First Midterm Exam

Your name: ____________________________________________

This is a closed book exam, except that you may consult your single 8 1/2-inch by 11-inch sheet of notes if you have prepared one. You may use a calculator. You’ll have an hour and ten minutes to work the five problems. Each problem is worth 10 points. If you limit yourself to 12 minutes per problem, you will have 10 minutes left over to check your work.

Please do your work on these sheets. You may use sheets from the pile of scratch paper at the front of the room if you need more space.

In each problem be sure to show the logical steps of your reasoning. Getting the reasoning correct is just as important as getting the correct answer. If there is a numerical answer, be sure to include the appropriate units.

\[ \varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2 / \text{N-m}^2, \text{ or } \]
\[ k = 1/(4\pi\varepsilon_0) \approx 9 \times 10^9 \text{ N-m}^2/\text{C}^2 \]
\[ e = 1.6 \times 10^{-19} \text{ Coulombs} \]

1 Ångstrom (= 1 Å) = 10^{-10} meters; 1 μF = 10^{-6} Farads.

Problem 1. Suppose there is an electron at the origin.

(a) What is the magnitude of the electric field \( \mathbf{E} \) at the point \( x = A = 2 \) Ångstroms? Please also draw an arrow on the diagram showing the direction of \( \mathbf{E} \).

(b) What is the value of the electric potential \( V \) at the point \( x = A \)? You may assume that \( V = 0 \) infinitely far from the electron.

(c) Now suppose a second electron is placed at \( x = A \). What is the potential energy of the resulting configuration of the two electrons? Make the same assumption as in (b), i.e., that \( V = 0 \) infinitely far from the electrons. Express your answer in both electron-volts and in Joules. Try to get the right sign for your answer.
Problem 2. Now suppose a proton is placed at \( y = B = 2 \text{ Å} \), and an electron is placed at \( x = A = 2 \text{ Å} \). (No charge exists at \( x = y = 0 \).) (a) Show by drawing an arrow on the diagram the direction of the electric field \( E \) at the origin.

(b) What is the magnitude of \( E \)?

(c) What is the value of the electric potential \( V \) at the origin? Again assume that \( V = 0 \) infinitely far from the origin.

(d) Now imagine a Gaussian surface consisting of a sphere of radius \( R = 3 \text{ Å} \) centered on the origin. What is the magnitude of the total electric flux \( \Phi \) through this surface?
Problem 3. I have a 10-watt headlamp for my bicycle that is driven by a 7-volt battery. A diagram appears at the right, with the lamp represented by the resistor $R$.

(a) If the lamp runs for 1 hour, how many Joules of energy are dissipated in the lamp?

(b) How much current flows in the lamp?

(c) What is $R$, the resistance of the lamp?

(d) If two lamps, each of resistance $R$, are connected in series to the battery, how much power does each lamp dissipate?
Problem 4. Suppose a capacitor is constructed from two circular metal plates, as shown by the diagram at the right—much like the one we used in our lecture demonstration. The plate separation $d = 1$ cm, and the radius of each plate is $r = 10$ cm. Closing the switch will apply a voltage of 100 volts to the capacitor plates.

(a) What is the magnitude of the electric field $E$ in the region between the plates when the switch is closed? In which direction does $E$ point?

(b) What is $Q$, the charge on the positive plate?

(c) What is $C$, the capacitance of this capacitor? (Include the units.)

(d) The switch is now opened. If the plate separation is then halved to 0.5 cm, what happens to (i) the field between the plates, and (ii) the voltage between the plates?

Problem 5. For this problem, $R = 1000\Omega$, and $C = 0.01\mu F$.

(a) What is the capacitance between A and B for the diagram shown at the right?

(b) What is the resistance between A and B for the diagram shown at the right?