**Show all work!! Report all numbers to three (3) significant figures.**

**A.** [17 pts.] A car (mass $m = 1000$ kg and charge $q = +7.2$ C) is at rest in a driveway. A uniform electric field (strength $E = 5000$ N/C) is turned on to propel the car toward the street, a distance $x = 10$ m from the car’s starting point. Find the car’s speed $v$ when it reaches the street. Assume that the car acts like a point charge.

\[ qE = F = ma \quad \Rightarrow \quad a = \frac{\frac{qE}{m}}{E} \]

\[ x = \frac{1}{2} at^2 \quad \Rightarrow \quad \sqrt{\frac{2x}{a}} = t \quad \Rightarrow \quad v = at = \sqrt{\frac{2x}{a}} \cdot a = \sqrt{2ax} \]

\[ v = \sqrt{144 \times 10 \times 5 \frac{m^2}{s^2}} = \sqrt{2 \times \frac{7.2C}{100 \, \text{Dkg}} \times 10m \times 5000 \frac{N \, C}{s^2}} = \sqrt{2 \left( \frac{qE}{m} \right) \cdot x \cdot E} \]

\[ v = 12.15 \frac{m}{s} = 26.8 \, \text{m/s} \]

**B.** [16 pts.] A simple model of the hydrogen atom consists of an electron in a circular orbit of radius $r = 5.29 \times 10^{-11}$ m about a stationary proton. Find $v$, the speed of the electron around the proton.

\[ k \frac{q_1 q_2}{r^2} = F = ma = m \frac{v^2}{r} \quad \Rightarrow \quad v = \sqrt{k \frac{e^2}{m \, r}} \]

\[ k \frac{e^2}{m \, r} = v^2 \quad \Rightarrow \quad v = \sqrt{\frac{k}{m \, r}} \cdot e \]

\[ v = \sqrt{\frac{8.99 \, \text{Nm}^2 \, \text{C}^{-2}}{9.11 \times 10^{-31} \, \text{Kg} \times 5.29 \times 10^{-8} \, \text{m}}} \times 1.6 \times 10^{-19} \text{C} = 2.19 \times 10^6 \, \text{m/s} \]
Show all work!! Report all numbers to three (3) significant figures.

A. [16 pts.] Find the electric field vector \( \mathbf{E} \), evaluated at point \( P (x,y) = (1,1) \text{ m} \), that arises from the point charges shown in the figure.

\[
\mathbf{E}_x = 3 \left( \frac{kq}{r^2} \cos 45^\circ \right) \mathbf{i} = 3 \left[ \frac{9 \times 10^9 (2)}{(\sqrt{2})^2} \cos 45^\circ \right] \mathbf{i} = 1.9 \times 10^9 \mathbf{i} \text{ N/C}
\]

\[
\mathbf{E}_y = \frac{kq}{r^2} \sin 45^\circ = \frac{9 \times 10^9 (2)}{(\sqrt{2})^2} \sin 45^\circ = 6.36 \times 10^9 \mathbf{j} \text{ N/C}
\]

\[
|\mathbf{E}| = 2 \times 10^{10}
\]

B. [17 pts.] A straight wire segment of length \( L \), aligned on the y-axis and centered at the origin, has a linear charge density is \( \lambda(y) = C \left( y^2 + \frac{a^2}{2} \right) \), where \( C \) is a constant. Find the strength of the electric field at a point located distance \( a \) from the wire on the x-axis.

\[
\mathbf{E}_x \cdot \mathbf{E}_x = \frac{k \lambda d_y \cos \theta}{r^2} \]

\[
\mathbf{E}_x = \int_{-1/2}^{1/2} \frac{k \lambda d_y a}{r^2} = 2ka \int_{-1/2}^{1/2} \frac{C (y^2 + a^2)^{3/2}}{(y^2 + a^2)^{3/2}} dy
\]

\[
= 2kaC \int_{0}^{1/2} dy = \frac{2kaC}{3} \mathbf{E}
\]
Show all work!! Report all numbers to three (3) significant figures.

An infinitely long, straight coaxial cable has a thin wire running along its axis surrounded by a conducting cylindrical pipe of inner radius \( r_i \) and outer radius \( r_o \). The pipe is electrically neutral, while the wire carries a uniform charge, with linear charge density \( \lambda \).

(a) \( [7 \text{ pts.}] \) Write the E field strength just outside the outer surface of the conducting pipe \((r \rightarrow r_o)\) in terms of the surface charge density \( \eta \).

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

(b) \( [8 \text{ pts.}] \) Find the strength of the electric field \( E \) outside of the coaxial cable at a distance \( r > r_o \) from the cable's axis. \( Q_{in} = \lambda L \) \( \varepsilon \)-field for positive charge cylinder points radially out

\[
\oint E \cdot d\vec{A} = \oint_{\text{surface}} E \cdot d\vec{A} + \oint_{\text{edges}} E \cdot d\vec{A} = EA_{\text{surface}} + 0
\]

\[
E A_{\text{surface}} = \frac{Q_{in}}{\varepsilon_0} \quad \Rightarrow \quad E = \frac{\lambda L}{2\pi r L \varepsilon_0} = \frac{\lambda}{2\pi r \varepsilon_0}
\]

(c) \( [9 \text{ pts.}] \) Find the surface charge density \( \eta \) on the pipe's outer surface in terms of radius \( r_o \) and \( \lambda \).

\[
\eta = \frac{Q}{A} = \frac{Q}{2\pi r_o L} \quad \left\{ \begin{array}{l}
Q = Q \quad \text{*some Q for both } \lambda \text{ and } \eta \\
2\pi r_o L \eta = \lambda L
\end{array} \right.
\]

(d) \( [10 \text{ pts.}] \) Find the electric field \( E' \) outside the pipe \((r > r_o)\) if the wire was removed and the pipe was filled entirely with a medium of uniform charge density \( p \).

\[
p = \frac{Q}{V} \quad \Rightarrow \quad Q_{in} = p V = p \pi r_i^2 L
\]

\[
\oint E \cdot d\vec{A} = \frac{Q_{in}}{\varepsilon_0} \quad \Rightarrow \quad EA_{\text{surface}} = \frac{p \pi r_i^2 L}{\varepsilon_0}
\]

\[
E = \frac{p \pi r_i^2 L}{2\pi r L \varepsilon_0} = \frac{p r_i^2}{2r \varepsilon_0}
\]