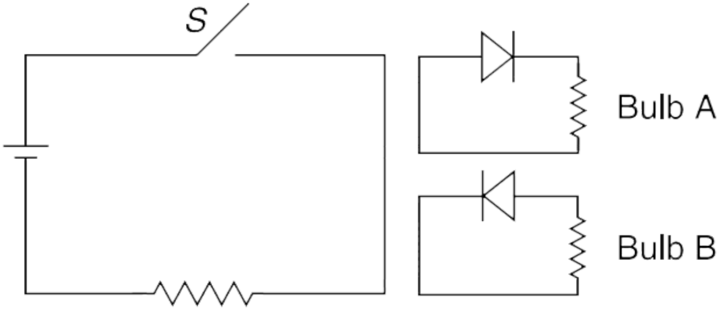
PHYSICS

BOOKS - ARIHANT PHYSICS (HINGLISH)

ELECTROMAGNETIC INDUCTION

Level 1

1. In the Figure shown, when the switch S is closed, one of the two bulbs glows momentarily. Which one?



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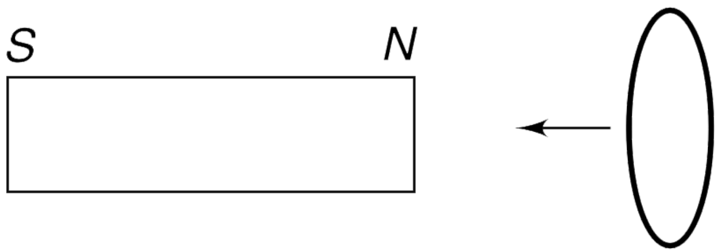
2. A short circuited coil is moved towards a fixed magnet at a constant velocity. When the coil is at a distance x from the magnet it experiences a magnetic force F. Now the number of turns in the coil is doubled and the experiment is repeated with the coil moving with same constant velocity towards the magnet. What will be the magnetic force on the coil when it is at a distance x from the magnet?



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3. A horizontal conducting loop of radius R is fixed in air. A uniformly charged rod having charge Q on it is held vertically above the conducting loop at a height h above it. The rod is released and it begins to fall along the axis of the loop. Calculate the emf induced in the conducting loop.

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4. (a) When a small magnet is moved towards a sole- noid, an emf is induced in it. However, if a magnet is moved inside the hole of a toroid, no emf is induced. Explain.

(b) A wire is kept horizontal along North-South direction. It is allowed to fall freely. How much emf will be induced across the ends of the wire due to presence of Earth's magnetic field.

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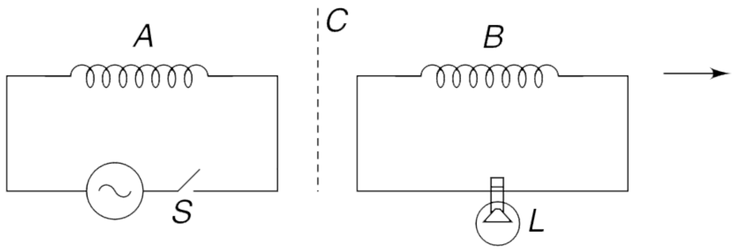
5. Coil A is connected to an ac source through a switch S. Coil B, kept close to A, is connected to a low voltage bulb (L). Explain the following observations.

(i) When S is closed, the bulb lights up.

(ii) With S closed if B is moved away from A, the bulb gets dimmer.

(iii) With S closed, if a copper plate C is inserted between the coils, the bulb gets dimmer.



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6. A coil is rotated with constant angular speed in a uniform magnetic field about an axis that is perpendicular to the field. Tell, with reason, if the following statement is true– “The emf induced in the coil is maximum at

the instant the magnetic flux through the coil is zero".

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7. ABC is a triangular frame made of a conducting wire and is right angled at B. Its side BC is vertical and AB is horizontal. The frame is placed in a uniform magnetic field B in vertically upward direction. The frame is rotated about its side BC with constant angular speed ω. Resistance of the entire frame is R. Neglect gravity. Length $AB = L, BC = 2L.$

(a) Find the torque needed to keep the frame rotating with constant angular speed.

(b) Find the potential difference between points A and C.

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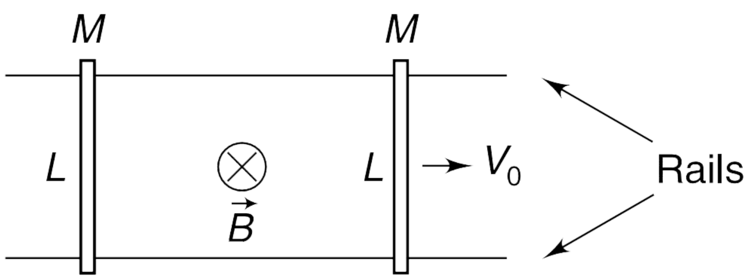
8. Two parallel conducting rails are separated by a distance L. Two identical conducting wires are placed on the rails perpendicular to them.

Each wire has mass M. One of the wires is given a velocity v_0 parallel to the rails away from the other wire. There is a uniform magnetic field directed into the plane of the figure everywhere. Answer following questions for the system comprising of two wires. [Ignore friction and self inductance]



(i) Will the momentum of the system decrease with time?

(ii) What is kinetic energy of the system in steady state?

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9. A stretchable conducting ring is in the shape of a circle. It is kept in a uniform magnetic field (B) that is perpendicular to the plane of the ring. The ring is pulled out uniformly from all sides so as to increase its radius at a constant rate $\frac{dr}{dt} = V$ while maintaining its circular shape. Calculate the rate of work done by the external agent against the magnetic force when the radius of the ring is r_0. Resistance of the ring remains constant at R.

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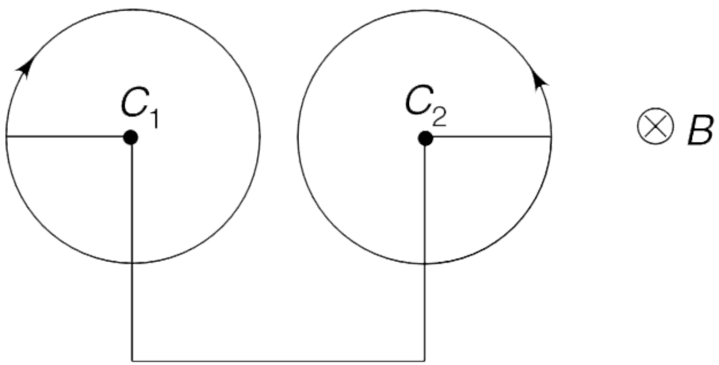
10. Two rods, each of length $L = 0.6m$, are rotating in same plane about their ends C_1 and C_2. The distance between C_1 and C_2 is 1.201 m. The rods rotate in opposite directions with same angular speed ω and they are found to be in position shown in the Figure at a given instant of time. The ends C_1 and C_2 are connected using a conducting wire. There exists a uniform magnetic field perpendicular to the figure having magnitude $B = 5.0T$. At what angular speed ω do we expect to see sparks in air? The dielectric breakdown of air happens if electric field in it exceeds $3 \times 10^6 V m^{-1}$.



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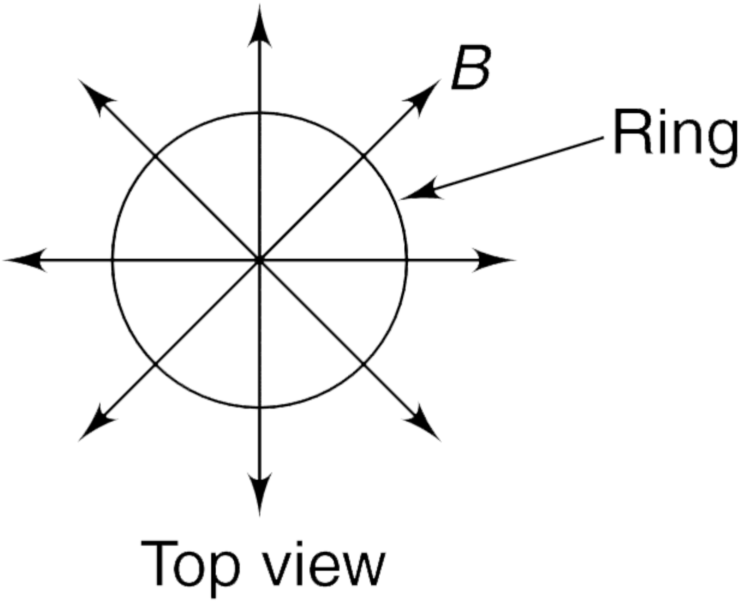
11. A vertical cylindrical region has a horizontal radial magnetic field inside it. A wire ring is made of a wire of cross section S, density d and resistivity ρ. Radius of the ring is r. The ring is kept horizontal with its centre on the axis of the cylindrical region and released. The field strength at all points on the circumference of the ring is B. At a certain instant velocity of the ring is v downward. Find

(a) Current in the ring and

(b) Acceleration of the ring at the instant.



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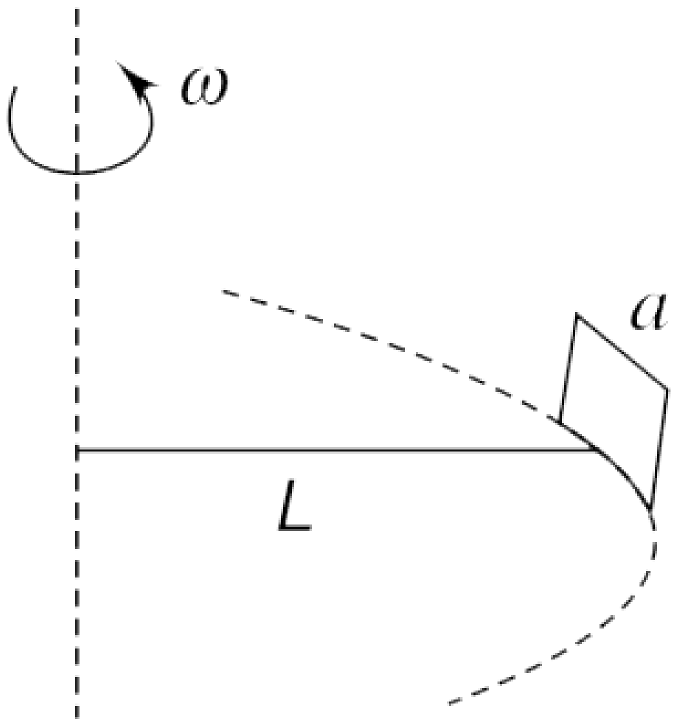
12. A conducting square loop of side length a is held vertical with the help of a non conducting rod of length L. The rod is made to rotate in horizontal circle about a vertical axis through its end. The loop rotates with the rod while its plane always remains perpendicular to the rod. The resistance of the loop is R and angu- lar speed of the rod is ω. There is a uniform horizontal magnetic field B in the entire space. Find the average rate of heat dissipation in the loop during one rotation.



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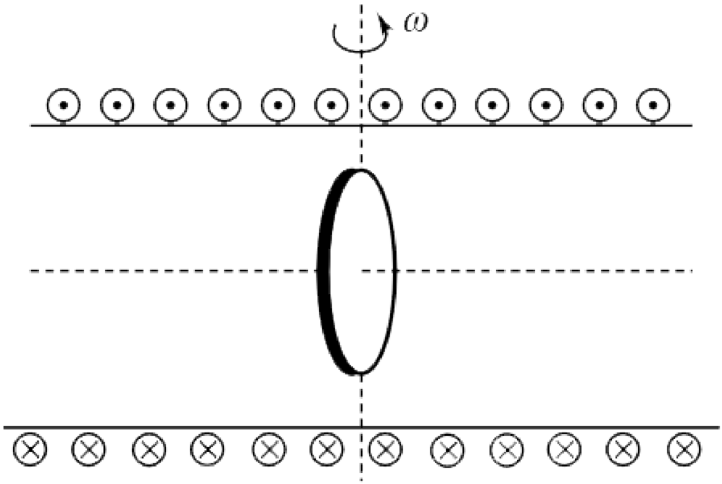
13. A long solenoid has n turns per unit length and carries a current $i = i_0 \sin \omega t$. A coil of N turns and area A is mounted inside the solenoid and is free to rotate about its diameter that is perpendicular to the axis of the solenoid. The coil rotates with angular speed ω and at time t = 0 the axis of the coil coincides with the axis of the solenoid as shown in figure. Write emf induced in the coil as function of time.



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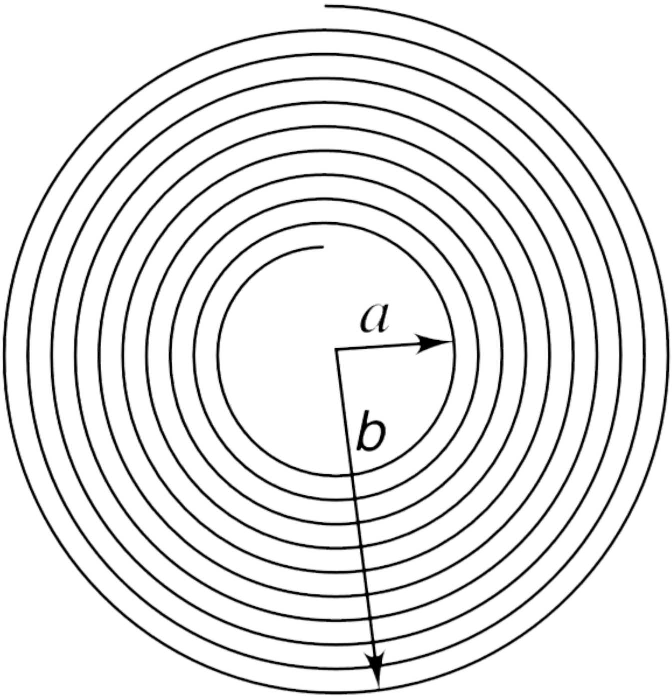
14. A flat coil, in the shape of a spiral, has a large number of turns N. The turns are wound tightly and the inner and outer radii of the coil are a and b respectively. A uniform external

magnetic field (B) is applied perpendicular to the plane of the coil. Find the emf induced in the coil when the field is made to change at a rate $\frac{dB}{dt}$.



