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Republic of the Philippines
Department of Education
NATIONAL CAPITAL REGION
Misamis Street, Bago-Bantay, Quezon City

UNIFIED SUPPLEMENTARY LEARNING MATERIALS
(USLeM)

GENERAL PHYSICS 2
Week 1

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EXPECTATIONS

This Unified Supplementary Learning Material will help you to:

- describe charging by rubbing and charging by induction using a diagram;
- describe the role of electron transfer in electrostatic charging by rubbing;
- perform simple experiments to show electrostatic charging by induction;
- calculate the net electric force on a point charge exerted by a system on point charges;
- explain an electric field as a region in which an electric charge experiences a force;
- calculate the electric field due to a system of point charges using Coulomb's Law and the superposition principle; and
- calculate electric flux.

PRE-TEST

Directions: Read each question carefully, then write the letter that best answers each question.

1. If the balloon can attract tiny bits of tissue paper, which of the following cannot be the charge of the small bits of tissue paper?
   A. Neutral B. Negative C. Positive D. All of these
2. During rubbing, what has been transferred between the woolen cloth and the balloon?
   A. Electrons B. Neutrons C. Protons D. Atoms
3. How does a positively charged rod attract a neutral object?
   A. The rod can attract the neutral object because the attraction between the rod and the negatively induced charge is more significant.
   B. The rod can attract the neutral object because the repulsion between the rod and the negatively induced charge is more significant.
   C. The rod can attract the neutral object because the attraction between the rod and the negatively induced charge is lesser.
   D. The rod can attract the neutral object because the repulsion between the rod and the negatively induced charge is lesser.
4. What is the force's magnitude on each point charge of $+3.00 \times 10^{-6}$ C is 12.0 cm distant from a second point charge of -1.50×10^{-6} C?
   A. 2.61N B. 2.71N C. 2.81N D. 2.91N
5. If an electron's mass is 75.0 kg, what is its total charge?
   A. -1.32×10^{13} C B. -1.42×10^{13} C C. -1.52×10^{13} C D. -1.62×10^{13} C

LOOKING BACK

PICTURE ANALYSIS. Analyze the given picture below by completing the given FRAME.

I know that ______________________________

First, ___________________________________

Second, _________________________________

Third, ___________________________________

Finally, _________________________________

BRIEF INTRODUCTION

We live in an age when we rely on electricity as much as we do on food, and water. The appliances, gadgets and lights give us comfort and satisfaction in our daily existence. But do we know how these things work? What is the electricity made up of?

The discovery of a various phenomenon over several centuries eventually led to our mastery of this incredible power of electricity. For example, Benjamin Franklin did experimentation with charges during the 18th century. It made him known after he named the two kinds of charges – positive and negative. He processed this experiment through collected electric charges from thunderstorm clouds that produce lightning through a wet string from a kite.

Let's learn more about it now!

ACTIVITIES

How can you charge an object? To understand further the idea about charges, you are required to perform the following simple experiments involving charges.

Activity 1. Visual Thinking Approach: Types of Charging

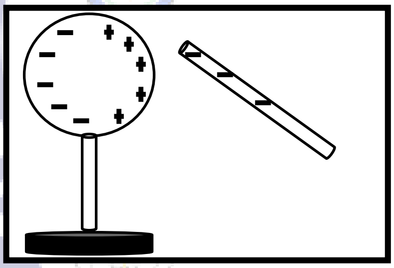
Directions. Decide what type of charging is depicted on each of the given illustrations by writing your answer on the space provided.

1. After being rubbed, a plastic ruler can attract paper scraps.

____

2. Charging a balloon through friction and place the balloon near pieces of paper.

____



3. You are touching a charged piece of metal with a negatively charged glass rod.

____

Processing Questions:

1. What are the types of charging? ____
2. Based on the pictures above, describe each type of charging. __________________.

Activity 2. Charging objects by friction

Objectives: Explain the role of electron transfer in electrostatic charging by rubbing.

Materials: tissue paper, a human hair, balloons, silk, plastic ruler, glass rod, copper

Procedures:

1. Cut the tissue paper into tiny bits.
2. Rub the balloon across a human hair. Move the balloon near the tiny bits of tissue paper. (Optional: Rub the other balloon across human hair and move it closer to the other rubbed balloon.)

