CBSE 12th Physics

Unit - 1 Electrostatics

Competency-Based Questions

Q1. The capacitance of a capacitor is Co. It is connected to a battery of voltage V which charges the capacitor. With the capacitor still connected to the battery, a slab of dielectric material is introduced between the plates of the capacitor.

Which of the following explains the effect of the dielectric slab in the above situation?

A. The electric field between the plates of the capacitor rises.

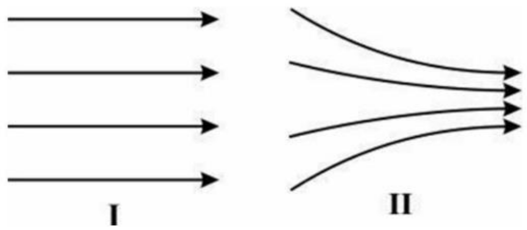
B. The potential difference between the plates falls.

C. The total charge on the capacitor increases.

D. The ability of the capacitor to store charge decreases.

Ans. C. The total charge on the capacitor increases.

Q2. The image below shows two examples of electric field lines



Which of the following statements is true?

A. The electric fields in both I and II arise due to a single positive point charge located somewhere on the left.

B. The electric fields in both I and II can be created by negative charges located somewhere on the left and positive charges somewhere on the right.

C. The electric field in I is the same everywhere but the electric field in II becomes stronger as we move from left to right.

D. As you move from left to right, the electric fields in both I and II become stronger.

Ans. C. The electric field in I is the same everywhere but the electric field in II becomes stronger as we move from left to right.

Q3. In a given region, electric potential varies with position as $V(x) = 3 + 2x^2$.

Identify which of the following statements is correct.

A. Potential difference between the two points x = 2 and x = -2 is 2 V.

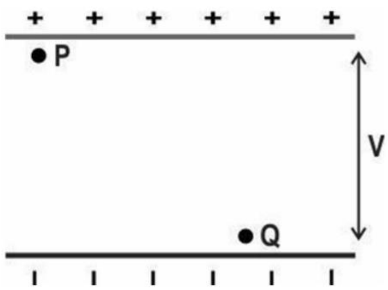
B. A charge of 1 C placed at x = 2 experiences a force of 6 N.

C. The force experienced by the above charge is along +x - axis.

D. The electric field in the given region is non-uniform along x - axis.

Ans. D. The electric field in the given region is non-uniform along x - axis.

Q4. A parallel plate capacitor is charged to a potential difference V. Two protons P and Q are placed at the two locations inside the capacitor as shown.



Which one of the statements is correct?

A. The forces on the two protons are identical.

B. The force on proton P near the positive plate is more than the force on proton Q.

C. The force on proton Q near the negative plate is more than the force on proton P.

D. The forces on both the protons are zero.

Ans. A. The forces on the two protons are identical.

Q5. In a given region of an electric field, there is no charge present. A closed container is placed in this region of the electric field.

What is the requirement for the total flux through the closed container to be zero?

A. The field must be uniform.

B. The container must be symmetric.

C. The container must be oriented in a particular direction.

D. There is no such requirement. The total flux through the container is zero no matter what.

Ans. D. There is no such requirement. The total flux through the container is zero no matter what.

Q6. A uniform electric field of 5000 V/m exists in a certain region. What volume of this space will contain energy equal to 10^{-6} J? (Take $\epsilon_o = 8.8 \times 10^{-12}$ SI units)

