PHYSICS

NCERT - FULL MARKS PHYSICS(TAMIL)

ELECTROMAGNETIC INDUCTION

Examples

1. Consider Experiment II in Section 6.2.

a. What would you do to obtain a large deflection of the galvanometer?

b. How would you demonstrate the presence of an induced current in the absence of a galvanometer?

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2. A square loop of side 10 cm and resistance 0.5 Ω is placed vertically in the east-west plane. A uniform magnetic field of 0.10 T is set up across the plane in the north-east direction. The magnetic field is decreased to zero in 0.70 s at a steady rate. Determine the magnitudes of induced emf and current during this time-interval.

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3. A circular coil of radius 10 cm, 500 turns and resistance 2 Omega is placed with its plane prependicular to the horizontal component of the earth's magnetic field. It is rotated about its vertical diameter through 180° in 0.25 s. Estimate the magnitude of the e.m.f and current induced in the coil. Horizotal component of earth's magnetic field at the place is $3 \times 10^{-5}T$.

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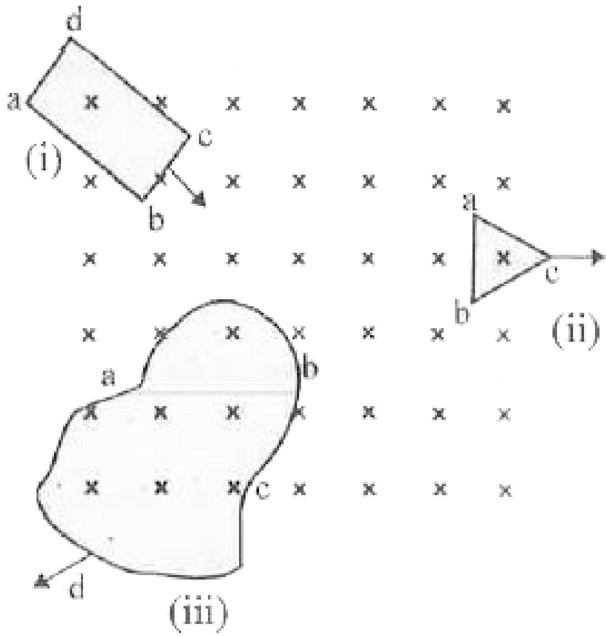
4. Figure shows planar loops of different shapes moving out of or into a region of a magnetic field which is directed normal to the plane of the loop away from the reader. Determine the direction of induced current in each loop using Lenz's law.



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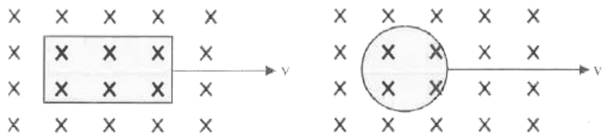
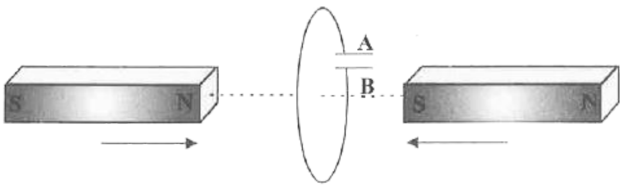
5. a. A closed loop is held stationary int eh magnetic field between the north and south poles of two permanent magnets held fixed. Can we hope to generate current in the loop by using very strong magnets?

b. A closed loop move normal to the constant electric field between the plates of a large capacitor. Is a current induced in the loop (i) when it is wholly inside the region between the capacitor plates (ii) when it is partially outside the plates of the capacitor? The electric field is normal to the plane of the loop.

c. A rectangular loop and a circular loop are moving out of a uniform magnetic field (region). (see fig.) to field-free region with a constant velocity v. In which loop do you expect the induced emf to be constant during the passage out of the field region? The field is normal to the loops.



d. Predict the polarity of the capacitor in the situation described by the figure below.



