Your name: ____________________ **Lab section:** M Tu Wed Th F

TA name: _____________________ 8 10 12 2 4

Lab 2. Electric Fields

INTRODUCTION:

In class we have learned about electric charges and the electrostatic force that charges exert on each other. Another way of looking at this is to recognize that every charge creates an **electric field** all around it. When a *second* charge is placed in the electric field, it feels a force due to the field – but the field from the original charge is always there, whether or not it is acting on any other charges.

The electric field is a vector quantity and has a magnitude and direction at each point in space. The magnitude of the electric field at a point is the magnitude of the force that would be exerted on a test charge of 1 Coulomb that was placed at that point. The direction of the electric field gives the direction of the force on that test charge. Although it may not be obvious to you why this is a useful way of thinking about the interaction of two simple charges, splitting the problem into charges that produce an electric field and other charges that interact with this field turns out to be a very powerful technique when many charges are involved or when the geometrical arrangement is complicated.

In today's lab we'll explore the electric fields around charges. The goal is to gain some intuition about the electric fields and to learn how to add electric fields.

PART I: ELECTRIC FORCES AND FIELDS

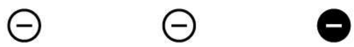
A. In the lab you should have a number of diagrams, printed on paper and transparency foil, of the electric field around a single point charge (either positive or negative). Describe as many details about the field patterns for both the positive and negative charges as you can notice.

In general, how does the electric field at a point in space relate to the electric force on a charge placed at that point?

B. In each of the figures below, draw a vector representing the **net force** felt by the **dark-colored charge**. (To indicate the force on an object, draw a force vector arrow coming out of that object.) Draw the vectors to scale, so that longer arrows represent larger forces. Assume all single charges have the same magnitude.

1. 

2. 

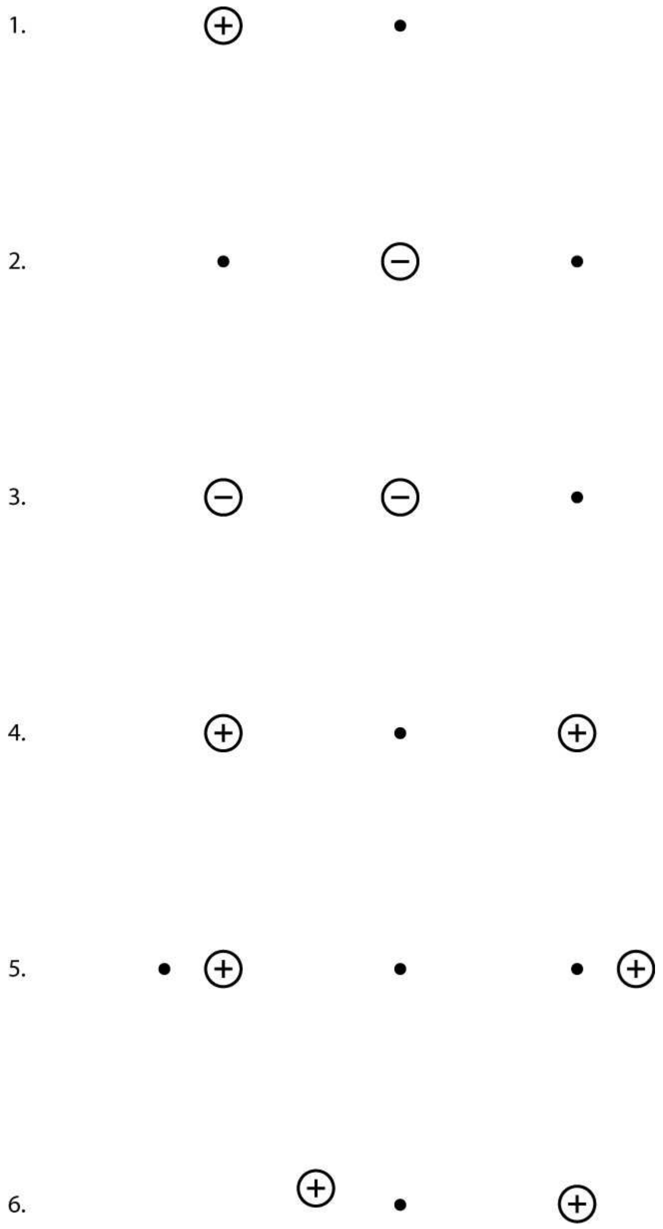
3. 

