Period 10 Activity Sheet Solutions: Electric Charge and Force

Activity 10.1: How Do Electric Charges Exert Forces?

a) **Evidence of Electric Forces:**

1) Your instructor will show you how to give a Styrofoam ring an electric charge by rubbing it between two pieces of foam. What happens when you place the charged ring on the table and hold the foam square above the ring?

The ring moves toward the foam square because the electric charge on the ring is attracted to the electric charge on the foam.

2) Rub a plastic rod with a second piece of foam to give the rod an electric charge. Charge the Styrofoam ring again as you did in part 1). Float the Styrofoam ring above the rod. Why does the ring float?

The ring moves away from the rod because the electric charge on the rod repels the electric charge on the ring. A repulsive force between the charges on the rod and on the ring causes the ring to float above the rod.

b) **Electric Force and Gravitational Force:**

1) We have learned that the force of gravity is always an attractive force. Based on your experiments in part a), is the electrical force always attractive? How do you know?

The electric force can be attractive or repulsive. The Styrofoam ring is attracted to foam square on which it was rubbed. But when the rod is rubbed with foam, the rod repels the Styrofoam ring.

2) The Styrofoam ring you floated in part a) has a mass of 0.0065 grams or 6.5×10^{-6} kg.
   a) When the ring floats, what two forces act on the ring?

A repulsive electric force between the rod and the ring pushes up on the ring. The attractive gravitational force pulls down on the ring.

   b) Calculate the amount of electrical force that supports the ring when it floats.

With the information given, you cannot directly calculate the electrical force. However, when the ring floats (does not move vertically), the amount of electrical force pushing up on the ring is equal to the amount of gravitational force pulling down on it. In this case,

$$F_{electric} = F_{grav} = M\,g = 6.5 \times 10^{-6}\ \text{kg} \times 9.8\ \text{m/s}^2 = 6.4 \times 10^{-5}\ \text{N}$$

3) If you floated a ring that had twice the mass but kept the same charges on the rod and ring, would the ring float higher above the rod, closer to the rod, or at the same distance from the rod? **_closer to the rod_** Why?

If the mass doubles, the force of gravity pulling the ring down also doubles. Therefore, the ring floats closer to the rod. Because the distance between the ring and the rod has now decreased, the electric force between the ring and the rod increases to balance the additional gravitational force.

c) Group Discussion Question: When you rub the plastic rod with foam, where does the charge on the rod come from? Do you "create" charge when you rub the rod? Does the piece of foam end up with a charge?

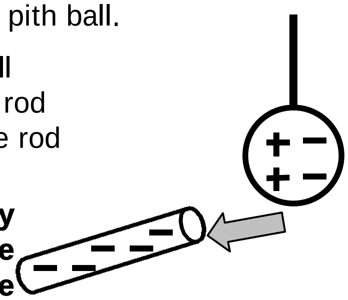
Rubbing the rod with the foam transfers negative electrons in the atoms of the foam onto the rod, giving the rod a net negative charge. Having lost some negative charge, the foam now has a net positive charge.

According to the law of Conservation of Charge, the total amount of charge in the universe is constant. You can transfer charge from one object to another, but you cannot create or destroy charge.

Activity 10.2: What Happens When Charge is Separated?

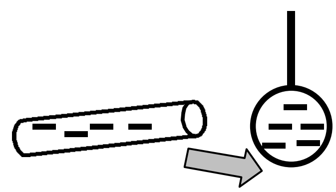
a) **Conductors:** Rub the plastic rod with a piece of foam. This gives the rod a net negative charge. Use the charged rod to exert electrical forces on a hanging pith ball.

1) Bring the charged rod underneath and to the side of the pith ball (but not touching the pith ball). Is the pith ball attracted to the rod or repelled by it? Draw + and – charges on the pith ball and the rod and explain the ball's movement.



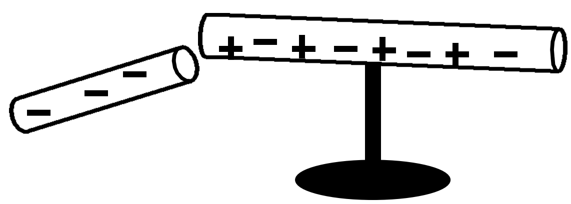
The neutral pith ball is attracted to the negatively charged rod. The negative charges on the rod repel the negative charges on the pith ball, leaving the side of the pith ball closer to the rod positively charged.

