Midterm Exam 1

Print your full LAST name: ____________________________________________

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Prob. 1: __________
Prob. 2: __________
Prob. 3: __________
Prob. 4: __________
Adjustment: __________
Appeal: __________
TOTAL: __________ / 250
1. **(70 points total)**

   **a. (40 points)** On a set of coordinate axes (all coordinates in m), in an otherwise-empty space, a line segment of charge is placed along the x-axis, as shown. It is 4.00 m long, with its left end located at the origin.

   The linear charge density of this segment is given by $\lambda = bx^{2/3}$, where $x$ is measured in meters and $b = 1.50 \text{ C/m}^{5/3}$.

   Calculate the electric field value (both magnitude and direction) at the point (6789, 0).

   **b. (30 points)** On a set of coordinate x-y axes in an otherwise-empty space, two line segments of charge are placed as shown. The segments are of equal length. However, segment 1 has a total charge of +1.00 C, while segment 2 has a total charge of –2.00 C. Both segments have uniform charge distribution.

   Defining $\angle 0^\circ$ to the right (i.e. conventional angle measure), find the direction of the total electric field at point A.
Use this page as additional space, if needed, for problem 1
2. (70 points total) Two infinite planes (sheets) of uniformly distributed charge (+$\eta$ and $-\eta$, respectively) are positioned parallel to each other as shown. A proton and an electron are positioned as shown and are free to move, but they are at rest. You may regard the following as known values (so they may appear in your answers): $\eta$, $e$, $k$, $\varepsilon_0$

a. (25 points) Find an expression (using only known values) for the distance $d$.

b. (20 points) Evaluate the following statement (T/F/N). Justify your answer fully.

“In this situation, Gauss’ Law would be a convenient (mathematically easy) way to calculate the electric field in region 1.”

c. (25 points) Assuming that $d$ is now a known value, find the electric field (magnitude and direction) at point P, which is empty and is directly aligned with the two particles.
Use this page as additional space, if needed, for problem 2
3. **(60 points total)** Refer to the diagram here (not to scale)....

![Diagram of a long solid cylinder](image)

A very long solid cylinder of outer radius $R$ is uniformly charged throughout its volume. A short portion of this cylinder—contained within the surface drawn—has a length $L$ and a total charge $+Q$.

You may regard the following as known values (so they may appear in your answers): $R$, $L$, $Q$, $k$, $\varepsilon_0$

a. **(30 points)** Find the electric field (magnitude and direction) within the cylinder (for $0 \leq r < R$).

b. **(20 points)** Find the electric field (magnitude and direction) outside the cylinder (for $r > R$).

c. **(10 points)** What other field equation result should your result from b resemble (at least for $r >> R$)?
4. **(50 points total)** Refer to the diagram here (not to scale)....
A ball of known outer radius $R_B$ (m) is made of solid metal except for a spherical cavity (empty space) located at its center. That cavity has a known radius $R_C$ (m).

Fixed at the center of the ball’s inner cavity is a point charge $-3Q$. The ball as a whole carries no net charge (i.e. it is electrically neutral).

You may regard the following as **positive known values**: $R_B, R_C, Q, k, \varepsilon_0$

Evaluate the following statements (T/F/N). **You must fully justify each answer with a valid mix of words, diagrams and/or equations.**

a. **(25 points)** The electric field, $E_{outer}$, just beyond (outside of) the outer surface of the ball is zero.

b. **(25 points)** The electric field, $E_{center,cavity}$, within the central inner cavity of the ball has the same **non-zero** magnitude at all points $0 < r < R_C$. 

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For question 4, to be answered on this page...
Show full math/reasoning to support your solution and answer.
If you need more space, use the next page. ---->
Use this page as additional space, if needed, for problem 4
Physical constants and other possibly useful information:

\[ k = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \quad \text{Surface Area}_{\text{sphere}} = 4\pi R^2 \]

\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N} \cdot \text{m}^2) \quad \text{Volume}_{\text{sphere}} = (4/3)\pi R^3 \]

\[ e = 1.60 \times 10^{-19} \text{ C} \quad \text{Surface Area}_{\text{cylinder}} = 2\pi RL + 2\pi R^2 \]

\[ m_e = 9.11 \times 10^{-31} \text{ kg} \quad \text{Volume}_{\text{cylinder}} = \pi R^2 L \]

\[ m_p = 1.67 \times 10^{-27} \text{ kg} \]

Line segment of charge of length \( L \) and total charge \( Q \) (uniform charge distribution):

\[ |E_{\text{Bisector}}| = \frac{k|Q|}{r\sqrt{r^2 + (L/2)^2}} \quad (r \text{ is distance along bisector from segment’s midpoint)} \]

Line of charge with uniform charge distribution \( \lambda \):

\[ |E_{\text{line}}| = \frac{2k|\lambda|}{r} \quad (r \text{ is perpendicular distance from the line)} \]