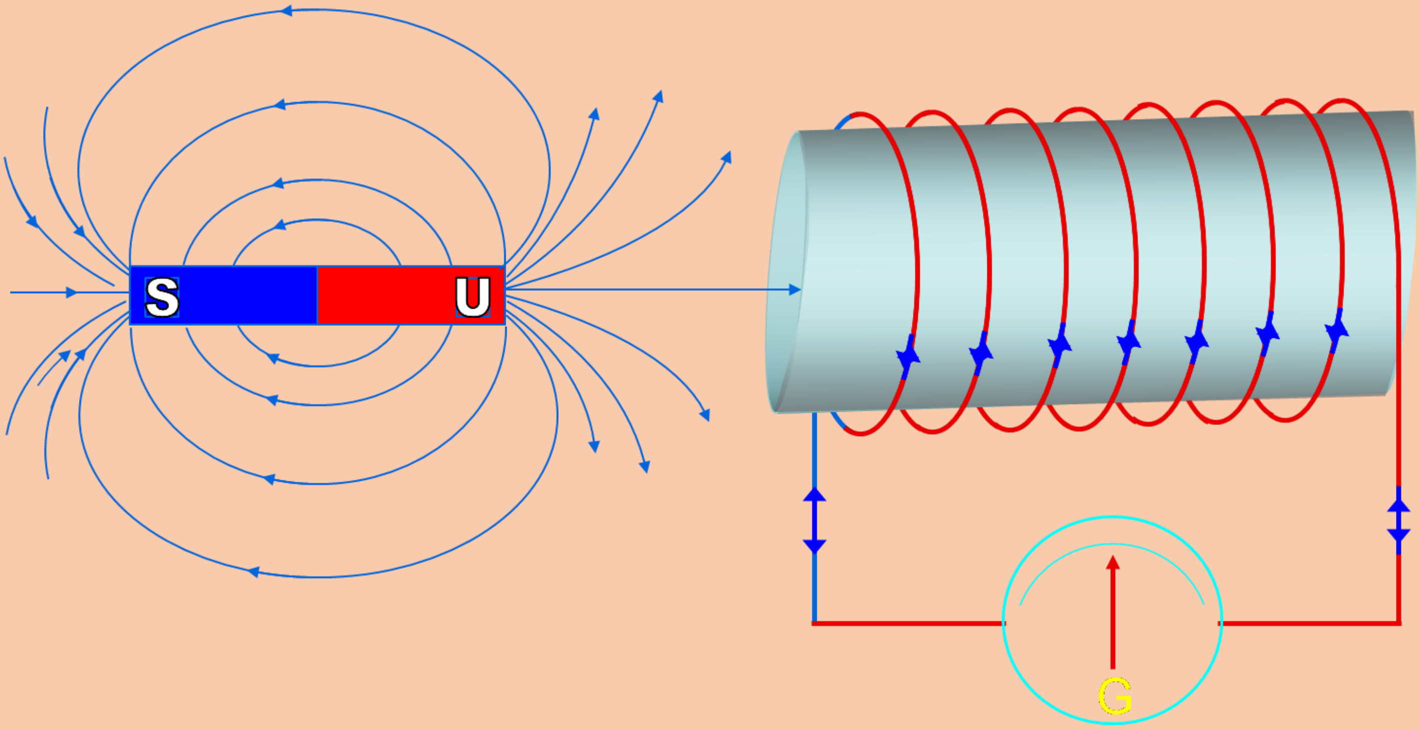
6. ELECTROMAGNETIC INDUCTION



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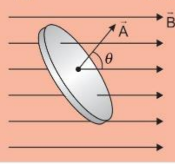
ELECTROMAGNETIC INDUCTION

MAGNETIC FLUX

It is defined as the number of magnetic field lines passing through a surface normally.

$\phi_B = \vec{B} \cdot \vec{A} = BA_{\cos\theta}$



ELECTROMAGNETIC INDUCTION

It is phenomena of inducing an electric field or emf in a conductor by varying the magnetic field.

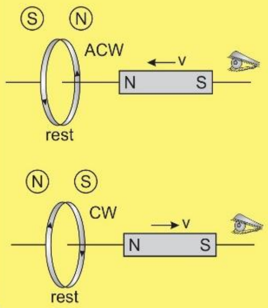
FARADAY'S LAW

This law states that magnitude of the induced emf in a circuit is equal to the rate of change in magnetic flux through a circuit.

$\varepsilon = \frac{d\phi_b}{dt} = -\frac{d(BA_{\cos\theta})}{dt}$

LENZ'S LAW

This law states that polarity of induced emf is such that it tends to produce a current which apposes the change in magnetic flux that produced it.



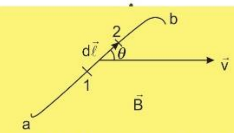
METHODS TO CHANGE IN MAGNETIC FLUX

- Magnetic flux can be increased by increasing the strength of magnetic field and vice – versa.
- The magnetic flux can be increased by increasing the area of coil and vice – versa.
- The magnetic flux can vary from maximum to, minimum value for variation in θ.
- The magnetic flux can be increased by increasing the number of coils.

Induced current:
$i = \frac{1}{R}\left(\frac{-d\phi_B}{dt}\right)$

Induce charge:
$q = \frac{(\Delta\phi_B)}{R}$

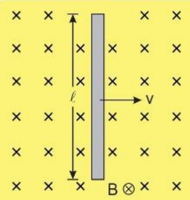
MOTIONAL EMF



- When a conductor moves in a magnetic field it will experience a force and emf is induced in the coil. This emf is know as motional emf.

$\varepsilon = \int_D^{\alpha} (\vec{dl} \times \vec{v}).\vec{B}$

STRAIGHT CONDUCTOR IN $\vec{B}$



Induced emf, $\varepsilon = Bwl^2$

SELF INDUCTANCE

- Inherent property which the change in current.
- Dimensional Formula: $[ML^2T^{-2}A^{-2}]$
- SI unit: henry, Wb/A or S/A^2

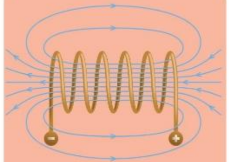
- When current flowing in coil change with respect to rime, then Self – inductance:

$L = \frac{-\varepsilon}{dI/dt}$

- When current flowing in coil is constant then Coefficient of Self – inductance:

$L = \frac{\phi_{total}}{I}$

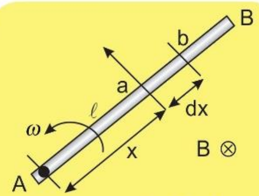
SOLENOID



- $L = \frac{\mu_0 N^2 A}{l}$

A = Cross-section Area
l = Length
N = No. of turns

STRAIGHT CONDUCTOR ROTATING IN MAGNETIC FIELD



Induced emf, $\varepsilon = \frac{1}{2}Bwl^2$

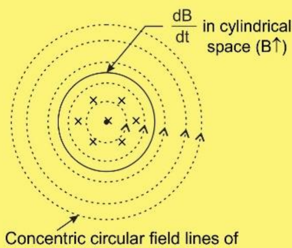
INDUCED ELECTRIC FIELD

When magnetic field in a region varies with time then an electric field will induce within and outside that region.

$\oint\vec{E} \cdot \vec{dl} = \frac{-d\phi}{dt}$

PROPERTIES

- Induced electric field is different from electric field produced due to stationary charges.
- Induced electric field lines always form closed curves.
- For induced electric field $\oint\vec{E} \cdot \vec{dl} \neq 0$ but for electrostatic field $\oint\vec{E} \cdot \vec{dl} = 0$, always.
- The direction of induced electric field will be same as direction of induced current.



Concentric circular field lines of $\vec{E}_{induce}$ (inside/outside)

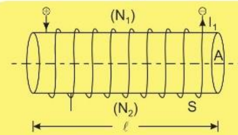
MUTUAL INDUCTANCE

The phenomena in which emf is induced in a circuit due to change in magnetic flux in its neighbouring circuit is called mutual induction.

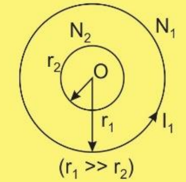
- When current in primary coil is constant, then coefficient of mutual inductance:

$M = \frac{N_2\phi_2}{I_1} = \frac{N_2B_2A_2}{I_1}$

- When current in primary coil change with respect to time, then coefficient of mutual inductance: $M = \frac{-\varepsilon_2}{dI_1/dt}$



- When coils are Co – axial: $M_{12} = \frac{\mu_0 N_1 N_2 A}{l}$



$(r_1 >> r_2)$

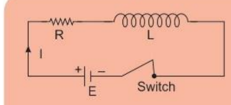
- When coils are concentric and coplanar: $M = \frac{\mu_0 N_1 N_2 \pi r_2^2}{2r}$

EDDY CURRENT

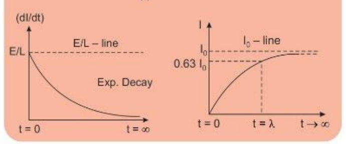
The current induced in a conductor when placed in a changing magnetic flux is known as eddy currents.

R – L DC CIRCUIT

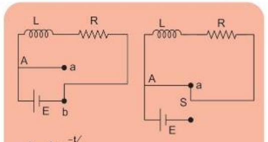
CURRENT GROWTH



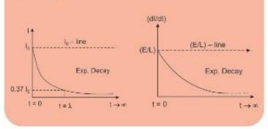
- $I = I_0(1 - e^{-t/\tau})$
- Decay constant $\tau = \frac{L}{R}$



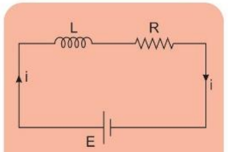
CURRENT DECAY



- $I = I_0 e^{-t/\tau}$

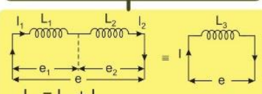


ENERGY STORED IN AN INDUCTOR COIL

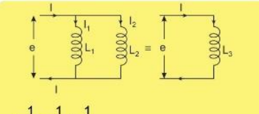


- $U = \frac{1}{2}LI^2$

COMBINATIONS OF INDUCTORS



- $L_s = L_1 + L_2$

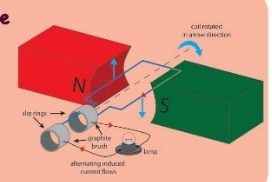


- $\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2}$

AC GENERATOR

- It works on the principle of EMI.
- Magnetic flux, $\phi_B = NBA_{\cos wt}$
- Induced emf $\varepsilon = \frac{-d\phi_B}{dt}$

$= NBA\omega \sin wt$



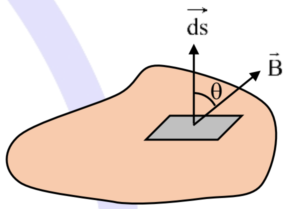
Electromagnetic Induction

Introduction

Experiments performed by scientists like Oersted, Ampere etc, during the early years of 19th century established that magnetic fields may be produced using electric currents. It was natural to enquire whether an electric current be produced using magnetic fields. Producing electric currents from magnetic fields was not so easy as to produce magnetic fields from currents. However, careful experimental observations made independently by Michael Faraday in England and Joseph Henry in USA around the year 1831, showed that under certain conditions electrical current can be produced using magnetic fields. It was found that when the magnetic flux linked with a loop of a conductor changes there will be an electric current in the loop. The phenomenon in which an emf is developed in a conductor due to the change in the magnetic flux linked with it is called the electromagnetic induction. Almost all the entire electrical energy used in the world today is produced making use of electromagnetic induction.

Magnetic flux

The number of field lines passing normally across a surface is called the flux across the surface. The flux associated with a magnetic field is defined in a manner similar to that used to define electric flux. Let dS be an element of area on an arbitrary shaped surface as shown. If the magnetic field at this element is $\vec{B}$, the magnetic flux through the element is,



$d\phi_B = \vec{B}\cdot\vec{dS} = BdS\cos\theta$.

$\vec{dS}$ here is a vector that is perpendicular to the surface and has a magnitude equal to the area dS and θ is the angle between $\vec{B}$ and $\vec{dS}$. In general $d\phi_B$ varies from element to element. The total magnetic flux through the surface is the sum of the contributions from the individual area elements.

$\therefore \phi_B = \int B ds\cos\theta = \int \vec{B}\cdot\vec{dS}$

☞	(i)Magnetic flux is a scalar quantity (dot product of two vector quantities is a scalar quantity) (ii) The SI unit of magnetic flux is tesla–meter² (1 T-m²). This unit is called *weber* (1 Wb) 1 Wb = 1 T-m² = I N-m/A Thus unit of magnetic field is also weber/m² (1 Wb/m²), or 1 T = 1 Wb/m² In the special case where B is uniform over a plane surface with total area S and is normal to the surface then cos θ ≈ 1 and $\phi_B = BS$

Faraday's law of electromagnetic induction

The results of systematic experimental observations made by Faraday may be summarised in the form laws called Faradays laws of electromagnetic induction.

These laws states that

(i) whenever the flux of magnetic field through the area bounded by a closed conducting loop changes, an emf is produced in the loop, and

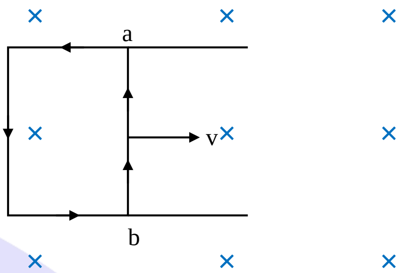
(ii) the magnitude of emf induced in a coil is equal to the rate of change of magnetic flux linked with the coil.

The induced emf is given by $E = -\dfrac{d\Phi}{dt}$ ...(1)

where $\Phi = \int \vec{B}\cdot\vec{dS}$ is the flux of the magnetic field through that area.

The law described by equation (1) is called *Faraday's law of electromagnetic induction*. The flux may be changed in a number of ways. One can change the magnitude of the magnetic field $\vec{B}$ at the site of the loop, the area of the loop or the angle between the area-vector $\vec{dS}$ and the magnetic field $\vec{B}$. In any case, as long as the flux keeps changing, the emf is present. The emf produced so drives an electric current through the loop. If R is the resistance of the loop, the current then is

$$i = \frac{E}{R} = -\frac{1}{R}\frac{d\Phi}{dt} \qquad ...(2)$$



The emf developed by a changing flux is called induced emf and the current produced by this emf is called *induced current*.

Suppose the circuit (loop) consists of N loops all of same area and if ϕ_B is the flux through one loop, then the total induced emf is given by

$$e = -N\frac{d\varphi_B}{dt}$$

significance of –ve sign will be explained below.

Direction of induced current

Lenz's law

Soon after Faraday gave his law of induction, Lenz devised a rule-now known as Lenz's law for finding the direction of an induced current in a loop.

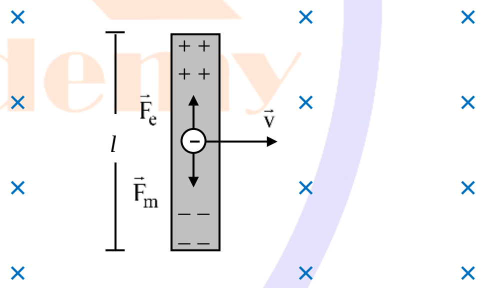
An induced current has a direction such that the magnetic field due to this current opposes the change in the magnetic flux that induces the current.

Furthermore, the direction of an induced emf is same as that of the induced current.

Motional electromotive force

(emf induced in a rod moving in a magnetic field)

(emf Until now, we considered the cases where an emf is induced in a stationary circuit placed in a magnetic field when the field changes with time. We now describe what is called *motional emf*, which is the emf induced in a conductor when it is moving through a constant magnetic field.



The straight conductor of length l shown in figure is moving through a uniform magnetic field directed into the page (denoted by the sign ×). For simplicity let us assume that the conductor is moving in a direction perpendicular to the field with constant velocity under the influence of some external agent.

