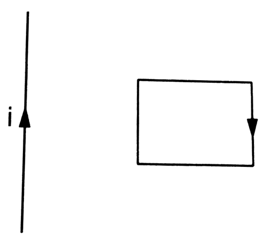
PHYSICS

BOOKS - HC VERMA PHYSICS (HINGLISH)

ELECTROMAGNETIC INDUCTION

Examples

1. Show a conduction loop placed near a long, straight wire carrying I as shown. If the current increases continuously, find the direction of the induced current in the loop.



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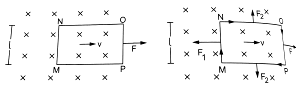
2. Show a rectangular loop MNOP being pulled out of a magnetic field with a uniform velocity v by applying an external force F. The length MN is equal to l and the total resistance of the loop is R. Find(a) the current in the loop,(b) the magnetic force on the loop, (c) the external force F needed to move it at constant velocity, (d) the power delivered by the external force and (e) the thermal power developed in the loop.



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3. An average induced emf of 0.20 V appears in a coil when the current in it is changed from 5.0 A in one direction to 5.0 A in the opposite direction in 0.20 s. find the self inductance of the coil.

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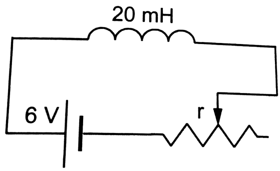
4. Consider the circuit shown in the sliding contact is being pulled towards right so that the resistance in the circuit is increasing. Its value at the instant shown in 12Ω. Will the current be more then 0.50 A or less than it at this instant?



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5. An inductor $(L = 20mH)$, a resistor $(R = 100\Omega)$ and a battery $(\varepsilon = 10V)$ are connected in series. Find (a) the time constant, (b) the maximum current and (c) the time elapsed before the current reaches 99% of the maximum value.

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6. An inductor $(L = 20mH)$, a resistor $(R = 100\Omega)$ and a battery (verepsilon = 10 V) are connected in series. After along time the circuit is short- circuited and then the battery is disconnected. Find the current in the cirucit 1ms after short- circuititig.

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7. Calculate the energy stored in an inductor of inductance 50 mH when a current of 2.0 A is passed through it.

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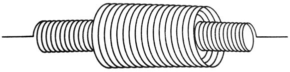
8. A solenoid S_1 is placed inside another solenoid S_2 as shown in The radii of he inner and the outer solenoids are r_1 and r_2 respectively and the numbers of turns per unit length are n_1 and n_2 respectively. Consider a length l of each solenoid. Calculate the mutual inductance between them.



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Worked Out Examples

1. A conducting circular loop is placed is a uniform magnetic field B =0.20 T with its plane perpendicular to the field . Somehow, the radius of the loop starts shrinking at a constant rate of `1.0 mm s^(-1). Find the induced emf in the loop at an instant when the radius is 2 cm.

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2. A uniform magnetic field B exists in a direction perpendicular to the plane of a square frame made of copper wire. The wire has a diameter of 2 mm and a total length of 40cm. The magntic field changes with time at a steady rate

$d\frac{B}{dt} = 0.02Ts^{-1}. F \in dthecurrent \in duced \in theame. Resistivityofcop$

=1.7 X 10 ^(-8) Wm`.

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3. A conducting circular loop of face are $2.5X10^{-3}m^2$ is placed perpendicular to a magnetic field which varies as $B = (0.20T)\sin\left[\left(50\pi s^{-1}\right)t\right]. (a)F \in dthechar \geq jflow \in gthroughanycr$

10 Omega`, find the thermal energy developed in the loop in this period.

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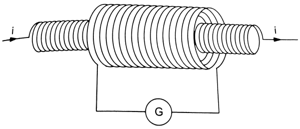
4. A long solenoid of radius 2 cm has 100 turns/cm and is surrounded by a 100- turn coil of radius 4cm having a total resistance of 20Ω. The coil is connected to a galvanometer as shown in if the current in the solenoid is changed form 5 A in one direction to 5 A in the opposite direction, find the charge which flows through the galvanometer.



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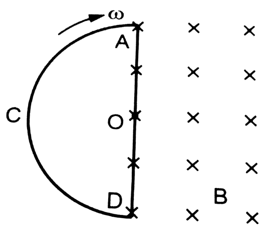
5. The magnetic field B shown in is directed into the plane of the paper. ACDA is a semicircular conducting loop of radius r with the centre at O. The loop is now made ot rotate clockwise with a constant angular velocity ω about on axis passing through O and perpendicular to the plane of the paper. The resistance of the loop is R. Obtain an expression for the magnitude of the induced current in the loop. Plot a graph between the induced current i and ωt, for two periods of rotation.



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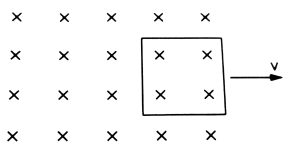
6. Shows a square loop having 100 turns, an area of $2.5X10^{-3}m^2$ and a resistance of 100Ω. The magnetic field has a magnitude B =0.40 T. Find the work done in pulling the loop out of the field, slowly and uniformly is 1.0 s.



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7. Magadh express takes 16 hors to cover the distance of 960km between patna and Gaziabad. The rails are separated by 130 cm and the vertical component of the earth's magnetic field is `4.0 X 10^(-5) T. (a) Find the average emf induced across the width of the train. (b) If the leakage resistance between the rails is 100 Omega, find the retarding force on the train due to magnetic field.

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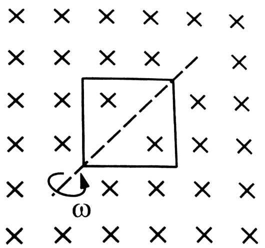
8. A square loop of edge a having n turns Is rotated with a uniform angular velocity ω about one of its diagonals which is kept fixed in a horizontal position . A uniform magnetic field B exists in the vertical direction. Find the emf induced in the coil.



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9. A conducting circular loop of radius r is rotated about its diameter at a constant angular velocity ω in a magnetic field B perpendicular to the axis of rotation. In what position of the loop is the induced emf zero?

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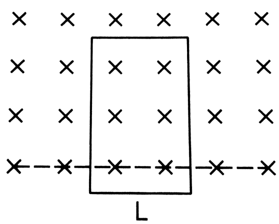
10. Shows a horizontal magnetic field which is uniform above the dotted line and is zero below it. A long, rectangular, conducting loop of width L, mass m and resistance R is placed partly above and partly below the dotted line with the lower edge parallel to it . with what velocity should it be pushed downwards so that it may continue ot fall without any acceleration?



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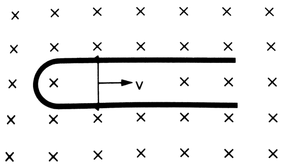
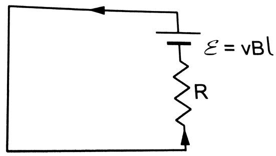
11. Shows a wire of length l which can slide on a U- shaped rail of negligible resistance. The resistance of the wire is R. The wire is pulled to the right with a constant speed v. Draw an equivalent circuit diagram representing the induced emf by a battery. Find the current in the wire using this diagram.





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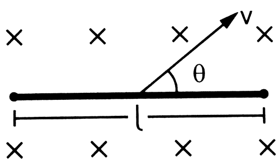
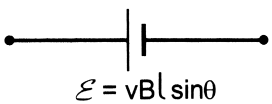
12. A rod of length l is translating at a velocity v making an angle θ with its length. A uniform magnetic field B exists in a direction perpendicular to the plane of motion. Calculate the emf induced In the rod, Draw a figure representing the induced emf by on equivalent battery.





