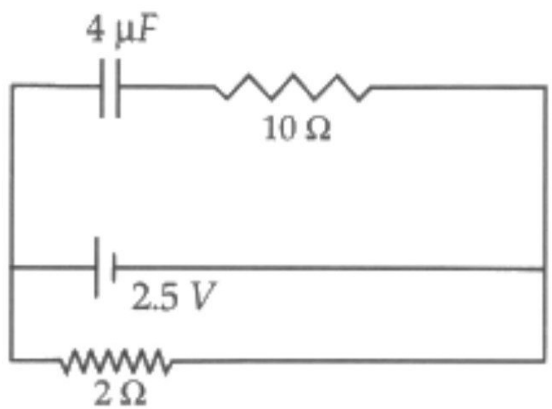
**1.** A capacitor of 4 $\mu$F is connected as shown in the circuit Figure. The internal resistance of the battery is 0.5 $\Omega$. The amount of charge on the capacitor plates will be :




a. 8$\mu$C

b. 16$\mu$C

c. 4$\mu$C

d. 0

**Sol. a)** 8$\mu$C

At steady state, the capacitor is open-circuited so no current flows through the 10-ohm resistor. So current will flow across 2 ohm resistor is

$$I = \frac{V}{R+r} = \frac{2.5}{2+0.5} = \frac{2.5}{2.5} = 1Amp$$

So P.D. across 2Ω resistance V = RI = 2 × 1 = 2 Volt.

As a battery, capacitor and 2Ω branches are in parallel. So P.D. will remain the same across all three branches.

As current does not flow through the capacitor branch so no potential drop will be across 10Ω

So P.D. across 4$\mu$F capacitor = 2 Volt

charge on the capacitor plate is given by:

$[q = CV] = 4\mu F \times 2 = 8\mu C$

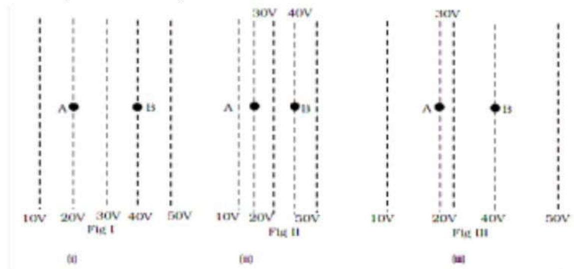
**2.** A positively charged particle is released from rest in a uniform electric field. The electric potential energy of the charge

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

**Sol. b)** decreases because the charge moves along the electric field.

An equipotential surface is always perpendicular to the direction of the electric field. Positive charge experiences the force in the direction of the electric field. When a positive charge is released from rest in the uniform electric field, its velocity increases in the direction of the electric field. So K.E. increases, and the P.E. decreases due to the law of conservation of energy.
So P.E. of the positively charged particle decreases because the speed of charged particle moves in the direction of the field due to force $q\bar{E}$
When a particle is released it moves (in the uniform field). It moves along the electric field from higher potential to the lower potential. Hence, energy decreases.

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




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

**Sol. d)** The work done is the same in Fig. (i), Fig. (ii) and Fig. (iii).

Work done in electrostatic is given by:- W = q×(change in potential)As the potential difference between A and B in all three figures are equal (20 V) so work done $(\Delta V q)$ by any charge in moving from A to B surface will be equal.

**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, $S_2$ is also true and $S_1$ is the cause of $S_2$.
b. $S_1$ is true but $S_2$ is false.
c. Both $S_1$ & $S_2$ are false.
d. $S_1$ is true, $S_2$ is also true but the statements are independent.

**Sol. a)** $S_1$ is true, $S_2$ is also true and $S_1$ is the cause of $S_2$.

A charged sphere doesnt enclosed any charge due to which electric field is zero inside the sphere. The relation between electric field intensity E and potential

$(\mathrm{V})$ is $\left[E=-\frac{dV}{dr}\right]$

Here, E = 0 inside the sphere then $\frac{dV}{dr}=0$

i.e., V = constant.

E = 0 inside charged sphere, the potential is constant or V = 100

Everywhere inside the sphere and it verifies the shielding effect also. Hence verifies the option

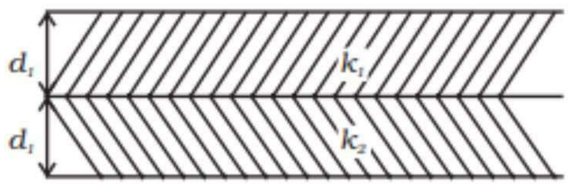
**5.** Equipotentials at a great distance from a collection of charges whose total sum is not zero are approximately

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

**Sol. c)** spheres

Here we have to find out the shape of the equipotential surface. These surfaces are perpendicular to the field lines. So there must be an electric field which cannot be without charge. So the algebraic sum of all charges must not be zero. Equipotential surface at a great distance means that the space of charge is negligible as compared to distance. So the collection of charges is considered as a point charge. The electric potential due to point charge is given by $V=1/4\pi \in_0 r$. It means that potential due to a point charge is same for all equidistant points, which are at the same potential form spherical shape. The lines of the field from point charges are radial. So the equipotential surface (perpendicular to the field lines) form a sphere.

