rm B}.\vec{\rm A} = \text{BA}\cos\theta = \text{BA}\cos\omega t \qquad \qquad \qquad \dots \dots \dots (1)
$$

 $\pi\sqrt{LC}$  The rate of change of magnetic flux is

$$
\frac{d\phi_B}{dt} = -BA\omega \sin \omega t \qquad \qquad \dots \dots \dots (2)
$$

Since there are N turns in the loop, the total induced emf across the two ends of the loop is

$$
\varepsilon = -N \frac{d\phi_B}{dt} = NBA\omega \sin \omega t \qquad \qquad \dots \dots \dots (3)
$$

If we connect the generator to a circuit which has a resistance R, then the current generated in the circuit is given by

$$
I = \frac{|e|}{R} = \frac{NBA\omega}{R} \sin \omega t
$$
 .........(4)

 $\omega$ 

The current is an alternating current which oscillates in

sign and has an amplitude  $I_0 = \frac{NBA\omega}{R}$ .  $R$  and  $R$  a

The power delivered to this circuit is

the electric flux through the loop may be written as  
\n
$$
φ_B = \vec{B}.\vec{A} = BA \cos \theta = BA \cos \omega t
$$
 .........(1)  
\nrate of change of magnetic flux is  
\n
$$
\frac{dφ_B}{dt} = - BA \omega \sin \omega t
$$
 .........(2)  
\net there are N turns in the loop, the total induced emf  
\nas the two ends of the loop is  
\n
$$
\epsilon = -N \frac{dφ_B}{dt} = NBA \omega \sin \omega t
$$
 .........(3)  
\net connect the generator to a circuit which has a resistance  
\nthen the current generated in the circuit is given by  
\n
$$
I = \frac{|e|}{R} = \frac{NBA\omega}{R} \sin \omega t
$$
 .........(4)  
\ncurrent is an alternating current which oscillates in  
\nand has an amplitude I<sub>0</sub> =  $\frac{NBA\omega}{R}$ .  
\npower delivered to this circuit is  
\n
$$
P = I | e | = \frac{(NBA\omega)^2}{R} \sin^2 \omega t
$$
 .........(5)

.



On the other hand, the torque exerted on the loop is  $\tau = \mu B \sin \theta = \mu B \sin \omega t$  .......... (6) Thus, the mechanical power supplied to rotate the loop is  $P_m = \tau \omega = \mu B \omega \sin \omega t$  .......... (7)

Since the dipole moment for the N-turn current loop is

$$
\mu = NIA = \frac{N^2 A^2 B \omega}{R} \sin \omega t \qquad \qquad \dots \dots \dots (8)
$$

the above expression becomes

$$
P_m = \left(\frac{N^2 A^2 B \omega}{R} \sin \omega t\right) B \omega \sin \omega t
$$
 is a  
secu  

$$
= \frac{(NAB\omega)^2}{R} \sin^2 \omega t
$$
........(9)

As expected, the mechanical power put in is equal to the electrical power output.

### **TRANSFORMER**

**Principle :** It work on the phenomenon of mutual induction. It is a device for transforming a low alternating voltage of high current into a high alternating voltage of lower current and vice versa, without increasing power or changing frequency.



### **Construction :**

It has three main parts described below :

- **1. A laminated core (C) of sand-mixed iron in shell type :** It has more resistance due to laminations and mixing of sand. It is done to reduce eddy current the core and minimize <sup>or</sup> its heating.
- **2. A primary coil P :** It is a coil of enamelled copper wire wrapped over the central arm of the core and is insulated from it by varnish.
- **3. A secondary coil S :** It is also a coil of enamelled copper wire. It is wrapped over the primary and insulated from it by wax paper. Transformed alternating voltage is obtained from it. It forms output section of the transformer.

If a low voltage is to be transformed into a high voltage, then the number of turns in secondary is more than those in primary. The transformer is called a step up transformer. If a high voltage is to be transformed into a low voltage, then the number of turns in secondary is less than those in primary. The transformer is called step-down transformer. Transformation ratio of the transformer (K) n parts described below:<br>  $E_p - N_p \frac{w}{dt} = 0$ <br>  $\text{re (C) of anad-mixed iron in shell type :}\n\text{distance due to laminations and mixing of\nof the central arm of the core and minimizes}\n\text{or } E_p - N_p \frac{d\Phi}{dt}$   $\text{...}(a)$ <br>  $\text{re 1 } P : 1 \text{ is a coil of enamelled copper wire}\n\text{where the central arm of the core and is insulated}\n\text{or } N = S : 1 \text{ is also a coil of semalled copper.}\n\text{From (a) and (b),}\n\text{in 3 : It is also a coil of enamelled copper wire$ e(C) of sand-mixed iron in shell type:<br>
reduce edg to laminations and mixing of<br>
reduce dely current the core and minimize<br>  $P : It is a coil of anamelled copper wire$ <br>
2. It is a coil of enamelled copper wire<br>
2. It is a coil of enamelled copper wi

Number of turns in secondary $(N_s)$	But in practice to
Number of turns in primary $(N_p)$	so input power

 $\frac{s}{p}$ 

 $N_{\rm s}$ 

 $N_p$ 

 $K = \frac{1}{N}$ 

$$
K > 1
$$
, for step-up transformer.

 $K < 1$ , for step-down transformer.

The whole arrangement is kept immersed in a special oil called transformer oil, taken in metallic cans. The oil provides insulation as well as cooling.

**MAGNETIC INDUCTION**<br>
ther hand, the torque exerted on the loop is<br>
2 BOMMAD EST (3 A SUP)<br>
2 2 B and  $\tau$  o =  $\mu$ B osin of<br>
2 A Super singular of the N-turn current loop is<br>  $\text{NIA} = \frac{N^2 A^2 B\omega}{R} \sin \omega t$  (8)<br>
2 alled tr R as well as in secondary. Due to mutual induction, an e.m.f.  $\frac{\omega}{\sin \omega}$  it produces a continuous change in magnetic flux in primary **EROMAGNETIC INDUCTION**<br>
he other hand, the torque exerted on the loop is<br>  $\kappa = \mu B \sin \theta = \mu B \sin \omega t$  (6)<br>  $\mu = NIA = \frac{N^2 A^2 B \omega}{R} \sin \omega t$  (8)<br>  $P_m = \left(\frac{N^2 A^2 B \omega}{R} \sin \omega t\right) \cos \omega t$  (8)<br>  $\mu = \frac{N}{\mu}$  (1) and the loop is<br>  $\mu = NIA = \$ **EXECTED INDUCTION**<br> **EXECTED INDUCTION**<br>
LED SIGN OF EVERTIC INDUCTION<br>  $\mu = NIs$  and  $\theta = \mu B \sin \omega t$  (b)  $\mu = NIs$  and  $\mu = \left(\frac{N^2 A^2 B\omega}{R}\right) \sin^2 \omega t$ <br>  $\mu = NIA = \frac{(N^2 A^2 B\omega)}{R} \sin \omega t$ <br>  $\mu = NIA = \frac{(N^2 A^2 B\omega)}{R} \sin \omega t$ <br>  $\mu = NIA = \frac{(N$ **AAGNETIC INDUCTION**<br>
ler hand, the torque exerted on the loop is<br>
sin  $\theta = \mu B \sin \omega t$ <br>
sin  $\theta = \mu B \sin \omega t$ <br>
mechanical power supplied to rotate the loop is<br>
mechanical power supplied to rotate the loop is<br>  $\pi$  and  $\theta = \mu B \sin$ **MAGNETIC INDUCTION**<br>
In the torque exerted on the loop is<br>
IE sin  $\theta = \mu B \sin \omega t$  (B) is  $\pi(t) = \pi(t)$ <br>
and  $\theta = \mu B \sin \omega t$  (b) is  $\pi(t) = \pi(t)$ <br>
and  $\theta = \frac{1}{2}$  and  $\theta = \frac{1}{2}$  and  $\theta = \frac{1}{2}$  and  $\theta = \frac{1}{2}$  and  $\theta = \frac{1}{$ **Working :** As voltage applied on the primary is alternating, is induced in secondary. It is higher or lower than that induce in primary depending upon whether the transformer is a step or step-down transformer. The induced e.m.f. in secondary gives output voltage.

**EVALUATE SOMAGE (SOMAGE SET AS A SUBLIMED AND SOMAGE SET AND SOMAGE SET AND SOMAGE (SOMET A SUBLA SIGNATIC INDUCTION THE HIS SIGNATION THE HIS SIGNATION THE THE SIGNATION CONDUCTION THE THE SIGNATION CONDUCTION THE THE S**  $\omega$ t (9) and a current I<sub>s</sub> in the secondary circuit. The currents in the **Theory**: An alternating e.m.f.  $E_p$  is applied across the primary which produces current  $I_p$  in the primary circuit coils produce a magnetization in the soft-iron core and there is a corresponding magnetic field B inside the core. The field due to magnetization of the core is large as compared to the field due to the currents in the coils. We assume that the field is constant in magnitude everywhere in the core and hence its flux (BA) through each turn is same for the primary as well as for the secondary coil. between the correction of the core. The<br>
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and hence its flux (BA) through each turn is same for the<br>
primary as well as for the secondary coil.<br>
Let the flux through each turn be  $\Phi$ . The emf induced in a current  $I_s$  in the secondary circuit. The currents in the<br>produce a magnetization in the soft-iron core and there<br>corresponding magnetic field B inside the core. The<br>due to magnetization of the core is large as compare field due to magnetization of the core is large as compared<br>to the field due to the crurrents in the coils. We assume that<br>the field is constant in magnitude everywhere in the core<br>and hence its flux (BA) through each tur Example the core. The original matrix of the core. The<br>
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d due to the currents in the coils. We assume that<br>
s constant in

Let the flux through each turn be  $\Phi$ . The emf induced in the

$$
primary = -N_p \frac{d\Phi}{dt}
$$

and induced in the secondary =  $-N_s \times \frac{d\Phi}{dt} = E_s$ .  $dt \qquad \qquad \simeq$  s  $\Phi$  $=E$ <sub>s</sub>.

If we neglect the resistance in the primary circuit, Kirchhoff's loop law applied to the primary circuit gives

$$
E_p - N_p \frac{d\Phi}{dt} = 0
$$
  

$$
E_p = N_p \frac{d\Phi}{dt}
$$
 ......(a)

Also, 
$$
E_s = -N_s \frac{d\Phi}{dt}
$$
 ......(b)

From (a) and (b),

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

duced in the secondary =  $-N_s \times \frac{d\Phi}{dt} = E_s$ .<br>
eglect the resistance in the primary circuit, Kirchhoff's<br>
aw applied to the primary circuit gives<br>  $p - N_p \frac{d\Phi}{dt} = 0$ <br>  $p = N_p \frac{d\Phi}{dt}$  ......(a)<br>  $E_s = -N_s \frac{d\Phi}{dt}$  ......(b)<br> ary as well as for the secondary coil.<br>
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ary =  $-N_p \frac{d\Phi}{dt}$ <br>
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......(a)<br>
......(b)<br>
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circu ......(a)<br>......(a)<br>......(b)<br>......(b)<br>E<sub>s</sub> is 180° out of phase with E<sub>p</sub>.<br>for all values of currents in the<br>v circuits. If there is no loss of<br>circuits<br>power<br> $\frac{I_p}{I_s} = \frac{E_s}{E_p} = \frac{N_s}{N_p}$ <br>ays energy loss<br>wer the primary circuit, Kirchhoff's<br>
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r all values of currents in the<br>
rcuits. If there is no loss of<br>
cuits<br>
wer<br>
=  $\frac{E_s}{E_p} = \frac{N_s}{N_p}$ <br>
s

then **input power = output power**

$$
E_p \times I_p = E_s \times I_s
$$
 or  $\frac{I_p}{I_s} = \frac{E_s}{E_p} = \frac{N_s}{N_p}$ 

But in practice there is always energy loss so input power > output power and hence  $E_p \times I_p > E_s \times I_s$ 



### **Energy Losses in a Transformer :**

- **(i)** Energy lost in winding of the transformer is known as copper loss. Primary and secondary coils of a transformer are generally made of copper wires. These copper wires have resistance (R). When current (I) flows through these wires, power loss  $(I<sup>2</sup>R)$  takes place. This loss appears as the heat produced in the primary and secondary coils. Copper losses can be reduced by using thick wires for the windings.
- **(ii) Flux Losses :** In actual transformer, the coupling between primary and secondary coil is not perfect. It means that magnetic flux linked with the primary coil is not equal to the So magnetic flux linked with secondary coil. so a certain amount of electric energy supplied to the primary coil is wasted.

### **(iii) Iron Losses :**

**(a) Eddy Currents Losses :** When a changing magnetics flux links with the iron core of the transformer, eddy currents are set up. These eddy currents produce heat which leads to the wastage of energy. This energy loss is reduced by using laminated on cores (Fig).



Eddy currents are reduced in a laminated core because their paths are broken as compared to solid core as shown in fig.



Solid core Laminated core

**(b) Hysteresis Losses :** When alternating current passes through the primary coil, core of the transformer is magnetized and demagnetised over a complete cycle. Some energy is lost in magnetising and de-magnetising the iron core. The energy loss in a complete cycle is equal to area of the hysteresis loop.

This energy loss can be minimized by using suitable material having narrow hysteresis loop for the core of a transformer.

**(c) Losses due to Vibration of core or humming losses :** A transformer produces humming noise due to magnetostriction effect. Some electrical energy is lost in the form of mechanical energy to produce vibration in the core.

**Efficiency of a transformer :** In an ordinary transformer, there is some loss of energy due to coil resistance, hysteresis in the core, eddy currents in the core etc. The efficiency of a transformer is defined as

$$
l = \frac{\text{output power}}{\text{input power}}
$$

Efficiency of the order of 99% can be easily achieved.

### **Example 11:**

**STUDY MATERIAL: PHYSICS**<br>  $\eta = \frac{\text{output power}}{\text{input power}}$ <br>
ciency of the order of 99% can be easily achieved.<br>
11:<br>
ansformer having efficiency 90% is working on 100 V<br>
at 2.0 by name if the summatin the season demonsities **STUDY MATERIAL: PHYSICS**<br>
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y of the order of 99% can be easily achieved.<br>
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late (i) the current i A transformer having efficiency 90% is working on 100 V and at 2.0 kW power. If the current in the secondary coil is 5A, calculate (i) the current in the primary and (ii) voltage across the secondary coil.

**STUDY MATERIAL: PHYSICS**  
\n
$$
\eta = \frac{\text{output power}}{\text{input power}}
$$
\nEfficiency of the order of 99% can be easily achieved.  
\n**Example 11:**  
\nA transformer having efficiency 90% is working on 100 V  
\nand at 2.0 kW power. If the current in the secondary coil is  
\n5A, calculate (i) the current in the primary and (ii) voltage  
\nacross the secondary coil.  
\n**Sol.** Here,  $\eta = 90\% = \frac{9}{10}$ ,  $I_s = 5A$ ,  $E_p = 100$  V.  
\n $E_p I_p = 2 \text{ kW} = 2000 \text{ W}$   
\n(i)  $E_p I_p = 2000 \text{ W}$   
\n(ii)  $E_p I_p = 2000 \text{ W}$   
\n(i)  $\eta = \frac{2000}{E_p I_p} \text{ or } I_p = \frac{2000}{100} = 20 \text{ A}$   
\n(ii)  $\eta = \frac{\text{Output power}}{\text{Input power}} = \frac{E_s I_s}{E_p I_p}$   
\nor  $E_s I_s = \eta \times E_p I_p = \frac{9}{10} \times 2000 = 1800 \text{ W}$   
\n $\therefore \frac{1800}{I_s} = \frac{1800}{5} = 360 \text{ Volt}$   
\n**Applications :** The most important application of a  
\ntransformer is in long distance transmission of electric power  
\nfrom generating station to consumers hundreds of  
\nkilometers away through transmission lines at reduced loss  
\nof power.

**Applications :** The most important application of a transformer is in long distance transmission of electric power from generating station to consumers hundreds of kilometers away through transmission lines at reduced loss of power.

Transmission lines having resistance R and carrying current I have loss of power  $I^2R$ .

This loss is reduced by reducing the current by stepping up the voltage at generating station.

This high voltage is transmitted through high-tension transmission lines supported on robust pylons (iron girder pillars).

The voltage is stepped down at consumption station.

### **Example 12 :**

A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric power plant generating power at 440 V. The resistance of the two wire line carrying power is  $0.5 \Omega$  per km. The town gets from the line through a 4000 – 220 V step down transformer at a substation in the town.

(b) Estimate the line power loss in the form of heat.

(b) How much power must be plant supply, assuming there is a negligible power loss due to leakage?

(c) Characterise the step up transformer at the plant.

**STUDY MATERIAL : PHYSICS**



t

**Sol.** The diagram shows the network :



For sub-station,  $P = 800 \text{ kW} = 800 \times 10^3 \text{ watts}$  $V = 22$ 

$$
00 \text{ kW} = 800 \times 10^2
$$
  
20 V

$$
I_{\rm S} = \frac{P}{V} = \frac{800 \times 10^3}{220} = \frac{40}{11} \times 10^3 \,\mathrm{A}.
$$

Primary current  $(I_p)$  in sub-station transformer will be given by  $4000 \times I_p = 220 \times I_s$ 

$$
I_{\rm P} = \frac{220 \times 40 \times 10^3}{11 \times 4000} = 200 \,\text{A}
$$

(a) Hence transmission line current  $= 200 \text{ A}$ transmission line resistance =  $2 \times 15 \times 0.5 = 15 \Omega$ 

transmission line power loss

 $= I^2R = 200 \times 200 \times 15 = 6 \times 10^5$  watt = 600 kW. (b) power to be supplied by plant = power required at substation + loss of power of transmission

 $= 800 + 600 = 1400$  kW. (c) Voltage in secondary at power plant has characteristics

$$
= \frac{\text{Power}}{\text{Current}} = \frac{1400 \text{ kW}}{200 \text{ A}} = \frac{1400 \times 1000}{200} = 7000 \text{ V}
$$

Step-up transformer at power plant has characteristics 440 - 7000 V.

### **GROWTHAND DECAY OF CURRENT IN L-R CIRCUIT**

Let a battery of e.m.f. E connected to a series combination of an inductance L and resistance R as shown in fig. The resistor R may be a separate circuit element, or it may be the resistance of the inductor windings. HAND DECAY OF CURRENT IN LACIRCUIT<br>
binductance L and resistance R as shown in fig.<br>
inductance L and resistance R as shown in fig.<br>
resistor R may be a separate circuit element, or it may<br>
triangly, an inductor acts to c 000 V.<br>
AND DECAY OF CURRENT IN L-R CIRCUIT<br>
attery of e.m.f. E connected to a series combination<br>
duratery of e.m.f. E connected to a series combination<br>
order and resistance of the inductor windings.<br>
is interest:<br>
atte

### **Growth of Current :**

If K is closed at  $t = 0$ , so at  $t = 0$ , current in the circuit  $I = 0$ after closing the key K at time t let current in the circuit= I for small time in the circuit, current varies with time,

so if rate of change of current with time = 
$$
\frac{dI}{dt}
$$

Then due to phenomenon of self induction induced emf

$$
across inductance = -L \frac{dI}{dt}
$$
 Let the

Potential difference across the resistance = IR During growth of current in L-R circuit, if we applying Kirchhoff's loop rule then

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

On solving it we get the value of current at any time t during growth of current in LR-circuit.  $\mathbf{I}$   $\mathbf{A}$  $I_0 = E/R$ 

$$
I = I_0 (1 - e^{-\frac{R}{L}t})
$$

**Time Constant :**

R<sub>1</sub>  $\vert$  /  $\vert$  $t_{\perp}$  and  $\parallel$  $L$ )  $\vert / \vert$  $0(1-e^{-t})$  / bolving it we get the value<br>
the value<br>
turned at any time t<br>  $I_0 = E/R$ <br>  $I_1 = I_0 (1 - e^{-\frac{R}{L}})$ <br>  $I = I_0 (1 - e^{-\frac{R}{L}})$ <br>  $I_2$  (Constant:<br>  $I_3$  and the sume of time. It is called inductive time<br>
tant of LR-circuit.  $0.63$  I<sub>0</sub> **EXECUTE ARISING**<br>
The value<br>
the value<br>  $\frac{1}{10} = E/R$ <br>  $0.631$ <br>
of time. It is called inductive time<br>  $\frac{R L}{L R}$ <br>  $= \frac{1}{L R}$ <br>  $= 10 (1 - e^{-1})$ <br>  $\left(\frac{2.71 - 1}{2.71}\right) = 0.6321$ <br>
mstant of an LR-circuit is the time in<br>
vs fr **EXECUTE ARRIVERS**<br>
The value<br>
the value<br>  $\frac{1}{10} = E/R$ <br>  $0.631$ <br>  $\frac{1}{10}$ <br>

L

 $L$ ,  $\ldots$   $\ldots$   $\ldots$  $\frac{1}{R}$  has dimensions of time. It is called inductive time

constant of LR-circuit.

On solving it we get the value  
\nof current at any time t  
\nof current at any time t  
\nduring growth of current  
\n
$$
I = I_0 (1 - e^{-\frac{R}{L}t})
$$
\n
$$
I = I_0 (1 - e^{-\frac{R}{L}t})
$$
\n
$$
\frac{L}{R}
$$
\nhas dimensions of time. It is called inductive time  
\nconstant of LR-circuit.  
\nAt  $t = \frac{L}{R}$ ,  $I = I_0 (1 - e^{-\frac{R}{L} \cdot R}) = I_0 (1 - e^{-1})$   
\n
$$
= I_0 \left(\frac{e-1}{e}\right) = I_0 \left(\frac{2.71-1}{2.71}\right) = 0.632 I_0.
$$
\nThe inductive time constant of an LR-circuit is the time in which the current grows from zero to 0.632 (or 63.2%) of its maximum value.  
\nWhen  $t \rightarrow \infty$ .  
\n
$$
I = I_0 (1 - e^{-\frac{R}{L} \cdot \infty}) = I_0 (1 - e^{-\infty}) = I_0 (1 - 0)
$$
\nPotential difference across resistance:  
\n
$$
V_R = E (1 - e^{-\frac{R}{L}t})
$$

The inductive time constant of an LR-circuit is the time in which the current grows from zero to  $0.632$  (or  $63.2\%$ ) of its maximum value.

When  $t \rightarrow \infty$ .

$$
I = I_0(1 - e^{-\frac{R}{L}\infty}) = I_0(1 - e^{-\infty}) = I_0(1 - 0)
$$

**Potential difference across resistance :**



Initially, an inductor acts to oppose changes in the current through it. A long time later, it acts like ordinary connecting wire.

### **DECAY OF CURRENT**

dI Let the current has reached its steady state value  $I_0$  through inductor. Now switch K in the circuit shown in fig. has been closed.



Let this time is  $t = 0$ .

Let at t = 0 current in the circuit (which is maximum) =  $I_0$ After time  $t$  current in the circuit = I Apply Kirchhoff's loop rule to this circuit.

$$
)+(-L\frac{dI}{dt}) = IR
$$
 (since there is no source of e.m.f.)





The eq<sup>n</sup>. gives the value of current at any time t during decay of current in LR-circuit.

Again, dimensions of  $\frac{L}{R}$  are same as that of time  $\frac{1}{R}$  are same as that of time

The inductive time constant of the LR-circuit can also be defined by using  $eq<sup>n</sup>$ .

Setting  $t = \frac{L}{R}$  in eq<sup>n</sup>., we get  $\frac{R}{\mu}$  =  $\frac{L}{\mu}$  =  $\frac{R}{\text{Eq}^1}$   $\frac{1}{\text{Eq}^0}$   $\frac{1}{\text{G}^0}$   $\frac{1}{\text{G}^0$  $1_{\text{I}}$  or  $I \approx 0.27$  J  $e^{-\theta}$  and  $e^{-\theta}$  $\frac{K}{L} \frac{E}{R} = I_0 e^{-1} = \frac{1}{L} I_0$  or  $I \approx 0.37 I_0$ . as  $t \rightarrow \infty$   $I \rightarrow 0$ 

$$
as t \to \infty, \quad 1 \to 0
$$



### **ENERGY STORED INAN INDUCTOR**

Consider that a source of e.m.f. is connected to an inductor L. As the current starts growing, an induced e.m.f. is set up in the inductor and the induced e.m.f. then, opposes the growth of current through it. The source of e.m.f. has to spend energy in sending current through the circuit against the induced e.m.f. The energy spent by the source of e.m.f. is stored in the inductor in the form of magnetic field. Initially  $(t = 0)$ , the current in the inductor is zero. Let at any instant t, the current in the inductor is I

and the rate of growth of current at this time t is  $=$   $\frac{dI}{dt}$ .  $\frac{d}{dt}$ .

Then, induced e.m.f. produced in the inductor,  $e = L \frac{di}{dt}$ 

(in magnitude)

We can consider current through the inductor for a small time dt = I (approximately constant)

so charge dq = Idt is flown across potential difference "e" hence small amount of work done by the source

$$
dW = e.dq = \left( L \frac{dI}{dt} \right) Idt = LIdI
$$

**STUDY MATERIAL: PHYSICS**<br>
can consider current through the inductor for a small<br>
dt = I (approximately constant)<br>
harge dq = Idt is flown across potential difference "e"<br>
e small amount of work done by the source<br>
dW = e **STUDY MATERIAL: PHYSICS**<br>
consider current through the inductor for a small<br>
I (approximately constant)<br>
e dq = Idt is flown across potential difference "e"<br>
and amount of work done by the source<br>
= e.dq =  $\left(L\frac{dI}{dt}\right)$ The total amount of work done by the source of e.m.f, till the current increases from its initial value to its final value **STUDY MATERIAL: PHYSICS**<br>
can consider current through the inductor for a small<br>
dt = I (approximately constant)<br>
harge dq = Idt is flown across potential difference "e"<br>
e small amount of work done by the source<br>
dW = e

I is 
$$
W = \int_0^1 LI \, dI = L \left| \frac{I^2}{2} \right|_0^1 = \frac{1}{2}LI^2
$$

**STUDY MATERIAL: PHYSICS**<br>
consider current through the inductor for a small<br>  $= I$  (approximately constant)<br>
ge dq = Idt is flown across potential difference "e"<br>
mall amount of work done by the source<br>  $V = e.dq = \left( L \frac{dI}{dt$ **STUDY MATERIAL: PHYSICS**<br>
We can consider current through the inductor for a small<br>
ime dt = I (approximately constant)<br>
o charge dq = Idt is flown across potential difference "e"<br>
ence small amount of work done by the s This work done by the source of e.m.f. in building up current from zero to I is stored inside the inductor in the form of magnetic field energy.

### **Note :**

- (i) The energy is stored in the inductor at the expense of the energy of the source of e.m.f.
- (ii) The energy resides in the inductor in the form of magnetic field.
- (iii) In case of an alternating source of e.m.f., during one half cycle energy is stored in the inductor from the source and during the next half cycle, the same amount of energy is returned to the source. It is for this reason that average electric power of an inductor is zero. Energy stored in the inductor  $U = \frac{1}{2}LI^2$ <br>This work done by the source of e.m.f. in building up current<br>rom zero to I is stored inside the inductor in the form of<br>magnetic field energy.<br>**Note:**<br>**Note:**<br>**Note:**<br>**Rome an**

If current flowing through an inductor is I then energy stored in the form of magnetic field in the inductor is

$$
U = \frac{1}{2}LI^2
$$
, when change in I occurs in the circuit U

 $R_{\text{H}}$  netic field and hence back e.m.f. induces. changes it value accordingly. If  $I \downarrow$  then U  $\downarrow$  so loss in energy develops in the form of induced e.m.f. in the circuit and if I  $\uparrow$  then U  $\uparrow$  so energy required for increasing mag-

### **EDDY CURRENTS**

We know that when a conducting loop moves through a magnetic field, current is induced as the result of changing magnetic flux. If a solid conductor were used instead of a loop, as shown in figure, current can also be induced. The induced current appears to be circulating and is called an eddy current.





The induced eddy currents also generate a magnetic force that opposes the motion, making it more difficult to move the conductor across the magnetic field (Figure).



### **Figure : Magnetic force arising from the eddy current that opposes the motion of the conducting slab.**

Since the conductor has non-vanishing resistance R, Joule heating causes a loss of power by an amount  $P = e^2/R$ . Therefore, by increasing the value of R, power loss can be reduced. One way to increase R is to laminate the conducting slab, or construct the slab by using gluing together thin strips that are insulated from one another (see Figure a). Another way is to make cuts in the slab, thereby disrupting the conducting path (Figure b).



### **Figure : Eddy currents can be reduced by**

**(a) laminating the slab, or (b) making cuts on the slab.** There are important applications of eddy currents. For example, the currents can be used to suppress unwanted mechanical oscillations. Another application is the magnetic braking systems in high-speed transit cars.

### **Example 13 :**

Why a thick metal plate oscillating about a horizontal axis stops when a strong magnetic field is applied on the plate?

**Sol.** This is because eddy currents are produced and eddy currents oppose mechanical motion.

### **Example 14 :**

A magnet is dropped in a very long copper tube. Even in the absence of air resistance it acquires a constant terminal velocity. Explain why?

**Sol.** When the magnet is dropped in a copper tube, eddy currents are produced in the tube. These eddy currents produce the magnetic field which opposes the motion of the magnet. After some time, the opposing force becomes equal to the gravitational pull on the magnet. Thus the net force acting on the magnet is zero and hence the magnet acquires a constant velocity.

### **Example 15 :**

What happens if an iron piece is dropped between the poles of a strong magnet?

**Sol.** When the iron is dropped, eddy current are produced in it. These eddy currents oppose the motion of the piece of iron so it falls as it is moving through a viscous fluid.

### **D.C. MOTOR**

A d.c. motor converts direct current energy from a battery into mechanical energy of rotation.

**Principle :** It is based on the fact that when a coil carrying current is held in a magnetic field, it experiences a torque, which rotates the coil.

**Construction :** It consists of the five parts.

**Armature :** The armature coil ABCD consists of a large number of turns of insulated copper wire wound over a soft iron core.

**Field Magnet :** The magnetic field is supplied by a permanent magnet NS.

**Split-rings or Commutator :** These are two halves of the same ring. The ends of the armature coil are connected to these halves which also rotate with the armature.

**Brushes :** These are two flexible metal plates or carbon rods  $B_1$  and  $B_2$ , which are so fixed that they constantly touch the revolving rings.

**Battery :** The battery consists of a few cells of voltage V connected across the brushes. The brushes convey the current to the rings, from where it is carried to the armature. **Working :** The battery sends current through the armature coil in the direction shown in fig. Applying Fleming's Left Hand Rule, CD experiences a force directed inwards and perpendicular to the plane of the coil. Similarly, AB experiences a force directed outwards and perpendicular to the plane of the coil. These two forces being equal, unlike and parallel form a couple. The couple rotates the armature coil in the anticlockwise direction. After the coil has rotated through 180°, the direction of the current in AB and CD is reversed, fig. Now CD experiences an outward force and AB experiences an inward force. The armature coil thus continues rotating in the same i.e., anticlockwise direction.



**Back E.M.F. :** As the armature rotates in the magnetic field, the amount of magnetic flux linked it the coil changes. Therefore, an e.m.f. is induced in the coil. The direction of the induced e.m.f. is such that it opposes the battery current in the circuit. This e.m.f. is called the back e.m.f. and its magnitude goes on increasing with the speed of the armature.

D <sub>1</sub> A

 $B_1$   $B_2$  $R_2$   $R_1$ 

V

Let V = e.m.f. applied across  $B_1$  and  $B_2$ , R = resistance of the armature coil,

I=current flowing through the armature coil, at any instant  $1$ .  $E =$  back e.m.f. at that instant.

As V and E are acting in the opposite directions,

 $\therefore$  effective e.m.f. across B<sub>1</sub> and B<sub>2</sub> = V – E

According to Ohm's law 
$$
I = \frac{V - E}{R}
$$
 or  $V - IR = E$  **MOTOR STAR**

**Efficiency of the d.c. motor :** Since the current I is being supplied to the armature coil by the external source of e.m.f.

V, therefore, Input electric power = VI

According to Joule's law of heating,

Power lost in the form of heat in the coil =  $I^2 R$ 

If we assume that there is no other loss of power, then

Power converted into external work i.e., Output mechanical power =  $VI - I^2 R = (V - IR) I = EI$ 

:. Efficiency of the d.c. motor

or 
$$
\eta = \frac{EI}{VI} = \frac{E}{V} = \frac{back \text{ e.m.f.}}{\text{applied e.m.f.}}
$$

**Maximum efficiency :** When  $E = V$ , then  $\eta = 1$  or 100%. Therefore, for  $\eta$  to be maximum i.e. 100%, back e.m.f. E should be equal to the applied e.m.f. V. But in that case, the current I flowing through the armature coil becomes zero. Obviously, the motor in this case will just cease to work. This is an anomaly. Practically, the efficiency of the d.c. motor will be maximum, when output mechanical power is  $maximum$ . i.e.  $EI = maximum$ If we assume that there is no other loss of power, then<br>
Dutput mechanical power = VI-1<sup>2</sup> R = (V - IR)1 = EI<br>  $\therefore$  Efficiency of the d.c. motor<br>  $\frac{E1}{\sqrt{1-\frac{1}{N}}} = \frac{E}{V} = \frac{\text{back emf}}{\text{applied emf}}.$ <br>  $\therefore$  Efficiency of the d.

using, 
$$
E \cdot \frac{(V - E)}{R}
$$
 = maximum

**STUDY MATERIAL : PHYSICS**

R White Communities, which its distribution  $-E$ )  $\frac{1}{2}$   $\frac{1}{$ will be maximum, when its differential

coefficient is zero.

V E <sup>I</sup> Now, E(V E) i.e. d E(V E) <sup>0</sup> dE R or d 1 <sup>2</sup> (VE E ) 0 dE R or 1 (V 2E) 0 <sup>R</sup> (<sup>R</sup> 0) or V – 2E = 0 or E = V/2 From E V , when E = V/2, V / 2 1 1 100% 50% V 2 2

Hence a d.c. motor delivering maximum output has an efficiency of only 50%. Further, when  $E = V/2$ , then current I in the coil may become too large as R is low. Hence in practice, we do not try to get maximum output mechanical power. **Uses :**

The d.c. motors are used in d.c. fans (exhaust, ceiling or table) for cooling and ventilation.

- **2.** They are used for pumping water.
- **3.** Big d.c. motors are used for running tram-cars and even trains.

## $=\frac{V - L}{R}$  or V-IR=E<br>**MOTOR STARTER OR STARTING RESISTANCE**

Motor starter regulates the current to safe limits while the motor gains the speed.



A starter is basically a variable high resistance connected in series with the motor coil in order to protect it from burning. A heavy duty motor should not be started without a starter whereas a light duty motor can be started without a starter because it gains speed in very short interval of time. When the motor just starts, there is no back e.m.f. in the coil of the motor.

In the beginning, the motor draws a large amount of current due to full applied voltage which may burn the armature coil of the motor.

To avoid it, a starting resistance known as starter is used in series with the motor to regulate the current.

### **ELECTROMAGNETIC INDUCTION**

Motor starter consists of an iron handle (H) one end of Q.5 which is connected to the spring system. The other end can slide over different resistances. The resistances are in series with an electromagnet (E) and armature coil (M) of the motor. Initially, whole of the resistance is in the circuit and the handle (H) makes the contact at point C of the resistances. So when the motor starts, a large resistance in the circuit and hence small starting current flows through the armature coil. As the motor picks up the speed, the Q.6 resistance is switched out gradually. When the motor acquires the maximum speed all the resistance are switched out and the handle is attracted by the electromagnet.

At this stage, the current through the armature coil is normal. When the supply is switched off, the electromagnet loses Q.7 its magnetisation and leaves the handle. The spring throws the handle back to its initial position C. The above process is to be repeated to start the motor again.

### **TRY IT YOURSELF-2**

**Q.1** In the given circuit, the switch is closed to the position bc from the earlier position of ac at  $t = 0$ . The current in<br>the inductor after 2s of closing the switch between b and Q.9 the inductor after 2s of closing the switch between b and c is



**Q.2** The diagrams show three circuits with identical batteries, identical inductors, and identical resistors. Rank them according to the current through the battery just after the switch is closed, from least to greatest.



**Q.3** The potential at a is higher than the potential at b. Which of the following statements about the ideal inductor bential at b.<br>the ideal in<br> $v_a > v_b$  b

current I could be true ?  $\frac{a}{\sqrt{a}} \frac{v_a - v_b}{6000000}$ 

- (A) I is from a to b and increasing
- (B) I is from a to b and decreasing
- (C) I is from b to a and increasing.
- (D) I is from b to a and decreasing.
- ്ര പ<br>അത്ത്ത്ത് **Q.4** In the circuit shown in figure switch S is closed at time  $t = 0$ . current through inductor after long time of closing of switch.  $(A) E/R$  (B)  $E/2R$ (C) zero (D) none



- **Q.5** A rectangular loop of sides 'a' and 'b' is placed in xy plane. A very long wire is also placed in xy plane such that side of length 'a' of the loop is parallel to the wire. The distance between the wire and the nearest edge of the loop is 'd'. The mutual inductance of this system is proportional to
	- $(A)$  a  $(B)$  b
	- (C) 1/d (D) current in wire Mutual inductance  $M_{12}$  of coil 1 with respect to coil 2
	- (A) increases when they are brought nearer.
		- (B) depends on the current passing through the coils.
		- (C) increases when one of them is rotated about an axis.
		- (D) is the same as  $M_{21}$  of coil 2 with respect to coil 1.
- Two circular coils, one of radius r and the other of radius R are placed coaxially with their centres coinciding. For  $R \gg r$ , obtain expression for the mutual inductance of the arrangement
- **Q.8** How does the mutual inductance of a pair of coils change when
	- (i) distance between the coils is decreased and (ii) number of turns in the coils is decreased ?
- A coil of inductance 8.4 mH and resistance  $6 \Omega$  is connected to a 12V battery. The current in the coil is 1.0 A at approximately the time :

(A) 500 s (B) 20 s (C) 35 ms (D) 1 ms

**Q.10** Two circular coils can be arranged in any of the three situations shown in the figure. Their mutual inductance will be :



- (A) maximum in situation (a)
- (B) maximum in situation (b)
- (C) maximum in situation (c)
- (D) the same in all situations

**Q.11** Which of the following is true for an ideal transformer

- (A) Total magnetic flux linked with primary coil equals flux linked with secondary coil
- (B) Flux per turn in primary is equal to flux per turn in secondary
- (C) Induced emf in secondary coil equals induced emf in primary
- (D) Power associated with primary coil at any moment equals power associated with secondary coil.



 $2R$ **(9)** (D) **(10)** (A) **(11)**(BD)



### **USEFUL TIPS**

\* **Faraday's law** of induction imply that the emf induced in a coil of N turns is directly related to the rate of change of

flux through it,  $\varepsilon = -N \frac{d\phi_B}{dt}$ 

- \* **Lenz's law** states that the polarity of the induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produces it. The negative sign in the expression for Faraday's law indicates this fact.
- When a metal rod of length  $\ell$  is placed normal to a uniform magnetic field B and moved with a velocity v perpendicular to the field, the induced emf (called motional emf) across
- Induce emf due to rotation =  $\frac{1}{2}$ B $\omega \ell^2$
- When a current in a coil changes, it induces a back emf in the same coil. The self-induced emf is given by,  $\varepsilon = -L \frac{dI}{dt}$ dt L is the self-inductance of the coil. It is a measure of the to the rieta, the induced emtit (called motional emit) across<br>
its ends is  $\varepsilon = B(v$ .<br>
That the same coil. The self-induced emf is given by,  $\varepsilon = -L\frac{dI}{dt}$ <br>
Lis the self-inductance of the coil. It is a measure of the **So**

inertia of the coil against the change of current through it. A changing current in a coil (coil 2) can induce an emf in a

nearby coil (coil 1).  $\varepsilon_1 = -M_{12} \frac{dI_2}{dt}$ , The quantity  $M_{12}$  is<br>**Example 2**: called mutual inductance of coil 1 with respect to coil 2.

\* For ideal transformer : 
$$
\frac{E_s}{E_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}
$$

\* LR circuit : For growth current,  $i = i_0[1 - e^{-Rt/L}]$  induced in the coincident

For decay of current,  $i = i_0 e^{-Rt/L}$  Sol. Giv

\* **Analogies between mechanical and electrical quantities:**



## **ADDITIONAL EXAMPLES**

### **Example 1 :**

Predict the direction of induced current in the situations described by the following fig. (1) to (5).





**Sol.** Applying Lenz's law

(1) along  $a \rightarrow b$  (2) along  $b \rightarrow a$ , along  $d \rightarrow c$  (3) along cba (4) along  $a \rightarrow b(5)$  No induced current since field lines lie in the plane of the loop.

### **Example 2 :**

A coil 10 turns and a resistance of  $20\Omega$  is connected in series with B.G. of resistance  $30\Omega$ . The coil is placed with its plane perpendicular to the direction of a uniform magnetic field of induction  $10^{-2}$  T. If it is now turned through an angle of 60° about an axis in its plane. Find the charge induced in the coil. (Area of a coil =  $10^{-2}$  m<sup>2</sup>) 1 Decreasing at<br>
1 Decreasing at<br>
1 Perceasing at<br>
Lenz's law<br>
a→b (2) along b→a, along d→c (3) along cba<br>
a→b (5) No induced current since field lines lie in<br>
of the loop.<br>
turns and a resistance of 20Ω is connected in A<br>
Fig. 4<br>
Fig. 4<br>
Sing Lenz's law<br>
long a → b (2) along b → a, along d → c (3) along cba<br>
long a → b (5) No induced current since field lines lie in<br>
lane of the loop.<br>
2:<br>
2:<br>
all 10 turns and a resistance of 20Ω is c  $\frac{1}{\sqrt{2}}$ <br>  $\frac{1}{\sqrt{2}}$ fig. 4<br>
hplying Lenz's law<br>
(1) along a → b (2) along b → a, along d → c (3) along cba<br>
(4) along a → b (5) No induced current since field lines lie in<br>
the plane of the loop.<br> **uple 2:**<br>
accise with B.G of resistance o enz's law<br>
→ b (2) along b → a , along d → c (3) along cba<br>
→ b (5) No induced current since field lines lie in<br>
the loop.<br>
urns and a resistance of 20Ω is connected in<br>
3.G of resistance 30Ω. The coil is placed with it (1) along  $a \rightarrow b (z)$  along  $b \rightarrow a$ , along  $\rightarrow c (3)$  along  $\rightarrow b (5)$  No induced current since field lines lie in<br>the plane of the loop.<br>And coil 10 turns and a resistance of 20Ω is connected in<br>series with B.G of resistance 30 From the loop.<br>
Ims and a resistance of 20Ω is connected in<br>
the loop.<br>
Ims and a resistance 302. The coil is placed with its<br>
dictiular to the direction of a uniform magnetic<br>
action 10<sup>-2</sup> T. If it is now turned throug ing Lenz's law<br>
ong a → b (2) along b → a, along d → c (3) along cba<br>
ong a → b (5) No induced current since field lines lie in<br>
110 turns and a resistance of 20Ω is connected in<br>
with B.G. of resistance 30Ω. The coil is

**Sol.** Given : n = 10 turns,  $R_{\text{coil}} = 20\Omega$ ,<br> $R_G = 30\Omega$ , Total resistance in the circuit = 20 + 30 = 50 $\Omega$ .  $A = 10^{-2}$  m<sup>2</sup>,  $B = 10^{-2}$  T,  $\phi_1 = 0^\circ$ ,  $\phi_2 = 60^\circ$ 

$$
q = \frac{\phi_1 - \phi_2}{R} = \frac{BnA\cos\theta_1 - BnA\cos\theta_2}{R}
$$
  

$$
\frac{BnA(\cos\theta - \cos 6\theta)}{R} = \frac{BnA(1 - 0.5)}{R}
$$
  

$$
\frac{0.5 \times 10^{-2} \times 10 \times 10^{-2}}{50} = \frac{50 \times 10^{-5}}{50}
$$

 $= 1 \times 10^{-5}$  C (Charge induced in a coil)

### **Example 3 :**

A coil having 100 turns and area of  $0.001$  metre<sup>2</sup> is free to rotate about an axis. The coil is placed perpendicular to a magnetic field of 1.0 weber/metre<sup>2</sup>. If the coil is rotate rapidly through an angle of 180°, how much charge will flow through the coil? The resistance of the coil is 10 ohm.

**Sol.** The flux linked with the coil when the plane of the coil is perpendicular to the magnetic field is

 $\phi$  = nAB cos  $\theta$  = nAB.

The change in flux on rotating the coil by 180° is  $d\phi = nAB - (-nAB) = 2nAB$ 



$$
\therefore \text{ Induced charge} = \frac{d\phi}{R} = \frac{2nAB}{dt} = \frac{2 \times 100 \times 0.001 \times 1}{10}
$$

 $\therefore$  Induced charge = 0.01 coul.

### **Example 4 :**

As shown in fig. the electric current in a wire in the direction is increasing. What is the direction of induced current in the metallic loop kept above the wire.



**Sol.** When the increasing current flows through the wire the increasing magnetic field is produced, which is directed perpendicular to the plane of the loop (or the plane of paper) and in inward direction. Due to this, induced e.m.f. is produced in the loop which opposes the magnetic field produced due to the current flowing through the wire i.e. induced current in the loop should flow in a direction so that it produces magnetic field perpendicular to the plane of the loop and in outward direction. Maxwell's cork screw rule tells that induced current in the loop will flow in anticlockwise direction.

### **Example 5 :**

A cylindrical bar magnet is kept along the axis of a circular coil and near it as shown in fig. Will there be any induced e.m.f. at the terminals of the coil, when the magnet is rotated (a) about its own axis and (b) about an axis perpendicular to the length of the magnet?



**Sol.** (a) When the magnet is rotated about its own axis, there is no change in the magnetic flux linked with the coil. Hence, no induced e.m.f. is produced in the coil.

(b) When the magnet is rotated about an axis perpendicular to its length, the orientation of the magnetic field due to the magnet will change continuously. Due to this, the magnetic flux linked with the coil will also change continuously and it will result in the production of induced e.m.f. in the coil.

### **Example 6 :**

In fig. (a) and fig. (b) below show planar loops of different shapes moving out or into a region of magnetic field, which is directed normal to the plane of the loop and away from the reader. Determine the direction of induced current.





flux downwards through it is increasing so induced current in loop flows such that flux associate with it should reduce. Hence, the current through the loop flows in the direction CBADC. (Due to induced current flux is upwards)

### **Example 7 :**

A bar magnet is freely falling along the axis of a circular loop as shown in fig. State whether its acceleration "a" is equal to, greater than or less than the acceleration due to gravity g.



**Sol.** According to Lenz's law, whatever may be the direction of induced current, it will oppose the cause. Here the cause is, the free fall of magnet and so the induced current will oppose it and the acceleration of magnet will be less than the acceleration due to gravity g. This can be understood in a different manner. When the magnet falls downwards with its north pole downwards. The magnetic field lines passing through the coil in the downward direction increase. Since the induced current opposes this, the upper side of the coil will become north pole, so that field lines of coil's magnetic field are upwards. Now like poles repel each other. Hence,  $a < g$ .

### **Example 8 :**

An irregular shaped wire PQRS (as shown in fig.) placed in a uniform magnetic field perpendicular to the plane of the paper changes into a circular shape. Show with reason the direction of the induced current in the loop.





**Sol.** When an irregular shaped wire PQRS changes to circular loop, the magnetic flux linked with the loop increases due to increase in area of the loop. The induced e.m.f. will cause current to flow in the direction, so that the wire is pulled inward from all sides. According to Fleming's left hand rule, force on wire PQRS will act inward from all sides, if the current flows in the direction PSRQ.

### **Example 9 :**

Twelve wires of equal lengths are connected in the form of a skeleton-cube which is moving with a velocity  $\vec{v}$  in the

direction of a magnetic field  $\vec{B}$ . Find the e.m.f. in each arm **Sol.** Given :  $n = 250$ , of the cube.



**Sol.** Force on a charge particle moving inside magnetic field is

current to flow in the direction, so that the wire is pulled<br>
some. As there is no relative motion<br>
finance on wire PQRS will act imvard from all sides, if the<br>
current flows in the direction PSRQ.<br>
The papel of the curre Sol. Given:<br>Since  $\vec{v}$  and  $\vec{B}$  are parallel, the  $B_1$  is the force on electrons in any arm of the skeleton cube will be zero. As such, there cannot be drift of electrons in any arm from its one end to the other. Hence, no induced e.m.f. will be produced in any arm of the skeleton-cube.

### **Example 10 :**

Three identical coils A, B and C are placed with their planes parallel to one another. Coils A and C carry currents as shown in fig. Coils B and C are fixed in position and coil A is moved towards B with uniform motion. Is there any induced current in B? If no, give reasons. If yes, mark the direction of induced current in the diagram.



**Sol.** Yes, the current is induced in coil B, when A moves with uniform motion towards B.



The direction of current induced is such that is opposes the approach of A towards B. For this the currents in A and B will be opposite i.e., current in B will be anticlockwise sense. As there is no relative motion between B and C, no current is induced in B due to current in C. **STUDY MATERIAL: PHYSICS**<br>
e direction of current induced is such that is opposes<br>
e approach of A towards B. For this the currents in A and<br>
will be opposite i.e., current in B will be anticlockwise<br>
nse. As there is no **STUDY MATERIAL: PHYSICS**<br>
irection of current induced is such that is opposes<br>
proach of A towards B. For this the currents in A and<br>
be opposite i.e., current in B will be anticlockwise<br>
As there is no relative motion b **STUDY MATERIAL: PHYSICS**<br>
direction of current induced is such that is opposes<br>
approach of A towards B. For this the currents in A and<br>
rill be opposite i.e., current in B will be anticlockwise<br>
ie. As there is no relat

### **Example 11 :**

The magnetic induction passing normally through a coil of 250 turns and area  $5 \times 10^{-3}$  m<sup>2</sup> is changing at the rate of 0.4 T/s. Find induced e.m.f.

**Sol.** Given : 
$$
n = 250
$$
,  $A = 5 \times 10^{-3}$  m<sup>2</sup>,  $\frac{dB}{dt} = 0.4$  T/s

Induced e m f

$$
e = \frac{d\phi}{dt} = n \text{ A } \frac{dB}{dt} = 250 \times 5 \times 10^{-3} \times 0.4
$$
  
= 100.0 × 5 × 10<sup>-3</sup> = 500 × 10<sup>-3</sup> = 0.5 V

### **Example 12 :**

A coil of effective area 4  $m<sup>2</sup>$  is placed at right angles to the magnetic induction B. The e.m.f. of 0.32 V is induced in the coil. When the field is reduced to 20% of its initial value in 0.5 sec. Find B. The magnetic induction passing normally through a coil of<br>
250 turns and area  $5 \times 10^{-3}$  m<sup>2</sup> is changing at the rate of<br>
3.4 T/s. Find induced e.m.f.<br>
Given : n = 250, A = 5 × 10<sup>-3</sup> m<sup>2</sup>,  $\frac{dB}{dt}$  = 0.4 T/s<br>
Induced e turns and area  $> \times 10^{-3}$  m<sup>2</sup> is changing at the rate of<br>  $\frac{7}{5}$ . Find induced e.m.f.<br>  $n : n = 250$ ,  $A = 5 \times 10^{-3}$  m<sup>2</sup>,  $\frac{dB}{dt} = 0.4$  T/s<br>
ced e.m.f.<br>  $= \frac{d\phi}{dt} = n \frac{dB}{dt} = 250 \times 5 \times 10^{-3} \times 0.4$ <br>  $= 100.0 \times 5 \times 10^{$ le 11:<br>
le 11:<br>
e magnetic induction passing normally through a coil of<br>
of oturns and area  $5 \times 10^{-3}$  m<sup>2</sup> is changing at the rate of<br>
4 T/s. Find induced e.m.f.<br>
iven : n = 250, A = 5 × 10<sup>-3</sup> m<sup>2</sup>,  $\frac{dB}{dt}$  = 0.4 T/s sing normally through a coil of<br>
m<sup>2</sup> is changing at the rate of<br>  $3 \text{ m}^2$ ,  $\frac{dB}{dt} = 0.4 \text{ T/s}$ <br>  $5 \times 10^{-3} \times 0.4$ <br>  $\times 10^{-3} = 0.5 \text{ V}$ <br>
<sup>2</sup> is placed at right angles to the<br>
.m.f. of 0.32 V is induced in the<br>
eed to f.<br>  $y^{-3}$  m<sup>2</sup>,  $\frac{dB}{dt} = 0.4$  T/s<br>  $\times 5 \times 10^{-3} \times 0.4$ <br>  $y = 0.5$  V<br>  $y = 0.5$ <br>  $y = 0.5$ <br>

**Sol.** Given :  $A = 4$  m<sup>2</sup>,  $e = 0.32$  V, dt = 0.5sec.

and  $\vec{B}$  are parallel, the  $B_1$  is the initial magnetic induction and when it is reduced to 20%  $B_2 = 0.2 B_1$ 

$$
= \frac{d\phi}{dt} = \frac{A(B_1 - B_2)}{\Delta t} \quad \text{or} \quad 0.32 = \frac{4(B_1 - 0.2 B_1)}{0.5}
$$

Magnetic induction 
$$
B_1 = \frac{0.16}{0.32} = 0.05 \text{ Wb/m}^2
$$

**Example 13 :**

<sup>2</sup> (10<sup>-3</sup> m<sup>2</sup>,  $\frac{dB}{dt} = 0.4$  T/s<br>  $50 \times 5 \times 10^{-3} \times 0.4$ <br>  $= 500 \times 10^{-3} = 0.5$  V<br>
4 m<sup>2</sup> is placed at right angles to the<br>
The e.m.f. of 0.32 V is induced in the<br>
reduced to 20% of its initial value in<br>
32 V, dt = 0. A square wire loop with side 2 m in placed in a uniform magnetic field with its plane perpendicular to the field. The resistance of loop is  $10\Omega$ . Find at what rate the magnetic induction should be changed so that a current of 0.1 A is induced in the loop. coil. When the field is reduced to 20% of its initial value in<br>
D.5 sec. Find B.<br>
Given : A = 4 m<sup>2</sup>, e = 0.32 V, dt = 0.5sec.<br>
B<sub>1</sub> is the initial magnetic induction and when it is reduced<br>  $\omega$  20% B<sub>2</sub> = 0.2 B<sub>1</sub><br>  $e = \$ agnetic induction B. The e.m.f. of 0.32 V is induced in the<br>ii. When the field is reduced to 20% of its initial value in<br>5 sec. Find B.<br>ven : A = 4 m<sup>2</sup>, e = 0.32 V, dt = 0.5sec.<br>1 is the initial nagnetic induction and wh 2 V, dt = 0.5sec.<br>
b 2 V, dt = 0.5sec.<br>
c induction and when it is reduced<br>
or  $0.32 = \frac{4(B_1 - 0.2B_1)}{0.5}$ <br>  $1 = \frac{0.16}{0.32} = 0.05 \text{ Wb/m}^2$ <br>
a side 2 m in placed in a uniform<br>
ane perpendicular to the field. The<br>
D. Fin <sup>9%</sup> B<sub>2</sub> = 0.2 B<sub>1</sub><br>  $\frac{d\Phi}{dt} = \frac{A(B_1 - B_2)}{\Delta t}$  or 0.32 =  $\frac{4(B_1 - 0.2 B_1)}{0.5}$ <br>
netic induction B<sub>1</sub> =  $\frac{0.16}{0.32}$  = 0.05 Wb/m<sup>2</sup><br>
13 :<br>
netic induction B<sub>1</sub> =  $\frac{0.16}{0.32}$  = 0.05 Wb/m<sup>2</sup><br>
13 :<br>
tance of loo the initial magnetic induction and when it is reduced<br>  $\frac{4}{5}$   $\frac{4}{2} = 0.2 B_1$ <br>  $\frac{4}{1}$   $\frac{4}{1} = \frac{A(B_1 - B_2)}{At}$  or  $0.32 = \frac{4(B_1 - 0.2 B_1)}{0.5}$ <br>
attic induction  $B_1 = \frac{0.16}{0.32} = 0.05 Wb/m^2$ <br>
33:<br>
anare wire loop

**Sol.** Given: 
$$
I = 0.1 A
$$
,  $R = 10 \Omega$ 

Since,  $e = IR$ ;  $e = 0.1 \times 10 = 1$  V and  $\ell = 2$  m area,  $A = \ell^2 = 2^2 = 4$ 

$$
e = \frac{d}{dt}(BA) = A \frac{dB}{dt} ; 1 = 4 \frac{dB}{dt}
$$

Rate of change of magnetic induction

$$
\frac{dB}{dt} = \frac{1}{4} = 0.25 \text{ Wb/m}^2
$$

### **Example 14 :**

An earth coil is kept so that its plane is horizontal and axis of rotation in the magnetic meridian. The coil is suddenly rotated about its axis through an angle of 180°. Which magnetic field does it cut? Find the charge that has passed through coil. Given : no. of turns in the coil is 1000. Each average area 100  $\pi$  sq.m, resistance of coil  $= 40\Omega, B_v = 2 \times 10^{-5}$  Wb/m<sup>2</sup>

**Sol.** Given:  $n = 1000$ ,  $A = 100 \pi m^2$ ,

 $R = 40\Omega$ ,  $B_v = 2 \times 10^{-5}$  Wb/m<sup>2</sup>

The coil when rotated cuts the vertical component of earth's magnetic field. The charge passed through the coil

$$
q = \frac{2nAB_v}{R} = \frac{2 \times 1000 \times 100\pi \times 2 \times 10^{-5}}{40} = 0.3142 C
$$

### **Example 15 :**

A closed loop with the geometry shown in fig. is placed in a uniform magnetic field directed into the plane of the paper. If the magnetic field decreases with time, determine the direction of the induced currents in this loop.



**Sol.** (A) There are two loops that are immersed in the magnetic field namely, ABEFA and BCDEB.



(B) Consider loop ABEFA. Magnetic flux is into the paper. For loop BCDEB too, the magnetic flux is into the paper. (C) In both loops, the magnetic flux is decreasing with time. (D) Hence the induced current in loop ABEFA,  $i_1$ , in the clockwise direction so as to induce a flux into the paper. Similarly in loop BCDEB the current  $i_2$  will be in a direction so as to induce a flux into the paper. The direction of  $i_2$  is also clockwise. The final induced currents in all the arms of the loop are shown in fig.

### **Example 16 :**

A square metal wire loop of side 10 cm and resistance

1 ohm is moved with a constant velocity v in a uniform magnetic field of induction  $B = 2$  Wb/m<sup>2</sup> as shown in fig. The magnetic field lines are perpendicular to the plane of the loop (directed into the paper). The loop is connected to a network of resistors each of value 3 ohm. The resistance of the lead wires OS and PQ are negligible. What should be the speed of the loop so as to have a steady current of 1 mA in the loop? Give the direction of the current in the loop.





**Sol.** B = 2 Wb m<sup>-2</sup> normal in the page,  $\ell = 10$  cm = 0.1 m Loop resistance = 1 ohm induced current I = 1 mA =  $10^{-3}$  A Resistance of balanced bridge, equivalent to two 6 ohm resistors in parallel  $=$  3 ohm.

Total circuit resistance,  $R = 1 + 3 = 4$  ohm,  $v = ?$ Induced emf e =  $B \ell v$ 

$$
I = {B \ell v \over R}
$$
 and  $v = {R I \over B \ell} = {4 \times 10^{-3} \over 2 \times 0.1} = 2 \times 10^{-2}$  m/s

As flux is decreasing, the induced current in loop will set up a downward magnetic field (to support field B). Hence the current will flow in clockwise direction in the loop from O to P.

### **Example 17 :**

A square loop ACDE of area 20 cm<sup>2</sup> and resistance 5 $\Omega$  is  $\vec{B} = 2T$  through 180° (a) in 0.01s

and (b) in 0.02 s. Find the magnitude of e, i and  $\Delta q$  in both the cases.

**Sol.** Let us take the area vector  $\vec{S}$  perpendicular to plane of Loop resistance = 1 ohm induced current 1= 1 mA = 10<sup>-3</sup> A<br>
Resistance of balanced bridge, equivalent to two 6 ohm<br>
resistors in parallel = 3 ohm.<br>
Total circuit resistance, R = 1 + 3 = 4 ohm, v = ?<br>
Total circuit resista loop inwards. So initially,  $\vec{S} \uparrow \vec{B} \uparrow$  and when it is rotated Eventishment or balanced principle 3 ohm.<br>
Fresistors in parallel = 3 ohm.<br>
Total circuit resistance, R = 1 + 3 = 4 ohm, v = ?<br>
Induced emf e = B  $\ell$  v<br>  $I = \frac{B \ell v}{R}$  and  $v = \frac{R I}{B \ell} = \frac{4 \times 10^{-3}}{2 \times 0.1} = 2 \times 10^{-2}$  by 180°,  $\vec{S} \uparrow \vec{B} \downarrow$ . <sup>B</sup> 8.0 10 | e | 0.8 is.<br>
s.<br>
ake the area vector  $\vec{S}$  perpendicular to plane of<br>
vards. So initially,  $\vec{S} \uparrow \vec{B} \uparrow$  and when it is rotated<br>  $\vec{S} \uparrow \vec{B} \downarrow$ .<br>  $\begin{pmatrix} \circ & \circ & \circ \\ \circ & \circ & \circ \\ \circ & \circ & \circ \\ \circ & \circ & \circ \end{pmatrix}$ <br>  $\begin{pmatrix} \circ & \circ & \circ \\ \circ & \circ$ 

 $A \longrightarrow C$  $E \rightarrow$  D  $\otimes$   $\overline{B}$ 

Hence, initial flux passing through the loop,

 $\phi_i = BS \cos 0^\circ = (2) (20 \times 10^{-4}) (1) = 4.0 \times 10^{-3}$  Wb Flux passing through the loop when it is rotated by 180°,

 $\phi_f$  = BS cos 180° = (2) (20 × 10<sup>-4</sup>) (-1) = -4.0 × 10<sup>-3</sup> Wb Therefore, change in flux,  $\Delta \phi_B = \phi_f - \phi_i = -8.0 \times 10^{-3}$  Wb (a) Given  $\Delta t = 0.01$ s, R = 5 $\Omega$ 

 3 t 0.01 volt | e | 0.8 i 0.16A R 5

and  $\Delta q = i \Delta t = 0.16 \times 0.01 = 1.6 \times 10^{-3}$  C



(b)  $\Delta t = 0.02$  s

**SVDY MATERIAL:1**  
\n(b) 
$$
\Delta t = 0.02 s
$$
  
\n
$$
\therefore |e| = \left| -\frac{\Delta \phi_B}{\Delta t} \right| = \frac{8.0 \times 10^{-3}}{6.22} = 0.4 \text{ volt}
$$
\n
$$
i = \frac{|e|}{R} = \frac{0.4}{5} = 0.08 \text{ A}
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i = \frac{|e|}{R} = \frac{0.4}{5} = 0.08 \text{ A}
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i = \frac{|e|}{R} = \frac{0.4}{5} = 0.08 \text{ A}
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= 6.286 \times 10^{-5} \text{ V},
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### **Example 18 :**

A metal rod 1.5 m long rotates about its one end in a vertical plane at right angles to the magnetic meridian. If the frequency of rotation is 20 rev/sec., find the emf induced between the ends of the rod ( $H = 0.32$  gauss).  $\frac{\text{B}_\text{B}}{\text{dt}}$  =  $\frac{8.0 \times 10^{-3}}{0.02}$  = 0.4 volt<br>
= 0.08 A<br>
= 6.286 × 10<sup>-3</sup> V,<br>
(0.08) (0.02) = 1.6 × 10<sup>-3</sup> C<br>
(0.08) (0.02) = 1.6 × 10<sup>-3</sup> C<br>
= 6.286 × 10<sup>-5</sup> V,<br>
since all spokes are ir<br>
same as due to one sp<br>  $\frac{0.4}{\Delta t}$  = 0.08 A<br>
= 0.08 A<br>
= (0.08) (0.02) = 1.6 × 10<sup>-3</sup> C<br>
= 6.286 × 10<sup>-5</sup> V,<br>
= 6.286 × 10<sup>-5</sup> V,<br>
since all spokes are in parameters about its one end in a vertical<br>
1.5 m long rotates about its one end in a v

**Sol.** When the rod rotates in a vertical plane perpendicular to the magnetic meridian, it will cut horizontal component of S the magnetic meridian, it will cut horizontal component of earth's field so that

$$
e = \frac{1}{2} B_H \ell^2 \omega = \pi \ell^2 f B_H \qquad (as \omega = 2\pi f)
$$

Substituting the given data

$$
e = \pi \times (1.5)^2 \times 20 \times 0.32 \times 10^{-4} = 4.5
$$
 mV

### **Example 19 :**

A metal rod of length 1 m is rotated about one of its ends in a plane right angles to a field of inductance

 $2.5 \times 10^{-3}$  Wb/m<sup>2</sup>. If it makes 1800 revolutions/min. Calculate induced e.m.f. between its ends.

**Sol.** Given :  $\ell = 1$ m,  $B = 5 \times 10^{-3}$  Wb/m<sup>2</sup>

$$
f = \frac{1800}{60} = 30
$$
 rotations/sec

In one rotation, the moving rod of the metal traces a circle of radius  $r = \ell$ 

 $\therefore$  Area swept in one rotation =  $\pi r^2$ 

when the rod rotates in a vertical plane perpendicular to  
\nthe magnetic meridian, it will cut horizontal component of  
\nse-th's field so that  
\n
$$
e = \frac{1}{2} B_H \ell^2 \omega = \pi \ell^2 f B_H
$$
\nSubstituting the given data  
\n
$$
e = \pi \times (1.5)^2 \times 20 \times 0.32 \times 10^{-4} = 4.5 \text{ mV}
$$
\nSolution  
\n
$$
= \pi \times (1.5)^2 \times 20 \times 0.32 \times 10^{-4} = 4.5 \text{ mV}
$$
\nSolution  
\n
$$
= \pi \times 10^{-3} \text{ Wb/m}^2
$$
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= 160 \text{ m}^2 \text{ m}^2
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= 160 \text{ m}^2
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**Example 20 :**

A wheel with 10 metallic spokes each 0.50 m long is rotated with a speed of 120 rev/min in a plane normal to the earth's magnetic field at the place. If the magnitude of the field is 0.40 G, what is the induced emf between the axle and the rim of the wheel? dus  $r = \ell$ <br>
Are a seept in one rotation =  $\pi r^2$ <br>  $\frac{d\phi}{dt} = B\pi r^2 v = BA = B\pi r^2 v$ <br>  $\frac{d\phi}{dt} = B\pi r^2 v = BA = B\pi r^2 v$ <br>  $\frac{d\phi}{dt} = B\pi r^2 v = BA = B\pi r^2 v$ <br>  $\therefore I_1 = I_2 = \frac{E}{R} = \frac{10}{3} = 3.3$ <br>  $\frac{310}{10}$ <br>
Alternative of the callulat F =  $f$  = Ref and to the metal traces a circle<br>
it is  $f = f$  one and the metal of  $f$  = B  $\frac{dA}{dt} = \frac{B\pi r^2}{T}$ <br> **Example 3:**<br>
Example is one and the place of the metal traces a circle<br>
E of the set of the set of the s

**Sol.**  $n = 10$ ,  $r = 0.50$  m,  $v = 120$  rev/min.  $= 2$  rev/sec.  $B = 0.40$  G =  $0.4 \times 10^{-4}$  T Area of wheel =  $\pi r^2$ Area swept by each spoke per sec,  $A = \pi r^2 v$ .

Magnetic flux cut by each spoke per sec

$$
\frac{d\phi}{dt} = B\pi r^2 v = BA = B\pi r^2 v
$$

**STUDY MATERIAL: PHYSICS**  
Induced e.m.f., 
$$
e = \frac{d\phi}{dt}
$$
 (numerically)  

$$
= B\pi r^2 v = \frac{0.4 \times 10^{-4} \times 22 \times 0.5 \times 0.5 \times 2}{7}
$$

$$
= 6.286 \times 10^{-5} V,
$$
Since all spokes are in parallel, total e.m.f. induced will be  
same as due to one spoke.

 $= 6.286 \times 10^{-5}$  V,

Since all spokes are in parallel, total e.m.f. induced will be same as due to one spoke.

