1. Two parallel plates having charges of equal magnitude but opposite sign are separated by 21.0 cm. Each plate has a surface charge density of 40.0 nC/m². A proton is released from rest at the positive plate.

(a) Determine the potential difference between the plates.
\[ 948.7 \text{ V} \]

(b) Determine the kinetic energy of the proton when it reaches the negative plate.
\[ 1.5 \times 10^{-16} \text{ J} \]

(c) Determine the speed of the proton just before it strikes the negative plate.
\[ 4.235 \text{ km/s} \]

(d) Determine the acceleration of the proton.
\[ 2.43 \times 10^{11} \text{ m/s}^2 \text{ (towards the negative plate)} \]

(e) Determine the force on the proton.
\[ 1.2 \times 10^{-16} \text{ N (towards the negative plate.)} \]

(f) From the force, find the magnitude of the electric field.
\[ 4.55 \text{ kN/C} \]

Show that it is equal to that electric field found from the charge densities on the plates. (Do this on paper. Your instructor may ask you to turn in this work.)

\( (a) \quad V = Ed \)

\[ E = \frac{\sigma}{\varepsilon_0} \]

\[ \Rightarrow V = \frac{\sigma}{\varepsilon_0} d = \frac{40 \times 10^{-9} \text{ C/m}^2 \times 21 \times 10^{-2} \text{ m}}{8.85 \times 10^{-12} \text{ N} \cdot \text{m}^2/\text{C}^2} \]

\[ = \frac{40 \times 21 \times 10}{8.85419} \text{ N} \cdot \text{m/C} \]

\[ = 948.7 \text{ V} \]

\( (b) \quad \text{According to energy conservation} \)

\[ E_k = qV \]

\[ = 1.6 \times 10^{-19} \times \frac{40 \times 21 \times 10}{8.85419} \text{ J} \]

\[ = 1.5 \times 10^{-16} \text{ J} \]

\[ \frac{1}{2} \frac{Z}{V^2} = \frac{1}{2} m V^2 \]

\[ V = \sqrt{\frac{Z}{m}} \]

\[ = \sqrt{\frac{2 \times 1.5 \times 10^{-16}}{1.6726 \times 10^{-27}}} \]

\[ = 4.235 \times 10^5 \text{ m/s} \]

\[ = 423.5 \text{ km/s} \]

\[ d: \quad T = \frac{q^2}{m} \]

\[ \Rightarrow q T = \frac{q^2}{m} \]

\[ \Rightarrow a = \frac{q T}{m} \]

\[ = \frac{1.6 \times 10^{-19} \times 4 \times 10^{-9}}{1.6726 \times 10^{-27} \times 8.85419 \times 10^{-12}} \]

\[ = 4.3 \times 10^{11} \text{ m/s}^2 \]

\[ E: \quad T = \frac{q^2}{m} \]

\[ = \frac{1.6 \times 10^{-19} \times 4 \times 10^{-9}}{1.6726 \times 10^{-27} \times 8.85419 \times 10^{-12}} \]

\[ = 7.2 \times 10^{-16} \text{ N} \]

\[ f = \frac{Z}{q} = \frac{7.2 \times 10^{-16}}{1.6 \times 10^{-19}} = 4.5 \text{ kN/C} \]
An electron starts from rest 8.00 cm from the center of a uniformly charged insulating sphere of radius 6.00 cm and total charge 1.00 nC. What is the speed of the electron when it reaches the surface of the sphere? (Note: Assume a reference level of potential \( V = 0 \) at \( r = \infty \)).

\[
3.6 \times 10^6 \text{ m/s}
\]

According to energy conservation,}

\[
K \frac{q_1 q_2}{r_1} - K \frac{q_1 q_2}{r_2} = \frac{1}{2} m v^2
\]

\[
\Rightarrow \quad \frac{2K}{m} \frac{q_1 q_2 (r_2 - r_1)}{r_1 r_2} = v^2
\]

\[
V = \sqrt{\frac{2K}{m} \frac{q_1 q_2 (r_2 - r_1)}{r_1 r_2}}
\]

\[
= \sqrt{\frac{2 \times 8.9875 \times 10^9 \times 1.6 \times 10^{-19} \times 2 \times 10^{-2}}{9.11 \times 10^{-31} \times 8 \times 10^{-2} \times 6 \times 10^{-2}}}
\]

\[
= \frac{2 \times 8.9875 \times 10^{14} \times 1.6 \times 2}{9.11 \times 8 \times 6}
\]

\[
= 3.6 \times 10^6 \text{ m/s}
\]
3. The potential in a region between \( x = 0 \) and \( x = 6.00 \) m is \( V = a + bx \) where \( a = 18.0 \) V and \( b = -5.00 \) V/m.