The electrons in the conductor experience a force, $\vec{F}_m = -e(\vec{v} \times \vec{B})$

Under the influence of this force, the electrons move to the lower end of the conductor and accumulate there, leaving a net positive charge at the upper end. As a result of this charge separation, an electric field is produced inside the conductor. The charges accumulate at both ends until magnetic force evB which is along downward direction is balanced by the upward electric force eE. At equilibrium electrons stop moving. The condition for equilibrium requires that, $eE = evB$ or $E = vB$

The electric field produced in the conductor (once the electrons stop moving and E is constant) is related to the potential difference across the ends of the conductor by,

$\Delta V = El = Blv$

$\therefore\ \Delta V = Blv$

where the upper end is at a higher electric potential than the lower end.

Thus, "*a potential difference is maintained between the ends of the conductor as long as the conductor continues to move through the uniform magnetic field*."

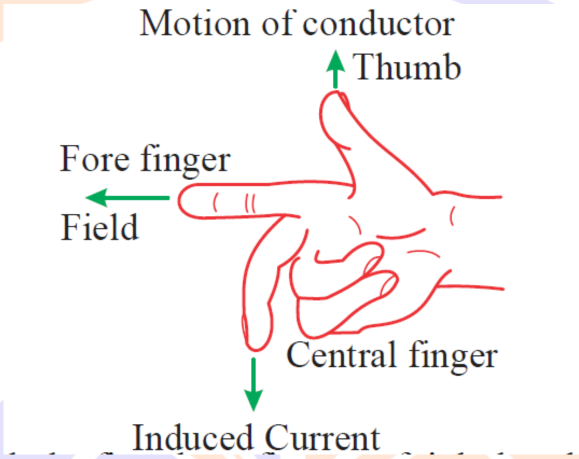
Now let us suppose the moving rod slides along a stationary U-shaped conductor, forming a complete circuit. No magnetic force acts on the charges in the stationary U-shaped conductor, but there is an electric field resulting from the charge accumulations at a and b. Under the action of this field a counter clockwise current is established around this complete circuit. The moving rod acts as a source of electromotive force. Within it, positive 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,

$$\mathbf{e = Bv}\boldsymbol{l} \qquad \ldots(1)$$

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

$$\mathbf{i} = \frac{e}{R} = \frac{Bv\boldsymbol{l}}{R} \qquad \ldots(2)$$

Fleming's right hand rule



The direction of induced emf in a conductor in a magnetic field is given by **Fleming's right hand rule.**

If the fingers of the right hand are held such that the fore finger, middle finger and the thumb are mutually perpendicular and the fore finger shows the direction of field and the thumb shows the direction of motion of the conductor then the middle finger shows the direction of induced current. This principle is used in ac generator.

Induced electric field

Consider a conducting loop which is located in a magnetic field $\vec{B}$. The free electrons cannot flow in the loop until an electric field is applied. As long as $\vec{B}$ is constant no electric field is induced. Suppose the flux of magnetic induction through the loop starts changing say at t = 0, then an electric field $\vec{E}$ is produced. Obviously this electric field is produced by the changing magnetic field and not by charged particles.

Using Faraday's law of induction, induced emf 'e' is given by $e = -\frac{d\Phi}{dt}$ or, $\oint \vec{E}\cdot\vec{dl} = -\frac{d\Phi}{dt}$.

A conducting closed loop need not be there to have an induced electric field $\vec{E}$. As long as B keeps changing, the induced electric field is present. If a closed loop is there, the free electrons start drifting and consequently an induced current results. Changing of $\vec{B}$ is not the only method of producing an induced electric field and consequently an induced emf. There are other methods also.

Various methods of producing induced emf

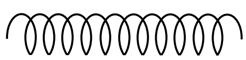
The three major methods generally employed are

(i) change of $\vec{B}$, the magnetic field acting on the object

(ii) change of area of material

(iii) change of relative orientation of surface area and the applied magnetic field

Inductors and inductance



An inductor is a coil of wire (conductor) with a number of turns as shown in the figure. Such an inductor can be used to produce a desired magnetic field. It is essentially a short solenoid. Here we consider a long solenoid (specifically, a short length near the middle of a long solenoid) as our basic type of inductor. If a current i is established in the windings of an inductor (a solenoid), the current produces a magnetic flux Φ_B through the central region of the inductor.

$\phi_B \propto I$ or $\phi_B = LI$

The constant of proportionality L is called the inductance of the inductor. Then,

$$L = \frac{N\Phi_B}{i} \qquad \ldots (1)$$

where N is the number of turns. The windings of the inductor share the flux, and the product $N\Phi_B$ is called the magnetic flux linkage. The inductance L is thus a measure of the flux linkage produced in the inductor per unit of current.

As the SI unit of magnetic flux is tesla-square meter, the SI unit of inductance is the tesla-square meter per ampere (T. m^2/A). This is called henry (H), after American physicist Joseph Henry.

Thus, 1 henry = 1 H = 1 T . m^2/A.

Inductance of a solenoid

Let us consider a long solenoid of cross-sectional area A. Let us find the inductance per unit length near its middle. Consider a length *l* near the middle of this solenoid. The flux linkage for this section of the solenoid with total number of turns N is

$$N\Phi_B = (nl)(BA)$$

n being the number of turns per unit length of the solenoid and B being the magnitude of the magnetic field within the solenoid.

The magnitude B as we already know, is given by B = μ_0 in,

so from equation

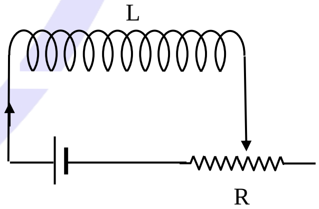
$$L = \frac{N\Phi_B}{i} = \frac{(nl)(BA)}{i} = \frac{(nl)(\mu_0 in)(A)}{i} = \mu_0 n^2 lA$$

The inductance per unit length for a long solenoid near its centre is $\frac{L}{l} = \mu_0 n^2 A$

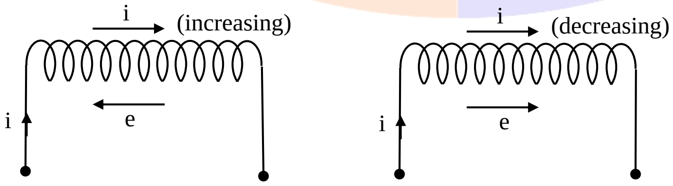
Hence one can conclude that the inductance only depends on the geometry of the device.

Self induction

Self induction is the property of a coil by virtue of which, the coil opposes any change in the current flowing through it by inducing an emf in itself. For this reason, self induction is also referred to as the inertia of electricity. In the figure, current in a coil L is changed by varying the contact position on a variable resistor, a self induced emf appears in the coil while the current is changing.



With current increasing, the self induced emf (e) across the coil appears in a direction which opposes the increase.



With decrease of current, the self induced emf (e) appears across the coil in a direction, such that it opposes the decrease. Therefore, it would be in the direction of i.

Coefficient of self induction

Suppose I is the current flowing through a coil at any time and ϕ is the amount of magnetic flux linked with the coil at that time.

It is found that $\phi \propto I$ or $\phi = Li$,

where L is a constant of proportionality and is called coefficient of self induction or self inductance of the coil.

The emf induced in the coil is given by

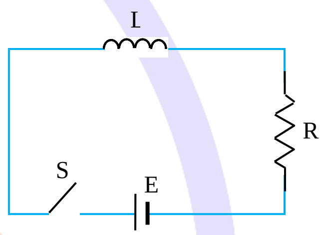
$$e = -\frac{d\varphi}{dt} = -\frac{d}{dt}(LI) \quad \text{or } e = -L\frac{dI}{dt}$$

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

Hence *coefficient of self induction of a coil is numerically equal to the emf induced in the coil when rate of change of current through the coil is unity*.

The SI unit of L is henry. Self inductance of a coil is said to be one henry (H) if a current changing at the rate of 1 ampere/sec through the coil induces an emf of 1 volt in the coil.

Energy stored in an inductor



In the LR circuit shown the current grows in the circuit and the magnetic field increases in the inductor. Part of the work done by the battery during the process is stored in the inductor as magnetic field energy and the rest appears as thermal energy in the resistor. After sufficient time, the current and hence the magnetic field becomes constant and further work done by the battery appears completely as thermal energy. If I is the current in the circuit at time t, we have $E = L\frac{di}{dt} + iR$

or, $E i dt = i^2 R\, dt + L i\, di$ or, $\int_0^t E i\, dt = \int_0^t i^2 R\, dt + \int_0^i L i\, di$

or, $\int_0^t E i\, dt = \int_0^t i^2 R\, dt + \frac{1}{2} L i^2$ … (1)

The first term on right-hand side of equation (1) is the total thermal energy (Joule heat) developed in the resistor in time t. Thus $\frac{1}{2}Li^2$ is the energy stored in the inductor as the current in it increases from 0 to i. As the energy is zero when the current is zero, the energy stored in an inductor, carrying the current i, is

$$U = \frac{1}{2} L i^2$$

Energy density in magnetic field

Let us consider a long solenoid of radius r, length l and with n turns per unit length. If it carries a current i, the magnetic field within it is $B = \mu_0 ni$

Neglecting the end effects, the field outside is zero. The self-inductance of this solenoid is $L = \mu_0 n^2 \pi r^2 l$

The magnetic energy is, therefore, $U = \frac{1}{2}Li^2 = \frac{1}{2}\mu_0 n^2 \pi r^2 l i^2$

$$= \frac{1}{2\mu_0}(\mu_0 ni)^2 V = \frac{B^2}{2\mu_0} V$$

where $V = \pi r^2 l$ being the volume enclosed by the solenoid. As the field is uniform throughout the volume of the solenoid and zero outside, the energy density, is

$$u = \frac{U}{V} = \frac{B^2}{2\mu_0}$$

Self inductance of a long solenoid

A long solenoid is defined as one of length very large compared to its radius of cross-section. The magnetic field B at any point inside such a solenoid is practically constant and is given by

$$B = \frac{\mu_0 NI}{l} \qquad \dots (1)$$

μ_0 being the absolute magnetic permeability of free space/air, which forms the core of the solenoid, *l* being the length of the solenoid, and N the total number of turns in the solenoid.

$\therefore$ Magnetic flux through each turn of the solenoid $= B \times$ area of each turn

$$= \left(\mu_0 \frac{N}{l} I\right) A$$

where A is area of each turn of the solenoid.

Total magnetic flux linked with the solenoid is therefore equal to flux through each turn $\times$ total number of turns

i.e., $\phi = \mu_0 \frac{n}{l} I A \times N \qquad \dots (2)$

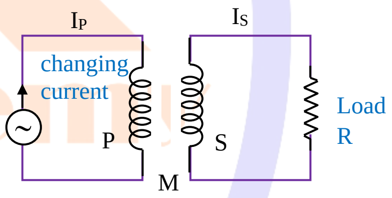
Induced emf $= -\frac{d\varphi}{dt} = \frac{-\mu_0 N^2 A}{l} \frac{dI}{dt} \qquad \dots (3)$

Comparing this equation with $e = -L\frac{dI}{dt}$

We have $L = \frac{\mu_0 N^2 A}{l}$. In this expression μ_0 is replaced by $\mu = \mu_0 \mu_r$ in any other material.

Mutual induction

When the current passing through a coil or circuit changes, the magnetic flux linked with a neighbouring coil or circuit will also change. Hence an emf will therefore be induced in the neighbouring coil or circuit. *The phenomenon in which an emf is induced in one coil due to the changing current in a neighbouring coil is called as mutual induction*. The coil or circuit in which the current changes is called *primary* while the other in which emf is set up is called *secondary*.



In case for two coils situated close to each other, flux linked with the secondary due to current in the primary, i.e., ϕ_s is given by

$\phi_S \propto I_P$ or $\phi_S = MI_P \qquad \dots (1)$

where M is a constant of proportionality called coefficient of mutual induction or simply mutual inductance of the pair of coils. From equation (1)

$M = \phi_S$ if $I_P = 1A$

That is coefficient of mutual inductance of two coils or circuits is numerically equal to the flux linked with one circuit or coil when unit current flows through the other.

☞

According to Faraday's law of electromagnetic induction $e = -\frac{d\varphi}{dt}$

so, $e = -L\frac{dI}{dt}$ or $e_S = -M\frac{dI_P}{dt} \qquad \dots (2)$

i.e., coefficient of self induction is numerically equal to emf induced in a coil when the rate of change of current in it is unity. While coefficient of mutual induction is numerically equal to emf induced in one coil when the rate of change of current in the other coil is unity.

1. As $|e| = L\left(\frac{dI}{dt}\right)$ or $|e| = M\left(\frac{dI}{dt}\right)$, the dimensions of inductance, i.e., [L] as well as [M] is

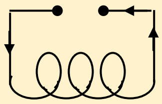
$$[e] \times \left[\left(\frac{dI}{dt}\right)^{-1}\right] = \left[\frac{Ml^2T^{-2}}{AT} \times \frac{T}{A}\right] = [ML^2T^{-2}A^{-2}] \quad \dots (3)$$

And so SI unit of L as well as M is

$$kg\ m^2\ s^{-2}\ A^{-2} = \frac{J}{A^2} = \frac{V \times s}{A} = \Omega \times s = \frac{Wb}{A} = \frac{Tm^2}{A} \quad \dots (4)$$

and is called henry (H).

2. An inductance is said to be ideal with no resistance. In practice inductance always has a resistance, i.e., one cannot have inductance without having resistance. i.e., one can have a resistance with or without having inductance. A resistance without inductance is called non-inductive resistance.



$R \neq 0$ and $L \neq 0$

Relation between mutual inductance and self inductance

The mutual inductance M of two coils or circuits having self-inductance L_1 and L_2 is given by

$$M = k\sqrt{L_1L_2} \quad \dots (1)$$

k being a constant called coefficient of coupling. If the coils are wound over each other the coupling is said to be 'tight' otherwise 'loose'. For tight coupling k = 1 and so $M = \sqrt{L_1L_2}$ while for loose coupling

$0 < k < 1$ and hence $M < \sqrt{L_1L_2}$.

Furthermore, from expression (1) it is also clear that if L = 0, M will be zero, i.e., a system cannot have mutual inductance without having self-inductances. However, converse may or may not be true, i.e., if mutual inductance of a system is zero it may or may not have self-inductances, as M = 0 can be satisfied either by setting k = 0 or L = 0.

Inductors in series and parallel

If two coils of inductance L_1 and L_2 are connected in series, then the effective inductance of the combination of coils is $L = L_1 + L_2 + 2M$ ... (1)

where M is the coefficient of mutual inductance between the coils.

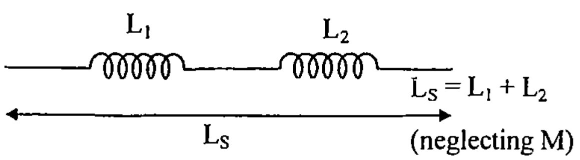
If the two coils are separated by a large distance

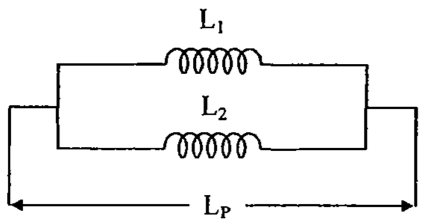
$M \approx 0$ and $L_s = L_1 + L_2$ ... (2)

If the two coils are connected in parallel and separated by a large distance, the effective inductance of the combination L is given by the relation

$$\frac{1}{L_P} = \frac{1}{L_1} + \frac{1}{L_2} \quad \dots (3) \qquad \text{or } L_p = \frac{L_1L_2}{L_1 + L_2} \quad \dots (4)$$

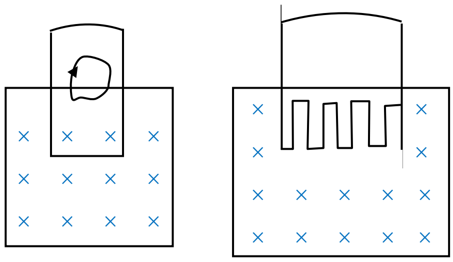
We see that combination of inductances behave as that of resistances, when mutual inductance is negligible.





$$L_P = \frac{L_1 \times L_2}{L_1 + L_2} \text{ (neglecting M)}$$

Eddy currents



Consider a solid plate of metal which is introduced into a region having a magnetic field. Suppose a loop is drawn on the plate, a part of which is inside the field. As the plate moves, the magnetic flux through the area bound by the loop undergoes a change and induces a current. There may be a number of such loops on the plate and hence currents are induced on the surface along various paths. Such currents are referred to as *eddy currents*. We do not have a definite conducting loop to guide the induced current. The system itself looks for the loops on the surface along which eddy currents are induced. Because of the eddy currents in the metal plate, thermal energy is produced in it. This energy comes at the cost of the kinetic energy of the plate and the plate slows down. This is known as electromagnetic damping. To reduce electromagnetic damping, one can cut slots in the plate. This reduces the possible paths of the eddy current considerably.

