[Current Electricity]

Conceptual Questions :

1. If a copper wire is stretched to make it 0·1% longer, what is the percentage change in its resistance? (I.I.T. 1978)

2. Three equal resistors connected in series across a source of e.m.f. together dissipate 10 watts of power. What would be power dissipated if the same resistors are connected in parallel across the same source of emf?

3. A primary and a secondary cell have the same e.m.f. Which of these will provide higher value of the maximum current that can be drawn? Explain briefly. (I.I.T. 1977)

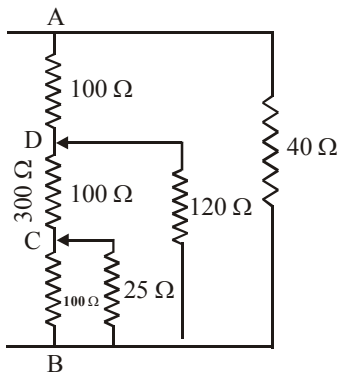
4. A steady current is flowing in a cylindrical conductor. Is there any electric field with in the conductor? (I.I.T. 1982)

5. Is a current – carrying conductor electrically charged?

6. The drift velocity of electrons is quite small. How then does a bulb light up as soon as the switch is turned on, although the bulb may be quite far from the switch?

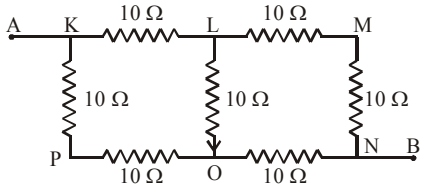
PART – A

1. A long resistor between A and B (in given fig.) have resistance of 300 ohm and are tapped at one-third points.

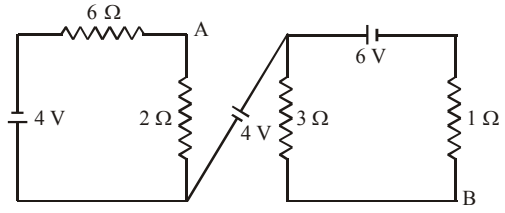


   (a) What is equivalent resistance between A and B.
   (b) If the potential difference between A and B is 320 V, what will be the potential difference between B and C?
   (c) Will this change, if the 40-ohm resistor is disconnected?

2. What is the equivalent resistance between the terminal point A and B in the network shown in figure. Assume that the resistance of each resistor is 10 ohm.



3. In the network shown in the figure below, calculate the potential difference between A and B.



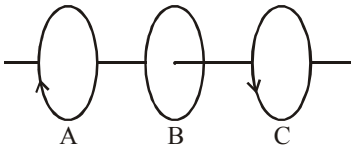
4. In the network of resistors each of value R shown in the figure, calculate the equivalent resistance between the junction A and E first without using Kirchhoff's rules and then check the result by applying Kirchhoff's rules.

Capacitor

Electromagnetic Induction

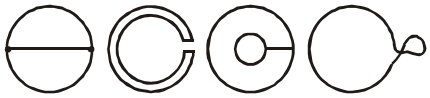
Conceptual Questions: -

1. Three identical coils A, B and C shown in figure are placed with their planes parallel to one another. Coil A and C carry current as shown. Coils B and C are fixed in position and coil A is moved towards B with uniform motion. Is there any induced current in B? If no, give reason. If yes, make the direction of induced current in diagram. (I.I.T. 1982)



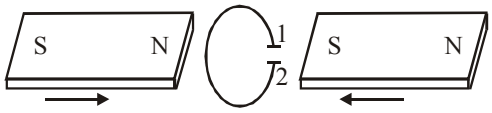
2. Why is the core transformer laminated?

3. Figure illustrates plane figures made of thin conductors, which are located in a uniform magnetic field directed away from a reader beyond the plane of the drawing. The magnetic induction starts diminishing. Find how the currents induced in these loops are directed.



4. An electric lamp is connected in series with a long solenoid of copper wire an with air core. When the combination is connected to an a.c. source, the bulb glows producing the desired illumination. Now if an iron rod is inserted the solenoid, explain what will happen and why?

