MORE SUPER SCIENCE with SIMPLE STUFF!

Susan R. Popelka

GOOD YEAR BOOKS

Dedication

To my mom, Dorothy Huberty, my sister, Lynn Johnson, my high school English teacher, Mrs. Muelmanns, and my college physics teacher, Mr. Bergsten.

Acknowledgments

Many people helped me with this book. I would like to thank my family, Carl, Erin, Mike, and Gail Popelka, who encouraged me and waited patiently for their turn on the computer while I did yet one more rewrite. I would not have been able to finish the book without the daily question, *Are you done with your book yet?*

For the past ten years I have been teaching hands-on science workshops to elementary teachers. I wrote this book because those teachers asked me to write it. The activities in the book are their favorites, and they have tried and tested all of them. I owe them a heartfelt thank you for teaching me as I was teaching them.

GOOD YEAR BOOKS

Our titles are available for most basic curriculum subjects plus many enrichment areas. For information on other Good Year Books and to place orders, contact your local bookseller or educational dealer, or visit our website at www.goodyearbooks.com. For a complete catalog, please contact:

A Division of Social Studies School Service
10200 Jefferson Boulevard
Culver City, CA 90232-0802

(800) 421-4246

Cover Design and Illustration: Raymond Ortiz Godfrey
Book Design: Don Taka
Interior Illustrations: George Barile

Printed in the United States of America.

ISBN-13: 978-1-59647-270-9
ISBN-eBook: 978-1-59647-162-7
Previous ISBN-10: 1-59647-270-7

Contents

Introduction 1
- How This Book Is Set Up 1
  - Overview 2
  - Teacher page 2
  - Student page 4
  - Assessment 5
  - Glossary 5
  - Selected bibliography 5
  - Index 6
- How to Use This Book 6

Prologue: A Word or Two About Prediction 9
- Prediction Philosophy 9
- Prediction Practice 10

Chapter 1: Astronomy 12
- **Astronomy Assumptions** 13
- Angles and Astrolabes 14
- How High Is That Tree? 16
- Shifting Shadows 18
- Surveying the Sun 21
- Shifting Sunshine 24
- Simulating a Sensational Sunset 27
- Sunscreen Study 29
- How High? 31
- Lunar Illusion 34
- Moon Measurements 36
- Creating Craters 39
- Bouncing-Back Beam 42
- Bigger Beam 44
- Bright Bulb 47
- Spectacular Spectroscope 50

Chapter 2: Energy 52
- **Experiencing Energy** 53
- Catapult Cannon 54
- Rubber Band Blast 57
- Rubber Band Barrage 60
- Speedy Spool 63
- Changing-Course Can 66
- Penny Pendulum 68
- Tube Target 71
- Tube Target Two 74
- Tube Target Three 76
- Spring Stretch 78
- Spring Swing 81
- Warming Water 84
- Shimmering Stream 88
- Laser Light 90
- Light in a Liquid 93
- Seeing Sound 95
- Superior Sounds 97
- String Sounds 99

Chapter 3: Machines 101
- **Machine Material** 102
- Simple Spring Scale 104
- Lifting Lever 106
- First-Class Lever Lift 109
- Second-Class Lever Lift 112
- Third-Class Lever Lift 115
- Pulling Up a Plane 118
- Plane Pretenders 121
- Paper Clip Pulley 124
- Frictional Force 127
- Fighting Friction 129

Chapter 4: Newton's Laws 131
- **Newton Knowledge** 132
- Seat Belt Safety 134
- Plunging Pennies 136
- Energetic Eggs 138
- Easy Egg Exhibit 140
- Fowl Forces 142
- Precarious Package 144
- Balloon Blast-Off 146
- Better Balloon Blast-Off 149
- Best Balloon Blast-Off 152
- Balloon Blast 154

Chapter 5: Playground Physics 156
- **Principles of Playground Physics** 157
- Slipping, Sliding Stuff 158
- Slipping, Sliding Stuff Sequel 160
- Super Swings 163
- S'more Swings 166
- Swell Swingers 169
- Ball Bounce 172

Another Ball Bounce 174
Sizes of Shadows 177
Sorting Sand Scraps 180
Skateboard Slosh 182
Soccer Skills 184

Chapter 6: Properties of Matter 186

Matter Measurements 187
Measuring Mass 188
Density Discoveries 190
Water Weight 192
Buoyant Beverages 194
Bobbing Beverages 196
Freezing Fluids 198
Penny Puddle 201
Penny Puddle Practice 204
Sturdy Spaghetti 206
Spaghetti Scaffold 209
Bridge Building 212
Pleated Paper 214
Paper Pillars 217

Chapter 7: Speed 222

Speed Stuff 223
Speedy Straw 224
Falling Fruit 227
Carton Cars 229
Quick Carton Cars 232
Measuring Many Moves 234
Many More Moves 236
Circling Cans 240
Circling Can Contest 242
Pumping a Pendulum 244
Finding Frequency 246

Chapter 8: Weather 249

Weather Wonders 250
Which Way, Wind? 252
Balloon Barometer 254
Thrifty Thermometer 257
Brisk Breeze 259
Snow Scale 261
Doing Dew Points 263
Cloud Chamber 265
Packed Particles 267
Trailing Temperatures 269
Minimums and Maximums 273

Glossary 276

Selected Bibliography 280

Index 281

Introduction

The basic premise of this book comes from what a high school science teacher once told me: "Science is less scary when it is done with less scary stuff." If you can do science activities using "simple stuff" found around the house and that you feel comfortable with, science will seem interesting, fun, and understandable. The activities in this book use simple stuff that is readily available at home or can be purchased at a grocery store, hardware store, or school supply store.

The trend in science education has been to introduce more hands-on activities, like those in this book, into the classroom. Hands-on activities allow children to experiment with and manipulate materials. They foster teamwork and cooperative skills. And they lead to lively discussions about scientific principles and to more experimentation as children ask the question, "What will happen if . . . ?"

While hands-on science activities allow students to have fun by manipulating materials, it is important for students to understand what is going on conceptually. The activities need to be accompanied by a well-thought-out plan of making predictions, gathering and recording data, and drawing conclusions. In this book, every activity is accompanied by an activity sheet asking students to make predictions, collect data, record observations, and explain what it means.

A Chinese proverb is often quoted to summarize the point of hands-on science activities:

> I hear, and I forget.
> I see, and I remember.
> I do, and I understand.

To this proverb, I would add a final line: I explain what it means, and I *really* understand.