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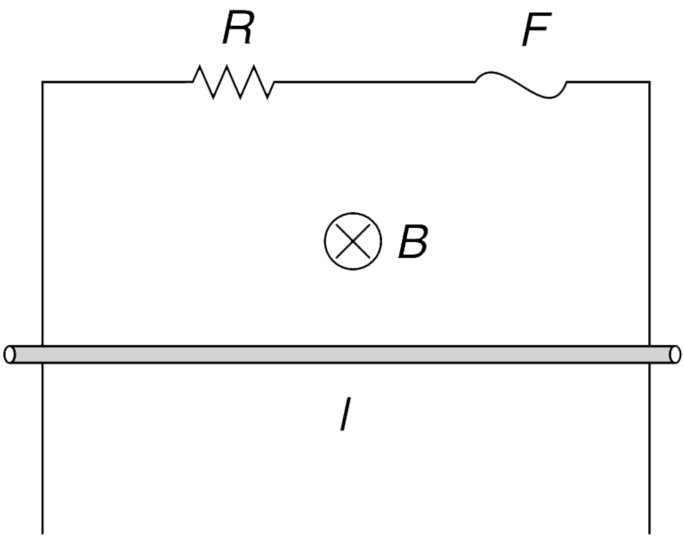
15. A pair of long conducting rails are held vertical at a separation $l = 50cm.$ The top ends are connected by a resistance of $R = 0.5\Omega$ and a fuse (F) of negligible resistance. A conducting rod is free to slide along the rails under gravity. The whole system is in a uniform horizontal magnetic field B = 1.5 T as shown. Resistance of the rod and rails are negligible and the rod remains horizontal as it moves. The rod is released from rest. Find the minimum mass of the rod that will ensure that the fuse blows out. It is known that rating of the fuse is 4 A.



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16. A thin uniform conducting rod of mass M and length L oscillates in a vertical plane about a fixed horizontal axis passing through

its top end. The rod is oscillating with angular amplitude θ_0. A uniform horizontal magnetic field B, perpendicular to the plane of the oscillation is switched on.

(a) Calculate the maximum emf induced between the ends of the rod.

(b) If the rod has a finite thickness (any real life rod will definitely have a thickness), what difference in oscillation is expected in absence of magnetic field and in presence of magnetic field. Describe qualitatively.

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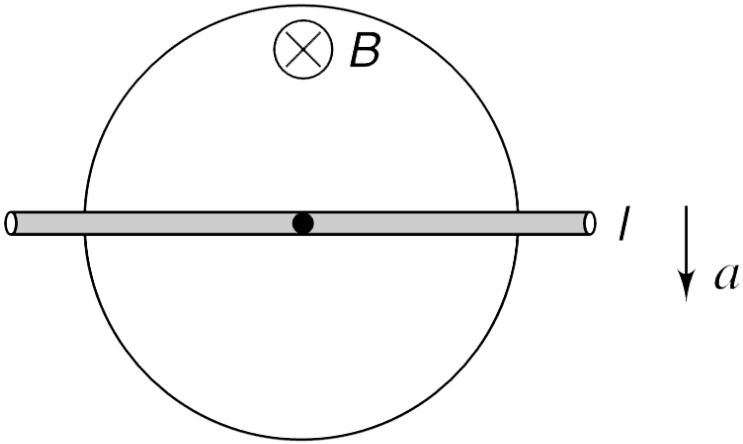
17. A wire ring of radius R is fixed in a horizontal plane. The wire of the ring has a resistance of $\lambda \Omega m^{-1}$. There is a uniform vertical magnetic field B in entire space. A perfectly conducting rod (l) is kept along the diameter of the ring. The rod is made to move with a constant acceleration a in a direction perpendicular to its own length. Find the current through the rod at the instant it has travelled through a distance $x = \frac{R}{2}$.



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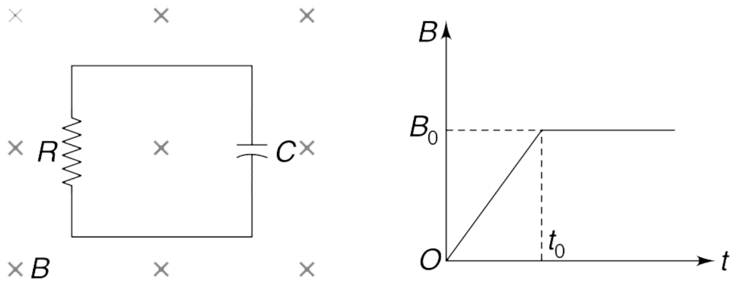
18. A conducting loop having resistance R contains a capacitor of capacitance C. A uniform magnetic field B is applied perpendicular to the plane of the loop. The magnetic field is made to change with time as depicted in the graph $[t_0 = 2RC]$. Plot the variation of charge on the capacitor as a function of time (t).



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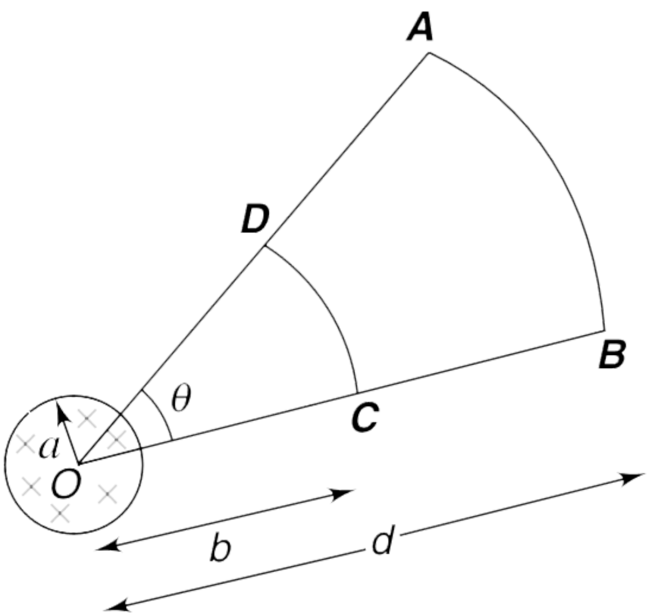
19. There is a uniform magnetic field (B) perpendicular to the plane of the figure in a circular region of radius a centred at O. ABCD is a conducing loop in the plane of the figure with its arms BC and DA along two radial lines from O having an angle θ between them. AB is circular arc of radius OB = d centred at O. CD is also a circular arc of radius $OC = b$ centred at O. The magnetic field is changed at a rate $\frac{dB}{dt}$.



(a) The emf induced in the loop ABCD.

(b) Find emf induced in arc AB.

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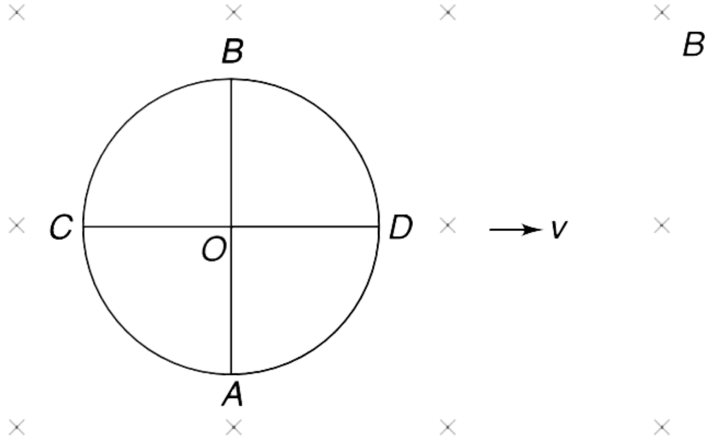
20. A uniform conducting wire is used to make a ring and its two diameters AB and CD. The ring is placed in a uniform magnetic field B perpendicular to its plane. The resistance of the wire per unit length is $\lambda\Omega / m$.



(a) Find the current in BO and BC when the ring is moved with constant velocity v in its plane.

(b) Find current in BO and BC when the ring is kept stationary but the magnetic field is increased at a constant rate of $\frac{dB}{Dt} = \alpha T/s$. Assume that magnetic field is confined inside the circular ring only. Take radius of the ring to be a.

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21. A bar magnet is kept along the axis of a conducting loop. When the magnet is moved along the axis, a current is seen in the loop. Which force is responsible for driving electrons in the loop if the observer is in

(a) Reference frame attached to the loop.

(b) Reference frame attached to the magnet.

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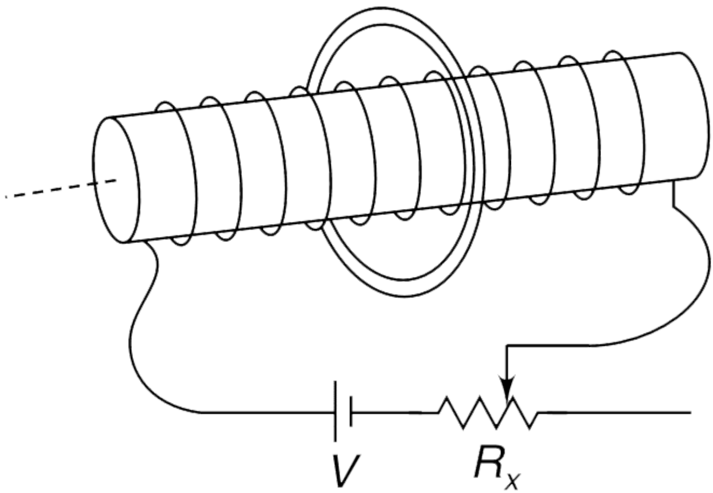
22. A long narrow solenoid of radius a has n turns per unit length and resistance of the wire wrapped on it is R. The solenoid is connected to a battery of emf V through a variable resistance R_x. There is a conducting ring of radius 2a held fixed around the solenoid with its axis coinciding with that of the solenoid. The relaxation time of free electrons inside the material of the conducting ring at given temperature is τ and specific charge of an electron is α. The variable resistance R_x is changed linearly with time from zero to R in an interval $\Delta\ t$. Calculate the drift speed of the free electrons in the ring during this interval. [Neglect inductance]



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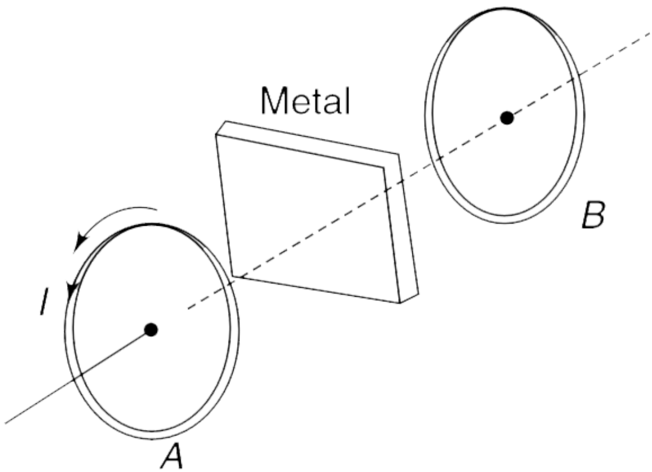
23. Two coils A and B are mounted co-axially some distance apart. Coil A is given a current that changes sinusoidally with time. A current gets induced in coil B. How does the magnitude of current in coil B change if a metal plate is placed between the two coils.



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24. A thin conducting ring of radius R has a thin layer of insulation on its inner face. A superconducting ring of radius R is pressed into it. The insulation layer separates the two rings. Find the self inductance of the conducting ring.

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25. A certain volume of copper is drawn into a wire of radius a and is wrapped in shape of a helix having radius $r(> > a)$. The windings are as close as possible without overlapping. Self inductance of the inductor so obtained is L_1. Another wire of radius 2 a is drawn using same volume of copper and wound in the fashion as described above. This time the inductance is L_2. Find $\frac{L_1}{L_2}$

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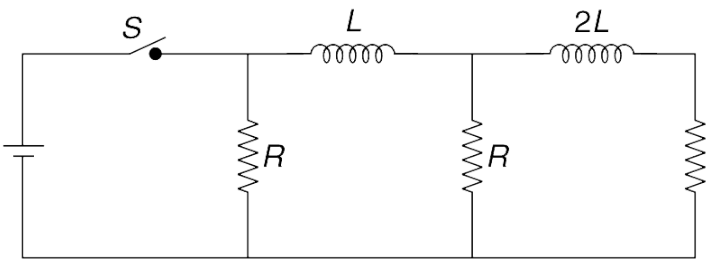
26. In the circuit shown in figure, the current through each resistor is I. Find the currents through the resistors immediately after the switch 'S' is opened. How much heat will get dissipated in the circuit after thw switch is opened ?



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27. "The current through an inductor cannot change instantaneously. However, the potential difference across an inductor can change abruptly". Do you agree with this statement. Give reason.

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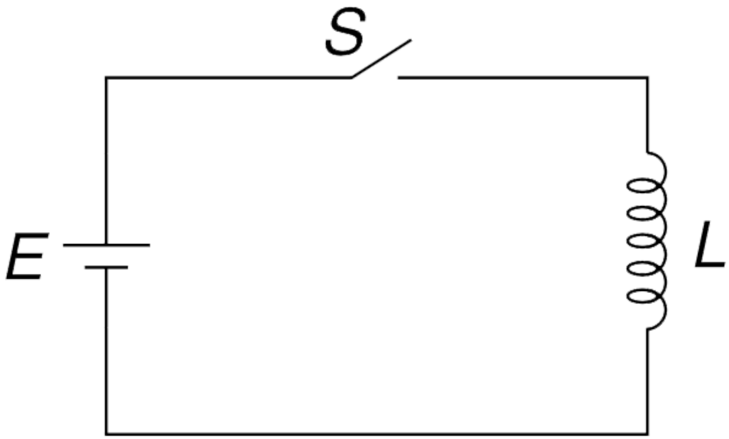
28. Consider an ideal inductor (having no resistance) of inductance L which is connected to an ideal cell (no resistance) of emf E by closing the switch S at time $t = 0$. Plot the variation of current through the inductor versus time.



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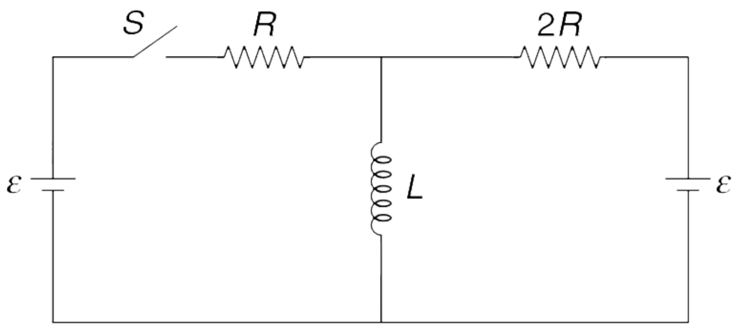
29. The circuit shown in the Figure is in steady state. Find the rate of change of current through L immediately after the switch S is closed.