5. Predict the polarity of the capacitor C in figure when S and N poles of two identical magnets approach the coil from opposite sides with equal velocity.



6. Two parallel beams of protons and electrons, carrying equal current, are fixed at a separation d. The protons and electrons move in opposite directions. P is a point on a line joining the beams, at a a distance x from any one beam. The magnetic field at P is B. Plot the curve B against x.

True – False

1. Birds fly off a high-tension wire when the current is switched on.

2. Time varying magnetic field can generate electric field.

3. Induced electric field is not conservative.

4. Induced electric field forms closed loop.

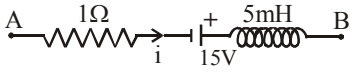
5. An inductor tends to keep the flux constant.

Fill in the Blanks

1. A uniform wound solenoidal coil of self inductance $1{\cdot}8 \times 10^{-4}$ henry and resistance 6 ohm is broken up into two identical coil. These identical coils are then connected in parallel across a 12-volt battery of negligible resistance. The time constant for the current of the circuit is …… seconds and the steady state current through the battery is …… amperes. (I.I.T. 1989)

2. If the coils of self-inductance L_1 and L_2 are placed so closed that all the flux produced by one is linked with the other, than the coefficient of mutual induction between them is ……

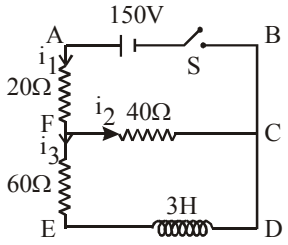
3. The network shown in figure is part of a complete circuit. If at a certain instant, the current I is 5A and is decreasing at a rate 10^3 A/s then $V_B - V_A$ is ……



4. In the previous question, if the direction of I is reversed, $V_B - V_A$ will be ……

Exercise

1. A circuit containing resistors and an inductor is shown in figure. Find the values of currents i_1, i_2 and i_3.
   (a) Soon after the switch is closed
   (b) Long after the switch is closed
   (c) Immediately after the switch is opened
   (d) Long after the switch is opened

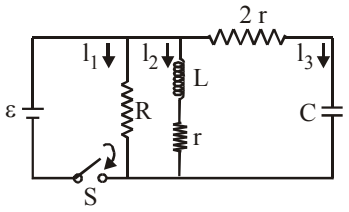


2. The figure shown an LCR circuit, when the switch S is closed the current through resistor R, inductor L

and capacitor C are I_1, I_2 and I_3 respectively. Determine the values of I_1, I_2 and I_3.

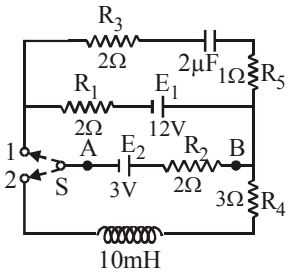
(i) at $t = 0$

(ii) at $t = \infty$



3. A circuit containing a two-position switch S is shown in figure.
   (a) The switch S is in position 1. Find the potential difference $V_A - V_B$ and the rate of production of joule heat in R_1.
   (b) If now the switch S is put in position 2 at $t = 0$, find
      (i) steady current in R_4 and
      (ii) the time when the current in R_4 is half the steady value. Also calculate the energy steady stored in the inductor L at that time.

(I.I.T. 1991)



4. An inductor of inductance 2·0 mH is connected across a charged capacitor of capacitance 5·0 μF and the resulting LC circuit is set oscillating at its natural frequency. Let Q denotes the instantaneous charge on the capacitor and I the current. It is found that the maximum value of Q is 200 μC.
   (a) When Q = 100 μC. what is the value of |dI/dt|?
   (b) When Q = 200 μC what is the value of I
   (c) When I is equal to one-half its maximum value, what is the value, what is the value of |Q|

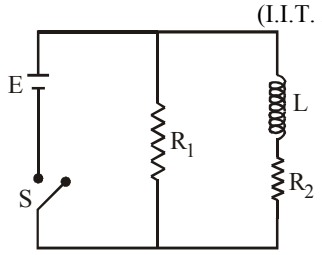
(I.I.T. 1998)

5. A rectangular conducting loop in the vertical X-Z plane has length L, width W, mass M and resistance R. It is dropped length wise from rest. At $t = 0$ the bottom of the loop is at a height h above the horizontal X-axis. There is a uniform magnetic field B perpendicular to X-Z plane, below the X-axis. The bottom and top of the loop cross the axis at $t = t_1$ and $t = t_2$ respectively. Obtain the expression for the velocity of the loop for the time $t_1 \le t \le t_2$.