How This Book Is Set Up

This book is designed to be a resource to augment your existing science curriculum. You probably won't use all of the activities in the book, only those that apply to the science concepts you teach.

The activities in this book are designed for students in grades three through six. Many of the activities can be adapted for lower grades or higher grades. The vocabulary you use and the students' level of understanding will reflect the grade level at which the activity is presented.

Within each chapter, activities presenting similar concepts are grouped together. The activities can also stand alone. You can pick almost any activity in the book and use it successfully without having done any particular one before it. You can start any chapter without doing the chapters before it, too.

Some of the activities involve several concepts and could be placed in more than one chapter. For example, some playground activities could be grouped with energy. In fact, energy is a common thread that runs through most of the activities in the book, and it is presented in several different contexts. Other key science concepts also provide a common thread, appearing over and over again and in different topic areas. Frequency is an example of such a concept; it is involved in light, sound, and motion. Recognizing and understanding the concepts that are interwoven through different activities will help students better grasp these scientific principles and perceive the interconnectedness of all science.

Some of the simplest activities are the most elegant from a scientific point of view. When you present an activity that involves several concepts, it is a good idea to follow the student page, which focuses on the key concept(s) being taught in the activity. After that, you may want to point out that there is more science going on and then challenge the students to figure out what other concepts are involved. If the activity presents concepts you have already discussed in your science class, take the opportunity to review those concepts in light of the new activity. If the activity presents concepts that will be taught later, it's a good idea to wait until that time and use the activity to introduce the new concepts.

Overview
Each chapter opens with an overview of the key concepts presented in the chapter's activities. In order to get general background information about the chapter, read through this overview before doing an activity from the chapter. Many of the technical terms used in the chapter are defined in the overview. You may find it useful to refer to the Glossary for additional information.

Teacher page
For each activity in the book, there is a teacher page and student page(s). The teacher page provides you with background information and directions for performing the activity. The scientific concept covered in the activity is presented in the **Science** section. This section helps you to pick activities that will fit into your science curriculum and to determine where they will fit. The concept is stated briefly and simply.

Stuff lists materials needed to do the activity. Most of the materials are available at home or can be purchased at a grocery, hardware, or school supply store. In the few cases in which materials are not readily available, suggestions about obtaining them are given. You will notice that the **Stuff** list uses both the English system and the metric system rather than sticking to the more scientific metric system. Most science books use the metric system, but most grocery stores and hardware store in the United States don't. To make it easier for you to purchase and prepare the materials you need for the activities, measurements are given in the most convenient (albeit not scientific) terms. When you are doing the activity, you may chose to use the metric system in order to be consistent with your science curriculum. Or you may chose to use the English system, reminding your students that there are many ways to measure things.

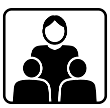
Note that **Stuff** consists of the materials needed for *one* group or individual. As you gather supplies for an activity, you will need to multiply the materials by the number of groups or individuals who will be doing the activity.

Step-by-step instructions for the activity are provided in the **What to Do** section. Do the activity before you present it in the classroom. When presenting the activity in the classroom, you may either read the directions out loud from the teacher page or summarize the directions in your own words.

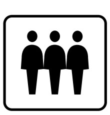
A brief explanation of the main scientific concept(s) comes next in **What's Going on Here**. Information in this section will help you guide your students as they answer questions on the student page. You may run across some technical terms that you can look up in the Glossary.

A number of ideas for extending the activity are suggested in **Try It!** Sometimes the suggested changes will yield similar results, sometimes the results will be better, and sometimes you won't get good results at all. The point of this section is to try new things and to determine what effect the new materials or procedure has on the activity. As in any good science activity, you must remember to change only one thing (for example, material, temperature, quantity) at a time.

Group-size icons recommend the optimum group size for the activity. The recommendations range from teacher-directed demonstrations to small groups and individual work. You know your classroom resources and your students best; the group size you use will ultimately depend on the availability and cost of materials and on the developmental skills of your students.



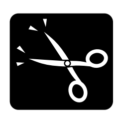
Teacher-directed activities should be done by you as demonstrations. Most of the teacher-directed activities involve a safety issue or require materials that may be impractical to obtain for small groups or individuals. These activities have been chosen and designed to be appropriate for demonstrating in front of a group of students. However, even in teacher demonstrations, try to get the students involved by having them assist with the activity. This helps demystify science, showing students that teachers aren't the only ones who can do it, and helping students gain confidence and experience in presenting science to their classmates.



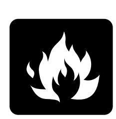
Small group activities should be done in small groups; the actual size will depend on the class size and the availability of needed materials. When the students work on science activities in small groups, they should exchange roles often so that everyone has the opportunity to manipulate the hands-on materials. Have the students do the activities in small groups or individually whenever possible.

Individual activities are best done by students working alone. Often the activity results in something that students are able to take home. For some individual activities, the observations that are made would be hard to notice in a group or teacher-directed demonstration. Even so, there is much that can be learned from working together in groups, and the discussions that take place as students work on science activities together are themselves learning experiences. Thus, even if the activities are done individually, it is still a good idea to have the students work together in small groups while doing them.

The activities in this book are designed for elementary students. They should be done with adult supervision, using the recommended materials and carefully following directions. You know your class best; you know what they are capable of doing. You may need to adapt some of the activities to suit your classroom. For example, you may need to prepare materials that require using pointed scissors ahead of time. Or you may decide that your students can prepare all of the materials that are needed. Whatever your decision, you and your students should pay attention to the following safety precautions as indicated by the **safety icons** listed below.



The **sharp objects** icon identifies activities where the pointed end of a pair of scissors or a pencil is used to make a hole in something, or knives and needles are used to prepare some materials. When using sharp objects, everyone should be careful to avoid injury. Watch out for soup cans that have rough edges that can cut skin. Glass plates and mirrors also often have rough edges, so tape the edges ahead of time and be careful. Wear goggles when working with sharp objects.



The **heat and fire** icon warns you to use caution near open flames and to wear goggles. When using hot tap water, make sure that the water temperature is below 104°F. Use insulated gloves when working with boiling water and when using batteries that get hot.

The **flying objects** icon warns you that objects that are twirled need open space away from people so that no one is hit by them. Thrown or launched objects need an area that is free from obstructions; care should be taken so that no one is in the way when any object is thrown or launched. Goggles should be worn.

Keep **magnets** away from computers, computer disks, credit cards, videotapes, audio tapes, televisions, video recorders, tape recorders, telephones, answering machines, radios, and loudspeakers.

Student page

The student page is written for the students to read and work on as you guide the activity.

