

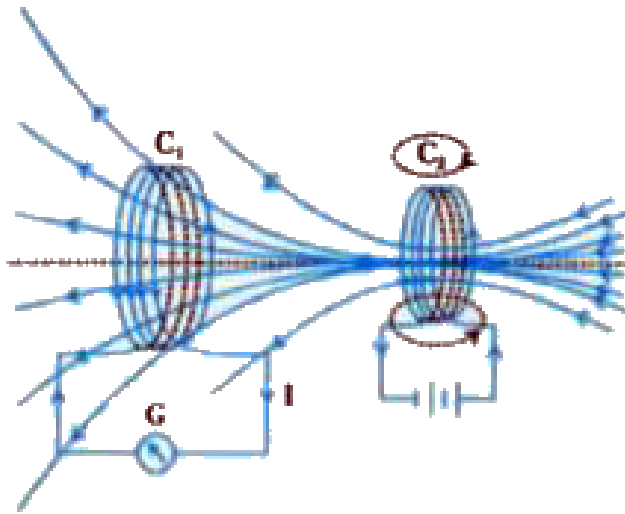


PHYSICS

NCERT - NCERT PHYSICS(GUJRATI)

ELECTROMAGNETIC INDUCTION

Examples



1.

Consider Experiment:

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

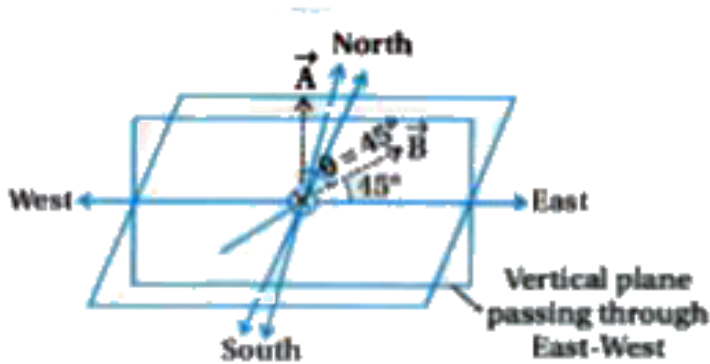
(b) How would you demonstrate the presence of an induced current in the absence of a galvanometer ?



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2. A square loop of side 10 cm and resistance 0.5Ω 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 2Ω is placed with its plane perpendicular to the horizontal component of the earth's magnetic field. It is rotated about its vertical diameter through 180° in 0.25 s.

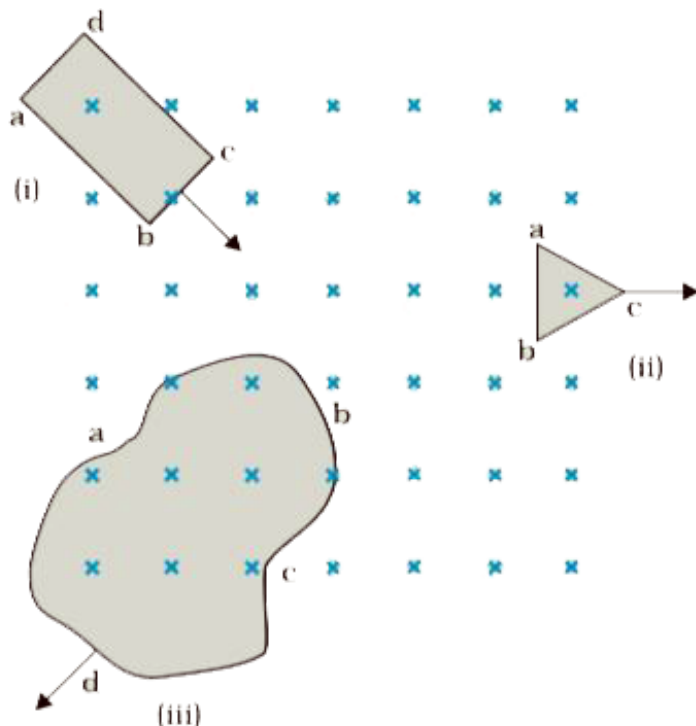
Estimate the magnitudes of the emf and current induced in the coil. Horizontal component of the earth's magnetic field at the place is $3.0 \times 10^{-5} \text{ T}$.