(Roorkee 2000)

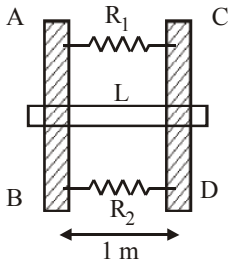
6. An inductor of inductance L = 400 mH and resistor of resistances R_1 = 2 ohm and R_2 = 2ohm are connected to a battery of e.m.f. E of 12 V as shown in figure. The internal resistance of the battery is negligible. The switch is closed at time $t = 0$. What is the potential drop across L as a function of time? After the steady state is reached, the switch is opened. What is the direction and magnitude of current through R_1 as a function of time?

(I.I.T. 2001)



7. Two parallel vertical metallic rails AB and CD are separated by 1m. They are connected at the two ends by resistance R_1 and R_2 as shown in figure. A horizontal metallic bar L of mass 0·2 kg slides without friction, vertically down the rails under the action of gravity. There is a uniform horizontal magnetic field of 0·6 T perpendicular to the plane of the rails. It is observed that when the terminal velocity is attained, the powers dissipated in R_1 and R_2 are 0·76 W and 1·2 W respectively. Find the terminal velocity of the bar L and values of R_1 and R_2.

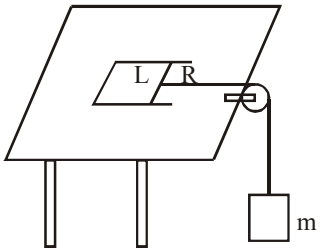
(I.I.T. 1994)



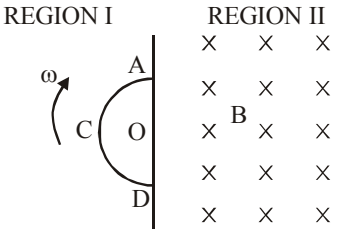
8. A thermo Cole vessel contains 0·5kg of distilled water at 30ºC. A metal coil of area 5×10^{-3} m^2, number of turns 100, mass 0·06kg and resistance 1·6 ohm is lying horizontally at the bottom of vessel. A uniform, time varying magnetic field is set up to pass vertically through the coil at the time $t = 0$. The field is first increased from zero to 0·8 T at a constant rate

between 0 and 0·2 s and then decreased to zero at the same rate between 0·2 and 0·4 s. This cycle is repeated 12000 times. Make sketches of the current through the coil and the power dissipated in the coil as function of the time for the first two cycles. Clearly indicate the magnitude of the quantities on the axes. Assume that no heat is lost to the vessel or the surroundings. Determine the final temperature of the water under thermal equilibrium. Specific heat of the metal = 500 Jkg^{-1} K^{-1} and the specific heat of water = 4200Jkg^{-1} K^{-1}. Neglect the inductance of coil.
(I.I.T. 2000)

9. A pair of parallel horizontal conducting rails of negligible resistance shorted at one end is fixed on a table. The distance between the rail is L. A conducting mass less rod of resistance R can slide on the rails frictionlessly. The rod is tied to a mass less string, which passes over a pulley fixed to the edge of the table. A mass m, tied to the other end of the string, hangs vertically. A constant magnetic field B exists perpendicular to the table. If the system is released from rest, calculate
   (i) The terminal velocity achieved by the rod, and
   (ii) The acceleration of the mass at the instant when the velocity of rod is half the terminal velocity.
   (I.I.T. 1997)