The student page follows the scientific method. The **What You Want to Know** section is a statement of the problem in the form of one or more questions. **What You Think Will Happen** allows the student to make predictions, or hypothesize, usually by completing one or more multiple-choice statements. The **What Happened** section requires the students to gather and record data and/or make observations. **What It Means** is the conclusion that the students draw on the basis of their observations.

As the students fill out the page, they often will be writing the same information in different sections. This redundancy is built into the page to reinforce the scientific concepts involved in the hands-on science activities.

Most of the student pages include a drawing of the activity. The drawing serves as a visual reminder and also is handy when the students take the page home and explain the activity to others. A few student pages do not have any drawings on them because even a simple drawing would take away the feeling of discovery during the activity. In these cases, the students should be encouraged to draw their own pictures of the activity on the back of the student page after doing the activity.

What You Want to Know lists one or more questions that give the students an idea of what the activity is about. It suggests a purpose for doing the activity and starts the students wondering about what they will learn.

Prediction is an important skill to be learned in any science program. Most of the activities in this book have multiple-choice statements that require the students to predict what they think will happen. Multiple-choice statements are used instead of open-ended questions so that the students are able to focus their thoughts and so that they gain confidence in making predictions. The students should be told that there are no right and wrong answers when it comes to making predictions. The multiple-choice statements are written so that the students can pick more than one answer; in fact, you should encourage the students to pick as many answers as they think appropriate. Some multiple-choice statements even have a blank answer line, allowing students to write in their own predictions. There may appear to be clues to the answers to these questions in the title of the activity, in the drawings, or in some of the questions that follow. The students should be encouraged to look for such clues to make their predictions. Looking for clues is an important skill in science.

In **What Happened,** students make observations and record their data. Activities include questions to answer or tables to fill in. In this section, students should be encouraged to record exactly what they observed; they should not draw any conclusions at this point or try to make their observations fit what they thought would happen.

What It Means usually starts out with the phrase "what do your observations tell you about" or "what can you now say about." This section requires students to draw conclusions based on what they observed in the activity; they make deductions using their own senses. The aim here is to relate what happened in the activity to the scientific concept involved. You should use information from the **Science** and **What's Going On Here** sections of the teacher page to help guide the students. Depending on the experience and background of your students, you may have to guide them step-by-step through some or all the sections on the student page.

In some activities, students vary one quantity and determine what effect it has on another quantity. They record their data in a table. Since graphs give meaning to tables of numbers, the students use the **Graph It!** pages to visualize the relationship between the numbers in the data table. They may discover that increasing one quantity will result in an increase in the other quantity; this is a direct relationship. At other times, an increase in one quantity will result in a decrease in the other quantity; this is an inverse or indirect relationship. Direct and inverse relationships can be linear (data points lie on a straight line or close to it) or nonlinear (data points lie on a smooth curve). After graphing the data, students respond to questions that require them to interpret the graph or summarize what it means.

Assessment
The activities in this book are designed to supplement an existing science curriculum in which many types of assessment are used. Standardized paper-and-pencil tests are not appropriate for hands-on activities. But that does not mean that assessment cannot or should not be used. In fact, assessment is embedded in every activity in this book. The questions in the **What It Means** section of the student page have been formulated so that students explain the meaning of what they observed; their statements about the key concepts of each activity provide the basis for assessment. Students should not be assessed by the accuracy of the results they get, but rather by the process by which they get their results. As the students are doing the activity, you may also assess their skills in working in groups and in using the scientific method.

Glossary
The **Glossary** contains easy-to-understand definitions of the terms used in the **What's Going On Here** sections of the teacher pages. Often the definition of a term will also include an example to help explain it. The **Glossary** is written for the teacher, but most of the definitions can be used as is or with slight modifications for the middle elementary student.

Sometimes a definition is given on the student page. For example, the definition for *density* appears on several student pages. Definitions used on the student page are reserved for those terms that seem to be most often misunderstood by students.

Selected bibliography
The **Selected Bibliography** is a list of science activity books appropriate for the middle elementary grades. The books in the list will give you ideas for more science activities to use in your classroom. If you are doing a unit on weather, for example, and run out of activities from this book, check out a book from the bibliography. Some of the books in the bibliography contain activities that are similar to the activities in this book but take a different approach. If your students become really interested in a particular activity, you may want to try to find a similar one in one of these books and let them try the activity from a different perspective.

Index

The **Index** consists mainly of entries for the concepts covered in the book. If you are teaching a unit on energy, you will discover that it is very easy to find the activities dealing with the various aspects of energy by simply referring to the entry "energy." If you want to locate an activity dealing specifically with light energy, you will be able to find those activities by looking under "light" in the Index. A few entries in the **Index** are activity related—for example, "balloon rockets." The activity-related entries have been included to make it easy for you to find the few activities that are best remembered not by their topic area (Newton's laws, in the case of balloon rockets) but by the activity itself.

How to Use This Book

There are many ways to do the activities in this book. Your individual teaching style will determine what method works best for you. The class size and classroom environment will also determine how the activities are presented. It is a good idea to allow the students to do as much of an activity as they are capable of doing. The results that they get may not look refined, but their sense of ownership and accomplishment will far outweigh any lack of finesse. What follows is a suggested presentation format.

Before presenting the activity in the classroom:

1. Try the activity at home or school. Find a place that will not be harmed if the activity is messy. Gather the materials, follow the directions carefully, and observe what happens. Take notes on the activity.
2. Make predictions as you proceed from one step to the next. Ask yourself the questions "What will happen if . . . ?" or "What will happen when . . . ?"
3. Try a few of the ideas in the **Try It!** section. Graph the data if the activity has a **Graph It!** page.
4. Decide how you will introduce the activity in the classroom. Review the student page so that you understand how the science concepts are integrated into the activity.
5. Decide how much time you will need to do the activity in your classroom. Most of the activities in this book take between 30 and 60 minutes, but your individual teaching style and other factors will affect the actual time that any activity takes.
6. Decide what group size—whole class, small groups, or individuals—will be used for the activity.
7. Gather one set of materials for each individual or group. Plan to have extras of items that may break or roll under cabinets. Bring any other items that students may need if they want to attempt the ideas in the **Try It!** section.
8. Make the required number of copies of the student page.