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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 in the 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 moves 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?

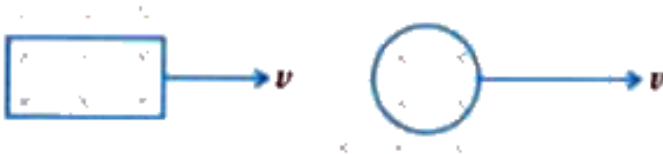
The electric field is normal to the plane of the

loop.

(c) A rectangular loop and a circular loop are

moving out of a uniform magnetic field region

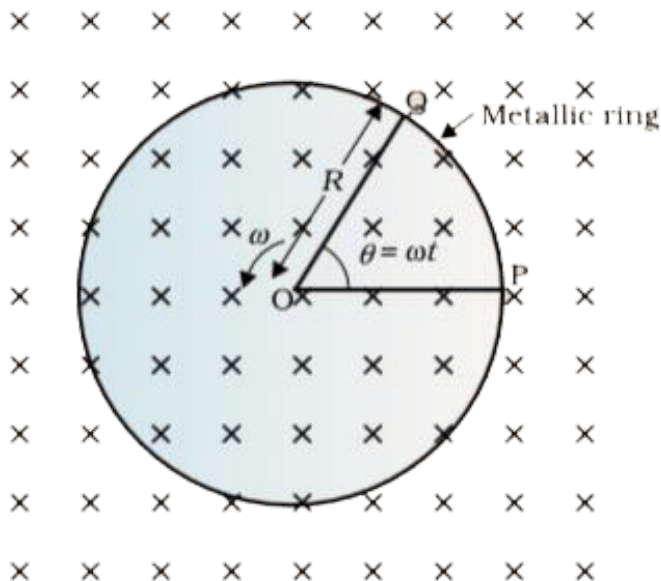
(Figure) to a field-free region with a constant velocity v . In which loop do you expect the induced emf to be constant during the passage out of the field region? The field is normal to the loops.



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6. A metallic rod of 1 m 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 metallic ring of radius 1 m, about an axis passing through the centre and perpendicular to the plane of the ring (Fig.). A constant and uniform magnetic field of 1 T parallel to the axis is 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?

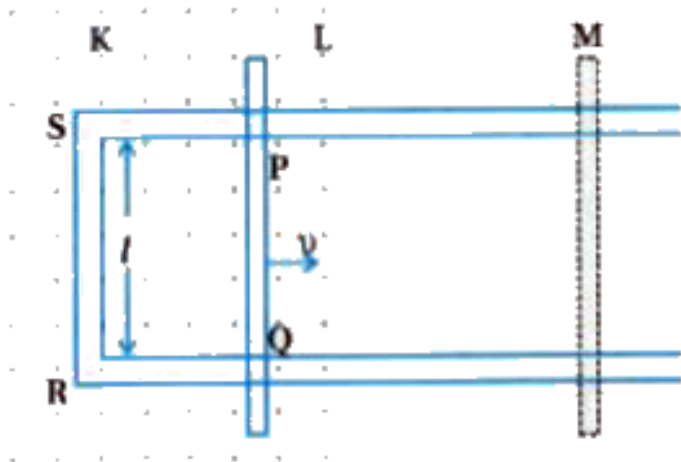
Note that $1G = 10^{-4}$ T.