(a) Determine the potential at \( x = 0 \).

\[
\begin{align*}
18.0 \text{ V}
\end{align*}
\]

Determine the potential at \( x = 3.00 \) m.

\[
\begin{align*}
3.0 \text{ V}
\end{align*}
\]

Determine the potential at \( x = 6.00 \) m.

\[
\begin{align*}
42.0 \text{ V}
\end{align*}
\]

(b) Determine the magnitude and direction of the electric field at \( x = 0 \).

\[
\begin{align*}
5.00 \text{ V/m} \quad +x
\end{align*}
\]

Determine the magnitude and direction of the electric field at \( x = 3.00 \) m.

\[
\begin{align*}
5.00 \text{ V/m} \quad +x
\end{align*}
\]

Determine the magnitude and direction of the electric field at \( x = 6.00 \) m.

\[
\begin{align*}
5.00 \text{ V/m} \quad +x
\end{align*}
\]

\[\begin{align*}
(a) \quad V(0) &= a + 0 = a = 18.0 \text{ V} \\
V(3) &= a + b \times 3 = 18.0 - 5.00 \times 3.00 \\
      &= 3.0 \text{ V} \\
V(6) &= a + b \times 6 = 18.0 - 5.00 \times 6.00 \\
      &= -12.0 \text{ V}
\end{align*}\]

(b) \[E = -\frac{dV}{dx} = -b = 5.00 \text{ V/m} \]
4. Over a certain region of space, the electric potential is \( V = 4x - 9x^2y + 2yz^2 \). Find the expression for the \( x \) component of the electric field over this region. (Use \( x, y, \) and \( z \) as necessary.)

\[-(4-18xy)\]

Find the expression for the \( y \) component of the electric field over this region.

\[-2xy - 2z^2\]

Find the expression for the \( z \) component of the electric field over this region.

\[-4yz\]

What is the magnitude of the field at the point \( P \), which has coordinates \((4, 0, -7)\) m?

\[46.17 \text{ N/C}\]

\[\hat{E} = -\nabla V\]

\[= -\frac{\partial V}{\partial x} \hat{e}_x - \frac{\partial V}{\partial y} \hat{e}_y - \frac{\partial V}{\partial z} \hat{e}_z\]

\[= -(4-18xy) \hat{e}_x - (-9x^2+2z^2) \hat{e}_y - 4yz \hat{e}_z\]

\[\hat{E}(P) = -(4 - 18x4\times0) \hat{e}_x - (-9 \times 16 + 2 \times 49) \hat{e}_y\]

\[= -4 \hat{e}_x + 46 \hat{e}_y\]

\[|\hat{E}| = \sqrt{16 + 46^2} = 46.17 \text{ N/C}\]
5. A wire having a uniform linear charge density $\lambda$ is bent into the shape shown in Figure P25.47. Find the electron potential at point O.

- $k_0 \lambda \pi$
- $k_0 \lambda (\pi + 2 \ln 3)$  \( \checkmark \)
- $(2 \ln 3)(k_0 \lambda)$
- $k_0 \lambda (\pi - 2 \ln 3)$

Left part is:

$$\int_{0}^{2R} \frac{k_0 \lambda dr}{R+r} = k_0 \lambda \ln \frac{3R}{R}$$

Right part is equal to the left part.

Middle part is:

$$\int K \frac{zr \lambda}{R} \, dz = 1K \pi 2\lambda$$

So the total is:

$$2K \lambda \ln 3 + 10.2\lambda = k_0 \lambda (2 \ln 3 + \pi)$$
6. PSE6 25.P.049. A spherical conductor has a radius of 18.0 cm and charge of 22.0 \( \mu \text{C} \). Calculate the electric field and the electric potential at the following distances from the center.

(a) \( r = 10.0 \text{ cm} \)
- Electric field: \( 0 \text{ MN/C} \)
- Electric potential: \( 1.098 \text{ MV} \)

(b) \( r = 20.0 \text{ cm} \)
- Electric field: \( 4.94 \text{ MN/C} \)
- Electric potential: \( 0.989 \text{ MV} \)

(c) \( r = 18.0 \text{ cm} \)
- Electric field: \( 67 \text{ MN/C} \)

The magnitude is zero.

Outward.

Outward.
(a) In the conductor, the electric field is zero. The potential is equal to the potential of the surface of the conductor.

\[ V = K \frac{Q}{r} = \frac{8.9875 \times 10^9 \times 22 \times 10^{-6}}{18 \times 10^{-2}} \]

\[ = 1.098 \text{ MV} \]

(b) \[ Z = K \frac{Q}{r^2} = \frac{8.9875 \times 10^9 \times 22 \times 10^{-6}}{20 \times 20 \times 10^{-4}} \]

\[ = 4.94 \text{ MN/C} \]

\[ V = K \frac{Q}{r} = \frac{8.9875 \times 10^9 \times 22 \times 10^{-6}}{20 \times 10^{-2}} = 0.989 \text{ MV} \]

(r = 18.0 cm)

\[ Z = K \frac{Q}{r^2} = \frac{8.9875 \times 10^9 \times 22 \times 10^{-6}}{18 \times 18 \times 10^{-4}} = 6.1 \text{ MN/C} \]

\[ V = V(r=10\text{ mm}) = \frac{18 \times 18 \times 10^{-4}}{1.098 \text{ MV}} \]