When presenting the activity in the classroom:

1. Hand out the student pages. If appropriate, divide the students into groups.
2. Have the students read the questions in the **What You Want to Know** section.
3. Describe the activity to the students, and have them make a prediction in the **What You Think Will Happen** section. Discuss the predictions. Ask them how they arrived at their predictions. Do not be critical of any predictions. In order for students to take the risk that is sometimes necessary to make predictions, they need to feel comfortable that it is all right if they are wrong. What is more important than making a correct prediction is that they use their

own background and previous experience to make an educated guess (another term for *prediction* or *hypothesis*). Discourage students from haphazardly picking any choice simply to get on with the activity. Encourage them to explain why they made the prediction that they did. Different predictions from various students will facilitate good discussions.

4. If students are working individually or in small groups, hand out or have the students pick up the materials. In cooperative groups, it often works well to have one person gather the materials.
5. Read or summarize the directions to the students as you guide them through the activity, or do the activity in front of them.
6. Have the students record the required information in the **What Happened** section. In order for the scientific concepts to really sink in, it is important that individual students fill out their own pages.
7. Discuss the activity with the whole class before the students fill out the **What It Means** section. Reading the **Science** and **What's Going on Here** sections from the teacher page will help you generate discussion questions and guide the students to an understanding of how what they observed relates to answering the questions. Encourage students to use the blank side of the student page if they do not have enough room on the front. If appropriate to the activity, you may also want to encourage students to use the blank side of the student page to draw a picture of the activity.
8. After the students have completed the activity, ask them what else they could try in order to expand the activity or to answer questions that came up while they were doing the activity. Ask the students to complete the question "What would happen if . . . ?" Provide the opportunity to continue their investigation immediately if time and materials allow; if that's not feasible, suggest a plan to continue the activity the following day.

In some activities, the students record data in a table with two or more columns of numbers. Graphs give meaning to tables of numbers, so in those activities an extra student page called **Graph It!** enables students to see the relationship between the quantities they measured. When graphing data, students should be encouraged to follow these procedures:

1. The graph should have a descriptive title at the top.
2. Each axis of the graph should be labeled with the name of the quantity measured and the units (centimeters, seconds, and so on) of the quantity.
3. Each axis should have numbers on it (a scale) that should be convenient and use as much of the graph paper as possible.
4. The pairs of values in the data table constitute ordered pairs, which are used to plot data points on the graph.
5. Students should not connect the points on the graph dot-to-dot, except when instructed to do so. Instead, a smooth curve or straight line (using a ruler) should be drawn through as many points as possible. The curve or line may miss some points, but it should miss them by as small an amount as possible.

After graphing the results, discuss the graph and have students answer the questions that accompany the graph.

Finally, ask the students if they would like to try any of the activities suggested in the **Try It!** section on the teacher page. To motivate the students, you can preface each suggestion with, "I wonder what would happen if we did this activity again and changed . . . " If you have the materials available in the classroom and time permits, allow them to try the activity again right away, making the necessary changes. Otherwise, they can try it in class the next day. Some of the **Try It!** activities, incidentally, make excellent science fair projects.

All the activities in this book have been pretested by teachers, elementary students, and the author. You may encounter an activity that does not work the first time. If that happens to you, relax. Make sure that you have all the recommended materials. Try the activity again, following the instructions very carefully.

Hands-on science can be messy, and it can also be unpredictable. That is why it is so much fun! Sometimes an activity that worked perfectly well on the kitchen table will fail in the classroom with a group of students. So if things don't always work out as you anticipated, console yourself with the knowledge that basic science principles always govern how things work. Science never fails when an activity does; it is the materials or procedure that are inadequate. Rarely does the scientist goof!

I hope that you enjoy doing the activities in this book, learn more science, and have a lot of fun doing it. I certainly have!

Prologue

A WORD OR TWO ABOUT PREDICTION

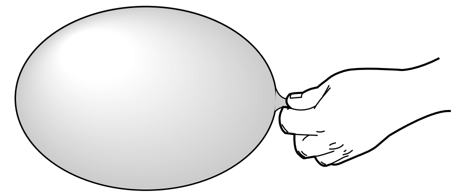
Prediction Philosophy

- The scientific method consists of (1) recognizing a problem or question, (2) making a prediction or hypothesis, (3) designing and doing an experiment, (4) observing or collecting data, and (5) drawing a conclusion. Based on the results, other experiments may follow.
- Often in the excitement to get an experiment going, scientists overlook the prediction step and skip right to designing and doing an experiment. That is not a good idea.
- It's difficult to determine the success of an experiment if you haven't thought about how it would turn out. Thinking about how it will turn out is predicting. You should write your prediction down so that you recognize that you have completed an important step in the scientific method.
- Predictions are made using past experiences and educated guesses. The more experiences you have, the better able you are to make predictions. Experience comes from age, but it also comes from reading, observing, and asking questions in your everyday life.
- The more you perform a certain experiment, the better you will become at predicting the outcome. You may make changes, one at a time, to see how they affect your results. Sometimes you may get unexpected results, but the important thing is that you made the prediction and followed the scientific method.
- People who gain experience making predictions in science experiments find practical applications for their prediction skills in their daily lives.
- People make predictions on a daily basis without realizing it. Prediction is a skill you should practice and develop.
- Football teams decide on their defense based on what they predict the next play will be. If they just wait to see what will happen instead of making a prediction, they may be caught off guard. Many times they are tricked, but most of the time predicting—and doing so intelligently—helps.
- People who invest in the stock market make predictions. They research a stock, buy it when they predict it will be increasing in value, and sell it when they think it will decrease in value. If they make good predictions, they will make money on the stock.

PREDICTION PRACTICE

Science Predictions are made using past experiences and educated guesses.

Stuff 2 small pieces of paper (about 4 square inches); balloon; yardstick or meter stick



What to Do

1. Write the word *launch* on one piece of paper. Write the word *target* on the other piece of paper.
2. Place the paper marked "launch" on the floor. This is where you will stand when you release the balloon after fully inflating it.
3. Place the paper marked "target" on the floor where you think the balloon will land after you have launched it.
4. Stand on the launch paper. Inflate the balloon, hold it horizontally, and release it.
5. Measure the distance from the target paper to where the balloon landed.
6. Move the target paper to a spot on the floor where you think the balloon will land on a second attempt. You may leave the target in the same spot. The goal is to have the balloon land as close to the target as possible.
7. Repeat steps 4 and 5.
8. Move the target to a new spot and repeat steps 4 and 5. Do a total of five launches.
9. Repeat steps 3 through 8, but this time hold the balloon vertically, with the open end pointing downward.

