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 $0.5\,\Omega$. The amount of charge on the capacitor plates will be

(a) 0
(b) $4\,\mu\,C$
(c) $16\,\mu\,C$
(d) $8\,\mu\,C$

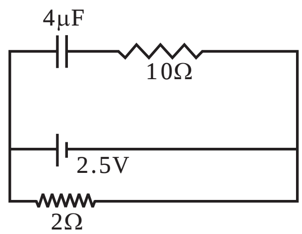
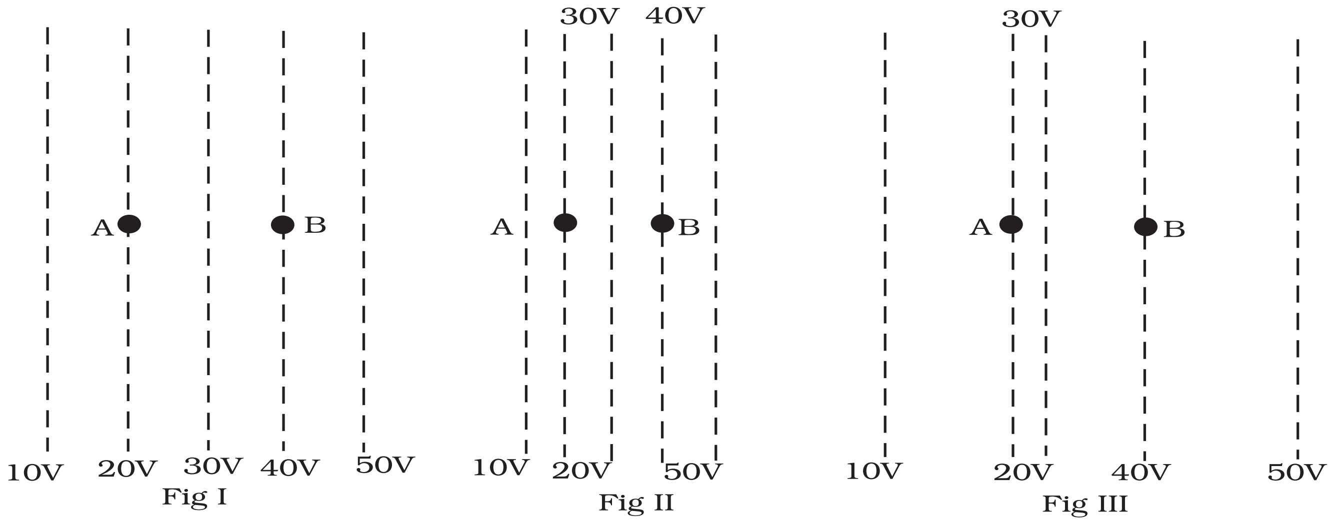


Fig. 2.1

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

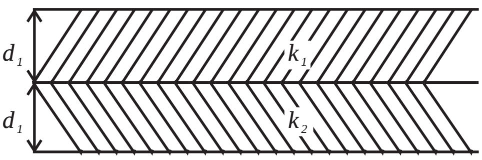


Fig. 2.3

(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.]

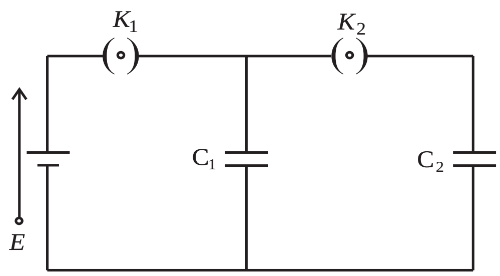


Fig. 2.4

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.

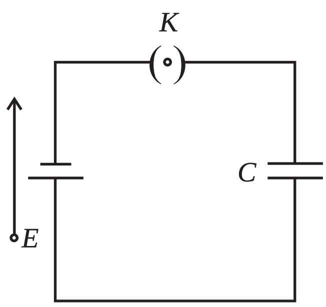


Fig. 2.5

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?

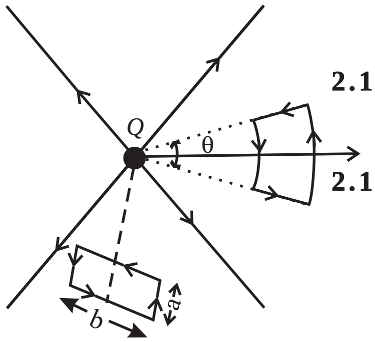


Fig. 2.6

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? [$C = 1\mu F$]

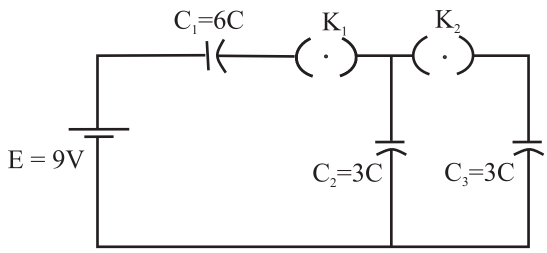


Fig. 2.7

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.