General Physics - E&M (PHY 1308) Lecture Notes

Homework001

SteveSekula, 26 January 2011 (created 20 August 2010)

no tags

Expectations for the quality of your handed-in homework are available at http://www.physics.smu.edu/sekula/phy1308/homework.pdf. Failure to meet these guidelines will result in loss of points as detailed in that document. This assignment covers material from Wolfson Chapter 20.

This homework is due no later than 8:00 pm on Monday, January 31.

Reading Assignment:

Chapter 20 (all): This was assigned last week, but this week we will delve deeply into the mathematics of electricity. Read through the chapter again in lieu of the lectures to better understand the material.

Optional Practice

If you would like to "warm up" for the homework, I recommend the following (*these problems are not required*):

- Work the examples in the body of the chapter text. They are a decent template toward approaching and solving new problems. They cover basic technique, which when mastered will serve you very well.
- Try solving the following odd-numbered problems, answers to which are available in the back of your textbook or in the student solution manual:
  - CH20-15
  - CH20-21
  - CH20-25

Required Problems:

The following problems are REQUIRED in this homework assignment:

- SS-2 (see below) [50 Points]
- SS-3 (see below) [10 Points]
- SS-4 (see below) [5 Points]

Problem SS-2: Exploring Charge, Force, Field, and Motion

To understand the mathematical concepts behind the description of the electric force and field, you need to practice repeatedly using the mathematics to attack problems. This long problem will give you such exercise, and teach you something about acceleration, energy, and what you should expect from electric charges in material.

Part 1: the force between two particles

Consider two charged particles, as illustrated below. Charge 1 posses an electric charge of $q_1 = 3.8 \times 10^{-19}\mathrm{C}$ and charge 2 posses an electric charge of $q_2 = -1.6 \times 10^{-19}$. Charge 1 has a mass of $m_1 = 3.34 \times 10^{-27}\mathrm{kg}$ and charge 2 has a mass of $m_2 = 9.11 \times 10^{-31}\mathrm{kg}$. The coordinates of the two charges in this Cartesian Coordinate System are indicated in the drawing.

1. **What is the *total electric charge* of this system of charges?**

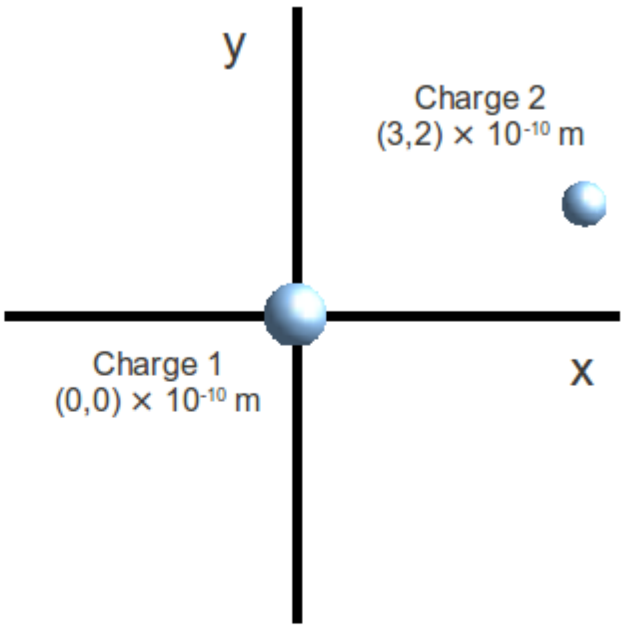
2. **What is the distance separating the two charges?**

3. **What is the unit vector that points from charge 1 to charge 2? (write this as a vector in the notation (x, y), where x and y are the components of the unit vector)**

4. **What is the electric force exerted by charge 1 on charge 2? (write this as a vector, $\vec{F} = (F_x, F_y)$)**

5. **What is the electric force exerted by charge 2 on charge 1? (again, write this as a vector)**

6. **What is the initial acceleration of charge 2 due to the force exerted by charge 1? (write this as a vector)**



Part 2: acceleration of charges in electric fields

Consider now an electron, charge $q = -1.6 \times 10^{-19}\mathrm{C}$ and mass $9.11 \times 10^{-31}\mathrm{kg}$. The electron is immersed in a uniform electric field whose strength is $1.20 \times 10^{-6}\mathrm{N/C}$ and which points entirely along the negative direction of the x-axis. If we let $\hat{\imath}$ denote a unit vector along the x-axis and $\hat{\jmath}$ a unit vector along the y-axis (of a Cartesian coordinate system), then we can write this electric field as

$$\vec{E} = (-1.20\hat{\imath} + 0\hat{\jmath}) \times 10^{-6}\mathrm{N/C} = (-1.20 \times 10^{-6}\mathrm{N/C})\hat{\imath}.$$

1. **Assume that there are no obstacles in the path of this electron. If it begins at rest (zero speed), after $1.0\mathrm{s}$, what is the speed of the electron?**

Part 3: accelerated charges with obstacles

Now let us place the electron in the same electric field as in Part 2, but let's consider the electron being accelerated inside of a material, such as copper. Copper is a metal made from copper atoms. The atoms are arrange in a periodic (regular) structure called a "crystal lattice" - imagine this as a 3-dimensional grid of atoms, where each node on the grid marks the location of an atom. Now the electron has a chance of hitting a copper atom and losing all of its energy to the atom. It then must be re-accelerated by the electric field each time it loses all of its energy.

1. **If the average distance an electron can travel before hitting a copper atom and losing all of its energy is $3.9 \times 10^{-8}\mathrm{m}$, what is the kinetic energy possessed by the electron just before it collides with a copper atom? (assume it began at rest)**

2. **Consider a different material, and consider an electron in that material still exposed to the same strength uniform electric field. If the average distance an electron can travel in this second material is *shorter*, $3.9 \times 10^{-12}\mathrm{m}$, what is the kinetic energy possessed by an electron just before striking an atom in this material? (again assume it was accelerated by the electron field from zero speed).**

3. **When a collision occurs inside a material, and energy is transfered to atoms in the lattice, the atoms will vibrate back and forth in the lattice. This vibration of atoms is the origin of *heat* and other forms of radiated energy from materials (e.g. light), called *radiation*; more energy means more vibration, and more vibration means more radiation. Let us assume that each electron collision transfers all of the electron kinetic energy to the struck atom. Which situation do you expect to lead to more radiation: the case of the longer collision distance (copper), or the shorter collision distance (the second material)? Defend your answer.**

Problem SS-3: Carpet Shock

1. A typical static electric shock from rubbing your feet on the carpet involves delivering about -3.0×10^{-8} C from your hand to the doorknob. **How many electrons are transferred from your hand in the process?**

2. Assuming that just before the spark jumps from your hand to the doorknob that the charge on the doorknob has the same magnitude as the charge on your fingertip, **what is the magnitude of the electric force between your fingertip and the doorknob if they are 5.0mm apart?**

Problem SS-4: The Electric Field of the Heart

The human heart lies about 40mm below the surface of the chest. It operates, in part, through the use of electric charge to induce a rhythmic contraction of the muscle tissue (systole). For examples of this, visit http://thevirtualheart.org/. During the systolic phase of heart operation, when blood is forced through the heart, the net electrical charge in the heart is about 2.0×10^{-13} C. Treat the heart as if all of its charge is located at a single point whose size can be neglected.

1. **What is the magnitude of the electric field, emitted by the heart during systole, at the surface of the human chest?**