What's Going On Here

Prediction is a very important step in the scientific method. Predictions are made based on past experiences and by carefully thinking about the experiment. In this activity, it may seem impossible to predict where the balloon will land; its motion is erratic. Actually, your ability to make a prediction about where the balloon will land is better than you might think. If you are doing the activity in a room, you are certain that the balloon will not go through the wall to the outside, so you will not place the target outside the room. You have past experiences with gravity, so you are certain that the balloon will not attach itself to the ceiling. Generally speaking, if you perform an experiment repeatedly and continue to modify your predictions, your guesses will get better. In this activity, you may have reached a point where you couldn't improve much on your prediction. Also, your prediction may have been exactly correct on your first try, and then may have been off on successive tries. The important thing is that you have made a prediction and used the scientific method.

Try It!

★ Try inflating the balloon with less air.

★ Try launching the balloon at other angles.

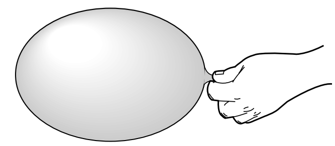
★ Try doing the activity outside.

Name Date

PREDICTION PRACTICE

What You Want to Know

How well are you able to predict where an inflated balloon will land after you release it?



What You Think Will Happen

When you release a balloon held horizontally, its distance from the target will be

a. less than 6 feet. **b.** more than 6 feet.

When you release a balloon held vertically, its distance from the target will be

a. less than 6 feet. **b.** more than 6 feet.

What Happened

Record the distance that the balloon landed from the target.

Horizontal launch number	Distance from target
1	
2	
3	
4	
5	

Vertical launch number	Distance from target
1	
2	
3	
4	
5	

What It Means

Did your prediction of where the balloon would land get better as you launched the balloon more times? Why do you think that happened?

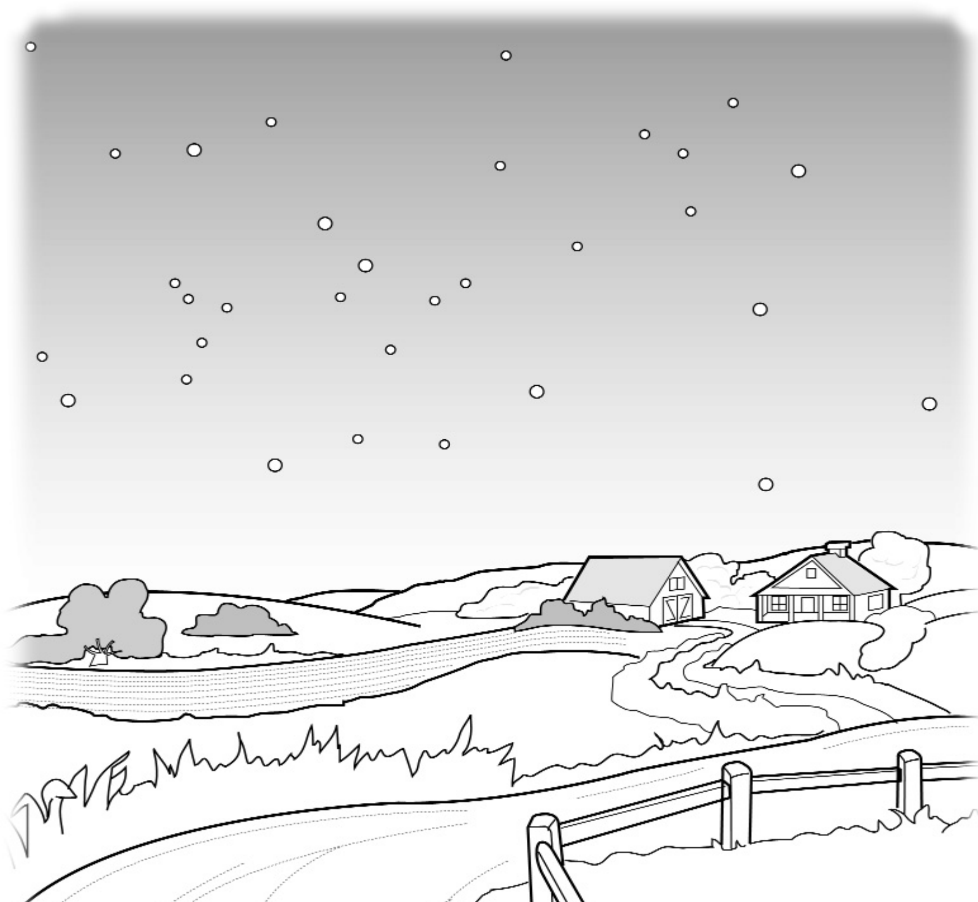
____

For which launch type (vertical or horizontal) did you make better predictions?

____

CHAPTER 1

ASTRONOMY



ASTRONOMY ASSUMPTIONS

- Astronomy is the study of our universe and its galaxies, stars, planets, moons, and other matter. It is an awesome endeavor. This chapter focuses on a few basic concepts in astronomy in the context of the earth, moon, and sun.

- An *astrolabe* is an instrument that measures the angular separation of objects. Among other things, it is used to measure the height of an object, the angle above the horizon that an object is located, and the angular distance between objects.

- As the sun rises and sets, its angular measure above the horizon changes, being greatest at midday and least at sunrise and sunset.

- The brightness of the sun changes over the course of a day and over the course of a year. Factors that affect the amount of sunlight reaching us are time of day, time of year, and weather conditions.

- The sun appears orangish-red at sunset because its rays pass through more atmosphere at sunset than at midday. The blue light is scattered by the atmosphere, leaving the light from the sun an orangish-red color.

- Sunscreen is used to protect our skin from the damaging ultraviolet rays of the sun.

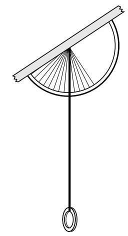
- The moon appears to be larger when it is rising or setting than when it is at its greatest angle above the horizon. This is due to an optical illusion. The same phenomenon is true for the sun, but we don't notice it because we don't look at the sun as closely as we look at the moon (and for very good reasons!).

- Craters on the moon were caused by high-speed meteorites crashing into the moon.

- The brightness of a light decreases as you move away from the light. This phenomenon is used to determine the distance of various objects in the universe.

- A *spectroscope* is a scientific instrument that is used to study the colors of light coming from stars. By analyzing the colors, scientists can determine the composition of the stars.

ANGLES AND ASTROLABES



Science An astrolabe is an instrument that measures the angular distance between two objects.

Stuff Cardboard; protractor; straw; string (12 inches); washer; tape

What to Do

The astrolabe made in this activity is used in several other activities in this book.

