Nature of Electronics

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Overview

As we go about our everyday lives, many people are not aware of how much electronics plays a part. In the morning, most of us use an alarm clock to wake up. We then turn on the lights to get dressed. If you're a woman, you immediately flip on the hot curlers and if you're a man, you need to use your electric shavers. You then hurry to get dressed and throw a hot pocket into the microwave for breakfast and grab your microwavable meal out of the freezer for lunch. All of these things we do on a daily basis without even thinking. No one pauses and asks, "How did the radio on my alarm clock come on? Why didn't my hot curling iron or electric shaver short out the electricity in my house? How can I have on the lights, hot curling iron, electric shaver and microwave all at the same time without burning down my house? And finally, "Why didn't they all shut off when I turned one of them off? Many of these questions we'll explore while we study the nature of electronics.

This curriculum unit is designed to introduce my students to electronics. It is designed for students between the ages of 16 – 18 and presently taking physics in grades 11 -12. This unit will cover a span of 2-3 weeks.

Rationale

Modern electronics was sparked at the beginning of the 20th century when John Fleming developed the vacuum tube. From the development of this tube, telegraph, telephone and radio waves were established. In 1948, the transistor replaced this tube and electronics ascended to new heights. The integrated circuit was introduced which is now responsible for our microcomputers, audio/video equipment and our communication satellites. Truly, we are benefiting from all of these electronic gadgets.

Why learn about electronics? My answer is why not? We live in a day and age where electronics have ascended to the forefront of our lives. To some, electronics are the key to their survival. The use of cell phones, computers, palm pilots, microwaves, digital cable, etc. are luxuries many have chosen to live without. Electronics has also played a big part in saving lives. The use of heart monitors, MRI's, CAT scans and many of the instruments doctors use for surgery have been very beneficial. Not only are hospital stays shorter but detection of harmful diseases are discovered faster and many surgical procedures are shortened with a speedy recovery.

My goal is to expose my students to the fundamentals of electronics. I want them to know what a charge is and how to detect it, how circuits work in series and parallel and the correlation between these circuits and Ohm's Law. I want to teach the advantages and the disadvantages of electronics. I want them to gain an appreciation for gadgets that have helped people to cook lot easier, people use the computer, run the sweeper, iron clothes and play playstation much more efficiently. I want my students to also understand that with electronics comes a price and that all the uses that they take for granted are not free. By the time we are done with this lesson, I hope that students will have a greater appreciation for electronics.

Electrostatics

Have you ever wondered why a balloon is attracted to your hair or why on a dry day a balloon can stick to the walls for hours? Why running a plastic comb through your hair on a dry day can attract small pieces of paper? Why your body gives off an electric charge by rubbing your shoes on a wool rug? All of these questions can be answered when you have an understanding of the concept of charge. Benjamin Franklin names the two different kinds of charge as positive and negative. A positively charged particle is a proton and a negatively charged particle is an electron. Positive and negative charges are said to be opposite because an object with and equal amount of positive and negative charge has no net charge or is neutrally charged. This neutrally charged particle is known as a neutron.

These charged particles play a major role in the understanding of electrostatics. Electrostatics is defined as the study of electrical charges that can be collected and held in one place. For example, when you rub a comb through your hair and bring the comb close to pieces of paper, they will begin to stick to the comb. Rubbing a comb through your hair transfers electrons to the comb which gives the comb a negative charge. When the comb is brought close to the bits of paper a charge separation is induced on the paper bits. The attractive electrical force accelerates the paper bits upward against the force of gravity to the comb. This strong attractive force will only last a little while. After a while, the attractive property will disappear returning the comb and the paper back to their neutral states.

Another simple example of electrical charge is the attraction between two pieces of transparent tape. When one piece of tape is stuck to the other and pulled a part, they are charged and not only do they stick to your hand but they stick to each other as well. Last but not least, the rubbing of wool or fur to a rubber rod or a glass rod and silk is often used to detect charge using an electroscope. These objects when rubbed with these fabrics become charged thus making the leaves in the electroscope pull a part. If the rod is negatively charged, the charged rod pushes electrons down the leaves causing them to spread more. If the rod is positively charged and attracts some of the electrons, the leaves will spread a part less.

When dealing with material objects to find a charge it is important to know whether they are conductors or insulators. As you can recall, electrostatics deals with charges being held in one place. Depending on the object that is used, when charges are transferred they will stay contained only in the area where contact was made or become spread throughout the object. This is the difference between an insulator and a conductor. Insulators are materials through which charges will not move easily. If you rub the wool on half of the rubber rod and touch the electroscope with that end, the leaves will move a part. If you take the other end of the rod and touch the electroscope, nothing will happen. The charge was contained to just that part that was rubbed.