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13. The horizontal component of the earth's magnetic field at a place is $3.0X10^{-4}T$ and the dip is 53°. A metal rod of length 25cm is placed in the north - south direction and is moved at a constant speed of 10cm s^(-1) towards east. Calculate the emf induced in the rod.

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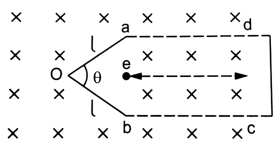
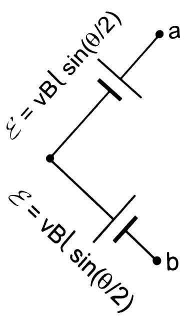
14. An angle aob made of a conducting wire moves along its bisector through a magnetic field B as suggested by figure. Find the emf induced between the two free ends if the magnetic field is perpendicular ot the plane of the angle.





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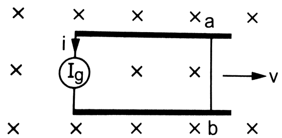
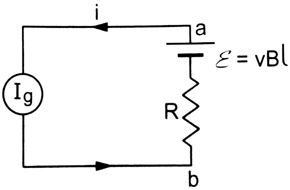
15. Shows a wire ab of length l and resistance R which can slide on a smooth pair of rails. I_g is a current generator which supplies a constant current in in the circuit. If the wire ab slides at a speed v towards right, find the potential difference between a and b.





(b)

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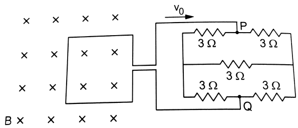
16. A square loop of side 10 cm and resistance 1 Omega is moved towards right with a constant velocity V_0 as shown in . The left arm of the loop is in a uniform magnetic field of 2 T. the field is perpendicular to the plane of the drawing and is going into it. the loop is connected to a network of resistors each of value 3 Omega with what speed should the loop be moved so that a steady current of 1 mA flows in the loop.



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17. A metal rod length l rotates about on end with a uniform angular velocity ω. A uniform magnetic field $\overrightarrow{B}$ exists in the direction of the axis of rotation. Calculate the emf induced between the ends of the rod. Neglect the centripetal force acting on the free electrons as they money in circular paths.

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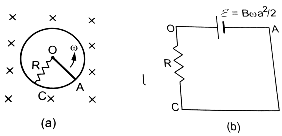
18. Shows a conducting circular loop radius a placed in a uniform, perpendicular magnetic field B. A metal rod OA is pivoted at the centre O of the loop. The other A of the rod touches the loop. The rod OA and the loop are resistanceless but a resistor having a resistance R is connected between O and a fixed point C on the loop . the rod OA is made to rotate anticlockwise at a small but uniform angular speed ω by an external force. Find (a) the current in the resistance R and (b) the torque of the external force needed to keep the rod rotating with the constant angular velocity omega.



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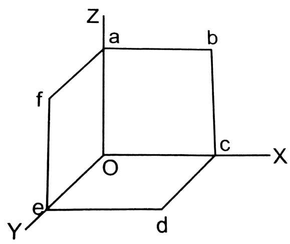
19. shows a conducting loop abcdefa made of six segment ab, bc cd, de, ef and fa, each of length l. Each segment makes a right angle with the next so that abc is in the x-z plane, cda in the x-y plane and efa is in the y-z plane. A uniform magnetic field B exists along the x- axis. If the magnetic field changes at a rate (dB)/(dt), find the emf induced in the loop.



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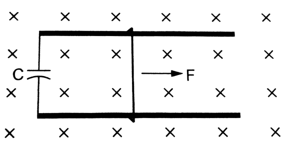
20. A wire of mass m and length l can freely slide on a pair of parallel, smooth, horizontal rails placed in a vertical magnetic field B . The rails are connected by a capacitor of capacitance C. The electric resistance of the rails and the wire is zero. If a constant force F acts on the wire as shown in the figure, find the acceleration of the wire.



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21. An inductor coil stores 32 J of magnetic field energy and dissipates energy as heat at the rate of 320 W when a current of 4 A is passed through it. Find the time constant of the circuit when this coil is joined across on ideal battery.

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22. $A12V$ battery connected to a $6\Omega, 10H$coil through a switch drives a constant current in the circuit. The switch is suddenly opened. Assuming that it took 1 ms to open the switch, calculate the average emf induced across the coil.

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23. A solenoid of inductance 50 mH and resistance 10 Omega is connected to a battery of 6V. Find the time elapsed before the current acquires half of its steady - stae value.

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24. An LR circuit having $L = 4.0H, R = 1.0\Omega$ and $\varepsilon = 6.0V$ is switched on at $t = 0$. find the power dissipated in joule heating at $t = 4.0s$.

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25. An LR combination is connected to an idal battery. If l = 10 mH, R = 2.0 Omega and epsilon = 2.0 V, how much time will it take for the current ot reach 0.63 A?

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26. An inductor-resistance -battery circuit is switched on at t = 0. If the emf of the battery in one time constant tau.

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27. A coil of inductance $1.0H$ and resistance 100Ω is connected to a battery of emf $12V$. Find the energy stored in the magnetic field associated with the coil at an instant $10ms$ after the circuit is switched on.

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28. An inductance L and a resistance R are connected in series with a battery of emf epsilon. Find the maximum rate at which the energy is stored in the magnetic field.

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29. Two conducting circular loops of radii R_1 and R_2 are placed in the same plane with their centres coincidingt. Find the mutual inductane between them assuming $R_2 < \; < R_1$.

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Short Answer

1. A metallic loop is placed in a nonuiform magnetic field. Will an emf be induced in the loop?

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2. An inductor is connected to a battery through a switch. Explain why the emf induced in the inductor is much larger when the switch is opened as compared to the emf induced when the switch is closed.

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3. The coil of a moving-coil galvanometer keeps on oscillating for along time if it is deflected and released. If the ends of the coil are connected together, the oscillation stops at once. Explain.

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4. A short magnet is moved along the axis of a conducting loop. Show that the loop repels the magnet if the magnet is approaching the loop and attracts the magnet if it is going away from the loop. Two circular loops are placed coaxially but separated by a distance. A battery is suddenly connected at one of the loops establishing a current in it. Will there be a current induced in the other loop? If yes, when does the current start and when does it end? Do the loops attract each other or do they repel?

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5. Two circular loops are placed coaxially but separated by a distance. A battery is suddenly connected to one of the loops establishing a current in it. Will there be a current induced in the other loop? If yes, when does the current start and when does it end? Do the loops attract each other or do they repel?

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6. The battery discussed in the previous question is suddenly disconnected. Is a current induced in the other loop? If yes, when does it start and when does it end? Do the loops attract each other or repel?

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7. if the magnetic field outside a copper box is suddenly changed, what happens to the magnetic field inside the box? Such low-resistivity metals are used to form enclosures which shield objects inside them against varying magnetic fields.

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8. Metallic(noferrmagnetic) and nometallic particles in a solid waste may be separted as follows. The wasts is allowed to slide down an inclin over permanent magnets. The metallic particles slow down as compared to the nonmetallic ones and hence are separted. Discuss the role of eddy currents in the process.