For example, when we move a metal plate out of a magnetic field, the relative motion between the field and the conductor again induces a current in the conductor. The conduction electrons making up the induced current whirl about within the plate as if they were caught in an eddy (or whirlpool) of water. This is called the eddy current.

The magnitude of eddy current is $i = \dfrac{\text{induced emf}}{\text{resistance}} = \dfrac{e}{R}$

But $e = -\dfrac{d\varphi}{dt}$ $\quad \therefore\ i = -\dfrac{d\varphi/dt}{R}$

The direction of eddy currents is given by Lenz's law, or Fleming's right hand rule.

Eddy currents give rise to loss of energy in devices like transformers, generators and motors. However, eddy currents are used in induction heaters, speedometer, electromagnetic damping of oscillations etc.

Illustrations

1. A rectangular coil of metallic wire is placed on a uniform field 30 mT with its plane perpendicular to the field. If the area of loop is shrinking at a constant rate of 0.4 m^2s^{-1}, the induced emf in the coil is

(A) 20 mV (B) 18 mV (C) 10 mV (D) 12 mV

Ans (D)

$$\varepsilon = \left|-\frac{d\phi}{dt}\right| = \left|-B\frac{dA}{dt}\right| = \left|-(30\times10^{-3})(0.4)\right| = 12\,\text{mV}$$

2. An air core solenoid has 1000 turns and is one metre long. Its cross-sectional area is 10 cm^2. Its self-inductance is

(A) 2.56 mH (B) 1.92 mH (C) 1.26 mH (D) 2.78 mH

Ans (C)

For solenoid, $B = \mu_0 n i = \mu_0 \dfrac{N}{l} i$

$$\therefore\ \phi = NBA = N\left[\mu_0 \frac{N}{l} i\right]A = \mu_0 \frac{N^2A}{l} i$$

Also $\phi = Li \ \therefore\ L = \dfrac{\mu_0 N^2 A}{l}$. So, $L = 4\pi\times10^{-7}\times\dfrac{(1000)^2}{1}\times10\times10^{-4} = 0.0012566\,\text{H} = 1.26\,\text{mH}$

3. Two coils are wound on the same iron rod so that the flux generated by one, also passes through the other. The first coil has 100 turns and second has 200 turns. When a current of 2 A flows through the first one, the flux in it is 2.5 × 10^{-4} Wb. The coefficient of mutual inductance of the coil is

(A) 15 mH (B) 25 mH (C) 35 mH (D) 45 mH

Ans (B)

$$\varepsilon_s = \left|N_s \frac{d\phi_s}{dt}\right| \text{ and } \varepsilon_s = \left|M\frac{di_p}{dt}\right|$$

$$\therefore\ N_s \frac{d\phi_s}{dt} = M\frac{di_p}{dt}$$

$$\Rightarrow M = N_s \frac{d\phi_s}{di_p} = 200\left[\frac{2.5\times10^{-4}-0}{2-0}\right]$$

$$\therefore\ M = 25\times10^{-3}\,H = 25\text{ mH}$$

4. When the current through a solenoid increases at a constant rate, the induced current.

(A) is a constant and is in the direction of inducing current.

(B) Is a constant and is opposite to the direction of the inducing current

(C) Increasing with time and is in the direction of inducing current

(D) Increases with time and is opposite to the direction of the inducing current

Ans (B)

$$\varepsilon = L\left(\frac{di}{dt}\right);$$

$\therefore$ induced current $i = \frac{\varepsilon}{R} = \frac{1}{R}L\left(\frac{di}{dt}\right)$

It is given that $\frac{di}{dt}$ is constant. So induced current is constant. From Lenz's law it opposes the increase in opposing current.

5. A car moves on a plane road. Induced emf produced across its axle is maximum when it moves

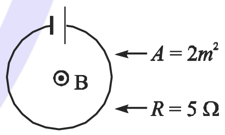
(A) at the poles (B) moves at equator (C) remains stationary (D) no emf is induced at all

Ans (A)

$\varepsilon = Blv\sin\theta$. At poles θ = 90° and B_v of earth is maximum

$\therefore\ \varepsilon = Blv$ at poles and is maximum

6. Figure shows a coil placed in a magnetic field decreasing at a rate of 10 Ts^{-1}. There is also a source of emf 30 V in the coil. The amplitude and direction of the current in the coil are



(A) 2A, anticlockwise (B) 2A, clockwise (C) 4A, anticlockwise (D) 4A, clockwise

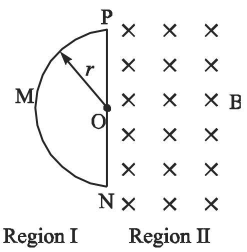
Ans (B)

$\varepsilon_{induced} = \frac{d\phi_B}{dt} = A\frac{dB}{dt} = 2\times10 = 20V$, $i_{induced} = \frac{20}{5} = 4A$, anticlockwise

$i = \frac{30}{5} = 6A$, clockwise

$i_{net} = 6A - 4A = 2A$, clockwise.

7. In the figure space is divided by the line PN into two regions. Region I is field free and region II has a uniform magnetic field B directed into the plane of the paper. PMN is a semicircular conducting loop of radius r with centre at 'O'. The plane of the loop is in the plane of the paper. The loop is rotated in clockwise direction with a constant angular velocity ω about an axis passing through O and perpendicular to plane of paper. The resistance of the loop is R. The expression for the magnitude of current in the loop is

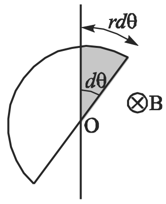


(A) $\frac{Br^2}{2R}\omega$ (B) $\frac{2Br^2}{R}\omega$ (C) $\frac{Br^2}{\sqrt{2}R}\omega$ (D) $\frac{\sqrt{2}Br^2}{R}\omega$

Ans (A)

$$dA = \frac{1}{2}(rd\theta)\cdot r = \frac{r^2}{2}d\theta$$

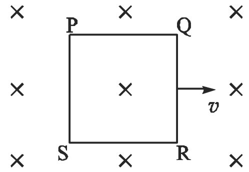
$$d\phi = BdA = B\frac{r^2}{2}d\theta$$



$$\varepsilon = -\frac{d\phi}{dt} = -B\frac{r^2}{2}\frac{d\theta}{dt} = -\frac{Br^2}{2}\omega$$

$$|\varepsilon| = \frac{Br^2}{2}\omega \qquad i = \frac{|\varepsilon|}{R} = \frac{Br^2}{2R}\omega$$

8. A metallic square loop PQRS is moving in its own plane with velocity v in a uniform magnetic field perpendicular to its plane as shown in the figure. An electric field is induced



(A) in PS but not in QR (B) in QR but not in PS

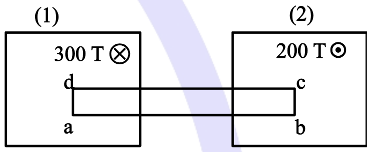
(C) neither in PS nor in QR (D) in both PS and QR

Ans (D)

Here, $V_S - V_P = V_R - V_Q = Blv$

[**Note:** No current flows in the coil because change in magnetic flux linked with the coil is zero]

9. Two magnetic fields exist in the region as shown in figure. A loop abcd of 40 × 10 cm^2 is placed in the fields. The resistance per unit length of the loop is r = 2 Ω cm^{-1}. All of a sudden the loop is given a velocity $V_0 = 20\ \text{cms}^{-1}$ towards right. What is the potential difference $V_c - V_b$?



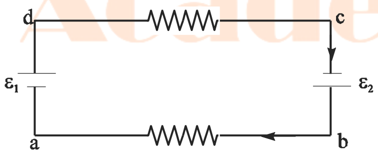
(A) 3 V (B) 2 V (C) –3 V (D) –2V

Ans (C)

$\varepsilon_1 = Blv = 300 \times 0.1 \times 0.2 = 6$ V,

$\varepsilon_2 = 200 \times 0.1 \times 0.2 = 4$V

The equivalent circuit is

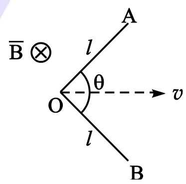


$$i = \frac{\varepsilon_1 + \varepsilon_2}{R} = \frac{6+4}{200} = 0.05\text{A}$$

$$R_{cb} = 10 \times 2 = 20\Omega$$

$V_C + 4 - 0.05 \times 20 = V_b \Rightarrow V_c - V_b = -3$V

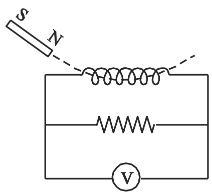
10. An angle ∠AOB made of a conducting wire moves along its bisector through a magnetic field B as suggested by figure. The emf induced between the two free ends if the magnetic field is perpendicular to the plane of the wire is

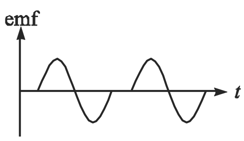


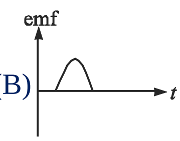
(A) Blv sin θ (B) Blv sin $\frac{\theta}{2}$

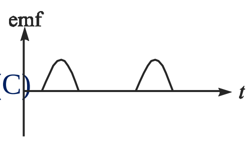
(C) 2Blv sin θ (D) 2Blv sin $\frac{\theta}{2}$

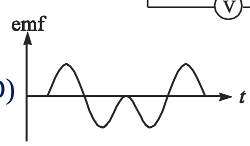
11. A magnet is made to oscillate with a particular frequency, passing through a coil as shown in the figure. The variation of emf induced across the coil during one cycle with time is best represented by the graph



(A) 

(B) 

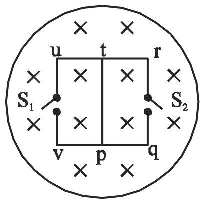
(C) 

(D) 

Ans (A)

When North Pole of the magnet approaches the coil, emf is induced such that left face behaves like North Pole. When South Pole leaves coil, the emf is induced such that right face behaves like North Pole (thus left face like South Pole). At the right side external bar is momentarily at rest and thus there has to be a break after half cycle. Similar arguments hold good when magnet moves from right to left. The correct option is (A).

12. The magnetic field in the cylindrical region, shown in the figure, increases at a constant rate of 20 mTs^{-1}. The two square loops pqrtp and ptuvp have sides each equal to 1 cm and each side has resistance of 4 Ω. If the switch S_1 is closed and S_2 is open, the current in the wire pt is



(A) 0.125 μA from p and t (B) 0.125 μA from t to p

(C) 0.25 μA from p to t (D) 0.25 μA from t to p

Ans (A)

The flux is associated with ptuv loop only (in the given conditions)

$$|\varepsilon| = \frac{d\phi}{dt} = A\frac{dB}{dt} = \left(1\times1\times10^{-4}\right)\left(20\times10^{-3}\right) = 2\times10^{-6}\text{ V}$$

$$i = \frac{\varepsilon}{R} = \frac{2\times10^{-6}}{4\times4} = 0.125\mu A$$

As B, increases, South Pole nature of loop ptuv is increasing. So induced current should be in anticlockwise direction to oppose this, and hence current is from p to t.

13. At what rate should the current change to induce an emf of 60 V?

(A) By changing current at the rate of 10 As^{-1} (B) By changing current at the rate of 7.5 As^{-1}

(C) By changing current at the rate of 5 As^{-1} (D) By changing current at the rate of 2.5 As^{-1}

Ans (C)

$$|\varepsilon| = L\frac{di}{dt} \Rightarrow \frac{di}{dt} = \frac{|\varepsilon|}{L} = \frac{60}{12} = 5\,As^{-1}$$

14. A coil has an inductance of 53 mH and a resistance of 0.35 Ω. If a 12 V emf is applied across the coil, the energy is stored in the magnetic field after the current has built up to its maximum value is

(A) 11 J (B) 21 J (C) 31 J (D) 41 J

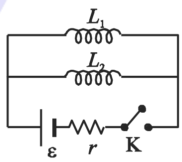
Ans (C)

The maximum current in the coil is $i_0 = \frac{\varepsilon}{R} = \frac{12}{0.35} = 34.3\,A$

So, the maximum energy stored is $U_0 = \frac{1}{2}Li_0^2 = \frac{1}{2}(53\times10^{-3})(34.3)^2$

Or $U_0 \approx 31J$

15. In the circuit shown, the emf ε of the cell, its internal resistance r and the inductances L_1 and L_2 of the superconducting coils are known. The current established in the coil L, after the key K is closed is



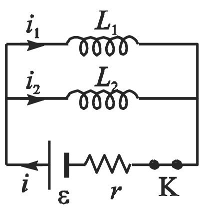
(A) $\frac{\varepsilon L_1}{r(L_1+L_2)}$ (B) $\frac{\varepsilon L_2}{r(L_1+L_2)}$

(C) $\frac{\varepsilon(L_1+L_2)}{L_1 r}$ (D) $\frac{\varepsilon(L_1+L_2)}{L_2 r}$

Ans (B)

If current i is drawn from the battery, then

$$i = \frac{\varepsilon}{r} = i_1 + i_2 \quad \ldots \text{(i)}$$



Inductors L_1 and L_2 are in parallel and so $\varepsilon_1 = \varepsilon_2$

Or $L_1\frac{di_1}{dt} = L_2\frac{di_2}{dt}$

On integrating we get $L_1 i_1 = L_2 i_2$ … (ii)

From (ii) $i_2 = \frac{L_1}{L_2}i_1$. Using this in equation (i) $\frac{\varepsilon}{r} = i_1 + \frac{L_1}{L_2}i_1$

$$i_1\left(\frac{L_1+L_2}{L_2}\right) = \frac{\varepsilon}{r} \Rightarrow i_1 = \frac{\varepsilon L_2}{r(L_1+L_2)}$$

16. An inductor of inductance 3 H and resistance 6 Ω is connected to the terminals of a battery of emf 12 V and of negligible internal resistance. The initial rate of increase of current is

(A) 2 As^{-1} (B) 3 As^{-1} (C) 3.5 As^{-1} (D) 4 As^{-1}

Ans (D)

$$i = i_0\left(1 - e^{-t/\tau}\right) \quad \ldots (i)$$

$$\Rightarrow \frac{di}{dt} = -i_0 e^{-t/\tau}\left(-\frac{1}{\tau}\right)$$

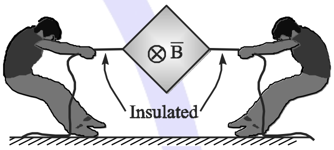
$$= \frac{i_0}{\tau} e^{-t/\tau} \quad \ldots (ii)$$

$$i_0 = \frac{\varepsilon}{R} = \frac{12}{6} = 2\text{ A},\ \tau = \frac{L}{R} = \frac{3}{6} = 0.5\text{ s}$$

$$\therefore \frac{di}{dt} = \frac{2}{0.5} e^{\circ} = 4\text{ As}^{-1}$$

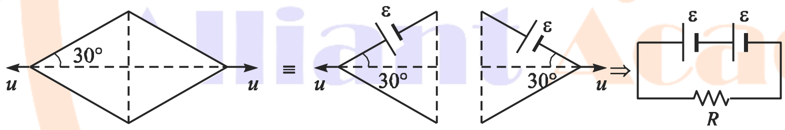
[∵ At the beginning, t = 0]

