PHYSICS

BOOKS - VIKRAM PUBLICATION (ANDHRA PUBLICATION)

ELECTROMAGNETIC INDUCTION

Textual Example

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

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

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3. A square loop of side 10 cm and resistance 0.5Ω is placed vertically in the east-west plane. A uniform magnetic field of 0.10T 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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4. A circular coil of radius 10cm, 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 $0.25s$. Estimate the magnitudes of the emf and current induced in the coil. Horizontal component of the earth's magnetic field at the place is $3.0 \times 10^{-5} T$.

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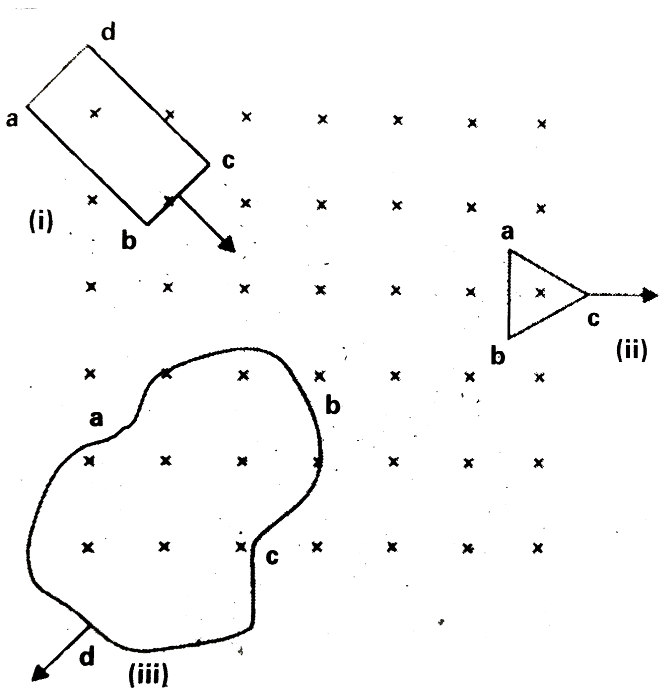
5. The following figure shows planar loops of different shapes moving out of or into a region of a magnetic field which is directed normal to the plane of the loop away from the reader. Determine the direction of induced current in each loop using Lenz's law.



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

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7. A closed loop moves normal to the constant electric field between the plates 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 plates (ii) When it is partially outside the plates of the capacitor? The electric field is normal to the plane of the loop.

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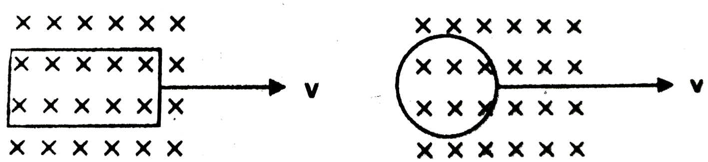
8. A rectangular loop and a circular loop are moving out ofa uniform magnetic form, region with a constant velocity v. In which loop do you expect the induced emf to be constant during the passage out of field region? The field is normal to the loops.



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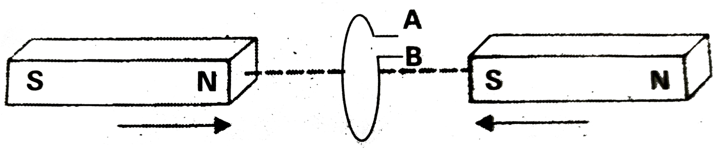
9. Predict the polarity of the capacitor in the situation described by the following figure