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9. A pivoted aluminium bar falls much more slowly through a small region containing a magnetic field then a similar bar of an insulating material. Explain.

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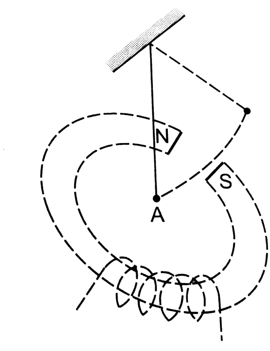
10. A metallic bob A oscillates throgh the space between the poles of an electromagnet . The oscillation are more quickly damped when the circuit is on, as compared to the case when the circuit is off. Explain.



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11. Two circular loops are placed with their centres separted by a fixed distance. How would you orient the loops to have (a) the largest mutual inductance (b) the smallest mutual inducatance?

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12. Consider the self-inductance per unit length of a solenoid at its centre and that near its ends. Which of the two is greater?

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13. Consider the energy density in a solenoid at its centre and that near its ends. Which of the two is greater?

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Objective 1

1. A rod of length l rotates with a small but uniform angular velocity ω about its perpendicular bisector. A uniform magnetic field B exists parallel to the axis of rotation. The potential difference between the centre of the rod and an end is

A. zero

B. $\frac{1}{8}\omega Bl^2$

C. $\frac{1}{2}\omega Bl^2$

D. $B\omega l^2$

Answer: B

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2. A rod of length l rotates with a uniform angular velocity omega about its perpendicular bisector. A uniform magnetic field B exists parallel to the axis of rotation. The potential difference between the two ends of the rod is

A. zero

B. $\frac{1}{2}Bl\omega^2$

C. $Bl\omega^2$

D. $2Bl\omega^2$

Answer: A

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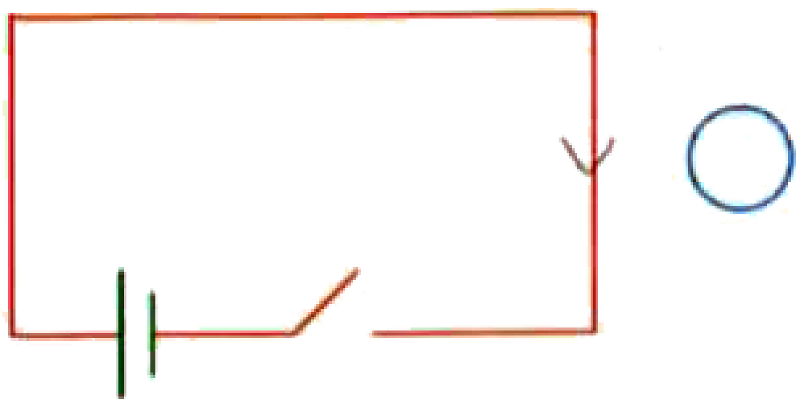
3. Consider the situation shown in figure. If the switch is closed and after some time it is opened again, the closed loop will show



A. an anticlock wise current pulse

B. a clockwise current pulse

C. an anticlockwise current pulse and then a clockwise curent pulse

D. a clockwise current pulse and then an anticlockwise current pulse.

Answer: D

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4. Solve the previous question if the closed loop is completely enclosed in the circuit containing the switch.

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5. A bar magnet is released from rest along the axis of a very long, vertical copper tube. After some time the magnet.

A. Will stop in the tube

B. Will move with almost contant speed

C. will moce with an acceleration g

D. will oscillate.

Answer: B

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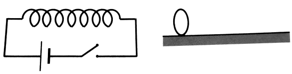
6. shows a horizontal solenoid connected to a battery and a switch. A coper ring is placed on a frictionless track, the axis of the ring being along the axis of the solenoid. As the switch is closed, the ring will



A. remain stationary

B. move towards the solenoid

C. move away form the solenoid

D. move towards the solenoid or away from it depending on which terminal (positive or negative) of the battery is connected to the left end of the solenoid.

Answer: C

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7. Consider the following statements: (a)An emf can be induced by moving a conductor in a magnetic field. (b)An emf can be induced by changing the magnetic field.

A. Both A and B are true.

B. A is true but B is false.

C. B is true but A is false.

D. Both A and B are false.

Answer: A

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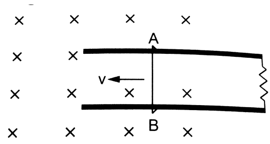
8. Consider the situation shown in . The wire AB is slid on the fixed rails rails with a constant velocity. If the wire AB is replaced by a semicircular wire, the magnitude of the induced current will



A. increase

B. remain the same

C. decrease

D. increase or decrease depending on whether the semi-circle bulges towards the resistance or away form it.

Answer: B

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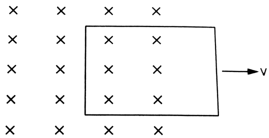
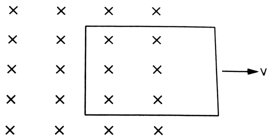
9. shows a conducting loop being pulled out of a magnetic field with a speed v. Which of the four plots shown in may represent the power delivered by the pulling agent as a function of the speed v ?





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10. Two circular loops of equal radii are placed coaxially at some separation. The first is cut and a battery is inserted in between to drive a current in it. The current changes slightly because of the variation in resistance with temperature. During this period, the two loops

A. attract each other

B. repel each other

C. do not exert any force on each other

D. attract or repel each other depending on the sense of the current.

Answer: A

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11. A small, conducting circular loop is placed inside a long solenoid carrying a current. The plane of the loop contains the axis of the solenoid. If the current in the solenoid is varied, the current induced in the loop is

A. clock wise

B. anticlockwise

C. zero

D. clockwise or anticlockwise depending on whether the resistance is increased or decreased.

Answer: C

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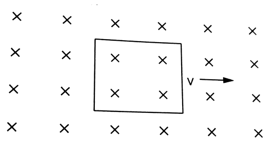
12. A conducting square loop of side l and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A uniform and constant magnetic field B exists along the perpendicular ot the plane of the loop as shown in . The current induced in the loop is



A. Blv/R clockwise

B. Blv/R anticlockwise

C. 2 Blv/R anticlockwise

D. zero.

Answer: D

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Objective 2

1. A bar magnet is moved along the axis of a copper ring placed far away from the magnet. Looking from the side of the magnet, an anticlockwise current is found to be induced in the ring. Which of the following may be true?

A. The south pole faces the ring and the magnet moves towards it.

B. The north pole faces the ring and the magnet moves towards it.

C. The south pole faces the ring and the magnet moves away form it.

D. The north pole faces the ring and the magnet moves away form it.

Answer: B::C

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2. A conducting rod is moved with a constant velocity v in a magnetic field. A potential difference appears across the two ends

A. if $\overrightarrow{v} \mid \mid \overrightarrow{l}$

B. if $\vec{v} \mid \mid \vec{B}$

C. if $\vec{l} \mid \mid \vec{B}$

D. none of these.

Answer: D

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3. A conducting loop is placed in front of a strong magnetic pole. A force is needed to

A. hold the sheet there if the metal is magnetic

B. hold the sheet there if the metal is nonmagnetic

C. move the sheet away from the pole with uniform velocity if the metal is nonmagnetic. Neglect and effect of peramagnetism, diamagnetism and gravity.

D.

