PHYSICS

BOOKS - NEW JYOTHI PHYSICS (TAMIL ENGLISH)

ELECTROMAGNETIC INDUCTION

Solved Problems

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 0.5Ω 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 rauis 10cm, 500 turns and resistance 2Ω is placed with its plane perpendicualr 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 emf and

current induced in the coil. Horizontal component of earth's magnetic field at the place is $3 \times 10^{-5} T$.

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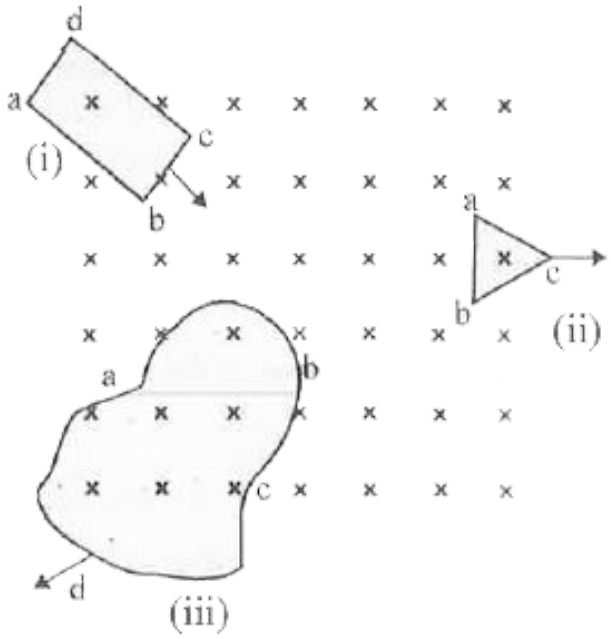
4. Figure shows planar loops of different shapes moving out of or into a region of a magnetic field which is directed normal to the plane of the loop away from the reader. Determine the direction of induced current in

each loop using Lenz's law.



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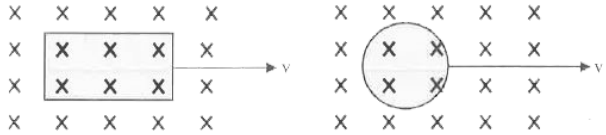
5. a. A closed loop is held stationary int eh magnetic field between the north and south

poles of two permanent magnets held fixed. Can we hope to generate current in the loop by using very strong magnets?

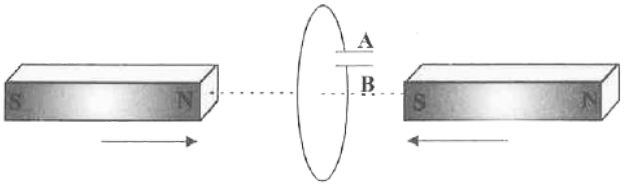
b. A closed loop move normal to the constant electric field between the plates of a large capacitor. Is a current induced in the loop (i) when it is wholly inside the region between the capacitor plates (ii) when it is partially outside the plates of the capacitor? The electric field is normal to the 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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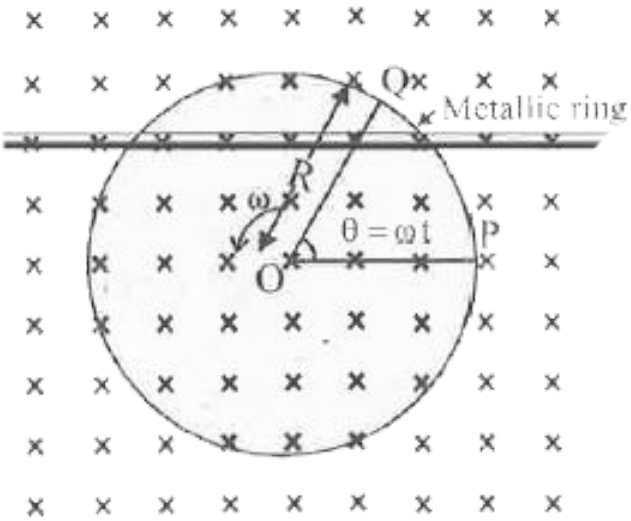
6. A metallic rod of 1m length is rotated with a frequency of 50 rev/s, with one end hinged at the centre and the other end at the circumference of a circular me tallic ring of radius 1m, about an axis passing through the centre and perpendicular to the plane of the ring (see figure). A constant and 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 0.5m 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 $H_E = 0.4G$ 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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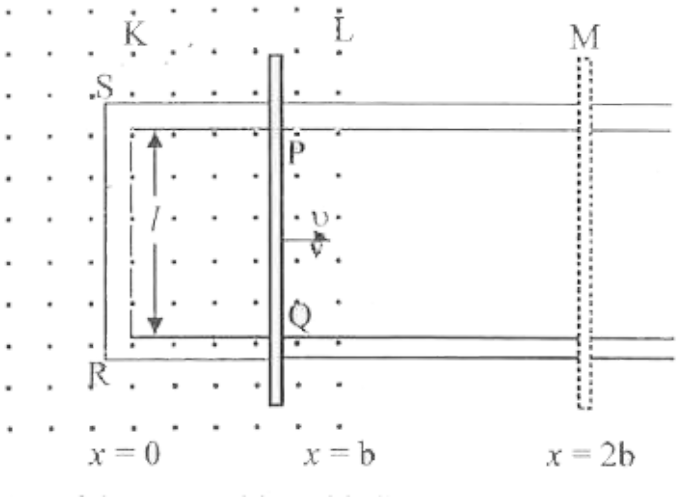
8. The arm PQ of the rectangular conductor is moved from $x = 0$, outwards. The uniform magnetic field is perpendicular to the plane and extends from $x = 0$ to $x = b$ and is zero for $x > b$. Only the arm. PQ possesses