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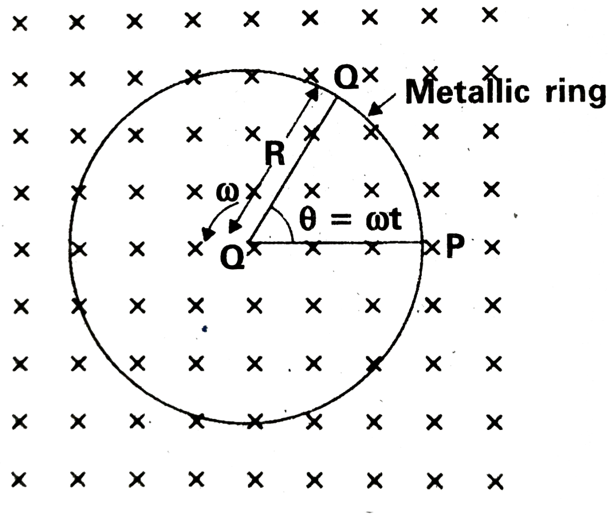
10. A metallie rod of 1 m length is rotated with a frequency of 50 revis, with one end hinged at the centre and the other end at the eireumference of a circular metallic ring of radius 1m, about an axis passing through the centre and perpendicular to the plane of the ring as in figure. A constant and uniform magnetic field of the parallel to the axis is present everywhere. What is the emf between the centre and the metallic ring?



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11. 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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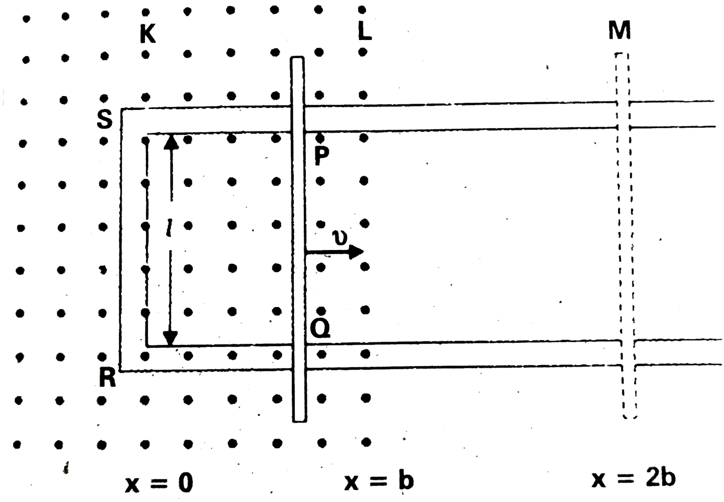
12. Refer to fig. The arm PQ of the rectangular conductor is moved from x=0 outwards. The uniform magnetic field is perpendicular to the plane and extends from x=0 to x=b and is zero for $x > b$. Only the arm PQ possesses substantial resistance r. Consider the situation when the arm PQ is pulled outwards from x=0 to x=2b, and is then moved back 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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13. 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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14. 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.

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15. How does the magnetic energy compare with the electrostatic energy stored in a capacitor?

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16. Kamla peddles a stationary bicyle, the pedals of the bicycle are attached to a 100 turns coil of area $0.10m^2$. The coil rotates at half a revolution per second and it is placed in a uniform magnetic field of 0.01T perpendicular to the axis of rotation of the coil. What is the maximum voltage generated in the coil.

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Problems

1. 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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2. Number of turns in a coil are 100. When a current of 5A is flowing through the coil, the magnetic flux is $10^{-6}Wb$. Find the self induction.

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Very Short Answer Questions

1. What did the experiments of Faraday and Henry show?

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2. Define magnetic flux.

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3. State Faraday's law of electromagnetic induction.

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4. State Lenz's law.

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5. What happens to the mechanical energy (of motion) when a conductor is moved in a uniform magnetic field?

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6. What are Eddy currents ?

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7. Define 'inductance'.

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8. What do you understand by 'self inductance'?

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Short Answer Questions

1. Obtain an expression for the emf induced across a conductor which is moved in a uniform magnetic field which is perpendicular to the plane of motion.

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2. Describe the ways in which Eddy currents are used to advantage.

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3. Obtain an expression for the mutual inductance of two long co-axial solenoids.

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4. 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.

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Long Answer Questions

1. Outline the path-breaking experiments of Faraday and Henry and highlight the contributions of these experiments to our understanding of electromagnetism.

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2. Explain the working of AC electric generator with a neat diagram.

