Resource for Middle School Classrooms

PhysicsQuest

BENJAMIN FRANKLIN'S SECRET MESSAGE

Distributed by the
American Physical Society

APS physics

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Table of Contents

Welcome to PhysicsQuest 2006!

Materials List

Included in this kit

- This PhysicsQuest manual
- 1 page inserts (3)
- Wool
- Plastic comb
- Light bulb and socket
- Insulated wires with clips (2)
- Felt (4 colors)
- Thermometers (2)
- Convex lenses (2)
- Concave lens

For more information on these items and where they can be purchased, please visit our website.

If your kit is missing any of these materials, please contact the kit vendor according to the directions on our website.

Not included in this kit

- Scotch tape
- Masking tape
- Metric ruler
- Meter stick
- String
- Plain white paper
- Graph paper
- Desk lamp
- Scissors
- Colored pencils / markers
- Stop watch or clock with second hand
- D batteries (2)
- Large paperclips (3)
- Penny
- Nickel

About PhysicsQuest

As part of the World Year of Physics 2005 celebration, the American Physical Society produced PhysicsQuest: The Search for Albert Einstein's Hidden Treasure. Designed as a resource for middle school science classrooms and clubs, the quest was received enthusiastically by nearly 10,000 classes during the course of 2005. Feedback indicated that this activity met a need within the middle school science community for fun and accessible physics material, so the American Physical Society (APS) has decided to continue this program. APS is pleased to present this second kit, PhysicsQuest 2006: Benjamin Franklin's Secret Message.

As a science teacher, you may have found that students are not always intrinsically motivated to learn about the physical world. The PhysicsQuest kits are designed with this in mind — each kit follows a mystery-based storyline and requires students to correctly complete four activities in order to solve the mystery and be eligible for a prize drawing. We hope this goal will entice students to actively participate — and that once students begin participating they will find that physics is interesting and fun!

About the American Physical Society

APS is the professional society for physicists in the United States. APS works to advance and disseminate the knowledge of physics through its journals, meetings, public affairs efforts, and educational programs. Information about APS and its programs can be found at www.aps.org.

APS also runs PhysicsCentral, a website aimed at communicating the excitement and importance of physics to the general public. At this site, www.physicscentral.com, you can find out about APS educational programs, current physics research, people in physics, and more.

PhysicsQuest 2006-2007 Competition

About the Competition

APS sponsors a PhysicsQuest competition in conjunction with the PhysicsQuest kits. This competition is optional and is designed to encourage students to actively invest in the project. If you chose to participate in the competition, your class must complete the four activities and you must submit their answers online by March 2, 2007. All classes that submit answers online will receive a certificate of completion. Those that complete the activities correctly will be entered into a prize drawing. Details on the prizes will be posted on the website as they become available.

The online results submission form requires the answers to all of the questions on the Final Report. Each step must be correct (not just the decoded message) in order for classes to qualify for prizes. Each class can only submit one entry form, so class discussions of results are encouraged.

Answers can be submitted online through the PhysicsQuest website beginning November 15, 2006.

Competition Timeline

November 1-15, 2006:
Teachers receive kits

November 1, 2006 to March 2, 2007:
Classes perform challenges

March 2, 2007:
Deadline for submitting results

March 12, 2007:
Answers posted and winners notified

The PhysicsQuest Materials

PhysicsQuest is a set of four activities designed to engage students in scientific inquiry. The activities are linked together via a storyline that follows Benjamin Franklin's role as a spy during the revolutionary war. As students study the different physics topics and perform the experiments, they will be collecting information that will help them decode a (fictional) secret message from Franklin.

The PhysicsQuest activities directly correspond to many of the National Science Education Standards. The standards addressed by each of the PhysicsQuest activities are listed on page 48.

PhysicsQuest is designed with flexibility in mind – it can be done in one continuous session or split up over a number of weeks. The activities can be conducted in the classroom or as an extra credit or science club activity. The challenges can be completed in any order. Be sure that your students understand, however, that to get the correct final result all of the challenges must be completed correctly.

The PhysicsQuest kit includes this manual, three inserts, and most of the materials you need to complete the activities. This manual includes a Teacher Guide and Student Guide for each of the four activities. The PhysicsQuest website has extension activities for each of the PhysicsQuest activities and suggestions for correlating the topics with other subject areas — such as mathematics and history.

The Teacher Guide

The Teacher Guide for each activity includes:

Key Question

This question highlights the goal of the activity.

Key Terms

This section lists terms related to the activity that the students will encounter in the Student Guide.

Before the Activity...

Before beginning the activity, students should be familiar with these concepts and skills. You may need to introduce or review these ideas with your students before they start working on the PhysicsQuest challenge.

After the Activity...

By participating in the activity, students are practicing the skills and studying the concepts listed in this section.

The Science Behind...

This section includes history related to the activity and the science behind the result. The Student Guide does not include most of this information; it is left to you to decide how much background to cover with your students.

Safety

This section describes potential hazards and safety precautions associated with the activity.

Materials

This section lists the materials needed for the activity. Materials that are provided in the kit are in bold type; you will need to provide the rest.

Corresponding Extension Activities

Extension activities are available for each activity on our website. This section gives a brief description of the related extension activities.

Bibliography/Suggested Resources

This section lists the books and web sources used to research this activity. These references are good resources for teachers wanting more information on the concepts in the activity.

The Student Guide

Each activity has a Student Guide that you will need to copy and hand out to all of the students before they begin the activity. The Student Guide includes:

Key Question

This question highlights the goal of the activity.

Materials

This section lists the materials students will need for the activity.

Getting Started

This section has discussion questions designed to get students thinking about the key question, why it's important, and how they might find an answer with the materials provided.

Setting Up the Experiment

This section leads students step-by-step through the set-up for the activity.

Collecting Data

This section leads students step-by-step through the data collection process.

Analyzing your Results

This section leads students through data analysis and has multiple questions for them to answer about the experiment and their results.

Using your Results to Decode Ben's Message

This section turns some of the results from the activity into information that students will need to decode Franklin's message.

Inserts

Included with this kit are three additional inserts that students will need to decode Ben's secret message.

Final Report

The relevant part of this form should be filled out by students at the end of each activity. Although groups may fill out the form independently, each class should come to a consensus on their results and present the teacher with one collective Final Report if the class plans to enter the online competition.

About Magic Squares

In order to decode the message, students need to complete a magic square – a numbers game that Franklin enjoyed. This insert explains magic squares and contains hints that students will need to decode the message. This can be given to students when introducing them to PhysicsQuest, but is not required until students have completed the second activity.

Franklin's Letter

Franklin's secret message is hidden within the enclosed (fictional) letter that he wrote to his daughter Sally. Copies of the letter can be distributed when introducing students to PhysicsQuest, but are not required until students have completed all of the activities and are ready to decode the message. A plain text version of this letter is available on the PhysicsQuest website.

Activity Hardware

For a list of the hardware included in the kit, see page 2. For more information on these items and where they can be purchased, see the PhysicsQuest website.

Extension Activities

In addition to the activities included in this manual, extension activities are available for each of the four PhysicsQuest topics on the PhysicsQuest website. These activities are resources for classes that want to further explore the PhysicsQuest topics and are specifically designed to accompany the PhysicsQuest materials.

Using PhysicsQuest in Your Classroom

This section suggests ways to use PhysicsQuest in your classroom. Since logistics and goals vary across schools, we encourage you to read through the suggestions and then decide how best to use PhysicsQuest in your classroom.

Time Allotment

The time required to complete the PhysicsQuest activities will depend on the level of your class and how much lab experience they have had. Most groups will be able to complete one activity in a 45-minute class period.

Safety Notice

While following the precautions in this guide can help teachers foster inquiry in a safe way, no manual could ever predict all of the problems that might occur. Good supervision and common sense are always needed. Activity-specific safety notices are included in the Teacher Guide when appropriate.

Creating Cooperative Groups

Working in small groups may be challenging for your students. However, working effectively in a group is one of the most important parts of scientific inquiry. To help you create the cooperative environment necessary for PhysicsQuest, one example of a successful group work model is given in this section. If your students are already comfortable working in groups, continue to use your model. However, if you would like to add more structure to their small groups, you may want to consider adopting this model.

Group Work Model

Give each student one of the following roles. You may want to have them rotate roles for each activity so they can try many different jobs.

Lab Director
Coordinates the group and keeps students on task.

Chief Experimenter
Sets up the equipment and makes sure the procedures are carried out correctly.

Measurement Officer
Monitors data collection and determines the values for each measurement.

Report Writer
Records the results and makes sure all of the questions in the Student Guide are answered.

Equipment Manager
Collects all equipment needed for the experiment. Makes sure equipment is returned at the end of the class period and that the lab space is clean before group members leave.

