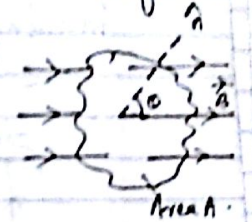
6 Electro Magnetic Induction.

Magnetic flux: The magnetic flux linked through any surface placed in a magnetic field is the total numbers of magnetic lines of force crossing this surface normally.

It is measured as the product of the component of the mag. field normal to the surface and the surface area

i.e. Magnetic flux $\phi_B = B\cos\theta \cdot A$
$= BA\cos\theta$
$= \vec{B}\cdot\vec{A}$.



It is a scalar quantity.

Dimension of ϕ.

$$\phi_B = BA$$
$$[\phi_B] = [B][A]$$
$$= MT^{-2}A^{-1} \cdot L^2$$
$$= \underline{ML^2T^{-2}A^{-1}}$$

S.I unit of ϕ_B = S.I unit of B × S.I unit of A
$= T \times m^2$
$=$ Wb (Weber)

$1\,Wb = 1\,T \times 1\,m^2$.

i.e. 1Wb is the flux produced when a uniform mag: field of 1T acts normally over an area of $1\,m^2$

C.G.S unit of ϕ = $G\,cm^2$
= maxwell (Mx)

$$1\,Wb = 1\,T \times 1\,m^2$$
$$= 10^4 G \times (10^2)^2 cm^2$$
$$= 10^8\,Mx.$$

Electromagnetic Induction:

The phenomenon of production of induced emf and hence induced current due to a change of magnetic flux linked with a closed circuit is called EM induction.

The phenomenon of EM induction was discovered by Michel Faraday.

Faraday's Experiments: Experiment 1.

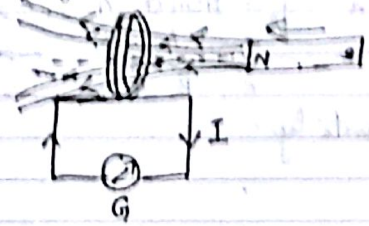


Figure shows a coil C_1 connected to a galvanometer G.

(i) When the N-pole of a strong bar magnet is moved towards the coil the galvanometer shows a deflection in one direction.

(ii) When the N-pole of a bar magnet is moved away from the coil the galvanometer shows a deflection in the opposite direction.

(iii) When the magnet is held stationary anywhere near or inside the coil, the galvanometer does not show any deflection.

(iv) When the S-pole of the bar magnet is moved towards or away from the coil, the deflections in the Galvanometer are opposite to that observed with the N-pole for similar movements.

The above observation shows that the relative motion between the magnet and the coil changes the magnetic flux through the coil. This changing magnetic flux is the responsible for the generation of electric current in the coil.

Experiment II.

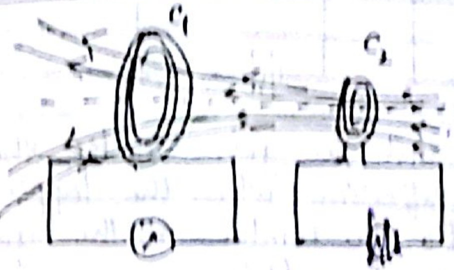


Figure shows two coils C_1 and C_2. C_1 is connected to a galvanometer and C_2 is connected to a battery.

The steady current in the coil C_2 produces a steady magnetic field. As coil C_2 is moved towards the coil C_1 the galvanometer shows a deflection. This indicates that electric current is induced in coil C_1.

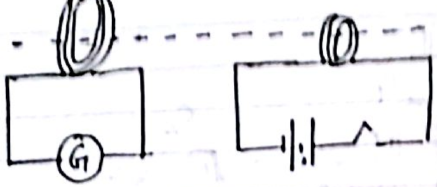
When the coil C_2 is moved away, the galvanometer shows a deflection again but in the opposite direction. The deflection lasts as long as coil C_2 is in motion.

When the coil C_2 is held fixed and C_1 is moved the same effects are observed.

(i.e the relative motion between the coils that induces the electric current.)

