Module 6
Experiencing Electricity

What this module is about

Electricity is everywhere around us. The incandescent bulbs that light our homes, the batteries that power up our appliances, the transmission lines that supply energy to our homes are but few of the many things that utilize electricity. There are also some far more simple phenomena that let us experience electricity, and many of these are indeed amazing. However, if we understand the principles behind electricity, we will find out that what lies behind these wonders are just simple laws of nature. This module discusses the fundamental concept of electricity and its effects and applications in our everyday living. Specifically, it tackles the following lessons:

- **Lesson 1 - Development of Electricity**
- **Lesson 2 - Static Electricity**
- **Lesson 3 - Charges and Coulomb's Law**
- **Lesson 4 - Conductors and Insulators**

What you are expected to learn

After going through this module, you are expected to:

1. cite the contributions of some scientists in the development of electricity;
2. demonstrate the effects of static electricity and transfer of charges for different materials;
3. relate electrical force to the magnitude and separation of charges; and
4. distinguish conductors from insulators.

How to learn from this module

Going through this module can be both a fun and a meaningful learning experience. All you need to do is make use of your time and resources efficiently. To do this, here are some tips for you:

1. Take time in reading and understanding each lesson. It is better to be slow but sure than to hurry finishing the module only to find out that you missed the concepts you are supposed to learn.
2. Do not jump from one chapter to another. The lessons are arranged such that one is built upon another. Hence, an understanding of the first is essential in comprehending the succeeding lessons.
3. Be honest. When answering the test items, do not turn to the key to correction page unless you are done. Likewise, when performing experiments, record only what you have really observed.
4. Safety first. Perform the experiments with extra precaution. Wear safety gears whenever necessary.
5. Don't hesitate to ask. If you need to clarify something, approach your teacher or any knowledgeable person.

What to do before (Pretest)

A. Match the scientist listed in Column A with their respective discoveries in Column B

A	**B**
_____ 1. Thomas Alva Edison	a. Voltaic Pile
_____ 2. Charles Augustos Coulomb	b. Torsion Balance
_____ 3. Luigi Galvani	c. Electric Motor
_____ 4. Alesandro Volta	d. Incandescent Bulb
_____ 5. Benjamin Franklin	e. Animal Electricity

B. On the space provided, write **C** if the object is a conductor and **I** if it is an insulator.

_____ 6. Rubber band
_____ 7. Iron Rod
_____ 8. Wood tiles
_____ 9. Cement
_____ 10. Tin Can

C. Put a checkmark on the space provided if the statement is correct. Otherwise, put a cross mark.

_____ 11. An object whose atoms have excess electrons is negatively charged.
_____ 12. If two objects are oppositely charged, they attract each other.
_____ 13. Insulators have many electrons that are randomly and freely moving.
_____ 14. The force two charged objects exert on each other is directly proportional to their distance of separation
_____ 15. Static electricity deals with charges at rest.

Key to answers on page 21

Introduction

Fig. 1.1 Girl on a charged sphere

Let us begin our discussion by looking at the picture in figure 1.1

Have you ever had an experience similar to the one in the picture? What do you think explains this? What made the girl's hair stand when she touched the charged sphere?

The one in the picture is a simple illustration of a rather rare concept of electricity. When you hear the word **electricity**, perhaps you will attribute it to lights and appliances at home, transformers and transmission lines or the shock that may harm you once you touch a live electrical wire. While it is true that all of these are manifestations of electricity, we can explain both the girl's experience in the charged sphere and your common observations at home in common terms.

Have you ever experienced ironing a piece of linen cloth or pair of pants? What do you feel when you put your skin near the just ironed cloth? Is there a crackling sound produced? What do you feel when you immediately grab a doorknob after walking through a carpeted floor? How do you explain the slight shock that you feel considering that there is no physical connection to a source of electricity in these instances?

Do you remember what happens when you rub an object against your hair and put such object near a piece of paper? You used to play with this at school and were once amazed. But now do you know that by explaining this phenomenon, we will come to an understanding of the nature of electricity?