3. Repeat procedure number 2 in a glass rod, plastic ruler, and copper after rubbing with a piece of silk.

Table 1. Observation After Rubbing

Materials	**Human Hair**	**Silk**		
	Balloon	Glass Rod	Plastic Ruler	Copper
Observation				

Processing Questions:

1. What can you predict about the polarities of charges? Why?
2. What happens when you move the two balloons near each other after rubbing?
3. What is the role of electron transfer in electrostatic charging by rubbing?

You probably noticed that there was such a thing as **electric charge** among the given illustrations. The most effortless demonstration of this involved the rubbing of a balloon on your hair and see how the balloon then attracted your hair with some mysterious force. Two balloons that had been rubbed on hair repel each other away. These occurred because of electric charge. It was displaced by rubbing together these materials. The hair became positively charged and the balloon becomes negatively charged. Opposite charges attracted one another; that's why your hair stuck to the balloon.

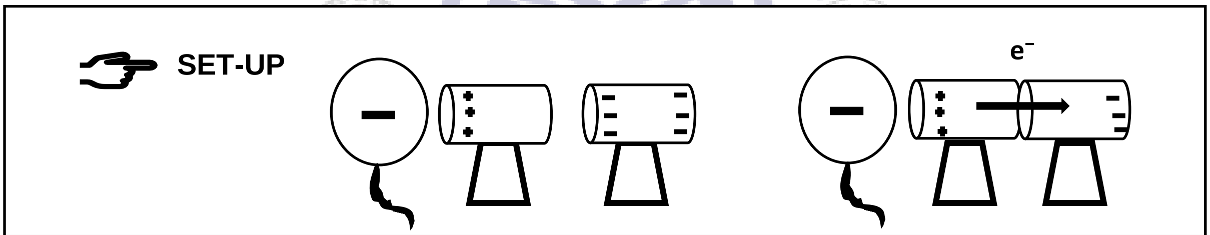
Activity 3. Charging Objects by Induction

Objectives: Perform the balloon-cans experiment to show electrostatic charging by induction.

Materials: 2 pieces cola cans, plastic cups, glue stick, 2 pieces balloons

Procedures:

1. Using a glue stick, mount the 2 cola cans at the top of a plastic cups.
2. Place the ends of two cans together and a negatively charged balloon (having been rubbed with human hair) is brought near to one end of the cans. See the diagram below.



Processing Questions:

1. What happens when the two cans are moved closer together? What happens when they are separated?
2. What is the role of the balloon during the induction process?
3. Based on the experiment, describe the electrostatic charging by induction.

All matter is made up of atoms. It contains Protons (+), Neutrons (0), and Electrons (-). Electrostatics is the interaction between static electric charges. Where do these charges come from? If electrons are equal to a proton, it is a neutral charge. If an electron is greater than a proton, it will gain an electron, and therefore, the charge is negative. If an

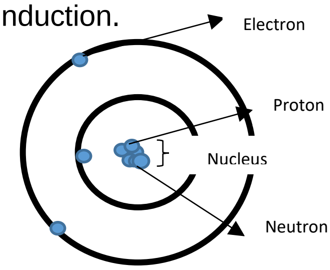


Figure 1: Parts of an Atom

electron is less than a proton, it will lose electrons, and therefore, it is positively charged.

The fundamental law of electric charges states that **like charges repel, and opposite charges attract**. Protons are positively charged, and electrons are negatively charged, so they are attracted to each other. This attraction is the main reason why electrons are held in atoms.

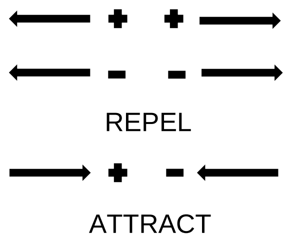


Figure 2: Forces on Charges

Each electron carries the fundamental charge which is **1.6 x 10^{-19}C.** This magnitude is negative for the electron and positive for the proton. This amount of charge is present among all substances, which means electric charge is **quantized**. We can categorize substances by the ability to transfer electric charge. A **conductor** is any substance that can quickly transfer electric charge. The one that cannot quickly share electric charge is called an **insulator**.

An **electrical conductor** is a material in which charges can move easily. A lamp cord that has a metal wire and metal prongs is an example of a conductor. Copper, aluminum, and mercury are good conductors. Materials in which charges cannot flow easily is called an **electrical insulator**. Some of the good insulators are plastic, rubber, glass, wood, and air.

