Chapter One

ELECTRIC CHARGES AND FIELDS

MCQ I

1.1 In Fig.1.1, two positive charges q_2 and q_3 fixed along the y axis, exert a net electric force in the + x direction on a charge q_1 fixed along the x axis. If a positive charge Q is added at $(x, 0)$, the force on q_1

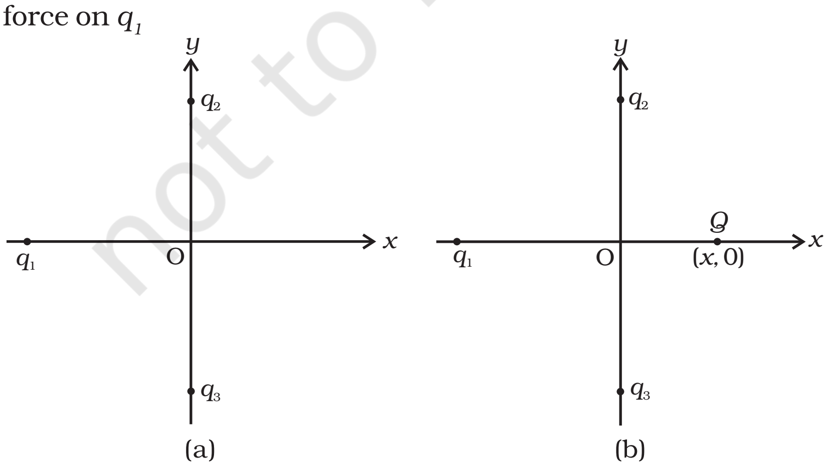


Fig. 1.1

(a) shall increase along the positive x-axis.
(b) shall decrease along the positive x-axis.
(c) shall point along the negative x-axis.
(d) shall increase but the direction changes because of the intersection of Q with q_2 and q_3.

1.2 A point positive charge is brought near an isolated conducting sphere (Fig. 1.2). The electric field is best given by

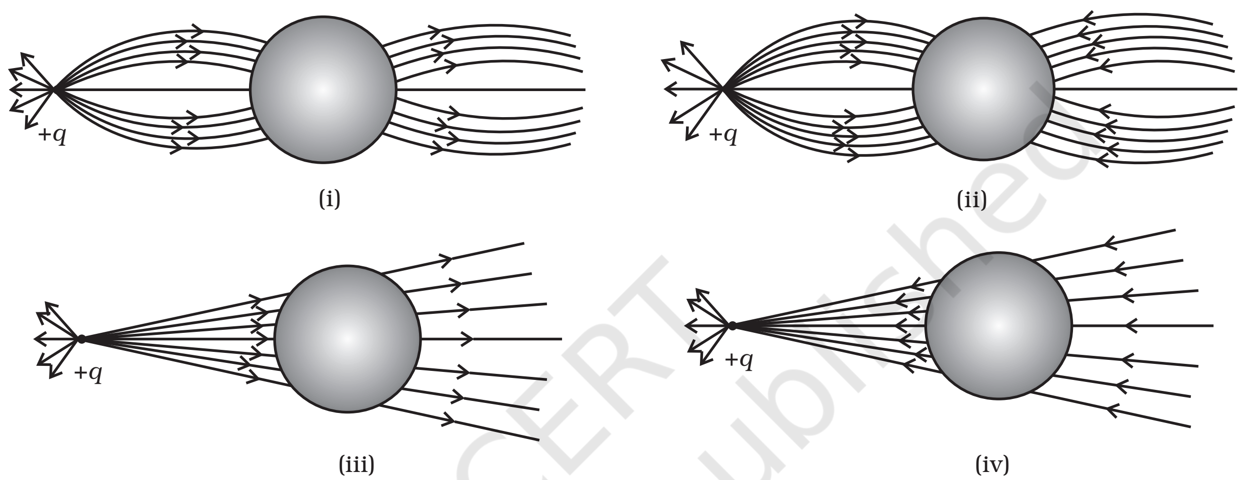


Fig. 1.2

(a) Fig (i) (c) Fig (iii)
(b) Fig (ii) (d) Fig (iv)

1.3 The Electric flux through the surface

(a) in Fig.1.3 (iv) is the largest.
(b) in Fig. 1.3 (iii) is the least.
(c) in Fig. 1.3 (ii) is same as Fig. 1.3 (iii) but is smaller than Fig. 1.3 (iv)
(d) is the same for all the figures.

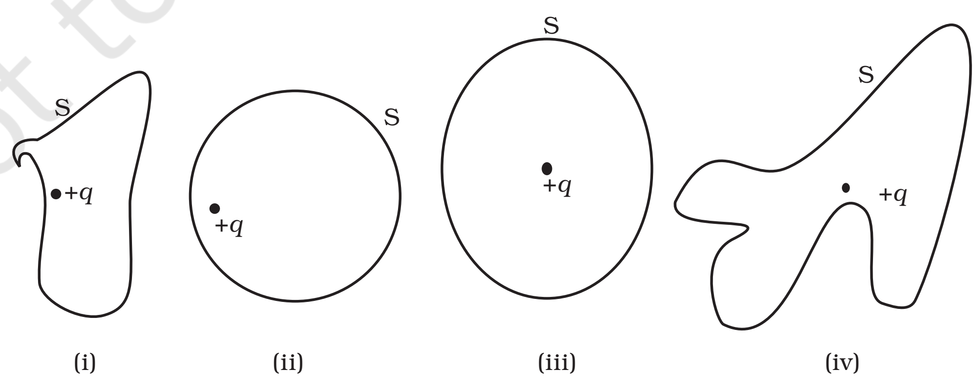


Fig. 1.3

1.4 Five charges q_1, q_2, q_3, q_4, and q_5 are fixed at their positions as shown in Fig. 1.4. S is a Gaussian surface. The Gauss's law is given by

$$\oint_S \mathbf{E}.d\mathbf{s} = \frac{q}{\varepsilon_0}$$

Which of the following statements is correct?

(a) **E** on the LHS of the above equation will have a contribution from q_1, q_5 and q_3 while q on the RHS will have a contribution from q_2 and q_4 only.

(b) **E** on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_2 and q_4 only.

(c) **E** on the LHS of the above equation will have a contribution from all charges while q on the RHS will have a contribution from q_1, q_3 and q_5 only.

(d) Both **E** on the LHS and q on the RHS will have contributions from q_2 and q_4 only.

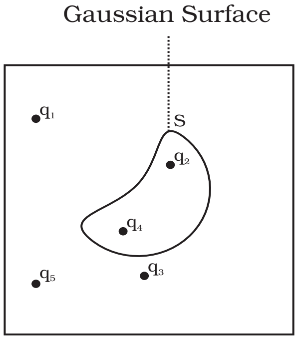


Fig. 1.4

1.5 Figure 1.5 shows electric field lines in which an electric dipole **p** is placed as shown. Which of the following statements is correct?

(a) The dipole will not experience any force.

(b) The dipole will experience a force towards right.

(c) The dipole will experience a force towards left.

(d) The dipole will experience a force upwards.

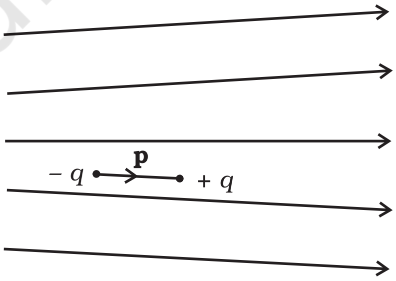


Fig. 1.5

1.6 A point charge $+q$, is placed at a distance d from an isolated conducting plane. The field at a point P on the other side of the plane is

(a) directed perpendicular to the plane and away from the plane.

(b) directed perpendicular to the plane but towards the plane.

(c) directed radially away from the point charge.

(d) directed radially towards the point charge.

1.7 A hemisphere is uniformly charged positively. The electric field at a point on a diameter away from the centre is directed

(a) perpendicular to the diameter

(b) parallel to the diameter

(c) at an angle tilted towards the diameter

(d) at an angle tilted away from the diameter.

MCQ II

1.8 If $\oint_s \mathbf{E}.d\mathbf{S} = 0$ over a surface, then

(a) the electric field inside the surface and on it is zero.
(b) the electric field inside the surface is necessarily uniform.
(c) the number of flux lines entering the surface must be equal to the number of flux lines leaving it.
(d) all charges must necessarily be outside the surface.

1.9 The Electric field at a point is

(a) always continuous.
(b) continuous if there is no charge at that point.
(c) discontinuous only if there is a negative charge at that point.
(d) discontinuous if there is a charge at that point..

1.10 If there were only one type of charge in the universe, then

(a) $\oint_s \mathbf{E}.d\mathbf{S} \neq 0$ on any surface.

(b) $\oint_s \mathbf{E}.d\mathbf{S} = 0$ if the charge is outside the surface.

(c) $\oint_s \mathbf{E}.d\mathbf{S}$ could not be defined.

(d) $\oint_s \mathbf{E}.d\mathbf{S} = \frac{q}{\varepsilon_0}$ if charges of magnitude q were inside the surface.

1.11 Consider a region inside which there are various types of charges but the total charge is zero. At points outside the region

(a) the electric field is necessarily zero.
(b) the electric field is due to the dipole moment of the charge distribution only.
(c) the dominant electric field is $\propto \frac{1}{r^3}$, for large r, where r is the distance from a origin in this region.
(d) the work done to move a charged particle along a closed path, away from the region, will be zero.

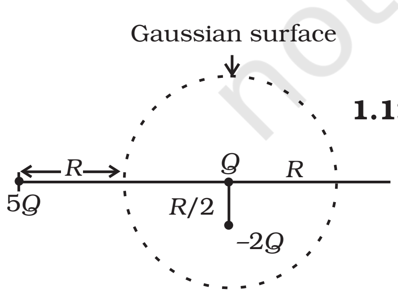


Fig. 1.6

1.12 Refer to the arrangement of charges in Fig. 1.6 and a Gaussian surface of radius R with Q at the centre. Then

(a) total flux through the surface of the sphere is $\frac{-Q}{\varepsilon_0}$.

(b) field on the surface of the sphere is $\frac{-Q}{4\pi\varepsilon_0 R^2}$.

(c) flux through the surface of sphere due to $5Q$ is zero.

(d) field on the surface of sphere due to $-2Q$ is same everywhere.

1.13 A positive charge Q is uniformly distributed along a circular ring of radius R. A small test charge q is placed at the centre of the ring (Fig. 1.7). Then

(a) If $q > 0$ and is displaced away from the centre in the plane of the ring, it will be pushed back towards the centre.

(b) If $q < 0$ and is displaced away from the centre in the plane of the ring, it will never return to the centre and will continue moving till it hits the ring.

(c) If $q < 0$, it will perform SHM for small displacement along the axis.

(d) q at the centre of the ring is in an unstable equilibrium within the plane of the ring for $q > 0$.

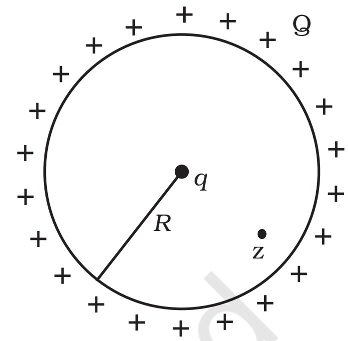


Fig. 1.7

VSA

1.14 An arbitrary surface encloses a dipole. What is the electric flux through this surface?

1.15 A metallic spherical shell has an inner radius R_1 and outer radius R_2. A charge Q is placed at the centre of the spherical cavity. What will be surface charge density on (i) the inner surface, and (ii) the outer surface?

1.16 The dimensions of an atom are of the order of an Angstrom. Thus there must be large electric fields between the protons and electrons. Why, then is the electrostatic field inside a conductor zero?

1.17 If the total charge enclosed by a surface is zero, does it imply that the elecric field everywhere on the surface is zero? Conversely, if the electric field everywhere on a surface is zero, does it imply that net charge inside is zero.