Lesson 1 Development of Electricity

For our distant ancestors, perhaps one of the earliest manifestations of electrical phenomenon is a lightning strike. When a lightning strikes a tree, the tree can explode in flames.

Fig 1.2. Lightning

Even in ancient times, many different sources of power have been used such as the controlled burning of wood, crops or animal wastes, and various types of coal. The Greeks and Romans utilized the power from the water in their windmills. The power of steam became available with the development of steam engines. As early as the 19th century, gas lamps became available but were later replaced by incandescent bulbs. When generators were invented in the 20th century, the use of electricity to supply power in multitude of applications has started.

Although electrical effects have been known since the time of ancient Greeks, the development of electricity as a usable power really happened only in the last twenty decades. Luigi Galvani discovered animal electricity after he made the muscle of a frog twitch by touching the nerve with various types of metals without a source of electrostatic charge. He found out that the best reaction of the frog's muscle was obtained when two kinds of metals were used.

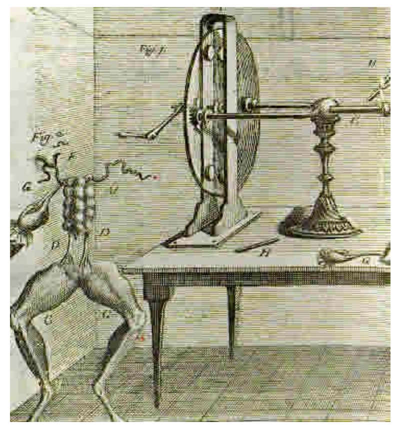


Fig 1.3. Animal electricity

Contrary to the idea of "animal electricity", Alessandro Volta demonstrated the production of electricity with inanimate materials alone. He believed that the electricity produced by Galvani did not come from the frog's muscle but from the interaction of dissimilar metals. With this, he invented the first battery called the voltaic pile, which provided continuous electric current source.

Fig 1.4. Voltaic pile

After the issue of producing electricity was dealt with, the next question was: What is the nature of electricity? Some experimenters speculated that electricity was like a fluid flowing as a result of its interaction with other objects. This stemmed from the earlier discovery that certain materials would mysteriously attract or repel each other after being rubbed. With this, Benjamin Franklin concluded that there was only a single fluid exchanged between the rubbed objects, and that the two different "charges" were nothing more than an excess or deficiency of such a fluid. After experimenting with wax and wool, he suggested that the coarse wool removed some of the fluid from the smooth wax. The resulting disparity of fluid content then causes an attractive interaction between the two objects as the fluid tries to regain its former balance.

Interestingly, it was soon discovered that the fluid they used to speculate in the experiment is comparable to small bits of matter called the electrons. The excess or deficiency of electrons in an object makes it electrically charged. Later in this module, we shall briefly review electrons and atomic structure.

Precise measurement of electrical charges was carried out by Charles Augustus Coulomb using a device called the torsion balance. We shall discuss how it operates when we discuss Coulomb's Law in **Lesson 2.**

Fig 1.5 Torsion balance

Since then studies of electricity began to flourish. Some of the important discoveries are listed in the following table

Study this:

Table 7.1 Chronology of events in the development of electricity

Date	Scientist	Discovery
1820	Michael Faraday	Postulated that electrical current moving through a wire creates "fields of force" surrounding the wire. With this, he showed electromagnetic induction and built the first electric motor
1826	Georg Simon Ohm	Measured the electromotive force of electrical currents. He found that some conductors worked better than others and quantified the differences in a law named after him.
1830	Joseph Henry	Worked on electromagnets by superimposing coils of wires wrapped on an iron core
1844	Samule Finley Breese Morse	Invented the morse code
1845	Gustav Robert Kirchoff	Developed the laws that allow easy calculation of currents, voltages and resistance of electrical networks

If you notice, the development of the field of electricity came hand-in-hand with that of magnetism. In fact, the two fields complemented each other. In the next few modules, we will study in depth the intertwining aspects of electricity and magnetism and some important applications of the combinations of the two.

Over the years, our society has become increasingly dependent on electricity as a source of power. Now, it is almost unthinkable how electricity has made life easier and more comfortable. Almost all facets of modern living depend on electricity – lighting, heating or cooling, food preparation, transport, communication, manufacturing of goods and materials, entertainment, data storage, medical applications, household cleaning tasks, building and construction of industries, to mention a few.

