CBSE Test Paper-02

Class - 12 Physics (Electrostatics Potential and Capacitance)

1. Equal charges q each are placed at the vertices A and B of an equilateral triangle ABC of side a. The magnitude of electric intensity at the centre is:
   a. $\frac{\sqrt{2}q}{4\pi\varepsilon_0^2}$
   b. $\frac{3q}{4\pi\in_0\ a^2}$
   c. $\frac{2q}{4\pi\varepsilon_0 a^2}$
   d. $\frac{\sqrt{3}q}{4\pi\varepsilon_0 a^2}$
2. The force with which the plates of a parallel plate capacitor, having charge Q and area of each plate as A, attract each other is
   a. directly proportional to Q only
   b. directly proportional to A and Q
   c. directly proportional to A only
   d. inversely proportional to A^2
3. In electrolytic capacitors positive terminal is
   a. one on which aluminium oxide film is not formed
   b. one on which aluminium oxide film is formed
   c. none of the these
   d. either of the two terminals
4. Work done by a uniform electric field E in moving a charge q a distance d from a to b is
   a. qEd
   b. $\mathrm{q/(Ed)}$
   c. $\mathrm{qE/d^2}$
   d. $\mathrm{qE/d}$
5. The capacitance of a parallel plate capacitor is 5 $\mu\mathrm{F}$. When a glass slab of thickness equal to the separation between the plates is introduced between the plates, the potential difference reduces to 1/8 of the original value. The dielectric constant of glass is
   a. 8

b. 5
c. 1.6
d. 40

6. Two point charges q and -2q are kept d distance apart. Find the location of point relative to charge q at which potential due to this system of charges is zero.
7. A hollow metal sphere of radius 5 cm is charged such that potential on its surface is 10V. What is the potential at the centre of the sphere?
8. Why there is no work done in moving a charge from one point to another on an equipotential surface?
9. Given a battery how would you connect two capacitors, in series or in parallel for them to store the greater (a) total charge (b) total energy?
10. A man fixes outside his house one evening a two metre high insulating slab carrying on its top a large aluminium sheet of area $1m^2$. Will he get an electric shock if he touches the metal sheet next morning?
11. A small test charge is released at rest at a point in an electrostatic field configuration. Will it travel along the field line passing through that point?
12. i. Plot a graph comparing the variation of potential V and electric field E due to a point charge Q as a function of distance R from the point charge.
    ii. Find the ratio of the potential differences that must be applied across the parallel and the series combination of two capacitors, C_1 and C_2 with their capacitances in the ratio 1 : 2, so that the energy stored in the two cases becomes the same.
13. 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 connectedto a 120 V supply?
14. What is the area of the plates of a 2 F parallel plate capacitor, given that the separation between the plate is 0.5 cm?
15. Two tiny spheres carrying charges $1.5\mu C$ and $2.5\mu C$ are located 30 cm apart. Find the potential and electric field:(a) at the mid point of the line joining the two charges, and(b) at a point 10 cm from this mid point in a plane normal to the line and passing through the mid point.

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Answers

1. b. $\frac{3q}{4\pi\epsilon_0\ a^2}$

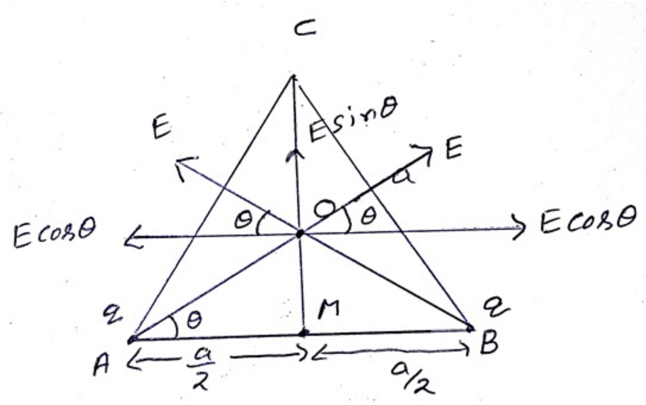
   Explanation: If a =side of the triangle then, the height of the equilateral triangle= $\frac{\sqrt{3}\times a}{2}$

   Now, the centroid of a triangle divides the median in the ratio 2:1

   Therefore, the distance between centroid to any vertices of the equilateral triangle

   $= \frac{2}{3}$ of a height of the equilateral triangle

   $= \frac{2}{3} \times \frac{\sqrt{3}\times a}{2} = \frac{a}{\sqrt{3}}$

   $E_{net} = 2E\sin\theta$

   $= 2 \times \frac{1}{4\pi\varepsilon_0}\frac{q\times 3}{a^2} \times \frac{a\times\sqrt{3}}{2\sqrt{3}\times a} = \frac{3q}{4\pi\varepsilon_0 a^2}$

2. b. directly proportional to A and Q

   Explanation: Consider a parallel plate capacitor with area A and energy density (energy per unit volume) u and let the force between the plates be F.