1.18 Sketch the electric field lines for a uniformly charged hollow cylinder shown in Fig 1.8.

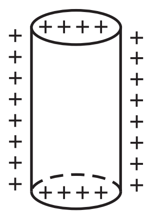


Fig. 1.8

1.19 What will be the total flux through the faces of the cube (Fig. 1.9) with side of length a if a charge q is placed at

(a) A: a corner of the cube.
(b) B: mid-point of an edge of the cube.
(c) C: centre of a face of the cube.
(d) D: mid-point of B and C.

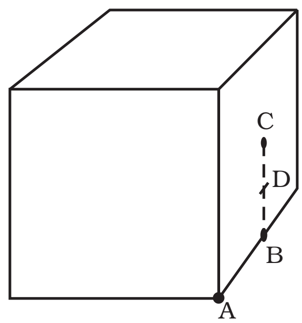


Fig. 1.9

S.A

1.20 A paisa coin is made up of Al-Mg alloy and weighs 0.75g. It has a square shape and its diagonal measures 17 mm. It is electrically neutral and contains equal amounts of positive and negative charges.

Treating the paisa coins made up of only Al, find the magnitude of equal number of positive and negative charges. What conclusion do you draw from this magnitude?

1.21 Consider a coin of Example 1.20. It is electrically neutral and contains equal amounts of positive and negative charge of magnitude 34.8 kC. Suppose that these equal charges were concentrated in two point charges seperated by (i) 1 cm $\left(\sim \frac{1}{2} \times \text{diagonal of the one paisa coin}\right)$, (ii) 100 m (~ length of a long building), and (iii) 10^6 m (radius of the earth). Find the force on each such point charge in each of the three cases. What do you conclude from these results?

1.22 Fig. 1.10 represents a crystal unit of cesium chloride, CsCl. The cesium atoms, represented by open circles are situated at the corners of a cube of side 0.40nm, whereas a Cl atom is situated at the centre of the cube. The Cs atoms are deficient in one electron while the Cl atom carries an excess electron.

(i) What is the net electric field on the Cl atom due to eight Cs atoms?

(ii) Suppose that the Cs atom at the corner A is missing. What is the net force now on the Cl atom due to seven remaining Cs atoms?

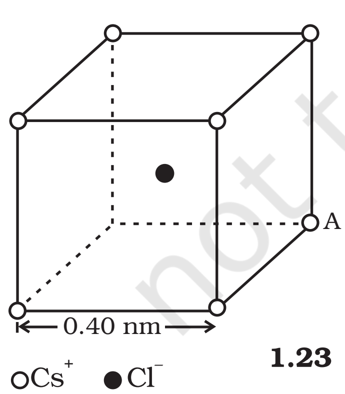


Fig. 1.10

1.23 Two charges q and $-3q$ are placed fixed on x-axis separated by distance 'd'. Where should a third charge $2q$ be placed such that it will not experience any force?

1.24 Fig. 1.11 shows the electric field lines around three point charges A, B and C.

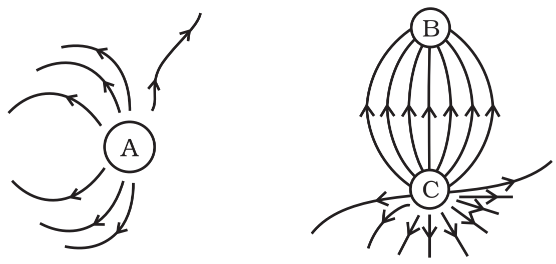


Fig. 1.11

(a) Which charges are positive?

(b) Which charge has the largest magnitude? Why?

(c) In which region or regions of the picture could the electric field be zero? Justify your answer.

(i) near A, (ii) near B, (iii) near C, (iv) nowhere.

1.25 Five charges, q each are placed at the corners of a regular pentagon of side 'a' (Fig. 1.12).

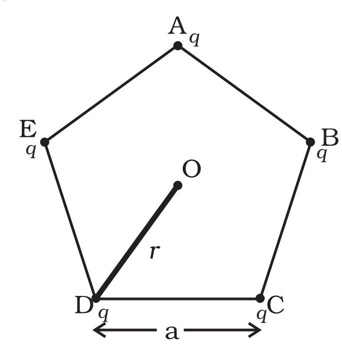


Fig. 1.12

(a) (i) What will be the electric field at O, the centre of the pentagon?

(ii) What will be the electric field at O if the charge from one of the corners (say A) is removed?

(iii) What will be the electric field at O if the charge q at A is replaced by $-q$?

(b) How would your answer to (a) be affected if pentagon is replaced by n-sided regular polygon with charge q at each of its corners?

LA

1.26 In 1959 Lyttleton and Bondi suggested that the expansion of the Universe could be explained if matter carried a net charge. Suppose that the Universe is made up of hydrogen atoms with a number density N, which is maintained a constant. Let the charge on the proton be: $e_p = -(1 + y)e$ where e is the electronic charge.

(a) Find the critical value of y such that expansion may start.

(b) Show that the velocity of expansion is proportional to the distance from the centre.

1.27 Consider a sphere of radius R with charge density distributed as

$$\rho(r) = kr \quad \text{for } r \le R$$
$$= 0 \quad \text{for } r > R.$$

(a) Find the electric field at all points r.

(b) Suppose the total charge on the sphere is $2e$ where e is the electron charge. Where can two protons be embedded such that the force on each of them is zero. Assume that the introduction of the proton does not alter the negative charge distribution.

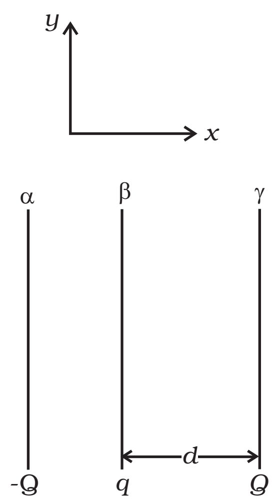


Fig. 1.13

1.28 Two fixed, identical conducting plates $(\alpha \,\&\, \beta)$, each of surface area S are charged to $-Q$ and q, respectively, where $Q > q > 0$. A third identical plate (γ), free to move is located on the other side of the plate with charge q at a distance d (Fig 1.13). The third plate is released and collides with the plate β. Assume the collision is elastic and the time of collision is sufficient to redistribute charge amongst $\beta \,\&\, \gamma$.

(a) Find the electric field acting on the plate γ before collision.

(b) Find the charges on β and γ after the collision.

(c) Find the velocity of the plate γ after the collision and at a distance d from the plate β.

1.29 There is another useful system of units, besides the SI/mks A system, called the cgs (centimeter-gram-second) system. In this system Coloumb's law is given by

$$\mathbf{F} = \frac{Qq}{r^2}\hat{\boldsymbol{r}}$$

where the distance r is measured in cm (= 10^{-2} m), F in dynes (=10^{-5} N) and the charges in electrostatic units (es units), where

$$1\text{es unit of charge} = \frac{1}{[3]} \times 10^{-9}\,\text{C}$$

The number [3] actually arises from the speed of light in vaccum which is now taken to be exactly given by $c = 2.99792458 \times 10^8$ m/s. An approximate value of c then is $c = [3] \times 10^8$ m/s.

(i) Show that the coloumb law in cgs units yields

1 esu of charge = 1 (dyne)$^{1/2}$ cm.

Obtain the dimensions of units of charge in terms of mass M, length L and time T. Show that it is given in terms of fractional powers of M and L.

(ii) Write 1 esu of charge = x C, where x is a dimensionless number. Show that this gives

$$\frac{1}{4\pi\epsilon_0} = \frac{10^{-9}}{x^2}\frac{\text{N.m}^2}{\text{C}^2}$$

With $x = \frac{1}{[3]} \times 10^{-9}$, we have

$$\frac{1}{4\pi\epsilon_0} = [3]^2 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2}$$

$$\text{or, } \frac{1}{4\pi\epsilon_0} = (2.99792458)^2 \times 10^9 \frac{\text{Nm}^2}{\text{C}^2} \text{ (exactly).}$$

1.30 Two charges $-q$ each are fixed separated by distance $2d$. A third charge q of mass m placed at the mid-point is displaced slightly by x (x<<d) perpendicular to the line joining the two fixed charged as shown in Fig. 1.14. Show that q will perform simple harmonic oscillation of time period.

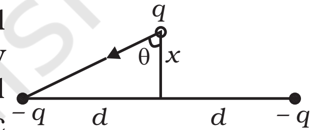


Fig. 1.14

$$T = \left[\frac{8\pi^3\varepsilon_0 m d^3}{q^2}\right]^{1/2}$$

1.31 Total charge $-Q$ is uniformly spread along length of a ring of radius R. A small test charge $+q$ of mass m is kept at the centre of the ring and is given a gentle push along the axis of the ring.

(a) Show that the particle executes a simple harmonic oscillation.

(b) Obtain its time period.

Chapter Two

ELECTROSTATIC POTENTIAL AND CAPACITANCE

MCQ I

2.1 A capacitor of 4 μ F is connected as shown in the circuit (Fig. 2.1). The internal resistance of the battery is 0.5 Ω. The amount of charge on the capacitor plates will be

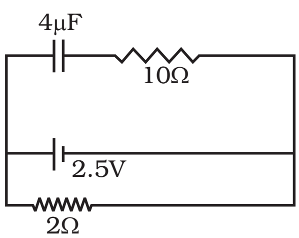


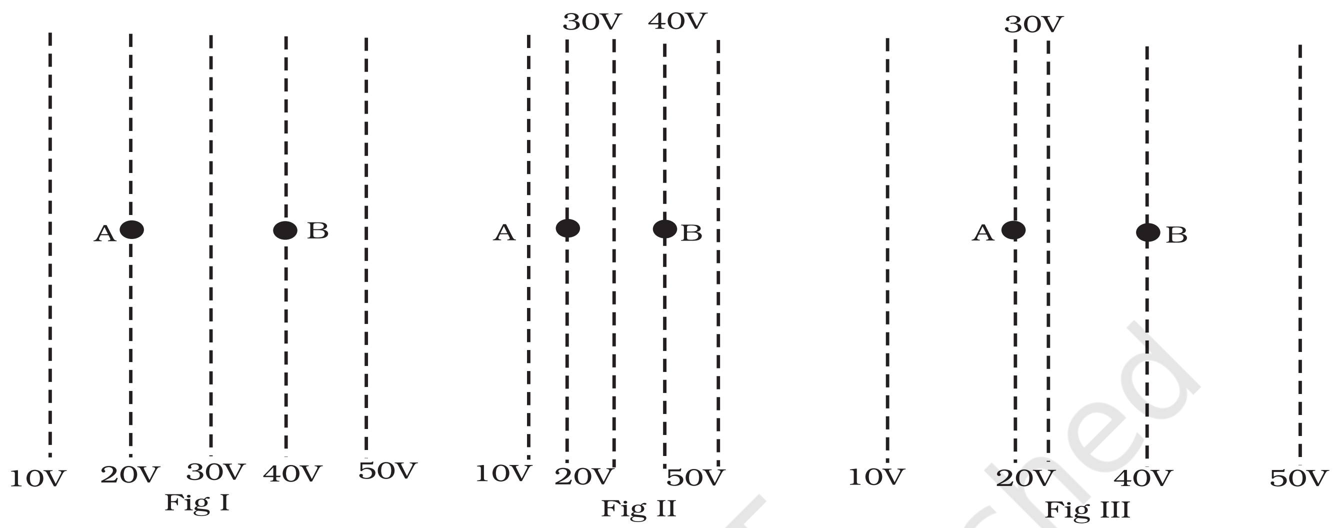
Fig. 2.1

(a) 0
(b) 4 μ C
(c) 16 μ C
(d) 8 μ C

2.2 A positively charged particle is released from rest in an uniform electric field. The electric potential energy of the charge

(a) remains a constant because the electric field is uniform.
(b) increases because the charge moves along the electric field.
(c) decreases because the charge moves along the electric field.
(d) decreases because the charge moves opposite to the electric field.