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. If a coil of area $0.15m^2$ and 50 turns is perpendicular to a magnetic field, which changes from 5×10^{-3} to $2 \times 10^{-3}T$ in 30 ms. Calculate the induced e.m.f.

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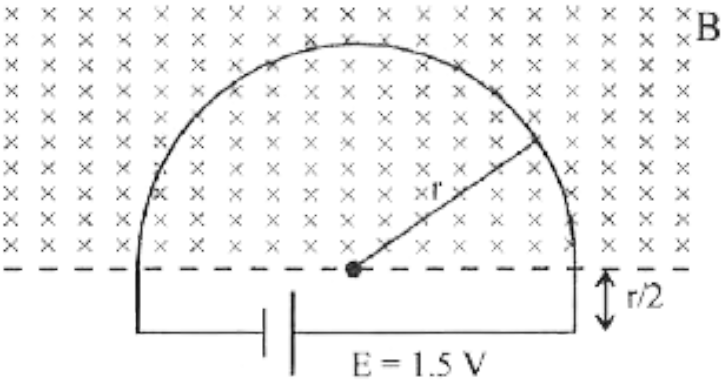
10. A conducting loop in the form of a half circle of $r = 10cm$ is placed in a magnetic

field as shown. The strength of the magnetic field is given by the relation $B = 5t^2 + 3t + 5$ where B is in Tesla and t- the time in seconds. The resistance of the loop is 3Ω. An ideal cell of e.m.f. E = 1.5V is connected to the loop. Calculate the induced e.m.f. and net current in the loop at t = 15 sec.



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11. A train travels at 108 kmph towards east. Earth's magnetic field is $B = 0.4 \times 10^{-4}$ Tesla and acts downwards at 60° to the horizontal. Calculate the induced e.m.f. between the ends of a horizontal axis PQ of the train. Given PQ = 2m. Also find which end of PQ is at a higher potential?

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12. A horizontal frame KLMN moves with a uniform velocity of 30 cm/s into a uniform magnetic field of strength $B = 10^{-3}$ Tesla acting verticaly downwards. KN = 12 cm and KL = 25 cm and resistance of the frame is 10Ω. The sides LM and KN enter the field in a direction perpendicular lar to the field boundary. Calculate the current in the metal frame when,

a. LM just enters the field

b. the entire frame inside the field

c. LM just leaves the field through the other side

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13. A flat search coil of 100 turns and each of area $3 \times 10^{-4} m^2$ is connected to a galvanometer, so that the total resistance of the circuit is 90Ω. The plane of the coil is normal to a magnetic field, B = 0.4T. Calculate the change in flux when the coil is moved to a

region of negligible magnetic field and the charge passes through the galvanometer.

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14. Two concentric circular coils, 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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15. 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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16. An inductor of self inductance 12 H carries a steady current of 2A. How can a 60V self-

induced e.m.f. be made to appear in the inductor?

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17. Two inductors of inductance L_1 and L_2 are put in (a) series and (b) parallel with a large separation. Given $L_1 = 6H$ and $L_2 = 4H$. Calculate the equivalent inductance.