Integrating PhysicsQuest with your Curriculum

The PhysicsQuest material can be integrated with standard school curriculum in a variety of ways; some of the most popular and creative ways are:

PhysicsQuest as a stand-alone class activity

PhysicsQuest is designed to be self-contained – it can be easily done as a special project during the day(s) following a test, immediately preceding/following winter break, or other such times. PhysicsQuest also works well as a science club activity and extra credit opportunity.

PhysicsQuest as a fully integrated part of required curriculum

The topics covered in PhysicsQuest are covered in many physical science classes, so another option is to have students do each PhysicsQuest activity during the regularly scheduled corresponding unit.

PhysicsQuest as an all-school activity

Some schools have found it worthwhile to set up PhysicsQuest activity stations around the school gym for an afternoon. Then, the schools have small groups of students work through the stations at assigned times.

PhysicsQuest as a mentoring activity

Some teachers have used PhysicsQuest as an opportunity for older students to mentor younger students. In this case, 8th or 9th grade classes first complete the activities themselves, and then go into 6th grade classrooms and help students with the activities.

Implementing PhysicsQuest Activities in the Classroom

The PhysicsQuest kit comes with only one set of materials. This means that if your students are working in small groups (as recommended), all groups should work simultaneously on different activities (Option 1) or you will need to buy supplemental materials (Options 2 and 3). The Materials List on the PhysicsQuest website includes specific descriptions of the materials.

Option 1 | Small groups work on different activities simultaneously

Divide students into four groups and have each group work on a different challenge at the same time. Have students discuss their findings and come to a consensus on the Final Report.

Option 2 | All students work on the same challenge at the same time

Divide the class into small groups and devote one class period to each challenge. Have each group complete the challenge independently. Near the end of each period, have all of the students come together and discuss their results as a class. At this time they should come to a consensus on the answer for the Final Report.

Option 3 | All students work on the same physical concept at the same time

Divide students into small groups and have all of the groups work on the same physical concept, although not all on the PhysicsQuest challenge at the same time. One way to do this is to set up stations corresponding to each topic – for example static electricity – during your class unit on the same topic. Then students can rotate through the stations and try many different experiments (the extension activities provided on the PhysicsQuest website are a good resource for this). One station should have the corresponding PhysicsQuest activity.

The PhysicsQuest Challenge

Did you know…in addition to being an inventor, scientist, and politician, Benjamin Franklin was one of America's first spies? His mission was to convince the French to support American revolutionary war efforts, as well as keep an eye on the British agents in France. Ben also worked with people appointed by the Second Continental Congress to secretly get military supplies, send spies to other countries, and write codes used to send secret messages during the revolutionary war.

While he was stationed in France, Ben wrote many letters to people back in America. The British often intercepted letters by Americans to see if there was any intelligence information in them, so many American spies coded classified information into normal-sounding letters. Included with your kit is a (fictional) letter from Ben to his daughter Sally that contains one of these secret messages. Your challenge is to decode this message.

As you work through PhysicsQuest you will meet a variety of challenges inspired by Benjamin Franklin's many interests. The first experiment in your kit will reveal who Sally is supposed to give the message to once it has been decoded. The last three activities will help you create a magic square that you will need in order to decode Ben's secret message. The materials in front of you and some curiosity are all you need to find the secret message and help the Americans gain their independence.

Good luck!

Activity 1 Opposites Attract

Franklin's first experiments with electricity involved a glass tube, flannel, wax, and other objects he and his friends had lying around. This activity also uses everyday objects — tape, a plastic comb, and wool — to study electric charges, in particular static charges. You experience static charge every time you're shocked by a door knob and your clothes have static cling. Through this activity, students will investigate how these charges build up. Their results will tell them who Ben's daughter Sally should give the secret message to after she decodes it.

Key Question

How do neutral objects get charged?

Key Terms

Electric charge (positive/negative/neutral)

Electricity

Static

Attract

Repel

Before the activity students should know...

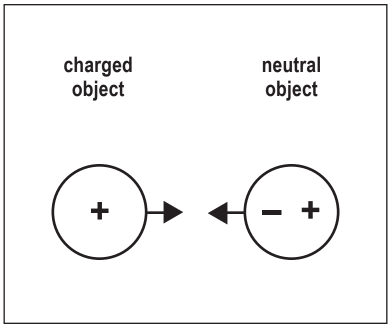
- Electric charges are an important part of life and can be seen in shocks, static, and lightning
- A charged object will be attracted to objects with opposite charges and repelled by objects with the same charge
- Neutral objects are affected by charges and can be attracted — but not repelled — by them

After the activity students should be able to...

- Explain how to charge a neutral piece of plastic
- Test whether an object is electrically charged
- Organize their data into meaningful categories
- Use their observations as a basis for explaining related events

The science behind static electricity

When a 2-ft long glass tube and an article from *Gentleman's Magazine* about research on electricity arrived in Ben Franklin's mailbox from London, he was drawn in immediately. Electrical "experiments" were not new to Franklin — in fact there was a market for electrical devices in the entertainment industry. Their presence in street shows and at dinner parties was not uncommon. However, Franklin was intrigued by the article's description of how science experiments were illuminating the cause of the strange behavior. Despite having only two years of formal



A charged object can attract a neutral object if the charge in the neutral object is arranged as shown.

education, Franklin's forthcoming research on electricity would make him one of the most important and influential contributors to the field.

Through his experiments Franklin showed that objects generally have a normal amount of what he called electrical fluid (we now call this a neutral amount of charge). But when objects of different types are rubbed together, Franklin showed that some of the electrical fluid can be transferred from one object to the other. This leaves one object with a positive amount of electrical fluid and one object with a negative amount of electrical fluid, according to the terminology Franklin introduced.

With discovery of the electron (1897) and the nucleus (1911), we now know that an atom is made of a positively charged nucleus surrounded by a cloud of negatively charged electrons. In a neutral atom, the total charge of the protons in the nucleus is equal to and opposite the total charge of the electrons.

Some materials hold on to their electrons more tightly than others. When two different neutral objects make very close contact and then are separated, for example by rubbing them together, the one with a stronger attraction to electrons will take electrons from the one with a weaker attraction. This leaves one object with an excess of electrons and one with a deficiency. Electrons carry negative charge, therefore objects with extra electrons are negatively charged.

Just as magnets exert magnetic forces on other magnets, electric charges exert forces on other electric charges. These forces get weaker as the distance between the charges increases. As with magnetic poles, like charges repel and opposite charges attract. Since forces apply pushes and pulls to an object, you can control the motion of a charged object by bringing other charges nearby. The size of the movement depends on the strength and sign of the charges and the mass of the object.

In addition, since all objects are made of charged parts, an object with excess charge will affect even a neutral object, as shown in the picture. This means that an attraction between two objects only indicates that at least one of them is charged. Only when we see repulsion do we know for sure that both objects are charged.

In this activity, students will investigate how neutral pieces of tape can be charged. They will see that after you stick two pieces of tape together — sticky side to non-sticky side — and pull them apart quickly, one piece will be positively charged and the other will be negatively charged. They will see evidence of the different charges in how the pieces of tape interact with one another and with other objects, charged and uncharged.

One of Franklin's most significant contributions to the field of electrostatics was his explanation of charge conservation. Franklin was the first person to show that the total amount of "electrical fluid" never changes — in other words, when one object loses charge, anther object gains exactly the amount of charge that was lost by the first one. Although students will not be able to measure this quantitatively in Activity 1, you may want to discuss this when preparing them for the experiment.

Materials

Wool

Plastic comb

Masking tape

Scotch tape

Meter stick made of insulating material (wood or plastic), or the edge of a wood or plastic table

Metric ruler

Scrap paper

Safety

Students will be building up small amounts of static charge in this activity and could receive slight shocks.

Corresponding Extension Activities

Directions for these activities are located at www.physicscentral.com/physicsquest.

1. **Dancing Fleas:** Watch as objects dance underneath a charged plate (level 1).
2. **Electrophorus:** Make a static electricity generator out of household items (level 2).
3. **Leyden Jar:** Use this jar to have fun with the charge from your electrophorus (level 2).
4. **Franklin Bells:** Construct a simple device for detecting static electricity (level 2).

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Activity 1 Opposites Attract

In this challenge you will investigate electric charges — one of Benjamin Franklin's favorite subjects. Ben did many experiments with charged objects and our current understanding of electricity was greatly influenced by his experiments and ideas. In this experiment you will be working with static (not moving) charges. Your results will tell you who Ben's daughter Sally should give the secret message to after she decodes it.

Key Question

How do neutral objects, like your clothes, get charged with electricity?