A. 9 m^3

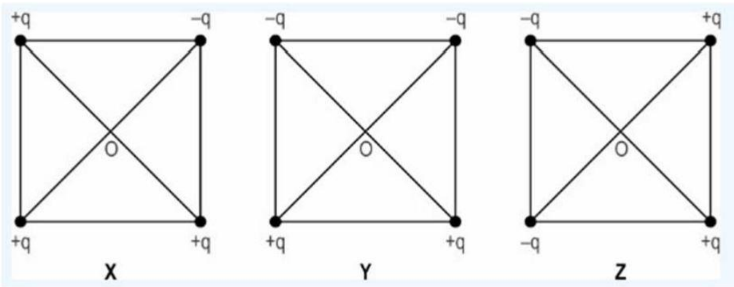
B. 9 x 10^{-3} m^3

C. 9 x 10^{-6} m^3

D. 9 x 10^3 m^3

Ans. B. 9 x 10^{-3} m^3

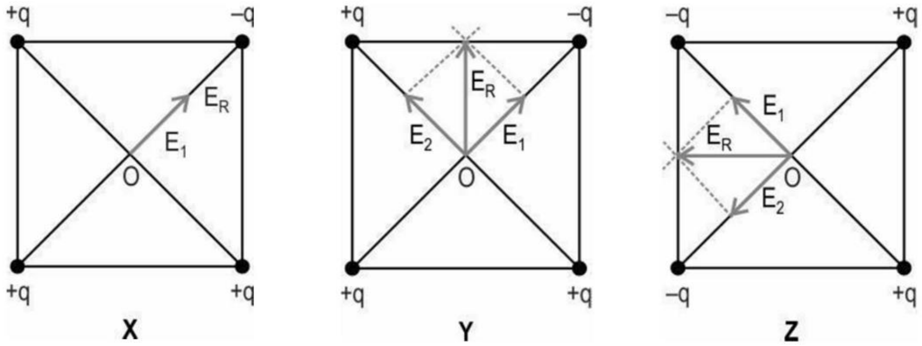
Q7. Given are three different square arrangements of charges.



(a) Draw relevant vector diagrams to represent the resultant electric field ER at the center of the square in each case.

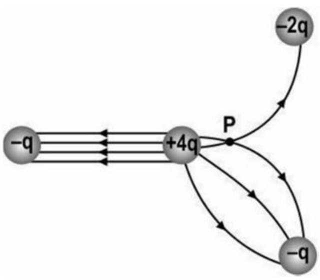
(b) Identify the arrangement in which the resultant electric field is the smallest at the center of the square.

Ans. (a) 1 mark each for the correct vector representation of the electric field in the three cases:



(b) E_R vector in X is the smallest in length.

Q8. The figure below shows an arrangement of four charges along with some electric field lines drawn between the charges.



(a) Identify three things that are incorrect in this figure.

(b) Draw a correct diagram representing the electric field lines for this system of charges.

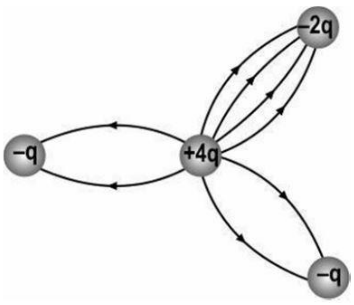
Ans. (a) 1 mark for each correct point:

- Electric field lines cross each other as shown at point P.

- Number of field lines that end on the negative charges is not proportional to their charges.

- The field lines drawn between +4q and −q is shown as parallel and equidistant.

(b) The correct representation:



[1 mark for the correct representation of the electric field lines]

Q9. In the case of a spherical charged conductor of radius R, hollow or solid, the electric potential is constant and maximum inside and on the surface.

On the outside, the electric potential varies as,

$$V \propto \frac{1}{r}$$

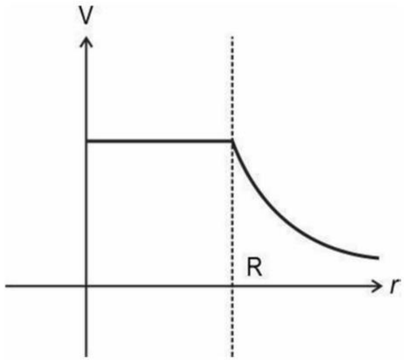
where r is the distance from the center of the sphere.

(a) Represent the variation of electric potential due to a charged sphere with distance graphically.

(b) How does the electric field intensity due to a charged sphere vary with distance r from the center in the above case?

(c) Represent the variation of electric field intensity due to a charged sphere with distance graphically.

Ans. (a)

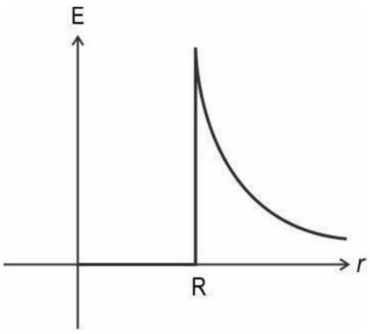


[1 mark for the correct graph]

(b) Electric field intensity is zero inside the charged sphere. Maximum at the surface. On the outside of the sphere, it falls as E proportional to $1/r^2$

[1 mark for the correct statement of variation of E with r]

(c)



[1 mark for the correct graph]

Q10. For a given charge distribution, an equipotential surface is the locus of all points having the same potential.

