Due by 6:00 pm on Thursday, February 13

Assignments should be dropped into your Section TF's locked mailbox (not the cubby underneath), located on the 2nd floor near room 201, and will be graded by your TF.

Reading: Chapter 16 of Giambattista et al *Physics, 2nd edition*, pp 561-584

Problems: [4 pts each]

1. Suppose that you approach an elephant with two known oppositely charged Styrofoam puffs in order to determine if the beast is itself charged. The first puff (+) is attracted, the second (-) repelled. What does that tell you? Which puff provides the unambiguous evidence? Explain.

2. How many electrons are there in a tablespoon (15 cc) of water? What is the net charge of all of these electrons?

3. Two identical metal balls are suspended by insulating strings. Both balls have the same net charge.

   (a) Draw a separate free-body diagram for each ball. Label the forces to indicate i) the object exerting the force, ii) the object on which the force is exerted, iii) the type of force (gravitational, normal, etc.).
   (b) Predict what will happen if the charge on the second ball is reduced slightly, so it is less than that of the first bell. Draw a sketch to illustrate your answer. Is the angle that ball 1 makes with the vertical, greater than, less than, or equal to the angle that ball 2 makes with the vertical? Explain your reasoning. How does the free-body diagram for each ball in this case compare to the corresponding free-body diagram that you drew in part (a)? If the magnitude or directions of any of the forces change, explain how they change.
   (c) Predict what will happen if the net charge on the second ball is reduced to zero. Draw a sketch to illustrate you answer.

4. Coulomb’s law allows us to find the force between two point charges. Imagine two point charges are held fixed in place on the x-axis. One has positive charge +Q and is fixed to the origin. The other has negative charge –Q and is fixed at x=6. Another positive point charge +q is released from rest halfway between them (at x=3). Consider the following student comment about this situation: “There will be zero net force on the charge in the middle. Using Coulomb’s law, the force due to the +Q charge is positive, and the force due to the –Q charge is negative. The forces cancel.”

   (a) Do you agree with the statement?
   (b) How does Coulomb’s law apply to situations in which there are more than two point charges?
5. Two charges of +4.0 \(\eta\)C and -1.0 \(\eta\)C are fixed to a baseline at a separation of 1.0 m. Where on the baseline should a third charge of +2.0 \(\eta\)C be placed if it is to experience zero net electric force?

The last three problems are directly related to the first take-home lab. You may wish to read the first part of that if the following questions don’t make sense to you.

6. *The number of excess electron charges on the surface of a negatively charged tape:* (These excess electron charges may be individual electrons that have been stripped out of the other tape or, more probably, they are negative ions that are fragments of large organic molecules which broke at a weak point in the molecule, or the excess negative charge may be due to a loss of positive ions to the other surface.)

A piece of \(\frac{1}{2}\)-inch-wide (1.2 cm) tape, 8 inches long (20 cm), has a mass of about 0.16 grams. Suppose you charged two pieces of tape and, having suspended one piece horizontally, you somehow managed to electrostatically levitate the second piece of tape above the first. If the second piece of tape levitates about 1 cm above the first, calculate the charge in Coulombs (and also in terms of the equivalent number of electrons) on each piece of tape. Reason from the fundamental Newton’s second law and Coulomb’s law. Make any simplifying assumptions or approximations that seem necessary, but state explicitly what they are.

7. *Fraction of surface molecules affected:* After you have determined the number of excess electron charges on the surface of a tape, it is interesting to compare this number with the number of molecules on the surface of the tape. Assume that the distance between the centers of adjacent molecules on the surface is about \(3\times10^{-8}\) cm. What is the fraction of excess electron charges on the surface divided by the number of molecules on the surface? This gives you some idea of how rare an event it is for a tape to pull a singly charged ion or a single electron off another tape and hold onto it. It also gives you some idea of the great strength of electric interactions: adding or removing only a miniscule fraction of the charge from the surface of a tape is sufficient to yield easily observable forces.

8. *Critical density of charge on a tape:* If the density of charge on the surface is greater than about \(5\times10^{-5}\) Coulomb/m\(^2\) (\(5\times10^{-9}\) Coulomb/cm\(^2\)), the charges will exert electric forces on the neighboring air sufficient to trigger a spark in the air. How does the density of charge you computed in the previous problem compare with this critical density? (If the critical density is about to be exceeded as you pull the tapes apart, there will be a spark which prevents exceeding the critical density!)
Multiple Choice Questions: Each multiple choice question or incomplete statement has one best answer — determine the best answer and explain your choice by invoking the appropriate concept, principle, and/or mathematical relation. Answers without explanation will not receive full credit, even if correct. [2 pts each]

1. Sphere A carries a net charge and sphere B is neutral. Both are conducting spheres and they are placed near each other on an insulated table. Which statement best describes the electrostatic force between them?
   a) There is no force between them since one is neutral.
   b) There is a force of attraction between them.
   c) There is a force of repulsion between them.
   d) The force is attractive if A is charged positively and repulsive if A is charged negatively.

2. Sphere A carries a net positive charge and sphere B is neutral. Both are conducting spheres and they are placed near each other on an insulated table. Sphere B is briefly touched with a wire that is grounded. Which statement is correct after the ground wire is removed?
   a) Sphere B remains neutral.
   b) Sphere B is now positively charged.
   c) Sphere B is now negatively charged.
   d) The charge on sphere B cannot be determined without additional information.

3. The graph that best represents the relation between the electrostatic force $F$ associated with two point charges and the distance $d$ separating the point charges is

![Graphs (a) to (e)]
4. Does a neutral object experience a net force in an electric field?

a) no
b) only in a uniform field
c) only in a non-uniform field
d) yes, because the field polarizes the object