### **Example 21 :**

Find the self inductance of a coil in which an e.m.f. of 10 V is induced when the current in the circuit changes uniformly from 1 A to 0.5 A in 0.2 sec. STUDY MATERIAL: PHYSICS<br>
(numerically)<br>  $\times 22 \times 0.5 \times 0.5 \times 2$ <br>
7<br>
n parallel, total e.m.f. induced will be<br>
ooke.<br>
ce of a coil in which an e.m.f. of 10 V<br>
urrent in the circuit changes uniformly<br>
2 sec.<br>
dH =  $\frac{1-0.5$ STUDY MATERIAL: PHYSICS<br>  $\frac{1}{2}$  (numerically)<br>  $\times 22 \times 0.5 \times 0.5 \times 2$ <br>
7<br>
1 parallel, total e.m.f. induced will be<br>
ooke.<br>
ce of a coil in which an e.m.f. of 10 V<br>
turrent in the circuit changes uniformly<br>
2 sec.<br>
dI STUDY MATERIAL: PHYSICS<br>
numerically)<br>  $\frac{22 \times 0.5 \times 0.5 \times 2}{7}$ <br>
rallel, total e.m.f. induced will be<br>
e.<br>
of a coil in which an e.m.f. of 10 V<br>
mt in the circuit changes uniformly<br>
ec.<br>  $= \frac{1-0.5}{0.2} = \frac{0.5}{0.2} = 2.5$ STUDY MATERIAL: PHYSICS<br>
(numerically)<br>  $\frac{22 \times 0.5 \times 0.5 \times 2}{7}$ <br>
parallel, total e.m.f. induced will be<br>
ke.<br>
c of a coil in which an e.m.f. of 10 V<br>
yerent in the circuit changes uniformly<br>
sec.<br>  $I = \frac{1-0.5}{0.2} = \frac{0$ STUDY MATERIAL: PHYSICS<br>
umerically)<br>  $2 \times 0.5 \times 0.5 \times 2$ <br>
7<br>
callel, total e.m.f. induced will be<br>
.<br>
.<br>
f a coil in which an e.m.f. of 10 V<br>
it in the circuit changes uniformly<br>
.<br>
.<br>  $=\frac{1-0.5}{0.2} = \frac{0.5}{0.2} = 2.5$  A/

**Sol.** Given : 
$$
e = 10
$$
 V and  $\frac{dI}{dt} = \frac{1 - 0.5}{0.2} = \frac{0.5}{0.2} = 2.5$  A/s

Self inductance of coil 
$$
L = \frac{e}{dI/dt} = \frac{10}{2.5} = 4
$$
 H

$$
\therefore
$$
 e = L $\frac{dI}{dt}$  (Considering magnitude only)

### **Example 22 :**

uced e.m.f.,  $e = \frac{d\phi}{dt}$  (numerically)<br>  $3\pi r^2 v = \frac{0.4 \times 10^{-4} \times 22 \times 0.5 \times 0.5 \times 2}{7}$ <br>  $\frac{1.286 \times 10^{-5} v}{7}$ <br>
ce all spokes are in parallel, total e.m.f. induced will be<br>
e as due to one spoke.<br>
e21:<br>
d the self ind The mutual inductance of a pair of coils is 0.75 H. If current in the primary coil changes from 0.5 A to zero in 0.01 s find average induced e.m.f. in secondary coil. e.<br>
fa coil in which an e.m.f. of 10 V<br>
t in the circuit changes uniformly<br>
c.<br>  $=\frac{1-0.5}{0.2} = \frac{0.5}{0.2} = 2.5 A/s$ <br>  $=\frac{e}{dl/dt} = \frac{10}{2.5} = 4 H$ <br>
(magnitude only)<br>
a pair of coils is 0.75 H. If current<br>
s from 0.5 A to zero f a coil in which an e.m.f. of 10 V<br>t in the circuit changes uniformly<br>c.<br> $=\frac{1-0.5}{0.2} = \frac{0.5}{0.2} = 2.5 \text{ A/s}$ <br> $=\frac{e}{dl/dt} = \frac{10}{2.5} = 4 \text{ H}$ <br>(magnitude only)<br>a pair of coils is 0.75 H. If current<br>s from 0.5 A to zero i el, total e.m.f. induced will be<br>
coil in which an e.m.f. of 10 V<br>
n the circuit changes uniformly<br>  $\frac{-0.5}{0.2} = \frac{0.5}{0.2} = 2.5 \text{ A/s}$ <br>  $\frac{e}{dI/dt} = \frac{10}{2.5} = 4 \text{ H}$ <br>
agnitude only)<br>
air of coils is 0.75 H. If current duced when the current in the circuit changes uniformly<br>
1 A to 0.5 A in 0.2 sec.<br>  $\ln : e = 10$  V and  $\frac{dI}{dt} = \frac{1-0.5}{0.2} = \frac{0.5}{0.2} = 2.5$  A / s<br>
inductance of coil  $L = \frac{e}{dI/dt} = \frac{10}{2.5} = 4$  H<br>  $= L \frac{dI}{dt}$  (Conside  $\therefore$ <br>  $\cos \theta = \text{seIf inductance of a coil in which an e.m.f. of 10 V  
\nA to 0.5 A in 0.2 sec.  
\n
$$
\therefore e = 10 \text{ V and } \frac{dI}{dt} = \frac{1 - 0.5}{0.2} = \frac{0.5}{0.2} = 2.5 \text{ A/s}
$$
\n
$$
\text{ductance of coil L} = \frac{e}{dI/dt} = \frac{10}{2.5} = 4 \text{ H}
$$
\n
$$
\text{L} \frac{dI}{dt} \text{ (Considering magnitude only)}
$$
\n
$$
\therefore
$$
\n
$$
\therefore
$$$ 

**Sol.** Given : M = 0.75 H and 
$$
\frac{dI}{dt} = \frac{0.5 - 0}{0.01} = 50 \text{ A/s}
$$

Average induced e.m.f. in secondary coil

$$
e = M \frac{dl}{dt} = 0.75 \times 50 = 37.5 \text{ V}
$$

### **Example 23 :**

T Find the values of currents  $I_1$ ,  $I_2$  and  $I_3$ :  $\overline{\text{m}}^2$  In fig. E = 10V, R<sub>1</sub> = 1.0 Ω, R<sub>2</sub> = 2.0 Ω, R<sub>3</sub> = 3Ω and L = 2H.



(i) immediately after switch S is closed (ii) sufficient time after the switch S is closed (iii) immediately after opening the switch (iv) sufficient time after opening the switch

**Sol.** (i) When switch S is closed, the circuit is completed, but due to electrical inertia of inductance coil, the current  $I_3$ immediately after closing the switch is zero i.e.,  $I_3 = 0$ . The currents  $I_1$  and  $I_2$  will then be equal since  $R_1$  and  $R_2$ are in series to form the closed circuit. The net resistance  $R = R_1 + R_2 = 1.0 + 2.0 = 3.0 \Omega$ , E<br>
E<br>  $\frac{1}{12}$ <br>  $\frac{1}{5}$ <br>  $\frac{1}{2}$ <br>  $\frac{1$ g. E = 10V, R<sub>1</sub> = 1.0 Ω, R<sub>2</sub> = 2.0 Ω, R<sub>3</sub> = 3Ω and L = 2H.<br>the values of currents 1<sub>1</sub>, 1<sub>2</sub> and 1<sub>3</sub>:<br>the values of currents 1<sub>1</sub>, 1<sub>2</sub> and 1<sub>3</sub>:<br> $\frac{R_1}{R_3}$ <br> $\frac{R_2}{R_3}$ <br> $\frac{R_4}{R_3}$ <br> $\frac{R_5}{R_2}$ <br> $\frac{R_3}{R_3}$ <br> $\frac{3}{2}$  = 10V, R<sub>1</sub> = 1.0 Ω, R<sub>2</sub> = 2.0 Ω, R<sub>3</sub> = 3Ω and L = 2H.<br>
e values of currents 1<sub>1</sub>, 1<sub>2</sub> and 1<sub>3</sub>:<br>  $\frac{8}{11}$  = <sup>R</sup><sub>1</sub>, 1<sub>2</sub> and 1<sub>3</sub>:<br>  $\frac{8}{11}$  = <sup>R</sup><sup>1</sup> = <sup>1</sup> = <sup></sup>

$$
\therefore I_1 = I_2 = \frac{E}{R} = \frac{10}{3.0} = 3.3 \text{ amp.}
$$



(ii) Sufficient time after closing the switch, the inductance offers no resistance and current becomes steady in circuit containing  $R_3$  and L. Now  $R_2$  and  $R_3$  are in parallel, their equivalent resistance CONETIC INDUCTION<br>
to time after closing the switch, the inductance Example 26:<br>
sistance and current becomes steady in circuit<br>  $R_3$  and L. Now  $R_2$  and  $R_3$  are in parallel, their<br>
esistance which case the<br>  $\frac{2R_3}{$ **EXECUTE INDUCTION**<br>
Example 26:<br>
example 26:<br>
Example 26:<br>
Example 26:<br>
Example 26:<br>
R<sub>3</sub> and L. Now R<sub>2</sub> and R<sub>3</sub> are in parallel, their<br>
resistance<br>  $\frac{R_2R_3}{2+R_3} = \frac{2 \times 3}{2+3} = \frac{6}{5} = 1.2\Omega$ <br>  $\frac{R_2R_3}{2+R_3} = \frac$ **EXECUTE INDUCTION**<br>
Sufficient time after closing the switch, the inductance<br>
SERVIGION SUFFICIENT UNDIVIDUAL UNITS IN ORDINATOR SUFFICIENT SUFFICIENT TWO identical loops, one of copper and another of<br>
sining R<sub>3</sub> and L. **MAGNETIC INDUCTION**<br>
Example 26:<br>
resistance and current becomes steady in circuit<br>
resistance and current becomes steady in circuit<br>
Two identical loops, one of copper and another<br>
resistance<br>
resistance which case the CONETIC INDUCTION<br>
t time after closing the switch, the inductance<br>
istance and current becomes steady in circuit<br>
3 and L. Now R<sub>2</sub> and R<sub>3</sub> are in parallel, their<br>
<sup>2R</sup><sub>3</sub> =  $\frac{2 \times 3}{2+3} = \frac{6}{5} = 1.2\Omega$ <br>
<sup>1R<sub>3</sub> =  $\frac{$ 

$$
R' = \frac{R_2 R_3}{R_2 + R_3} = \frac{2 \times 3}{2 + 3} = \frac{6}{5} = 1.2 \Omega
$$

Effective resistance of circuit,

 $R = R_1 + R' = 1 + 1.2 = 2.2 \Omega$ .

$$
\therefore \text{ Current in circuit is } = \frac{E}{R} = \frac{10}{2.2} = 4.5 \text{A}
$$

Potential difference across  $R_2$  and  $R_3 = I_1R'$ 

**LECTROMAGNETIC INDUCTION)**  
\n(i) Sufficient time after closing the switch, the inductance  
\nofers no resistance and current becomes steady in circuit  
\ncontaining R<sub>3</sub> and L. Now R<sub>2</sub> and R<sub>3</sub> are in parallel, their  
\nequivalent resistance  
\n
$$
R' = \frac{R_2R_3}{R_2 + R_3} = \frac{2 \times 3}{2 + 3} = \frac{6}{5} = 1.2\Omega
$$
  
\n $R = R_1 + R' = 1 + 1.2 = 2.2\Omega$   
\n $R = R_1 + R' = 1 + 1.2 = 2.2\Omega$   
\n $R = R_1 + R' = 1 + 1.2 = 2.2\Omega$   
\n $R = \frac{10}{R} = \frac{10}{2.2} = 4.5\text{ A}$   
\n $R = \frac{10}{R} = \frac{(60/11)}{2.2} = \frac{60}{11}$  volt  
\n $R = \frac{V}{R} = \frac{(60/11)}{2.0} = \frac{60}{22} = 2.7\text{ A}$   
\n $\therefore I_2 = \frac{V}{R_2} = \frac{(60/11)}{2.0} = \frac{60}{22} = 2.7\text{ A}$   
\n $I_3 = \frac{V}{R} = \frac{(60/11)}{8.8} = \frac{60}{11} = 1.8\text{ A}$   
\n $I_1 = 1 + 8\text{ A}$   
\n $I_2 = 1 + 8\text{ A}$   
\n $I_3 = \frac{V}{R} = \frac{(60/11)}{2.8} = \frac{60}{11} = 1.8\text{ A}$   
\n $I_4 = 1 + 8\text{ A}$   
\n $I_5 = 1 + 8\text{ A}$   
\n $I_6 = 1 + 8\text{ A}$   
\n $I_7 = 1 + 8\text{ A}$   
\n $I_8 = 1 + 8\text{ A}$   
\n $I_9 = 1 + 8\text{ A}$   
\n $I_9 = 1 + 8\text{ A}$   
\n $I_1 = 1 + 8\text{ A}$   
\n $I_2 = 1 + 8\text{ A}$ 

(iii) When switch S is opened, the main circuit is broken and so current delivered by cell,  $I_1 = 0$ .

But  $R_2$ ,  $R_3$  and L are still in closed circuit, therefore, due to electrical inertia of self inductance, immediately after opening the switch, currents  $I_2$  and  $I_3$  are not zero and Sol  $I_2 = I_3 = 1.8 A$ .

(iv) Sufficient time after opening the switch, the inductance has no role and so all current  $I_1$ ,  $I_2$  and  $I_3$  are zero.

### **Example 24 :**

and runs from a dc source of 12 volt. When running unloaded it draws a current of 2 amp. When a certain load is connected, its speed becomes one-half of its unloaded value. What is the new value of current drawn?  $\frac{(1+x)^2}{3} = \frac{60}{33} = 1.8A$  ( $1+x^2$ ) currents through battery.<br>
S is opened, the main circuit is broken<br>
restill in closed circuit, therefore, due to<br>
restill in closed circuit, therefore, due to<br>
restill in closed circu of current densities the specific process of  $3\sqrt{2}$ ,  $\sqrt{2}$ ,  $\sqrt{2}$  and  $\sqrt{2}$  and What swatch is signed to content delivered by cell,  $1_1 = 0$ .<br>
So current delivered by cell,  $1_1 = 0$ .<br>
So current delivered by cell,  $1_1 = 0$ .<br>
So current delivered by cell,  $1_1 = 0$ .<br>
So content delivered by cell,  $1_1 =$ 

**Sol.** Let initial e.m.f. induced  $= e$ .

$$
\therefore \quad \text{Initial current } i = \frac{E - e}{R} \text{ i.e., } 2 = \frac{12 - e}{1} \qquad \qquad \text{Example 28:} \qquad \text{A 20 mH coil i}
$$

This gives 
$$
e = 12 - 2 = 10
$$
 volt. As  $e \propto \omega$ .

when speed is halved, the value of induced e.m.f. becomes

$$
\frac{e}{2} = \frac{10}{2} = 5
$$
 volt

$$
\therefore \text{ Final value of current } i = \frac{E - e}{R} = \frac{12 - 5}{1} = 7 \text{ A}
$$

### **Example 25 :**

An induced emf has no direction of its own. Comment.

**Sol.** The given statement is correct. This is because, according to Lenz's law, the direction of the induced emf is such as to oppose the cause of production of induced emf. Thus, the direction of induced emf is to be determined by the cause of emf.

### **Example 26 :**

- **EXECUTE INDUCTION**<br>
To Example 26:<br>
The inductance Example 26:<br>
The interaction of the same and current becomes steady in circuit<br>
Two identical loops, one of copper and another of aluming R<sub>3</sub> and L. Now R<sub>2</sub> and R<sub>3</sub> a **DUCTION**<br>
losing the switch, the inductance<br>
losing the switch, the inductance<br>
urrent becomes steady in circuit<br>
w R<sub>2</sub> and R<sub>3</sub> are in parallel, their<br>
which case the induced (a) e.m.f. and (b) cu<br>
more? Explain.<br>
sol. **INDUCTION**<br> **EXECUTED ACT CONSTANT CONST** Two identical loops, one of copper and another of aluminium are rotated with same speed in the same magnetic field. In which case the induced (a) e.m.f. and (b) current will be more? Explain. **EXECUTE 26 EXAMINE SURFERENT (a) The change in magnetic flux** 
	- **Sol.** (a) The change in magnetic flux linked with both the loop will be same. So the induced e.m.f. produced in both the loops is same.

(b) Current (I) = 
$$
\frac{e.m.f.(E)}{Resis tan ce (R)}
$$

Since the resistance of copper loop is less than that of the aluminium loop, so more current will flow through the copper loop than that in the aluminium loop.

### **Example 27 :**

Two resistors of 10  $\Omega$  and 20  $\Omega$  and an ideal inductor of 10H are connected to a 2 V battery as shown. The key K is inserted at time  $t = 0$ . Find the initial  $(t = 0)$  and final  $(t \rightarrow \infty)$  currents through battery. Resistance (K)<br>
ance of copper loop is less than that of the<br>
p, so more current will flow through the<br>
m that in the aluminium loop.<br>
<sup>2</sup> 1 0  $\Omega$  and 20  $\Omega$  and an ideal inductor of 10H<br>
is through battery.<br>
<br>
<br>
<br>
<br>
<br> Resistance (R)<br>
Resistance (R)<br>
ce of copper loop is less than that of the<br>
so more current will flow through the<br>
that in the aluminium loop.<br>  $\Omega$  and  $20 \Omega$  and an ideal inductor of 10H<br>
a 2 V battery as shown. The key 2 1 I A



**Sol.** At  $t = 0$  i.e. when the key is just pressed, no current exists inside the inductor. So 10  $\Omega$  and 20  $\Omega$  resistors are in series and a net resistance of  $(10 + 20) = 30 \Omega$  exists across the inside the inductor. So 10  $\Omega$  and 20  $\Omega$  resistors are in series<br>and a net resistance of  $(10 + 20) = 30 \Omega$  exists across the<br>circuit. Hence  $I_1 = \frac{2}{30} = \frac{1}{15} A$ <br>As  $t \to \infty$ , the current in the inductor grows to atta

circuit. Hence 
$$
I_1 = \frac{2}{30} = \frac{1}{15} A
$$

A simple electric motor has an armature resistance of 1  $\Omega$  As t  $\rightarrow \infty$ , the current in the inductor grows to attain a maximum value i.e. the entire current passes through the inductor and no current passes through  $10\Omega$  resistor.

Hence 
$$
I_2 = \frac{2}{20} = \frac{1}{10} A
$$

 $\frac{-e}{R}$  i.e.,  $2 = \frac{12 - e}{1}$  Example 28:<br>A 20 mH coil is connected in series with a 2000 ohm resistor .8A<br>
Are main circuit is broken<br>  $\begin{array}{r}\n\text{(t \rightarrow \infty)} \text{ currents through battery.}\n\end{array}$ <br>
Are main circuit is broken<br>  $\begin{array}{r}\n\text{(t \rightarrow \infty)} \text{ currents, therefore, due to}\n\end{array}$ <br>
And  $\begin{array}{r}\n\text{(t = 0)}\n\end{array}$ <br>
ance, immediately after<br>
and  $\begin{array}{r}\n1_1 = 0.\n\end{array}$  So ts 1<sub>2</sub> and 1<sub>3</sub> are not zero and<br>
Sol. At t = 0 i.e. when the key is just pressed, no current exists<br>
eming the switch, the inductance<br>
and a net resistance of (10 + 20) = 30 Ω exists across the<br>
circuit. Hence  $1_1 = \frac{2$ Hence, immediately after<br>
and I<sub>3</sub> are not zero and<br>
inside the inductor. So 10 Ω and 20 Ω resistors are in seri-<br>
inside the inductor. So 10 Ω and 20 Ω resistors are in seri-<br>
I<sub>12</sub> and I<sub>3</sub> are zero.<br>
I<sub>12</sub> and I<sub>3</sub> a olductance, ummediately alter<br>  $\text{H}_2$  and  $\text{H}_3$  are not zero and<br>  $\text{H}_2$  and  $\text{H}_3$  are not zero and<br>  $\text{H}_1$ ,  $\text{H}_2$  and  $\text{H}_3$  are zero.<br>
inside the inductor. So 10  $\Omega$  and 20  $\Omega$  resistors are in series and a 12-V battery. Calculate the time constant of the circuit. After what time the current attains 99% of its final value after the switch is closed? EVENTIFY EVENTIFY EVENTIFY AND SURVEY IN A 100 1<br>
Sub 10 Ω and 20 Ω resistors are in series<br>
of  $(10 + 20) = 30$  Ω exists across the<br>  $\frac{2}{30} = \frac{1}{15}$  A<br>
ent in the inductor grows to attain a<br>
the entire current passes e key is just pressed, no current exists<br>
so 10  $\Omega$  and 20  $\Omega$  resistors are in series<br>
of  $(10 + 20) = 30 \Omega$  exists across the<br>  $\frac{2}{30} = \frac{1}{15}$  A<br>
the inductor grows to attain a<br>
the entire current passes through the of the inductor. So 10 Ω and 20 Ω resistors are in series<br>
de the inductor. So 10 Ω and 20 Ω resistors are in series<br>
a net resistance of (10 + 20) = 30 Ω exists across the<br>
uit. Hence  $I_1 = \frac{2}{30} = \frac{1}{15} A$ <br>  $t \rightarrow \infty$ , Hence  $I_2 = \frac{2}{20} = \frac{1}{10} A$ <br>
aple 28:<br>
A 20 mH coil is connected in series with a 2000 ohm resistor<br>
and a 12-V battery. Calculate the time constant of the circuit.<br>
After what time the current attains 99% of its final  $I_1 = \frac{1}{30} = \frac{1}{15}$  A<br>
current in the inductor grows to attain a<br>
e i.e. the entire current passes through the<br>
o current passes through 10Ω resistor.<br>  $= \frac{1}{10}$  A<br>
connected in series with a 2000 ohm resistor<br>
er actor and no current passes through 1022 resistor.<br>
cce  $I_2 = \frac{2}{20} = \frac{1}{10} A$ <br>
28:<br>
20 10 mH coil is connected in series with a 2000 ohm resistor<br>
a 12-V battery. Calculate the time constant of the circuit.<br>
12-V batte e, the current in the inductor grows to attain a<br>value i.e. the entire current passes through the<br>nd no current passes through 10Ω resistor.<br> $= \frac{2}{20} = \frac{1}{10}$  A<br>coil is connected in series with a 2000 ohm resistor<br>V b and no current passes through 10Ω resistor.<br>
=  $\frac{2}{20} = \frac{1}{10}$  A<br>
coil is connected in series with a 2000 ohm resistor<br>
V battery. Calculate the time constant of the circuit.<br>
t time the current attains 99% of its fin s with a 2000 ohm resistor.<br>
time constant of the circuit.<br>
ns 99% of its final value<br>  $\frac{-3}{-} = 10 \times 10^{-6}$  s = 10 µs<br>  $\frac{99}{100} = 1 - e^{-10^5 t}$ ont passes through the<br>the 10Ω resistor.<br>the a 2000 ohm resistor<br>constant of the circuit.<br>9% of its final value<br>=  $10 \times 10^{-6}$  s = 10 μs<br>=  $1 - e^{-10^5}$  t

**Sol.** (i) Time constant = 
$$
\frac{L}{R} = \frac{20 \times 10^{-3}}{2000} = 10 \times 10^{-6} \text{ s} = 10 \text{ }\mu\text{s}
$$

(ii) 
$$
I = I_0 (1 - e^{-\frac{R}{L}t})
$$

Here, I = 99%, I<sub>0</sub> = 
$$
\frac{99}{100}
$$
I<sub>0</sub>

$$
\therefore \frac{99}{100} = \left(1 - e^{-\frac{2000}{20 \times 10^{-3}}t}\right) \Rightarrow \frac{99}{100} = 1 - e^{-10^5t}
$$



ONANGEDILJARNING	STUDY MATLAB
OT $e^{-10^5 t} = 1 - \frac{99}{100} = \frac{1}{100}$ or $e^{-10^5 t} = 100$	Example 31:
Taking log of both sides $10^5 t = \log_e 100 = 2.303 \log_{10} 100$ $= 2.303 \times 2.0000 = 4.606$	A circular wire loop, without touching it. The correct statement(s) is (are) (A) The emf induced in the loop is zero if the current is constant.

### **Example 29 :**

A coil of resistance 50  $\Omega$  is connected across a 5.0 V battery, 0.1 s after the battery is connected, the current in the coil is 60 mA. Calculate the inductance of the coil.

**EXAMPLE 21**  
\nor 
$$
e^{-10^5t} = 1 - \frac{99}{100} = \frac{1}{100}
$$
 or  $e^{-10^5t} = 100$   
\nTaking log of both sides 10<sup>5</sup> t = log<sub>6</sub> 100 = 2.303 log<sub>10</sub> 100  
\n= 2.303 × 2.0000 = 4.606  
\nor t = 4.606 × 10<sup>-5</sup> = 46.06 × 10<sup>-6</sup> = 46.06 μs.  
\n**Example 29**:  
\nA coil of resistance 50 Ω is connected across a 5.0 V bat-  
\ntory, 0.1 s after the battery is connected, the current in the  
\ncol is 60 mA. Calculate the inductance of the coil.  
\n**Sol.** Here, I<sub>0</sub> =  $\frac{E}{R} = \frac{5}{50} = 0.1$  A  
\nI = 60 mA = 60 × 10<sup>-3</sup> A, t = 0.1  
\nNow, I = I<sub>0</sub>  $\left(1 - e^{-\frac{R}{L}t}\right)$   
\n $\therefore$  60 × 10<sup>-3</sup> = 0.1  $\left(1 - e^{-\frac{50}{L} \times 0.1}\right)$  = 0.1  $\left(1 - e^{-\frac{50}{L} \times 0.1}\right)$   
\n $\therefore$   $\frac{50I}{R} = 60$  and  $\frac{50I}{R} = 60$ 

$$
\therefore \quad 60 \times 10^{-3} = 0.1 \left( 1 - e^{-\frac{50}{L} \times 0.1} \right) = 0.1 \left( 1 - e^{-\frac{5}{L}} \right)
$$

or 
$$
1 - e^{-5/L} = 0.6
$$

$$
\therefore
$$
 e<sup>-5/L</sup> = 1 – 0.6 = 0.4 =  $\frac{4}{10}$  or e<sup>5/L</sup> = 10/4

Taking log of both sides

Here, 
$$
I_0 = \frac{E}{R} = \frac{5}{50} = 0.1 \text{ A}
$$
  
\n $I = 60 \text{ mA} = 60 \times 10^{-3} \text{ A}, t = 0.1$   
\nNow,  $I = I_0 \left( 1 - e^{-\frac{R}{L}} t \right)$   
\n $\therefore 60 \times 10^{-3} = 0.1 \left( 1 - e^{-\frac{50}{L} \times 0.1} \right) = 0.1 \left( 1 - e^{-\frac{50}{L}} \right)$   
\n $\therefore 60 \times 10^{-3} = 0.1 \left( 1 - e^{-\frac{50}{L} \times 0.1} \right) = 0.1 \left( 1 - e^{-\frac{50}{L}} \right)$   
\nor  $I = e^{-5/L} = 0.6$   
\n $\therefore e^{-5/L} = 1 - 0.6 = 0.4 = \frac{4}{10}$  or  $e^{5/L} = 10/4$   
\n $\therefore L = \frac{5}{0.9164} = 5.5 \text{ H}$   
\n $\therefore L = \frac{5}{0.9164} = 5.5 \text{ H}$   
\n $\therefore L = 0.6$   
\n $\therefore L = 0.4$   
\n<

### **Example 30 :**

Two identical bulbs are connected as shown in the fig. resistance R is equal to D.C. resistance of coil wire.

(a) Which of the bulbs light up earlier when key K is closed (b) Will the bulbs be equally bright after some time?



**Sol.** (a) When key (K) is closed. Current begins to flow through both the area. Induced e.m.f. is produced across the inductor which oppose the growth of current in the circuit. So current through  $B_1$  is delayed. Hence bulb  $B_2$  lights up earlier than that of bulb  $B_1$ .

(b) When current becomes constant after some time in both the arms, no induced e.m.f. is produced in L. So both the bulbs will be equally bright.

### **Example 31 :**



(B) The emf induced in the loop is infinite if the current is constant.

(C) The emf induced in the loop is zero if the current decreases at a steady rate.

(D) The emf induced in the loop is finite if the current decreases at a steady rate.

**Sol. (AC).** Since flux of wire on the loop is zero therefore, emf will not be induced.

### **Example 32 :**

=  $\frac{1}{100}$  or e<sup>-105</sup><sup>t</sup> = 100<br>
A current carrying infinitely long<br>
les 10<sup>5</sup>t = log<sub>s</sub> 100 = 2.303 log<sub>10</sub> 100<br>
= 2.303 × 2.0000 = 4.606<br>
touching it. The correct statement(s)<br>
to Co × 10<sup>-6</sup> s = 46.06 μs.<br>
(A) The =  $\frac{1}{100}$  or  $e^{-10^5 t} = 100$ <br>
A current carrying infinitely long<br>
des 10<sup>5</sup> t = log<sub>s</sub> 100 = 2.303 log<sub>10</sub> 100<br>
= 2.303 × 2.0000 = 4.606<br>
= 2.303 × 2.0000 = 4.606<br>
= 2.303 × 2.0000 = 4.606<br>
touching it. The correct  $\frac{5}{2}$  Two metallic rings A and B, identical in shape and size =100<br>
A current carrying infinitely long<br>
wire is kept along the diameter of<br>  $\times 2.0000 = 4.606$ <br>
acircular wire loop, without<br>  $\times 2.0000 = 4.606$ <br>
to acircular wire loop, without<br>  $\times 2.0000 = 4.606$ <br>
to to the included i **STUDY MATERIAL: PHYSICS**<br>  ${}^{5}t = 100$  Reversible 31:<br>  ${}^{4}t = 100$  Reversible 21:<br>  ${}^{4}t = 100$  Reversible and the distribution of the distribution of the distribution in the correct statement(s)<br>  ${}^{4}6.06 \text{ }\mu\text{s}$ .<br> **Example 31:**<br>
A current carrying infinitely long<br>  $2.303 \log_{10} 100$  acircular wire loop, without<br>  $0.0000 = 4.606$  acircular wire loop, without<br>  $\mu$ s.<br>  $\mu$ = 2.303 × 2.0000 = 4.606<br>
= 4.6.06 × 10<sup>-6</sup> s = 46.06 μs.<br>
= 46.06 × 10<sup>-6</sup> s = 46.06 μs.<br>
= 6.00 is connected across a 5.0 V bat<br>
= 6.00 is connected across a 5.0 V bat<br>
= 6.01 if the entri-field in the loop is is (are but having different resistivity  $\rho_A$  and  $\rho_B$ , are kept on top of two identical solenoids as shown in the figure. When current I is switched on in both the solenoids in identical manner, the rings A and B jump to heights  $h_A$  and  $h_B$ , respectively, with  $h_A > h_B$ . The possible relation(s) between their resistivity and their masses  $m_A$  and  $m_B$  is (are)  $A \textcircled{a} B \textcircled{b}$ and the indiced.<br>
allic rings A and B, identical in shape and size<br>
g different resistivity  $\rho_A$  and  $\rho_B$ , are kept on top<br>
entical solenoids as shown in the figure. When<br>
is switched on in both the solenoids in identic lux of wire on<br>
is zero therefore,<br>
mot be induced.<br>
rings A and B, identical in shape and size<br>
fferent resistivity  $\rho_A$  and  $\rho_B$ , are kept on top<br>
vitched on in both the solenoids in identical<br>
rings A and B jump to h is zero interesting<br>
and B, identical in shape and size<br>
ifferent resistivity  $\rho_A$  and  $\rho_B$ , are kept on top<br>
interfect the induced set of the figure. When<br>
witched on in both the solenoids in identical<br>
rings A and B j



**Sol. (BD).**The horizontal component of magnetic field due to solenoid will exert force on ring in vertical direction







# **ALTERNATING CURRENT**

### **DIRECT CURRENT (D.C.)**

If a circuit contents a battery and a resistance in series then e.m.f. and current in circuit are as shown below and known as direct e.m.f. and direct current.



Magnitude of e.m.f. and current does not varies with time in D.C. circuits.

### **ALTERNATING EMF**

Magnitude of emf (or voltage) changes continuously with time between zero and a maximum value and also direction reverses periodically.



A sinusoidal alternating emf is developed in a coil of wire rotating with constant angular velocity  $\omega$  in a uniform magnetic field. The magnitude of the alternating emf changes with time and its direction reverses peiodically as shown in figure. The alternating emf  $E = E_0 \sin \omega t$ .

Here  $E =$  the instantaneous value of emf,

 $E_0$  = the maximum or peak value,

 $\omega$  = angular speed of the coil and  $\omega$  = phase of alternating emf.

### **ALTERNATING CURRENT (AC) :**

When an alternating emf is applied across a coil or a bulb, it sends a similarly varying current (i.e. of the same nature as that of e.m.f.) through the coil. The currents is called alternating current.



The alternating current also varies in magnitude with time and reverses its direction periodically.

The alternating current is similarly expressed by  $I = I_0 \sin \omega t$ 

 $I_0$  = the peak value or the amplitude of the alternating current and  $\omega t$  = phase of alternating current.

The alternating current continuously varies in magnitude and periodically reverses its direction.

### **DIFFERENTTYPES OF E.M.F.AND CURRENTS**







### **IMPORTANTTERMS**

**Cycle of alternating e.m.f. and current :** The variation of e.m.f. from zero to maximum in one direction, through zero to maximum in the opposite direction and back to zero again is called a cycle of the alternating emf.

One cycle of a.c. to be variation of current from zero to maximum in one direction, through zero to maximum in the opposite direction and back to zero again.

**Period and frequency of alternating emf (or current) :**

Alternating e.m.f. is defined by the equation :

 $E = E_0 \sin \omega t$ 

This shows that after a time interval of  $T = \frac{2\pi}{\omega}$ , alternating Mean value for half cycle in betw

e.m.f. (or current) repeats its nature.



**Time Period :** Time taken by the alternating emf (or current) to complete one cycle of its variations.

Time interval  $\frac{2\pi}{ }$  is called as time period of alternating emf  $\frac{\partial}{\partial \omega}$  is called as time period of alternating emf  $1^2 = \frac{\pi}{1}$ 

(or current)  $T = \frac{2\pi}{r}$  $\pi$  $=\frac{2\pi}{\omega}$ 

**Frequency :** Number of cycles completed by alternating current (or emf) in one second.

frequency 
$$
f = \frac{1}{T}
$$
 But  $T = \frac{2\pi}{\omega}$   $\therefore$   $f = \frac{\omega}{2\pi}$  is 0.707 times the peak value of a.c. Similarly

**Unit of frequency :** cycles/second (C/s) or hertz (Hz). In India frequency of A.C. is 50 Hz and in America it is 60Hz. The frequency of the domestic A.C. 50 Hz. Alternating current in electric wires or bulbs flows 50 times in one direction and 50 times in opposite direction in 1 second. Since in one cycle the current becomes zero two times, hence bulb lights up 100 times and is off 100 times in one second, but due to persistence of vision, it appears lighted continuously.

### **MEAN ORAVERAGEVALUE OFALTERNATING CURRENT (ORVOLTAGE)**

The mean or average value of a.c. over one complete cycle is zero. The mean value of alternating current over half a cycle is defined as the mean value. The mean or average value of alternating current over any half cycle is defined as that value of steady direct current which would send the same amount of charge through a circuit in half time period  $(i.e. T/2)$  as is sent by the a.c. through the same circuit in the same time. It is represented by  $I_m$ . frequency of the domestic A.C. 50 Hz. Alternating<br>ent in electric wires or bulbs flows 50 times in one<br>tion and 50 times in opposite direction in 1 second.<br>e in one cycle the current becomes zero two times,<br>e bulb lights **STUDY MATERIAL: PHYSICS**<br>quency of the domestic A.C. 50 Hz. Alternating<br>in electric wires or bulbs flows 50 times in one<br>n and 50 times in opposite direction in 1 second.<br>1 one cycle the current becomes zero two times,<br>t **STODY MATERIAL: PHYSICS**<br>
in electric vies or bubs flows 50 times in one in a dotting<br>
in electric wies or bubs flows 50 times in one<br>
in and 50 times in opposite direction in 1 second.<br>
1 one cycle the current becomes z stic A.C. 50 Hz. Alternating<br>bulbs flows 50 times in one<br>pposite direction in 1 second.<br>ent becomes zero two times,<br>les and is off 100 times in one<br>ce of vision, it appears lighted<br>FALTERNATINGCURRENT<br>f a.c. over one comp **EXAMERAGE VALUE OF ALTERNATING CURRENT**<br> **CAGE)**<br>
cann or average value of a.c. over one complete cycle<br>
o. The mean value of alternating current over half a<br>
is defined as the mean value. The mean or average<br>
of alterna Entrance was or outlos hows or outlos in the same in the entrance was the matternal and 50 times in opposite direction in 1 second.<br>
Entrance the current becomes zero two times,<br>
the bulb lights up 100 times and is off 10 is defined as the mean value. The mean or average<br>of alternating current over any half cycle is defined<br>value of steady direct current which would send the<br>mount of charge through a circuit in half time period<br>(2) as is s muously.<br> **RAVERAGE VALUE OF ALTERNATING CURRENT**<br> **TAGE)**<br>
mean or average value of a.c. over one complete cycle<br>
mean or average value of alternating current over half a<br>
is defined as the mean value. The mean or averag

$$
I_{m}\left(\frac{T}{2}\right) = \int_{0}^{T/2} I \, dt \quad \text{or} \quad I_{m}\frac{2}{T} = \int_{0}^{T/2} I \, dt \qquad \qquad \text{....(i)}
$$

i.e., 
$$
I_m = \frac{2I_0}{\pi} = 0.637 I_0
$$
 ......(ii)

Similarly, it can be proved that the mean or average value of alternating e.m.f. over positive half cycle  $(0 \text{ to } T/2)$  is

$$
E_m = \frac{2E_0}{\pi} = 0.637 E_0
$$

The average value of alternating e.m.f. over one complete cycle is also equal to zero.

Mean value for half cycle in between 
$$
t = \frac{T}{4} \& \frac{3T}{4}
$$
 is zero.

### **ROOT MEAN SQUAREVALUE (rms) OFALTERNATING CURRENT (VIRTUAL VALUE)**

The root mean square (rms) value of alternating current is defined as that value of steady current, which would generate the same amount of heat in a given resistance in a given time as is done by the a.c. when passed through the same resistance for the same time. It is represented by  $I_{rms}$ . It is also called effective value or virtual value of the alternating current. The ammeter, when connected in the circuit, always measures rms value of a.c. cycle is also equal to zero.<br>
Mean value for half cycle in between  $t = \frac{T}{4}$  &  $\frac{3T}{4}$  is zero.<br> **OT MEAN SQUARE VALUE (rms) OF ALTERNATING**<br> **RRENT (VIRTUAL VALUE)**<br>
The root mean square (rms) value of alternating cu  $E_m = \frac{2E_0}{\pi} = 0.637 E_0$ <br>
The average value of alternating e.m.f. over one complete<br>
cycle is also equal to zero.<br>
Mean value for half cycle in between  $t = \frac{T}{4}$  &  $\frac{3T}{4}$  is zero.<br> **OOT MEAN SQUARE VALUE** (rms) OF **REVALUE (rms) OF ALTERNATING**<br> **VALUE)**<br>
uare (rms) value of alternating current is<br>
value of steady current, which would<br>
a mount of heat in a given resistance in a<br>
one by the a.c. when passed through the<br>
or the same and to zero.<br>
alf cycle in between  $t = \frac{T}{4}$  &  $\frac{3T}{4}$  is zero.<br> **REVALUE (rms) OFALTERNATING**<br> **IVALUE)**<br>
quare (rms) value of alternating current is<br>
value of steady current, which would<br>
e amount of heat in a given alternating e.m.f. over one complete<br>zero.<br>
ycle in between  $t = \frac{T}{4}$  &  $\frac{3T}{4}$  is zero.<br>
ZALUE (rms) OFALTERNATING<br>
LUE)<br>
(rms) value of alternating current is<br>
confisted of strange virent, which would<br>
count of heat the a.c. when passed through the<br>ame time. It is represented by I<sub>rms</sub>.<br>ve value or virtual value of the<br>ammeter, when connected in the<br>rms value of a.c.<br>taneous value of a.c. I = I<sub>0</sub> sin ot)<br> $\frac{I_0}{\sqrt{2}}$  = 0.707 I<sub>0</sub><br> UE)<br>
(rms) value of alternating current is<br>
of steady current, which would<br>
unt of heat in a given resistance in a<br>
same time. It is represented by I<sub>rms</sub>:<br>
tive value or virtual value of the<br>
ne ammeter, when connected i E (rms) OF ALTERNATING<br>value of alternating current is<br>teady current, which would<br>f heat in a given resistance in a<br>a.c. when passed through the<br>time. It is represented by  $I_{rms}$ <br>value or virtual value of the<br>meter, when

$$
\overline{I}^2 = \frac{1}{T} \int_0^T I^2 dt
$$
 (:: instantaneous value of a.c. I = I<sub>0</sub> sin  $\omega$ t)

$$
\therefore I^2 = \frac{I_0^2}{2} \; ; \quad I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = 0.707 I_0
$$

 $T = \frac{2\pi}{\pi}$  :  $f = \frac{\omega}{2\pi}$  is 0.707 times the peak value of a.c. or 70.7% of the peak  $=\frac{\omega}{2\pi}$  value of a.c. Similarly r.m.s. value or virtual value of Thus the rms value or effective value or virtual value of a.c.

alternating e.m.f.

$$
E_{\rm rms} = \frac{E_0}{\sqrt{2}} = 0.707 E_0
$$



### **FORM FACTOR**

Form factor =  $\frac{\text{rms value of AC}}{\text{Mean value of AC over half cycle}}$ 

**For sinusoidal AC :**

Form factor = 
$$
\frac{I_0 / \sqrt{2}}{2I_0 / \pi}
$$
 or Form factor =  $\frac{\pi}{2\sqrt{2}}$ 

**Note :**

- (i) The heating effect of a A.C.  $I = I_0 \sin \omega t$  is same as that of a steady current =  $0.707 I_0$ .
- **(ii)** Alternating current and emf are usually described in terms of their effective value or rms value.

If a bulb marked 250 V  $\sim$  and 25 Watt it means 250 V rms value.

Alternating potential difference between the supply mains of a house hold power line is 220 Volt, it means that the rms or effective potential difference is 220 Volt and hence the

maximum potential difference is  $220 \times \sqrt{2} = 311$  Volt. The Voltage in domestic supply varies from  $+311$  Volt to  $-311$ Volt in each cycle. tor =  $\frac{1}{2I_0/\pi}$  or Form factor =  $\frac{1}{2\sqrt{2}}$  and sudden, hence fatal.<br>
Example 4:<br>
ing effect of a A.C. I = I<sub>0</sub> sin ot is same as that of<br>
current = 0.707 I<sub>0</sub>.<br>
ffective value or ms value.<br>
ffective value or ms v

### **Example 1 :**

The instantaneous current from an a.c. source is  $I = 6\sin 314t$ . What is the rms value of the current ?

**Sol.** 
$$
I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = \frac{6}{\sqrt{2}} = 3\sqrt{2}
$$
 amp.

### **Example 2 :**

What is the relation between the mean and virtual values of a.c.?

**Sol.** 
$$
I_m = \frac{2\sqrt{2}}{\pi} I_{rms}
$$

### **Example 3 :**

Explain why A.C. is more dangerous than D.C. of same value.

**Sol.** There are two reasons for it :

(1) A.C. attracts while D.C. repels.



(2) A.C. gives a huge and sudden shock. An A.C. main of 220 V has  $V_{rms} = 220 V$ 

**EXECUTE:**<br>
FRIDE THE SURVEY OF MADISON THEN THE SURVEY OF MALE THE SURVEY OF MALE THE SURVEY OF MALE THE SURVEY OF THIS CHARGE THE CHARGED THE SURVEY OF THIS Change takes place in half cycle i.e., in  $\frac{1}{100}$  see or F **CURRENT**<br>
MEAT **EXECUTE:**<br>
Mean value of AC over half cycle<br>
Mean value of AC over half cycle<br>
Mean value of AC over half cycle<br>  $\frac{10}{\sqrt{2}}$ <br>
Mean factor =  $\frac{\pi}{2\sqrt{2}}$ <br>
(for a 50 Hz A.C.) A shock of 622.16 within 0.0 **CURRENT**<br>
Thence,  $V_0 = \sqrt{2}$ .  $V_{rms} = 12.414 \times 22$ <br>
Thence,  $V_0 = \sqrt{2}$ .  $V_{rms} = 12.414 \times 22$ <br>
Voltage change from + $V_0$  (positive<br>
peak)=311.08 – (-311.08) = 622.16<br>
AC:<br>  $I_0/\sqrt{2}$ <br>
In Scharge takes place in half cycl<br> **CURRENT**<br>
Thence,  $V_0 = \sqrt{2}$ .  $V_{rms} = 12.414 \times 2$ <br>
Mean value of AC over half cycle<br>
Mean value of AC over half cycle<br> **AC:**<br>
This change them +V<sub>0</sub> (positive peak) = 311.08 – (-311.08) = 622.16<br>
AC:<br>
This change takes p **EXECUTE AN INTEREST AND SOLUTE AND SURVEY OF A 200 MADYANGED LEARNING<br>
2 2 2 2 3 11.08 V<br>
2 2 2 3 11.08 V<br>
2 2 2 3 11.08 (positive peak) to -V<sub>0</sub> (negative peak) = 311.08 - (-311.08) = 622.16 V<br>
2 1 1 1 1 0 3 - (-311.08)** Hence,  $V_0 = \sqrt{2}$ .  $V_{rms} = 12.414 \times 220 = 311.08$  V **EDIMADVANCED LEARNING**<br>  $= \sqrt{2}$ . V<sub>rms</sub> = 12.414 × 220 = 311.08 V<br>
nange from +V<sub>0</sub> (positive peak) to -V<sub>0</sub> (negative<br>
1.08 – (-311.08) = 622.16 V<br>
ge takes place in half cycle i.e., in  $\frac{1}{100}$  sec<br>
Iz A.C.) A shoc Voltage change from  $+V_0$  (positive peak) to  $-V_0$  (negative  $peak$ ) = 311.08 – (–311.08) = 622.16 V NING<br>
I dt<br>
I dt<br>
it is<br>
it is<br>
it is<br>
it is

This change takes place in half cycle i.e., in  $\frac{1}{100}$  sec

 $\pi$  (for a 50 Hz A.C.) A shock of 622.16 within 0.01 sec is huge and sudden, hence fatal.

### **Example 4 :**

If I = I<sub>0</sub> cos 
$$
\omega
$$
 t, can we define I<sub>a</sub> =  $\frac{2}{T} \int_{0}^{T/2} I dt$ . Why ?

**Sol.** No, because from 0 to T/4, I will be +ve and from T/4 to  $T/2$ , it will be –ve. So  $I_a$  will come out zero.

For I = I<sub>0</sub> cos 
$$
\omega t
$$
, average value of current I<sub>a</sub> =  $\frac{2}{T} \int_{-T/4}^{T/4} I dt$ 

### **Example 5 :**

The effective value of current in a 50 cycle a.c. circuit is 5.0amp. What is the value of the current 1/300 sec after it is zero?

**Sol.** Here,  $I_{rms} = 5.0$  amp,  $f = 50$  cps

Now, I = I<sub>0</sub> sin 
$$
\omega t = \sqrt{2}
$$
 I<sub>rms</sub> sin 2  $\pi$  ft

$$
= \sqrt{2} \times 5.0 \sin 2 \pi \times 50 \times (1/300) = 6.124 \text{ amp}
$$

### **MEASUREMENT OFA.C.**

**Example 4:**<br> **Example 4:**<br>  $1.7071_0$ <br>  $1.7071_0$ <br>
and emfore usually described in terms<br>
and emform are usually described in terms<br>
Sol. No, because from 0 to T/4, I will be +<br>
sol. No, because from 0 to T/4, I will be Alternating current and voltages are measured by a.c. ammeter and a.c. voltmeter respectively. Working of these instruments is based on heating effect of current, hence they are also called hot wire instruments.





### **PHASE INA.C.**

The frequency of alternating current and alternating emf is same. Generally, when current is maximum, emf if not maximum and vice versa. This lead or lag is the phase difference between the emf (voltage) and current in A.C. circuits any may be represented by  $\phi$ . If e.m.f. (or Voltage) in A.C. is  $E = E_0 \sin \omega t$  and the current  $I = I_0 \sin (\omega t + \phi)$ The phase difference  $\phi$ : Positive if current leads and Negative if current lags zero if current is in phase with the emf (or voltage).







### **PHASORS**

In order to the simplify the study of A.C. circuits, it is preferred to treat alternating current and alternating e.m.f. as vectors with the angle between the vectors equal to the phase difference between the current and the emf. The current and emf vectors are more appropriately called phasors.

### **PHASOR DIAGRAMS**

A diagram representing alternating current and alternating voltage (of same frequency) as vectors (phasors) with the phase angle between them is called a phasor diagram.

### **DIFFERENTTYPES OFA.C. CIRCUITS**

In order to study the behaviour of A.C. circuits we classify them into two categories :

(a) Simple circuits containing only one basic element i.e. resistor  $(R)$  or inductor  $(L)$  or capacitor  $(C)$  only.

(b) Complicated circuit containing any two of the three circuit elements R, L and C or all of three elements.

### **A.C. CIRCUIT CONTAINING PURE RESISTANCE**

A circuit containing a pure resistance R (non-inductive) connected with a source of alternating e.m.f.



Suppose the alternating e.m.f. is represented by  $E = E_0 \sin \omega t$ 

Let at any instant t the current in the circuit  $=$  I. Potential difference across the resistance = I R. with the help of kirchoff's circuital law  $E - IR = 0$ 

or 
$$
E_0 \sin \omega t = IR
$$
 or  $I = \frac{E_0}{R} \sin \omega t = I_0 \sin \omega t$ 

 $(I_0 = \frac{E_0}{R}$  = peak or maximum value of cu  $I_0 = \frac{E_0}{R}$  = peak or maximum value of current)

Alternating current developed in a pure resistance is also of sinusoidal nature. In an a.c. circuits containing pure



The vector or phasor diagram which represents the phase relationship between alternating current and alternating e.m.f. as shown in fig.



In the a.c. circuit having R only, as current and voltage are in the same phase, hence in fig. both phasors  $E_0$  and  $I_0$  are in the same direction, making an angle of with OX. Their projections on Y-axis represent the instantaneous values of alternating current and voltage. The vector or phasor diagram which represents the phase<br>relationship between alternating current and alternating<br>e.m.f. as shown in fig.<br> $\frac{P}{P}$ <br> $\frac{$ E<br>
E<br>
Shown in fig.<br>
E<br>  $E$ <br>  $\frac{P}{\sqrt{10}}$ 

i.e. 
$$
I = I_0 \sin \omega t
$$
 and  $E = E_0 \sin \omega t$ .

Since 
$$
I_0 = \frac{E_0}{R}
$$
,

hence 
$$
\frac{I_0}{\sqrt{2}} = \frac{E_0}{R\sqrt{2}}
$$
 or  $I_{rms} = \frac{E_{rms}}{R}$ 



### **A.C. CIRCUIT CONTAINING PURE INDUCTANCE**

A circuit containing a pure inductance L (having zero ohmic resistance) connected with a source of alternating emf. Let the alternating e.m.f. **CURRENT**<br> **EXPRESSION 10** Expression  $I_0 = \frac{E_0}{\omega L}$  resembles the<br>
thmic resistance)<br>
the source of<br>  $E = E_0 \sin \omega t$ <br>  $\omega = -L \frac{dI}{dt}$ <br>
different the circuit, emf induced across<br>  $e = -L \frac{dI}{dt}$ <br>
different the content.<br>
Li CURRENT<br>
IN INSIGPURE INDUCTANCE<br>
ting a pure<br>
mic resistance)<br>
a source of<br>
a source of<br>  $E = E_0 \sin \omega t$ <br>  $E = E_0 \sin \omega t$ <br>  $E = E_1 \sin \omega t$ <br>  $\Delta T = 2 \pi f L$ , where  $f = f \cos \omega t$ <br>  $\Delta T = 2 \pi f L$ , where  $f = f \cos \omega t$ <br>  $= -L \frac{dI}{dt}$ <br>  $= -L \frac{dI}{$ 

 $E = E_0 \sin \omega t$ When a.c. flows through the circuit, emf induced across

 $\mathbf{L}$ 

 $E = E_0 \sin \omega t$ 

inductance = 
$$
e = -L \frac{dI}{dt}
$$

 $\frac{dI}{dt}$  = the rate of change of the current.

-ive sign indicates that induced emf acts in opposite direction to that of applied emf.

Because there is no other circuit element present in the circuit other then inductance so with the help of Kirchoff's

$$
\text{circular law} \quad \mathbf{E} + \left(-\mathbf{L}\frac{\mathrm{d}\mathbf{I}}{\mathrm{d}\mathbf{t}}\right) = 0 \quad \text{or} \quad \mathbf{E} = \mathbf{L}\frac{\mathrm{d}\mathbf{I}}{\mathrm{d}\mathbf{t}}
$$

so we get  $I = \frac{E}{\omega}$ 

$$
\frac{E_0}{\omega L} \sin \left( \omega t - \frac{\pi}{2} \right)
$$



Maximum current

$$
I_0 = \frac{E_0}{\omega L} \times 1 = \frac{E_0}{\omega L} \text{ [when sin } \left( \omega t - \frac{\pi}{2} \right) \text{ is max.} = 1 \text{]}
$$

Hence,  $I = I_0 \sin \left( \omega t - \frac{\pi}{2} \right)$ 

In a pure inductive circuit current always lags behind the emf by  $\pi/2$  or alternating emf leads the a. c. by a phase angle of  $\pi/2$ .



Expression 
$$
I_0 = \frac{E_0}{\omega L}
$$
 resembles the expression  $\frac{E}{I} = R$ .

This non-resistive opposition to the flow of A.C. in a circuit is called the inductive reactance  $(X_L)$  of the circuit.

 $X_L = \omega L = 2 \pi f L$ , where f = frequency of A.C. **Unit of X<sup>L</sup> :** ohm

$$
(\omega L)
$$
 = Unit of L × Unit of  $\omega$  = henry × sec<sup>-1</sup>

**EXAMPLE 1 CDMADVANIGED LEARNING**  
\n
$$
\frac{E_0}{\omega L}
$$
 resembles the expression  $\frac{E}{I} = R$ .  
\nwe opposition to the flow of A.C. in a circuit  
\nactive reactance (X<sub>L</sub>) of the circuit.  
\nL, where f = frequency of A.C.  
\n
$$
\frac{V \circ V}{\sqrt{C}} = \frac{V \circ V}{V} \times \sec^{-1} = \frac{V \circ V}{V} \times \sec^{-1}
$$
\n
$$
= \frac{V \circ V}{\sqrt{C}} \times \sec^{-1} = \frac{V \circ V}{\sqrt{C}}
$$
\n
$$
= \frac{V \circ V}{\sqrt{C}}
$$
\n

### **Inductive reactance**  $X_L \propto f$

Higher the frequency of A.C. higher is the inductive reactance offered by an inductor in an A.C. circuit.



## $= L \frac{du}{dt}$  **For d.c. circuit,**  $f = 0$ <br> $\therefore$   $V = cI = 2 - fI = 0$

 $\therefore$   $X_L = \omega L = 2 \pi f L = 0$ 

Hence, inductor offers no opposition to the flow of d.c. or where as a resistive path to a.c.

ANCE<br>
Letter the contract axists of  $L_0 = \frac{E_0}{\omega L}$ .<br>
This non-resistive opposition to the flow of A.C. in a circuit<br>
is called the inductive reactance  $(X_1)$  of the circuit.<br>  $E = E_s$ sinot<br>  $X_L = \omega L = 2 \pi f L$ , where  $f = \text{frequency$ In a circuit containing resistance R only, opposition to the flow of current arises on account of obstruction to the passage of electrons through the resistor. xi<sub>I</sub><br>
c. circuit,  $f=0$ <br>
=  $\omega L = 2 \pi f L = 0$ <br>
inductor offers no opposition to the flow of d.c. or<br>
as a resistive path to a.c.<br>
cuit containing resistance R only, opposition to the<br>
f current arises on account of obstruct Ampere / sec<br>
tive reactance  $X_L \propto f$ <br>
or the frequency of A.C. higher is the inductive<br>
mee offered by an inductor in an A.C. circuit.<br>  $X_1$ <br>  $\vdots$ <br>  $X_2 = \omega L = 2 \pi f L = 0$ <br>  $\vdots$ <br>  $L = \omega L = 2 \pi f L = 0$ <br>  $\vdots$ <br>
as a resistive p L X =  $\frac{\text{Vott}}{\text{Ampere}} \times \text{sec}^{-1} = \frac{\text{Vott}}{\text{Ampere}} = \text{ohm}$ <br>
luctive reactance  $X_L \propto f$ <br>
there the frequency of A.C. higher is the inductive<br>
ctance offered by an inductor in an A.C. circuit.<br>  $X_1 = \frac{X_1}{\sqrt{1 - \frac{X_2}{\sqrt{1 - \frac{X_1$ o opposition to the flow of d.c. or<br>
to a.c.<br>
sistance R only, opposition to the<br>
on account of obstruction to the<br>
ough the resistor.<br>
self induced emf that opposes the<br>  $\frac{0}{2} = \frac{1}{X_L} \frac{E_0}{\sqrt{2}}$  or  $I_{rms} = \frac{E_{rms}}{X_L$ ere/sec<br>  $\frac{f}{f}$  of A.C. higher is the inductive<br>
inductor in an A.C. circuit.<br>  $\frac{f}{f}$ <br>  $\frac{f}{f$ 2 2 <sup>X</sup>

But in a inductor, it is the self induced emf that opposes the growth of current.

$$
I_0 = \frac{E_0}{\omega L} = \frac{E_0}{X_L}
$$
 gives  $\frac{I_0}{\sqrt{2}} = \frac{1}{X_L} \frac{E_0}{\sqrt{2}}$  or  $I_{rms} = \frac{E_{rms}}{X_L}$ 

Above equation is identical to Ohm's law equation.

### **Example 6 :**

2) Is that a 1 what will be its reactance in requelity of restaurance? duced emf acts in opposite<br>
r.cuit element present in the<br>
so with the help of Kirchoff's<br>  $\frac{\pi}{d}$   $\frac{1}{\pi}$   $\frac{\pi}{d}$   $\frac{\pi}{d}$ duced emf acts in opposite<br>
reuti element present in the<br>
so with the help of Kirchoft's<br>  $0$  or  $E = L\frac{dI}{dt}$  **For d.c. circuit**,  $f = 0$ <br>
Hence, induction of the flux of the help of Kirchoft's<br>
where as a resistive path The reactance of inductor is 20 ohm. What does it mean? What will be its reactance if frequency of AC is doubled? What is its consequence?

 $2$   $\frac{301.115}{1.1}$ **Sol.** The reactance of inductor is 20 ohm. It means that the hindrance offered by it to the flow of AC at a specific frequency is equivalent to a resistance of 20 ohm.

> The reactance of inductance,  $X_L = \omega L = 2 \pi f L$ . Therefore by doubling frequency, the reactance is doubled and it becomes 40 ohm.

In DC circuit  $f = 0$ ; therefore reactance of inductor = 0. Therefore inductor can not be used to control DC.

### **Example 7 :**

A a.c. circuit consists of only an inductor of inductance 2H. If the current is represented by a sine wave of amplitude 0.25 amp. and frequency 60 Hz, calculate the effective potential difference across the inductor

**Sol.** The effective potential difference across the inductor is

given by 
$$
V_{eff} = I_{eff} \tcdot X_L = \frac{I_0}{\sqrt{2}} \tcdot 2 \pi f L
$$



$$
V_{\text{eff}} = V_{\text{rms}}
$$
  
Given that  $I_0 = 0.25$  amp, f = 60 Hz, L = 2H  
∴  $V_{\text{eff}} = \frac{0.25}{\sqrt{2}} \times 2 \times 3.14 \times 60 \times 2 = 133.2$  Volt

### **A.C. CIRCUIT CONTAINING PURE CAPACITANCE**

A circuit containing an ideal capacitor of capacitance C connected with a source of alternating emf as shown in figure.



The alternating e.m.f. in the circuit

 $E = E_0 \sin \omega t$ 

When alternating e.m.f. is applied across the capacitor a similarly varying alternating current flows in the circuit.

The two plates of the capacitor become alternately positively and negatively charged and the magnitude of the charge on the plates of the capacitor varies sinusoidally with time.

Also the electric field between the plates of the capacitor varies sinusoidally with time.

Let at any instant t charge on the capacitor  $= q$ Instantaneous potential difference across the capacitor



The instantaneous value of current

Let at any instant a base of the capacitor is the direction 
$$
-\frac{d}{d}
$$
 or  $q = CE$  or

Maximum current I<sub>0</sub> when  $\sin \left(\omega t + \frac{\pi}{2}\right)$  is max. =1

In a pure capacitive circuit, the current always leads the

e.m.f. by a phase angle of 
$$
\frac{\pi}{2}
$$
.

The alternating emf lags behinds the alternating current by

a phase angle of 
$$
\frac{\pi}{2}
$$
.



 $E_{\text{rel}}$   $\rightarrow$   $E_{\text{rel}}$   $\rightarrow$   $E_{\text{rel}}$   $\rightarrow$   $E_{\text{rel}}$   $\rightarrow$   $E_{\text{rel}}$  $\frac{1}{I}$  is the resistance R when both E and I are in phase,

in present case they differ in phase by  $\frac{1}{2}$ , hence  $\frac{1}{\omega C}$  is  $\pi$ , 1, , hence  $\frac{1}{\sqrt{G}}$  is  $\omega$ C  $\sim$ not the resistance of the capacitor, the capacitor offer opposition to the flow of A.C.

This non-resistive opposition to the flow of A.C. in a pure capacitive circuit is known as capacitive reactance  $X_C$ .

$$
X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}
$$

**Unit of**  $X_C$  **:** ohm

Capacitive reactance  $X_C$  is inversely proportional to frequency of A.C.



 $X_C$  decreases as the frequency increases.

This is because with an increase in frequency, the capacitor charges and discharges rapidly following the flow of current. For d.c. circuit  $f = 0$ 

$$
\therefore X_C = \frac{1}{2\pi fC} = \infty
$$

but has a very small value for a.c. This shows that capacitor blocks the flow of d.c. but provides an easy path for a.c.

 $\frac{3\pi/2}{2\pi}$ <br>  $\frac{3\pi}{2\pi}$  x<br>  $\frac{1}{2\pi}$  x<br>  $\frac{1}{2\pi}$  x<br>  $\frac{1}{2\pi}$  x<br>  $\frac{1}{2\pi}$  x<br>  $\frac{1}{2\pi}$  is max =1<br>
This is because with an increase in frequency increases.<br>
This is because with a mergen of the consoling  $\frac{3\pi/2}{2\pi}$ <br>  $\frac{1}{2\pi}$ <br>  $\frac{1}{2\pi$ 2 fC The physical process involved in the capacitance is entirely different to that involved in a resistance. In a resistive circuit, the resistance is due to the obstruction to the passage of electrons through the resistor. But in a capacitive circuit, resistance to the flow of current is due to the charged  $X_C$  decreases as the frequency increases.<br>This is because with an increase in frequency, the capacitor<br>charges and discharges rapidly following the flow of current.<br>For d.c. circuit  $f = 0$ <br> $\therefore X_C = \frac{1}{2\pi fC} = \infty$ <br>but has E E **EXECUTE:**<br>
The frequency increases.<br>
then increase in frequency, the capacitor<br> **=0**<br>  $\infty$ <br>  $\infty$ <br> the frequency increases.<br>
with an increase in frequency, the capacitor<br>
arges rapidly following the flow of current.<br> **f** = **0**<br>  $=\infty$ <br>
all value for a.c. This shows that capacitor<br>
of d.c. but provides an easy path for a

$$
I_0 = \frac{E_0}{1/\omega C} = \frac{E_0}{X_C}
$$



gives that 
$$
\frac{I_0}{\sqrt{2}} = \frac{1}{X_C} \frac{E_0}{\sqrt{2}}
$$
 or  $I_{rms} = \frac{E_{rms}}{X_C}$ 

**LTERNATING CURRENT**<br>gives that  $\frac{I_0}{\sqrt{2}} = \frac{1}{X_C} \frac{E_0}{\sqrt{2}}$  or  $I_{rms} = \frac{E_{rms}}{X_C}$  or  $I_{cm}$ <br>Above expression is similar to ohm's law equation.<br>In a high frequency A.C. circuit, the capacitor acts like a<br>conductor. **NG CURRENT**<br>  $\frac{I_0}{\sqrt{2}} = \frac{1}{X_C} \frac{E_0}{\sqrt{2}}$  or  $I_{rms} = \frac{E_{rms}}{X_C}$ <br>
ession is similar to ohm's law equation.<br>
equency A.C. circuit, the capacitor acts like a<br>
This is the reason that no energy is dissipated<br>
circuit Above expression is similar to ohm's law equation. In a high frequency A.C. circuit, the capacitor acts like a conductor. This is the reason that no energy is dissipated in an A.C. circuit when capacitor is present unless the dielectric has finite resistance. Solution COKIENTS and  $\frac{1}{\sqrt{2}} = \frac{1}{X_C} \frac{E_0}{\sqrt{2}}$  or  $I_{\text{rms}} = \frac{E_{\text{rms}}}{X_C}$ <br>
we expression is similar to ohm's law equation.<br>
high frequency A.C. circuit, the capacitor acts like a<br>
n.C. circuit, the capacitor act  $\frac{0}{2} = \frac{1}{X_C} \frac{E_0}{\sqrt{2}}$  or  $I_{rms} = \frac{E_{rms}}{X_C}$ <br>
sission is similar to ohm's law equation.<br>
this is the recalistic the capacitor acts tike a<br>
this is the reason that no energy is dissipated<br>
finite resistance.<br>
e of TING CURRENT<br>
TIME CURRENT<br>  $\frac{1}{\sqrt{2}} = \frac{1}{X_C} \frac{E_0}{\sqrt{2}}$  or  $I_{rms} = \frac{E_{rms}}{X_C}$ <br>
expression is similar to ohm's law equation.<br>
This is he reason that no energy is dissipated<br>
C. circuit when capacitor is present unles

### **Example 8 :**

The reactance of capacitor is 20 ohm. What does it mean? What will be its reactance if frequency of AC is doubled? What will be its, reactance when connected in DC circuit? What is its consequence?

**Sol.** The reactance of capacitor is 20 ohm. It means that the hindrance offered by it to the flow of AC at a specific frequency is equivalent to a resistance of 20 ohm. The reactance of capacitance

$$
X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}.
$$

Therefore by doubling frequency, the reactance is halved i.e., it becomes 10 ohm. In DC circuit  $f = 0$  therefore reactance of capacitor =  $\infty$  (infinite). Hence the capacitor can not be used to control DC.

### **RESISTANCEAND INDUCTANCE IN SERIES (L-R CIRCUIT)**

A circuit containing a series combination of a resistance R and an inductance L, connected with a source of alternating e.m.f. E as shown in fig.



### **Phasor diagram For L-R circuit :**

Let in a L-R series circuit, applied alternating emf is  $E = E_0 \text{sin}\omega t$ .

As R and L are joined in series, hence current flowing through both will be same at each instant. Let I be the current in the circuit at any instant and  $V_L$  and  $V_R$  the potential differences across L and R respectively at that instant.

Then  $V_L = IX_L$  and  $V_R = IR$ 

Now,  $V_R$  is in phase with the current while  $V_L$  leads the

current by  $\frac{1}{2}$ . So V<sub>R</sub> and V<sub>L</sub> are mutually perpendic  $\frac{\pi}{2}$  . So V<sub>R</sub> and V<sub>L</sub> are mutually perpendicular

(The sum of  $V_R$  and  $V_L$  cannot be put equal to applied e.m.f. E).