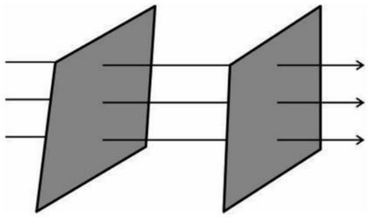
Draw two equipotential surfaces for each of the following:

(a) a uniform electric field

(b) a point charge

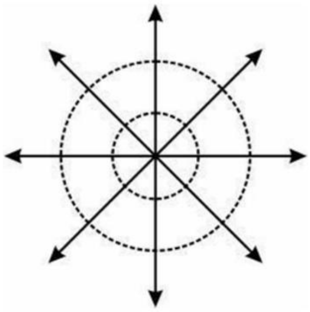
(c) an infinite straight line of charge

Ans. (a) A uniform electric field



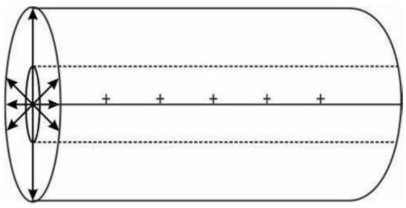
[1 mark for the correct drawing of two equipotential surfaces]

(b) A point charge



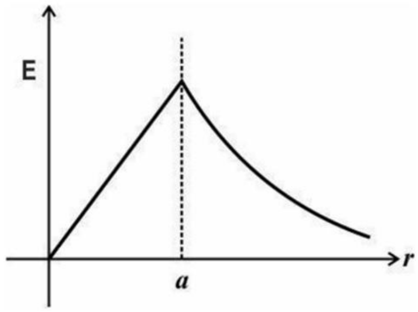
[1 mark for the correct drawing of two equipotential surfaces]

(c) An infinite straight line of charge



[1 mark for the correct drawing of two equipotential surfaces]

Q11. Study the graph between electric field intensity E versus the distance r.



(a) Describe the nature of variation of electric field intensity between $r = 0$ and $r \leq a$.

(b) Describe the nature of variation of electric field intensity for $r > a$.

(c) Give an example of the body of charge distribution that can exhibit the above studied electric field distribution.

Ans. $E = 0$ at $r = 0$.

Between r = 0 and r < a, the electric field intensity increases linearly.

E is maximum at r = a.

[0.5 mark for each point]

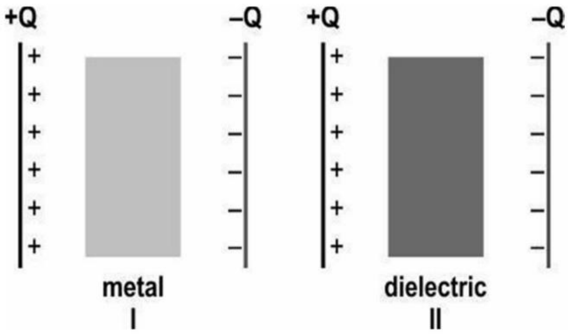
(b) For r > a, the electric field intensity decreases as $1/r^2$.

[0.5 mark for this point]

(c) A uniformly charged insulating solid sphere.

[1 mark for the example]

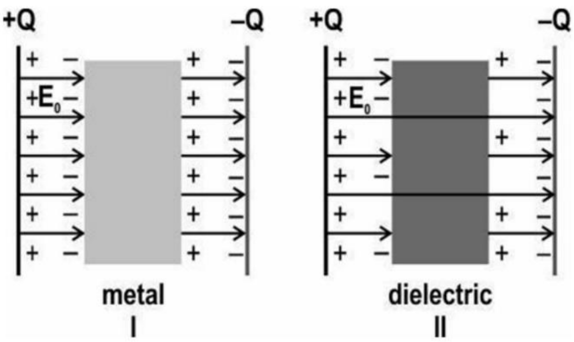
Q12. Given is a pair of parallel charged metal plates in the arrangement as shown.



(a) Sketch the electric field lines between the plates in I and II.

(b) Mention whether net electric field intensity is zero or non-zero in each case.