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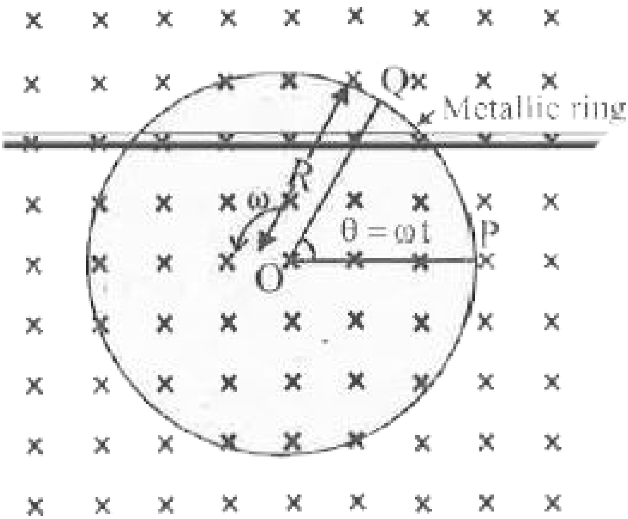
6. A metallic rod of 1m length is rotated with a frequency of 50 rev/s, with one end hinged at the centre and the other end at the circumference of a circular me tallic ring of radius 1m, about an axis passing through the centre and perpendicular to the plane of the ring (see figure). A constant and uniform magnetic field of 1T parallel to the axis present everywhere. What is the emf between the centre and the metallic ring?



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7. A wheel with 10 metallic spokes each 0.5 m long is rotated with a speed of 120 rev/min in a plane normal to the horizontal component of earth's magnetic field H_E at a place. If H_E 0.4 G at the place, what is the induced emf between the axle and the rim of the wheel ? Note that $1G = 10^{-4}T$.

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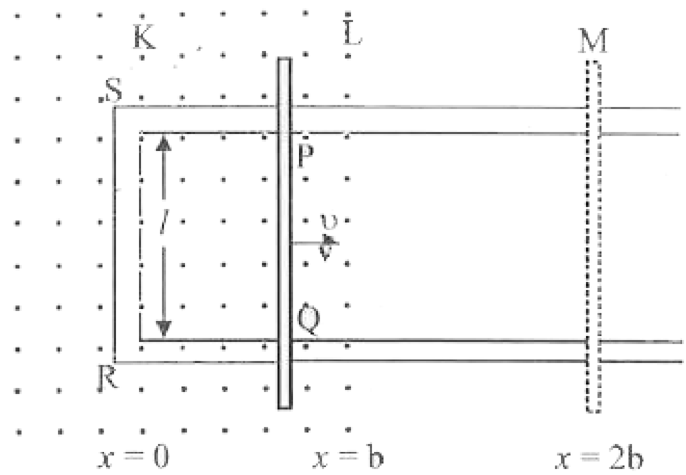
8. The arm PQ of the rectangular conductor is moved from $x = 0$, outwards. The uniform magnetic field is perpendicular to the plane and extends from $x = 0$ to $x = b$ and is zero for $x > b$. Only the arm. PQ possesses substantial resistance r. Consider the situation when the arm PQ is pulled outwards from $x = 0$ to $x = 2b$, and is then moved back to $x = 0$ with constant speed v. Obtain expressions for the flux, the induced emf, the force necessary to pull the arm and the power dissipated as Joule heat. Sketch the variation of these quantities with distance.



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9. Two concentric circular coil,s one of small radius r_1 and the other of large radius r_2, such that $r_1 < \; < r_2$, are placed co-axially with centres coinciding. Obtain the mutual inductance of the arrangement.

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10. (a) Obtain the expression for the magnetic energy stored in a solenoid in terms of magnetic field B, area A and length l of the solenoid. (b) How does this magnetic energy compare with the electrostatic energy stored in a capacitor?

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11. Suppose the loop in Exercies.4 is stationary but the current feeding the electromagnetic net that produces the magnetic field is gradually reduced so that the field decreases from its initial value of 0.3 T at the rate of 0.02 T s^{-1}. If the cut is joined and the loop has a resistance of 1.6Ω, how much power is dissipated by the loop as heat? What is the source of this power?