4. 

5. 

6. 

C. In each of the figures below, draw a vector representing the **electric field** at the dots. Draw the arrows to scale, so that longer arrows represent stronger fields.



PART II: SUPERPOSITION OF ELECTRIC FIELDS

In case more than one electric field is present, the **principle of superposition** is used to find the total electric field at a given point in space. This just means that at any given point, the **total** electric field is equal to the **vector sum** of the electric fields produced by each charge: $\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 + ...$

A. Overlay a transparency foil over a paper diagram, so that you can see two sets of **electric field** vectors – one set from each of two point charges. Describe the *total* electric field surrounding the charges if a **positive** charge is placed *exactly on top of* a **negative** charge. Is this similar to any situation found in nature?

B. Using a pair of electric field vector diagrams for two charges of **opposite** sign, offset the transparency relative to the paper (by some **even** number of grid spacings), and lay a piece of tracing paper over the whole thing. On the tracing paper, mark the location and sign of the charges. At each grid point, draw an arrow which represents the **total** electric field at that point.

Where is the field the strongest? Where is it the weakest? Does it go to zero anywhere? Are there any other noticeable details?

C. Repeat part B for two charges of the **same** sign.

Where is the field the strongest? Where is it the weakest? Does it go to zero anywhere? Are there any other noticeable details?

PART III: SUPERPOSITION OF ELECTRIC FIELDS (REVISITED)

Go to the simulation web-site (http://phet.colorado.edu/simulations), select under “Physics” the section “Electricity, Magnets and Circuits” and then run the “Charges and Fields” simulation. Here you can place positive and/or negative charges wherever you like on the screen.

A. Drag a positive charge from the red box to near the left side of the screen. Check the “Show E-field” box only. Notice that the strength of the field is indicated by the darkness of the arrows, rather than the arrow length as on your paper.

Now drag a negative charge to near the right side of the screen. Is the electric field pattern similar to what you drew on paper? If not, why not?

B. Repeat part A, but now with two charges of the same sign. Describe the differences between the two cases.

PART IV: ELECTRIC FIELD HOCKEY – THE CHALLENGE

Go to the simulation web-site (http://phet.colorado.edu/simulations), select under “Physics” the section “Electricity, Magnets and Circuits” and then run the “Electric Field Hockey” simulation. The aim of the game is to direct the black (positive) charge into the goal by placing positive (red) and/or negative (blue) charges on the screen. You can drag the charges from the boxes near the top side of the screen. Place one (or several) charges wherever you like on the screen. (*Hint: Switch on the “field” button to view the electric field generated by the charges*). Once you believe you have set up your configuration of charges, press the “start” button and see if you score a goal. No, try again after pressing “clear”.

It is likely that you will score on the “practice” level, but here is the challenge: Will you be able to score on levels 1 to 3 as well? Discuss the configuration of charges needed to direct the charge in the goal. What do you have to change if the black charge is negative?

REVIEW: POTENTIAL EXAM QUESTIONS

You may want to use the rest of the lab for an optional exam review. The following questions are not part of the lab, ***you won't be graded on the answers****. Questions like these – but not identical – may appear on the exam. You are welcome to discuss the questions and your answers with your fellow students or the instructors.*

1. Which of the following statements is/are true?

a) It is possible to charge up a steel ball *positively* using a *positively* charged plastic rod and a grounding plate.