Experiment III

Consider two coils C_1 and C_2 held stationary. Coil C_1 is connected to a galvanometer G while the second coil C_2 is connected to a battery through a tapping key K.



It is observed that the galvanometer shows a momentary deflection when the tapping key K is pressed. The the pointer in the galvanometer returns to zero immediately.
If the key is held pressed continuously, there is no deflection in the galvanometer. When the key is released a momentary deflection is observed again, but in the opposite direction.
It is observed that the deflection increases dramatically when an iron rod is inserted into the coils along their axis.

Faraday's Laws of Electromagnetic Induction.

I law :- Whenever the magnetic flux linked with a closed circuit changes, an emf is induced in it which lasts only so long as the change in flux is taking place.

II law :- The magnitude of the induced emf is equal to the rate of change of magnetic flux linked with the closed circuit

i.e. $$\mathcal{E}_0 = \frac{d\phi}{dt}$$

Lenz's law

The law states that the direction of the induced current is such that it opposes the cause which produces it.
i.e. it opposes the change in magnetic flux

$$\mathcal{E}_0 = -\frac{d\phi_B}{dt}.$$

In the case of N turns

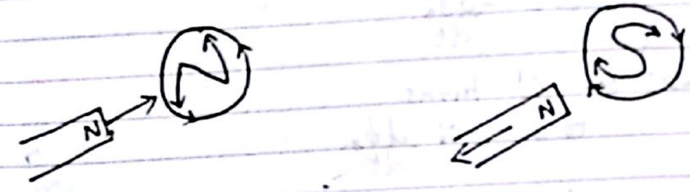
$$\mathcal{E}_0 = -N\frac{d\phi_B}{dt}.$$

If the flux changes from ϕ_1 to ϕ_2 in time 't'.
then $$\mathcal{E}_0 = -N\frac{(\phi_2 - \phi_1)}{t}.$$

Lenz's law and law of Conservation of energy.

When the N-pole of a bar magnet is moved towards a closed coil, the induced current in the coil flows in the anti clockwise direction. The face of the coil towards the magnet develops north polarity and thus it ~~opposes the motion of the N-pole~~ repels the north pole of the magnet. Work has to be done in moving the magnet closer to the coil against the force of repulsion.
When the N-pole of the magnet is moved away from the coil, the induced current in the coil flows in the clockwise direction. The face of the coil towards the magnet develops south polarity and thus attracts the north pole of the magnet. Work has to be done in moving the magnet away from the coil against the force of attraction.

It is this work done against the force of repulsion or attraction - that appears as electric energy in the form of induced current.
i.e one form of energy can be converted in to another form. This is law of conservation of energy.



Motional emf

The emf across the ends of a conductor due to its motion in a magnetic field is called motional emf.

Consider a conductor PQ of length 'l' free to move in a uniform and time independent magnetic field 'B', directed normally into the plane of the paper.

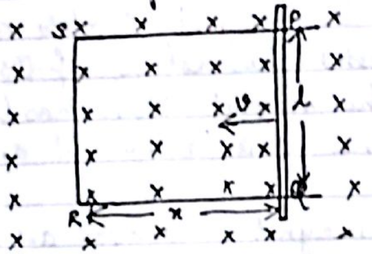


Figure shows a rectangle conductor PQRS in which PQ is free to move. The rod PQ is moved towards left with a constant velocity v.

As the conductor slides towards left, the area of the rectangle PQRS decreases.

Magnetic flux $\phi_B = \vec{B}\cdot\vec{A}$

$= BA\cos\theta$ $\quad \vec{B} \not\parallel \vec{v}$ $\perp^r$

$= BA^{(\theta = 0°)}$ $(\theta = 90°)$

$= Blx$ $\quad$ ($A = lx$ area of the loop)

According to the law of EM induction

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

$$= -\frac{d}{dt}(Blx)$$

$$= -Bl\frac{dx}{dt} = -Bl\times -v$$

$$\boxed{\mathcal{E} = Blv}$$

where $\frac{dx}{dt} = -v$ the velocity decreasing in the direction of x.

The induced emf Blv is called motional emf.

Motional emf from Lorentz force.