Materials

Masking tape

Scotch tape

Wood or plastic meter stick

Ruler

Scrap paper

Wool

Plastic comb

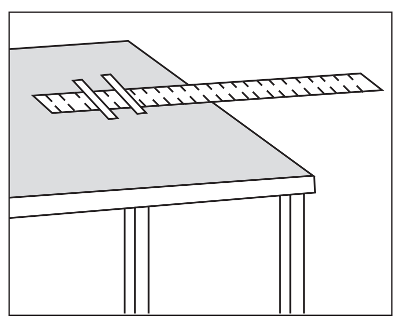
Getting Started

Discuss the following questions with your group.

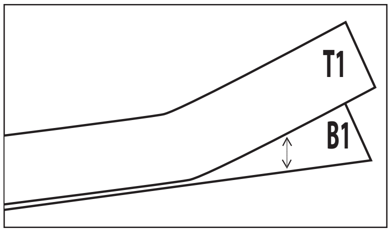
1. How do you think neutral objects, like your clothes, get charged with electricity?
2. Have you ever been shocked before? If so, what have you been shocked by?
3. Look at the materials you have to work with – how might you use them to investigate electric charge?

Setting up the Experiment

1. Use masking tape to secure one end of the meter stick to a table or desk, as shown. You may want to place a book on the end of the meter stick to keep it steady. If you do not have a wood or plastic meter stick, skip this step and hang the tape from the end of a non-metal table when you get to Step 8.
2. Cut two small pieces of paper, each slightly wider than the width of the scotch tape and about 1-cm long. Label one strip "B1" (for "Bottom 1") and one strip "T1" (for "Top 1").
3. Cut a strip of scotch tape 10-cm long. Stick the B1 piece of paper to one end of the strip so that it forms a non-sticky tab at the end of the strip.



Attach the meter stick to the table as shown above. About 2/3 of the stick should hang off the end.

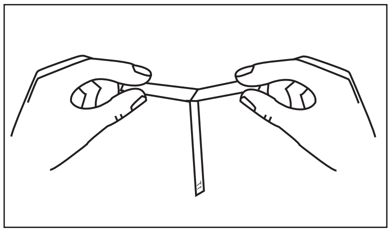


Stick the sticky side of T1 to the non-sticky side of B1.

4. Cut another strip of tape that is the same length as the previous piece, and attach the T1 tab to the end of the strip.

5. While one group member holds B1 taut, another group member should hold T1 taut and carefully stick the sticky side of T1 to the non-sticky side of B1. Make sure they are firmly stuck together.

6. Hold the combination by the paper tabs and let the other end hang down. Then, quickly rip apart the two pieces of tape.

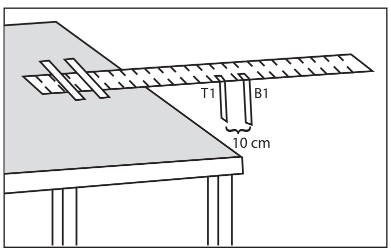


Take the "T1" tab in one hand and the "B1" tab in the other. Quickly rip apart the two pieces.

7. Bring the non-sticky sides of the two pieces of tape near each other, but don't let them touch. Do they attract, repel, or have no effect on each other?

This means that T1 and B1 have (circle one):		
the same charge	opposite charge	no charge

8. Attach B1 and T1 to the meter stick, about 10cm apart, as shown in the figure.

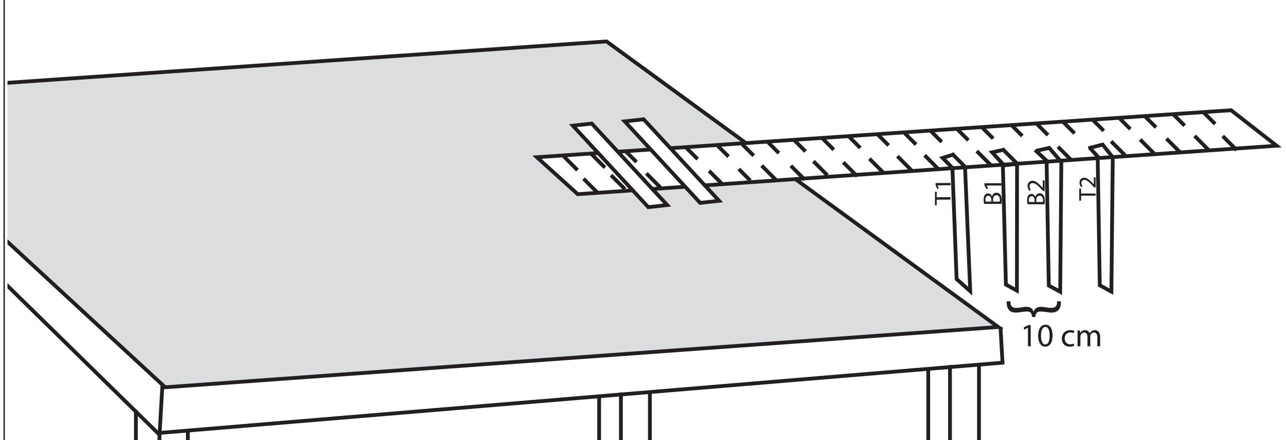


Hang B1 from the meter stick, 10 cm from the edge of the table. Hang T1 10cm from B1.

9. Repeat steps 2-6 to make another set, only label the first strip of tape B2 and the second strip T2. Make sure that you stick the sticky side of T2 to the non-sticky side of B2. Hang the two new pieces of tape on the meter stick.

10. You should now have four pieces of tape hanging from the meter stick, as shown below. If this sketch matches your setup, you are ready to begin collecting data. If not, correct your setup before moving on.

The complete set-up for Activity 1.



Collecting Data

Record the answers to the following questions in the chart below by writing "attract," "repel," or "no effect" in the box corresponding to each question.

1. Pick up T2 and bring it close to T1. Does it attract, repel, or have no effect on T1?
2. Bring T2 close to B1. Does it attract, repel, or have no effect on B1?
3. Pick up B2 and bring it close to T1. Does it attract, repel, or have no effect on T1?
4. Bring B2 close to B1. Does it attract, repel, or have no effect on B1?
5. Bring the plastic comb near T1. Does it attract, repel, or have no effect on T1?
6. Now bring the comb close to B1. Does it attract, repel, or have no effect on B1?
7. Rub the comb with wool for about 15 seconds. Now bring the comb close to T1. Does it attract, repel, or have no effect on T1?
8. Bring the comb close to B1. Does it attract, repel, or have no effect on B1?

	T1	B1
T2	1.	2.
B2	3.	4.
plastic comb	5.	6.
plastic comb after rubbed with wool	7.	8.

Analyzing your Results

1. Using what you know about how charges react to one another, list the materials that fall into each category (T1, B1, T2, B2, comb before rubbing, comb after rubbing).

Same charge as T1	Same charge as B1	No charge

2. Based on what you have observed in this experiment, how can you give a plastic comb static charge?

   How can you charge a piece of tape?

3. You've probably been shocked by a doorknob before or noticed your clothes sticking together because of static. Based on what you know about static electricity, how do you think your clothes became charged?

   How might your hand have become charged before it touched the doorknob?

Using Your Results to Decode Ben's Message

To figure out who Sally should give the message to once she decodes it, answer the following question:

How many of the following objects have the same charge as B1? ___________

T1

B2

T2

Rubbed comb

The name next to the number that matches your answer to the above question is the person Sally should to give the secret message to. The rest of the activities will help you decode the message.

0 Thomas Paine

1 John Adams

2 Thomas Jefferson

3 George Washington

4 Patrick Henry

Sally should give the secret message to ____

because the following object(s) has/have the same charge as B1:____.

Activity 2 Traveling Charges

Ben Franklin and his friends used their electrical discoveries for jokes and entertainment, but they could see little practical use for electricity other than killing an occasional chicken or turkey for dinner. Activity 2 introduces students to insulators and conductors and how we use them to direct electricity. By classifying materials as insulators and conductors, students will learn where one number goes in Ben's magic square.

Key Question

What kinds of materials does electricity travel through best?

Key Terms

Electricity

Insulator

Conductor

Electrical Circuit

Before the activity students should know...

- Matter is made of atoms
- Atoms contain negatively charged electrons
- Electricity is the movement of electrons over time
- Batteries store electrical energy
- A light bulb turns electrical energy into light

After the activity students should be able to...

- Build a simple circuit
- Predict whether a material is a good insulator or conductor
- Test whether a material is a good insulator or conductor
- Explain how the insulating and conducting properties of materials enable us to direct electrical energy

The science behind insulators and conductors

"If I have seen further, it is by standing of the shoulders of giants," said Isaac Newton[1]. Newton understood that science is not one person, hidden away in a lab unlocking the keys to the universe. Science is a process where people all over the world make discoveries that they share with one another. New generations of scientists build on the work of past generations, and science advances. In this way a small boy, suspended horizontally and shocked on the nose by a glass rod, helped lay the foundation for computers, cell phones, and iPods.