2.3 Figure 2.2 shows some equipotential lines distributed in space. A charged object is moved from point A to point B.



(i) (ii) (iii)

Fig. 2.2

(a) The work done in Fig. (i) is the greatest.
(b) The work done in Fig. (ii) is least.
(c) The work done is the same in Fig. (i), Fig. (ii) and Fig. (iii).
(d) The work done in Fig. (iii) is greater than Fig. (ii)but equal to that in Fig. (i).

2.4 The electrostatic potential on the surface of a charged conducting sphere is 100V. Two statments are made in this regard:

S_1 : At any point inside the sphere, electric intensity is zero.
S_2 : At any point inside the sphere, the electrostatic potential is 100V.

Which of the following is a correct statement?

(a) S_1 is true but S_2 is false.
(b) Both S_1 & S_2 are false.
(c) S_1 is true, S_2 is also true and S_1 is the cause of S_2.
(d) S_1 is true, S_2 is also true but the statements are independant.

2.5 Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately

(a) spheres.
(b) planes.
(c) paraboloids
(d) ellipsoids.

2.6 A parallel plate capacitor is made of two dielectric blocks in series. One of the blocks has thickness d_1 and dielectric constant k_1 and the other has thickness d_2 and dielectric constant k_2 as shown in Fig. 2.3. This arrangement can be thought as a dielectric slab of thickness $d\,(= d_1 + d_2)$ and effective dielectric constant k. The k is

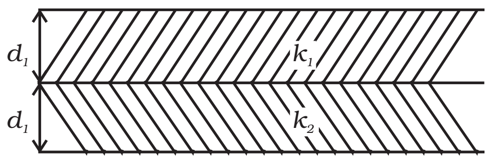


Fig. 2.3

(a) $\dfrac{k_1 d_1 + k_2 d_2}{d_1 + d_2}$ (b) $\dfrac{k_1 d_1 + k_2 d_2}{k_1 + k_2}$ (c) $\dfrac{k_1 k_2 (d_1 + d_2)}{(k_1 d_1 + k_2 d_2)}$ (d) $\dfrac{2k_1 k_2}{k_1 + k_2}$

MCQ II

2.7 Consider a uniform electric field in the $\hat{\mathbf{z}}$ direction. The potential is a constant

(a) in all space.
(b) for any x for a given z.
(c) for any y for a given z.
(d) on the x-y plane for a given z.

2.8 Equipotential surfaces

(a) are closer in regions of large electric fields compared to regions of lower electric fields.
(b) will be more crowded near sharp edges of a conductor.
(c) will be more crowded near regions of large charge densities.
(d) will always be equally spaced.

2.9 The work done to move a charge along an equipotential from A to B

(a) cannot be defined as $-\int_A^B \mathbf{E}.d\mathbf{l}$

(b) must be defined as $-\int_A^B \mathbf{E}.d\mathbf{l}$

(c) is zero.
(d) can have a non-zero value.

2.10 In a region of constant potential

(a) the electric field is uniform
(b) the electric field is zero
(c) there can be no charge inside the region.
(d) the electric field shall necessarily change if a charge is placed outside the region.

2.11 In the circuit shown in Fig. 2.4. initially key K_1 is closed and key

K_2 is open. Then K_1 is opened and K_2 is closed (order is important). [Take Q_1' and Q_2' as charges on C_1 and C_2 and V_1 and V_2 as voltage respectively.]

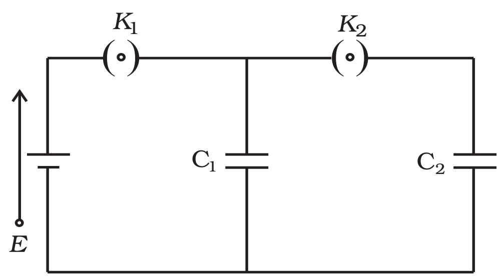


Fig. 2.4

Then

(a) charge on C_1 gets redistributed such that $V_1 = V_2$
(b) charge on C_1 gets redistributed such that $Q_1' = Q_2'$
(c) charge on C_1 gets redistributed such that $C_1V_1 + C_2V_2 = C_1 E$
(d) charge on C_1 gets redistributed such that $Q_1' + Q_2' = Q$

2.12 If a conductor has a potential $V \neq 0$ and there are no charges anywhere else outside, then

(a) there must be charges on the surface or inside itself.
(b) there cannot be any charge in the body of the conductor.
(c) there must be charges only on the surface.
(d) there must be charges inside the surface.

2.13 A parallel plate capacitor is connected to a battery as shown in Fig. 2.5. Consider two situations:

A: Key K is kept closed and plates of capacitors are moved apart using insulating handle.
B: Key K is opened and plates of capacitors are moved apart using insulating handle.

Choose the correct option(s).

(a) In A : Q remains same but C changes.
(b) In B : V remains same but C changes.
(c) In A : V remains same and hence Q changes.
(d) In B : Q remains same and hence V changes.

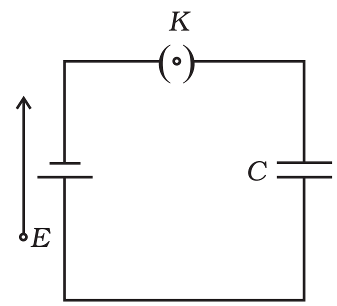


Fig. 2.5

VSA

2.14 Consider two conducting spheres of radii R_1 and R_2 with $R_1 > R_2$. If the two are at the same potential, the larger sphere has more charge than the smaller sphere. State whether the charge density of the smaller sphere is more or less than that of the larger one.

2.15 Do free electrons travel to region of higher potential or lower potential?

2.16 Can there be a potential difference between two adjacent conductors carrying the same charge?

2.17 Can the potential function have a maximum or minimum in free space?

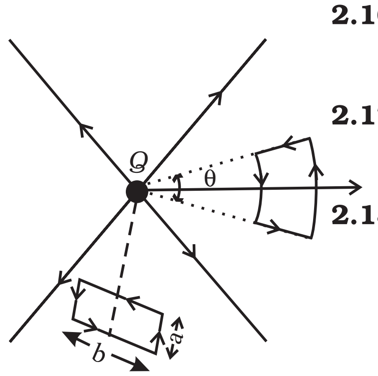


Fig. 2.6

2.18 A test charge q is made to move in the electric field of a point charge Q along two different closed paths (Fig. 2.6). First path has sections along and perpendicular to lines of electric field. Second path is a rectangular loop of the same area as the first loop. How does the work done compare in the two cases?

SA

2.19 Prove that a closed equipotential surface with no charge within itself must enclose an equipotential volume.

2.20 A capacitor has some dielectric between its plates, and the capacitor is connected to a DC source. The battery is now disconnected and then the dielectric is removed. State whether the capacitance, the energy stored in it, electric field, charge stored and the voltage will increase, decrease or remain constant.

2.21 Prove that, if an insulated, uncharged conductor is placed near a charged conductor and no other conductors are present, the uncharged body must be intermediate in potential between that of the charged body and that of infinity.

2.22 Calculate potential energy of a point charge $-q$ placed along the axis due to a charge $+Q$ uniformly distributed along a ring of radius R. Sketch P.E. as a function of axial distance z from the centre of the ring. Looking at graph, can you see what would happen if $-q$ is displaced slightly from the centre of the ring (along the axis)?

2.23 Calculate potential on the axis of a ring due to charge Q uniformly distributed along the ring of radius R.

LA

2.24 Find the equation of the equipotentials for an infinite cylinder of radius r_0, carrying charge of linear density λ.

2.25 Two point charges of magnitude $+q$ and $-q$ are placed at $(-d/2, 0,0)$ and $(d/2, 0,0)$, respectively. Find the equation of the equipoential surface where the potential is zero.

2.26 A parallel plate capacitor is filled by a dielectric whose relative permittivity varies with the applied voltage (U) as $\varepsilon = \alpha U$ where $\alpha = 2V^{-1}$ .A similar capacitor with no dielectric is charged to $U_0 = 78$ V. It is then connected to the uncharged capacitor with the dielectric. Find the final voltage on the capacitors.

2.27 A capacitor is made of two circular plates of radius R each, separated by a distance $d<<R$. The capacitor is connected to a constant voltage. A thin conducting disc of radius $r<<R$ and thickness $t<<r$ is placed at a centre of the bottom plate. Find the minimum voltage required to lift the disc if the mass of the disc is m.

2.28 (a) In a quark model of elementary particles, a neutron is made of one up quarks [charge $(2/3)\ e$] and two down quarks [charges $-(1/3)\ e$]. Assume that they have a triangle configuration with side length of the order of 10^{-15} m. Calculate electrostatic potential energy of neutron and compare it with its mass 939 MeV.

(b) Repeat above exercise for a proton which is made of two up and one down quark.

2.29 Two metal spheres, one of radius R and the other of radius $2R$, both have same surface charge density σ. They are brought in contact and separated. What will be new surface charge densities on them?

2.30 In the circuit shown in Fig. 2.7, initially K_1 is closed and K_2 is open. What are the charges on each capacitors.
Then K_1 was opened and K_2 was closed (order is important), What will be the charge on each capacitor now? [$C = 1\mu$F]

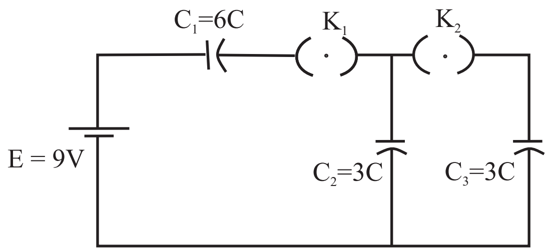


Fig. 2.7

2.31 Calculate potential on the axis of a disc of radius R due to a charge Q uniformly distributed on its surface.

2.32 Two charges q_1 and q_2 are placed at $(0, 0, d)$ and $(0, 0, -d)$ respectively. Find locus of points where the potential a zero.

2.33 Two charges $-q$ each are separated by distance $2d$. A third charge $+q$ is kept at mid point O. Find potential energy of $+q$ as a function of small distance x from O due to $-q$ charges. Sketch P.E. v/s x and convince yourself that the charge at O is in an unstable equilibrium.

Chapter Three

CURRENT ELECTRICITY

MCQ I

3.1 Consider a current carrying wire (current I) in the shape of a circle. Note that as the current progresses along the wire, the direction of **j** (current density) changes in an exact manner, while the current I remain unaffected. The agent that is *essentially* responsible for is

(a) source of emf.

(b) electric field produced by charges accumulated on the surface of wire.

(c) the charges just behind a given segment of wire which push them just the right way by repulsion.

(d) the charges ahead.

3.2 Two batteries of emf ε_1 and ε_2 ($\varepsilon_2 > \varepsilon_1$) and internal resistances r_1 and r_2 respectively are connected in parallel as shown in Fig 3.1.

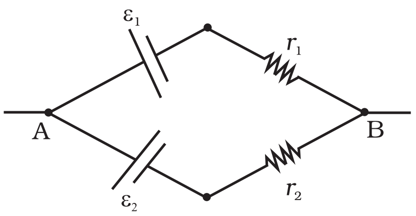


Fig 3.1

(a) The equivalent emf ε_{eq} of the two cells is between ε_1 and ε_2, i.e. $\varepsilon_1 < \varepsilon_{eq} < \varepsilon_2$.

(b) The equivalent emf ε_{eq} is smaller than ε_1.
(c) The ε_{eq} is given by $\varepsilon_{eq} = \varepsilon_1 + \varepsilon_2$ always.
(d) ε_{eq} is independent of internal resistances r_1 and r_2.

3.3 A resistance R is to be measured using a meter bridge. Student chooses the standard resistance S to be 100Ω. He finds the null point at $l_1 = 2.9$ cm. He is told to attempt to improve the accuracy. Which of the following is a useful way?

