PHYS143
Physics for Engineers
Tutorial - Chapter 25 - Solutions

Question 1

Oppositely charged parallel plates are separated by 5.33 mm. A potential difference of 600 V exists between the plates. (a) What is the magnitude of the electric field between the plates? (b) What is the magnitude of the force on an electron between the plates? (c) How much work must be done on the electron to move it to the negative plate if it is initially positioned 2.90 mm from the positive plate?

(a) From,

$$E = \frac{|\Delta V|}{d} = \frac{600 \text{ J/C}}{5.33 \times 10^{-3} \text{ m}} = \boxed{1.13 \times 10^{5} \text{ N/C}}$$

(b) The force on an electron is given by

$$F = |q|E = (1.60 \times 10^{-19} \text{ C})(1.13 \times 10^{5} \text{ N/C}) = \boxed{1.80 \times 10^{-14} \text{ N}}$$

(c) Because the electron is repelled by the negative plate, the force used to move the electron must be applied in the direction of the electron's displacement. The work done to move the electron is

$$W = F.s\cos\theta = (1.8 \times 10^{-14})[(5.33 - 2.90) \times 10^{-3}]\cos 0$$

$$W = 4.37 \times 10^{-17}$$

Question 2

A uniform electric field of magnitude 250 V/m is directed in the positive x direction. A +12.0-μC charge moves from the origin to the point (x, y) = (20.0 cm, 50.0 cm). (a) What is the change in the potential energy of the charge–field system? (b) Through what potential difference does the charge move?

(a) We follow the path from (0, 0) to (20.0 cm, 0) to (20.0 cm, 50.0 cm).

$$\Delta U = -(\text{work done})$$

$$\Delta U = -[\text{work from origin to (20.0 cm, 0)}]$$
$$- [\text{work from (20.0 cm, 0) to (20.0 cm, 50.0 cm)}]$$

Note that the last term is equal to 0 because the force is perpendicular to the displacement.

$$\Delta U = -(qE_x)\Delta x = -(12.0 \times 10^{-6} \text{ C})(250 \text{ V/m})(0.200 \text{ m})$$
$$= \boxed{-6.00 \times 10^{-4} \text{ J}}$$

(b) $$\Delta V = \frac{\Delta U}{q} = -\frac{6.00 \times 10^{-4} \text{ J}}{12.0 \times 10^{-6} \text{ C}} = -50.0 \text{ J/C} = \boxed{-50.0 \text{ V}}$$

Question 3

Two point charges are on the y axis. A 4.50-µC charge is located at y = 1.25 cm, and a -2.24-µC charge is located at y = -1.80 cm. Find the total electric potential at (a) the origin and (b) the point whose coordinates are (1.50 cm, 0).

The total electric potential is the sum of the potentials from the individual charges,

$$V = k_e \sum_i \frac{q_i}{r_i} = k_e \left(\frac{q_1}{r_1} + \frac{q_2}{r_2} \right)$$

(a) The 4.50-μC and –2.24-μC charges are distances 1.25 cm and 1.80 cm, respectively, from the origin. The electric potential is then

$$V = \left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right) \left[\frac{4.50 \times 10^{-6} \text{ C}}{1.25 \times 10^{-2} \text{ m}} + \frac{-2.24 \times 10^{-6} \text{ C}}{1.80 \times 10^{-2} \text{ m}} \right]$$

$$V = \boxed{2.12 \times 10^6 \text{ V}}$$

(b) The distance of the 4.50-μC charge to the point is

$$r_1 = \sqrt{(0.0150 \text{ m})^2 + (0.0125 \text{ m})^2} = 0.0195 \text{ m},$$

and the distance of the –2.24-μC charge to the point is

$$r_2 = \sqrt{(0.0150 \text{ m})^2 + (0.0180 \text{ m})^2} = 0.0234 \text{ m}$$

The potential is

$$V = \left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right) \left[\frac{4.50 \times 10^{-6} \text{ C}}{r_1} + \frac{-2.24 \times 10^{-6} \text{ C}}{r_2} \right]$$

$$V = \boxed{1.21 \times 10^6 \text{ V}}$$

Question 4

At a certain distance from a charged particle, the magnitude of the electric field is 500 V/m and the electric potential is -3.00 kV. (a) What is the distance to the particle? (b) What is the magnitude of the charge?

At a distance r from a charged particle, the voltage is $V = \frac{k_e Q}{r}$ and the field magnitude is $E = \frac{k_e |Q|}{r^2}$.

(a) $r = \frac{|V|}{|E|} = \frac{3.00 \times 10^3 \text{ V}}{5.00 \times 10^2 \text{ V/m}} = \boxed{6.00 \text{ m}}$

(b) $V = -3\,000 \text{ V} = \frac{Q}{4\pi \epsilon_0 (6.00 \text{ m})}$

Then, $Q = (6.00 \text{ m})(-3\,000 \text{ V})(4\pi \epsilon_0) = \boxed{-2.00\ \mu\text{C}}$

Question 5

How many electrons should be removed from an initially uncharged spherical conductor of radius 0.300 m to produce a potential of 7.50 kV at the surface?

Substituting given values into $V = \frac{k_e Q}{r}$, with $Q = Nq$:

$$7.50 \times 10^3 \text{ V} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2\right) Q}{0.300 \text{ m}}$$

Substituting $q = 2.50 \times 10^{-7}$ C,

$$N = \frac{2.50 \times 10^{-7} \text{ C}}{1.60 \times 10^{-19} \text{ C}/e^-} = \boxed{1.56 \times 10^{12} \text{ electrons}}$$

Question 6

A spherical conductor has a radius of 14.0 cm and a charge of 26.0 μC. Calculate the electric field and the electric potential at (a) r = 10.0 cm, (b) r = 20.0 cm, and (c) r = 14.0 cm from the center.

For points on the surface and outside, the sphere of charge behaves like a charged particle at its center, both for creating field and potential.

(a) Inside a conductor when charges are not moving, the electric field is zero and the potential is uniform, the same as on the surface, and $E = \boxed{0}$.

$$V = \frac{k_e q}{R} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{0.140 \text{ m}} = \boxed{1.67 \text{ MV}}$$

(b) $$E = \frac{k_e q}{r^2} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{(0.200 \text{ m})^2}$$

$$= \boxed{5.84 \text{ MN/C}} \text{ away}$$

$$V = \frac{k_e q}{R} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{0.200 \text{ m}} = \boxed{1.17 \text{ MV}}$$

(c) $$E = \frac{k_e q}{R^2} = \frac{\left(8.99 \times 10^9 \text{ N} \cdot \text{m}^2 / \text{C}^2\right)\left(26.0 \times 10^{-6} \text{ C}\right)}{(0.140 \text{ m})^2}$$

$$= \boxed{11.9 \text{ MN/C}} \text{ away}$$

$$V = \frac{k_e q}{R} = \boxed{1.67 \text{ MV}}$$