The phasor diagram is drawn in fig. the vector OP represents  $V_R$  (which is in phase with I), while OQ represents  $V_L$  (which leads I by 90°). The resultant of  $V_R$  and  $V_L$  = the magnitude of vector OR 2 2 or diagram is drawn in fig.<br>
OP represents  $V_R$  (which is in phase with I),<br>
represents  $V_L$  (which leads I by 90°).<br>
ant of  $V_R$  and  $V_L$  = the magnitude of vector OR<br>  $V_R^2 + V_L^2$ <br>  $= V_R^2 + V_L^2 = I^2 (R^2 + X_L^2)$ <br>  $\frac{E}{\sqrt{R^$ 

$$
E = \sqrt{V_R^2 + V_L^2}
$$
  
Thus  $E^2 = V_R^2 + V_L^2 = I^2 (R^2 + X_L^2)$   
or 
$$
I = \frac{E}{\sqrt{R^2 + X_L^2}}
$$

The phasor diagram shown in fig. also shows that in L-R circuit the applied emf E leads the current I or conversely the current I lags behind the e.m.f. E. by a phase angle  $\phi$ 

V<sub>L</sub>  
\nV<sub>L</sub>  
\nV<sub>R</sub>  
\n
$$
V_R
$$
  
\n $V_R$   
\n $V_L$   
\n $V_R$   
\n $V_R$ 

$$
\tan \phi = \frac{\omega L}{R} \qquad \text{or} \quad \phi = \tan^{-1} \left( \frac{\omega L}{R} \right)
$$

**Inductive Impedance Z<sup>L</sup> :** In L-R circuit the maximum value

of current 
$$
I_0 = \frac{E_0}{\sqrt{R^2 + \omega^2 L^2}}
$$

by L-R circuit to the flow of a.c. through it. It is known as impedance of L-R circuit and is represented by  $Z_I$ . or  $\phi = \tan^{-1} \left( \frac{\omega L}{R} \right)$ <br>
or  $\phi = \tan^{-1} \left( \frac{\omega L}{R} \right)$ <br>
predance  $Z_L$ : In L-R circuit the maximum value<br>  $\frac{E_0}{\sqrt{R^2 + \omega^2 L^2}}$ <br>  $\frac{Z}{R^2 + \omega^2 L^2}$ <br>  $\frac{Z_L}{R^2 + \omega^2 L^2}$  or  $Z_L = \sqrt{R^2 + (2\pi f L)^2}$ <br>
cal of impedance is  $I_0$  or  $\phi = \tan^{-1} \left(\frac{\omega L}{R}\right)$ <br>
Impedance  $Z_L$ : In L-R circuit the maximum value<br>  $I_0 = \frac{E_0}{\sqrt{R^2 + \omega^2 L^2}}$ <br>  $\frac{1}{L^2}$  represents the effective opposition offered<br>
cuit to the flow of a.c. through it. It is known as A<br>  $\phi = \tan^{-1} \left( \frac{\omega L}{R} \right)$ <br>  $Z_L$ : In L-R circuit the maximum value<br>  $\frac{v_0}{\omega - \omega^2 L^2}$ <br>
mts the effective opposition offered<br>
low of a.c. through it. It is known as<br>
with and is represented by  $Z_L$ .<br>  $\frac{1}{2}$  or  $Z_L =$ 

$$
Z_{L} = \sqrt{R^{2} + \omega^{2}L^{2}}
$$
 or  $Z_{L} = \sqrt{R^{2} + (2\pi f L)^{2}}$ 

The reciprocal of impedance is called admittance

$$
Y_{L} = \frac{1}{Z_{L}} = \frac{1}{\sqrt{R^{2} + \omega^{2}L^{2}}}
$$

### **RESISTANCEAND CAPACITOR IN SERIES (C-R CIRCUIT)**

A circuit containing a series combination of a resistance R and a capacitor C, connected with a source of e.m.f. of peak value  $E_0$ .




# **Phasor diagram For C-R circuit :**

Current through both the resistance and capacitor will be same at every instant and the instantaneous potential differences across C and R are

 $V_C = IX_C$  and  $V_R = IR$ 

where  $X_C$  = capacitive reactance and I = instantaneous Sol current. Now,  $V_R$  is in phase with I, while  $V_C$  lags behind I by 90°. The phasor diagram is shown in fig.



The vector OP represents  $V_R$  (which is in phase with I) and the vector OQ represents  $V_C$  (which lags behind I by  $\pi/2$ ). The vector OK represents the resultant of V<sub>R</sub> and  $V_C$  = the applied e.m.f. E.



Hence,  $V_R^2 + V_C^2 = E^2$  or  $E = \sqrt{\frac{E}{V}}$ 

or 
$$
E^2 = I^2 (R^2 + X_C^2)
$$
 or  $I = \frac{E}{\sqrt{R^2 + X_C^2}}$  Voltage will la

The term  $\sqrt{(R^2 + X_C^2)}$  represents the effective resistance of the C-R circuit and called the capacitive impedance  $Z_C$ of the circuit. Hence, in C-R circuit  $V_C^2 = E^2$  or  $E = \sqrt{V_R^2 + V_C^2}$ <br>  $V_C^2 = E^2$  or  $E = \sqrt{V_R^2 + V_C^2}$ <br>  $V_C^2 = E^2$  or  $E = \sqrt{V_R^2 + V_C^2}$ <br>  $V_C^2 = E^2$  or  $E = \sqrt{V_R^2 + V_C^2}$ <br>  $V = 1.551 \times 10^{-3}$  sec<br>  $V = 1.551 \times 10^{-3}$  sec<br>  $V = 1.551 \times 10^{-3}$  sec<br>  $V = 1.551 \times 10^{-3}$  $Q$ <br>  $Q$ <br>  $(2.51 \times 10^{-10})$ <br>  $Q = 1^2 (R^2 + X_C^2)$  or  $I = \frac{E}{\sqrt{R^2 + X_C^2}}$ <br>  $= 1.551 \times 10^{-10}$ <br>  $= 1.551$ 

$$
Z_{C} = \sqrt{R^{2} + X_{C}^{2}} = \sqrt{R^{2} + \left(\frac{1}{\omega C}\right)^{2}}
$$

**Capacitive Impedance**  $Z_C$ **: In C-R circuit the term**  $\sqrt{R^2 + X_C^2}$  effective opposition offered by C-R circuit to

 $\frac{1}{2 \times 3.14}$ <br>
Fine lead,<br>
ence,  $V_R^2 + V_C^2 = E^2$  or  $E = \sqrt{V_R^2 + V_C^2}$ <br>  $E^2 = I^2 (R^2 + X_C^2)$  or  $I = \frac{E}{\sqrt{R^2 + X_C^2}}$ <br>  $E^2 = I^2 (R^2 + X_C^2)$  or  $I = \frac{E}{\sqrt{R^2 + X_C^2}}$ <br>  $\frac{1.551 \times 10^{-3} \text{ sec}}{\text{Voltage will lag current}}$ <br>  $\frac{1.551 \times 10^{-3} \text{ sec$ the flow of a.c. through it. It is known as impedance of C-R circuit and is represented by  $Z_C$ . The phasor diagram also shows that in C-R circuit the applied e.m.f. lags behind the current I (or the current I leads the emf E) by a phase angle

 $\phi$  given by

STUDY MATERIAL: PHYSICS  
\nφ given by  
\n
$$
\tan \phi = \frac{V_C}{V_R} = \frac{X_C}{R} = \frac{1/\omega C}{R} = \frac{1}{\omega CR}
$$
  
\nor  $\tan \phi = \frac{X_C}{R} = \frac{1}{\omega CR}$  or  $\phi = \tan^{-1}(\frac{1}{\omega CR})$   
\n**nple 9:**  
\nA 100 μF capacitor in series with a 40 Ω resistance is  
\nconnected to a 110 V, 60 Hz supply.  
\n(a) What is the maximum current in the circuit?  
\n(b) What is the time lag between current maximum and  
\nvoltage maximum?  
\n(a) Here, C = 100 μF = 100 × 10<sup>-6</sup> F, R = 40 Ω,  
\nV<sub>rms</sub> = 110 V, f = 60 Hz  
\nPeak voltage, V<sub>0</sub> =  $\sqrt{2} . V_{rms} = 100 \sqrt{2} = 155.54$  V  
\nCircuit impedance,  
\nZ =  $\sqrt{R^2 + \frac{1}{\omega^2 C^2}} = \sqrt{40^2 + \frac{1}{(2 \times \pi \times 60 \times 100 \times 10^{-6})^2}}$   
\n=  $\sqrt{1600 + 703.60} = \sqrt{2303.60} = 48 \Omega$   
\nhence, maximum current in coil,  
\n $I_0 = \frac{V_0}{Z} = \frac{155.54}{48} = 3.24$  A  
\n(b) Phase lead angle (for current),

### **Example 9 :**

A 100  $\mu$ F capacitor in series with a 40  $\Omega$  resistance is connected to a 110 V, 60 Hz supply. and<br>the same signal parameter is more is  $\frac{1}{\sqrt{6}}$ 

(a) What is the maximum current in the circuit?

(b) What is the time lag between current maximum and voltage maximum?

**Sol.** (a) Here, 
$$
C = 100 \mu F = 100 \times 10^{-6} F
$$
,  $R = 40 \Omega$ ,  
 $V_{\text{rms}} = 110 V$ ,  $f = 60 Hz$ 

Circuit impedance,

$$
E_{0} \sin \omega t
$$
\nE<sub>0</sub>sin $\omega$  for  $\tan \phi = \frac{X_{C}}{R} = \frac{1}{\omega_{C}R}$  or  $\phi = \tan^{-1}(\frac{1}{\omega_{C}R})$   
\n $E_{0} \sin \omega t$   
\n $R = \frac{1}{\omega_{C}R}$  (a) What is the maximum current in the circuit?  
\n $R = \pi e$   
\n $R = \frac{1}{\omega_{C}R}$  (b) What is the maximum current maximum and  
\nreactance and 1 = instantaneous  
\nresetance and 1 = instantaneous  
\nresetance and 1 = instantaneous  
\n $R = \frac{1}{\omega_{C}R}$  (b) What is the time lag between current maximum and  
\n $\omega_{C}R = \frac{1}{\omega_{C}R}$  (c)  $\omega_{C}R = \frac{1}{\omega_{C}R}$  (d)  $\omega_{C}R = \frac{1}{\omega_{C}R}$  (e)  $\omega_{C}R = \frac{1}{\omega_{C}R}$   
\n $\omega_{C}R = \frac{1}{\omega_{C}R}$  (f)  $\omega_{C}R = \frac{1}{\omega_{C}R}$  (g)  $\omega_{C}R = \frac{1}{\omega_{C}R}$  (h)  $\omega_{C}R = \frac{1}{\omega_{C}R}$  (i)  $\omega_{C}R = \frac{1}{\omega_{C}R}$  (ii)  $\omega_{C}R = \frac{1}{\omega_{C}R}$  (iii)  $\omega_{C}R = \sqrt{2. V_{rms}} = 100 \sqrt{2} = 155.54$  V  
\n $\omega_{C}R = \sqrt{R^2 + \frac{1}{\omega_{C}^2C^2}} = \sqrt{40^2 + \frac{1}{(2 \times \pi \times 60 \times 100 \times 10^{-6})^2}}$   
\n $= \sqrt{1600 + 703.60} = \sqrt{2303.60} = 48 \Omega$   
\n $\omega_{C}R = \sqrt{R^2 + \frac{1}{\omega_{C}R}}$  (b) Phase lead angle (for current),  
\n $\omega_{C}R = \frac{1}{\omega_{C}R}$   
\n $\omega_{C}R = \frac$ 

hence, maximum current in coil,

$$
I_0 = \frac{V_0}{Z} = \frac{155.54}{48} = 3.24 \text{ A}
$$

(b) Phase lead angle (for current),

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

$$
= \tan^{-1} \frac{1}{2 \times 3.14 \times 60 \times 100 \times 10^{-6} \times 40}
$$
  
= tan<sup>-1</sup> 0.66315 = 33° 33′ (taken 33.5°)

Time lead,

$$
t = \frac{\theta}{\omega} = \frac{\theta}{2 \pi v} = \frac{33.5}{360 \times 60} = 0.001551 \text{ sec}
$$
  
= 1.551 × 10<sup>-3</sup> sec

 $=\frac{E}{\sqrt{E}}$  Voltage will lag current by = 1.551 ms.

# **INDUCTANCE, CAPACITANCEAND RESISTANCE IN SERIES (LCR SERIES CIRCUIT)**

E<br>
E<br>
Reflective resistance<br>
E<br>
Reflect A circuit containing a series combination of an resistance R, a coil of inductance L and a capacitor of capacitance C, connected with a source of alternating e.m.f. of peak value of  $E_0$ , as shown in figure.





# **Phasor Diagram For Series LCR circuit :**

Let in series LCR circuit applied alternating emf is

 $E = E_0 \sin \omega t$ .

As L,C and R are joined in series, therefore, current at any instant through the three elements has the same amplitude and phase.

However voltage across each element bears a different phase relationship with the current.



Let at any instant of time t the current in the circuit is I Let at this time t the potential differences across L, C, and R  $V_L = IX_L$ ,  $V_C = IX_C$  and  $V_R = IR$ 

Now,  $V_R$  is in phase with current I but  $V_L$  leads I by 90 $^{\circ}$ While  $V_C$  legs behind I by 90°.

The vector OP represents  $V_R$  (which is in phase with I) the vector OQ represent VL (which leads I by 90°) and the vector OS represents  $V_C$  (which legs behind I by 90°) Let at any instant of time the current is the correct in the circuit.<br>
Let at any instant of time the current in the circuit is 1<br>
Let at this lime t the potential differences across L, C, and R<br>
V<sub>L</sub> = 1 X<sub>L</sub> = N<sub>L</sub> = N<sub></sub>

 $V_L$  and  $V_C$  are opposite to each other.

If  $V_L > V_C$  (as shown in figure) the their resultant will be  $(V_L - V_C)$  which is represented by OT.

Finally, the vector OK represents the resultant of  $V_R$  and  $(V_L - V_C)$ , that is, the resultant of all the three = applied is

e.m.f. Thus, 
$$
E = \sqrt{V_R^2 + (V_L - V_C)^2}
$$



$$
E^{2} = V_{R}^{2} + (V_{L} - V_{C})^{2} \text{ or } E^{2} = I^{2} [R^{2} + (X_{L} - X_{C})^{2}]
$$
  
or 
$$
I = \frac{E}{\sqrt{R^{2} + (X_{L} - X_{C})^{2}}}
$$

"effective resistance" of the circuit and is called impedance Z of the circuit.

Thus, 
$$
Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}
$$

The phasor diagram also shown that in LCR circuit the applied e.m.f. leads the current I by a phase angle  $\phi$ 



# **Three cases :**

(a) When  $\omega L > \frac{1}{\omega C}$ , then tan  $\phi$  is +ve i.e.,  $\phi$  is positive. In  $\frac{1}{\omega C}$ , then tan  $\phi$  is +ve i.e.,  $\phi$  is positive. In this case, the alternating emf leads the current I by a phase angle  $\phi$ . The a.c. circuit is then inductance dominated circuit.

**(b)** When 
$$
\omega L < \frac{1}{\omega C}
$$
, then  $\tan \phi$  is –ve i.e.,  $\phi$  is negative. In this

case, the alternating e.m.f. lags behind the current I by a phase angle  $\phi$ . The a.c. circuit is then capacitance dominated circuit.

(c) When 
$$
\omega L = \frac{1}{\omega C}
$$
, then  $\tan \phi = 0$  i.e.,  $\phi = 0$ . In the case, the

alternating e.m.f. and current I are in phase. The a.c. circuit is then non-inductive.

# **POWER INANA.C. CIRCUIT**

Power in D.C. circuits  $P =$  voltage  $E \times$  current I. If current is measured in amperes and voltage in Volts, the power is measured in Watts.

# **The instantaneous power P of an a.c. circuit:**

The instantaneous power

 $P =$ Instantaneous e.m.f.  $E \times$  instantaneous current I Let the instantaneous alternating e.m.f.  $E = E_0 \sin \omega t$ 

and the instantaneous current in an a.c. circuit  $I = I_0 \sin(\omega t \pm \phi)$ 

Instantaneous power in the circuit  $P = E I$ 

$$
= E_0 \sin \omega t
$$
. I<sub>0</sub> sin ( $\omega t \pm \phi$ )

 $=$  E<sub>0</sub> I<sub>0</sub> sin ot sin ot cos  $\phi$  ± cos ot sin  $\phi$ 

 $=$  E<sub>0</sub> I<sub>0</sub> sin<sup>2</sup> ot cos  $\phi$   $\pm$  E<sub>0</sub> I<sub>0</sub> sin ot cos ot sin  $\phi$ 

or 
$$
P = P_1 + P_2
$$

 $P_1 = E_0 I_0 \sin^2 \omega t \cos \phi$ 

and  $P_2 = E_0 I_0 \sin \omega t \cos \omega t \sin \phi$ 

1 current is measured in wheres and voltage in volts, the<br>
power is measured in Wats.<br>
The instantaneous power P of an a.c. circuit :<br>
The instantaneous power P of an a.c. circuit :<br>
The instantaneous current I<br>  $P =$  Inst FOWER INFANCAL CHRCOIT<br>
Power in D.C. circuits P = voltage E x current 1.<br>
If current is measured in Antss.<br>
The instantaneous power P of an a.c. circuit:<br>
The instantaneous operner Pof an a.c. circuit:<br>
The instantaneous First part of power is  $P_1 = (E_0 \sin \omega t) (I_0 \sin \omega t) \cos \phi$ In this part of power emf (E<sub>0</sub> sin  $\omega$  t) and current (I<sub>0</sub> cos  $\phi$  $sin \omega t$ ) both are in same phase.  $\cos \phi$ ) **EVENTIFY THEORY THEOTES THEOTEST**<br> **Power in D.C. circuits P** = voltage E × current I.<br> **If current is measured in Watss.**<br> **The instantaneous power P of an a.c. circuit :**<br> **The instantaneous over P of an a.c. circuit :** 

In this part amplitude of current = 
$$
(I_0 \cos \phi)
$$

 $\mathbf{C}^f$ 



(average of  $\sin^2 \omega t = \frac{\sin^2 \omega t}{1} = \frac{1}{2}$ )

$$
= \frac{1}{2} E_0 I_0 \cos \phi = \frac{E_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}} \times \cos \phi
$$

or  $\overline{P}_1 = E_{rms} \times I_{rms} \times \cos \phi$ Second part of power is  $P_2$  = (E<sub>0</sub> sin  $\omega t$ ) (I<sub>0</sub> cos  $\omega t$ ) sin  $\phi$ 

$$
= (E_0 \sin \omega t) [(I_0 \sin \phi) \sin (\omega t + \frac{\pi}{2})]
$$

In this part of power emf and current are in phase difference

of 
$$
\frac{\pi}{2}
$$

In this part amplitude of current =  $(I_0 \sin \phi)$ 

Average of second part of power  $P_2 = P_2$ 

$$
\overline{P}_2 = \overline{E}_0 I_0 \sin \omega t \cdot \cos \omega t \cdot \cos \phi =
$$
  

$$
\overline{E}_0 \overline{I_0} \overline{\sin \omega t} \overline{\cos \omega t} \cdot \overline{\cos \phi} = \frac{1}{2} E_0 I_0 \overline{\sin 2\phi}
$$

Hence, average power over one complete cycle

$$
\overline{P} = \overline{P_1} + \overline{P_2} = E_{rms} \times I_{rms} \times \cos \phi + 0
$$

Average power is also known as True power.

The quantity  $E_{rms} I_{rms}$  is known as the apparent power or virtual power.

# **POWER FACTOR**

 $\cos \phi$  is known as Power Factor.

Average power = Apparent Power  $\times$  Power Factor It is customary to express true power in KW and apparent power in KVA.

The value of power factor and hence the amount of average F power consumed depends on the nature of a.c. circuit (i.e. nature of circuit element present in the circuit).

# **A.C. circuit contains pure resistance**

Phase angle between voltage and current i.e.  $\phi = 0$ 

$$
\therefore P_{\text{av}} = E_{\text{rms}} I_{\text{rms}} \cos 0^{\circ} = E_{\text{rms}} I_{\text{rms}} = E_{\text{rms}} \frac{E_{\text{rms}}}{R} = \frac{E_{\text{rms}}^2}{R}
$$

# **A.C. circuit contains pure inductance**

Phase angle  $\phi = \frac{\pi}{2}$  $\pi$ 

$$
\therefore \quad P_{\text{av}} = E_{\text{rms}} I_{\text{rms}} \cos \frac{\pi}{2} = E_{\text{rms}} I_{\text{rms}} \times 0 = 0 \tag{T}
$$

**A.C. circuit contains pure capacitance**

Phase angle  $\phi = \frac{\pi}{2}$  $\pi$ 

STUDY MATERIAL: PHYSICS  
\n
$$
\overline{\omega t} = \frac{1}{2}
$$
\n
$$
\therefore P_{av} = E_{rms} I_{rms} \cos \frac{\pi}{2} = E_{rms} \times I_{rms} \times 0 = 0
$$
\nA.C. circuit contains a series combination of L and R  
\n
$$
\tan \phi = \frac{\omega L}{2}
$$
so that  $\cos \phi = \frac{R}{2}$ 

# **A.C. circuit contains a series combination of L and R**

EXAMPLE 6  
\n**EXAMPLE 8** (average of sin<sup>2</sup> ωt = sin<sup>2</sup> ωt = 
$$
\frac{1}{2}
$$
)  
\n
$$
= \frac{1}{2} E_0 I_0 \cos \phi = \frac{E_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}} \times \cos \phi
$$
\n
$$
= E_0 \sin \omega t \text{ of } (I_0 \sin \phi) \sin (\omega t + \frac{\pi}{2})
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 10.11)}
$$
\n
$$
= E_0 \sin \omega t \text{ of } 0 \cos \omega t \sin \phi
$$
\n
$$
= (E_0 \sin \omega t) (I_0 \sin \phi) \sin (\omega t + \frac{\pi}{2})
$$
\n
$$
= (E_0 \sin \omega t) (I_0 \sin \phi) \sin (\omega t + \frac{\pi}{2})
$$
\nIn this part of power and current are in phase difference  
\nof  $\frac{\pi}{2}$   
\nIn this part amplitude of current = (I<sub>0</sub> sin θ)  
\n
$$
= \frac{\pi}{2} \text{ (Eq. 11.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 12.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 13.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 14.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 15.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 16.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 17.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 18.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 19.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 10.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 11.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 12.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq. 13.1)}
$$
\n
$$
= \frac{\pi}{2} \text{ (Eq.
$$

**A.C. circuit contains a series combination of C and R**

$$
P_{av} = \frac{E_{rms}^{2} R}{R^{2} + \omega^{2} L^{2}}
$$
  
circuit contains a series combination of C and R  

$$
\tan \phi = \frac{1/\omega C}{R}, \qquad \text{so that} \qquad \cos \phi = \frac{R}{\sqrt{R^{2} + \frac{1}{\omega^{2} C^{2}}}}
$$

$$
P_{av} = E_{rms} I_{rms} \frac{R}{\sqrt{R^{2} + \frac{1}{\omega^{2} C^{2}}}}
$$

$$
= E_{rms} \cdot \frac{E_{rms}}{\sqrt{R^{2} + \frac{1}{\omega^{2} C^{2}}}} \times \frac{R}{\sqrt{R^{2} + \frac{1}{\omega^{2} C^{2}}}}
$$

$$
P_{av} = \frac{E_{rms}^{2} R}{R^{2} + \frac{1}{\omega^{2} C^{2}}}
$$

$$
P_{av} = \frac{E_{rms}^{2} R}{R^{2} + \frac{1}{\omega^{2} C^{2}}}
$$
interesting to note here, that in case of every A.C.  
nit we can use the following general formula to calculate average consumed power.

$$
\therefore \quad P_{\text{av}} = E_{\text{rms}} I_{\text{rms}} \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}
$$

$$
=E_{rms}\cdot\frac{E_{rms}}{\sqrt{R^2+\frac{1}{\omega^2C^2}}}\times\frac{R}{\sqrt{R^2+\frac{1}{\omega^2C^2}}}
$$

or 
$$
P_{av} = \frac{E_{rms}^2 R}{R^2 + \frac{1}{\omega^2 C^2}}
$$

It is interesting to note here, that in case of every A.C. circuit we can use the following general formula to calculate  $\sqrt{R^2 + \frac{1}{\omega^2 C^2}}$ <br>  $= E_{rms} \cdot \frac{E_{rms}}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}} \times \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$ <br>
or  $P_{av} = \frac{E_{rms}^2 R}{R^2 + \frac{1}{\omega^2 C^2}}$ <br>
It is interesting to note here, that in case of every A.C.<br>
circuit we can use the following  $P_{\text{av}} = E_{\text{rms}} I_{\text{rms}} \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$ <br>  $= E_{\text{rms}} \cdot \frac{E_{\text{rms}}}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}} \times \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$ <br>
or  $P_{\text{av}} = \frac{E_{\text{rms}}^2 R}{R^2 + \frac{1}{\omega^2 C^2}}$ <br>
(It is interesting to note here, that in case of eve  $\sqrt{\frac{R^2}{R^2 + \frac{1}{\omega^2 C^2}}}$ <br>  $=$   $\frac{E_{rms}}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$   $\times \frac{R}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$ <br>
or  $P_{av} = \frac{E_{rms}^2 R}{R^2 + \frac{1}{\omega^2 C^2}}$ <br>
It is interesting to note here, that in case of every A.C.<br>
circuit we can use the fol

$$
P_{\text{av}} = E_{\text{rms}} I_{\text{rms}} \cdot \frac{R}{Z} = E_{\text{rms}} I_{\text{rms}} \cos \phi \quad (\cos \phi = \frac{R}{Z})
$$

# **WATTLESS CURRENT**

Since average of the second part of power  $(P_2)$  is zero

 $(\overline{P_2} = 0)$ . Current related with second part of power  $(P_2)$  in

 $=\frac{2 \text{ rms}}{R}$  which emf and current having phase difference of  $\pi/2$  in known as watt less current.

Amplitude of watt less current =  $I_0 \sin \phi$ 

Figure 0.1 (1' a in 2er of the same power is also known as True power by the same power one complete cycle<br>  $\overline{P} = \overline{P_1 + P_2} = \overline{E_{rms}} \times I_{rms} \times \cos \phi + 0$ <br>
or  $P_w = E_{rms} I_{rms} I_{rms} \cos \phi$ <br>
Average power is also known as True powe If the circuit consist of either inductance only or capacitance only (having no ohmic resistance), the phase difference  $\phi$ between voltage and current is 90°.

The average power consumed

 $P = E_{rms} I_{rms} \times cos 90^{\circ} = 0$  (cos 90° = 0) Thus, if the resistance of an a.c. circuit is zero, although current flows in the circuit but the average power consumed in the circuit remains zero.





**The current in such a circuit is called wattless current.** Let  $E_{rms}$  leads  $I_{rms}$  by phase angle  $\phi$ , as shown in fig. It can be assumed in general that  $I_{rms}$  is the vector sum of two perpendicular components

 $I_{rms} \cos \phi$  and  $I_{rms} \sin \phi$ .

Since phase angle between  $E_{rms}$  and  $I_{rms}$  sin  $\phi$  is  $\frac{\pi}{2}$ , average , average

power consumed in the circuit due to components  $I_{rms}$  sin  $\phi$  is zero. Only the component I<sub>rms</sub> cos  $\phi$  which is to actually responsible for consumption of power in an a.c. circuit.

As the circuit consumed no power due to the component  $I_{rms}$  sin  $\phi$ , hence it is called the wattless component of a.c.

# **SERIES RESONANT CIRCUIT**

For an A.C. circuit with resistance R, inductance L and capacitance C, in series. The impedance of the circuit

$$
Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}
$$
  
\n
$$
\phi = \tan^{-1} \frac{X}{R}
$$
  
\napplied volt:  
\n
$$
I_{\text{rms}} = \frac{E_{\text{rms}}}{Z} = \frac{E_{\text{rms}}}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}
$$
  
\n
$$
\phi = \tan^{-1} \frac{X}{R}
$$
  
\napplied volt:  
\n
$$
\text{voltage cross} \quad \text{each other so} \quad \text{each other so} \quad \text{the } V_X = V_L
$$
  
\nAt this frequency

It is clear that both the impedance and current depend on the frequency of the applied e.m.f.

### **At very low frequencies,**

Inductive reactance  $X_L = \omega L$  is negligible but capacitive reactance ( $X_C = 1/\omega C$ ) is very high. As frequency of alternating emf applied to the circuit is increased  $X_L$  goes on increasing and  $X_C$  goes on decreasing.

For a particular value of  $f = f_r$ :  $X_L = X_C$  'inductive reactance' is equal to capacitive reactance.



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

**SOLUTAD VANCED LEARNING**<br>  $Z = \sqrt{R^2 + X^2} = R$ <br>
impedance of the circuit becomes minimum  $Z_{min} = R$  is<br>
al to resistance. At frequency  $f_r$  the current becomes<br>
simum. This particular frequency  $f_r$  at which the<br>
edance of th The impedance of the circuit becomes minimum  $Z_{min} = R$  is equal to resistance. At frequency  $f_r$  the current becomes maximum. This particular frequency  $f_r$  at which the impedance of the circuit becomes minimum and therefore current becomes maximum, is called resonance frequency of the circuit.  $Z = \sqrt{R^2 + X^2} = R$ <br>
nonMADVANCEED LEARNING<br>
in the impedance of the circuit becomes minimum  $Z_{min} = R$  is<br>
ual to resistance. At frequency  $f_r$  the current becomes<br>
aximum. This particular frequency  $f_r$  at which the<br>
ppedan **EXECUTE AND MANUSION CONTROVANCED LEARNING**<br> **EXECUTE A**<br> **EXECU** 

$$
I_0 = \frac{E_0}{Z} = \frac{E_0}{R}
$$
 = max., i.e., current in the circuit is maximum.



**Before Resonance**  $(f < f_r)$ **: Current in the circuit lags** inphase by the applied voltage  $(X_L > X_C)$ 

**After Resonance**  $(f > f_r)$ **: Current leads is phase by the** applied voltage ( $X_C > X_L$ ) At Resonance  $(f = f_r)$ :

$$
\phi = \tan^{-1} \frac{X}{R} = \tan^{-1} \frac{0}{R} = 0
$$
, i.e., current is in 'phase' with

applied voltage. Currents through L and C are same but voltage cross these two 180° out of phase with respect to each other so that net PD across reactance is zero

i.e.  $V_X = V_L - V_C = 0$  with  $V = V_R$ 

 $C$  At this frequency  $f_r$  or angular frequency  $\omega_r$  circuit is known as series resonant circuit.

# The **'power factor' of the Series resonant circuit (at**  $f = f_r$ **):**

Power factor 
$$
\cos \phi = \frac{R}{Z} = 1 \text{ (max.)}
$$
  $( \because Z = R = \text{min.})$ 

and hence power consumed by the circuit

$$
P_{av} = V_{rms} I_{rms} \cos \phi = \frac{1}{2} V_0 I_0 \text{ (maximum.)}
$$

The series resonant circuit is called 'acceptor circuit' as at resonance its impedance is minimum and it most readily accepts that current out of many currents whose frequency is equal to its natural frequency. In radio or TV tuning we receive the desired station by making the frequency of the circuit equal to that of the desired station. Hence, at resonance  $\omega = \omega_r$ , , voltage cross these two 180° out of phase with respect to<br>each other so that net PD aross reactance is zero<br>each other so that net PD aross reactance is zero<br>At this frequency  $f_r$  or angular frequency  $\omega_r$  circuit is kn EVENTIFY and the process reactance is zero<br>
net PD across reactance is zero<br>  $= 0$  with  $V = V_R$ <br>  $= 0$  with  $V = V_R$ <br>
or angular frequency  $\omega_r$  circuit is known<br>
circuit.<br>
<br> **'** of the Series resonant circuit (at f = f<sub>r</sub>): plase with respect to<br>actance is zero<br>mey  $\omega_r$  circuit is known<br>ponant circuit (at  $f = f_r$ ):<br> $(\because Z = R = min.)$ <br>circuit<br>ximum.)<br>"acceptor circuit" as at<br>m and it most readily<br>rents whose frequency<br>radio or TV tuning we<br>g the freq

$$
\omega_r L = \frac{1}{\omega_r C}
$$
 or  $\omega_r^2 = \frac{1}{LC}$  or  $\omega_r = \frac{1}{\sqrt{LC}}$ 

 $X = X_L - X_C = 0$  i.e., 'reactance' of the circuit is zero.



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

2 $\pi f_r = \frac{1}{\sqrt{LC}}$  or  $f_r = \frac{1}{2\pi\sqrt{LC}}$  or  $Q = \frac{(\omega_0 L) I}{R I}$  or  $Q = \frac{(\omega_0 L) I}{R I}$  or  $Q = \frac{(\omega_0 L) I}{R I}$  or  $Q = \frac{1}{R I}$  or  $Q = \frac{1}{\sqrt{LC}} \times \frac{L}{R}$ <br>variation of I with angular frequency  $\omega$  is shown in thence  $Q = \frac{1}{\$ The station of I with angular frequency  $\omega$  is shown in<br>
ariation of I with angular frequency  $\omega$  is shown in<br>
ariation of I with angular frequency  $\omega$  is shown in<br>
Let may seen that current amplitude is maximum for<br>
a The variation of I with angular frequency  $\omega$  is shown in figure. It may seen that current amplitude is maximum for angular frequency  $\omega_r$  and falls off to zero for both  $\omega < \omega_r$ <br>and  $\omega > \omega_r$ . However, the peak value of amplitude falls off and  $\omega > \omega_r$ . However, the peak value of amplitude falls off with increase in the value of resistance R i.e. Higher the value of ohmic resistance present amplitude in the resonance.



In the figure,  $R_3 > R_2 > R_1$ .

Thus maximum value of virtual current for  $\omega = \omega_r$ , is given

by  $(I_{rms})_{max} = \frac{E_{rms}}{R}$ 

This value decreases with increase in value of R.

For all values of  $\omega$  other than  $\omega_r = 2\pi f_r$ , the amplitude of **CI** current is less than peak value.

# **QUALITY FACTORAND SHARPNESS OF RESONANCE**

From the current versus frequency curve is quite flat for a larger value of resistance and becomes more and more sharp as the value of the resistance is decreased.

A slight change in angular frequency produces comparatively a large change in current, when the resistance in the circuit is low than in the case, when the resistance is high.

If the value of resistance in the LCR series circuit is very low; then a large current flows, when the angular frequency of a.c. source is near the resonance frequency  $\omega_r$ . Such an LCR-series circuit is said to be more sharp or more selective.

### **The sharpness or selectively of a resonance circuit :**

Sharpness of the circuit it is measured by quality-factor (Q-factor). The Q-factor of series resonant circuit is defined as the ratio of the voltage developed across the inductance or capacitance at resonance to the impressed voltage (the voltage applied across R) **LITY FACTORAND SHARPNESS OF RESONANCE**<br>
and across the qualited value and some the current versus frequency curve is quite flat for a applied veltage.<br>
From the current versus frequency curve is quite flat for a spin eva applied voltage across the current versus frequency curve is quite flat for a<br>
value of the resistance and becomes more sharp<br>
Let us take a concrete example to make this point cl-<br>
value of the resistance is decreased.<br>

$$
Q = \frac{\text{voltage across L or C}}{\text{applied voltage } (= \text{voltage across R})}
$$

**STUDY MATERIAL: PHYSICS**  
\n
$$
\frac{1}{2\pi\sqrt{LC}}
$$
\nor  $Q = \frac{(\omega_0 L) I}{R I}$  or  $Q = \frac{\omega_r L}{R}$   
\n
$$
\text{or frequency } \omega \text{ is shown in}
$$
\namplitude is maximum for  
\n
$$
\text{or } \omega < \omega_r
$$
\n
$$
\text{or } \omega < \omega_r
$$
\n
$$
\text{value of amplitude falls off}
$$
\n
$$
\text{value of amplitude falls off}
$$
\n
$$
\text{at resonance, } I_0 = \frac{E_0}{R}
$$
\n
$$
\text{or } V_L = I_0 X_L = \frac{\omega L}{R} E_0
$$

R At resonance the voltage drops across inductance (or capacitance) is Q times the applied voltage.

The chief characteristic of series resonant circuit is 'voltage magnification'.

## **Note :**

- (a) Q is just a number.
- (b) Q factor is also called voltage amplification factor of the circuit.
- (c) If R is low or L is larger or C is low Q-factor of LCR series circuit will be large i.e. the circuit will have more sharpness.
- (d) The electronic circuits with high Q values would respond to a very narrow range of frequencies and for low Q values circuit will respond to a wide range of frequencies.
- (e) The value of Q varies from 10 to 100. However the electronic circuits dealing with very high frequencies may have Q even 200.

# **IMPORTANT CHARACTERISTIC OF SERIES RESONANT CIRCUIT**

A unique characteristic of the series resonant circuit is that the potential differences available across the inductance L and across the capacitor C may be much more than the applied voltage.

Let us take a concrete example to make this point clear. Suppose in a LCR series circuit,  $R = 10$  ohm,  $X_L = X_C = 40$ ohm and the root mean square value of applied voltage is 100 volt. is low or L is larger or C is low Q-factor of LCR series<br>tit will be large i.e. the circuit will have more sharpness.<br>electronic cricuits with high Q values would respond<br>electronic cricuits with high Q values<br>tit will re

The current in the circuit

$$
I = \frac{E}{Z} = \frac{E}{R} = \frac{100}{10} = 10
$$
 ampere

Potential difference across the resistance R is  $V_R = IR = 10 \times 10 = 100$  Volt

Potential difference across the inductance L is  $V_L = IX_L = 10 \times 40 = 400$  Volt

Potential difference a across the capacitor C is  $V_C = IX_C = 10 \times 40 = 400$  Volt

A series resonant circuit gives voltage amplification. It is also called voltage resonant circuit.



# **HALF POWER POINTS**

On the resonance curve there are two points where power in the circuit is half of the power at resonance.



Since, power  $P = I^2_{rms} R$ ,

At the half power points current becomes 
$$
\frac{I_m}{\sqrt{2}}
$$
 **PARALLEL RESONANT CIRCUT**  
The parallel LCR circuit shown in fig.

so that power at half power points

$$
= \left(\frac{I_m}{\sqrt{2}}\right)^2 R = \frac{1}{2}I_{m}^{2}R = \text{half power.}
$$

On the curve these points are A and B.

The 
$$
\omega_1 = \omega_r - \frac{R}{2 L}
$$
 and  $\omega_2 = \omega_r + \frac{R}{2 L}$  (if  $\frac{R}{2 L} << \omega_r$ ).

Frequencies corresponding to half power points are known as half power point frequencies.

These are denoted in graph by  $f_1$  and  $f_2$ .

At lower half power frequency  $f_1$ , the circuit is capacitive  $X_C > X_L$ 

At upper half power frequency  $f_2$ , the circuit is inductive  $X_L > X_C$ 

The current is 0.707  $I_{0m}$  or 70.7% of the maximum peak current.

# **BAND WIDTH**  $(\Delta f \text{ or } \Delta \omega)$

The band width  $\Delta f = f_2 - f_1$ 

so that power at half power points  
\n
$$
= \left(\frac{I_m}{\sqrt{2}}\right)^2 R = \frac{1}{2} I^2_m R = \text{half power.}
$$
\nOn the curve these points are A and B.  
\nThe  $\omega_1 = \omega_r - \frac{R}{2L}$  and  $\omega_2 = \omega_r + \frac{R}{2L}$  (if  $\frac{R}{2L} << \omega_r$ ).  
\n
$$
= \frac{R}{2L} \left(\frac{I_m}{2L} - \frac{R}{2L}\right) \left(\frac{I_m}{2L} - \frac{R}{2L}\right)
$$
\n
$$
= \frac{R}{2L} \left(\frac{I_m}{2L} - \frac{R}{2L}\right)
$$
\n<math display="block</p>

It is found that the full width at half maximum (FWHM) for the resonance curve, that is the band width  $\Delta\omega$ , depends on R and L in the circuit.

$$
\Delta \omega = \frac{R}{L} \quad \text{or} \quad \Delta f = \frac{R}{2\pi L}
$$

The band width is large for large R and small for small R.



The band width  $\Delta\omega$  does nor depends on C in the circuit (note that resonance frequency  $\omega_r$  does not depends on R while band width depends on R).

2 The parallel LCR circuit shown in fig.

$$
\bigcirc e \overset{\mathbf{i}_R}{\underset{\mathbf{a}}{\geq} \mathbf{R}} \overset{\mathbf{i}_L}{\underset{\mathbf{a}}{\geq} \mathbf{B}} \mathbf{L} \overset{\mathbf{i}_L}{\underset{\mathbf{a}}{\triangleq} \mathbf{C}}
$$

 $+\frac{R}{2I}$  (if  $\frac{R}{2I} << \omega_r$ ). Same can  $L = V_0$  since is approxsame emf.  $E = E_0 \sin \omega t$  is applied across R, L and C,

but the currents in R, L and C are different. Using phase difference knowledge currents in : resistance R is  $I_R = I_{OR} \sin \omega t$ 

Inductance, 
$$
I_L = I_{OL} \sin (\omega t - \frac{\pi}{2})
$$

Capacitance, 
$$
I_C = I_{OC} \sin(\omega t + \frac{\pi}{2})
$$

Here 
$$
I_{OR} = \frac{E_0}{R}
$$
;  $I_{OC} = \frac{E_0}{X_C}$ ;  $I_{OL} = \frac{E_0}{X_L}$ 

for vector addition of currents the phasor diagram is shown in fig.



cies.  
\n
$$
\begin{array}{ll}\n\text{resstance K is } I_R = I_{OR} \sin \omega t \\
\text{by } f_1 \text{ and } f_2.\n\end{array}
$$
\nresistance K is  $I_R = I_{OR} \sin \omega t$ 

\nInductance,  $I_L = I_{OL} \sin (\omega t - \frac{\pi}{2})$ 

\nnot  $I_{2}$ , the circuit is inductive

\nConacitance,  $I_C = I_{OC} \sin (\omega t + \frac{\pi}{2})$ 

\nTherefore addition of currents the phasor diagram is shown in fig.

\n $\frac{R}{2L} - \left(\omega_0 - \frac{R}{2L}\right)$ 

\npower current  $Z = R\sqrt{2}$ 

\nat half maximum (FWHM) for the band width  $\Delta\omega$ , depends

\n $I_0 = \sqrt{I_{OR}^2 + (I_{OL} - I_{OC})^2} = E_0 \sqrt{\frac{I_0}{R^2} + \left(\frac{I_0 - I_0}{X_L}\right)^2}$ 

\nand  $\frac{I_0}{2L} = \sqrt{I_{OR}^2 + (I_{OL} - I_{OC})^2} = E_0 \sqrt{\frac{I_0}{R^2} + \left(\frac{I_0 - I_0}{X_L}\right)^2}$ 





The admittance of the parallel LCR circuit is

$$
\frac{1}{Z} = \sqrt{\frac{1}{R^2} + \left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}.
$$

 $=E_0 Y$ .

If  $I_{OL} > I_{OC}$ , then resultant current in the circuit lags behind<br>the applied emf by a phase  $\phi$ ,

$$
\tan \varphi = \frac{I_{OL} - I_{OC}}{I_{OR}} = \frac{B_L - B_C}{G}.
$$

value of current  $I_0$ , for a parallel LCR circuit is shown in fig.



### **RESONANCE**

When the impedance of the circuit is maximum  $(Z = R)$  or

admittance of the circuit becomes minimum  $\left(Y = G = \frac{1}{R}\right)$ ,

In this condition  $B_L = B_C$  or or  $X_L = X_C$ 

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

In parallel circuit at resonance :

- $I_{\text{OL}} = I_{\text{OC}}$ , the phase  $\phi = 0$ , cos  $\phi = 1$
- The peak current is minimum
- \* The quality factor  $Q = \frac{R}{\omega_r L}$

\* The band width 
$$
BW = \frac{f_r}{Q}
$$
 The

# **PRACTICAL PARALLEL RESONANT CIRCUIT**

The inductance coil has some resistance R and it is connected in parallel to a capacitor C.



For this circuit, the impedance is obtained from  $\frac{1}{Z} = Y$ ,

where the admittance is  $Y = \sqrt{\frac{(1-\omega)L}{2} + (\omega L) \over 2}$ istance R and it is<br>
.<br>
ined from  $\frac{1}{Z} = Y$ ,<br>  $\frac{2LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}$ <br>
ttance is minimum.<br>  $R^2C$ <sup>1/2</sup> ned from  $\frac{1}{Z} = Y$ ,<br>  $\underline{LC}$ )<sup>2</sup> + ( $\omega$ CR)<sup>2</sup><br>  $\frac{2}{Z}$  + ( $\omega$ L)<sup>2</sup><br>
ance is minimum.<br>  $\underline{R}$ <sup>2</sup>C)<sup>1/2</sup> (1 LC) ( CR) <sup>Y</sup> R ( L) **MATERIAL: PHYSICS**<br> **TCIRCUIT**<br>
resistance R and it is<br>
or C.<br>
obtained from  $\frac{1}{Z} = Y$ ,<br>  $-\omega^2 LC)^2 + (\omega CR)^2$ <br>  $R^2 + (\omega L)^2$ <br>
dmittance is minimum.<br>  $(R^2C)^{1/2}$ RIAL: PHYSICS<br>
TUIT<br>
ance R and it is<br>
d from  $\frac{1}{Z} = Y$ ,<br>  $\frac{1}{(2)^2 + (\omega CR)^2}$ <br>  $+(\omega L)^2$ <br>
ace is minimum.<br>  $\frac{2C}{L}\bigg)^{1/2}$ <sup>r</sup> 1 R C <sup>1</sup> FCIRCUIT<br>resistance R and it is<br>r C.<br>btained from  $\frac{1}{Z} = Y$ ,<br> $-\frac{\omega^2 LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}$ <br>lmittance is minimum.<br> $\left(1 - \frac{R^2C}{L}\right)^{1/2}$ c = is obtained from  $\frac{1}{Z} = Y$ ,<br>
=  $\sqrt{\frac{(1 - \omega^2 LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}}$ <br>
the admittance is minimum.<br>  $\frac{1}{\sqrt{LC}} \left(1 - \frac{R^2 C}{L}\right)^{1/2}$ <br>  $f_r = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$ <br>
es a parallel LC circuit.<br>
=  $\frac{1}{\sqrt{LC}}$ ;  $f_r = \$ obtained from  $\frac{1}{Z} = Y$ ,<br>  $\frac{1 - \omega^2 LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}$ <br>
admittance is minimum.<br>  $\frac{1}{\sqrt{2\pi}} \left(1 - \frac{R^2C}{L}\right)^{1/2}$ <br>  $\frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$ <br>
aarallel LC circuit.<br>  $\frac{1}{\sqrt{LC}}$ ,  $f_r = \frac{1}{2\pi \sqrt{LC}}$ is obtained from  $\frac{1}{Z} = Y$ ,<br>  $\sqrt{\frac{(1-\omega^2 LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}}$ <br>
e admittance is minimum.<br>  $\frac{1}{LC} \left(1 - \frac{R^2 C}{L}\right)^{1/2}$ <br>  $= \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$ <br>
a parallel LC circuit.<br>  $\frac{1}{\sqrt{LC}}$ ;  $f_r = \frac{1}{2\pi \sqrt{LC}}$ Example 1<br>
Example 1 and the main of the set of the set of the set of the set of  $Y = \sqrt{\frac{(1 - \omega^2 LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}}$ <br>
when the admittance is minimum.<br>  $\omega_r = \frac{1}{\sqrt{LC}} \left(1 - \frac{R^2C}{L}\right)^{1/2}$ <br>
or  $f_r = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R$ 

The resonance occurs when the admittance is minimum.

resonance frequency 
$$
\omega_r = \frac{1}{\sqrt{LC}} \left( 1 - \frac{R^2 C}{L} \right)^{1/2}
$$

or 
$$
\omega_r = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}
$$
 or  $f_r = \frac{1}{2\pi} \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$ 

If  $R = 0$  in fig. then it becomes a parallel LC circuit.

resonance occurs at 
$$
\omega_r = \frac{1}{\sqrt{LC}}
$$
;  $f_r = \frac{1}{2\pi\sqrt{LC}}$ 

If  $\overline{IC}$ 2  $LC \t L<sup>2</sup>$  has negative value then resonance does not  $-\frac{\pi}{2}$  has negative value then resonance does not

In tags bennot<br>
where the admittance is  $Y = \sqrt{\frac{(1-\omega^2 LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}}$ <br>
The resonance occurs when the admittance is minimum.<br>
<br>
The resonance frequency  $\omega_r = \frac{1}{\sqrt{LC}} \left(1 - \frac{R^2 C}{L}\right)^{1/2}$ <br>  $\int \cot^2 \theta = 0$  or  $\int \frac{1}{$  $R^{\frac{1}{2}}$  impedance between frequencies  $f_1$  and  $f_2$  is large, current from  $\frac{1}{Z} = Y$ ,<br>  $\frac{2 + (\omega CR)^2}{(\omega L)^2}$ <br>  $\therefore$  is minimum.<br>  $\therefore$ <br>  $\frac{R^2}{L^2}$ <br>
circuit.<br>  $\frac{1}{2\pi \sqrt{LC}}$ <br>
onance does not<br>
mimpedance at<br>
If  $> f_r$ . Since the is circuit, the impedance is obtained from  $\frac{1}{Z} = Y$ ,<br>
the admittance is  $Y = \sqrt{\frac{(1 - \omega^2 LC)^2 + (\omega CR)^2}{R^2 + (\omega L)^2}}$ <br>
esonance occurs when the admittance is minimum.<br>
ance frequency  $\omega_r = \frac{1}{\sqrt{LC}} \left(1 - \frac{R^2C}{L}\right)^{1/2}$ <br>  $r = \sqrt$ occurs. A parallel LCR circuit offers maximum impedance at  $f = f_r$ . The impedance decreases for  $f < f_r$  and  $f > f_r$ . Since the between this band is small. nen resonance does not<br>
maximum impedance at<br>  $\langle f_1 \text{ and } f \rangle f_1$ . Since the<br>
and  $f_2$  is large, current<br>  $\rightarrow$  f<br>  $\frac{Z \ge Z_{\text{max}}}{\sqrt{2}}$ . In between<br>
current in the circuit i



 $BW = \frac{f_r}{G}$  The parallel LCR circuit is, therefore, also called Band Q Rejector circuit.  $f_1$  and  $f_2$  are half power frequencies and

> impedance in between these two is  $\frac{1}{\sqrt{2}}$  $\geq Z_{\rm max}$ . In between

these frequencies (i.e. Band width) current in the circuit is frequency.



# **CHOKE COIL**

A choke coil is simply an inductor with a large selfinductance and negligible resistance (zero in ideal case). It is used in A.C. circuits for reducing current without consuming power.

The choke coil is put in series with the electrical device, (ii) such as fluorescent tube requiring a low value of current. The inductive reactance decreases the current. Since the

e current by phase angle 
$$
\frac{\pi}{2}
$$
.

The average power consumed by the choke coil

$$
P_{av} = E_v I_v \cos \frac{\pi}{2} = 0.
$$

However, a practical inductance possesses a small resistance i.e., a practical inductance may be treated as a series combination of inductance L and a small resistance r. Average power consumed in a practical inductance mating e.m.f. leads the current by phase angle  $\frac{\pi}{2}$ .<br>
average power consumed by the choke coil<br>  $P_{av} = E_v I_v \cos \frac{\pi}{2} = 0$ .<br>  $P_{av} = E_v I_v \cos \frac{\pi}{2} = 0$ .<br>  $P_{av} = E_v I_v \times \frac{\pi}{\sqrt{r^2 + \omega^2 L^2}}$ <br>  $P_{av} = E_v I_v \times \frac{\pi}{\sqrt{r^2 + \omega^2 L^2}}$ 

$$
P_{av} = E_v I_v \times \frac{r}{\sqrt{r^2 + \omega^2 L^2}}
$$

for practical inductance power factor

$$
\therefore \phi) = \frac{r}{\sqrt{r^2 + \omega^2 L^2}}
$$



**Uses :** In a.c. circuits, a choke coil is used to control the current in place of a resistance. If a resistance is used to control the current, the electrical energy will be wasted in the form of heat. A choke coil decreases the current without wasting electrical energy in the form of heat.

# **Comparison Among Resistance, Reactance and Impedance :**

# **ADVANTAGE OFALTERNATING CURRENT OVER DIRECT CURRENT**

- A.C. can be obtained over a wide range of voltages. These voltages can be easily stepped up or stepped down with the help of transformers.
- The generation of a.c. is found to be economical than that of d.c.
- $\pi$  without any significant wastage of electrical energy. (iii) Alternating current can be controlled by using a choke coil
- alternating e.m.f. leads the current by phase angle  $\frac{1}{2}$ . (iv) Alternating current may be transmitted at a high voltage from the power house to any place where it can again be the neighboroughta in series with the electrical device,<br>
une neighborought and the content of a.c. is for<br>
une requiring a low value of current.<br>
since the (iii) Alternating current can be contened by the choke coil<br>
to **EVALUATE ANYING CONSUMPATE ANYING CORRENT**<br>
Englisher esistance (zero in idazes). It (i) A.C. can be obtained over a wide range of<br>
recuits for reducing current without voltages can be easily stepped up or step<br>
turin se Fr. Cuttins for leading tenent who in the belp of transformers.<br>
Fr. Cuttins for leading a late while the decircal device, (ii) The generation of a.c. is found to be easily separation of a.c. is found to be easily separat from the power house to any place where it can again be brought down to low voltage. The cost in such a transmission is low and energy losses are minimized. Transformers cannot be used for d.c. Hence the cost of d.c. transmission from one place to other is quite high.
	- (v) A.C. equipments such as electric motors etc are more durable and convenient as compared to d.c. equipments.
	- (vi) Alternating can be conveniently converted in to d.c. with the help of rectifiers.

# **DISADVANTAGE OFALTERNATING CURRENT OVER DIRECT CURRENT**

- (i) Alternating current in more dangerous as compared to direct current. An a.c. wire if touched by chance, gives a more serious shock as compared to a d.c. wire.
- (ii) A.C. is transmitted more by the surface of the conductor. This is called SKIN EFFECT. It is due to this reason that several strands of thin insulated wires, instead of a simple thick wire need be used.
- (iii) A.C. is not available in pure frequency. It contains higher harmonics. So it is not suitable for certain purposes.
- (iv) For electroplating, electrotyping only d.c. can be used and not a.c.





# **Expressions For Various Physical Quantities in A.C. Circuits :**





# **TRY IT YOURSELF**

- **Q.1** 110 volts (rms) is applied across a series circuit having resistance  $11\Omega \&$  impedance  $22\Omega$ . The power consumed is (A) 366 W (B) 550 W (C) 1100 W (D) 275 W
- **Q.2** A series R-C combination is connected to an AC voltage

of angular frequency  $\omega$  = 500 radian/s. If the impedance of the R-C circuit is R $\sqrt{1.25}$ , the time constant (in millisecond) of the circuit is

- **Q.3** A series LCR circuit is operated at resonance. Then (A) voltage across R is minimum
	-
	- (B) impedance is minimum
	- (C) power transferred is maximum
	- (D) current amplitude is minimum
- **Q.4** An inductance L, a capacitance C and a resistance R may be connected to an AC source of angular frequency  $\omega$ , in three different combinations of RC, RL and RLC in series.

Assume that  $\omega L = 1/\omega C$ . The power drawn by the three combinations are  $P_1$ ,  $P_2$ ,  $P_3$  respectively. Then,  $(A)$  P<sub>1</sub> > P<sub>2</sub> > P<sub>3</sub>  $(B) P_1 = P_2 < P_3$ 

- $(C) P_1 = P_2 > P_3$  $(D) P_1 = P_2 = P_3$
- **Q.5** The peak value of an alternating emf E given by  $E = E_0 \cos \omega t$  is 10 V and its frequency is 50 Hz. At a time  $t = 1/600$  s, the instantaneous value of emf is (A) 10 V (B)  $5\sqrt{3}$  V  $(C) 5 V$  (D) 1 V
- **Q.6** Resonance occurs in a series L-C-R circuit when the frequency of the applied emf is 1000 Hz. Then :
	- (A) When  $f = 900$  Hz, the circuit behaves as a capacitative circuit.
	- (B) The impedance of the circuit is maximum at  $f = 1000 Hz$ .
	- (C) At resonance the voltage accross L and voltage accross C differ in phase by 180°.
	- (D) If the value of C is doubled resonance occurs at  $f = 2000$  Hz.



**Q.7** In the figure shown hot wire voltmeter and hot wire ammeter are ideal. The reading of voltmeter is



- (A)  $5\sqrt{2}$  V (B)  $5V$  $(C) 10 V$  (D) None of these
- **Q.8** In the circuit shown if the emf of source at an instant is 5V, the potential difference across capacitor at the same instant is 4 V. The potential difference across R at that

instant may be  
\n(A)3V  
\n(B)9V  
\n(C) 
$$
\frac{3}{\sqrt{2}}
$$
V  
\n(D) none

**Q.9** In the given circuit,



- (A) current leads the voltage in phase
- (B) voltage leads the current in phase.
- 
- (D) Applied voltage is 15 V.
- **Q.10** Which of the following combinations should be selected for better tuning of an LCR circuit used for communication?

 $(A)$  R = 20 $\Omega$ , L = 1.5 H, C = 35 $\mu$ F.

- $(B)$  R = 25 $\Omega$ , L = 2.5 H, C = 45 $\mu$ F.
- $(C)$  R = 15 $\Omega$ , L = 3.5 H, C = 30 $\mu$ F.
- $(D)$  R = 25 $\Omega$ , L = 1.5 H, C = 45 $\mu$ F.
	- **ANSWERS**



**(10)**(C)

# **USEFUL TIPS**

\* For an alternating current  $i = i_m \sin \omega t$  passing through a resistor R, the average power loss P (averaged over a cycle)  $\frac{2}{m}R$ .

Root mean square (rms) current  $I = \frac{I_m}{\sqrt{2}} = 0.707 i_m$ .

given for ac voltage or current, it is ordinarily the rms

value.

\* An ac voltage  $v = v_m$  sinot applied to a pure inductor L, drives a current in the inductor

 $i = i_m \sin(\omega t - \pi/2)$ , where  $i_m = v_m/X_L$ ,

 $X_L$  =  $\omega$ L is called inductive reactance.

The current in the inductor lags the voltage by  $\pi/2$ .

The average power supplied to an inductor is zero.

An ac voltage  $v = v_m$  sinot applied to a capacitor drives a current in the capacitor :  $i = i_m \sin(\omega t + \pi/2)$ .

Here, 
$$
i_m = \frac{v_m}{X_C}
$$
,  $X_C = \frac{1}{\omega C}$  is called capacitive reactance.

**SOURABURG EXECUTE ARRIVES**<br>
voltage  $v = v_m$  sinot applied to a pure inductor L,<br>
in sin (ot  $-\pi/2$ ), where  $i_m = v_m/X_L$ .<br>
L is called inductive reactance.<br>
L is called inductive reactance.<br>
rerare n in the inductor lags the **SOLUTARY EXECUTE ANDEL SURFARING**<br> **SOLUTARY ANDEL DEARNING**<br> **SOLUTE:**  $i_m$  sin (ot  $-\pi/2$ ), where  $i_m = v_m/X_L$ ,<br>
oL is called inductive reactance.<br>
Let is called inductive reactance.<br>
In the inductor lags the voltage by EVALUATED LEARNING<br>
ge  $v = v_m$  sinot applied to a pure inductor L,<br>
rent in the inductor<br>
in (ot –  $\pi/2$ ), where  $i_m = v_m/X_L$ ,<br>
called inductive reactance.<br>
in the inductor lags the voltage by  $\pi/2$ .<br>
power supplied to an i **EXECUTE:**<br> **EXECUTE:**<br> **EXECUTE:**<br> **An ac voltage**  $v = v_m$  **sinot applied to a pure inductor L,<br>
drives a current in the inductive reactance.<br>**  $X_L = \omega L$  **is called inductive reactance.<br>
The current in the inductor lags the vo** phenomenon of resonance. The circuit exhibits resonance, i.e., the amplitude of the current is maximum at the resonant Ari ac voltage  $v = v_m$  shown applied to a plut matched E,<br>
drives a current in the inductor<br>  $i = i_m \sin (\omega t - \pi/2)$ , where  $i_m = v_m/X_L$ ,<br>  $X_L = \omega L$  is called inductive reactance.<br>
The current in the inductor lags the voltage by  $\pi$  $v_m$  sinot applied to a pure inductor L,<br>the inductor<br> $\pi/2$ ), where  $i_m = v_m/X_L$ ,<br>maluctive reactance.<br>inductor lags the voltage by  $\pi/2$ .<br>maluctive reactance.<br> $v_m$  sinot applied to an inductor is zero.<br> $v_m$  sinot applied Notate.<br>
An ac voltage  $v = v_m$  sinot applied to a pure inductor L,<br>
drives a current in the inductor<br>  $i = i_m \sin (\omega t - \pi/2)$ , where  $i_m = v_m/X_L$ ,<br>  $X_L = \omega L$  is called inductive reactance.<br>
The current in the inductor lags the volta voltage v = v<sub>m</sub> sinot applied to a pure inductor L,<br>a current in the inductor<br>a current in the inductor<br>L, is called inductive reactance.<br>D. Is called inductive reactance.<br>turnent in the inductor lags the voltage by  $\pi/$ **EXECUTE 10**<br>
ac coltage  $v = v_m$  sinot applied to a pure inductor L,<br>
ves a current in the inductor<br>  $i = i_m \sin (cot - \pi/2)$ , where  $i_m = v_m / X_L$ ,<br>  $= \omega L$  is called inductive reactance.<br>
e current in the inductor lags the voltage by

$$
\text{frequency, } \omega_0 = \frac{1}{\sqrt{\text{LC}}} \left( X_L = X_C \right).
$$

$$
Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR}
$$
 is an indicator of the sharpness of the

resonance, the higher value of Q indicating sharper peak in the current.



# **ADDITIONAL EXAMPLES**

# **Example 1 :**

When a series combination of inductance and resistance are connected with a 10V, 50Hz a.c. source, a current of 1A flows in the circuit. The voltage leads the current by a phase angle of  $\pi/3$  radian. Calculate the values of resistance and inductive reactance.

$$
x = \sqrt{R^2 + X_L^2} = \frac{E}{I} = \frac{10}{1} = 10Ω
$$
\n
$$
x = \sqrt{R^2 + X_L^2} = \frac{E}{I} = \frac{10}{1} = 10Ω
$$
\n
$$
\frac{X_L}{R} = \tan \phi = \tan \frac{\pi}{3} = \sqrt{3} \Rightarrow X_L = \sqrt{3}R
$$
\n
$$
Z = \sqrt{R^2 + 3R^2} = 10
$$
\n
$$
x = \sqrt{R^2 + 3R^2} = 10
$$
\n
$$
x = 5Ω \text{ and } X_L = \sqrt{3}R = 5\sqrt{3} Ω
$$



# **Example 2 :**

- For a series LCR circuit I = 100 sin (100 $\pi$ t  $\pi$ /3) mA (1
- and  $V = 100 \sin(100\pi t)$  volt, then
- (a) Calculate resistance and reactance of circuit.
- (b) Find average power loss.
- **Sol.** (a) Impedance,

EXAMPLE 21.17  
\nEXAMPLE 22.18  
\nand V = 100 sin (100πt) with the  
\nand V = 100 sin (100πt) with the  
\n(a) Calculate resistance and reactance of circuit.  
\n(b) Find average power loss.  
\n
$$
Z = \frac{V_0}{I_0} = \frac{100}{100 \times 10^{-3}} = 1000 \Omega
$$
\n
$$
R = Z \cos \phi = 1000 \cos \left(\frac{\pi}{3}\right) = 500 \text{ ohm}
$$
\n
$$
X = Z \sin \phi = 1000 \sin \left(\frac{\pi}{3}\right) = 500 \text{ ohm}
$$
\n
$$
X = Z \sin \phi = 1000 \sin \left(\frac{\pi}{3}\right) = 500 \text{ ohm}
$$
\n
$$
= \frac{100}{\sqrt{2}} \times \frac{100}{\sqrt{2} \times 1000} \times \cos \left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5 \text{ watts}
$$
\n
$$
= \frac{V_0}{\sqrt{2}} = \frac{2.5 \text{ minutes}}{4.00} = 8.13 \text{ A}
$$
\n
$$
= \frac{V_0}{\sqrt{2}} \times \frac{100}{\sqrt{2} \times 1000} \times \cos \left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5 \text{ watts}
$$
\n
$$
= \frac{V_0}{\sqrt{2}} = \frac{230\sqrt{2}}{4.00} = 8.13 \text{ A}
$$
\n
$$
= \frac{V_0}{\sqrt{2}} = \frac{230\sqrt{2}}{4.00} = 8.13 \text{ A}
$$
\n
$$
= \frac{V_0}{\sqrt{2}} = \frac{V_0}{\sqrt{2} \times 1000} \times \cos \left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5 \text{ watts}
$$
\n
$$
= \frac{V_0}{\sqrt{2}} = \frac{230\sqrt{2}}{4.00} = 8.13 \text{ A}
$$
\n
$$
= \frac{V_0}{\sqrt{2}} = \frac{230\sqrt{2}}{4.00} = 8.13 \text{
$$

# $=\overline{\sqrt{2}} \times \frac{1}{\sqrt{2} \times 1000} \times \cos\left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5$  watts

# **Example 3 :**

A R-L circuit draws a power of 440W from a source of 220V, 50Hz. The power factor of the circuit is 0.5. To make the power factor of the circuit as 1.0, what capacitance will have to be connected with it ?

**Sol.** 
$$
\therefore
$$
 Power P = VI cos  $\phi = \frac{V^2}{Z} \cos \phi$   
\n $\therefore Z = \frac{V^2 \cos \phi}{P} = \frac{(220)^2 (0.5)}{(440)} = 55 \Omega$   
\nIn dc only restart

Also power factor

$$
\cos \phi = \frac{R}{Z} \Rightarrow R = Z \cos \phi = (55)(0.5) = 27.5 \,\Omega
$$

:. 
$$
X_L = \sqrt{Z^2 - R^2} = \sqrt{(55)^2 - (\frac{55}{2})^2} = \frac{55\sqrt{3}}{2} \Omega
$$

when power factor is 1.0 then  $X_L = X_C$ 

$$
X_{\text{L}} = \frac{1}{\omega C} \Rightarrow C = \frac{1}{\omega X_{\text{L}}} = \frac{1}{(314) \left(\frac{55\sqrt{3}}{2}\right)} = 6.68 \times 10^{-5} \text{ F}
$$
  
Example 6.68 × 10<sup>-5</sup> F

# **Example 4 :**

A series LCR circuit with  $L = 0.12$  H,  $C = 480$  nF,  $R = 23\Omega$  is connected to a 230V variable frequency supply find – (a) Source frequency for which current is maximum. (b) Q-factor of the given circuit.

$$
x_{\text{L}} = \sqrt{2^2 - R^2} = \sqrt{(55)^2 - (\frac{55}{2})^2} = \frac{55\sqrt{3}}{2} \Omega
$$
\n
$$
x_{\text{L}} = \sqrt{2^2 - R^2} = \sqrt{(55)^2 - (\frac{55}{2})^2} = \frac{55\sqrt{3}}{2} \Omega
$$
\n
$$
x_{\text{L}} = \frac{1}{\omega C} \Rightarrow C = \frac{1}{\omega X_{\text{L}}} = \frac{1}{(314)(\frac{55\sqrt{3}}{2})} = 6.68 \times 10^{-5} \text{ F}
$$
\n
$$
x_{\text{L}} = \frac{1}{\omega C} \Rightarrow C = \frac{1}{\omega X_{\text{L}}} = \frac{1}{(314)(\frac{55\sqrt{3}}{2})} = 6.68 \times 10^{-5} \text{ F}
$$
\n
$$
x_{\text{When an alternating voltage}
$$
\n
$$
x_{\text{evice}} = 2.3 \Omega \text{ is given in the applied area.}
$$
\n
$$
x_{\text{A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 \Omega \text{ is in phase with the applied volume.}
$$
\n
$$
(a) \text{ Source frequency for which current is maximum.}
$$
\n
$$
x_{\text{A} = 230 \text{ is in the same time.}} = 0.08 \text{ hen.}
$$
\n
$$
x_{\text{A} = 230 \text{ is in the same time.}} = 0.08 \text{ hem.}
$$
\n
$$
x_{\text{M} = 230 \text{ is in the same time.}} = 0.08 \text{ hem.}
$$
\n
$$
x_{\text{M} = 230 \text{ is in the same time.}} = 0.08 \text{ hem.}
$$
\n
$$
x_{\text{M} = 100 \text{ in the same time.}} = 0.08 \text{ hem.}
$$
\n
$$
x_{\text{M} = 100 \text{ in the same time.}} = 0.08 \text{ hem.}
$$
\n
$$
x_{\text{M} = 100 \text{ in the same time.}} = 0.08 \text{ hem.}
$$
\n
$$
x_{\text{M} = 100 \text{ in the same time.
$$

**STUDY MATERIAL: PHYSICS**  
\n(b) Quality factor, 
$$
Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7
$$
  
\n**Example 5:**  
\nA variable frequency 230V alternating voltage source is connected across a series combination of L = 5.0H.