(a) He should measure l_1 more accurately.
(b) He should change S to 1000Ω and repeat the experiment.
(c) He should change S to 3Ω and repeat the experiment.
(d) He should give up hope of a more accurate measurement with a meter bridge.

3.4 Two cells of emf's approximately 5V and 10V are to be accurately compared using a potentiometer of length 400cm.

(a) The battery that runs the potentiometer should have voltage of 8V.
(b) The battery of potentiometer can have a voltage of 15V and R adjusted so that the potential drop across the wire slightly exceeds 10V.
(c) The first portion of 50 cm of wire itself should have a potential drop of 10V.
(d) Potentiometer is usually used for comparing resistances and not voltages.

3.5 A metal rod of length 10 cm and a rectangular cross-section of $1\text{cm} \times \frac{1}{2}$ cm is connected to a battery across opposite faces. The resistance will be

(a) maximum when the battery is connected across 1 cm $\times \frac{1}{2}$ cm faces.
(b) maximum when the battery is connected across 10 cm $\times$ 1 cm faces.
(c) maximum when the battery is connected across 10 cm $\times \frac{1}{2}$ cm faces.
(d) same irrespective of the three faces.

3.6 Which of the following characteristics of electrons determines the current in a conductor?

(a) Drift velocity alone.
(b) Thermal velocity alone.
(c) Both drift velocity and thermal velocity.
(d) Neither drift nor thermal velocity.

MCQ II

3.7 Kirchhoff's junction rule is a reflection of

(a) conservation of current density vector.
(b) conservation of charge.
(c) the fact that the momentum with which a charged particle approaches a junction is unchanged (as a vector) as the charged particle leaves the junction.
(d) the fact that there is no accumulation of charges at a junction.

3.8 Consider a simple circuit shown in Fig 3.2.  stands for a variable resistance R'. R' can vary from R_0 to infinity. r is internal resistance of the battery ($r<<R<<R_0$).

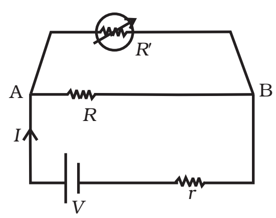


Fig 3.2

(a) Potential drop across AB is nearly constant as R' is varied.
(b) Current through R' is nearly a constant as R' is varied.
(c) Current I depends sensitively on R'.
(d) $I \geq \frac{V}{r+R}$ always.

3.9 Temperature dependence of resistivity $\rho(T)$ of semiconductors, insulators and metals is significantly based on the following factors:

(a) number of charge carriers can change with temperature T.
(b) time interval between two successive collisions can depend on T.
(c) length of material can be a function of T.
(d) mass of carriers is a function of T.

3.10 The measurement of an unknown resistance R is to be carried out using Wheatstones bridge (see Fig. 3.25 of NCERT Book). Two students perform an experiment in two ways. The first students takes R_2 = 10Ω and R_1 = 5Ω. The other student takes R_2 = 1000Ω and R_1 = 500Ω. In the standard arm, both take R_3 = 5Ω.

Both find $R = \frac{R_2}{R_1} R_3 = 10\Omega$ within errors.

(a) The errors of measurement of the two students are the same.
(b) Errors of measurement do depend on the accuracy with which R_2 and R_1 can be measured.
(c) If the student uses large values of R_2 and R_1, the currents through the arms will be feeble. This will make determination of null point accurately more difficult.
(d) Wheatstone bridge is a very accurate instrument and has no errors of measurement.

3.11 In a meter bridge the point D is a neutral point (Fig 3.3).

(a) The meter bridge can have no other neutral point for this set of resistances.

(b) When the jockey contacts a point on meter wire left of D, current flows to B from the wire.

(c) When the jockey contacts a point on the meter wire to the right of D, current flows from B to the wire through galvanometer.

(d) When R is increased, the neutral point shifts to left.

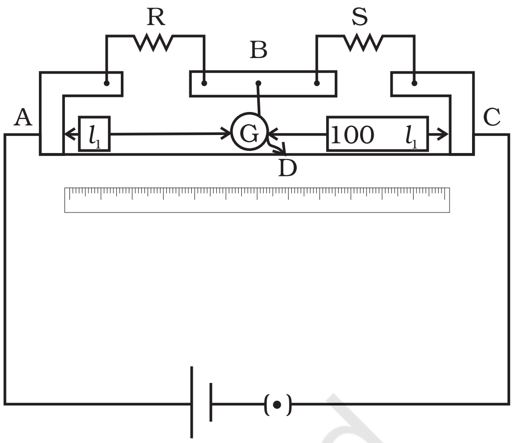


Fig 3.3

VSA

3.12 Is the momentum conserved when charge crosses a junction in an electric circuit? Why or why not?

3.13 The relaxation time τ is nearly independent of applied E field whereas it changes significantly with temperature T. First fact is (in part) responsible for Ohm's law whereas the second fact leads to variation of ρ with temperature. Elaborate why?

3.14 What are the advantages of the null-point method in a Wheatstone bridge? What additional measurements would be required to calculate $R_{unknown}$ by any other method?

3.15 What is the advantage of using thick metallic strips to join wires in a potentiometer?

3.16 For wiring in the home, one uses Cu wires or Al wires. What considerations are involved in this?

3.17 Why are alloys used for making standard resistance coils?

3.18 Power P is to be delivered to a device via transmission cables having resistance R_C. If V is the voltage across R and I the current through it, find the power wasted and how can it be reduced.

3.19 AB is a potentiometer wire (Fig 3.4). If the value of R is increased, in which direction will the balance point J shift?

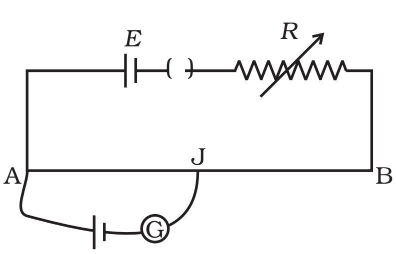


Fig 3.4

3.20 While doing an experiment with potentiometer (Fig 3.5) it was found that the deflection is one sided and (i) the deflection decreased while moving from one end A of the wire to the end B; (ii) the deflection increased. while the jockey was moved towards the end B.

(i) Which terminal +or –ve of the cell E_1, is connected at X in case (i) and how is E_1 related to E?

(ii) Which terminal of the cell E_1 is connected at X in case (ii)?

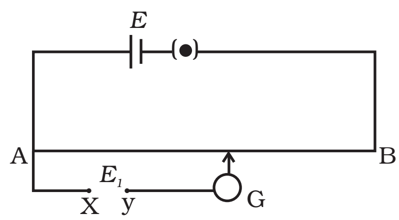


Fig 3.5

3.21 A cell of emf E and internal resistance r is connected across an external resistance R. Plot a graph showing the variation of P.D. across R, verses R.

SA

3.22 First a set of n equal resistors of R each are connected in series to a battery of emf E and internal resistance R. A current I is observed to flow. Then the n resistors are connected in parallel to the same battery. It is observed that the current is increased 10 times. What is 'n'?

3.23 Let there be n resistors R_1 ....R_n with R_{max} = max (R_1......... R_n) and R_{min} = min {R_1 ..... R_n}. Show that when they are connected in parallel, the resultant resistance $R_P < R_{min}$ and when they are connected in series, the resultant resistance $R_S > R_{max}$. Interpret the result physically.

3.24 The circuit in Fig 3.6 shows two cells connected in opposition to each other. Cell E_1 is of emf 6V and internal resistance 2Ω; the cell E_2 is of emf 4V and internal resistance 8Ω. Find the potential difference between the points A and B.

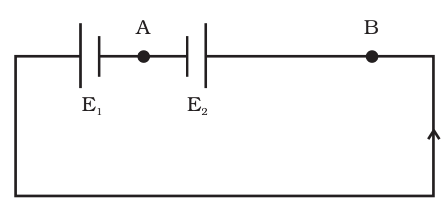


Fig 3.6

3.25 Two cells of same emf E but internal resistance r_1 and r_2 are connected in series to an external resistor R (Fig 3.7). What should be the value of R so that the potential difference across the terminals of the first cell becomes zero.

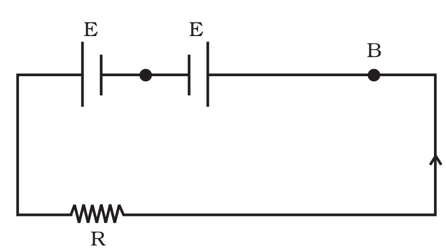


Fig. 3.7

3.26 Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1mm. Conductor B is a hollow tube of outer diameter 2mm and inner diameter 1mm. Find the ratio of resistance R_A to R_B.

3.27 Suppose there is a circuit consisting of only resistances and batteries and we have to double (or increase it to n-times) all voltages and all resistances. Show that currents are unaltered. Do this for circuit of Example 3.7 in the NCERT Text Book for Class XII.

LA

3.28 Two cells of voltage 10V and 2V and internal resistances 10Ω and 5Ω respectively, are connected in parallel with the positive end of 10V battery connected to negative pole of 2V battery (Fig 3.8). Find the effective voltage and effective resistance of the combination.

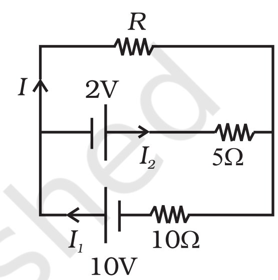


Fig 3.8

3.29 A room has AC run for 5 hours a day at a voltage of 220V. The wiring of the room consists of Cu of 1 mm radius and a length of 10 m. Power consumption per day is 10 commercial units. What fraction of it goes in the joule heating in wires? What would happen if the wiring is made of aluminium of the same dimensions?

[$\rho_{cu} = 1.7 \times 10^{-8}\,\Omega m$, $\rho_{Al} = 2.7 \times 10^{-8}\,\Omega m$]

3.30 In an experiment with a potentiometer, V_B = 10V. R is adjusted to be 50Ω (Fig. 3.9). A student wanting to measure voltage E_1 of a battery (approx. 8V) finds no null point possible. He then diminishes R to 10Ω and is able to locate the null point on the last (4th) segment of the potentiometer. Find the resistance of the potentiometer wire and potential drop per unit length across the wire in the second case.

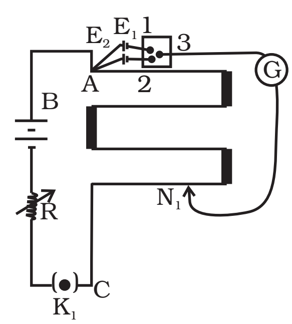


Fig 3.9

3.31 (a) Consider circuit in Fig 3.10. How much energy is absorbed by electrons from the initial state of no current (ignore thermal motion) to the state of drift velocity?

(b) Electrons give up energy at the rate of RI^2 per second to the thermal energy. What time scale would one associate with energy in problem (a)? n = no of electron/volume = $10^{29}/m^3$, length of circuit = 10 cm, cross-section = A = $(1mm)^2$

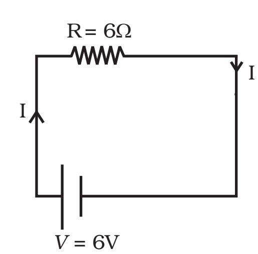


Fig 3.10

Chapter Four

MOVING CHARGES AND MAGNETISM

MCQ I

4.1 Two charged particles traverse *identical* helical paths in a completely opposite sense in a uniform magnetic field $\mathbf{B} = B_0 \hat{\mathbf{k}}$.

(a) They have equal z-components of momenta.
(b) They must have equal charges.
(c) They necessarily represent a particle-antiparticle pair.
(d) The charge to mass ratio satisfy : $\left(\frac{e}{m}\right)_1 + \left(\frac{e}{m}\right)_2 = 0$.