   If the plate separation be increased by Δx, the work done $\Delta W = F \bullet \Delta x$.

   The volume of the capacitor increases by $A \times \Delta x$.

   The increase in the potential energy of the capacitor $\Delta U = uA \times \Delta x$

   The work done is equal to the increase in potential energy.

   $F \bullet \Delta x = uA \times \Delta x$

   therefore $F \propto A$.

   Since $u = \frac{1}{2}\varepsilon_0 E^2$;

therefore $F = u \times A = \frac{1}{2}\varepsilon_0 E^2 \times A$
Since $E = \frac{\sigma}{\varepsilon_0} = \frac{Q}{A\varepsilon_0}$,
therefore $F = \frac{1}{2}\sigma AE = \frac{1}{2}QE \; F \propto Q$

3. b. one on which aluminium oxide film is formed

Explanation: Aluminium electrolytic capacitors have the Aluminium foil anode (positive terminal) which is etched and covered with a layer of Aluminium Oxide which acts as a dielectric. The whole assembly is covered using a paper separator soaked in electrolyte such as, Borax or Glycol and covered by Aluminium foil which acts as cathode (negative electrode)

4. a. qEd

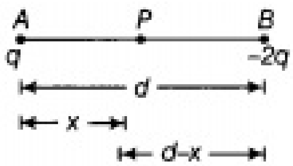
Explanation : Force F = qE and the work done w = F . d = qED

5. a. 8

Explanation: When a dielectric of constant K is introduced between the plates of a capacitor,the capacitnce becomes KC where C is initial capacitance with air as medium between plates.

Q=CV after filling the medium charge remains same thus potential V changes thus Vα $\frac{1}{c}$ thus, the potential V reduces to V/K. Therefore K=8

6. According to the question, q_A = q and q_B = -2q. Say at a distance x from the charge q_A, potential will be zero.



$\therefore V_{PA} = \frac{kq}{x} \; and \; V_{PB} = \frac{(k)\times(-2q)}{(d-x)}$

As, the potential due to system of charges is zero,

hence $V_{PA} + V_{PB} = 0 \Rightarrow \frac{kq}{x} = \frac{2kq}{(d-x)}$

$\therefore d - x = 2x \Rightarrow 3x = d \Rightarrow x = d/3$

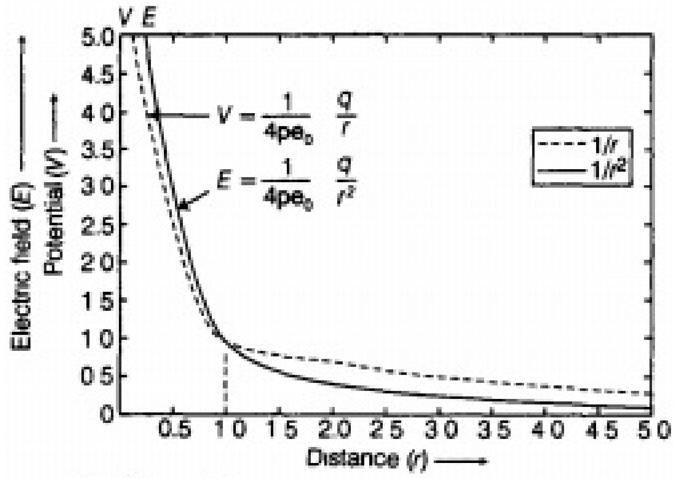
7. Electric field inside the hollow spherical charged conductor is zero, as no charge resides inside the hollow portion where there is no material of the body.

The relation between electric field intensity and potential is $\vec{E} = -\frac{dV}{dr}\hat{n}$

So if $\vec{E} = 0, \; then \; dV = 0$. Thus, the potential(V) is constant throughout the whole spehere and equal to the value at the surface, i.e. equal to its value at the surface =

10V.