Ans. (a)



[1 mark for correct representation of electric field inside metal]

[1 mark for correct representation of electric field inside dielectric]

(b) The net electric field intensity inside a metal is zero.

The net electric field intensity inside a dielectric is non-zero.

[0.5 mark for each point]

Q13. The dielectric strength of a medium is the minimum electric field required to cause ionization of the medium. For air, this value is taken as 3 million V/m.

With this information, find out if a metal sphere of radius 1 cm, surrounded by air, can hold a charge of 1 coulomb.

Ans. Electric field on the surface of a metal sphere:

$$E = \frac{Q}{4\pi\epsilon_0 R^2} = 9 \times 10^9 \frac{1}{(1 \times 10^{-2})^2} = 9 \times 10^{13} \text{ V/m}$$

[1 mark for the correct formula and calculation]

As this field is much higher than the dielectric strength of the surrounding air (= 3×10^6 V/m), a sphere of radius 1 cm CANNOT hold 1 C of charge in air.

[1 mark for the correct interpretation and conclusion]

Q14. Two hollow spherical conductors of different sizes are charged positively. The smaller one is at 50 V and the larger one is at 100 V.

Suggest a method in which the two conductors can be arranged so that the charge flows from the smaller to the bigger conductor when connected by a wire.

Give a mathematical working to justify the arrangement.

Ans. The smaller conductor can be enclosed inside the larger conductor and the two are connected by a conducting wire.

[1 mark for the correct arrangement of the two conductors]

Potential on the surface of the smaller conductor placed inside the bigger conductor will be

$V_i = 50 \text{ V} + 100 \text{ V} = 150 \text{ V}$

[0.5 mark for the correct formula]

Potential on the surface of the outer conductor will be:

$$V_o = 100 + \frac{1}{4\pi\epsilon_0 R} \times \text{charge on conductor inside}$$

$$= 100 + \frac{1}{4\pi\epsilon_0 R} \times 4\pi\epsilon_0 r \times 50 = \left[\, 100 + 50\frac{r}{R} \,\right] < 150\text{V}$$

[1 mark for the correct formula and calculation]

Hence when the inner conductor is connected by a conducting wire to the outer conductor, the charge flows from the higher potential surface of the inner conductor to the lower potential surface of the outer conductor.

[0.5 mark for the correct conclusion]

Q15. A parallel plate capacitor of capacitance C is charged to a potential V by a battery. Q is the charge stored on the capacitor. Without disconnecting the battery, the plates of the capacitor are pulled apart to a larger distance of separation.

What changes will occur in each of the following quantities? Will they increase, decrease or remain the same? Give an explanation in each case.

(a) Capacitance

(b) Charge

(c) Potential difference

(d) Electric field

(e) Energy stored in the capacitor

Ans. (a) Capacitance decreases.

Capacitance is inversely proportional to the distance of separation.

[0.5 mark for correct change]

[0.5 mark for correct explanation]

(b) Charge decreases.

From Q = CV, C decreases and V remains the same, so Q decreases.

[0.5 mark for correct change]

[0.5 mark for correct explanation]

(c) Potential difference remains the same

As the capacitor is connected to the battery, the potential V of the capacitor will remain the same as that of the battery.

[0.5 mark for correct change]

[0.5 mark for correct explanation]

(d) Electric field decreases.

E due to a plane sheet of charge = σ/ϵ_0 is independent of the distance from the sheet. But charge density σ on the plate decreases, so E decreases.

OR:

Alternatively,

As $E = V/d = Q/Cd = Q/\epsilon oA$

Since Q decreases, E also decreases.

[0.5 mark for correct change]

[0.5 mark for correct explanation]

(e) Energy stored in the capacitor decreases.

Energy stored is proportional to both Q and V. Charge Q decreases but potential V is constant.

[0.5 mark for correct change]

[0.5 mark for correct explanation]

Q16. A parallel plate capacitor C with a dielectric in between the plates is charged to a potential V by connecting it to a battery. The capacitor is then isolated.

If the dielectric is withdrawn from the capacitor,

(a) Will the energy stored in the capacitor increase or decrease? What causes the change in energy?

(b) Will the potential difference across the capacitor plates increase or decrease? Give an explanation.

Ans. (a) The energy of the capacitor will increase.

