

**I. Electrical interactions**

- A. Press a piece of sticky tape, about 15–20 cm in length, firmly onto a smooth unpainted surface, for example, a notebook or an unpainted tabletop. (For ease in handling, make “handles” by folding each end of the tape to form portions that are not sticky.) Then peel the tape off the table and hang it from a support (*e.g.*, a wooden dowel or the edge of a table).

Describe the behavior of the tape as you bring objects toward it (*e.g.*, a hand, a pen).

- B. Make another piece of tape as described above. Bring the second tape toward the first. Describe your observations.

It is important, as you perform the experiment above, that you keep your hands and other objects away from the tapes. Explain why this precaution is necessary.

How does the distance between the tapes affect the interaction between them?

- C. Each member of your group should press a tape onto the table and write a “*B*” (for bottom) on it. Then press another tape on top of each *B* tape and label it “*T*” (for top).

Pull each pair of tapes off the table as a unit. After they are off the table, separate the *T* and *B* tapes. Hang one of the *T* tapes and one of the *B* tapes from the support at your table.

Describe the interaction between the following pairs of tape when they are brought near one another.

- two *T* tapes
- two *B* tapes
- a *T* and a *B* tape

- D. Obtain an acrylic rod and a piece of wool or fur. Rub the rod with the wool, and then hold the rod near newly made *T* and *B* tapes on the wooden dowel.

Compare the interactions of the rod with the tapes to the interactions between the tapes in part C. Describe any similarities or differences.

We say that the rod and tapes are *electrically charged* when they interact as you have observed.

- E. Base your answers to the following questions on the observations you have made thus far.

1. Is it possible that there is only one type of charge? If not, what is the minimum number of different types of charge needed to account for your observations thus far? Explain.
2. By convention, a glass rod is said to be "positively charged" when rubbed with silk. Your instructor will tell you whether your acrylic rod is positively or negatively charged when rubbed with the particular material you are using.

How do two objects that are positively charged interact? Explain how you can tell.

Which tape, *T* or *B*, has a positive charge? Explain.

- ⇨ Discuss part I with a tutorial instructor before continuing.

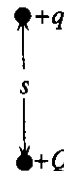
*Please remove all tape from the tabletop before continuing.*

## II. Superposition

*Coulomb's law* states that the electric force between two *point charges* acts along the line connecting the two points. (A *point charge* is a charged object that is sufficiently small that the charge can be treated as if it were all located at a single point.) The magnitude of the force on either of the charges is proportional to the product of the charges and is inversely proportional to the square of the distance between the charges.

A. Two positive point charges  $+q$  and  $+Q$  (with  $|Q| > |q|$ ) are held in place a distance  $s$  apart.

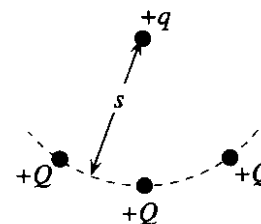
1. Indicate the direction of the electric force exerted on each charge by the other.
2. Is the force on the  $+q$  charge by the  $+Q$  charge *greater than, less than, or equal to* the force on the  $+Q$  charge by the  $+q$  charge? Explain.
3. By what factor would the magnitude of the electric force on the  $+q$  charge change if the charges were instead separated by a distance  $2s$ ?



B. Two more  $+Q$  charges are held in place the same distance  $s$  away from the  $+q$  charge as shown. Consider the following student dialogue concerning the net force on the  $+q$  charge:

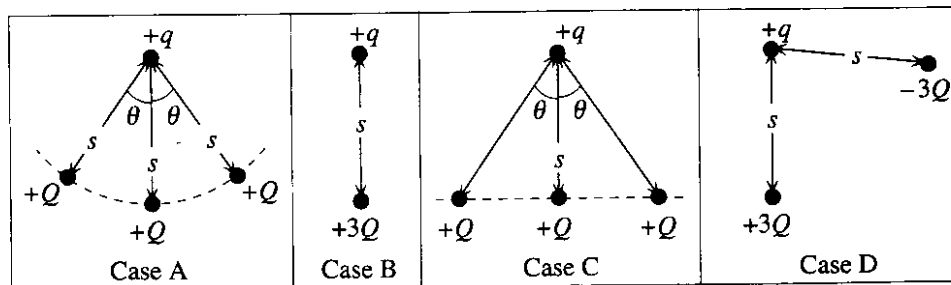
Student 1: "The net electric force on the  $+q$  charge is now three times as large as before, since there are now three positive charges exerting forces on it."

Student 2: "I don't think so. The force from the  $+Q$  charge on the left will cancel the force from the  $+Q$  charge on the right. The net electric force will be the same as in part A."



1. Do you agree with either student? Explain.
2. Indicate the direction of the net electric force on the  $+q$  charge. Explain.
3. What, if anything, can be said about how the magnitude of the net electric force on the  $+q$  charge changes when the two  $+Q$  charges are added? Explain.

C. Rank the four cases below according to the magnitude of the net electric force on the  $+q$  charge. Explain how you determined your ranking.



⇒ Check your ranking with a tutorial instructor before continuing.

