

NCERT Solutions for Class-XII Physics

Chapter-2

NCERT Physics Class 12

1. Two charges $5 \times 10^{-8} \text{ C}$ and $-3 \times 10^{-8} \text{ C}$ are located 16 cm apart. At what point(s) on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.

1. There are two charges,

$$q_1 = 5 \times 10^{-8} \text{ C}$$

$$q_2 = -3 \times 10^{-8} \text{ C}$$

Distance between the two charges, $d = 16 \text{ cm} = 0.16 \text{ m}$

Consider a point P on the line joining the two charges, as shown in the given figure.

r = Distance of point P from charge q_1

Let the electric potential (V) at point P be zero.

Potential at point P is the sum of potentials caused by charges q_1 and q_2 respectively.

$$\therefore V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{r} + \frac{1}{4\pi\epsilon_0} \cdot \frac{q_2}{(d-r)} \dots\dots\dots(1)$$

Where,

ϵ_0 = Permittivity of free space

For $V = 0$, equation (i) reduces to

$$0 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{r} + \frac{1}{4\pi\epsilon_0} \cdot \frac{q_2}{(d-r)} \Rightarrow \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{r} = -\frac{1}{4\pi\epsilon_0} \cdot \frac{q_2}{(d-r)}$$

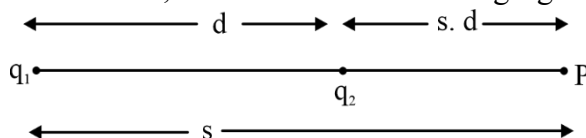
$$\Rightarrow \frac{q_1}{r} = -\frac{q_2}{(d-r)} \Rightarrow \frac{5 \times 10^{-8}}{r} = -\frac{(-3 \times 10^{-8})}{(0.16-r)}$$

$$\Rightarrow 5(0.16 - r) = 3r$$

$$\Rightarrow 0.8 = 8r \Rightarrow r = 0.1 \text{ m} = 10 \text{ cm}$$

Therefore, the potential is zero at a distance of 10 cm from the positive charge between the charges.

Suppose point P is outside the system of two charges at a distance s from the negative charge, where potential is zero, as shown in the following figure.



For this arrangement, potential is given by,

$$V = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{s} + \frac{1}{4\pi\epsilon_0} \cdot \frac{q_2}{(s-d)} \dots\dots\dots(2)$$

Where,

ϵ_0 = Permittivity of free space

For $V = 0$, equation (2) reduces to

$$0 = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{s} + \frac{1}{4\pi\epsilon_0} \cdot \frac{q_2}{(s-d)} \Rightarrow \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1}{s} = -\frac{1}{4\pi\epsilon_0} \cdot \frac{q_2}{(s-d)}$$

$$\Rightarrow \frac{q_1}{s} = -\frac{q_2}{(s-d)}$$

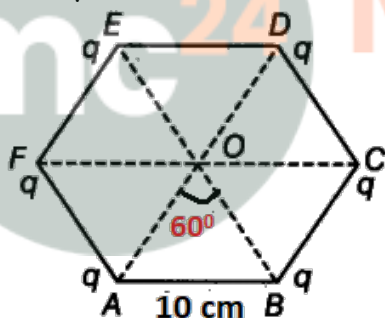
$$\Rightarrow \frac{5 \times 10^{-8}}{s} = -\frac{(-3 \times 10^{-8})}{(s-0.16)}$$

$$\Rightarrow 5(s-0.16) = 3s$$

$$\Rightarrow 0.8 = 2s \Rightarrow s = 0.4 \text{ m} = 40 \text{ cm}$$

Therefore, the potential is zero at a distance of 40 cm from the positive charge outside the system of charges.

2. A regular hexagon of side 10 cm has a charge $5 \mu\text{C}$ at each of its vertices. Calculate the potential at the centre of the hexagon.
2. Let O be the center of the hexagon. It contains the charges at all its 6 vertices, each charge $= +5 \mu\text{C} = 5 \times 10^{-6} \text{ C}$. The side of the hexagon is $10 \text{ cm} = 0.1 \text{ m}$



It follows that the point O, when joined to the two ends of a side of the hexagon forms an equilateral triangle

Electric potential at O due to one charge,

$$V_1 = \frac{q}{4\pi\epsilon_0 r}$$

Here, q = amount of charge $= 5 \times 10^{-6} \text{ C}$

r = distance between charge and O $= 0.1 \text{ m}$

ϵ_0 = absolute permittivity of free space

Since at each of the hexagon, a charge of $5 \mu\text{C}$ ($5 \times 10^{-6} \text{ C}$) is placed, total electric potential at the point O due to the charges at the six corners,

