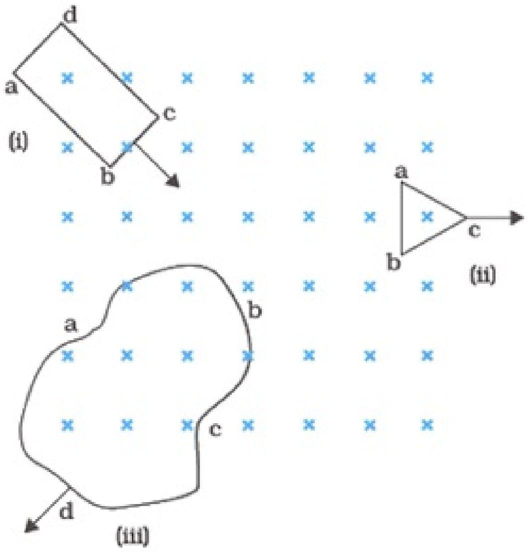
CBSE Test Paper-04

Class - 12 Physics (Electromagnetic Induction)

1. Figure shows planar loops of different shapes moving out of or into a region of a magnetic field which is directed normal to the plane of the loop away from the reader. Direction of induced current in i,ii and iii are



   a. clockwise, clockwise, clockwise
   b. anti-clockwise, clockwise, clockwise
   c. anti-clockwise, anti-clockwise, clockwise
   d. anti-clockwise, clockwise, anti-clockwise

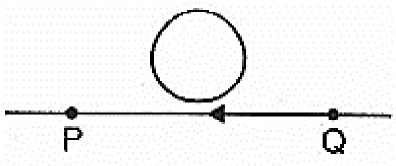
2. The coefficient of mutual inductance, when magnetic flux changes by 2 x 10^{-2} Wb and current changes by 0.01 A in 1 sec is:
   a. 3 H
   b. 2 H
   c. 4 H
   d. 28 H

3. A 500-loop circular wire coil with radius 4.00 cm is placed between the poles of a large electromagnet. The magnetic field is uniform and makes an angle of 60° with the plane of the coil; it decreases at 0.200 T/s . Magnitude of induced emf is
   a. 0.435 V
   b. 0.455 V
   c. 0.495 V

   d. 0.475 V

4. Kamla peddles a stationary bicycle the pedals of the bicycle are attached to a 100 turn coil of area $0.10 m^2$. The coil rotates at half a revolution per second and it is placed in a uniform magnetic field of 0.02 T perpendicular to the axis of rotation of the coil. What is the maximum voltage generated in the coil?
   a. 0.314
   b. 0.628
   c. 0.714
   d. 0.554
5. Eddy Currents are
   a. gaseous currents
   b. induced solar currents that circulate through out a river and are swirling.
   c. plasma currents
   d. induced currents that circulate throughout the volume of a material similar to swirling eddies in a river.

6. The electric current passing through a wire in the direction from Q to P is decreasing. What is the direction of induced current in the metallic loop kept above the wire as shown in the figure?



7. How does the self inductance of a coil change when an iron rod is introduced in the coil?

8. How does the mutual inductance of a pair of coils change when the number of turns in each coil is decreased?

9. A coil of inductance 2 mH carrying a current 2A is given. If the current is reversed in 0.01 seconds, how much back emf is produced?

10. A cylindrical bar magnet is kept along the axis of a circular coil. Will there be a current induced in the coil if the magnet is rotated about its axis? Give reasons.

11. A metallic rod of length Lis rotated with angular frequency of ω with one end hinged

at the centre and the other end at the circumference of a circular metallic ring of radius L, about an axis passing through the centre and perpendicular to the plane of the ring. A constant and uniform magnetic field B parallel to the axis is present everywhere. Deduce the expression for the emf between the centre and the metallic ring.

12. The two rails of a railway track, insulated from each other, and the ground, are connected to a millivoltmeter. What is the reading of the voltmeter when a train travels at a speed of 180 km h-1 along the track? Given vertical component of earth's magnetic field $= 0.2 \times 10^{-4}\ T$ and the separation between the rails = 1m.

13. A square loop of side 12 cm with its sides parallel to X and Y-axis is moved with a velocity of $8\ cms^{-1}$ in the positive x-direction in an environment containing a magnetic field in the positive z-direction. The field is neither uniform in space nor constant in time. It has a gradient of $10^{-3}\ Tcm^{-1}$ along the negative x-direction (i.e. it increases by $10^{-3}\ Tcm^{-1}$ as one moves in negative x-direction), and it is decreasing in time at the rate of $10^{-3}\ Ts^{-1}$. Determine the direction and magnitude of the induced current in the loop if its resistance is $4.5\ m\Omega$.