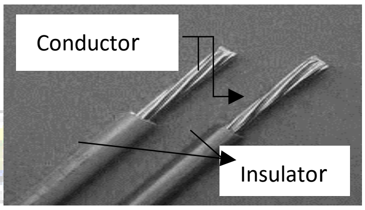


Figure 3: Conductor and Insulator

Due to the **electric force,** opposite charges are attracted from one another. This is outlined in Coulomb's Law, which states that "***the magnitude of the electric force between two objects is equal to Coulomb constant times the charge of one object times the charge of the other divided by the square of the distance between them."*** Remarkably, this is practically identical to Newton's Law of Universal Gravitation. The only difference is that the electric force can be attractive or repulsive depending the charges' signs, and resulting sign on the force, while gravity is always attractive.

It is also interesting to know that Coulomb's constant is much greater of magnitude than the gravitational constant. It was Illustrating the discrepancy in the strength of the two forces. This law also tells us that the electric force between two objects increases as the charge increases and decreases as the distance between them increases.

Coulomb's law measures the forces of an electric charge. A charge is a scalar quantity and is measured in Coulombs. The coulomb is defined in terms of electric current (the flow of electrons), measured in amperes, when the current in a wire is 1 ampere. At a given point in the wire, 1 second is 1 coulomb-the amount of charge that flows.

When charges are transferred by simple rubbing, negatively charge is being transferred. We call these fundamental particles electrons. The charge of an electron is

$$\mathbf{e = 1.602177 \times 10^{-19}\ C}$$

The electron's charge is −e while the proton has charge +p. The mass of the electron is

$$\boldsymbol{m_e} \mathbf{= 9.1094 \times 10^{-31}\ kg.}$$

Coulomb's Law gives the force of attraction or repulsion between two-point charges. The magnitude of the force of repulsion or attraction between two-point charges q1 and q2 are separated by a distance r, and it is written as

$$\boldsymbol{F = k\frac{(q_1)(q_2)}{r^2}} \qquad \text{where } \mathbf{k = 8.9876 \times 10^{9}}\ \frac{N.m^2}{C^2}\ .$$

Comparing to Newton's 3rd law, the magnitude of the force which each charge exerts on the other charge is somehow the same in Coulomb's Law. The symbol *k* as used here has to do with electrical forces. The force is repulsive if the charges q1 and q2 are of the same sign (both positive or both negative). The force is attractive if the charges are of opposite signs (one positive, one negative). The constant k is often written below for historical reasons, and because in later applications, the constant ε_0 is more convenient. ε_0 is known as the **permittivity constant**.

$$k = \frac{1}{4\pi\varepsilon_0}$$ where $\boldsymbol{\varepsilon_0} = \mathbf{8.85419 \times 10^{-12}} \frac{C^2}{N.m^2}$

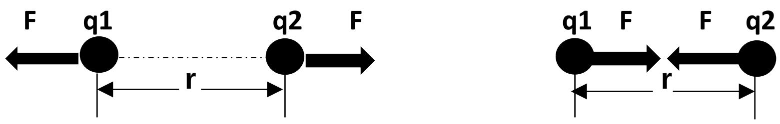


Figure 4A Figure 4B

Figure 4 (a) electric force is repulsive. (b) electric force is attractive

When several points charges are present, the total force on a particular charge q0 is the vector sum of the individual forces gotten from Coulomb's law. (Thus, the electric forces have a superposition property.) For a continuous distribution of charges, we need to divide up the charge distribution into infinitesimal pieces and add the individual forces with integrals to get the net force.

Vector addition must be applied if there are more than two charges present to determine the net force upon any particle in the system. Just as a gravitational field is what helps the gravitational force to propagate, it is an **electric field** that allows electric force to propagate.

The electric force is much stronger than gravity. This is evident because the repulsion between particles in your feet and particles in the ground is more than strong enough to keep you attracted towards the center of the Earth.

Any charged object will manifest an electric field around itself. If another charged object enters this field interaction will occur. The strength of an electric field generated by a point charge is equal to the Coulomb constant times the charge of the object producing the field divided by the square of the distance between this object and whatever it is acting on.