What you will do

Activity 1.1 How has electricity changed the ways you live?

How has electricity changed the way of life in your community? Ask your parents what transformations occurred since electrical energy was made available in your community. Compare and contrast your lifestyle now with the lifestyle of the people when electricity was not used in your community. Write a short essay about this.

When there was yet no electric power,	**Now, with electricty**
Mother would have to iron our clothes using burned charcoal	**Mother does not burn charcoal anymore because she now uses flat iron… It makes the task less messy and easier**

What you will do

Self-Test 1.1

Identify the scientists associated with each discovery or idea. You may look into the word hunt puzzle to gain clues. Encircle the names of the scientists in the puzzle. Names may be written vertically, diagonally , horizontally or reversed.

________________ 1. Discovered animal electricity

________________ 2. Used torsion balance to measure the force exerted by electrical charges on other charges

________________ 3. Demonstrated electromagnetic induction

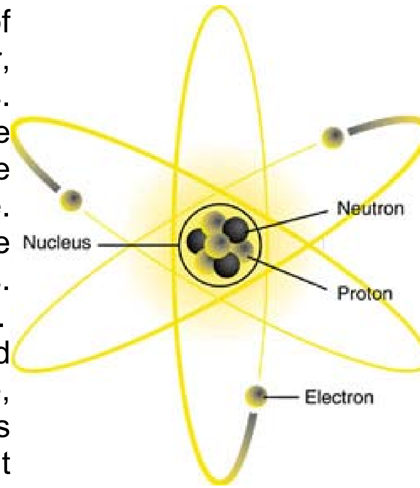
________________ 4. Opposed the existence of animal electricity and invented an inanimate source of electric current

________________ 5. Found out that across conductors, the voltage is directly proportional to the current.

A	D	T	Y	A	D	A	R	A	F
V	R	C	G	C	A	L	R	A	D
O	L	O	F	D	O	R	O	A	A
V	Y	U	C	G	F	U	P	M	H
V	O	L	T	A	T	V	L	H	U
O	D	O	E	A	A	N	P	O	M
L	A	M	D	L	N	O	I	K	Y
G	E	B	T	B	S	A	E	E	C
A	R	L	G	A	L	V	A	N	I
F	A	A	A	O	O	V	R	A	L

Key to answers on page 21

Lesson 2 Static Electricity



You have learned that everything we see is made up of tiny parts called atoms. **Atom**s are composed of even smaller, sub-atomic particles, namely, electrons, protons and neutrons. They are different from each other in many ways. One of the ways they are different is their charge. **Protons,** which are located in the nucleus of the atom, have positive charge. **Electrons,** which are located and revolving around the nucleus, have an equal but negative charge as protons. Neutrons which are located inside the nucleus have no charge. Usually, atoms have the same number of protons and electrons. Such atoms are called **neutral atoms**. Otherwise, they are called **ions**. The electrons located outside the nucleus may be attracted or repelled by other electrons of different atoms. Electrons can then move from one atom to another. As a result, some atoms can get extra electrons and acquire a net negative charge. Other atoms lose electrons and acquire a net positive charge. When charges are separated like this, static electricity is produced as the electrons regain their former state of balance.

The transfer of electrons creates charges that also interact with other charges. If two materials have different charges, they attract or pull towards each other. If two things have the same charge, they repel or push away from each other. What about the interaction of charged and uncharged materials? Quite surprisingly, a neutral object always has an attractive interaction with charged material. We will discuss the magnitude of such forces of attraction or repulsion in **Lesson 3**.