**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. This arrangement can be thought of as a dielectric slab of thickness d (= $d_1+d_2$) and effective dielectric constant k. Then k is




a. $\frac{k_1 d_1+k_2 d_2}{d_1+d_2}$

b. $\frac{k_1 d_1+k_2 d_2}{k_1+k_2}$

c. $\frac{k_1 k_2 (d_1+d_2)}{(k_1 d_1+k_2 d_2)}$

d. $\frac{2k_1 k_2}{k_1+k_2}$

**Sol. c)** $\frac{k_1 k_2 (d_1+d_2)}{(k_1 d_1+k_2 d_2)}$

Capacitance of a parallel plate capacitor filled with dielectric of constant $k_1$ and thickness $d_1$ is

$C_1 = \frac{k_1 \varepsilon_0 A}{d_1}$

Similarly for other, $C_2 = \frac{k_2 \varepsilon_0 A}{d_2}$ ,having dielectric of constant $k_2$ and thickness $d_2$

Both capacitors are in series so equivalent capacitance C is related as:

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} = \frac{d_1}{k_1 \varepsilon_0 A} + \frac{d_2}{K_2 \varepsilon_0 A} = \frac{1}{\varepsilon_0 A}\left[\frac{k_2 d_1+k}{k_1 k_2}\right.$

So $C = \frac{k_1 k_2 \varepsilon_0 A}{(k_1 d_2+k_2 d_1)}$ ...(i)

$C' = \frac{k \varepsilon_0 A}{d}$ ...(ii)

Where d = ($d_1+d_2$)

So, Multiply the numerator and denominator of Eqn. i with ($d_1+d_2$),

$C = \frac{k_1 k_2 \varepsilon_0 A}{(k_1 d_2+k_2 d_1)} \cdot \frac{(d_1+d_2)}{(d_1+d_2)} = \frac{k_1 k_2 (d_1+d_2)}{(k_1 d_2+k_2 d_1)} \cdot \frac{\varepsilon_0 A}{(d_1+d_2)}$ ...(iii)

Comparing Eq. II and III, the dielectric constant of the new capacitor is:

$k = \frac{k_1 k_2 (d_1+d_2)}{(k_1 d_2+k_2 d_1)}$

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

a. in all spaces.
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.

**Sol.**

(b), (c) and (d): As we know that equipotential surfaces are perpendicular to the $\hat{z}$ direction electric field lines. Here electric field is in +z direction. So, equipotential surfaces will be the plane perpendicular to z axis, i.e., along x-y, plane, which includes any x or y-axes.
So answers (b), (c) and (d) are verified respectively.

**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.

**Sol.**

(b) (c).
onstant potential dV = 0 so by relation $E = \frac{-dV}{dr}$, E = 0
i.e., the E.F. is not uniform discards answer (a) and agree on which answer (b).
As potential may be outside the charge also so there can be no charge inside the region of constant potential. It verifies the answer (c).
If a charge is placed in the outside region, the potential difference in the region will not be changed or the electric field will not be changed. It makes answer (d) false.

**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.

**Sol.**

(a) (b): As the excess charge can reside only on the surface of a conductor and inside the net positive and negative charge is zero. Any charge can reside inside the hollow shell or body. So verifies answer (a) and discards answer (c). Inside the solid material of the conducting body, there is no charge, it comes to the outer surface. So verifies answer (b) and discards answer (d).

**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 largest one.

**Sol.**

Let $Q_1$ and $Q_2$ be the charges on radii $R_1$ and $R_2$ we know that

$$V_1 = \frac{1}{4\pi\varepsilon}\frac{Q_1}{R_1} \text{ and } V_2 = \frac{1}{4\pi\varepsilon}\frac{Q_2}{R_2}$$

As $V_1 = V_2$, so:

$$\Rightarrow \frac{1}{4\pi\in}\frac{Q_1}{R_1} = \frac{1}{4\pi\in}\frac{Q_2}{R_2}$$

$$\Rightarrow \frac{Q_1}{R_1} = \frac{Q_2}{R_2}$$

$$\Rightarrow \frac{Q_1}{Q_1} = \frac{R_1}{R_2}$$

$$\Rightarrow \frac{\sigma_1 \times 4\pi(R_1)^2}{\sigma_2 \times 4\pi(R_2)^2} = \frac{R_1}{R_2}$$

$$\Rightarrow \frac{\sigma_1}{\sigma_2} = \frac{R_2}{R_1}$$

Since $R_1 > R_2$ it follows that

$$\sigma_1 < \sigma_2$$

i.e. the charge density of smaller sphere is less than that of larger sphere.

**15.** Do free electrons travel to region of higher potential or lower potential?

**Sol.**

As free electrons has negative charge so the direction of flow will be opposite to positive charge, i.e., free electrons will move from lower potential to higher potential.

**16.** Can there be a potential difference between two adjacent conductors carrying the same charge?

**Sol.**

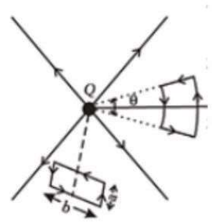
If in two conductors flowing current is the same then both may be considered in series. So Ohm's law becomes $V \propto R$. i.e. if the resistances (which depend on $\rho$, l and A) are different then the potential differences will be different.
So there can be a potential differences between two adjacent conductors carrying the same charge or current if either their length or area of cross-section (A) and resistivity are different.

**17.** Can the potential function have a maximum or minimum in free space?

**Sol.**

In the absence of free space or atmosphere, the phenomenon of electric field or potential leakage cannot be prevented. Hence, the potential function do not have maximum or minimum in free space.

**18.** A test charge q is made to move in the electric field of a point charge Q along two different closed paths (Fig). 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?



**Sol.**

We know that electrostatic work done is conservative. So work done in closed loop is always zero, it does not depend on the nature of closed path.