17. Figure shows a metallic square frame of edge l in a vertical plane. A uniform magnetic field $\bar{B}$ is horizontal and perpendicular to the plane of square. Two boys pull the opposite corners of the square to deform it into a rhombus. They start pulling the corners at t = 0 and displace the corners at a uniform speed u. The induced emf in the frame at the instant when the angles at these corners reduce to 60° is



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

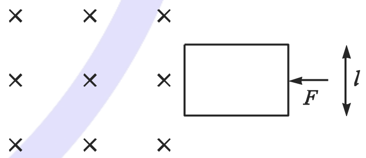
Ans (B)



The loop can be divided into two equal parts. The emf across each part will be

$$\varepsilon = B(l\sin 30^\circ \times 2)u = Blu\ ;\ \varepsilon_{net} = \varepsilon + \varepsilon = 2Blu$$

18. The rectangular wire frame shown in figure has a width l, mass m, resistance R and a large length. A constant force F starts acting on the frame pushing it into magnetic field at time, t = 0. The acceleration of the frame, when its speed has increased to v, is



(A) $\frac{\sqrt{2}(FR - B^2l^2v)}{mR}$ (B) $\frac{(FR - B^2l^2v)}{\sqrt{2}mR}$ (C) $\frac{(FR - B^2l^2v)}{2mR}$ (D) $\frac{(FR - B^2l^2v)}{mR}$

Ans (D)

When the left side of the frame is inside the field and when the speed of frame is v, the emf induced is $\varepsilon = Blv$ and induced current is $i = \frac{\varepsilon}{R} = \frac{Blv}{R}$. The force F ′(towards right) exerted by magnetic field is given by

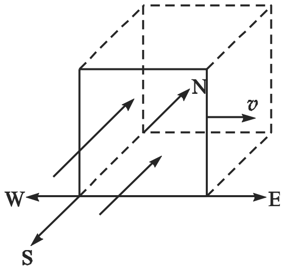
$$F' = Bil = B\cdot\frac{Blv}{R}\cdot l = \frac{B^2l^2v}{R}$$

$$F_{net} = F - F' = ma \Rightarrow a = \frac{F - \frac{B^2l^2v}{R}}{m} = \frac{FR - B^2l^2v}{mR}$$

19. The earth's magnetic field (B_E) at the equator is horizontal, uniform and points north – south. A conducting square loop of side l and resistance R is kept in the vertical plane with two of its sides pointing east-west direction. This loop is moved in east direction with a velocity v. The current induced in the loop is

(A) zero (B) $\frac{B_E lv}{R}$ (C) $\frac{2B_E lv}{R}$ (D) $\frac{4B_E lv}{R}$

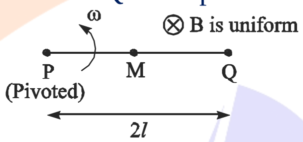
Ans (A)



Magnetic flux linked with the coil is not changing. So $\Delta\phi = 0$.

So, net emf induced is zero. Thus, the current is zero.

20. *The emf induced between M and Q if the potential between P and Q is 100 V. M is mid point of P and Q.



(A) 25 V (B) 50 V (B) 75 V (C) 100 V

Ans (C)

For a rotating conductor of an arbitrary shape in uniform magnetic field $\vec{B}$, induced emf is $\varepsilon_{ba} = \frac{1}{2}B\omega L^2$

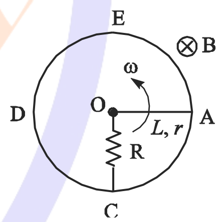
$$\varepsilon_{PQ} = \frac{1}{2}B\omega(2l)^2 = 2B\omega l^2 = 100\text{ V}$$

$$\varepsilon_{PM} = \frac{1}{2}B\omega l^2 = \frac{1}{4}\varepsilon_{PQ} = 25\text{V}$$

$$(\varepsilon_P - \varepsilon_Q) - (\varepsilon_P - \varepsilon_M) = 100 - 25$$

$$\therefore \varepsilon_{MQ} = 75\text{V}$$

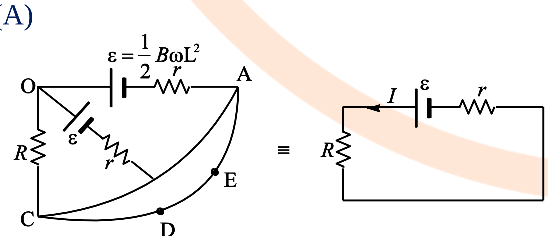
21. A rod of length L and resistance r rotates about one end as shown in figure. Its other end touches a conducting ring of negligible resistance. A resistance R is connected between the center and periphery. The current in resistance R is



(A) $\frac{B\omega l^2}{R+r}$ (B) $\frac{B\omega l^2}{2(R+r)}$

(C) $\frac{B\omega l^2}{\sqrt{2}(R+r)}$ (D) $\frac{B\omega l^2}{R+r}$

Ans (A)



$$i = \frac{\varepsilon}{R+r} = \frac{B\omega l^2}{2(R+r)}$$

NCERT LINE BY LINE QUESTIONS

1. Direction of current induced in a wire by moving it in a uniform magnetic field is found using [NCERT Pg. 215]

(a) Newton's laws (b) Lenz's law

(c) Ampere's rule (d) Right hand grip rule

2. A metallic plate is getting heated. It cannot be due to [NCERT Pg, 218]

(a) A direct current passing through plate

(b) An alternating current passing through it

(c) It is placed Static in Space varying magnetic field but does not vary with time

(d) It is placed in time varying magnetic field

3. A rectangular coil expands on pulling from two diagonal edges in a region of magnetic field and no emf is induced in the coil. This can be because of [NCERT Pg. 230]

(a) Magnetic field is constant

(b) Magnetic field is in the plane of rectangular coil

(c) Magnetic field has a perpendicular component to the plane of coil whose magnitude is decreasing

(d) There is a uniform magnetic field perpendicular to plane of coil

4. The self-inductance L of a solenoid of length l and area of cross section A, with fixed number of turns per unit length increases as [NCERT Pg. 223]

(a) l and A increases

(b) l decreases and A increases

(c) Both l and A decreases

(d) l increases and A decreases

5. The mutual inductance of pair of co-axial neighbouring coils [NCERT Pg. 220]

(a) Increases when they are brought nearer

(b) Increases when one of them is rotated about an axis

(c) Is independent of current passing through coils

(d) Both (a) and (c) are correct

6. A square loop of side length L meter lies in x-y plane in a region, where the magnetic field is given by $\vec{B} = B_0(\hat{i} + 2\hat{j} + 3k)\,T$, Bo is positive constant. The magnitude of magnetic flux passing through square is [NCERT Pg. 207]

(a) $5B_0L^2 Wb$ (b) $3B_0L^2 Wb$ (c) $\sqrt{14}B_0L^2 Wb$ (d) $B_0L^2 Wb$

7. A 20 cm long conductor carrying a current of 10 A is kept perpendicular to magnetic field of 0.6T. The mechanical power required to move conductor with a speed of 1 ms^{-1} is [NCERT Pg. 215]

(a) 1.2 W (b) 1.5 W (c) 0.6 W (d) 0.4 W

8. A square loop of edge 20 cm and resistance of $1\,\Omega$ is placed vertically in horizontal plane. A uniform magnetic field of 0.5T is set up across the plane in the direction at 45° to the plane. The magnetic field is decreased to zero in 0.2 s, at a steady rate. Calculate magnitude of current induced in this time interval. [NCERT Pg. 208]

(a) 20 mA (b) 50 mA (c) 60 mA (d) 70 mA

9. A circular loop with its plane parallel to plane of paper is entering into uniform magnetic field directed into the plane of paper perpendicularly. The loop is moved at constant speed V. Then [NCERT Pg. 212]

(a) No. emf will be induced in the coil
(b) Induced emf is constant in magnitude only
(c) Induced emf is varying with time
(d) Induced emf is constant in magnitude as well as in direction

10. A metallic rod of length 20 cm is rotated with, frequency of 50 rev/s with one end pivoted at the centre and other end at circumference of circular metallic ring of radius 20 cm about an axis passing through centre and perpendicular to plane of the ring. A constant and uniform magnetic field 1.5 T parallel to axis is present everywhere. What is emf induced between centre and periphery of circular ring. [NCERT Pg. 214]
(a) 2.6 V (b) 9.4 V (c) 4.7 V (d) 12.3 V

11. A cycle wheel with 20 metallic spokes each 1 m long is rotated with speed of 60 rad/s in a plane normal to horizontal component of earth's magnetic field B_H = 0-5 G at a place. The emf induced between axle and rim of wheel is [NCERT Pg. 215]
(a) 1.5 mV (b) 12.3 mV (c) 3.0 mV (d) 0.75 mV

12. A conducting arm ***AB*** of length 30 cm moves on conducting rails held parallel. A uniform magnetic field 6 = 0.2 T exists perpendicular to planes of rails. Only the conducting arm has resistance of 0.5Ω . The arm is pulled out with constant speed of 20 ms^{-1}, how much force is required parallel to rails to keep it moving at same speed. [NCERT Pg. 216]
(a) 0.14 N (b) 8 N (c) 16 N (d) 0.25 N

13. Which statement regarding eddy currents among the following is incorrect? [NCERT Pg. 218]
(a) If rectangular slots are made in copper plate, the magnitude of eddy currents will decrease
(b) Dissipation of heat produced is proportional to strength of eddy currents
(c) Dead beat galvanometer has fixed core made of non-magnetic metallic material
(d) Magnetic brakes in train use the application of eddy current

14. Two circular coils one of small radius r and other of larger radius R $(r << R)$ are placed co-axially with centres coinciding. The mutual inductance of the arrangement is [NCERT Pg. 221]
(a) $\frac{\mu_0 \pi R^2}{2r}$ (b) $\frac{\mu_0 \pi r^2}{2R}$ (c) $\frac{\mu_0 \pi r R}{(r+R)}$ (d) $\frac{2\mu_0 \pi r^2}{R}$

15. A long solenoid is of length 1.25 m and 600 turns per unit length. It is connected to a source which establishes a current of 2A in circuit. Magnetic energy stored in the solenoid coil with cross-sectional area 0.1 $m^2$is [NCERT Pg. 224]
(a) 0.1 J (b) 0.4 J (c) 0-6 J (d) 1.2 J

16. A rectangular coil of 100 turns with area 0.1 m^2 is rotated at 10 revolution per second and paced in a uniform magnetic field of 0.01 T perpendicular to axis of rotation of the coil. The maximum voltage generated in coil is [NCERT Pg. 226]
(a) 3.14 V (b) 6.28 V (c) 9.42 V (d) 31.4 V

17. Two thin cylindrical pipes of equal internal diameters made of aluminum and plastic are taken. The pipes are kept vertical. A small cylindrical magnet without touching sides of

wall of pipe is allowed to fall one by one. Then correct observations are [NCERT Pg. 219]

(a) Magnet takes longer time to cross aluminum pipe

(b) Magnet takes longer time to cross plastic pipe

(c) Eddy currents are generated in aluminum pipe but not in plastic

(d) Both (a) and (c) are correct

18. Which of the following statement is wrong? [NCERT Pg. 225]

(a) In ac generator when flux through coil is maximum, emf induced is minimum

(b) Maximum emf is induced when plane of col is parallel to magnetic field

(c) The emf induced changes periodically with time if coil is rotated at uniform rate

(d) The frequency of rotation of armature coil is 60 Hz in India and 50 Hz in USA

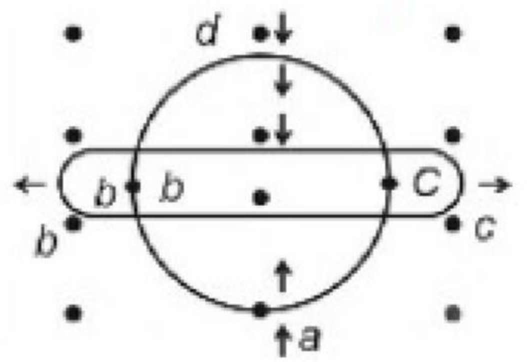
19. A pair of adjacent coils has mutual inductance of 1.5 H. If the Current in one coil changes from 0 to 10 A in 0.5 s. the rate of change of flux linkage with other coil is

[NCERT Pg. 219]

(a) 20 V (b) 30 V (c) 4 V (d) 5 V

20. A circular coil is being deformed into a narrow straight wire at regular stretch. Then

[NCERT Pg. 230)



(a) The direction of induced current is clockwise

(b) The direction of induced current is anticlockwise

(c) Magnetic flux through coil increases

(d) The amount of charge flowing in coil depends on time

NCERT BASED PRACTICE QUESTIONS

1. Whenever the magnetic flux linked with an electric circuit changes, an emf is induced in the circuit. This is called

(a) electromagnetic induction (b) lenz's law

(c) hysteresis loss (d) kirchhoff's laws`111

2. According to Faraday's law of electromagnetic induction

(a) electric field is produced by time varying magnetic flux.

(b) magnetic field is produced by time varying electric flux.

(c) magnetic field is associated with a moving charge.

(d) None of these

3. Lenz's law is a consequence of the law of conservation of

(a) charge (b) mass (c) energy (d) momentum

4. A magnet is moved towards a coil (i) quickly (ii) slowly, then the induced e.m.f. is

(a) larger in case (i) (b) smaller in case (i)

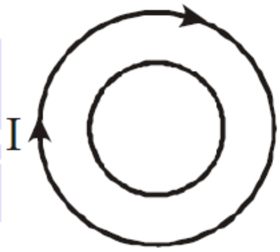
(c) equal in both the cases (d) larger or smaller depending upon the radius of the coil

5. A current carrying infinitely long wire is kept along the diameter of a circular wire loop, without touching it, the correct statement(s) is(are)
I. The emf induced in the loop is zero if the current is constant.
II. The emf induced in the loop is finite if the current is constant.
III. The emf induced in the loop is zero if the current decreases at a steady rate.
(a) I only (b) II only
(c) I and II (d) I, II and III

6. An induced e.m.f. is produced when a magnet is plunged into a coil. The strength of the induced e.m.f. is independent of
(a) the strength of the magnet
(b) number of turns of coil
(c) the resistivity of the wire of the coil
(d) speed with which the magnet is moved

7. A coil of insulated wire is connected to a battery. If it is taken to galvanometer, its pointer is deflected, because
(a) the induced current is produced
(b) the coil acts like a magnet
(c) the number of turns in the coil of the galvanometer are changed
(d) None of these

8. Two different wire loops are concentric and lie in the same plane. The current in the outer loop (I) is clockwise and increases with time. The induced current in the inner loop



(a) is clockwise (b) is zero (c) is counter clockwise
(d) has a direction that depends on the ratio of the loop radii.