1. Draw a line down the middle of the piece of cardboard. Place the flat edge of a protractor on this line, and mark the angles in steps of 10°. Mark the angle corresponding to 90° as 0°, the angle corresponding to 80° as 10°, the angle corresponding to 70° as 20°, and so on. Draw lines to each of the marked angles; label these lines with the corresponding angle measures.
2. Cut the half-circle out of the cardboard.
3. Tie a washer to one end of a piece of string. Tape the other end of the piece of string to the middle of the cardboard, where the angle marked as 0° begins.
4. Tape a straw on top of the straight edge of the cardboard. You have now created an astrolabe.
5. Look through the straw as you move the astrolabe up and down, from vertical to horizontal. Notice that the string passes over the lines you marked on the cardboard.
6. Make sure that when you change the position of the astrolabe, you don't move it right or left or tilt it. Also, make sure that the string with the washer hangs straight down.
7. Take the astrolabe outside. Look through the straw at the tops of several objects that you know are about the same distance from you, and measure the angle.
8. Look at distant trees through the straw, and measure the angle of the top of the trees. Look at nearby trees, and measure the angle.

What's Going On Here

When the straw is held horizontally, the string hangs straight down, passing over the line corresponding to 0°. When the straw is held vertically, the string still hangs straight down, but this time it passes over the line corresponding to 90°. If the straw is held at some position between horizontal and vertical, the string will pass over a line between 0° and 90°. The closer the straw is to being vertical, the closer the angle will be to 90°; the closer the straw is to being horizontal, the closer the angle will be to 0°. Navigators use astrolabes to determine the position of their ships or aircraft. In the Northern Hemisphere, the angle between the horizon and the North Star is the latitude.

Try It!

★ Try measuring the angle of the North Star at night and comparing it to your latitude. Measure the angle of the North Star several nights and at different times of night.

★ Try measuring the angle of another star in the night sky at different times of night.

Name Date

ANGLES AND ASTROLABS

What You Want to Know

How does the angle change as you look at objects that are about the same height but are at different distances from you? How does the angle change when you look at objects that are the same distance from you but have different heights?

What You Think Will Happen

When you look at the top of an object through your astrolabe, the angle will be larger when

a. you look at an object that is closer to you.

b. you look at a taller object.

c. both (a) and (b).

d. neither (a) nor (b).

What Happened

Record the angle shown on your astrolabe when you looked at objects that were about the same distance from you.

Object	Angle on astrolabe

Record the angle shown on your astrolabe when you looked at objects that are about the same height but were at various distances from you.

Distance	Angle on astrolabe
Nearby	
Not too far away	
Far away	
Very far away	

What It Means

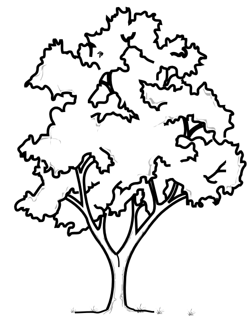
What do your observations tell you about how the angle on your astrolabe depends on the height of an object?

What do your observations tell you about how the angle on your astrolabe depends on the distance to an object?

HOW HIGH IS THAT TREE?

Science You can use the astrolabe from the previous activity to measure the height of a building or tree.

Stuff Measuring tape; yardstick or meter stick; astrolabe from "Angles and Astrolabes"



What to Do

1. Go outdoors and find a tree (or a flagpole, tall building, or light pole).
2. Measure a distance on the ground at least 30 feet away from the tree. Stand at that distance.
3. Look through the straw of the astrolabe, and line it up with the top of the tree. Make sure that the string is hanging straight down and is not caught on your hand or on the cardboard.
4. Have your partner record the angle that the string lines up with on the astrolabe. If it is between two numbers, estimate what the number is. For example, if it is midway between 10° and 20°, call it 15°.
5. Now all you need to do is multiply some numbers together to get the height of the tree.
   Use this equation to determine the height of the tree: $\mathbf{H = tan (A) \times D + L}$. In this equation "H" is the height of the tree, "A" is the angle on the astrolabe to the top of the thing, "D" is the distance you are from the thing, "tan" is the abbreviation for tangent, and "L" is the distance from the ground to the eyes of the person holding the astrolabe.
6. Repeat steps 1 through 5 for two other high objects.

What's Going On Here

When you look through the straw at the top of the tree, the string hangs straight down and indicates the angle above the ground that corresponds to the top of the tree. To determine the height of the tree, first multiply the tangent of the angle by the distance from the astrolabe to the tree. Tangents are listed on the next page. They also can be found using a calculator. Just enter the angle measure that you read from the astrolabe, and press the "tan" key on your calculator. On some calculators you may have to press the "tan" key first and then the angle. After you have multiplied the tangent of the angle by the distance to the tree, you need to add the distance from the ground to the astrolabe, or, in other words, from the ground to the person's eyes.

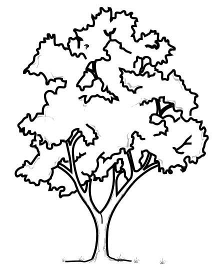
Try It!

★ Try measuring the heights of different things indoors—for example, the height of the gymnasium ceiling at your school.

★ Try measuring the height of your house.

Name Date

HOW HIGH IS THAT TREE?



What You Want to Know

How can you use an astrolabe to measure the height of things?

What You Think Will Happen

What do you think is the height of the different objects you are going to measure?

Object ____________ Height _____ Object ____________ Height _____

Object ____________ Height _____ Object ____________ Height _____

What Happened

1. In the column labeled "A," record the angle measure shown on your astrolabe when you looked at the top of the object.
2. Look in the table below to find out what "tan (A)" is equal to, and put that number in the table.
3. In the column labeled "D," record the distance from where you were standing to the object.
4. In the column labeled "L," record the distance from the ground to your eyes.
5. Multiply the number in the "tan (A)" column by the number in the "D" column. Add the number in the "L" column to it, and write that number in the column labeled "H." That is the height of the thing you are measuring.

Thing	A	tan (A)	D	L	H

Angle	Tangent	Angle	Tangent	Angle	Tangent
0	0.000	30	.577	60	1.732
5	.087	35	.700	65	2.145
10	.176	40	.839	70	2.747
15	.268	45	1.000	75	3.732
20	.364	50	1.192	80	5.671
25	.466	55	1.428	85	11.430

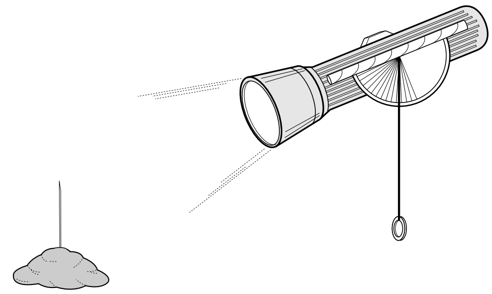
What It Means

Do the heights of the different objects you measured make sense? Explain your answer. ________________________________

SHIFTING SHADOWS

Science The length of the shadow depends on the position of the light source.