4.2 Biot-Savart law indicates that the moving electrons (velocity **v**) produce a magnetic field **B** such that

(a) $\mathbf{B} \perp \mathbf{v}$.
(b) $\mathbf{B} \parallel \mathbf{v}$.
(c) it obeys inverse cube law.
(d) it is along the line joining the electron and point of observation.

4.3 A current carrying circular loop of radius R is placed in the x-y plane with centre at the origin. Half of the loop with $x > 0$ is now bent so that it now lies in the y-z plane.

(a) The magnitude of magnetic moment now diminishes.
(b) The magnetic moment does not change.
(c) The magnitude of $\mathbf{B}$ at $(0.0.z)$, $z >> R$ increases.
(d) The magnitude of $\mathbf{B}$ at $(0.0.z)$, $z >> R$ is unchanged.

4.4 An electron is projected with uniform velocity along the axis of a current carrying long solenoid. Which of the following is true?

(a) The electron will be accelerated along the axis.
(b) The electron path will be circular about the axis.
(c) The electron will experience a force at 45° to the axis and hence execute a helical path.
(d) The electron will continue to move with uniform velocity along the axis of the solenoid.

4.5 In a cyclotron, a charged particle

(a) undergoes acceleration all the time.
(b) speeds up between the dees because of the magnetic field.
(c) speeds up in a dee.
(d) slows down within a dee and speeds up between dees.

4.6 A circular current loop of magnetic moment M is in an arbitrary orientation in an external magnetic field $\mathbf{B}$. The work done to rotate the loop by 30° about an axis perpendicular to its plane is

(a) MB.
(b) $\sqrt{3}\,\dfrac{MB}{2}$.
(c) $\dfrac{MB}{2}$.
(d) zero.

MCQ II

4.7 The gyro-magnetic ratio of an electron in an H-atom, according to Bohr model, is

(a) independent of which orbit it is in.
(b) negative.
(c) positive.
(d) increases with the quantum number n.

4.8 Consider a wire carrying a steady current, I placed in a uniform magnetic field **B** perpendicular to its length. Consider the charges inside the wire. It is known that magnetic forces do no work. This implies that,

(a) motion of charges inside the conductor is unaffected by **B** since they do not absorb energy.
(b) some charges inside the wire move to the surface as a result of **B**.
(c) if the wire moves under the influence of **B**, no work is done by the force.
(d) if the wire moves under the influence of **B**, no work is done by the magnetic force on the ions, assumed fixed within the wire.

4.9 Two identical current carrying coaxial loops, carry current I in an opposite sense. A simple amperian loop passes through both of them once. Calling the loop as C,

(a) $\oint_c \mathbf{B.dl} = \mp 2\mu_0 I$.
(b) the value of $\oint_c \mathbf{B.dl}$ is independent of sense of C.
(c) there may be a point on C where **B** and **dl** are perpendicular.
(d) **B** vanishes everywhere on C.

4.10 A cubical region of space is filled with some uniform electric and magnetic fields. An electron enters the cube across one of its faces with velocity **v** and a positron enters via opposite face with velocity - **v**. At this instant,

(a) the electric forces on both the particles cause identical accelerations.
(b) the magnetic forces on both the particles cause equal accelerations.
(c) both particles gain or loose energy at the same rate.
(d) the motion of the centre of mass (CM) is determined by **B** alone.

4.11 A charged particle would continue to move with a constant velocity in a region wherein,

(a) $\mathbf{E} = 0$, $\mathbf{B} \neq 0$.
(b) $\mathbf{E} \neq 0$, $\mathbf{B} \neq 0$.
(c) $\mathbf{E} \neq 0$, $\mathbf{B} = 0$.
(d) $\mathbf{E} = 0$, $\mathbf{B} = 0$.

VSA

4.12 Verify that the cyclotron frequency $\omega = eB/m$ has the correct dimensions of $[T]^{-1}$.

4.13 Show that a force that does no work must be a velocity dependent force.

4.14 The magnetic force depends on **v** which depends on the inertial frame of reference. Does then the magnetic force differ from inertial frame to frame? Is it reasonable that the net acceleration has a different value in different frames of reference?

4.15 Describe the motion of a charged particle in a cyclotron if the frequency of the radio frequency (rf) field were doubled.

4.16 Two long wires carrying current I_1 and I_2 are arranged as shown in Fig. 4.1. The one carrying current I_1 is along is the x-axis. The other carrying current I_2 is along a line parallel to the y-axis given by $x = 0$ and $z = d$. Find the force exerted at O_2 because of the wire along the x-axis.

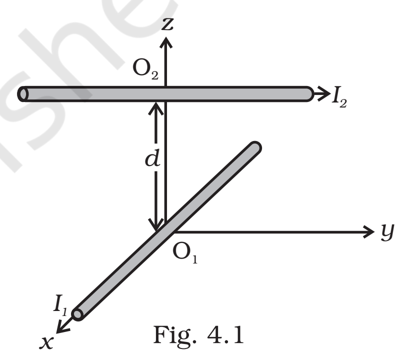


Fig. 4.1

SA

4.17 A current carrying loop consists of 3 identical quarter circles of radius R, lying in the positive quadrants of the x-y, y-z and z-x planes with their centres at the origin, joined together. Find the direction and magnitude of **B** at the origin.

4.18 A charged particle of charge e and mass m is moving in an electric field **E** and magnetic field **B**. Construct dimensionless quantities and quantities of dimension $[T]^{-1}$.

4.19 An electron enters with a velocity $\mathbf{v} = v_0\hat{\mathbf{i}}$ into a cubical region (faces parallel to coordinate planes) in which there are uniform electric and magnetic fields. The orbit of the electron is found to spiral down inside the cube in plane parallel to the x-y plane. Suggest a configuration of fields **E** and **B** that can lead to it.

4.20 Do magnetic forces obey Newton's third law. Verify for two current elements $\mathbf{dl_1} = dl\,\hat{\mathbf{i}}$ located at the origin and $\mathbf{dl_2} = dl\,\hat{\mathbf{j}}$ located at $(0, R, 0)$. Both carry current I.

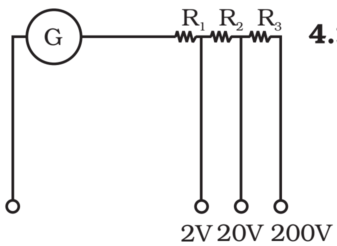


Fig. 4.2

4.21 A multirange voltmeter can be constructed by using a galvanometer circuit as shown in Fig. 4.2. We want to construct a voltmeter that can measure 2V, 20V and 200V using a galvanometer of resistance 10Ω and that produces maximum deflection for current of 1 mA. Find R_1, R_2 and R_3 that have to be used.

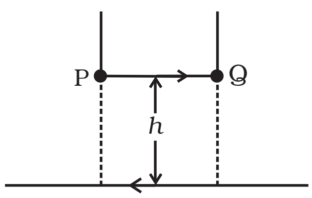


Fig. 4.3

4.22 A long straight wire carrying current of 25A rests on a table as shown in Fig. 4.3. Another wire PQ of length 1m, mass 2.5 g carries the same current but in the opposite direction. The wire PQ is free to slide up and down. To what height will PQ rise?

LA

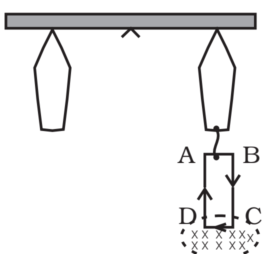


Fig. 4.4

4.23 A 100 turn rectangular coil ABCD (in XY plane) is hung from one arm of a balance (Fig. 4.4). A mass 500g is added to the other arm to balance the weight of the coil. A current 4.9 A passes through the coil and a constant magnetic field of 0.2 T acting inward (in *xz* plane) is switched on such that only arm CD of length 1 cm lies in the field. How much additional mass '*m*' must be added to regain the balance?

4.24 A rectangular conducting loop consists of two wires on two opposite sides of length l joined together by rods of length d. The wires are each of the same material but with cross-sections differing by a factor of 2. The thicker wire has a resistance R and the rods are of low resistance, which in turn are connected to a constant voltage source V_0. The loop is placed in uniform a magnetic field **B** at 45° to its plane. Find $\boldsymbol{\tau}$, the torque exerted by the magnetic field on the loop about an axis through the centres of rods.

4.25 An electron and a positron are released from (0, 0, 0) and (0, 0, 1.5R) respectively, in a uniform magnetic field $\mathbf{B} = B_0\hat{\mathbf{i}}$, each with an equal momentum of magnitude $p = e\,BR$. Under what conditions on the direction of momentum will the orbits be non-intersecting circles?

4.26 A uniform conducting wire of length 12a and resistance R is wound up as a current carrying coil in the shape of (i) an equilateral triangle of side a; (ii) a square of sides a and, (iii) a regular hexagon of sides a. The coil is connected to a voltage source V_0. Find the magnetic moment of the coils in each case.

4.27 Consider a circular current-carrying loop of radius R in the x-y plane with centre at origin. Consider the line intergral

$$\Im(L) = \left| \int_{-L}^{L} \mathbf{B.dl} \right| \text{ taken along z-axis.}$$

(a) Show that $\Im$ (L) monotonically increases with L.

(b) Use an appropriate Amperian loop to show that $\Im(\infty) = \mu_0 I$, where I is the current in the wire.

(c) Verify directly the above result.

(d) Suppose we replace the circular coil by a square coil of sides R carrying the same current I. What can you say about $\Im(L)$ and $\Im(\infty)$?

4.28 A multirange current meter can be constructed by using a galvanometer circuit as shown in Fig. 4.5. We want a current meter that can measure 10mA, 100mA and 1A using a galvanometer of resistance 10Ω and that prduces maximum deflection for current of 1mA. Find S_1, S_2 and S_3 that have to be used

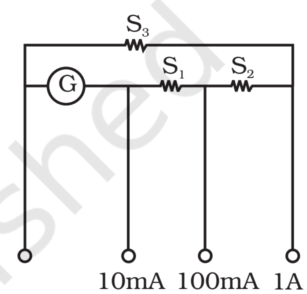


Fig. 4.5

4.29 Five long wires A, B, C, D and E, each carrying current I are arranged to form edges of a pentagonal prism as shown in Fig. 4.6. Each carries current out of the plane of paper.

(a) What will be magnetic induction at a point on the axis O? Axis is at a distance R from each wire.

(b) What will be the field if current in one of the wires (say A) is switched off?

(c) What if current in one of the wire (say) A is reversed?

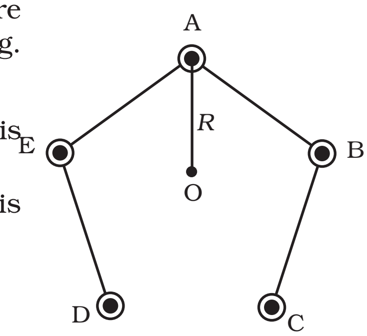


Fig. 4.6

Chapter Five

MAGNETISM AND MATTER

MCQ I

5.1 A toroid of n turns, mean radius R and cross-sectional radius a carries current I. It is placed on a horizontal table taken as x-y plane. Its magnetic moment $\mathbf{m}$

(a) is non-zero and points in the z-direction by symmetry.

(b) points along the axis of the tortoid ($\mathbf{m} = m\hat{\boldsymbol{\phi}}$).

(c) is zero, otherwise there would be a field falling as $\frac{1}{r^3}$ at large distances outside the toroid.

(d) is pointing radially outwards.

5.2 The magnetic field of Earth can be modelled by that of a point dipole placed at the centre of the Earth. The dipole axis makes an angle of 11.3° with the axis of Earth. At Mumbai, declination is nearly zero. Then,

(a) the declination varies between 11.3° W to 11.3° E.

(b) the least declination is 0°.

(c) the plane defined by dipole axis and Earth axis passes through Greenwich.

(d) declination averaged over Earth must be always negative.

5.3 In a permanent magnet at room temperature

(a) magnetic moment of each molecule is zero.

(b) the individual molecules have non-zero magnetic moment which are all perfectly aligned.

