CBSE Test Paper-03

Class - 12 Physics (Electromagnetic Induction)

1. It is desired to measure the magnitude of field between the poles of a powerful loud speaker magnet. A small flat search coil of area 2 cm^2 with 25 closely wound turns, is positioned normal to the field direction, and then quickly snatched out of the field region. Equivalently, one can give it a quick 90° turn to bring its plane parallel to the field direction). The total charge flown in the coil (measured by a ballistic galvanometer connected to coil) is 7.5 mC. The combined resistance of the coil and the galvanometer is 0.50Ω. Field strength of magnet is

    a. 0.85 T
    b. 0.75 T
    c. 0.90 T
    d. 0.65 T

2. The instantaneous magnetic flux linked with a coil is given by
    $\phi = 5t^3 - 100t + 300$ Wb
    The EMF induced in the coil at time t = 2 second is

    a. 140V
    b. 300V
    c. -40V
    d. 40V

3. According to Lenz's law.

    a. The polarity of induced emf is such that it tends to produce a current which aids the change in magnetic flux that produced it.
    b. The induced emf is proportional rate of change in magnetic flux that produced it.
    c. The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.
    d. The induced emf is proportional change in magnetic flux that produced it.

4. A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of a region of uniform magnetic field of magnitude 0.3 T directed normal to the loop. What is the emf developed across the cut if the velocity of the loop is 1 cm s^{-1} in a direction normal to the shorter side of the loop? For how long does the induced voltage last _____?

   a. $0.6 \times 10^{-4}\mathrm{V}$, lasting 8 s
   b. $1.1 \times 10 - 4\mathrm{V}$, lasting 8 s
   c. $0.6 \times 10 - 4\mathrm{V}$, lasting 6 s
   d. $0.8 \times 10 - 4\mathrm{V}$, lasting 8 s

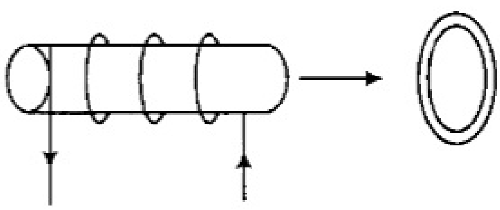
5. Two coils C_1 , C_2 have N_1 and N_2 turns respectively. Current i_1 in coil C_1 is changing with time. If $\Phi 2$ is the magnetic flux through C_2, Mutual inductance given by

   a. $\frac{N_2 \Phi_2}{i_1}$
   b. $\frac{i_1}{N_2 \Phi_2}$
   c. $\frac{N_2 \Phi_2}{i_2}$
   d. $\frac{i_2}{N_2 \Phi_2}$

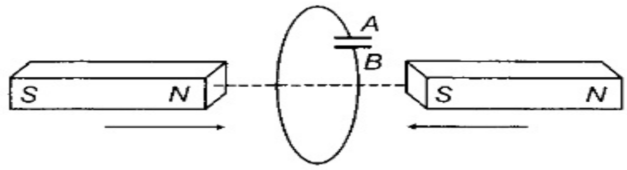
6. When a magnet falls through a vertical coil, will its acceleration be different from the 'acceleration due to gravity'?

7. Magnetic field lines can be entirely confined within the core of a toroid, but not within a straight solenoid. Why?

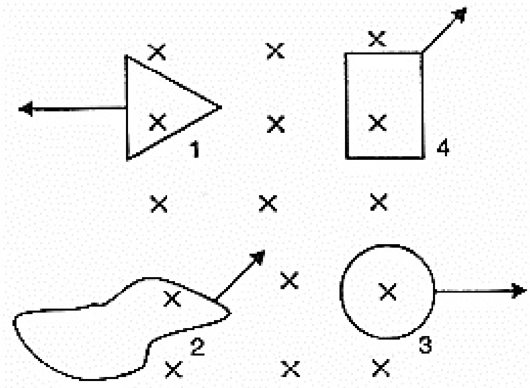
8. Figure shows a current carrying solenoid moving towards conducting loop. Find the direction of the current induced in the loop.



9. Predict the polarity of the capacitor in the situation described by adjoining as shown in figure. Explain the reason too.