Answer: C::D

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4. A metal sheet is placed in front of a strong magnetic pole. A force is needed to

A. hold the sheet there if the metal is magnetic

B. hold the sheet there if the metal is nonmagnetic

C. move the sheet away from the pole with uniform velocity if the metal is nonmagnetic.

D. move the sheet away from the pole with uniform velocity if the metal is nonmegnetic. Neglect any effect of paramagnetism, diamagnetism and gravity.

Answer: A::C::D

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5. A constant current I is maintained in a solenoid. Which of lthe following quantities will increase if an iron rod is inserted in the solenoid along its asix?

A. magnetic field at the centre

B. magnetic flux linked with the solenoid

C. self inductance of the solenoid

D. rate of Joule heating.

Answer: A::B::C

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6. Two solenoids have identical geometrical construction but one is made of thick wire and the other of thin wire. Which of the following quantities are different for the two solenoids?

A. self inductance

B. rate of Joule heating if the same current goes through them

C. magnetic field energy if the same current goes throgh them

D. time constant if one solenoid is conneted to one battery and the other is connected to another battery.

Answer: B::D

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7. An LR circuit with a battery is connected at t=0. Which of the following quantities is not zero just after the connection?

A. Current in the circuit

B. Magetic field energy in the inductor

C. Power delivered by the battery

D. Emf induced int the inductor

Answer: D

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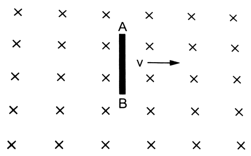
8. A rod AB moves with a uniform velocity v in a uniform magnetic field as shown in figure



A. The rod becomes electrically charged.

B. The end A becomes positively charged.

C. The end B becomes positively charged.

D. The rod becomes hot becaues of Joule heating

Answer: B

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9. L,C and R represent the physical quantities inductance, capacitance and resistance respectively. Which of the following combinations have dimensions of frequency?

A. (1)/(RC)

B. (R)/(L)

C. (1)/(sqrtLC)

D. C/L

Answer: A::B::C

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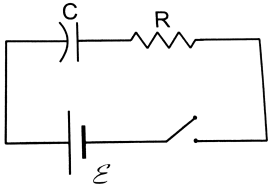
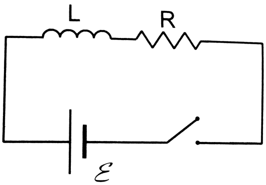
10. The switches in figure and are closed at $=0$ and reopended after al long time at $t=t_0$.





A. The charge on C just after t=0 is epsilon c.

B. The charge on C long after t = 0 is epsilon C.

C. The current in L just before t= t_0 is epsilon l/R.

D. The current in L long after t= t_0 is `epsilon /R.

Answer: B::C

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Exercises

1. Calculate the dimensions of (a) $\int \overrightarrow{E} . d\overrightarrow{l}$, $(b) vBl$ and $\frac{d\Phi_0}{dt}$. The symbols have their usual meanings.

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2. The flux of magnetic field through a closed conducting loop changes with time according to the equation, $\Phi = at^2 + bt + c$. (a) Write the SI units of a,b and c. (b) if the magnitudes of a,b and c are 0.20, 0.40 and 0.60 respectively, find the induced emf at t = 2 s.

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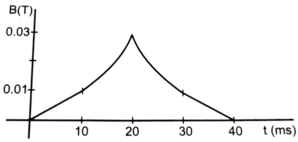
3. (a) the magnetic field in a region varies as shown in . Calculate the average induced emf in a conducting loop of area `2.0X10^(-3) m^2 placed perpendicular to the field in each of the10ms intervals shown. (b) In which intervals is the emf not constant? Neglect the behaviour near the ends of

10 ms intervals.



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4. A conducing circular loop having a radius of 5.0cm, is placed perpendicular to a magnetic field of 0.50 T. It is removed from the field in 0.50 s. Find the average emf produced In the loop during this time.

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5. A coducting circular loop of area $1mm^2$ is placed coplanarly with a long, straight wire at a distance of 20 cm from if. The straight wire carries an electric current which changes from 10A to zero is 0.1 s. Find the average emf induced in the loop in 0.1 s.

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6. A square- shaped copper coil has edges of length 50cm and contains 50 turns. It is placed perpendicular to 1.0 T magnetic field. It is removed form the magnetic field in 0.25 s and restored in its joriginal place in the next 0.25 s. Find the magnitude of the average emf induced in the loop during (a) its removal, (b) its restoration and (c) its motion.

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7. Suppose the resistance of the coil in the previous problem is 25Ω. Assume that the coil moves with uniform velocity during its removal and restoration. Find the thermal energy developed in the coil during (a) its removal, (b) its restoration and (c) its motion.

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8. A conducting loop of area $5.0cm^2$ is placed in a magnetic field which varies sinusodially with time as $B = B_0 \sin \omega t$ where $B_0 = 0.20T$ and $\omega = 300s^{-1}$. The normal to the coil makes an angle of 60° with the field.

Find (a) the maximum emf induced in the coil, (b) the emf induced at $\tau = \left(\frac{\tau}{900}\right)s$ and (c) the emf induced at $t = \left(\frac{\pi}{600}\right)s$.

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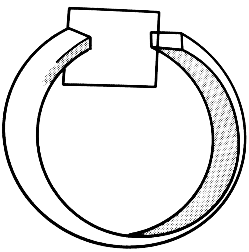
9. Shows a conducting square loop placed parallel to the pole faces of a ring magnet. The pole faces have an are of 1cm^2 each and the field between the poles is 0.10 T. The wires making the loop are all outside the magnetic field. If the magnet is removed in 1.0 s, what is the average emf induced in the loop?



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10. A conducting square loop having edges of length2.0 cm is rotated through 180° about a diagonal in 0.20s. A magnetic field B exists in the region which is perpendicular to the loop in its initial position. If the average induced emf during the rotation is 20 mV, find the magnitude of the magnetic field.

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11. A conducting loop of face area A and resistance R is plaed perpendicular to a magnetic field B. The loop is withdrawn completely from the field. Find the charge which flows through any cross section of the wire in the process. Note that it is independent of the shape of the loop as well as the way it is withdrawn.

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12. A long solenoid of radius 2 cm has 100 turns/cm and carries a current of 5A. A coil of radius 1 cm having 100 turns and a total resistance of 20 Omega is placed inside the solenoid coaxially. The coil is connected to a galvanometer. If the current in the solenoid is reversed in direction, find the charge flown through the galvanometer.

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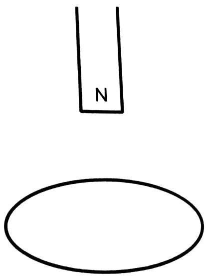
13. The north pole of a magnet is brought down along the axis of a horizontal circular coil . As a result, the flux through the coil changes from 0.35 weber to 0.85 weber in an interval of half a second. Find the average emf induced during this period. Is the induced current clockwise or anticlockwise as you look into the coil from the side of the magnet?



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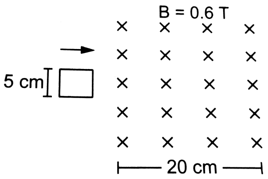
14. Shown a square loop of side 5 cm beign moved towards right at a constant speed of 1 cm/s. the front edge enters the 20 cm wide magnetic field at $t = 0$. Find the emf induced in the loop at

$(a)t = 2s, (b)t = 10s, (c)t = 22s, (d)t = 30s.$



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15. Find the total heat produced in the loop of the previous problem during the interval 0 to 30 s if the resistance of the loop is `4.5 mOmega.

