SCOPE, SEQUENCE, and COORDINATION

A National Curriculum Project for High School Science Education

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National Science Education Standard—Physical Science

The Structure of Atoms

Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.

Motions and Forces

The electric force is a universal force that exists between any two charged objects. Opposite charges attract while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

Teacher Materials

Learning Sequence Item:

943

Electric Charge and Static Electricity

March 1996

Adapted by: *Bill G. Aldridge, Arthur Eisenkraft, Tom Ivy, Lois Range, and Ragan Spain*

The Nuclear Atom and its Components: Electrons, Protons, and Neutrons. (a) Students should observe direct electrical properties of matter, such as static electricity and conductivity. *(Chemistry, A Framework for High School Science Education, p. 74.)*

Electric Force: Coulomb's and Gauss's Laws. (b) At this level, students should review fundamental observations of electric charge and develop an understanding of how we know that there are only two kinds of electric charge. They should observe that two objects of the same material treated the same way to become charged repel each other, and that only when two objects of the same material are treated differently to produce charges do they attract each other. (Depending upon the treatment, two objects of the same material but treated differently may attract each other or repel each other, but two objects of the same material will never attract each other if they are treated the same way.) Students should learn that negative charge is defined as the charge of a rubber rod rubbed with fur. No attempt should be made at this level to discuss electrons or protons. Instead, students should concentrate on the basic idea of two kinds of electrical condition called plus and minus. They should learn the difference between conductors and insulators in terms of their ability to transfer charge from one object to another. The history of electricity is a rich source from which to draw when examining various models of electricity and testing them through observation. Students should use electroscopes as a means of observing effects of charges. Students should observe direct electrical properties of matter, such as static electricity and conductivity. *(Physics, A Framework for High School Science Education, p. 20.)*

Contents

This micro-unit was adapted by: **Bill G. Aldridge** (SS&C Project Director)**, Arthur Eisenkraft** (Fox Lane H.S., Bedford, N.Y.), **Thomas Ivy** (Lee H.S., Houston, Texas), **Lois Range** (Jefferson Davis H.S., Houston), and **Ragan Spain** (Tarboro H.S., Tarboro, N.C.)

943

Learning Sequence

The Nuclear Atom and its Components: Electrons, Protons, and Neutrons. (a) Students should observe direct electrical properties of matter, such as static electricity and conductivity. (Chemistry, A Framework for High School Science Education, p. 74.)

Electric Force: Coulomb's and Gauss's Laws. (b) At this level, students should review fundamental observations of electric charge and develop an understanding of how we know that there are only two kinds of electric charge. They should observe that two objects of the same material treated the same way to become charged repel each other, and that only when two objects of the same material are treated differently to produce charges do they attract each other. (Depending upon the treatment, two objects of the same material but treated differently may attract each other or repel each other, but two objects of the same material will never attract each other if they are treated the same way.) Students should learn that negative charge is defined as the charge of a rubber rod rubbed with fur. No attempt should be made at this level to discuss electrons or protons. Instead, students should concentrate on the basic idea of two kinds of electrical condition called plus and minus. They should learn the difference between conductors and insulators in terms of their ability to transfer charge from one object to another. The history of electricity is a rich source from which to draw when examining various models of electricity and testing them through observation. Students should use electroscopes as a means of observing effects of charges. Students should observe direct electrical properties of matter, such as static electricity and conductivity. (Physics, A Framework for High School Science Education, p. 20.)

Science as Inquiry	Science and Technology	Science in Personal and Social Perspectives	History and Nature of Science
What Is Much Stronger Than Gravity? **Activity 1**	Static Electricity and Computers **Assessment 3**	Pith Balls: Conditions Changed **Assessment 2**	Benjamin Franklin **Reading 1**
Getting a Charge Out of Balloons **Activity 2**	Electrostatic Separators **Assessment 4**	Static Electricity and Computers **Assessment 3**	Experiments and Observations on Electricity **Reading 2**
Strange Things with Charged Balloons **Activity 3**		Electrostatic Separators **Assessment 4**	New Experiments and Observations on Electricity **Reading 3**
The Electroscope: Keep Your Distance **Activity 4**			Attraction and Repulsion **Reading 4**
Testing for Conductivity **Activity 5**			Storing Electricity in the Capacitor **Reading 5**
Pith Balls **Assessment 1**			Ben Franklin and the Nature of Lightning **Reading 6**
Pith Balls: Conditions Changed **Assessment 2**			Ben Franklin's Electrical Research **Reading 7**
Is This Gravity or Electrostatics? **Assessment 5**			

Suggested Sequence of Events

Event #1

Lab Activity
1. What Is Much Stronger Than Gravity?