14. A circular coil of radius 8.0 cm and 20 turns rotates about its vertical diameter with an angular speed of $50\ rads^{-1}$ in a uniform horizontal magnetic field of magnitude $3 \times 10^{-2}\ T$. Obtain the maximum and average emf induced in the coil. If the coil forms a closed loop of resistance $10\ \Omega$ calculate the maximum value of current in the coil. Calculate the average power loss due to Joule heating. Where does this power come from?

15. Two long parallel horizontal rails, distance d apart and each having a resistance λ per unit length, are joined at one end by a resistance R. A perfectly conducting rod MN of mass m is free to slide along the rails without friction. There is a uniform magnetic field of induction B normal to the plane of the paper and directed into the paper. A variable force F is applied to the rod MN such that as the rod moves, constant current flows through R.
    i. Find the velocity of the rod and the applied force F as function of the distance x of the rod from R.
    ii. What fraction of the work done per second by F is converted into heat?

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Answers

1. b. anti-clockwise, clockwise, clockwise

   Explanation:

   i. Due to motion, the magnetic flux linked with the loop abcd increases. According to lenz's law this increase in flux is opposed by the induced current. Therefore, the induced current must flow anticlockwise
   ii. Due to motion, the magnetic flux linked with the loop abc decreases. So that induced current is clockwise.
   iii. Due to motion, the magnetic flux linked with the loop decreases. So that induced current is clockwise.

2. b. 2 H

   Explanation: rate of change of flux = induced emf

   hence e = 2×10^{-2}

   $\frac{di}{dt} = 0.01$

   $\mathrm{M} = \frac{e}{di/dt} = \frac{2\times10^{-2}}{0.01} = 2\mathrm{H}$

3. a. 0.435 V

   Explanation: $e = \frac{d\phi}{dt} = 0.2 \times 500 \times 3.14 \times \left(4 \times 10^{-2}\right)^2 \times \sqrt{\frac{3}{2}} = 0.435\mathrm{V}$

4. b. 0.628

   Explanation: Maximum voltage

   $e_0 = NBA\omega$

   $\omega = 2\pi n = 2 \times 3.14 \times 0.5$

   $e_0 = NBA\omega = 100 \times 0.02 \times 0.1 \times 2 \times 3.14 \times 0.5 = 0.628\mathrm{V}$

5. d. induced currents that circulate throughout the volume of a material similar to swirling eddies in a river.

   Explanation: Eddy currents (also called Foucault currents) are loops of electrical current induced within conductors by a changing magnetic field in the conductor, due to Faraday's law of induction. Eddy currents flow in closed loops within conductors, in planes perpendicular to the magnetic field. By lenz's law an eddy current creates a magnetic field that opposes a change in the magnetic field that created it, and thus eddy currents react back on the source of the magnetic field.

6. Clockwise.

7. The self-inductance shall increase, since $L \propto \mu_r$.

8. It will decrease $[\because M \propto N_1 N_2]$.

9. The current reverses in 0.01 s, this means the time period is 0.01/2 = 0.005 s
Induced EMF, $\varepsilon = -L\frac{dI}{dt}$
$= 2 \times 10^{-3} \times \frac{2}{0.005}$ = 0.8 V

10. No because, ϕ = NBA = constant
$\therefore e = \frac{d\phi}{dt} = 0$; i = 0

11. To calculate the induced emf first we have to find the change in flux, here change in flux occurs due to change in area because of the revolution of the rod.

    Angular velocity of rod, $\omega = \frac{2\pi}{T}$.
    Where, T = time period
    $\therefore$ Change in flux in one revolution = $BA = B(\pi L^2)$
    According to Faraday's law of EMI, magnitude of induced emf
    $e = d\phi/dT = B\pi L^2/T \Rightarrow e = B\pi L^2/(2\pi/\omega)[\because T = 2\pi/\omega]$
    $e = \frac{1}{2}B\omega L^2$
    This is the required expression.

12. The induced emf generated is given by
$\varepsilon = -\frac{dQ}{dt} = -\frac{d}{dt}(B.A) = -B\frac{dA}{dt}$
where A is the area and B, the magnetic field. If l is the distance between the rails and v, the speed of the train, then
$\frac{dA}{dt} = lv$
$e = -Blv$
Here l = 1 m and B $= 0.2 \times 10^{-4}\ T$ Thus we have
$v = \frac{180 \times 1000}{3600} = 50\ ms^{-1}$

$|e| = 0.2 \times 10^{-4} \times 1 \times 50$

$= 1 \times 10^{-3}\ V$ = 1 mV

Hence, the millivoltmeter will read 1 mV.