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8. Refer to figure 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

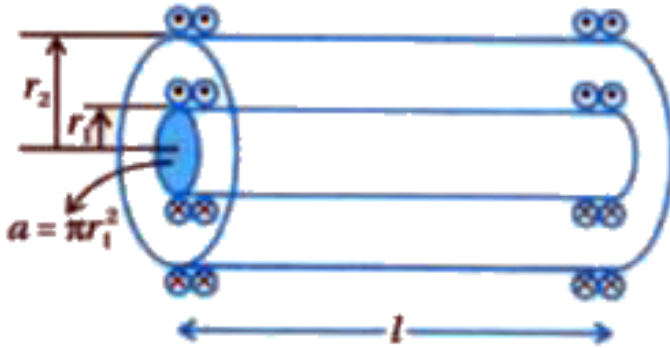
variation of these quantities with distance.



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9. Two concentric circular coils, one of small radius r_1 and the other of large radius r_2 , such that $r_1 \ll r_2$, 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 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 $1.6 \text{ } \Omega$, how much power is dissipated by the

loop as heat ? What is the source of this power ?

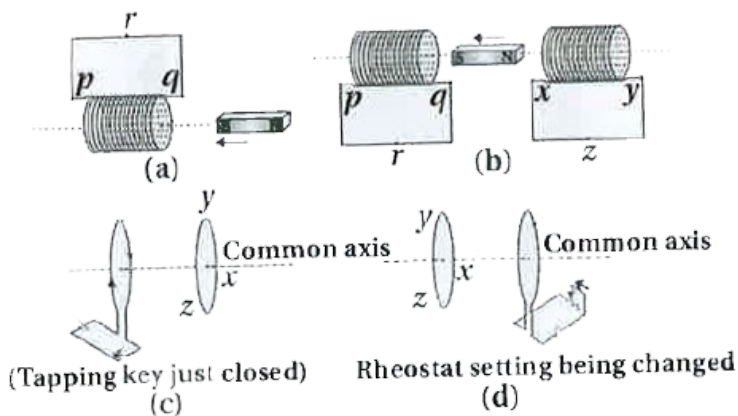


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Exercises

1. Predict the direction of induced current in the situations described by the following

figures (a) to (d).



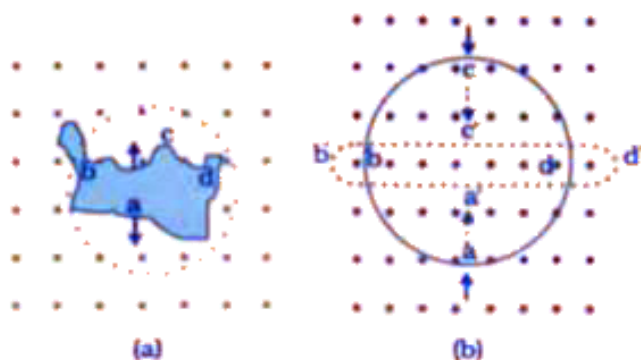
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2. Use Lenz's law to determine the direction of induced current in the situations described by figure.

(a) A wire of irregular shape turning into a

circular shape,

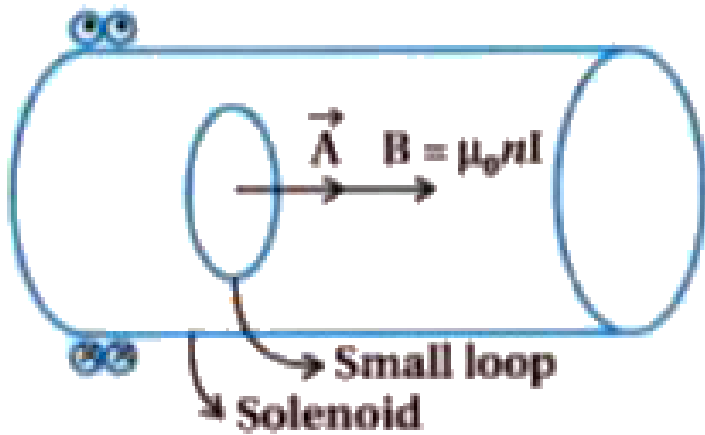
(b) A circular loop being deformed into a narrow straight wire.