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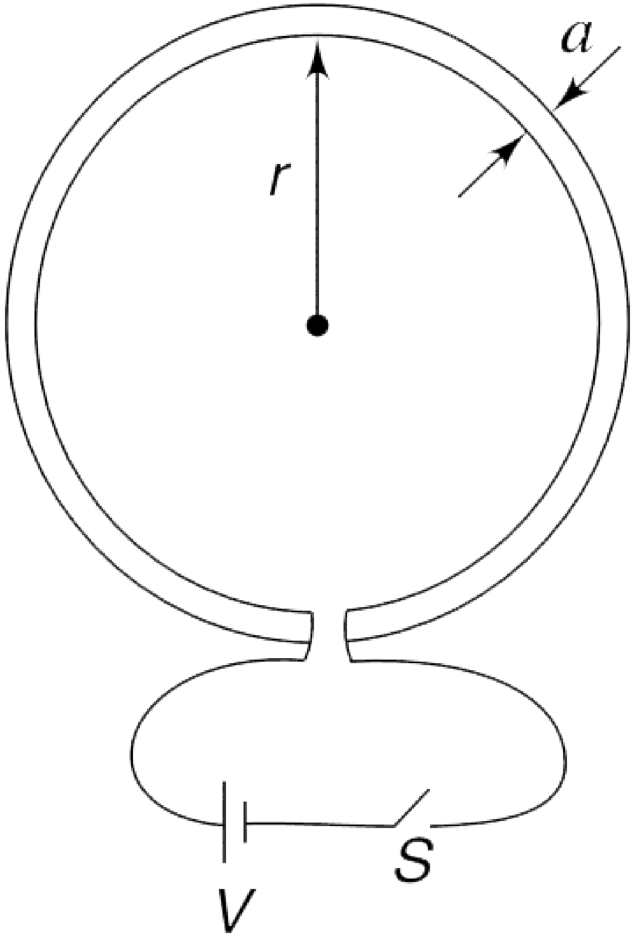
30. A circular loop of radius r is made of a wire of circular cross section of diameter 'a'. When current I flows through the loop the magnetic flux linked with the loop due to self induced magnetic field is given by

$\phi = \mu_0 r\left[\ln\left(\frac{16r}{a}\right) - \frac{7}{4}\right] l$. The resistivity of the material of teh wire is ρ and $r >> a$ .Switch S is closed at time $t = 0$ so as to connect the loop to a cell of emf V. Find the current in the loop at time t.



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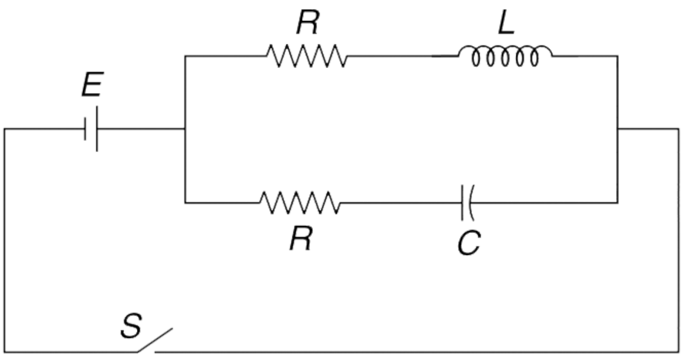
31. In the circuit shown, find the value of resistance R in terms of inductance L and capacitance C such that the current through the cell remains constant forever after the switch is closed.



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32. A proton beam has a circular cross sectional area A and it carries a current I distributed uniformly over its cross section. Calculate the magnetic energy per unit length of the beam within the beam.

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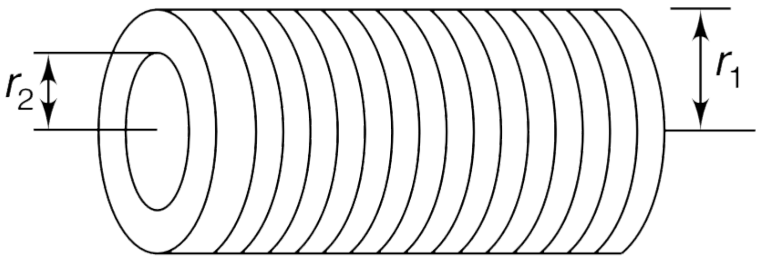
33. Two long co-axial solenoids have radii, and number of turns per unit length equal to r_1, r_2 and n_1, n_2 respectively where suffix 1 refers to the outer solenoid and 2 refers to the inner solenoid. Length of both is l. The current in the outer solenoid is made to grow as $I_1 = kt$ where t is time. Resistance of the wire used in inner solenoid is R. Write the current induced in the inner solenoid assuming that it is shorted.



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34. A capacitor of capacitance C is having a charge Q_0. It is connected to a pure inductor of inductance L. The inductor is a solenoid having N turns. Find the magnitude of magnetic flux through each of the N turns in the coil at the instant charge on the capacitor becomes $\frac{Q_0}{2}$.

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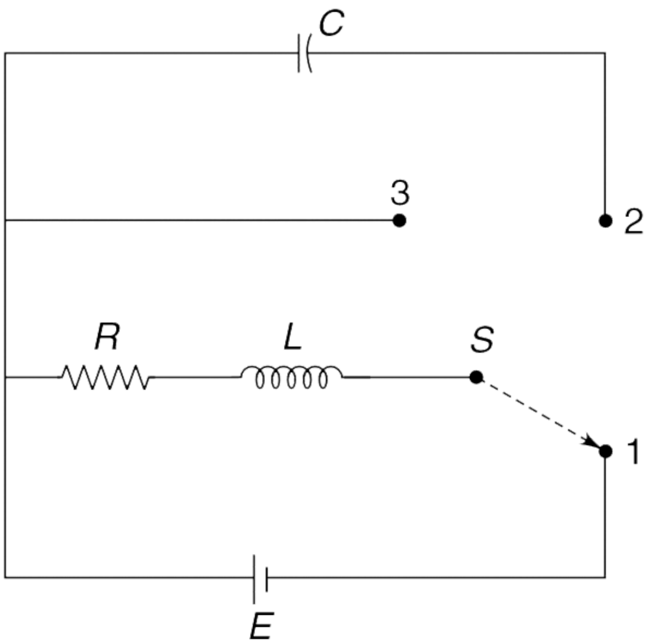
35. In the circuit arrangement shown in Figure, the three way switch S is kept in position 1 for a long time.



(a) Find the potential difference across the inductor immediately after the switch is thrown from posi- tion 1 to position 2.

(b) After being left in position 2 for a long time, the switch is moved to position 3. Find the potential difference across R immediately after the switch is moved to position 3. Assume no time lag in moving the switch from one position to another.

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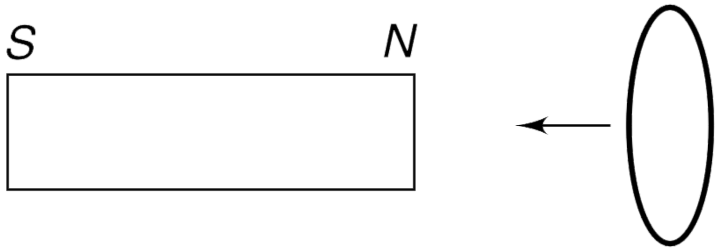
36. A short circuited coil is moved towards a fixed magnet at a constant velocity. When the coil is at a distance x from the magnet it experiences a magnetic force F. Now the number of turns in the coil is doubled and the experiment is repeated with the coil moving with same constant velocity towards the magnet. What will be the magnetic force on the coil when it is at a distance x from the magnet?



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37. A coil is rotated with constant angular speed in a uniform magnetic field about an axis that is perpendicular to the field. Tell, with reason, if the following statement is true– “The emf induced in the coil is maximum at the instant the magnetic flux through the coil is zero”.

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38. ABC is a triangular frame made of a conducting wire and is right angled at B. Its side BC is vertical and AB is horizontal. The frame is placed in a uniform magnetic field B in vertically upward direction. The frame is rotated about its side BC with constant angular speed ω. Resistance of the entire frame is R. Neglect gravity. Length $AB = L, BC = 2L$.

(a) Find the torque needed to keep the frame rotating with constant angular speed.

(b) Find the potential difference between points A and C.

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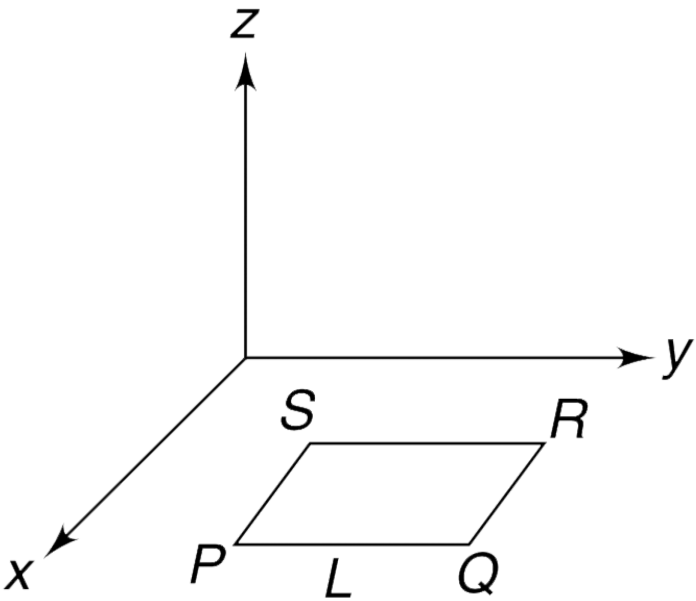
Level 2

1. A rectangular conducting loop PQRS is kept in xy plane with its adjacent sides parallel to x and y axes. A mag- netic field $\overrightarrow{B}$ is switched on in the region which varies in posi- tion and time as $\overrightarrow{B} = [B_0 \sin(ky - \omega t)]\hat{k}$. It was found that the emf induced in the loop is always zero. Express the length (L) of the loop in terms of constant k and ω.



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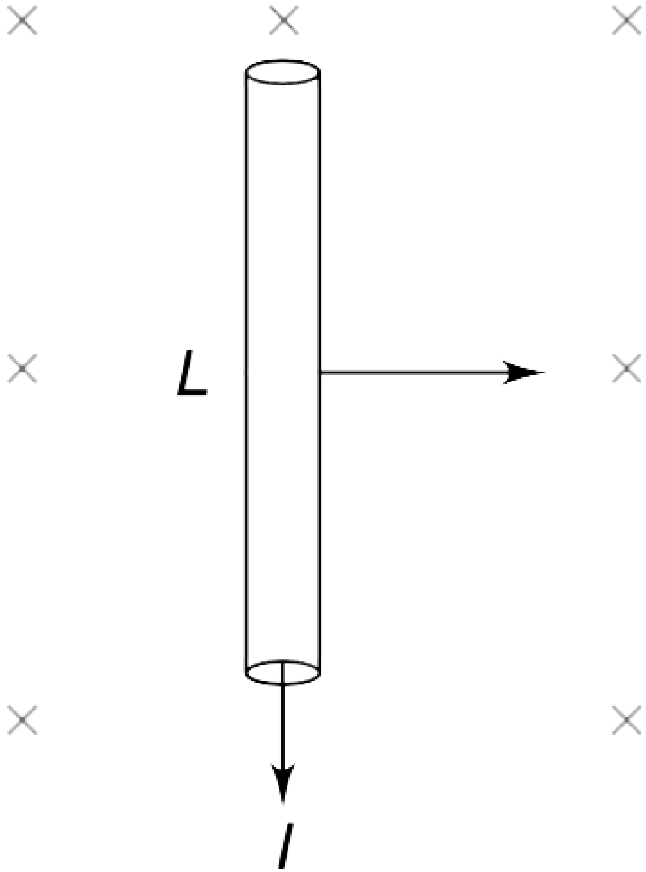
2. A conducting rod of length L is carrying a constant current I. There exists a magnetic field B perpendicular to the rod. Due to the magnetic force the rod moved through a distance x in a direction perpendicular to the field (B) as well as its own length. The rod acquires a kinetic energy. A student says that a magnetic force ILB acted on the rod and it performed a work $W = ILBx$ on the rod. But we know that magnetic force is always perpendicu- lar to the velocity of the charge and it cannot perform work on a moving charge. Which agency has actually spent energy to impart kinetic energy to the rod?



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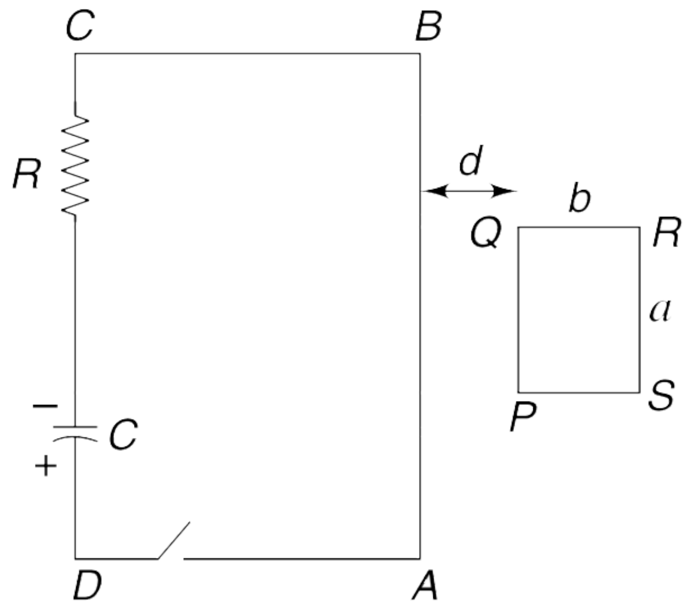
3. In a rectangular circuit ABCD a capacitor having capacitance $C = 20\mu F$ is charged to a potential difference of 100 V. Resistance of circuit is $R = 10\Omega$. Another rectangular conducting loop PQRS is kept side by side to the first circuit with sides AB and PQ parallel and close to each other. The length and width of rectangle PQRS is a = 10 cm and b = 5 cm respectively and AB as well as BC is large compared to a. PQ is located near the centre of side AB with d = 5 cm. The loop PQRS has 25 turns and the wire used has resistance of

$1\Omega\ m^{-1}$. The switch S is closed at time t = 0.

Neglect self inductance of loops.



(a) Find the current in ABCD at $t = 200\mu s$.

(b) Find the current in PQRS at $t = 200\mu s$.

