Induced EMF and Current, Lenz's law

CLASS-XII

SUBJECT : PHYSICS
CHAPTER NUMBER: 06
CHAPTER NAME : ELECTROMAGNETIC INDUCTION

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Lenz’s Law:

The direction of the induced emf or induced current is such that it opposes the change that is producing it.

i.e. If the current is induced due to motion of the magnet, then the induced current in the coil sets itself to stop the motion of the magnet.

If the current is induced due to change in current in the primary coil, then induced current is such that it tends to stop the change.

Lenz’s Law and Law of Conservation of Energy:

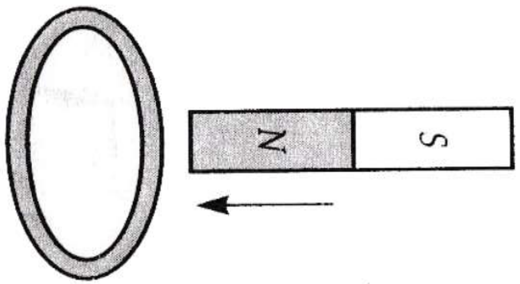
According to Lenz’s law, the induced emf opposes the change that produces it. It is this opposition against which we perform mechanical work in causing the change in magnetic flux. Therefore, mechanical energy is converted into electrical energy. Thus, Lenz’s law is in accordance with the law of conservation of energy.

If, however, the reverse would happen (i.e. the induced emf does not oppose or aids the change), then a little change in magnetic flux would produce an induced current which would help the change of flux further thereby producing more current. The increased emf would then cause further change of flux and it would further increase the current and so on. This would create energy out of nothing which would violate the law of conservation of energy.

Lenz's Law:

Example – 1, (Attraction and repulsion concept)

Suppose an N-pole of a bar magnet is being pushed towards the coil.

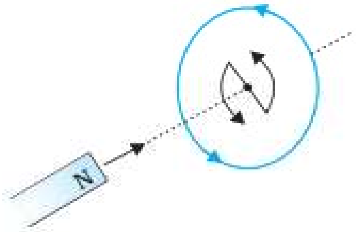


As it moves, the magnetic flux through the coil increases

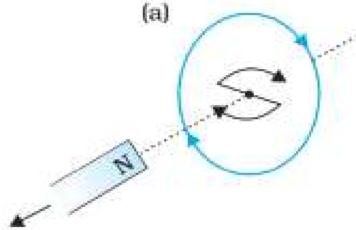
Current is induced in the coil

The direction of induced current in the coil is in such a direction that it opposes the increase in flux

This is possible only if the current in the coil is in anticlockwise direction w.r.t an observer situated on the side of the magnet.



(a)

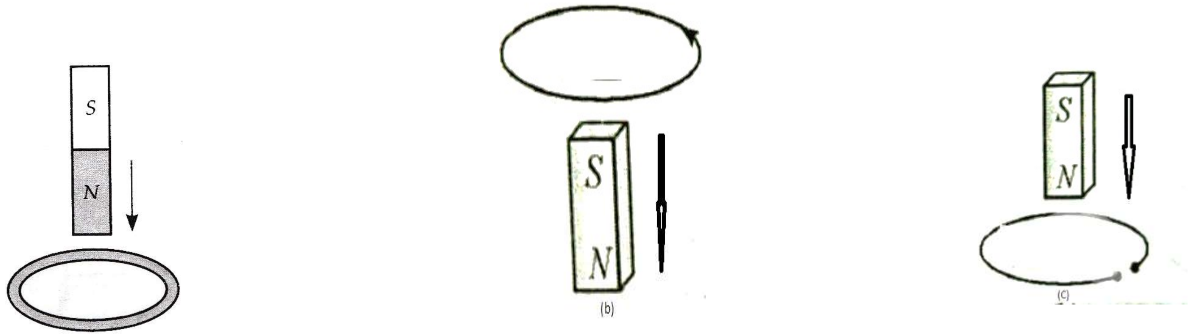


(b)

Note:-The direction shown by N and S indicate the directions of induced current.

NUMERICAL

Question: -A copper ring is held horizontally and a bar magnet is dropped through the ring with its length along the axis of the ring as shown in the following diagrams. State whether its acceleration a is equal to greater than or less than the acceleration due to gravity g.



NUMERICAL

Solution:-

(a) $a = \frac{mg - F}{m} = g - \frac{F}{m}$

Whereof the bar magnet

$F \rightarrow$ Force of repulsion on approaching magnet

Hence a < g

(b) $a = \frac{mg - F}{m} = g - \frac{F}{m}$

$\Rightarrow a < g$

Here, F is the force of attraction on receding magnet

(c) Here an emf will be induced in the ring but no current will flow. So the coil can no more oppose the approach of the magnet. Hence a = g

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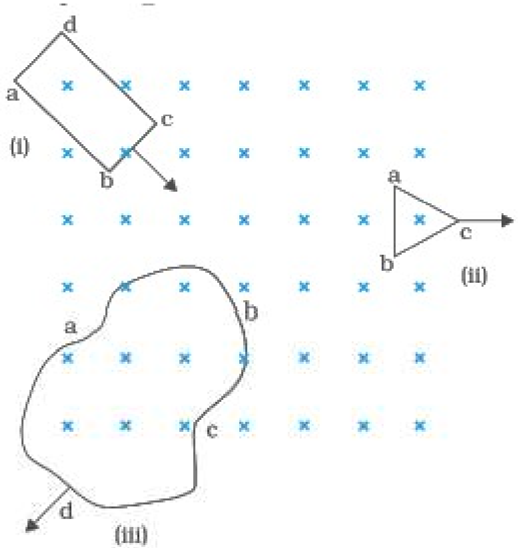
Lenz’s Law:

The figure shows planar loops of different shapes moving out of or into a region of the magnetic field which is directed normal to the plane of the loop away from the reader. Determine the direction of induced current in each loop using Lenz’s law.