A conductor has a large no. of free electrons. When it moves through a magnetic field, a Lorentz force acting on the free electrons can set up a current

As the arm PQ is moved towards left with a speed v the free electrons of PQ also move with the same speed

The electrons experience a magnetic Lorentz force

$F = qvB.$ $(\theta = 90°)$

Electric field set up in the conductor is E. This field exerts a force

$F = qE$

$\therefore qvB = qE$

$vB = E.$

The potential difference between the ends of the conductor $V = E\times l$

$= vB\times l$

$= Blv.$

This potential is called motional emf $\mathcal{E} = Blv$.

Current induced in the loop :- Let R be the resistance of the arm PQ

The current $I = \frac{\mathcal{E}_0}{R} = \frac{Blv}{R}$ ——— (1)

Force on the movable arm :- The conductor PQ of length l and carrying current I experiences force F in the ⊥ magnetic field

$F = BIl \sin 90$

$= BIl$

$= B \times \frac{Blv}{R} \times l \times 1 = \frac{B^2l^2v}{R}$ ——— (2)

Power delivered by the external force

$P = Fv$

$= \frac{B^2l^2v}{R} \times v = \frac{B^2l^2v^2}{R}$ ——— (3)

Power dissipated as Joule's loss :-

According to Joule's law $H = I^2Rt$

$P_J = \frac{H}{t} = I^2R = \left(\frac{Blv}{R}\right)^2 \cdot R$

$= \frac{B^2l^2v^2}{R}$ ——— (4)

Clearly from (3) and (4)

Power delivered by the external force = Power dissipated as Joule loss

ie $P = P_J$

ie mechanical energy expended to maintain the motion in the movable arm is first converted into electrical energy and then to thermal energy. This is consistent with the law of conservation of energy.

Relation between induced charge and change in magnetic flux.

According to the law of electromagnetic induction

$\mathcal{E}_0 = \frac{d\phi_B}{dt}$

If R is the resistance of the closed loop, then the induced current will be

$I = \frac{\mathcal{E}_0}{R}$

$\frac{dq}{dt} = \frac{1}{R} \cdot \frac{d\phi_B}{dt}$

$\therefore dq = \frac{d\phi_B}{R}$

Charge induced in the circuit

$$\boxed{dq = \frac{\text{Net change in magnetic flux}}{\text{Resistance}}}$$

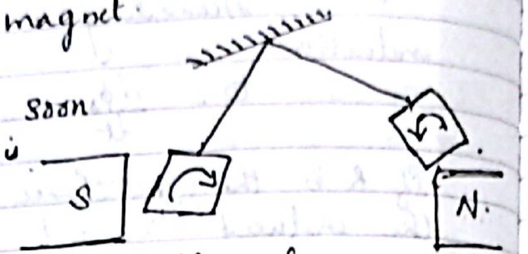
Eddy Currents

Currents can be induced, not only in conducting wires, but also in conducting sheets or blocks. Whenever the magnetic flux linked with a metal sheet or blocks changes an emf is induced in it. The induced currents flow in closed paths throughout the body of the metal. These currents look like eddies or whirl-pools. These currents are known as eddy currents or Focault currents

Experimental demonstration of eddy currents

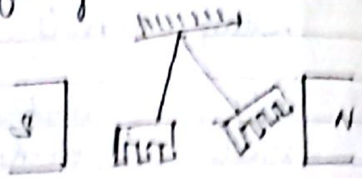
Expt 1 :- Take a pendulum having its bob in the form of a flat copper plate. As shown in figure it is free to oscillate between the pole pieces of ~~a~~ strong magnet.

It is found that the motion is damped and soon it comes to rest. This is because as the copper plate moves in between



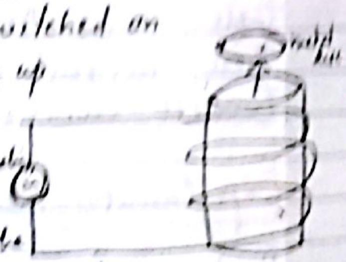
the poles of a magnet, magnetic flux changes. So eddy currents are set up in it. Directions of eddy currents are opposite when the plate swings into the region between the poles and when it swings out of the region.