Conductors are materials that allow charges to move about easily. A good example is metals. You can rub one end of a metal rod and the charge will move through the whole rod. This has been proven using an electroscope as well.

What one must take into consideration is the condition of the weather surrounding these experiments. These experiments work best on dry days. When the weather is rainy or humid, charges leak off onto the water molecules into the air. So on humid days, be careful. It is probably best to do these experiments in the fall or early spring.

Electricity and Circuitry

The flow of charged particles is called an electric current. Electric current powers our lights, radios, computers, refrigerators, etc. Electric currents are even in part of our body. Current exists whenever there is a net movement of electric charge through a medium. Conventional current is defined as the positive charge flowing from a positive source to a negative source. However, the moving charges that make up current can be either positive, negative or a combination of the two. In a conductor, such as copper, current is due to the motion of negatively charged electrons. This is because the atomic structure of solid conductors allows the electrons to be transferred easily from one atom to the next, while the protons are relatively fixed inside the nucleus.

There are two types of current: direct current (dc) and alternating current (ac). In direct current, charges move only in one direction. If direct current was graphed, there would be a straight, parallel line across the x-axis. Alternating current has charges that continuously change in the forward and reverse directions. This graph would resemble a sin graph.

When you drop a ball, it falls to the ground, moving from a place of higher gravitational potential energy to one of lower potential energy. This is how charges behave. Free electrons move freely in a conductor when all points in a conductor are at the same potential. When a potential difference is applied across a conductor, the charges move slowly from a higher electric potential to a lower electric potential. Thus, a difference in potential maintains a current in the circuit.

Batteries, generators or photovoltaic cells (solar cells) maintain a potential difference across a circuit by converting chemical energy to electric energy, kinetic energy into electric energy and light energy to electric energy, respectively. Power measures the rate at which energy is transferred. It is found by multiplying the potential difference, V, by the current, I. Therefore, $P = IV$. Suppose two conductors have a potential difference between them. The property that determines how much current will flow is called resistance. Resistance is measured by placing a potential difference across two points on a conductor and measuring the current. Resistance is defined as the ratio of potential difference, V, to the current, I. Therefore, $R = V/I$. The electric current I, is in amperes. The potential difference, V, is in volts. To measure current, you use an ammeter. To measure the potential difference you use a voltmeter.

A German scientist, Georg Simon Ohm, discovered that the ratio of the potential difference to the current is always a constant for a given conductor. Therefore, the resistance for most conductors does not vary as the magnitude or the direction of the potential applied to it changes. A device that has a constant resistance that is independent of the potential difference is said to obey Ohm's law.

Ohm's law is used to measure the resistance, current and voltage in series and parallel circuits. A series circuit flows through one path. The equivalent resistance of a series circuit is the sum of the resistances of its parts. It is denoted by the formula $R = Ra + Rb + Rc$…. A parallel circuit has many paths that are independent of one another. An example of this is the electricity in your home. If the lights were connected in series, all of the lights would shut off when you turned off one switch. Because our homes are set up in parallel, you can turn the lights off and on in one or more rooms, and operate several appliances at the same time. In a parallel circuit, the total current is equal to the sum of the current in the branches. If any branch of a parallel circuit is open, there is no current in that branch. The formula for equivalent resistance in a parallel circuit is 1/R = 1/Ra + 1/Rb+ 1/Rc….

Objectives

The goal of this curriculum unit is to accomplish the following goals:

1) an understanding of how charges behave
2) calculate the electrical force between two charges
3) define electric current and the conditions that create it
4) how to draw and construct series and parallel circuits
5) use Ohm's Law to measure the resistance, voltage, and current in a series or parallel circuit
6) relate many of the lessons to their everyday lives
7) develop assignments that students can take home and share with family members.

Strategies

At the onset of this unit, through a small questionnaire, I intend to find out who knows what or lack thereof about electronics. This questionnaire will be used as an assessment tool. After the questionnaire, I plan to begin my lesson with the concept of electrostatics. Knowing the behavior of charges is vital to the students understanding of currents and circuitry. Next, we will discuss electric current and conditions that create current. Ohm's Law will be introduced and the students will be able to calculate the resistance, voltage, current or power of several circuits. After electric current, we'll begin drawing and constructing series and parallel circuits. From these circuits, we'll be able to measure their current, voltage and resistance. Students will also use several online sources to help with their understanding of electronics as well as several demonstrations and laboratory experiments. Students will be required to participate and keep a notebook that will be checked daily. These lessons and activities were designed to fit the National Teaching and Learning Standards that were adopted for the state of Pennsylvania (See Appendix A).