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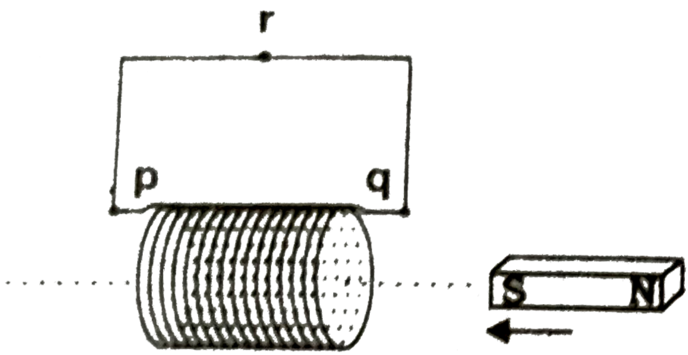
Textual Exercise

1. Predict the direction of induced current in the situation described by follow (a)



(a)

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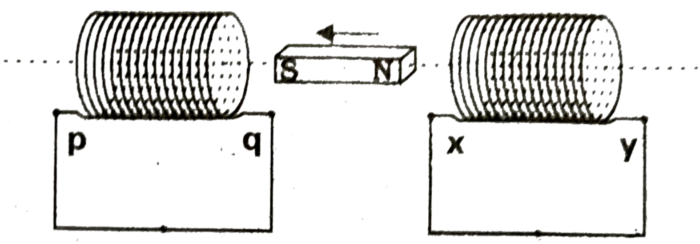
2. Predict the direction of induced current in the situation described by follow (b)



(b)

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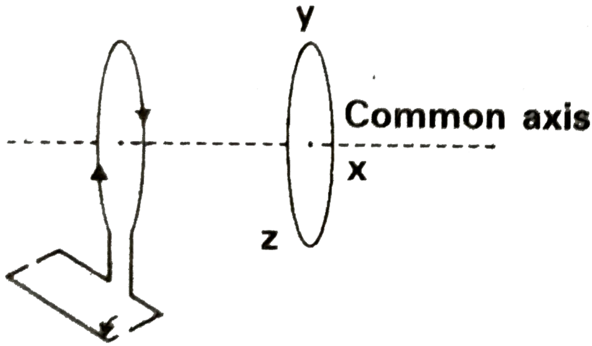
3. Predict the direction of induced current in the situation described by follow (c)



(Tapping key just closed)

(c)

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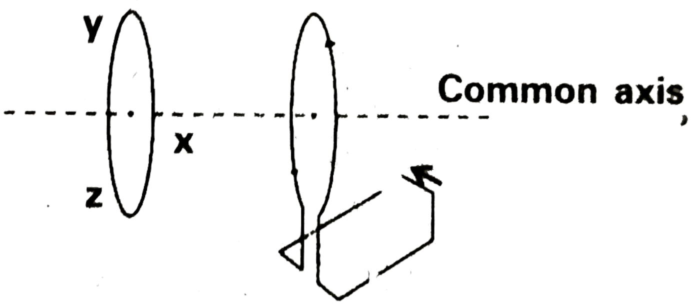
4. Predict the direction of induced current in the situation described by follow (d)



Rheostat setting being changed

(d)

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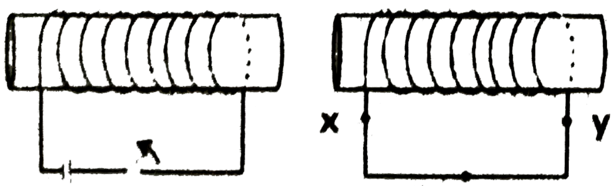
5. Predict the direction of induced current in the situation described by follow (e)



(Tapping key just released)

(e)