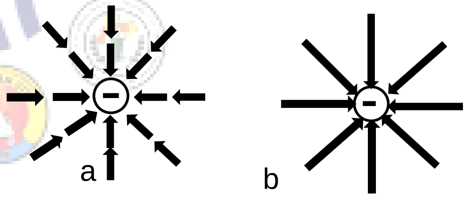
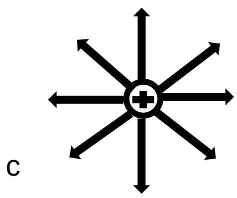


Figure 5: Electric field representation of negative charge.
a. Vector representation
b. Line-of -force representation
c. Field lines of a single positive charge



One way we depict electric fields is by drawing **electric field lines,** which generally point towards negative charges and away from positive charges and do not intersect. Like the field produced by two oppositely charged particles, which we can call an electric dipole. The more densely pack the field lines are in a particular region, the field's strength. Lines like this can be especially useful if many particles are producing the field. What do we do with electric force?

TRY THIS! Draw the electric field lines of:
a. two negative charges
b. two positive charges
c. two opposite charges

There are unlimited knowledge and information that one should know when it comes to studying science and the concept of electricity. One of the fields of study of science is the concept of electric flux. It is relevant in understanding the behavior of electric force. What is Electric flux?

One of the fundamental properties of an electric field is the electric flux. They may be taught of as the number of field lines that intersect a given area. The field lines start on a positive electric charge and to end on a negative charge. The field lines are considered negative if it is produced into a closed surface; then positive if it is produced out of a closed surface. Every field line directed into the given surface continues through the interior. It is usually produced outward elsewhere on the surface if there is no given net charge within a given closed surface. The net electric flux is zero since positive flux is equal in the magnitude of negative flux. The total flux through the surface is proportional to the enclosed charge if a net charge was contained inside a closed surface. It means that the total flux is positive if it is positive, negative if it is negative.

Practice Problems:

1. **If an electron weighs 65.0 kg, what is its total charge?**
The mass of one electron is 9.11×10^{-31} kg, so that a mass M = 65.0 kg contains

$$N = \frac{M}{m_e} = \frac{65kg}{9.11\ x\ 10^{-31}kg} = \mathbf{7.14 \times 10^{31}\ electrons}$$

The charge of one electron is −e = -1.60×10^{-19} C, so that the total charge of N electrons is:

$$\mathbf{Q = N(-e) = (7.14 \times 10^{31})(-1.60 \times 10^{-19}\ C) = -1.14 \times 10^{13}\ C}$$

2. **(a) For a coin to leave it with a charge of $+1.1\times10^{-7}$ C, how many electrons would have to be removed from it? (b) What is the fraction of the electrons present in the coin? (Note: The coin has a mass of 3.90 g, assuming that it is purely made of copper.)**

(a) We know that as each electron is removed, the coin picks up a charge of $+1.60 \times 10^{-19}$ C. We need to remove N electrons to be left with the given charge, where N is:

$$N = \frac{q_{total}}{q_e} = \frac{1.1\ x\ 10^{-7}C}{1.60\ x\ 10^{-19}C} = \mathbf{6.9 \times 10^{11}}$$

(b) We will need the total number of electrons in a neutral coin; to find this, we need to find the number of copper atoms in a coin that carry 29 electrons. To get the moles of copper atoms in the coin, divide its mass by the atomic weight of copper:

$$n_{Cu} = \frac{3.90g}{63.54g/mol} = \mathbf{6.14 \times 10^{-2}\ mol}$$

The number of Copper atoms is

$$N_{Cu} = n_{Cu}\, N_A = \mathbf{(6.14 \times 10^{-2}\ mol)(6.022 \times 10^{23}\ mol) = 3.70 \times 10^{22}}$$

and (originally) the number of electrons in the coin was 29 times this number,

$$N_e = 29N_{Cu} = \mathbf{29(3.70 \times 10^{22}) = 1.07 \times 10^{24}}$$

So, the fraction of electrons removed in giving the coin the given electric charge is

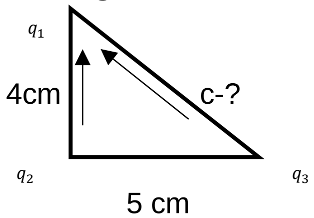
$$f = \frac{6.9\ x\ 10^{11}}{1.07\ x\ 10^{24}} = 6.4\ x\ 10^{-13}$$ A very small fraction.