Lenz's Law:

Solution:-

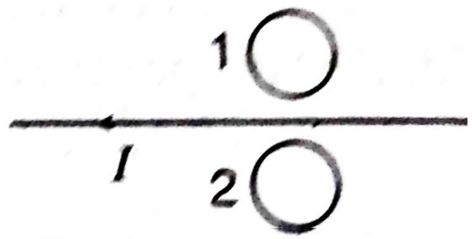
(a) Due to the motion of loop abcd into the region of the magnetic field. The cross magnetic field ⊗ through loop increases. Then induced current will produce dot magnetic field to produce ⊙ a magnetic field, the induced current should be anti-clockwise (follow along the path bcdab)

(b) Due to the outward motion of the triangular loop (abc), the cross magnetic field ⊗ through abc decreases. Then induced current will produce a cross magnetic field to produce ⊗ magnetic field, the induced current should be clockwise (follow along the path bacb)

(c) Clockwise (along path cdabc)

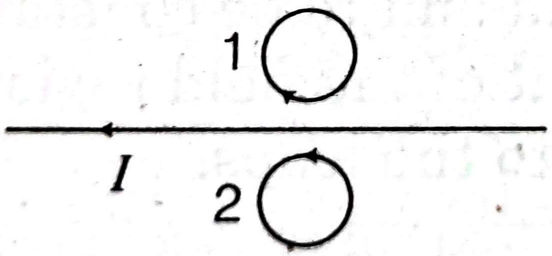
Numerical

Question: Predict the direction of induced current in metal rings 1 and 2 when current I in the wire is steadily decreasing?



Numerical

12. Current in the wire is steadily decreasing, so the induced current in rings 1 and 2 will flow in such a way that it opposes the decrease of current. So, it will flow in same direction. Now, from the figure. It is clear that the direction of induced current in



(i) ring 1 is clockwise.
(ii) ring 2 is anti-clockwise. **(1)**

Numerical

Question: An aeroplane is flying horizontally from west to east with a velocity of 900 km/h. Calculate the potential difference developed between the ends of its wings having a span of 20 m. The horizontal component of the earth's magnetic field is $5 \text{ x } 10^{-4}\ T$ and the angle of dip is 30^0.

Numerical

15. Given, $v = 900$ km/h

$$= 900 \times \frac{5}{18} = 250 \text{ m/s}$$

l = distance between the ends of the wings

$= 20$ m

Dip angle, $\delta = 30^\circ$

Horizontal component of earth's field

$= B_H = 5 \times 10^{-4}$ T **(1)**

Potential difference induces due to cutting of vertical field lines. So, induced emf

$$= B_V \cdot l \cdot v = \frac{B_H}{\cos\delta} \cdot \sin\delta \cdot l \cdot v$$

$$= B_H \cdot \tan\delta \cdot l \cdot v$$

$(\because B_H = B\cos\delta \text{ and } B_V = B\sin\delta)$

$$= 5 \times 10^{-4} \times \tan 30^\circ \times 20 \times 250$$

$$= \frac{2.5}{\sqrt{3}} \approx 1.45 \text{ V}$$

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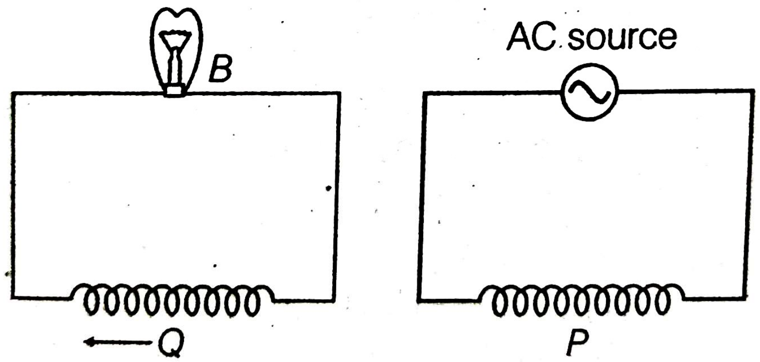
Numerical

Question: A coil Q is connected to low voltage bulb B and placed near another coil P as shown in the figure. Give reasons to explain the following observations.

a) The bulb B lights.

b) Bulb gets dimmer, if the coil Q is moved towards left.



Numerical

23. Induced current, is responsible for the lighting of the bulb, which depends on change of flux.

(i) Due to varying current in *P*, the flux linked with *P* change and hence *Q* changes, which in turn induces the emf in *Q* and bulb *B* lights, where *P* and *Q* are coils. **(1)**

(ii) When *Q* is moved left or it goes away from *P*, the lesser flux change takes place in *Q*. This leads to decrease in the value of rate of change of magnetic flux and hence, lesser emf and bulb *B* gets dimmer. **(1)**

THANKING YOU

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