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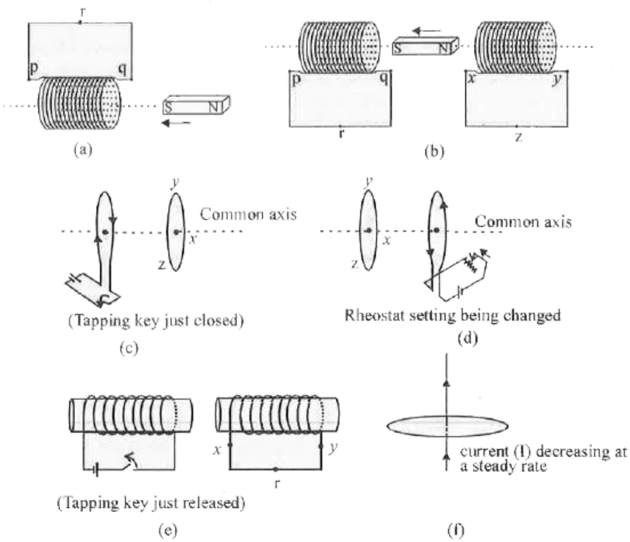
Exercises

1. Predict the direction of induced current in the situations described by the following figures (a) to (f).



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2. Use Lenz's law to determine the direction of induced current in the situations described by Fig.

(a) A wire of irregular shape turning into a circular shape,

(b) A circular loop being deformed into a narrow straight wire.

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3. A long solenoid with 15 turns per cm has a small loop of area $2.0cm^2$ placed inside the solenoid normal to its axis. If the current carried by the solenoid changes steadily from 2.0 A to 4.0 A in 0.1 s, then what is the induced emf in the loop while the current is changing ?

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4. A rectangular wire loop of sides 8 cm and 2 cm with a small cut is moving out of 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 (a) longer side, (b) shorter side of the loop ? For how long does the induced voltage last in each case?

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5. A 1m long calculating rod rotates with an angular frequency of 400 rad s^{-1} an axis normal to the rod passing through its one one end. The other end of the rod is contact with a circular metallic ring. A constant magnetic field of 0.5 T parallel to the axis everywhere. Calculate the e.m.f. developed between the centre and the ring.

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6. A circular coil of radius 8.0 cm and 20 turns rotates about its vertical diameter with an angular speed of 50 s^{-1} in a uniform horizontal magnetic field of magnitude $3 \times 10^{-2} T$. Obtain the maximum and average e.m.f. induced in the coil . If the coil forms a closed loop of resistance 10Ω, calculate the maximum value of current in the coil. Calculate the average power loss due to Joule heating.

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7. A horizontal straight wire 10 m long extending from east to west falling with a speed of 0.5 ms^{-1} at right angles to the horizontal component of the earth's magnetic field $0.30 \times 10^{-4} Wbm^{-2}$

(a) What is the instantaneous value of the e.m.f. induced in the wire ?

(b) What is the direction value of the e.m.f. (c) Which end of the wire is at higher electric potential ?

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8. Current in a circuit falls from 5.0 A to 0.0 A in 0.1 s. If an average emf of 200 V induced, give an estimate of the self-inductance of the circuit.

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9. A pair of adjacent coils has a mutual inductance of 1.5 H. If the current in one coil changes from 0 to 20 A in 0.5 s, what is the change of flux linkage with the other coil?

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10. A jet plane is travelling towards west at a speed of 1800 km/h. What is the voltage difference developed between the ends of the wing having a span of 25 m, if the Earth's magnetic field at the location has a magnitude of $5 \times 10^{-4} T$ and the dip angle is 30°.

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Additional Exercises

1. Suppose the loop in Textual Exercise 4 is stationary but the current feeding the electromagnet that produces the magnetic field is gradually reduced so that the field decreases from its initial value of 0.3 T at the rate of $0.02 T s^{-1}$ .If the cut is joined and the loop has a resistance of 1.6Ω how much power is dissipated by the loop as heat ? What is the source of this power ?

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2. A square loop of side 12 cm with its sides parallel to X and Y axes is moved with a velocity of 8 cm s^{-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 (that is it increases by $10^{-3} Tcm^{-1}$ as one moves in the 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 4.50 $m\Omega$.

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3. 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 $2cm^2$ 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 flowing in the coil (mesured by a ballistic galbanometer connected to the coil) is 7.5 mC. The resistance of the coil and galvanometer is 0.5Ω. Estimate the field strength of the magnet.