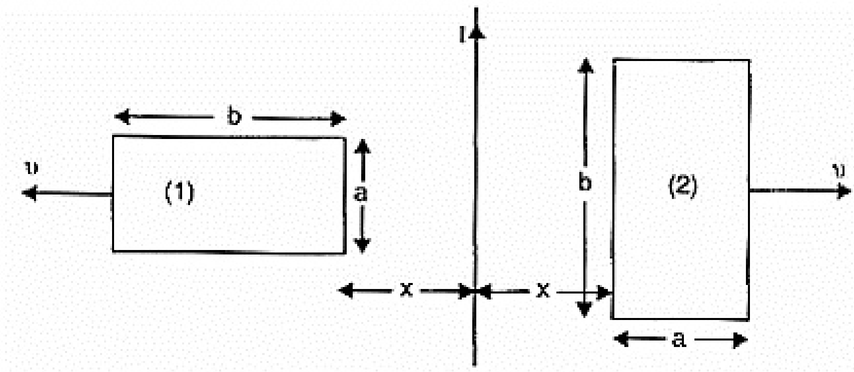
10. The loops in the figure move into or out of the field which is along the inward normal to the plane of the paper. Indicate the direction of currents in loops 1, 2, 3, 4.



11. The induced emf is sometimes called 'back emf' why?

12. The figure shows two identical rectangular loops (1) and (2) placed on a table along with a straight long current carrying conductor between them.

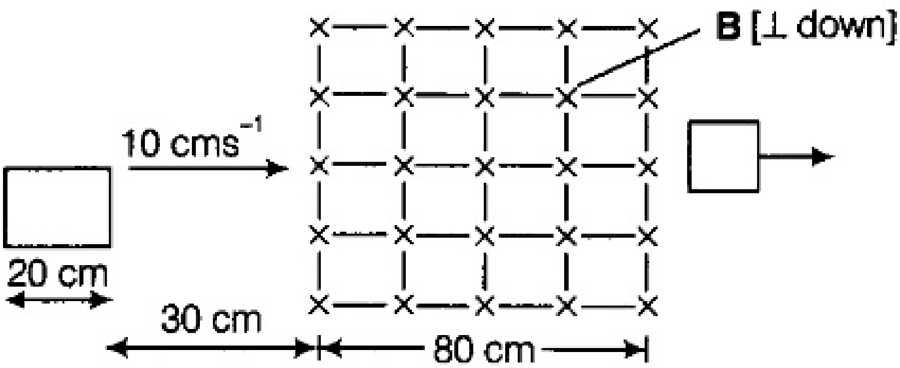
    i. What will be the directions of the induced current in the loops when they are pulled away from the conductor with same velocity v?
    ii. Will the emf induced in the two loops be equal?



13. A square loop of side 20 cm is initially kept 30 cm away from a region of uniform magnetic field of 0.1 T as shown in the figure. It is then moved towards the right with a velocity of 10 cm s^{-1} till it goes out of the field. Plot a graph showing the variation of

    i. magnetic flux (ϕ) through the loop with time (t).

ii. induced emf (ε) in the loop with time t.
iii. induced current in the loop, if it has resistance of 0.1Ω



14. Two different coils have self inductances, L_1 = 8mH and L_2 = 2mH. At a certain instant, the current in the two coils is increasing at the same constant rate and the power supplied to the two coil is the same.
Find the ratio of :

a. induced voltage
b. current and
c. energy stored in the two coils at that instant?

15. i. Explain the meaning of the term mutual inductance. Consider two concentric circular coils, one of the radius r_1 and the other of radius $r_2(r_1 < r_2)$ placed coaxially with centres coinciding with each other. Obtain the expression for the mutual inductance of the arrangement.
ii. A rectangular coil of area A, having number of turns N is rotated at f revolutions per second in a uniform magnetic field B, the field being perpendicular to the coil. Prove that the maximum emf induced in the coil is.