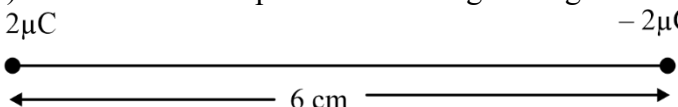
$$V = 6 \times \frac{q}{4\pi\epsilon_0 r}$$

$$\Rightarrow V_1 = 6 \times \frac{1}{4\pi\epsilon_0} \times \frac{5 \times 10^{-6} \text{ C}}{0.1 \text{ m}}$$

$$\Rightarrow V_1 = 6 \times \frac{9 \times 10^9 \text{ Nm}^2\text{C}^{-2} \times 5 \times 10^{-6} \text{ C}}{0.1 \text{ m}}$$

$$\Rightarrow V_1 = 2.7 \times 10^6 \text{ V}$$

3. Two charges $2 \mu\text{C}$ and $-2 \mu\text{C}$ are placed at points A and B 6 cm apart.
- (a) Identify an equipotential surface of the system.
- (b) What is the direction of the electric field at every point on this surface?

3. (a) The situation is represented in the given figure.
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An equipotential surface is the plane on which total potential is zero everywhere. This plane is normal to line AB. The plane is located at the mid-point of line AB because the magnitude of charges is the same.

(b) The direction of the electric field at every point on this surface is normal to the plane in the direction of AB.

4. A spherical conductor of radius 12 cm has a charge of $1.6 \times 10^{-7} \text{ C}$ distributed uniformly on its surface. What is the electric field?
- (a) Inside the sphere.
- (b) Just outside the sphere.
- (c) At a point 18 cm from the centre of the sphere?

4. Given, $q = 1.6 \times 10^{-7} \text{ C}$

Radius of the sphere, $r = 12 \text{ cm} = 0.12 \text{ m}$

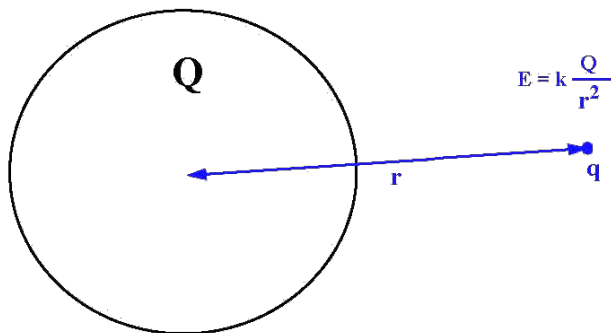
(a) Inside the sphere: The charge on a conductor resides on its outer surface. Therefore, electric field inside the sphere is zero.

(b) Just outside the sphere: For a point on the charged spherical conductor or outside it, the charge may be assumed to be concentrated at its center.

Therefore, the electric field just outside the sphere is given as:

$$E = \frac{q}{4\pi\epsilon_0 r^2}$$

where, q is the charge due to which the field is being calculated



putting the values of “r” and “q” in the equation, we get,

$$E = 9 \times 10^9 \text{ Nm}^2 \text{C}^{-2} \times \frac{1.6 \times 10^{-7} \text{ C}}{(0.12 \text{ m})^2}$$

$$\therefore E = 10^5 \text{ N/C}$$

(c) At a point 18 cm from the center: Given, $R = 18 \text{ cm}$

Electric field at a point 18 cm from the center.

$$E = \frac{q}{4\pi\epsilon_0 R^2}$$

$$\therefore E = 9 \times 10^9 \text{ Nm}^2 \text{C}^{-2} \times \frac{1.6 \times 10^{-7} \text{ C}}{(0.18 \text{ m})^2}$$

$$\therefore E = 4.4 \times 10^4 \text{ N/C}$$

5. A parallel plate capacitor with air between the plates has a capacitance of 8 pF ($1 \text{ pF} = 10^{-12} \text{ F}$). What will be the capacitance if the distance between the plates is reduced by half, and the space between them is filled with a substance of dielectric constant 6?

5. Capacitance between the parallel plates of the capacitor, $C = 8 \text{ pF}$

Initially, distance between the parallel plates was d and it was filled with air.