(c) domains are partially aligned.

(d) domains are all perfectly aligned.

5.4 Consider the two idealized systems: (i) a parallel plate capacitor with large plates and small separation and (ii) a long solenoid of length $L >> R$, radius of cross-section. In (i) **E** is ideally treated as a constant between plates and zero outside. In (ii) magnetic field is constant inside the solenoid and zero outside. These idealised assumptions, however, contradict fundamental laws as below:

(a) case (i) contradicts Gauss's law for electrostatic fields.

(b) case (ii) contradicts Gauss's law for magnetic fields.

(c) case (i) agrees with $\oint \mathbf{E}.d\mathbf{l} = 0$.

(d) case (ii) contradicts $\oint \mathbf{H}.d\mathbf{l} = I_{en}$

5.5 A paramagnetic sample shows a net magnetisation of 8 Am^{-1} when placed in an external magnetic field of 0.6T at a temperature of 4K. When the same sample is placed in an external magnetic field of 0.2 T at a temperature of 16 K, the magnetisation will be

(a) $\frac{32}{3}\,Am^{-1}$

(b) $\frac{2}{3}\,Am^{-1}$

(c) $6\,Am^{-1}$

(d) $2.4\,Am^{-1}$.

MCQ II

5.6 *S* is the surface of a lump of magnetic material.

(a) Lines of **B** are necessarily continuous across *S*.

(b) Some lines of **B** must be discontinuous across *S*.

(c) Lines of **H** are necessarily continuous across *S*.

(d) Lines of **H** cannot all be continuous across *S*.

5.7 The primary origin(s) of magnetism lies in

(a) atomic currents.
(b) Pauli exclusion principle.
(c) polar nature of molecules.
(d) intrinsic spin of electron.

5.8 A long solenoid has 1000 turns per metre and carries a current of 1 A. It has a soft iron core of $\mu_r = 1000$. The core is heated beyond the Curie temperature, T_c.

(a) The **H** field in the solenoid is (nearly) unchanged but the **B** field decreases drastically.
(b) The **H** and **B** fields in the solenoid are nearly unchanged.
(c) The magnetisation in the core reverses direction.
(d) The magnetisation in the core diminishes by a factor of about 10^8.

5.9 Essential difference between electrostatic shielding by a conducting shell and magnetostatic shielding is due to

(a) electrostatic field lines can end on charges and conductors have free charges.
(b) lines of **B** can also end but conductors cannot end them.
(c) lines of **B** cannot end on any material and perfect shielding is not possible.
(d) shells of high permeability materials can be used to divert lines of **B** from the interior region.

5.10 Let the magnetic field on earth be modelled by that of a point magnetic dipole at the centre of earth. The angle of dip at a point on the geographical equator

(a) is always zero.
(b) can be zero at specific points.
(c) can be positive or negative.
(d) is bounded.

VSA

5.11 A proton has spin and magnetic moment just like an electron. Why then its effect is neglected in magnetism of materials?

5.12 A permanent magnet in the shape of a thin cylinder of length 10 cm has $M = 10^6$ A/m. Calculate the magnetisation current I_M.

5.13 Explain quantitatively the order of magnitude difference between the diamagnetic susceptibility of N_2 ($\sim 5 \times 10^{-9}$) (at STP) and Cu ($\sim 10^{-5}$).

5.14 From molecular view point, discuss the temperature dependence of susceptibility for diamagnetism, paramagnetism and ferromagnetism.

5.15 A ball of superconducting material is dipped in liquid nitrogen and placed near a bar magnet. (i) In which direction will it move? (ii) What will be the direction of it's magnetic moment?

SA

5.16 Verify the Gauss's law for magnetic field of a point dipole of dipole moment **m** at the origin for the surface which is a sphere of radius *R*.

5.17 Three identical bar magnets are rivetted together at centre in the same plane as shown in Fig. 5.1. This system is placed at rest in a slowly varying magnetic field. It is found that the system of magnets does not show any motion. The north-south poles of one magnet is shown in the Fig. 5.1. Determine the poles of the remaining two.

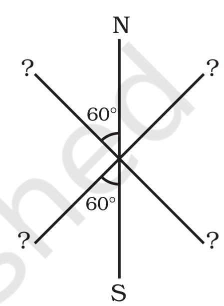


Fig. 5.1

5.18 Suppose we want to verify the analogy between electrostatic and magnetostatic by an explicit experiment. Consider the motion of (i) electric dipole **p** in an electrostatic field **E** and (ii) magnetic dipole **m** in a magnetic field **B**. Write down a set of conditions on **E**, **B**, **p**, **m** so that the two motions are verified to be identical. (Assume identical initial conditions.)

5.19 A bar magnet of magnetic moment *m* and moment of inertia *I* (about centre, perpendicular to length) is cut into two equal pieces, perpendicular to length. Let *T* be the period of oscillations of the original magnet about an axis through the mid point, perpendicular to length, in a magnetic field **B**. What would be the similar period *T*′ for each piece?

5.20 Use (i) the Ampere's law for **H** and (ii) continuity of lines of **B**, to conclude that inside a bar magnet, (a) lines of **H** run from the *N* pole to *S* pole, while (b) lines of **B** must run from the *S* pole to *N* pole.

LA

5.21 Verify the Ampere's law for magnetic field of a point dipole of dipole moment $\mathbf{m} = m\hat{\mathbf{k}}$. Take C as the closed curve running clockwise along (i) the *z*-axis from $z = a > 0$ to $z = R$; (ii) along the quarter circle of radius *R* and centre at the origin, in the first quadrant of *x-z* plane; (iii) along the *x*-axis from $x = R$ to $x = a$, and (iv) along the quarter circle of radius *a* and centre at the origin in the first quadrant of *x-z* plane.

5.22 What are the dimensions of χ, the magnetic susceptibility? Consider an H-atom. Guess an expression for χ, upto a constant by constructing a quantity of dimensions of χ, out of parameters of the atom: e, m, v, R and μ_0. Here, m is the electronic mass, v is electronic velocity, R is Bohr radius. Estimate the number so obtained and compare with the value of $|\chi| \sim 10^{-5}$ for many solid materials.

5.23 Assume the dipole model for earth's magnetic field B which is given by B_V = vertical component of magnetic field = $\dfrac{\mu_0}{4\pi}\dfrac{2m\cos\theta}{r^3}$

B_H = Horizontal component of magnetic field = $\dfrac{\mu_0}{4\pi}\dfrac{\sin\theta\, m}{r^3}$

θ = 90° – lattitude as measured from magnetic equator.

Find loci of points for which (i) $|\mathbf{B}|$ is minimum; (ii) dip angle is zero; and (iii) dip angle is ± 45°.

5.24 Consider the plane S formed by the dipole axis and the axis of earth. Let P be point on the magnetic equator and in S. Let Q be the point of intersection of the geographical and magnetic equators. Obtain the declination and dip angles at P and Q.

5.25 There are two current carrying planar coils made each from identical wires of length L. C_1 is circular (radius R) and C_2 is square (side a). They are so constructed that they have same frequency of oscillation when they are placed in the same uniform **B** and carry the same current. Find a in terms of R.

Chapter Six

ELECTROMAGNETIC INDUCTION

MCQ 1

6.1 A square of side L meters lies in the x-y plane in a region, where the magnetic field is given by $\mathbf{B} = B_o(2\hat{\mathbf{i}} + 3\hat{\mathbf{j}} + 4\hat{\mathbf{k}})\,\mathrm{T}$, where B_o is constant. The magnitude of flux passing through the square is

(a) $2\,B_o\,L^2$ Wb.
(b) $3\,B_o\,L^2$ Wb.
(c) $4\,B_o\,L^2$ Wb.
(d) $\sqrt{29}\,B_o\,L^2$ Wb.

6.2 A loop, made of straight edges has six corners at A(0,0,0), B(L,O,0) C(L,L,0), D(0,L,0) E(0,L,L) and F(0,0,L). A magnetic field $\mathbf{B} = B_o\,(\hat{\mathbf{i}} + \hat{\mathbf{k}})\,\mathrm{T}$ is present in the region. The flux passing through the loop ABCDEFA (in that order) is

(a) $B_o\,L^2$ Wb.
(b) $2\,B_o\,L^2$ Wb.
(c) $\sqrt{2}\,B_o\,L^2$ Wb.
(d) $4\,B_o\,L^2$ Wb.

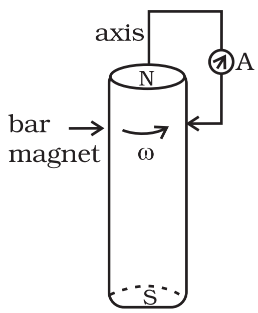


Fig. 6.1

6.3 A cylindrical bar magnet is rotated about its axis (Fig 6.1). A wire is connected from the axis and is made to touch the cylindrical surface through a contact. Then

(a) a direct current flows in the ammeter A.
(b) no current flows through the ammeter A.
(c) an alternating sinusoidal current flows through the ammeter A with a time period $T=2\pi/\omega$.
(d) a time varying non-sinosoidal current flows through the ammeter A.

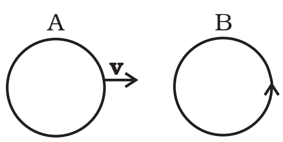


Fig. 6.2

6.4 There are two coils A and B as shown in Fig 6.2. A current starts flowing in B as shown, when A is moved towards B and stops when A stops moving. The current in A is counterclockwise. B is kept stationary when A moves. We can infer that

(a) there is a constant current in the clockwise direction in A.
(b) there is a varying current in A.
(c) there is no current in A.
(d) there is a constant current in the counterclockwise direction in A.

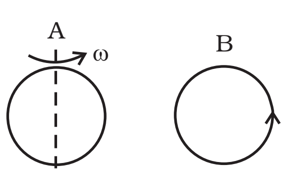


Fig. 6.3

6.5 Same as problem 4 except the coil A is made to rotate about a vertical axis (Fig 6.3). No current flows in B if A is at rest. The current in coil A, when the current in B (at $t = 0$) is counterclockwise and the coil A is as shown at this instant, t = 0, is

(a) constant current clockwise.
(b) varying current clockwise.
(c) varying current counterclockwise.
(d) constant current counterclockwise.

6.6 The self inductance L of a solenoid of length l and area of cross-section A, with a fixed number of turns N increases as

(a) l and A increase.
(b) l decreases and A increases.
(c) l increases and A decreases.
(d) both l and A decrease.

MCQ II

6.7 A metal plate is getting heated. It can be because

(a) a direct current is passing through the plate.
(b) it is placed in a time varying magnetic field.

(c) it is placed in a space varying magnetic field, but does not vary with time.
(d) a current (either direct or alternating) is passing through the plate.

6.8 An e.m.f is produced in a coil, which is not connected to an external voltage source. This can be due to

(a) the coil being in a time varying magnetic field.
(b) the coil moving in a time varying magnetic field.
(c) the coil moving in a constant magnetic field.
(d) the coil is stationary in external spatially varying magnetic field, which does not change with time.

6.9 The mutual inductance M_{12} of coil 1 with respect to coil 2

(a) increases when they are brought nearer.
(b) depends on the current passing through the coils.
(c) increases when one of them is rotated about an axis.
(d) is the same as M_{21} of coil 2 with respect to coil 1.

6.10 A circular coil expands radially in a region of magnetic field and no electromotive force is produced in the coil. This can be because

(a) the magnetic field is constant.
(b) the magnetic field is in the same plane as the circular coil and it may or may not vary.
(c) the magnetic field has a perpendicular (to the plane of the coil) component whose magnitude is decreasing suitably.
(d) there is a constant magnetic field in the perpendicular (to the plane of the coil) direction.

VSA

6.11 Consider a magnet surrounded by a wire with an on/off switch S (Fig 6.4). If the switch is thrown from the off position (open circuit) to the on position (closed circuit), will a current flow in the circuit? Explain.