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18. Two coils P and Q are at fixed position. When coil P has no current in coil Q increases at the rate of $5As^{-1}$, the e.m.f. in coil P is 20 mV. What is the mutual inductance? When the coil Q has no current and coil P has a current of 3A, what is the flux linkage in coil Q?

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19. Kamla peddles a stationary bicycle the pedals of the bicycle are attached to a 100

turn 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 0.01 T perpendicular to the axis of rotation of the coil. What is the maximum voltage generated in the coil?

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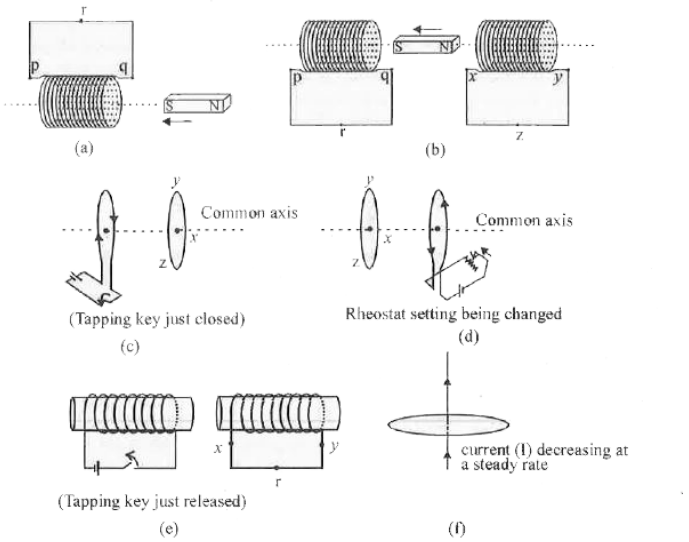
Solutions To Exercises From Ncert Text

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



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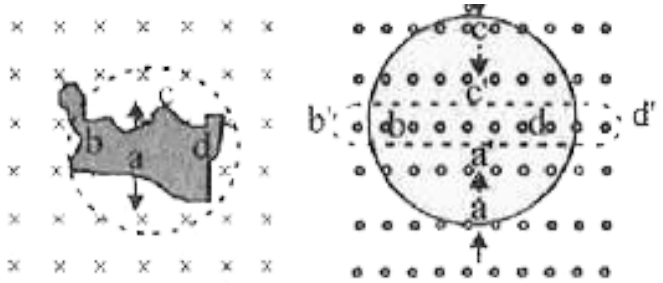
2. Use Lenz's law to determine the direction of induced current in the situations described by the following figures.



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 area $2.0cm^2$ placed inside the solenoid normal to its axis. If the current carried by the solenoid changed steadiy from 2.0A to 4.0A 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 0.3T 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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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 $3.0 \times 10^{-2} T$. Obtain the maximum and average emf induced in the coil. If the coil forms a closed loop of resistance 10Ω, calculate teh maximum value of current in the coil Calculated 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 $5.0ms^{-1}$, 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 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 0.1s. If an average emf of 200 V is 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 25m, 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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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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12. A square loop of side 12 cm with its sides parallel to X and Y axes is moved with a velocity of $8cms^{-1}$ in the possitive 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 $10^{-3}T$ 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 of its resistance is $4.50m\Omega$.

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13. It is desired to measure the magnitude of field between the poles 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° turns to bring its plane parallel to the field direction. The total charge flown in the coil (measured by a ballistic galvanometer connected to the coil) is 7.5mC. The combined resistance of the coil and the galvanometer is 0.50Ω. Estimate the field strength of magnet.

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14. 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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Practice Problems For Self Assessment

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

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2. 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 25m, 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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3. The magnetic flux ϕ through a coil is varying w.r.t. time 't' according to the relation $\phi = 5t^2 + 4t + 3$ weber. Calculate the induced e.m.f. and current in the coil at $t = 3$ sec. The resistance of the coil is 2Ω.

