I. (34)
Three identical positive point charges q are placed at each of three corners of a square whose side is L.

1. (20) What are the magnitude and direction of the net electric field at the vacant corner of the square?

2. (4) What are the magnitude and direction of the net force on a point charge -3q placed at this vacant corner?

3. (10) What should be the magnitude and sign of the charge Q to be placed at the center of the square to make a net force on a point charge -3q to be zero?

\[ E_{\text{tot}} = 2E_1 + E_3 \]
\[ E_3 = \frac{kq}{2L^2} \]
\[ E_1 = \frac{kq}{L^2}, \quad E_{1x} = \frac{kq}{(\sqrt{2}L)^2} \]
\[ E_{\text{tot}} = \frac{12kq}{\sqrt{2}L^2} + \frac{kq}{2L^2} = \frac{kq}{L^2} \left( \frac{1}{2} + \sqrt{2} \right) \]

2. \[ F = 3 \frac{kq^2}{L^2} \left( \frac{1}{2} + \sqrt{2} \right) \]

3. \[ E_a = -E_{\text{tot}} \Rightarrow \frac{2kq}{L^2} = -k \frac{q}{L^2} \left( \frac{1}{2} + \sqrt{2} \right) \]
\[ Q = -\frac{q}{2} \left( \frac{1}{2} + \sqrt{2} \right) \]
II. (33) A uniformly charged thin ring has radius 10 cm and a total charge -12 nC.
A positron (an elementary particle with a charge equal in magnitude and opposite in sign to the charge of an electron) is placed on the ring's axis a distance 25 cm from the center of the ring. The positron is then released from rest.

1. (27) Find the speed of the positron when it reaches the center of the ring.

2. (6) Describe the subsequent motion of the positron.

\[ \frac{dV}{dx} = \frac{kQ}{\sqrt{x^2 + a^2}} \]

\[ V = \frac{kQ}{\sqrt{x^2 + a^2}} \]

\[ \Delta V = V(0) - V(r) \]

\[ \Delta V = k \left( \frac{2 \times 10^{-3} C}{0.1 m} \right) \left( \frac{1}{0.1 m} - \frac{1}{\sqrt{0.25 m^2 + 0.1 m^2}} \right) = -678 V \]

\[ U(x) + K(x) = U(0) + K(0) \]

\[ m \frac{v^2}{2} = K(0) = U(x) - U(0) = \frac{Q^2 (V(x) - V(0))}{\epsilon_0} \]

\[ v = \sqrt{\frac{2 \Delta V}{m}} = \sqrt{\frac{2 \times 6.6 \times 10^{-19} C \cdot 678 V}{1.1 \times 10^{-3}}} \approx 1.54 \times 10^7 \text{ m/s} \]

2. In the center of the ring (where it has minimum potential energy) it attains maximum velocity.
So it will be harmonic motion (back and forth through the center of the ring).
A slab of insulating material has thickness \( d \) and is oriented so that its faces are parallel to the \( yz \)-plane and given by the planes \( x = -d \) and \( x = d \).

The \( y \)- and \( z \)-dimensions of the slab are very large in comparison to \( d \) and may be treated as essentially infinite. The slab has a uniform negative charge density \( \rho \).

1. Using Gauss's Law, find the electric field due to the slab (magnitude and direction) at all points in space.

2. Choosing zero potential in the middle of the slab, find the potential at all points in space.

\[
\text{III. (13)}
\]

\[
\begin{align*}
\text{a) } |x| &< d \\
-2E \cdot Ax & = \lambda d \times x \\
E & = -\frac{\rho x}{\varepsilon_0} \\
\varepsilon & = -\frac{|d|}{\varepsilon_0}
\end{align*}
\]

\[
\begin{align*}
\text{b) } |x| &> d \\
-2E \cdot Ax & = \rho x \times 2d \\
E & = -\frac{\xi}{2\varepsilon_0} \\
\varepsilon & = -\frac{|0|}{2\varepsilon_0}
\end{align*}
\]

2.\(a) \, |x| < d \)

\[
V(x = 0) - V(x) = -\int_0^x \frac{\rho x}{\varepsilon_0} \, dx = -\frac{\rho x^2}{2\varepsilon_0}
\]

\[
V(x) = -\frac{\rho x^2}{2\varepsilon_0} \\
V(d) = \frac{\rho (2d)^2}{2\cdot 2\varepsilon_0} = \frac{\rho d^2}{2\varepsilon_0}
\]

2.\(b) \, x > d \)

\[
V(x) = V(d) + \int_d^x \frac{\rho}{2\varepsilon_0} \, dx = \frac{\rho}{2\varepsilon_0} \frac{d^2}{2} + \frac{\rho}{2\varepsilon_0} (x-d)
\]

\[
V(x) = V(-d) + \int_{-d}^x \frac{\rho}{2\varepsilon_0} \, dx = \frac{\rho}{2\varepsilon_0} \frac{d}{2} + \frac{\rho}{2\varepsilon_0} (x+d)
\]