1 *From a letter written to Robert Hooke, 5 February 1676.*

In the late 17th century, the dyer and science-enthusiast Stephen Gray discovered that electricity can travel through some materials, but not through others. He demonstrated this with a charged glass tube and a piece of cork. Gray connected one end of a wire to the charged tube and the other end to a cork as much as 800-ft away. He found that the charge from the tube traveled down the wire to cork. When he replaced the wire with a silk thread, however, the cork stayed neutral. Gray tested the conductivity of a fire poker, dead rooster, map, umbrella, and many other objects (including small boys). Gray's work set the course for Franklin's soon-to-follow studies and the current theory of electricity.

The difference between materials that electricity can easily travel through (conductors) and materials that it can't easily travel through (insulators) is how tightly the electrons are bound to the atom. Activity 1 discussed how charged objects have either an excess or a deficiency of electrons. In this activity students will learn that it is easy for electrons to move in materials like metals that don't hold on tightly to at least some of their electrons. On the other hand, in materials like wax and silk all the electrons are tightly bound and aren't free to move around. This makes them poor conductors of electricity (good insulators).

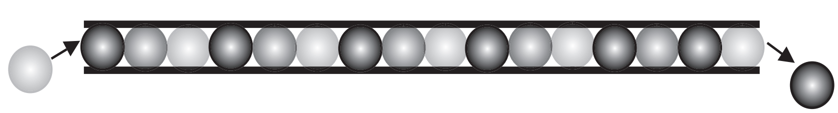
A common misperception is that when you plug a wire into an outlet, electrons flow through the wire like cars driving along a highway. In reality this is not the case. The conducting material that makes up wire is made of atoms. Each atom has a certain number of electrons. When you complete a circuit and switch on the electricity, you add new electrons to the wire. These electrons join nearby atoms, and the atoms each spit out an old electron. These old electrons join other atoms further up the wire and those atoms spit out their old electrons. This process continues, all along the wire.

Like adding a marble to a pipe already full of marbles, you can see the effect of completing a circuit almost immediately, even though a particular electron that started out near the outlet hasn't moved very far yet.

The fact that electrons can move easily through some materials and poorly through others enables us to take advantage of electrical energy. By arranging materials with different conductivities, we can make closed conducting paths—or circuits. Circuits can direct electric charges to light bulb filaments, buzzers, or other devices that turn the electrical energy into heat, sound, or light.

In this activity students build a simple circuit and use it to test how well electricity travels through different types of materials.

Adding a marble to a pipe already full of them will knock out a marble on the other end, even though the marble you just added didn't travel very far.



Safety

In this activity students will be working with wires and batteries. Students should use the materials only in the manner described in the directions, because the wires are sharp and electricity can be dangerous.

Corresponding Extension Activities

Directions for these activities are located at www.physicscentral.com/physicsquest.

1. **Human Circuit:** Use a static charge to test whether people conduct electricity (level 1).
2. **SOS:** Investigate switches and use them to send messsages in Morse code (level 2).
3. **Types of Circuits:** Explore how the type of wiring affects the brightness of a set of light bulbs (level 2).
4. **Electromagnets:** Make a simple electromagnet and test its strength (level 2).
5. **Homemade Light Bulb:** Demonstrate how a light bulb filament works using a thin wire (level 3, demonstration).

Bibliography/Suggested Resources

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Rudy, Lisa Jo. *The Ben Franklin Book of Easy & Incredible Experiments: A Franklin Institute Science Museum Book.* New York: John Wiley & Sons, Inc. 1995.

Materials

Light bulb and socket
Wires with clips (2)
D batteries (2)
Scotch tape
String
Penny
Nickel
Paper clips (3)
Assorted objects (glass, plastic, wood, etc.)

Activity 2 Traveling Charges

It seems silly to us now, but Ben Franklin and his friends couldn't imagine how electricity could be used for anything practical. The most practical thing they ever used it for was to kill a turkey for dinner. Of course we now use electricity to power lights, computers, iPods, medical devices, and many other things.

How did we get from using electricity in practical jokes to using it to power big city skylines?

In this activity you will investigate how well electricity travels through different types of materials, and how we use this knowledge to turn electricity into useable energy. You can use what you discover about insulators and conductors to determine the placement of one number in Ben's magic square.

Key Question

What kinds of materials does electricity travel through best?

Materials

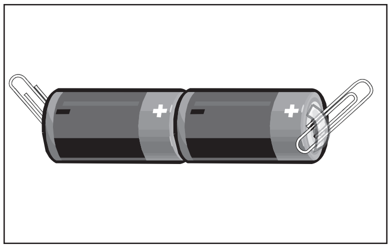
- Light bulb and socket
- D batteries (2)
- Wires with alligator clip ends (2)
- Scotch tape
- String
- Penny
- Nickel
- Paper clips (3)
- Assorted objects (glass, plastic, wood, etc.)

Getting Started

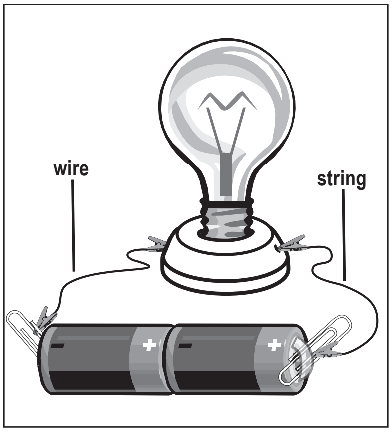
Discuss the following questions with your group.

1. Look around the room, what things run on electricity?
2. How does electricity get to where it needs to be?
3. What kinds of materials do you think electricity travels through best?

Satellite photograph of the USA at night. Courtesy International Dark Sky Association, www.darksky.org.



The battery system



Replace one of the wires with a piece of string.

Setting Up the Experiment

1. Tape two D batteries together, positive end (+) to negative end (-).
2. Tape a paperclip to each end of the battery system, as shown in the picture.
3. Screw the light bulb into the base.
4. Connect a wire between one of the paperclips and one of the screws on the base of the light bulb.
5. Connect the other wire between the free paperclip and free screw.
6. The light bulb should now light up. If it does not, check to make sure that you have good connections between the batteries, wires, and screws. If the light bulb still does not light up, ask your teacher for help.
7. You have created what we call an electrical circuit. In the last activity you learned about charges — a circuit is a path through which charges travel. Draw your circuit below.

Collecting Data

1. Disconnect one of the wires from the light bulb base.
2. Take a piece of string and connect one end of it to the free end of the wire, and the other end to the free screw on the light bulb base. Does the light bulb light up? Record your answer in the first column of the chart on page 25.
3. Remove the string and repeat Step 2 with the others materials listed in the chart — tape, penny, nickel, paper clip, plastic, glass, and wood. There are also blank spots on the chart where you can add the results from other classroom objects.

	Does the light bulb light up? (check one)		How would you classify this material? (check one)	
	YES	NO	INSULATOR	CONDUCTOR
String				
Tape				
Penny				
Nickel				
Paperclip				
Plastic				
Glass				
Wood				

Analyzing Your Results

1. Materials that electrons can pass through easily are called conductors. Materials that electrons don't pass through easily are called insulators. Classify the materials you tested as insulators or conductors by checking the appropriate box in the second column of the chart.

2. Which of the materials are conductors?

   What do these materials have in common?

3. Which of the materials are insulators?

   What do these materials have in common?

4. Put your original circuit back together. Your circuit is made of insulators and conductors.

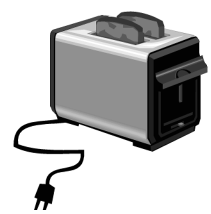
   Which parts of your circuit are conductors? (Hint: What parts of the bulb/base do the wires have to be touching in order for the light bulb to light up?)

   Which parts of your circuit are insulators?

6. Could you make a circuit with only conductors and no insulators? Why or why not?

7. Based on what you have observed in this experiment, what kinds of materials does electricity travel through best?

5. Look at these pictures. Which parts of each object are made of conductors? Which are made of insulators?



8. How do we use conducting and insulating materials in designing electrical appliances?

Using your Results to Decode Ben's Message

How many of the objects listed below are insulators? That number belongs in the upper left corner of the magic square.

- ❏ String
- ❏ Penny
- ❏ Nickel
- ❏ Tape
- ❏ Paperclip

The number _____ appears in the top left corner of Ben's magic square because the following object(s) is/are insulators:

____.

Activity 3 Soak Up the Sun

You've probably noticed that you warm up much faster in the sunlight if you are wearing black clothes. Eighteenth century fashion may not hold up to modern day fashion critics, but Ben Franklin was well aware of the advantage of wearing white on hot days. In one of his experiments, Franklin showed this effect qualitatively. Activity 3 takes students through this process in an activity inspired by Franklin's experiment. The results of this activity will give students another clue for the magic square.