# **Example 5 :**

- **STUDY MATERIAL: PHYSICS**<br>  $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7$ <br>
uency 230V alternating voltage source is<br>
sa a series combination of L = 5.0H,<br>
= 40 $\Omega$ . Calculate<br>
frequency of the source at r A variable frequency 230V alternating voltage source is connected across a series combination of  $L = 5.0H$ , STUDY MATERIAL: PHYSICS<br>
or,  $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7$ <br>
frequency 230V alternating voltage source is<br>
cross a series combination of L = 5.0H,<br>
d R = 40Ω. Calculate<br>
ular frequency of **STUDY MATERIAL: PHYSICS**<br>
lity factor,  $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7$ <br>
5:<br>
striable frequency 230V alternating voltage source is<br>
sected across a series combination of L = 5.0H,<br>
80µ F an **STUDY MATERIAL: PHYSICS**<br>  $= \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7$ <br>
30V alternating voltage source is<br>
so combination of L = 5.0H,<br>
Calculate<br>
cy of the source at resonance.<br>
at at resonance<br>
the source expr
- $C = 80 \mu F$  and R = 40 $\Omega$ . Calculate
- (a) The angular frequency of the source at resonance.
- (b) Amplitude of current at resonance frequency.
- **Sol.** (a) Angular frequency at resonance

$$
\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5.0 \times 80 \times 10^{-6}}} = \frac{10^2}{2} = 50 \text{ rad/s}
$$

(b) Amplitude of current at resonance

$$
I_{\rm m} = \frac{V}{R} = \frac{230\sqrt{2}}{40} = 8.13 \text{ A}
$$

# **Example 6 :**

**STUDY MATERIAL: PHYSICS**<br>  $\pi - \pi/3$ ) mA<br>
(b) Quality factor,  $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7$ <br>
circuit.<br> **Example 5:**<br>
A variable frequency 230V alternating voltage source is<br>
connected acr **STUDY MATERIAL: PHYSICS**<br>
lity factor,  $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7$ <br>
5:<br>
5:<br>
Strivable frequency 230V alternating voltage source is<br>
eiected across a series combination of L = 5.0H,<br>
80 **STUDY MATERIAL: PHYSICS**<br>
factor,  $Q = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{10^5 \times 0.12}{24 \times 23} = \frac{10^3}{46} = 21.7$ <br>
ble frequency 230V alternating voltage source is<br>
ed across a series combination of L = 5.0H,<br>
F and R = 40Ω. Calculate<br> A current of 4A flows in a coil when connected to a 12V dc source. If the same coil is connected to a 12V, 50 rad/s a.c. source, a current of 2.4A flows in the circuit. Determine the inductance of the coil.

> **Sol.** A coil consists of an inductance (L) and a resistance (R). In dc only resistance is effective. Hence,

$$
Z = \frac{V_0}{I_0} = \frac{100}{100 \times 10^{-3}} = 1000 \Omega
$$
\n
$$
R = Z \cos \phi = 1000 \cos \left(\frac{\pi}{3}\right) = 500 \text{ J}
$$
\n
$$
R = Z \cos \phi = 1000 \cos \left(\frac{\pi}{3}\right) = 500 \sqrt{3} \text{ ohm}
$$
\n
$$
R = Z \cos \phi = 1000 \sin \left(\frac{\pi}{3}\right) = 500 \sqrt{3} \text{ ohm}
$$
\n
$$
S = \frac{100}{\sqrt{2}} \times \frac{100}{\sqrt{2 \times 1000}} \times \cos \left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5 \text{ watts}
$$
\n(b) Amplitude of current at resonance  
\n
$$
= \frac{100}{\sqrt{2}} \times \frac{100}{\sqrt{2 \times 1000}} \times \cos \left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5 \text{ watts}
$$
\n
$$
= \frac{1}{\sqrt{2}} \frac{1}{K} = \frac{1}{\sqrt{5.0 \times 80 \times 10^{-6}}} = \frac{10^{2}}{2} = 50 \text{ rad/s}
$$
\n
$$
R = Z \cos \phi = 1000 \sin \left(\frac{\pi}{3}\right) = 500 \sqrt{3} \text{ ohm}
$$
\n
$$
= \frac{100}{\sqrt{2}} \times \frac{100}{\sqrt{2 \times 1000}} \times \cos \left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5 \text{ watts}
$$
\n
$$
= \frac{1}{\sqrt{2}} = \frac{2.30 \sqrt{2}}{4.0 \times 10^{-6}} = 8.13 \text{ A}
$$
\n
$$
= \frac{1}{\sqrt{2}} \cos \phi = \frac{100}{\sqrt{2 \times 1000}} \times \cos \left(\frac{\pi}{3}\right) = 5 \times \frac{1}{2} = 2.5 \text{ watts}
$$
\n
$$
= \frac{1}{\sqrt{2}} = \frac{1}{\sqrt{5.0 \times 10 \times 10^{-6}}} = \frac{1}{\sqrt{2
$$

# **Example 7 :**

When an alternating voltage of 220V is applied across a device X, a current of 0.5 A flows through the circuit and is in phase with the applied voltage. When the same voltage is applied across another device Y, the same current again flows through the circuit but it leads the applied voltage by  $\pi/2$  radians.

(a) Name the devices X and Y.

 $\frac{5}{100}$  (b) Calculate the current flowing in the circuit when same voltage is applied across the series combination of X & Y.

**Sol.** (a) X is resistor and Y is a capacitor.

(b) Since the current in the two devices is the same (0.5A at 220 volt)

When R and C are in series across the same voltage then



ALTERNATING CURRENT	
\n $R = X_C = \frac{220}{0.5} = 440\Omega$ \n	\n $X_C = \frac{1}{\omega C} = \frac{1}{9 \times 10^3 \times 10^{-6}} = 11$ \n
\n $\Rightarrow I_{rms} = \frac{V_{rms}}{\sqrt{R^2 + X_C^2}} = \frac{200}{\sqrt{(440)^2 + (440)^2}} = \frac{220}{440\sqrt{2}} = 0.35 \text{ A}$ \n	\n $\text{so, } X = X_C - X_L = 111.11 - 90 = 21$ \n
\n $\text{and hence, } Z = \sqrt{R^2 + X^2} = \sqrt{3^2 + (440)^2 + (440)^2} = \frac{111.11 - 90}{440\sqrt{2}} = 0.35 \text{ A}$ \n	
\n $\text{Example 8: } \text{Use, } Z = \sqrt{9 + 445.63} = 21.32 \Omega$ \n	

# **Example 8 :**

A 100  $\Omega$  resistor is connected to a 220 V, 50 Hz a.c. supply.

(a) What is the rms value of current in the circuit ?

- (b) What is the net power consumed over a full cycle?
- **Sol.** (a) The rms value of current in the circuit,

$$
I_{\rm rms} = \frac{V_{\rm rms}}{R} = \frac{220}{100} = 2.2 \text{ A}
$$

(b) Net power consumed over full cycle,

$$
P = Irms2 R = (2.2)2 \times 100 = 484
$$
 watt

# **Example 9 :**

An LCR circuit has  $L = 10$  mH,  $R = 3 \Omega$  and  $C = 1 \mu F$  connected in series to a source of 15 cos of V. Calculate the current amplitude and the average power dissipated per cycle at a frequency that is 10% lower than the resonance frequency. Sol. As here resonance frequency,

$$
\sqrt{R^2 + X_C^2} \sqrt{(440)^2 + (440)^2} = \frac{440\sqrt{2}}{400^2}
$$
  
\n
$$
\sqrt{R^2 + X_C^2} \sqrt{(440)^2 + (440)^2} = \frac{440\sqrt{2}}{400^2}
$$
  
\nand hence,  $Z = \sqrt{R^2 + X^2} = \sqrt{3^2 + (21.11)^2}$   
\n
$$
\text{in. } Z = \sqrt{9 + 445.63} = 21.32\Omega
$$
  
\nand also hence,  $Z = \sqrt{8 + 45.63} = 21.32\Omega$   
\nand as here E = 15 cos or, i.e., E<sub>0</sub> = 15 V,  
\n(a) What is the net power consumed over a full cycle?  
\n(b) What is the net power consumed over a full cycle?  
\n
$$
I_0 = \frac{E_0}{Z} = \frac{15}{21.32} = 0.704 \text{ A}
$$
  
\nThe average power dissipated,  
\n
$$
I_{\text{rms}} = \frac{V_{\text{rms}}}{Z} = \frac{220}{21.32} = 0.704 \text{ A}
$$
  
\nThe average power dissipated,  
\n
$$
P = I_{\text{rms}}^2 R = (2.2)^2 \times 100 = 484 \text{ watt}
$$
  
\n
$$
P = I_{\text{rms}}^2 R = (2.2)^2 \times 100 = 484 \text{ watt}
$$
  
\n
$$
I_{\text{on LCR}} = \frac{E_0}{V_{\text{av}}} = \frac{V_{\text{rms}}I_{\text{rms}} \cos \phi = (I_{\text{rms}} \times Z) \times I_{\text{rms}} \times \frac{R}{Z}
$$
  
\ni.e.,  $P_{\text{av}} = I^2 \text{ms} R = \frac{1}{2}I_0^2 R$   
\n
$$
I_0 = \frac{I_0}{V_{\text{rms}}} = \frac{I_0}{\sqrt{2}}I_0
$$
  
\n
$$
I_1 = \frac{I_0}{V_{\text{rms}}} = \frac{I_0}{V_{\text{rms}}} = \frac{I_0}{\sqrt{2}}I_0
$$
  
\n
$$
I_2 = \frac{I_0}{V_{
$$

$$
R = X_C = \frac{220}{0.5} = 440Ω
$$
\n
$$
R = X_C = \frac{220}{0.5} = 440Ω
$$
\n
$$
S = \frac{V_{rms}}{\sqrt{R^2 + X_C^2}} = \frac{200}{\sqrt{(440)^2 + (440)^2}} = \frac{220}{440√2} = 0.35 A
$$
\n
$$
S = X_C - X_L = 111.11 - 90 = 21.11Ω
$$
\n
$$
S = X_C - X_L = 111.11 - 90 = 21.11Ω
$$
\n
$$
S = X_C - X_L = 111.11 - 90 = 21.11Ω
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\n
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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S = X_C - X_L = 111.11 - 90 = 21.11Ω
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\n
$$
S = X_C - X_L = 111.11 - 90 = 21.112 Ω
$$
\n
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S = X_C - X_L = 111.11 - 90 = 21.112 Ω
$$
\n
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S = X_C - X_L = 111.11 - 90 = 21.112 Ω
$$
\n
$$
S = X_C - X_L = 111.11 - 90 = 21.112 Ω
$$
\n
$$
S = X_C - X_L = 111.11 - 90 = 21.112 Ω
$$
\n
$$
S = X_C - X_L = 111.11
$$

$$
P_{\text{av}} = V_{\text{rms}} I_{\text{rms}} \cos \phi = (I_{\text{rms}} \times Z) \times I_{\text{rms}} \times \frac{R}{Z}
$$

i.e., 
$$
P_{av} = I^2_{rms}R = \frac{1}{2}I_0^2R
$$
  $\left[ \text{as } I_{rms} = \frac{I_0}{\sqrt{2}} \right]$ 

so, 
$$
P_{av} = \frac{1}{2} \times (0.704)^2 \times 3 = 0.74 \text{ W}
$$

$$
= \frac{200}{\sqrt{(440)^2 + (440)^2}} = \frac{220}{440\sqrt{2}} = 0.35 \text{ A}
$$
  
\nso,  $X = X_C - X_L = 111.11 - 90 = 21.11\Omega$   
\nand hence,  $Z = \sqrt{R^2 + X^2} = \sqrt{3^2 + (21.11)^2}$   
\ni.e.,  $Z = \sqrt{9 + 445.63} = 21.32\Omega$   
\nis connected to a 220 V, 50 Hz a c. supply  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\nand a s here E = 15 cos out, i.e., E<sub>0</sub> = 15 V,  
\n $I_0 = \frac{E_0}{Z} = \frac{15}{21.32} = 0.704 \text{ A}$   
\n $P_{av} = V_{rms}I_{rms} \cos \phi = (I_{rms} \times Z) \times I_{rms} \times \frac{R}{Z}$   
\n $I_0 = \frac{1}{100} \times 10^{-2} = 484 \text{ with}$   
\ni.e.,  $P_{av} = \frac{1}{2} \times (0.704)^2 \times 3 = 0.74 \text{ W}$   
\n $I_0 = \frac{9}{2} \times 10^3 \text{ cycle}$   
\n $I_0 = \frac{9}{\sqrt{10^{-2} \times 10^{-6}}} = 10^4 \frac{\text{rad}}{\text{s$ 

i.e., 
$$
\frac{P_{av}}{cycle} = 5.16 \times 10^{-4} \frac{J}{cycle}
$$



# **ESTION BANK** CHERITON BANK<br>
ENTION BANK CHAPTER 4 : ELECTROMAGNETIC INDUCTION & ALTERNATING CURR<br>
DESTION BANK CHAPTER 4 : ELECTROMAGNETIC INDUCTION & ALTERNATING CURR<br>
one correct response for each question.<br>
PART 1 : M **EXERCISE - 1 [LEVEL-1] QUESTION BANK | CHAPTER 4 : ELECTROMAGNETIC INDUCTION & ALTERNATING CURRENT**

# **Choose one correct response for each question. PART 1 : MAGNETIC FLUX**

- **Q.1** A square of side L meters lies in the x-y plane in a region, where the magnetic field is given by  $\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})T$ , where  $B_0$  is constant. The magnitude of flux passing through the square is  $(A)$   $2B_0L^2$  Wb Wb  $(B)$  3B<sub>0</sub>L<sup>2</sup> Wb  $(C)$  4B<sub>0</sub>L<sup>2</sup> Wb Wb  $(D)$   $\sqrt{29} B_0 L^2 Wb$  galvanometer for **Q.1** A square of side L meters lies in the x-yplane in a region,<br>
where the magnetic field is given by<br>  $\hat{\mathbf{u}} = \mathbf{b}_0(2i + 3j + 4k)\mathbf{T}$ , where  $\mathbf{B}_0$  is constant. The<br>
magnitude of flux passing through the square i A sphere the magnetic field is given by<br>  $B = B_0(2i + 3j + 4k)T$ , where  $B_0$  is constant. The<br>
magnetic field is given by<br>  $(λ) 2B_0L^2 Wb$ <br>  $(λ) 2B_0L^2 Wb$
- **Q.2** A square coil  $10^{-2}$ m<sup>2</sup> area is placed perpendicular to a uniform magnetic field of intensity 10<sup>3</sup> Wb/m<sup>2</sup> . The magnetic flux through the coil
	- (A) 10 weber (B)  $10^{-5}$  weber
	- $(C)$  10<sup>5</sup> weber  $(D)$  100 weber
- **Q.3** A circular loop of radius R carrying current I lies in x-y plane with its centre at origin. The total magnetic flux through x-y plane is
	- (A) Directly proportional to I
	- (B) Directly proportional to R
	- (C) Directly proportional to  $\mathbb{R}^2$
	- (D) Zero
- A loop of wire is placed in a magnetic field  $\vec{B} = 0.02\hat{i}$  (C) 177 volts tesla. Then the flux through the loop is its area vector is

 $\vec{A} = 30\hat{i} + 16\hat{j} + 23\hat{k}$  cm<sup>2</sup>, is .



**Q.5** The magnetic flux linked with a coil of N turns of area of cross section A held with its plane parallel to the field B is:



# **PART 2 : FARADAY'S LAW OF INDUCTION** (C)140V

- **Q.6** A conducting loop is placed in a uniform magnetic field with its plane perpendicular to the field. An emf is induced in the loop if
	- (A) It is rotated about its axis
	- (B) It is rotated about a diameter
	- (C) It is not moved
	- (D) It is given translational motion in the field
- **Q.7** Faraday's laws are consequence of conservation of (A) Energy (B) Energy & magnetic field (C) Charge (D) Magnetic field
- **Q.8** A magnetic field of  $2 \times 10^{-2}$  T acts at right angles to a coil of area 100 cm<sup>2</sup> with 50 turns. The average emf  $\alpha$ induced in the coil is 0.1 V, when it is removed from the field in time t. The value of t is<br> $(1)$  0.1  $(A)$  0.1



**Q.9** The diagram below shows two coils A and B placed parallel to each other at a very small distance. Coil A is

connected to an ac supply. G is a very sensitive galvanometer. When the key is closed –



- (A) Constant deflection will be observed in the galvanometer for 50 Hz supply.
- (B) Visible small variations will be observed in the galvanometer for 50 Hz input.
- (C) Oscillations in the galvanometer may be observed when the input ac voltage has a frequency of 1 to 2Hz.
- (D) No variation will be observed in the galvanometer even when the input ac voltage is 1 or 2 Hz.
- **Q.10** A 50 turns circular coil has a radius of 3cm, it is kept in a magnetic field acting normal to the area of the coil. The magnetic field B increased from 0.10 tesla to 0.35 tesla in 2milliseconds. The average induced e.m.f. in the coil is (A) 1.77 volts (B) 17.7 volts  $(D) 0.177$  volts
- **Q.11** A rectangular coil of 20 turns and area of cross- section 25sq cm has a resistance of 100 ohm. If a magnetic field which is perpendicular to the plane of the coil changes at the rate of 1000 Tesla per second, the current in the coil is

(A) 1.0 ampere (B) 50 ampere (C) 0.5 ampere (D) 5.0 ampere

- **Q.12** The magnetic flux linked with a coil at any instant 't' is given by  $\phi = 5t^3 - 100t + 300$ , the e.m.f. induced in the coil at  $t = 2$  second is  $(A) - 40 \text{ V}$  (B) 40 V
	- $(D)$  300 V
- **Q.13** When a small piece of wire passes between the magnetic poles of a horse-shoe magnet in 0.1sec, emf of  $4 \times 10^{-3}$ volt is induced in it. Magnetic flux between the poles is<br>(A)  $4 \times 10^{-2}$  weber (B)  $4 \times 10^{-3}$  weber (A)  $4 \times 10^{-2}$  weber  $(C)$  4 × 10<sup>-4</sup> weber (D) 4 × 10<sup>-6</sup> weber

# **PART 3 : LENZ'S LAW**

- **Q.14** Two similar circular co-axial loops carry equal currents in the same direction. If the loops be brought nearer, the currents in loops
	- (A) Decreases (B) Increases
	- (C) Remains same (D) Different in each loop
- **Q.15** The current flowing in two coaxial coils in the same direction. On increasing the distance between the two, the electric current will –
	- (A) Increase
	- (B) Decrease
	- (C) Remain unchanged
	- (D) The information is incomplete



- **Q.16** Two different loops are concentric and lie in the same plane. The current in the outer loop is clockwise and increasing with time. The induced current in the inner loop then, is
	- (A) Clockwise
	- (B) Zero
	- (C) Counter clockwise
	- (D) In a direction that depends on the ratio of the loop radii.

Ring

 $\pm$   $\mathcal{L}$ 

- **Q.17** An infinitely long cylinder is kept parallel to an uniform magnetic field B directed along positive z axis. The direction of induced current as seen from the z axis will be –
	- (A) Clockwise of the +ve z axis
	- (B) Anticlockwise of the +ve z axis
	- (C) Zero

(D) Along the magnetic field

- **Q.18** A conducting ring is placed around the core of an electromagnet as shown in fig. When key K is pressed, the ring
	- (A) Remain stationary.
	- (B) Is attracted towards the electromagnet.
	- (C) Jumps out of the core.
	- (D) None of the above.
- **Q.19** A current carrying solenoid is approaching a conducting loop as shown in the figure. The direction of induced current as observed by an observer on the other side of the loop will be -



(A) anticlockwise (B) clockwise (C) east (D) west

**Q.20** Consider the arrangement shown in figure in which the north pole of a magnet is moved away from a thick conducting loop containing capacitor. Then excess positive charge will arrive on -



(A) plate a (B) plate b

(C) On both plates a and b (D) On neither a nor b plates.

# **PART 4 : MOTIONAL ELECTROMOTIVE FORCE**

**Q.21** Direction of current induced in a wire moving in a magnetic field is found using

> (A) Fleming's left hand rule (B) Fleming's right hand rule (C) Ampere's rule (D) Right hand clasp rule

**Q.22** A conductor is moving with the velocity v in the magnetic field and induced current is I. If the velocity of conductor becomes double, the induced current will be :  $(A) 0.5 I$  (B) 1.5 I



**Q.23** A rod of length  $\ell$  rotates with a uniform angular velocity  $\omega$  about an axis passing through its middle point but normal to its length in a uniform magnetic field of induction B with its direction parallel to the axis of rotation. The induced emf between the two ends of the rod is **SOMADWANCED LEARNING**<br> **SOMADWANCED LEARNING**<br> **SOMADWANCED LEARNING**<br> **SOMADWANCED LEARNING**<br>
IDME durated current is 1. If the velocity of conductor<br>
on 5.1 (B) 1.51<br>
(B) 2.51<br>
d of length  $\ell$  rotates with a uniform a **SOMADVANGED LEARNING**<br> **SOMADVANGED LEARNING**<br> **SOMADVANGED LEARNING**<br> **SOMADVANGED LEARNING**<br>
IDDED SOME UNITED. IT (B) LST<br>
O.51 (B) LST<br>
(D) 2.51<br>
d of length  $\ell$  rotates with a uniform angular velocity<br>
bout an axis

(A) 
$$
\frac{B\ell^2 \omega}{2}
$$
 (B) Zero  
\n(C)  $\left(\frac{B\ell^2 \omega}{8}\right)$  (D)  $2B\ell^2 \omega$ 

- $V K$ **Q.24** A conductor of 3 m in length is moving perpendicularly to magnetic field of  $10^{-3}$  tesla with the speed of  $10^{2}$ m/s, then the e.m.f. produced across the ends of conductor will be –
	- (A) 0.03 volt (B) 0.3 volt  $(C)$  3 × 10<sup>-3</sup> volt (D) 3 volt
	- **Q.25** An aeroplane in which the distance between the tips of wings is 50 m is flying horizontally with a speed of 360km/hr over a place where the vertical components of earth magnetic field is  $2.0 \times 10^{-4}$  weber/m<sup>2</sup>. The potential difference between the tips of wings would be –  $(A) 0.1 V$  (B)  $1.0 V$



**Q.26** A wheel with ten metallic spokes each 0.50 m long is rotated with a speed of 120 rev/min in a plane normal to the earth's magnetic field at the place. If the magnitude of the field is 0.4 Gauss, the induced e.m.f. between the axle and the rim of the wheel is equal to –

(A) 
$$
1.256 \times 10^{-3} \text{ V}
$$
  
\n(B)  $6.28 \times 10^{-4} \text{ V}$   
\n(C)  $1.256 \times 10^{-4} \text{ V}$   
\n(D)  $6.28 \times 10^{-5} \text{ V}$ 

**Q.27** A circular coil of mean radius of 7 cm and having 4000 turns is rotated at the rate of 1800 revolutions per minute in the earth's magnetic field ( $B = 0.5$  gauss), the maximum e.m.f. induced in coil will be –

(A) 1.158 V (B) 0.58 V (C) 0.29 V (D) 5.8 V

**Q.28** The magnitude of the earth's magnetic field at a place is  $B_0$  and the angle of dip is  $\delta$ . A horizontal conductor of length  $\ell$  lying along the magnetic north-south moves eastwards with a velocity v. The emf induced across the conductor is

(A) Zero  
\n(B) 
$$
B_0 \ell v \sin \delta
$$
  
\n(C)  $B_0 \ell v$   
\n(D)  $B_0 \ell v \cos \delta$ 

**Q.29** A wire of length 1 m is moving at a speed of 2ms–1 perpendicular to its length and a homogeneous magnetic field of 0.5 T. The ends of the wire are joined to a circuit of resistance  $6\Omega$ . The rate at which work is being done to keep the wire moving at constant speed is

(A) W/12 (B) W/6 (C) W/3 (D) W



 $2r^2f$ 

**Q.30** A thick wire in the form of a semicircle of radius 'r' is rotated with a frequency 'f' in a magnetic field. What will be the peak value of emf induced?

(A) 
$$
B \pi r^2 f
$$
 (B)  $B \pi^2 r^2 f$ 

$$
(C) 2Br2f \t\t\t(D) 2
$$

- **Q.31** Consider the situation shown in the figure. The wire AB is sliding on the fixed rails with a × × ×  $\times$   $\times$   $\times$   $\times$   $\times$ × × × ×  $\times$   $\times$   $\times$   $\times$   $\Gamma$ × × × × × A  $\bar{\mathbf{B}}$ constant velocity. If the wire AB is replaced by semicircular wire, the magnitude of the induced current will –
	- (A) Increase
	- (B) Remain the same
	- (C) Decrease
	- (D) Increase or decrease depending on whether the semicircle bulges towards the resistance or away from it.

# **PART 5 : EDDY CURRENTS**

- **Q.32** Induction furnace make use of (A) Self induction (B) Mutual induction (C) Eddy current (D) None of these
- **Q.33** A metal plate can be heated by
	- (A) Passing either a direct or alternating current through the plate.
	- (B) Placing in a time varying magnetic field.
	- (C) Placing in a space varying magnetic field, but does not vary with time.
	- (D) Both (A) and (B) are correct.

# **PART 6 : INDUCTANCE**

- **Q.34** When the rate of change of current is unity, the induced emf is equal to
	- (A) Thickness of coil
	- (B) Number of turns in coil
	- (C) Coefficient of self inductance
	- (D) Total flux linked with coil
- **Q.35** A short solenoid of radius a, number of turns per unit length  $n_1$ , and length L is kept coaxially inside a very long solenoid of radius b, number of turns per unit length  $n_2$ . What is the mutual inductance of the system ?

$$
(A) μ0πb2n1n2L
$$
\n
$$
(B) μ0πa2n1n2L2
$$
\n
$$
(C) υ1πa2n1n1L2
$$
\n
$$
(D) ω1π2n2n1L2
$$

(C)  $\mu_0 \pi a^2 n_1 n_2 L$  ${}^{2}n_{1}n_{2}L$  (D)  $\mu_{0}\pi b^{2}n_{1}n_{2}L^{2}$ **Q.36** The unit of inductance is equivalent to

(A) 
$$
\frac{\text{volt} \times \text{amper}}{\text{second}}
$$
 (B)  $\frac{\text{amper}}{\text{volt} \times \text{second}}$   
(C)  $\frac{\text{volt}}{\text{amper} \times \text{second}}$  (D)  $\frac{\text{volt} \times \text{second}}{\text{amper}}$ 

- **Q.37** The self inductance of a long solenoid cannot be increased by
	- (A) Increasing its area of cross section
	- (B) Increasing its length
	- (C) Increasing the current through it
	- (D) Increasing the number of turns in it



 $(C)$  Becomes 1/4 times f (D)  $2B \pi^2 r^2 f$  **Q.39** If N is the number of turns in a coil, the value of self-(D) Remains unchanged inductance varies as :

- $(A) N<sup>0</sup>$  $(B) N$
- $(C) N<sup>2</sup>$  $(D) N^{-2}$
- **Q.40** Two pure inductors each of self inductance L are connected in parallel but are well separated from each other. The total inductance is –
	- $(A)$  2L  $(B)$  L  $(C) L/2$  (D) L/4
- **Q.41** A coil and a bulb are connected in series with a dc source, a soft iron core is then inserted in the coil. Then –
	- (A) Intensity of the bulb remains the same
	- (B) Intensity of the bulb decreases
	- (C) Intensity of the bulb increases
	- (D) The bulb ceases to glow
- **Q.42** Self induction of a solenoid is
	- (A) Directly proportional to current flowing through the coil.
		- (B) Directly proportional to its length.
	- (C) Directly proportional to area of cross-section.
	- (D) Inversely proportional to area of cross-section.
- **Q.43** When the number of turns and the length of the solenoid are doubled keeping the area of cross-section same, the inductance –
	- (A) Remains the same (B) Is halved (C) Is doubled (D) Becomes four times
- CO Excellent and the multiple and behavior and the set of the behavior of the behavior of the behavior of the behavior (A) Passing either a fire the heat of the plats (A) Passin CD Directly proportional to area of cross-section.<br>
(c) Directly proportional to area of cross-section.<br>
nating current firough (D) Inversely proportional to area of cross-section.<br>
engertic field, that does<br>
(A) Reemans the plate.<br>
Placing in a time varying magnetic field.<br>
Delaring in a space varying magnetic field, but does<br>
Placing in a space varying magnetic field, but does<br>
not are doubled keeping the eart of Cross-section<br>
Delaring ating current through<br>
(2) Inversely proportional to area of cross-section.<br>
Registre field,<br>
inductance – doubled keeping the area of cross-section same, the<br>
genetic field, but does<br>
inductance – (A) Benalism the same<br> **Q.44** The mutual inductance of an induction coil is 5H. In the primary coil, the current reduces from 5A to zero in  $10^{-3}$ s. What is the induced emf in the secondary coil – (A) 2500V (B) 25000V (C) 2510V (D) Zero (B) Directly proportional to its length.<br>
(C) Directly proportional to area of cross-section.<br>
(D) Inversely proportional to area of cross-section.<br>
When the number of turns and the length of the solenoid<br>
are doubled kee ubled keeping the area of cross-section same, the<br>
ance –<br>
manns the same (B) Is halved<br>
doubled (D) Becomes four times<br>
utual inductance of an induction coil is 5H. In the<br>
y coil, the current reduces from 5A to zero in<br> ss-section same, the<br>halved<br>ecomes four times<br>ion coil is 5H. In the<br>m 5A to zero in<br>the secondary coil –<br>000V<br>roo<br>of two coils is 6mH.<br>ere, then the induced<br>nV<br>wron<br>experience, then the induced<br>nN<br> $\frac{1}{2}$ <br>(i<sub>i</sub> + i<sub>2</sub>) doubled (D) Becomes four times<br>
utual inductance of an induction coil is 5H. In the<br>
utual inductance of an induction coil is 5H. In the<br>
What is the induced enfi in the secondary coil-<br>
00V (D) Zero<br>
10V (D) Zero<br>
eeffic Becomes four times<br>
stion coil is 5H. In the<br>
rom 5A to zero in<br>
the secondary coil –<br>
5000V<br>
Zero<br>
ce of two coils is 6mH.<br>
Pere, then the induced<br>  $2 \text{ mV}$ <br>  $2 \text{ m$ 
	- **Q.45** The coefficient of mutual inductance of two coils is 6mH. If the current flowing in one is 2 ampere, then the induced e.m.f. in the second coil will be  $(A) 3 \text{ mV}$  (B) 2 mV  $(C)$  3 V  $(D)$  Zero The mutual inductance of an induction coil is 5H. In the<br>
	primary coil, the current reduces from 5A to zero in<br>
	10<sup>-3</sup>s. What is the induced emf in the secondary coil –<br>
	(A) 2500V (B) 2600W<br>
	(C) 2510V (D) Zero<br>
	The coeffi coil is 5H. In the<br>iA to zero in<br>secondary coil –<br>V<br>two coils is 6mH.<br>then the induced<br>**ILE OF AC**<br>equation<br>nt is given by<br> $i + i/2$ <br> $+ i/2$ <br> $+ i/2$ <br>X.<br>What would be 10 S. with the multed ein in the secondary contract (C) 2510V<br>
	(C) 2510V (D) Zero<br>
	The coefficient of mutual inductance of two coils is 6mH.<br>
	If the current flowing in one is 2 ampere, then the induced<br>
	e.m.f. in the seco (B) 25000V<br>
	(D) Zero<br>
	icient of mutual inductance of two coils is 6mH.<br>
	ent flowing in one is 2 ampere, then the induced<br>
	the second coil will be<br>
	(B) 2mV<br>
	(D) Zero<br> **EAN AND RMS VALUE OF AC**<br>
	ating current is given by th (B) 25000V<br>
	(D) Zero<br>
	ient of mutual inductance of two coils is 6mH.<br>
	1. flowing in one is 2 ampere, then the induced<br>
	second coil will be<br>
	(B) 2 mV<br>
	(D) Zero<br>
	(D) Zero<br> **AN AND RMS VALUE OF AC**<br>
	ing current is given by t 00V<br>
	o<br>
	f two coils is 6mH.<br>
	re, then the induced<br>
	V<br>
	o<br> **LUE OF AC**<br>
	e equation<br>
	rent is given by<br>  $(i_1 + i_2)^2$ <br>  $(i_1 + i_2)^2$ <br>
	P V. What would be<br>
	alf cycle<br>
	V<br>
	where of these

# **PART 7 : MEAN AND RMS VALUE OF AC**

**Q.46** An alternating current is given by the equation

(B) 
$$
\frac{\text{amper}}{\text{volt} \times \text{second}}
$$
 (A)  $\frac{1}{\sqrt{2}}(i_1 + i_2)$  (B)  $\frac{1}{\sqrt{2}}(i_1 + i_2)^2$   
volt x second (C)  $\frac{1}{\sqrt{2}}(i_2 + i_1)^2$  (D)  $\frac{1}{\sqrt{2}}(i_1 + i_2)^2$ 

$$
\frac{d}{dx} \times \text{second} \qquad (C) \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2} \qquad (D) \frac{1}{2} (i_1^2 + i_2^2)^{1/2}
$$

**Q.47** If an ac main supply is given to be 220 V. What would be the average e.m.f. during a positive half cycle (A) 198V (B) 386V (C) 256V (D) None of these

# **EMI AND AC QUESTION BANK**



**Q.48** If the value of potential in an ac, circuit is 10V, then the Q. peak value of potential is –



**Q.49** The maximum value of a.c. voltage in a circuit is 707V. Its rms value is



- **Q.50** An ac source is rated at 220V, 50 Hz. The time taken for voltage to change from its peak value to zero is (A) 50 sec (B) 0.02 sec (C) 5 sec (D)  $5 \times 10^{-3}$  sec
- **Q.51** The peak voltage of an ac supply is 440V, then its rms voltage is
	- $(A)$ 31.11 V (B) 311.1 V  $(C)$ 41.11 V (D) 411.1 V
- **Q.52** When a voltage measuring device is connected to ac mains, the meter shows the steady input voltage of 220V. This means
	- (A) Input voltage cannot be ac voltage, but a dc voltage.
	- (B) Maximum input voltage is 220V.
	- (C) The meter reads not V but  $\langle V^2 \rangle$  and is calibrated to
		-
	- defect.
- **Q.53** An ac source is of  $\frac{200}{5}V$ , 50 Hz. The value of voltage (A) More reactance 2 , 50 Hz. The value of voltage

after  $(1/600)$  s from the start is

(A) 200 V (B) 
$$
\frac{200}{\sqrt{2}}
$$

$$
(C) 100 V \t\t (D) 50 V
$$

# **PART 8 : AC VOLTAGE TO A RESISTOR**

- **Q.54** A 280 ohm electric bulb is connected to 200V electric line. The peak value of current in the bulb will be (A) About one ampere (B) Zero (C) About two ampere (D) About four ampere
- **Q.55** A 100 $\Omega$  resistor is connected to a 220V, 50Hz ac supply. The rms value of current in the circuit is (A) 1.56 A (B) 1.56 mA  $(C) 2.2 A$  (D) 2.2 mA

# **PART 9 : AC VOLTAGE TO AN INDUCTOR**

- **Q.56** In a circuit containing an inductance of zero resistance, Q.6 the e.m.f. of the applied ac voltage leads the current by  $(A) 90^{\circ}$  $(B) 45^{\circ}$  $(C)$  30<sup>o</sup>  $(D)$  $0<sup>o</sup>$
- **Q.57** A a.c. circuit consists of only an inductor of inductance Q.6 2H. If the current is represented by a sine wave of amplitude 0.25 amp. and frequency 60 Hz, calculate the effective potential difference across the inductor (A) 133.2 Volt (B) 122.2 Volt (C) 143.2 Volt (D) 113.2 Volt



- (C) amplitude of current
- (D) both (A) and (B)
- **AND AC**<br> **AND AC**<br>
If the value of potential in an ac, circuit is 10V, then the<br>  $\begin{array}{ll}\n\text{QUESTION BANK}\n\end{array}$ All inductive reactance is directly proportional to-<br>
reak value of potential is  $\begin{array}{ll}\n\text{(A) } 10/\sqrt{2} & \text{(B) }$ **AND AC**<br> **(OUESTION BANK**<br> **If the value of potential in an ac, circuit is 10V, then the Q.58 The inductive reactance is directly proportional to –<br>
peak value of potential is – (A) inductance<br>
(A)**  $10/\sqrt{2}$  **(B) 10\sqrt{2} Q.59** An ideal inductor is in turns put across 220V, 50Hz and 220V, 100Hz supplies. The current flowing through it in the two cases will be (A) Equal (B) Different
	- (C) Zero (D) Infinite
	- **Q.60** A 44 mH inductor is connected to 220V, 50Hz ac supply. The rms value of the current in the circuit is  $(A) 12.8 A$  (B) 13.6 A  $(C) 15.9 A$   $(D) 19.5 A$

# **PART 10 : AC VOLTAGE TO A CAPACITOR**

- (A)  $10/\sqrt{2}$  (B)  $10\sqrt{2}$  (C)  $20\sqrt{2}$  (C) amplitude of current<br>
The maximum value of a.c. voltage in a circuit is 707V. Its **Q.59** An ideal inductor is in turns put a<br>
The maximum value of a.c. voltage in a circuit is **Q.61** An alternating e.m.f. is applied to purely capacitive circuit. The phase relation between e.m.f. and current flowing in the circuit is – (A) e.m.f. is ahead of current by  $\pi/2$ (B) Current is ahead of e.m.f. by  $\pi/2$ (C) Current lags behind e.m.f. by  $\pi$ (D) Current is ahead of e.m.f. by  $\pi$ **Q.62** A capacitor is a perfect insulator for (A) Alternating currents (B) Direct currents (C) Both ac and dc (D) None of these **Q.63** For high frequency, a capacitor offers (A) More reactance (B) Less reactance (C) Zero reactance (D) Infinite reactance **Q.60** A 44 mH inductor is connected to 220V, 50Hz ac supply.<br>
The rms value of the current in the circuit is<br>
(A) 12.8 A (B) 13.6 A (B) 13.6 A<br>
(C) 15.9 A (B) 19.5 A<br> **PART 10 : AC VOLTAGE TO A CAPACITOR**<br> **PART 10 : AC** 
	- $\frac{200}{\sqrt{2}}$  V connected to a 1 microiarized capacitor infough an a ammeter. The reading of the ammeter shall be  $(A) 10mA$ connected to a 1 microfarad capacitor through an ac  $(B) 20$  mA  $(C)$  40 mA (D) 80 mA
		- **Q.65** The frequency for which a 5µF capacitor has a reactance of  $(1/1000)$  ohm is given by

(A) 
$$
\frac{100}{\pi}
$$
 MHz (B)  $\frac{1000}{\pi}$  Hz  
(C)  $\frac{1}{1000}$  Hz (D) 1000 Hz

**Q.66** Reactance of a capacitor of capacitance CµF for ac

frequency 
$$
\frac{400}{\pi}
$$
 Hz is 25 $\Omega$ . The value C is  
\n(A) 50  $\mu$ F  
\n(C) 100  $\mu$ F  
\n(D) 75  $\mu$ F  
\n**Q.67** A30 $\mu$ F capacitor is connected to a 150 V, 60Hz ac supply.  
\nThe rms value of current in the circuit is  
\n(A) 17 A  
\n(B) 1.7 A  
\n(B) 1.7 A  
\n(D) 2.7 A  
\n**Q.68** In a pure capacitive circuit if the frequency of ac source

**Q.68** In a pure capacitive circuit if the frequency of ac source is doubled, then its capacitive reactance will be (A) Remain same (B) Doubled (C) Halved (D) Zero



- **Q.69** When an ac voltage of 220V is applied to the capacitor C, then
	- (A) The maximum voltage between plates is 220V.
	- (B) The current is in phase with the applied voltage.
	- (C) The charge on the plate is not in phase with the applied voltage.

(D) Power delivered to the capacitor per cycle is zero.

**Q.70** Phase difference between voltage and current in a capacitor in an ac circuit is



# **PART 11 : AC VOLTAGE APPLIED TO A LR CIRCUIT**

**Q.71** An inductive circuit contains a resistance of 10ohm and<br>an inductance of 2.0 henry. If an ac voltage of 120 yout 0.79 an inductance of 2.0 henry. If an ac voltage of 120 volt and frequency of 60 Hz is applied to this circuit, the current in the circuit would be nearly –



- **Q.72** If an 8 $\Omega$  resistance and 6 $\Omega$  reactance are present in an ac series circuit then the impedance of the circuit will be (A) 20 ohm (B) 5 ohm
	-
- **Q.73** A 12 ohm resistor and a 0.21 henry inductor are connected in series to an ac source operating at 20 volts, 50 cycle/ second. The phase angle between the current and the source voltage is



**Q.74** An alternating voltage is connected in series with a resistance R and an inductance L If the potential drop across the resistance is 200 V and across the inductance is 150 V, then the applied voltage



**Q.75** A 220 V, 50 Hz ac source is connected to an inductance of 0.2 H and a resistance of 20 ohm in series. What is the current in the circuit



**Q.76** A resistance of 40 ohm and an inductance of 95.5millihenry are connected in series in a 50 cycles/ second ac circuit. The impedance of this combination is very nearly



**Q.77** A circuit is made up of a resistance  $1\Omega$  and inductance 0.01 H. An alternating voltage of 200V at 50 Hz is connected, then the phase difference between the current and the voltage in the circuit is

(A) 
$$
\tan^{-1} (\pi)
$$
 (B)  $\tan^{-1} (\pi/2)$ 

(C) 
$$
\tan^{-1} (\pi/4)
$$
 (D)  $\tan^{-1} (\pi/3)$ 

# **PART 12 : AC VOLTAGE APPLIED TO A RC CIRCUIT**

**Q.78** A 50 Hz ac source of 20 volts is connected across R and C as shown in figure. The voltage across R is 12 volt. The voltage across  $C$  is  $-$ 





(C) 10V

(D) Without values of R and C calculation is not possible.

- In an alternating current circuit consisting of elements in series, the current increases on increasing the frequency of supply. Which of the following elements are likely to constitute the circuit ?
	- (A) Only resistor (B) Resistor and inductor
	- (C) Resistor and capacitor (D) Only inductor
- (C) IR charge on the plate is not in phase with the<br>
(D) Power delivered to the capacitor per cycle is zero.<br>
(D) Power delivered to the capacitor per cycle is zero.<br>
(A)  $\pi$ <br>
Capacitor in an ac circuit is<br>
(C) 0<br>
(D)  $\$ **Q.80** A circuit containing a 20  $\Omega$  resistor and 0.1 µF capacitor in series is connected to 230 V ac supply of angular frequency 100 rad  $s^{-1}$ . The impedance of the circuit is (A)  $10^5 \Omega$  (B)  $10^4 \Omega$ (C)  $10^6 \Omega$  (D)  $10^{10} \Omega$ 
	- **Q.81** A 0.2 k $\Omega$  resistor and 15 $\mu$ F capacitor are connected in series to a 220V, 50Hz ac source. The impedance of the circuit is  $(A) 250 \Omega$  (B)  $268 \Omega$



# **PART 13 : AC VOLTAGE APPLIED TO A SERIES LCR CIRCUIT**

**Q.82** If q is the charge on the capacitor and i the current, at time t, then voltage will be –



**Q.83** In LCR circuit, the amplitude of the current is given by –

(A) 
$$
i_m = \frac{v_m}{\sqrt{R^2 + (X_C - X_L)^2}}
$$
 (B)  $i_m = \frac{v_m}{\sqrt{R^2 - (X_C - X_L)^2}}$   
(C)  $i_m = \frac{v_m}{\sqrt{2R^2 + (X_C - X_L)^2}}$  (D)  $i_m = \frac{v_m}{\sqrt{R^2 + (X_C + X_L)^2}}$ 



**Q.84** An alternating current source of frequency 100Hz is joined to a combination of a resistance, a capacitance<br>and a coil in series. The potential difference across the Q.93 In an accircuit, the current is given by  $i = 5 \sin \left( 100 t - \frac{\pi}{2} \right)$ and a coil in series. The potential difference across the coil, the resistance and the capacitor is 46, 8 and 40 volt respectively. The electromotive force of alternating current source in volt is



- **Q.85** In a series circuit R = 300  $\Omega$ , L = 0.9 H, C = 2.0  $\mu$ F and  $\omega$  = 1000 rad/sec. The impedance of the circuit is (A)  $1300 \Omega$  (B)  $900 \Omega$ (C)  $500 \Omega$  (D)  $400 \Omega$
- **Q.86** In a LCR circuit the pd between the terminals of the inductance is 60 V, between the terminals of the capacitor is 30V and that between the terminals of resistance is 40V. the supply voltage will be equal to (A)  $50 \text{ V}$  (B)  $70 \text{ V}$  $(C) 130 V$  (D) 10 V
- **Q.87** In series LCR circuit voltage drop across resistance is 8volt, across inductor is 6 volt and across capacitor is 12 volt. Then –
	- (A) voltage of the source will be leading current in the circuit.
	- (B) voltage drop across each element will be less than the applied voltage.
	- (C) power factor of circuit will be 4/3.
	- (D) none of these.
- **Q.88** In a series LCR circuit  $R = 10 \Omega$  and the impedance  $Z = 20\Omega$ . Then the phase difference between current and voltage is :  $(A) 45^{\circ}$  (B) 90°
- $(C) 60^{\circ}$  (D) 30° **Q.89** An LCR series circuit is under resonance. If  $I_m$  is current amplitude,  $V_m$  is voltage amplitude, R is the resistance,  $Z$  is the impedance,  $X_L$  is the inductive reactance and  $X_C$  is the capacitive reactance, then

(A) 
$$
I_m = \frac{Z}{V_m}
$$
  
\n(B)  $I_m = \frac{V_m}{X_L}$   
\n(C)  $I_m = \frac{V_m}{X_C}$   
\n(B)  $I_m = \frac{V_m}{X_L}$   
\n(D)  $I_m = \frac{V_m}{R}$   
\n(D)  $I_m = \frac{V_m}{R}$   
\n(D)  $I_m = \frac{V_m}{R}$   
\n3.8 m/s  
\n4. The resonance frequency are at the resonating frequency.

**Q.90** In a series LCR circuit the voltage across an inductor, capacitor and resistor are 20V, 20V and 40V respectively. The phase difference between the applied voltage and the current in the circuit is  $(A) 30^{\circ}$  (B) 45<sup>°</sup>



**Q.91** In a series LCR circuit, the phase difference between the voltage and the current is 45º. Then the power factor will be



**Q.92** 200 V ac source is fed to series LCR circuit having  $X_L$  = 50  $\Omega$ ,  $X_C$  = 50  $\Omega$  and R = 25  $\Omega$ . Potential drop across the inductor is  $(A) 100 V$  (B) 200 V  $(C)$  400 V (D) 10 V

# **PART 14 : POWER IN AC CIRCUIT**

 $2<sup>j</sup>$ 

**PART 14 : POWER IN AC CIRCUIT**<br> **Q.93** In an ac circuit, the current is given by  $i = 5 \sin \left( 100 t - \frac{\pi}{2} \right)$ <br>
and the ac potential is  $V = 200 \sin (100)$  volt Then the<br>
power consumption is<br>
(A) 20 watts<br>
(C) 1000 watts<br> **Q.**  $\sqrt{\frac{N \text{ of } \text{FANRNNM}}{N \text{ of } \text{FANRNNM}}}$ <br>(100 t -  $\frac{\pi}{2}$ )<br>blt Then the DIVERIVANCED LEARNING<br>  $\frac{1}{2}$  = 5 sin  $\left(100t - \frac{\pi}{2}\right)$ <br>
(00) volt Then the watts and the ac potential is  $V = 200 \sin(100)$  volt Then the power consumption is  $(A)$  20 watts  $(B)$  40 watts  $(C)$  1000 watts  $(D)$  0 watt **EXECUTE:**<br> **EXECUTE:**<br> **EXECUTE:**<br>
In an accircuit, the current is given by  $i = 5 \sin \left( 100t - \frac{\pi}{2} \right)$ <br>
and the ac potential is  $V = 200 \sin (100)$  volt Then the<br>
power consumption is<br>
(A) 20 watts<br>
(C) 1000 watts<br>
In an ac MEEDLEARNING<br>
(100 t -  $\frac{\pi}{2}$ )<br>
olt Then the<br>
f e.m.f. and<br>
(314 t +  $\frac{\pi}{3}$ )<br>
vatt is MADVANCED LEARNING<br>
IRCUIT<br>
= 5 sin  $\left(100t - \frac{\pi}{2}\right)$ <br>
00) volt Then the<br>
atts<br>
tt<br>
ues of e.m.f. and<br>
= sin  $\left(314t + \frac{\pi}{3}\right)$ <br>
d in watt is<br>  $I = 20 \cos \omega t$  the

**Q.94** In an ac circuit, the instantaneous values of e.m.f. and

current are e = 200 sin 314 t volt and i = sin
$$
\left(314t + \frac{\pi}{3}\right)
$$

ampere. The average power consumed in watt is (A) 200 (B) 100  $(C) 50$  (D) 25

- **Q.95** For an ac circuit  $V = 15 \sin \omega t$  and  $I = 20 \cos \omega t$  the average power consumed in this circuit is (A) 300 Watt (B) 150 Watt (C) 75 Watt (D) zero
- **Q.96** A series LCR-circuit with  $R = 20\Omega$ ,  $L = 1.5H$  and  $C = 35\mu F$ is connected to a variable frequency 200 V ac apply. When the frequency of the supply equals the natural frequency of the circuit the average power transferred to the circuit in one complete cycle is<br> $(4)$  200 W

(A) 200 W (B) 2000 W (C) 100 W (D) 4000 W

- **Q.97** An inductor of reactance 1  $\Omega$  and a resistor of  $2\Omega$  are connected in series to the terminals of a 6V (rms) ac source. The power dissipated in the circuit is (A) 8 W (B) 12 W (C) 100 W<br>
An inductor of reactance 1  $\Omega$  and a resistor of  $2\Omega$  are<br>
connected in series to the terminals of a 6V (rms) ac<br>
source. The power dissipated in the circuit is<br>
(A) 8 W<br>
(C) 14.4 W<br>
(B) 12 W<br>
(C) 14.4 W<br>
(B)
	- (C) 14.4 W (D) 18 W
- **Q.98** Expression for Wattless current is (A)  $I_{rms} \sin \phi$  $(B)$  I<sub>rms</sub> cos  $\phi$ (C)  $\,$  I $_{\rm rms}$ tan $\phi$  $(B)$  I<sub>rms</sub> cot  $\phi$

# **PART 15 : RESONANCE**

 $=\frac{L}{V_m}$  (B) I<sub>m</sub> =  $\frac{v_m}{X_L}$  (B)  $\frac{V_m}{V_m}$  the resonance frequency and the a L<br>at the resonating frequency V<sub>m</sub> **Q.99** For the series LCR circuit shown in the figure, what is  $t = \frac{v_{\text{m}}}{X_{\text{r}}}$  the resonance frequency and the amplitude of the current minals of a bV (rms) ac<br>
in the circuit is<br>
(B) 12 W<br>
(D) 18 W<br>
mt is –<br>
(B) I<sub>rms</sub> cos  $\phi$ <br>
(B) I<sub>ms</sub> cot  $\phi$ <br> **NANCE**<br>
own in the figure, what is<br>
ne amplitude of the current<br>
amplitude of the current<br>
(B) 2500 rad-s<sup></sup>



(C) 2500 rad-s<sup>-1</sup> and 
$$
\frac{5}{\sqrt{2}}
$$
 A (D) 25 rad-s<sup>-1</sup> and 5 $\sqrt{2}$ A

**Q.100** In the circuit given, what will be the reading of the



**Q.101** The resonance point in  $X_L$  – f and  $X_C$  – f curves is



 $(A)$  P (B) Q  $(C)$  R  $(D)$  S

**Q.102** In an LCR circuit, the sharpness of resonance depends on–



- $(C)$  Resistance  $(R)$  (D) All of these
- **Q.103** In LCR circuit, if the resistance increases, the quality factor –



(C) remain constant (D) none of these

**Q.104** At resonance frequency the impedance in series LCR  $\qquad \qquad (C)$  50 circuit is

(A) Maximum (B) Minimum (C) Zero (D) Infinity

- **Q.105** To reduce the resonant frequency in an LCR series circuit with a generator
	- (A) The generator frequency should be reduced.
	- (B) Another capacitor should be added in parallel to the first.
	- (C) The iron core of the inductor should be removed.
	- (D) Dielectric in the capacitor should be removed.
- **Q.106** Quality factor and power factor both have the dimensions of



# **PART 16 : LC OSCILLATIONS**

**Q.107** An oscillator circuit consists of an inductance of 0.5mH and a capacitor of 20µF. The resonant frequency of the circuit is nearly (A) 15.92 Hz (B) 159.2 Hz (C) 1592 Hz (D) 15910 Hz

 $Q.108$  A charged  $30\mu$ F capacitor is connected to a  $27\text{mH}$ inductor. The angular frequency of free oscillations of the circuit is



capacitor with an initial charge of 5mC. The total energy stored in the circuit initially is  $(A) 5 J$  (B) 0.5 J  $(C) 50 J$  (D) 500 J

# **PART 17 : AC GENERATOR AND TRANSFORMERS**

- **Q.110** In a transformer 220 ac voltage is increased to 2200 volts. If the number of turns in the secondary are 2000, then the number of turns in the primary will be **–**  $(A) 200$  (B) 100  $(D) 20$
- **Q.111** The ratio of secondary to the primary turns in a transformer is  $3:2$ . If the power output be P, then the input power neglecting all loses must be equal to –  $(A) 5 P$  (B) 1.5 P (C) P (D) (2/5) P
- **Q.112** The primary winding of a transformer has 100 turns and its secondary winding has 200 turns. The primary is connected to an ac supply of 120V and the current flowing in it is 10A. The voltage and the current in the secondary are –

(A) 240 V, 5 A (B) 240 V, 10 A (C) 60 V, 20 A (D) 120 V, 20 A

- **Q.113** In a step up transformer, 220 V is converted into 200 V. The number of turns in primary coil is 600. What is the number of turns in the secondary coil  $(A) 60$  (B) 600 (C) 6000 (D) 100
- **Q.114** The core of a transformer is laminated to reduce (A) Flux leakage (B) Hysteresis (C) Copper loss (D) Eddy current

# **EXERCISE - 2 (LEVEL-2)**

# **Choose one correct response for each question.**

- **Q.1** A circular coil of radius 8 cm, 400 turns and resistance  $2\Omega$  is placed with its plane perpendicular to the horizontal component of the earth's magnetic field. It is rotated about its vertical diameter through 180º in 0.30 s. Horizontal component of earth magnetic field at the place is  $3 \times 10^{-5}$  T. The magnitude of current induced in the coil is approximately  $(A) 4 \times 10^{-2} A$  (B)  $8 \times 10^{-4} A$ 
	- (C)  $8 \times 10^{-2}$  A (D)  $1.92 \times 10^{-3}$  A
- **Q.2** In a coil current falls from 5A to 0A in 0.2 s. If an average emf of 150 V is induced, then the self inductance of the coil is



- **Q.3** A metal conductor of length 1m rotates vertically about one of its ends with an angular velocity 5 rad  $s^{-1}$ . If the horizontal component of earth's magnetic field is  $0.2 \times 10^{-4}$  T, then the emf developed between the ends of the conductor is  $(A) 5\mu V$  (B) 5mV  $(C)$  50 $\mu$ V (D) 50 $\text{mV}$ **Q.4** The line that draws power supply to your house from
- street has
	- (A) 220  $\sqrt{2}$  V average voltage
	- (B) 220V average voltage
	- (C) Voltage and current out of phase by  $\pi/2$
	- (D) Voltage and current possibly differing in phase  $\phi$ such that  $|\phi| < \pi/2$ .

# **EMI AND AC QUESTION BANK**



- **Q.5** A conducting wire of 100 turns is wound over 1 cm near Q.14 the centre of a solenoid of 100 cm length and 2 cm radius having 1000 turns. The mutual inductance of the two coils is
	- (A)  $1.58 \times 10^{-4}$  V (B)  $1.58 \times 10^{-3}$  V
	- (C)  $2.11 \times 10^{-4}$  V (D)  $2.11 \times 10^{-3}$  V
- **Q.6** The magnetic flux through a coil perpendicular to its plane and directed into paper is varying according to the relation  $\phi = (2t^2 + 4t + 6)$  mWb. The emf induced in the loop at  $t = 4s$  is  $(A) 0.12 V$  (B) 2.4 V



**Q.7** The self inductance of an inductor coil having 100 turns is 20mH. The magnetic flux through the cross-section of the coil corresponding to a current of 4mA is<br>(A)  $2 \times 10^{-5}$  Wb<br>(B)  $4 \times 10^{-7}$  Wb  $(A)$  2  $\times$  10<sup>-5</sup> Wh

(C) 
$$
8 \times 10^{-7}
$$
 Wb (D)  $8 \times 10^{-5}$  Wb  
(C)  $8 \times 10^{-7}$  Wb (D)  $8 \times 10^{-5}$  Wb

$$
(D) 0^{\wedge} 10^{\wedge} 10^{\w
$$

- **Q.8** If the number of turns per unit length of a coil of solenoid is doubled, the self-inductance of the solenoid will (A) Remain unchanged (B) Be halved (C) Be doubled (D) Become four times
- **Q.9** A circular coil expands radially in a region of magnetic field and no electromotive force is produced in the coil. This is because
	- (A) The magnetic field is constant.
	- (B) The magnetic field is in the same plane as the circular coil and it may or may not vary.
	- (C) The magnetic field has a perpendicular (to the plane of the coil) component whose magnitude is decreasing suitably.
	- (D) Both  $(B)$  and  $(C)$ .
- **Q.10** Two coils have self-inductance  $L_1 = 4 \text{mH}$  and  $L_2 = 1 \text{mH}$  Q.17 The rwo coils have sen-inductance  $L_1$  = 4mH and  $L_2$  = 1mH  $Q$ , 17<br>respectively. The currents in the two coils are increased at the same rate. At a certain instant of time both coils are given the same power. If  $I_1$  and  $I_2$  are the currents in the two coils at that instant of time respectively, then the value of  $(I_1/I_2)$  is
	- $(A) 1/8$  (B) 1/4
	- $(C)$  1/2 (D) 1
- **Q.11** The magnetic flux linked with coil, in weber is given by the equation,  $\phi = 5t^2 + 3t + 16$ . The induced emf in the coil in the fourth second is –  $(A) 10 V$  (B) 30 V



- **Q.12** If a coil of 40 turns and area 4.0 cm<sup>2</sup> is suddenly removed from a magnetic field, it is observed that a charge of  $2.0 \times 10^{-4}$ C flows into the coil. If the resistance of the coil is 80  $\Omega$ , the magnetic flux density in Wb/m<sup>2</sup> is  $(A) 0.5$  (B) 1.0  $(C) 1.5$  (D) 2.0
- **Q.13** A circular coil is radius 5 cm has 500 turns of a wire. The approximate value of the coefficient of self induction of the coil will be-



- When the current in a coil changes from 8 ampere to 2 ampere in  $3 \times 10^{-2}$  second, the e.m.f. induced in the coil is 2volt. The self inductance of the coil (in millihenry) is (A) 1 (B) 5
	- (C) 20 (D) 10
- **Q.15** If a current of 3.0 amperes flowing in the primary coil is reduced to zero in 0.001 second, then the induced e.m.f. in the secondary coil is 15000 volts. The mutual inductance between the two coils is
	- (A) 0.5 henry (B) 5 henry
	- (C) 1.5 henry (D) 10 henry
- **Q.16** An equilateral triangular loop ABC made of uniform thin wires is being pulled out of a region with a uniform speed

v, where a uniform magnetic field  $\vec{B}$  perpendicular to the plane of the loop exists. At time  $t = 0$ , the point A is at the edge of the magnetic field. The induced current (I) vs time (t) graph will be as



- The inductance of a coil is  $60\mu$ H. A current in this coil increases from 1.0 A to 1.5 A in 0.1 second. The magnitude of the induced e.m.f. is (A)  $60 \times 10^{-6}$ V (B)  $300 \times 10^{-4}$ V  $(C) 30 \times 10^{-4} V$  (D)  $3 \times 10^{-4} V$
- **Q.18** If in a coil rate of change of area is  $5 \text{ m}^2/\text{milli}$  second and current become 1 amp from 2 amp in  $2 \times 10^{-3}$  sec. If magnitude of field is 1 tesla then self inductance of the coil is
	- $(A) 2 H$  (B) 5 H  $(C) 20 H$  (D) 10 H
- **Q.19** A metallic square loop ABCD is moving in its own plane with velocity v in a uniform magnetic field perpendicular to its plane as shown in the figure. Electric field is induced:

 $000000000000$  $000000000000$  $\circ$   $\circ$   $\circ$   $\circ$  $0000$  $\circ$   $\circ$   $\circ$   $\circ$   $\circ$   $\circ$  $000$  $\circ \circ \circ^D \theta$ <del>. . . .</del> 6  $000000000000$ 

(A) in AD, but not in BC

- (B) in BC, but not in AD
- (C) neither in AD nor in BC
- (D) in both AD and BC



- **Q.20** A coil resistance  $20\Omega$  and inductance 5H is connected with a 100V battery. Energy stored in the coil will be  $(A)$  41.5 J  $(B)$  62.50 J  $(C)$  125 J  $(D)$  250 J
- **Q.21** In the figure magnetic energy stored in the coil is





- **Q.22** The armature of dc motor has  $20\Omega$  resistance. It draws current of 1.5 ampere when run by 220volts dc supply. The value of back e.m.f. induced in it will be  $(A) 150 V$  (B) 170 V (C) 180 V (D) 190 V
- **Q.23** A step-down transformer is connected to 2400 volts line and 80 amperes of current is found to flow in output load. The ratio of the turns in primary and secondary coil is 20 : 1. If transformer efficiency is 100%, then the current flowing in primary coil will be –  $(A) 1600 A$  (B) 20 A
- $(C) 4A$  (D) 1.5 A **Q.24** A 100% efficient transformer has 100 turns in the primary and 25 turns in its secondary coil. If the current in the secondary coil is 4 amp, then the current in the pri-



- **Q.25** A bicycle wheel of radius 0.5 m has 32 spokes. It is  $Q.31$ rotating at the rate of 120 revolutions per minute, perpendicular to the horizontal component of earth's magnetic field  $B_H = 4 \times 10^{-5}$  tesla. The emf induced between the rim and the centre of the wheel will be-<br>(A)  $6.28 \times 10^{-5}$  V (B)  $4.8 \times 10^{-5}$  V  $(A)$  6.28  $\times$  10<sup>-5</sup> V  $(C) 6.0 \times 10^{-5} \text{ V}$  (D)  $1.6 \times 10^{-5} \text{ V}$
- **Q.26** A short-circuited coil is placed in a time-varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved, the electrical power dissipated would be



**Q.27** Current growth into L-R circuits (b) and (c) is as shown in figure (a). Let  $L_1$ ,  $L_2$ ,  $R_1$  and  $R_2$  be the corresponding values in two circuits, then –





 $(A) R_1 > R_2$  $(B) R_1 < R_2$  $(C) L_1 > L_2$  $(D) L_1 < L_2$ 

**Q.28** A wire in the form of a circular loop of radius 10cm lies in a plane normal to a magnetic field of 100 T. If this wire is pulled to take a square shape in the same plane in 0.1 s, average induced emf in the loop is:

(A) 6.70 volt (B) 5.80 volt (C) 6.75 volt (D) 5.75 volt

- **Q.29** A short circuited coil is placed in a time varying magnetic field. Electrical power is dissipated due to the current induced in the coil. If the number of turns were to be quadrupled and the wire radius halved, the electrical power dissipated would be
	- (A) halved (B) the same
	- (C) doubled (D) quadrupled
- **Q.30** A semicircular wire of radius R is rotated with constant angular velocity  $\omega$  about an axis passing through one end and perpendicular to the plane of the wire. There is a uniform magnetic field of strength B. The induced emf between the ends is

 $(A)$  BoR<sup>2</sup>/2

(C) is variable

(D) none of these

 $(B)$  2B $\omega$ R<sup>2</sup>



**Q.31** A conducting square loop is placed in a magnetic field B with its plane perpendicular to the field. The sides of the loop start shrinking at a constant rate  $\alpha$ . The induced emf in the loop at an instant when its side is  $a'$  is –

(A) 
$$
2a\alpha B
$$
  
\n(C)  $2a^2\alpha B$   
\n(B)  $a^2\alpha B$   
\n(D)  $a\alpha B$ 

**Q.32** A rectangular loop of wire with dimensions shown in coplanar with a long wire carrying current I. The distance between the wire and the left side of the loop is r. The loop is pulled to the right as indicated. What are the directions of the induced current in the loop and the magnetic forces on the left and right sides of the loop as the loop is pulled?



**current left side right side** (A) Counter To the left To the left clockwise (B) Counter To the right To the left

clockwise

(C) Clockwise To the right To the left

(D) Clockwise To the left To the right

**340**



**Q.33** The emf  $E = 4 \cos 1000t$  volts is applied to an L-R circuit  $Q.38$ containing inductance 3mH and resistance  $4\Omega$ . The amplitude of current is –



**Q.34** A capacitor and a resistor are connected with an A.C. source as shown in figure. Reactance of capacitor is  $X_{\rm C}$  = 3 $\Omega$  and resistance of resistor is 4 $\Omega$ . The phase



**Q.35** In the circuit shown, assuming all ammeters to be ideal, **Q.41** if readings of the hot wire ammeters  $A_1$  and  $A_2$  are  $i_1$  and  $i_2$  respectively then reading of the hot wire ammeter  $A_3$ is –



- (A) equal to  $(i_1 + i_2)$ (B) greater than  $(i_1 + i_2)$ (C) less than  $(i_1 + i_2)$ (D) equal to 2  $(i_1 - i_2)$
- **Q.36** For a LCR series circuit with an A.C. source of angular frequency  $\omega$ .

(A) Circuit will be capacitive if 
$$
\omega > \frac{1}{\sqrt{LC}}
$$

- (B) Circuit will be inductive if  $\omega = \frac{1}{\sqrt{LC}}$
- (C) Power factor of circuit will by unity if capacitive reactance equals inductive reactance.
- (D) Current will be leading voltage if  $\omega > \frac{1}{\sqrt{LC}}$
- **Q.37** An infinitely long cylinder is kept parallel to an uniform magnetic field B directed along positive z-axis. The direction of induced current as seen from the z-axis will be –
	- (A) clockwise of the positive z-axis
	- (B) anticlockwise of the positive z-axis
	- (C) zero
	- (D) along the magnetic field
- **Q.38** An inductor of 30 mH is connected to a 220V, 100Hz ac source. The inductive reactance is
	- (A)  $10.58 \Omega$  (B)  $12.64 \Omega$ (C)  $18.85 \Omega$  (D) 22.67  $\Omega$
- **AND AC**<br>
The emf E = 4 cos 1000t volts is applied to an L-R circuit **Q.38** An inductor of 30 mH is containing inductance 3mH and resistance 4Ω. The<br>
amplitude of current is –<br>
(A)  $4\sqrt{7}$  A (B) 1.0 A (C) 18.85 Ω<br>
(C) (4 4  $\sqrt{520}$  segments ab and cd. **OUESTIONBANK**<br> **EDERTIONBANK**<br> **EDERTIONBANK IDESTION BANK**<br>
OUESTION BANK<br>
ONES is applied to an L-R circuit Q.38 An inductor of 30 mH is connected to a 220V, 100Hz ac<br>
mH and resistance 42. The<br>
(A) 10.58  $\Omega$  (B) 12.64  $\Omega$ <br>
(B) 1.0A<br>
(D) 0.8A<br>
(D) 0.8A<br>
(D) and **Q.39** The figure shows certain wire segments joined together to form a coplanar loop. The loop is placed in a perpendicular magnetic field in the direction going into the plane of the figure. The magnitude of the field increases with time.  $I_1$  and  $I_2$  are the currents in the

(A) 
$$
I_1 > I_2
$$

(B)  $I_1 < I_2$ (C) I<sub>1</sub> is in the  $\frac{x + x + x}{a}$ direction ba and  $I_2$ is in the direction cd (D)  $I_1$  is in the direction ab and  $I_2$  is in the direction dc



- **Q.40** The rms value of current in an  $a^{\times} a^{\times} c^{\times} c^{\times} d\tilde{x}$  is 25Å, then peak current is
	- (A) 35.36 mA (B) 35.36 A  $(C) 3.536A$   $(D) 49.38A$
- **(a)**<br>
Sinot<br>
Sinot<br>
(a)  $\chi$ <br>
(c)  $\chi$ <br>
and  $\chi$  and  $\chi$ <br>
a 3) 37°<br>
(a) 3.536 m<br>
(c) 49.38 m<br>
all ammeters to be ideal, **Q.41** When an AC source of emf e=E<sub>0</sub>sin (100t) is contained by the bot wire ammet **Q.41** When an AC source of emf  $e = E_0 \sin(100t)$  is connected across a circuit, the phase difference between the emf e and the current i in the circuit is observed to be  $\pi/4$  as shown in the diagram. If the circuit consists possibly only of R-C or R-L or L-C series, find the relationship between the two elements.