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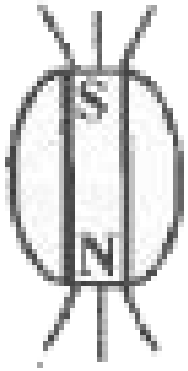
Evalutaion Questions And Answers

1. A solenoid with large number of turns is in a closed circuit and a short bar magnet is dropped through each with its length along the axis. State the acceleration of the falling magnet when it is :



a. Well above A b. At the end A

c. At the middle d. At the end B

e. Far away, down, from B

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2. A rectangular closed loop moves horizontally in a uniform magnetic field.

i. Will there be any induced current in the loop if the loop is completely in the magnetic field?

ii. Will there be any induced current in the loop if the loop is partially out of the magnetic field?

iii. Will the induced current in the loop remain if the loop is stationary and the magnetic field changes with time?

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3. a. How is the flux linkage through a coil related to current?

b. What is the constant of proportionality that appears in the above relation?

c. Define the constant of proportionality

d. Give its dimensions and S.I. unit.

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4. The induced emf is sometimes called back emf. Why?

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5. Why is spark produced in the switch of a fan when it is switched off?

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6. Fig. E.I show s magnet coil experiment of electromagnetic induction.

What happens when

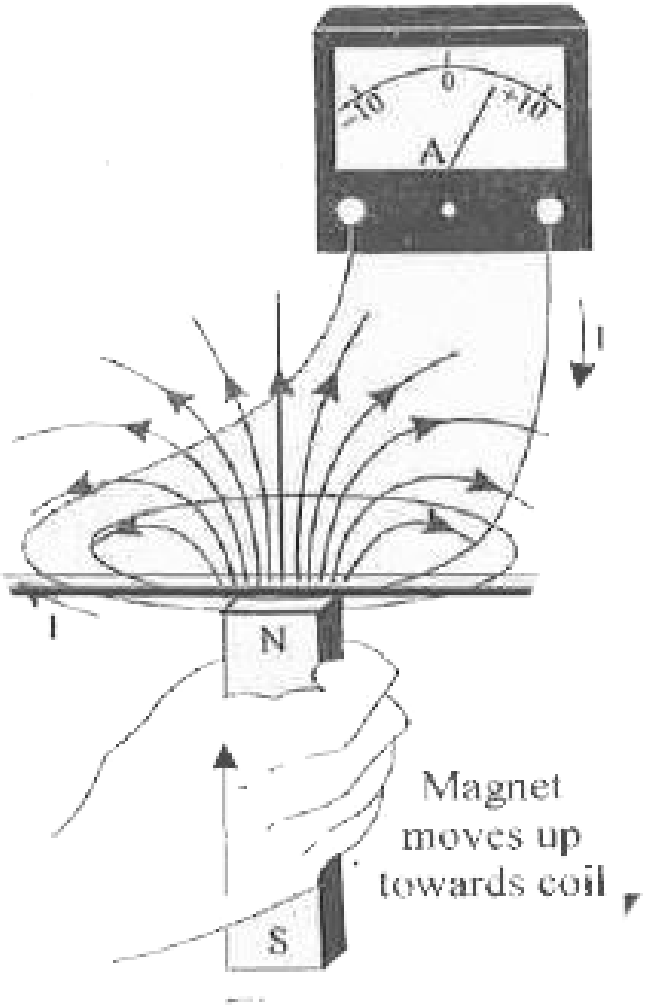
a. i. The number of turns of the coil is inceased.

ii. The streangth of the magnet is increased.

iii. The speed of motion of the magnet is increased.

b. An induced e.m.f. has no direction of its

own. Why?



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7. Take a strong cylindrical electromagnet connected to AC source and place a light metallic disc at the top of it. When the current is switched 'on', the disc is thrown up in the air.

a. Why does the disc go up?

b. How is the repulsive force produced?

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8. A short bar magnet is dropped through a coil of wire of similar length. Which one of the

graphs below shows best how the current through the coil varies with time?

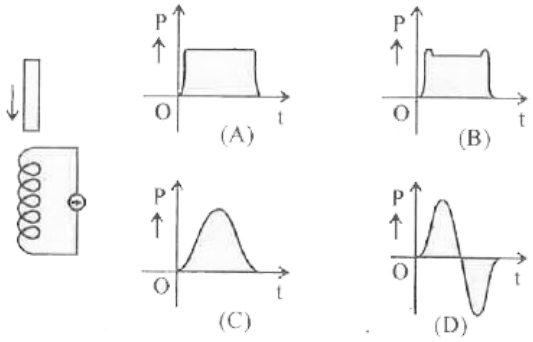

Fig. E. 2

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9. When a metallic block moves in a magnetic field induced currents are developed in the body of the block.

a. What is this type of current called?

b. Which law gives the direction of such currents?

c. What is the strength of the induced current?