13. $A = (12 \times 10^{-2}) = 144 \times 10^{-4}\ m^2$

$v = 8\ cm/s = 8 \times 10^{-2}\ m/s$

$\frac{dB}{dt} = 10^{-3}\ T/sec$

$\frac{dB}{dx} = 10^{-3}\ T/cm = 10^{-1}\ T/m$

Induced emf due to change of magnetic field B with time t

$\varepsilon_1 = \frac{dQ}{dt} = \frac{dB.A}{dt} = \frac{A.dB}{dt} = 144 \times 10^{-4} \times 10^{-3}$

$\varepsilon_1 = 144 \times 10^{-7}\ V \ldots (I)$

Induced emf due to change of magnetic field B with distance (x)

$\varepsilon_2 = \frac{dQ}{dt} = \frac{d}{dt}BA = A.\frac{dB}{dt}$

$\varepsilon_2 = A.\frac{dB}{dt}.\frac{dx}{dt} = 144 \times 10^{-4} \times 10^{-1} \times 8 \times 10^{-2}$

$\varepsilon_2 = 1152 \times 10^{-7}$

Total emf$= \varepsilon_1 + \varepsilon_2 = 144 \times 10^{-7} + 1152 \times 10^{-7}$

$= 1296 \times 10^{-7}\ V$

$\varepsilon = 129.6 \times 10^{-6}\ V$

R = 4.5 milli ohm

Induced current $\frac{\varepsilon}{R} = \frac{129.6 \times 10^{-6}}{4.5 \times 10^{-3}} \cong 2.9 \times 10^{-2}\ A$

14. Flux through each turn,

$\phi = \overrightarrow{B}.\overrightarrow{A} = BA\cos\theta$

or $\phi = B\pi r^2 \cos(\omega t)$

For N turns, $\phi_T = NB\pi r^2 \cos(\omega t)$

The induced emf $|\varepsilon| = \frac{d\phi_T}{dt}$

$= \frac{d[NB\pi r^2 \cos(\omega t)]}{dt}$

$|\varepsilon| = NB\pi r^2 \omega \sin(\omega t)$

The maximum emf,

$\varepsilon_0 = NB\pi r^2 \omega$

$= 20 \times 50 \times \pi \times 64 \times 10^{-4} \times 3.0 \times 10^{-2}$

= 0.603 V

The average emf over a cycle = 0

The maximum current,
$I_0 = \frac{\varepsilon}{R} = \frac{0.603}{10}$ = 0.0603 A
Power loss,$P = \frac{1}{2} E_0 I_0 = \frac{1}{2} \times 0.603 \times 0.0603$ = 0.018 W
The induced current causes a restoring torque in the coil. An external source is responsible for the supply of energy for this torque. So we can say that source of this power is the external rotor.

15. Let the distance from R to MN be x. Then the area of the loop between MN and R is xd and the magnetic flux linked with the loop is B x d. As the rod moves, the emf induced in the loop is given by
$|\varepsilon| = \frac{d}{dt}(Bxd) = Bd\frac{dx}{dt} = Bvd$
Where v is the velocity of MN. The total resistance of the loop between R and MN is $R + 2\lambda r$. The current in the loop is given by$i = \frac{|e|}{R+2\lambda x} = \frac{Bvd}{R+2\lambda x}$
    i. Force acting on the rod,
    $F = iBd = \frac{B^2 d^2}{R+2\lambda x} v$
    $\therefore m\frac{dv}{dt} = \frac{B^2 d^2}{R+2\lambda x} \cdot \frac{dx}{dt}$
    or $dv = \frac{B^2 d^2}{m} \cdot \frac{dx}{R+2\lambda x}$
    On integrating both sides, we get
    $v = \frac{B^2 d^2}{2\lambda m} In\left(\frac{R+2\lambda x}{R}\right)$
    and Force $= \frac{B^2 d^2}{R+2\lambda x} \cdot \frac{B^2 d^2}{2\lambda m} In\left(\frac{R+2\lambda x}{R}\right)$
    ii. Work done per second = Fv
    Heat produced per second $= i^2 (R + 2\lambda x)$
    $= \left(\frac{Bvd}{R+2\lambda x}\right)^2 (R + 2\lambda x)$
    $= \left(\frac{B^2 d^2 v}{R+2\lambda x}\right) \cdot v$
    = F . v
    Thus, the ratio of heat produced to work done is I. The entire work done by F per second is converted into heat.