Multiple Choice

1. In a certain region of space, the electric field is zero. From this fact, what can you conclude about the electric potential in this region?

(a) It is zero.

(b) **It is constant.**

(c) It is positive.

(d) It is negative.

(e) None of these answers is necessarily true.

2. A particle with charge $-40\,\mathrm{nC}$ is on the x axis at the point with coordinate $x = 0$. A second particle, with charge $-20\,\mathrm{nC}$, is on the x axis at $x = 500\,\mathrm{mm}$. Is there a point at finite distance where the electric potential is zero?

(a) Yes; it is to the left of $x = 0$.

(b) Yes; it is between $x = 0$ and $x = 500\,\mathrm{mm}$.

(c) Yes; it is to the right of $x = 500\,\mathrm{mm}$.

(d) **No.**

3. A metallic sphere A of radius $1\,\mathrm{cm}$ is several centimeters away from a metallic spherical shell B of radius $2\,\mathrm{cm}$. Charge $450\,\mathrm{nC}$ is placed on A, with no charge on B or anywhere nearby. Next, the two objects are joined by a long, thin, metallic wire, and finally the wire is removed. How is the charge shared between A and B?

(a) 0 on A, $450\,\mathrm{nC}$ on B.

(b) $50\,\mathrm{nC}$ on A, $400\,\mathrm{nC}$ on B, with equal volume charge densities

(c) $90\,\mathrm{nC}$ on A, $360\,\mathrm{nC}$ on B, with equal surface charge densities

(d) **$150\,\mathrm{nC}$ on A, $300\,\mathrm{nC}$ on B.**

Short Answer

Consider a proton.

(a) Find the potential at a distance of 1.00 cm from a proton.

(b) What is the potential difference between two points that are 1.00 cm and 2.00 cm from a proton?

Now, suppose one proton was fixed in space and a second was positioned at $r_0 = 1.00\,\text{cm}$ from the first. Then the second proton is released.

(c) What is the second proton's speed at $r = 2.00\,\text{cm}$?

(d) What is the second proton's speed as $r \to \infty$?

Part (a)

Following the usual formula, at 1.00 cm the potential is

$$V_1 = \frac{k_e q}{r} = \frac{8.99 \times 10^9\,\text{Nm}^2/\text{C}^2(1.60 \times 10^{-19}\,\text{C})}{1.00 \times 10^{-2}\,\text{m}}$$

$$\boxed{V_1 = 1.44 \times 10^{-7}\,\text{V}.}$$

Part (b)

At 2.00 cm the potential is

$$V_2 = \frac{k_e q}{r} = \frac{8.99 \times 10^9\,\text{Nm}^2/\text{C}^2(1.60 \times 10^{-19}\,\text{C})}{2.00 \times 10^{-2}\,\text{m}} = 0.719 \times 10^{-7}\,\text{V}.$$

Thus the difference in potential between the two points is

$$\boxed{\Delta V = V_2 - V_1 = -7.19 \times 10^{-8}\,\text{V}.}$$

Part (c)

We already have the potential difference from $r = 1.00\,\text{cm}$ to $r = 2.00\,\text{cm}$. The difference in potential energy is $\Delta U = q\Delta V$. By conservation of energy,

$$0 = \Delta K + \Delta U = \tfrac{1}{2}m_p(v_2^2 - v_1^2) + q\Delta V.$$

We set $v_1 = 0$ and solve for v_2:

$$\tfrac{1}{2}m_p v_2^2 = -q\Delta V$$

$$v_2 = \sqrt{\frac{2q\Delta V}{m_p}} = \sqrt{-\frac{2\,(1.60 \times 10^{-19}\,\text{C})(-7.19 \times 10^{-8}\,\text{V})}{(1.673 \times 10^{-27}\,\text{kg})}}$$

$$\boxed{v_2 = 3.71\,\text{m/s}.}$$

Part (d)

This time, the final potential goes to 0. Therefore, $\Delta V = -V_1$. The rest of part (c)'s answer still applies, so substituting $\Delta V = -V_1$, we get

$$v_2 = \sqrt{\frac{2q\Delta V}{m_p}} = \sqrt{-\frac{2\,(1.60 \times 10^{-19}\,\mathrm{C})(-1.44 \times 10^{-7}\,\mathrm{V})}{(1.673 \times 10^{-27}\,\mathrm{kg})}}$$

$$\boxed{v_2 = 5.25\,\mathrm{m/s}.}$$