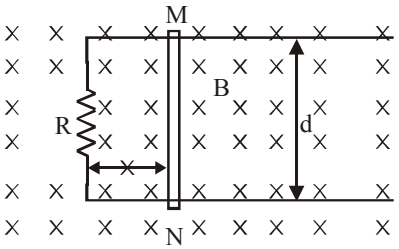


10. Space is divided by the line AD into two regions. Region I is field free and the region II has a uniform magnetic field B directed into the plane of paper. ACD is semicircular conducting loop of radius *r* with center at O, the plane of the loop being in the plane of the paper. The loop is now made to rotate with a constant angular velocity ω about an axis passing through O and perpendicular to the plane of the paper. The effective resistance of the loop is R.
   (i) Obtain an expression for the magnitude of the induced current in the loop.
   (ii) Show the direction of the current when the loop is entering into the region II.
   (iii) Plot a graph between the induced e.m.f. and time for two periods of rotation.
   (I.I.T. 1985)



11. A current of 10A is flowing in a long straight wire situated near a rectangular circuit whose two sides of length 0·2m are parallel to the wire. One of them is at a distance of 0·05m and the other at a distance of 0·10m from the wire. The wire is in the plane of the rectangle. Find the magnetic flux through the rectangular circuit. If the current decays uniformly to zero in 0·02 s, find the e.m.f. induced in the circuit and indicate the direction in which the induced current flows. (Roorkee 1994)

12. Two long parallel horizontal rails, a distance *d* apart and each having a resistances λ per unit length, are joined at one end by a resistance R. A perfectly conducting rod MN of mass *m* is free to slide along the rails without friction. There is a uniform magnetic field of induction B normal to the plane of the paper and directed into the paper. A variable force F is applied to the rod MN such that, as the rod moves, a constant current flows through R.
   (i) Find the velocity if the rod and the applied force F as function of the distance *x* of the rod from R.
   (ii) What fraction of the work done per second by F is converted into heat? (I.I.T. 1988)



13. A copper rod length 0·19m is moving with a uniform velocity 10m/s parallel to a long straight wire carrying a current of 5·0 amp. the rod itself is perpendicular to the wire with its ends at distance 0·01m and 0·02m from it. Calculate the e.m.f. induced in the rod.
   (Roorkee 1989)

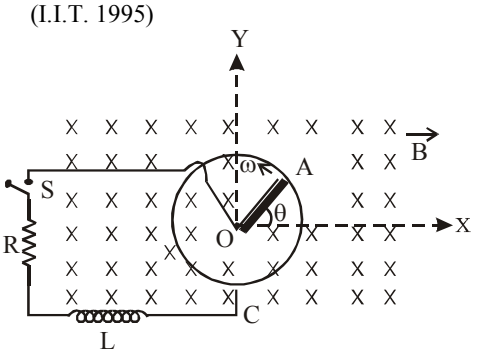
14. A small coil of radius 0·002m is placed on the axis of a magnet of magnetic moment 10^5 joule/tesla and length 0·1m at distance of 0·15m from the center of the magnet. The plane of the coil is perpendicular to the axis of the magnet. Find the force on the coil when the current of 2·0 amp. is passed through it.
(Roorkee 1989)

15. A very small circular loop of area 5×10^{-4} m^2, resistance 2 ohm and negligible inductance is initially coplanar and concentric with a much larger fixed circular loop of radius 0·1m. A constant current of 1 ampere is passed in the bigger loop and the smaller loop is rotated with angular velocity ω rad/sec about a diameter. Calculate
(i) The flux linked with the smaller loop
(ii) Induced e.m.f.
(iii) Induced current in the smaller loop, as s function of time. (Roorkee 1992)

16. A wire frame of area $3{\cdot}92 \times 10^{-4}$ m^2 and resistance 20ohm is suspended freely from a 0·392m long thread. There is a uniform magnetic field of 0·784 tesla and the plane of wire frame is perpendicular to the magnetic field. The frame made to oscillate under gravity by displacing it through 2×10^{-2}m from its initial position along the direction of magnetic field. The plane of the frame is always along the direction of the thread and does not rotate about it. What is the induced e.m.f. in wire-frame as a function of time? Also find the maximum current in the frame.
(Roorkee 1993)

17. A solenoid has an inductance of 10henry and a resistance of 2ohm. It is connected to a 10volt battery. How long will it take for the magnetic energy to reach ¼ of its maximum value?
(I.I.T. 1996)