Dielectric constant of air, $k = 1$

Capacitance, C is given by the formula,

$$C = \frac{k\epsilon_0 A}{d} = \frac{\epsilon_0 A}{d} \dots\dots\dots(1)$$

Where,

A = Area of each plate

ϵ_0 = Permittivity of free space

If distance between the plates is reduced to half, then new distance, $d_1 = d/2$

Dielectric constant of the substance filled in between the plates, $k_1 = 6$

Hence, capacitance of the capacitor becomes

$$C_1 = \frac{k_1\epsilon_0 A}{d_1} = \frac{6\epsilon_0 A}{\frac{d}{2}} = \frac{12\epsilon_0 A}{d} \dots\dots\dots(2)$$

Taking ratios of equations (1) and (2), we obtain

$$C_1 = 2 \times 6 \text{ C} = 12 \text{ C} = 12 \times 8 \text{ pF} = 96 \text{ pF}$$

Therefore, the capacitance between the plates is 96 pF.

6. Three capacitors each of capacitance 9 pF are connected in series.
(a) What is the total capacitance of the combination?
(b) What is the potential difference across each capacitor if the combination is connected to a 120 V supply?

6. Given, $C_1 = C_2 = C_3 = 9 \text{ pF} = 9 \times 10^{-12} \text{ F}$

$$V = 120 \text{ volt}$$

(a) Total capacitance of the series combination is given by

$$\frac{1}{C_{\text{net}}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$$

$$\Rightarrow \frac{1}{C_{\text{net}}} = \frac{1}{C} + \frac{1}{C} + \frac{1}{C}$$

$$\Rightarrow \frac{1}{C_{\text{net}}} = \frac{3}{C}$$

$$\Rightarrow \frac{1}{C_{\text{net}}} = 3 \times \frac{1}{9 \times 10^{-12}} = \frac{1}{3 \times 10^{-12}}$$

$$C_{\text{net}} = 3 \times 10^{-12} \text{ F} = 3 \text{ pico-Farad.}$$

(b) Let q be the charge on each capacitor.

Sum of the potential difference across the plates of the three capacitors must be equal to 120 V.

$$\Rightarrow V_1 + V_2 + V_3 = V_{\text{net}}$$

$$\Rightarrow \frac{q}{C_1} + \frac{q}{C_2} + \frac{q}{C_3} = 120 (\because V_{\text{net}} = 120 \text{ V})$$

$$\Rightarrow \frac{q}{9 \times 10^{-12}} + \frac{q}{9 \times 10^{-12}} + \frac{q}{9 \times 10^{-12}} = 120$$

$$\Rightarrow \frac{3q}{9 \times 10^{-12}} = 120$$

$$\Rightarrow q = 360 \times 10^{-12} \text{ C}$$

Therefore, potential difference across a capacitor.

$$= \frac{q}{\text{capacitance}} = \frac{360 \times 10^{-12}}{9 \times 10^{-12}} = 40 \text{ V}$$

7. Three capacitors of capacitance 2pF, 3pF and 4pF are connected in parallel.
(a) What is the total capacitance of the combination?

- (b) Determine the charge on each capacitor if the combination is connected to a 100 V supply.
7. (a) Capacitances of the given capacitors: $C_1 = 2 \text{ pF}$, $C_2 = 3 \text{ pF}$ and $C_3 = 4 \text{ pF}$
 For the parallel combination of the capacitors, equivalent capacitor is given by C_{eq} the algebraic sum,
 Therefore $C_{eq} = C_1 + C_2 + C_3 = 2 + 3 + 4 = 9 \text{ pF}$
 Therefore, total capacitance of the combination is 9 pF.
 (b) Supply voltage, $V = 100 \text{ V}$
 The voltage through all the three capacitance is same $= V = 100 \text{ V}$
 Charge on a capacitor of capacitance C and potential difference V is given by the relation,
 $q = VC \dots(i)$
 For $C = 2 \text{ pF}$, charge $= VC = 100 \times 2 = 200 \text{ pC} = 2 \times 10^{-10} \text{ C}$
 For $C = 3 \text{ pF}$, charge $= VC = 100 \times 3 = 300 \text{ pC} = 3 \times 10^{-10} \text{ C}$
 For $C = 4 \text{ pF}$, charge $= VC = 100 \times 4 = 400 \text{ pC} = 4 \times 10^{-10} \text{ C}$
8. In a parallel plate capacitor with air between the plates, each plate has an area of $6 \times 10^{-3} \text{ m}^2$ and the distance between the plates is 3 mm. Calculate the capacitance of the capacitor. If this capacitor is connected to a 100 V supply, what is the charge on each plate of the capacitor?
8. Given, $A = 6 \times 10^{-3} \text{ m}^2$
 $D = 3 \text{ mm} = 3 \times 10^{-3} \text{ m}$
 Capacitance of the capacitor,