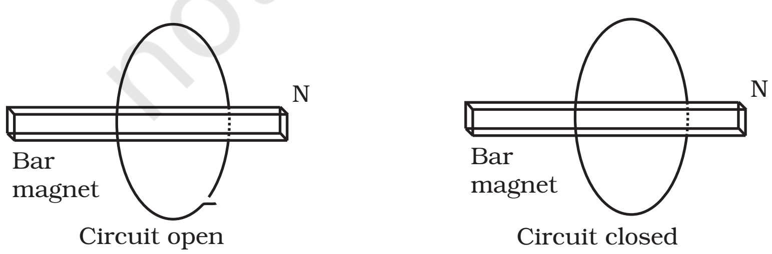


Fig. 6.4

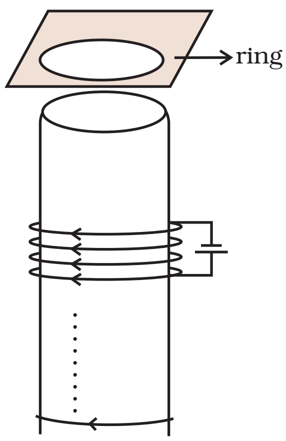


Fig. 6.5

6.12 A wire in the form of a tightly wound solenoid is connected to a DC source, and carries a current. If the coil is stretched so that there are gaps between successive elements of the spiral coil, will the current increase or decrease? Explain.

6.13 A solenoid is connected to a battery so that a steady current flows through it. If an iron core is inserted into the solenoid, will the current increase or decrease? Explain.

6.14 Consider a metal ring kept on top of a fixed solenoid (say on a carboard) (Fig 6.5). The centre of the ring coincides with the axis of the solenoid. If the current is suddenly switched on, the metal ring jumps up. Explain

6.15 Consider a metal ring kept (supported by a cardboard) on top of a fixed solenoid carrying a current *I* (see Fig 6.5). The centre of the ring coincides with the axis of the solenoid. If the current in the solenoid is switched off, what will happen to the ring?

6.16 Consider a metallic pipe with an inner radius of 1 cm. If a cylindrical bar magnet of radius 0.8cm is dropped through the pipe, it takes more time to come down than it takes for a similar unmagnetised cylindrical iron bar dropped through the metallic pipe. Explain.

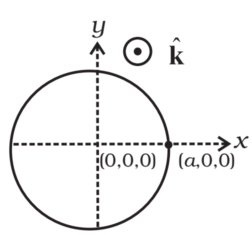


Fig. 6.6

SA

6.17 A magnetic field in a certain region is given by $\mathbf{B} = B_o \cos(\omega t)\hat{\mathbf{k}}$ and a coil of radius *a* with resistance *R* is placed in the *x*-*y* plane with its centre at the origin in the magnetic field (see Fig 6.6) . Find the magnitude and the direction of the current at (*a*, 0, 0) at $t = \pi/2\omega$, $t = \pi/\omega$ and $t = 3\pi/2\omega$.

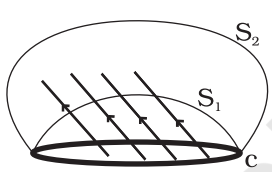


Fig. 6.7

6.18 Consider a closed loop C in a magnetic field (Fig 6.7). The flux passing through the loop is defined by choosing a surface whose edge coincides with the loop and using the formula $\phi = \mathbf{B}_1.\boldsymbol{dA}_1 + \boldsymbol{B}_2.\boldsymbol{dA}_2 + ...$ Now if we chose two different surfaces S_1 and S_2 having C as their edge, would we get the same answer for flux. Jusity your answer.

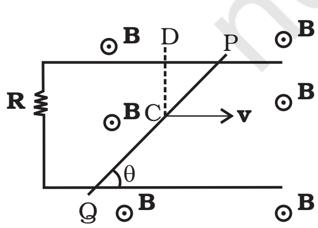


Fig. 6.8

6.19 Find the current in the wire for the configuration shown in Fig 6.8. Wire PQ has negligible resistance. **B**, the magnetic field is coming out of the paper. θ is a fixed angle made by PQ travelling smoothly over two conducting parallel wires seperated by a distance *d*.

6.20 A (current vs time) graph of the current passing through a solenoid is shown in Fig 6.9. For which time is the back electromotive force (u) a maximum. If the back emf at t = 3s is e, find the back emf at t = 7 s, 15s and 40s. OA, AB and BC are straight line segments.

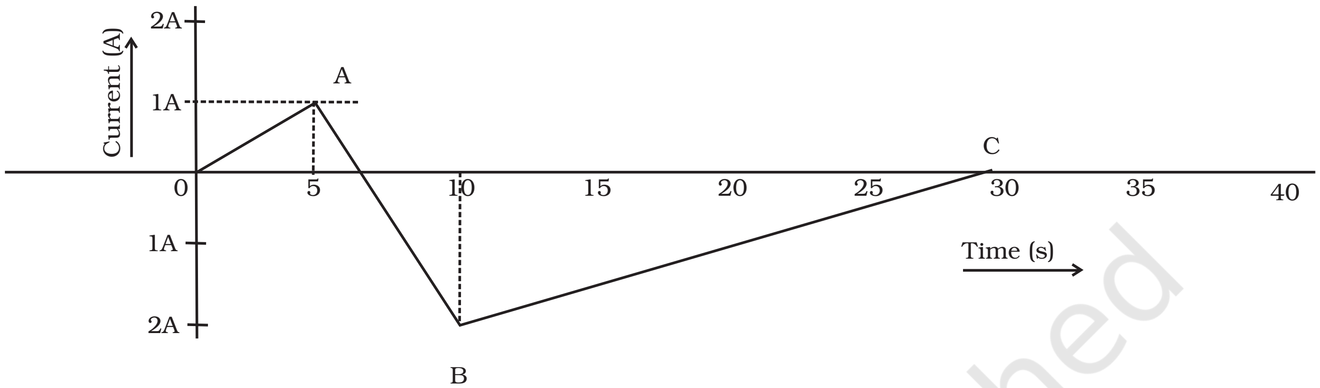


Fig. 6.9

6.21 There are two coils A and B seperated by some distance. If a current of 2 A flows through A, a magnetic flux of 10^{-2} Wb passes through B (no current through B). If no current passes through A and a current of 1 A passes through B, what is the flux through A?

LA

6.22 A magnetic field $\mathbf{B} = B_o \sin(\omega t)\hat{\mathbf{k}}$ covers a large region where a wire AB slides smoothly over two parallel conductors separated by a distance d (Fig. 6.10). The wires are in the x-y plane. The wire AB (of length d) has resistance R and the parallel wires have negligible resistance. If AB is moving with velocity $\boldsymbol{v}$, what is the current in the circuit. What is the force needed to keep the wire moving at constant velocity?

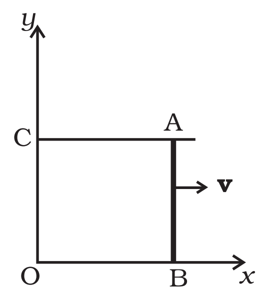


Fig. 6.10

6.23 A conducting wire XY of mass m and neglibile resistance slides smoothly on two parallel conducting wires as shown in Fig 6.11. The closed circuit has a resistance R due to AC. AB and CD are perfect conductors. There is a magnetic field $\mathbf{B} = B(t)\hat{\mathbf{k}}$.

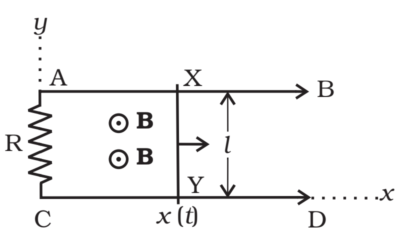


Fig. 6.11

(i) Write down equation for the acceleration of the wire XY.

(ii) If **B** is independent of time, obtain $v(t)$, assuming $v(0) = u_0$.

(iii) For (b), show that the decrease in kinetic energy of XY equals the heat lost in R.

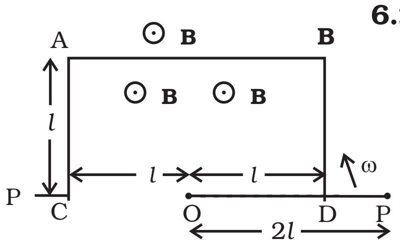


Fig. 6.12

6.24 ODBAC is a fixed rectangular conductor of negilible resistance (CO is not connnected) and OP is a conductor which rotates clockwise with an angular velocity ω (Fig 6.12). The entire system is in a uniform magnetic field **B** whose direction is along the normal to the surface of the rectangular conductor ABDC. The conductor OP is in electric contact with ABDC. The rotating conductor has a resistance of λ per unit length. Find the current in the rotating conductor, as it rotates by 180°.

6.25 Consider an infinitely long wire carrying a current I (t), with $\frac{dI}{dt} = \lambda =$ constant. Find the current produced in the rectangular loop of wire ABCD if its resistance is R (Fig. 6.13).

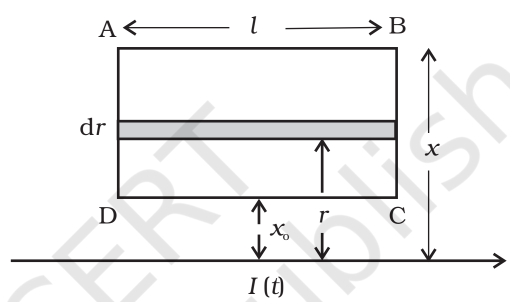


Fig. 6.13

6.26 A rectangular loop of wire ABCD is kept close to an infinitely long wire carrying a current $I(t) = I_o(1 - t/T)$ for $0 \le t \le T$ and $I(0) = 0$ for $t > T$ (Fig. 6.14). Find the total charge passing through a given point in the loop, in time T. The resistance of the loop is R.

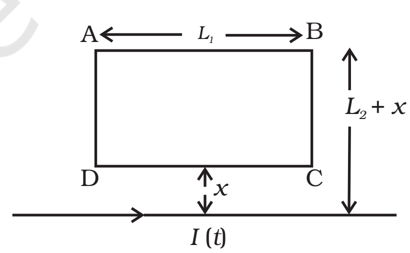


Fig. 6.14

Q.27 A magnetic field **B** is confined to a region $r \le a$ and points out of the paper (the z-axis), $r = 0$ being the centre of the circular region. A charged ring (charge = Q) of radius b, $b > a$ and mass m lies in the x-y plane with its centre at the origin. The ring is free to rotate and is at rest. The magnetic field is brought to zero in time Δt. Find the angular velocity ω of the ring after the field vanishes.

6.28 A rod of mass m and resistance R slides smoothly over two parallel perfectly conducting wires kept sloping at an angle θ with respect to the horizontal (Fig. 6.15). The circuit is closed through a perfect conductor at the top. There is a constant magnetic field **B** along the vertical direction. If the rod is initially at rest, find the velocity of the rod as a function of time.

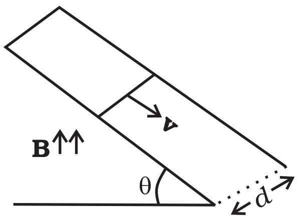


Fig. 6.15

6.29 Find the current in the sliding rod AB (resistance = R) for the arrangement shown in Fig 6.16. **B** is constant and is out of the paper. Parallel wires have no resistance. **v** is constant. Switch S is closed at time $t = 0$.

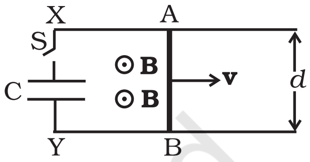


Fig. 6.16

6.30 Find the current in the sliding rod AB (resistance = R) for the arrangement shown in Fig 6.17. **B** is constant and is out of the paper. Parallel wires have no resistance. $\boldsymbol{v}$ is constant. Switch S is closed at time $t = 0$.