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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, 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 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 (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 1.0 m long metallic rod is rotated with an angular frequency of 400 rad s^{-1} about an

axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field of 0.5 T parallel to the axis exists everywhere. Calculate the emf developed between the centre and the ring.



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6. A circular coil of radius 8.0 cm and 20 turns is rotated about its vertical diameter with an angular speed of 50 rad s^{-1} in a uniform

horizontal magnetic field of magnitude 3.0×10^{-2} T. Obtain the maximum and average emf 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. Where does this power come from ?



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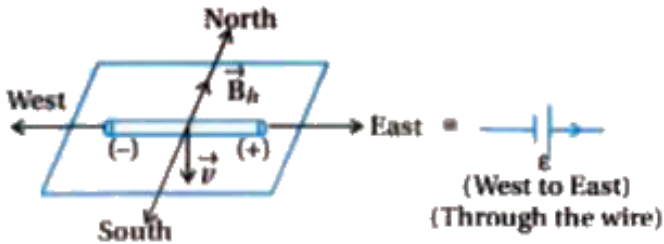
7. A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 m s^{-1} , at right angles to the horizontal component of the earth's magnetic field, $0.30 \times 10^{-4}\text{ Wb m}^{-2}$.

(a) What is the instantaneous value of the emf induced in the wire ?

(b) What is the direction of the emf ?

(c) Which end of the wire is at the higher

electrical 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 5×10^{-4} T and the dip angle is 30° .



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Additional Exercises

1. Suppose the loop 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 8cm 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}T cm^{-1} along the negative x-direction (that is it increases by 10^{-3}T cm^{-1} as one moves in the negative x-direction), and it is decreasing in time at the rate of 10^{-3}T s^{-1} . Determine the direction and magnitude of the induced current in the loop if its resistance is $4.50\text{m}\Omega$.



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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 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 . Estimate the field strength of magnet.



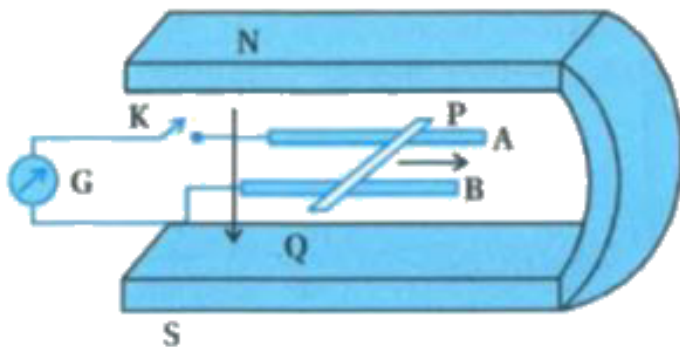
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4. Figure shows a metal rod PQ resting on the smooth rails AB and positioned between the poles of a permanent magnet. The rails, the rod, and the magnetic field are in three mutual perpendicular directions. A galvanometer G connects the rails through a switch K. Length of the rod = 15 cm, $B = 0.50 \text{ T}$, resistance of the

closed loop containing the rod $9.0 \text{ m}\Omega$.

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 even though 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 ?

How much power is required (by an external agent) to keep the rod moving at the same speed ($= 12 \text{ cm s}^{-1}$) 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 2.5 A. The current is suddenly switched off in a brief time of 10^{-3} s. How much is the average back emf

induced across the ends of the open switch in the circuit ? 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 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, $v = 10\text{ m/s}$.

Calculate the induced emf in the loop at the instant when $x = 0.2$ m. Take $a = 0.1$ m 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 nonconducting spokes and is free to rotate without friction about its axis as per figure. A uniform magnetic field extends over a circular

region within the rim. It is given by,

$$B = -B_0 k (r \leq a, a < R)$$

=0 (otherwise)

What is the angular velocity of the wheel after the field is suddenly switched off ?



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