$$C = \frac{\epsilon_0 A}{d} = \frac{8.854 \times 10^{-12} \text{ Fm}^{-1} \times 6 \times 10^{-3} \text{ m}^2}{3 \times 10^{-3} \text{ m}}$$

$$\Rightarrow C = 1.77 \times 10^{-11} \text{ F} = 17.7 \text{ pF}$$
 When the capacitor is connected to a 100 V supply, the charge on the each plate of the capacitor,
 $q = CV = 1.77 \times 10^{-11} \times 100 = 1.77 \times 10^{-9} \text{ C}$
9. Explain what would happen if in the capacitor given in Exercise 2.8, a 3 mm thick mica sheet (of dielectric constant = 6) were inserted between the plates,
 (a) While the voltage supply remained connected.
 (b) After the supply was disconnected.
9. (a) Dielectric constant of the mica sheet, $k = 6$
 If voltage supply remained connected, voltage between two plates will be constant.
 Supply voltage, $V = 100 \text{ V}$
 Initial capacitance, $C = 1.771 \times 10^{-11} \text{ F}$
 New capacitance, $C_1 = kC = 6 \times 1.771 \times 10^{-11} \text{ F} = 106 \text{ pF}$
 New charge, $q_1 = C_1 V = 106 \times 100 \text{ pC} = 1.06 \times 10^{-8} \text{ C}$

Potential across the plates remains 100 V.

(b) Dielectric constant, $k = 6$

Initial capacitance, $C = 1.771 \times 10^{-11} \text{ F}$

New capacitance, $C_1 = kC = 6 \times 1.771 \times 10^{-11} \text{ F} = 106 \text{ pF}$

If supply voltage is removed, then there will be constant amount of charge in the plates.

Charge = $1.771 \times 10^{-9} \text{ C}$

Potential across the plates is given by,

$$V_1 = \frac{q}{C_1} = \frac{1.771 \times 10^{-9}}{106 \times 10^{-12}} = 16.7 \text{ V}$$

10. A 12 pF capacitor is connected to a 50V battery. How much electrostatic energy is stored in the capacitor?

10. Given, $C = 12 \text{ pF} = 12 \times 10^{-12} \text{ F}$

$V = 50 \text{ V}$

The electrostatic energy stored in the capacitor,

$$W = \left(\frac{1}{2}\right) CV^2 = \left(\frac{1}{2}\right) \times 12 \times 10^{-12} \times (50)^2 = 1.5 \times 10^{-8} \text{ J}$$

11. A 600 pF capacitor is charged by a 200 V supply. It is then disconnected from the supply and is connected to another uncharged 600 pF capacitor. How much electrostatic energy is lost in the process?

11. Capacitance of the capacitor, $C = 600 \text{ pF}$

Potential difference, $V = 200 \text{ V}$

Electrostatic energy stored in the capacitor is given by,

$$E_1 = \frac{1}{2} CV^2$$

$$= \frac{1}{2} \times (600 \times 10^{-12}) \times (200)^2 \text{ J}$$

$$= 1.2 \times 10^{-5} \text{ J}$$

If supply is disconnected from the capacitor and another capacitor of capacitance $C = 600 \text{ pF}$ is connected to it, then equivalent capacitance (C_{eq}) of the combination is given by,

$$\frac{1}{C_{eq}} = \frac{1}{C} + \frac{1}{C}$$

$$\Rightarrow \frac{1}{C_{eq}} = \frac{1}{600} + \frac{1}{600} = \frac{2}{600} = \frac{1}{300}$$

$$\Rightarrow C_{eq} = 300 \text{ pF}$$

New electrostatic energy can be calculated as

$$E_2 = \frac{1}{2} C_{eq} V^2$$

$$= \frac{1}{2} \times 300 \times (200)^2 \text{ J}$$

$$= 0.6 \times 10^{-5} \text{ J}$$

$$\text{Loss in electrostatic energy} = E_1 - E_2$$

$$= 1.2 \times 10^{-5} - 0.6 \times 10^{-5} \text{ J}$$

$$= 0.6 \times 10^{-5} \text{ J}$$

$$= 6 \times 10^{-6} \text{ J}$$

Therefore, the electrostatic energy lost in the process is $6 \times 10^{-6} \text{ J}$.



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