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10.

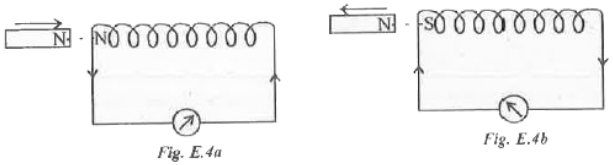

Fig. E.4a Fig. E.4b

a. Which law is demonstrated in the above figures?

b. State the law.

c. Explain the action that takes place in the above figures.

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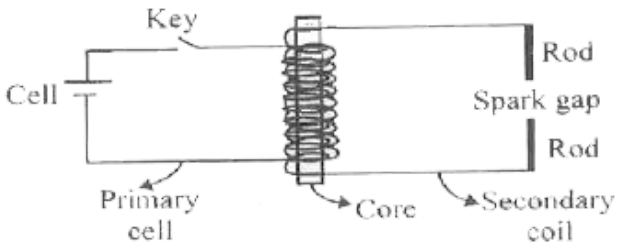
11. When the key is closed, a spark is generated between the ends of the rods.



a. Explain the cause of the spark.

b. Explain why a spark is also produced when the key is opened.

c. Why are no sparks produced when the key is left closed?

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12. You are given a solenoid of length 'l', number of turns per unit length 'n' and area of cross-section A. When a current 'I' passes through it,

a. What is the total magnetic flux through the solenoid?

b. What is the self inductance of the solenoid?

c. How does the value of self inductance get affected if some material of high relative permeability is filled inside the solenoid?

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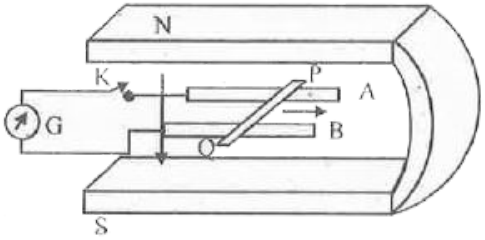
13. Figure shows a metal rod PQ resting on the smooth rails AB and positioned between the poles of a permanent magnet. The rails, the rod and the magnetic field are in three mutually perpendicular directions. A galvonometer G connects the rails through a

switch K. Length of rod = 15 cm, B = 0.50 T, resistance of the closed loop containing the rod = $9.0m\Omega$. Assume the field to be uniform.



a. Suppose K is open and the rod is moved with a speed of $12cms^{-1}$ 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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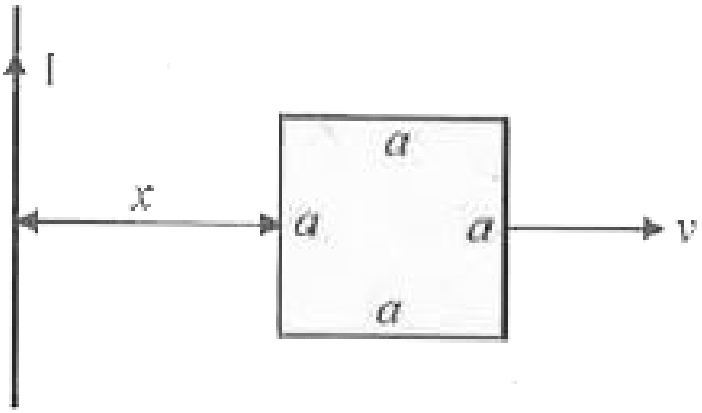
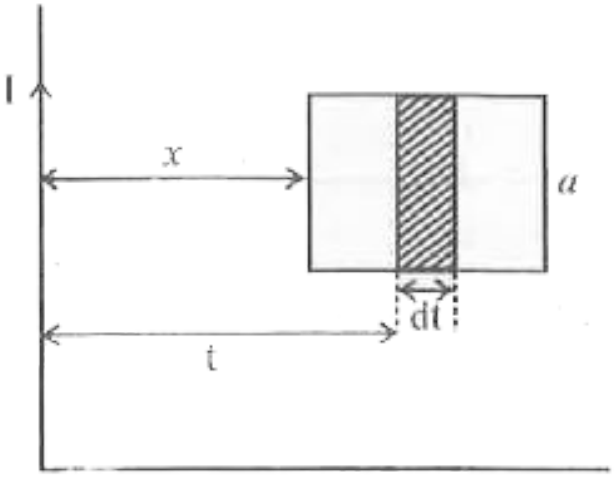
14. a. Obtain an expression for the mutual inductance between a long straight wire and a square loop of side a as shown in the figure.