Event #2

Lab Activity
2. Getting a Charge Out of Balloons

Event #3

Lab Activity
3. Strange Things with Charged Balloons

Event #4

Lab Activity
4. The Electroscope: Keep Your Distance

Event #5

Lab Activity
5. Testing for Conductivity

Event #5

Readings from Science as Inquiry, Science and Technology, Science in Personal and Social Perspectives, and History and Nature of Science

Students should select from the following:

Reading 1 Benjamin Franklin
Reading 2 Experiments and Observations on Electricity
Reading 3 New Experiments and Observations on Electricity
Reading 4 Attraction and Repulsion
Reading 5 Storing Electricity in the Capacitor
Reading 6 Ben Franklin's Electrical Research
Reading 7 Ben Franklin and the Nature of Lightning

Readings can be found in the student version of this publication.

Assessment items are at the back of this volume.

Assessment Recommendations

This teacher materials packet contains a few items suggested for classroom assessment. Often, three types of items are included. Some have been tested and reviewed, but not all.

1. Multiple choice questions accompanied by short essays, called justification, that allow teachers to find out if students really understand their selections on the multiple choice.

2. Open-ended questions asking for essay responses.

3. Suggestions for performance tasks, usually including laboratory work, questions to be answered, data to be graphed and processed, and inferences to be made. Some tasks include proposals for student design of such tasks. These may sometimes closely resemble a good laboratory task, since the best types of laboratories are assessing student skills and performance at all times. Special assessment tasks will not be needed if measures such as questions, tabulations, graphs, calculations, etc., are incorporated into regular lab activities.

Teachers are encouraged to make changes in these items to suit their own classroom situations and to develop further items of their own, hopefully finding inspiration in the models we have provided. We hope you may consider adding your best items to our pool. We also will be very pleased to hear of proposed revisions to our items when you think they are needed.

Teacher Sheet

Science as Inquiry

What Is Much Stronger Than Gravity?

Materials:

balloons, 1 for each student.
pieces of fur or wool, 1 for every two students
sheets of paper, 1 for each student.

Procedure:

This is a very simple activity. Students are expected to carefully observe the fact that a charged balloon can pick up bits of paper. They should rub the end of the balloon, which they will bring near the pieces of paper. They should not touch the bits of paper with the balloon. If it is a very hot and humid day and you do not have air conditioning, the balloon may not acquire and keep charge. This activity is best done in an environment that is very dry.

Background:

The whole point of this activity is to demonstrate the enormous force exerted by electric charge in contrast to the force of gravity. The fact that the charge is induced on the paper is not important to this discussion at this time. Nor is the exact mechanism in terms of electron transfer. None of this should be discussed by you or allowed to be part of student explanation. Nor should they use terms like plus or minus. This is often difficult because students have memorized, but not understood or known about, evidence for such things in their past educational experience. Still, it can be fun to see how much they can derive from this limited set of observations. Let them try to create a model for what is happening in terms of something being rubbed off of or onto the balloon, and somehow the balloon attracts the bits of paper through some mechanism. Do not dwell on this aspect, as the key point of the activity is simply that electrical forces are far stronger than gravitational forces

Science as Inquiry

Getting a Charge Out of Balloons

How do two "charged" balloons interact?

Materials:

balloons
fur
transparent tape (e.g., Scotch™ tape)
plastic wrap (e.g., Saran Wrap™)
string

Procedure:

Have students blow up balloons, hang one of them from the ceiling (or a suitable hanger), charge them, and watch them interact with charged objects and each other. Do the same with transparent tape, using the tape strips placed onto a tabletop and quickly ripped off as one treatment and the strips placed, one on top of the other and ripped apart, as the other treatment. Using the tabletop itself is not as effective, since the tape will probably induce charge on any part of the table to which it is brought close.

Background:

Balloons will acquire a strong negative charge when rubbed with a piece of fur or wool and will acquire a strong positive charge when rubbed with plastic wrap. If a balloon is suspended by a string, or held on the side opposite to where a charge has been placed, it will be well insulated from the environment and will hold its charge for a few minutes. In humid weather the charge will dissipate more quickly. Students will test like-charged balloons and unlike-charged balloons and learn about grounding. After students have had this experience, it is reasonable to inform them that Ben Franklin defined the two kinds of charge: negative, if rubber is rubbed with fur, and positive for the fur doing the rubbing. If glass is rubbed with silk, the charged glass is defined to be positive and the silk negative. Do not get into the concept of electrons or into a discussion at this stage of what a charge is fundamentally, even though many students think they know because they have memorized terms like electrons and protons. They have no idea what evidence exists that leads us to believe there is a fundamental unit of charge. Students should be able to summarize the empirical law that like charges repel and unlike charges attract.

