Physics 272. Midterm I

Please write your name at the top of the page. There are 4 problems. Each is assigned 25 points. Show your work.

Problem 1: 25 points

Three point charges are placed on the x-axis. \( q_1 = -6.0 \mu \text{C} \) is at \( x = -3.0 \) m, \( q_2 = 4.0 \mu \text{C} \) is at the origin and \( q_3 = -6.0 \mu \text{C} \) is at \( x = 3.0 \) m.
(Useful constant: \( k = 8.99 \times 10^9 \text{ N/m}^2\text{C}^2 \))

(a) Find the magnitude of the force on \( q_1 \).

(b) What is the magnitude of the electric field at the position of \( q_1 \)?

(c) What is the direction of the electric field at the position of \( q_1 \)?
Problem 2: 25 points

An infinitely long cylinder of radius $R$ carries a uniform *volume* charge density $\rho(r) = \rho_0$.

(a) Find the magnitude of the electric field inside the cylinder as a function of radius. (draw a diagram which shows the Gaussian surface used.)

(b) Find the magnitude of the electric field outside the cylinder as a function of radius.

(c) What is the direction of the electric field? (show it on your diagram)
Problem 3: 25 points

Two concentric spherical shell conductors carry equal and opposite charges. The inner shell has radius $a$ and charge $q$; the outer shell has radius $b$ and charge $-q$.

(a) Draw a sketch of this configuration.

(b) Find the potential difference between the two shells (i.e. $V_a - V_b$). (your answer should be given in terms of $a$, $b$ and $q$.)

(c) Find the capacitance of this arrangement. (your answer should be given in terms of $a$, $b$ and $q$.)
Problem 4: 25 points

(a) Half the charge is removed from a capacitor without changing the capacitance. What fraction of its stored energy is removed along with the charge?

(b) Two charged metal spheres are connected by a conducting wire and sphere A is larger than sphere B, is the magnitude of the electric potential of sphere A (larger, smaller, or the same) as that of sphere B? Explain.

(c) Two metal balls have charge $+q$ and $-q$. How will the force on them change if the balls are placed in water, the distance between them being unchanged?

(d) Three charges $+q$, $+Q$, $-q$ are placed at the corners of an equilateral triangle as shown. What is the direction of the net force on charge $+q$?

(e) A dielectric with dielectric constant $\kappa = 3.0$ is inserted between the plates of a parallel plate capacitor, by what factor does the potential difference and capacitance change?