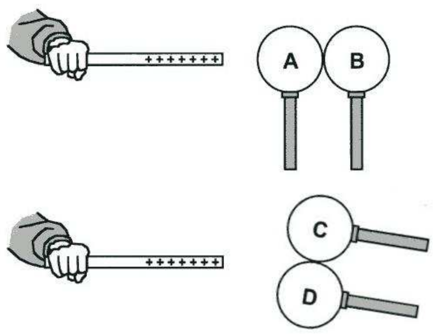
b) It is possible to charge up a steel ball *negatively* using a *positively* charged plastic rod and a grounding plate.

c) Both statements a) and b) are true.

d) Neither statement a) nor b) is true.

2. In the following diagram, the spheres in each pair are initially in contact, but they are then separated while the rod is still in place. The rod is then removed.

Which of the following is the correct order of the final charge on the spheres, from most negative to most positive?



a) ABCD

b) ADCB

c) BCDA

d) DCBA

e) All of the spheres have the same charge

3. Two conducting spheres are hanging next to each other. Which of the following cases demonstrate unambiguously that BOTH spheres are charged:

a) The spheres are attracted to each other.

b) The spheres are repelled from one another.

c) The spheres are either repelled or attracted from one another.

d) The spheres do not affect one another.

e) There is no definitive way to tell.

4. Two point charges $Q_1 = 100\mu C$ and $Q_2 = 2\mu C$ are separated by a distance of $l = 1m$. Which of the following statements is/are true?

a) The force F_{12} that Q_1 exerts on Q_2 is larger than the force F_{21} that Q_2 exerts on Q_1.

b) The force F_{12} that Q_1 exerts on Q_2 is smaller than the force F_{21} that Q_2 exerts on Q_1.

c) Both forces, F_{12} and F_{21}, have the same magnitude.

d) The ratio of the forces F_{12}/F_{21} depends on the magnitudes of Q_1 and Q_2.

e) The ratio of the forces F_{12}/F_{21} does not depend on the magnitude of l.

5. Which of the following statements is/are true?

a) The electric field is a scalar.

b) Electric field and force have the same dimensions.

c) Both statements a) and b) are true.

d) Neither statement a) nor b) is true.

6. Which of the following statements is/are true?

a) The electric field is zero at the midpoint between two negative charges of equal magnitude.

b) The electric field is zero at the midpoint between two positive charges of equal magnitude.

c) The electric field is zero at the midpoint between a positive and a negative charge of equal magnitude.

d) Both (a) and (b) are true.

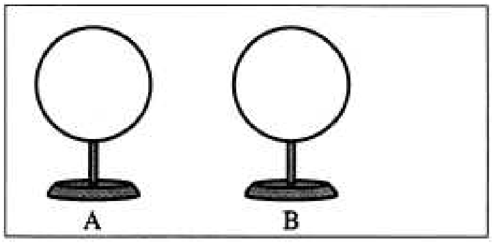
e) None of the above statements is true.

Note: There is one more problem at the back of this page

7. Two identical conducting balls, A and B, are attached to insulating stands. The net charge on ball A is +*Q*, and there is no net charge on ball B.

a. In the diagram below, sketch the charge distribution on ball B.

b. Balls A and B are observed to attract. Use your sketch (and a brief explanation in the space beside the diagram) to account for this attraction.

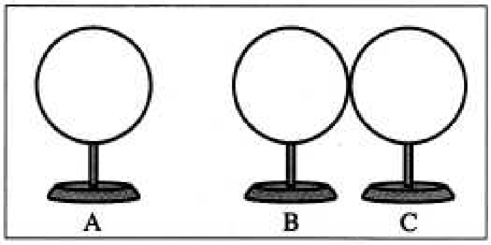


A third identical conducting ball, ball C, with zero net charge is brought into contact with ball B. The distance between balls A and B does not change.

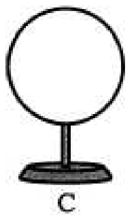
c. Does the attraction between balls A and B (**circle one!**)

increase *decrease* or *remain the same*

Explain your answer.



d. We have redrawn ball C (only) (for your convenience) below: Please indicate the direction of the electric force on ball C by ball A. If this force is zero, state that explicitly. Explain your reasoning.



e. The three balls are arranged so that they all touch, as shown in the top view diagram. What is the sign and the magnitude of the charge on ball C? Explain.