Class Activities

Week One **(ST#1,2,4-9 CS#2-4,6 MS#1-5)**
Electrostatics

Students will answer a questionnaire to probe their knowledge about electrostatics and electronics (See Appendix B). Once we have discussed the questionnaire and recorded notes, we will engage in a laboratory experiment that will encompass the notes and our discussions. This lab is going to be broken down into several mini-stations where the students will spend 20 minutes at each station experimenting with the concept of electrostatics. Students will receive their instructions and sheets at each station. The lab stations will contain the following experiments and directions:

Station A: Transparent Charge
Part I: Take a comb and run it through your hair. Place the comb near the pieces of paper on the table. Record what happened.

Part II. Place two strips of transparent tape on the table side by side. Quickly, lift them both up simultaneously. Place the strips near each other. Record what happened.

Part II. Obtain two pieces of transparent tape. Make sure your lab surface is dry. Label the first piece B and the second piece T. Place B on the surface and stick T on top. Lift both of pieces of tape off of the table. Rub both strips with your fingers until they are no longer attracted to your hand. Pull the strips a part quickly. Record what happened.

Station B: Static Cling
Make sure the electroscope is discharged (neutral) by touching the probe with your finger. The leaves will drop. Then begin the following steps:

1. Rub a rubber rod with fur and the glass rod with silk. The rubber rod will become negatively charged and silk positively charged. Touch the probe of the electroscope with the charged rod. Record what happened to the electroscope.
2. Touch the electroscope to discharge it. Follow the same instructions as above but on rub half of the rubber and silk rod with the same materials. Touch the probe with both ends. Record what happens.
3. Discharge the probe. Rub the metal rod with wool. Touch the probe and record what happens. Discharge the metal rod again. This time rub half of the rod with the wool. Touch the electroscope with both ends. Record what happens.

Station C: Hanging High
Part I. Take a balloon and blow it up. Rub the balloon through your hair and place it on the wall. Record how long the balloon stays on the wall.

Part II. Take two balloons and blow them up. Place a string at the end of each balloon. Rub them both on your hair. Pull the strings together. Record what happens to the balloons.

After the students are done at each station with each experiment, they will answer the following questions in their analysis section and write a formal lab report. The following questions will be in the analysis section:

Analysis

Station A: Transparent Charge

1. Explain why the bits of paper were attracted to the comb after you ran it through your hair?
2. Explain what happened to the transparent strips once they were pulled from the table?
3. What happened to the strips when they were pulled a part?

Station B: Static Cling

4. What did you rub the rubber, plastic and glass rods against the wool, fur and silk objects? Could another material be used?
5. When asked to rub half of the glass and plastic rod with silk and wool, why was there an attraction to the electroscope with this half and not the other?
6. At the same time, you were asked to rub the silk and wool against half of the metal rod. Explain why both of the ends were attracted to the electroscope although you only rubbed half of the rod.

Station C: Hangin High

7. Why did the two balloons repel each other?
8. How long did your balloon hang on the wall? What prevented it from hanging longer?
9. If your hair was wet, do you think this experiment would work?

After this laboratory experiment, the students will then analyze Coulomb's Law. Using the formula, they will calculate the electric force between charges (See Appendix C).

Week Two **(ST#1,2,4-9 CS#2-4,6 MS#1-5)**
Electricity

Students will gather in groups of two to devise concept map about electronics. They will have to identify 10- 15 concepts that relate to electronics. Once they are done, we will discuss their concepts amongst the class and begin our lesson on electricity. We will observe a film entitled *Electricity* which is part of the mechanical universe series. We will then engage in a discussion whereby we pinpoint how obtain electric energy and how this makes up a circuit. Ohm's law will be introduced and students will begin to build simple circuits. From these circuits they will be able to calculate the current. In the course of this lesson, students will be assigned the following at-home lab:

At-Home Lab

Directions: Assuming that all of the appliances in your home have a maximum of 120 V, find 6-10 electrical appliances and record the power and current of each. Determine the resistance of each appliance.

Name of Appliance	Voltage	Current	Power	Resistance
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				

You will then be asked to figure out the cost of operating an electric device. This activity will give you an idea of just how much electrical energy is being used and perhaps encourage them to learn how to save energy. This activity is entitled, "How much is this appliance costing me?"