Stuff Toothpick; clay; tape; flashlight; meter stick; astrolabe from "Angles and Astrolabes"



What to Do

1. Stand the toothpick upright in a small piece of clay.
2. Tape the straw of the astrolabe on the long side of the flashlight. The washer on the astrolabe should hang straight down and be able to swing freely. Darken the room.
3. Hold the flashlight about 50 centimeters from the toothpick, and shine the light directly at the toothpick. Change the tilt of the flashlight so that the string on the astrolabe goes through 10°.
4. Have a partner measure the length of the toothpick's shadow, in centimeters, from the toothpick to where the shadow ends.
5. Repeat steps 3 and 4 for flashlight tilts of 20°, 30°, 40°, 50°, 60°, 70°, and 80°.

What's Going On Here

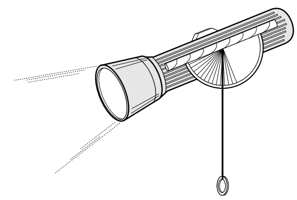
The length of an object's shadow depends on the height of the object and the position of the light making the shadow. Taller objects make longer shadows than shorter objects. When the light shines straight down on an object, the shadow is not very long. If the light shines in a horizontal direction toward the object, the shadow is long. Light shining at angles between vertical and horizontal will produce shadows of differing lengths, from very short to very long. One example is shadows made by the sun. The length of your shadow changes during the day even though your height does not (usually!) change. When the sun is rising or setting, your shadow is much longer than it is at midday, when the sun is shining more directly down on you. The same thing happens during the course of the year, but it is harder to notice because you don't stand in one place watching your shadow all year. In the Northern Hemisphere, the sun is higher in the sky in the summer than in the winter, so our shadows are shorter in the summer than in the winter, if we measure them at the same time of the day.

Try It!

- ★ Try changing the distance from the flashlight to the toothpick.
- ★ Try using a pencil instead of a toothpick.
- ★ Try keeping the flashlight at the same angle and changing the angle of the toothpick.

Name Date

SHIFTING SHADOWS



What You Want to Know

Does the length of an object's shadow depend on the angle of the light that shines on it?

What You Think Will Happen

As you make the angle that a flashlight shines on a toothpick larger, the shadow of the toothpick

a. becomes longer.

b. becomes shorter.

c. stays about the same length.

What Happened

Record the length of the toothpick's shadow for each angle of the flashlight.

Angle of flashlight	Length of toothpick's shadow
10°	
20°	
30°	
40°	
50°	
60°	
70°	
80°	

What It Means

What do your observations tell you about how the angle of the flashlight affects the length of the toothpick's shadow?

____

How does the length of your shadow outside on a sunny day at noon compare to its length on the same day at sunset? Explain your answer.

____

____

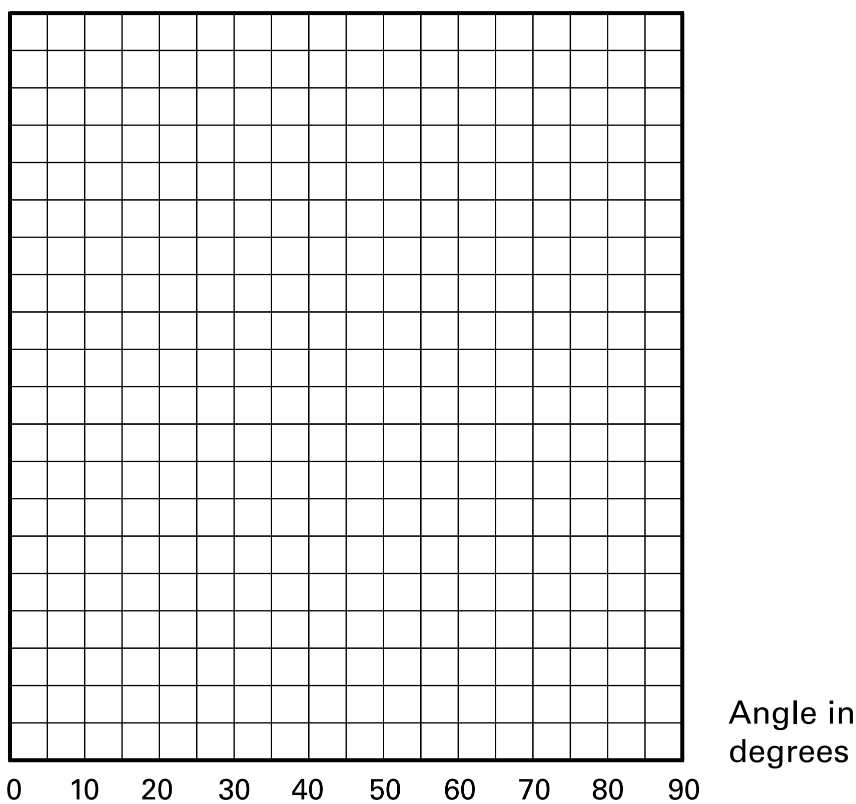
Graph It Next

Name Date

SHIFTING SHADOWS

GRAPH IT!

1. Label the vertical axis “length in centimeters.” Pick a convenient scale, and put numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. Your line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

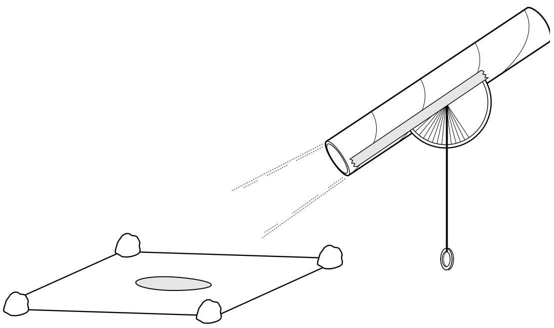


What happens to the length of the shadow as the angle of the flashlight increases?

SURVEYING THE SUN

Science The angle of the sun above the horizon changes over the course of a day and also over the course of a year.