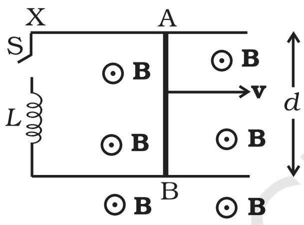


Fig. 6.17

6.31 A metallic ring of mass m and radius l (ring being horizontal) is falling under gravity in a region having a magnetic field. If z is the vertical direction, the z-component of magnetic field is $B_z = B_o (1+\lambda z)$. If R is the resistance of the ring and if the ring falls with a velocity v, find the energy lost in the resistance. If the ring has reached a constant velocity, use the conservation of energy to determine v in terms of m, B, λ and acceleration due to gravity g.

6.32 A long solenoid 'S' has 'n' turns per meter, with diameter 'a'. At the centre of this coil we place a smaller coil of 'N' turns and diameter 'b' (where $b < a$). If the current in the solenoid increases linearly, with time, what is the induced emf appearing in the smaller coil. Plot graph showing nature of variation in emf, if current varies as a function of $mt^2 + C$.

Chapter Seven

ALTERNATING CURRENT

MCQ 1

7.1 If the rms current in a 50 Hz ac circuit is 5 A, the value of the current 1/300 seconds after its value becomes zero is

(a) $5\sqrt{2}$ A

(b) $5\sqrt{3/2}$ A

(c) $5/6$ A

(d) $5/\sqrt{2}$ A

7.2 An alternating current generator has an internal resistance *Rg* and an internal reactance *Xg*. It is used to supply power to a passive load consisting of a resistance *Rg* and a reactance X_L. For maximum power to be delivered from the generator to the load, the value of X_L is equal to

(a) zero.

(b) X_g.

(c) $-X_g$.

(d) R_g.

7.3 When a voltage measuring device is connected to AC mains, the meter shows the steady input voltage of 220V. This means

(a) input voltage cannot be AC voltage, but a DC voltage.

(b) maximum input voltage is 220V.

(c) the meter reads not υ but $<\upsilon^2>$ and is calibrated to read $\sqrt{<\upsilon^2>}$.

(d) the pointer of the meter is stuck by some mechanical defect.

7.4 To reduce the reasonant frequency in an LCR series circuit with a generator

(a) the generator frequency should be reduced.
(b) another capacitor should be added in parallel to the first.
(c) the iron core of the inductor should be removed.
(d) dielectric in the capacitor should be removed.

7.5 Which of the following combinations should be selected for better tuning of an *LCR* circuit used for communication?

(a) $R = 20\ \Omega,\ L = 1.5\ \text{H},\ C = 35\mu\text{F}$.
(b) $R = 25\ \Omega,\ L = 2.5\ \text{H},\ C = 45\mu\text{F}$.
(c) $R = 15\ \Omega,\ L = 3.5\ \text{H},\ C = 30\mu\text{F}$.
(d) $R = 25\ \Omega,\ L = 1.5\ \text{H},\ C = 45\mu\text{F}$.

7.6 An inductor of reactance 1 Ω and a resistor of 2 Ω are connected in series to the terminals of a 6 V (rms) a.c. source. The power dissipated in the circuit is

(a) 8 W.
(b) 12 W.
(c) 14.4 W.
(d) 18 W.

7.7 The output of a step-down transformer is measured to be 24 V when connected to a 12 watt light bulb. The value of the peak current is

(a) $1/\sqrt{2}$ A.
(b) $\sqrt{2}$ A.
(c) 2 A.
(d) $2\sqrt{2}$ A.

MCQ II

7.8 As the frequency of an ac circuit increases, the current first increases and then decreases. What combination of circuit elements is most likely to comprise the circuit?

(a) Inductor and capacitor.
(b) Resistor and inductor.
(c) Resistor and capacitor.
(d) Resistor, inductor and capacitor.

7.9 In an alternating current circuit consisting of elements in series, the current increases on increasing the frequency of supply. Which of the following elements are likely to constitute the circuit ?

(a) Only resistor.
(b) Resistor and an inductor.
(c) Resistor and a capacitor.
(d) Only a capacitor.

7.10 Electrical energy is transmitted over large distances at high alternating voltages. Which of the following statements is (are) correct?

(a) For a given power level, there is a lower current.
(b) Lower current implies less power loss.
(c) Transmission lines can be made thinner.
(d) It is easy to reduce the voltage at the receiving end using step-down transformers.

7.11 For an *LCR* circuit, the power transferred from the driving source to the driven oscillator is $P = I^2 Z \cos\phi$.

(a) Here, the power factor $\cos\phi \geq 0$, $P \geq 0$.
(b) The driving force can give no energy to the oscillator ($P = 0$) in some cases.
(c) The driving force cannot syphon out ($P < 0$) the energy out of oscillator.
(d) The driving force can take away energy out of the oscillator.

7.12 When an AC voltage of 220 V is applied to the capacitor *C*

(a) the maximum voltage between plates is 220 V.
(b) the current is in phase with the applied voltage.
(c) the charge on the plates is in phase with the applied voltage.
(d) power delivered to the capacitor is zero.

7.13 The line that draws power supply to your house from street has

(a) zero average current.
(b) 220 V average voltage.
(c) voltage and current out of phase by 90°.
(d) voltage and current possibly differing in phase ϕ such that

$$|\phi| < \frac{\pi}{2}.$$

VSA

7.14 If a *LC* circuit is considered analogous to a harmonically oscillating spring block system, which energy of the *LC* circuit would be analogous to potential energy and which one analogous to kinetic energy?

7.15 Draw the effective equivalent circuit of the circuit shown in Fig 7.1, at very high frequencies and find the effective impedance.

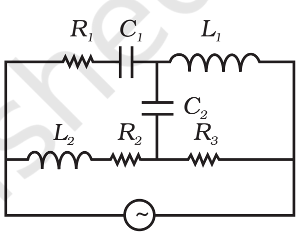


Fig. 7.1

7.16 Study the circuits (a) and (b) shown in Fig 7.2 and answer the following questions.

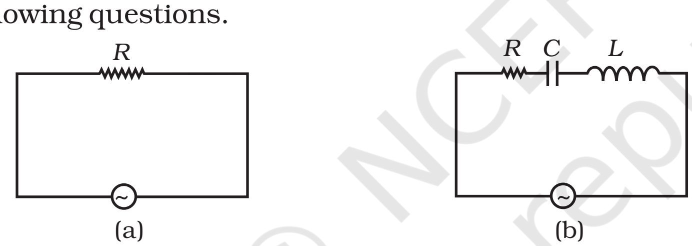


Fig. 7.2

(a) Under which conditions would the rms currents in the two circuits be the same?
(b) Can the rms current in circuit (b) be larger than that in (a)?

7.17 Can the instantaneous power output of an ac source ever be negative? Can the average power output be negative?

7.18 In series LCR circuit, the plot of I_{max} vs ω is shown in Fig 7.3. Find the bandwidth and mark in the figure.

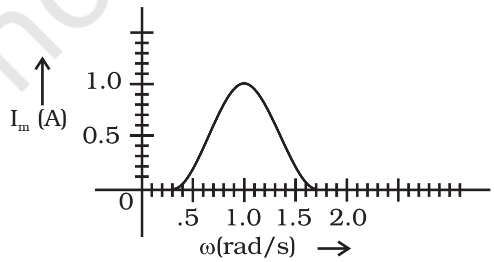


Fig. 7.3

7.19 The alternating current in a circuit is described by the graph shown in Fig 7.4 . Show rms current in this graph.

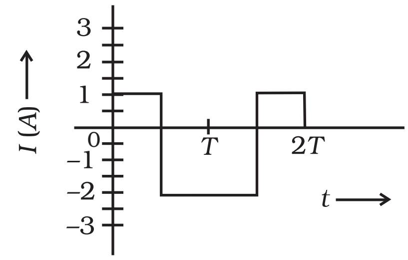


Fig. 7.4

7.20 How does the sign of the phase angle ϕ, by which the supply voltage leads the current in an *LCR* series circuit, change as the supply frequency is gradually increased from very low to very high values.

SA

7.21 A device 'X' is connected to an a.c source. The variation of voltage, current and power in one complete cycle is shown in Fig 7.5.

(a) Which curve shows power consumption over a full cycle?

(b) What is the average power consumption over a cycle?

(c) Identify the device 'X'.

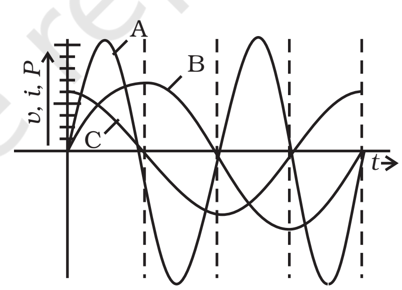


Fig. 7.5

7.22 Both alternating current and direct current are measured in amperes. But how is the ampere defined for an alternating current?

7.23 A coil of 0.01 henry inductance and 1 ohm resistance is connected to 200 volt, 50 Hz ac supply. Find the impedance of the circuit and time lag between max. alternating voltage and current.

7.24 A 60 W load is connected to the secondary of a transformer whose primary draws line voltage. If a current of 0.54 A flows in the load, what is the current in the primary coil? Comment on the type of transformer being used.

7.25 Explain why the reactance provided by a capacitor to an alternating current decreases with increasing frequency.

7.26 Explain why the reactance offered by an inductor increases with increasing frequency of an alternating voltage.

LA

7.27 An electrical device draws 2kW power from AC mains (voltage 223V (rms) = $\sqrt{50,000}$ V). The current differs (lags) in phase by $\phi\left(\tan\phi = \frac{-3}{4}\right)$ as compared to voltage. Find (i) R, (ii) $X_C - X_L$, and (iii) I_M. Another device has twice the values for R, X_C and X_L. How are the answers affected?

7.28 1MW power is to be delivered from a power station to a town 10 km away. One uses a pair of Cu wires of radius 0.5 cm for this purpose. Calculate the fraction of ohmic losses to power transmitted if

(i) power is transmitted at 220V. Comment on the feasibility of doing this.

(ii) a step-up transformer is used to boost the voltage to 11000 V, power transmitted, then a step-down transfomer is used to bring voltage to 220 V.

$(\rho_{Cu} = 1.7 \times 10^{-8}$ SI unit)

7.29 Consider the LCR circuit shown in Fig 7.6. Find the net current i and the phase of i. Show that $i = \frac{v}{Z}$. Find the impedence Z for this circuit.

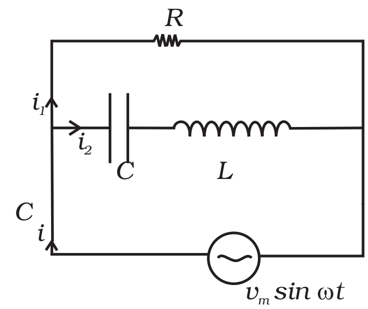


Fig. 7.6

7.30 For an LCR circuit driven at frequency ω, the equation reads

$$L\frac{di}{dt} + Ri + \frac{q}{C} = v_i = v_m \sin \omega t$$

(i) Multiply the equation by i and simplify where possible.

(ii) Interpret each term physically.

(iii) Cast the equation in the form of a conservation of energy statement.

(iv) Intergrate the equation over one cycle to find that the phase difference between v and i must be acute.

7.31 In the *LCR* circuit shown in Fig 7.7, the ac driving voltage is $v = v_m \sin \omega t$.

(i) Write down the equation of motion for $q\,(t)$.

(ii) At $t = t_0$, the voltage source stops and R is short circuited. Now write down how much energy is stored in each of L and C.

(iii) Describe subsequent motion of charges.

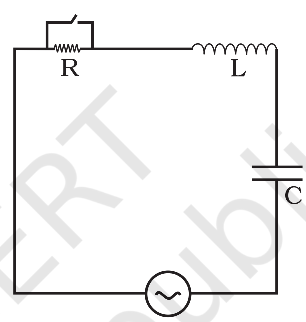


Fig. 7.7