If rectangular slots are made in the copper plate, area available to the flow of eddy currents is less. Thus the pendulum plate with holes or slots reduces electromagnetic damping and the plate swings more freely.



Expt. 2

Take a cylindrical electromagnet fed by an A.C source and place a small metal disc over its top. As the current is switched on the magnetic field increases setting up eddy currents in the disc in the same direction as that of electromagnet current. Thus if upper surface of electromagnet acquires N polarity, the lower surface of disc also acquire N polarity. As same magnetic poles repel each other, the disc thrown up.



Undesirable effects of eddy currents

Eddy currents are produced inside the iron cores of the rotating armatures of electric motors and dynamos and also in the cores of transformers, which experiences flux change when they are in use. Eddy currents cause unnecessary heating and wastage of power.

The eddy currents can be reduced by using laminated core ~~which~~

Applications of eddy current.

1. Magnetic braking in trains:- Strong electromagnets are situated above the rails in some electrically powered trains. When the electromagnets are activated the eddy currents induced in the rails oppose the motion of the train.
2. Electromagnetic damping:- Certain galvanometers have a fixed core made of non magnetic metallic material. When the coil oscillates, the eddy currents generated in the core oppose the motion and bring the coil to rest quickly.
3. Induction furnace:- Induction furnace can be used to produce high temperatures and can be utilised to prepare alloys, by melting the constituent metals. A high frequency A.C current is passed through a coil which surrounds the metals to be melted. The eddy currents generated in the metals produce high temperatures sufficient to melt it.
4. Electric power meters:- The shiny metal disc in the electric power meter rotates due to the eddy currents. Electric currents are induced in the disc by magnetic fields produced by sinusoidally varying currents in the coil.

Self Induction.

When a current flows in a coil, it gives rise to a magnetic flux through the coil itself. As the strength of the current changes, the magnetic flux changes and an opposing emf is induced in the coil. This emf is called back emf or self induced emf. The phenomenon is called Self induction.

i.e. Self Induction is the phenomenon of production of induced emf in a coil when a changing current passes through it.

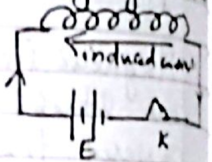
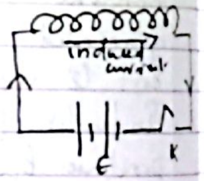


Figure shows a battery and a tapping key connected in series to a coil. As the switch is closed the current increases and hence magnetic flux through the coil increases from 0 to maximum and an induced current flows in the opposite direction of the battery current.



As the tapping switch is opened the current and hence the magnetic flux through the coil decreases from maximum value to 0 and the induced current flows in the same direction as that of the battery current.

Coefficient of Self Induction

At any instant the magnetic flux ϕ linked with a coil is proportional to the current I through it.

i.e. $\phi \propto I$

or $\phi = LI$ —— ①

where L is a constant for a given coil and is called self inductance or coefficient of self induction.

Also Induced emf $\mathcal{E} = \frac{-d\phi}{dt} = \frac{-d}{dt}(LI)$

$= -L\frac{dI}{dt}$ —— ②

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

Self inductance may be defined as the induced emf set up in the coil due to a unit rate of change of current through it.

Unit of Self Inductance:-

form equ ② $\mathcal{E} = -L\frac{dI}{dt}$

or $L = \frac{\mathcal{E}}{dI/dt} = \frac{1V}{1A/1s} = 1VsA^{-1}$
$= 1WbA^{-1}$
$= 1henry(H)$

The self inductance of a coil is said to be 1H if an induced emf of 1Volt is set up in it when the current in it changes at the rate of 1A/s.

Dimension of Self Inductance

We have $\phi = LI$

$L = \frac{\phi}{I} = \frac{BA}{I} = \frac{F}{qv\sin\theta} \cdot \frac{A}{I}$

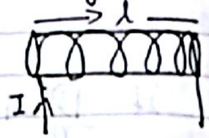
$[L] = \frac{[F][A]}{[q][v][I]} = \frac{MLT^{-2} \cdot L^2}{AT \cdot LT^{-1} A}$

$= ML^2T^{-2}A^{-2}$

Self Inductance of a long solenoid.