Key Question

How does the color of an object influence its ability to absorb heat?

Key Terms

Absorb

Heat

Temperature

Before the activity students should know...

- Light is absorbed and reflected by objects
- When light is absorbed by a material, energy is radiated as heat
- Energy takes many different forms but the total amount of energy is conserved
- How to graph data

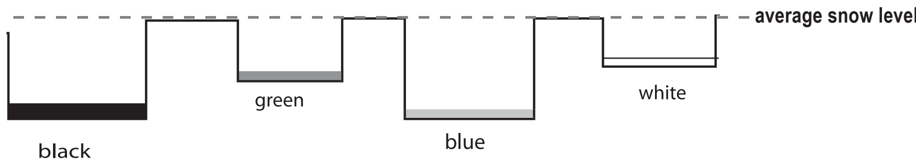
After the activity students should be able to...

- Predict the temperature ranking of (otherwise identical) different colored objects left in sunlight
- Use graphs to compare and analyze data

The science behind color and heat absorption

In one of his first documented experiments, Franklin tested how the color of a fabric affects its rate of heat absorption. Your students will investigate the same concept here in a slightly different form. Franklin placed squares of different colored cloth outside in the snow on a sunny day. After a couple of hours, he came back and noted the respective heights of the materials in the snow. He found that much of the snow beneath the black fabric had melted, causing the black fabric to sink well below the average snow level. In contrast, little of the snow beneath the white fabric had melted, so the white fabric stayed near the average snow level. The other colors sank to varying heights between the white and black fabrics.

An illustration of Franklin's experiment on color and heat absorption.



An object gets its color from selective absorption — for example a piece of blue cloth absorbs all colors except blue. The blue light is reflected back and so your eyes perceive the cloth as the color blue. The rest of the light, meanwhile, is turned into thermal energy, or heat. Light and heat are two forms of energy. The more light an object absorbs, the more energy it radiates as heat.

A black-colored object looks black because it doesn't reflect any visible light. Since it absorbs all of the light, it radiates a lot of heat. A white-colored object, however, reflects most of the incident light and therefore can't radiate as much heat. Darker colors absorb more light than light colors, so a dark blue cloth will radiate more heat than a light blue cloth.

In addition to influencing your decision on what color to wear on a hot day, the relationship between color and heat absorption has important consequences for climatology, astronomy, and energy production. A few examples are given below.

- One way to keep energy costs down in warm climates is to coat the roofs of buildings with a highly reflective material. The buildings will stay cooler because the roofs absorb less light and therefore radiate less heat.[1]
- NASA missions have measured the reflectivity of the moon, planets, and other objects in space. Scientists use these data to investigate the surface compositions of the objects.[2]
- Some researchers use satellites and computer models to study the amount of sunlight reflected back into space by the earth. This information can be used to study the effects of greenhouse gases.[3]

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1 "Roofing." Global Green USA, 1998. http://www.globalgreen.org/pha-energytoolbox.tech_roofing.htm

2 Viau, Elizabeth Anne. "Albedo." World Builders, 2003. http://curriculum.calstatela.edu/courses/builders/lessons/less/les3/albedo.html

3 "New satellite set to collect most-detailed data yet about atmospheric particles." UWNews.org, 2006. http://www.uwnews.org/article.asp?articleID=24978
"Earth's Albedo in Decline." Earth Observatory. http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3:img_id=16905

Safety

Students should be careful not to touch the hot lamp during the data collection process.

Corresponding Extension Activities

Directions for these activities are located at www.physicscentral.com/physicsquest.

1. **A Day at the Beach:** Investigate how the temperatures of water and sand change throughout the day (level 1).
2. **Cold Floors:** Explore how the actual temperatures of different materials compare to how the materials feel to the touch (level 1).
3. **Colored Filters:** Observe how colored filters change what we see (level 1).
4. **Color Coded Secret Messages:** Use colored filters to make and read secret messages (level 2).
5. **Soak up the Sun II:** A variety of suggestions for expanding on the PhysicsQuest "Soak up the Sun" activity (level 2).
6. **Solar Ovens:** Build solar ovens using your knowledge of how materials absorb and reflect heat (level 2).

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Rudy, Lisa Jo. *The Ben Franklin Book of Easy & Incredible Experiments: A Franklin Institute Science Museum Book.* New York: John Wiley & Sons, Inc., 1995.

"The Science of Light." Annenberg Media Math and Science Project. http://www.learner.org/teacherslab/science/light/index.html

Materials

Felt (4 colors)

Thermometers (2)

Desk lamp with 60W or higher light bulb

Plain white paper

Graph paper

Stop watch or clock with second hand

Scissors

Metric ruler

Colored pencils / markers

Masking tape

Important Note

Although the instructions have students take data every minute for five minutes per color, you may need to extend this time as the heat output of lamps varies. Please test this activity with the lamp you plan to use before your students do the activity. If the heat output of your lamp is not very high, you may want to have students move the thermometer closer to the lamp.

Activity 3 Soak Up the Sun

- *If you were playing soccer on a hot day, would you rather be wearing a black uniform or a white uniform? Why?*
- *If you were designing a house for a hot climate and wanted it to use as little energy as possible, what color would you make the roof?*

Key Question

How does the color of an object influence its ability to absorb heat?

Materials

Felt (4 colors)
Thermometers (2)
Desk lamp
Graph paper
Plain white paper
Stop watch or clock with second hand
Scissors
Metric ruler
Colored pencils / markers
Masking tape

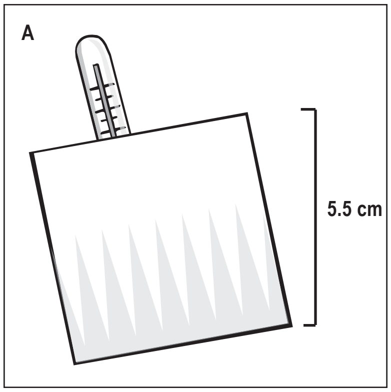
In this activity you will do an experiment similar to one of Ben's first recorded experiments — studying how the color of an object affects its ability to absorb heat. As you do this experiment think about the questions listed above and discuss them with your group.

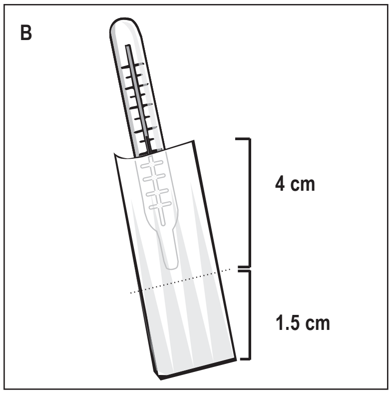
The results of this activity will tell you the next number that goes in your magic square. You will have to do Activity 4 to find out where this number goes in the square.

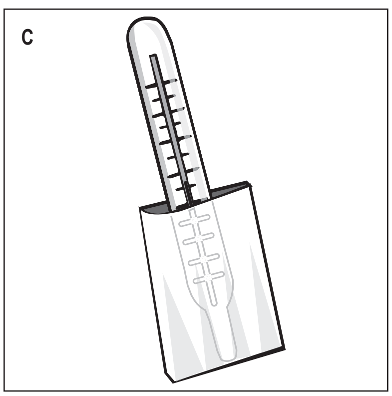
Getting started

Discuss the following questions with your group.

1. Do you think that black objects absorb heat differently than white objects? Why or why not?
2. Can you think of any examples to support your hypothesis?
3. Look at the materials you have to work with. How might you use them to investigate the connection between color and heat absorption?



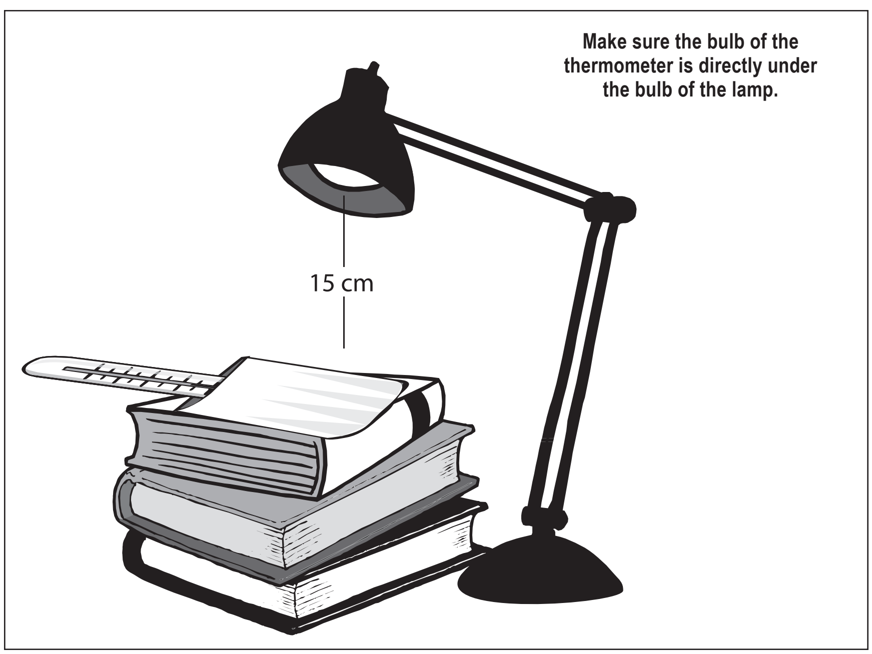




Creating the felt pocket.