9. Two identical coaxial circular loops carry a current i each circulating in the same direction. If the loops approach each other, you will observe that the current in
(a) each increases (b) each decreases
(c) each remains the same (d) one increases whereas that in the other decreases

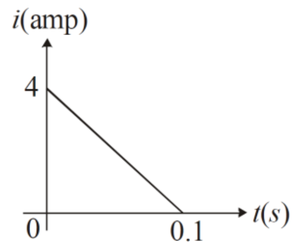
10. In electromagnetic induction, the induced charge is independent of
(a) change of flux (b) time
(c) resistance of the coil (d) None of these

11. A conducting loop is placed in a uniform magnetic field with its plane perpendicular to the field. An e.m.f. is induced in the loop, if
(a) it is translated (b) it is rotated about its axis
(c) both (a) and (b) (d) it is rotated about its diameter

12. Two coils, A and B, are lined such that emf e is induced in B when the current in A is changing at the rate I. If current i is now made to flow in B, the flux linked with A will be
(a) $(\varepsilon/I)i$ (b) $\varepsilon\, i\, I$ (c) $(\varepsilon\, I)i$ (d) $i\, I/\varepsilon$

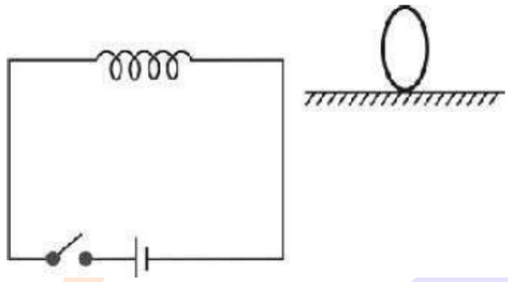
13. Whenever the magnetic flux linked with a coil changes, an induced e.m.f.is produced in the circuit. The e.m.f. lasts
I. for a short time
II. for a long time
III. so long as the change in flux takes place
The correct statement(s) is/are
(a) I and II (b) II and III (c) I and III (d) III only

14. In a coil of resistance 10 W, 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



(a) 8 (b) 2 (c) 6 (d) 4

15. **Assertion :** Figure shows a horizontal solenoid connected to battery and a switch. A copper ring is placed on a smooth surface, the axis of the ring being horizontal. As the switch is closed, the ring will move away from the solenoid.



Reason : Induced emf in the ring, $e = d\phi/dt$.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(c) Assertion is correct, reason is incorrect
(d) Assertion is incorrect, reason is correct.

16. The north pole of a bar magnet is moved towards a coil along the axis passing through the centre of the coil and perpendicular to the plane of the coil. The direction of the induced current in the coil when viewed in the direction of the motion of the magnet is

(a) clockwise (b) anti-clockwise
(c) no current in the coil (d) either clockwise or anti-clockwise

17. If a current increases from zero to one ampere in 0.1 second in a coil of 5 mH, then the magnitude of the induced e.m.f. will be

(a) 0.005 volt (b) 0.5 volt (c) 0.05 volt (d) 5 volt

18. A coil has 200 turns and area of 70 cm^2. The magnetic field perpendicular to the plane of the coil is 0.3 Wb/m^2 and take 0.1 sec to rotate through 180º.The value of the induced e.m.f. will be

(a) 8.4 V (b) 84 V (c) 42 V (d) 4.2 V

19. **Assertion :** An emf can be induced by moving a conductor in a magnetic field.
Reason : An emf can be induced by changing the magnetic field.

(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(c) Assertion is correct, reason is incorrect
(d) Assertion is incorrect, reason is correct.

20. The north pole of a long horizontal bar magnet is being brought closer to a vertical conducting plane along the perpendicular direction. The direction of the induced current in the conducting plane will be

(a) horizontal (b) vertical (c) clockwise (d) anticlockwise

21. A metal disc of radius 100 cm is rotated at a constant angular speed of 60 rad/s in a plane at right angles to an external field of magnetic induction 0.05 Wb/m^2. The emf induced between the centre and a point on the rim will be

(a) 3 V (b) 1.5 V (c) 6 V (d) 9 V

22. A rectangular coil of 100 turns and size 0.1 m × 0.05 m is placed perpendicular to a magnetic field of 0.1 T. The induced e.m.f. when the field drops to 0.05 T in 0.05s is

(a) 0.5 V (b) 1.0 V (c) 1.5 V (d) 2.0 V

23. A solenoid has 2000 turns wound over a length of 0.3 m. Its cross-sectional area is 1.2×10^{-3} m^2. Around

its central section a coil of 300 turns is wound. If an initial current of 2 A flowing in the solenoid is reversed in 0.25 s, the emf induced in the coil will be
(a) 2.4×10^{-4} V (b) 2.4×10^{-2} V (c) 4.8×10^{-4} V (d) 4.8×10^{-2} V

24. A straight conductor of length 2m moves at a speed of 20 m/s. When the conductor makes an angle of 30° with the direction of magnetic field of induction of 0.1 wbm^2 then induced emf
(a) 4V (b) 3V (c) 1V (d) 2V

25. A square coil of side 25cm having 1000 turns is rotated with a uniform speed in a magnetic field about an axis perpendicular to the direction of the field. At an instant t, the emf induced in the coil is e = 200 sin 100πt. The magnetic induction is
(a) 0.50 T (b) 0.02 T (c) 0.01 T (d) 0.1 T

26. When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The self – inductance of the coil is :
(a) 6 H (b) 0.67 H (c) 3 H (d) 1.67 H

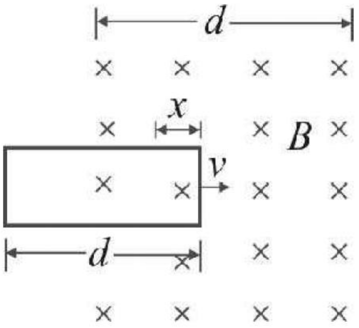
27. When current i passes through an inductor of self inductance L, energy stored in it is 1/2. L i^2. This is stored in the
(a) current (b) voltage (c) magnetic field (d) electric field

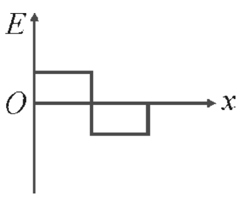
28. Two conducting circular loops of radii R_1 and R_2 are placed in the same plane with their centres coinciding. If $R_1 >> R_2$, the mutual inductance M between them will be directly proportional to
(a) R_1/R_2 (b) R_2/R_1 (c) R_1^2 / R_2 (d) R_2^2 / R_1

29. A coil is wound on a frame of rectangular cross-section. If all the linear dimensions of the frame are increased by a factor 2 and the number of turns per unit length of the coil remains the same, self-inductance of the coil increases by a factor of
(a) 4 (b) 8 (c) 12 (d) 16

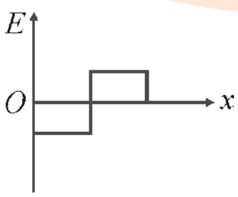
30. A wire of length 1 m is moving at a speed of 2ms^{-1} perpendicular to its length in a homogeneous magnetic field of 0.5 T. The ends of the wire are joined to a circuit of resistance 6W. The rate at which work is being done to keep the wire moving at constant speed is
(a)1/12W (b)1/6W (c)1/3W (d) 1W

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

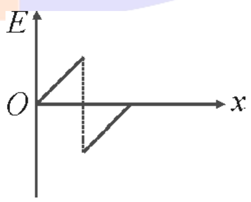




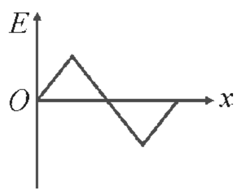
(a)



(b)



(c)



(d)

32. A six pole generator with fixed field excitation develops an e.m.f. of 100 V when operating at 1500 r.p.m. At what speed must it rotate to develop 120V?
(a) 1200 r.p.m (b) 1800 r.p.m (c) 1500 r.p.m (d) 400 r.p.m

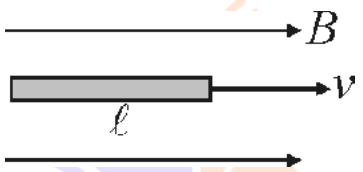
33. The self inductance associated with a coil is independent of
(a) current (b) time (c) induced voltage (d) resistance of coil

34. The plane in which eddy currents are produced in a conductor is inclined to the plane of the magnetic field at an angle equal to
(a) 45° (b) 0° (c) 180° (d) 90°

35. Eddy currents are produced when
(a) A metal is kept in varying magnetic field
(b) A metal is kept in the steady magnetic field
(c) A circular coil is placed in a magnetic field
(d) Through a circular coil, current is passed

36. When strength of eddy currents is reduced, as dissipation of electrical energy into heat depends on the ...A... of the strength of electrical energy into heat depends on the...*A*... of the strength of electric current heat loss is substantially ...*B* ... . Here, *A* and *B* refer to
(a) cube, increase
(b) inverse, increased
(c) inverse, decreased
(d) square, reduced

37. **Assertion :** Figure shows a metallic conductor moving in magnetic field. The induced emf across its ends is zero.



Reason : The induced emf across the ends of a conductor is given by $e = Bvl\sin\theta$.
(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(c) Assertion is correct, reason is incorrect
(d) Assertion is incorrect, reason is correct.

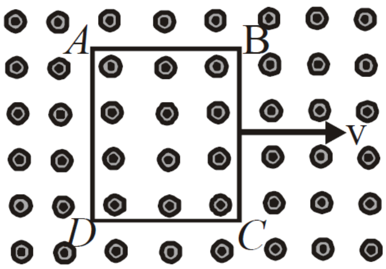
38. When the current in a coil changes from 2 amp. to 4 amp. in 0.05 sec., an e.m.f. of 8 volt is induced in the coil. The coefficient of self inductance of the coil is
(a) 0.1 henry (b) 0.2 henry (c) 0.4 henry (d) 0.8 henry

39. Two coils of self inductances 2 mH and 8 mH 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
(a) 6 mH (b) 4 mH (c) 16 mH (d) 10 mH

40. The coefficient of self inductance of a solenoid is 0.18mH. If a core of soft iron of relative permeability 900 is inserted, then the coefficient of self inductance will become nearly.
(a) 5.4 mH (b) 162 mH (c) 0.006 mH (d) 0.0002 mH

41. **Assertion :** When number of turns in a coil is doubled, coefficient of self-inductance of the coil becomes 4 times.
Reason : This is because L α N2.
(a) Assertion is correct, reason is correct; reason is a correct explanation for assertion.
(b) Assertion is correct, reason is correct; reason is not a correct explanation for assertion
(c) Assertion is correct, reason is incorrect
(d) Assertion is incorrect, reason is correct.

42. A metallic square loop *ABCD* is moving in its own plane with velocity *v* in a unifrom magnetic field perpendicular to its plane as shown in figure. An electric field is induced



(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*

43. A circular coil and a bar magnet placed nearby are made to move in the same direction. If the coil covers a distance of 1 m in 0.5. sec and the magnet a distance of 2 m in 1 sec, the induced e.m.f. produced in the coil is

(a) zero (b) 0.5 V (c) 1 V (d) 2 V.

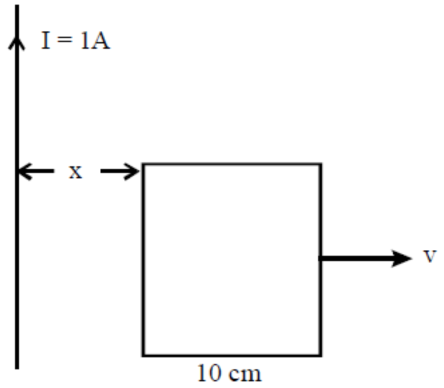
44. Two solenoids of same cross-sectional area have their lengths and number of turns in ratio of 1 : 2 both. The ratio of self-inductance of two solenoids is

(a) 1 : 1 (b) 1 : 2 (c) 2 : 1 (d) 1 : 4

45. A coil is wound on a frame of rectangular cross-section. If all the linear dimensions of the frame are increased by a factor 2 and the number of turns per unit length of the coil remains the same, self-inductance of the coil increases by a factor of

(a) 4 (b) 8 (c) 12 (d) 16

46. A square frame of side 10 cm and a long straight wire carrying current 1 A are in the plate of the paper. Starting from close to the wire, the frame moves towards the right with a constant speed of 10 ms–1 (see figure). The e.m.f induced at the time the left arm of the frame is at x = 10 cm from the wire is



(a) 2 μV (b) 1 μV (c) 0.75μV (d) 0.5 μV

47. A generator has an e.m.f. of 440 Volt and internal resistance of 4000 hm. Its terminals are connected to a load of 4000 ohm. The voltage across the load is

(a) 220 volt (b) 440 volt (c) 200 volt (d) 400 volt

48. A generator of 220 V having internal resistance r = 10W and external resistance R = 100W. What is the power developed in the external circuit?

(a) 484 W (b) 400 W (c) 441 W (d) 369 W

49. In the given figure *MNPQ* which falls through the magnetic field has conductivity s and mass density ρ. The frame's terminal velocity assuming it to be small enough so that it reaches its final velocity before leaving the region occupied by the magnetic field is

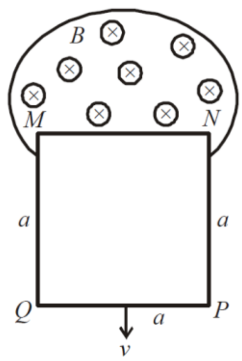
Ans-b

(a) $\frac{12c^2\rho g}{eB^2\sigma}$

(b) $\frac{16c^2\rho g}{eB^2\sigma}$

(c) $\frac{16c^2\rho^2 g}{eB\sigma}$

(d) $\frac{16c\rho g}{e^2B\sigma}$



50. A conducting ring of radius l *m* kept in a uniform magnetic field *B* of 0.01 *T*, rotates uniformly with an angular velocity 100 rad s^{-1} with its axis of rotation perpendicular to *B*. The maximum induced emf in it is

(a) 1.5πV (b) πV (c) 2πV (d) 0.5πV

TOPIC WISE PRACTICE QUESTIONS

Topic 1: Magnetic Flux, Faraday's and Lenz's Law

1. An induced e.m.f. is produced when a magnet is plunged into a coil. The strength of the induced e.m.f. is independent of

(a) the strength of the magnet

(b) number of turns of coil

(c) the resistivity of the wire of the coil

(d) speed with which the magnet is moved

2. A cylindrical bar magnet is kept along the axis of a circular coil. On rotating the magnet about its axis, the coil will have induced in it

(a) a current

(b) no current

(c) only an e.m.f.

(d) both an e.m.f. and a current

3. Two identical coaxial coils P and Q carrying equal amount of current in the same direction are brought nearer. The current in

(a) P increases while in Q decreases

(b) Q increases while in P decreases

(c) both P and Q increases

(d) both P and Q decreases

4. A rectangular coil of 20 turns and area of cross-section 25 sq. cm has a resistance of 100 Ω. If a magnetic field which is perpendicular to the plane of coil changes at a rate of 1000 tesla per second, the current in the coil is

(a) 1 A (b) 50 A (c) 0.5 A (d) 5 A

5. If a current increases from zero to one ampere in 0.1 second in a coil of 5 mH, then the magnitude of the induced e.m.f. will be

(a) 0.005 volt (b) 0.5 volt (c) 0.05 volt (d) 5 volt

6. A coil of insulated wire is connected to a battery. If it is taken to galvanometer, its pointer is deflected, because

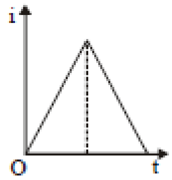
(a) the induced current is produced

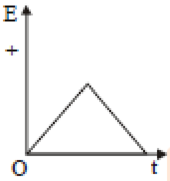
(b) the coil acts like a magnet

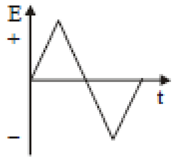
(c) the number of turns in the coil of the galvanometer are changed

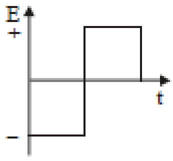
(d) None of these

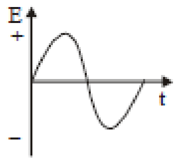
7. The current i in an inductance coil varies with time t according to the graph shown in fig. Which one of the following plots shows the variation of voltage in the coil with time?



(a) 

(b) 

(c) 

(d) 

8. The magnetic flux (in weber) linked with a coil of resistance $10\,\Omega$ is varying with respect to time t as $\phi = 4t^2 + 2t + 1$. Then the current in the coil at time t = 1 second is

(a) 0.5 A (b) 2 A (c) 1.5 A (d) 1 A

9. 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 :

(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.