Consider a long solenoid of length 'l' and radius r having n turns per unit length. Let I be the current flows through the coil, then a magnetic field is set up inside the coil given by

$B = \mu_0 n I$



Flux linked with each turn

$= BA$

$= \mu_0 n I A$

Magnetic flux linked the entire solenoid

$\phi = N \times$ flux linked with each turn

$= N \times \mu_0 n I A \qquad n = \frac{N}{l}$

$= nl \times \mu_0 n I A$

$= \mu_0 n^2 l A I$

But $\phi = LI$

$\therefore LI = \mu_0 n^2 l A I$

$\boxed{L = \mu_0 n^2 l A}$ is the self inductance of the long solenoid.

If $N = nl$ is the total number of turns.

$n = \frac{N}{l}$

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

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

If the coil is wound over a material of high relative magnetic permeability μ_r $\therefore L = \frac{\mu_0 \mu_r N^2 A}{l} = \mu_0 \mu_r n^2 A l$.

Factors on which self inductance depends.

1. $L \propto N^2$, larger the self inductance, larger is the number of turns.

2. $L \propto A$. larger the self inductance, larger is the area of crossection.

3. Permeability of the core material: the self inductance of a solenoid increases μ_r times if it is wound over an iron core

~~Energy stored in a solenoid.~~

~~Consider a long solenoid of length 'l' area of crossection A and number of turns per unit length n. Then self inductance is given by~~

~~$L = \mu_0 n^2 l A$.~~

Energy stored in a solenoid.

Consider a source of emf is connected to an inductor L. As the current starts growing, an emf is induced in the coil which opposes the growth of current.

Consider at any instant, the current in the inductor is I. then $|\mathcal{E}| = L \frac{dI}{dt}$

If the source sends a constant current I through the inductor in time dt

Work done $= P \times t$

$= |\mathcal{E}| I \, dt$

$dW = L \frac{dI}{dt} I \, dt$

$dW = L I \, dI$

Total work done in establishing the current

$$W = \int_I dW$$

$$= \int_0^I LI\,dI$$

$$= L\int_0^I I\,dI$$

$$= L\left(\frac{I^2}{2}\right)_0^I$$

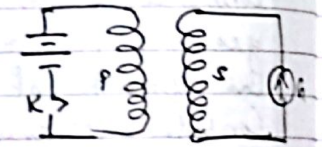
$$= \frac{1}{2}LI^2$$

This work done is called the energy

$$\therefore \boxed{U = \frac{1}{2}LI^2}$$

Mutual Inductance.

Mutual inductance is the phenomenon of production of induced emf in one coil due to a change of current in the neighbouring coil.



Consider two coils P and S placed close to each other. The coil P is connected in series to a battery and a key. The coil S is connected to a galvanometer. When a current flows through coil P, it produces a magnetic field which produces a magnetic flux through coil S. If the current in the coil P is varied the magnetic flux linked with the coil S changes which induces an emf and hence current in it, as is seen from the deflection in the galvanometer.

Coefficient of mutual induction

At any instant magnetic flux linked with one coil $\propto$ current in the other coil

ie $\phi \propto I$

$\phi = MI$

The proportionality constant M is called coefficient of mutual induction or mutual inductance.

Also the induced emf

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

$$= \frac{-d}{dt}(MI)$$

$$= -M\frac{dI}{dt}$$

If $\frac{dI}{dt} = 1$ then $\mathcal{E} = -M$

Mutual inductance of two coils may be defined as the induced emf set up in one coil when the current in the neighbouring coil changes at unit rate.

S.I unit of mutual Inductance =

$$\mathcal{E} = -M\frac{dI}{dt}$$

$$M = \frac{\mathcal{E}}{dI/dt} = \frac{1V}{1A/1s} = 1VsA^{-1}$$

$$= 1WbA^{-1}$$

$$= 1\text{ Henry (H)}$$

Dimension of Mutual inductance

$\phi = MI$

$$M = \frac{\phi}{I} = \frac{BA}{I}$$

$$= \underline{ML^2T^{-2}A^{-2}}$$

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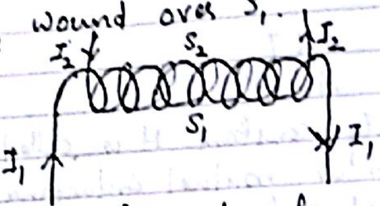
Mutual inductance of two long solenoids

Consider two long co-axial solenoids S_1 & S_2 with S_2 wound over S_1.