### III. Distributed charge

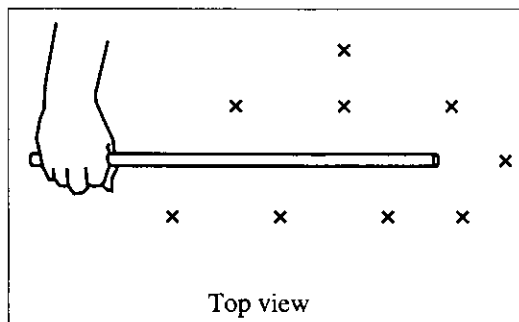
- A. Charge an acrylic rod by rubbing it with wool.

Obtain a small pith ball attached to an insulating thread. Touch the ball to the charged rod and observe the behavior of the ball after it touches the rod.

Is the ball charged after it touches the rod? If so, does the ball have the same sign charge as the rod or the opposite sign charge? Explain how you can tell.

- B. Hold the charged rod horizontally. Use a charged pith ball to explore the region around the rod. On the basis of your observations, sketch a *vector* to represent the net electric force on the ball at each of the points marked by an "x."

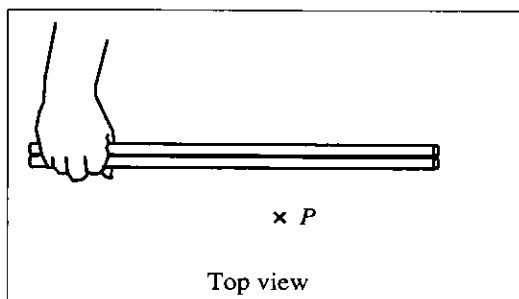
Is all of the charge on the rod located at a single point? (e.g., Is all the charge at the tip of the rod? At the middle?) Explain how you can tell.



On the basis of the vectors you have drawn, is it appropriate to consider the charged rod as a point charge? Explain.

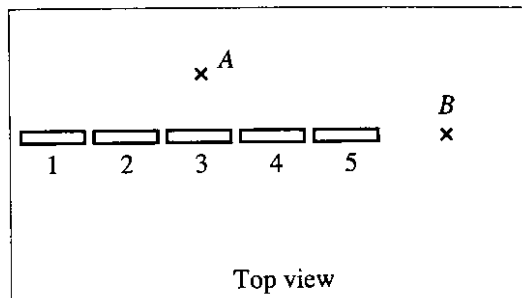
- C. Imagine that two charged rods are held together as shown and a charged pith ball is placed at point  $P$ .

Predict whether the rod farther from point  $P$  would exert an electric force on the pith ball. Explain.



Check your prediction by placing a charged pith ball at point  $P$  near two charged rods and then slowly moving one rod away from the other. Describe your observations and discuss with your partners whether your results from this experiment support your prediction.

- D. Five short segments (labeled 1–5) of acrylic rod are arranged as shown. All were rubbed with wool and have the same magnitude charge. A charged pith ball is placed in turn at the locations marked by points A and B.



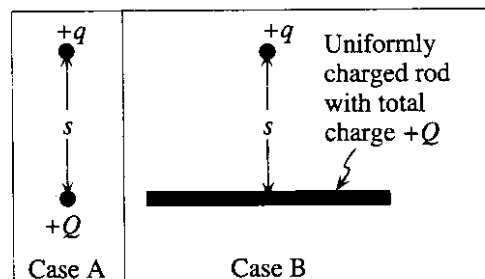
Indicate the approximate direction of the force on the pith ball at points A and B due to segment 5 alone.

What is the direction of the *net force* on the pith ball at points A and B? Explain how you determined your answer.

Does segment 2 exert a force on the pith ball when the pith ball is placed at point B? Explain.

- E. In case A at right, a point charge  $+q$  is a distance  $s$  from the center of a small ball with charge  $+Q$ .

In case B the  $+q$  charge is a distance  $s$  from the center of an acrylic rod with a total charge  $+Q$ .



Consider the following student dialogue:

Student 1: *“The charged rod and the charged ball have the same charge,  $+Q$ , and are the same distance from the point charge,  $+q$ . So the force on  $+q$  will be the same in both cases.”*

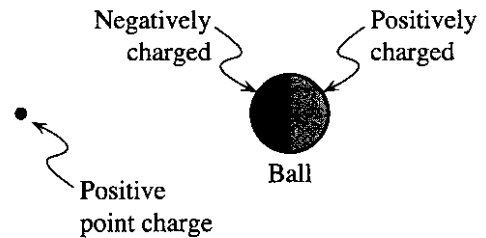
Student 2: *“No, in case B there are charges spread all over the rod. The charge directly below the point charge will exert the same force on  $+q$  as the ball in case A. The rest of the charge on the rod will make the force in case B bigger.”*

Neither student is correct. Discuss with your partners the errors made by each student. Write a correct description of how the forces compare in the space below. Explain.

**IV. A model for electric charge**

- A. A small ball with zero net charge is positively charged on one side, and equally negatively charged on the other side. The ball is placed near a positive point charge as shown.

Would the ball be *attracted toward*, *repelled from*, or *unaffected by* the positive point charge? Explain.



Is your answer consistent with Coulomb's law? Explain.

- B. Hang an uncharged metal or metal-covered ball from an insulating string. Then charge a piece of tape as in section I and bring the tape toward the ball.

Describe what you observe.

- C. The situation in part A suggests a way to think about the attraction in part B between a charged piece of tape and an uncharged metal ball.

Try to account for the attraction in part B. As part of your answer, draw a sketch of the charge distribution on the tape and ball both before and after they are brought near one another.