3. **Find the force's magnitude on a point charge of a $+3.00 \times 10^{-6}$ C is 12.0 cm distant from a second point charge of a -1.50×10^{-6} C.** The two charges attract one another because of the opposite charges, and the magnitude of this force is given by Coulomb's Law:

$$F = k\frac{(q_1)(q_2)}{r^2} = \mathbf{(8.99 \times 10^9\ N{\cdot}m^2/C^2)}\frac{(3.00\ x\ 10^{-6}C)(1.50\ x\ 10^{-6}C)}{(12.0\ x\ 10^{-2}m)^2} = \mathbf{2.81\ N}$$

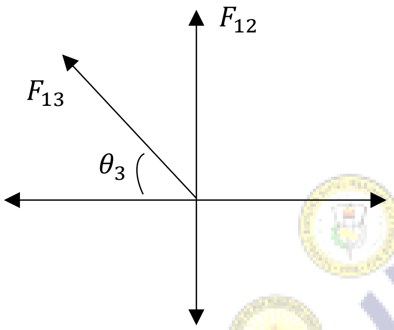
4. **As shown below, three-point charges, q=15uC, are placed at the corners of a right triangle. What is the net electric charge on q1?**

Given:



Required: F_{net} at pt. 1

Free body diagram at q_1



$\theta_3 = tan^{-1}\left[\frac{4}{5}\right]$

$\boldsymbol{\theta_3 = 38.66°}$

$\sum Fx = F_{12}]_x + F_{13}]_x$

∑Fx=-494.385 cos 38.66

∑Fx=-386.05N

$r_{13} = c$

$r_{13} = \sqrt{4^2 + 5^2}$

$\boldsymbol{r_{13} = 6.4cm}$

Equations: $F_{net} = \sqrt{(\sum Fx)^2 + (\sum Fy)^2}$ $\quad F_{12} = \frac{k(q_1 q_2)}{r^2}$

Solutions: $F_{12} = \frac{k(q_1 q_2)}{(r_{12})^2}$ $\quad q_1 = q_2 = q_3 = 15\mu C$

$F_{12} = k\left(\frac{q}{r_{12}}\right)^2 = 9x10^9\left(\frac{15x10^{-6}}{0.04}\right)^2 = \mathbf{1265.63N}$

$F_{13} = \frac{kq_1q_3}{(r_{13})^2} = 9x10^9\left(\frac{15x10^{-6}}{0.064}\right)^2 = \mathbf{494.385N}$

$\sum Fy = F_{12}]y + F_{13}]_x$

∑Fy=1265.65N + 494.385 sin 38.66

∑Fy=1574.49N

: $F_{net} = \sqrt{(\sum Fx)^2 + (\sum Fy)^2}$

: $F_{net} = \sqrt{(-386.05)^2 + (1574.49)^2}$

$\boldsymbol{F_{net} = 1621.13N}$

$\theta_{resultant} = tan^{-1}\left[\frac{\sum Fy}{\sum Fx}\right]$

$\theta_{resultant} = tan^{-1}\left[\frac{1374.49}{-386.05}\right]$**=-76.22 with respect to +y axis**

5. **An electric field E = 8000 N/C passing through a flat square with an area A = 10 m² are distributed uniformly. What is the electric flux?**

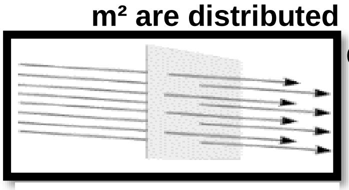


Figure 6: Electric Field Passing through a flat square area.

Given:
(E) = 8000 N/C
(A) = 10 m²
θ = 0° (the angle between the electric field direction and a line drawn a perpendicular to the area)

Required: Electric flux (Φ) **Equation**: **Φ = E A cos q**

Solution: **Φ = E A cos q = (8000N/C)(10m²)(cos 0) = (8000)(10)(1) = 80,000 = 8 x 10⁴ Nm²/C**

Answer: **8 x 10⁴ Nm²/C** the electric flux passing through the given flat square area.

Activity 4-PROBLEM SOLVING.

Directions: Follow the G-R-E-S-A (*Given, Required, Equation, Solution, and Answer*) format in solving each word problem.