The length of each solenoid $= l$

r_1 and r_2 are the radii of the two solenoids.

N_1 and N_2 = number of turns in the two solenoids

The magnetic field setup inside S_2 due to I_2 is

$$B_2 = \mu_0 n_2 I_2$$

Total magnetic flux linked with the inner solenoid S_1

$$\phi_1 = B_2 A N_1$$

$$= \mu_0 n_2 I_2 A N_1 = \mu_0 \frac{N_2}{l} N_1 A I_2 \quad \text{— (1)}$$

$$\phi_1 \propto I_2$$

$\phi_1 = M_{12} I_2$ —(2) where M_{12} is the mutual inductance of coil 1 w.r.t. coil 2

from (1) & (2) $\quad M_{12} I_2 = \mu_0 \frac{N_1 N_2 A}{l} I_2$

$$\therefore \boxed{M_{12} = \frac{\mu_0 N_1 N_2 A}{l}} \quad \text{— (3)}$$

III^{ly} Magnetic field setup in S_1 due to I_1 is

$$B_1 = \mu_0 n_1 I_1$$

Total magnetic flux linked with the outer solenoid.

$$\phi_2 = B_1 A N_2$$

$$= \mu_0 n_1 I_1 A N_2$$

$$= \mu_0 \frac{N_1}{l} I_1 A N_2$$

$$= \mu_0 \frac{N_1 N_2 A}{l} I_1 \quad \text{— (4)}$$

$$\phi_2 \propto I_1$$

$\phi_2 = M_{21} I_1$ — (5) where M_{21} is the mutual inductance of coil 2 w.r.t. coil 1.

from (4) and (5)

$$M_{21} I_1 = \frac{\mu_0 N_1 N_2 A}{l} I_1$$

$$\boxed{M_{21} = \frac{\mu_0 N_1 N_2 A}{l}} \quad \text{— (6)}$$

Clearly $\quad M_{12} = M_{21} = M$

$\therefore$ Mutual inductance of two long solenoids

$$\boxed{M = \frac{\mu_0 N_1 N_2 A}{l}}$$

$$M = \frac{\mu_0 n_1 l \, n_2 l \, A}{l} \qquad \boxed{M = \frac{\mu_0 n_1 n_2 A l^2}{\cancel{l}}}$$

$$\boxed{M = \mu_0 n_1 n_2 A l}$$

Factors on which mutual inductance depends

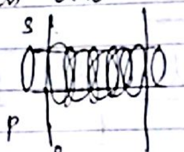
1. Number of turns :- Larger the number of turns in the two solenoids, larger will be their mutual inductance.

$$M \propto N_1 N_2.$$

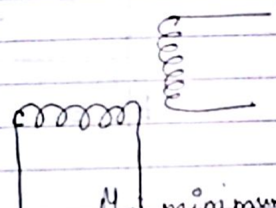
2. Common area of crossection :- Larger the area of the two solenoids, larger will be their mutual inductance $M \propto A$.

3. Relative seperation :- Larger the distance between the two solenoids, smaller will be the magnetic flux linked with the secondary coil due to current in the primary coil. Hence smaller will be the value of M.

4. Relative orientation of the two coils :- M is maximum when the ~~coil~~ ~~concentric~~ entire flux of the primary is linked with the secondary.
i.e when the primary coil completely envelopes the secondary coil.
M is minimum when the two coils are perpendicular to each other.



M is maximum.

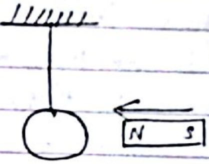

M is minimum.

Previous Year's CBSE Questions
HOT Question.