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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Continuous Evaluation Assignments

1. Discuss briefly the various methods of producing induced e.m.f.

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2. Write a note on eddy current.

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Previous Year Questions

1. A current carrying wire produces a magnetic field in its surrounding space

A. The S.I. unit of magnetic flux density is

a. henry

b. tesla

c. Am^2

d. A-m

B. With the help of a diagram, derive an expression for the magnetic field at the point on the axis of a circular current loop.

C. Consider a tightly wound 100 turn coil of radius 10 cm, carrying a current of 1 A. What is

the magnitude of the magnetic field at the centre of the coil?

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2. When the magnetic flux associated with a coil changes an emf is induced in the circuit.

A. State Faraday's law of electromagnetic induction.

B. Mention the physical significance of Len'z law with an example.

C. When an electrical appliance is switched off, sparking occurs. Why?

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Competitive Exam Corner

1. A 50 Hz ac current of peak value 2 A flows through one of the pair of coils. If the mutual inductance between the pair of coils is 150 mH, then the peak value of voltage induced in the second coil is

A. $30\pi V$

B. $60\pi V$

C. $15\pi V$

D. $3\pi V$

Answer:

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2. The unit of self-inductance is

A. a) weber /ampere

B. b) weber^{-1} ampere

C. c) ohm second

D. d) farad

Answer:

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3. A 0.1 m long conductor carrying a current of 50 A is held perpendicular to a magnetic field of 1.25 mT. The mechanical power required to move the conductor with a speed of $1ms^{-1}$ is

A. a) 62.5m W

B. b) 625 mW

C. c) 6.25 mW

D. d) 12.5 mW

Answer:

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4. Two solenoids of equal number of turn have their lengths and the radii in the same ratio 1:2. The ratio of their self inductances will be

A. a. $1:2$

B. b. $2:1$

C. c. $1:1$

D. d. $1:4$

Answer:

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5. Two identical coaxial coils P and Q carrying equal amount of current in the same direction are brought nearer. The current in

A. a. P increases while in Q decreases

B. b. Q increases while in P decreases

C. c. both P and Q increases

D. d. both P and Q decreases

Answer:

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6. The self inductance of a long solenoid cannot be increased by

A. a. increasing its area of cross section

B. b. decreasing its length

C. c. changing the medium with greater permeability

D. d. increasing the current through it

Answer:

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7. The rate of change of current of $10As^{-1}$ in a coil produces an emf of 5 V. Then the self inductance of the coil in henry is

A. a. 0.5

B. b. 0.25

C. c. 1

D. d. 1.25

Answer:

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8. The magnetic flux (in weber) linked with a coil of resistance 10Ω is varying with respect to time t as $\phi = 4t^2 + 2t + 1$. Then the current in the coil at time $t = 1$ second is

A. a. 0.5 A

B. b. 2A

C. c. 1.5A

D. d. 1A

Answer:

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9. The self-inductance of an air core solenoid of 100 turns is 1 mH. The self-inductance of another solenoid of 50 turns (with the same length and cross-sectional area) with a core having relative permeability 500 is

A. a. 125 mH

B. b. 24 mH

C. c. 60 mH

D. d. 30 mH

Answer:

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10. Identify the wrong statement

A. a. Eddy currents are produced in a steady magnetic field

B. b. Eddy currents can be minimized by using laminated core

C. c. Induction furnace uses eddy current to produce heat

D. d. Eddy current can be used to produce breaking force in moving vehicles

Answer:

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11. Electromagnetic induction is not used in

A. a. speedometer

B. b. transformer

C. c. A.C. generator

D. d. room heater

Answer:

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12. The polarity of induced emf is given by

A. a. Ampere's circuital law

B. b. Biot-Savart law

C. c. Lenz's law

D. d. Fleming's right hand rule

Answer:

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13. A conducting ring of radius 1 m kept in a uniform magnetic field B of 0.01 T, rotates uniformly with an angular velocity 100 rad s^{-1} with its axis of rotation perpendicular to B. The maximum induced emf in it is

A. a. $1.5\pi V$

B. b. πV

C. c. $2\pi V$

D. d. $0.5\pi V$

Answer: D

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