(A)  $R = 1kQ$ ,  $C = 10\mu F$  (B)  $R = 1kQ$ ,  $C = 1\mu F$ (C)  $R = 1kQ$ ,  $L = 10H$  (D)  $R = 1kQ$ ,  $C = 1H$ 

 $Q.42$  A step down transformer converts transmission line LC transformer has 6000 turns and efficiency of the shown in the diagram. If the circuit consists possibly<br>
only of R-C or R-L or L-C series, find the relationship<br>
between the two elements.<br>
Let than  $(i_1 + i_2)$ <br>
ater than  $(i_1 + i_2)$ <br>
ater than  $(i_1 + i_2)$ <br>  $(i_1 - i_2)$ <br>
sour voltage from 11000 V to 220 V. The primary of the transformer is 60%. If the output power is 9kW, then the input power will be Let unguain. The best alternative in the contract of the relationship<br>  $2 \cdot C = 10 \mu F$  (B)  $R = 1k\Omega$ ,  $C = 1 \mu F$ <br>  $2 \cdot L = 10H$  (D)  $R = 1k\Omega$ ,  $C = 1 \mu F$ <br>  $2 \cdot L = 10H$  (D)  $R = 1k\Omega$ ,  $C = 1H$ <br>
on the 11000 V to 220 V. The primary C or R-L or L-C series, find the relationship<br>
two elements.<br>  $\sum_{k=1}^{n} C_k^e$ <br>  $\sum_{k=1}^{n} C_k^e$ 

LC (A) 11 kW (B) 12 kW (C) 14 kW (D) 15 kW

**Q.43** If  $V = 100 \sin(100 t) V$  and

$$
\frac{1}{LC}
$$
 I = 100 sin  $\left(100t + \frac{\pi}{3}\right)$  mA are the instantaneous values

of voltage and current, then the rms values of voltage and current are respectively



 $(C) 25$  (D) 30



**Q.45** A 5µF capacitor is connected to a 200 V, 100 Hz ac source. The capacitive reactance is



**Q.46** Resonance frequency of a circuit is f. If the capacitance is made 4 times the initial value, then the resonance frequency will become :



**Q.47** A pure resistive circuit element X when connected to an ac supply of peak voltage 200V gives a peak current of 5A which is in phase with the voltage. A second circuit element Y, when connected to the same ac supply also gives the same value of peak current but the current lags behind by 90º. If the series combination of X and Y is connected to the same supply, what will be the rms value of current ?

(A) 
$$
\frac{10}{\sqrt{2}}
$$
A (B)  $\frac{5}{\sqrt{2}}$ A (C)  $\frac{5}{2}$ A (D) 5A (A) 7.0  $\Omega$   
(C) 9.9  $\Omega$ 

**Q.48** In a series LCR circuit the voltage across the resistance, capacitance and inductance is 10V each. If the capacitance is short circuited, the voltage across the inductance will be

(A) 10V (B)  $10\sqrt{2}$  V

 $(C) (10/\sqrt{2})V$  (D) 20V

- **Q.49** A series LCR circuit with  $R = 22\Omega$ ,  $L = 1.5H$  and  $C = 40\mu F$ is connected to a variable frequency 220V ac supply. When the frequency of the supply equals the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle ? (A) 2000 W (B) 2200 W (C) 2400 W (D) 2500 W
- **Q.50** A circuit consists of a resistance of  $10\Omega$  and a capacitance of  $0.1 \mu$ F. If an alternating emf of 100V, 50Hz is applied, the current in the circuit is (A) 3.14 mA (B) 6.28 mA
	- (C) 1.51 mA (D) 7.36 mA
- **Q.51** The relation between an ac voltage source and time in SI units is  $V = 120 \sin(100 \pi t) \cos(100 \pi t)$  V. The value of peak voltage and frequency will be respectively

$$
(A) 120 V and 100 Hz \t\t (E)
$$

(B) 
$$
\frac{120}{\sqrt{2}}
$$
 V and 100Hz shall be

(C) 60V and 200Hz (D) 60V and 100Hz

**Q.52** A voltage of peak value 283 V and varying frequency is applied to series LCR combination in which  $R = 3\Omega$ , L = 25 mH and  $C = 400 \mu F$ . Then the frequency (in Hz) of the source at which maximum power is dissipated in the above is



**Q.53** A small town with a demand of 800 kW of electric power at 220 V is situated 15 km away from an electric plant generating power at 440V. The resistance of the two wire line carrying power is  $0.5 \Omega$  per km. The town gets power from the line through a 4000, 220V step down transformer at a substation in the town. The line power loss in the form of heat is

(A) 400 kW (B) 600 kW (C) 300 kW (D) 800 W

**Q.54** A coil of 0.01 H inductance and  $1\Omega$  resistance is connected to 200 V, 50 Hz ac supply. The time lag between maximum alternating voltage and current is  $(A)$  (1/250) s (B) (1/300) s  $(C)$  (1/200) s (D) (1/350) s

**Q.55** A sinusoidal voltage of peak value 293 V and frequency 50 Hz is applied to a series LCR circuit in which  $R = 6\Omega$ .  $L = 25$  mH and  $C = 750 \mu$ F. The impedance of the circuit is

$$
\frac{5}{2}A \t(D) 5A \t(A) 7.0 \Omega \t(B) 8.9 \Omega(C) 9.9 \Omega \t(D) 10.0 \Omega
$$

- **Q.56** A 60 $\mu$ F capacitor is connected to a 110V (rms), 60 Hz ac supply. The rms value of current in the circuit is  $(A) 1.49A$  (B) 14.9 A
- $(C)$  2.49 A  $(D)$  24.9 A **Q.57** A 100  $\mu$ F capacitor in series with a 40  $\Omega$  resistor is connected to a 100 V, 60 Hz supply. The maximum current in the circuit is
- $(A) 2.65 A$  (B) 2.75 A  $(C) 2.85 A$   $(D) 2.95 A$ **Q.58** The equation of AC voltage is  $E = 200 \sin{(\omega t + \pi/6)}$  and the A.C. current is I = 10 sin ( $\omega t$  +  $\pi/6$ ). The average power dissipated is –
	- (A) 150 W (B) 550 W (C) 250 W (D) 50 W
- **Q.59** If a capacitor of  $8\mu$ F is connected to a 220 V, 100 Hz ac source and the current passing through it is 65 mA, then the rms voltage across it is (A) 129.4 V (B) 12.94 V
	- $(C) 1.294 V$  (D) 15 V

**Q.60** An alternating voltage (in volts) given by

(A) 120 V and 100 Hz (B)  $\frac{120}{5}$  V and 100 Hz ammeter and the average power consumed in the circuit  $V = 200\sqrt{2} \sin(100t)$  is connected to 1µF capacitor through an ideal ac ammeter in series. The reading of the shall be





# **EXERCISE - 3 (NUMERICAL VALUE BASED QUESTIONS)**

# **NOTE : The answer to each question is a NUMERICAL VALUE. PART-A - Electromagnetic induction**

**Q.1** A metallic rod of mass 1 kg and length  $\sqrt{\pi}$ m is hinged at point D can rotate in the plane of the paper. Other end of the rod slides on the metallic semicircular wire ABC. Point D of the rod and point C of the semicircular portion is connected by a resistance of  $1\Omega$ . If a constant inward perpendicular magnetic field of magnitude 2T exists in the region, find the minimum angular velocity (in radian/ sec) given to the rod in position DA so that it reaches position DC. Neglect force due to gravity, friction, resistance of rod and semicircular wire  $(\pi^2 = 10)$ .



**Q.2** A square loop of area  $2.5 \times 10^{-3}$  m<sup>2</sup> and having 100 turns with a total resistance of  $100\Omega$  is moved out of a uniform magnetic field of 0.40T in 1 sec. with a constant speed. Then what is the work done, in pulling the loop (in  $\mu$ J)



**Q.3** Consider the circuit shown in figure. With switch  $S_1$  **Q.6** closed and the other two switches open, the circuit has a time constant  $0.05$  sec. With switch  $S_2$  closed and the other two switches open, the circuit has a time constant 2 sec. With switch  $S_3$  closed and the other two switches open, the circuit oscillates with a period T. Find T  $(in \sec.)$  (Take  $\pi^2 = 10$ )



**Q.4** Side rail of length 2L are fixed on a horizontal plane at a distance  $\ell$  from each other. These ends are connected by two identical ideal batteries with emf E by resistanceless wires (see figure). On the rails is a rod of mass m, which may slide along them. The entire system

is placed in a uniform vertical magnetic field B. Assuming that the resistance of the rod is R and the resistance per unit length of each of the rails equal to  $\rho$ , find the period of small oscillation (in sec.) arising from shifting the rod from the equilibrium along the rails. Neglect friction, internal resistance of batteries and induced emf in the rod. [Take :  $B = \pi T$ ,  $E = \pi$  volt,  $\ell = 0.5$ m,  $L = 1$ m,  $\rho = 1\Omega/m$ ,  $R = 0.25\Omega$ , m = 100gm]



**Q.5** Two long straight wires of telephone circuit inside a house are coplanar with and run parallel to a third long straight conductor that carries a current  $i = i_0$  sin ot. The wires are at a distance of  $d_1$  and  $d_2$  from the conductor. The conductor induced a noise in the telephone circuit. The rms voltage per unit length of this induced emf is  $2 \times 10^{-x}$  V. Find the value of x. <sup>=</sup> 2 2 <sup>A</sup> and the set of the phone circuit inside a<br>  $\frac{1}{2}$  and  $\frac{1}{2}$  and  $\frac{1}{2}$  and  $\frac{1}{2}$  and  $\frac{1}{2}$  from the conductor.<br>  $\frac{1}{2}$  and  $\frac{1}{2}$  from the conductor and the telephone circuit.<br>  $\frac{1}{2}$  and  $\frac{1}{$ Example 1<br>
For long straight wires of telephone circuit inside a<br>
nouse are coplanar with and run parallel to a third long<br>
traight conductor that carries a current  $i = i_0 \sin \omega t$ . The<br>
wires are at a distance of  $d_1$  and

[Take 
$$
d_2 = 2d_1
$$
,  $i_0 = \frac{2\sqrt{2}}{\ln 2} A$ ,  $\omega = 50 \text{ rad/s}$ ]  
\n



**Q.6** A uniform magnetic field exists in region given by  $\vec{B} = 3\hat{i} + 4\hat{j} + 5\hat{k}$ . A rod of length 5m is placed along

y-axis is move along x-axis with constant speed 1 m/sec. Then induced emf in the rod 5x volt then find the value of x.

**Q.7** A long circular tube of length 10 m and radius 0.3 m carries a current I along its curved surface as shown. A wire-loop of resistance 0.005 ohm and of radius 0.1 m is placed inside the tube with its axis coinciding with the axis of the tube. The current varies as  $I = I_0 \cos \theta$ (300 t) where  $I_0$  is constant. If the magnetic moment of the loop is  $N\mu_0 I_0 \sin(300t)$ , then N is





# **PART-B : Alternating current**

**Q.1** In the circuit diagram shown,  $X_C = 100 \Omega$ ,  $X_L = 200 \Omega$  & AC  $R = 100 \Omega$ . The effective current through the source is



**Q.2** A series R-C combination is connected to an AC voltage of angular frequency  $\omega$  = 500 radian/s. If the impedance

> of the R-C circuit is  $R\sqrt{1.25}$ , the time constant (in millisecond) of the circuit is

- **Q.3** In a series L-R circuit, connected with a sinusoidal as source, the maximum potential difference across L and R  $_{Q,6}$ are respectively 3 volts and 4 volts. At an instant the potential difference across resistor is 2 volts. The potential difference in volt, across the inductor at the  $Q.7$ same instant is  $(X)$  cos 30°. Find the value of X. 2VX A then lind value of x.<br>  $\frac{1}{2}$  is found that<br>  $\frac{1}{2}$  is 50V. Then the value of<br>  $\frac{1}{2}$ <br>
A series R-C combination is connected to an AC voltage<br>
of angular frequency  $\omega = 500$  radian/s. If the impedance<br>
of t
- **Q.4** In the above question at the same instant, the magnitude of the potential difference in volt, across the ac source

is 
$$
\frac{X+3\sqrt{3}}{2}
$$
. Find the value of X.

**Q.5** Consider the RLC circuit shown below connected to an AC source of constant peak voltage  $V_0$  and variable frequency  $\omega_0$  value of L = 20 mH. For a certain value  $\omega_0$ <br>=  $\omega_1$ , rms voltage across L, C, R are shown in the diagram.  $=\omega_1$ , rms voltage across L, C, R are shown in the diagram. At  $\omega_0 = \omega_2$ , it is found that rms voltage across resistance **EXECTS AND SET SET SET SAMPLE SET SOURCE SET SOURCE SET SOURCE THE VALUE OF SAMPLE SET SOURCE A SOLUTION TO SOLUTION THE VALUE IS 50 V X V. Find the value**  $\frac{R}{30 \text{V}}$ 

is 50V. Then the value of  $V_0$  is 50 $\sqrt{X}$  V. Find the value of X.



**Q.6** In above question the value of  $\omega_2$  is  $\sqrt{\frac{X}{5}}\omega_1$ . Find the  $\frac{1}{5}$  $\omega_1$ . Find the

value of X.

In above question the phase difference between voltage on L and C is  $X\pi$ . Find the value of X.

**EMI AND AC QUESTION BANK**



# **EXERCISE - 4 [PREVIOUS YEARS JEE MAIN QUESTIONS]**

**Q.1** When a rectangular loop pulled out from uniform **Q.8** magnetic field. The induced current is proportional to **[AIEEE-2002]**



**Q.2** Resultant inductance of the circuit will be **[AIEEE-2002]**



**Q.3** The power factor of an A.C. circuit having resistance (R) and inductance (L) connected in series and an angular velocity  $\omega$  is – [AIEEE-2002]

(A) 
$$
\frac{R}{\omega L}
$$
 (B)  $\frac{R}{(R^2 + \omega^2 L^2)^{1/2}}$ 

(C) 
$$
\frac{\omega L}{R}
$$
 (D)  $\frac{R}{(R^2 - \omega^2 L^2)^{1/2}}$ 

- **Q.4** In a transformer, number of turns in the primary are 140 and that in the secondary are 280. If current in primary is 4 A, then that in the secondary is – **[AIEEE-2002]**  $(A) 4A$  (B) 2 A  $(C) 6A$  (D) 10 A
- **Q.5** Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon

### **[AIEEE-2003]**

- (A) Relative position and orientation of the two coils
- (B) The materials of the wires of the coils
- (C) The currents in the two coils
- (D) The rates at which currents are changing in the two coils.
- **Q.6** When the current changes from  $+2A$  to  $-2A$  in 0.05 second, an e.m.f. of 8 V is induced in a coil. The coefficient of self-induction of the coil is & **[AIEEE-2003]**  $(A) 0.4 H$  (B) 0.8 H  $(C) 0.1 H$  (D) 0.2 H
- **Q.7** Power factor of the circuit is – **[AIEEE-2003]**



- The core of any transformer is laminated so as to  $-$ 
	- (A) Make it light weight **[AIEEE-2003]**
	- (B) Make it robust and strong
	- (C) Increase the secondary voltage
	- (D) Reduce the energy loss due to eddy current
- **Q.9** A coil having n turns and resistance  $R\Omega$  is connected with a galvanometer of resistance  $4R\Omega$ . This combination is moved in time t seconds from a magnetic field  $W_1$ weber to  $W_2$  weber. The induced current in the circuit is **EE MAIN QUESTIONS**<br> **EE MAIN QUESTIONS**<br>
The core of any transformer is laminated so as to –<br>
(A) Make it light weight [AIEEE-2003]<br>
(B) Make it robust and strong<br>
(D) Incease the secondary voltage<br>
(D) Reduce the energy **SOLUTATE SET AND SURFAINING**<br> **SOLUTATE SURFAINING**<br> **SOLUTATE SURFAINING**<br> **SOLUTATE SURFAINING**<br> **SOLUTATE SURFAINERE 1003**<br> **E** it robust and strong<br>
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d so as to –<br>
[AIEEE-2003]<br>
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d so as to –<br>
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c urrent<br>  $\Omega$  is connected<br>
his combination<br>
gnetic field W<sub>1</sub><br>
in the circuit is<br>
[AIEEE-2004]<br>  $V_2 - W_1$ )<br>
5 R t<br>  $W_2 - W_1$ )<br>
R t<br>
B

**[AIEEE-2004]**

(A) 
$$
-\frac{(W_2 - W_1)}{5 R n t}
$$
 (B)  $-\frac{n (W_2 - W_1)}{5 R t}$ 

(C) 
$$
-\frac{(W_2 - W_1)}{R n t}
$$
 (D)  $-\frac{n (W_2 - W_1)}{R t}$ 

→ v<br>
(B)  $t^{-1}$ <br>
(B)  $t^{-1}$ <br>
(B)  $t^{-1}$ <br>
(B)  $t^{-2}$ <br>
(B)  $t^{-1}$ <br>
(B)  $t^{-2}$ <br>
(B) 9H<br>
(B) 9H<br>
(B) 2.10 In a uniform magnetic field of induction B a we be to W<sub>2</sub> weber. The induced current in the<br>
(B) 9H<br>
(B) 9H<br>
(B) 7.5 R of the circuit is R the mean power generated per period d out from uniform **Q.8** The core of any transformer is laminated so as to—<br>
(AIEEE-2003) (A) Make it light weight weight weight weight (C) Increase the secondary voltage<br>
(C) Increase the secondary voltage<br>  $e^{-1}$ <br> **(AIE** (B)  $\frac{1}{\sqrt{12}}$ <br>
(B)  $\frac{1}{\sqrt{2}}$ <br>
(D)  $\frac{1}{\sqrt{2}}$ <br>
(D) (C) Increase the secondary voltage<br>
(C) Incelase the energy loss due to eddy current<br>
(D) Reduce the energy loss due to ddy current<br>  $\frac{1}{\sqrt{2}}$ <br>  $\frac{1}{\sqrt{2}}$ <br>  $\frac{1}{\sqrt{2}}$ <br>  $\frac{1}{\sqrt{2}}$ <br>  $\frac{1}{\sqrt{2}}$ <br>  $\frac{1}{\sqrt{2}}$ <br>  $\frac{$ **EE MAIN QUESTIONS**<br> **EE MAIN QUESTIONS**<br>
The core of any transformer is laminated so as to –<br>
(A) Make it tight weight<br>
(B) Make it trobust and strong<br>
(C) Increase the secondary voltage<br>
(D) Reduce the energy loss due t **IN QUESTIONS**<br> **EXECUTE:**<br> **S**<br> **EDENTADE ANDERE SERVE AND SET CONSUMISTED ATTENTION**<br>
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S laminated so as to -<br>
[AIEEE-2003]<br>
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SO as to -<br>
AIEEE-2003]<br>
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2 is connected<br>
is combination<br>
metic field  $W_1$ <br>
in the circuit is<br>
[AIEEE-2004]<br>  $\frac{2-W_1}{Rt}$ <br>
R t<br>  $B$  a wire in the<br>
ut the diameter<br>
co. The axis of<br>
total resistance<br> **Q.10** In a uniform magnetic field of induction B a wire in the form of a semicircle of radius r rotates about the diameter of the circle with an angular frequency  $\omega$ . The axis of rotation is perpendicular to the field. If the total resistance of rotation is – **[AIEEE-2004]** Make it robust and strong<br>
ncrease the secondary voltage<br>
Reduce the energy loss due to eddy current<br>
and mains and resistance RQ is connected<br>
and all naving n turns and resistance AR2. This combination<br>
oved in time t s ore of any transformer is laminated so as to-<br>
ake it light weight<br>
ake it robust and strong<br>
crease the secondary voltage<br>
clude the energy loss due to eddy current<br>
having n turns and resistance RΩ is connected<br>
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o eddy current<br>
nce RΩ is connected<br>
RΩ. This combination<br>
a magnetic field W<sub>1</sub><br>
current in the circuit is<br>
[AIEEE-2004]<br>
-  $\frac{n (W_2 - W_1)}{5 R t}$ <br>
-  $\frac{n (W_2 - W_1)}{R t}$ <br>
uction B a wire in the<br>
ttes about the diameter<br> aded so as to –<br>
[AIEEE-2003]<br>
ddy current<br>
e RΩ is connected<br>
2. This combination<br>
magnetic field W<sub>1</sub><br>
rent in the circuit is<br>
[AIEEE-2004]<br>
1 (W<sub>2</sub> – W<sub>1</sub>)<br>
5 R t<br>
1 (W<sub>2</sub> – W<sub>1</sub>)<br>
R t<br>
tion B a wire in the<br>
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vil having n turns and resistance RΩ is connected<br>
a galvanometer of resistance RΩ is connected<br>
oved in time t seconds from a magnetic field W<sub>1</sub><br>
er to W<sub>2</sub> weber. The induced Ke it rotoust and strong<br>
rease the secondary voltage<br>
rease the secondary voltage<br>
duce the energy loss due to eddy current<br>
having n turns and resistance RΩ is connected<br>
real and mime t seconds from a magnetic field W o eddy current<br>nce RΩ is connected<br>RΩ. This combination<br>a magnetic field W<sub>1</sub><br>uurrent in the circuit is<br> $[AIEEE-2004]$ <br> $-\frac{n (W_2 - W_1)}{5 R t}$ <br> $-\frac{n (W_2 - W_1)}{R t}$ <br>uction B a wire in the<br>tes about the diameter<br>uency ω. The axis o ddy current<br>
2. RΩ is connected<br>
2. This combination<br>
magnetic field W<sub>1</sub><br>
rent in the circuit is<br>
[AIEEE-2004]<br>
5 R t<br>
1 (W<sub>2</sub> - W<sub>1</sub>)<br>
5 R t<br>
1 (W<sub>2</sub> - W<sub>1</sub>)<br>
R t<br>
tion B a wire in the<br>
about the diameter<br>
ncy ω. The ax

$$
\frac{R}{v^{2} L^{2}} \qquad (A) \frac{B \pi r^{2} \omega}{2R} \qquad (B) \frac{(B \pi r^{2} \omega)^{2}}{8 R^{2}} \qquad (C) \frac{(B \pi r \omega)^{2}}{2R} \qquad (D) \frac{(B \pi r \omega^{2})^{2}}{8 R^{2}} \qquad (E \omega)^{2}
$$

- having n turns and resistance RΩ is connected<br>alwanometer of resistance 4RΩ. This combination<br>ed in time t seconds from a magnetic field W<sub>1</sub><br>o W<sub>2</sub> weber. The induced current in the circuit is<br> $[AIEEE-2004]$ <br> $\frac{W_2 W_1}{5 R t$ **Q.11** A metal conductor of length 1 m rotates vertically about one of its ends at angular velocity 5 radians per second. If the horizontal component of earth's magnetic field is  $0.2 \times 10^{-4}$ T, then the e.m.f. developed between the two ends of the conductor is – **[AIEEE-2004]** (A)  $5 \mu V$  (B)  $50 \mu V$  $(C) 5 mV$  (D) 50 mV
- Friemdual<br>
on the mutual<br>
on the conductor is—<br>
(A) 5 pV<br>
(C) 5 mV<br>
(C) 5 mV<br>
(C) 5 mV<br>
(C) 8 methands (C) 5 mV<br>
(C) 8 methands (C) 8 methands by D.C. ammeter<br>
condis<br>
(A) A.C. can not pass through D.C. Ammeter<br>
changing **Q.12** Alternating current can not be measured by D.C. ammeter because – **[AIEEE-2004]** (A) A.C. can not pass through D.C. Ammeter (B) A.C. changes direction (C) Average value of current for complete cycle is zero
	- (D) D.C. Ammeter will get damaged
	- **Q.13** In an LCR series a.c. circuit, the voltage across each of the components, L, C and R is 50 V. The voltage across the LC combination will be – **[AIEEE-2004]**

$$
(A) 50 V \t\t (B) 50 \sqrt{2}
$$

- (C)  $100 \text{ V}$  (D)  $0 \text{ V (zero)}$
- **Q.14** In a LCR circuit capacitance is changed from C to 2C. For the resonant frequency to remain unchanged, the inductance should be changed from L to **[AIEEE-2004]**  $(A)$  4 L  $(B)$  2 L  $(C) L/2$  (D)  $L/4$
- bils<br>
is (B) A.C. channot distance distance in the two<br>
(B) A.C. channels direction<br>
(C) Average value of current for complete cy<br>
om +2A to -2A in 0.05<br>
(D) D.C. Ammeter will get damaged<br>
eed in a coil. The coefficient<br> R **Q.15** A coil of inductance 300 mH and resistance  $2\Omega$  is connected to a source of voltage 2 V. The current reaches half of its steady state value in **[AIEEE-2005]**  $(A) 0.05 s$  (B) 0.1 s  $(C) 0.15 s$  (D) 0.3 s
- **Q.16** The self inductance of the motor of an electric fan is 10 H. In order to impart maximum power at 50 Hz, it should be connected to a capacitance of – **[AIEEE-2005]**  $(A)$  4 $\mu$ F (B) 8 $\mu$ F  $(C) 1 \mu F$  (D)  $2 \mu F$
- **Q.17** One conducting U tube can slide inside another as shown in figure, maintaining electrical contacts between the tubes. The magnetic field B is perpendicular to the plane of the figure. If each tube moves towards the other at a constant speed V, then the emf induced in the circuit in terms of B,  $\ell$  and V where  $\ell$  is the width of each tube, will be  $\times$   $\times$   $\times$   $\times$   $\times$   $\times$   $\times$   $\phantom{0}$  [AIEEE-2005]



- **Q.18** A circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be – (A) 0.8 (B) 0.4 **[AIEEE-2005]**  $(C)$  1.25  $(D)$  0.125
- **Q.19** The phase difference between the alternating current and emf is  $\pi/2$ . Which of the following cannot be the constituent of the circuit ? **[AIEEE-2005]**  $(A)$  C alone  $(B)$  R L  $(C) LC$  (D) L alone
- **Q.20** The flux linked with a coil at any instant 't' is given by  $\phi$ =10t<sup>2</sup>–50t+250. The induced emf at t = 3 s is (A) 10 V (B) 190 V **[AIEEE 2006]**  $(C) - 190 V$  (D) – 10 V
- **Q.21** In an AC generator, a coil with N turns, all of the same area A and total resistance R, rotates with frequency  $\omega$ in a magnetic field B. The maximum value of emf generated in the coil is – **[AIEEE 2006]**  $(A)$  N.A.B.R. (B) N.A.B. $\omega$  $(C) N.A.B.R.\omega$  (D) N.A.B.
- **Q.22** An inductor (L = 100 mH), a resistor (R = 100  $\Omega$ ) and a battery ( $E = 100$  V) are initially connected in series as shown in the figure. After a long time the battery is disconnected after short circuiting the points A and B. The current in the circuit 1 ms after the short circuit is – <sup>L</sup> **[AIEEE 2006]**



**Q.23** In a series resonant LCR circuit, the voltage across R is 100 volts and R = 1 k $\Omega$  with C = 2 µF. The resonant frequency  $\omega$  is 200 rad/s. At resonance the voltage across L is – **[AIEEE 2006]** (A) 250 V (B)  $4 \times 10^{-3}$  V  $(C) 2.5 \times 10^{-2}$  V (D) 40 V

**Q.24** In an a.c. circuit the voltage applied is  $E = E_0$  sinot. The

**STUDY MATERIAL: PHYSICS**  
\nIn an a.c. circuit the voltage applied is 
$$
E = E_0
$$
 sin $\omega t$ . The resulting current in the circuit is  $I = I_0 \sin \left(\omega t - \frac{\pi}{2}\right)$ . The power consumption in the circuit is given by  
\n(A)  $P = \frac{E_0 I_0}{\sqrt{2}}$  (B)  $P =$  zero [AIEEE 2007]

power consumption in the circuit is given by

**EXAMPLE 12.2 PROOF MATERIAL: PHYSICS**  
\nIn an a.c. circuit the voltage applied is 
$$
E = E_0
$$
 sin $\omega t$ . The resulting current in the circuit is  $I = I_0 \sin \left(\omega t - \frac{\pi}{2}\right)$ . The power consumption in the circuit is given by  
\n(A)  $P = \frac{E_0 I_0}{\sqrt{2}}$  (B)  $P =$  zero [**AIEEE 2007**]  
\n(C)  $P = \frac{E_0 I_0}{2}$  (D)  $P = \sqrt{2} E_0 I_0$   
\nAn ideal coil of 10H is connected in series with a resistance of 5 $\Omega$  and a battery of 5V. 2 seconds after the connection is made the current flowing in amperse in

**STUDY MATERIAL: PHYSICS**<br>
2. circuit the voltage applied is  $E = E_0$  sinot. The<br>
g current in the circuit is  $I = I_0 \sin \left(\omega t - \frac{\pi}{2}\right)$ . The<br>
consumption in the circuit is given by<br>  $\frac{E_0 I_0}{\sqrt{2}}$  (B) P = zero [AIEEE 200 **Q.25** An ideal coil of 10H is connected in series with a resistance of  $5\Omega$  and a battery of 5V. 2 seconds after the connection is made, the current flowing in amperes in the circuit is - **[AIEEE 2007]**  $(A)(1-e)$  (B) e

(C) 
$$
e^{-1}
$$
 (D)  $(1 - e^{-1})$ 

**Q.26** Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area  $A = 10$  cm<sup>2</sup> and length = 20 cm. If one of the solenoids has 300 turns and the other 400 turns, their mutual inductance is<br> $\mu = 4\pi \times 10^{-7}$  T m A<sup>-1</sup>) [AIEEE 2008]  $(\mu = 4\pi \times 10^{-7} \text{ T m A}^{-1})$  [AIEEE 2008]

$$
(A 4.8 \pi \times 10^{-4} H
$$
  
\n
$$
(A 4.8 \pi \times 10^{-4} H
$$
  
\n
$$
(B) 4.8 \pi \times 10^{-5} H
$$
  
\n
$$
(D) 2.4 \pi \times 10^{-5} H
$$
  
\n
$$
(D) 2.4 \pi \times 10^{-5} H
$$

resistances  $R_1 = 2 \square$  and  $R_2 = 2 \square$  are connected to a **Q.27** An inductor of inductance  $L = 400$  mH and resistors of battery of emf 12V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at  $t = 0$ . The potential drop across L as a function of time is – **[AIEEE 2009]**



**Q.28** A rectangular loop has a sliding connector PQ of length l and resistance R  $\Omega$  and it is moving with a speed v as shown. The set-up is placed in a uniform magnetic field going into the plane of the paper. The three currents  $I_1$ ,  $\overline{1}$ and I are – **[AIEEE 2010]**

E  
\n
$$
\begin{array}{c}\nE\n\end{array}
$$
\n(A) 6 e<sup>-5t</sup>V\n  
\n(C) 6 [1 - e<sup>-t/0.2</sup>) V\n  
\nA rectangular loop has a sliding connection PQ of length  $\ell$  and resistance R  $\Omega$  and it is moving with a speed v as shown. The set-up is placed in a uniform magnetic field going into the plane of the paper. The three currents I<sub>1</sub>, I<sub>2</sub> and I are\n
$$
\begin{array}{c}\nI_2 \text{ and } I_1 \text{ are}\n\end{array}
$$
\n(A) I<sub>1</sub> = -I<sub>2</sub> =  $\frac{B\ell v}{R}$ , I =  $\frac{2B\ell v}{R}$   
\n(B) I<sub>1</sub> = I<sub>2</sub> =  $\frac{B\ell v}{3R}$ , I =  $\frac{2B\ell v}{3R}$   
\n(C) I<sub>1</sub> = I<sub>2</sub> = I =  $\frac{B\ell v}{R}$  (D) I<sub>1</sub> = I<sub>2</sub> =  $\frac{B\ell v}{6R}$ , I =  $\frac{B\ell v}{3R}$ 

(C) 
$$
I_1 = I_2 = I = \frac{B\ell v}{R}
$$
 (D)  $I_1 = I_2 = \frac{B\ell v}{6R}$ ,  $I = \frac{B\ell v}{3R}$ 



**Q.29** In the circuit shown below, the key K is closed at  $t = 0$ . **Q.34** The current through the battery is – **[AIEEE 2010]**



- **Q.30** In a series LCR circuit R =  $200 \Omega$  and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30°. On taking out the inductor from the circuit the current leads the voltage by  $30^{\circ}$ . The power dissipated in the LCR  $_{0.36}$ circuit is – **[AIEEE 2010]** (A) 305 W (B) 210 W (C) Zero (D) 242 W <sup>K<sub>2</sub>  $\sqrt{R_1^2 + R_2^2}$ <br>
(D)  $\frac{V(R_1 + R_2)}{(R_1 + R_2)}$  at  $t = 0$  and  $\frac{V}{R_2}$  at  $t = \infty$ <br>
In a series LCR circuit R = 200 Ω and the voltage and the<br>
frequency of the main supply is 220 V and 50 Hz<br>
frequency of the main </sup>
- **Q.31** A fully charged capacitor C with initial charge  $q_0$  is connected to a coil of self inductance L at  $t = 0$ . The time at which the energy is stored equally between the electric and the magnetic fields is – **[AIEEE 2011]**

(A) 
$$
\pi\sqrt{LC}
$$
  
\n(B)  $\frac{\pi}{4}\sqrt{LC}$   
\n(C)  $2\pi\sqrt{LC}$   
\n(D)  $\sqrt{LC}$   
\n(A) Work done by the batted  
\ndissipated in the resist

- **Q.32** A boat is moving due east in a region where the earth's magnetic field is  $5.0 \times 10^{-5}$  NA<sup>-1</sup>m<sup>-1</sup> due north and horizontal. The boat carries a vertical aerial 2m long. If the speed of the boat is  $1.50 \text{ ms}^{-1}$ , the magnitude of the<br>induced emfinities wire of aerial is: [AIEEE 2011] 0.37 induced emf in the wire of aerial is : **[AIEEE 2011]**  $(A) 1 mV$  (B) 0.75 mV  $(C) 0.50 \text{ mV}$  (D)  $0.15 \text{ mV}$
- **Q.33** A coil is suspended in a uniform magnetic field, with the plane of the coil parallel to the magnetic lines of force. When a current is passed through the coil it starts oscillating; it is very difficult to stop. But if an aluminium plate is placed near to the coil, it stops. This is due to –  **[AIEEE 2012]**
	- (A) development of air current when the plate is placed.
	- (B) induction of electrical charge on the plate
	- (C) shielding of magnetic lines of force as aluminium is a paramagnetic material.
	- (D) Electromagnetic induction in the aluminium plate giving rise to electromagnetic damping.

A metallic rod of length  $\ell$  is tied to a string of length  $2\ell$ and made to rotate with angular speed  $\omega$  on a horizontal table with one end of the string fixed. If there is a verticalmagnetic field .B. in the region, the e.m.f. induced across the ends of the rod is – **[JEE MAIN 2013]**



- **Q.35** A circular loop of radius 0.3 cm lies parallel to a much bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0A flows through the smaller loop, then the flux linked with bigger
	- loop is **[JEE MAIN 2013]**<br>(A)  $9.1 \times 10^{-11}$  weber **(B)**  $6 \times 10^{-11}$  weber  $(A)$  9.1 × 10<sup>-11</sup> weber (C)  $3.3 \times 10^{-11}$  weber (D)  $6.6 \times 10^{-9}$  weber
- In an LCR circuit as shown below both switches are open initially. Now switch  $S_1$  is closed,  $S_2$  kept open. (q is charge on the capacitor and  $\tau = RC$  is Capacitive time constant). Which of the following statement is correct



- (A) Work done by the battery is half of the energy dissipated in the resistor.
- (B) At  $t = \tau$ ,  $q = CV/2$
- (C) At  $t = 2\tau$ ,  $q = CV(1 e^{-2})$
- (D) At  $t = \tau/2$ ,  $q = CV (1 e^{-1})$
- In the circuit shown here, the point 'C' is kept connected to point 'A' till the current flowing through the circuit becomes constant. Afterward, suddenly, point 'C' is disconnected from point 'A' and connected to point 'B' at time  $t = 0$ . Ratio of the voltage across resistance and the inductor at  $t = L/R$  will be equal to **[JEE MAIN 2014]**



**Q.38** An inductor (L = 0.03 H) and a resistor (R = 0.15 k $\Omega$ ) are connected in series to a battery of 15 V EMF in a circuit shown below. The key  $K_1$  has been kept closed for a long time. Then at  $t = 0$ ,  $K_1$  is opened and key  $K_2$  is closed simultaneously. At  $t = 1$  ms, the current in the circuit will be  $(e^5 \approx 150)$  [JEE MAIN 2015]





**Q.39** An LCR circuit is equivalent to a damped pendulum. In an LCR circuit the capacitor is charged to  $Q_0$  and then connected to the L and R as shown **[JEE MAIN 2015]**



If a student plots graphs of the square of maximum charge  $(Q<sup>2</sup><sub>max</sub>)$  on the capacitor with time (t) for two different values  $L_1$  and  $L_2(L_1 > L_2)$  of L then which of the following represents this graph correctly?

(Plots are schematic and not drawn to scale)



- **Q.40** A red LED emits light at 0.1 watt uniformly around it. The amplitude of the electric field of the light at a distance of 1 m from the diode is **[JEE MAIN 2015]** (A) 2.45 V/m (B) 5.48 V/m (C) 7.75 V/m (D) 1.73 V/m
- **Q.41** An arc lamp requires a direct current of 10 A at 80 V to function. If it is connected to a 220 V (rms), 50 Hz AC supply, the series inductor needed for it to work is close to **[JEE MAIN 2016]**  $(A) 0.08$  H (B) 0.044 H  $(C) 0.065 H$  (D) 80 H

**Q.42** For an RLC circuit driven with voltage of amplitude  $v_m$ **STUDY MATERIAL: PHYSICS**<br>
For an RLC circuit driven with voltage of amplitude v<sub>m</sub><br>
and frequency  $\omega_0 = 1/\sqrt{LC}$  the current exhibits<br>
resonance. The quality factor, Q is given by :<br> **[JEE MAIN 2018]**<br>
(A)  $\frac{R}{\omega_0 C}$  resonance. The quality factor, Q is given by : **[JEE MAIN 2018] STUDY MATERIAL: PHYSICS**<br>
For an RLC circuit driven with voltage of amplitude v<sub>m</sub><br>
and frequency  $\omega_0 = 1/\sqrt{LC}$  the current exhibits<br>
resonance. The quality factor, Q is given by :<br> **[JEE MAIN 2018]**<br>
(A)  $\frac{R}{\omega_0 C}$  **EXECUTE 10** VANTERIAL: PHYSICS<br>
th voltage of amplitude v<sub>m</sub><br>  $\overline{C}$  the current exhibits<br>  $\overline{C}$ , Q is given by :<br> **[JEE MAIN 2018]**<br> **(B)**  $\frac{CR}{\omega_0}$ <br> **(D)**  $\frac{\omega_0 R}{L}$ <br>
aneous e.m.f. and current<br>  $= 20 \sin \left(30t -$ 

(A) 
$$
\frac{R}{\omega_0 C}
$$
 (B)  $\frac{CR}{\omega_0}$   
(C)  $\frac{\omega_0 L}{R}$  (D)  $\frac{\omega_0 R}{L}$ 

**Q.43** In an a.c. circuit, the instantaneous e.m.f. and current

are given by 
$$
e = 100\sin 30t
$$
,  $i = 20\sin\left(30t - \frac{\pi}{4}\right)$ . In one

cycle of a.c., the average power consumed by the circuit and the wattless current are, respectively:

### **[JEE MAIN 2018]**

(A) 
$$
\frac{50}{\sqrt{2}}
$$
, 0 (B) 50, 0

(C) 50, 10   
 (D) 
$$
\frac{1000}{\sqrt{2}}
$$
, 10

- **Q.44** A conducting circular loop made of a thin wire, has area  $3.5 \times 10^{-3}$  m<sup>2</sup> and resistance 10 $\Omega$ . It is placed perpendicular to a time dependent magnetic field  $B(t) = (0.4T) \sin (50\pi t)$ . The field is uniform in space. Then the net charge flowing through the loop during  $t = 0$  s and  $t = 10$  ms is close to: [JEE MAIN 2019 (JAN)]  $(A) 0.14$  mC  $(B) 21$  mC  $(C) 6 \text{ mC}$  (D) 7 mC x 10<sup>-3</sup> m<sup>2</sup> and resistance 10Ω. It is placed<br>mdicular to a time dependent magnetic field<br>endicular to a time dependent magnetic field<br>endicular to a time dependent magnetic field<br>the met charge flowing through the loo magnetic field<br>is uniform in space.<br>the loop during<br>**MAIN 2019 (JAN)**]<br>mC<br>mductor (20 mH), a<br>mcmductor (20 mH), a<br>gy dissipated in the<br>**MAIN 2019(JAN)**]<br> $39 \times 10^3$  J<br> $17 \times 10^2$  J<br>ected to a 10 ohm<br>e. The time at which<br>v
- **Q.45** A series AC circuit containing an inductor (20 mH), a capacitor (120  $\mu$ F) and a resistor (60 $\Omega$ ) is driven by an AC source of 24V (50 Hz). The energy dissipated in the circuit in 60 s is : **[JEE MAIN 2019(JAN)]**  $(A)$  2.26  $\times$  10<sup>3</sup> J J  $(B) 3.39 \times 10^3$  J (C)  $5.65 \times 10^2$  J  $J$  (D)  $5.17 \times 10^2$  J
- **Q.46** A 20 Henry inductor coil is connected to a 10 ohm resistance in series as shown in figure. The time at which rate of dissipation of energy (joule's heat) across resistance is equal to the rate at which magnetic energy is stored in the inductor is**[JEE MAIN 2019 (APRIL)]**



(C) 
$$
2 \ln 2
$$
 (D)  $\frac{1}{2} \ln 2$ 

# **EMI AND AC QUESTION BANK**



- **Q.47** A long solenoid of radius R carries a time dependent current  $I = I_0$  t (1 – t). A ring of radius 2R is placed coaxially near its centre. During the time interval  $0 \le t \le 1$ , the induced current I<sub>R</sub> and the induced emf V<sub>R</sub> in the ring vary as: **[JEE MAIN 2020 (JAN)]**
	- (A) Current will change its direction and its emf will be zero at  $t = 0.25$ sec.
	- (B) Current will not change its direction  $&$  emf will be maximum at  $t = 0.5$ sec
	- (C) Current will not change direction and emf will be zero at 0.25sec.
	- (D) Current will change its direction and its emf will be zero at  $t = 0.5$ sec.
- **Q.48** A planar loop of wire rotates in a uniform magnetic field. Initially, at  $t = 0$ , the plane of the loop is perpendicular to the magnetic field. If it rotates with a period of 10 s about an axis in its plane then the magnitude of induced emf will be maximum and minimum, respectively at :



**Q.49** An inductor of inductance 10 mH and a resistance of  $5\Omega$ is connected to a battery of 20 V at  $t = 0$ . Find the ratio of current in circuit at  $t = \infty$  to current at  $t = 40$  sec.



**Q.50** At time  $t = 0$  magnetic field of 100 Gauss is passing perpendicularly through the area defined by the closed loop shown in the figure. If the magnetic field reduces linearly to 500 Gauss, in the next 5s, then induced EMF in the loop is : **[JEE MAIN 2020 (JAN)]**



- **Q.51** In a fluorescent lamp choke (a small transformer) 100 V of reverse voltage is produced when the choke current changes uniformly from 0.25 A to 0 in a duration of 0.025ms. The self-inductance of the choke (in mH) is estimated to be \_\_\_\_\_. **[JEE MAIN 2020 (JAN)**]
- **Q.52** An alternating voltage v(t) = 220 sin 100  $\pi$ t volt is applied to a purely resistance load of 50  $\Omega$ . The time taken for the current to rise from half of the peak value to the peak value is : **[JEE MAIN 2019 (APRIL)]** (A) 2.2 ms (B) 5 ms (C) 3.3 ms (D) 7.2 ms
- **Q.53** A circuit connected to an ac source of emf  $e = e_0 \sin$ (100t) with t in seconds, gives a phase difference of  $\pi/4$ between the emf e and current i. Which of the following circuits will exhibit this ? **[JEE MAIN 2019 (APRIL)]** (A) RC circuit with  $R = 1$  k $\Omega$  and  $C = 1 \mu F$ (B) RL circuit with  $R = 1k\Omega$  and  $L = 1mH$ (C) RL circuit with  $R = 1 k\Omega$  and  $L = 10$  mH (D) RC circuit with R =  $1k\Omega$  and C = 10  $\mu$ F
- **Q.54** In LC circuit the inductance  $L = 40$  mH and capacitance  $C = 100 \mu F$ . If a voltage V(t) = 10sin (314 t) is applied to the circuit, the current in the circuit is given as :

# **[JEE MAIN 2020 (JAN)]**





# **EXERCISE - 5 [PREVIOUS YEARS AIPMT / NEET QUESTIONS]**

**Q.1** As a result of change in the magnetic flux linked to the **Q.8** closed loop shown in the figure, an emf of V volt is induced in the loop. The work done (joules) in taking a charge Q coulomb once along the loop is **[AIPMT 2005]**



**Q.2** In a circuit L, C and R are connected in series with an alternating voltage source of frequency f. The current leads the voltage by 45°. The value of C is

**[AIPMT 2005]**

OMANCA	STUDY P	
AS a result of change in the magnetic flux linked to the closed loop shown in the figure, an emtric flow is	Q.8 A transformer is used to light a induced in the loop. The work done (joules) in taking a charge Q coulomb once along the loop is $[AIPMT 2005]$	(A) 50% (C) 10% (D) 10% (E) 11% (E) 15% (E) 16% (E) 17% (E) 17% (E) 18% (E) 19% (E)

- **EXERCISE 5 [PREVIOUS VEARS AIPMIT /NEET QUESTION**<br>
result of change in the magnetic flux linked to the Q.8 A transformer is used to light<br>
ed loop shown in the figure, an emf of V volt is<br>
enced in the loop. The work d **Q.3** Two coils of self inductance 2mH and 8mH are placed so close together that the effective flux in one coil is completely linked with the other. The mutual inductance between these coils is – **[AIPMT 2006]** (A) 6mH (B) 4mH (C) 16mH (D) 10mH
- **Q.4** The core of a transformer is laminated because

**[AIPMT 2006]**

- (A) the weight of the transformer may be reduced.
- (B) rusting of the core may be prevented.
- (C) ratio of voltage in primary and secondary may be increased.
- (D) energy losses due to eddy currents may be minimised.
- **Q.5** A coil of inductive reactance  $31\Omega$  has a resistance of  $8\Omega$ . It is placed in series with a condenser of capacitive reactance  $25\Omega$ . The combination is connected to an a.c. source of 110volt. The power factor of the circuit is – (A) 0.64 (B) 0.80 **[AIPMT 2006]**  $(C) 0.33$  (D) 0.56
- **Q.6** What is the value of inductance L for which the current is maximum in a series LCR circuit with  $C = 10 \mu F$  and  $\omega = 1000s^{-1}$ . . **[AIPMT 2007]**
	- $(A)$  1mH
	- (B) cannot be calculated unless R is known
	- (C) 10mH
	- (D) 100mH
- **Q.7** The primary and secondary coil of a transformer have 50 and 1500 turns respectively. If the magnetic flux  $\phi$  linked with the primary coil is given by  $\phi = \phi_0 + 4t$ , where  $\phi$  is in webers, t is time in seconds and  $\phi_0$  is a constant, the output voltage across the secondary coil is –

# **[AIPMT 2007]**



- **Q.8** A transformer is used to light a 100W and 110V lamp from a 220V mains. If the main current is 0.5 amp, the efficiency of the transformer is approximately (A) 50% (B) 90% **[AIPMT 2007]**  $(C) 10\%$   $(D) 30\%$ **EVALUATE PUTATE ATTLE TO CONTROVER SET ATTLE ATTLE TO SET AND A SURFALL STATE AND A SURFALL AND A SURFALL SOUPS (B) 90% (B) 30% (B) EXERIAL: PHYSICS**<br>
OOW and 110V lamp<br>
urrent is 0.5 amp, the<br>
proximately<br>
00% [**AIPMT 2007**]<br>
10%<br>
the current (i) at any<br>  $e = E_0 \sin \omega t$ ;<br>
wer in the circuit over<br>
[**AIPMT 2008**]<br>  $E_0I_0/2$ <br>
When a current of 2<br>
sulting
- **Q.9** In an a.c. circuit the e.m.f. (e) and the current (i) at any instant are given respectively by  $e = E_0 \sin \omega t$ ;  $i = I_0 \sin(\omega t - \phi)$ . The average power in the circuit over one cycle of a.c. is **[AIPMT 2008]**  $(A) E_0 I_0$  $(B) E_0 I_0 / 2$

(C) 
$$
\frac{E_0 I_0}{2} \sin \phi
$$
 (D)  $\frac{E_0 I_0}{2} \cos \phi$ 

- 1 linked with each turn of the solenoid is  $4 \times 10^{-3}$  Wb. The **EXECUTE CONSTRAINT SUGNATIONS STEAD STEA** 1 (C) 2.0 henry (D) 1.0 henry **PREVIOUS VEARS AIPMT/NEET QUESTIONS**<br>
etic flux linked to the **Q.8** A transformer is used to light a 100W and 110V lamp<br>
an emf of V volt is<br>
from a 220V mains. If the main current is 0.5 amp, the<br>
etic (oules) in taking **Q.10** A long solenoid has 500 turns. When a current of 2 ampere is passed through it, the resulting magnetic flux self-inductance of the solenoid is – **[AIPMT 2008]**  $(A)$  4.0 henry (B) 2.5 henry ht a 100W and 110V lamp<br>
aain current is 0.5 amp, the<br>
is approximately<br>
(B) 90% [AIPMT 2007]<br>
(D) 30%<br>
e) and the current (i) at any<br>
y by e = E<sub>0</sub> sin ot ;<br>
[AIPMT 2008]<br>
(B) E<sub>0</sub>I<sub>0</sub>/2<br>
(D)  $\frac{E_0I_0}{2}$  cos  $\phi$ <br>
arm **NSI**<br>
a 100W and 110V lamp<br>
in current is 0.5 amp, the<br>
is approximately<br>
B) 90% [AIPMT 2007]<br>
D) 30%<br>
and the current (i) at any<br>
by  $e = E_0 \sin \omega t$ ;<br>
power in the circuit over<br>
[AIPMT 2008]<br>
B)  $E_0I_0/2$ <br>
D)  $\frac{E_0I_0}{2$ ht a 100W and 110V lamp<br>nain current is 0.5 amp, the<br>is approximately<br>(B) 90% [AIPMT 2007]<br>(D) 30%<br>e) and the current (i) at any<br>y by e = E<sub>0</sub> sin oot ;<br>ge power in the circuit over<br>[AIPMT 2008]<br>(B) E<sub>0</sub>I<sub>0</sub>/2<br>(D)  $\frac{E_0$ 
	- **Q.11** A circular disc of radius 0.2 meter is placed in a uniform

magnetic field of induction  $\frac{1}{\pi} \left( \frac{Wb}{m^2} \right)$  in such a way that

its axis makes an angle of  $60^{\circ}$  with B. The magnetic flux  $\vec{B}$  . The magnetic flux



**Q.12** A rectangular, a square, a circular and an elliptical loop, all in the  $(x - y)$  plane, are moving out of a uniform (A)  $E_0I_0$  (B)  $E_0I_0$  (B)  $E_0I_0$ <br>
(C)  $\frac{E_0I_0}{2}$  cos  $\phi$ <br>
A long solenoid has 500 turns. When a current of 2<br>
ampere is passed through it, the resulting magnetic flux<br>
linked with each turn of the solenoid is  $\vec{V} = v\hat{i}$ . The magnetic field is directed along the negative z axis direction. The induced emf, during the passage of these loops, out of the field region, will not remain constant for

(A) the circular and the elliptical loops. **[AIPMT 2009]**

- (B) only the elliptical loop.
- (C) any of the four loops.
- (D) the rectangular, circular and elliptical loops.
- **Q.13** A conducting circular loop is placed in a uniform magnetic field 0.04 T with its plane perpendicular to the magnetic field. The radius of the loop starts shrinking at 2 mm/s. The induced emf in the loop when the radius is 2 cm is:

(A) 
$$
4.8 \pi \mu V
$$
  
\n(B)  $0.8 \pi \mu V$  [AIPMT 2009]  
\n(C)  $1.6 \pi \mu V$   
\n(D)  $3.2 \pi \mu V$ 

**Q.14** Power dissipated in an LCR series circuit connected to an a.c source of emf  $\varepsilon$  is: **[AIPMT 2009]** 

its axis makes an angle of 60° with 
$$
\vec{B}
$$
. The magnetic flux  
\nlinked with the disc is [AIPMT 2008]  
\n(A) 0.01 Wb (B) 0.02 Wb  
\n(C) 0.06 Wb (D) 0.08 Wb  
\nArectangular, a square, a circular and an elliptical loop,  
\nall in the (x - y) plane, are moving out of a uniform  
\nmagnetic field with a constant velocity,  $\vec{V} = v\hat{i}$ . The  
\nmagnetic field is directed along the negative z axis  
\ndirection. The induced emf, during the passage of these  
\ntoors, out of the field region, will not remain constant  
\nfor  
\n(A) the circular and the elliptical loops. [AIPMT 2009]  
\n(B) only the elliptical loop.  
\n(C) any of the four loops.  
\nA conducting circular loop is placed in a uniform  
\nmagnetic field 0.04 T with its plane perpendicular to the  
\nmagnetic field. The radius of the loop starts shrinking at  
\n2 mm/s. The induced emf in the loop when the radius is  
\n2 cm is:  
\n(A) 4.8  $\pi V$  (B) 0.8 $\pi \mu V$  [AIPMT 2009]  
\n(A) 4.8  $\pi V$  (B) 0.8 $\pi \mu V$  [BIII2009]  
\n(A)  $\frac{\varepsilon^2 \sqrt{R^2 + (L\omega - \frac{1}{C\omega})^2}}{R}$  (B)  $\frac{\varepsilon^2 [R^2 + (L\omega - \frac{1}{C\omega})^2]}{R}$   
\n(C)  $\frac{\varepsilon^2 R}{\sqrt{R^2 + (L\omega - \frac{1}{C\omega})^2}}$  (D)  $\frac{\varepsilon^2 R}{[R^2 + (L\omega - \frac{1}{C\omega})^2]}$ 

**350**



**Q.15** In the given circuit the reading of voltmeter  $V_1$  and  $V_2$  **Q.21** are 300 volts each. The reading of the voltmeter  $V_3$  and ammeter A are respectively – **[AIPMT 2010 (PRE]**



 $(A) 150 V, 2.2 A$  (B) 220 V, 2.2 A  $(C)$  220 V, 2.0 A  $(D)$  100 V, 2.0 A

**Q.16** A220 volt input is supplied to a transformer. The output circuit draws a current of 2.0 ampere at 440 volts. If the efficiency of the transformer is 80% the current drawn by the primary windings of the transformer is –



**Q.17** A conducting circular loop is placed in a uniform magnetic field,  $B = 0.025$  T with its plane perpendicular to the loop. The radius of the loop is made to shrink at a constant rate of 1 mm  $s^{-1}$ . The induced emf when the radius is 2 cm, is **[AIPMT 2010 (PRE)]**  $(A) 2\pi \mu V$  (B)  $\pi \mu V$ primary windings of the transformer is-<br>  $\frac{1}{2}$  (B) 2.8 ampere<br>
(B) 2.8 ampere<br>
(D) 5.0 am If are<br>we a current of 2.0 ampere at 440 Vonis. Ir me<br>
iency of the tunsformer is 80% the current drawn<br>
le primary windings of the transformer is<br>
1.5 ampere<br>
(B) 5.0 ampere<br>
(B) 2.8 ampere<br>
(D) 5.0 ampere<br>
(D) 5.0 amper ency of the transformer is 80% the current drawn<br>
b/s ampere<br>
b/s map except (B) 2.8 ampere<br>
el cop. The radius of the loop is placed in a uniform<br>
tele (B) conducting circular loop is placed in a uniform<br>
netable, B = 0.025 with its plane perpendicular is  $(2)$ <br>
netable, B = 0.025 with its plane perpendicular<br>  $\frac{\pi}{2} \mu V$  (D) 2 $\mu V$ <br>
(B)  $\frac{\pi}{2} \mu V$  (D) 2 $\mu V$ <br>  $\frac{\pi}{2} \mu V$ 

(C) 
$$
\frac{\pi}{2} \mu V
$$
 (D)  $2\mu V$ 

**Q.18** A condenser of capacity C is charged to a potential difference of  $V_1$ . The plates of the condenser are then connected to an ideal inductor of inductance L. The current through the inductor when the potential difference across the condenser reduces to  $V_2$  is

**[AIPMT 2010 (MAINS)]**

Consider the two sum of two points in the  
constant rate of 1 mm s<sup>-1</sup>. The induced emf when the  
radius is 2 cm, is  

$$
(A)2\pi\mu V
$$
 (B)  $\pi\mu V$  (C)  $\frac{\pi}{2}\mu V$  (D)  $2\mu V$   
 $(C) \frac{\pi}{2}\mu V$  (D)  $2\mu V$   
 $(D) \frac{\pi}{2}\mu V$  (D)  $2\mu V$   
 $(D) \frac{\pi}{2}\mu V$  (D)  $2\mu V$   
 $(E) \frac{\pi}{2}\mu V$  (E)  $2\mu V$   
 $(E) \frac{\pi}{2}\mu$ 

volts is connected to capacitor of capacity 1µF. The r.m.s. value of the current in the circuit is



**Q.20** An ac voltage is applied to a resistance R and inductor L in series. If R and the inductive reactance are both equal to  $3\Omega$ , the phase difference between the applied voltage and the current in the circuit is –



**Q.21** The current i in a coil varies with time as shown in the figure. The variation of induced emf with time would

# **[AIPMT 2011 (PRE)]**



**Q.22** The rms value of potential difference Vshown in the figure is– **[AIPMT 2011 (MAINS)]**



(A) V<sub>0</sub> (B) V<sub>0</sub> / 
$$
\sqrt{2}
$$

 $(C) V_0/2$ 

Sommer is = 100 (PRE)<br>
[AIPMT 2010 (PRE)]<br>
2.8 ampere<br>
2.8 ampere<br>
2.8 ampere<br>
2.8 ampere<br>
2.8 ampere in a uniform<br>
is palae to shrink at a<br>
is palae erependicular<br>
is made to shrink at a<br>
44 ampere is—<br>
44 ampere is—<br>
44 L 100Hz, is connected across the coil, the current in the  $-\frac{V_2^2}{2}$  20ohm at 50 Hz frequency. If an ac source, of 200 volt, and to shrink at a<br>
laced in a uniform<br>
plane perpendicular<br>
1/2 3 3 M T 1 (D)<br>
1/2 2 The rms value of potential difference Vshown in the<br>
time the potential<br>
inductance L. The<br>
condenser are then<br>
inductance L. The<br>
then 2.8 ampere<br>
splane perpendicular<br>
splane perpendicular<br>
is made to shrink at a<br>
spane perpendicular<br>
(C)<br>
(PRE)<br>
(C)<br>
(PRE)<br>
(C)<br>
(A)<br>
(A)<br>
(A)<br>
(B)<br>
(B)<br>
(C)<br>
(B)<br>
(C)<br>
(A)<br>
(D)<br>
(B)<br>
(D)<br>
(D)<br>
(D)<br>
(D)<br>
(D)<br>
(D)<br>
(D)<br>
( 5.0 ampere<br>
gladed in a uniform<br>
is made to shrink at a<br>
is made to shrink at a<br>
dydiced of m when the<br>
dydical of the metrod of  $\sqrt{t}$  and  $t = \sqrt{t}$ <br>  $\sqrt{t}$ **Q.23** A coil has resistance 30 ohm and inductive reactance coil will be : **[AIPMT 2011 (MAINS)]**  $(A) 4.0 A$  (B) 8.0 A

L   
 (C) 
$$
\frac{20}{\sqrt{13}}A
$$
 (D) 2.0A

**Q.24** The current (I) in the inductance is varying with time according to the plot shown in figure. Which one of the following is the correct variation of voltage with time in the coil ? **[AIPMT 2012 (PRE)]**







- **Q.25** A coil of resistance  $400\Omega$  is placed in a magnetic field. If the magnetic flux  $\phi$  (wb) linked with the coil varies with time t (sec) as  $\phi = 50t^2 + 4$ . The current in the coil at  $t = 2 \sec is$ : **[AIPMT 2012 (PRE)]**  $(A) 0.5A$  (B) 0.1 A  $(C) 2A$  (D) 1 A
- **Q.26** In an electrical circuit R, L, C and an a.c. voltage source are all connected in series.When L is removed from the circuit, the phase difference between the voltage the current in the circuit is  $\pi/3$ . If instead, C is removed from the circuit, the phase difference is again  $\pi/3$ . The power factor of the circuit is : **[AIPMT 2012 (PRE)] COLLESTIONENTS**<br> **COLLESTIONENTS**<br> **COLLESTIONENTS**<br> **COLLESTIONENTS**<br> **COLLESTIONENTS**<br> **COLLESTIONENTS**<br> **COLLESTIONENTS**<br> **COLLESTIONENTS**<br> **COLLESTING**<br> **COLLESTING**<br> **COLLESTING**<br> **COLLESTING**<br> **COLLESTING**<br> **COLLES** (C) 1 (D) 3 / 2 C)  $\frac{1}{1/2}$  field B, as shown in figure. The<br>
A coil of resistance 40002 is placed in a magnetic field. If<br>
A coil of resistance 40002 is placed in a magnetic field. If<br>
the magnetic flux  $\phi$  (wb) linked with the coil

(A) 
$$
1/2
$$
 (B)  $1/\sqrt{2}$ 

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

**Q.27** The instantaneous values of alternating current and voltages in a circuit are given as :

$$
i = \frac{1}{\sqrt{2}} \sin (100\pi t) \text{ ampere }; \ e = \frac{1}{\sqrt{2}} \sin (100\pi t + \frac{\pi}{3}) \text{ volt} \text{ shown in} \text{
$$

The average power in Watts consumed in the circuit is **[AIPMT 2012 (MAINS)]**



**Q.28** In a coil of resistance  $10\Omega$ , the induced current developed by changing magnetic flux through it, is shown in figure as a function of time. The magnitude of change in flux through the coil in Weber is :



- **Q.29** A wire loop is rotated in magnetic field. The frequency of change of direction of the induced e.m.f. is – (A) Six times per revolution **[NEET 2013]** (B) Once per revolution
	- (C) twice per revolution
	- (D) four times per revolution
- **Q.30** A coil is self-inductance L is connected in series with a bulb B and an AC source. Brightness of the bulb decreases when **[NEET 2013]**
	- (A) an iron rod is inserted in the coil.
	- (B) frequency of the AC source is decreased.
	- (C) number of turns in the coil is reduced.
	- (D) A capacitance of reactance  $X_C = X_L$  is included in the same circuit.