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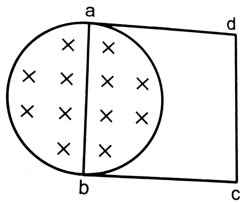
16. A uniform magnetic field B exists in a cylindrical region of radius 10 cm as shown in. A uniform wire of length 80 cm and resistance 4.0 Omega is bent into a square frame and is placed with one side along a diameter of the cylindrical region. If the magnetic field increases at a constant rate of

0.010 T/s, find the current induced in the frame.



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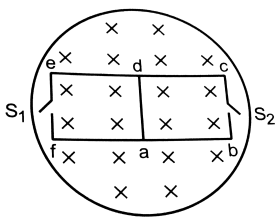
17. The magnetic field in the cylindrical region shown in increases at a constant rate of 20.0 mT/s. Each side of the square loop abcd and defa has a length of 1.00 cm and a resistance of 4.00Ω. Find the current (magnitude and sense) in the wire ad if (a) the switch S_1) is closed but S_2 is open, (b) S_1 is open but S_2 is closed, (c) both S_1 and S_2 are open and (d) both S_1 and S_2 are closed.



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18. A circular coil of radius 2.00 cm has 50 turns. A uniform magnetic field B= 0.200 T exists in the space is a direction parallel to the axis of the loop. The coil is now rotated about a diameter through an angle of 60.0°. The operation takes 0.100 s. (a) find the average emf induced in the coil. (b) if the coil is a closed one(with the two ends joined together) and has a resistance of 4.00Ω. calculate the net charge crossing a cross- section of the wire of the coil.

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19. A closed coil having 100 turns is rotated in a uniform magnetic field $B = 4.0 \times 10^{-4}$ T about a diameter which is perpendicular to the field. The angular velocity of rotation is 300 revolutions per minute. The area of the coil is $25cm^2$ and its resistance is 4.0Ω. Find (a) the average emf developed in the half a turn form a position where the coil is perpendicular to the magnetic field, (b) the average emf in a full turn and (c) the net charge displaced in part (a).

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20. A coil of radius 10 cm and resistance 40Ω has 1000 turns. It is placed with its plane vertical and its axis parallel to the magnetic meridian. The coil is connected to a galvanometer and is rotated about the vertical diameter through an angle of 180°. Find the charge which flows through the galvanometer if the horizontal component of the earth's magnetic field is $B_H = 3.0 \times 10^{-5} T$.

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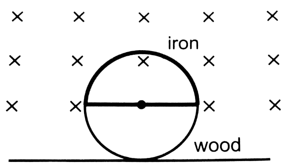
21. shows a circular wheel of radius 10.0 cm whose upper half, shown dark in the figure, is made of iron and the lower half of wood. The two junctions are joinded by an iron rod. A uniform magnetic field B of magnitdue 2.00X 10^(-4) T exists in the space above the central line as suggested by the figure. The wheel is set into pure rolling on the horizontal surface. The wheel is set into pure rolling on the horizontal surface. If it takes 2.00 seconds for the iron part to come down and the wooden part to go up, find the average emf induced during this period.



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22. A 20 cm long conducting rod is set into pure translation with a uniform velocity of `10cm s ^(-1) perpendicuarl to its length. A uniform magnetic field jof magnitude 0.10 T exissts in a direction perpendicuarl to the plane of motion.

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23. A metallic metre sitck moves with a velocity of ` 2 ms ^(-1) in a direction perpendicular to its length and perpendicular to a uniform magnetic field of magnitude 0.2 T. Find the emf indcued between the ends of the stick.

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24. A 10 m wide spacecraft moves through the interstellar space at a speed $3 \times 10^7 ms^{-1}$. A magnetic field $B = 3 \times 10^{-10} T$ exists in the space in a direction perpendicular to the plane of motion. Treating the spacecraft as a conductor, calculate the emf induced across its width.

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25. The two rails of a railway track, insulated form each other and from the ground, are connected to a millivoltmeter. What will be the reading of the millivoltmeter when a train travels on the track at a speed of $180 kmh^{-1}$? The vertical component of earth's magnetic field is 0.2×10^{-4} and the rails are separated by 1m.

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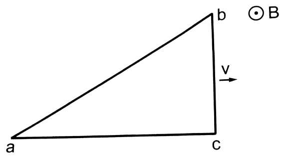
26. A right angled triangle abc, made from a metallic wire, moves at a uniform speed v in its plane as shown in . A uniform magnetic field B exists in the perpendicular direction. Find the emf induced (a) in the loop abc, (b) in the segment bc, (c) in the segment or and (d) in the segment ab.



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27. A copper wire bent in the shape of a semicircle of radius r translates in its plane with a constant velocity v. A uniform magnetic field B exists in the direction perpendicular to the plane of the wire. Find the emf induced between the ends of the wire if (a) the velocity is perpendicular ot the diameter joining free ends, (b) the velocity is parallel to this diameter.

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28. A wire of length 10cm translates in a direction making an angle of 60° with its length. The plane of motion is perpendicular ot a uniform magnetic field of 1.0 T that exists in the space. Find the emf induced between the ends of the rod if the speed of translation of `20 cm s^(-1).

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29. A circular copper ring of radius r translates in its plane with a constant velocity v. A uniform magnetic field b exists in the space in a direction perpendicular ot the plane of the ring. Consider different pairs of diametrically opposite points on the ring. (a) Between which pair of points is the emf? (b) Between which pair of points is the emf minimum? What is the value of this minimum emf?

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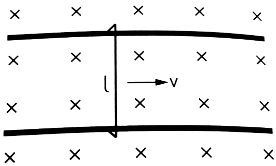
30. Shows a wire sliding on two parallel, conducting rails placed at a separation l. A magnetic field B exists in a direction perpendicular to the plane of the rails. What force is necessary to keep the wire moving at a constant velocity v ?



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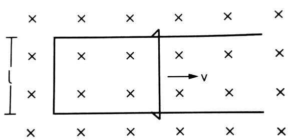
31. shows a long U shaped wire of width l placed in a perpendicular magnetic field B. A wire of length l is slid on the U shaped wire with a constant velocity v towards right. The resistance of all the wires is r per unit length. At t =0, the sliding wire is close to the left edge of the U shaped wire. Draw an equivalent circuit diagram, showing the induced emf as a battery. Calculate the current in the circuit.



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32. Consider the situation of the previous problem. (a) Calculate the force needed to keep the sliding wire moving with a constant velocity v. (b) If the force needed just after t = 0 is F_0, find the time at which the force needed will be F_0 /2.

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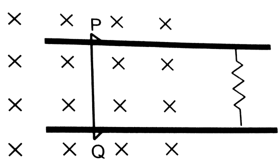
33. Consider the situation shown in . The wire PQ has mass m, resistance r and can slide on the smooth, horizontal parallel rails separted by a distance l. The resistance of the rails is negligible. A uniform magnetic field B exists in the rectangualr region and a resistance R connects the rails outsided the field region At t= 0, the wire PQ is puched towards right with a speed v_0. find (a) the current in the loop at an instant when the speed of the wire PQ is v, (b) the acceleration of the wire at this instatn, (c) the velocity v as a function of x and (d) the maximum distance the wire will move.