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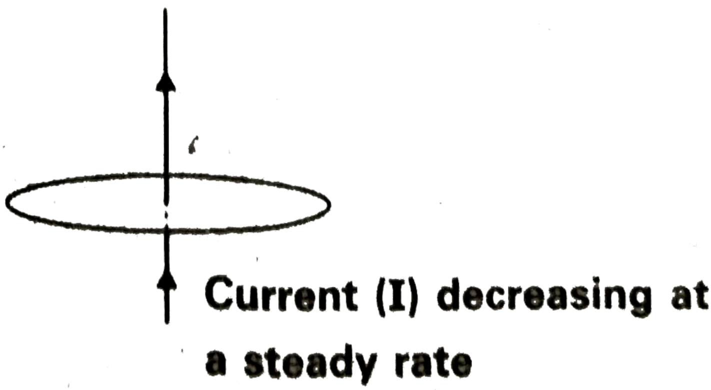
6. Predict the direction of induced current in the situation described by follow (f)



(f)

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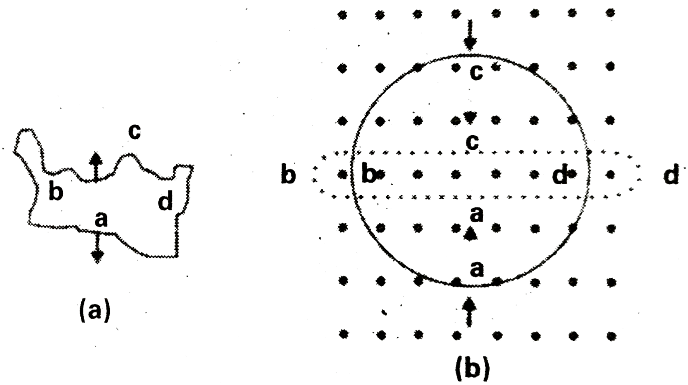
7. Use Lenz's law to determine the direction of induced current in the situations described by fig. a, b.

A wire of irregular shape turning into a circular shape.



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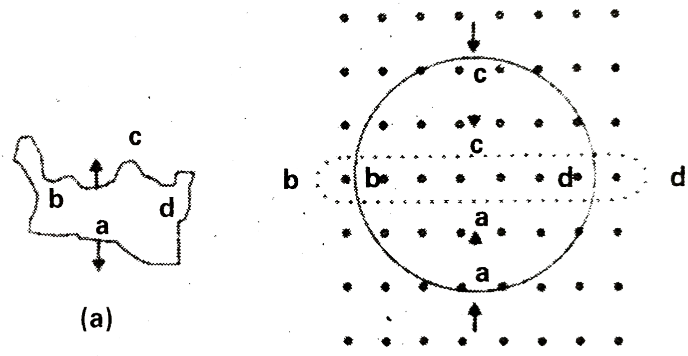
8. Use Lenz's law to determine the direction of induced current in the situations described by fig. a, b.

A circular loop being deformed into a narrow straight wire.



(a) (b)

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9. A tong solenoid with 15 turns per em has a small loop of area $2.0 cm^2$ 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 inducced emf in the loop while the current is changing?

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10. 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 $1cms^{-1}$ 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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11. A 1.0 m long metallic rod is rotated with an angular frequency of $400 \mathrm{rad\,s}^{-1}$ 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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12. 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 $3.0 \times 10^{-2} T$ Obtain the maximum and average emf induced in the coil. If the coil forms a closed loop of resistance 100, 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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13. A horizontal straight wire 10 m long extending from east to west is falling with a speed of 5.0 ms, at right angles to the horizontal component of the earth's magnetic field, $0.30 \times 10^{-4} Wbm^{2}$

What is the instantaneous value of the emf induced in the wire?

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

What is the direction of the emf?

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

Which end of the wire is at the higher electrical potential?

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16. 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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17. 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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18. 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 velocity of 8 cm s in the positive x-direction in an environment containing a magnetic field in the positive zdirection. The field is neither uniform in space nor constant in time. It has a gradient of 10 T cm along the negative x-direction (that is it increases by 103 T cm- as one moves in the negative x-direction), and it is decreasing in time at the rate of 103 Ts. Determine the direction and magnitude of the induced current in axes is moved with a the loop if its resistance is 4.50 m2. Sol. Given, side of loop a = 12 cm . Area of loop (A) = a = (12) = 144 cm = 144 x 10 m? (. Area of square = (side))

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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 directio). 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. Following figure shows a metal rod PQ resting on the smooth ralls AH 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 T, resistance of the closed loop containing the rod $9.0 m\Omega$. Assume the field to be uniform.