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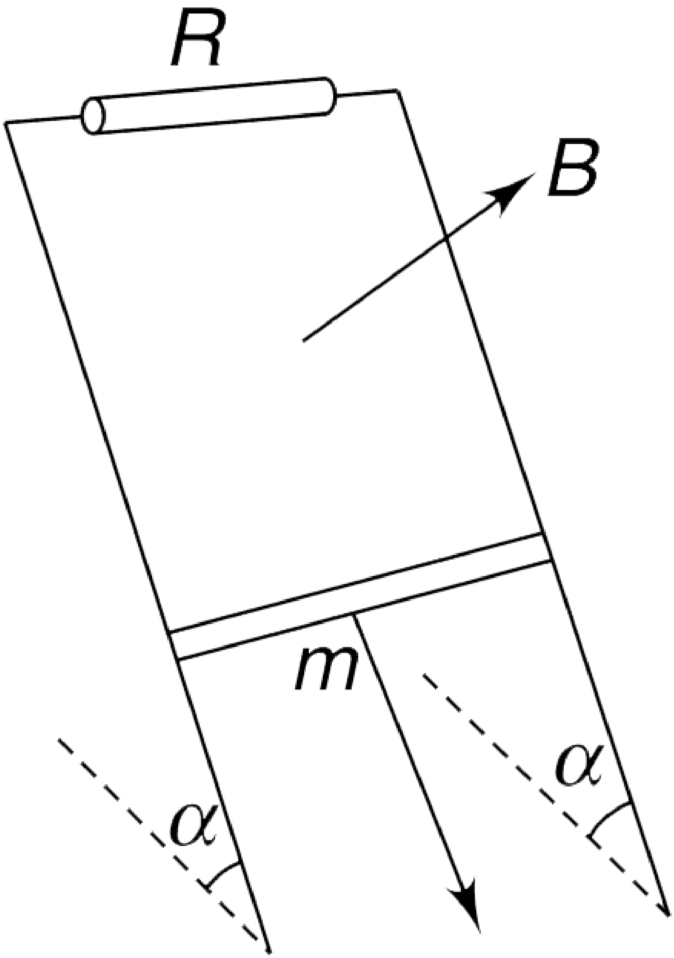
4. A copper connector of massm, starting from rest, slides down two conducting bars set at angle α to the horizontal, due to gravity (see figure). At the top the bars are interconnected trhough a resistance R. The separation between the bars is equal to l. The system is located in uniform magnetic field of induction B, perpendicular to the plane in which the connectr slides. The resistance of the bars the connector and the sliding contacts, as well as the self inductance of the loop, are assumed to be negligible. The coefficient of friction between the connector and the bars is equal

to $\frac{1}{2}$ and α

(a) Find the steady-state velocity of the connector.

(b) How will your answer differ if the magnetic field was in opposite direction.



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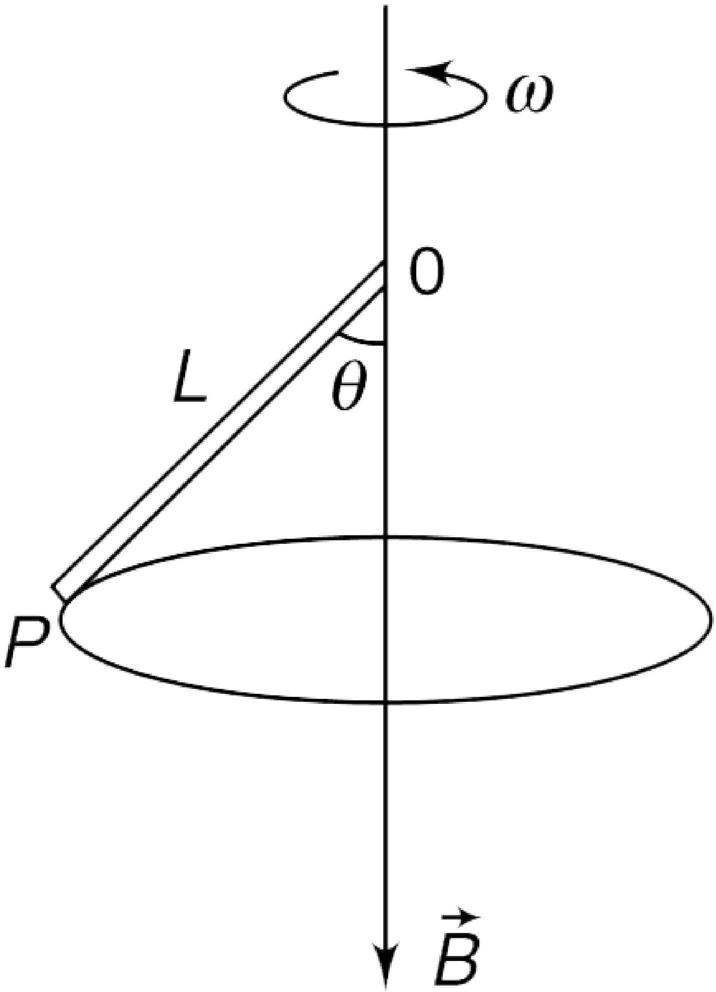
5. A conducting rod (OP) of length L rotates in form of a conical pendulum with an angular velocity ω about a fixed vertical axis passing through its end O. There is a uni- form magnetic field B in vertically downward direction. The rod makes an angle θ with the direction of the magnetic field. Calculate the emf induced across the ends of the rod. Which end is positive?



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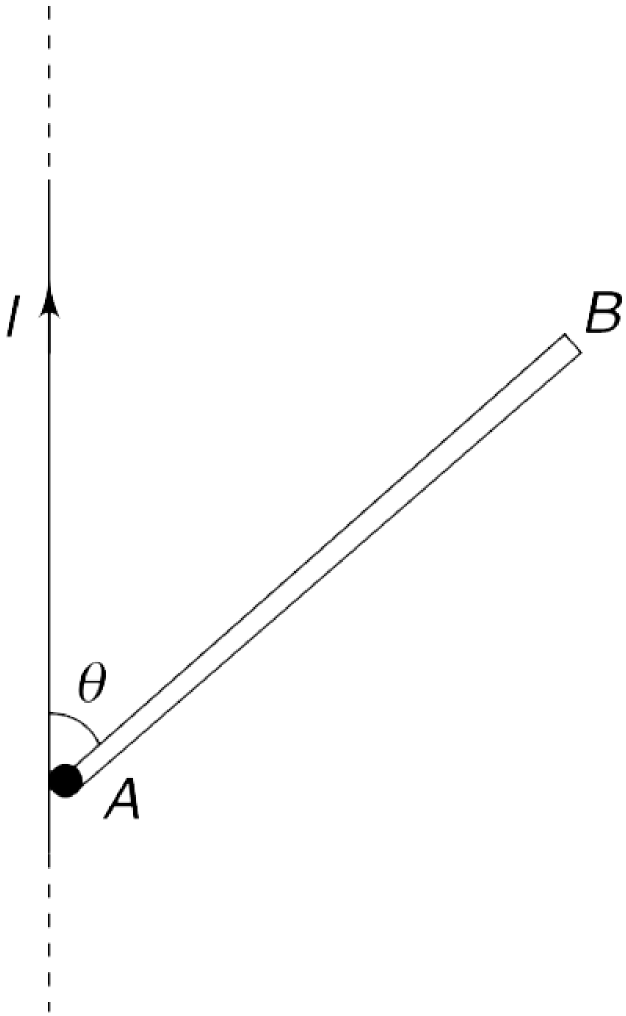
6. A conducting rod AB of mass M and length L is hinged at its end A. It can rotate freely in the vertical plane (in the plane of the Figure). A long straight wire is vertical and carrying a current I. The wire passes very close to A. The rod is released from its vertical position of unstable equilibrium. Calculate the emf between the ends of the rod when it has rotated through an angle θ (see Figure).



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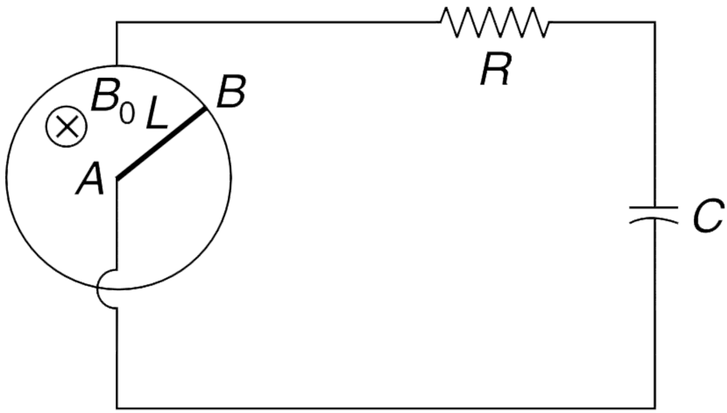
7. A perfectly conducting ring of radius L is kept fixed on a horizontal surface. A vertical uniform magnetic field B_0 exists in the region. A conducting rod (AB) of length L is hinged at the centre of the ring at A and its other end (B) touches the ring. The ring and the end A of the rod are connected to an external circuit having resistance R and capacitance C. The rod is made to rotate at a constant angular speed ω_0. Neglect friction and self inductance of the circuit.

(i) Find work done by the external agent in rotating the rod by the time the capacitor acquires a charge q_0.

(ii) Find heat generated in resistance R by the time the capacitor acquires a charge q_0.



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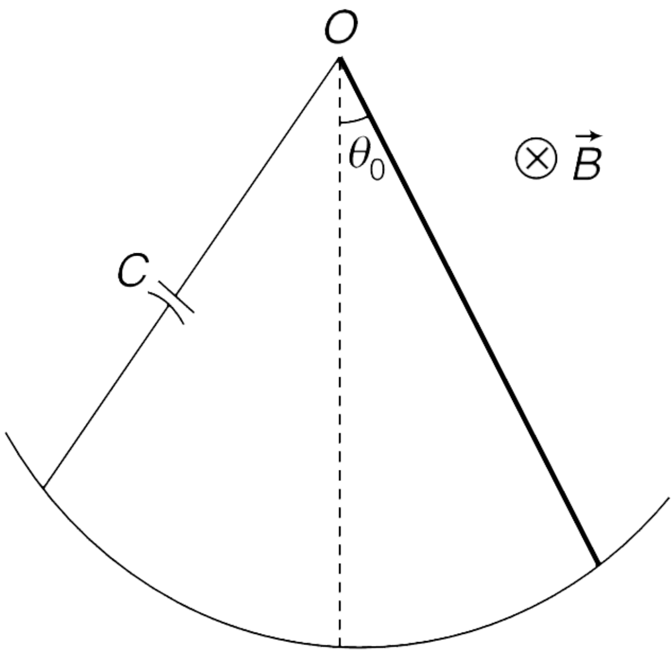
8. A conducting rod of mass M and length L can oscillate like a pendulum in a vertical plane about point O. The lower end of the rod glides smoothly on a circular conducting arc of radius L. The circular arc is connected to point O of the rod through a capacitor of capacitance C. The entire device is kept in a uniform horizontal magnetic field B directed into the plane of the Figure. Disregard resistance of any component. The rod is deflected through a small angle θ_0 from vertical position and released at time t = 0.

(a) Write the deflection angle (θ) of the rod as a function of time t.

(b) If the capacitor is replaced with a resistor what kind of motion do you expect? Give qualitative description only.



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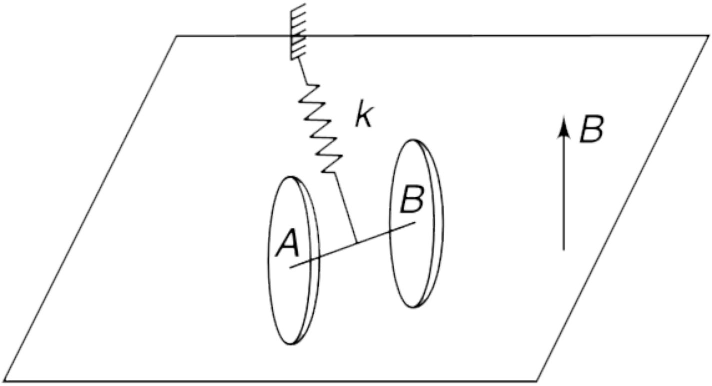
9. Two identical thin circular, metal plates are at a small separation d. They are connected by a thin conducting rod (AB) of length d. Each plate has area A. An ideal spring of stiffness k is connected to a rigid support and midpoint of rod AB as shown in the figure. Spring is made of insulating material. The system is on a smooth horizontal surface. The entire region has a uniform vertical upward magnetic field B.



The discs are pulled away from the support and released. Find time period of oscillations. Mass of the two disc plus rod system is M. Neglect any eddy current.

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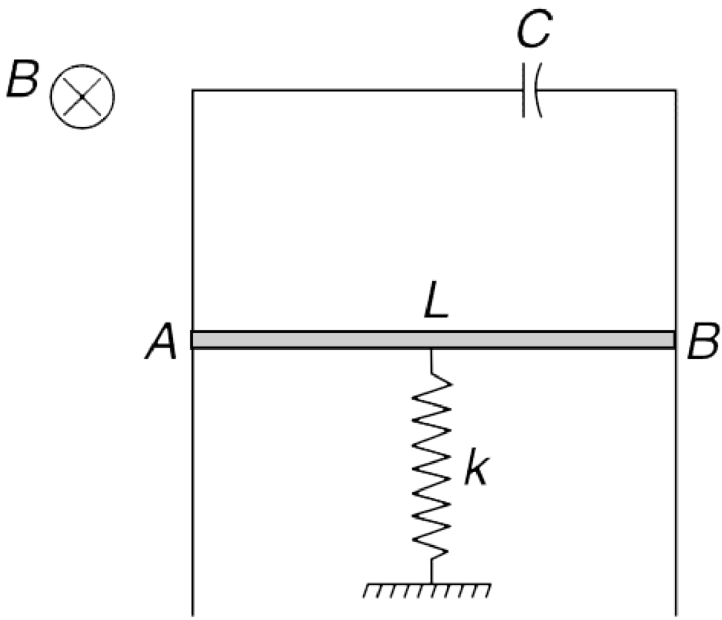
10. Two metal bars are fixed vertically and are connected on top by a capacitor of capacitance C. A sliding conductor AB can slide freely on the two bars. Length of conductor AB is L and its mass is m. It is connected to a vertical spring of force constant k. The conductor AB is released at time t = 0, from a position where the spring is relaxed. Taking initial position of the conductor as origin and downward direction as positive x axis, write the x co-ordinate of the conductor as a function of time. The entire space has a uniform horizon- tal magnetic field B. Neglect resistance and inductance of the circuit and assume that the bar AB always remains horizontal.



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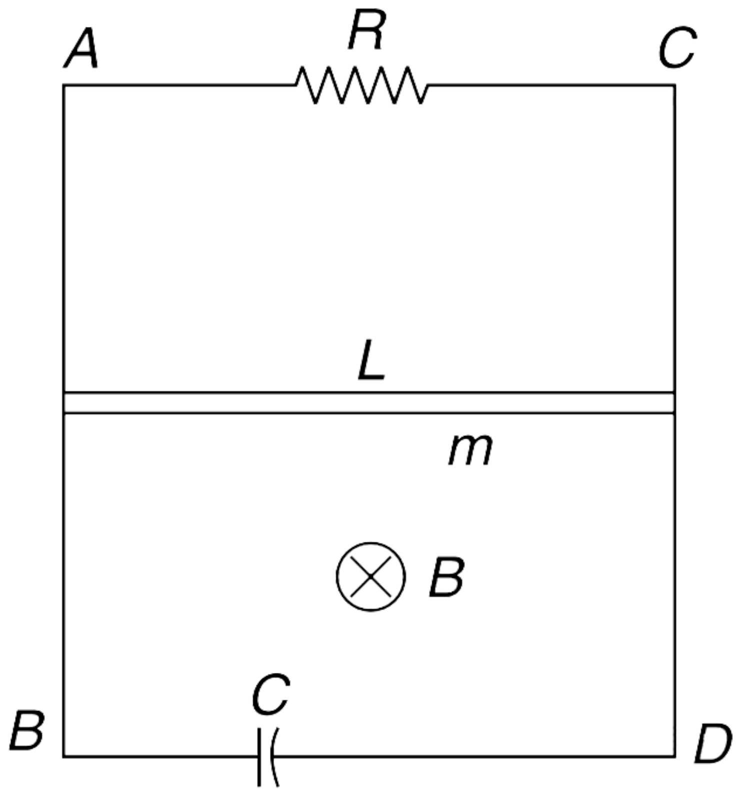
11. Two long fixed parallel vertical conducting rails AB and CD are separated by a distance L. They are connected by resistance R and a capacitance C at two ends as shown in the figure. There is a uniform magnetic field B directed horizon- tally into the plane of the figure. A horizontal metallic bar of length L and mass m can slide without friction along the rails. The bar is released from rest at t = 0. Neglect resistance of bar and rails and also neglect the self inductance of the loop.