Setting Up the Experiment

1. Turn on the lamp so it can warm up.
2. Cut a 7-cm x 5.5-cm rectangle from each of the four colors of felt.
3. Wrap one piece of felt loosely around your thermometer so that the seam is in the back and tape the seam closed. The front side of the thermometer should be covered by a single layer of felt—the only overlap should be in the back.
4. Slide the felt down to the bulb end of the thermometer so that about 1.5-cm hangs off the end (see picture B). Fold this overlap to the back of the thermometer and secure it with masking tape. You should now have a little pocket of felt that you can easily slide on and off of your thermometer.
5. Repeat steps 2-3 for the three other colors of felt.
6. Position a desk lamp so that the bulb points directly down at the surface of a table or desk. Turn the lamp off.
7. Place your thermometer so that the bulb of the lamp is 10-15 cm from the bulb of the thermometer. You may need to put books under the thermometer to bring it closer to the lamp.
8. Put a piece of plain paper directly under your thermometer and tape the paper to the table (or book) so that it cannot slide around.
9. Put your thermometer on the piece of paper with the bulb directly below the bulb of the lamp. Trace the outline of the thermometer with a pen or pencil. This drawing will help you return the thermometer to the exact same place every time.



Collecting Data

1. Slide one of your felt pockets onto the bulb end of the thermometer.
2. Record the temperature of the thermometer in the chart under the column for that color. The lamp should still be turned off.
3. Turn on the lamp and record the temperature on the thermometer (in degrees C) every minute for a total of 5 minutes.
4. Turn off the lamp. Remove the thermometer you just used and take off the pocket. Place the thermometer far away from the lamp so that it can cool back down to room temperature.
5. Put the other thermometer on the piece of paper and record its initial temperature on the chart (should be equal to the initial temperature you recorded in Step 2). Be sure that you put the thermometer in the exact same place as the previous one, so that the same amount of light hits it.
6. Slide on a different colored pocket. Repeat Step 3.
7. Repeat steps 4-6 for the two other colors. You should now have data for your four pockets.

Temperature (in degrees C)

	Red	Yellow	Green	Blue
0 minutes (initial temperature)				
1 minute				
2 minutes				
3 minutes				
4 minutes				
5 minutes				

Analyzing Your Results

1. Why do you think the temperature of the felt went up when you turned the light on?

2. Which color of felt heated up the fastest?

   Which color of felt heated up the slowest?

4. On graph paper, graph temperature v. time for each of the four colors of felt you used. The horizontal axis should be "Time (in seconds)" and the vertical axis should be "Temperature (in degrees C)." Graph all of the data on the same graph, but use different colored pencils or markers for each pocket so that you can compare them easily.

5. What does your graph show about how the color of an object is related to how fast it heats up?

6. Why does the color of the felt affect how fast it heats up?

7. What are some real life applications of what you studied today?

Using your Results to Decode Ben's Secret Message

		A
	B	

Rank the colors listed below from the one that absorbs the most light (1) to the one that absorbs the least amount of light (5) in the space provided. The number that corresponds to "black" will go either in square A or B of your magic square. Activity 4 will tell you whether it goes in square A or B.

Pink
Black
Green
White
Yellow

1. ______________________ (absorbs the most light)
2. Green
3. ______________________
4. Yellow
5. ______________________ (absorbs the least light)

The number _____ appears in square A or square B because this is the number that "black" is ranked when you list the colors from the one that absorbs the most light to the one that absorbs the least amount of light.

Activity 4 Bring it into Focus

Franklin was not only a scientist, he was also an inventor. He liked to create things that made life better — such as the lightning rod and an improved version of the stove. Bifocals, glasses that enable the wearer to easily switch focus from near to far objects despite aging eyes, are also commonly attributed to Franklin. This experiment takes students through how light interacts with lenses and how glasses and contacts correct vision. By measuring the focal lengths of two different lenses, the students will find out where the number found in Activity 3 goes in the magic square. This last piece of information should enable them to solve the magic square and decode Franklin's message.

Key Question

How do contact lenses and glasses improve vision?

Key Terms

Lens
Bifocals
Nearsighted
Farsighted
Focal length
Optical power
Cornea
Retina
Convex lens
Concave lens

Before the activity students should know...

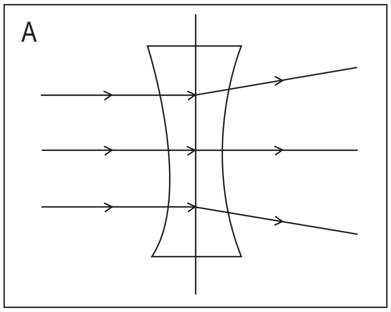
- Light travels in straight lines
- Lenses bend light
- The basic structure of the human eye
- What it means for an object to be in focus

After the activity students should be able to...

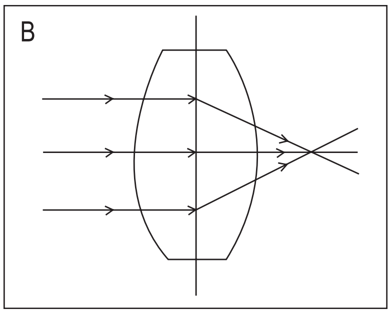
- Measure the focal length of a lens
- Calculate the power of a lens
- Explain the causes of nearsightedness and farsightedness
- Discuss how glasses and contact lenses correct vision problems

The science behind bifocals

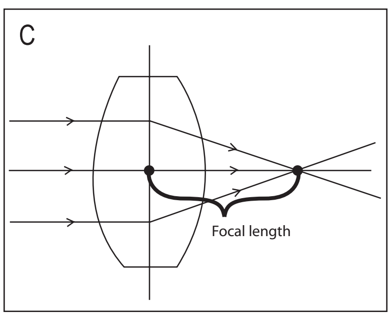
In the 1780s, the aging Franklin was frustrated with his vision. When he looked from the scenery outside his carriage window to a fellow passenger, it took a few minutes for his eyes to focus clearly on the passenger. Franklin needed one pair of glasses to focus on near objects and another pair to focus on far objects. Tired of constantly changing glasses, Franklin cut each pair of lenses in half and stuck them together — creating bifocals.



Concave lenses spread out light rays.



Convex lenses focus light rays.

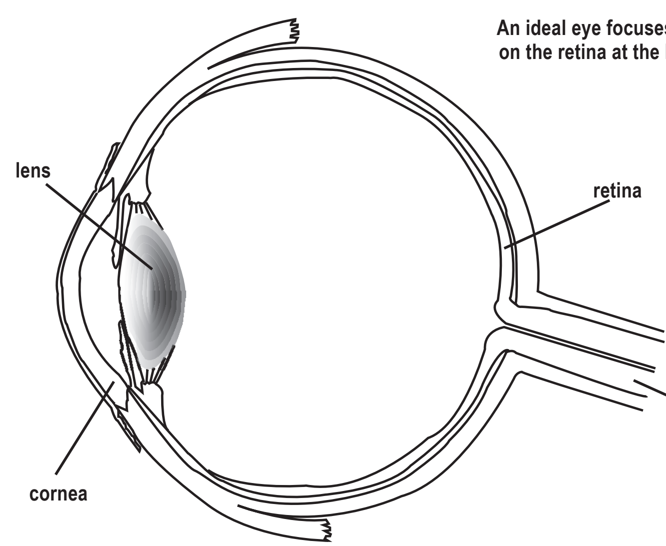


The focal length of a lens is the distance between the lens and where it focuses the image of an object far away.

A lens is a piece of transparent material (often glass or plastic) that is curved so that light passing through it will be refracted, or bent. Concave lenses, lenses that are thicker at the edges than in the middle, are diverging lenses and spread out light rays. Convex lenses, lenses that are thicker at the middle than at the edges, are converging lenses and bend light rays toward one another.