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Answers

1. b. 0.75 T

   Explanation: $i = \frac{dq}{dt} = \frac{e}{R}$

   $|e| = \frac{d\phi}{dt} = \frac{(dNBA)}{dt}$

   $q = \frac{NBA}{R}$

   $B = \frac{qR}{NA} = \frac{7.5 \times 10^{-3} \times 0.5}{25 \times 2 \times 10^{-4}} = 0.75T$

2. d. 40 V

   Explanation: $e = -\frac{d\phi}{dt} = -\frac{d(5t^3 - 100t + 300)}{dt}$

   $e = -\left(15t^2 - 100\right)$

   at t = 2 sec

   $e = -[(15 \times 4) - (100)]$

   e = 40 V

3. c. The polarity of induced emf is such that it tends to produce a current which opposes the change in magnetic flux that produced it.

   Explanation: The direction of an induced emf, or the current, in any circuit is such as to oppose the cause that produces it.

   If the direction of the induced current were such as not to oppose then we would be obtaining electrical energy continuously without doing work, which is impossible.

4. a. $0.6 \times 10^{-4}\mathrm{V}$, lasting 8 s

   Explanation: $|e| = Bl_2 v = 0.3 \times (2 \times 10^{-2}) \times 10^{-2} = 0.6 \times 10^{-4}$

   Duration of |e| is equal to $\frac{l_1}{v} = \frac{8 \times 10^{-2}}{10^{-2}} = 8\text{sec}$