8. An equipotential surface is a surface at which electric potential at each and every point on the surface is same.
   As, work done in moving a charged particle having charge +q from one point to another on any surface is defined as
   $W = q \times (V_A - V_B)$ (Say, V_A and V_B are potentials at two points A and B on the surface)
   On an equipotential surface, the potential everywhere always remains constant. So, change in potential $V_A - V_B = 0$
   $\Rightarrow$ Work done, $W = 0$
9. Total charge q = CV, and total energy $U = \frac{1}{2}CV^2$. Now V is constant and $C_p > C_{s'}$ therefore, parallel combination is required for storing greater charge and greater energy.
10. Yes, the aluminium sheet gradually is charged up by the steady discharging current in the atmosphere and raises its voltage to an extent depending on the capacitance of the capacitor. (formed by the sheet, slab and the ground).
11. Not definitely. If the field line is a straight line then only the small test charge will move along the line of force. The direction of velocity is not given by line of force, it gives direction of acceleration.
12. i. The graph comparing the variation of potential V and electric field.



Variation of electrostatic potential V and electric field E with distance r

   ii. Let C_1 = C and C_2 = 2C

   Equivalent capacitance

   In parallel combination, C_P = 2C + C = 3C

In series combination, $C_s = \frac{2C \times C}{2C + c} = \frac{2C^2}{3C} = \frac{2C}{3}$

Let V_P and V_S are potential difference across the equivalent capacitance in parallel and series combination respectively, to have same potential energy.

i.e. $U_P = U_S$

$\therefore \frac{1}{2} C_p V_p^2 = \frac{1}{2} C_s V_s^2 \Rightarrow \frac{V_p}{V_s} = \sqrt{\frac{C_s}{C_p}}$

$\Rightarrow \frac{V_P}{V_S} = \sqrt{\frac{(2C/3)}{(3C)}} = \sqrt{\frac{2}{9}}$

$\therefore V_p : V_s = \sqrt{2} : 3$, this is the required ratio of the potential differences across the parallel and series combination of the capacitors.

13. Given three capacitors

    $C_1 = C_2 = C_3 = 9_p F = 9 \times 10^{-12} F$

    a. Since the capacitors are connected in series.

    $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

    $\frac{1}{C} = \frac{1}{9 \times 10^{-12}} + \frac{1}{9 \times 10^{-12}} + \frac{1}{9 \times 10^{-12}}$

    $= \frac{1}{10^{-12}} \left[\frac{1}{9} + \frac{1}{9} + \frac{1}{9} \right]$

    $\frac{1}{C} = \frac{1}{10^{-12}} \times \frac{3}{9} = \frac{1}{3 \times 10^{-12}}$

    $C = 3 \times 10^{-12} = 3pF$

    b. Given, V = 120 volt

    $V = V_1 + V_2 + V_3$

    as capacitance are equal so

    $V_1 = V_2 = V_3 = V'$(let)

    V = 3V'

    $V' = \frac{V}{3} = \frac{120}{3} (\because C_1 = C_2 = C_3 = C)$

    = 40 volt.

14. Given, the separation between plates (d) = 0.5 cm $= 5 \times 10^{-3} m$ the capacitance (c) = 2F

    Now, $C = \varepsilon_0 \frac{A}{d}$

    $A = \frac{Cd}{\varepsilon_0} \left(\varepsilon_0 = 8.85 \times 10^{-12} F m^{-1} \right)$

    $= \frac{2 \times 5 \times 10^{-3}}{8.85 \times 10^{-12}}$

    $A = 1.13 \times 10^9 m^2$

$= 1.13 \times 10^3 km^2 = 1130 km^2$

The area of plates should be in kilometers in order to get the capacitance in Farads. Therefore, the ordinary capacitors are in the range of μF.

15. a. Potential at the mid point of the line joining the two charges is

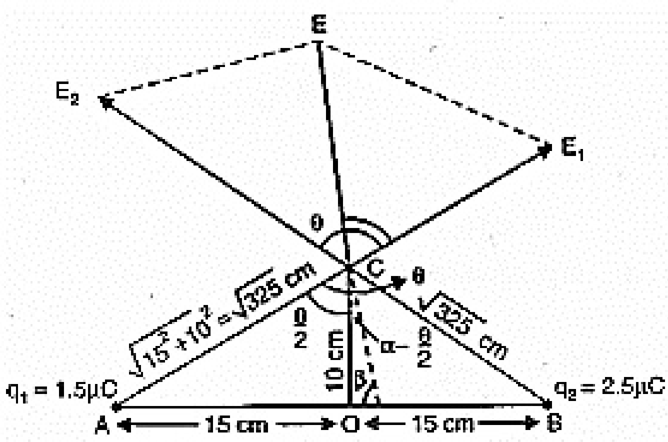
$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$