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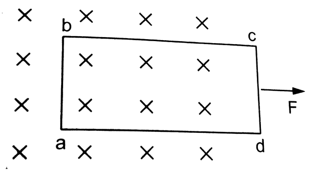
34. A rectangular frame of wire abcd has dimensions 32cm X 8.0 cm and a total resistance of 2.0Ω. It is pulled out of a magnetic field $B = 0.020T$ by applying a force of 3.2×10^{-5} N . It is found that the frame moves with constant speed. Find (a) this constant speed, (b) the emf induced in the loop, (c) the potential difference between the points c and d.



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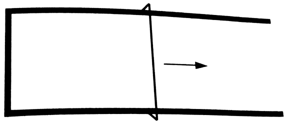
35. Shows a metallic wire of resistance 0.20Ω sliding on a horizontal, U shaped metallic rail The separation between the parallel arms is 20 cm. jAn electric current of $2.0\mu A$ passes through the wire when it is slid at a rate of $20cms^{-1}$. If the horizontal component of the earth's magnetic field is $3.0X10^{-5}$ T, calculate the dip at the place.



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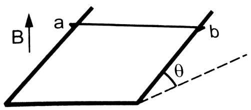
36. A wire ab of length l, mass m and resistance R slide on a smooth, thick pair of metallic rails joined at the bottom as shown in . The plane of the the rails makes an angle θ with the horizontal. A vertical magnetic field B exists in the region. if the wire slides on the rails at a constant speed v, show that $B = \frac{\sqrt{mgR\sin\theta}}{vl^2\cos^{\theta}}$.



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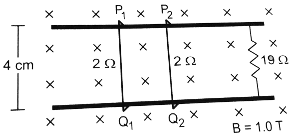
37. Consider the situation shown in . The wires P_1Q_1 and P_2Q_2 are made to slide on the rails with the same speed

$5cms^{-1}. F \in dthee \leq ctriccurrent \in the$19Omega

$resis \rightarrow r$ if $(a) \perp hthewiresmove \rightarrow wardsright$ and (b) if P_1

Q_1$moves \rightarrow wards \leq ftbut$P_2 Q_2` moves towards right.



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38. Suppose the 19Ω resistor of the previous problem is disconnected. Find the current through P_2Q_2 in the two situations (a) and (b) of that problem.

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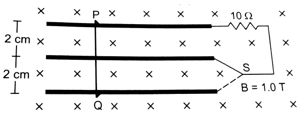
39. Consider the situation shown in . The wire PQ has a negligible resistance and is made to slide on the three rails with a constant speed of $5cms^{-1}. F \in dthecurrent \in the$10 Omega` resistor when the switch

S is thrown to (a) the middle rail (b) the bottom rail.



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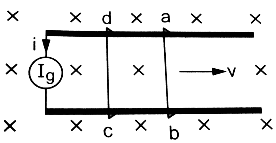
40. The current generator I_g, shown in . Sends a constant current I through the circuit. The wire cd is fixed and ab is made to slide on the smooth, thick rails with a constant velocity v towards right. Each of these wire has resistance r. Find the current through the wire cd.



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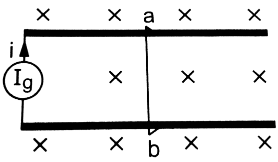
41. The current generator i_g, shown in , sends a constant current I through the circuit. The wire ab has a length l and mass m and can slide on the smooth, horizontal rails connected to l_g. The entire system lies in a vertical magnetic field B. Find velocity of the wire as a function of time.



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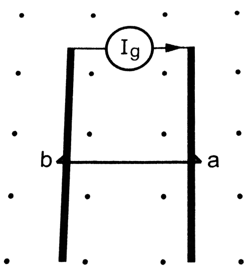
42. The system containing the rails and the wire of the previous problem is kept vertically in a uniform horizontal magnetic field B that is perpendicular to the plane of the rails. It is found that the wire stays in equilibrium. If the wire ab is replaced by another of double its mass, how long will it take in falling through a distance equal ot its length?



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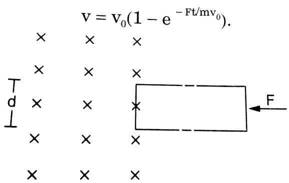
43. The rectangualr wire- frame, shown in has a width d, mass m, resistance R and a large length. A uniform magnetic field B exists to the left of the frame. A constant force F starts pushing the frame into the magnetic field at t =0. (a) Find the acceleration of the frame when its speed has increased to v. (b) Show that after some time the frame will move with a constant velocity till the whole frame enters into the magnetic field. find this velocity v_0. (c) show that the velocity at tiem t is given by $v = v_0\left(1 - e^{-F\frac{t}{m}v_0}\right.$.



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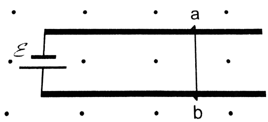
44. Shows a smooth pair of thick metallic rails connected across a battery of emf ε having a negligible internal resistance. A wire ab of length l and resistance r can slide smoothly on the rails. The entire system lien in a horizontal plane and is immersed in a uniform vertical magnetic field B. At an instant t, the wire is given a small velocity v towards right. (a) find the current in it at this instant. What is the direction of the current? (b) What is the force acting on the wire at this instant? (c) Show that after some time the wire ab will slide with a constant velocity. Find this velocity.



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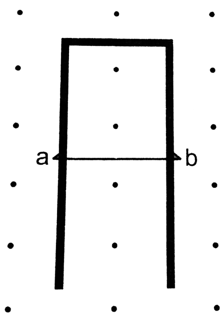
45. A conducting wire ab of length l, resistance r and mass m starts sliding at t = 0 down a smooth, vertical, thick pair of connected rails as shown in . A uniform magnetic field B exists in the space in a diraction perpendicular to the plane of the rails. (a) Write the induced emf in the loop at an instant t when the speed of the wire is v. (b) what would be the magnitude and direction of the induced current in the wire? (c) Find the downward acceleration of the wire at this instant. (d) After sufficient time, the wire starts moving with a constant velocity. Find this velocity `v_m. (e) Find the velocity of the wire as a function of time. (f) Find the displacement of the wire as a functong of time. (g) Show that the rate of heat developed inte wire is equal to the rate at which the gravitational potential energy is decreased after steady state is reached.



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46. A bicycle is resting on its stand in the east - west direction and the rear wheel is rotated at an angular speed of 100 revolutions per minute. If the length of each spoke is 30.0 cm and the horizontal component of the earth's magnetic field is $2.0 \times 10^{-5} T$, find the emf induced between the axis and the outer end of a spoke. Neglect centripetal force acting on the free electrons of the spoke.

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47. A conducting disc of radius r rotates with a small but constant angular velocity ω about its axis. A uniform magnetic field B exists parallel to the axis of rotation. Find the motional emf between the centre and the periphery of the disc.

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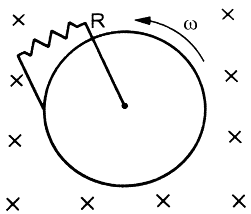
48. shows a conducting disc rotating about its axis in a perpendicular magnetic field B. A resistor of resistance R is connected between the centre and the rim. Calculate the current in the resistor. Does it enter the disc or leave it at the centre? The radius of the disc is 5.0 cm , angular speed $\omega = 10ra\frac{d}{s}, B = 0.40T$ and $R = 10\Omega$.