(a) Find the maximum speed acquired by the bar after it is released.

(b) Find the speed of the bar as a function of time t.



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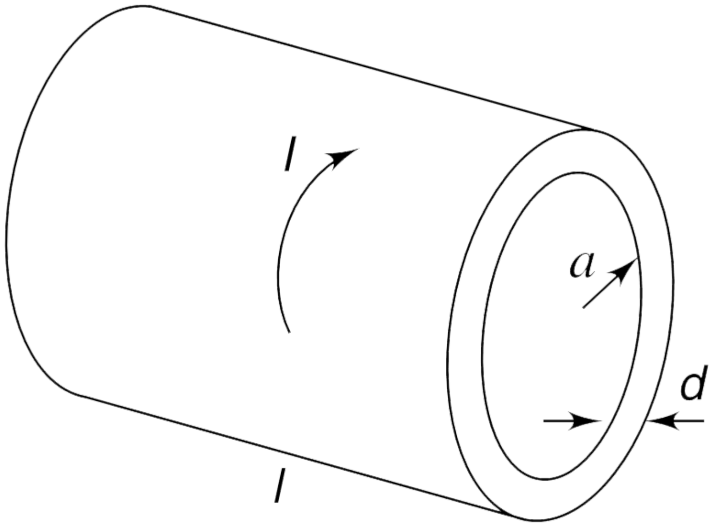
12. A hollow cylinder made of material of resistivity ρ has length a and wall thickness $d(l > > a > > d)$. A current I flows through the cylinder in tangential direction and is uniformly distributed along its length.

(a) Find the emf developed along the circumference of the cylinder if the current changes at a rate $\frac{dl}{dt} = \beta$

(b) Assume that no external source is present and the current at time t = 0 is I_0. The current decays with time. Write I as a function of time.



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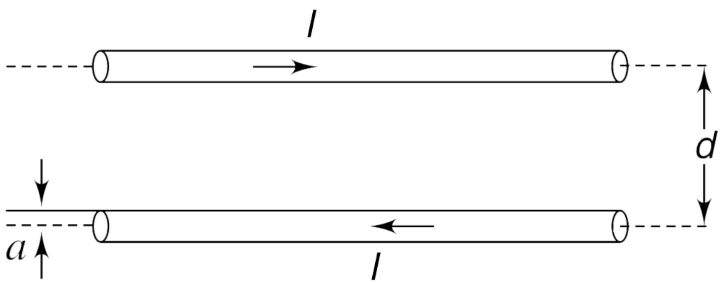
13. A long straight wire of cross sectional radius a carries a current I. The return current is carried by an identical wire which is parallel

to the first wire. The centre to centre distance between the two wires is d. Find the inductance (L) of a length x of this arrangement. Neglect magnetic flux inside the wires.



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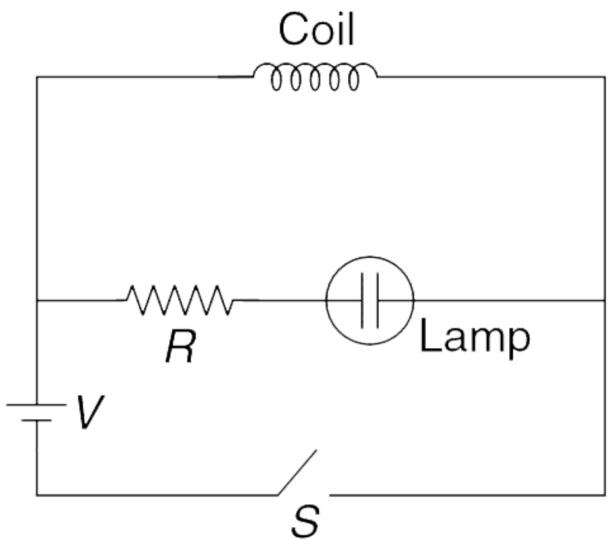
14. In the circuit shown in the figure the neon lamp lights up if potential difference across it becomes 60 V and goes out if the potential difference falls below 30 V. The inductor coil has a very small resistance and emf of the cell is V = 4 volt. The lamp does not light when the switch is closed. The neon light flashes once when the switch is opened. Explain why?



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15. Determine the mutual inductance of a toroid and an infinite straight wire located along the central axis of the toroid. The toroid

has a rectangular cross section with inner and outer radii a and b respectively. The width of the rectangular cross section parallel to the straight wire is h. Total turns in the toroid is N.

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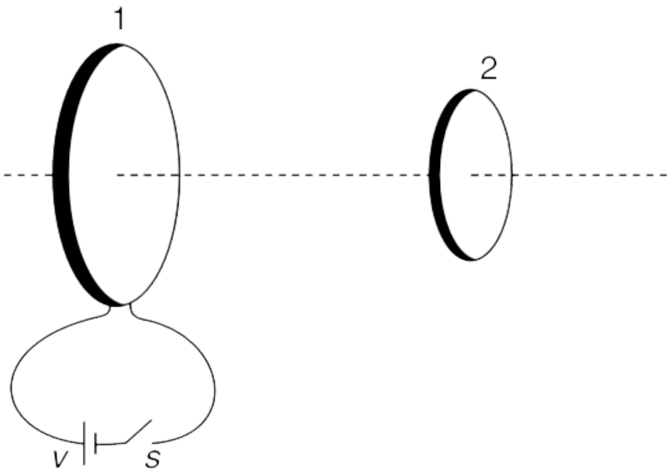
16. Two coils – 1 and 2 – are mounted co axially as shown in the figure. The resistance of the two coils are R_1 and R_2 and their self inductances are L_1 and L_2 respectively. Switch S is closed at time t = 0 to connect the coil 1 to an ideal cell of emf V. It is observed that by the time current reaches its steady value in coil 1, the quantity of charge that flows in coil 2 is Q_0. Calculate the mutual inductance (M) between the two coils.



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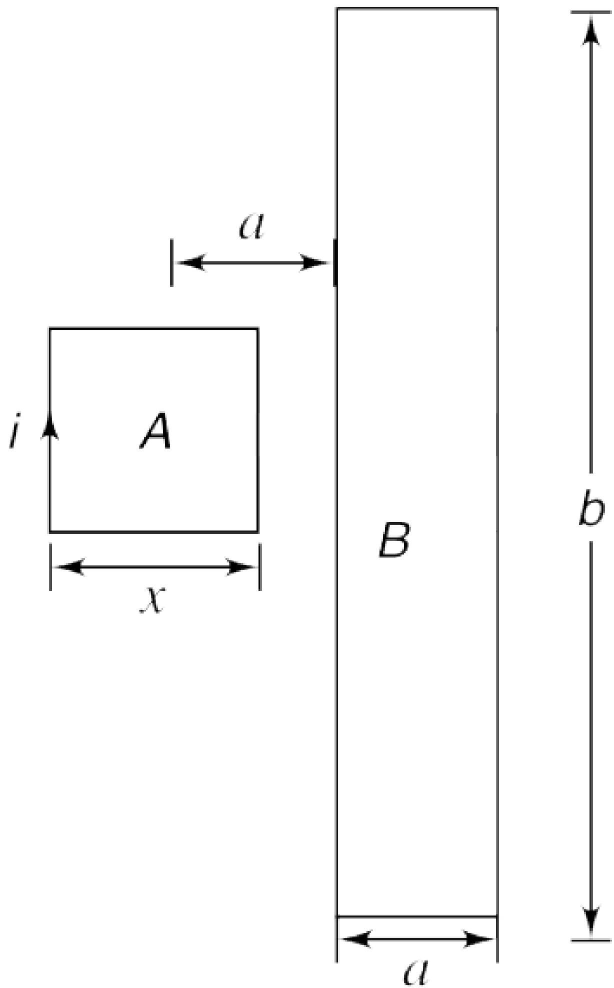
17. A rectangular conducting loop B has its side lengths equal to b and $a(< < b)$. In the plane of the loop there is another very small loop A in shape of a square of side length x. Loop A is placed symmetrically with respect to B with its centre at a distance a from one of its longer side (see Figure). There is a current (i) in loop A which is made to increase at a constant rate of $\frac{di}{dt} = \alpha A s^{-1}$. Calculate the emf induced in the bigger loop.



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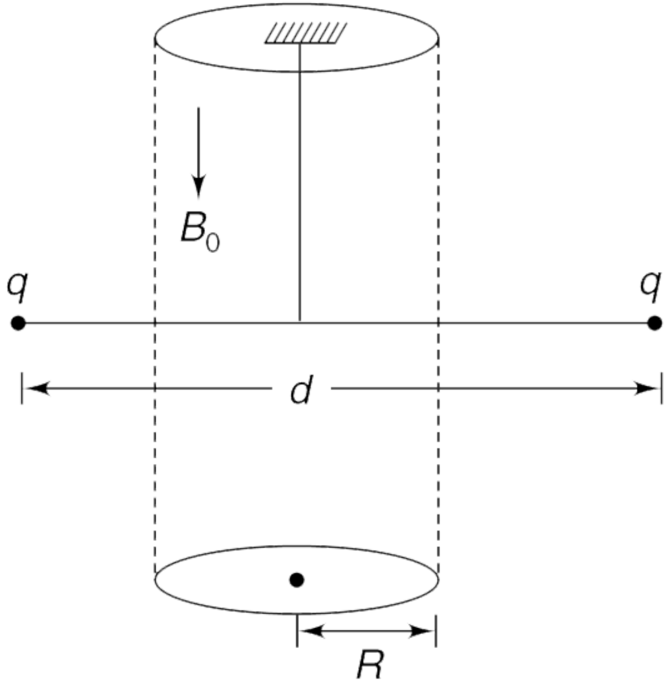
18. Two identical small balls, made of insulting material are attached to the ends of a light insulating rod of length d. The rod is suspended from the ceiling by a thin torsion free fibre as shown in figure. Each ball is given a charge q. There is a uniform magnetic field B_0, pointing vertically down, in a cylindrical region of radius R. The fibre is along the axis of the cylindrical region. The system is initially at rest. Now the magnetic field is suddenly switched off. Calculate the angular velocity acquired by the system. Each ball has mass m.



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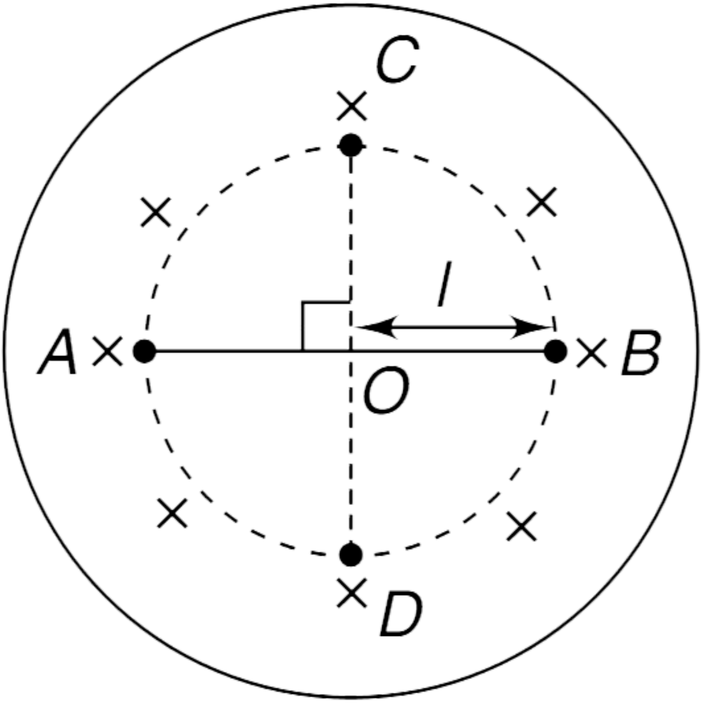
19. A massless non conducting rod AB of length 2l is placed in uniform time varying magnetic field confined in a cylindrical region of radius $(R > l)$ as shown in the figure. The center of the rod coincides with the centre of the cylin- drical region. The rod can freely rotate in the plane of the Figure about an axis coinciding with the axis of the cylinder. Two particles, each of mass m and charge q are attached to the ends A and B of the rod. The time varying magnetic field in this cylindrical region is given by $B = B_0\left[1 - \frac{t}{2}\right]$ where B_0 is a constant. The field is switched on at time $t = 0$. Consider

$$B_0 = 100T, l = 4cm\frac{q}{m} = \frac{4\pi}{100}C/kg.$$

Calculate the time in which the rod will reach position CD shown in the figure for th first time. Will end A be at C or D at this instant ?



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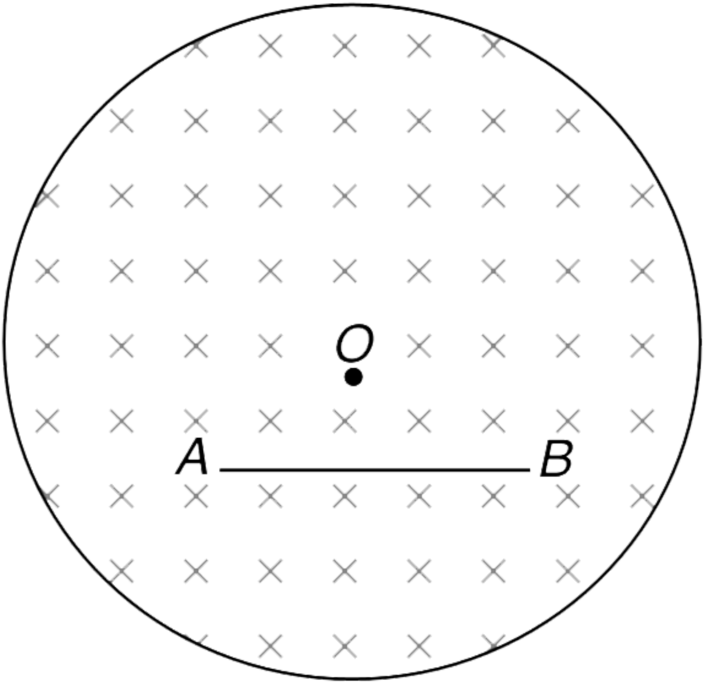
20. A cylindrical region of radius R is filled with a uniform magnetic field B as shown in the figure. A metal wire (AB) of length L is placed inside the field such that its ends are symmetrically located with respect to the centre (O) of the circular cross section of the region. If the magnetic field is changed at a rate $\frac{dB}{dt}$ the emf induced in the metal wire is e. Find change in value of ε if the wire is displaced by a small distance ΔL parallel to its own length. Assume that the wire remains inside the field region.