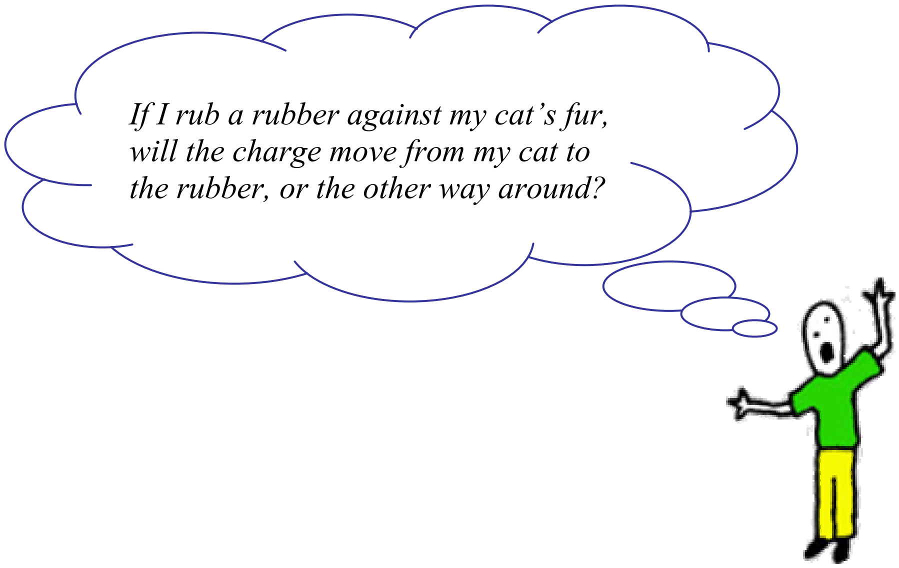
Perhaps you are asking yourself this question: How then can I transfer electron in an atom, so I can create a charge and, eventually, electricity? We will discuss the two most common ways to do this: charging by friction and induction.

When objects are rubbed against each other, the electrons of their atoms have the tendency to move from one atom to another. The manner by which electrons move depends on the electron affinity of the atoms. Some objects like metals share electrons easily while some like plastic and rubber don't. Objects that share electrons easily are **conductors** and those that do not share electrons easily are **insulators**. Materials that may or may not share electrons are called **semiconductors**. Semiconductors are often used in electronics.

How do we know which among the objects being rubbed together gains or loses electrons? By rubbing a variety of objects against each other and taking their interaction with a known charge, the tested materials can be ordered according to the affinity with electrons. Such order is known as **triboelectric series**.

Among the objects listed here, celluloid has the greatest electron affinity. This means that of all the conductors, celluloid has the least tendency to share an electron.

Triboelectric Series
Celluloid
Sulfur
Rubber
Copper, Brass
Amber
Wood
Cotton
Human Skin
Silk
Cat Fur
Wool
Glass
Rabbit Fur
Asbestos



We shall do some simple experiments to find out how objects gain or lose charges.

What you will do

Activity 2.1 A simple charging experience

What you will need

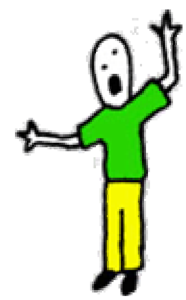
- A piece of bond paper
- Plastic ballpen case

What to do

1. Cut the piece of bond paper into several small pieces (bits) and lay them on a wooden table. What do you think is the charge of these bits of papers?
2. Get the plastic ballpen case and rub it several times against your hair or silk clothes. Which do you think has greater electron affinity, the ballpen or your hair? What becomes of the charge of each after rubbing?
3. Now, place the ballpen near the laid bits of paper. What do you observe? What happened to the bits of paper?

If the bits of paper clung to the plastic ballpen case, it is right to say that either the ballpen case or the paper was charged. Since you did not do anything but tear the paper into pieces and, if initially it was uncharged, then the pieces of paper remained uncharged. The ballpen has greater electron affinity than your hair. When it was rubbed against your hair, the ballpen case gained extra electrons and became negatively charged. Thus, when placed near the bits of paper, the negatively charged ballpen case attracted the uncharged paper.

Try performing the experiment in front of a mirror to see how your hair looks like when you rub the ballpen case more strongly. Explain this phenomenon in the same manner as how we explained the result of Activity 2.1?



To help you understand and experience static electricity more, try doing the following experiments. You can choose from the four sets of experiments depending on the availability of materials. Write your observations on a separate sheet of paper. Explain your observations using the concept of charges we have just discussed.