2) Touch the pith ball with the charged rod. Is the pith ball now attracted to the rod or repelled by it? Draw charges on the pith ball and the rod. Explain the ball's movement.



The pith ball is repelled. When the negatively charged rod touches the neutral pith ball, negative charge flows from the rod to the ball. Now, both the rod and the ball have a negative charge and they repel. The pith ball moves away from the rod.

b) **Insulators**: Turn a wooden dowel by holding the charged rod near it. Does the plastic rod attract or repel the dowel? **_attract_**



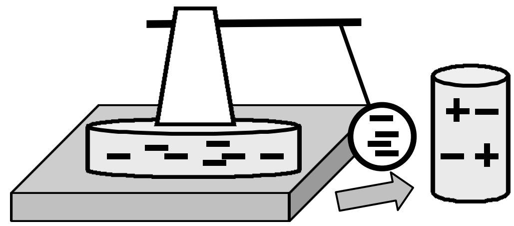
Draw charges on the rod and dowel. Explain why the dowel moves.

The negative charges in the wooden dowel are repelled by the negatively charged rod. However, the negative charges in wood are not free to flow as they are in metal. The negative charges in the wood's atoms lean away from the negative rod. The more positively charged sides of the atoms are attracted to the negative rod.

c) **Oscillator:** Rub the dull side of the blue foam briskly with a cloth. Place the electrostatic oscillator on the foam, holding it only by its foam cup. Push a soda can near to (but not touching) the ball of foil hanging from the plastic straw.

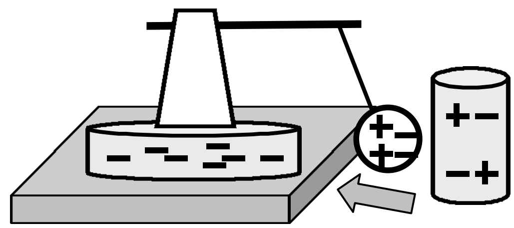
1) Why does the foil ball move away from the pan and toward the can? Draw + and – charges on the diagram to show the net charges on the objects. Draw arrows to show the movement of the foil ball. Explain why the ball initially moves toward the can.

Rubbing the blue foam pan transfers negative charge to the foam. The charges move onto the foil pan and the foil ball. The negative charges on the pan and the ball repel, and the ball moves away from the pan toward the soda can.



2) After the foil ball touches the soda can, why does the ball then move away from the can and toward the pan? Draw + and – charges on the diagram to show the net charge on the object. Explain why the foil ball moves back and forth.

When the ball touches the neutral can, its negative charge drains onto the can and the ball becomes neutral. The negative pan then repels the ball's negative charges and attracts its positive charges. The positively charged side of the ball is attracted toward the pan. The can remains neutral because the amount of negative charge transferred from the ball to the can is too small to affect the net charge on the can.



d) Group Discussion Question: The activities involving electric charge work best when a dehumidifier is operated in the classroom. Why is this true?

Activity 10.3: Why Is Separating Charge Useful?

a) **Separating Charge on a Metal Jar:**
A Leyden jar consists of two metal cylinders separated by a clear plastic cup. First, we use only the inner metal cylinder in the plastic cup. Place a charge on the inner cylinder by rubbing a plastic rod with foam and sliding the rod along the ball on the cylinder's handle. Repeat 5 or 6 times without touching the ball with your hand. Then hold one wire of a small neon light bulb and touch the other wire to the charged cylinder. Describe what happens.

The negative charges on the inner cylinder repel one another. They flow from the cylinder, through the bulb, and into your hand. As they flow through the bulb, they cause it to light.

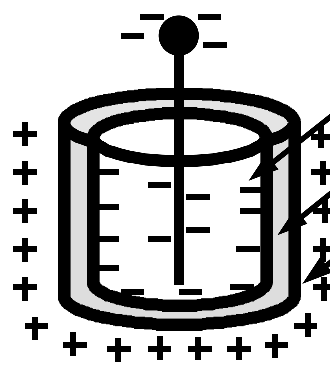
b) **Separating Charge on a Leyden Jar:**
Assemble the two metal Leyden jar cylinders and the plastic cup. Using a connecting wire, attach the outer cylinder to the ground wire above your table. Charge the inner cylinder with the charged plastic rod the same as you did in part a). Now touch one wire of a small neon bulb to the outer cylinder and the other bulb wire to the handle of the inner cylinder.