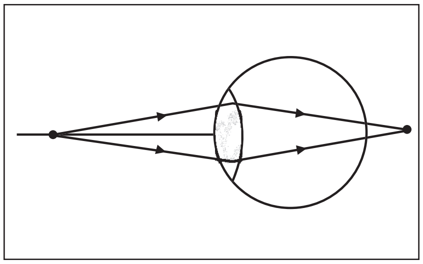
Lenses are characterized by their shape (convex, concave), diameter, and focal length. The focal length of a lens is the distance between the lens and where it focuses the image of a far away object. The optical power of a lens is the reciprocal of the focal length and indicates how much a lens bends light. In this activity students will be measuring the focal length of different lenses and calculating their power. They will compare this to the focal length and power of the lens/cornea system in a human eye.

Light entering a human eye is bent by the cornea and the lens. In an ideal eye, this focuses the image exactly on the retina. The retina lines the back of the inner eyeball and is sensitive to light. When it is stimulated by light, it sends signals to the brain via the optic nerve.

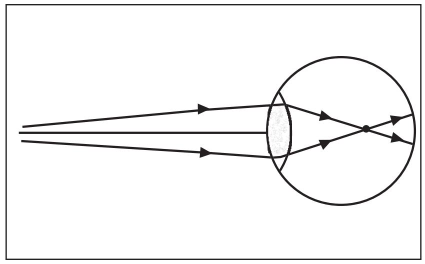


An ideal eye focuses incoming light on the retina at the back of the eye.

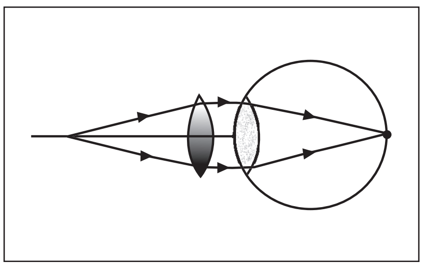
Many people need glasses or contacts to correct their vision. A farsighted eye focuses near objects behind the retina. A nearsighted eye focuses distant objects in front of the retina. Placing a carefully chosen lens in front of the eye can change its optical power so that images are correctly focused on the retina.



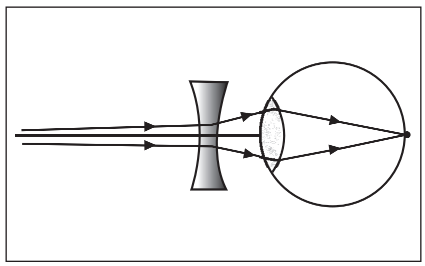
A farsighted eye focuses near objects behind the retina.



A nearsighted eye focuses far objects in front of the retina.

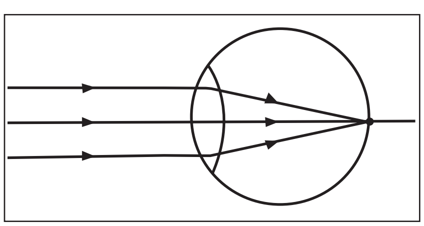


Farsighted vision is corrected by adding a convex lens in front of the eye.

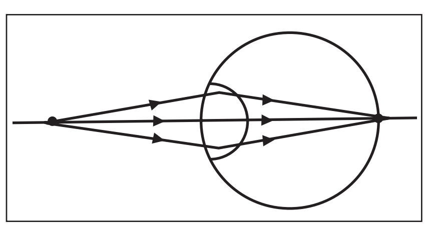


Nearsighted vision is corrected by adding a concave lens in front of the eye.

When Franklin made his bifocals he was suffering from Presbyopia, a common vision problem in people over forty. The lens of an ideal eye has some flexibility that allows it to change shape and thereby change optical power. This enables the eye to focus both near and far objects on the retina even though the light rays coming from far objects are almost parallel and don't need to be bent as much as light coming from near objects. As the eye ages, however, the lens often becomes less flexible. This makes it difficult to switch focus from far objects to near objects and often makes it harder for people to focus on near objects at all — which is why reading distance often increases with age.



The eye focuses a far object.



The lens changes shape (increases in curvature) to focus a near object.

Materials

Convex lenses (2)

Concave lens

Meter stick

White paper

Important Note

The lenses in your kit are in envelopes marked with their focal lengths. Since students will be measuring the focal length of two of the lenses in this activity, please prepare the lenses in the following way:

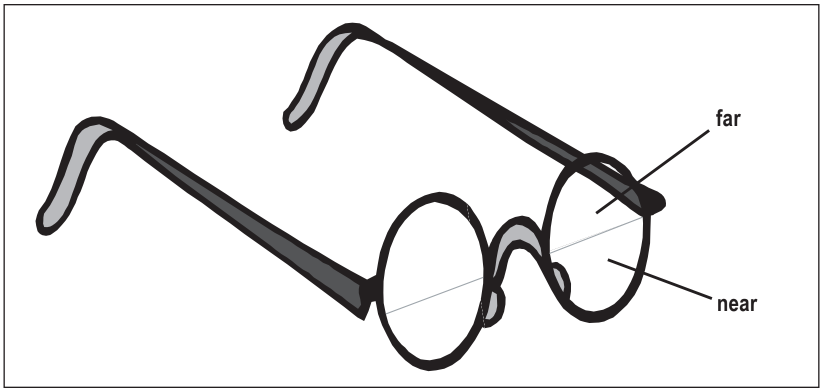
- **Write the number corresponding to each lens (see below) on a small piece of scotch tape and stick it to the lens, near the rim.**
- **Use a marker to block out the focal length written on each envelope.**
- **Write the number corresponding to each lens on its envelope.**

Lens numbers

1.....f=10 cm biconvex lens

2.....f=20 cm biconvex lens

3.....f=5 cm biconcave lens



Franklin's bifocals. The bottom half of the lenses were used to view near objects and the top half to view far objects.

People with Presbyopia can use reading glasses to focus on near objects, but they have to remove the glasses to focus on far objects. Those that want to avoid this inconvenience, as well as people that are have other vision problems in addition to Presbyopia, often use bifocals or multifocals — glasses that contain lenses of two or more focal lengths. The different lenses are housed together in one frame and people look though different areas of the glasses depending on whether they are looking at near or far objects.

Corresponding Extension Activities

Directions for these activities are located at www.physicscentral.com/physicsquest.

1. **Disappearing Test Tube:** Make clear objects visible or invisible using what you know about how light bends (level 1 demonstration)
2. **Total Internal Reflection:** Explore how information travels through fiber optic cables with these experiments (level 1)
3. **TV Image Projection:** Use your results from the core activity to project images from a TV screen (level 1, level 2)
4. **Homemade Telescope:** Make a simple refracting telescope and read messages from across the room (level 2)

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Activity 4 Bring it into Focus

Key Question

How do contact lenses and glasses improve vision?

Materials

2 convex lenses

Concave lens

Piece of white paper

Meter stick

Ben Franklin liked to invent useful things, and he once made his own glasses. He needed one pair of glasses to see things close by and another to see things far away, so he cut both pairs of lenses in half. He then attached the bottom of the first pair to the top of the second pair. If he wanted to look at something close by, he would look though the bottom half of the glasses. If he wanted to see something far away, he would look though the top half.

Glasses like these, called bifocals, are still used today. In this experiment you will look at how lenses are used to correct poor vision. By measuring the focal lengths of two lenses, you will find out where the number you found in Activity 3 goes in your magic square. This is the last piece of information you need to solve the magic square and decode Ben's secret message.

Getting Started

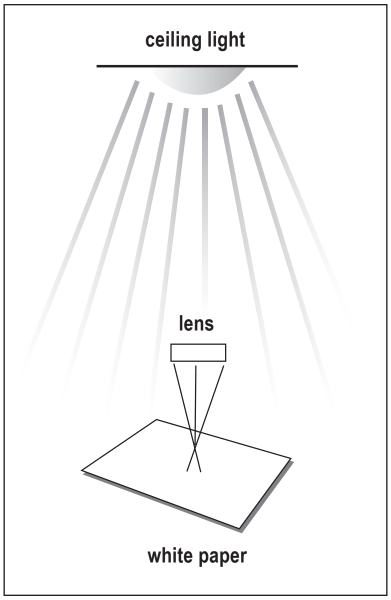
If no one in your group wears glasses, talk to someone in another group who does and record his or her answers.

1. What do things look like without your glasses?

2. Are you nearsighted or farsighted?

3. What are the lenses in your glasses shaped like?

Collecting Data



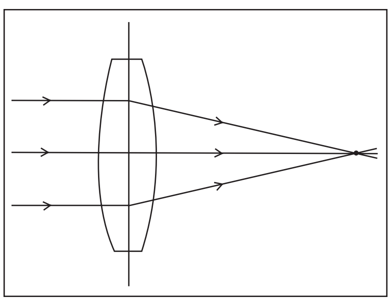
Set-up for Activity 3.

1. Put a piece of plain white paper on the floor, directly below an overhead ceiling light. The paper should be at least 2.5-m below the light. If you don't have access to a ceiling light, you can use a light shining vertically across the room (or a window, if it is sunny outside). In this case, hold the paper directly across the room from the light, at least 2.5-m away, so that it looks like the picture turned on its side.