10. A 100 turns coil of area of cross section 200 cm^2 having $2\,\Omega$ resistance is held perpendicular to a magnetic field of 0.1 T. If it is removed from the magnetic field in one second, the induced charge produced in it is

(a) 0.2 C (b) 2 C (c) 0.1 C (d) 1 C

11. Two identical circular loops of metal wire are lying on a table without touching each other. Loop–A carries a current which increases with time. In response, the loop–B

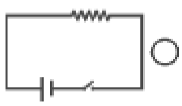
(a) remains stationary

(b) is attracted by the loop-A

(c) is repelled by the loop-A

(d) rotates about its CM, with CM fixed (CM is the centre of mass)

12. Consider the situation shown in figure. If the switch is closed and after some time it is opened again, the closed loop will show



(a) a clockwise current

(b) an anticlockwise current

(c) an anticlockwise current and then clockwise

(d) a clockwise current and then an anti-clock wise current.

13. A magnetic field of 2×10^{-2} T acts at right angles to a coil of area 100 cm^2, with 50 turns. The average e.m.f. induced in the coil is 0.1 V, when it is removed from the field in t sec. The value of t is

(a) 10 s (b) 0.1 s (c) 0.01 s (d) 1 s

14. A rectangular coil of 100 turns and size 0.1 m × 0.05 m is placed perpendicular to a magnetic field of 0.1 T. The induced e.m.f. when the field drops to 0.05 T in 0.05s is

(a) 0.5 V (b) 1.0 V (c) 1.5 V (d) 2.0 V

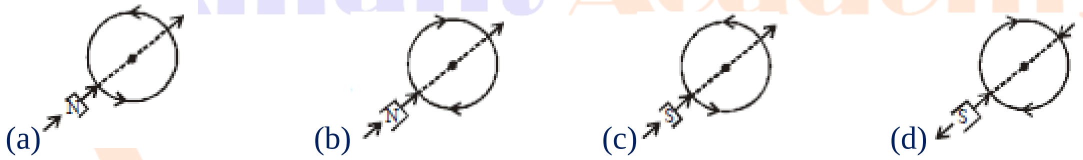
15. The inductance of a closed-packed coil of 400 turns is 8 mH. A current of 5 mA is passed through it. The magnetic flux through each turn of the coil is

(a) $\frac{1}{4\pi}\mu_0 wb$ (b) $\frac{1}{2\pi}\mu_0 wb$ (c) $\frac{1}{3\pi}\mu_0 wb$ (d) $0.4\mu_0 wb$

16. The magnetic flux through a circuit of resistance R changes by an amount $\Delta\phi$ in a time Δt. Then the total quantity of electric charge Q that passes any point in the circuit during the time Δt is represented by

(a) $Q = R.\frac{\Delta\phi}{\Delta t}$ (b) $Q = \frac{1}{R}.\frac{\Delta\phi}{\Delta t}$ (c) $Q = \frac{\Delta\phi}{R}$ (d) $Q = \frac{\Delta\phi}{\Delta t}$

17. Which of the following figure correctly depicts the Lenz's law. The arrows show the movement of the labelled pole of a bar magnet into a closed circular loop and the arrows on the circle show the direction of the induced current



18. A coil having an area A_0 is placed in a magnetic field which changes from B_0 to $4B_0$ in time interval t. The e.m.f. induced in the coil will be

(a) $3A_0B_0 / t$ (b) $4A_0B_0 / t$ (c) $3B_0 / A_0t$ (d) $4A_0 / B_0t$

19. A horizontal telegraph wire 0.5 km long running east and west in a part of a circuit whose resistance is 2.5 Ω. The wire falls to g = 10.0 m/s^2 and B = 2×10^{-5} weber/ m^2, then the current induced in the circuit is

(a) 0.7 amp (b) 0.04 amp (c) 0.02 amp (d) 0.01 amp

20. 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

(a) $-\frac{(W_1 - W_2)}{Rnt}$ (b) $-\frac{n(W_2 - W_1)}{5Rt}$ (c) $-\frac{(W_2 - W_1)}{5Rnt}$ (d) $-\frac{n(W_2 - W_1)}{Rt}$

Topic 2: Motional and Static EMI

21. Whenever, current is changed in a coil, an induced e.m.f. is produced in the same coil. This property of the coil is due to

(a) mutual induction (b) self-induction (c) eddy currents (d) hysteresis

22. The self-inductance of a long solenoid cannot be increased by

(a) increasing its area of cross section

(b) increasing its length

(c) changing the medium with greater permeability

(d) increasing the current through it

23. 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 0.2×10^{-4}T, then the e.m.f. developed between the two ends of the conductor is

(a) 5 mV (b) 50 mV (c) 5 mV (d) 50 mV

24. A straight conductor of length 2m moves at a speed of 20 m/s. When the conductor makes an angle of 30° with the direction of magnetic field of induction of 0.1 wbm^2 then induced emf

(a) 4V (b) 3V (c) 1V (d) 2V

25. Two coils have a matual inductance 0.005 H. The current changes in the first coil according to equation I = $I_0 \sin\omega t$, where I_0 = 10A and ω = 100 π radian/sec. The maximum value of e.m.f. in the second coil is

(a) 2 π (b) 5 π (c) π (d) 4 π

26. A varying current in a coil changes from 10A to zero in 0.5 sec. If the average e.m.f induced in the coil is 220V, the self-inductance of the coil is

(a) 5 H (b) 6 H (c) 11 H (d) 12 H

27. When the current in a coil changes from 8 amp to 2 amp in 3×10^{-2} seconds, the emf induced in the coil is 2 volt. The self-inductance of the coil is

(a) 10 mH (b) 20 mH (c) 5 mH (d) 1 mH

28. A coil of N = 100 tuns carries a current I = 5A and creates a magnetic flux $\phi = 10^{-5}$ Tm^2 per turn. The value of its inductance L will be

(a) 0.05 mH (b) 0.10 mH (c) 0.15 mH (d) 0.20 mH

29. In an induction coil the current increases from 0 to 6 amp in 0.3 sec by which induced emf of 30 volt is produced in it then the value of coefficient of self-inductance of coil will be

(a) 3 henry (b) 2 henry (c) 1 henry (d) 1.5 henry

30. 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.

(a) 25.5 V (b) 12.5 V (c) 22.5 V (d) 37.5 V

31. The coefficient of self-inductance of a solenoid is 0.18 mH. If a core of soft iron of relative permeability 900 is inserted, then the coefficient of self-inductance will become nearly.

(a) 5.4 mH (b) 162 mH (c) 0.006 mH (d) 0.0002 mH

32. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon

(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

33. A current of 2.5 A flows through a coil of inductance 5 H. The magnetic flux linked with the coil is

(a) 2 Wb (b) 0.5 Wb (c) 12.5 Wb (d) Zero

34. Two neighbouring coils A and B have a mutual inductance of 20mH. The current flowing through A is given by $i = 3t^2 - 4t + 6$. The induced emf at t = 2s is

(a) 160 mV (b) 200 mV (c) 260 mV (d) 300 mV

35. When the current in a coil changes from 2 amp. to 4 amp. in 0.05 sec., an e.m.f. of 8 volt is induced in the coil. The coefficient of self-inductance of the coil is

(a) 0.1 henry (b) 0.2 henry (c) 0.4 henry (d) 0.8 henry

36. A coil is wound on a frame of rectangular cross-section. If all the linear dimensions of the frame are increased by a factor *x* and the number of turns per unit length of the coil remains the same, self-inductance of the coil increases by a factor of

(a) x^2 (b) x^3 (c) x^4 (d) x^5

37. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area A = 10 cm^2 and length = 20 cm. If one of the solenoid has 300 turns and the other 400 turns, their mutual inductance is ($\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1})

(a) $2.4\pi \times 10^{-5}$H (b) $4.8\pi \times 10^{-4}$H (c) $4.8\pi \times 10^{-5}$ H (d) $2.4\pi \times 10^{-4}$ H

38. A copper rod of length *l* is rotated about one end perpendicular to the magnetic field B with constant angular velocity ω. The induced e.m.f. between the two ends is

(a) $\frac{1}{2}B\omega l^2$ (b) $\frac{3}{4}B\omega l^2$ (c) $B\omega l^2$ (d) $2B\omega l^2$

39. A conductor of length 0.4 m is moving with a speed of 7 m/s perpendicular to a magnetic field of intensity 0.9 Wb/m^2. The induced e.m.f. across the conductor is

(a) 1.26 V (b) 2.52 V (c) 5.04 V (d) 25.2 V

40. A wire of length 1 m is moving at a speed of 2ms^{-1}perpendicular to its length in 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) $\frac{1}{12}W$ (b) $\frac{1}{6}W$ (c) $\frac{1}{3}W$ (d) $1W$

41. Two identical induction coils each of inductance L are jointed in series are placed very close to each other such that the winding direction of one is exactly opposite to that of the other, what is the net inductance?

(a) L^2 (b) 2 L (c) L /2 (d) zero

42. A wire of length 1m is perpendicular to x-y plane. It is moved with velocity $\vec{v} = \left(3\hat{i} + 3\hat{j} + 2\hat{k}\right)$m/ s through a region of uniform induction $\vec{B} = \left(\hat{i} + 2\hat{j}\right)$T. The potential difference between the ends of the wire is

(a) 1V (b) 1.5V (c) 2.5V (d) 3V

43. A rectangular coil of single turn, having area A, rotates in a uniform magnetic field B with an angular velocity ω about an axis perpendicular to the field. If initially the plane of the coil is perpendicular to the field, then the average induced emf when it has rotated through 90° is

(a) $\frac{\omega BA}{\pi}$ (b) $\frac{\omega BA}{2\pi}$ (c) $\frac{\omega BA}{4\pi}$ (d) $\frac{2\omega BA}{\pi}$

44. The two rails of a railway track, insulated from each other and the ground, are connected to millivoltmeter. What is the reading of the millivoltmeter when a train passes at a speed of 180 km/hr along the track, given that the vertical component of earth's magnetic field is 0.2×10^{-4} wb/m^2 and rails are separated by 1 metre

(a) 10^{-2} volt (b) 10 mV (c) 1 volt (d) 1 mV

45. If we drop a piece of metal and a piece of non-metl from the same height near the surface of the earth, which will reach the ground first?

(a) metal

(b) non-metal

(c) both will reach simultaneously

(d) None of these

46. The mutual inductance of a pair of coils, each of N turns, is M henry. If a current of I ampere in one of the coils is brought to zero in t second, the emf induced per turn in the other coil, in volt, will be

(a) $\frac{MI}{t}$ (b) $\frac{NMI}{t}$ (c) $\frac{MN}{It}$ (d) $\frac{MI}{Nt}$

47. A coil has 200 turns and area of 70 cm^2. The magnetic field perpendicular to the plane of the coil is 0.3 Wb/m^2 and take 0.1 sec to rotate through 180°.The value of the induced e.m.f. will be

(a) 8.4 V (b) 84 V (c) 42 V (d) 4.2 V

48. A car moves on a plane road. The induced emf in the axle connecting the two wheels is maximum when it moves

(a) eastward at equator

(b) westward at equator

(c) eastward at latitude of 45°

(d) at poles

49. A small square loop of wire of side ℓ is placed inside a large square loop of side L (L >> ℓ). The loop are coplanar and their centres coincide. The mutual inductance of the system is proportional is

(a) $\frac{\ell}{L}$ (b) $\frac{\ell^2}{L}$ (c) $\frac{L}{\ell}$ (d) $\frac{L^2}{\ell}$

50. Two coils of inductances L_1 and L_2 are linked such that their mutual inductance is M. Then

(a) $M = L_1 + L_2$

(b) $M = \frac{1}{2}(L_1 + L_2)$

(c) the maximum value of M is $(L_1 + L_2)$

(d) the minimum value of M is $\sqrt{L_1 L_2}$

51. Two coils, one primary of 500 turns and one secondary of 25 turns, are wound on an iron ring of mean diameter 20 cm and cross-sectional area 12 cm^2. If the permeability of iron is 800, the mutual inductance is :

(a) 0.48 H (b) 2.4 H (c) 0.12 H (d) 0.24 H

52. Two conducting circular loops of radii R_1 and R_2 are placed in the same plane with their centres coinciding. If $R_1 >> R_2$, the mutual inductance M between them will be directly proportional to

(a) R_1/R_2 (b) R_2/R_1 (c) R_1^2/R_2 (d) R_2^2/R_1

53. A long solenoid has 500 turns. When a current of 2 ampere is passed through it, the resulting magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self- inductance of the solenoid is

(a) 2.5 henry (b) 2.0 henry (c) 1.0 henry (d) 40 henry

54. A metal disc of radius 100 cm is rotated at a constant angular speed of 60 rad/s in a plane at right angles to an external field of magnetic induction 0.05 Wb/m^2. The emf induced between the centre and a point on the rim will be

(a) 3 V (b) 1.5 V (c) 6 V (d) 9 V

55. A copper disc of radius 0.1 m rotated about its centre with 10 revolutions per second in a uniform magnetic field of 0.1 tesla with its plane perpendicular to the field. The e.m.f. induced across the radius of disc is

(a) $\frac{\pi}{10}$ volt (b) $\frac{2\pi}{10}$ volt (c) $\pi \times 10^{-2}$ volt (d) $2\pi \times 10^{-2}$ volt

56. The current in a coil of L = 40 mH is to be increased uniformly from 1A to 11A in 4 milli sec. The induced e.m.f. will be

(a) 100 V (b) 0.4 V (c) 440 V (d) 40 V

57. A wire loop is rotated in a uniform magnetic field about an axis perpendicular to the field. The direction of the current induced in the loop reverses once each

(a) quarter revolution (b) half revolution (c) full revolution (d) two revolutions

Topic 3: Applications of EMI

58. A dynamo converts

(a) mechanical energy into thermal energy

(b) electrical energy into thermal energy

(c) thermal energy into electrical energy

(d) mechanical energy into electrical energy

59. When the speed of d.c. motor increases the armature current

(a) increases

(b) decreases

(c) does not change

(d) increses and decreases continuously

60. If a coil made of conducting wires is rooted between poles pieces of the permanent magnet. The motion will generate a current and this device is called

(a) electric motor

(b) electric generator

(c) electromagnet

(d) All of the above

61. The armature of a dc motor has 20W resistance. It draws a current of 1.5 A when run by a 220 V dc supply. The value of the back emf induced in it is

(a) 150 V (b) 170 V (c) 180 V (d) 190 V

62. When a metallic plate swings between the poles of a magnet

(a) no effect on the plate

(b) eddy currents are set up inside the plate and the direction of the current is along the motion of the plate

(c) eddy currents are set up inside the plate and the direction of the current opposes the motion of the plate

(d) eddy currents are set up inside the plate

63. A generator has an e.m.f. of 440 Volt and internal resistance of 4000 hm. Its terminals are connected to a load of 4000 ohm. The voltage across the load is

(a) 220 volt (b) 440 volt (c) 200 volt (d) 400 volt

64. An AC generator of 220V having internal resistance r = 10 Ω and external resistance R = 100 Ω. What is the power developed in the external circuit?

(a) 484 W (b) 400 W (c) 441 W (d) 369 W

65. A six pole generator with fixed field excitation develops an e.m.f. of 100 V when operating at 1500 r.p.m. At what speed must it rotate to develop 120V?