**Q.31** A thin semicircular conducting ring (PQR) of radius r is falling with its plane vertical in a horizontal magnetic field B, as shown in figure. The potential difference developed across the ring when its speed is v, is

### **[AIPMT 2014]**



(A) Zero

(B)  $Bv\pi^2/2$  and P is at higher potential

- (C)  $\pi$ rBv and R is at higher potential (D) 2rBv and R is at higher potential
- **Q.32** A transformer having efficiency of 90% is working on 200V and 3 kW power supply. If the current in the secondary coil is 6A, the voltage across the secondary coil and the current in the primary coil respectively are –

**[AIPMT 2014]**

 $(A) 300 V, 15 A$  $(C)$  450 V, 13.5 A



LETTERT TREET THE SECTION TREAT TREAT TREAT TREAT TREET THE SECTION TREAT TREET TO USER THE SCREET TREET TO USER THE D)<br>  $\frac{1}{1/2}$ <br>  $\frac{1}{1/2}$ <br>
Field B, as shown in figure. The potential difference<br>
are developed across the ring when its speed is v, is<br>
and with the coli varies with<br>
e current in the coli at<br>
B)0.1A<br>
B)1A<br>
B)1A<br>
AlP **Q.33** A conducting square frame of side 'a' and a long straight wire carrying current I are located in the same plane as shown in the figure. The frame moves to the right with a constant velocity 'V'. The emf induced in the frame will be proportional to : **[AIPMT 2015]** Transfer that the control of 90% is working on<br>
If the current in the<br>
across the secondary<br>
coil respectively are —<br>
[AIPMT 2014]<br>
450 V, 15 A<br>
600 V, 15 A<br>
<sup>1</sup> a' and a long straight<br>
1 in the same plane as<br>
west to the



**Q.34** A resistance 'R' draws power 'P' when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes 'Z', the power drawn will be: **[AIPMT 2015]**

(A) 
$$
P\sqrt{R/Z}
$$
 \n(B)  $P(R/Z)$  \n(C)  $P$  \n(D)  $P(R/Z)^2$ 

**Q.35** An electron moves on a straight line path XY as shown. The abcd is a coil adjacent to the path of electron. What will be the direction of current, if any, induced in the coil



- (A) No current induced **[RE-AIPMT 2015]**
- (B) abcd
- (C) adcd
- (D) The current will reverse its direction as the electron goes past the coil

**EMI AND AC QUESTION BANK**



**Q.36** A series R-C circuit is connected to an alternating voltage source. Consider two situations :- (a) When capacitor is air filled. (b) When capacitor is mica filled. Current through resistor is i and voltage across capacitor is V then – **[RE-AIPMT 2015]**  $(A) V_a = V_b$  $(B)V_a < V_b$ 

 $(C)V_a > V_b$  $(D) i_a > i_b$ 

- **Q.37** A long solenoid has 1000 turns. When a current of 4 A flows through it, the magnetic flux linked with each turn of the solenoid is  $4 \times 10^{-3}$  Wb. The self inductance of the solenoid is **[NEET 2016 PHASE 1]**  $(A) 4 H$  (B) 3 H  $(C) 2 H$  (D) 1 H
- **Q.38** An inductor 20 mH, a capacitor 50  $\mu$ F and a resistor 40  $\Omega$  (C) 16  $\pi \mu$ C are connected in series across a source of emf  $V = 10\sin$ 340t. The power loss in A.C. circuit is



- **Q.39** A small signal voltage V (t) =  $V_0 \sin \omega t$  is applied across an ideal capacitor C **[NEET 2016 PHASE 1]**
	- (A) Current I (t) lags voltage V (t) by  $90^\circ$ .
	- (B) Over a full cycle the capacitor C does not consume any energy from the voltage source.
	- (C) Current I (t) is in phase with voltage V (t).
	- (D) Current I (t) leads voltage V (t) by  $180^\circ$ .
- **Q.40** Which of the following combinations should be selected for better tuning of an L-C-R circuit used for communication? **[NEET 2016 PHASE 2]**  $(A)$  R = 20  $\Omega$ , L = 1.5 H, C = 35 µF  $(B)$  R = 25  $\Omega$ , L = 2.5 H, C = 45 µF  $(C)$  R = 15  $\Omega$ , L = 3.5 H, C = 30 µF
	- (D)  $R = 25 \Omega$ ,  $L = 1.5$  H,  $C = 45 \mu F$
- **Q.41** A uniform magnetic field is restricted within a region of radius r. The magnetic field changes with time at a rate
	- $\frac{d\vec{B}}{dt}$ . Loop 1 of radius R > r encloses the region r and Q.47 If

loop 2 of radius R is outside the region of magnetic field as shown in the figure below. Then the e.m.f. generated is **[NEET 2016 PHASE 2]**



(A) Zero in loop 1 and zero in loop 2

(B) 
$$
\frac{d\vec{B}}{dt}\pi r^2
$$
 in loop 1 and  $-\frac{d\vec{B}}{dt}\pi r^2$  in loop 2. (A) 2  
(C) 2

(C) 
$$
-\frac{d\vec{B}}{dt} \pi r^2
$$
 in loop 1 and zero in loop 2

(D) 
$$
-\frac{dB}{dt} \pi r^2
$$
 in loop 1 and zero in loop 2

**Q.42** The potential differences across the resistance, capacitance and inductance are 80 V, 40 V and 100 V respectively in an L-C-R circuit. The power factor of this circuit is **[NEET 2016 PHASE 2]**  $(A) 0.4$  (B) 0.5

(C) 0.8 (D) 1.0

- **Q.43** A long solenoid of diameter 0.1 m has  $2 \times 10^4$  turns per meter. At the centre of the solenoid, a coil of 100 turns and radius 0.01 m is placed with its axis coinciding with the solenoid axis. The current in the solenoid reduces at a constant rate to 0A from 4 A in 0.05 s. If the resistance of the coil is  $10\pi^2\Omega$ . The total charge flowing through the coil during this time is  $-$  [NEET 2017]  $(A) 16 \mu C$  (B) 32  $\mu C$ (D)  $32 \pi \mu C$
- **Q.44** Figure shows a circuit that contains three identical resistors with resistance  $R = 9.0 \Omega$  each, two identical inductors with inductance  $L = 2.0$  mH each, and an ideal battery with emf  $e = 18$  V. The current 'i' through the battery just after the switch closed is – **[NEET 2017]**



- $(C)$  0 ampere  $(D)$  2 mA
- **Q.45** The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60mA. This inductor is of inductance **[NEET 2018]** (A) 1.389 H (B) 138.88 H  $(C) 0.138 H$  (D) 13.89 H
- **Q.46** An inductor 20 mH, a capacitor 100 µF and a resistor  $50\Omega$  are connected in series across a source of emf,  $V = 10 \sin 314$  t. The power loss in the circuit is (A) 2.74 W (B) 0.43 W **[NEET 2018]**  $(C) 0.79 W$  (D) 1.13 W
- **Q.47** In which of the following devices, the eddy current effect is not used? **[NEET 2019]** (A) Induction furnace
	-
	- (B) Magnetic braking in train
	- (C) Electromagnet (D) Electric heater
- $\mathbf{R}$ **Q.48** A 800 turn coil of effective area 0.05 m<sup>2</sup> is kept perpendicular to a magnetic field  $5 \times 10^{-5}$  T. When the plane of the coil is rotated by 90° around any of its coplanar axis in 0.1 s, the emf induced in the coil will be:  **[NEET 2019]**

$$
\frac{dB}{dt} \pi r^2 \text{ in loop 2.} \tag{A) 2 V} \tag{B) 0.2 V} \tag{B) 0.2 V} \tag{B) 0.2 V} \tag{C) 2 × 10-3 V} \tag{D) 0.02 V}
$$



# **ANSWER KEY**















# **ELECTROMAGNETIC INDUCTION**

# **TRY IT YOURSELF-1**

- **(1)** (D)
- **(2)** (B)
- **(3)** (B)
- **(4) (B).** If B is increasing at a constant rate  $\phi = B \cdot \pi R^2$

$$
V_{ind} = \left| \frac{d\phi}{dt} \right|
$$
  
\n
$$
= \pi R^2 \cdot \frac{dB}{dt} = E \cdot 2\pi R
$$
  
\n
$$
\Rightarrow E = \frac{R}{2} \frac{dB}{dt}
$$
. Acceleration of ring =  $\frac{dE}{m}$ ; a  $\propto q$   
\n(B)  
\n(C) Magnetic field lines in right direction are decreasing,  
\nso direction of I will be clockwise. The part of the loop  
\nfacing the north pole of magnet behaves as a south  
\n(1) A L =  $2\pi r$ ;  $\frac{2L}{\pi} = r$   
\n
$$
A = L^2
$$
;  $A = \pi \left( \frac{2L}{\pi} \right)^2 = \pi \frac{4L^2}{\sqrt{2}}$ ;  $\phi = B \frac{dA}{dt}$   
\n(C) Determine the right direction.  
\n
$$
A = \frac{L^2}{\sqrt{2}} \Rightarrow A = \pi \frac{2L}{\sqrt{2}}
$$
  
\n
$$
= \frac{L}{\sqrt{2}} \Rightarrow \phi = B \frac{dA}{dt}
$$
  
\n
$$
V = \frac{L}{R} \cos \theta
$$

- **(5)** (D)
- **(6)** (B)
- **(7) (C).** Magnetic field lines in right direction are decreasing, so direction of I will be clockwise. The part of the loop facing the north pole of magnet behaves as a south pole, so net force will be in right direction.

(9) (A). 
$$
4L = 2\pi r
$$
;  $\frac{2L}{\pi} = r$ 

$$
A = L2 ; A = \pi \left(\frac{2L}{\pi}\right)^{2} = \pi \frac{4L^{2}}{\sqrt{2}}; \phi = B \frac{dA}{dt}
$$

Clockwise lenz law

- **(10) (D).** Perpendicular length is more so induced emf is more.
- **(11) (AD).**

# **TRY IT YOURSELF-2**

**(1) (B).**  $I = I_0 e^{-t/\tau}$ ,  $\tau = L/R$ 

- **(2)** (D)
- **(3) (AD).** Pd =  $-\frac{Ldi}{dt}$ ;  $\frac{di}{dt}$  = -ve
- **(4)** (A)
- **(5)** (A)
- **(6)** (AD)
- (7) Suppose a current  $I_2$  flows through the outer cicular coil. Magnetic field at the centre of the coil is

$$
B_2 = \frac{\mu_0 I_2}{2R}
$$

 $\frac{0I_2}{000 \text{ MADVANCED LEARNING}}$ <br>
(a) be considered constant over the cross-sec-<br>
of the inner smaller coil. Hence Field  $B_2$  may be considered constant over the cross-sectional area of the inner smaller coil. Hence

$$
B_2 = \frac{\mu_0 I_2}{2R}
$$
  
\nField  $B_2$  may be considered constant over the cross-  
\national area of the inner smaller coil. Hence  
\n
$$
\phi_1 = \pi R^2 B_2 = \frac{\mu_0 \pi r^2 I_2}{2R} = M I_2
$$
\n
$$
M = \frac{\phi_1}{I_2} = \frac{\mu_0 \pi r^2}{2R}
$$
  
\n(i) Mutual inductance increased on decreasing distance.  
\n(ii) Mutual inductance decreased on decreasing the number  
\nof turns.  
\n**(b)**. The current-time (i-t) equation in L-R circuit is given  
\nby [Growth of current in L-R circuit]  
\n $i = i_0 (1 - e^{-t/\tau L})$  ......... (1)  
\nwhere  $i_0 = \frac{V}{R} = \frac{12}{6} = 2A$   
\nand  $\tau_L = \frac{L}{R} = \frac{8.4 \times 10^{-3}}{6} = 1.4 \times 10^{-3} s$   
\nand  $i = 1A$  (given),  $t = ?$   
\nSubstituting these values in eq. (1), we get  
\n $t = 0.97 \times 10^{-3} s = 0.97$  ms  
\n $t \approx 1$  ms

**(8)** (i) Mutual inductance increased on decreasing distance.

(ii) Mutual inductance decreased on decreasing the number of turns.

dE **(9) (D).** The current-time (i-t) equation in L-R circuit is given  $m \rightarrow a \times q$  by [Growth of current in L-R circuit]

$$
i = i_0 (1 - e^{-t/\tau L})
$$
 .........(1)

where 
$$
i_0 = \frac{V}{R} = \frac{12}{6} = 2A
$$

and 
$$
\tau_L = \frac{L}{R} = \frac{8.4 \times 10^{-3}}{6} = 1.4 \times 10^{-3} \text{ s}
$$

and  $i = 1$ A (given),  $t = ?$ 

Substituting theses values in eq. (1), we get

 $t = 0.97 \times 10^{-3}$  s = 0.97 ms

 $t \approx 1$  ms

 $\frac{1}{2}$ ,  $\varphi - B \frac{d\tau}{dt}$  (10) (A). When current flows in any of the coils, the flux linked  $(10)$ with the other coil will be maximum in the first case. Therefore, mutual inductance will be maximum in case (a).

$$
(11) (BD)
$$

# **ALTERNATING CURRENT TRY IT YOURSELF**

**(1)** (D)



$$
Z = \sqrt{\left(\frac{1}{\omega L}\right)^2 + R^2} = R\sqrt{1.25}
$$

**355**


**PROVANCEEDLEARINING**  
\n
$$
\left(\frac{1}{\omega L}\right)^2 + R^2 = R^2 (1.25)
$$
\nIf 'f' is decreased then 'o' will decrease and he  
\nwill increase therefore at f < f<sub>r</sub>, circuit beh  
\ncapacitive. V<sub>L</sub> and V<sub>C</sub> always difference in ph  
\n180° at any frequency.  
\n
$$
CR = \frac{2}{\omega} = \frac{2}{500} \sec = \frac{2}{500} \times 10^3 \sec
$$
\n
$$
= \frac{2 \times 1000}{500} \text{ ms } = 4 \text{ ms}
$$
\n
$$
r = \frac{2 \times 1000}{500} \text{ ms } = 4 \text{ ms}
$$
\n
$$
r = \frac{10/\sqrt{2}}{5/\sqrt{2}} = 1
$$
\n
$$
V = 1 \times (X_L - X_C) = 1 \times 5 = 5 \text{ Vol}
$$
\n
$$
V_0 = \sqrt{(V_L - V_C)^2 + V_R^2}
$$
\n
$$
V_0 = \sqrt{(V_L - V_C)^2 + V_R^2}
$$
\n
$$
V_C - V_L
$$

**(3) (BC). (4)** (B)

(5) **(B).** E = 
$$
10\cos(2\pi \times 50 \times \frac{1}{600}) = 5\sqrt{3} \text{ V}
$$

(6) (AC). At resonance 
$$
X_L = X_C
$$
 and  $Z = Z_{min} = R$ 

$$
X_{L} = \omega L \text{ and } \frac{1}{\omega C} = X_{C}
$$

If 'f' is decreased then ' $\omega$ ' will decrease and hence X<sub>C</sub> will increase therefore at  $f < f_r$ , circuit behaves as capacitive.  $V_L$  and  $V_C$  always difference in phase by 180° at any frequency.

**THEOREMING**  
\n
$$
\frac{1}{0L}\int_{0}^{2} + R^{2} = R^{2} (1.25)
$$
\n**EXERCISE 21.12.25**\n
$$
\frac{1}{0L}\int_{0}^{2} + R^{2} = R^{2} + \frac{R^{2}}{4} \Rightarrow \frac{1}{\omega L} = \frac{R}{2}
$$
\n**EXERCISE 21.25**\n
$$
\frac{1}{10L}\int_{0}^{2} + R^{2} = R^{2} + \frac{R^{2}}{4} \Rightarrow \frac{1}{\omega L} = \frac{R}{2}
$$
\n**EXERCISE 21.26**\n
$$
R = \frac{2}{\omega} = \frac{2}{500} \sec = \frac{2}{500} \times 10^{3} \sec
$$
\n
$$
R = \frac{2 \times 1000}{500} \text{ ms } = 4 \text{ ms}
$$
\n**EXERCISE 21.27**\n**EXERCISE 21.28**\n
$$
R = \frac{2 \times 1000}{500} \text{ ms } = 4 \text{ ms}
$$
\n**EXERCISE 21.29**\n
$$
R = \frac{10}{\sqrt{2}} = 1
$$
\n
$$
R = \frac{10}{\sqrt{2}} = 1
$$
\n**EXERCISE 21.20**\n
$$
R = \frac{10}{\sqrt{2}} = 1
$$
\n
$$
R = \frac{10}{\sqrt{2}} = 1
$$
\n**EXERCISE 21.21.23**\n
$$
R = \frac{10}{\sqrt{2}} = 1
$$
\n
$$
R = \frac{10}{\sqrt{
$$

**(8)** (B)

**(9) (AC).** Current leads the voltage  $\overrightarrow{N}$ 

**ION**  
\n**STUDY MATERIAL: PHYSICS**  
\nIf 'f' is decreased then 'o' will decrease and hence X<sub>C</sub>  
\nwill increase therefore at f < 
$$
f
$$
<sub>c</sub> circuit behaves as  
\ncapacitive. V<sub>L</sub> and V<sub>C</sub> always difference in phase by  
\n $180^\circ$  at any frequency.  
\n**(B).**  $Z = \sqrt{(X_L - X_C)^2 + R^2} = \sqrt{25 + 25} = 5\sqrt{2}$   
\n $I_{rms} = \frac{10/\sqrt{2}}{5\sqrt{2}} = 1$   
\n $V = 1 \times (X_L - X_C) = 1 \times 5 = 5$  Volt  
\n**(B)**  
\n**(AC).** Current leads the voltage  
\n $V_0 = \sqrt{(V_L - V_C)^2 + V_R^2}$   
\n $= \sqrt{100 + 25} = 5\sqrt{5}$  V  
\n $P.F. = \frac{V_R}{V_0} = \frac{5}{5\sqrt{5}} = \frac{1}{\sqrt{5}}$   
\n**(C)**

 $(10)$   $(C)$ 



# **CHAPTER- 4 : ELECTROMAGNETIC INDUCTIONANDALTERNATING CURRENT EXERCISE-1 (EMIANDAC)**<br> **(B.A. SOLUTIONS)**<br> **(CHAPTER-4: ELECTROMAGNETIC** (15) (A). Induced current in both the coils assist the main<br> **INDUCTION AND ALTERNATING**<br> **EXERCISE 1 (I)**<br> **EXERCISE CONTING**<br> **EXERCISE CONTING**<br> **EXERCI DAC**<br> **O.B.- SOLUTIONS**<br> **APTER-4: ELECTROMAGNETIC** (15) (A). Induced current in both the coils assist the main<br> **NDUCTION AND ALTERNATING**<br> **EXERENT**<br>
Here  $\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})I \cdot \hat{k} = 4B_0L^2Wb$ <br>
Area of the **O.B.-SOLUTIONS**<br> **O.B.-SOLUTIONS**<br> **O.B.-SOLUTIONS**<br> **O.B.-SOLUTIONS**<br> **O.B.-SOLUTIONS**<br> **O.B. CONDADALTERNATING**<br>
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CONDERNAT **(2) (A) (A) CHAPTER-4: ELECTROMAGNETIC** (15) (A) Induced current in both **INDUCTION AND ALTERNATING** current so current through **CURRENT**<br> **EXERCISE-1 EXERCISE-1 EXERCISE**<br>
(1) **(C)** Here  $\vec{B} = B_0(2\hat{i} + 3\$ **(EMIANDAC) (B. SOLUTIONS**<br> **CHAPTER-4: ELECTROMAGNETIC** (15) (A). Induced current<br> **CURRENT**<br> **EXERCISE-1**<br>
(1) **(C)**, Here  $\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})T$ ,<br>
Area of the square =  $L^2\hat{k}m^2$ <br>  $\therefore$  Flux passing throu

(C). Here  $\vec{B} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})T$ ,

 $\therefore$  Flux passing through the square.

$$
\phi = \vec{B} \cdot \vec{A} = B_0 (2\hat{i} + 3\hat{j} + 4\hat{k}).L^2 \hat{k} = 4B_0 L^2 W b
$$

**(3) (D).** Circular loop behaves as a magnetic dipole whose one surface will be N-pole and another will be Spole.

> Therefore magnetic lines a force emerges from N will meet at S. Hence total magnetic flux through x-y plane is zero.

(4) (A). 
$$
\phi = \vec{B} \cdot \vec{A} = (0.02\hat{i}) \cdot (30\hat{i} + 16\hat{j} + 23\hat{k}) \times 10^{-4}
$$
  
= 0.6 × 10<sup>-4</sup> Wb = 60 $\mu$  Wb

- **(5) (D).** Magnetic flux lined with a coil  $\phi = NBA \cos \theta$ Since the magnetic field B is parallel to the area A, i.e.,  $\theta = 90^\circ$   $\therefore \phi = 0$
- **(6) (B).** An emf is induced only when magnetic flux linked with the loop changes. This is possible when the loop is rotated about a diameter.
- **(7) (A).** Faraday's laws involve conversion of mechanical energy into electric energy. This is in accordance with the law of conservation of energy.

(2) (A). 
$$
\theta = BA - 10
$$
 where  
\none surface will be N-pole and another will be S-  
\none surface will be N-pole and another will be SS-  
\nother degree magnetic lines. More emerges from Null to model  
\nthe loop change in flux hence no current  
\nthe rate of S. Hence total magnetic flux through x-y plane  
\ntherefore the magnetic lines are force emerges from Null to model  
\n(3) (C). When key k is pressed, current through  
\nthe loop change in flux hence no current  
\none at S. Hence total magnetic flux through x-y plane  
\n(4) (A).  $\phi = B\overline{A} = (0.02\hat{i}) \cdot (30\hat{i} + 16\hat{j} + 23\hat{k}) \times 10^{-4}$   
\n(5) (D). Magnetic flux line  
\nSime the magnetic field B is parallel to the area A,  
\n(6) (B). A n emF is induced only when magnetic flux linked  
\nwhich is  $\theta = 90^\circ$  ∴  $\phi = 0$   
\n(7) (A). Faraday's law is involve conversion of mechanical  
\n(8) (A).  $e = \frac{-N(B_2 - B_1)A \cos \theta}{\Delta t}$   
\n(9) (A).  $C = -\frac{N(B_2 - B_1)A \cos \theta}{\Delta t}$   
\n(10) (B).  $\alpha = -\frac{N(B_2 - B_1)A \cos \theta}{\Delta t}$   
\n(20) (30.4.16) and (30.16) and (40.16) and (50.16) and (60.16) and (70.16) and (80.16) and (90.16) and (90.17) and (90.18) and (90.19) and (90.19) and (90.10) and (90.10) and (90.10) and (90.

**(9) (C).** At low frequency of 1 to 2 Hz, oscillations may be observed as our eyes will be able to detect it.

(10) (B). 
$$
e = -\frac{N(B_2 - B_1)A\cos\theta}{\Delta t}
$$

$$
= -\frac{50(0.35 - 0.10) \times \pi (3 \times 10^{-2})^2 \times \cos 0^{\circ}}{2 \times 10^{-3}} = 17.7 \text{V}
$$
\n(24) (E)

(11) **(C).** 
$$
i = \frac{|e|}{R} = \frac{N}{R} \cdot \frac{\Delta B}{\Delta t} A \cos \theta = \frac{20}{100} \times 1000 \times (25 \times 10^{-4}) \cos 0^{\circ}
$$
  
\t\t\t $i = 0.5 A$  (25) (B).

(12) **(B).** 
$$
e = -\frac{d\phi}{dt} = -\frac{d}{dt}(5t^3 - 100t + 300)
$$
  
=  $-(15t^2 - 100)$  at  $t = 2\sec$ ;  $e = 40$  V

(13) (C). 
$$
E = -\frac{d\phi}{dt}
$$
 or  $d\phi = -Edt = (0 - \phi)$   
or  $\phi = 4 \times 10^{-3} \times 0.1 = 4 \times 10^{-4}$  weber

**(14) (A).** As the loops are brought closer, the magnetic flux linked with them increases. An emf is induced in each (28) loop which opposes the change in flux. So the current in each loop decreases.

**(15) (A).** Induced current in both the coils assist the main current so current through each coil increases.



- **(16) (C).** The induced current will be in such a direction so that it opposes the change due to which it is produced.
- **(17) (C).** Since the magnetic field is uniform therefore there will be no change in flux hence no current will be induced.
- **(18) (C).** When key k is pressed, current through the electromagnet start increasing i.e. flux linked with ring increases which produces repulsion effect.
- **ELECTROMAGNETIC** (15) (A). Induced current in both the coil assist the main<br> **EVERCISE-1 EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **EVERCISE:**<br> **(19) (A).** The direction of current in the solenoid is clockwise. On displacing it towards the loop a current in the loop will be induced in clockwise direction so as to oppose its approach. Therefore the direction of induced current as observed by the observer will be anticlockwise.
- = B $\overline{A} = B_0(2\hat{i} + 3\hat{j} + 4\hat{k})1.\hat{k} = 4B_0L^2WD$  that it opposes the change due<br>
= B $A = 10$  weber<br>
incular loop behaves as a magnetic dipole whose<br>
e surface will be N-pole and another will be S-<br>
be surface will be M-p surface will be N-pole and another will be S<br>
e.<br>
e. Surface the magnetic times a force emerges from N will<br>
electromagnet start increasing i.e. flux like with the<br>
end as Hence total magnetic flux through x-y plane<br>
end Circular loop behaves as a magnetic dipole whose<br>
Circular loop behaves as a magnetic dipole whose<br>
will be no change in flux hence no current will be<br>
Dele.<br>
Therefore magnetic lines a force emerges from N will<br>
Dele.<br>
D 2010<br>
(a) (A). The direction of current in the solenoid<br>
on displacing it towards the loop a<br>
on displacing it towards the loop a<br>
agnetic flux lined with a coil φ = NBA cos θ<br>
agnetic flux lined with a coil φ = NBA cos assis possible when the<br>
six is possible when the<br>
of the magnet i.e. as seen from the<br>
eter.<br>
clockwise induced current flows in<br>
version of mechanical<br>
This is in accordance<br>
of energy.<br>
(21) (B). Direction of current i entic flux lined with a coil  $\phi = \text{NBA}$  induced current as observed by the observer will be  $\theta = 90^\circ$  .:.  $\phi = 0^\circ$  ...  $\phi = 0^\circ$  ... efield B is parallel to the area A,<br>
anticlockwise.<br>
4 10 dly when magnetic flux linked<br>
1 only when magnetic flux linked<br>
20 (B). When north pole of the magnet is m<br>
usua diameter.<br>
woult adiscribe south pole is induced <sup>1</sup>Wb = 60µ Wb<br>
<sup>1</sup>Wb = 60µ Wb<br>
usined with a coil  $\phi$  = NBA cos 0<br>
approximate it is approach. Therefore the direction<br>
and  $\phi$  = NBA cos 0<br>
and  $\phi$  = NBA cos 0<br>
and  $\phi$  = NBA cos 0<br>
induced curvent as observed by th line the magnetic field B is parallel to the area A,<br>
anticlockwise.<br>
a.,  $\theta = 90^\circ$   $\therefore \phi = 0$ <br>
a.  $\theta = 90^\circ$   $\therefore \phi = 0$ <br>
in the loop changes. This is possible when the six of the magnetic summer<br>
b in the open is rotate when magnetic flux linked<br>
south pole is induced on the frace of the loop in front<br>
This is possible when the<br>
induced control from the magnetic idea<br>
diameter.<br>
conversion of mechanical<br>
diameter.<br>
conversion of mechanic eld B is parallel to the area A,<br>
anticlockwise.<br>
The control parametric flux linked<br>
(20) (B). When north pole is induced on the face of the loop in first<br>
a diameter.<br>
a diameter.<br>
a diameter.<br>
a diameter.<br>
a diameter.<br> **(20) (B).** When north pole of the magnet is moved away, then south pole is induced on the face of the loop in front of the magnet i.e. as seen from the magnet side, a clockwise induced current flows in the loop. This makes free electrons to move in opposite direction, to plate a. Thus excess positive charge appear on plate b. in flux hence no current will be<br>pressed, current through the<br>pressed, current through the<br>tinerasing i.e. flux linked with<br>produces repulsion effect.<br>Trent in the solenoid is clockwise.<br>wavards the loop a current in the<br> in flux hence no current will be<br>pressed, current through the<br>t increasing i.e. flux linked with<br>ch produces repulsion effect.<br>rrent in the solenoid is clockwise.<br>wards the loop a current in the<br>cokwise direction so as to pressed, current through the<br>t increasing i.e. flux linked with<br>the produces repulsion effect.<br>rrent in the solenoid is clockwise.<br>bwards the loop a current in the<br>di in clockwise direction so as to<br>ch. Therefore the dire induced current as observed by the observer will be<br> **(20)** (B). When north pole of the magnet is moved away, then<br>
south pole is induced on the face of the loop in front<br>
of the magnet i.e. as seen from the magnet side, south pole is induced on the face of the loop in front<br>of the magnet i.e. as seen from the magnet side, a<br>clockwise induced current flows in the loop. This<br>makes free electrons to move in opposite direction,<br>o plate a. Th of the magnet is moved away, then<br>ced on the face of the loop in front<br>as seen from the magnet side, a<br>d current flows in the loop. This<br>ons to move in opposite direction,<br>excess positive charge appear on<br>ent induced in a then north pole of the magnet is moved away, then<br>uth pole is induced on the face of the loop in front<br>the magnet i.e. as seen from the magnet side, a<br>ockwise induced current flows in the loop. This<br>akes free electrons to analog contrained be magnet is moved away, then the halog anticlockwise.<br> **(26)** (B). When north pole of the magnet is and the magnet is all colocations of the magnet is all colocal current flows in the loop. This makes f ole of the magnet is moved away, then<br>nduced on the face of the loop in front<br>ri.e. as seen from the magnet side, a<br>tiuced current flows in the loop. This<br>ectrons to move in opposite direction,<br>nus excess positive charge event as observed by the observet win be<br>se.<br>se.<br>se.<br>se.<br>as induced on the face of the loop in front<br>et i.e. as seen from the magnet side, a<br>naduced current flows in the loop. This<br>electrons to move in opposite direction, Solution the matrix of the magnetic solution the magnetic as seen from the magnet side, a lockwise induced current flows in the loop. This above in opposite direction, and a wire moving in a populate of the mass free decl
	- **(21) (B).** Direction of current induced in a wire moving in a magnetic field is found by using Fleming's right hand rule.
	- **(22) (C).** When the velocity of conductor becomes double, area intercepted becomes twice. Therefore induced current becomes twice.
	- **(23) (B).** Magnitude of induced emf between the axis and the

other end is also  $\left(\frac{Bl^2\omega}{8}\right)$ . These two emf's are in  $\frac{l^2\omega}{8}$ . These two emf's are in opposite directions. Hence, the potential difference between the two ends of the rod is zero.

**24** (B). 
$$
e = Bv\ell = 3 \times 10^{-3} \times 10^{2} = 0.3
$$
 volt

(25) **(B).** 
$$
e = B_v.v.\ell = 2 \times 10^{-4} \times \left(\frac{360 \times 1000}{3600}\right) \times 50 \implies e = 1 \text{ V}
$$

(26) **(D).** 
$$
e = B\ell^2 \pi v = 0.4 \times 10^{-4} \times (0.5)^2 \times (3.14) \times \frac{120}{60}
$$
  
= 6.28 × 10<sup>-5</sup> V

clockwise induced current flows in the loop. This makes free electrons to move in opposite direction, to plate a. Thus excess positive charge appear on plate b.

\n**(21) (B).** Direction of current induced in a wire moving in a magnetic field is found by using Fleming's right hand rule.

\n**(22) (C).** When the velocity of conductor becomes double, area intercepted becomes twice. Therefore induced current becomes twice.

\n**(23) (B).** Magnitude of induced emf between the axis and the other end is also 
$$
\left(\frac{Bt^2\omega}{8}\right)
$$
. These two emf's are in opposite directions. Hence, the potential difference between the two ends of the rod is zero.

\n**(24) (B).** e = Bvℓ = 3 × 10<sup>-3</sup> × 10<sup>2</sup> = 0.3 volt

\n**(25) (B).** e = B<sub>v</sub>·v.ℓ = 2 × 10<sup>-4</sup> ×  $\left(\frac{360 \times 1000}{3600}\right) \times 50 \Rightarrow e = 1V$ 

\n**(26) (D).** e = Bℓ<sup>2</sup>πv = 0.4 × 10<sup>-4</sup> × (0.5)<sup>2</sup> × (3.14) ×  $\frac{120}{60}$  = 6.28 × 10<sup>-5</sup> V

\n**(27) (B).** e<sub>0</sub> = ωNBA = (2πv)NB(πr<sup>2</sup>) = 2 × π<sup>2</sup>v NBr<sup>2</sup> = 2 × (3.14)<sup>2</sup> ×  $\frac{1800}{60} \times 4000 \times 0.5 \times 10^{-4} \times (7 \times 10^{-2})^2 = 0.58V$ 

\n**(28) (B).** When a conductor lying along the magnetic north-south, moves eastwards it will cut vertical component of B<sub>0</sub>.

**(28) (B).** When a conductor lying along the magnetic northsouth, moves eastwards it will cut vertical component of  $B_0$ .



So induced emf

$$
e = vB_V \ell = v (B_0 \sin \delta \ell) = B_0 \ell \text{ v} \sin \delta
$$

(29) (B). Rate of work = 
$$
\frac{W}{t}
$$
 = P = Fv ; F = Bi $\ell$  = B $\left(\frac{Bv\ell}{R}\right)\ell$ 

$$
\Rightarrow P = \frac{B^2 v^2 \ell^2}{R} = \frac{(0.5)^2 \times (2)^2 \times (1)^2}{6} = \frac{1}{6} W
$$
 (46) (C). i<sub>rms</sub> =

(30) **(B).** φ = BA cos ωt ; φ = BA cos 2 π ft\n
$$
(45)
$$
 (b) N

**EXAMPLE 12.2** (Q.B.-SOLUTIONS  
\nSo induced emf  
\n
$$
e = vB_V \ell = v (B_0 \sin \delta \ell) = B_0 \ell \text{ v} \sin \delta
$$
  
\n $e = vB_V \ell = v (B_0 \sin \delta \ell) = B_0 \ell \text{ v} \sin \delta$   
\n**23.3** (44) (B)  $e = -M \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$   
\nB) The secondary e.m.f. induces only when current through primary changes.  
\n $P = \frac{B^2 v^2 \ell^2}{R} = \frac{(0.5)^2 \times (2)^2 \times (1)^2}{6} = \frac{1}{6} \text{ W}$   
\n $\Phi = BA \cos \omega t$ ;  $\phi = BA \cos 2 \pi \text{ ft}$   
\n $\phi = \frac{B \pi r^2}{2} \cos 2\pi \text{ ft}$ ;  $e = -\frac{d\phi}{dt} = \frac{B \pi r^2}{2}$ .  $2\pi \text{ f} \sin 2\pi \text{ ft}$   
\n $e = B\pi^2 r^2 \text{ f} \sin 2\pi \text{ ft}$   
\n $e = B\pi^2 r^2 \text{ f} \sin 2\pi \text{ ft}$   
\n $2 \text{ F} \cot \theta = \frac{A\pi}{2}$   
\n $\text{P} \cot \theta = \frac{B\pi r^2}{2}$   
\n<

- **(31) (B).** Effective length between A and B remains same.
- **(32) (C).**Induction furnace make use of eddy current
- **(33) (D).** When a metal plate is getting heated, it may be due to the passage of direct current, alternating current or even induced current through the plate. As time varying magnetic field produces induced current in the plate, so both (A) and (B) are correct. **EXECUTE US AN ORDER COLUTIONS**<br>
Blued emf<br>
Blued emf<br>
Blued emf<br>  $B_V\ell = v(B_0 \sin \delta t) = B_0\ell v \sin \delta$ <br>  $= 12 \sqrt{10^2 + 10^2}$ <br>  $= 12 \sqrt{10^2 + 1$

(34) (C). As, 
$$
\varepsilon = L \frac{dI}{dt}
$$
. When  $\frac{dI}{dt} = 1$   $\therefore \varepsilon = L$ 

**(35) (C).** The mutual inductance of the system is  $M = \mu_0 \pi a^2 n_1 n_2 L$ .

(36) **(D).** As 
$$
\varepsilon = L \frac{dI}{dt}
$$
,  $L = \varepsilon \frac{dt}{dl} \Rightarrow L = \frac{\text{volt} \times \text{second}}{\text{ampere}}$ 

**(37) (C).** The self inductance of a long solenoid is given by

$$
L = \frac{\mu_0 N^2 A}{\ell}
$$

where,  $N =$  Number of turns,  $\ell =$  Length

 $A = Cross-sectional area$ 

From the above expression it is clear that the self inductance of a long solenoid does not depend upon the current flowing through it.

(38) (A). 
$$
M = \frac{\mu_0 N_1 N_2 A}{\ell}
$$
 : M becomes 4 times. (54)

(39) (C). Self inductance = 
$$
\frac{\mu_0 N^2 A}{\ell}
$$

- **(40) (C).** Inductors obey the laws of parallel and series combination of resistors.
- **(41) (B).** There will be self induction effect when soft iron core is inserted.

(42) (C). 
$$
\phi
$$
=Li ; NBA=Li

$$
\mu_0 \frac{N^2 i}{\ell} A = Li \ ; \quad L = \frac{\mu_0 N^2 A}{\ell}
$$

(43) (C). 
$$
L = \mu_0 \frac{N^2}{\ell} A
$$
.

When N and  $\ell$  are doubled. L is also doubled.

(44) **(B).** 
$$
e = -M \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}
$$

 $\overline{R}$   $\ell$  through primary changes.  $\ell$  (45) **(D).** In secondary e.m.f. induces only when current STUDY MATERIAL: PHYSICS<br>  $e = -M \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>
In secondary e.m.f. induces only when current<br>
through primary changes.<br>  $i_{\text{rms}} = \sqrt{\frac{i_1^2 + i_2^2}{2}} = \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$ STUDY MATERIAL: PHYSICS<br>=  $-M \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>secondary e.m.f. induces only when current<br>rough primary changes.<br> $\sqrt{\frac{2}{11} + \frac{2}{12}} = \sqrt{2} \times 2^{1/2}$ STUDY MATERIAL: PHYSICS<br>=  $-5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>dary e.m.f. induces only when current<br>rimary changes.<br> $\frac{2}{2} + i\frac{2}{2} = \frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$ <br> $0 = \frac{2}{\pi} \times (V_{\text{rms}} \times \sqrt{2})$ STUDY MATERIAL: PHYSICS<br>=  $-5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>dary e.m.f. induces only when current<br>rimary changes.<br> $\frac{2}{2} + i\frac{2}{2} = \frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$ <br> $i_0 = \frac{2}{\pi} \times (V_{\text{rms}} \times \sqrt{2})$ STUDY MATERIAL: PHYSICS<br>  $\frac{1}{t} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>
dary e.m.f. induces only when current<br>
primary changes.<br>  $\frac{i_1^2 + i_2^2}{2} = \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$ <br>  $V_0 = \frac{2}{\pi} \times (V_{\text{rms}} \times \sqrt{2})$ <br>  $\frac{\sqrt{2}}{2}$ .  $V_{$ **STUDY MATERIAL: PHYSICS**<br>  $A \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>
ondary e.m.f. induces only when current<br>
th primary changes.<br>  $\sqrt{\frac{i_1^2 + i_2^2}{2}} = \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$ <br>  $\frac{2}{\pi} V_0 = \frac{2}{\pi} \times (V_{rms} \times \sqrt{2})$ <br>  $\$ STUDY MATERIAL: PHYSICS<br>  $\frac{-5}{2}$  = 25000 V<br>
.f. induces only when current<br>
anges.<br>  $\frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$ <br>  $V_{\text{rms}} \times \sqrt{2}$ <br>  $= \frac{2\sqrt{2}}{\pi} \times 220 = 198 \text{ V}$ <br>  $\sqrt{2}$ <br>
= 500V<br>  $\Gamma/4 = \frac{1}{4 \times 50} = 5 \times 10^{-3} \text{ sec}$ STUDY MATERIAL: PHYSICS<br>  $M \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>
condary e.m.f. induces only when current<br>
gh primary changes.<br>  $= \sqrt{\frac{i_1^2 + i_2^2}{2}} = \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$ <br>  $= \frac{2}{\pi} V_0 = \frac{2}{\pi} \times (V_{\text{rms}} \times \sqrt{2})$  $\frac{x}{10^{-3}} = 25000 \text{ V}$ <br>  $\frac{x}{10^{-3}} = 25000 \text{ V}$ <br>  $\therefore$  m.f. induces only when current<br>
y changes.<br>  $\frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$ <br>  $\times (\text{V}_{\text{rms}} \times \sqrt{2})$ <br>  $\text{ms} = \frac{2\sqrt{2}}{\pi} \times 220 = 198 \text{ V}$ <br>  $10\sqrt{2}$ <br>  $\frac{07}{41} = 500 \text$ STUDY MATERIAL: PHYSICS<br>  $\frac{(-5)}{10^{-3}} = 25000 \text{ V}$ <br>
m.f. induces only when current<br>
changes.<br>  $= \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$ <br>  $(V_{rms} \times \sqrt{2})$ <br>  $s = \frac{2\sqrt{2}}{\pi} \times 220 = 198 \text{ V}$ <br>  $0\sqrt{2}$ <br>  $\frac{7}{1} = 500 \text{ V}$ <br>  $= T/4 = \frac{1}{4 \$ 

Q.B.-SOLUTIONS	STUDY MATERIAL: PHYSICS		
So induced emf	$e = vB_V \ell = v (B_0 \sin \delta \ell) = B_0 \ell \text{ v} \sin \delta$	$(44)$	$(B). e = -M \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}$
Rate of work = $\frac{W}{t} = P = Fv$ ; $F = Bi\ell = B\left(\frac{Bv\ell}{R}\right) \ell$	$(45)$	$(D). In secondary e.m.f. induces only when current through primary changes.$	
$P = \frac{B^2 v^2 \ell^2}{R} = \frac{(0.5)^2 \times (2)^2 \times (1)^2}{6} = \frac{1}{6} \text{ W}$	$(46)$	$(C). i_{rms} = \sqrt{\frac{i_1^2 + i_2^2}{2}} = \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}$	
$\phi = BA \cos \omega t$ ; $\phi = BA \cos 2 \pi ft$	$(47)$	$(A). V_{av} = \frac{2}{\pi} V_0 = \frac{2}{\pi} \times (V_{rms} \times \sqrt{2})$	

$$
(B0 sin δ t) = B0 t sin δ
$$
\n
$$
(44) (B) e = -M \frac{di}{dt} = -5 \times \frac{(-5)}{10^{-3}} = 25000 \text{ V}
$$
\n
$$
= \frac{W}{t} = P = Fv ; F = Bi t = B(\frac{Bv t}{R}) t
$$
\n
$$
= \frac{(0.5)^2 \times (2)^2 \times (1)^2}{6} = \frac{1}{6} W
$$
\n
$$
= \frac{(0.5)^2 \times (2)^2 \times (1)^2}{6} = \frac{1}{6} W
$$
\n
$$
(46) (C) i_{rms} = \sqrt{\frac{i_1^2 + i_2^2}{2}} = \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}
$$
\n
$$
= \frac{1}{\sqrt{2}} (i_1^2 + i_2^2)^{1/2}
$$
\n
$$
= \frac{2\sqrt{2}}{4} \times 20 = 198 \text{ V}
$$
\n
$$
= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
$$
\n
$$
= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
$$
\n
$$
= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
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= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
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= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
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= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
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= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
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$$
= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
$$
\n
$$
= \frac{2\sqrt{2}}{8} \times 20 = 198 \text{ V}
$$
\n
$$
= \frac{1}{\sqrt{2}} = \frac{2\sqrt{2}}{1.41} = 500 \text{ V}
$$
\n
$$
= 6 \text{ direct current, alternating current}
$$
\n

$$
=\frac{2\sqrt{2}}{\pi}.
$$
V<sub>rms</sub> =  $\frac{2\sqrt{2}}{\pi}$  × 220 = 198 V

(48) (B). 
$$
V_0 = \sqrt{2} V_{\text{rms}} = 10\sqrt{2}
$$

(49) (C). 
$$
E_{\text{rms}} = \frac{E_0}{\sqrt{2}} = \frac{707}{1.41} = 500 \text{V}
$$

(50) **(D).** Required time 
$$
t = T/4 = \frac{1}{4 \times 50} = 5 \times 10^{-3} \text{ sec}
$$

**(51) (B).** Here,  $V_m = 400 \text{ V}$ 

$$
\therefore R_{rms} = \frac{V_m}{\sqrt{2}} = \frac{440}{\sqrt{2}} = 311.1 \text{V}
$$

 $\frac{dx \times \text{second}}{\text{ampere}}$  voltage.  $=\frac{\sqrt{6} \times \text{second}}{2}$  voltage. 4 50 **(52) (C).** The voltmeter connected to ac mains is calibrated to read root mean square value or virtual value of ac voltage.

So induced emf  
\ne -vF<sub>V</sub>(-x (R<sub>0</sub>sinδ/5) – R<sub>0</sub> (x sinδ)  
\n(29) (B). Rate of work = 
$$
\frac{W}{t} = P = Fv
$$
,  $F = Hit = H(\frac{Hvt}{R})$  (45) (D). In secondary em.f. findues only when current  
\nthrough primary changes.  
\n⇒ P =  $\frac{B^2v^2t^2}{r^2} = \frac{(0.5)^2 \times (2)^2 \times (1)^2}{r^2} = \frac{1}{6}w$   
\n(30) (R). A = BAs cos α t;  $\phi = BAs cos 2π$  f  
\n $\phi = \frac{Bm^2}{2} cos 2πt$ ;  $c = -\frac{d\phi}{dt} = \frac{Bar^2}{2} = 2π sin 2πt$   
\n(30) (R). A = BAs cos α t;  $\phi = BAs cos 2π$  f  
\n $\phi = \frac{Bm^2}{2} \sin 2πt^2$   
\n(31) (B). Effective length between A and B remains same.  
\n(32) (C). Inductive length between A and B remains same.  
\n(33) (D). When a metal plate is getting heated, it may be due  
\nor even induced current, the partial x is time  
\nusing a specific effect current, alternative current in (50) (D). Figure,  $\frac{E_0}{\sqrt{2}} = \frac{707}{14} = 500V$   
\nor because of the system is  
\n $\frac{W}{\sqrt{2} sin 2πt}$  (51) (B). Here,  $V_{\text{max}} = 400V$   
\n(32) (C). Inductive length between A and B remains current.  
\n(33) (D). When  $4x = 1$  (E). When  $\frac{dI}{dt} = 1$  ∴  $c = -1$   
\n(34) (C). As  $c = L \frac{dI}{dt}$ . When  $\frac{dI}{dt} = 1$  ∴  $c = -L$   
\n(35) (C). The mutual inductance of the system is  
\n $\frac{W}{\sqrt{2} sin 2πt}$  and  $\frac{dI}{dt} = 1$  ∴  $c = -L$   
\n(36) (D). A,  $z = L \frac{dI}{dt}$ ,  $V = \$ 

(54) (A). 
$$
i_{\text{rms}} = \frac{200}{280} = \frac{5}{7} A
$$
. So  $i_0 = i_{\text{rms}} \times \sqrt{2} = \frac{5}{7} \times \sqrt{2} \approx 1 A$ .

$$
\therefore \text{ M becomes 4 times.} \qquad \qquad \textbf{(54)} \qquad \textbf{(C). Here, R = 100 \, \Omega,} \\
V_{\text{rms}} = 220 \, \text{V, \Omega, v = 50 \, \text{Hz}} \\
\therefore I_{\text{rms}} = \frac{V_{\text{rms}}}{R} = \frac{220}{100} = 2.2 \text{A}
$$

- **(56) (A).** In a pure inductor (zero resistance), voltage leads the current by 90 $^{\circ}$  i.e.  $\pi/2$
- **(57) (A).** The effective potential difference across the inductor

$$
L = \frac{V}{\ell}
$$
  
\n
$$
V = V_0 \sin 2\pi vt = 200 \sin \left(2\pi \times 50 \times \frac{1}{600}\right)
$$
\n
$$
V = V_0 \sin 2\pi vt = 200 \sin \left(2\pi \times 50 \times \frac{1}{600}\right)
$$
\n
$$
V = V_0 \sin 2\pi vt = 200 \sin \left(2\pi \times 50 \times \frac{1}{600}\right)
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \sin \frac{\pi}{6} = 200 \times \frac{1}{2} = 100 \text{ V.}
$$
\n
$$
= 200 \
$$

**(58) (D).** The inductive reactance is directly proportional to inductance and frequency of the current.



**(59) (B).** The current in the inductor coil is given by

$$
I = \frac{V}{X_L} = \frac{V}{2\pi vL}
$$
 (70)

**(Q.B.- SOLUTIONS**<br>
The inductor coil is given by<br>  $= \frac{V}{X_L} = \frac{V}{2\pi v L}$ <br>
(70) (B). In a capacitor per cycle is  $P = V_r$ <br>
(70) (B). In a capacitive ac circuits,<br>
frequency v in the two cases is different, hence<br>
the curre Since frequency  $v$  in the two cases is different, hence the current in two cases will be different.

**(60) (C).** Here,  $L = 44$  mH =  $44 \times 10^{-3}$  H  $V_{\text{rms}} = 220 V, v = 50 Hz$ The inductive reactance is  $X_L = \omega L = 2\pi vL$  $= 2 \times 3.14 \times 50 \times 44 \times 10^{-3} = 13.82 \,\Omega$ **DAC**<br>
The current in the inductor coil is given by<br>
The current in the inductor coil is given by<br>  $I = \frac{V}{X_L} = \frac{V}{2\pi vL}$ <br>
(**70**) (**B**). In a capacitive ac circuit<br>
the current in two cases will be different.<br>
thence ac **EXECUTE 10 18**<br> **EXECUTE:** The inductor coil is given by<br>
The inductor coil is given by<br>
The angele of 90°. Hence, p<br>
phase angle **AC**<br> **AC**<br> **EXECUTIONS**<br> **DAC**<br>
The current in the inductor coil is given by<br>
The current in the inductor coil is given by<br>  $1 = \frac{V}{X_L} = \frac{V}{2\pi v L}$ <br>
Since frequency v in the two cases sighterent, hence<br>  $1 = \frac{V}{X_L} = \frac{V}{2\pi v L}$ <br>
Since frequency **EXECUTIONS**<br>
The inductor coil is given by<br>
The two cases is different, hence phase angle of 90°. Hence, po<br>
phase angle of 90°. Hence, po<br>
capacitive accurations of the two cases is different.<br>
The two cases is differen **C**<br>
Current in the inductor coil is given by<br>  $I = \frac{V}{X_L} = \frac{V}{2\pi v L}$ <br>  $= \frac{V}{2\pi v L}$ <br>
(70) (B). In a capacitive ac circuits, the<br>
energiency v in the two cases is different, hence<br>  $I = \frac{V}{X_L} = \frac{V}{2\pi v L}$ <br>
(70) (B). I **EXAMPLE (ALCONSTRANT CONTROLLATE SUBMISSION CONTROLLATE (200)<sup>2</sup> (T4) (B). The qualitative signal of expiring the applied of 0, there, power de-<br>
The current in the inductor coil is given by the current developed leads t (60) (C).** Here, L=44 mH = 44 × 10<sup>-3</sup> H<br>  $V_{\text{rms}} = 220 V$ , v = 50 Hz<br>
The inductive reactance is  $X_1 = \omega L = 2\pi v L$ <br>
The inductive reactance is  $X_1 = \omega L = 2\pi v L$ <br>  $= 2 \times 3.14 \times 50 \times 44 \times 10^{-3} = 13.82 \Omega$ <br>  $\therefore I_{\text{rms}} = \frac{V_{$ I =  $\frac{V}{X_L} = \frac{V}{2\pi V}$ <br>
since frequency v in the two cases is different, hence<br>
Since frequency in the two cases is different, hence<br>
the current in phase by π/2 radian.<br>
the current in phase by π/2 radian.<br>
the curr  $\frac{W}{X_L} = \frac{2\pi v L}{2\pi v L}$  (70) (B). In a capacitive ac circuiting the spectrum in the two cases is different.<br>
The different in the current in phase by π<br>
L = 44 mH = 44 × 10<sup>-3</sup> H (71) (B).  $Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + 10$ careful members whose angle of 90°. Hence, power<br>  $I = \frac{V}{X_L} = \frac{V}{2\pi v L}$ <br>
the frequency v in the two cases is different, hence<br>  $= \frac{V}{X_L} = \frac{V}{2\pi v L}$ <br>  $= 220 V, v = 50 Hz$ <br>  $= 220 V, v = 50 Hz$ <br>  $= 2 \times 3.14 \times 50 \times 44 \times 10^{-3} = 1$ 

$$
\therefore I_{\text{rms}} = \frac{V_{\text{rms}}}{X_{\text{L}}} = \frac{220}{13.82} = 15.9 \text{A}
$$

**(61) (B).** For purely capacitive circuit,  $e = e_0 \sin \omega t$  $\int_0^{\infty}$  SIN( $\omega$ + $\frac{1}{2}$ ) 1.e. current is ahead of emf by  $\pi/2$ 

**(62) (B).** 
$$
X_C = \frac{1}{\omega C} = \frac{1}{2\pi vC}
$$

For dc 
$$
v = 0
$$
,  $\therefore X_C = \infty$ 

(63) (B). 
$$
X_C = \frac{1}{2\pi vC} \Rightarrow X_C \propto \frac{1}{v}
$$

(64) **(B).** Reading of ammeter = 
$$
i_{\text{rms}} = \frac{V_{\text{rms}}}{X_C} = \frac{V_0 \omega C}{\sqrt{2}}
$$
 =  $\sqrt{(40)}$ 

$$
= \frac{200\sqrt{2} \times 100 \times (1 \times 10^{-6})}{\sqrt{2}} = 2 \times 10^{-2} \text{A} = 20 \text{ mA}
$$
 (77)

(65) (A). 
$$
X_C = \frac{1}{2\pi vC}
$$
  
Also  
 $\therefore \phi = t$ 

$$
\frac{1}{1000} = \frac{1}{2\pi \times v \times 5 \times 10^{-6}} \Rightarrow v = \frac{100}{\pi} \text{MHz}
$$
 (78)

(66) (A). 
$$
X_C = \frac{1}{2\pi vC} \Rightarrow C = \frac{1}{2\pi vX_C} = \frac{1}{2 \times \pi \times \frac{400}{\pi} \times 25} = 50 \mu F
$$
  $\therefore$   $V_C = \sqrt{\frac{1}{2\pi vC}} = \frac{1}{2 \times 25} = 50 \mu F$ 

**(67) (B).** Here,  $C = 30\mu$ F =  $30 \times 10^{-6}$  F  $V_{\text{rms}} = 150 \text{ V}, v = 60 \text{ Hz}$ 

Capacitive reactance 
$$
X_C = \frac{1}{\omega C} = \frac{1}{2\pi vC} = 88.46 \Omega
$$

$$
I_{\rm rms} = \frac{V_{\rm rms}}{X_{\rm C}} = \frac{150}{88.46} = 1.7 \text{A}
$$
 (80)

**(68) (C).** Capacitive reactance,  $X_C = \frac{1}{2\pi rC}$ 

$$
\Rightarrow X_C \propto \frac{1}{v} : \frac{X_{C_1}}{X_{C_2}} = \frac{v_2}{v_1} = \frac{2v}{v} = 2
$$

$$
\Rightarrow X_{C_2} = \frac{X_{C_1}}{2}
$$

**(69) (D).** When an ac voltage of 220V is applied to a capacitor C, the charge on the plates is in phase with the applied voltage. As the circuit is pure capacitive so, the

current developed leads the applied voltage by a phase angle of 90º. Hence, power delivered to the capacitor per cycle is  $P = V_{rms} I_{rms} \cos 90^\circ = 0$ . **EXECUTE:**<br>
lied voltage by a<br>
is cos 90° = 0.<br>
litage lags behind<br>
l.<br>  $\sqrt{2}$ <br>  $\times 2$  = 753.7<br>  $\sqrt{2^2 + (6)^2} = 10\Omega$ <br>  $\Rightarrow \phi = 80^\circ$ <br>  $\Rightarrow \phi = 80^\circ$ <br>  $\Rightarrow \phi = 80^\circ$ <br>  $\Rightarrow \frac{220}{66} = 3.33 \text{ A}$ 

**(70) (B).** In a capacitive ac circuits, the voltage lags behind the current in phase by  $\pi/2$  radian.

Q.B.-SOLUTIONS  
\ncurrent in the inductor coil is given by current developed leads the applied voltage by a  
\n
$$
I = \frac{V}{X_L} = \frac{V}{2\pi vL}
$$
\n
$$
= \frac{V}{2\pi vL}
$$
\n
$$
= \frac{V}{2\pi vL}
$$
\n(70) (B) In a capacitor per cycle is P = V<sub>rms</sub> I<sub>rms</sub> cos 90° = 0.  
\n
$$
I = \frac{V}{X_L} = \frac{V}{2\pi vL}
$$
\n(71) (B)  $Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + (2\pi \times 60 \times 2)^2} = 753.7$   
\n
$$
= 220 V, v = 50 Hz
$$
\n
$$
= 220 V, v = 50 Hz
$$
\n
$$
= 2.20 V, u = 50 Hz
$$
\n
$$
= 15.9 A
$$
\n
$$
= \frac{V_{rms}}{X_L} = \frac{220}{13.82} = 15.9 A
$$
\n
$$
= \frac{V_{rms}}{X_L} = \frac{220}{13.82} = 15.9 A
$$
\n(72) (C) Impedance  $Z = \sqrt{R^2 + X^2} = \sqrt{(8)^2 + (6)^2} = 10\Omega$   
\n
$$
= \frac{V_{rms}}{X_L} = \frac{220}{13.82} = 15.9 A
$$
\n(73) (C)  $\tan \phi = \frac{\omega L}{R} = \frac{2\pi \times 50 \times 0.21}{12} = 5.5 \Rightarrow \phi = 80^\circ$   
\n
$$
sin(\omega t + \frac{\pi}{2})
$$
 i.e. current is ahead of emf by π/2  
\n
$$
= \frac{1}{\omega C} = \frac{1}{2\pi vC}
$$
\n
$$
= \frac{1}{\omega C} = \frac{1}{2\pi vC}
$$
\n(75) (D). i =  $\frac{220}{\sqrt{(202)^2 + (2 \times \pi \times 50 \times 0.2)^2}} = \frac{220}{66} = 3.33 A$ 

$$
\frac{V_{\text{rms}}}{V_{\text{rms}}} = \frac{220}{12.82} = 15.9 \text{A}
$$
 (72) (C). Impedance  $Z = \sqrt{R^2 + X^2} = \sqrt{(8)^2 + (6)^2} = 10 \Omega$ 

(73) (C) 
$$
\tan \phi = \frac{\omega L}{R} = \frac{2\pi \times 50 \times 0.21}{12} = 5.5 \implies \phi = 80^{\circ}
$$

**EMI AND AC**  
\n**(59) (B).** The current in the inductor coil is given by  
\n
$$
I = \frac{V}{X_L} = \frac{V}{2\pi v L}
$$
\n
$$
= \frac{V}{2\pi v L}
$$
\n
$$
= \frac{V}{2\pi v L}
$$
\n
$$
= \frac{V}{2\pi v L}
$$
\n**(60) (C).** Here,  $L = 44 \text{ mH} = 44 \times 10^{-3} \text{ H}$   
\n
$$
= \frac{V_{\text{rms}}}{2} = 220 \text{ V, v} = 50 \text{ Hz}
$$
\n
$$
= \frac{V_{\text{rms}}}{2} = 220 \text{ V, v} = 50 \text{ Hz}
$$
\n
$$
= \frac{V_{\text{rms}}}{2} = 220 \text{ V, v} = 50 \text{ Hz}
$$
\n
$$
= \frac{V_{\text{rms}}}{2} = 220 \text{ V, v} = 50 \text{ Hz}
$$
\n
$$
= \frac{V_{\text{rms}}}{2} = 220 \text{ V, v} = 50 \text{ Hz}
$$
\n
$$
= \frac{V_{\text{rms}}}{2} = 220 \text{ V, v} = 50 \text{ Hz}
$$
\n
$$
= \frac{V_{\text{rms}}}{2} = \frac{220}{13.82} = 15.9 \text{ A}
$$
\n
$$
= \frac{V_{\text{rms}}}{2} = \frac{220}{13.82} = 15.9 \text{ A}
$$
\n**(71) (B).**  $Z = \sqrt{R^2 + X_L^2} = \sqrt{10^2 + (2\pi \times 60 \times 2)^2} = 753.7$ \n
$$
\therefore I_{\text{rms}} = \frac{V_{\text{rms}}}{X_L} = \frac{220}{13.82} = 15.9 \text{ A}
$$
\n**(72) (C).**  $\text{Im}\phi = \frac{\omega L}{R} = \frac{2\pi \times 50 \times 0.21}{12} = 5.5 \Rightarrow \phi = 80^\circ$ \n
$$
i = i_0 \sin(\omega t + \frac{\pi}{2})
$$

(75) **(D).** 
$$
i = \frac{220}{\sqrt{(20)^2 + (2 \times \pi \times 50 \times 0.2)^2}} = \frac{220}{66} = 3.33
$$
 A

ductor coil is given by current developed leads the applied voltage by a  
\nphase angle of 90°. Hence, power derivative of the  
\ncapacitor per cycle is P = V<sub>rms</sub> I<sub>rms</sub> (or 90°).  
\nLet two cases is different, hence  
\n
$$
x_10^{-3}H
$$
 (71) (B). In a capacitive ac circuits, the voltage lags behind  
\ntec is X<sub>1</sub> = ω L = 2πvL  
\n $x^2 = \sqrt{R^2 + x_L^2} = \sqrt{10^2 + (2\pi \times 60 \times 2)^2} = 753.7$   
\n $x^2 = 15.9$ A (72) (C). Impedance  $Z = \sqrt{R^2 + X^2} = \sqrt{(8)^2 + (6)^2} = 1002$   
\ncircuit, e = e<sub>0</sub> sin ωt (73) (C). The applied voltage is given by  
\ncurrent is ahead of emf by π/2  
\n $y = \sqrt{v_R^2 + v_L^2}$   
\n $y = \sqrt{(200)^2 + (150)^2} = 250$  volt  
\n $= \infty$  (75) (D). i =  $\frac{220}{\sqrt{(20)^2 + (2 \times \pi \times 50 \times 0.2)^2}} = \frac{220}{66} = 3.33$  A  
\n $\frac{1}{\sqrt{6}}$   
\n $= \frac{V_{rms}}{X_C} = \frac{V_{00}C}{\sqrt{2}}$  (76) (C).  $Z = \sqrt{R^2 + (2\pi vL)^2}$   
\n $= \sqrt{(40)^2 + 4\pi^2 \times (50)^2 \times (95.5 \times 10^{-3})^2} = 50$  ohm  
\n $\frac{V_{rms}}{A} = \frac{V_{rms}}{X_C} = \frac{V_{00}C}{\sqrt{2}}$  (76) (C).  $Z = \sqrt{R^2 + (2\pi vL)^2}$   
\n $= \sqrt{(40)^2 + 4\pi^2 \times (50)^2 \times (95.5 \times 10^{-3})^2} = 50$  ohm  
\n $\frac{V_{15}}{A \times R} = (2\pi vL) = (2\pi)(50)(0.01) = \pi\Omega$   
\n $\frac{V_{15}}{A \times R} =$ 

1 = 
$$
\frac{V_1}{X_1} = \frac{V}{2\pi vt}
$$
  
\nSince the current in two cases is different, hence  
\nthe current in two cases with the different  
\nthe current in two cases with the other  
\nthe current in two cases with the other  
\nthe current in two cases with the other  
\n $V_{\text{rms}} = 220 V_1 v = 50$   
\n $V_{\text{rms}} = 22 V_{\text{rms}} = 22 V$ 

(78) (B). V<sub>source</sub> = 
$$
\sqrt{V_R^2 + V_C^2}
$$
  
\n
$$
\frac{1}{400 \times 25} = 50 \mu F
$$
\n
$$
\therefore V_C = \sqrt{V_{source}^2 - V_R^2} = \sqrt{(20)^2 - (12)^2} = 16V
$$

(79) (C). Reactance of a capacitor, 
$$
X_C = \frac{1}{\omega C} = \frac{1}{2\pi vC}
$$

As frequency increases,  $X_C$  decreases and therefore current increases. As R does not vary with frequency, therefore, likely elements constituting the circuit may be capacitor and resistor.

$$
\frac{200\sqrt{2} \times 100 \times (1 \times 10^{-6})}{\sqrt{2}} = 2 \times 10^{-2} A = 20 \text{ mA}
$$
\n
$$
X_{C} = \frac{1}{2\pi vC}
$$
\n
$$
X_{C} = \frac{1}{2\pi vC}
$$
\n
$$
X_{C} = \frac{1}{2\pi vC} \Rightarrow C = \frac{1}{2\pi vX_{C}} = \frac{1}{2 \times 10^{-4} \text{ A}} = 50 \mu\text{F}
$$
\n
$$
X_{C} = \frac{1}{2\pi vC} \Rightarrow C = \frac{1}{2\pi vX_{C}} = \frac{1}{2 \times 1 \times 400 \times 25} = 50 \mu\text{F}
$$
\nHere, C = 30 μF = 30 × 10<sup>-6</sup> F\n
$$
X_{D} = 150 V, v = 60 \text{ Hz}
$$
\n
$$
X_{D} = 150 V, v = 60 \text{ Hz}
$$
\n
$$
X_{D} = 150 V, v = 60 \text{ Hz}
$$
\n
$$
X_{D} = 150 V, v = 60 \text{ Hz}
$$
\n
$$
X_{D} = 150 V, v = 60 \text{ Hz}
$$
\n
$$
X_{D} = 150 V, v = 60 \text{ Hz}
$$
\n
$$
X_{D} = 150 V, v = 60 \text{ Hz}
$$
\n
$$
X_{D} = \frac{V_{D} = 150}{2 \times 10^{-6} \text{ F}}
$$
\n
$$
X_{D} = \frac{V_{D} = 150}{2 \times 10^{-6} \text{ F}}
$$
\n
$$
X_{D} = \frac{V_{D} = 150}{2 \times 10^{-6} \text{ F}}
$$
\n
$$
X_{D} = \frac{V_{D} = 150}{2 \times 10^{-6} \text{ F}}
$$
\n
$$
X_{D} = \frac{V_{D} = 150}{2 \times 10^{-6} \text{ F}}
$$
\n
$$
X_{D} = \frac{V_{D} = 150}{2 \times 10^{-6} \text{ F}}
$$
\n
$$
X_{D} = \frac{V_{D} =
$$

$$
\frac{v}{v} = 2
$$
\n
$$
= \sqrt{20^2 + \frac{1}{(100)^2 \times (10^{-7})^2}} = \sqrt{400 + 10^{10}} = 10^5 \,\Omega
$$

$$
X_{C_2}
$$
 v1 v (81) (D). Here, R = 0.2 kΩ = 200Ω  
C = 15μF = 15 × 10<sup>-6</sup> F  
V<sub>rms</sub> = 220V, v = 50 Hz  
Capacitive reactance,

$$
X_C = \frac{1}{2\pi vC} = \frac{1}{2 \times 3.14 \times 50 \times 15 \times 10^{-6}} = 212 \,\Omega
$$



The impedance of the RC circuit is

$$
Z = \sqrt{R^2 + X_C^2} = \sqrt{(200)^2 + (212)^2} = 291.5 \,\Omega
$$
  
CP circuit connected to an AC source V. The voltage

**(82) (C).** LCR circuit connected to an AC source V. The voltage of the source to be  $V = Vm \sin \omega t$ . If a is the charge **(92)** of the source to be  $V = Vm \sin \omega t$ . If q is the charge on the capacitor and i the current at time t, from

Kirchhoff's loop rule, 
$$
L\frac{di}{dt} + iR + \frac{q}{C} = V
$$

$$
i_{\rm m} = \frac{v_{\rm m}}{\sqrt{R^2 + (X_{\rm C} - X_{\rm L})^2}}
$$

**(84) (C).**  $V_L = 46$  volts,  $V_C = 40$  volts,  $V_R = 8$  volts

E.M.F. of source 
$$
V = \sqrt{8^2 + (46 - 40)^2} = 10
$$
 volts

**(85) (C).** For series R-L-C circuit,

$$
Z = \sqrt{R^2 + (X_L - X_C)^2}
$$
\n
$$
= \sqrt{(300)^2 + \left(1000 \times 0.9 - \frac{10^6}{1000 \times 2}\right)^2} = 500\Omega
$$
\n(94) (C)

(86) (A). 
$$
V = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(40)^2 + (60 - 30)^2}
$$
  
= 50V

**(87) (D).** Since  $\cos \theta = \frac{R}{7} = \frac{4R}{17} = \frac{6}{10} = \frac{1}{7}$ (Also cos  $\theta$  can never be greater than 1). Hence (C) is wrong. Also,  $Ix_C > Ix_L \Rightarrow x_C > x_L$  $\therefore$  Current will be leading In a LCR circuit,  $Z = \sqrt{R^2 + (X_L - X_C)^2}$ <br>  $= \sqrt{(300)^2 + (1000 \times 0.9 - \frac{10^6}{1000 \times 2})^2} = 500\Omega$ <br> **(86) (A).**  $V = \sqrt{v_R^2 + (V_L - V_C)^2} = \sqrt{(40)^2 + (60 - 30)^2}$ <br> **(86) (A)**  $V = \sqrt{v_R^2 + (V_L - V_C)^2} = \sqrt{(40)^2 + (60 - 30)^2}$ <br> **(87) (D)**. Since cos θ =  $\frac{R$ **(89) (A).**  $V = \sqrt{v_x^2 + (V_L - V_C)^2} = \sqrt{(40)^2 + (60 - 30)^2}$  **(95) (D).** P =  $V_{\text{rms}} \cdot \text{km} \cos \phi = \frac{200}{\sqrt{2}} \frac{1}{\sqrt{2}} \cos \frac{\pi}{3} = 50 \text{ watt}$ <br> **(86) (A).**  $V = \sqrt{v_x^2 + (V_L - V_C)^2} = \sqrt{(40)^2 + (60 - 30)^2}$  **(95) (D).** P =  $V_{\text{rms}} \cdot \text$  $\sqrt{v_R^2 + (v_L - v_C)^2} = \sqrt{(40)^2 + (60 - 30)^2}$  (95) (D). P =  $v_{\text{ms}} \rceil_{\text{rms}} \cos \phi$ ; since (ov<br>  $\cos 0 = \frac{R}{Z} = \frac{IR}{IZ} = \frac{8}{10} = \frac{4}{5}$  (96) (B). If the frequency of the ac sou<br>  $\cos 0 = \frac{R}{IZ} = \frac{IR}{10} = \frac{8}{5}$  (Figure except the (96) (B). If the frequency of the ac sources<br>  $s\theta = \frac{R}{Z} = \frac{IR}{IZ} = \frac{8}{10} = \frac{4}{5}$ <br>  $\theta = \arctan \theta$  by  $\theta = \frac{R}{Z} = \frac{8}{10} = \frac{4}{5}$ <br>  $\theta = \arctan \theta$  by  $\theta = \arctan \theta$ . Hence (C)<br>  $\theta = \frac{V_{rms}}{Z} = \frac{V_{rms}^2}{Z} = \frac{V_{rms}^2}{R} = \frac{(200)^2}{$ 

$$
v = \sqrt{(v_L - v_C)^2 + v_R^2} = \sqrt{(6 - 12)^2 + 8^2}
$$

 $v = 10$ , which is less than voltage drop across capacitor.

