Instructions

1) Do not open this exam until you are instructed to do so. Meanwhile, write your name and section number above. Allowed section numbers are 505, 506, 507, 508, and 509.

2) There are five problems worth a total of 100 points on this exam. The point value for each problem is noted at the top of the page. Please allot your time wisely.

3) Write your answers to each problem on the question page or the facing page. If you need more room and use extra work sheets be sure to indicate that you have done so. Write your name clearly on each sheet.

4) Remember most of the credit is given for correctness in setting up the problem, so if you are pressed for time, indicate the numbers you would like to evaluate in the expression and leave the calculations for later.

5) If you are unable to answer a question whose result is needed in a subsequent part of the problem, make an assumption for the needed result, indicating clearly what you are doing and then continue.

6) Partial credit will be given, however your work must be shown and clearly labeled if you expect to receive it. Further, you must show some work to receive full credit, the answer alone will not suffice.

7) You have the rest of the class period to complete this exam. Please read the problems carefully before launching into a solution.

8) Remember: A) if you are asked to find the value of a vector quantity your answer is not complete unless you give either its magnitude and direction or its components. B) answers missing units where applicable, will have points deducted.

Good Luck!
Consider three point charges, \( q_1, q_2, \) and \( q_3 \) with charges \( q_1 \) unknown, \( q_2 = 2.0 \mu \text{C} \) and \( q_3 = -2.0 \mu \text{C} \). These charges are located along the \( y \)-axis at positions \((0.0, -1.0 \text{ m})\), \((0.0, 0.0)\), and \((0.0, 1.0 \text{ m})\) respectively. These charges are fixed at these positions.

(A) (8 pts) Find the charge on \( q_1 \) necessary to have the total force on \( q_2 = 0 \).

(B) (8 pts) Find the electric field due to these three point charges at the point \((1.0 \text{ m}, 0.0 \text{ m})\).

(C) (4 pts) Sketch several electric field lines for each of the charges in the \( xy \)-plane. Note, please follow all of the rules for drawing these field lines and make sure that you draw at least 4 field lines to/from each of the charges.
PROBLEM 2 (20 points)

(A) (5 pts) A cube with dimension .3m X .3m X .3m is located in a region of uniform electric field with \( E = 5.0 \, \text{N/C} \) along the positive x-axis. The orientation of this cube relative to the E-field is shown in the figure. In addition, there is a point charge of \( 5.0 \times 10^{-10} \, \text{C} \) inside of this cube at its center. Find the flux of total E-field through this cubical surface.

(B) (5 pts) A point charge is located a distance of 50 cm from the center of a spherical surface of radius 45 cm as shown. If the charge is \( 7.0 \times 10^{-9} \, \text{C} \), find the flux of the electric field due to this charge through this surface.

(C) (5 pts) A short line segment of uniform charge with length of 0.25 m and a charge per unit length \( \lambda = 1.5 \times 10^{-10} \, \text{C/m} \) is located inside a cube of 2.50 m on a side. Find the total flux of the electric field through the surface of this cube.

(D) (5 pts) Consider a cylindrical insulating shell charge distribution of outer radius 20.0 cm and inner radius of 10.0 cm. This charge distribution has a uniform charge per unit length, \( \lambda = 0.5 \times 10^{-9} \, \text{C/m} \). Find the charge per unit volume \( \rho \) of this charge distribution.
**PROBLEM 3 (20 points)**

An early model of the atom had two electrons coming to equilibrium separated by a distance 2d inside a positive charged cloud of radius R and total charge of + 2 electron charges. See the figure below. In terms of the quantities given, answer the following:

(A) (8 pts) Using Gauss’s Law, find the electric field due to the positive charge cloud distribution for the following regions:

i) \( r < R \)

ii) \( r > R \)

(B) (8 pts) What will be the total Coulomb force felt by one of these electrons?

(C) (4 pts) In terms of the other constants given, what is the distance \( d \) where the electrons will come to equilibrium inside this charge cloud?
PROBLEM 4 (20 points)

Consider a uniformly charged semi-circular line segment of radius 0.5 m and total charge of $4.0 \times 10^{-6}$ C oriented with its center on the origin as shown in the figure.

(A) (8 pts) Find the electric field at the origin due to this charge.

(B) (12 pts) Find the electric field for any point on the z-axis due to this charge.

**Hint:** You might find the following expression for finding the electric field a good starting point:

$$E(r) = \int \frac{k dq'}{|\vec{r} - \vec{r}'|^2} \frac{\vec{r} - \vec{r}'}{|\vec{r} - \vec{r}'|}$$
PROBLEM 5 (20 points)

(A) (10 pts) An alpha particle (a helium nucleus (atomic number 2) with a charge of +2 electric charges) with energy 5.0 MeV approaches a stationary lead nucleus (atomic number 82) from infinity. If the alpha particle is heading directly at the lead nucleus and the lead nucleus is assumed to remain stationary during this process, how close will the alpha particle get before being deflected?

(B) (10 pts) You are given that the electric potential for a particular charge distribution has the functional form:

\[ V(r) = \frac{B}{(Ax^2 + By^2)} \]

where A and B are constants.

Find the electric field at any point in space due to this potential function.