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49. The magnetic field inn a region is given by $\overrightarrow{B} = \overrightarrow{k}\frac{B_0}{L} y where L is a fixed \le n > h. A conduct \in g rod of \le n > h L lie$

v= v_0 veci, find the emf induced between the ends of the rod.

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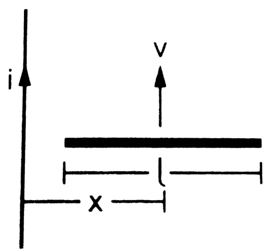
50. shows a straight, long wire carrying a current I and a rod of length l coplanar with the wire and perpendicular to it. The rod moves with a constant velocity v in a direction parallel to the wire. The distance of the wire from the centre of the rod is x. Find the motional emf induced in the rod.



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51. Consider a situation similar ot that of the previous problem except that the ends of the rod slide on a pair of thick metallic rails laid parallel to the wire. At one end the rails are connected by resistor of resistance R. (a) what force is needed ot keep the rod sliding at a constant speed v? (b) in this situation what is the current in the resistance R? (c) Find the rate of heat developed in the resistor. (d) find the power delivered by the external agent exerting the force on the rod.

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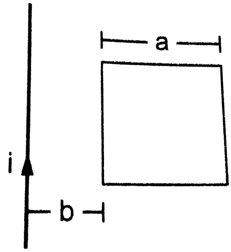
52. Shows a square frame of wire having a total resistance r placed coplanarly with a long, straight wire. The wire carries a current I given by $i = i_0 \sin \omega t$. Find(a) the flux of the magnetic field through the square frame, (b) the emf induced in the frame and (c) the heat developed in the frame in the time interval 0 to $\frac{20\pi}{\omega}$.



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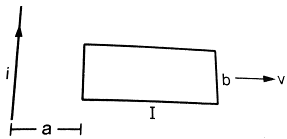
53. A rectangular metallic loop of length l and width b is placed coplanerly with a long wire carrying a current I . The loop is moved perpendicular to the wire with a speed v in the plane containing the wire and the loop. Calculate the emf induced in the loop when the rear end of the loop is at a distance a from the wire. Solve by using Faraday's law for the flux through the loop and also by replacing different segments with equivalent batteries.



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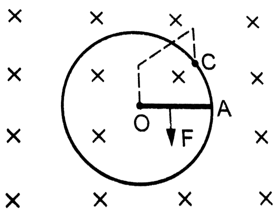
54. Shows a conducting circular loop of radius a placed in a uniform, perpendicular magnetic field B. A thick metal rod OA is pivoted at the centre O. The other end of the rod touches the loop at A. The centre O and a fixed point C on the loop are connected by a wire OC of resistance R. A force is applied at the middle point of the rod OA perpendicularly, so that the rod rotates clockwise at a uniform angular velocity ω. Find the force.



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55. Consider the situation shown in the figure o fthe previous problem. Suppose the wire connecting O and C has zero resistance but circular loop has a resistance R uniformly distributed along its length. The rod OA is made ot rotate with a uniform angular speed ω as shown in the figure. Find the current in the rod when $< AOC = 90^\circ$.

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56. Consider a variation of the previous problem. Suppose the circular loop lies in a vertical plane. The rod has a mass m. The rod and the loop have negligible resistances but the wire connecting O and C has a resistance R. The rod is made to rotate with a uniform angular velocity ω in the clockwise direction by applying a force at the midpoint of OA in a dirction perpendicular ot it. find the magnitude of this force when the rod makes an angle θ with the vertical.

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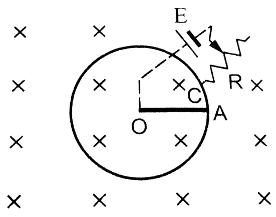
57. Shows a situation similar to the previous problem. All parameters are the same except that a battery of emf ε and a variable resistance R are connected wires. Let θ be the angle made by the rod from the horizontal position (shown in the figurer), measuredin the clockwise direction. During the part of the motion $O < \theta < \frac{\pi}{4}$ the only forces acting on the rod are gravity and the forces exerted by the magnetic field and the pivot.

However, during the part of the motion, the resistance R is varied in such a way that the rod continues to rotate with a constant angular velocity ω. Find the value of R in terms of the given quantities.



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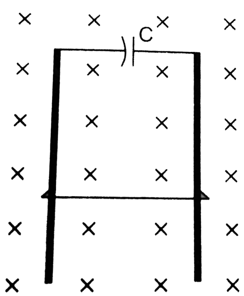
58. A wire of mass m and length l can slide freely on a pair of smooth, vertical rails. A magnetic field B exists in the region in the direction perpendicular to the plane of the rails. The rails are connected at the top end by a capacitor of capacitance C. Find the acceleration of the wire neglecting any electric resistance.



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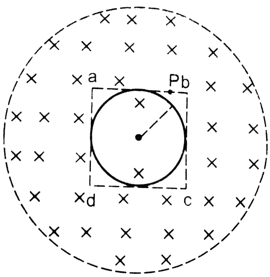
59. A uniform magnetic field B exists in a cylindrical region, shown dotted in. The magnetic field increases at a constant rate $\frac{dB}{dt}$ Consider a circle of radius r coaxial with the cylindrical region. (a) find the magnitude of the electric field E at a point on the circumference of the circle. (b) Consider a point P on the side of the square circumscribing the circle. Show that the component of the induced electric field at P along ba is the same as the magnitude found in part(a).



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60. The current in an ideal, long solenoid is varied at a uniform rate of $0.01As^{-1}$. The solenoid has 2000 turns/m and its radius 6.0 cm. (a)

Consider a circle of radius 1.0 cm inside the solenoid with its axis coinciding with the axis of the solenoid. write the change in the magnetic flux through this circle in 2.0 seconds. (b) find the electric field induced at a point on the circumference of the circle. (c) find the electric field induced at a point outside the solenoid at a distance 8.0cm from its axis.

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61. An average emf of 20 V is induced in an inductor when the current in it is changed from $2.5A$ in one direction to the same value in the opposite direction in 0.1 s. Find the self inductance of the inductor.

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62. A magnetic flux of 8×10^{-4} weber is linked with each turn of a 200 - turn coil when there is an electric current of 4 A in it. Calculate the self inductance of the coil.

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63. The current is a solenoid of 240 turns, having a length of 12 cm and a radius of 2 cm, changes at a rate of $0.8 A s^{-}$. Find the emf induced in it.

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64. Find the value of $\frac{t}{\tau}$ for which the current in an LR circuit builds up to (a) 90%, (b) 99% and (c) 99.9% of the steady-state value.

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65. An inductor coil carries a steady state current of 2.0 A when connected across an ideal battery of emf 4.0 V. if its inductance is 1.0 H, find the time constant of the circuit.

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66. A coil having inductance 2.0 H and resistance 20Ω is connected to a battery of emf 4.0 V. Find (a) the current a the instant 0.20 s after the connection Is made and (b) the magnetic energy at this instant.

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67. A coil of resistance 40Ω is connected across a 4.0 V battery. 0.10 s after the battery is connected, the current in the coil is 63 mA. Find the inductance of the coil.

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68. An inductor of inductance 5.0 H, having a negligible resistance, is connected in series with a 100Ω resistor and a battery of emf 2.0 V. Find the potential difference across the resistor 20 ms after the circuit is switched on.

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69. The time constant of an LR circuit is 40 ms. The circuit is connected at t= 0 and the steady state current is found ot be 2.0 A. Find the current at (a) t= 10 ms (b) t =20ms, (c) t =100ms and (d) t = 1 s.