Further Variations:

Students can experience the sharing of charge by touching two balloons with opposite charges to see if the charge can be neutralized, thereby reducing the net charge on each balloon to a value close to zero. They should create their own models of static electricity without reference to electrons, protons, ions, or plus or minus charges. Encourage model building and discourage attempts to recall previously conceived notions based upon electron transfer for which they have no evidence whatsoever, and which they have memorized without knowing why we now believe in such a theory. And do not get into the atomic or electron theory at this level.

Teacher Sheet

Science as Inquiry

Strange Things with Charged Balloons

How do charged balloons interact with uncharged objects?

Materials:

balloons
fur
transparent tape (e.g., Scotch™ tape)
plastic wrap (e.g., Saran Wrap™)
watch glass (from chemistry)
plastic ruler
strips of aluminum foil

Procedure:

Have students blow up a balloon, rub one side of it with fur (or wool), and try to make that side of it stick to the ceiling or parts of their body, head, back, etc. Have them do the same with transparent tape that has been charged. Also, have them charge the balloon with plastic wrap and use the balloon and plastic wrap against such surfaces. Let them use the charged side of a balloon to move a plastic ruler that is balanced on a watch glass by bringing the balloon near (but not touching) the ruler.

Background:

Balloons when charged will be attracted to neutral objects because of induction—that is, because the charges on the neutral object are redistributed so that the like charges are repelled (driven away) and the unlike charges are attracted (brought closer). For conductors those charges are moved along the conductor. For non-conductors, the plus and minus charges are moved away from their equilibrium positions, creating dipoles. Because the like charges are farther away from each other, and the unlike charges are closer to each other, the repelling force is weaker and the attractive force is stronger. The net force will therefore be attractive.

Students need to formulate this "explanation" as part of their model or theory. You should encourage their development of this model, but do not simply offer this as *the* explanation. Let them create their own theory, and if it is inadequate, suggest experiments or observations they can make to test their model. When they bring the charged balloon near a long strip of aluminum foil, the balloon will force negative charges toward the far end of the foil, leaving the near end charged positively. They will then see that end attracted to the balloon. If they touch the far end of the foil, the balloon is no longer attracted to the foil. If the balloon touches the foil, some charges are transferred to it, changing the situation even more. Several observations should be made with foil in contrast to nonconductors, with students offering explanations in terms of the aluminum readily "conducting" charges.

Further Variations:

The watch glass with a ruler balanced on it has very little friction and can spin easily. This can be done as a demonstration by putting the watch glass and ruler on the overhead projector so that the entire class can see it at once. In any case, the charged balloon will attract the neutral ruler by induction and the ruler can be made to spin quickly by keeping the balloon just ahead of the ruler as it rotates.

Teacher Sheet

Science as Inquiry

The Electroscope: Keep Your Distance

Materials:

Per lab group:
foil pie pan
paper clip
clear glass container
two 1 cm × 4 cm pieces of regular-weight aluminum foil

Charged Objects:
rubber rod/fur
Plexiglas™/silk
balloon/sweater
transparent tape/table
transparent tape/transparent tape
comb/hair

Procedure:

Have students open up the paper clip and use an end to make two holes near the center of the pie pan. They unfold the paper clip so it looks like an "S" and hang the paper clip from the pan. They then place the foil strips on the paper clip as shown on the student sheet and carefully smooth out the strips so they lie close to one another and can move freely. Have them place the pie pan with its paper clip and foil strips over a clear glass container.

Background:

The purpose of this lab is to build an electroscope and to experiment with charged objects in order to become familiar with how an electroscope reacts under different conditions. The rubber rod can be negatively charged by rubbing it with a piece of fur. This allows the electrons from atoms on the fur to transfer to the rod. The negative charge of the rod when brought close to the electroscope will force the electrons away from the pan. Because like charges repel, the negative charges in the foil strips will force themselves apart. Removing the rod allows electrons to shift back to an evenly distributed neutral state. In your explanations and discussions with students refer to charges, not to electrons.

Touching the pan with a negatively charged object will cause electrons to transfer to the electroscope. This causes an overall negative charge on the electroscope, which again forces the foil strips apart. Removing the rod will not bring the foil strips together because the electrons have been transferred to the electroscope in this case.

Positively charged objects will also cause the foil strips to separate. When the positive charge is brought close the electrons are attracted to the pan, causing the foil strips to become positive and repel. Touching the electroscope will transfer the electrons to the positively charged object, creating an overall positive electroscope, which again forces the strips apart.

Touching the electroscope with your hand always transfers electrons until the neutral condition has been reached. The foil strips will come together under these conditions. This is called grounding the electroscope. If the electroscope has been previously charged, the strips can be brought together using the oppositely charged object. The reasoning is the same as above.

