Homework 4

1. Two infinitesimally small point charges of +2.0 μC each are initially stationary and 5.0 m apart. (a) How much work is required to bring them to a stationary position 2.0 m apart? (b) 2.0 mm apart? (c) With a finite amount of energy, is it possible to push them together?

2. Beginning in 1906, Ernest Rutherford carried out a famous series of experiments at McGill University in which he bombarded thin gold foil with alpha particles having a mass of 6.68×10^{-27} kg and a charge of +2*e*. Most of the particles whizzed right through the foil, some were slightly deflected, and a very few were bounced (or "scattered") straight back. These results led him to speculate that every gold atom consisted of a tiny, compact, positively charged "nucleus" surrounded by a relatively huge volume of practically empty space, whose extent was defined by the orbits of its circling electrons. If an alpha particle is fired from a very distant source with an initial speed of 2.25×10^{7} m/s, straight at the nucleus of a gold atom, having a charge of +79*e*, how close does the particle get to the nucleus before it stops and gets scattered backwards?

3. Optional. Bonus 50 points in this homework.

   A Geiger-Mueller tube is a radiation detector that consists of a closed, hollow, metal cylinder (the cathode) of inner radius r_a and a coaxial cylindrical wire (the anode) of radius r_b, as shown in the figure. The charge per unit length on the anode is λ and the charge per unit length on the cathode is - λ. A special gas fills the space between the electrodes. When a high-energy elementary particle passes through this space, it ionizes atoms of the gas. The strong electric field makes the resulting ions and electrons accelerate in opposite directions. They strike other atoms of the gas to ionize them, producing an avalanche of electrical discharge. The pulse of the electric current between the wire and the cylinder is counted by an external circuit as a passing particle.

   (a) Show that the magnitude of the potential difference between the wire and the cylinder is

$$\Delta V = 2k_e\lambda \ln\left(\frac{r_a}{r_b}\right)$$

   (b) Show that the magnitude of the electric field in the space between the cathode and the anode is

$$E = \frac{\Delta V}{\ln\left(r_a/r_b\right)}\left(\frac{1}{r}\right)$$

   where *r* is the distance from the axis of the anode to the point where the field is to be calculated.