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

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5. Following figure shows a metal rod PQ resting on the smooth ralls AH 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 T, resistance of the closed loop containing the rod $9.0 m\Omega$. Assume the field to be uniform.

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

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6. Following figure shows a metal rod PQ resting on the smooth ralls AH 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 T, resistance of the closed loop containing the rod $9.0 m\Omega$. Assume the field to be uniform.

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.

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7. Following figure shows a metal rod PQ resting on the smooth ralls AH 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 T,

resistance of the closed loop containing the rod $9.0 m\Omega$. Assume the field to be uniform.

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

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8. Following figure shows a metal rod PQ resting on the smooth ralls AH 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 T, resistance of the closed loop containing the rod $9.0 m\Omega$. Assume the field to be uniform.

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

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9. Following figure shows a metal rod PQ resting on the smooth ralls AH 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 T, resistance of the closed loop containing the rod $9.0 m\Omega$. Assume the field to be uniform.

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

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10. Following figure shows a metal rod PQ resting on the smooth ralls AH 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 T, resistance of the closed loop containing the rod $9.0 m\Omega$. Assume the field to be uniform.

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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11. An air-cored solenoid with length 30 cm, area of cross-section $25cm^2$ and number of turus 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 magnetie field near the ends of the solenoid.

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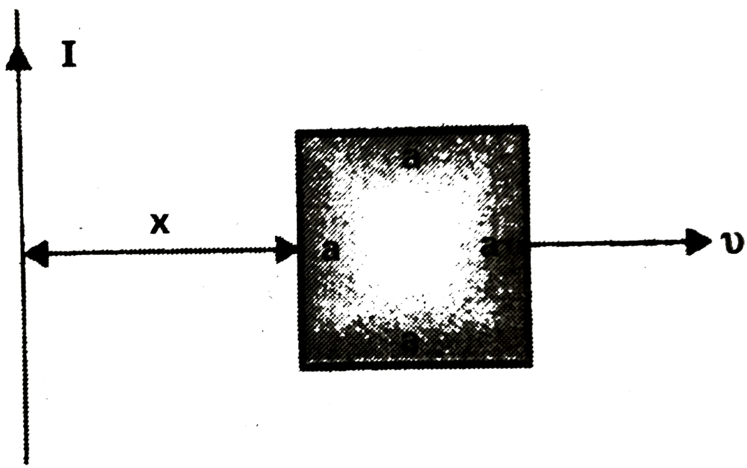
12. Obtain an expression for the mutual inductance between a long straight wire and a square loop of side a as shown in the figure.



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13. Now assume that the straight wire carries a current of 50A 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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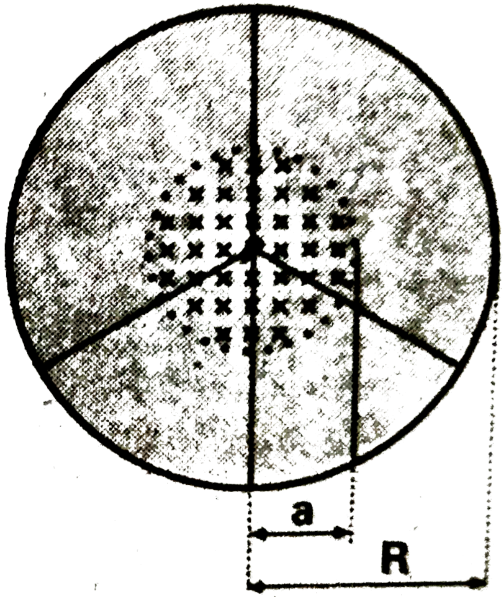
14. A line charge λ per unit length is lodged uniformly onto the rim of a whell of mass M and radius R. The whell has light non-conducting spokes and is free to rotate without friction about its axis (figure). A uniform magnetic field extends over a circular region withing the rim. It is given by,

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

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



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15. Obtain an expression for the self inductance of a solenoid.

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