Teacher Sheet

Science as Inquiry

Testing for Conductivity

How can we test for the conductivity of various substances using a simple light bulb and a battery?

Materials:

Per lab group:
6-volt lantern battery or Genecon hand-crank generator
6-volt light bulb with socket and copper wires
various common items to test (pencil, pen, plastic ruler, paper clip, etc.)

Procedure:

Have students attach a battery (or Genecon) to a light bulb and the material to be tested in a series arrangement (all three objects make a loop or circle with the connecting wires). If the light bulb lights, the object tested is a conductor, and if the object doesn’t light it is an insulator.

Background:

In a series circuit, if any object blocks the flow of charge the entire circuit is disabled. If an insulator is tested, the bulb will not light because the flow of charge everywhere will be stopped. If a conductor is tested, the bulb will light because the flow of charge will not be inhibited.

Students should have the opportunity to create a model in terms of charges. Their model should not be in terms of electrons or ions, since at this point, they have no direct evidence of the existence of either. What is needed is the student's own model. Most will create a model of plus and minus charges that move easily in metals but are held fixed in plastics, glass, etc. In the case of water and salt, their model will probably state that charges are held fixed in salt crystals, but when put into water, the salt changes in some way to free charges to move. This is, of course, what happens, since ions of sodium and chlorine are free to migrate within the water and thereby serve as the moving charges in the solution.

This is a good example of the fact that electric current is not always a flow of electrons. In this case electrons are moving in the wires but ions are moving in the liquid, and they are all part of the same circuit. Furthermore, in the solution you have both positive and negative charges moving but in opposite directions. It is important for you as teacher to know these things, but it is very important not to go into this kind of detail in discussions with students. They do not have the knowledge base to understand the evidence for electrons or ions; they can only memorize what you tell them. So leave it in the simpler terms of charges. Later in their sequence of learning science they will understand this same subject at that higher level of abstraction.

Science as Inquiry

Pith Balls*

Item:

Two small pith balls are hanging by threads so they touch. A plastic rod that has been rubbed on a piece of woolen cloth is brought near the balls. The following is observed:

At first, the two balls swing toward the rod as it is brought near. Next the balls are allowed to touch the rod. They appear to "stick" to it. After a few seconds the rod is pulled away. The two balls fly apart and stay separated for some time.

Explain this sequence of observations.

Is there any way that this experiment could be changed so that the balls would attract each other at the end rather than repel each other?

*A pith ball is a very lightweight small sphere covered with a layer of material that conducts electricity; it is usually suspended by a lightweight thread. Pith balls are used to study electrostatics.

Science as Inquiry/
Science in Personal and
Social Perspectives

Pith Balls: Conditions Changed

Item:
Two small pith balls are hanging by threads so they touch. A plastic rod that has been rubbed on a piece of woolen cloth is brought near the balls. The following is observed:

At first, the two balls swing toward the rod as it is brought near. Next the balls are allowed to touch the rod. They appear to "stick" to it. After a few seconds the rod is pulled away. The two balls fly apart and stay separated for some time.

A student who saw this experiment on Tuesday when the weather was dry and sunny told her friend that it took the pith balls several minutes to finally fall back together. Her friend had lab on Wednesday when it had started to rain outside. She was surprised to see that the balls only stayed apart for less than a minute.

Had one of the friends made a mistake in timing? What explains the difference if they hadn’t?

What practical implications does this have?

Science and Technology/
Science in Personal and
Social Perspectives

Static Electricity and Computers

Item:
Static electricity is a concern in industry and the home environment. For example, people who put new memory chips into computers are given instructions about how important it is to avoid static electricity. When you buy memory chips for your computer, the package usually includes a “grounding strap” to place around you wrist.

Why is this so important, and how does the grounding strap work?

Science and Technology/
Science in Personal and
Social Perspectives

Electrostatic Separators

Item:
Mix salt and pepper in a cup and spread the mix out on a flat surface. Take an electrically charged comb, rubber rod, or balloon and hold it approximately one centimeter above the surface of the mixture. Describe what you observe and explain this phenomenon in terms of your model or theory of static electricity. Next take the salt and pepper and dry it with a heat lamp. Repeat these observations. Is there any difference? If there is a difference, how can you explain that difference?

Design a method of separation of materials like salt and pepper. Is there another way you could separate the salt and pepper? Explain in some detail.

Science as Inquiry

Is This Gravity or Electrostatics?

Item:

A balloon is charged by rubbing it with wool. The charged side of the balloon is brought close to a narrow stream of water from a faucet. When the balloon is within about 2–3 cm, the stream moves toward the balloon, deflecting sideways its downward motion. Is this being caused by the force of gravity between the balloon and the water? Is it being caused by some kind of electrostatic force? Or is it caused by something else? Explain how you know it is one or the other of these reasons.