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70. An LR circuit has L = 1.0 H $R = 20\Omega$. It is connected across an emf of $2.0 V at t = 0$. Find $d\frac{i}{dt} at (a) t = 100 ms, (b) t = 200 ms \text{ and } (c) t = 1.0 s.$

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71. What are the values of the self induced emf in the circuit of the previous problem at the times indicated therein?

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72. An inductor-coil of inductance 20 mH having resistance 10Ω is joined to an ideal battery of emf 5.0 V. Find the rate of change of the induced emf at t=0, (b) t = 10 ms and (c) t = 1.0s.

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73. An inductor coil of resistance 10Ω and inductance 120 mH is connected across a battery of emf 6 V and internal resistance 2Ω. Find the charge which flows through the inductor in (a) 10 ms, (b) 20ms and (c) 100ms after the connections are made.

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74. An inductor coil of inductance 17 mH is constructed from a copper wire of length 100 m and cross - sectional are $1mm^2$. Calculate the time constant of the circuit if this inductor is joined across an ideal battery. The resistivity of copper =`1.7 X 10^(-8) Omega m.

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75. A coil having an inductance L and a resistance R is connected to a battery of $emf \varepsilon$. Find the time elapsed before (a) the current reaches half its maximum value, (b) the power dissipated in heat reaches half its maximum value and © the magnetic field energy stored in the circuit reaches half its maximum value.

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76. A solenoid having inductance 4.0 H and resistance 10 Omega is connected to a 4.0 V battery at t = 0. Find (a) the time constant, (b) the time elapsed before the current reached 0.63 of its steady state value, (c) the power delivered by the battery at this instant and (d) the power dissipated in Joule heating at this instant.

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77. The magnetic field at a point inside a 2.0 mH inductor coil becomes 0.80 of its maximum value in $20\mu s$ when the inductor is joined to a battery. Find the resistance of the circuit.

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78. An LR circuit with emf ε is connected at t = 0. (a) find the charge Q which flows through the battery during O to t. (b) Calculate the work done by the battery during this period. (d) find the magnetic field energy stored in the circuit at time t. (e) Verify that the results in the three parts above are consistent with energy conservation.

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79. an inductor of inductance 2.00 H is joined in series with a resistor of resistance 200Ω and a battery of emf 2.00 V. At t = 10 ms, find (a) th current in the circuit, (b) the power delivered by the batter, (c) the power dissipated in heating the resistor and (d) the rate at which energy is being stored in magnetic field.

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80. Two coil A and B have inductances 1.0 H and 2.0 H respectively. The resistance of each coil is 10Ω. Each coil is connected to an ideal battery of emf $2.0V$ at $t = 0$. Let i_A and i_B be the current in the two circuit at time t. Find the raito $\frac{i_A}{I_B}$ at (a) $t = 100ms$, (b) $t = 200ms$ and (c) $t = 1s$.

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81. The current in a discharging LR circuit without the battery drops from 2.0 A to 0.10 s. (a) find the time constant of the circuit. (b) if the inductance of the circuit is 4.0 H, what is its resistance?

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82. A constant current exists in an inductor coil connected to a battery. The coil is short circuited and the battery is removed. Show that the charge flown through the coil aftter the short circuiting is the same as that which flows in one time constant before the short circuiting.

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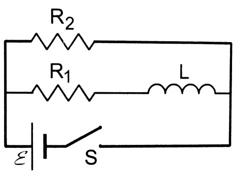
83. Consider the circuit shown in .(a) find the current through the battery a long time after the switch S is closed. (b) Suppose the switch is again opened at t = 0. What is the time constant of the discharging circuit? (c) Find t current through the inductor after one time constant.



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84. A current of 1.0 A is established in a tightly wound solenoid radius 2 cm having 1000 turns/metre. Find the magnetic energy stored in each metre of the solenoid.

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85. Consider a small cube of volume $1mm^3$ at the centre of a circular loop of radius 10 cm carrying a current of 4 A. Find the magnetic energy stored inside the cube.

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86. A long wire carries a current of 4.00 A. Find the energy stored in the magnetic field inside a volume of $1.\,mm^3$ at a distance of 10.0 cm from the wire.

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87. The mutual inductance between two coils is 2.5 H. If the current in one coil is changed at the rate of `1 As^(-1), what will be the emf induced in the other coil?

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88. A solenoid of length 20cm, area of cross- section $4.0 cm^2$ and having 4000 turns is placed inside another solenoid of 2000 turns having a cross - sectional area `8.0cm ^2 and length 10 cm. Find the mutual inductance between the solenoids.

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89. The current in a long solenoid of radius R and having n turns per unit length is given by $i = i_0 \sin \omega t$. A coil having N turns is wound around it near the centre. Find (a) the induced emf in the coil and (b) the mutual inductance between the solenoid and the coil.

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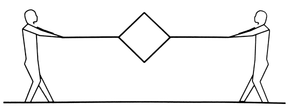
Exercise

1. Shown a metallic square frame of edga a in a vertical plane. A uniform magnetic field B exists in the space in a directon perpendicular to the plane of the figure. Two boys pull the opposite corners of the square ot deform it into a rhombus. They start pulling the corners t t=0 and sisplace the corners at a uniform speed u. (a) find the induced emf in the frame at the instant when the angles at these corners reduce to 60°. (b) find the induced current in the frame at this instatnt if the total resistance of the frame is R. (c) Find the total charge which flows through a side of the frame by the time the square is deformed into a straight line.



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2. A wire loop confined in a plane is rotated in its oen plane with some angular velocity. A uniform magnetic field exists in the region. Fid the emf induced in the loop.

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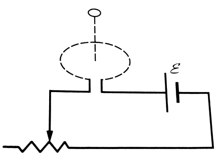
3. Shown a circular coil of N turns and radius a, connected to a battery of emf ε through a rheostat. The rheostat has a total length L and resistance R. The resistance of the coil is r. A small circular loop of radius a' and resistance r' is placed coaxially with the coil. The centre of the loop is at a distance x from the centre of the coil. In the beginning, the sliding contact of the rehostat is at the left end and then on wards it is moved towards right at a constant speed v. Find the emf induced in the small circular loop at the instant (a) the contact begins to slide and (b) it has slid through half the length of the rheostat.



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4. A circular coil of one turn of radiius 5.0 cm is rotated about a diameter with a constatn angular speed of 80 revolutions per minute. A uniform magnetic field B =0.010 T exists in a directon perpendicular to the axis of rotation. Find (a) the maximum emf induced, (b) the average emf induced in the coil over a long period and (c) the average of the squares of emf induced over a long period.

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5. suppose the ends of the coil in the previous problem are connected to a resistane of 100Ω. Neglecting the resistance of the coil, find the heat produced in the circuit in one minute.

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6. An LR circuit constains an inductor of 500 mH, a resistor of $25.\,O\Omega$ and an emf of 5.00 V in series. Find the potential difference across the resistor at t =(a) 20.0 ms, (b) 100 ms and (c) 1.00 s.

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7. An LR circuit having a time constant of 50 ms is connected with an ideal battery of emf ε . Find the time taken for the magnetic energy stored in the circuit to change from one fourth of the steady state value to half of the steady state value.

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8. Find the mutual inductance between the straight wire and the square loop of figure.

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9. Find the mutual inductance between the circular coil and the loop shown in figure.

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