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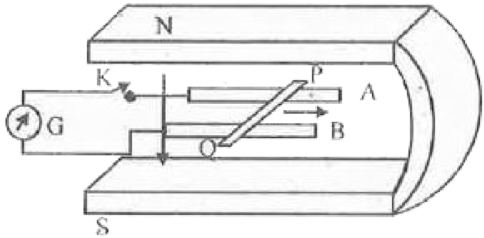
4. Figure shows a metal rod PQ resting on the smooth rails AB and positioned between the poles of a permanent magnet. The rails, the rod and the magnetic field are in three mutually perpendicular directions. A galvonometer G connects the rails through a switch K. Length of rod = 15 cm, B = 0.50 T, resistance of the closed loop containing the rod = $9.0 m\Omega$. Assume the field to be uniform.



a. Suppose K is open and the rod is moved with a speed of $12 cm s^{-1}$ in the direction shown. Give the polarity and magnitude of the induced emf.

b. Is there an excess charge built up at the ends of the rods when K is open? What if K is closed?

c. With K open and the rod moving uniformly, there is no net force on the electrons in the rod PQ eventhough they do experience magnetic force due to the motion of the rod. Explain.

d. What is the retarding force on the rod when K is closed?

e. How much power is required (by an external agent) to keep the rod moving at the same speed $\left(=12cms^{-1}\right)$ when K is closed? How much power is required when K is open?

f. How much power is dissipated as heat in the closed circuit? What is the source of this power?

g. What is the induced emf in the moving rod if the magnetic field is parallel to the rails instead of being perpendicular?

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5. An air cored solenoid with length 30 cm, area of cross-section $25cm^2$ and number of turns 500 carries a current of $2.5A$. The current is suddenly switched off in a brief time of 10^{-3} s. How much is the average back e.m.f.

induced across the ends of the open switch in the cuicuit ? Ignore the variation in magnetic field near the ends of the solenoid.

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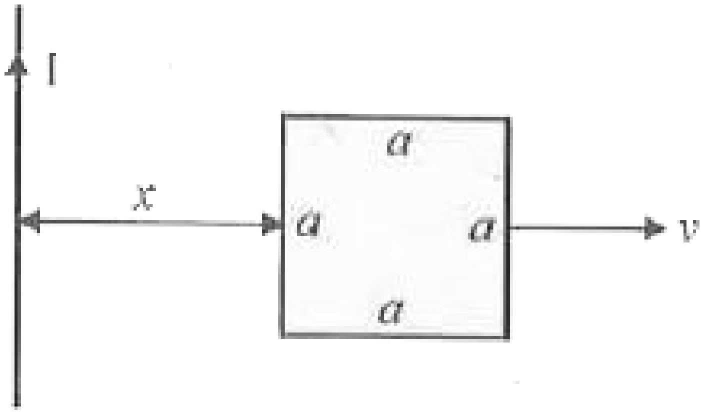
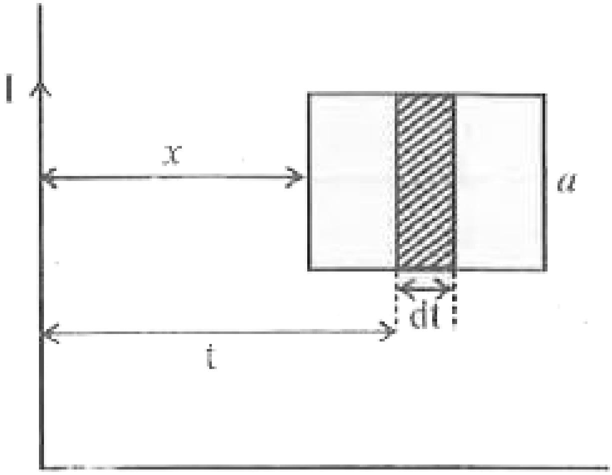
6. a. Obtain an expression for the mutual inductance between a long straight wire and a square loop of side a as shown in the figure.



b. Now assume that the straight wire carries a current of 50 A and the loop is moved to the right with a constant velocity, $v = 10m/s$. Calculate the induced emf in the loop at the instant when $x = 0.2m$. Take $a = 0.1m$ and assume that the loop has a large resistance.



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7. A line charge λ per unit length is lodged uniformly onto the rim of a wheel of mass M

and radius R. The wheel has light non-conducting spokes and is free to rotate without friction about its axis (Fig.) . A uniform magnetic field extends over a circular region within the rim. It is given by,

$$\begin{aligned} B &= -B_0 K \quad (r \le a, a < R) \\ &= 0 \quad \text{(otherwise)} \end{aligned}$$