1. The electric current flowing in a wire is in the direction B to A is decreasing. What is the direction of induced current in the metallic loop kept above the wire as shown

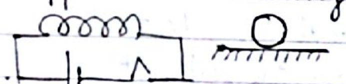
Ans: By right hand-thumb rule the magnetic field of the current in wire AB acts on the loop in a direction ⊥r to the plane of paper and inwards. By Lenz's law the induced current should oppose the change in magnetic flux so the current flows in the clockwise direction.

2. Give the direction in which the induced current flows in the wire loop, when the magnet moves towards it as shown in figure.



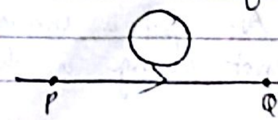
N-pole is moved in to the coil the induced current flows in the anticlockwise direction.

3. Figure shows a horizontal solenoid connected to a battery and a switch. A copper ring is placed on a frictionless track the axis of the ring being along the axis of the solenoid. What happens to the ring, as the switch is closed?



The ring moves away from the coil, because the current induced in the ring opposes the growth of current in the solenoid.

4. The current flowing in a wire is in the direction P to Q is increasing. What is the direction of induced current in the metallic loop?

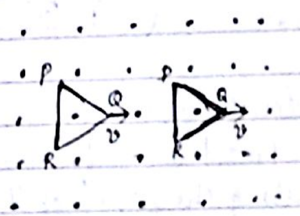


Ans. By right hand thumb rule, the magnetic field of the current in the wire PQ acts on the loop in a direction ⊥r to the plane of paper and outwards. By Lenz's law the induced current should oppose the increase of flux i.e it should produce inward flux. So the induced current flows in the clockwise direction.

5. What is the magnitude of the induced current in the circular loop KLMN, of radius 'r' of the straight wire PQ carries a steady current of magnitude 'i' A ?

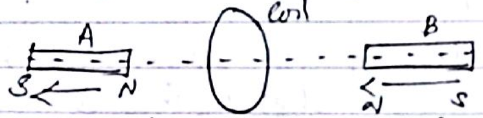
Ans. Zero, because the flux linked with the loop KLMN due to the steady current in PQ is not changing.

6. Figure shows two position of a loop PQR in a ⊥r uniform magnetic field. In which position of the coil is there an induced emf ?



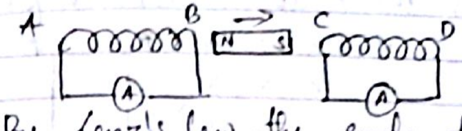
Ans: Induced emf is set up in the coil lying on the right hand side because as this coil moves out of the region of the mag. field.

7. In the given figure A & B are identical magnets. Magnet A is moved away from the coil with a given speed. Magnet B is moved towards the coil with the same speed. What is the induced emf in the coil ?



Ans. No emf is induced in the coil because there is no net change in the flux linked with the coil.

8. A magnet is moved in the direction indicated by an arrow between two coils AB and CD as shown in figure. Suggest the direction of current in each coil.



Ans. By Lenz's law, the ends of both the coils closer to the magnet will behaves as S-poles. Hence current induced in both the coils will flow clockwise.

9. How does the self-inductance of a coil change when an iron rod is introduce in it. ?

Ans. The soft iron has large relative permeability (μ_r). Its presence increases the magnetic flux μ_r times. The self inductance also increases by the same ratio.

10. A solenoid with an iron core and a bulb are connected to a d.c source. How does the brightness of the bulb change when the iron core is removed from the solenoid ?

Ans. The brightness of the bulb remains unchanged because the reactance of inductor is zero in a d.c circuit.

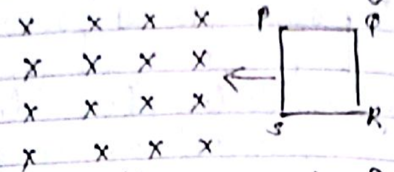
11. If the self inductance of an air core inductor increases from 0.01 mH to 10 mH on introducing an iron core into it, what is the relative permeability of the core used ?