The work done on the capacitor while removing the dielectric results in an increase in energy stored in the capacitor.

(or)

Energy of the capacitor after the dielectric is removed: $E' = Q^2 / 2C'$

The charge on the plates remains the same as the capacitor is isolated. But since the capacitance decreases when the dielectric is removed, the energy of the capacitor will increase.

[0.5 marks for the correct change]

[1 mark for correct explanation]

(b) Potential difference will increase.

Potential difference after the dielectric is removed is $V' = Q/C'$

where C' is capacitance without the dielectric.

Since $C' < C$ and the charge Q remains the same in an isolated capacitor, the potential difference $V' > V$.

[0.5 marks for the correct change]

[1 mark for correct explanation]

Q17. An isolated capacitor of unknown capacitance C is charged to a potential difference V. It is then connected in parallel to an uncharged capacitor of capacitance Co such that the potential difference across the combination becomes V/3.

Determine the unknown capacitance C.

Ans. Charge on unknown capacitor = Charge on the combination

[1 mark for a correct statement of equality of charge on the two capacitors]

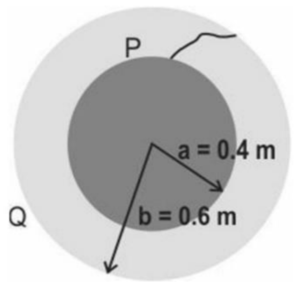
$CV = (C \text{ parallel } Co)_{eqv} .V/3$

$CV= (C + Co).V/3$

$C = Co/2$

[1 mark for correct calculation]

Q18. P and Q are two concentric conducting hollow shells connected to each other by a conducting wire.



If a total charge of 10 C is given to this system of two concentric shells, how much charge will settle on each shell? Explain.

Ans. There will be no charge on the inner sphere P. The entire charge of 10 C will be on the outer shell Q.

[1 mark for the correct charge distribution]

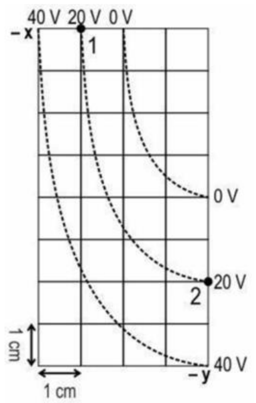
In case some charge does appear on the inner sphere P, it creates an electric field between the inner and the outer shell causing the charge to move to the outer shell. So only the outer sphere gathers all the charge.

OR

In case some charge does appear on the inner sphere P, the inner shell will be at a higher potential than the outer shell Q. This will cause the entire charge to move from P to Q, so that potentials on both the shells becomes the same.

[1 mark for the correct charge explanation]

Q19. Given below is the representation of equipotential lines in a given electric field region. Determine the strength and direction of electric field vectors at points 1 and 2.



Ans. At point 1:

40 V change over a distance 2 cm.

So electric field at point 1:

$E1 = 40/0.02 = 2000 \text{ V/m}$

The direction of E_1 will be along + x axis.

[1 mark for correct calculation of the E_1 value]

[0.5 mark for a correct direction of E_1]

At point 2:

40 V change over a distance of 4 cm.

So electric field at point 2:

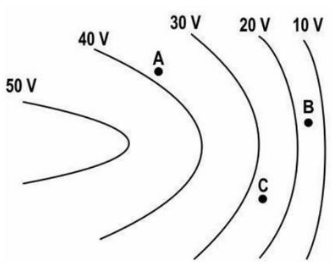
$E2 = 40/0.04 = 1000 \text{ V/m}$

The direction of E_2 will be along + y axis.

[1 mark for correct calculation of the E_2 value]

[0.5 mark for a correct direction of E_2]

Q20. The figure below shows lines of constant potentials in a region in which an electric field is present.



Using the relation between potential difference and electric field intensity, find which of the three points, A, B or C will have the greatest electric field intensity.

Ans. Relation between E and V is

$$E = -\frac{\Delta V}{\Delta r}$$

Here ΔV between successive lines is constant, that is 10V.

[1 mark for correct formula]

Therefore,

$$E \propto \frac{1}{\Delta r}$$

The smaller the distance of separation between two successive lines, the more is the electric field.

So, point B has the greatest electric field intensity.

[1 mark for correct explanation]