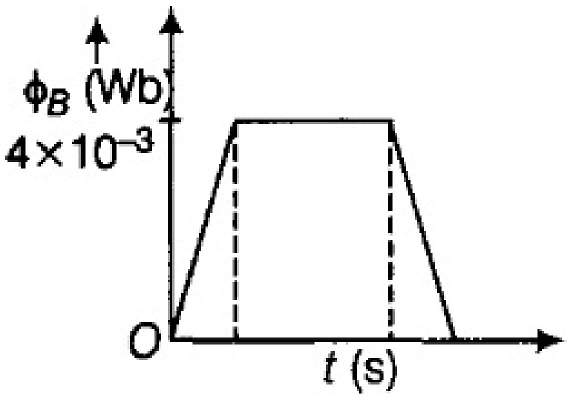
5. a. $\frac{N_2 \Phi_2}{i_1}$

   Explanation: $N_2 \phi_2 \propto i_1$

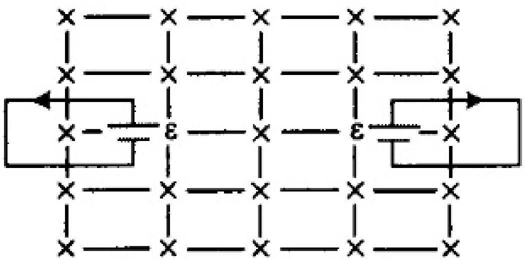
   $N_2 \phi_2 = M i_1$

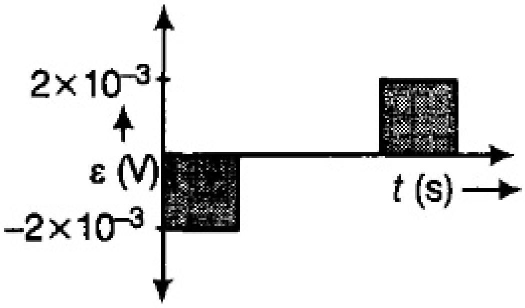
   $M = \frac{N_2 \phi_2}{i_1}$

6. Yes, this is because the motion of the magnet will be opposed in accordance with Lenz's law.

7. Because the magnetic field induction outside the toroid is zero.
8. According to Lenz law the direction of current in the coil is anti-clockwise.
9. According to figure shown in the question, induced current is in anti-clockwise, when seen from left hand side and its direction is in clockwise when seen from right hand side.(direction of current seen from both sides are identified from Lenz's law) Thus, direction of induced current is in clockwise sense.
   This implies that plate A of the capacitor is at the higher potential than plate B(since current is directed from higher to lower potential), i.e. B is a negative plate while A is a positive plate.
10. In 1, flux decreases and so induced current must be clockwise to increase the flux. Due to the same reason currents in 3 and 4 are clockwise but in 2 current must be anticlockwise as flux is increasing.
11. The induced emf is sometimes called 'back emf' because a large current in a coil that is suddenly removed will cause the magnetic field in the coil to collapse and cause a current in the opposite direction.
12. i. The direction of induced current will be such that it tends to maintain the original flux. So induced current flows anticlockwise in loop 1 and clockwise in loop 2.
    ii. No, the emf's induced in the two loops will not be equal.
13. Given, I = 20cm = 0.2m,
    $B = 0.1T, v = 10\text{cms}^{-1} = 0.1\text{ms}^{-1}$
    i. Magnetic flux through loop, $\phi_B = \vec{B} \cdot \vec{A} = BA\text{cos}0^0 = Blx$ (with A = lx)
       $\phi_{\text{max}} = 0.1 \times 0.2 \times 0.2 = 0.004\text{Wb} = 4 \times 10^{-3}\text{Wb}$ (for maximum flux x = l = 0.2m)
       

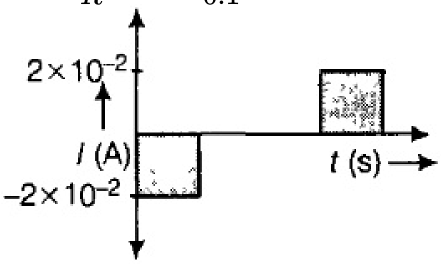
    ii. Induced emf, $\varepsilon = \frac{-d\phi}{dl} = -Blv$
       $|\varepsilon|_{max} = 0.1 \times 0.2 \times 0.1 = 0.002V = 2 \times 10^{-3}\text{V}$





iii. Induced current,

$$I = \frac{|\varepsilon|}{R} = \frac{2\times10^{-3}}{0.1} = 2 \times 10^{-2}\text{A}$$



14. From $e = L\frac{dI}{dt}, \frac{e_1}{e_2} = \frac{L_1}{L_2} = \frac{8}{2} = 4$

Since, P = e I = constant

$\frac{dI_1}{dt} = \frac{dI_2}{dt}$

$P_1 = P_2 = P$

$e_1I_1 = e_2I_2$

$\therefore \frac{I_1}{I_2} = \frac{e_2}{e_1} = \frac{1}{4}$

$\frac{I_1}{I_2} = \frac{e_2}{e_1}$

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

$\therefore \frac{U_1}{U_2} = \frac{\frac{1}{2}L_1}{\frac{1}{2}L_2}\left(\frac{I_1}{I_2}\right)^2 = \frac{8}{2}\left(\frac{1}{4}\right)^2 = \frac{1}{4}$

15. i. Whenever 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 be induced in the neighbouring coil or circuit. This phenomenon is called 'mutual induction'. Now, mutual inductance is the induced magnetic flux linked with one coil when unit current flows in the other neighbouring coil.

According to the question, let the current in big coil of radius r_2 be I_1, so, magnetic field at point o(i.e. at the centre) due to this coil will be $\mu_0 I_1/2r_2$.

Change in magnetic flux in the coil of radius

r_1 is, $\phi = BA = \frac{\mu_0 I_1}{2r_2} \times \pi r_1^2$

Now, mutual inductance, $M = \frac{\phi}{I_1} = \frac{\mu_0 I_1 \pi r_1^2}{2r_2 \times I_1} = \frac{\mu_0 \pi r_1^2}{2r_2}$

This is the required expression.

ii. According to question, if the coil having N turns rotates with an angular velocity of ω through an angle θ in time t, thus $\theta = \omega t$

$\therefore \phi = \vec{B}.\vec{A} = BA\cos\theta = BA\cos\omega t$

As the coil rotates, the magnetic flux linked with it changes. An induced emf is set up in the coil, which is given by

$e = \frac{-d\phi}{dt} = \frac{-d}{dt}(BA\cos\omega t) = BA\omega\sin\omega t$ (From Faraday's 2nd law of electromagnetic induction with Lenz's correction)

For N number of turns, $e = NBA\omega \sin \omega t$

For maximum value of emf, rotation of the coil must be equal to 90°.

So, maximum emf induced, is = $NBA\omega \sin 90^0 = NBA\omega$

$i.e. e = NBA \times 2\pi f = 2\pi NBAf \ [\because \omega = 2\pi f]$