1) Describe what happens. How does the brightness of the bulb compare to its brightness using only one charged cylinder?

The inner cylinder and the metal handle have a net negative charge. These negative charges repel the negative charges on the outer cylinder. Negative charges on the outer cylinder flow through the ground wire, leaving the outer cylinder with a net positive charge.

When the wires of the bulb touch the inner and outer cylinders, negative charges from the inner cylinder are attracted to the positive outer cylinder. As negative charge flows from the inner to the outer cylinders, charge flows through the bulb, lighting it. The neon bulb flashes a little more brightly than when touched to the inner cylinder and your hand because negative charges flow more easily to the positively charged cylinder than to your neutrally charged body.

2) On the diagram draw + and – charges to show the net charge on the inner and outer cylinders of the Leyden jar before the bulb is touched to it.



c) Group Discussion Question: What is the function of the plastic cup?

Activity 10.4: What Is the Voltage of a Charge?

Your instructor will discuss the voltage of an electric charge. Voltage is a measure of the amount of energy per charge.

a) **Measuring the voltage of the Leyden jar:** Leave the ground wire attached to the outer cylinder of the assembled Leyden jar. We will use two connecting wires to attach a tin can voltmeter. Clip the end of one connecting wire to the bottom of the tin can voltmeter and the other end to the ground wire. Attach the second connecting wire from the top of the voltmeter to the handle of the Leyden jar.

Place a charge on the jar by sliding the charged plastic rod along the ball on the jar handle as you did in Activity 10.3. How much voltage does the charge you placed on the Leyden jar have? _______________

b) Your instructor will demonstrate what happens to the voltage of the inner charged cylinder when it is carefully lifted above the outer cylinder.

1) When the inner cylinder is lifted, does the voltage of the charge increase or decrease? **_the voltage increases_**

2) Why does the voltage of the charges change as the inner cylinder is removed?

The negative charge on the inner cylinder is attracted to the positive charge on the outer cylinder. As you pull the Leyden jar cylinders apart, you must do work to separate the negative and positive charges. Conservation of energy tells us that the energy you used to separate the charges is not lost.

Some of the work you did goes into increasing the amount of energy of each charge (the voltage of the charges).

Activity 10.5: How is Charge Stored in Capacitors?

Your instructor will discuss capacitance. Capacitance is a measure of how easily an object stores electric charge.

a) In Activity 10.4 we found that charges on the Leyden jar have more voltage when the inner cylinder and plastic cup were removed. Next, your instructor will measure the capacitance of the charged Leyden jar when it is assembled and when the inner cylinder and plastic cup are removed. In which case will the Leyden jar have greater capacitance?

Prediction:__ Answer: _The Leyden jar has greater capacitance when it is assembled. That is, for a given voltage, the jar can store more charge._

Why does the capacitance of the Leyden jar change?

From the equation, $C = Q/V$, the capacitance decreases as the voltage of the charge increases. From Activity 10.4.a, the voltage increases when the negatively charged inner cylinder is removed from the positively charged outer cylinder. The voltage decreases when the Leyden jar is assembled. Therefore, when the Leyden jar is assembled, it will have greater capacitance.

b) **Foil Capacitors:** Examine a torn apart foil capacitor. What is the purpose of the foil and the plastic? How is this capacitor similar to the Leyden jar?

The foil layers store charge and the plastic layer is an insulator, separating the charges on the foil layers. The capacitor's two layers of foil separated by plastic act like the two metal cylinders and plastic cup of the Leyden jar.

c) **Capacitor Discharge**: Your instructor will demonstrate discharging a large capacitor by connecting it to a light bulb and by touching it with a metal-tipped rod

1) In which case did the capacitor discharge more quickly? **__through the metal rod__**
2) In which case is more energy released? **_ Since the capacitor stored the same amount of charge in both cases, the same amount of energy was released when it discharged through the metal rod or through the light bulb __**
3) In which case is more power produced? **__ through the metal rod __**
4) Explain why more power is produced in this case.

Power = Energy/time The same amount of energy was released but over a shorter period of time through the rod and over a longer time through the light bulb. Since the time variable is in the denominator of the power equation, the smaller the value of time, the larger the value of the power.