Ans. With air core $L_0 = \frac{\mu_0 N^2 A}{l}$

With iron core $L = \frac{\mu N^2 A}{l}$

$$\mu_r = \frac{\mu}{\mu_0} = \frac{L}{L_0} = \frac{10}{0.01} = \underline{\underline{1000}}$$

12. The closed loop PQRS is moving into a uniform magnetic field acting at right angles to the plane of the paper as shown in figure. State the direction in which the induced current flows in the loop.

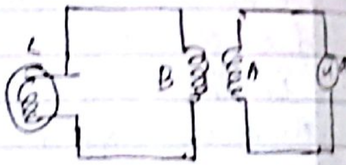


Ans: As the loop moves into the magnetic field the flux linked with the loop PQRS increases. According to Lenz's law, the induced current in the loop PQRS flows in such a direction so as to oppose this increase in flux. So induced current must flow anticlockwise i.e. along the path SRQP.

13. In figure a coil B is connected to low voltage bulb L and placed parallel to another coil A as shown. Explain the following observation

(i) Bulb lights

(ii) Bulb gets dimmer if the coil B is moved upwards.

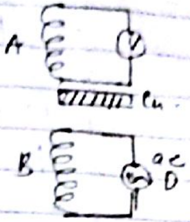


Ans. (i) Bulb lights up due to the induced current set up in coil B because of a.c in coil A.

(ii) Bulb gets dimmer when the coil B is moved upwards because the flux linked with coil B decreases and induced current also decreases.

14. A coil A is connected to a voltmeter and the other coil B to an alternating current source D. If a large 'Cu' plate C is placed between the two coils, how does the induced emf in the coil A change due to current in the coil B?

Ans: When the 'Cu' sheet is placed between the two coils, eddy currents are induced in it which oppose the passage of magnetic flux. The rate of change of magnetic flux linked with the coil A decreases. Hence the emf induced in coil A due to the change in current in coil B also decreases.



15. Predict the direction of induced current in resistance R in fig (a) & (b). Give reason for your answer.

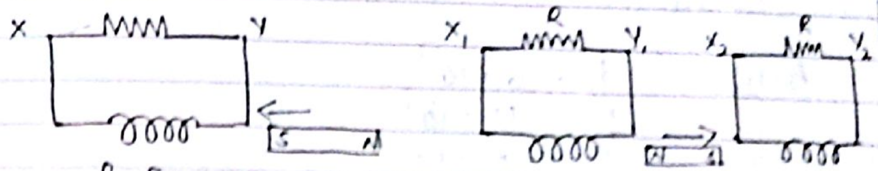
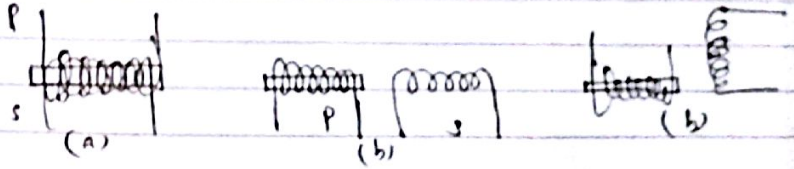


fig (a)

fig (a)

Ans: By Lenz's law, the end of the coil closer to the magnet develops S-polarity. The current induced in the coil flows clockwise when seen from the magnet side.

16. In which of the cases shown in figure, will the mutual inductance of two coils be (i) maximum and (ii) minimum if the number of turns remains the same in each case?



Ans: (i) Mutual inductance is maximum in case (a) because whole of the flux of primary is linked with the secondary.

(ii) Mutual inductance is minimum in case (c) because the flux due to the primary linked with the secondary is zero when the axes of the two coils are perpendicular to each other.

Numericals (Previous years CBSE questions).

1. The magnetic flux threading a coil changes from 12×10^{-3} Wb to 6×10^{-3} Wb in 0.01 s. Calculate the induced emf.

Ans: $\phi_2 = 6 \times 10^{-3}$

$\phi_1 = 12 \times 10^{-3}$

$t = 0.01$ s

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

$$= -\frac{(\phi_2 - \phi_1)}{t} = -\frac{[6\times10^{-3} - 12\times10^{-3}]}{0.01}$$

$$= \underline{\underline{0.6\,V}}$$