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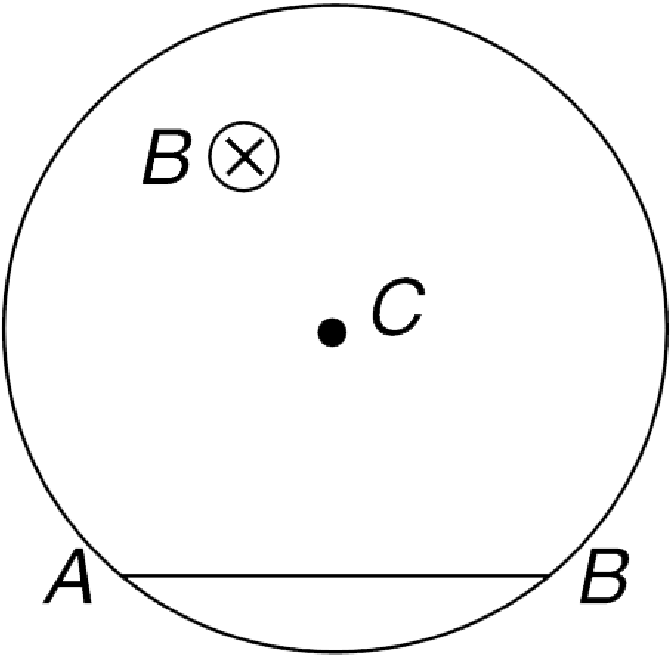
21. cylindrical volume of radius R has a uniform

axial magnetic field B, which is increasing at a rate of $\frac{dB}{Dt} = \alpha T s^{-1}$. A chord (AB) of the circular cross section of the cylindrical region has length L.Calculate the line integral of induced electric field $\left(\int_A^B \vec{E}\,\vec{dl}\right)$ as one moves along the chord from A to B. Try to find the answer without actually performing the integration. Is the value of integral same if one moves along the arc from A to B ?



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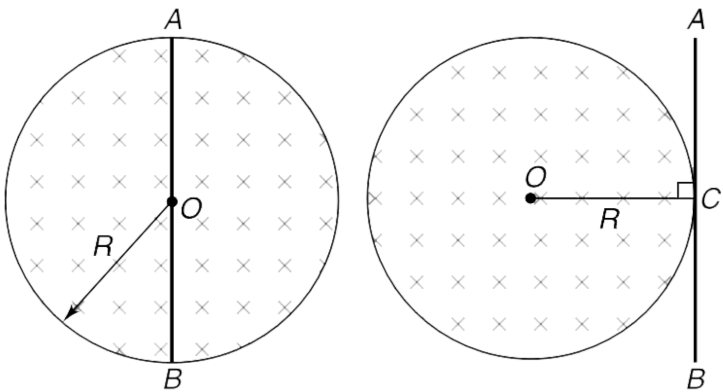
22. A uniform magnetic field B exists in a circular region of radius R. the field is

perpendicular to the plane and is increasing at a constant rate of $\frac{dB}{dt} = \alpha$. There is a straight conducing rod AB of length 2R. Find the emf induced in the rod when it is placed as shown in figure (a) & (b). Point C is midpoint of the rod in figure (b)



(a) (b)

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23. A thin beam of n identical positively charged particle are constrained to move in a circular orbit of radius R in a particle accelerator. Each particle has charge q and mass m and the current in the circular orbit is I_0. The magnetic flux through the circular path is made to increases at a constant rate of βWbs^{-1}. Calculate the current after the particles complete one turn.

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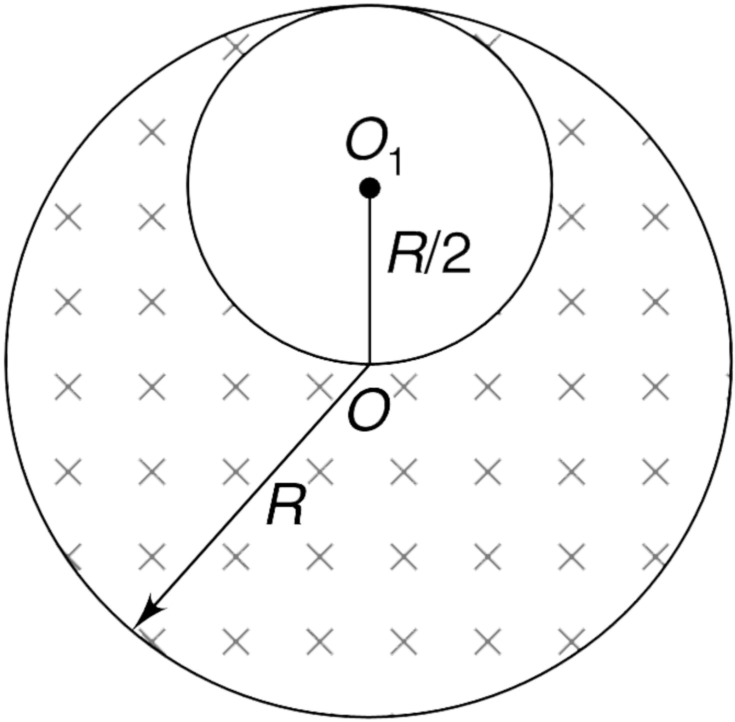
24. There is a long cylinder of radius R having a cylindrical cavity of radius $R/2$ as shown in the figure. Apart from the cavity, the entire space inside the cylinder has a uniform magnetic field parallel to the axis of the cylinder. The magnetic field starts changing at a uniform rate of $\frac{dB}{dt} = kT/s$. Find the induced electric field at a point inside the cavity.



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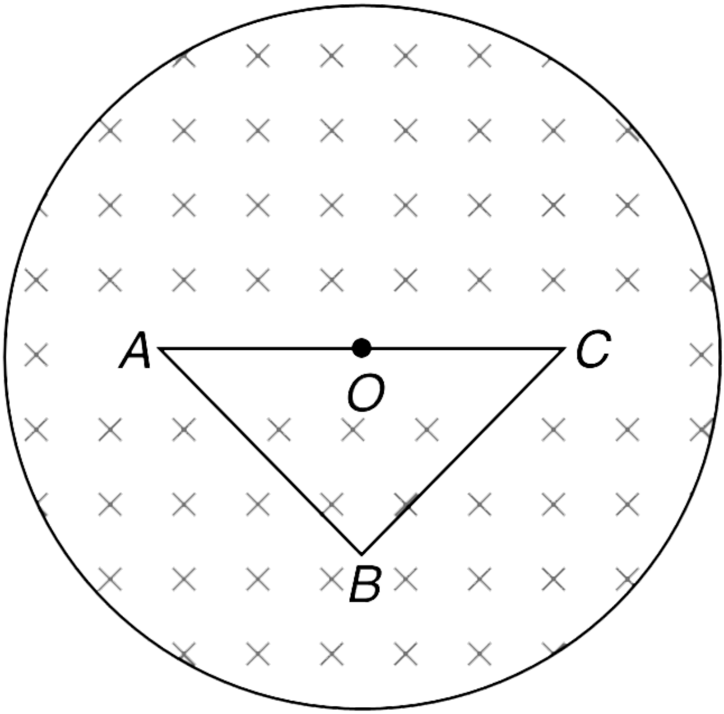
25. A uniform magnetic field B exists in a region of circular cross section of radius R. The field is directed perpendicularly into the plane of the figure. There is a tri- angular circuit ABC made of a uniform wire placed in the circular region. The triangle is a right angled isosceles tri- angle with equal sides $AB = BC = l$. The hypotenuse AC has its midpoint at the centre of the circle. Electrical resistance of the triangular circuit per unit length is $\frac{r_0}{l}$. If the magnetic field is changed at a constant rate of $\frac{dB}{dt} = \alpha$, find the potential difference between points C and A and that between B and A.



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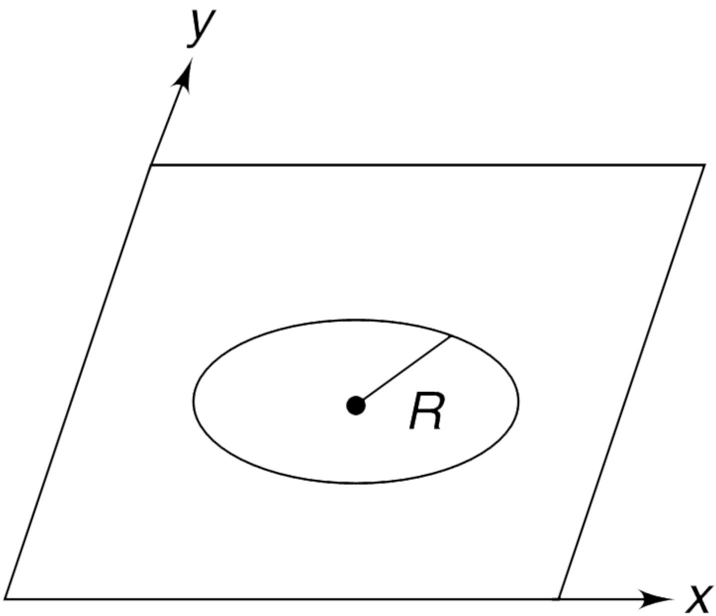
26. A conducting ring of mass $m = \pi kg$ and radius $R = \frac{1}{2}m$ is kept on a flat horizontal surface (xy plane). A uniform magnetic field is switched on in the region which changes with time (t) as $\vec{B} = \left(2\hat{j} + t^2\hat{k}\right)T$. Resistance of the ring is $r = \pi\Omega$ and $g = 10ms^{-2}$.

(a) Calculate the induced electric field at the circumference of the ring at the instant it begins to topple.

(b) Calculate the heat generated in the ring till the instant it starts to topple.



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27. A tightly wound solenoid of length l and cross sectional area A_1 is partly inserted co-axially into another tightly wound solenoid of length l and cross section $A_2(>A_1)$. The centres of the two solenoids are separated by $x(<l)$. Assume that $A_2 << x^2, A_2 << l^2$. Calculate the total magnetic field energy inside the solenoid when both of them carry same current (I) in the same sense. Number of turns in each solenoid is N.

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28. In the last problem calculate the emf induced in the outer coil if the inner coil is pulled out at a speed v. How much emf will be induced in the inner coil?

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29. In the last problem, calculate the force needed to pull out the inner coil at constant speed. The outer coil remains fixed.

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30. Two ends of an inductor of inductance L is connected to two parallel conducting rails. A conducting wire of length (that is equal to separation between the rails) can slide on the rails without friction. The wire has mass m. It is projected with a velocity v_0 parallel to the rails (see Figure). Neglect self inductance and resistance of the loop.

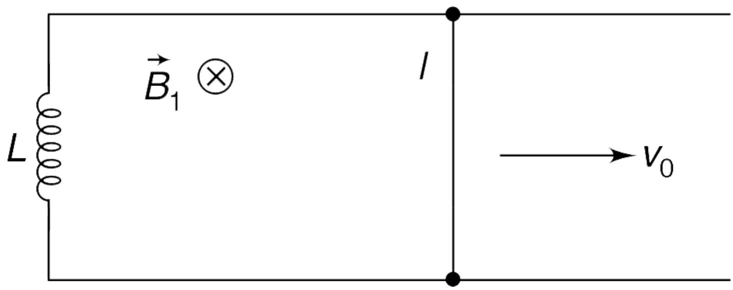
(a) Find velocity of the wire as a function of time.

(b) Write current through the wire at time t.

(c) Find speed of the wire as a function of its displacement.

(d) Is the current in the conductor zero when it stops? If no, find this current .

(e) Will the conductor move after it stops?



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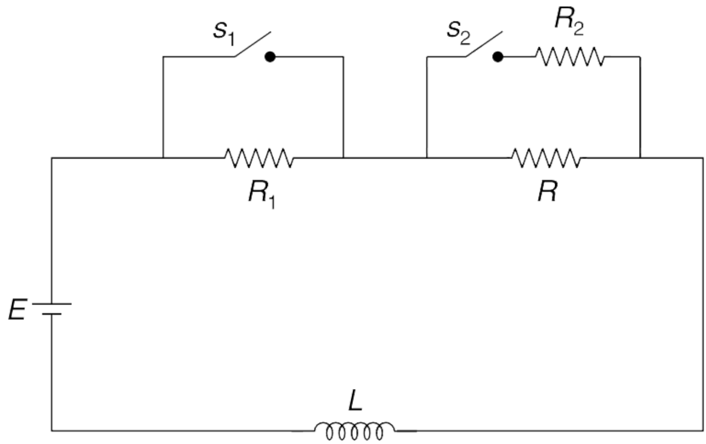
31. In the circuit shown in Figure, switch S_1 is kept closed and S_2 open for a long time. Resistance $R_1 = 1000R$ and $R_2 = 10^{-3}R$.

(a) Switch S_1 is opened at time t = 0. Write the current and potential drop across R_1 immediately after S_1 is opened. What will be value of current after a long time?

(b) Switch S_2 is closed (S_1 is already closed since long) at time t = 0. Write current and potential drop across R_2 immediately after this operation. Write current through the inductor as a function of time.



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32. A ring is made of a nearly superconducting mate- rial. Inductance of the ring is $L = 0.5H$. A current allowed to decay in the ring was observed to remain constant for a month. The instrument used to measure current could detect any change if it is greater than 1%. Estimate the resistance of the ring considering it as a L R circuit with decaying current.

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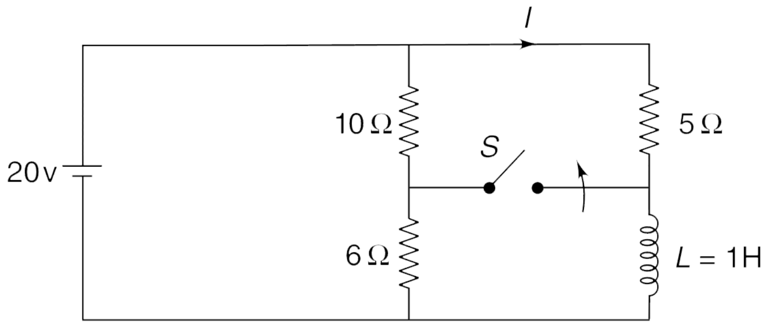
33. In the circuit shown, the switch 'S' has been closed for a long time and then opens at t = 0.

(a) Find the current through the inductor just before the switch is opened.

(b) Find the current I a long time after the switch is opened.

(c) Find current I as a function of time after the switch is opened. Also write the current through the cell as a function of time.



