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?

\[
\begin{align*}
1. \quad E_{\text{tot}} &= 2E_1 + E_3, \quad E_3 = \frac{kq}{2L^2} \\
E_1 &= \frac{kq}{L^2}, \quad E_{1x} = \frac{kq}{\sqrt{2}L^2} \\
E_{x1} &= \frac{12kq}{\sqrt{2}L^2} + \frac{kq}{2L^2} = \frac{kq}{L^2} \left( \frac{1}{2} + \sqrt{2} \right) \\
2. \quad |F| &= \frac{3kq^2}{L^2} \left( \frac{1}{2} + \sqrt{2} \right), \quad F = -3Q \cdot \sum E_{\text{tot}} \\
3. \quad E_Q &= -E_{\text{tot}} \Rightarrow \frac{2kq}{L^2} = -\frac{kq}{L^2} \left( \frac{1}{2} + \sqrt{2} \right) \\
Q &= -\frac{q}{2} \left( \frac{1}{2} + \sqrt{2} \right)
\end{align*}
\]
II. (33)  
A slab of insulating material has thickness 2d 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. (17) Using Gauss's law, find the electric field due to the slab (magnitude and direction) at all points in space.

2. (16) Choosing zero potential in the middle of the slab, find the potential at all points in space.
I. \( |x| < d \)
\[ -2 \varepsilon E_1 A = \frac{2P A v}{\varepsilon_0} \Rightarrow \varepsilon E_1 = \frac{1}{\varepsilon_0} \]
\[ \text{Gauss' Law} : E = \frac{1}{\varepsilon_0} \frac{P A}{2} \]
\[ x > d : E = \frac{1}{\varepsilon_0} \frac{P A}{2} \]
\[ x < d : E = \frac{1}{\varepsilon_0} \frac{P A}{2} \]

II. \( |x| > d \)

\[ V(x = 0) - V(x) = -\int_0^x \frac{191 x}{2 \varepsilon_0} dx = \frac{191 x^2}{2 \varepsilon_0} \]
\[ V(d) = \frac{191}{2 \varepsilon_0} \frac{d^2}{2} \]

\[ V(x) = \frac{191}{2 \varepsilon_0} \frac{d}{2} + \frac{191}{2 \varepsilon_0} (x-d) = \frac{191}{2 \varepsilon_0} \left( x - \frac{d}{2} \right) \]
\[ x < d : V(x) = \frac{191}{2 \varepsilon_0} \left( \frac{d}{2} - x \right) \]
A uniformly charged thin ring has radius 10 cm and a total charge 12 nC. An electron is placed on the ring’s axis a distance 25 cm from the center of the ring. The electron is then released from rest.

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

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

\[
dv = \frac{kdq}{r} \quad V = Sdv \\
V = \frac{k}{V^{2} + x^{2}} \quad \frac{dV}{dt} = \frac{kQ}{VR^{x}}
\]

\[
U(x) + K(x) = U(0) + K(0) \\
m\frac{U(0)}{2} = K(0) = U(x) - U(0) = q(V(x) - V(0))
\]

\[
V(x) - V(0) = k \Theta \left( \frac{1}{\sqrt{R^{2} + x^{2}}} \right) = -8.99 \cdot 10^{-9} \frac{e \cdot m}{c} \cdot 12.10^{-9} \text{C} \\
V(x) - V(0) = -678 \text{V} \quad q = -1.6 \cdot 10^{-19} \text{C}
\]

\[
V(0) = \sqrt{\frac{2q(V(x) - V(0))}{m}} = \sqrt{2 \cdot 1.6 \cdot 10^{-19} \text{C} \cdot (678 \text{V})} \\
= 1.8 \cdot 10^{-14} \text{m/s}
\]

2. In the center of the ring (where \( e \) has a min potential energy) it gets max velocity. So it will oscillate back and forth through the center of the ring. (From energy conservation, how it will go to left by 25 cm and then back.)