Before you begin this activity, ask your parents if they will allow you to look at one of the light bills. Show them this assignment so that you are not being accused of snooping in "grown folks business" since you do not pay the bill. Scan the bill to find out how much money you pay per kilowatt hour. If you can not find this information than call your local light bill company.

Find out how many amps the appliance uses and how many volts. Calculate the power of the appliance using the formula P = IV. Next, write down how many hours a day this appliance is used and what energy in kWh it consumes per month using the formula E = Pt. Using the cost per KWh, figure out how much it would cost you to run this appliance using the formula cost = E x ¢/kWh. Lastly, calculate the percentage of how much this appliance costs to operate a month.

Week Three

Series and Parallel Circuits (ST#1,2,4-8 CS#2-4,6 MS#1-5)

Students will engage in a laboratory experiment where they will draw diagrams and construct series and parallel circuits. They will observe the effects of electric current. From this lab they will analyze the brightness of the lamps and make predictions as to whether a circuit be made such that one lamp is brighter than the others and stays on if either of the others is loosened in its socket.

Students will build a simple circuit where they will place bulbs securely in the sockets. Using one light bulb, a battery, and wires, they will connect the battery to produce light. A brief description of the bulbs brightness and other observations will be recorded and the circuit will be drawn.

Next, the students will connect the socket of bulbs in a side-to side- row using two wires. They will use additional wires to connect the unattached ends to the battery so that all the bulbs light. Observing the brightness, a brief description will be recorded. The socket of bulbs will then be placed in columns and connected. The brightness will be observed and recorded then one of the bulbs will be unscrewed to see what happens. Students will comment on the position of the bulbs and whether or not the unscrewed bulb made a difference.

While the students are working on this lab, they will answer a series of analysis questions that pertain to each circuit that they construct. They will also calculate the resistance, voltage and current in several practice problems in their textbook. Examples of these problems are in appendix D.

Lastly, students will write an essay entitled "The Impact of Electronics on My Life." Students have to identify those things that are electronic that they presently use. They will elaborate on how these objects impact their lives and then predict what their lives would be without these electronic objects. This essay is to be no more than two pages and will be shared with their classmates.

Bibliography

Reading Materials

Serway, Raymond A. and Jerry S. Faughn. Holt Physics. Austin: Holt, Rinehart and Winston Publishing Company, 2002.

Zitzewski, Paul W. Glencoe Physics: Principles and Problems. Westerville: Glencoe/McGraw Hill Publishing Company, Inc., 1999.

Classroom Resources

Glencoe Physics: Principles and Problems. "Physics Lab and Pocket Lab Worksheets." Westerville: Glencoe/McGraw Hill Publishing Company, Inc., 1999.

Glencoe Physics: Principles and Problems. "Laboratory Manual." Westerville: Glencoe/McGraw Hill Publishing Company, Inc., 1999.

Holt Physics. "Laboratory Manual." Austin: Holt, Rinehart and Winston Publishing Company, 2002.

Online Resources

http://www.scilinks.org accessed on June 11, 2003

http://www.si.edu/hrw accessed on June 11, 2003

http://www.glencoe.com/sec/science accessed on June 11, 2003

Videos

Mechanical Universe: High School Adaptation. Intelecom Intelligent Communications: Pasadena, California.

Electricity
Millikan's Oil Drop Experiment
Series and Parallel Circuits

Materials Needed

Week One

pen/pencil	glass rod
marker	metal rod
comb	wool fabric
colored paper	silk fabric
transparent tape	10 balloons
rubber rod	electroscope

Week Two

battery	voltmeter
ammeter	calculator
3 miniature lightbulbs	light bill
resistors	wire
pen/pencil	paper

Week Three

3- 1.5 V batteries	five miniature lamps and sockets
connecting wires	rubber bands
calculator	paper
pen/pencil	tape

APPENDIX A

Standards

This curriculum unit focused on the following Standards that are used by Pittsburgh Public Schools.

Science and Technology (ST)

1. All students explain how scientific principles of chemical, physical, and biological phenomena have developed and relate them to real world situations.
2. All students demonstrate knowledge of basic concepts and principles of physical, chemical and biological and earth sciences
4. All students explain the relationships among science technology and society.
5. All students construct and evaluate scientific and technological systems using models to explain or predict results.
6. All students develop and apply skills of observations, data collection, analysis, pattern recognition, prediction and scientific reasoning and conducting experiments in solving technological problems.
7. All students evaluate advantages, disadvantages and ethical implications associated with the impact of science and technology of current and future life.
8. All students evaluate the impact of current and future life of the development and use of varied energy forms, natural and synthetic materials, production and processing of food and other agricultural products.
9. All students demonstrate basic computer literacy, including word processing, software applications, and the ability to access the global information infrastructure, using current technology.