(a) 1200 r.p.m (b) 1800 r.p.m (c) 1500 r.p.m (d) 400 r.p.m

66. The number of turns in the coil of an AC generator is 5000 and the area of the coil is 0.25 m^2, the coil is rotated at the rate of 100 turns per second in a magnetic field of 0.2 Weber 1 m^2. The peak value of the emf generated is nearly

(a) 786 KV (b) 440 KV (c) 220 KV (d) 1571 KV

67. Induction furnace is based on the heating effect of

(a) electric field (b) eddy current (c) magnetic field (d) gravitational field

68. The plane in which eddy currents are produced in a conductor is inclined to the plane of the magnetic field at an angle equal to

(a) 45° (b) 0° (c) 180° (d) 90°

69. The back e.m.f. in a d.c. motor is maximum, when

(a) the motor has picked up max speed

(b) the motor has just started moving

(c) the speed of motor is still on the increase

(d) the motor has just been switched off

70. A series would dc motor has a total resistance of 1.5 ohm. When connected across a 115 volt and running at a certain speed it draws a current of 10 A. The back emf in the motor is

(a) 100 V (b) 115 V (c) 15 V (d) 1.5 V

NEET PREVIOUS YEARS QUESTIONS

1. The magnetic potential energy stored in a certain inductor is 25 mJ, when the current in the inductor is 60 mA. This inductor is of inductance **[2018]**

(a) 0.138 H (b) 138.88 H (c) 13.89 H (d) 1.389 H

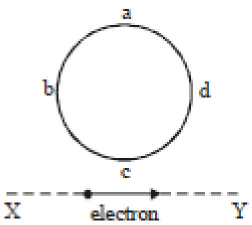
2. A long solenoid of diameter 0.1 m has 2×10^4 turns per meter. At the centre of the solenoid, a coil of 100 turns and radius 0.01 m is placed with its axis coinciding with the solenoid axis. The current in the solenoid reduces at a constant rate to 0A from 4 A in 0.05 s. If the resistance of the coil is $10\pi^2\Omega$, the total charge flowing through the coil during this time is :- **[2017]**

(a) 16 μC (b) 32 μC (c) 16π μC (d) 32π μC

3. A long solenoid has 1000 turns. When a current of 4A flows through it, the magnetic flux linked with each turn of the solenoid is 4×10^{-3} Wb. The self-inductance of the solenoid is : **[2016]**

(a) 4H (b) 3H (c) 2H (d) 1H

4. 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? **[2015]**



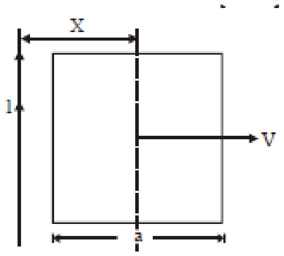
(a) adcb

(b) The current will reverse its direction as the electron goes past the coil

(c) No current induced

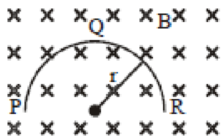
(d) abcd

5. 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 **[2015]**



(a) $\frac{1}{(2x-a)^2}$ (b) $\frac{1}{(2x+a)^2}$ (c) $\frac{1}{(2x-a)(2x+a)}$ (d) $\frac{1}{x^2}$

6. A thin semi-circular 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 : **[2014]**



(a) Zero
(b) $Bv\pi r^2/2$ and P is at higher potential
(c) πrBv and R is at higher potential
(d) 2rBv and R is at higher potential

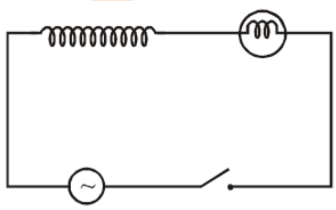
7. A 800 turn coil of effective area 0.05 m^2 is kept perpendicular to a magnetic field 5×10^{-5} T. When the plane of the coil is rotated by 90° around any of its coplanar axis in 0.1 s, the emf induced in the coil will be : **[NEET – 2019]**
(1) 2 V (2) 0.2 V (3) 2×10^{-3} V (4) 0.02 V

8. In which of the following devices, the eddy current effect is not used ? **[NEET – 2019]**
(1) induction furnace
(2) magnetic braking in train
(3) electromagnet
(4) electric heater

9. A cycle wheel of radius 0.5 m is rotated with constant angular velocity of 10 rad/s in a region of magnetic field of 0.1 T which is perpendicular to the plane of the wheel. The EMF generated between its centre and the rim is, **[NEET – 2019 (ODISSA)]**
(1) 0.25 V (2) 0.125 V (3) 0.5 V (4) zero

10. The magnetic flux linked with a coil (in Wb) is given by the equation $\phi = 5t^2 + 3t + 16$
The magnitude of induced emf in the coil at the fourth second will be **[NEET-2020 (Covid-19)]**
(1) 33 V (2) 43 V (3) 108 V (4) 10 V

11. A light bulb and an inductor coil are connected to an ac source through a key as shown in the figure below. The key is closed and after sometime an iron rod is inserted into the interior of the inductor. The glow of the light bulb **[NEET-2020 (Covid-19)]**



(1) decreases
(2) remains unchanged
(3) will fluctuate
(4) increases

12. A wheel with 20 metallic spokes each 1 m long is rotated with a speed of 120 rpm in a plane perpendicular to a magnetic field of 0.4 G. The induced emf between the axle and rim of the wheel will be, (1 G = 10^{-4} T) **[NEET-2020 (Covid-19)]**

(1) 2.51×10^{-4} V (2) 2.51×10^{-5}V (3) 4.0×10^{-5} V (4) 2.51 V

13. Two conducting circular loops of radii R_1 and R_2 are placed in the same plane with their centres coinciding. If $R_1 >> R_2$, the mutual inductance M between them will be directly proportional to **[NEET-2021]**

1) $\frac{R_2}{R_1}$ 2) $\frac{R_1^2}{R_2}$ 3) $\frac{R_2^2}{R_1}$ 4) $\frac{R_1}{R_2}$

14. Two point charges, $-q$ and $+q$ are placed at a distance of L as shown in the figure. **[NEET-2022]**

The magnitude of electric field intensity at a distance R (R>>L) varies as :

(1) $\frac{1}{R^2}$ (2) $\frac{1}{R^3}$ (3) $\frac{1}{R^4}$ (4) $\frac{1}{R^6}$

15.. A big circular coil of 1000 turns and average radius 10 m is rotating about its horizontal diameter at 2 rad s^{-1} If the vertical component of earth's magnetic field at that place is $2\times10^{-5}T$ and electrical resistance of the coil is 12.56 Ω then the maximum induced current in the coil will be : **[NEET-2022]**

1) 0.25A 2) 1.5A 3) 1A 4) 2A

NCERT LINE BY LINE QUESTIONS – ANSWERS

1) b 2) c 3) b 4) a 5) d 6) b 7) a 8) d 9) c 10) b
11) a 12) a 13) b 14) b 15) a 16) b 17) d 18) d 19) b 20) b

NCERT BASED PRACTICE QUESTIONS – ANSWERS

1) a	2) a	3) c	4) a	5) a	6) c	7) a	8) c	9) b	10) b
11) d	12) a	13) d	14) b	15) a	16) b	17) c	18) a	19) b	20) d
21) b	22) a	23) a	24) d	25) c	26) d	27) c	28) d	29) b	30) b
31) b	32) b	33) d	34) d	35) a	36) d	37) a	38) b	39) b	40) b
41) b	42) c	43) a	44) b	45) b	46) b	47) d	48) b	49) b	50) b

TOPIC WISE PRACTICE QUESTIONS - ANSWERS

1)	3	2)	2	3)	4	4)	3	5)	3	6)	1	7)	3	8)	4	9)	4	10)	3
11)	3	12)	4	13)	2	14)	1	15)	1	16)	3	17)	1	18)	1	19)	3	20)	2
21)	2	22)	4	23)	2	24)	4	25)	2	26)	3	27)	1	28)	4	29)	4	30)	4
31)	2	32)	1	33)	3	34)	1	35)	2	36)	2	37)	4	38)	1	39)	2	40)	2
41)	4	42)	4	43)	4	44)	4	45)	2	46)	1	47)	1	48)	4	49)	2	50)	4
51)	4	52)	4	53)	3	54)	2	55)	3	56)	1	57)	2	58)	4	59)	2	60)	2
61)	4	62)	3	63)	4	64)	2	65)	2	66)	4	67)	2	68)	2	69)	1	70)	1

NEET PREVIOUS YEARS QUESTIONS-ANSWERS

1)	3	2)	2	3)	4	4)	2	5)	3	6)	4	7)	4	8)	4	9)	2
10)	2	11)	1	12)	1	13)	3	14)	2	15)	3						

TOPIC WISE PRACTICE QUESTIONS - SOLUTIONS

1. **(c)** $\varepsilon = -\frac{Nd\phi}{dt} \Rightarrow \varepsilon \propto N$ and $\varepsilon \propto \frac{d\phi}{dt}$

If so the speed of magnet is fast then correspondingly rate of change of flux is fast & e is maximum. It does not depend on the resistance of coil.

2. (b) A cylindrical bar magnet is kept along the axis of a circular coil. If the magnet is rotated about its axis, then there is no change in magnetic flux, there is no emf induced in the coil, no current will be induced in the coil

3. **(d)** When the coils P and Q are brought nearer, the magnetic flux linked with each coil will increase and the induced current will induces in the direction opposite to original current according to Lenz law and hence current in both P and Q decreases.

4. **(c)** $i = \frac{e}{R} = \frac{dt}{R} = \frac{20\times\left(25\times10^{-4}\right)\times1000}{100} = 0.5A$

5. **(c)** $\varepsilon = \left(5\times10^{-3}\right)\left(1/0.1\right) = 0.05V$

6. (a) When electric current is passed through the coil inside the galvanometer, induction of magnetic field takes place and thus the coil acts like a magnet which experiences torque due to permanent magnet inside galvanometer and thus the pointer is deflected.

7. (c) emf $= L\frac{di}{dt}$

Rate of change of current is constant for one period at a positive value and is constant at negative value for the second time period. Therefore emf is a constant positive value for first half and constant negative value for second half.

8. **(d)** Given : $\phi = 4t^2 + 2t + 1wb$

$\therefore \frac{d\phi}{dt} = \frac{d}{dt}\left(4t^2 - 2t + 1\right) = 8t + 2 = |\varepsilon|$

Induced current, $I = \frac{|\varepsilon|}{R} = \frac{8t+2}{10\Omega} = \frac{8t+2}{10}A$

At $t = 1s$, $I = \frac{8\times1+2}{10}A = 1A$

9. **(d)** Because of the Lenz's law of conservation of energy.

10. **(c)** Initial magnetic flux linked with the coil is

$\phi_i = BA\cos\theta = 0.1\times200\times10^{-4}\times\cos0^0 = 2\times10^{-3}Wb$

Final magnetic flux linked with the coil is $\phi_f = 0$

$\therefore$ By Faraday's law, $\varepsilon = -\frac{N\Delta\phi}{\Delta t} = \frac{-N\left(\phi_f - \phi_i\right)}{\Delta t}$

$= \frac{-100\left(0 - 2\times10^{-3}\right)}{1} = 2\times10^{-1}V = 0.2V$

Induced current $I = \frac{\varepsilon}{R} = \frac{0.2V}{2\Omega} = 0.1A$

11. **(c)** If the current increases with time in loop A, then magnetic flux in B will increase. According to Lenz's law, loop -B is repelled by loop -A because current in loop B will be antiparallel to that in A.

12. **(d)** According to Lenz's law, when switch is closed, the flux in the loop increases out of plane of paper, so induced current will be clockwise

13. **(b)** $e = \frac{-\left(\phi_2 - \phi_1\right)}{t} = \frac{-\left(0 - NBA\right)}{t} = \frac{NBA}{t}$

$t = \frac{NBA}{e} = \frac{50\times2\times10^{-2}\times10^{-2}}{0.1} = 0.1s$

14. **(a)** $e = \frac{d\phi}{dt} = \frac{d}{dt}\left(NBA\right) = NA\frac{dB}{dt}$

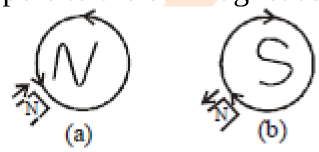
$$=100\times0.1\times0.05\left(\frac{0.1-0.05}{0.05}\right)=0.5V$$

15. **(a)** $N_{\varphi}=Li\Rightarrow\varphi=\frac{Li}{N}=\frac{8\times10^{-3}\times5\times10^{-3}}{400}$

$$=10^{-7}=\frac{\mu_0}{4\pi}wb$$

16. **(c)** $\frac{\Delta\phi}{\Delta t}=\varepsilon=iR\Rightarrow\Delta\phi=(i\Delta t)R=QR\Rightarrow Q=\frac{\Delta\phi}{R}$

17. **(a)** When a north pole of a bar magnet moves towards the coil, the induced current in the coil flows in a direction such that the coil presents its north pole to the bar magnet as shown in figure (a). Therefore, the induced current flows in the coil in the anticlockwise direction. When a north pole of a bar magnet moves away from the coil, the induced current in the coil flows in a direction such that the coil presents its south pole to the bar magnet as shown in figure (b).



Therefore induced current flows in the coil in the clockwise direction.

18. **(a)** Induced e.m.f $\varepsilon=\frac{d\phi}{dt}=\frac{dBA}{dt}=A_0\frac{dB}{dt}$

19. **(c)** $i=\frac{\varepsilon}{R}=\frac{1}{R}\frac{d\phi}{dt}$

Here $df=B\times A=(2\times10^{-5})\times(0.5\times10^{+3}\times5)$

dt = time taken by the wire to fall at ground

$$=(2h/g)^{1/2}=(10/10)^{1/2}=1sec$$

$$\therefore i=\frac{1}{2.5}\left[\frac{(2\times10^{-5})\times(0.5\times10^{3}\times5)}{1}\right]=0.02\,amp$$

20. **(b)** $\frac{d\phi}{dt}=\frac{(W_2-W_1)}{t}R_{tot}=(R+4R)\Omega=5R\Omega$

$i=\frac{nd\phi}{R_{tot}dt}=\frac{-n(W_2-W_1)}{5Rt}$ $\quad(\because W_2\ \&\ W_1$ are magnetic flux)

21. (b) When current is changed in a coil the magnetic flux is also changed but this flux is because of its own current and thus, this property is called self induction.

22. **(d)** The self inductance of a long solenoid is given by

$$L=\mu_r\mu_0n^2Al$$

Self inductance of a long solenoid is independent of the current flowing through it.

23. **(b)** $\ell=1m,\omega=5\,rad/s,B=0.2\times10^{-4}T$

$$\varepsilon=\frac{B\omega\ell}{2}=\frac{0.2\times10^{-4}\times5\times1}{2}=50\mu V$$

24. **(d)** Emf $=4\times10\times0.1\times\sin30^0$

$$=4\times\frac{1}{2}=2V$$

25. **(b)** $e=M\frac{di}{dt}=0.005\times\frac{d}{dt}(i_0\sin\omega t)=0.0005\times i\omega\cos\omega t$

$\therefore e_{max}=0.005\times10\times100\pi=5\pi\quad[\because\cos\omega t=1]$

26. **(c)** Initial current (I_1) = 10 A; Final current (I_2) = 0; Time (t)

= 0.5 sec and induced e.m.f. (ε) = 220 V.