What you will do

Activity 2.2 The Swinging Cereal

What you will need

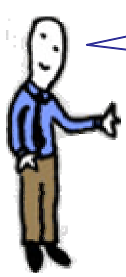
- a hard rubber, a plastic comb or a balloon
- thread, small pieces of dry cereal or puffed rice

What to do

1. Tie a piece of the cereal to one end of a 12-inch piece of thread. Find a place to attach the other end so that the cereal does not hang close to anything else.
2. Wash the comb to remove any oils and dry it well.
3. Charge the comb by running it through long, dry hair several times, or vigorously rubbing the comb on a wool sweater.
4. Slowly move the comb near the cereal. The cereal will swing to touch the comb. Hold it still until the cereal jumps away by itself.
5. Now try to touch the cereal again with the comb. The cereal will move away as the comb approaches.

This activity can also be done by substituting a balloon for the comb.

What happened?



Combing your hair moved electrons from your hair to the comb. The comb had a negative charge. The neutral cereal was attracted to it. When the comb and the cereal touched, electrons slowly moved from the comb to the cereal. Now both objects had the same negative charge, and the cereal was repelled.

What you will do

Activity 2.3 The Bending Water

What you will need

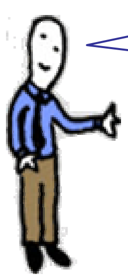
- a hard rubber, a plastic comb or a balloon
- a sink and water faucet

What to do

1. Turn on the faucet so that the water runs out in a small, steady stream about 1/8 inch thick.
2. Charge the comb by running it through long, dry hair several times or rub it vigorously on a sweater.
3. Slowly bring the comb near the water and watch the water "bend."

This activity can also be done with a balloon.

What happened?



The neutral water was attracted to the charged comb, and moved towards it.

What you will do

Activity 2.4 Light a bulb!

What you will need

- hard rubber comb or balloon
- a dark room
- fluorescent light bulb (not an incandescent bulb)

SAFETY NOTE: DO NOT USE ELECTRICITY FROM A WALL OUTLET FOR THIS EXPERIMENT. Handle the glass light bulb with care to avoid breakage. The bulb can be wrapped in sticky, transparent tape to reduce the chance of injury if it does break.

What to do?

1. Take the light bulb and comb into the dark room.
2. Charge the comb on your hair or sweater. Make sure to build up a lot of charge for this experiment.
3. Touch the charged part of the comb to the light bulb and watch very carefully. You should be able to see small sparks. Try touching different parts of the bulb with your hands and the comb.

What happened?

When the charged comb touched the bulb, electrons moved from it to the bulb, causing the small sparks of light inside. In normal operation, the electrons used to light the bulb come from the electrical power lines through a wire at the end of the tube.

What you will do

Self Test 2.1 Think about this…

Think about this and explain in terms of the concept on static electricity: Why does your hair stand after you take your hat off?

____
____
____
____
____
____
____
____
____
____

Key to answers on page 22

Lesson 3 Coulomb's Law of Charges

Charged objects create an invisible electric force field around themselves. The strength of this field depends on many things, including the amount of charge, the distance involved, and the shape of the objects. This can become very complicated. We can simplify things by working with "point sources" of charge. Point sources are charged objects that are much, much smaller than the distance between them.

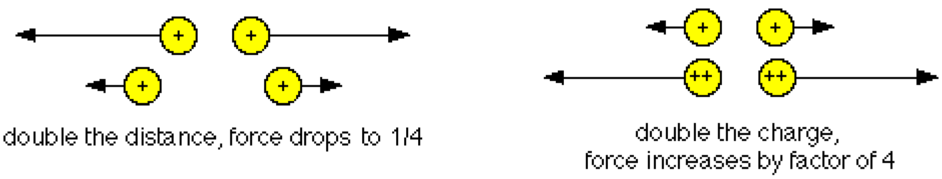
Charles Coulomb first described electric field strengths in the 1780's. Using a device called the **torsion balance**, he found that for point charges, the electrical force varies directly with the product of the charges. In other words, the greater the charges, the stronger the field. And the field varies inversely with the square of the distance between the charges. This means that the greater the distance, the weaker the force becomes. This relationship can be written as a formula:

Remember this:

$$F = k\frac{(q_1 \times q_2)}{d^2}$$

where **q** is the charge, and **d** is the distance between the charges, ***k*** is the **proportionality constant** which depends on the material separating the charges.