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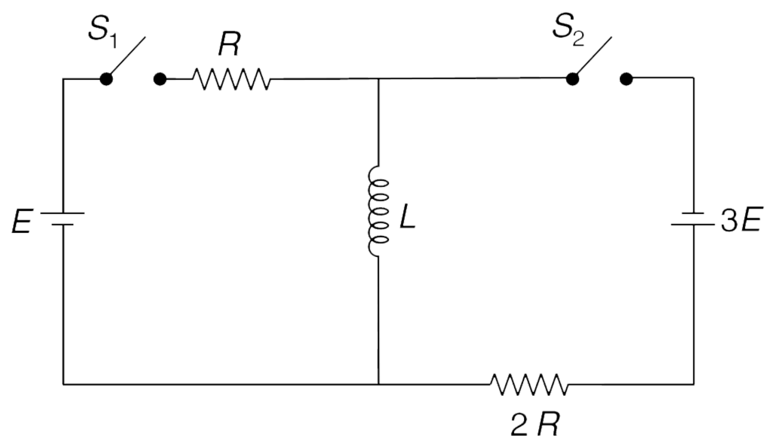
34. In the circuit shown, switch S_2 is open and S_1 is closed since long. Take $E = 20V$, $L = 0.5H$ and $R = 10\Omega$. Find the rate of change of energy stored in the magnetic field inside the inductor, immediately after S_2 is closed.



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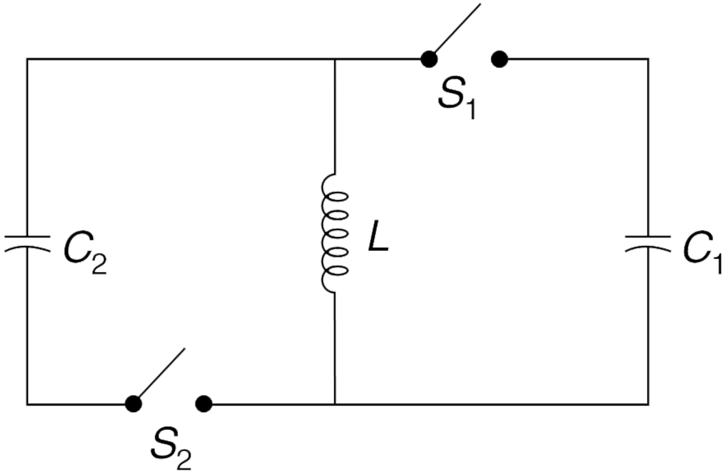
35. The circuit shown in the figure is used to transfer energy from one capacitor to another. Initially capacitor of capacitance $C_1 = C_0$ is charged to a potential difference of V_0. Switch S_1 is closed at time t = 0. After some time S_1 is opened and S_2 is closed simultaneously. At time $t = T$, S_2 was opened and it was found that the potential difference across capacitor of capacitance $C_2 = \frac{C_0}{9}$ was $3V_0$. Find the smallest possible value of time T. The coil has inductance L. Assume no resistance.



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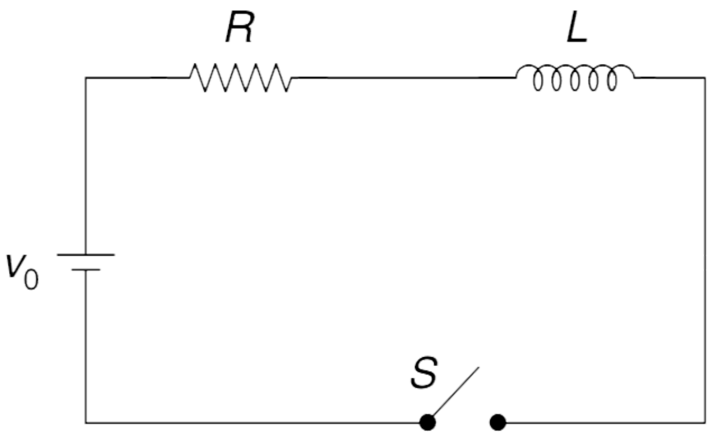
36. A pure inductor coil having inductance L is connected to a resistance R and a cell of emf V_0 as shown in the figure. Switch ‘S’ is closed at t = 0.

(a) Plot the variation of voltage across the resistance and the inductance as a function of time

(b) Find the time (t_1) when the two curves, obtained in (a) intersect.

(c) A student decides to start counting time from the instant the current becomes half its maximum value. Show the graphical plot of current vs time as obtained by this student.



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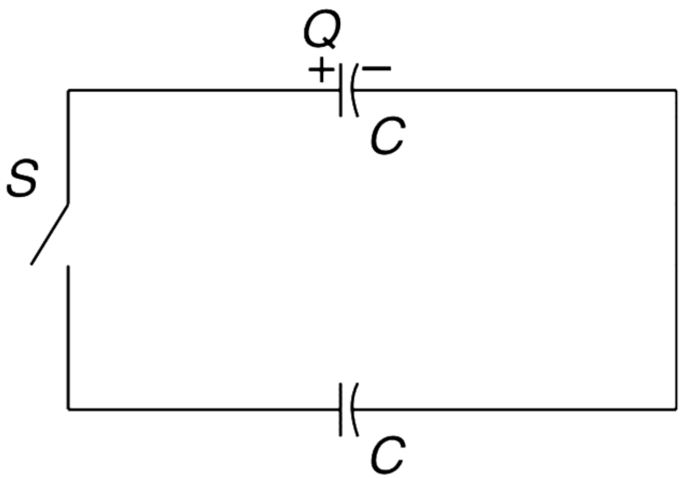
37. The circuit shown in figure has two identical capacitors one of which carries a charge Q and the other is having no charge. Switch S is closed. Find the maximum value of current in the circuit if self inductance of the loop is L and each capacitance C. Neglect resistance of the loop.



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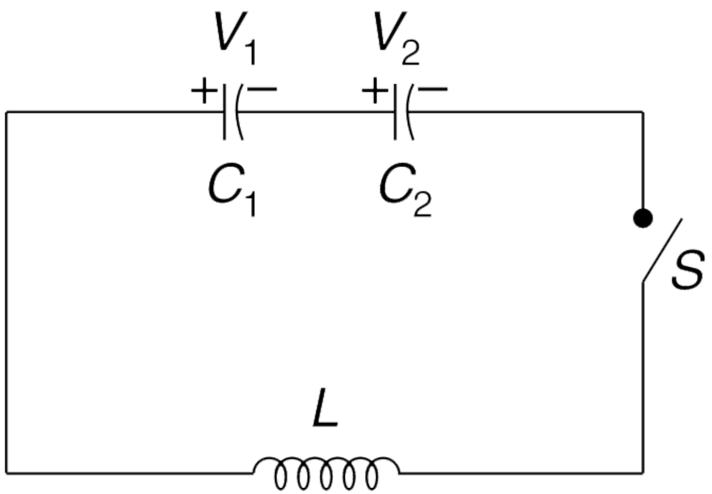
38. The capacitors shown in the circuit have capacitance $C_1 = C$ and $C_2 = 3C$ and they have been charged to potenitals $V_1 = 2V_0$ and $V_2 = 3V_0$ respectively. Switch S is closed to connect them to the inductor L.

(a) Find the maximum current through the inductor

(b) Find potential difference across C_1 and C_2 when the current in the inductor is maximum.



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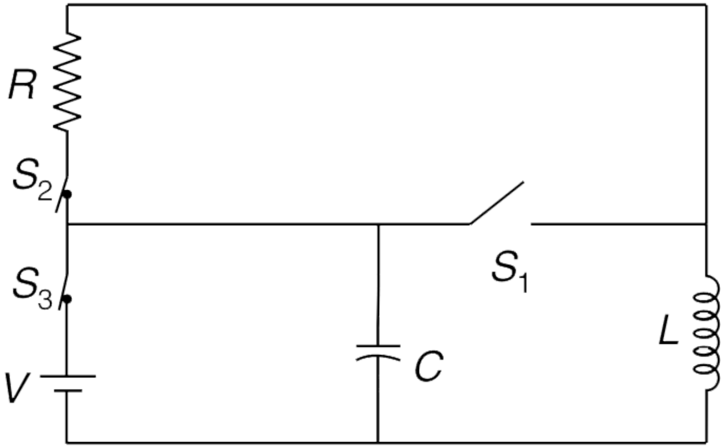
39. In the circuit shown in figure S_1 is open and, S_2 and S_3 are closed. The circuit is in steady state. At time t = 0, switch S_1 is closed and S_2 and S_3 are opened simultaneously. $V = 100\text{volt}, R = 10\Omega, C = 100\mu F, L = 0.03H$

(a) Find the maximum charge that will appear on the capacitor at any time.

(b) Find the time at which the charge on the capacitor will become zero for the first time.



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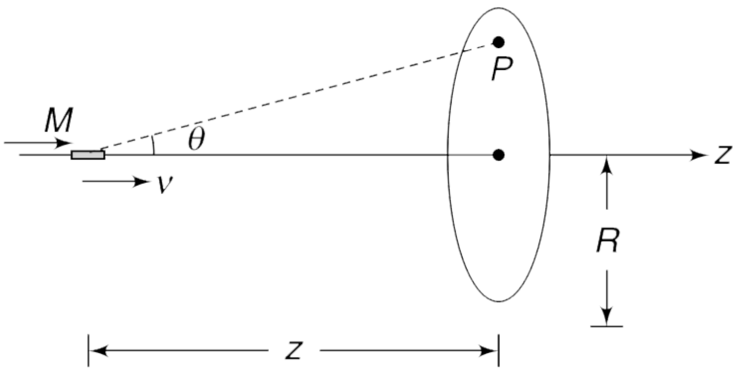
Level 3

1. A short bar magnet having magnetic dipole moment M is moving along the axis of a fixed

conducting (non magnetic) ring of radius R. The axis of the ring is along z direction.



(a) Write the z component of magnetic field due to the magnetic dipole at a point P in the plane of the ring, at the instant the magnet is at a distance z from the centre of the ring. Position of point P can be defined in terms of angle θ as shown.

(b) Write the magnetic flux through the ring due to the magnetic field produced by the magnet as a function of z.

(c) Write the magnitude of emf induced in the ring at the instant shown if speed of the magnet at the moment is v.

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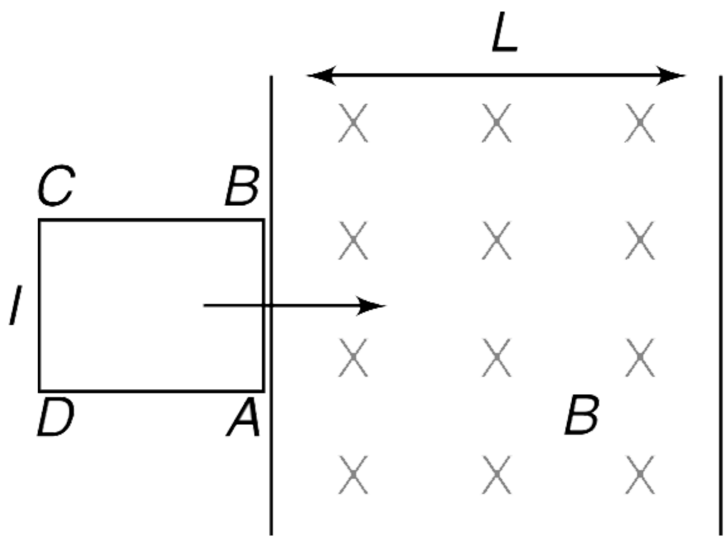
2. A region of width L contains a uniform magnetic field B directed into the plane of the figure. A square conducing loop of side length $l(<L)$ is kept with its side AB at the

boundary of the field region (see Figure). The loop is pushed into the field region with a speed such that it just manages to exit the field region. Calculate the time needed for the entire loop to enter the field region after it is pushed. Mass and resistance of the loop is M and R respectively.



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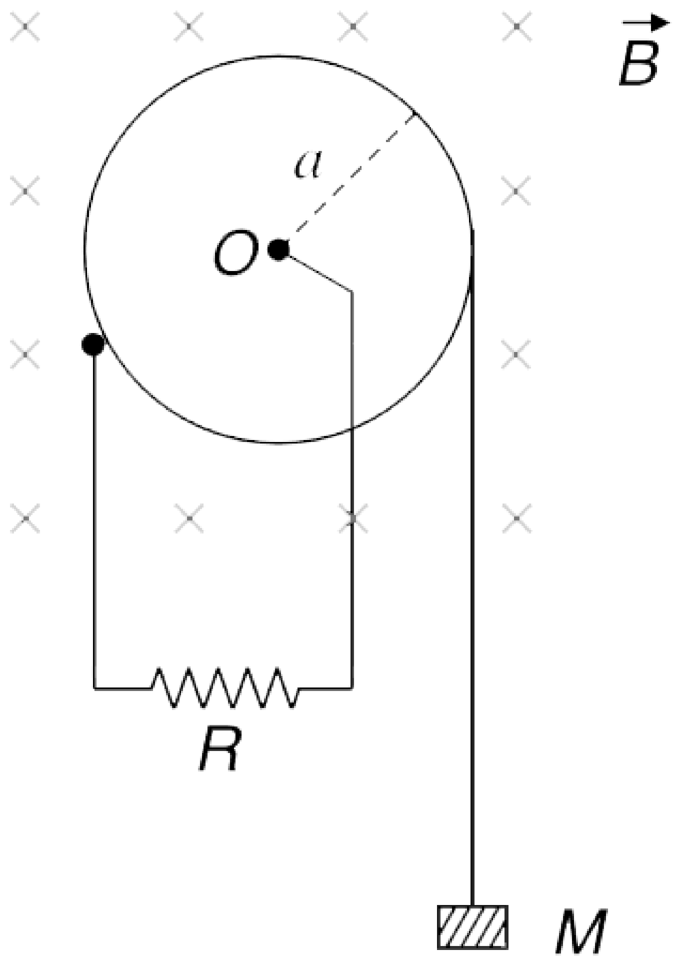
3. A metallic pulley is in the shape of a disc of radius a. It can rotate freely about a horizontal axis passing through its centre. The moment of inertia of the pulley about this axis is I. A light string is tightly wrapped around the pulley with its one end connected to a block of mass M. The centre of the pulley and its circumference are connected to a resistance R as shown. The contact of resistance at the circumference does not cause any friction. A uniform magnetic field B is switched on which is parallel to the axis of rotation of the pulley (see Figure). The mass M is allowed to fall. Assume that resistivity of the material of the pulley is negligible.

(a) Find the acceleration of the block of mass M at the instant its velocity becomes v_0.

(b) Assuming that the block can fall through a large distance, calculate the terminal speed (v_T) that it will acquire.

(c) Find the rate of change of kinetic energy of the pulley at the instant speed of the falling block is $\frac{v_T}{2}$.