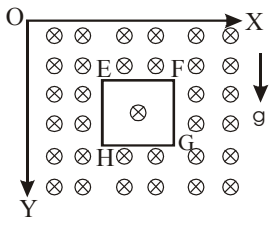
18. A metal rod OA of mass *m* and length *l* is kept rotating with a constant angular speed ω in a vertical plane about a horizontal axis at the end *O*. The free end A is arranged to slide without friction along the fixed conducting circular ring in the same plane as that to rotation. A uniform and constant magnetic field induction *B* is applied perpendicular and into the plane of rotation as shown in figure. An inductor and an external resistance R are connected through a switch S between the point *O* and the point *C* on the ring to from an electrical circuit. Neglect the resistance of the ring and the rod. Initially, the switch is open.
(a) What is the induced e.m.f. across the terminals of the switch?
(b) Obtain an expression for the current as a function of time.
(c) In the steady state, obtain the time dependence of the torque required to maintain the constant angular speed, given that the rod *OA* was along the positive X-axis at $t = 0$.
(I.I.T. 1995)



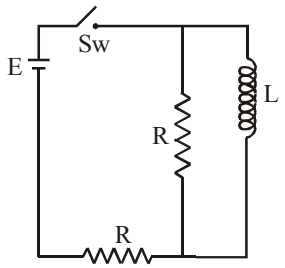
19. Two infinite long straight parallel wires A and B separated by 0·1m distance and carry equal currents in opposite directions. A square loop of wire C of side 0·1m lies in the plane of A and B. The loop of wire C is kept parallel to both A and B at a distance of 0·1m from the nearest wire. Calculate the e.m.f. induced in the loop C while the current in A and B are increasing at the rate of 10^3 A s^{-1}. Also indicate the direction of current in the loop C.
(Roorkee 1996)

20. An infinitesimally small bar magnet of dipole moment M is pointing and moving with the speed *v* is the X-direction. A small closed circular conducting loop of radius *a* and negligible self-inductance lies is the Y-Z plane with its center at $x = 0$, and its axis coinciding with the X-axis. Find the force opposing the motion of the magnet, if the resistance of the loop is R. Assume that the distance *x* of the magnet from the center of the loop is much greater than *a*.
(I.I.T. 1997)

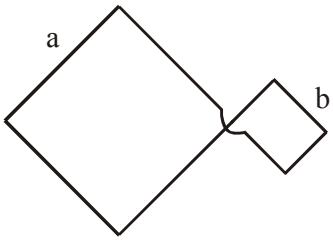
21. A magnetic field $B = (B_O\ y/a)\ \hat{k}$ is into the paper in the +Z direction. B_O and *a* are positive constants. A square loop EFGH of side *a* and mass *m* and resistance R, in X-Y plane, start falling under the influence of gravity. Note the direction of X and Y-axes in figure. Find
(a) The induced current in the loop and indicate its direction,
(b) The total lorentz force acting on the loop and indicate its direction, and
(c) An expression for the speed of the loop, $v(t)$ and its terminal velocity. (I.I.T. 1999)



22. Find the time dependence of the current flowing through the inductance L of the circuit shown in the figure after the switch *Sw* is shorted at the moment $t = 0$.



23. A plane loop shown in figure is shaped as two squares with sides $a = 20$cm and $b = 10$cm is introduced into a uniform magnetic field at the right angles to the loop's plane. The magnetic induction varies with time as $B = B_O \sin \omega t$, where $B_O = 10$ mT and $\omega = 100\ s^{-1}$. Find the amplitude of the current induced in the loop if its resistance per unit length is equal to $\rho = 50$m ohm/m. The inductance of the loop is to be neglected.



24. A thin wire AC shaped as a semi-circle of diameter $d = 20$cm rotates with a constant angular velocity $\omega = 100$ rad/s in a uniform magnetic field of inducting $B = 5{\cdot}0$ mT, with $\omega \uparrow\uparrow B$. The rotation axis passes through the end A of the wire and is perpendicular to the diameter AC. Find the value of a line integral $\int \mathbf{E}.\mathbf{dr}$ along the wire from point A to point C. Generalize the obtained result.