In vacuum the value of k is 9×10^9 N.m^2/C^2 Let us interpret the formula using the following diagrams



According to this law, when two positively-charged objects (2C and 4C, respectively) are brought near each other within a distance of 20 cm, the force of attraction between the two charges is

$$F = k\frac{q_1 q_2}{d^2} = 9x10^9\,N.m^2/C^2\,\frac{(2C)(4C)}{(0.20)^2} = 1.8x10^{12}\,N$$

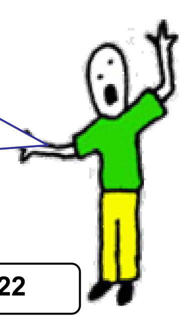
In solving problems, it is important to be consistent with the units. Inspect the units of the constant you are using and convert the units of the quantities, if necessary

What you will do
Self Test 3.1 Problem Solving

It's time for you to solve these problems!

1. Find the magnitude of the force between two charges of 1 C each that are 2 m apart.

2. A charge of 5 x10^{-9} C is attracted by a charge of –3x10^{-7} C with a force of 0.135 N. How far apart are they? (Hint: manipulate the equation to get an expression for **d**)



Key to answers on page 22

Lesson 4 Conductors and Insulators

In the activities you have just performed, you have learned and demonstrated that electrons may be made to move from one atom to another. However, some materials hold their electrons very tightly and electrons do not move through them very well. These materials are called **insulators**. On the other hand, some materials have very loosely held electrons, which move through them very well. These are called **conductors**.

The following activity helps you classify materials into conductors and insulators. The set-up involves the concept of circuit which we shall discuss in the next module. Our main objective now is to find out the response of the circuit to the materials.

What you will do

Activity 4.1 Identifying conductors

What you will need

- Battery, bulb and connecting wires
  ** the battery should match the kind of bulb and wires used*

Suggested materials to be gathered:
Plastic spoon, aluminum spoon, cloth, ceramic tiles, pair of scissors, plant leaf, pencil lead, glass, paper, coin

What to do

1. Gather the materials needed.
2. Connect wires to the two terminals of the bulb. It would be easier to make use of a bulb socket.
3. Using the wires, connect the battery to the bulb. Check that the bulbs must light on. What does the bulb indicate?
4. Break the circuit by connecting another wire at one end of the battery and inserting the materials between the wire connected at one terminal of the bulb and the other wire connected to the battery one by one.
5. Using the table, list down the materials that makes the bulb glow when inserted in the circuit.

Materials that made the bulb glow	Materials that did not make the bulb glow

What happened?

In the activity, you were able to classify the materials into two: those that made the bulb glow and those that did not. When a material inserted in the circuit allows the flow of electrons through it, its electrons are loosely held and it conducts electricity. Thus it makes the bulb glow. Such material is called a conductor.

What you will do

Self-Test 4.1

Name the materials found in the box and classify them as conductors or insulators. Encircle the materials that exhibit more conductive than insulating properties.

Key to answers on page 22

Let's summarize

In this module, you have learned that

1. Electrostatics is the study of charges at rest.

2. The fundamental entity in electrostatics is the electric charge. The standard unit for charge is coulomb (**C**).

3. A body could either be positively charged, negatively charged or neutral. Negatively charged bodies have excess electrons and positively charged bodies have deficiency of electron. Bodies that are electrically neutral have the same number of protons and electrons.

4. Electrification or charging is the process of producing an electrically charged object. Charging may be done by friction (contact) and induction.

5. Coulomb's law states that the force one charge exerts on another is directly proportional to the magnitudes of the charges and inversely proportional to the square of the distance between them

6. Materials could either be conductors, insulators or semiconductors. Conductors are materials that permit electric charges to move easily within them while insulators are materials that permit electric charges to move much less readily.

Posttest

Directions: Select the letter of the choice that correctly answers the given questions. Write your answer on a separate sheet of paper.