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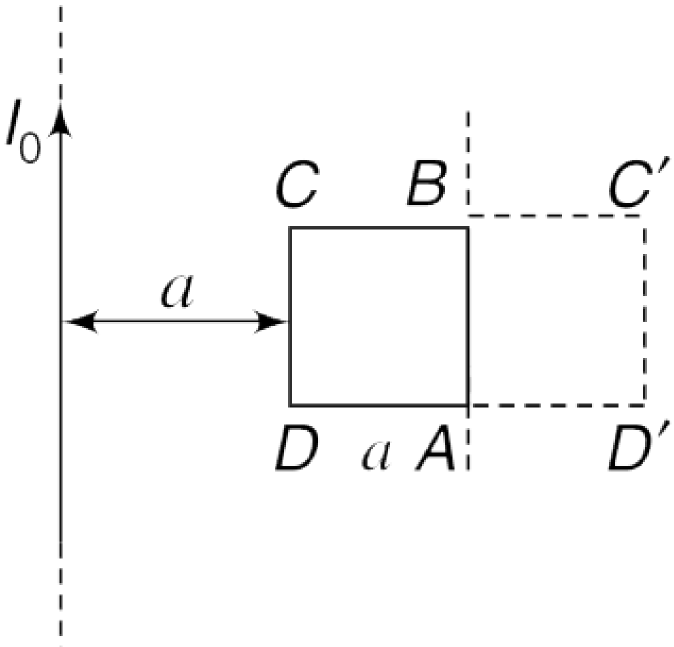
4. Figure shows a square conducting frame and a long wire-both lying in the same plane. The side length of the square loop is 'a' and it is at a distance 'a' from the long wire which is having a steady current I_0. The inductance and resistance of the square loop are L and R respectively. The loop is turned by 180° about its side AB so as to bring it to final position ABC'D' at rest. Calculate the net charge that flow past a side of the loop.



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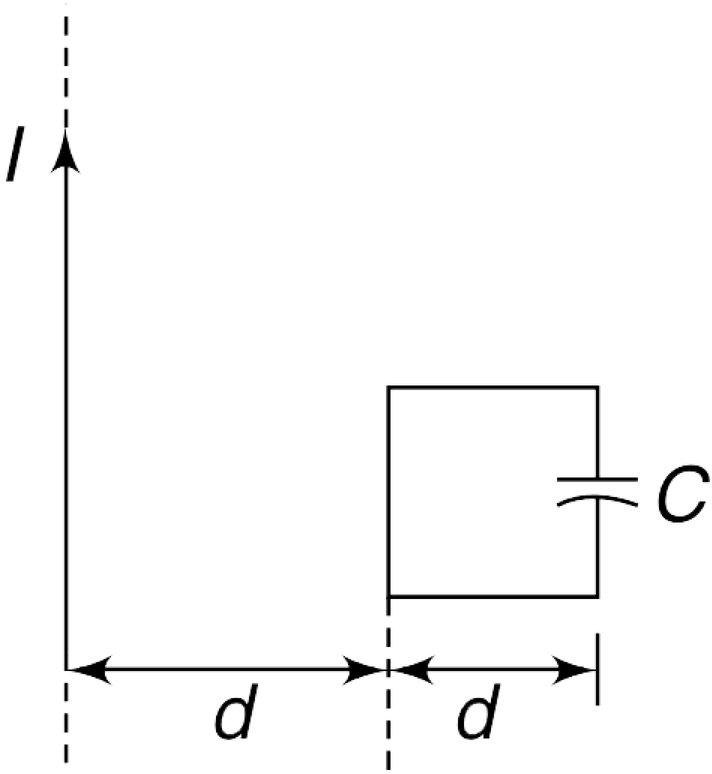
5. A square loop of side length d has a capacitor of capacitance C and the resistance of the loop is R. In the plane of the loop there is a long straight current carrying wire having current I. The distance of the straight wire from the loop is d as shown in figure. The current in the straight wire is made to grow with time as $I = \alpha\ t$ where $\alpha = 2As^{-1}$. Neglect self inductance of the loop.

(a) Find the charge on the capacitor as a function of time (t).

(b) Find the heat generated in the loop as a function of time.

(c) Who supplies energy for heat dissipation?



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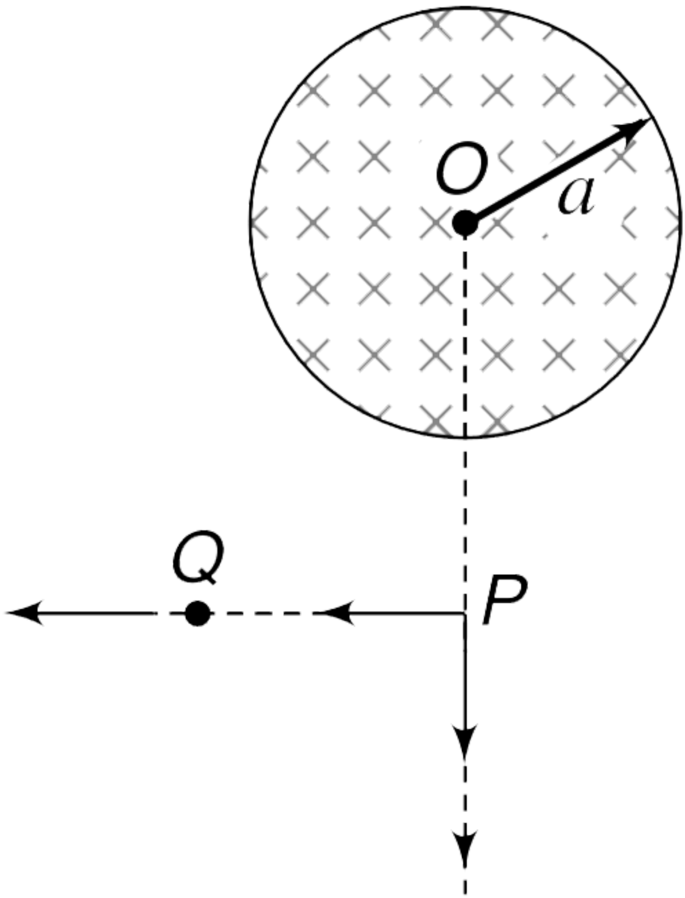
6. There exists a uniform magnetic field perpendicular to the plane of the figure in a cylindrical region of radius a. The magnetic field is increasing at a constant rate of $\alpha T s^{-1}$. A particle having charge q is at a point P outside the field region. The particle is slowly moved to infinity. Calculate work done by the external agent on the particle if-

(a) the particle is moved in radial direction OP.

(b) the particle is moved in a direction perpendicular to OP along PQ.



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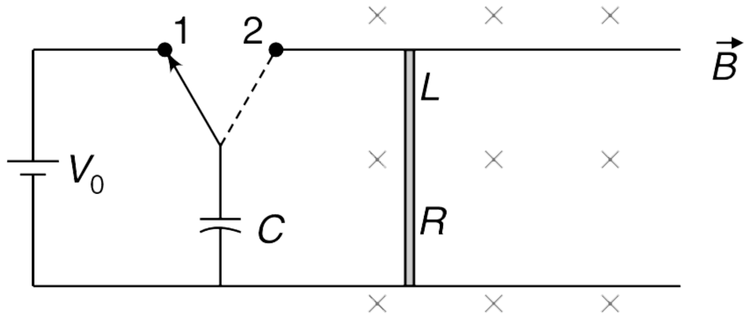
7. The Figure shows an electromagnetic gun. A bar of mass m, resistance R and length L is free to slide on two smooth rails separated by a distance L. A uniform magnetic field B is present perpendicular to the plane of the figure. A capacitor of capacitance C is charged using a battery of emf V_0 by placing switch (S) at 1. To fire the gun (i.e., to impart a kinetic energy to the rod) the switch is shifted to position 2 after the capacitor is fully charged. The rails end abruptly at the point where the speed of the rod becomes maximum. The efficiency of the gun can be defined as the kinetic energy imparted to the bar divided by the energy spent by the battery while charging the capacitor. Calculate the efficiency of the gun. Neglect self inductance of the circuit.



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8. A thin solenoid is made of a large number of turns of very thin wire tightly wound in several layers. The radii of innermost and outermost layers are a and b respectively and the length of the solenoid is $L(L > \ > a,)$. The total number of turns is N. Calculate the self inductance of the solenoid. Neglect edge effects.

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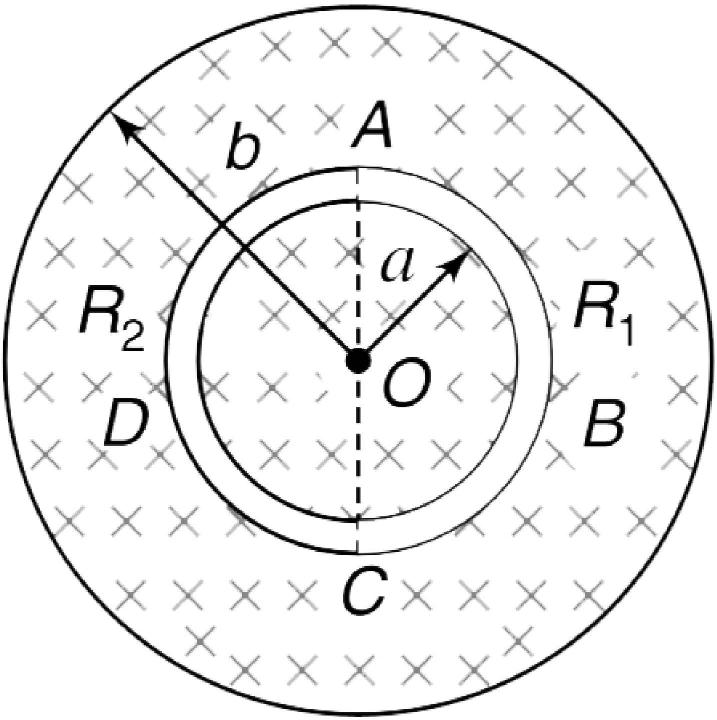
9. A uniform magnetic field B exists perpendicular to the plane of the Figure in a circular region of radius b with its centre at O. A cir- cular conductor of radius $a(< b)$ and centre at O is made by join- ing two semicircular wires ABC and ADC. The two segments have same cross section but different resistances R_1 and R_2 respectively. The magnetic field in increased with time and there is an induced current in the conductor.

(a) Find the ratio of electric fields inside the conductors ABC and ADC.

(b) Explain why the electric field in two conductors is different despite the fact that the magnetic field is symmetrical.



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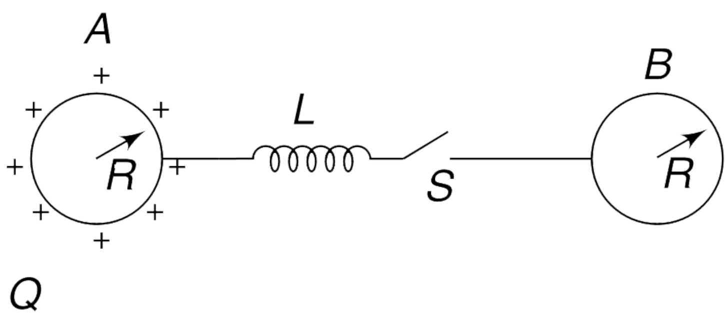
10. Two conducting sphere of radius R are placed at a large distance from each other. They are connected by a coil of inductance L, as shown in the figure. Neglect the resis- tance of the coil. The sphere A is given a charge Q and the switch 'S' is closed at time $t = 0$. Find charge on sphere B as a function of time. At what time charge on B is $\frac{Q}{2}$?



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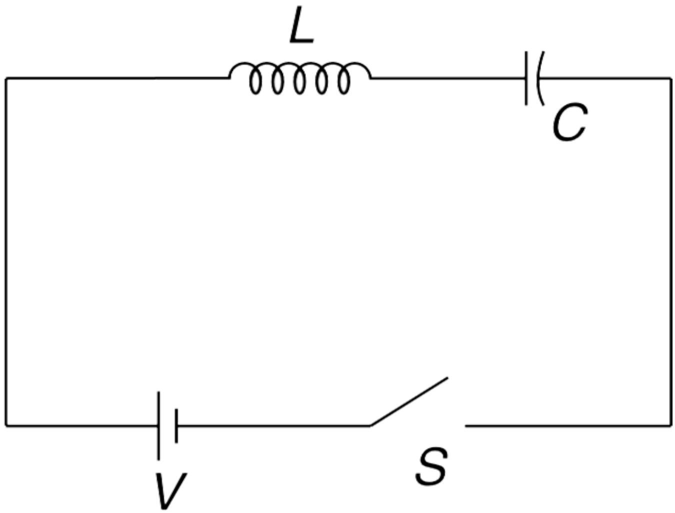
11. In the circuit shown in the figure, switch S is closed at time $t = 0$.

(a) Write current in the circuit and charge on capacitor as a function of time. Draw the graphical plot for the same.

(b) Find maximum charge on the capacitor. What is potential difference across the inductor when charge on the capacitor is maximum?



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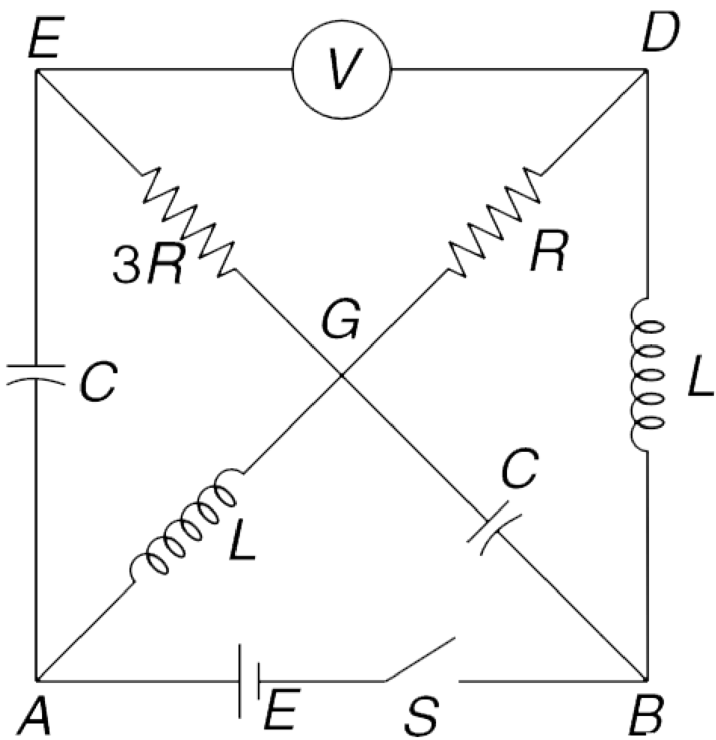
12. In the circuit shown, switch S is kept closed and the circuit is in steady state.

(a) Find reading of the ideal voltmeter

(b) Now the switch is opened. Find the reading of the voltmeter immedi- ately after the switch is opened.

(c) Fid the heat dissipated in resistance R after the switch is opened.



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