Induced e.m.f. $(\varepsilon) = -L\frac{dI}{dt} = -L\frac{(I_2 - I_1)}{t} = -L\frac{(0-10)}{0.5} = 20L$

or $L = \frac{220}{20} = 11H$

27. **(a)** According to Faraday's law of electro-magnetic inductions,

$e = \left|L\frac{dI}{dt}\right| \Rightarrow 2 = L\frac{(8-2)}{3\times10^{-2}} \Rightarrow L = 10mH$

28. **(d)** $N\phi = Li \Rightarrow L = \frac{N\phi}{i} = \frac{100\times10^{-5}}{5} = 0.20mH$

29. **(d)** $\Delta I = 6A,\ \Delta t = 0.3s, E = 30V$

$E = L\frac{dI}{dt} \qquad \therefore L = \frac{30\times0.3}{6} = 1.5H$

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

$\therefore$ Average induced e.m.f. in secondary coil

$e = M\frac{dI}{dt} = 0.75\times50 = 37.5V$

31. **(b)** $L = \mu_0 nI$

$\therefore \frac{L_2}{L_1} = \frac{\mu}{\mu_0}$ ----($\because$ n and I are same)

$\therefore L_2 = \mu_1 L_1 = 900\times0.18 = 162mH$

32. (a) The coupled flux of two coils system is used to define the mutual inductance between the coils. The mutual inductance between the coils is $M_{21} = \frac{N_2\phi_{21}}{I_1}$

So it is defined as the proportionality between the emf generated in coil 2 due to the current flows in coil 1. Thus It depends on the relative position and orientation of two coils

33. **(c)** Given: current I = 2.5 A
Inductance, L = 5H
Magnetic flux, ϕ = ?
We know, $\phi = LI \Rightarrow 5\times2.5Wb = 12.5Wb$

34. **(a)** $i = 3t^2 - 4t + 6$; $\frac{di}{dt} = 6t - 4$

At $t = 2s, \frac{di}{dt} = 8$; ; $e = \left|-M\frac{di}{dt}\right| = 160\,mV$

35. **(b)** $\varepsilon = M\frac{di}{dt}$ or $8 = M\left[\frac{(4-2)}{0.05}\right]$

$\therefore M = \frac{8\times0.05}{2} = 0.2$ henry

36. **(b)** Self inductance $= \mu_0 n^2 AL = \mu_0 n^2 AL = \mu_0 n^2(\ell\times b)\times L$

So, when all linear dimensions (ℓ , b and L) are increased by a factor of *x*. The new self-inductance increases by a factor of x

37. **(d)** $M = \frac{\mu_0 N_1 N_2 A}{\ell} = \frac{4\pi\times10^{-7}\times300\times400\times100\times10^{-4}}{0.2}$

$= 2.4\pi\times10^{-4}H$

38. **(a)** If in time t, the rod turns by an angle θ , the area generated by the rotation of rod will be

$= \frac{1}{2} l \times l\theta = \frac{1}{2} l^2 \theta$

So the flux linked with the area generated by the rotation of rod

$\phi = B\left(\frac{1}{2} l^2 \theta\right) \cos 0 = \frac{1}{2} B l^2 \theta = \frac{1}{2} B l^2 \omega t$

and so $e = \frac{d\phi}{dt} = \frac{d}{dt}\left(\frac{1}{2} B l^2 \omega t\right) = \frac{1}{2} B l^2 \omega$

39. **(b)** Length of conductor (l) = 0.4 m; Speed (v) = 7 m/s and magnetic field (B) = 0.9 Wb/ m^2. Induced e.m.f. (V) = Blv sin θ = 0.9 × 0.4 × 7 × sin 90° = 2.52 V.

40. **(b)** Rate of work $= \frac{W}{t} = P = Fv$; also $F = Bil = B\left(\frac{Bvl}{R}\right) l$

$\Rightarrow P = \frac{B^2 v^2 l^2}{R} = \frac{(0.5)^2 \times (2)^2 \times (1)^2}{6} = \frac{1}{6} W$

41. **(d)** When two inductance coil are joined in series, such that the winding of one is exactly opposite to each other the emf produced in the two coils are out of phase such that they cancel out.

42. **(d)** $e = [Bvl]$; $|e| = \begin{vmatrix} 3 & 3 & 2 \\ 1 & 2 & 0 \\ 0 & 0 & 1 \end{vmatrix}$

(as length of conductor is $0\hat{i} + 0\hat{j} + 1\hat{k}$)

43. **(d)** Initially flux, $\phi = BA\cos 0 = BA$

After rotating through an angle 90°.

Flux through the coil is zero.

So, $\Delta\phi = BA$

Angular speed = w, so, time period $= \frac{2\pi}{\omega} = T$

$T/4$ is time taken to rotate 90°.

So, $\frac{\Delta\phi}{\Delta t} = \frac{BA}{T/4} = \frac{2BA\omega}{\pi}$

44. **(d)** $\varepsilon = Blv = (0.2 \times 10^{-4})(1)(180 \times 5/8) = 10^{-3} V = 1 mV$

45. **(b)** Non-metallic piece will reach the ground first because there will be no induced current in it due to movement

46. **(a)** $E = \frac{d}{dt}(NMI) \Rightarrow E = NM\frac{dI}{dt} \Rightarrow E = \frac{NMI}{t}$

emf induced per unit turn $= \frac{E}{N} = \frac{MI}{t}$

47. **(a)** Change in flux = 2 B A N

$\therefore$ Induced e.m.f. $= \frac{2 \times 0.3 \times 200 \times 70 \times 10^{-4}}{0.1}$

48. (d) Induced emf in the axle =Blv

v– velocity of car

$l-$ length of car

B$-$ component of magnetic field perpendicular to both l and v .

That is B is the vertical component of magnetic field.

Vertical component of magnetic field is maximum at the poles.

Therefore emf induced in the axle will be maximum at the poles.

49. (b) Field at the center of outer square loop = $B=\dfrac{2\sqrt{2}\mu i}{\pi L}$ along the axis.

flux linking the smaller square loop $\lambda = B\ell^2 = \dfrac{2\sqrt{2}\mu i}{\pi L}\ell^2$

mutual inductance $= m\dfrac{\lambda}{i} = \dfrac{2\sqrt{2}\mu\ell^2}{\pi L}$

50. **(d)** the minimum value of M is $\sqrt{L_1L_2}$

51. **(d)** $M = \dfrac{\mu_0\mu_r N_1N_2}{2R_1}A$

$= \dfrac{4\pi\times10^{-4}\times800\times500\times25\times12\times10^{-4}}{2\times0.1}$

52. **(d)** Mutual inductance between two coil in the same plane with their centers coinciding is given by $M = \dfrac{\mu_0}{4\pi}\left(\dfrac{2\pi^2R_2^2N_1N_2}{R_1}\right)$henry.

53. **(c)** Total number of turns in the solenoid, N = 500

Current, I = 2A.

Magnetic flux linked with each turn = 4×10^{-3} Wb

54. **(b)** Induced emf produced between the centre and a point on the disc is given by

$e = \dfrac{1}{2}\omega BR^2$

Putting the values,

$W = 60\,\text{rad/s}, N = 0.05\text{Wb/m}^2$ and $R = 100\text{cm} = 1\text{m}$

We get $e = \dfrac{1}{2}\times60\times0.05\times(1)^2 = 1.5\text{V}$

55. **(c)** e.m.f. induced $= \dfrac{1}{2}BR^2\omega = \dfrac{1}{2}BR^2(2\pi n)$

$= \dfrac{1}{2}\times(0.1)\times(0.1)^2\times2\pi\times10 = (0.1)^2\,\pi\,\text{volts}$

56. **(a)** $e = \dfrac{LdI}{dt} = \dfrac{40\times10^{-3}(11-1)}{4\times10^{-3}} = 100\text{V}$

57. **(b)** It is because after every 1/2 revolution the current becomes zero and mode of change in flux changes thereafter (If before the current becomes zero, the mode of flux change was from left to right then after the current becomes zero the mode of flux change becomes right to left).

58. **(d)** A dynamo is a device which converts mechanical energy into electrical energy

59. **(b)** decreases does not change

60. **(b)** Electric generator works on the principle of EMI in which coil rotated against the magnetic field b/w the poles causing flux change and hence induced current.

61. **(d)** $\frac{E-e}{R} \Rightarrow 1.5 = \frac{220-e}{20} \Rightarrow e = 190V$

62. (c) When a changing magnetic flux is applied to a bulk piece of conducting material then circulating current is called eddy currents are induced

63. **(d)** Total resistance of the circuit = 4000 + 400 = 4400 W

Current flowing $i = \frac{V}{R} = \frac{440}{4400} = 0.1 amp$

Voltage across load = R i = 4000 × 0.1 = 400 volt.

64. **(b)** $V = 200V; r = 10\Omega$

$R^{|} = 10 + 100\Omega = 110\Omega$

$I = \frac{V}{R^{|}} = \frac{220}{100} = 2A$

$P = I^2 R = 4 \times 100 = 400W$

65. **(b)** The e.m.f. induced is directly proportional to rate at which flux is intercepted which in turn varies directly as the speed of rotation of the generator.

66. (d) $E = NBA\omega \sin \omega t$; $\varepsilon_p = NBA\omega$

$N = 5 \times 10^3$; $B = 2 \times 10^{-1} T$; $\omega = 2\pi f = 2\pi \times 10^2$; $A = \frac{1}{4} m^2$

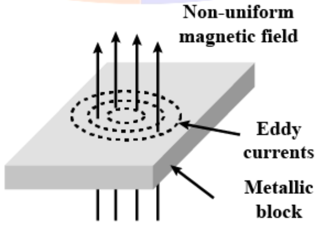
$\varepsilon_p = 5 \times 10^3 \times 2 \times 10^{-1} \times \frac{1}{4} \times 2\pi \times 10^2$

$= 5\pi \times 10^4 = 5(3.14) \times 10^4$

$\varepsilon_p = 157.1 kV$

67. (b) Though most of the times eddy currents are undesirable but they find some useful applications such as in inductance furnace. Joule's heat causes the melting of a metal piece placed in a rapidly changing magnetic field.

68. (b) Direction of eddy currents is given by Lenz's rule.



69. **(a)** The back e.m.f. in a motor is induced e.m.f., which is maximum, when speed of rotation of the coil is maximum.

70. **(a)** If e_b is the back emf in the motor, then

$i = \frac{\varepsilon - e_b}{R}$ or $10 = \left(\frac{115 - e_b}{1.5}\right)$

$\therefore e_b = 100V$

NEET PREVIOUS YEARS QUESTIONS-EXPLANATIONS

1. **(c)** From question energy stored in inductor, U = 25 × 10^{-3} J

Current, I = 60 mA

Energy stored in inductor $U = \frac{1}{2}LI^2$

$$25 \times 10^{-3} = = \frac{1}{2} \times L \times \left(60 \times 10^{-3}\right)^2$$

$$L = \frac{25 \times 2 \times 10^6 \times 10^{-3}}{3600} = 13.89 \text{ H}$$

2. **(b)** Given, no. of turns N = 100

radius, r = 0.01 m

resistance, R = $\pi^2\Omega$, n = 2 × 10^4

As we know,

$$\varepsilon = -N\frac{d\phi}{dt} \qquad \frac{\varepsilon}{R} = -\frac{N}{R}\frac{d\phi}{dt}$$

$$\Delta I = -\frac{N}{R}\frac{d\phi}{dt} \qquad \frac{\Delta q}{\Delta t} = -\frac{N}{R}\frac{\Delta\phi}{\Delta t}$$

$$\Delta q = -\left[\frac{N}{R}\left(\frac{\Delta d\phi}{\Delta t}\right)\right]\Delta t$$

'–' ve sign shows that induced emf opposes the change of flux.

$$\Delta q = \left[\mu_0 n N \pi r^2\left(\frac{\Delta i}{\Delta t}\right)\right]\frac{1}{R}\Delta t = \frac{\mu_0 n N \pi r^2 \Delta i}{R}$$

$$\Delta q = \frac{4\pi \times 10^{-7} \times 100 \times 4 \times \pi \times (0.01)^2 \times 2 \times 10^4}{10\pi^2}$$

$$\Delta q = 32\mu C$$

3. **(d)** Here, number of turns n = 100;

current through the solenoid i = 4A;

flux linked with each turn = 4 × 10^{-3}Wb

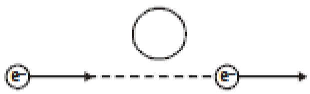
$\therefore$ Total flux linked, and total = 1000[4 × 10^{-3}] = 4Wb

$$\phi_{total} = 4 \Rightarrow Li = 4 \Rightarrow L = 1H$$

4. **(b)** Current will be induced,

when e^- comes closer the induced current will be anticlockwise

when e^- comes farther induced current will be clockwise



5. **(c)** Emf induced in side 1 of frame $e_1 = B_1 V\ell$

$$B_1 = \frac{\mu_0 I}{2\pi(x - a/2)}$$

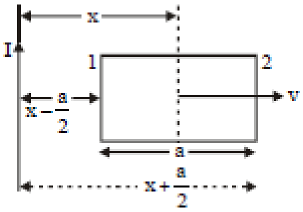
Emf induced in side 2 of frame $e_2 = B_0 V\ell$

$$B_2 = \frac{\mu_0 I}{2\pi(x + a/2)}$$

Emf induced in square frame $e = B_1 V\ell - B_2 V\ell$

$$= \frac{\mu_0 I}{2\pi(x - a/2)}\ell v - \frac{\mu_0 I}{2\pi(x + a/2)}\ell v$$

or $e \propto \frac{1}{(2x-a)(2x+a)}$

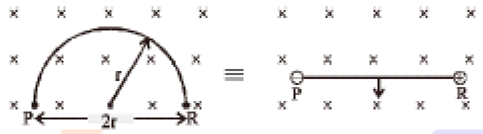


6. **(d)** Rate of decreasing of area of semi-circular ring

$= \frac{dA}{dt} = (2r)V$

From Faraday's law of electromagnetic induction

$e = -\frac{d\theta}{dt} = -B\frac{dA}{dt} = -B(2rV)$



As induced current in ring produces magnetic field in upward direction hence R is at higher potential.

7. Given

$N = 800,\ A = 0.05\ m^2,\ B = 5 \times 10^{-5}\ T$

$\Delta t = 0.15\ s$

$$\text{As } e = -\frac{(\phi_f - \phi_i)}{\Delta t} = -\frac{(0 - NBA)}{\Delta t}$$

$$= \frac{800 \times 5 \times 10^{-5} \times 5 \times 10^{-2}}{0.1} = 0.02\ V$$

8. Eddy current effect is not used in electric heater

9. $E = \frac{B\omega l^2}{2}$; $= \frac{0.1(10)(0.5)^2}{2} = 0.125v$

10. $\phi = 5t^2 + 3t + 60$

$|\varepsilon| = \left|\frac{d\phi}{dt}\right| = 10t + 3$

At t = 4 sec

$|\varepsilon| = 40 + 3 = 43\,\text{volt}$

11. Impedance, $z = \sqrt{R^2 + X_L^2}$

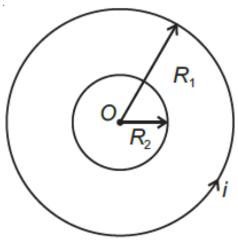
$X_L \uparrow, Z \uparrow, I \downarrow$

12. $\varepsilon = \frac{1}{2}B\omega r^2$

$\varepsilon = \frac{1}{2} \times (0.4 \times 10^{-4}) \times \left(2\pi\left[\frac{120}{60}\right]\right)(1)^2$

$\varepsilon = 0.8\pi \times 10^{-4} = 2.512 \times 10^{-4}\,V$

13. Two concentric coils are of radius R1 and R2 as shown



Let current in outer loop be i

Magnetic field at centre $= B = \frac{\mu_0 i}{2R_1}$

Magnetic flux through inner coil $= B \times \pi R_2^2$

$$\phi = \frac{\mu_0 i}{2R_1} \times \pi R_2^2$$

$$\phi = \frac{\mu_0 i}{2} \times \frac{\pi R_2^2}{R_1}$$

as per definition, $\phi = Mi$

$$\Rightarrow M = \left(\frac{\mu_0 \pi}{2}\right)\frac{R_2^2}{R_1}$$

$$\therefore M \propto \frac{R_2^2}{R_1}$$

14. $E = \frac{1}{4\pi \in_0} \cdot \frac{2P}{R^3} = \frac{1}{4\pi \in_0} \cdot \frac{2(qL)}{R^3}$

15. $e_{\max} = NABW = N\pi r^2 BW = 1000 \times \pi r^2 \times 2 \times 10^{-5} \times 2$

$$i_{\max} = \frac{e_{\max}}{R} = \frac{1000 \times \pi (10)^2 \times 2 \times 10^{-5} \times 2}{12.56} = 1A$$