Mathematics (MA)

1. All students use numbers, number systems, and equivalent forms to represent theoretical and practical situations.
2. All students compute, measure and estimate to solve theoretical and practical problems using appropriate tools, including modern technology such as calculators and computers.
3. All students apply the concepts of patterns, functions and relations to solve theoretical and practical problems.
4. All students formulate and solve problems and communicate the mathematical processes used and the reasons for using them.

5. All students understand and apply basic concepts of algebra, geometry, probability and statistics to solve theoretical and practical problems.
6. All students evaluate, infer, and draw appropriate conclusions from charts, tables and graphs showing the relationship between data and real world situations.

Communications (CO)

2. All students read and use a variety of methods to make sense of various kinds of complex texts.
3. All students respond orally and in writing to information and ideas gained by reading narrative and informational texts and use the information and ideas to make decisions and solve problems.
4. All students write for a variety of purposes, including to narrate, inform, and persuade in all subject areas.
6. All students exchange information orally, including understanding and giving spoken directions, asking and answering questions appropriately and promoting effective group communications.

APPENDIX B

Questionnaire

Name _____________________ Date ___________________

Directions: This questionnaire was designed to get a sense of what you know about electrostatics and electronics. Answer the questions to the best of your ability.

1. What is a positively charged particle called?

2. What is a negatively charged particles called?

3. What is a neutrally charged particle called?

4. Explain the behavior between like charges?

5. Explain the behavior between unlike charges?

6. What is a series circuit?

7. What is a parallel circuit?

8. Is your home wired in series or parallel? Explain.

9. What is Ohm's Law?

10. What do the variables I, V, and R stand for in Ohm's Law?

APPENDIX C

Name ______________________ Date ___________________

Coulomb's Law

Directions: Solve the following problems below using Coulomb's Law.

1. A balloon rubbed against denim gains a charge of -7.0µC. What is the electron force between the balloon and the denim when they are separated by a distance of 4.0 cm?

2. Two identical conducting spheres are placed with their centers 0.30 m apart. One is given a charge of $+8.0 \times 10^{-9}$ C and the other a charge of -5.0×10^{-9} C. Find the electric charge exerted on one sphere by the other.

3. A small glass ball rubbed with silk gains a charge of +3.0µC. The glass ball is placed 10 cm from a small charged rubber ball that carries a charge of -2.7µC.
    a. What is the magnitude of the electric force between the two balls?
    b. Is the force attractive or repulsive?
    c. How many electrons has the glass ball lost in the rubbing process?

4. Two electrostatic point charges of +50µC and 40µC exert a repulsive force on each other of 17 N. What is the distance between the two charges?

5. You have two charges q_1 and q_2. They are separated by a distance, d, and has a force, F, exerted upon them. What new force will exist if
    a. q_1 is doubled?
    b. q_1 and q_2 are cut in half?
    c. d is doubled?
    d. d is tripled?

APPENDIX D

Name _____________________ Date ____________________

Series and Parallel Circuits

1. A length of wire is cut into four equal pieces. The four pieces are then connected in parallel, with the resulting resistance being 2.00Ω. What was the resistance of the original length of wire before it was cut up?

2. A 12.0 V battery is connected to three resistors, 3.75 Ω, 7.40 Ω, and 13.8Ω, respectively. The resistors are joined in series.
   a. Calculate the equivalence resistance.
   b. What is the current in the circuit?

3. A 3.0 Ω resistor, a 7.0 Ω resistor, and an 11.0 Ω resistor are connected in parallel across a 24.0 V battery.
   a. What is the equivalence resistance of the circuit?
   b. What is the current in each resistor?

4. A 6.0 Ω resistor, 8.0 Ω resistor, and 10.0 Ω resistor are connected in series with a 24 V battery.
   a. Calculate the equivalence resistance of the circuit.
   b. What is the potential difference across the source?
   c. Calculate the current in each resistor.

5. A 15.0 Ω resistor, 10.0 Ω resistor, and 4.0 Ω resistor are connected in parallel to an emf source. A current of 5.00 A is in the 10.0 Ω resistor.
   a. Calculate the equivalence resistance of the circuit.
   b. What is the potential difference across the source?
   c. Calculate the current in the other resistors.