(88) (C). 
$$
\cos \phi = \frac{R}{Z} = \frac{10}{20} = \frac{1}{2} \implies \phi = 60
$$

At resonance, 
$$
X_L = X_C
$$
  $\therefore Z = R$   

$$
\therefore I_m = \frac{V_m}{Z} = \frac{V_m}{R}
$$
 (9)

**(90) (D).** Let  $\phi$  be the phase difference between the applied voltage and current. Then

$$
V = 10, \text{ which is less than voltage drop across capacitor.}
$$
\n
$$
I_{rms} = \frac{V_{rms}}{Z}
$$
\n
$$
(C) \cos \phi = \frac{R}{Z} = \frac{10}{20} = \frac{1}{2} \Rightarrow \phi = 60^{\circ}
$$
\n
$$
(D). Impedance of the circuit, Z = \sqrt{R^2 + (X_L - X_C)^2}
$$
\nAt resonance, X<sub>L</sub> = X<sub>C</sub> ∴ Z = R  
\n
$$
\therefore I_m = \frac{V_m}{Z} = \frac{V_m}{R}
$$
\n
$$
(98) (A). Watts sum (99) (B). Resonance voltage and current. Then voltage and current. Then  $\omega = \frac{1}{\sqrt{LC}} = \tan \phi = \frac{X_L - X_C}{R} = \frac{I_V(X_L - X_C)}{I_V R}$ \n
$$
= \frac{V_L - V_C}{V_R} = \frac{20V - 20V}{40V} = 0
$$
\n
$$
\therefore \phi = \tan^{-1}(0) = 0^{\circ}
$$
\n
$$
(100) (C). V2 = VR2 + (Since VL = V\n(B). Here,  $\phi = 45^{\circ}$  (101) (C). At resonance
$$
$$

**(91) (B).** Here,  $\phi = 45^{\circ}$ In series LCR circuit =  $\cos \phi$  Power factor cos  $\phi$ 

$$
\therefore \quad \cos \phi = \cos 45^\circ = \frac{1}{\sqrt{2}} = 0.707.
$$

**EXAMPLE 1.2** (a) (b) 
$$
P = V_{\text{rms}} I_{\text{rms}} \cos \phi = 200 \text{ J}
$$
  
\n**EXECUTE:** (a) (a) (b)  $V = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{4(0)^2 + (60-30)^2}$   
\n**EXECUTE:** (b) (a) (b) Since  $\cos \theta = \frac{R}{Z} = \frac{IR}{IL} = \frac{8}{10} - \frac{4}{5}$   
\n(b) (a) (b) Since  $\cos \theta = \frac{R}{Z} = \frac{IR}{IL} = \frac{8}{10} - \frac{4}{5}$   
\n**EXECUTE:** (a) (a) (b) Since  $\cos \theta = \frac{R}{Z} =$ 

$$
base difference \phi = \frac{\pi}{2} \Rightarrow P = zero
$$

(93) **(D).** P = Vi cos φ  
\nPhase difference 
$$
\phi = \frac{\pi}{2} \Rightarrow P =
$$
 zero  
\n(94) **(C).** V<sub>rms</sub> =  $\frac{200}{\sqrt{2}}$ , i<sub>rms</sub> =  $\frac{1}{\sqrt{2}}$   
\n= 500Ω  
\n $P = V_{rms} i_{rms} \cos \phi = \frac{200}{\sqrt{2}} \frac{1}{\sqrt{2}} \cos \frac{\pi}{3} = 50$  wat  
\n(60-30)<sup>2</sup> **(95) (D).** P = V<sub>rms</sub>I<sub>rms</sub> cos φ ; since  $\phi = 90^\circ$ . So P = 0  
\n(96) **(B).** If the frequency of the ac source equals the natural frequency of the circuit, the impedance Z = R = 20Ω  
\nThe average power dissipated per cycle,  
\n1). Hence (C)  $P_{av} = \frac{V_{rms}^2}{Z} = \frac{V_{rms}^2}{R} = \frac{(200)^2}{20} = 2000$  W  
\n(97) **(C).** Here, X<sub>L</sub> = 1Ω, R = 2Ω, V<sub>rms</sub> = 6V  
\nImpedance of the circuit

- 
- **(96) (B).** If the frequency of the ac source equals the natural frequency of the circuit, the impedance  $Z = R = 20\Omega$ The average power dissipated per cycle,

$$
v_{\text{av}} = \frac{V_{\text{rms}}^2}{Z} = \frac{V_{\text{rms}}^2}{R} = \frac{(200)^2}{20} = 2000 \text{ W}
$$

V<sub>L</sub> = 46 volts, V<sub>C</sub> = 40 volts, V<sub>R</sub> = 8 volts  
\nE.M.F. of source V = 
$$
\sqrt{8^2 + (46-40)^2} = 10
$$
 volts  
\n
$$
Z = \sqrt{R^2 + (X_L - X_C)^2}
$$
\n
$$
Z = \sqrt{R^2 + (X_L - X_C)^2}
$$
\n
$$
= \sqrt{(300)^2 + (1000 \times 0.9 - \frac{10^6}{1000 \times 2})^2} = 500\Omega
$$
\n
$$
= \sqrt{(300)^2 + (1000 \times 0.9 - \frac{10^6}{1000 \times 2})^2} = 500\Omega
$$
\n
$$
= \sqrt{(300)^2 + (1000 \times 0.9 - \frac{10^6}{1000 \times 2})^2} = 500\Omega
$$
\n
$$
= 500\Omega
$$

Power dissipated  $P = V_{rms} I_{rms} \cos \phi = V_{rms} I_{rms} \frac{R}{Z}$ Z<sub>2</sub>

$$
= 6 \times \frac{6}{\sqrt{5}} \times \frac{2}{\sqrt{5}} = \frac{72}{5} = 14.4 \,\mathrm{W}
$$

**(98) (A).** Wattless current is :  $I_{rms} \sin \phi$ 

**(99) (B).** Resonance frequency

$$
a = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{8 \times 10^{-3} \times 20 \times 10^{-6}}} = 2500 \text{ rad/s}
$$

Resonance current = 
$$
\frac{V}{R} = \frac{220}{44} = 5A
$$

(100) (C). 
$$
V^2 = V_R^2 + (V_L - V_C)^2
$$
  
Since  $V_L = V_C$  hence  $V = V_R = 200V$   
(101) (C). At resonance X, = X<sub>C</sub>

(101) (C). At resonance 
$$
X_L = X_C
$$

**EMI AND AC Q.B. - SOLUTIONS**



(102) (D). Since quality factor, 
$$
Q = \frac{1}{R} \sqrt{\frac{I}{C}}
$$

$$
(103) \quad \textbf{(B). Q-factor} = \frac{\omega_r L}{R}
$$

**(104) (B).** At resonance frequency, the inductive and capacitive reactance are equal, i.e.  $X_L = X_C$  $\therefore$  Impedance,

$$
Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 0^2} = R
$$

**(105) (B).** Resonant frequency in a series LCR circuit is

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

If capacitance C increases the resonant frequency will reduce, which can be achieved by adding another capacitor in parallel to the first.

**(106) (D).** Both are dimensionless quantities. Angle is a dimensionless quantity.

(103) (B). Q-factor = 
$$
\frac{\omega_r L}{R}
$$
  
\n(104) (B). At resonance frequency, the inductive and capacitive  
\nreactance are equal, i.e.  $X_L = X_C$   
\n $\therefore$  Impedance,  
\n $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 0^2} = R$   
\n(105) (B). Resonant frequency in a series LCR circuit is  
\n $V_r = \frac{1}{2\pi\sqrt{LC}}$   
\nIf capacitance C increases the resonant frequency  
\nwill reduce, which can be achieved by adding another  
\ncapacitor in parallel to the first.  
\n(106) (D). Both are dimensionless quantities.  
\nAngle is a dimensionless quantity.  
\n(107) (C).  $V_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{5 \times 10^{-4} \times 20 \times 10^{-6}}}$   
\n $V_0 = \frac{10^4}{6.28} = 1592$  Hz  
\n $V_0 = 27 \text{ mH} = 27 \times 10^{-3} \text{ H}$   
\n $\therefore \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}} \qquad (4)$   
\n(5) (A). Here,  $N = N_1 = 1000, I = 1000, I = 1000 \text{ m} = 1 \text{ m}$   
\n $\therefore \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}} \qquad (5)$   
\n $\therefore \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}} \qquad (6)$   
\n $\therefore \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}} \qquad (6)$   
\n $\therefore \omega = \sqrt{LC}$   
\n $\therefore \omega = \sqrt{LC} = \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}} \qquad (7)$   
\n $\therefore \omega = \sqrt{LC} =$ 

$$
v_0 = \frac{10}{6.28} = 1592
$$
 Hz

**(108) (A).** Here,  $C = 30\mu\text{F} = 30 \times 10^{-6}\text{F}$  $L = 27 \text{ mH} = 27 \times 10^{-3} \text{ H}$ 

$$
\therefore \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}}
$$

$$
= \frac{1}{\sqrt{81 \times 10^{-8}}} = \frac{10^4}{9} = 1.1 \times 10^3 \text{ rad s}^{-1}
$$

**(109) (B).** Here,  $C = 25 \mu F = 25 \times 10^{-6} F$ , L = 20 mH =  $20 \times 10^{-3}$  H,  $q_0 = 5$  mC =  $5 \times 10^{-3}$  C  $\therefore$  Total energy stored in the circuit initially is

$$
U = \frac{q_0^2}{2C} = \frac{(5 \times 10^{-3})^2}{2 \times 25 \times 10^{-6}} = \frac{25 \times 10^{-6}}{2 \times 25 \times 10^{-6}} = \frac{1}{2} = 0.5 J
$$

(110) (A). 
$$
\frac{V_p}{V_s} = \frac{N_p}{N_s} \Rightarrow N_p = \left(\frac{220}{2200}\right) 2000 = 200
$$

**(111) (C).** Provided no power looses, being assumed.

(109) (B). Here, 
$$
C = 25 \mu F = 25 \times 10^{-6} F
$$
,  
\n
$$
L = 20 \text{ mH} = 20 \times 10^{-3} H
$$
,  $q_0 = 5 \text{ mC} = 5 \times 10^{-3} C$   
\n
$$
U = \frac{q_0^2}{2C} = \frac{(5 \times 10^{-3})^2}{2 \times 25 \times 10^{-6}} = \frac{25 \times 10^{-6}}{2 \times 25 \times 10^{-6}} = \frac{1}{2} = 0.5 \text{ J}
$$
\n(109) (B). Here,  $C = 25 \mu F = 25 \times 10^{-6} F$ ,  
\n
$$
L = 20 \text{ mH} = 20 \times 10^{-3} H
$$
,  $q_0 = 5 \text{ mC} = 5 \times 10^{-3} C$   
\n
$$
U = \frac{q_0^2}{2C} = \frac{(5 \times 10^{-3})^2}{2 \times 25 \times 10^{-6}} = \frac{25 \times 10^{-6}}{2 \times 25 \times 10^{-6}} = \frac{1}{2} = 0.5 \text{ J}
$$
\n(110) (A).  $\frac{V_p}{V_s} = \frac{N_p}{N_s} \Rightarrow N_p = (\frac{220}{2200}) 2000 = 200$   
\n(111) (C). Provided no power looses, being assumed.  
\n(112) (A).  $\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{200}{100} = \frac{V_s}{120} \Rightarrow V_s = 240 \text{ V}$   
\nAlso  $\frac{V_s}{V_p} = \frac{i_p}{i_s} \Rightarrow \frac{240}{120} = \frac{10}{i_s} \Rightarrow i_s = 5 \text{ A}$   
\n(113) (C).  $\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{N_s}{600} = \frac{2200}{220} \Rightarrow N_s = 6000$   
\n(114) (D). The core of a transformer is laminated to reduce eddy  
\n(115) (D). The core of a transformer is laminated to reduce eddy  
\n
$$
E = B/V = B \times \text{ rate of change of area
$$

- 
- **(114) (D).** The core of a transformer is laminated to reduce eddy current.

## **EXERCISE-2**

**EMI AND AC)** (102) (D). Since quality factor, 
$$
Q = \frac{1}{R}\sqrt{\frac{L}{C}}
$$
  
\n(103) (B). Q-factor =  $\frac{\omega_r L}{R}$   
\n(104) (B). At resonance frequency, the inductive and capacitive  
\nreactance are equal, i.e.  $X_L = X_C$   
\n $\therefore$  Impedance,  
\n $Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 0^2} = R$   
\n(105) (B). Resonant frequency in a series LCR circuit is  
\n $V_r = \frac{1}{2\pi\sqrt{LC}}$   
\n $V_r = \frac{1}{2\pi\sqrt{LC}}$   
\n(106) (D). Both are dimensionsless quantity.  
\n(107) (C).  $v_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{5 \times 10^{-4} \times 20 \times 10^{-6}}}$   
\n $V_0 = \frac{1}{6} = \frac{1.6 \times 10^{-3} \text{ V}}{2 \times 10^{-6} \text{ V}} = \frac{1.6 \times 10^{-2} \text{ s}}{2 \times 10^{-6} \text{ V}} = -150 \text{ V}$   
\n(105) (20) The solution of the first.  
\n $V_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{5 \times 10^{-4} \times 20 \times 10^{-6}}}$   
\n(106) (20) The solution of the first.  
\n $V_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{5 \times 10^{-4} \times 20 \times 10^{-6}}}$   
\n(107) (21)  $v_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{5 \times 10^{-4} \times 20 \times 10^{-6}}}$   
\n(20)  $V_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{5 \times 10^{-4} \times 20 \times 10^{-6}}}$   
\n(21)  $V_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times$ 

$$
\varepsilon = N \frac{|\mathrm{d}\phi|}{\mathrm{d}t} = \frac{N |\phi_f - \phi_i|}{\mathrm{d}t} = \frac{400 \times (384\pi \times 10^{-9})}{0.30}
$$

$$
= 1.6 \times 10^{-3} \text{ V}
$$

Current, 
$$
I = \frac{\varepsilon}{R} = \frac{1.6 \times 10^{-3}}{2} = 8 \times 10^{-4} A
$$

(2) **(D).** Here, 
$$
\frac{dI}{dt} = \frac{0-5}{0.2} = -25 \text{ As}^{-1}
$$
  
 $\varepsilon = 150 \text{ V}$ 

As 
$$
|\varepsilon| = L \left| \frac{dI}{dt} \right|
$$
  $\therefore L = \frac{|\varepsilon|}{|dI/dt|} = \frac{150}{25} = 6H$ 

**(3) (C).** The emf developed between the ends of the

dive and capacitive

\n
$$
\frac{\Psi_{f}^2 \times 10^{-1} \times (8 \times 10^{-1}) \times \cos 160}{\sin 10^{-9} \text{ Wb}}
$$
\n:. The magnitude of induced emf is

\n
$$
\frac{-0^2}{0^2} = R
$$
\n• (a) 10<sup>-3</sup> V

\n
$$
= 1.6 \times 10^{-3} \text{ V}
$$
\n• (10<sup>-3</sup> V)

\n
$$
= 1.6 \times 10^{-3} \text{ V}
$$
\n• (2) (D). Here,  $\frac{dI}{dt} = \frac{0 - 5}{0.2} = -25 \text{ As}^{-1}$ 

\n• (3) (C). The emf developed between the ends of the conductor is

\n
$$
\varepsilon = \frac{1}{2} \omega B \ell^2 = \frac{1}{2} \times 5 \times 0.2 \times 10^{-4} \times (1)^2
$$
\n
$$
= 5 \times 10^{-5} \text{ V} = 50 \times 10^{-6} \text{ V}
$$
\n• (4) (D) As the line has some resistance (R  $\neq$  0) voltage and

**(4) (D).** As the line has some resistance  $(R \neq 0)$ , voltage and current differ in phase  $\phi$  such that  $|\phi| < \pi/2$ .

∴ Impedance.  
\n
$$
Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{R^2 + 0^2} = R
$$
  
\n $R = N \frac{d\phi}{dt} = \frac{N\phi r}{\phi r} = \frac{1}{d\theta}$   
\n $V_r = \frac{1}{2\pi\sqrt{LC}}$   
\n $V_r = \frac{1}{2\pi\sqrt{LC}}$   
\n $V_r = \frac{1}{2\pi\sqrt{LC}}$   
\n $V_r = \frac{1}{2\pi\sqrt{LC}}$   
\n $V_{\text{un}}$   
\n $V_{\text$ 

$$
\varepsilon = \frac{d\phi}{dt} = \frac{d}{dt} (2t^2 + 4t + 6) \times 10^{-3} \text{ Wb s}^{-1}
$$
  
= (4t + 4) × 10<sup>-3</sup> V  
At t = 4s  

$$
\varepsilon = (4 \times 4 + 4) \times 10^{-3} \text{ V} = 20 \times 10^{-3} \text{ V} = 0.02 \text{ V}
$$

**(7) (C).** Total magnetic flux,  $N\phi = LI = 20 \times 10^{-3} \times 4 \times 10^{-3} = 8 \times 10^{-5}$  Wb Magnetic flux through the cross-section of the coil,

$$
0 = \frac{8 \times 10^{-5}}{N} = \frac{8 \times 10^{-5}}{100} = 8 \times 10^{-7}
$$
 Wb

- **(8) (D).** Self inductance of a solenoid =  $\mu_0 n^2 Al$ where n is the number of turns per length  $\therefore$  Self inductance is directly proportional to  $n^2$ . Self
	- inductance becomes 4 times when n is doubled.
- **(9) (D).** When a circular coil expands radially in a region of magnetic field, induced emf developed is  $\varepsilon = B/v = B \times$  rate of change of area



Here, magnetic field B is in a plane perpendicular to the plane of the circular coil. As  $\varepsilon = 0$ , magnetic field must be in the plane of circular coil so that its component perpendicular to the plane of the coil, whose magnitude is decreasing suitably so that magnetic flux linked with the coil stays constant then **EXERUING**<br>
THEATENING<br>
Here, magnetic field B is in a plane perpendicular to<br>
the plane of the circular coil. As  $\epsilon = 0$ , magnetic field<br>
must be in the plane of circular coil so that its<br>
component perpendicular to the **EXERCUTED SET**<br>
HERE magnetic field B is in a plane perpendicular to<br>
the plane of the circular coil. As  $\varepsilon = 0$ , magnetic field<br>
must be in the plane of circular coil so that its<br>
component perpendicular to the plane o **CO.B.- SOLUTIONS**<br>
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UNISOR OF THE PLANE OF CONTROLLER TO THE PLANE OF THE PLANE OF THE PLANE OF THE PLANE OF THE ane of the circular coil. As  $\varepsilon = 0$ , magnetic field<br>
be in the plane of circular coil so that its<br>
conent perpendicular to the plane of the coil,<br>
e magnitude is decreasing suitably so that<br>
deficiently linked with the be in the plane of circular coil so that its<br>
onent perpendicular to the plane of the coil,<br>
e magnitude is decreasing suitably so that<br>
tetic flux linked with the coil stays constant then<br>  $\frac{d\phi}{dt} = 0$ . So both options **EXERCISE COLUTIONS**<br>
In a magnetic field B is in a plane perpendicular to<br>
the in the plane of the circular coil. As  $\varepsilon = 0$ , magnetic field<br>
benefit be interesting suitably so that<br>
see magnitude is decreasing suitably

$$
\varepsilon = \frac{d\phi}{dt} = 0
$$
. So both options (B) and (C) are correct.

$$
(10) \t(B).  $|\varepsilon| = L \frac{dI}{dt}$
$$

$$
L = \frac{|\varepsilon|}{dI/dt} = \frac{IR}{dI/dt} = \frac{IP/I^2}{dI/dt} = \frac{P}{I(dI/dt)}
$$
(17)

As P and (dI/dt) are same for both the coils

$$
\therefore \quad \frac{I_1}{I_2} = \frac{L_2}{L_1} = \frac{1}{4}
$$

(11) (A). 
$$
|e| = \frac{d\phi}{dt} = \frac{d}{dt}(5t^2 + 3t + 16) = (10t + 3)
$$

when 
$$
t = 3 \sec, e_3 = (10 \times 3 + 3) = 33
$$
 V

when  $t = 4 \sec, e_4 = (10 \times 4 + 3) = 43$  V

Hence emf induced in fourth second

$$
= e_4 - e_3 = 43 - 33 = 10 V
$$

(12) **(B).** 
$$
\Delta Q = \frac{\Delta \phi}{R} = \frac{n \times BA}{R}
$$

$$
\Rightarrow B = \frac{\Delta Q.R}{nA} = \frac{2 \times 10^{-4} \times 80}{40 \times 4 \times 10^{-4}} = 1 \text{ Wb} / \text{m}^2
$$
 (23)

 $rac{dI}{dt}$ <br>  $\frac{dI}{dt}$ <br>  $\frac{d$  $rac{\varepsilon}{\sqrt{dt}} = \frac{\text{IR}}{\text{d}t/dt} = \frac{\text{IP}/1^2}{\text{d}t/dt} = \frac{\text{P}}{1(\text{d}t/dt)}$  (17) (D), e = L  $\frac{di}{dt} = 60 \times 10^{-6} \times \frac{(1.5-1.0)}{0.1} = 3$ <br>
and (dl/dt) are same for both the coils<br>  $= \frac{L_2}{L_1} = \frac{1}{4}$  (18) (D). N $\phi = \text{Li} \Rightarrow \frac{\$ L  $\frac{d}{dt}$ <br>  $\frac{d}{dt}$ = L  $\frac{u}{dt}$ <br>
=  $\frac{|g|}{dI/dt} = \frac{IR}{dI/dt} = \frac{IP/1^2}{I(dI/dt)} = \frac{P}{I(dI/dt)}$ <br>
P and (dl/dt) are same for both the coils<br>
P and (dl/dt) are same for both the coils<br>  $\frac{I_1}{I_2} = \frac{L_2}{L_1} = \frac{1}{4}$ <br>  $\Rightarrow \frac{1 \times 1 \times 5}{10^{-3}} = \frac{1 \$ **(13) (A).**  $\phi = Li \Rightarrow NBA = Li$ Since magnetic field at the centre of circular coil carrying current is given by  $\frac{1}{12} = \frac{1-2}{L_1} = \frac{1}{4}$ <br>  $\Rightarrow \frac{1+2}{10^{-3}} = L \times (\frac{2-1}{2 \times 10^{-4}})$ <br>
when t = 3sec, e<sub>3</sub> = (10×3+3) = 33 V<br>
when t = 3sec, e<sub>3</sub> = (10×4+3) = 33 V<br>
eince emf induced in fourth second<br>  $= e_4 - e_3 = 43 - 33 = 10$  V<br>
(20) (B) 2  $L_1$  4<br>  $\frac{d\phi}{dt} = \frac{d}{dt}(5t^2 + 3t + 16) = (10t + 3)$ <br>  $t = 3\sec, e_3 = (10 \times 3 + 3) = 33 \text{ V}$ <br>  $t = 4\sec, e_4 = (10 \times 4 + 3) = 43 \text{ V}$ <br>  $= e_4 - e_3 = 43 - 33 = 10 \text{ V}$ <br>  $= 4\frac{\phi}{R} = \frac{n \times BA}{R}$ <br>  $= \frac{A\phi}{R} = \frac{n \times BA}{R}$ <br>  $= \frac{A\phi}{nA} = \frac{a \times$  $\frac{d\Phi}{dt} = \frac{d}{dt}(5t^2 + 3t + 16) = (10t + 3)$ <br>  $t = 3\sec, e_3 = (10 \times 3 + 3) = 33 \text{ V}$ <br>  $t = 4\sec, e_4 = (10 \times 4 + 3) = 43 \text{ V}$ <br>
ornf induced in fourth second<br>  $= e_4 - e_3 = 43 - 33 = 10 \text{ V}$  (20) (B).  $U = \frac{1}{2}Li^2 = \frac{1}{2}L(\frac{E}{R})^2 = \frac{1}{2$  $\frac{40}{4}$  =  $\frac{1}{4}$  = (10×3+3) = 33 V<br>
1 t = 3sec, e<sub>3</sub> = (10×3+3) = 33 V<br>
1 t = 4sec, e<sub>4</sub> = (10×4+3) = 43 V<br>
200 (B). U =  $\frac{1}{2}$  Li<sup>2</sup> =  $\frac{1}{2}$  Li<sup>2</sup> ( $\frac{1}{R}$ ) =  $\frac{1}{2}$  =  $\frac{1}{2}$  Li<sup>2</sup> ( $\frac{1}{R}$ ) =  $\$ 

$$
B = \frac{\mu_0}{4\pi} \frac{2\pi Ni}{r} : N \cdot \frac{\mu_0}{4\pi} \frac{2\pi Ni}{r} \cdot \pi r^2 = Li
$$
 (24) (A). For 1

$$
\Rightarrow L = \frac{\mu_0 N^2 \pi r}{2}
$$

Hence self inductance of a coil

when t = ssec, e<sub>3</sub> = (10×3+3) = 33 V  
\nwhen t = 4sec, e<sub>4</sub> = (10×4+3) = 43 V  
\nHence emf induced in fourth second  
\n
$$
= e_4 - e_3 = 43 - 33 = 10 V
$$
\n(20) (B).  $U = \frac{1}{2}Li^2 = \frac{1}{2}L(\frac{E}{R})^2 = \frac{1}{2} \times 5 \times (\frac{100}{20})^2 = 62.50J$ \n(12) (B).  $\Delta Q = \frac{\Delta \phi}{R} = \frac{n \times BA}{R}$   
\n
$$
= \frac{AQ}{R} = \frac{n \times BA}{R}
$$
\n(22) (D).  $i = \frac{E - e}{R} \Rightarrow 1.5 = \frac{220 - e}{20} \Rightarrow e = 190 V$ \n(13) (A).  $\Delta b = Li$   $\Delta t = \frac{2 \times 10^{-4} \times 80}{40 \times 4 \times 10^{-4}} = 1 \text{ Wb/m}^2$   
\n
$$
= \frac{100 \times 4 \times 10^{-4}}{40 \times 4 \times 10^{-4}} = 1 \text{ Wb/m}^2
$$
\n(14) (A).  $b = Li$   $\Rightarrow$  B =  $\frac{\Delta Q.R}{nR} = \frac{2 \times 10^{-4} \times 80}{40 \times 4 \times 10^{-4}} = 1 \text{ Wb/m}^2$   
\n
$$
B = \frac{\mu_0}{4\pi} \frac{2\pi Ni}{r} \therefore N \cdot \frac{\mu_0}{4\pi} \frac{2\pi Ni}{r} \cdot \pi r^2 = Li
$$
\n(24) (A). For 100% efficiency V<sub>5</sub><sup>1</sup><sub>5</sub> = V<sub>9</sub><sup>1</sup><sub>7</sub> =  $\frac{1}{3} \text{ N}_p$   
\n
$$
= \frac{1}{4} \frac{1}{100} \Rightarrow i_p = 1 \text{ A}
$$
\n(14) (D).  $e = -L \frac{di}{dt} \Rightarrow 2 = -L(\frac{8-2}{3 \times 10^{-2}})$   
\n
$$
L = 0.01 H =
$$

(15) (B). 
$$
e = M \frac{di}{dt} \Rightarrow M = \frac{15000}{3} \times 0.001 = 5 H
$$

$$
(16) \quad (B). \quad I = \frac{\varepsilon}{R} = \frac{|\mathrm{d}\phi/\mathrm{d}t|}{R} = \frac{B.\frac{\mathrm{d}A}{\mathrm{d}t}}{R}
$$

**IDENTIFY**  
\nHere, magnetic field B is in a plane perpendicular to the plane of the coil. As P and (d1/dt) are same to the plane of the coil.  
\nthe plane of the circular coil has the line of the point.  
\n
$$
\epsilon = \frac{d\phi}{dt} = 0.
$$
\nSo both options (B) and (C) are correct.  
\n
$$
|\epsilon| = L \frac{dI}{dt}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{IR}{dI/dt} = \frac{IP/I^2}{dI/dt} = \frac{P}{dI(dI/dt)}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{IR}{dI/dt} = \frac{IP/I^2}{dI/dt} = \frac{P}{dI(dI/dt)}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{I}{dI} \frac{dI}{dt} = \frac{IP/I^2}{dI}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{IP/I^2}{dI/dt} = \frac{P}{dI(dI/dt)}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{IP/I^2}{dI/dt} = \frac{P}{dI(dI/dt)}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{IP/I^2}{dI} = \frac{P}{dI}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{IP/I^2}{dI/dt} = \frac{P}{dI(dI/dt)}
$$
\n
$$
L = \frac{1}{dI} \frac{dI}{dt} = \frac{I}{dI} \frac{dI}{dt} = \frac{I}{dI} \frac{I}{dt} = \frac{I}{dI} \frac{I}{dt}
$$
\n
$$
\Rightarrow \frac{1 \times 1 \times 5}{10^{-3}} = L \times (\frac{2 - 1}{
$$

17) **(D).** 
$$
e = L \frac{di}{dt} = 60 \times 10^{-6} \times \frac{(1.5 - 1.0)}{0.1} = 3 \times 10^{-4} \text{ volt}
$$

(18) **(D).** 
$$
N\phi = Li \Rightarrow \frac{Nd\phi}{dt} = \frac{Ldi}{dt} \Rightarrow NB\frac{dA}{dt} = \frac{Ldi}{dt}
$$

$$
\Rightarrow \frac{1 \times 1 \times 5}{10^{-3}} = L \times \left(\frac{2 - 1}{2 \times 10^{-3}}\right) \Rightarrow L = 10H
$$

**(19) (D).** Electric field will be induced in both AD and BC.

$$
E = L \frac{1}{dt}
$$
  
\n
$$
L = \frac{|s|}{dt} = \frac{IR}{dt/dt} = \frac{IP/I^2}{dt/dt} = \frac{P}{I(d/dt)}
$$
  
\n
$$
L = \frac{|s|}{dt/dt} = \frac{IR}{dt/dt} = \frac{IP/I^2}{dt/dt} = \frac{P}{I(d/dt)}
$$
  
\n
$$
L = \frac{|s|}{dt} = \frac{1}{dt} = \frac{1}{
$$

(20) (B). 
$$
U = \frac{1}{2}Li^2 = \frac{1}{2}L(\frac{E}{R}) = \frac{1}{2} \times 5 \times (\frac{100}{20}) = 62.50J
$$
  
\n(21) (C).  $i = \frac{V}{R} = \frac{10}{2} = 5A$ ;  $U = \frac{1}{2}Li^2 = \frac{1}{2} \times 2 \times 25 = 25J$   
\n(22) (D).  $i = \frac{E - e}{R} \Rightarrow 1.5 = \frac{220 - e}{20} \Rightarrow e = 190 \text{ V}$   
\n(23) (C).  $\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{1}{20} = \frac{V_s}{2400} \Rightarrow V_s = 120 \text{ V}$   
\nFor 100% efficiency  $V_s i_s = V_p i_p$   
\n $\Rightarrow 120 \times 80 = 2400 i_p \Rightarrow i_p = 4A$   
\n(24) (A). For 100% efficient transformer  
\n $V_s i_s = V_p i_p \Rightarrow \frac{V_s}{V_p} = \frac{i_p}{i_s} = \frac{N_s}{N_p}$   
\n $\Rightarrow \frac{i_p}{4} = \frac{25}{100} \Rightarrow i_p = 1 \text{ A}$   
\n(25) (A). For each spoke, the induced emf between the centre O and the rim will be the same  
\n $e = \frac{1}{2} B_0 L^2 = B_0 L^2 f (\because \omega = 2 \pi f)$   
\nFurther for all spokes, centre O will be positive while

(22) **(D).** 
$$
i = \frac{E - e}{R} \Rightarrow 1.5 = \frac{220 - e}{20} \Rightarrow e = 190 \text{ V}
$$

(23) (C). 
$$
\frac{N_s}{N_p} = \frac{V_s}{V_p} \Rightarrow \frac{1}{20} = \frac{V_s}{2400} \Rightarrow V_s = 120 \text{ V}
$$

$$
\Rightarrow 120 \times 80 = 2400 i_p \Rightarrow i_p = 4A
$$

$$
V_{\rm s}i_{\rm s} = V_{\rm p}i_{\rm p} \Rightarrow \frac{V_{\rm s}}{V_{\rm p}} = \frac{I_{\rm p}}{i_{\rm s}} = \frac{N_{\rm s}}{N_{\rm p}}
$$

$$
\Rightarrow \frac{i_p}{4} = \frac{25}{100} \Rightarrow i_p = 1 \text{ A}
$$

 **(25) (A).** For each spoke, the induced emf between the centre O and the rim will be the same

$$
e = \frac{1}{2} B \omega L^2 = B \pi L^2 f(\because \omega = 2\pi f)
$$

Further for all spokes, centre O will be positive while rim will be negative. Thus all emf's are inparallel giving total emf e =  $B\pi L^2 f$ independent of the number of the spokes.

Substituting the values

$$
e = 4 \times 10^{-5} \times 3.14 \times (.5)^{2} \times 2 = 6.28 \times 10^{-5}
$$
 volt



- **(26) (B).** As number of turns are quadrupled, the induced emf will increase four times. Also, resistance of coil increases sixteen times. Hence power  $(e^2/R)$ will not change. **(Q.B.-SOLUTIONS**<br>
er of turns are quadrupled, the<br>
will increase four times. Also, resistance<br>
ses sixteen times. Hence power (e<sup>2</sup>/R)<br>
ge.<br>
(32) (D).<sup>1</sup><br>  $\uparrow$ <br>  $\$ **(A)** As number of turns are quadrupled, the<br>
induced emfwill increase four times. Also, resistance<br>
of coil increases sixteen times. Also, resistance<br>
will not change.<br> **(D)**. Steady state current for both the circuits i **AC**<br> **As number of turns are quadrupled, the**<br>
theed emf will increase four times. Also, resistance<br>
coil increases sixteen times. Hence power (e<sup>2</sup>/R)<br>
II not change.<br> **accely state current for both the circuits is same 1AC** As number of turns are quadrupled, the<br>
nduced em<sup>ritma</sup>linerease four times. Also, resistance<br>
of coil increases sixteen times. Hence power (e<sup>2</sup>/R)<br>
will not change.<br>
Steady state current for both the circuits i **Example 18** C.B. SOLUTIONS<br>
As number of turns are quadrupled, the<br>
As matured emf will increase four times. Also, resistance<br>
of coil increases sixteen times. Hence power (e<sup>2</sup>/R)<br>
will not change.<br>
Steady state current
- **(27) (D).** Steady state current for both the circuits is same.

Therefore, 
$$
\frac{V}{R_1} = \frac{V}{R_2}
$$
 or  $R_1 = R_2$ 

Further,  $\tau_{L_1} < \tau_{L_2}$  ( $\tau_L$  = time constant)

$$
\therefore \quad \frac{L_1}{R_1} < \frac{L_2}{R_2} \text{ or } L_1 < L_2
$$

**(28) (C).** According to Faraday's law of electromagnetic

induced  $=\frac{\ }{4t}=-\frac{4}{4}$  $-\Delta\phi$   $B(A_f - A_i)$ Let r be the radius of circle; then side of square formed

Change is area of loop

$$
= A_{i} - A_{f} = \pi r^{2} - \left(\frac{\pi r}{2}\right)^{2} = \frac{\pi (4 - \pi) r^{2}}{4}
$$
 (35) (C) i<sub>3</sub> =

Hence average emf induced

$$
= \frac{\pi (4 - \pi) r^2}{4} \cdot \frac{B}{t} = \frac{\pi (4 - \pi) \times (0.1)^2 \times 100}{4 \times 0.1} = 6.75 \text{ volt} \quad (36) \quad (C). \text{ The equation is } \frac{\pi}{4} = \frac{\pi}{4} = \frac{\pi}{4} = \frac{1}{4} = 6.75 \text{ volt} \quad (37)
$$

**(29) (B).** Power  $P = e^2/R$ 

Here,  $e =$  induced emf =  $-(d\phi/dt)$ , where  $\phi = NBA$ 

$$
e = -NA \left( \frac{dB}{dt} \right) \text{ Also, } R \propto \frac{\ell}{r^2}
$$

where R = resistance,  $r =$  radius,  $\ell =$  length

$$
\therefore P \propto \frac{N^2 r^2}{\ell} \qquad \therefore \qquad \frac{P_1}{P_2} = 1
$$

**(30) (B).** We connect a conducting wire from A to C and complete the semicircular loop.

> The loop emf in the semicircular loop is zero because its magnetic flux does not change.



- $\therefore$  emf of section APC + emf of section CQA = 0
- or emf o section APC = emf of section AQC =  $2BR<sup>2</sup>$   $\omega$

**(31) (A).** At any time t, the side of the square

 $a = (a_0 - \alpha t)$ , where  $a_0 =$  side at  $t = 0$ . At this instant, flux through the square :  $\phi = BA \cos 0^{\circ} = B (a_0 - \alpha t)^2$ 

$$
\therefore \quad \text{emf induced } E = -\, \text{d}\phi / \, \text{d}t
$$

$$
\Rightarrow E = -B.2 (a_0 - \alpha t) (0 - \alpha) = +2\alpha aB
$$

1 2 **(32) (D).** D C I <sup>r</sup> <sup>A</sup> <sup>B</sup> v

As flux decrease to maintain flux current in loop is clockwise. Force on DA due to long wire and BC is towards left while on wire BC toward right.

R R Further, L L 1 2 (<sup>L</sup> induction, f i B(A A ) <sup>E</sup> **(33) (D).** <sup>0</sup> 0 v i Z , 2 2 2 3 2 Z R ( L) 4 (1000 3 10 ) 5 i<sup>0</sup> = 4/5 ; i<sup>0</sup> = 0.8 A 4 <sup>3</sup>

1. A's number of turns are quadrupled, the  
induced m will not change. Since four times, 
$$
1.8
$$
, respectively.  $32$  (b).  $1$   
\n $\frac{1}{R_1} \times \frac{1}{R_2}$  or  $R_1 = R_2$   
\n $R_1 = \frac{1}{R_2}$  or  $R_1 = R_2$   
\n $R_2 = \frac{1}{R_1}$  or  $R_1 = R_2$   
\n $R_1 = \frac{1}{R_2}$  or  $R_1 = R_2$   
\n $R_2 = \frac{1}{R_1}$  or  $R_1 = R_2$   
\n $R_1 = \frac{1}{R_2}$  or  $L_1 < L_2$   
\n $R_2 = \frac{1}{R_1} \times \frac{1}{R_2}$  or  $L_1 < L_2$   
\n $R_1 = \frac{1}{R_1} \times \frac{1}{R_2}$  or  $L_1 < L_2$   
\n $R_2 = \frac{1}{R_1} \times \frac{1}{R_2}$  or  $L_1 < L_2$   
\n $L_1 = \frac{1}{R_1} \times \frac{1}{R_2}$  or  $L_1 < L_2$   
\n $L_2 = \frac{1}{R_1}$   
\n $L_1 = \frac{1}{R_1}$  or  $L_1 = \frac{1}{R_1}$   
\n $L_2 = \frac{1}{R_1}$   
\n $L_3 = \frac{1}{R_2}$   
\n $L_4 = \frac{1}{R_1}$   
\n $L_5 = \frac{1}{R_1}$   
\n $L_6 = \frac{1}{R_1}$   
\n $L_7 = \frac{1}{R_1}$   
\n $L_8 = \frac{1}{R_1}$   
\n $L_9 = \frac{1}{R_1}$   
\n $L_1 = \frac{1}{R_1}$   
\n $L_2 = \frac{1}{R_1}$   
\n $L_3 = \frac{1}{R_1}$   
\n $L_4 = \frac{1}{R_1}$   
\n $L_5 = \frac{1}{R_1}$ <

(36) (C). The circuit will have inductive nature if 
$$
\omega > \frac{\sqrt{LC}}{\sqrt{LC}}
$$

Hence A is false. Also if circuit has inductive nature the current will lag behind voltage. Hence (D) is also false.

$$
\propto \frac{1}{r^2}
$$
 If  $\omega = \frac{1}{\sqrt{LC}} \left( \omega L = \frac{1}{\omega C} \right)$  the circuit will have resis-

 $\mathbf{C}^{\perp}$ 

tance nature. Hence (B) is false. Power factor

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

(37) (C). Since B is constant 
$$
\therefore \frac{d\phi}{dt} = 0 \therefore i = 0
$$

**(38) (C).** Here,  $L = 30$  mH =  $30 \times 10^{-3}$  H  $V_{rms} = 220 V, v = 100 Hz$ Inductive reactance,  $X_L = 2\pi vL = 2 \times 3.14 \times 100 \times 30 \times 10^{-3} = 18.85\Omega$ 

(39) **(D).** Current 
$$
I_1 = I_2
$$
, Since magnetic field increases with time. So induced net flux should be outward i.e. current will flow from a to b.





**(40) (B).** Here,  $I_{rms} = 25A$  $\therefore I_m = \sqrt{2} I_{rms} = \sqrt{2} \times 25 = 35.36 A.$ 

(41) (A). Current leads emf so circuit is R – C  
\n
$$
\tan \phi = X_c / R, \ \phi = 45^\circ, R = 1000Ω,
$$
\n
$$
\omega = 100 C - 2
$$

since, 
$$
\tan 45^\circ = \frac{1}{\omega CR}
$$
 so  $C = 10 \mu F$  as a induct

**(42) (D).** Here,  $V_p = 11000 \text{ V}, V_s = 220 \text{ V}$  $N_p = 6000, \eta = 60\%$  $P_0 = 9$  kW =  $9 \times 10^3$  W

Efficiency, 
$$
\eta = \frac{\text{Output power}}{\text{Input power}} = \frac{P_0}{P_i}
$$

$$
P_i = \frac{P_0}{\eta} = \frac{9 \times 10^3}{60/100} = 1.5 \times 10^4 = 15 \text{kW}
$$

**(43) (A).** The instantaneous value of voltage is  $V = 100 \sin(100 t) V$ Compare it with  $V = V_0 \sin(\omega t) V_1$ we get  $V_0 = 100 \text{ V}, \omega = 100 \text{ rad s}^{-1}$ The rms value of voltage is

$$
\therefore V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = \frac{100}{\sqrt{2}} V = 70.7 V
$$

The instantaneous value of current is

$$
I = 100 \sin \left( 100t + \frac{\pi}{3} \right) \text{ mA}
$$
 (49)

Compare it with  $I = I_0 \sin(\omega t + \phi)$ we get  $I_0 = 100$  mA,  $\omega = 100$  rad s<sup>-1</sup> The rms value of current is

$$
I_{\rm rms} = \frac{I_0}{\sqrt{2}} = \frac{100}{\sqrt{2}} \text{mA} = 70.7 \text{mA}
$$

**(44) (C).** Here, L = 2H, C =  $32\mu$ F =  $32 \times 10^{-6}$ F, R =  $10\Omega$ : Resonance frequency,

$$
\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{2 \times 32 \times 10^{-6}}} = \frac{10^3}{8}
$$
 rad/s 
$$
Z = \sqrt{R}
$$

Quality factor = 
$$
\frac{\omega_r L}{R} = \frac{10^3 \times 2}{8 \times 10} = 25
$$
  $I_{rms}$  =

(45) (C). Here, 
$$
C = 5\mu F = 5 \times 10^{-6} F
$$
,  
 $V_{rms} = 200 V, v = 100 Hz$ 

The capacitive reactance is

**IDENTIFY**  
\nThe capacitive reactance is  
\n
$$
X_C = \frac{1}{2\pi vC} = \frac{1}{2 \times 3.14 \times 100 \times 5 \times 10^{-6}}
$$
\n= 3.18 × 10<sup>2</sup> Ω = 318 Ω  
\n**(A).**  $f = \frac{1}{2\pi \sqrt{LC}}$   
\ni.e.  $f \propto \frac{1}{\sqrt{C}} \rightarrow \frac{1}{\sqrt{4}} = \frac{1}{2}$  times  
\n**(C).** As current is in phase with the applied voltage, X must be R.  
\n
$$
R = \frac{V_0}{I_0} = \frac{200V}{5A} = 40Ω
$$
\nAs current lags behind the voltage by 90°, Y must be an inductor.  
\n
$$
X_L = \frac{V_0}{I_0} = \frac{200V}{5A} = 40Ω
$$
\nIn the series combination of X and Y,  
\n
$$
Z = \sqrt{R^2 + X_L^2} = \sqrt{40^2 + 40^2} = 40\sqrt{2} Ω
$$
\n
$$
I_{rms} = \frac{V_{rms}}{I_0} = \frac{V_0}{I_0} = \frac{200}{\sqrt{2}} = \frac{5}{4} A
$$

(46) (A). 
$$
f = \frac{1}{2\pi\sqrt{LC}}
$$
  
i.e.  $f \propto \frac{1}{2\pi\sqrt{LC}} \to \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{LC}}$ 

**(47) (C).** As current is in phase with the applied voltage, X must be R.

$$
A = \frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega
$$

As current lags behind the voltage by 90º, Y must be an inductor.

$$
X_{\rm L} = \frac{V_0}{I_0} = \frac{200 \text{V}}{5 \text{A}} = 40 \Omega
$$

In the series combination of X and Y,

The capacitive reactance is  
\n
$$
\begin{array}{ccc}\n\frac{x}{11} & \frac{x}{11} & \frac{x}{11} \\
x & x & x \\
x & x & x
$$

The set of  $\frac{V}{V}$  =  $\frac$  $\frac{1}{2\pi}$   $\frac{1}{2\pi}$ <br>  $\frac{1}{2\pi}$   $\frac{1}{2\pi}$ <br>  $\frac{1}{2\pi}$ <br> = 100, C = 7<br>
c, tan 45° =  $\frac{1}{0}$  so C = 10 μF<br>
c, v<sub>p</sub> = 1000 V γ<sub>x</sub> = 200V<br>
c, c = 7<br>
c, c = 1000 V γx = 220V<br>
c = 6 kW = 9 × 10<sup>3</sup> W<br>
ficiency, η =  $\frac{0u_{\text{put}}}{\ln u}$  power =  $\frac{p_0}{p_1}$ <br>
ficiency, η =  $\frac{0u_{\text$  $S^2 = \frac{1}{\omega CR}$  so C = 10 μF<br>
As current lags behind the voltage<br>
an inductor.<br>  $\frac{1}{2} = \frac{100}{100}$  V = 220V<br>  $\frac{1}{2} = \frac{1}{\sqrt{2}}$  v = 70.7V<br>  $\frac{0}{2} = \frac{100}{\sqrt{2}}$  V = 70.7V<br>  $\frac{1}{2}$  (49) (B). When the frequency of can be  $x_0 \times p_0 = 9 \text{ kN}$ .<br>  $\ln \ln 45^\circ = \frac{1}{\omega CR}$  so  $C = 10 \text{ }\mu\text{F}$ <br>  $N_p = 1000 \text{ V}, V_s = 220 \text{ V}$ <br>  $N_p = 600, \text{ } n = 1000 \text{ V}, V_s = 220 \text{ V}$ <br>  $N_p = 600, \text{ } n = 100 \text{ V}, V_s = 220 \text{ V}$ <br>  $N_p = 600, \text{ } n = 100 \text{ V}, V_s = 220 \text{ V}$ <br> 45° =  $\frac{1}{\omega CR}$  so C = 10 µF<br>  $\mu = 60\%$ <br>  $n = 200V$ <br> 45° =  $\frac{1}{0.00}$  OV,  $V_s$  = 220V<br>  $T = 60\%$ <br>  $T = 10\%$ 43° =  $\frac{1000 \text{ V} \text{ V}}{100 \text{ s}} = \frac{100 \text{ s}}{100 \text{ s}} = 1.5 \times 10^4 = 15 \text{kW}$ <br>  $\eta = 60\%$ <br>  $\eta = 60\%$ <br>  $\eta = 0.00 \text{ rad/s}^{-1}$ <br>  $\frac{9 \times 10^3}{60/100} = 1.5 \times 10^4 = 15 \text{kW}$ <br>  $\frac{9 \times 10^3}{60/100} = 1.5 \times 10^4 = 15 \text{kW}$ <br>  $\frac{1}{100$  $\sqrt{C} \rightarrow \sqrt{4} = 2$  times<br>
t is in phase with the applied voltage, X<br>
2.<br>  $= \frac{200V}{5A} = 40\Omega$ <br>
t lags behind the voltage by 90°, Y must be<br>
or.<br>  $L = \frac{200V}{5A} = 40\Omega$ <br>
ies combination of X and Y,<br>  $+X_L^2 = \sqrt{40^2 + 40^2} = 40$  $f = \frac{1}{2\pi\sqrt{LC}}$ <br>
i.e.  $f \propto \frac{1}{\sqrt{C}} \rightarrow \frac{1}{\sqrt{4}} = \frac{1}{2}$  times<br>
As current is in phase with the applied voltage, X<br>
must be R.<br>  $R = \frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
As current lags behind the voltage by 90°, Y must be<br> 8 × 10<sup>2</sup> Ω = 318 Ω<br>  $\frac{1}{2\pi\sqrt{LC}}$ <br>  $\frac{1}{\sqrt{C}}$   $\frac{1}{\sqrt{4}} = \frac{1}{2}$  times<br>
urrent is in phase with the applied voltage, X<br>
be R.<br>  $\frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
duted to:<br>  $\frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
duted to: **(48) (C).** Here,  $R = X_L = X_C$  ( $\because$  voltage across them is same) Total voltage in the circuit,  $V = I [R^2 + (X_L - X_C)^2]^{1/2} = IR = 10V$ When capacitor is short circuited, ctor.<br>  $\frac{V_0}{V_0} = \frac{200 \text{V}}{5 \text{A}} = 40 \Omega$ <br>
eries combination of X and Y,<br>  $\frac{V_{\text{rms}}}{2} = \frac{V_0}{\sqrt{2}L} = \frac{200}{\sqrt{2}(40\sqrt{2})} = \frac{5}{2} \text{A}$ <br>  $= X_L = X_C (\because \text{ voltage across them is same})$ <br>  $= 2 + (X_L - X_C)^2]^{1/2} = IR = 10 \text{V}$ <br>
apacitor is short circu nust be R.<br>  $R = \frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
As current lags behind the voltage by 90°, Y must be<br>
an inductor.<br>  $X_L = \frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
In the series combination of X and Y,<br>  $Z = \sqrt{R^2 + X_L^2} = \sqrt{40^2 + 40^2}$  $\frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
arrent lags behind the voltage by 90°, Y must be<br>
ductor.<br>  $=\frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
e series combination of X and Y,<br>  $\sqrt{R^2 + X_L^2} = \sqrt{40^2 + 40^2} = 40\sqrt{2} \Omega$ <br>  $=\frac{V_{rms}}{Z} = \frac{V_0}{\$ Is current is in phase with the applied voltage, X<br>
aust be R.<br>  $R = \frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
s. current lags behind the voltage by 90°, Y must be<br>
n inductor.<br>  $K_L = \frac{V_0}{I_0} = \frac{200V}{5A} = 40\Omega$ <br>
the series combina  $\sqrt{40^2 + 40^2} = 40\sqrt{2} \Omega$ <br>  $\frac{V_0}{2ZZ} = \frac{200}{\sqrt{2}(40\sqrt{2})} = \frac{5}{2} \text{ A}$ <br>  $\left[\frac{C}{ZZ}(\frac{V}{2} + V_0)\right]^{1/2} = IR = 10V$ <br>
Solve the circuit,<br>  $\left[\frac{V_0}{2}\right]^{1/2} = IR = 10V$ <br>
Substriance short circuited,<br>  $\frac{1}{Z} = \frac{10}{\sqrt{2}R}$ <br> on of X and Y,<br>  $\frac{200}{2+40^2} = 40\sqrt{2} \Omega$ <br>  $\frac{200}{\sqrt{2}(40\sqrt{2})} = \frac{5}{2} \text{ A}$ <br>
voltage across them is same)<br>  $\frac{1}{1^{1/2}} = \text{IR} = 10 \text{V}$ <br>
rt circuited,<br>  $\frac{10}{\sqrt{2} \text{R}}$ <br>
ss inductance<br>  $= \text{I'} \text{X}_{\text{L}} = \text{I'R} = \frac{1$ 

$$
r' = \frac{10}{(R^2 + X_L^2)^{1/2}} = \frac{10}{\sqrt{2}R}
$$

 $\therefore$  Potential drop across inductance

$$
= \Gamma X_L = \Gamma R = \frac{10}{\sqrt{2}} V.
$$

**(49) (B).** When the frequency of the supply equals to the natural frequency of circuit, resonance occurs.

$$
\therefore Z = R = 22\Omega \text{ and } I_{\text{rms}} = \frac{V_{\text{rms}}}{Z} = \frac{220}{22} = 10 \text{A}
$$
  
Average power transferred per cycle,

$$
P = V_{rms} I_{rms} \cos 0^\circ = 220 \times 10 \times 1 = 2200 W
$$

Efficiency, 
$$
\eta = \frac{U_{01}}{I_{m}} = \frac{V_{01}}{V_{m}}
$$
  
\n $P_{1} = \frac{P_{0}}{\eta} = \frac{9 \times 10^{3}}{60/100} = 1.5 \times 10^{4} = 15kW$   
\nThe instantaneous value of voltage is  
\n $V = 100 \sin(100 t) V$   
\n $V = 100 \sin$ 



**1** (51) (b) 
$$
\sqrt{6}
$$
 + 120 sin (100π) cos (100π)  
\n= 60 sin (200 π)  
\n $\sqrt{6}$  sin (100π) cos (100π)  
\n= 60 sin (200 π)  
\n $\sqrt{6}$  sin (100π)  
\n $\sqrt{6}$  sin 10π  
\n $\sqrt{6}$  sin 1

**(55) (A).** Here,  $R = 6\Omega$ ,  $L = 25mH = 25 \times 10^{-3}H$ ,  $C = 750 \mu F = 750 \times 10^{-6} F$ ,  $v = 50 Hz$  $X_L = 2\pi vL = 2 \times 3.14 \times 50 \times 25 \times 10^{-3} = 7.85 \Omega$  $C = \frac{1}{2\pi\sqrt{C}} = \frac{1}{2 \times 3.14 \times 50 \times 750 \times 10^{-6}} = 4.25 \,\Omega$  $\therefore X_L - X_C = 7.85 - 4.25 = 3.6 \Omega$ Impedence of the series LCR circuit is As  $\tan \phi = \frac{X_L}{R} = \frac{\omega L}{\omega L} = \frac{2\pi vL}{R}$ <br>  $\tan \phi = \frac{2 \times 3.14 \times 50 \times 0.01}{1} = 3.14$ <br>  $\tan \phi = \frac{2 \times 3.14 \times 50 \times 0.01}{1} = 3.14$ <br>  $\Rightarrow \tan^{-1}(3.14) = 72^{\circ} = 72^{\circ} \times \frac{\pi}{10}$  Fad<br>
The time lag between maximum alternating voltage<br>  $\mu \phi = \frac{2 \times 3.14 \times 50 \times 0.01}{1} = 3.14$ <br>  $\Rightarrow$  Given, E<sub>o</sub> = 220 and I<sub>0</sub> = 10<br>  $\Rightarrow$  time lag between maximum alternating voltage<br>  $\phi = \left[\frac{\pi}{6} - \left(-\frac{\pi}{6}\right)\right] = \frac{\pi}{3}$ <br>
de time lag between maximum alternating voltage<br> **(56) (C).** Here,  $C = 60\mu$ F =  $60 \times 10^{-6}$  F  $V_{\text{rms}} = 110 \text{ V}, v = 60 \text{ Hz}$ 

$$
I_{\rm rms} = \frac{V_{\rm rms}}{X_{\rm C}} = \frac{V_{\rm rms}}{1/2\pi v C} = 2\pi v C V_{\rm rms}
$$

**UITIONS**

\n
$$
I_{rms} = \frac{V_{rms}}{X_C} = \frac{V_{rms}}{1/2\pi vC} = 2\pi vCV_{rms}
$$
\n
$$
= 2 \times 3.14 \times 60 \times 60 \times 10^{-6} \times 110 = 2.49 \text{ A}
$$
\n**(57)**

\n**(D)** Here, C= 100µF = 100 × 10<sup>-6</sup> F = 10<sup>-4</sup>F R = 40Ω, V<sub>rms</sub> = 100V, v = 60 Hz

\n
$$
\therefore V_0 = \sqrt{2} V_{rms} = 100 \sqrt{2} V
$$
\nIn series RC circuit,

\n
$$
Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}
$$
\n
$$
= \frac{1}{\sqrt{R^2 + \frac{1}{4\pi^2 v^2 C^2}}} \quad [\because \omega = 2\pi v]
$$
\nMaximum current in the circuit,

\n
$$
I_0 = \frac{V_0}{Z} = \frac{V_0}{\sqrt{R^2 + \frac{1}{4\pi^2 v^2 C^2}}}
$$

 $\therefore$  V<sub>0</sub> =  $\sqrt{2}$  V<sub>rms</sub> = 100 $\sqrt{2}$  V In series RC circuit,

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

$$
= \frac{1}{\sqrt{R^2 + \frac{1}{4\pi^2 v^2 C^2}}}
$$
 [::  $\omega = 2\pi v$ ]

Maximum current in the circuit,

**Q.B. - SOOLUTIONS**  
\n
$$
\frac{V}{2 \sin \theta \cos \theta}
$$
\n
$$
I_{rms} = \frac{V_{rms}}{X_C} = \frac{V_{rms}}{1/2\pi v C} = 2\pi v C V_{rms}
$$
\n
$$
I_{rms} = \frac{V_{rms}}{X_C} = \frac{V_{rms}}{1/2\pi v C} = 2\pi v C V_{rms}
$$
\n
$$
I_{rms} = 2 \times 10^{-4} \text{ A}
$$
\n**(57) (D)** Here, C= 100µF = 100 × 10<sup>-6</sup> F = 10<sup>-4</sup>F  
\nR = 40\Omega, V\_{rms} = 100V, v = 60 Hz  
\n
$$
\therefore V_0 = \sqrt{2} V_{rms} = 100 V_V = 60 Hz
$$
\n
$$
\therefore V_0 = \sqrt{2} V_{rms} = 100 \sqrt{2} V
$$
\nat resonance, for which  
\nIn series RC circuit,  
\n
$$
Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}
$$
\n
$$
= \frac{1}{\sqrt{R^2 + \frac{1}{4\pi^2 v^2 C^2}}} = \frac{1}{\sqrt{R^2 + \frac{1}{4\pi^2 v^2 C^2}}}
$$
\n
$$
= \frac{100\sqrt{2}}{\sqrt{R^2 + \frac{1}{4\pi^2 v^2 C^2}}}
$$
\n**00A**  
\n
$$
= \frac{100\sqrt{2}}{\sqrt{(40)^2 + \frac{1}{4 \times (3.14)^2 \times (60)^2 \times (10^{-4})^2}}}
$$
\n
$$
= \frac{100\sqrt{2}}{48} = 2.95 \text{ A}
$$
\n**(58) (B)** We know that, Z = E<sub>0</sub>/I<sub>0</sub>  
\n
$$
= \frac{3.14}{180} \text{ rad}
$$
\n
$$
\Phi = \left[\frac{\pi}{6} - \left(-\frac{\pi}{6}\right)\right] = \frac{\pi}{3}
$$
\n
$$
\frac{\sin \pi}{100 \times 10^{-4} \text{ A}} = 4.25 \text{ Q} \text
$$

(58) **(B).** We know that, 
$$
Z = E_0 / I_0
$$
  
Given,  $E_0 = 220$  and  $I_0 = 10$ 

$$
4 \times (3.14)^2 \times (60)^2 \times (10^{-4})^2
$$
  
=  $\frac{100\sqrt{2}}{48} = 2.95$ A  
(**B**). We know that, Z = E<sub>0</sub>/I<sub>0</sub>  
Given, E<sub>0</sub> = 220 and I<sub>0</sub> = 10  
so Z =  $\frac{220}{10} = 22$  ohm  

$$
φ = \left[\frac{\pi}{6} - \left(-\frac{\pi}{6}\right)\right] = \frac{\pi}{3}
$$

$$
p_a = \frac{E_0}{\sqrt{2}} \times \frac{10}{\sqrt{2}} \times \cos φ = \frac{220}{\sqrt{2}} \times \frac{10}{\sqrt{2}} \times \cos \frac{\pi}{3} = 550
$$
W  
(**B**). Here, V<sub>rms</sub> = 220V, I<sub>rms</sub> = 65 mA = 0.065A  
C = 8μF = 8 × 10<sup>-6</sup> F, v = 100 Hz  
Capacitive reactance, X<sub>C</sub> =  $\frac{1}{2\pi vC}$   
=  $\frac{1}{2 \times 3.14 \times 100 \times 8 \times 10^{-6}} = 199 Ω$   
Then rms voltage across the capacitor is  
V<sub>Cms</sub> = I<sub>rms</sub>X<sub>C</sub> = 0.065 × 199 = 12.94V  
(**A**). On comparing V = 200 √2 sin (100t) with  
V = V<sub>0</sub> sin ωt, we get  
V<sub>0</sub> = 200 √2 V, ω = 100 rad s<sup>-1</sup>

(59) **(B).** Here, 
$$
V_{rms} = 220V
$$
,  $I_{rms} = 65 \text{ mA} = 0.065 \text{ A}$   
\n $C = 8 \mu \text{F} = 8 \times 10^{-6} \text{ F}$ ,  $v = 100 \text{ Hz}$ 

Capacitive reactance, 
$$
X_C = \frac{1}{2\pi vC}
$$

$$
= \frac{1}{2 \times 3.14 \times 100 \times 8 \times 10^{-6}} = 199 \,\Omega
$$
  
Then rms voltage across the capacitor is  

$$
V_{\text{Crms}} = I_{\text{rms}} X_{\text{C}} = 0.065 \times 199 = 12.94 V
$$
  
**A).** On comparing V = 200, /5 sin (100t) with

(60) (A). On comparing V = 200 
$$
\sqrt{2}
$$
 sin (100t) with  
\nV = V<sub>0</sub> sin  $\omega$ t, we get  
\nV<sub>0</sub> = 200  $\sqrt{2}$  V,  $\omega$  = 100 rad s<sup>-1</sup>



$$
\therefore V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{200\sqrt{2V}}{\sqrt{2}} = 200V
$$

The capacitive reactance is

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

ac ammeter reads the rms value of current. Therefore, the reading of the ammeter is

$$
I_{\rm rms} = \frac{V_{\rm rms}}{X_{\rm C}} = \frac{200 \text{V}}{10^4 \Omega} = 20 \times 10^{-3} \text{ A} = 20 \text{ mA}
$$

The average power consumed in the circuit,  $P = I_{rms} V_{rms} \cos \phi$ 

In an pure capacitive circuit, the phase difference between current and voltage is  $\pi/2$ .  $\therefore$  cos  $\phi = 0$  $\therefore$  P = 0

# **EXERCISE-3 PART-A**

**(1) 30.** Let  $\omega_0$  be the angular velocity given to rod so that it reaches position DC. Let at a time t rod is at an angular (4) displacement  $\theta$  and in further time dt is travels a distance  $d\theta$ . The equivalent circuit will be as shown in figure.



Current  $i = \frac{1}{2} \frac{B \omega l^2}{R}$ . Hence,  $F = \frac{1}{2} \frac{B^2 \omega l^3}{R}$ 

Now torque acting on the rod is  $\tau = F \times \frac{\ell}{2} = \frac{1}{4} \frac{B^2 \omega \ell^4}{R}$ 

$$
\therefore \text{ Angular retardation } \alpha = \frac{\tau}{\ell} = \frac{1}{4} \frac{B^2 \omega \ell^4}{R \frac{m \ell^2}{3}} = \frac{3}{4} \frac{B^2 \ell^2 \omega}{mR}
$$
  

$$
I = \frac{1}{2} \frac{B \omega \ell^2}{R}
$$
  

$$
A \left(\frac{F}{R}\right)
$$
  

$$
= \frac{1}{2} \frac{B \omega \ell^2}{R}
$$
  

$$
= \frac{B}{\rho (L^2 - L)}
$$
  

$$
= \frac{1}{2} \frac{B \omega \ell^2}{R}
$$
  

$$
= \frac{B \omega \ell^2}{R}
$$

(I is moment of inertia of rod about point D)

Q.B.-SOLUTIONS  
\n
$$
\therefore V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{200\sqrt{2}V}{\sqrt{2}} = 200V
$$
\n
$$
\Rightarrow \omega \frac{d\omega}{d\theta} = -\frac{3B^2 \ell^2 \omega}{4mR}
$$
\nThe capacitive reactance is  
\n
$$
X_C = \frac{1}{\omega C} = \frac{1}{100 \times 1 \times 10^{-6}} = 10^4 \Omega
$$
\n
$$
\Rightarrow \omega \frac{d\omega}{d\theta} = -\frac{3B^2 \ell^2 \omega}{4mR}
$$
\nThe capacitive reactance is  
\n
$$
\int_{\text{arc ammeter reads the rms value of current. Therefore,} \qquad (2) \qquad 100. \text{ Work done} = \Delta Q \text{ (heat dissipated)}
$$
\n
$$
I_{rms} = \frac{V_{rms}}{X_C} = \frac{200V}{10^4 \Omega} = 20 \times 10^{-3} A = 20 mA
$$
\n
$$
I_{rms} = \frac{V_{rms}}{X_C} = \frac{200V}{10^4 \Omega} = 20 \times 10^{-3} A = 20 mA
$$
\n
$$
I_{rms} = \frac{V_{rms}}{Z} = \frac{200V}{10^4 \Omega} = 20 \times 10^{-3} A = 20 mA
$$
\n
$$
I_{rms} = \frac{V_{rms}}{Z} = \frac{200V}{10^4 \Omega} = 20 \times 10^{-3} A = 20 mA
$$
\n
$$
I_{rms} = \frac{V_{rms}}{Z} = \frac{200V}{10^4 \Omega} = 20 \times 10^{-3} A = 20 mA
$$
\n
$$
I_{rms} = \frac{V_{rms}}{Z} = \frac{200V}{10^4 \Omega} = 20 \times 10^{-3} A = 20 mA
$$
\n
$$
I_{rms} = \frac{V_{rms}}{Z} = \frac{200V}{10^4 \Omega} = 20 \times 10^{-3} A = 20 mA
$$

**100.** Work done =  $\Delta Q$  (heat dissipated)

$$
\frac{1}{\text{max}} = \frac{V_0}{\sqrt{2}} = \frac{200\sqrt{2}V}{\sqrt{2}} = 200V
$$
\n⇒  $\omega \frac{d\omega}{d\theta} = -\frac{3B^2 \ell^2 \omega}{4mR}$   
\nappacitive reactance is  
\n $= \frac{1}{\omega C} = \frac{1}{100 \times 1 \times 10^{-6}} = 10^4 Ω$   
\n $= \frac{V_{rms}}{\omega C} = \frac{200V}{100 \times 1 \times 10^{-6}} = 10^4 Ω$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{200V}{10^4 Ω} = 20 \times 10^{-3} A = 20 mA$   
\n $= \frac{V_{rms}}{\lambda C} = 25 \times 10^{-3}; \quad \ell = \sqrt{25 \times 10^{-4}} = 5 \times 10^{-2} m$   
\n $= \frac{V_{rms}}{\lambda C} = \frac{1}{100} = 2 \times 10^{-2} A = 20.1 \text{ sec.}$   
\n $= 0$   
\

2. 
$$
\tau_1 = RC
$$
;  $\tau_2 = \frac{L}{R} \Rightarrow LC = t_1 t_2 = 0.1 \text{ sec.}$ 

$$
\Rightarrow T = 2\pi\sqrt{LC} = 2\pi\sqrt{\frac{1}{10}} = 2 \text{ sec.}
$$

**1.** If rod is in middle,  $i = 0 \implies F = 0$ 



x x x  
\n
$$
\begin{array}{ccc}\n& x & x \\
x & x \\
y & x \\
z & x\n\end{array}
$$
\nEq. emf =  $\frac{E}{2\rho(L-x)} - \frac{E}{3\rho(L+x)} = \frac{E}{2\left[\frac{2x}{\rho^2 - x^2}\right]} \Rightarrow \frac{Ex}{L}$   
\n
$$
= \frac{1}{2} \frac{B^2 \omega \ell^3}{R}
$$
\n
$$
\tau = F \times \frac{\ell}{2} = \frac{1}{4} \frac{B^2 \omega \ell^4}{R}
$$
\n
$$
\frac{1}{4} \frac{B^2 \omega \ell^4}{R \frac{m \ell^2}{3}} = \frac{3B^2 \ell^2 \omega}{4 \frac{B^2}{R \omega^2}} = \frac{1}{4} \frac{EX}{mR}
$$
\n
$$
= F \times \frac{1}{2} = \frac{1}{4} \frac{B^2 \omega \ell^4}{R}
$$
\n
$$
\Rightarrow R_{eq.} = \frac{\rho(L^2 - x^2)}{L}
$$
\n
$$
= \frac{EX}{\rho(L^2 - x^2)} + \frac{EX}{\rho(L^2 - x^2) + RL}
$$
\n
$$
= \frac{1}{4} \frac{EX}{R \frac{m \ell^2}{3}} = \frac{EX}{4 \frac{Ex}{mR}} = \frac{EX}{\rho(L^2 - x^2) + RL}
$$
\n
$$
= \frac{1}{4} \frac{EX}{R \frac{Ex}{\rho(L^2 - x^2)} + R} = \frac{EX}{\rho(L^2 - x^2) + RL} \approx \frac{-E/B}{\rho L^2 + RL} \times \frac{E}{\rho L^2 + RL}
$$
\n
$$
a = \frac{-E/B}{m(\rho L^2 + RL)} \times \Rightarrow T = 2\pi \sqrt{\frac{m(\rho L^2 + RL)}{E/B}}
$$

$$
\frac{1}{R_{eq.}} = \frac{1}{2\rho(L-x)} + \frac{1}{2\rho(L+x)} = \frac{1}{2\rho} \times \frac{2L}{L^2 - x^2}
$$

$$
\Rightarrow R_{eq.} = \frac{\rho (L^2 - x^2)}{L}
$$

$$
R \frac{m\ell^2}{3} - 4 mR
$$
  
\ni =  $\frac{Ex}{\rho(L^2 - x^2)} + R$   $E$   
\nL  
\n
$$
i = \frac{Ex}{\rho(L^2 - x^2)} + RL
$$

$$
\frac{E}{\rho(L+x)} = \frac{E}{\rho(L-x)}
$$
\n
$$
q. emf = \frac{\frac{E}{2\rho(L-x)} - \frac{E}{3\rho(L+x)}}{\frac{1}{2\rho(L-x)} + \frac{1}{2\rho(L+x)}} = \frac{E\left[\frac{2x}{\ell^2 - x^2}\right]}{\frac{2\ell}{L^2 - x^2}} \Rightarrow \frac{Ex}{L}
$$
\n
$$
\frac{1}{R_{eq}} = \frac{1}{2\rho(L-x)} + \frac{1}{2\rho(L+x)} = \frac{1}{2\rho} \times \frac{2L}{L^2 - x^2}
$$
\n
$$
\Rightarrow R_{eq.} = \frac{\rho(L^2 - x^2)}{L}
$$
\n
$$
i = \frac{Ex}{\rho(L^2 - x^2)} + R = \frac{Ex}{\rho(L^2 - x^2) + RL}
$$
\n
$$
ma = F = -i\ell B = \frac{-Ex\ell B}{\rho(L^2 - x^2) + RL} \approx \frac{-E\ell B}{\rho L^2 + RL}x
$$
\n
$$
a = \frac{-E\ell B}{m(\rho L^2 + RL)}x \Rightarrow T = 2\pi \sqrt{\frac{m(\rho L^2 + RL)}{E\ell B}}
$$
\n
$$
\Rightarrow T = 1 sec.
$$

 $(2)$ 

 $(3)$ 



**EMI AND AC**  
\n**(5)** 5. 
$$
d\phi = \frac{\mu_0 i}{2\pi x} \times \ell dx
$$
;  $\phi = \frac{\mu_0 i}{2\pi} \ell \ln\left(\frac{d_2}{d_1}\right)$   
\n
$$
\epsilon = \frac{d\phi}{dt} = \frac{\mu_0}{2\pi} \ell \ln\left(\frac{d_2}{d_1}\right) \times i_0 \omega \cos \omega t
$$
\n**(2)** 4.

$$
\varepsilon_{\rm rms} = \frac{\mu_0}{2\pi} \ell \ln\left(\frac{d_2}{d_1}\right) \times \frac{i_0 \omega}{\sqrt{2}} \underbrace{\overbrace{\qquad \qquad \downarrow x \qquad \qquad}_{x} \qquad \qquad}_{i_0 \text{in} \omega t} dx
$$

$$
= \frac{4\pi \times 10^{-7}}{2\pi} \times 1 \times \ln 2 \frac{2\sqrt{2}}{\ln 2} \times \frac{50}{\sqrt{2}} = 2 \times 10^{-5} \text{ V}
$$

**(6)** 5. 
$$
e = (\vec{v} \times \vec{B}).\ell
$$
;  $e = [\hat{i} \times (3\hat{i} + 4\hat{j} + 5\hat{k})].5\hat{j} = 25$  volt.