2. One group member should hold Lens 1 about 15-cm above the piece of paper. Note the image of the light source on the paper. Move the lens closer to and further from the paper until you get a very clear image.

3. Have another group member measure the distance between the paper and lens. The distance between a lens and where it most clearly focuses a far away object (such as the overhead light) is called the focal length. Record the focal length (in cm) of Lens 1 below.

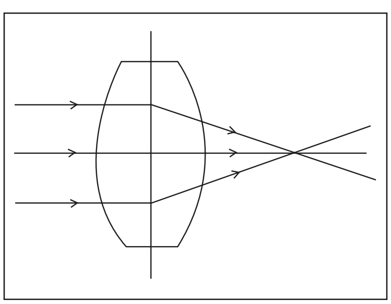
Focal length of Lens 1:



A lens with low optical power.

4. Replace Lens 1 with Lens 2 and repeat steps 2-3.

Focal length of Lens 2:



A lens with high optical power.

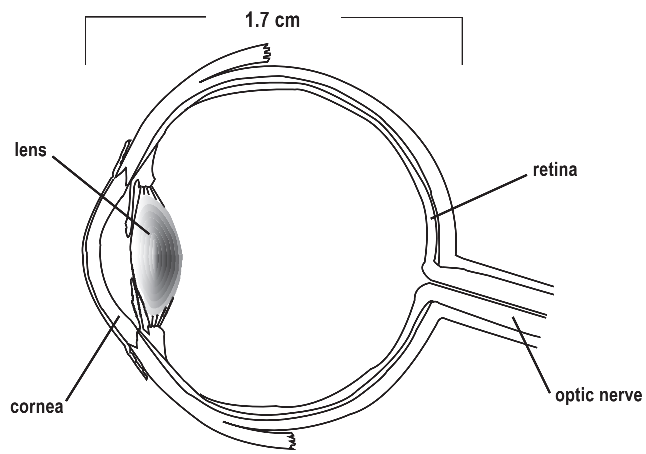
5. Eye doctors use a term called optical power to classify how much a lens bends light. A lens with high optical power bends light a lot, and a lens with low optical power bends light much less.

   A lens that bends light a lot (high optical power) will have a short focal length. Optical power is related to focal length by $P = 1/f$, where P is the power and f is the focal length in meters.

Calculate the optical power of Lens 1 and Lens 2.

Optical power of Lens 1:

Optical power of Lens 2:



An ideal eye focuses incoming light on the retina at the back of the eye.

6. Review this diagram of the human eye. Use the information there to figure out the optical power of the human eye.

Optical power of the average human eye:

How does this compare to the power of Lens 1 and Lens 2?

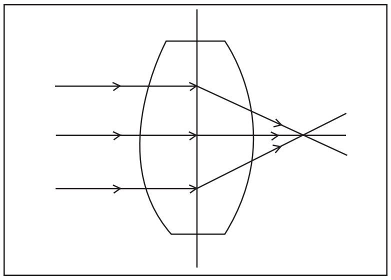
7. Replace Lens 2 with Lens 3 and repeat step 2.

What do you observe?

8. Compare the shape of Lens 3 to the shape of Lens 2.

How are they different?

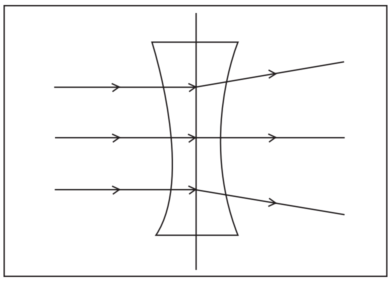
Analyzing Your Results



Convex lenses focus light rays.

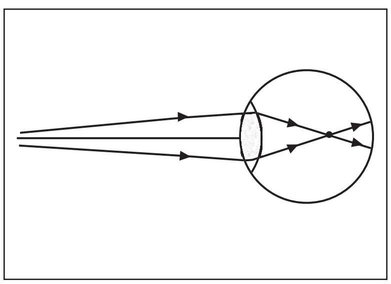
1. Lenses that are thicker at the middle than at the edges are called convex lenses. These lenses focus light. Lenses that are thinner at the middle than at the edges are called concave lenses. These lenses spread light out.

   If a person is nearsighted (has trouble seeing far away), that means his or her eyes focus light from distant objects in front of the retina.

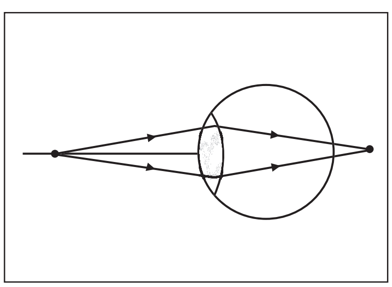


Concave lenses spread out light rays.

If you were designing a pair of glasses for someone who was nearsighted, would you use a convex or concave lens? Why?



A nearsighted eye focuses far objects in front of the retina.



A farsighted eye focuses near objects behind the retina.

2. If a person is farsighted (has trouble seeing things close by), that means his or her eyes focus light from near objects behind the retina.

If you were designing a pair of glasses for someone who was farsighted, would you use a convex or concave lens? Why?

Using your Results to Decode Ben's Secret Message

If Lens 1 has a longer focal length than Lens 2, the number you found in Activity 3 belongs in square A. If Lens 2 has a longer focal length than Lens 1, the number you found in activity 3 belongs in square B.

		A
	B	

The number found in Activity 3 belongs in square _____ because Lens _____ has a longer focal length.

National Science Education Standards

The PhysicsQuest activities directly correspond to many of the National Science Education Standards (http://newton.nap.edu/html/nses/). Standards addressed by each of the PhysicsQuest activities are listed below.

Activities 1-4

5-8 Science as Inquiry: Use Appropriate Tools and Techniques to Gather, Analyze, and Interpret Data. The use of tools and techniques, including mathematics, will be guided by the question asked and the investigations students design.

5-8 Science as Inquiry: Develop descriptions, explanations, predictions, and models using evidence. Students should base their explanation on what they observed, and as they develop cognitive skills, they should be able to differentiate explanation from description…

5-8 Science as Inquiry: Communicate Scientific Procedures and Explanations. With practice, students should become competent at communicating experimental methods, following instructions, describing observations, summarizing the results of other groups, and telling other students about investigations and explanations.

5-8 Science as Inquiry: Design and Conduct a Scientific Investigation. Students should develop general abilities, such as systematic observation, making accurate measurements, and identifying and controlling variables.

5-8 Science and Technology: Implement a Proposed Design. Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy.

5-8 History and Nature of Science: Nature of Science. Scientists formulate and test their explanations of nature using observation, experiments, and theoretical and mathematical models.

K-12 Unifying Concepts and Processes: Systems, Order, and Organization. There are physical laws governing the behavior of nature that exemplify its order, predictability, and regularity.

K-12 Unifying Concepts and Processes: Evidence, Models, and Explanation. Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements.

Activity 1

5-8 Science as Inquiry: Think Critically and Logically to Make the Relationship Between Evidence and Explanations. Specifically, students should be able to review data from a simple experiment, summarize the data, and form a logical argument about the cause-and-effect relationships in the experiment.

5-8 Physical Science: Properties and Changes of Properties of Matter. A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.

Activity 2

5-8 Physical Science: Transfer of Energy. Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.

8-8 Physical Science: Transfer of Energy. Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

5-8 Physical Science: Properties and Changes of Properties of Matter. A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.

5-8 Science in Personal and Social Perspectives: Science and Technology in Society. Societal challenges often inspire questions for scientific research.

Activity 3

8-8 Physical Science: Transfer of Energy. The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth.

8-8 Physical Science: Transfer of Energy. Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection).

5-8 Physical Science: Properties and Changes of Properties of Matter. A substance has characteristic properties, such as density, a boiling point, and solubility, all of which are independent of the amount of the sample.

5-8 Science as Inquiry: Use Mathematics in all Aspects of Scientific Inquiry. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations.

K-12 Unifying Concepts and Processes: Constancy, Change, and Measurement. Knowledge of mathematics is essential for accurate and communicable measurement. Changes in systems can be quantified. Mathematics is essential for accurately measuring change.

Activity 4

8-8 Physical Science: Transfer of Energy. Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object—emitted by or scattered from it—must enter the eye.

5-8 Science as Inquiry: Use Mathematics in all Aspects of Scientific Inquiry. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations.

5-8 Science in Personal and Social Perspectives: Science and Technology in Society. Societal challenges often inspire questions for scientific research.

K-12 Unifying Concepts and Processes: Constancy, Change, and Measurement. Knowledge of mathematics is essential for accurate and communicable measurement. Changes in systems can be quantified. Mathematics is essential for accurately measuring change.

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