$= 9 \times 10^9 \left[\frac{15\times10^{-6}}{0.15} + \frac{2.5\times10^{-6}}{0.15}\right] V$

$= 9 \times 10^9 \times 10^{-6}\left[10 + \frac{50}{3}\right]$

$= 9 \times 10^3 \times \frac{80}{3}$

Or $V = 2.4 \times 10^5 V$



Electric field at the mid point O due to charge at A

$= \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1^2} = 9 \times 10^9 \times \frac{1.5\times10^{-6}}{(0.15)^2}$

$= 6 \times 10^5 Vm^{-1}$ along OB

Electric field at the mid point O due to charge at B

$= \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2^2} = 9 \times 10^9 \times \frac{2.5\times10^{-6}}{(0.15)^2}$

$= 10 \times 10^5 Vm^{-1}$ along OA

Thus, the total electric field at the mid point O is

$E = 10 \times 10^5 - 6 \times 10^5$

$= 4 \times 10^5 Vm^{-1}$ (along BA)

b. Potential at the point C due to the two charges is

$V = \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1}{r_1} + \frac{q_2}{r_2}\right]$

$= 9 \times 10^9 \left[\frac{1.5\times10^{-6}}{\sqrt{3.25}\times10^{-2}} + \frac{2.5\times10^{-6}}{\sqrt{325}\times10^{-2}}\right] V$

$= \frac{9\times10^9\times10^{-6}}{10^{-2}} \cdot \frac{4.0}{\sqrt{325}} V$

$= \frac{9 \times 4}{18.02} \times 10^5 V = 2 \times 10^5 V$

Electric field at C due to charge at A

$E_1 = \frac{1}{4\pi\varepsilon_0}\frac{q_1}{r_1^2}$

$= 9 \times 10^9 \times \frac{1.5 \times 10^{-6}}{\left(\sqrt{325} \times 10^{-2}\right)^2} Vm^{-1}$

$= \frac{9 \times 1.5}{325} \times 10^7 Vm^{-1}$

$= 4.15 \times 10^5 Vm^{-1}$

Electric field at C due to charge at B

$E_2 = \frac{1}{4\pi\varepsilon_0}\frac{q_2}{r_2^2}$

$= 9 \times 10^9 \times \frac{2.5 \times 10^{-6}}{325 \times 10^{-4}} = 6.92 \times 10^5 Vm^{-1}$

If the angle between E_1 and E_2 be θ then

$\tan\frac{\theta}{2} = \frac{0.15}{0.10} = 1.5$

$\frac{\theta}{2} = 56.3^\circ$ or $\theta = 112.6^\circ$

Thus, magnitude of resultant field at C is

$E = \sqrt{E_1^2 + E_2^2 + 2E_1E_2\cos\theta}$

$= \sqrt{\left(4.15 \times 10^5\right)^2 + \left(6.92 \times 10^5\right)^2 + 2 \times 4.15 \times 10^5 \times 6.92 \times 10^5 \cos 112.6^\circ}$

$= 10^5\sqrt{17.2 + 47.8 - 2 \times 4.15 \times 6.92 \cos 67.4^\circ}$

$(\because \cos(180 - \theta) = -\cos\theta)$

$= 10^5\sqrt{43} = 6.56 \times 10^5 Vm^{-1}$

Let the field E makes angle α with the field E_1

Now, $\alpha = \frac{E_2 \sin\theta}{E_1 + E_2\cos\theta}$

$= \frac{6.92 \times 10^5 \times 0.9232}{4.15 \times 10^5 - 6.92 \times 10^5 \times 0.384}$

$= \frac{6.39}{4.15 - 2.66} = \frac{6.39}{1.49} = 4.2876$

$\alpha = \tan^{-1}(4.2876) = 76.9^\circ$

If field E makes angle β with the direction BA, then

$\beta = 90^\circ - \left(\alpha - \frac{\theta}{2}\right)$

$= 90^\circ + \frac{\theta}{2} - \alpha$

$= 90^\circ + 56.3^\circ - 76.9^\circ = 69.4^\circ$

Therefore, angle of 69.4° is made by the electric field with the line joining the two charges q_2 to q_1.