**(7) 6.** Flux through circular ring  $\phi = (\mu_0 \text{ni}) \pi r^2$ 

$$
\frac{4\pi \times 10^{-7}}{2\pi} \times 1 \times \ln 2 \frac{2\sqrt{2}}{\ln 2} \times \frac{50}{\sqrt{2}} = 2 \times 10^{-5} \text{ V}
$$
  
\ne =  $(\vec{v} \times \vec{B}) \cdot \ell$ ; e =  $[\hat{i} \times (3\hat{i} + 4\hat{j} + 5\hat{k})]$ .5 $\hat{j}$  = 25 volt.  
\nFlux through circular ring  $\phi = (\mu_0 \text{ni}) \pi r^2$   
\n $\phi = \frac{\mu_0}{L} \pi r^2 I_0 \cos 300t$   
\n $i = \frac{d\phi}{Rdt}$ ; i =  $\frac{\mu_0 \pi r^2 I_0}{R} \sin 300t \times 300$   
\n $i = \frac{d\phi}{Rdt}$ ; i =  $\frac{\mu_0 \pi r^2 I_0}{R} \sin 300t \times 300$   
\n $= \mu_0 I_0 \sin 300t \left[ \frac{\pi r^2 \cdot 300}{R} \right]$   
\n $M = I.\pi r^2 = \mu_0 I_0 \sin 300t \left[ \frac{\pi^2 r^4 \cdot 300}{R} \right]$   
\n $M = \frac{10 \times 10^{-4} \times 300}{100 \times 10}$   
\n $= \frac{10 \times 10^{-4} \times 300}{100 \times 10}$   
\n $M = \frac{1}{R} \frac{V_0}{R} = \frac{V_0}{R} \cos 300t$   
\n $= \frac{V_0}{R} = \frac{V_0}{R} \cos 300t$   
\n $= 5 \sin (\omega t + 37^\circ)$   
\n $= \sqrt{8 \sin \omega t}$   
\n $= \sqrt{8 \sin \omega t}$   
\n $= 5 \sin (\omega t +$ 

$$
\overline{00\times10}
$$

**PART-B**





$$
I_R = \frac{V}{R} = \frac{200}{100} = 2A
$$
,  $I' = \frac{V}{X_L - X_C} = \frac{200}{100} = 2A$   $I = \frac{100}{X_C} =$ 

**EMI AND AC**  
\n**(5) 5.** 
$$
d\phi = \frac{\mu_0 i}{2\pi x} \times dx
$$
;  $\phi = \frac{\mu_0 i}{2\pi} \sin\left(\frac{d_2}{d_1}\right)$   
\n $\varepsilon = \frac{d\phi}{dt} = \frac{\mu_0}{2\pi} \sin\left(\frac{d_2}{d_1}\right) \times i_0 \omega \cos \omega t$   
\n**6.**  $\varepsilon = \frac{4\pi}{2\pi} \sin\left(\frac{d_2}{d_1}\right) \times \frac{i_0 \omega}{\sqrt{2}} = \frac{\frac{\sqrt{2}}{\sqrt{2}} \cos \omega t}{\frac{\sqrt{2}}{\sqrt{2}}} = \frac{\frac{\sqrt{2}}{\sqrt{2}} \cos \omega t}{\frac{i_0 \pi \omega t}{\sqrt{2}}} = \frac{2}{\sqrt{2}} \sqrt{\frac{1}{2}} = 2 \times \sqrt{2} \sin \omega t$   
\n**6.**  $\sin x \sin \omega t = \frac{\pi}{2\pi} \sin \omega t$   $\frac{2\sqrt{2}}{2\pi} \times 1 \times \ln 2 \frac{2\sqrt{2}}{2\pi} \times \frac{50}{\sqrt{2}} = 2 \times 10^{-5} \text{ V}$   
\n**(6) 6.**  $\ln \omega$  throughout  $\sin \phi = (\mu_0 \pi i) \pi r^2$   
\n**(7) 6.**  $\ln \omega$  throughout  $\sin \phi = (\mu_0 \pi i) \pi r^2$   
\n**(7) 7.**  $\ln \omega t = \frac{\mu_0}{2\pi} \pi^2 I_0 \cos 300t$   
\n**(8)**  $\frac{1}{\pi} \frac{d\phi}{dt} \cdot i = \frac{\mu_0 \pi^2 I_0}{R L} \cos 300t \times 300$   
\n**(9) 1.**  $\frac{d\phi}{dt} = \frac{4\pi \times 10^{-7}}{8 \times 10^{-1} \text{ s}} \times \frac{1}{R L} = 1 \times 10^{-3} \text{ s}$   
\n**(10) (1) (1) (1) (1) (**

RL  $\boxed{\text{R1} = i_0 \sin \omega t, \ \text{V}_R = 4 \sin \omega t, \ \text{V}_L = 3 \cos \omega t}$ RL  $\left|\right|$  (Take  $\pi^2 = 10$ )  $\therefore$  V<sub>L</sub> = 3 cos  $\omega t = 3 \cos 30^\circ$  $e = 5 \sin (\omega t + 37^{\circ})$ 4 sin  $\omega t = 2 \implies \omega t = \pi/6$ e=5 sin ( $\omega$ t + 37°) : 5 sin (37° + 30°) =  $\frac{4+3\sqrt{3}}{2}$ CR =  $\frac{2}{\omega} = \frac{2}{500} \sec = \frac{2}{500} \times 10^3 \sec$ <br>
=  $\frac{2 \times 1000}{500}$  ms = 4 ms<br>
(4) 4.<br>
L<sub>0</sub> = 3, V<sub>R<sub>0</sub> = 4 :. e<sub>0</sub> =  $\sqrt{V_{L_0}^2 + V_{R_0}^2}$  = 5 volts<br>
= i<sub>0</sub> sin ot, V<sub>R</sub> = 4 sin ot, V<sub>L</sub> = 3 cos ot<br>
= 5 sin (ot + 37°)</sub>  $\frac{2}{\omega} = \frac{2}{500} \sec = \frac{2}{500} \times 10^3 \sec$ <br>  $\frac{2 \times 1000}{500} \text{ ms} = 4 \text{ ms}$ <br>
(4) 4.<br>  $V_{R_0} = 4$  ∴  $e_0 = \sqrt{V_{L_0}^2 + V_{R_0}^2} = 5 \text{ volts}$ <br>
ort,  $V_R = 4 \sin \omega t$ ,  $V_L = 3 \cos \omega t$ <br>  $t + 37^\circ$ )<br>  $\Rightarrow \omega t = \pi/6$ <br>  $\cos \omega t = 3 \cos 30^\circ$ <br>  $t + 37^\$ =  $\frac{1}{500}$  ms = 4 ms<br>
(4) 4.<br>
= 3, V<sub>R<sub>0</sub></sub> = 4 :. e<sub>0</sub> =  $\sqrt{V_{L0}^2 + V_{R0}^2}$  = 5 volts<br>
i<sub>0</sub> sin ot, V<sub>R</sub> = 4 sin ot, V<sub>L</sub> = 3 cos ot<br>
sin (ot + 37°)<br>
ot = 2  $\Rightarrow$  ot =  $\pi/6$ <br>
= 3 cos ot = 3 cos 30°<br>
sin (ot + 37°) : V<sub>L0</sub> = 3, V<sub>R<sub>0</sub> = 4 :. e<sub>0</sub> =  $\sqrt{V_{L_0}} + V_{R_0}^2$  = 5 volts<br>
If i = i<sub>0</sub> sin ot, V<sub>R</sub> = 4 sin ot, V<sub>L</sub> = 3 cos ot<br>
e = 5 sin (ot + 37°)<br>
4 sin ot = 2  $\Rightarrow$  ot =  $\pi/6$ <br>  $\therefore$  V<sub>L</sub> = 3 cos ot = 3 cos 30°<br>
e = 5 sin (ot +</sub> i = i<sub>0</sub> sin ot, V<sub>R</sub> = 4 sin ot, V<sub>L</sub> = 3 cos ot<br>
= 5 sin (ot + 37°)<br>
in ot = 2  $\Rightarrow$  ot =  $\pi$ /6<br>
V<sub>L</sub> = 3 cos ot = 3 cos 30°<br>
= 5 sin (ot + 37°)  $\therefore$  5 sin (37° + 30°) =  $\frac{4+3\sqrt{3}}{2}$ <br>
(6) 3 (7) 1<br>
MS value of suppl  $Q_2 = 4 \sin \omega t$ ,  $V_L = 3 \cos \omega t$ <br>  $= \pi/6$ <br>  $= 3 \cos 30^\circ$ <br>  $\therefore 5 \sin (37^\circ + 30^\circ) = \frac{4 + 3\sqrt{3}}{2}$ <br>
pply voltage is<br>  $\overline{(V_L - V_C)^2} = \sqrt{(30)^2 + (100 - 60)^2}$ <br>  $\overline{(V_L - V_C)^2} = 50V$ <br>  $\overline{V_L} = 50\sqrt{2}V$ <br>  $\overline{V_L} = 50\sqrt{2}V$ <br>  $\overline{V_L} = 50V$ 

$$
(5) \quad 2. \ (6) \ 3 \quad (7) \ 1
$$

RMS value of supply voltage is

300t 
$$
\left[\frac{x^2+3x}{RL}\right]
$$
 (Take  $\pi^2 = 10$ )  
\n
$$
= 5 \sin(\omega t + 37^\circ) : .5 \sin(37^\circ + 30^\circ) = \frac{4+3\sqrt{3}}{2}
$$
\n
$$
= 5 \sin(\omega t + 37^\circ) : .5 \sin(37^\circ + 30^\circ) = \frac{4+3\sqrt{3}}{2}
$$
\n
$$
(5) \quad 2. (6) \quad 3 (7) \quad 1
$$
\nRMS value of supply voltage is  
\n
$$
V_{rms} = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(30)^2 + (100 - 60)^2}
$$
\n
$$
= \sqrt{(30)^2 + (40)^2} = 50V
$$
\n
$$
= \sqrt{(30)^2 + (40)^2} = 50\sqrt{2}V
$$
\nIf voltage across resistor is 50V then this should be the resonance condition.  
\nAt resonance, X<sub>L</sub> = X<sub>C</sub>  
\n
$$
V = 200
$$
\n
$$
\omega_2 L = \frac{1}{\omega_2 C} ; \omega_2 = \frac{1}{\sqrt{LC}}
$$
\nAlso, At  $\omega = \omega_1$   
\n
$$
I' = \frac{V}{X_L - X_C} = \frac{200}{100} = 2A
$$
\n
$$
I = \frac{100}{X_L} = \frac{60}{X_C} ; \frac{100}{\omega_1 L} = \frac{60}{1/\omega_1 C}
$$

2

 $\therefore$  V<sub>0</sub> = V<sub>rms</sub>  $\times \sqrt{2}$  = 50 $\sqrt{2}$ V

If voltage across resistor is 50V then this should be the resonance condition.

$$
\omega_2 L = \frac{1}{\omega_2 C} \; ; \; \omega_2 = \frac{1}{\sqrt{LC}}
$$

Also, At  $\omega = \omega_1$ 

$$
I = \frac{100}{X_L} = \frac{60}{X_C} \quad ; \quad \frac{100}{\omega_1 L} = \frac{60}{1/\omega_1 C}
$$



2t  $\big)$ 

 $-3$  |

$$
C = \frac{100}{\omega_1^2 L \times 60} = \frac{5}{3\omega_1^2 L}
$$



Phase difference between voltage on L and C is  $\pi$ .

### **EXERCISE-4**

**(1) (A).**  $I_{ind} = \frac{1}{R} \propto B$  **(20)**  $\ell_{\infty}$  D

**(2) (C).** All three coils are parallel So  $L_{eq} = 1$  H

**(3) (B).** Power factor cos P S

(4) **(B).** 
$$
\frac{I_S}{I_P} = \frac{N_P}{N_S}
$$

**(5) (A).** Relative position and orientation of the two coils.

(6) (C). 
$$
e = -L \frac{dI}{dt}
$$

**(7) (B).** Power factor

$$
\cos \phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{R^2 + (\omega L)^2}}
$$

**(8) (D).** Reduce the energy loss due to eddy current

$$
(9) \qquad \textbf{(B). } \mathbf{I} = -\frac{1}{\mathbf{R}_{\text{eq}}} \left( \mathbf{n} \frac{\mathrm{d}\phi}{\mathrm{d}t} \right) = -\frac{1}{5\mathbf{R}} \left[ \frac{\mathbf{n}(\mathbf{W}_2 - \mathbf{W}_1)}{t} \right]
$$

**(10) (B).** Mean power per period

Prove factor 
$$
\cos \phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}
$$

\nRecUTE:

\nRecUTE:

\nRecUTE:

\nRecUTE:

\nEXECUTE:

**(11) (B).**  $e = \frac{1}{2} B \omega l^2$ 

**(12) (C).** D.C. Ammeter measures average value and average value for one cycle of A.C. is zero.

(13) **(D).** 
$$
V_L = V_C = V_R = 50
$$
 volt  
\n $V_L$  and  $V_C$  have opposite phasors so voltage across  
\nLC combination is zero. (28)

**EXAMPLE 2** (J4) (C). Frequency = 
$$
\frac{1}{2\pi\sqrt{LC}}
$$
  
\n $C \rightarrow 2C$ ;  $L \rightarrow L/2$   
\n $\frac{V_L}{V_R} \rightarrow i$   $\omega_2 = \frac{1}{\sqrt{L \times \frac{S}{3\omega_1^2}L}} = \sqrt{\frac{S}{S}} \omega_1$   
\n(15) (B).  $I = I_0 \left(1 - e^{-\frac{R}{L}t}\right)$ ;  $\frac{I_0}{2} = I_0 \left(1 - e^{-\frac{2t}{300 \times 10^{-3}}}\right)$   
\n $\frac{V_C}{V_C}$   
\n(16) (C). Frequency =  $\frac{1}{2\pi\sqrt{LC}}$   
\n(17) (D). 2B/V  
\n(18) (A). cos  $\phi = \frac{R}{Z} = \frac{1}{\sqrt{LC}} = 0.8$   
\n(A). cos  $\phi = \frac{R}{Z} = \frac{1}{\sqrt{LC}} = 0.8$   
\n(A). cos  $\phi = \frac{R}{Z} = \frac{1}{\sqrt{LC}}$   
\n(A). 1.4. The  
\n $\frac{Bv}{L} \propto B$   
\n(A). 1.4. The  
\n $\frac{Bv}{L} \propto \frac{V}{I_P} = \frac{R}{N_S}$   
\n(B). R. In as acute angle phase difference.  
\n(20) (D).  $e = \left(-\frac{d\phi}{dt}\right)_{t=3\sec}$   
\n(21) (B). In AC generator E = NAB $\omega$ sin  $\omega$ sin  $\omega$   
\n $\therefore$  E<sub>max</sub> = NAB $\omega$ sin  $\omega$   
\n $I = \frac{R}{R}e^{-\frac{R}{L}t} = \frac{100}{100}e^{-\frac{100}{100 \times 10^{-3}} \times 10^{-3}} = \frac{1}{e}$   
\n3. A. A trresonance,  $I = \frac{V}{Z} = \frac{V}{R$ 

 $t = 0.1$  sec.

$$
(16) \quad (C). \text{ Frequency} = \frac{1}{2\pi\sqrt{LC}}
$$

 $(17)$  **(D).** 2B $\ell$ V

(18) (A). 
$$
\cos \phi = \frac{R}{Z} = \frac{12}{15} = 0.8
$$

**(19) (B).** RL has acute angle phase difference.

$$
(20) (D). e = \left(-\frac{d\phi}{dt}\right)_{t=3\,\text{sec}}
$$

- **(21) (B).** In AC generator  $E = NAB\omega \sin \omega t$  $\therefore$  E<sub>max</sub> = NAB $\omega$
- **(22) (C).** Discharging of coil

$$
\frac{1}{3\omega_1^2 L} = \sqrt{\frac{3}{5}} \omega_1
$$
\n
$$
t = 0.1 \text{ sec.}
$$
\n(16) (C). Frequency =  $\frac{1}{2\pi\sqrt{LC}}$   
\nOn L and C is  $\pi$ .  
\n(18) (A). cos  $\phi = \frac{R}{Z} = \frac{12}{15} = 0.8$   
\n(19) (B). RL has acute angle phase difference.  
\n(20) (D).  $e = \left(-\frac{d\phi}{dt}\right)_{t=3\text{sec}}$   
\n(21) (B). In AC generator E = NAB $\omega$  sin  $\omega t$   
\n $\therefore E_{\text{max}} = \text{NAB}\omega$   
\n(22) (C). Discharging of coil  
\n $I = \frac{E}{R} e^{-\frac{R}{L}t} = \frac{100}{100} e^{-\frac{100}{100 \times 10^{-3}} \times 10^{-3}} = \frac{1}{e}$   
\n(23) (A). At resonance.  $I = \frac{V}{R} = \frac{V}{L} = \frac{V}{L} = \frac{100}{0.8} = 0.1A$ 

$$
\int_{V_C}^{V_L} \frac{1}{\sqrt{x}} e^{-\frac{1}{2}x} \int_{\sqrt{2}}^{1} \frac{1}{\sqrt{8}} e^{-\
$$

**(24) (B).** Phase difference  $= \pi/2$  $\therefore$  Power factor = 0  $\therefore$  Power consumption = 0

$$
V_{L} = V_{C} = I_{XC} = I \left(\frac{I}{\omega C}\right) = 250 V
$$
\n(24) (B). Phase difference =  $\pi/2$   
\n $\therefore$  Power factor = 0  
\n $\therefore$  Power consumption = 0  
\n $\therefore$  Power consumption = 0  
\n $\therefore$  W<sub>1</sub> = 0  
\n $\therefore$  W<sub>2</sub> = 1  
\n $\frac{V_{1}}{V}$   
\n(25) (D). i =  $\frac{5}{5}\left(1 - e^{-\frac{5\times2}{10}}\right) = (1 - e^{-1})$   
\n(26) (C). M =  $\frac{\mu_0 N_1 N_2 A}{\ell}$   
\n $= \frac{4\pi \times 10^{-7} \times 300 \times 400 \times 10 \times 10^{-4}}{20 \times 10^{-2}} = 2.4\pi \times 10^{-4} H$   
\n(27) (D). Current in LR<sub>2</sub> branch  
\n $i = \frac{E}{R_2}[1 - e^{-R_2t/L}]$ ;  $\frac{di}{dt} = \frac{E}{R_2} \frac{R_2}{L} e^{-R_2t/L}$   
\nDrop across L =  $(\frac{E}{L}e^{-R_2t/L})$  L  
\nllue and average  
\n= 12e<sup>-2t/400\times10^{-3}</sup> = 12e<sup>-5t</sup>V  
\n28) (B). A moving conductor is equivalent to a battery of emf

(26) (C). 
$$
M = \frac{\mu_0 N_1 N_2 A}{\ell}
$$

$$
V_{L} = V_{C} = I_{XC} = I\left(\frac{I}{\omega C}\right) = 250V
$$
  
Phase difference =  $\pi/2$   
Power factor = 0  
Power consumption = 0  

$$
i = \frac{5}{5} \left(1 - e^{-\frac{5 \times 2}{10}}\right) = (1 - e^{-1})
$$

$$
M = \frac{\mu_0 N_1 N_2 A}{\ell}
$$

$$
= \frac{4\pi \times 10^{-7} \times 300 \times 400 \times 10 \times 10^{-4}}{20 \times 10^{-2}} = 2.4\pi \times 10^{-4} H
$$
  
Current in LR<sub>2</sub> branch  

$$
\frac{E}{R_2} [1 - e^{-R_2 t/L}] , \frac{di}{dt} = \frac{E}{R_2} \frac{R_2}{L} e^{-R_2 t/L}
$$

$$
p \text{ across } L = \left(\frac{E}{L} e^{-R_2 t/L}\right) L
$$

**(27) (D).** Current in  $LR_2$  branch

$$
= \frac{E}{R_2} [1 - e^{-R_2 t/L}] \frac{di}{dt} = \frac{E}{R_2} \frac{R_2}{L} e^{-R_2 t/L}
$$

Drop across  $L = \left(\frac{E}{I}e^{-R_2t/L}\right)L$ 

$$
= 12e^{-2t/400 \times 10^{-3}} = 12e^{-5t}V
$$

= I<sub>XC</sub> = I( $\frac{1}{\omega C}$ ) = 250V<br>
Ference =  $\pi/2$ <br>
ctor = 0<br>
msumption = 0<br>  $-e^{-\frac{5 \times 2}{10}}$ ) = (1 -  $e^{-1}$ )<br>  $\frac{\sqrt{1 N_2 A}}{\ell}$ <br>  $\frac{0.5 \times 2}{\sqrt{10^{-2}}}$ <br>  $\frac{0.5 \times 2}{\sqrt{10^{-2}}}$ <br>  $\pi$  LR<sub>2</sub> branch<br>  $\pi$  LR<sub>2</sub> branch<br>  $\pi$  LR<sub>2</sub> Power factor = 0<br>
Power consumption = 0<br>
D.  $i = \frac{5}{5} \left( 1 - e^{-10} \right) = (1 - e^{-1})$ <br>
D.  $M = \frac{\mu_0 N_1 N_2 A}{\ell}$ <br>  $= \frac{4\pi \times 10^{-7} \times 300 \times 400 \times 10 \times 10^{-4}}{20 \times 10^{-2}} = 2.4\pi \times 10^{-4} \text{ H}$ <br>
D. Current in LR<sub>2</sub> branch<br>  $\frac{E}{R_2} [1 -$ = $\frac{5}{5}\left(1-e^{-\frac{5\times2}{10}}\right) = (1-e^{-1})$ <br>  $1 = \frac{\mu_0 N_1 N_2 A}{\ell}$ <br>  $\frac{4\pi \times 10^{-7} \times 300 \times 400 \times 10 \times 10^{-4}}{20 \times 10^{-2}} = 2.4\pi \times 10^{-4} \text{ H}$ <br>
urrent in LR<sub>2</sub> branch<br>  $-[1 - e^{-R_2 t/L}]$ ;  $\frac{di}{dt} = \frac{E}{R_2} \frac{R_2}{L} e^{-R_2 t/L}$ <br>
across  $L$ **(28) (B).** A moving conductor is equivalent to a battery of emf  $=$  v B  $\ell$  (motion emf) Equivalent circuit

## **EMI AND AC Q.B. - SOLUTIONS**





$$
I = \frac{2vB\ell}{3R} \; ; \; I_1 = I_2 = \frac{vB\ell}{3R} \tag{3}
$$

**(29) (B).** At  $t = 0$ , inductor behaves like an infinite resistance

So at 
$$
t = 0
$$
,  $i = \frac{V}{R_2}$  (38) (C).  $I =$ 

At  $t = \infty$ , inductor behaves like a conducting wire (39)

$$
i = \frac{V}{R_{eq}} = \frac{V (R_1 + R_2)}{R_1 R_2}
$$

**(30) (D).** The given circuit is under resonance as  $X_L = X_C$  **(40)** Hence power dissipated in the circuit is

$$
P = \frac{V^2}{R} = 242 \text{ W} \qquad \Rightarrow \qquad \frac{P}{4\pi r}
$$

**(31) (B).** In LC oscillation energy is transfered C to L

or L to C maximum energy in L is 
$$
=\frac{1}{2}LI_{\text{max}}^2
$$
 (41) (C).  $R = \frac{80}{10} =$ 

Maximum energy in C = 
$$
\frac{q_{\text{max}}^2}{2C}
$$

$$
I = \frac{1}{\sqrt{2}} I_{\text{max}} \quad ; \quad I = I_{\text{max}} \sin \omega t = \frac{1}{\sqrt{2}} I_{\text{max}}
$$
\n(42) (C). Quality factor  
\n
$$
\omega t = \frac{\pi}{4} \quad \text{or} \quad \frac{2\pi}{T} t = \frac{\pi}{4} \quad \text{or} \quad t = \frac{T}{8}
$$
\n(43) (D).  $\langle P \rangle = V_{\text{rms}} I_{\text{rms}}$ 

(32) **(D).** 
$$
E_{ind} = B \times v \times \ell = 5.0 \times 10^{-5} \times 1.50 \times 2
$$
  
= 10.0 × 10<sup>-5</sup> × 1.5 = 15 × 10<sup>-5</sup> volt = 0.15 mv



(34) **(D).** 
$$
\frac{\sqrt[0]{2\ell}}{x} \xrightarrow{ \ell} dx
$$

$$
e = \int_{2\ell}^{3\ell} (\omega x) B dx = B\omega \frac{[(3\ell)^2 - (2\ell)^2]}{2} = \frac{5B\ell^2 \omega}{2}
$$

**(35) (A).** = Mi = 2 2 <sup>0</sup> 2 2 2 2 (2) (20 10 ) (0.3 10 ) 2 [(0.2) (0.15) ] = 9.216 × 10–11 9.2 × 10–11 weber 1/5 10 <sup>0</sup> L 15 I I e , e 0.67mA R 150 2L A A e<sup>0</sup> (Since L plays the same role as m) I U c 4 r <sup>1</sup> U E 

(36) (C). 
$$
q = CV (1 - e^{-t/\tau})
$$
  
At t = 2,  $q = CV (1 - e^{-2})$ 

 $3R$  will be 1 **(37) (D).** Since resistance and inductor are in parallel, so ratio will be 1.

or behaves like an infinite resistance  
\n(38) (C). 
$$
I = I_0 e^{-t/\tau}
$$
,  $\tau = \frac{L}{R} = \frac{15}{150} e^{-\frac{1 \times 10^{-3}}{1/5 \times 10^3}} = 0.67 \text{ mA}$ 

**(39) (B).** For a damped pendulum,  $A = A_0 e^{-bt/2m}$ 

$$
2[(0.2)^{2} + (0.15)^{2}]
$$
  
\n= 9.216 × 10<sup>-11</sup> ≈ 9.2 × 10<sup>-11</sup> weber  
\n(C) . q = CV (1- e<sup>-t/r</sup>)  
\nAt t = 2, q = CV (1- e<sup>-2</sup>)  
\n(D). Since resistance and inductor are in parallel, so ratio  
\nwill be 1.  
\n(C) . I = I<sub>0</sub>e<sup>-t/τ</sup>,  $\tau = \frac{L}{R} = \frac{15}{150}e^{-\frac{1 \times 10^{-3}}{1/5 \times 10^{3}}} = 0.67 \text{ mA}$   
\n(B). For a damped pendulum, A = A<sub>0</sub>e<sup>-bt/2m</sup>  
\n $\Rightarrow$  A = A<sub>0</sub>e<sup>- $\frac{R}{2L}$</sup>  (Since L plays the same role as m)  
\n(A). I =  $\frac{P}{4\pi r^{2}} = U_{av} \times c$  ....... (1)  $U_{av} = \frac{1}{2} \epsilon_{0} E_{0}^{2}$  .... (2)  
\n $\Rightarrow \frac{P}{4\pi r^{2}} = \frac{1}{2} \epsilon_{0} E_{0}^{2} \times c \Rightarrow E_{0} = \sqrt{\frac{2P}{4\pi r^{2}} \epsilon_{0} c} = 2.45 \text{ V/m}$ 

(40) (A). 
$$
I = \frac{P}{4\pi r^2} = U_{av} \times c
$$
 .........(1)  $U_{av} = \frac{1}{2} \epsilon_0 E_0^2$  ....(2)

$$
\Rightarrow \frac{P}{4\pi r^2} = \frac{1}{2} \epsilon_0 E_0^2 \times c \Rightarrow E_0 = \sqrt{\frac{2P}{4\pi r^2 \epsilon_0 c}} = 2.45 \text{ V/m}
$$

$$
\frac{1+13}{1+3}
$$
  
\n
$$
\frac{1}{1+15}
$$
  
\n<

$$
2 \quad \text{max} \quad \text{(42)} \quad \text{(C). Quality factor } Q = \frac{\omega_0}{2\Delta\omega} = \frac{\omega_0 L}{R}
$$

(43) **(D).** 
$$
\langle P \rangle = V_{\text{rms}} I_{\text{rms}} \cos \phi \; ; \; \phi = -\frac{\pi}{4}
$$
  
 $\langle P \rangle = \frac{100}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \times \frac{1}{\sqrt{2}} = \frac{1000}{\sqrt{2}}$ 

Wattless current, 
$$
I = I_{rms} \sin \phi = \frac{20}{\sqrt{2}} \times \frac{1}{\sqrt{2}} = 10
$$

Maximum energy in C = 
$$
\frac{q_{max}^2}{2C}
$$
  
\nEqual energy will be when  $\frac{1}{2}LI^2 = \frac{1}{2}\frac{1}{2}LI_{max}^2$   
\n $I = \frac{1}{\sqrt{2}}I_{max}$ ;  $I = I_{max} \sin \omega t = \frac{1}{\sqrt{2}}I_{max}$   
\n $I = \frac{1}{\sqrt{2}}I_{max}$ ;  $I = I_{max} \sin \omega t = \frac{1}{\sqrt{2}}I_{max}$   
\n $\omega t = \frac{\pi}{4}$  or  $\frac{2\pi}{T}t = \frac{\pi}{4}$  or  $t = \frac{T}{8}$   
\n $t = \frac{1}{8}2\pi\sqrt{LC} = \frac{\pi}{4}\sqrt{LC}$   
\n $t = \frac{1}{100 \times 10^{-5} \times 1.5} = 15 \times 10^{-5} \text{ with } 100 \text$ 



**EXAMPLE 1.2**  
\n
$$
X_C = \frac{1}{\omega C} - 1100 \times 120 \times 10^{-5} = 2\pi \Omega; \quad X_C - X_L = 20\Omega
$$
\n
$$
X_L = \frac{1}{\omega C} - 1100 \times 20 \times 10^{-3} = 2\pi \Omega; X_C - X_L = 20\Omega
$$
\n
$$
X = \sqrt{\frac{1}{2} + \frac{3}{\sqrt{10}} \times 10^{-1} \times 20^{-1} \times 10^{-5} = 2\pi \Omega; X_C - X_L = 20\Omega
$$
\n
$$
\cos \phi = \frac{R}{L} = \frac{3}{\sqrt{10}} \times P_{RPS} - VI \cos \phi = \frac{V^2}{Z} \cos \phi = 8.64 \text{ W}
$$
\n**(46)** (G) 11.d1 = P<sup>1</sup>R  
\n
$$
V = \sqrt{\frac{V^2}{dL}} = \sqrt{\frac
$$

<b>DAC</b>	<b>Q.B.-SOLUTIONS</b>	<b>Q.B.-SOLUTIONS</b>	
$V_m = I_m (X_C - X_L)$	(8)	(B). Efficiency of the transformer	
$10 = I_m (31.84 - 12.56)$	$\eta = \frac{P_{output}}{P_{input}} \times 100 = \frac{100}{220 \times 0.5} \times 100 = 90.9\%$		
$I_m = \frac{10}{19.28} = 0.52 \text{ A}$	(9)	(D). Average power = $E_{rms} I_{rms} \cos \phi = \frac{E_0 I_0}{2} \cos \phi$	
$I = 0.52 \sin \left(314t + \frac{\pi}{2}\right)$	(9)	(D). Average power = $E_{rms} I_{rms} \cos \phi = \frac{E_0 I_0}{2} \cos \phi$	
$V = \frac{W}{Q} \Rightarrow W = QV$	(11)	(B). $\phi = BA \cos \theta = \frac{1}{\pi} \times \pi (0.2)^2 \cos 60^\circ = 0.02 \text{ Wb}$	
From figure,	$\frac{1}{\omega C} - \omega L$	(12)	(C). As the loop leaves the magnetic field, area in magnetic field decreases for all loops, so induced emf does not remain constant. (Any of four loops)

## **EXERCISE-5**

(A).  $V = \frac{W}{Q} \Rightarrow W = QV$  (11)<br>(D) From figure



**(3) (B).** Mutual Inductor of two coils

$$
M = \sqrt{M_1 M_2} = \sqrt{2mh \times 8mh} = 4mH
$$

**(4) (D).** Where there is change of flux in the core of a transformer due to change in current around it, eddy current is produced. The direction of this current is opposite to the current which produces it, so it will reduce the main current. We laminate the core so that flux is reduced resulting in the reduced production of eddy current.

(5) **(B).** Power factor, 
$$
\phi = \frac{R}{\sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2 + R^2}}
$$
 (16) **(D).** Efficiency  $\eta = \frac{8}{\sqrt{\left(\frac{R}{\omega L} - \frac{1}{\omega C}\right)^2 + R^2}}$   $I_p = \frac{V_s I_s}{\eta V_p} = \frac{(4}{\sqrt{\frac{R}{\omega C}}})$ 

**(6) (D).** Condition for which the current is maximum in a series LCR circuit is

$$
\omega = \frac{1}{\sqrt{LC}}
$$
;  $1000 = \frac{1}{\sqrt{L(10 \times 10^{-6})}}$   $\Rightarrow$  L = 100mH (17) (B).  $\frac{d}{d}$ 

(A). Since  $\frac{V_s}{V_p} = \frac{N_s}{N_p}$ 

where,  $N_s$  = No. of turns across primary coil = 50  $N_p$  = No. of turns across secondary coil  $= 1500$ 

and 
$$
V_p = \frac{d\phi}{dt} = \frac{d}{dt}(\phi_0 + 4t) = 4 \implies V_s = \frac{1500}{50} \times 4 = 120V
$$

**EMI AND AC Q.B. - SOLUTIONS**



**(8) (B).** Efficiency of the transformer

$$
\eta = \frac{P_{\text{output}}}{P_{\text{input}}} \times 100 = \frac{100}{220 \times 0.5} \times 100 = 90.9\%
$$

9) **(D).** Average power = E<sub>rms</sub> I<sub>rms</sub> cos 
$$
\phi = \frac{E_0 I_0}{2} \cos \phi
$$

Q.B.-SOLUTIONS	CDMADVANQEDILEARENING	
$c^{-X_L}$	(8)	(B). Efficiency of the transformer
$84-12.56$	$n = \frac{P_{output}}{P_{input}} \times 100 = \frac{100}{220 \times 0.5} \times 100 = 90.9\%$ \n	
$\left(314t + \frac{\pi}{2}\right)$	(9)	(D). Average power = E <sub>rms</sub> I <sub>rms</sub> cos $\phi = \frac{E_0 I_0}{2} cos \phi$
$EXERCISE-5$	(10)	(D). Net flux through solenoid $\phi = 500 \times 4 \times 10^{-3} = 2$ Wb $\phi = LI \Rightarrow 2Wb = L \times 2$ Amp $\Rightarrow$ L = 1 henry
$W = QV$	(11)	(B). $\phi = BA cos \theta = \frac{1}{\pi} \times \pi (0.2)^2 cos 60^\circ = 0.02$ Wb

(11) **(B).** 
$$
\phi = BA \cos \theta = \frac{1}{\pi} \times \pi (0.2)^2 \cos 60^\circ = 0.02 \text{ Wb}
$$

Efficiency of the transformer<br>  $\eta = \frac{P_{\text{output}}}{P_{\text{input}}} \times 100 = \frac{100}{220 \times 0.5} \times 100 = 90.9\%$ <br>
Average power = E<sub>rms</sub> I<sub>rms</sub> cos  $\phi = \frac{E_0 I_0}{2} \cos \phi$ <br>
Net flux through solenoid<br>  $\phi = 500 \times 4 \times 10^{-3} = 2 \text{ Wb}$ <br>  $\phi = LI \Rightarrow 2 \text$ SODM ADVANCED LEARNING<br>  $00 = 90.9\%$ <br>  $\theta = \frac{E_0 I_0}{2} \cos \phi$ <br>  $= 1$  henry<br>  $= 0.02$  Wb<br>
etic field, area in<br>
Ill loops, so induced<br>
(Any of four loops)<br>  $\times 10^{-3}$ **(12) (C).** As the loop leaves the magnetic field, area in magnetic field decreases for all loops, so induced emf does not remain constant. (Any of four loops)

**UTIONS**  
\n**(8) (B).** Efficiency of the transformer  
\n
$$
\eta = \frac{P_{output}}{P_{input}} \times 100 = \frac{100}{220 \times 0.5} \times 100 = 90.9\%
$$
\n**(9) (D).** Average power = E<sub>rms</sub> I<sub>rms</sub> cos  $\phi = \frac{E_0 I_0}{2} \cos \phi$   
\n**(10) (D).** Net flux through solenoid  
\n $\phi = 500 \times 4 \times 10^{-3} = 2$  Wb  
\n $\phi = LI \Rightarrow 2 \text{Wb} = L \times 2 \text{Amp} \Rightarrow L = 1 \text{ henry}$   
\n**(11) (B).**  $\phi = BA \cos \theta = \frac{1}{\pi} \times \pi (0.2)^2 \cos 60^\circ = 0.02$  Wb  
\n**(12) (C).** As the loop leaves the magnetic field, area in magnetic field of decreases for all loops, so induced emf does not remain constant. (Any of four loops)  
\n**(13) (D).**  $e = -B \frac{d}{dt} (\pi r^2) = -B\pi 2r \frac{dr}{dt}$ ,  
\n $e = -0.04 \times \pi \times 2 \times 2 \times 10^{-2} \times 2 \times 10^{-3}$   
\n $= 32\pi \times 10^{-7}$   
\n $= 3.2\pi \times 10^{-7}$   
\n**(14) (D).**  $P = I^2 R = \frac{\varepsilon^2}{|Z|^2} R = \frac{\varepsilon^2 R}{\left[R^2 + (\omega L - \frac{1}{\omega C})^2\right]}$   
\n**(15) (B).** As  $V_L = V_C = 300$  V, therefore the given series LCR circuit is in resonance.  
\n $\therefore V_R = V = 220$  V;  $Z = R = 100 \Omega$   
\nCurrent,  $I = \frac{V}{Z} = \frac{220V}{100\Omega} = 2.2A$   
\nHence, the reading of the voltmeter V<sub>3</sub> is 220V and the reading of ammeter A is 2.2A.  
\n**(16) (D).** Efficiency

(14) **(D).** 
$$
P = I^2 R = \frac{\varepsilon^2}{|Z|^2} R = \frac{\varepsilon^2 R}{\left[R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2\right]}
$$

**(15) (B).** As  $V_L = V_C = 300$  V, therefore the given series LCR circuit is in resonance. (Any of four loops)<br>
(Any of four loops)<br>  $\frac{1}{2}$ <br>  $\frac$ 

:. 
$$
V_R = V = 220 V
$$
;  $Z = R = 100 \Omega$   
Current,  $I = \frac{V}{Z} = \frac{220 V}{100 \Omega} = 2.2 A$ 

Hence, the reading of the voltmeter  $V_3$  is 220V and the reading of ammeter A is 2.2A.

(2) (b) From figure,  
\n
$$
\frac{1}{tan 45^\circ} = \frac{6C}{R}
$$
\n
$$
\frac{1}{cot 45^\circ} = \frac{6C}{R}
$$
\n
$$
\frac{1}{cot 45^\circ} = \frac{1}{cot 45^\circ}
$$
\n
$$
\frac{1}{cot 45^\circ} = \frac{1}{cot 45^\circ}
$$
\n
$$
\frac{1}{cot 45^\circ} = \frac{1}{cot 45^\circ}
$$
\n(3) (b)  $c = -B\frac{d}{dt}(\pi^2) = -B\pi^2 \frac{d}{dt}$ ,  
\n $c = \frac{1}{\omega (R + \omega L)} = \frac{1}{2\pi i (R + 2\pi L)}$ \n(4) (b) Atuual Inductor of two coils  
\n $M = \sqrt{M_1M_2} = \sqrt{2mh \times Rmh} = 4mH$   
\n(4) (b) What and the object of two coils  
\n $M = \sqrt{M_1M_2} = \sqrt{2mh \times Rmh} = 4mH$   
\n(5) (6) As  $V_L = V_C = 300 V$ , therefore the given series LCR  
\n
$$
\frac{1}{c} = \frac{1}{12l^2}R
$$
\n
$$
\frac{1}{2l^2} + \left(\omega L - \frac{1}{\omega C}\right)^2
$$
\n
$$
\frac{1}{c} = \frac{1}{12l^2}
$$
\n(6)  $\frac{1}{c} = \frac{1}{c^2}R$ \n
$$
\frac{1}{c^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}
$$
\n(7) What is in resonance.  
\n(8) A's  $V_L = V_C = 200 V$ , therefore the given series LCR  
\n
$$
\frac{1}{c} = \frac{1}{12l^2}
$$
\n
$$
\frac{1}{c} = \frac{1}{1000l^2} = 2.2A
$$
\nso that flux is reduced result in the reduced  
\n
$$
\frac{1}{c} = \frac{1}{\sqrt{(6L - \frac{1}{\omega C})^2} + R^2}
$$
\n
$$
= \frac{1}{\sqrt{(6L - \frac{1}{\omega C})^2} + R^2}
$$
\n(16) (D). Efficientity given by  
\n

$$
|\varepsilon| = \frac{d\phi}{dt} = \frac{d}{dt} (B\pi r^2) = B\pi 2r \frac{dr}{dt}
$$
  
= 0.025 × π × 2 × 2 × 10<sup>-2</sup> × 1 × 10<sup>-3</sup>  
= π × 10<sup>-6</sup>V = πμV

**(18) (D).** In case of oscillatory discharge of a capacitor through an inductor, charge at instant t is given by

$$
q = q_0 \cos \omega t
$$
, where  $\omega = \frac{1}{\sqrt{LC}}$ 



$$
\therefore \quad \cos \omega t = \frac{q}{q_0} = \frac{CV_2}{CV_1} = \frac{V_2}{V_1} \quad (\because q = CV) \quad \dots \dots \dots (1)
$$
\n
$$
I = \frac{dq}{dt} = \frac{d(q_0 \cos \omega t)}{dt} = -q_0 \omega \sin \omega t
$$
\n
$$
I = CV_1 \frac{1}{\sqrt{LC}} [1 - \cos^2 \omega t]^{1/2}
$$
\n
$$
= V_1 \sqrt{\frac{C}{L}} \left[ 1 - \left( \frac{V_2}{V_1} \right)^2 \right]^{1/2}
$$
\n
$$
= \left[ \frac{C (V_1^2 - V_2^2)}{L} \right]^{1/2}
$$
\n
$$
= \left[ \frac{C (V_1^2 - V_2^2)}{L} \right]^{1/2}
$$
\n
$$
= \left[ \frac{C (V_1^2 - V_2^2)}{L} \right]^{1/2}
$$
\n
$$
(using (1))
$$
\n
$$
\cos \phi = \cos \frac{\pi}{3} = \frac{1}{2} \quad \text{so}
$$
\n
$$
(Q) \quad \tan \theta = \frac{X_L}{R} = 1 \quad \therefore \phi = 45^\circ \text{ or } \pi/4
$$
\n
$$
= \left( \frac{1}{T} \int_0^{T/2} V_0^2 dt \right)^{1/2}
$$
\n
$$
= \left( \frac{1}{T} \int_0^{T/2} V_0^2 dt \right)^{1/2}
$$
\n
$$
= \left( \frac{1}{T} \int_0^{T/2} V_0^2 dt \right)^{1/2}
$$
\n
$$
= \frac{Q_0}{V_0} = \frac{Q_0}{V_0} \left( \frac{V_0}{V_0} \right)^{1/2}
$$
\n
$$
= \frac{Q_0
$$

(19) (A). 
$$
I_{RMS} = \frac{\varepsilon_0 / \sqrt{2}}{1/\omega C} = 200 \times 100 \times 10^{-6} A
$$

(20) (C). 
$$
\tan \theta = \frac{X_L}{R} = 1
$$
 :  $\phi = 45^\circ$  or  $\pi/4$ 

(21) **(B).** 
$$
\varepsilon \propto -\frac{di}{dt}
$$

$$
= \left[\frac{C(v_1 - v_2)}{L}\right] \text{ (using (1))}
$$
  
\n
$$
cos \phi = cos \frac{\pi}{3} = \frac{1}{2} \ ; \ \ c \ P > = \frac{1}{2} \times \frac{1}{2} \times \frac{1}{2} = \frac{1}{8} \text{ W}
$$
  
\n(20) (C)  $tan \theta = \frac{X_L}{R} = 1 \ : . \ \phi = 45^\circ \text{ or } \pi/4$   
\n(21) (B)  $\varepsilon \propto -\frac{di}{dt}$   
\n(22) (B)  $V_{\text{rms}} = \left[\frac{1}{T} \int_0^{T/2} \sqrt{3} dt\right]^{1/2}$   
\n
$$
= \left[\frac{V_0^2}{T} \left[t\right]_0^{T/2}\right]^{1/2} = \left[\frac{V_0^2}{T} \left(\frac{T}{2}\right)\right]^{1/2}
$$
  
\n(30) (A)  $\left[\begin{array}{c} \text{OPT} \\ \text{D} \end{array}\right]$   
\n
$$
= \left[\frac{V_0^2}{T} \left[t\right]_0^{T/2}\right]^{1/2} = \left[\frac{V_0^2}{T} \left(\frac{T}{2}\right)\right]^{1/2}
$$
  
\n(4) (b)  $V = -L \frac{di}{dt}$ . Here  $d\theta / 2 \pi$  in  $\theta$  in  $\$ 

**(23) (A).** If  $\omega = 50 \times 2\pi$  then  $\omega L = 20\Omega$ <br>If  $\omega' = 100 \times 2\pi$  then  $\omega' L = 40\Omega$ 

$$
I = \frac{200}{Z} = \frac{200}{\sqrt{R^2 + (\omega' L)^2}} = \frac{200}{\sqrt{30^2 + (40)^2}} = 4A
$$
 is included in decreases.

(24) **(D).** V = 
$$
-L\frac{di}{dt}
$$
. Here di/dt +ve for T/2 time and di/dt is  
-ve for next T/2 time.

(25) (A). Induced e.m.f. 
$$
e = -\frac{d\phi}{dt} = -(100t)
$$
 (33) (C)

$$
i = \left| \frac{\varepsilon}{R} \right| = +\frac{100 \times 2}{400} = +0.5 \text{ Amp}
$$

$$
V_{\text{rms}} = \left[\frac{V_0^2}{2}\right]^{1/2} = \frac{V_0}{\sqrt{2}}
$$
\n
$$
V_{\text{rms}} = \left[\frac{V_0^2}{2}\right]^{1/2} = \frac{V_0}{\sqrt{2}}
$$
\n
$$
V_{\text{B}} = \frac{200}{2} = \frac{200}{\sqrt{160}} = \frac{200}{\sqrt{160}} = \frac{200}{\sqrt{160}} = \frac{200}{\sqrt{160}} = \frac{200}{\sqrt{30^2 + (40)^2}} = 4 \text{ A}
$$
\n
$$
V_{\text{B}} = \frac{200}{Z} = \frac{200}{\sqrt{16^2 + (\omega' L)^2}} = \frac{200}{\sqrt{30^2 + (40)^2}} = 4 \text{ A}
$$
\n
$$
V_{\text{B}} = \frac{12 \text{ E}}{\text{B} \cdot \text{C}} \text{ or } V_{\text{C}} = \text{B} \cdot \text{C} \text{ or } V_{\text{D}} = \text{C} \cdot \text{C} \text{ or } V_{\text
$$

2 2 0 1 1 <sup>q</sup> CV V cos t q CV V (q = CV) .......... (1) dq d (q cos t) I q sin t dt dt 2 1/2 | I | CV [1 cos t] LC V 1 L V 1/2 2 2 C (V V ) 1 2 / 2 1/ C tan 1 = 45° or /4 rms 0 <sup>1</sup> V V dt 1/2 1/2 2 2 0 0 T/2 V V <sup>T</sup> [t] T T 2 0 0 rms V V <sup>V</sup> <sup>Z</sup> R ( L) 2 2 30 (40) X<sup>L</sup> tan R 3 /3 X<sup>L</sup> Z<sup>2</sup> X R tan <sup>L</sup> <sup>3</sup> ........... (2) Net impedance 2 2 Z R (X X ) R L C Power factor cos = R/Z = 1 **(27) (D).** < P > = Vrms . Irms cos rms <sup>1</sup> <sup>2</sup> <sup>1</sup> V volt <sup>2</sup> <sup>2</sup> ; rms <sup>1</sup> 2 1 I A 2 2 1 cos cos 3 2 ; 1 1 1 1 P W 2 2 2 8 **(28) (B).** Area of i-t graph = q = 1 0.1 4 <sup>2</sup> = 0.2C q 0.2 <sup>R</sup> ; = 2 weber

$$
q = 0.2 = \frac{\Delta \phi}{R}; \Delta \phi = 2 \text{ weber}
$$

**(29) (C).** A wire loop is rotated in magnetic field. The frequency of change of direction of the induced e.m.f. is twice per revolution. (once per half revolution)  $0.2 = \frac{\Delta\phi}{R}$ ;  $\Delta\phi = 2$  weber<br>
tire loop is rotated in magnetic field. The frequency<br>
of change of direction of the induced e.m.f. is twice<br>
ber revolution. (once per half revolution)<br> **WERENCES**<br> **WERENCESS** when an i ber<br>
algentic field. The frequency<br>
of the induced e.m.f. is twice<br>
per half revolution)<br>
ord is inserted in the coil as<br>
ncreases.<br>
mcy of the AC source is<br>
tit decreases.<br>
furns in the coil is reduced<br>
and the creases.<br> netic field. The frequency<br>the induced e.m.f. is twice<br>half revolution)<br>l is inserted in the coil as<br>reases.<br>y of the AC source is<br>of circuit decreases.<br>decreases.<br>ce of reactance  $X_C = X_L$ <br>as impedance of circuit<br>)<br> $= 2.7 \$ 

$$
(30) \quad (A). \begin{array}{|c|c|} \hline \text{W} & \text{W} \\ \hline \text{O} & \text{A} \end{array}
$$

Brightness of the bulb

- \* Decreases when an iron rod is inserted in the coil as impedance of circuit increases.
- \* Increases when frequency of the AC source is decreased as impedance of circuit decreases.
- \* Increases when number of turns in the coil is reduced as impedance of circuit decreases.
- 200 is included in the circuit as impedance of circuit \* Increases when a capacitance of reactance  $X_C = X_L$ decreases. bulb<br>
e bulb<br>
e bulb<br>
an iron rod is inserted in the coil as<br>
direct increases.<br>
frequency of the AC source is<br>
medance of circuit decreases.<br>
umber of turns in the coil is reduced<br>
of circuit decreases.<br>
capacitance of r the buttoman intervals in the coil as<br>an iron rod is inserted in the coil as<br>force in the coil is necessary<br>in frequency of the AC source is<br>impedance of circuit decreases.<br>a capacitance of reactance  $X_C = X_L$ <br>is the circui

(31) **(D).** 
$$
\varepsilon = BL_{eff}v
$$
 ( $L_{eff}$  = Diameter)  
=  $B 2Rv$ 

(32) **(B).** Power output = 
$$
3kW \times \frac{90}{100} = 2.7 kW
$$
; I<sub>b</sub> = 6A

$$
V_S = \frac{2.7 \text{ kW}}{6A} = 450 \text{ V}; \quad I_p = \frac{3 \text{ kW}}{200 \text{ V}} = 15 \text{ A}
$$

(33) (C). EMF induced = 
$$
B_1 V \ell - B_2 V \ell
$$

$$
q = 0.2 = \frac{\sqrt{w}}{R}
$$
; Δφ = 2 weber  
\n(29) (C). A wire loop is rotated in magnetic field. The frequency  
\nof change of direction of the induced e.m.f. is twice  
\nper revolution. (once per half revolution)  
\n(30) (A).  
\n
$$
\left[\begin{array}{c} \nabla q^2 dt \\ \nabla \end{array}\right]^{1/2} = \left[\begin{array}{c} \frac{V_0^2}{T} \left(\frac{T}{2}\right) \right]^{1/2} & (30) (A). \left[\begin{array}{c} \nabla q^2 dt \\ \nabla r \end{array}\right]^{1/2} = \left[\begin{array}{c} \frac{V_0^2}{T} \left(\frac{T}{2}\right) \right]^{1/2} & (30) (A). \left[\begin{array}{c} \nabla q^2 dt \\ \nabla r \end{array}\right]^{1/2} = \left[\begin{array}{c} \frac{V_0^2}{T} \left(\frac{T}{2}\right) \right]^{1/2} & \nabla r \end{array}\right]
$$
\nBridtheses of the bulb  
\nBridtimes of the cells  
\nincreases when non rod is inserted in the coil as  
\nincreases when number of circuit increases.  
\ndecreases when number of circuit decreases.  
\n2200  
\n2200  
\n232,  $200 - 200$   
\n240  
\n2200  
\n233  
\n24. Then of L = 40Ω  
\n2500  
\n2600  
\n27. Then  $dL = 40Q$   
\n281  
\n2920  
\n200  
\n200  
\n2200  
\n2200  
\n231  
\n240  
\n251  
\n261  
\n271  
\n282  
\n293  
\n294  
\n200  
\n201  
\n201  
\n202  
\n203  
\n203  
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\n206  
\n207  
\n208  
\n209  
\n200  
\n200  
\n201  
\n201  
\n202  
\n





- **(35) (D).** First current develops in direction of abcd but when electron moves away, then magnetic field inside loop decreases & current changes its direction.
- **(36) (C).** When capacitor is filled with mica then capacitance C increases so  $X_C$  decreases.
	- In case (b)  $X_C \rightarrow$  so voltage across capacitor (45) decreases. so  $V_a > V_b$ .
- **(37) (D).** N = 1000, I = 4 A,  $\phi = 4 \times 10^{-3}$

$$
L = \frac{\phi N}{I} = \frac{4 \times 10^{-3} \times 1000}{4} = 1 \text{ H}
$$

(38) (A). L = 20 mH, C = 50 µF, R = 40
$$
\Omega
$$
  
 $X_L = \omega L = 340 \times 20 \times 10^{-3} = 6.8 \Omega$ 

$$
P = i_{rms}^{2}R = \left(\frac{V_{s}}{R}\right)^{2}R = \frac{V_{s}^{2}}{R}
$$
\n
$$
P' = i_{rms}^{2}R = \left(\frac{V_{s}}{Z}\right)^{2}R = P\left(\frac{R}{Z}\right)^{2}
$$
\n(35) **(D).** First current develops in direction of abcd but when electron moves away, then magnetic field inside the side of the mass, and the battery is, i = 2i<sub>1</sub> = 2 × 2 = 4A  
\nloop decreases so  $V_{a} > V_{b}$ .  
\n36) **(C).** When capacitor is filled with mice then capacitance  
\nConcreases so  $V_{a} > V_{c}$ , decreases.  
\n37) **(D).** N = 1000, I = 4A,  $\phi = 4 \times 10^{-3}$   
\n
$$
L = \frac{\phi_{N}}{1} = \frac{4 \times 10^{-3} \times 1000}{4} = 1H
$$
\n(38) **(A).** L = 20 mH, C = 50  $\mu$ F, R = 40 $\Omega$   
\n
$$
X_{L} = \omega L = 340 \times 20 \times 10^{-3} = 6.8 \Omega
$$
\n
$$
X_{C} = \frac{1}{\omega C} = \frac{1}{340 \times 50 \times 10^{-6}} = 58.8 \Omega
$$
\n
$$
X_{C} = \left(\frac{F_{V}}{Z}\right)^{2}R
$$
\n
$$
P_{av} = 1\frac{2}{v}R = \left(\frac{F_{v}}{Z}\right)^{2}R
$$
\n
$$
Z = \sqrt{R^{2} + (X_{C} - X_{L})^{2}} = 65.6
$$
\n
$$
P_{av} = \left(\frac{10}{\sqrt{2 \times 65.6}}\right)^{2} \times 40 = 0.46 \text{ W}
$$
\n(39) **(B).** Current leads voltage by phase  $\frac{\pi}{2}(90^{\circ})$   
\n(40) **(C).** Master tuning means low bandwidth = R/L  
\n300  
\n310. (C). Interpret leads to the same solution, i = 48.800 kg by phase  $\frac{\pi}{2}(90^{\circ})$   
\n321. (a) <

**(B).** Current leads voltage by phase  $\frac{\pi}{2}(90^{\circ})$ 

Power consumed  $= 0$ .

- **(40) (C).** Better tuning means low bandwidth  $= R/L$
- **(41) (D).** Magnetic flux linked with area of loop 1 is  $\pi r^2$

So emf in loop 1 is 
$$
-\frac{dB}{dt}\pi r^2
$$

Magnetic flux linked with area of loop 2 is zero. So emf in loop  $2 = 0$ 

(42) (C). 
$$
\cos \theta = \frac{R}{Z} = \frac{V_R}{V} = \frac{80}{\sqrt{80^2 + (100 - 40)^2}} = \frac{80}{100} = 0.8
$$

(0.13. - SOILUTIONS  
\n
$$
\frac{1}{6000MADVANRGEEDI43RINRG}
$$
\n
$$
\frac{1}{\sqrt{2}}\sqrt{2}
$$
\n
$$
q = \left[4\pi \times 10^{-7} \times 2 \times 10^{4} \times 100 \times \pi \times (10^{-2})^{2} \times \left(\frac{4}{0.05}\right)\right] \frac{1}{10\pi^{2}} \times 0.05
$$
\n
$$
q = 32 \mu C
$$
\n(44) (B). At t = 0, i<sub>1</sub> =  $\frac{\varepsilon}{R} = \frac{18}{9} = 2A$   
\n
$$
\left(\frac{R}{Z}\right)^{2}
$$
\n
$$
\frac{1}{\left(\frac{R}{Z}\right)^{2}}
$$
\ndirection of abcd but when  
\nthen magnetic field inside  
\nat changes its direction.  
\n
$$
\frac{\varepsilon}{\sin(45)} = \frac{\varepsilon}{\sin(45)} = \frac{\varepsilon}{\sin(45)} = \frac{18}{\pi} \times 10^{-3} = \frac{18}{2} \times 10^{-3} = \frac{1}{2} \times 10^{-3} = \frac{1}{2} \times 10^{-3} = \frac{500}{36} = 13.89 \text{ H}
$$
\n
$$
= 58.8 \Omega
$$
\n(46) (C).  $P_{av} = \left(\frac{V_{rms}}{Z}\right)^{2} R$ 

Z **(44) (B).** At t = 0, <sup>1</sup> R R R i i i

Current through the battery is,  $i = 2i_1 = 2 \times 2 = 4A$ 

(45) **(D).** Energy stored in inductor, 
$$
U = \frac{1}{2}LI^2
$$

$$
10^{-7} \times 2 \times 10^{4} \times 100 \times \pi \times (10^{-2})^{2} \times \left(\frac{4}{0.05}\right) \frac{1}{10\pi^{2}} \times 0.05
$$
  
\n
$$
q = 32 \mu C
$$
  
\nAt t = 0, i<sub>1</sub> =  $\frac{\varepsilon}{R} = \frac{18}{9} = 2A$   
\n
$$
\sum_{R \atop R} \begin{array}{c}\n\frac{\varepsilon}{\varepsilon} & \frac{\varepsilon}{\varepsilon} \\
\frac{\varepsilon}{\varepsilon} & \frac{\varepsilon}{\
$$

(46) (C). 
$$
P_{\text{av}} = \left(\frac{V_{\text{rms}}}{Z}\right)^2 R
$$

$$
Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} = 56 \,\Omega
$$

$$
P_{\text{av}} = \left(\frac{10}{\left(\sqrt{2}\right)56}\right)^2 \times 50 = 0.79 \text{ W}
$$

- $\pi$  (47) **(D).** Electric heater does not involve Eddy currents. It uses Joule's heating effect.
- So emf in loop 1 is  $-\frac{d\vec{B}}{dt} \pi r^2$  Initial angle  $\theta_1 = 0^\circ$  $rac{dE}{dt} \pi r^2$ <br>Final angle  $\theta_2 = 90^\circ$  $\frac{18}{2}$  = 65.6<br>
40 = 0.46 W<br>
40 = 0.46 W<br>
47 (b). Electric heater does not involve Eddy curve by phase  $\frac{\pi}{2}$  (90°)<br>
47 (b). Electric heater does not involve Eddy curve by phase  $\frac{\pi}{2}$  (90°)<br>
48 (b). Electric h IT,  $\frac{1}{x-340 \times 20 \times 10^{-3} - 6.85 \Omega}$ <br>  $\frac{1}{x-340 \times 20 \times 10^{-3} - 6.85 \Omega}$ <br>  $\frac{1}{x-340 \times 30 \times 10^{-6} - 5.85 \Omega}$ <br>  $\frac{1}{x^2 + (x_0 - X_1)^2} = 65.6$ <br>  $\frac{10}{x^2 \times 65.6}$ <br>  $\frac{10}{x^2 \times 65.6}$ <br>  $\frac{1}{x^2 \times 65.6}$ <br>  $\frac{1}{x^2 \times 65.$  $\sum_{n=1}^{\infty} \frac{1}{n} \cos \frac{n\pi x}{340 \times 50 \times 10^{-8}} = 58.8 \Omega$ <br>  $\int_{n}^{\infty} = \frac{1}{16} \text{R} = \left(\frac{F_{2}}{K}\right)^{2} \text{R}$ ;  $F_{\text{v}} = \frac{10}{\sqrt{2}}$ <br>  $= \sqrt{\text{R}^{2} + (\text{cot} - \frac{1}{\text{cot} \text{C}})^{2}} = 65.6$ <br>  $\sum_{n}^{\infty} = \left(\frac{16}{\sqrt{2} \times 6.6}\right)^{2} \times 40 =$ 1<br>
and  $\frac{1}{16}$ ,  $C = 50 \mu F$ ,  $R = 40 \Omega$ <br>
col. = 340 × 20 × 10<sup>-3</sup> = 6 8 Ω<br>  $\frac{1}{900}$ <br>  $\frac{1}{16}$ ,  $R = \frac{1}{16}$ ,  $\frac{1}{29}$ <br>  $\frac{1}{16}$ ,  $\frac{1}{29}$ ,  $\frac{1}{8}$ ,  $\frac{1}{29}$ <br>  $\frac{1}{28}$ ,  $\frac{1}{28}$ ,  $\frac{1}{29}$ <br>  $\frac{1}{28}$ ,  $E = \frac{1000}{300}$ <br>  $D = 68.62$ <br>  $E = \frac{10}{\sqrt{2}}$ <br>  $E = \frac{10}{\sqrt{2}}$ <br>  $= 65.6$ <br>  $= 0.46$  W<br>  $= 0.946$  W<br>  $=$  $\frac{80}{8.8} = 0.8$   $e = -\frac{\Delta\phi}{\phi} = \frac{-(-)2 \times 10^{-3} \text{Wb}}{0.8} = 0.02 \text{ V}$ L =  $\frac{25 \times 2 \times 10^6 \times 10^{-3}}{3600} = \frac{500}{36} = 13.89 \text{ H}$ <br>
(46) (C).  $P_{\text{av}} = \left(\frac{V_{\text{rms}}}{Z}\right)^2 R$ <br>  $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2} = 56 \Omega$ <br>  $P_{\text{av}} = \left(\frac{10}{(\sqrt{2}).56}\right)^2 \times 50 = 0.79 \text{ W}$ <br>
(47) (D). Electric heater does no **(48) (D).** Magnetic field B =  $5 \times 10^{-5}$  T Number of turns in coil  $N = 800$ Area of coil  $A = 0.05$  m<sup>2</sup> Time taken to rotate  $\Delta t = 0.1$  s Change in magnetic flux  $\Delta\phi$  $=$  NBA cos 90 $^{\circ}$  – BA cos 0 $^{\circ}$  = – NBA  $=$   $-800 \times 5 \times 10^{-5} \times 0.05 = -2 \times 10^{-3}$  weber  $=\frac{1}{3600}$   $=\frac{1}{36}$  = 13.89 H<br>  $\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$  R<br>  $=\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$  = 56 Ω<br>  $\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$   $\times 50 = 0.79$  W<br>
Electric heater does not involve Eddy currents.<br>
Electric heater does n  $\frac{x^2 \times 10^6 \times 10^{-3}}{360} = \frac{500}{36} = 13.89 \text{ H}$ <br>  $\left(\frac{V_{\text{rms}}}{Z}\right)^2$  R<br>  $\left(\frac{V_{\text{rms}}}{Z}\right)^2$  = 56 Ω<br>  $\left(\frac{10}{\sqrt{2}}\right)^2$  × 50 = 0.79 W<br>
ic heater does not involve Eddy currents.<br>
S Joule's heating effect.<br>
etic fiel  $\frac{25 \times 2 \times 10^6 \times 10^{-3}}{3600} = \frac{500}{36} = 13.89 \text{ H}$ <br>=  $\left(\frac{V_{\text{rms}}}{Z}\right)^2$  R<br>=  $\left(\frac{V_{\text{rms}}}{Z}\right)^2$  R<br>=  $\left(\frac{10}{\sqrt{235}}\right)^2$  × 50 = 0.79 W<br>electric heater does not involve Eddy currents.<br>uses Joule's heating effect

$$
e = -\frac{\Delta \phi}{\Delta t} = \frac{-(-) 2 \times 10 \text{ Wb}}{0.1 \text{ s}} = 0.02 \text{ V}
$$