1. How do you describe an object that gains excess electrons after being rubbed against another object?
    a. Uncharged
    b. Negatively-charged
    c. Positively-charged
    d. Either a, b or c

2. Who among the following scientists believed in “animal electricity”?
    a. Alessandro Volta
    b. Luigi Galvani
    c. Georg Simon Ohm
    d. Michael Faraday

3. Which of the following can be said about two objects that attracted each other when held close together?
    a. The two objects have the same charges
    b. The two objects have opposite charges
    c. One of the objects is neutral (no charge)
    d. Both b and c

4. What do you call those materials that easily permit the flow of electricity through them?
    a. Insulators
    b. Conductors
    c. Resistors
    d. Current Sources

5. Two uncharged objects A and B were rubbed against each other. When object B was placed near a negatively charged object C, the two objects repelled each other. Which of these statements is true about object A?
    a. Object A remained uncharged.
    b. Object A became positively-charged.
    c. Object A became negatively-charged.
    d. Unpredictable

6. Which of the following is NOT a conductor?
    a. water
    b. aluminum utensils
    c. rubber band

d. pencil lead

7. During which of the following weather conditions is static electricity easiest to produce?
    a. Humid
    b. Windy
    c. Hot and dry
    d. Rainy

8. What apparatus did Charles Coulomb use to measure the force of interaction of charged bodies?
    a. Beam balance
    b. Spring balance
    c. Torsion balance
    d. Electronic balance

9. When you rub a plastic rod against your hair several times and put it near some bits of paper, the pieces of papers are attracted towards it. What does this observation indicate?
    a. The plastic and the paper are oppositely-charged.
    b. The plastic acquired a charge.
    c. The plastic and the paper have the same charges.
    d. All of the above

10. How do you describe an atom having the same number of protons and electrons?
    a. Positively-charged
    b. Negatively-charged
    c. Uncharged
    d. Both a and c

11. According to Coulomb's Law, what happens to the attraction of two oppositely-charged objects as their distance of separation increases?
    a. increases
    b. decreases
    c. remains unchanged
    d. cannot be determined

12. The handles of our cooking utensils at home are usually made of rubber or hard plastics that do not allow heat to pass through them. These materials

    a. have high resistance
    b. are conductors
    c. both and b
    d. Neither a or b

13. Which of the following materials does not belong to the group?
    a. rubber slippers
    b. ceramic plate
    c. aluminum frying pan
    d. electrical tape

14. Who among these scientists investigated different materials and found out that current passes through at different rates for different kinds of materials?
    a. Thomas Alva Edison
    b. Georg Simon Ohm
    c. Charles Coulomb
    d. Joseph Henry

15. When you rub a plastic rod against your skin, charges will likely move
    a. from the rod to your skin
    b. from your skin to the rod
    c. simultaneously to your skin and the rod
    d. cannot be predicted

Key to answers on page 22

Key to Answers

Pretest

1. d	6. I	11. √
2. b	7. C	12. x
3. e	8. I	13. x
4. a	9. I	14. x
5. c	10. C	15. √

Lesson 1

Self-Test 1.1
1. Galvani
2. Coulomb
3. Faraday
4. Volta
5. Ohm

Lesson 2

Self-Test 2.1

The hat and your skin rub against each other when your hat is removed. In this case, charges will move from your hair to the hat. Your hair strands become charged as a result of the rubbing process. Since each hair strand has the same charge, each will repell the other hair strands and the hair appears to stand.

Lesson 3

Self-Test 3.1

1. 2.25×10^{9} N
2. 10,000 m

Lesson 4

Self-Test 4.1

Materials	Classification
1. Ceramic plate	Conductor
2. Cooler	Insulator
3. Plastic mug	Insulator
4. Door knob	Conductor
5. Gloves	Insulator
6. Hollow Block	Insulator
7. Spoon	Conductor
8. Tires	Insulator
9. Aluminum pan	Conductor
10. Galvanized sheets	Conductor

Posttest

1. b	6. c	11. b
2. b	7. c	12. a
3. d	8. a	13. c
4. b	9. a	14. b
5. b	10. c	15. a

-End of Module-

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