1. If an electron weighs 95.0 kg, what is its total charge?

2. (a) For a coin to leave with a charge of $+2.0\times10^{-6}$ C, how many electrons would be removed? (b) What is the corresponding fraction of electron this coin has? (Assume that the coin has a mass of 4.11 g and made up of pure copper).
3. Calculate the magnitude of the force between a point charge $+2.60 \times 10^{-7}$ C is 9.0 cm far from a second point charge of -2.0×10^{-7} C.
4. Identify the force between a - 2.0 C charge and +3.0 C charge that are 80 cm away from each other.
5. An electric field E = 5000 N/C passing through a flat square area A = 2 m^2 are distributed uniformly. Solve for the electric flux.

REMEMBER

- Charging by friction or by rubbing occurs when electrons are "wiped" from one object onto another. When charges in an uncharged object are rearranged without direct contact with a charged object it is known as charging by induction.
- The magnitude of the force between two charged objects is directly proportional to the product of their charges but inversely proportional to the square of the distance between them. (Coulomb's Law)
- The property of an electric field is known as electric flux. It is the number of forces that intersect a given area.

CHECKING YOUR UNDERSTANDING

CRITICAL THINKING QUESTIONS:

Directions: From the list of words provided in the last part of the paragraph, select the correct word that logically completes each sentence.

1. **How does a positively charged rod attract a neutral object?**

When a + charged rod is put near neutral object, _______________ is induced on the side of the object near the rod and ______________ is induced on the side away from the rod. The rod can attract the neutral object because __________ between rod and – induced charge > the ________ between rod and + induced charge**. (attraction, repulsion, negative charge, positive charge)**

2. **What is the reason why gasoline tankers usually have metal chains at the back?**

When the car moves, each tire, and body are usually charged by _______. For gasoline tankers, if the accumulated charge is large enough, _______can be produced and __________ will occur if gasoline vapor was ignited. Those metal chains conduct the charge on the bodies of tankers to the _______ and avoid the danger**. (sparks, explosion, friction, ground)**

Valuing Question: Electrical forces between charges are significantly associated with gravitational forces. We don't usually sense electrical forces between us and our environment, and instead, we usually notice our gravitational interaction with the Earth. Why is this so?

POST-TEST

Directions: Read each question carefully, then write the letter that best answers each question.

1. If you charge up a balloon through friction and place the balloon near pieces of paper, the paper's charges will be rearranged, and the paper will be attracted to the balloon. What type of charging is in the given situation?
   A. Friction B. Rubbing C. Induction D. Conduction

2. If you use a fabric to rub a plastic ruler, electrons move from the cloth to the ruler. The ruler gains electrons and the fabric lose electron. What type of charging is shown in the given example?
   A. Friction B. Rubbing C. Induction D. Conduction

3. What is the magnitude of the force between charges of 5.0 x 10^8 C and 1.0 x 10^7 C if they are 5.0 cm apart?
   A. 1.8 x 10^{-2}N B. 1.9 x 10^{-2}N C. 2.0 x 10^{-2}N D. 2.1 x 10^{-2}N

4. What is the force's magnitude in a 1.5 x 10^6 C charge that exerts on a 3.2 x 10^4 C charge located 1.5 m away?
   A. 1.8 N B. 1.9 N C. 2.0 N D. 2.1N

5. An electric field E = 6000 N/C passing through a flat square area A = 10 m^2 are distributed uniformly. What is its electric flux?
   A. 0.6 x 10^4Nm²/C B. 6.0 x 10^4Nm²/C C. 1.6 x 10^4Nm²/C D. 6.8 x 10^4Nm²/C

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ANSWER KEY

ACTIVITY 4
1. -1.6 x 10^{13}C
2. (a.) 1.25 x 10^{13}; (b) 1.11 x 10^{-11}
3. 5.8 x 10^{-2}N
4. 8.53 x 10^6N
5. 5.0 x 10^3 N.m²/C

CHECKING YOUR UNDERSTANDING
1. Negative charge, positive charge, attraction, repulsion
2. Friction, sparks, explosion, ground

POSTTEST
1. C 2. A/B 3. A 4. B 5. B

PRETEST
1. B
2. A
3. A
4. C
5. A

LOOKING BACK: Answers may vary.

ACTIVITY 1
1. Charging by Rubbing/Friction
2. Charging by Induction
3. Charging by Conduction

ACTIVITY 2 – Answers may vary.
ACTIVITY 3 – Answers may vary.