Stuff Tape; cardboard tube (from roll of toilet paper or paper towels); astrolabe from "Angles and Astrolabes"; sheet of white paper; a few rocks



What to Do

1. Tape the straw of the astrolabe on the long side of the cardboard tube.
2. On a sunny day, take the cardboard tube outside. Place the white paper on the ground, and put a few rocks on the corners to keep it from blowing away.
3. Holding the tube about 12 inches from the paper, point it in the general direction of the sun. *Do not look through the tube at the sun.* Move the tube around until a thin elliptical shadow of the tube appears on the white paper. You will see the shadow of the tube change as you move it around, but at some point the shadow will be a thin elliptical shadow.
4. Record the angle that the string lines up with on the astrolabe when the tube casts a thin elliptical shadow.
5. Repeat steps 2 through 4 at intervals of one hour throughout the day.

What's Going On Here

When the tube is pointed directly at the sun, the sun's rays travel straight down the inside of the tube and straight down the outside of the tube so that the shadow formed on the paper is a thin elliptical one. When the tube is not pointed directly at the sun, the shadow will be wider because the sun's rays are not traveling straight down the tube; they hit the sides of the tube casting a wider shadow. At midday the sun is highest in the sky. The exact time that this occurs depends on where you are located within your time zone and whether it is daylight savings time (DST). If you are located in the middle of your time zone and are on standard time, the sun is highest in the sky at about noon. Most telephone books have time zone maps you can use to determine where you are located within your time zone. Before and after midday, the sun's angle is lower in the sky. The angle of the sun in the sky also depends on the time of year. The sun is highest in the sky at midday on the summer solstice (around June 21) and lowest in the sky at midday on the winter solstice (around December 21).

Try It!

★ Try measuring the angle of the sun at the same time once a week for several months.

★ Try measuring the angle of the moon in the sky. You can look directly through the cardboard tube at the moon if the shadow the moon casts is not noticeable.

Name Date

SURVEYING THE SUN

What You Want to Know

How does the angle of the sun above the horizon change over the course of a day?

What You Think Will Happen

If you measure the angle of the sun above the horizon over the course of a day it will

a. increase steadily from morning to afternoon.

b. decrease steadily from morning to afternoon.

c. increase steadily until midday and then decrease into the afternoon.

d. decrease steadily until midday and then increase into the afternoon.

What Happened

Record the angle measure of the sun at different times during the day.

Time	Angle on astrolabe

What It Means

What do your observations tell you about how the angle of the sun above the horizon changes over the course of a day?

What do you think would happen if you measured the angle of the sun above the horizon at the same time every day over the course of a year?

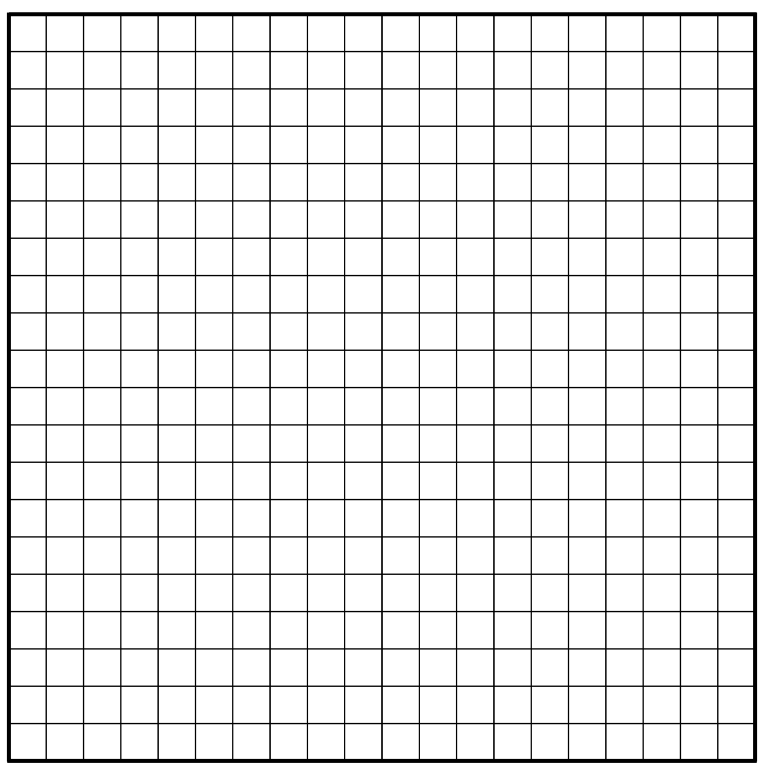
Graph It Next

Name Date

SURVEYING THE SUN

GRAPH IT!

1. Label the vertical axis “angle in degrees.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Make sure to keep the scale the same on the entire vertical axis. Put a scale on the horizontal axis, too.
2. Plot the data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



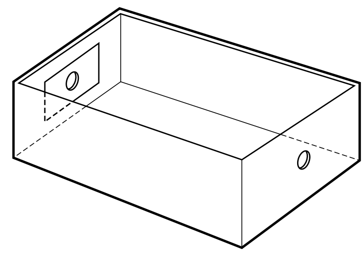
Time of day

Are there pairs of times during the day where the angle is about the same? What does it mean when two times of the day have the same angle?

SHIFTING SUNSHINE

Science The brightness of the sunlight reaching the earth changes during the day and during the year.

Stuff Scissors; small cardboard box (shoe box size); tape; index card; 2 clear plastic sandwich bags; several small books



What to Do

1. Use the pointy end of the scissors to punch a small hole about $\frac{1}{4}$ inch in diameter in the middle of one side of a small cardboard box. Put a small mark in the middle of the index card. Tape the index card on the inside of the box, opposite the side with the hole, with the mark directly opposite the hole.
2. Cut each sandwich bag down the middle. Then cut each section of the sandwich bag into sections that are about an inch wide. Each section will be composed of two pieces of clear plastic.
3. Place the cardboard box near a window on a clear day. Prop the box on a few books, and position it so that the sun shines into the hole in one end and hits the mark on the index card inside the box.
4. Put one section of the clear plastic over the hole in the box, and look at the spot of light on the index card.
5. Continue to add plastic sections, one at a time, until you are no longer able to see the spot of light on the index card.
6. Repeat steps 3 through 6 at intervals of one hour, noting the weather conditions each time (sunny or cloudy).

What's Going On Here

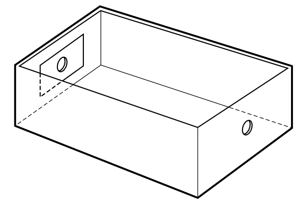
The relative intensity or brightness of the sunlight reaching the earth can be determined by measuring how many sheets of plastic it will pass through. When more sunlight reaches the earth, it will be able to pass through more sheets of plastic. During the course of a day, the sunlight reaching the earth is greatest when the sun is directly south, which is around noon (11:00 A.M. Daylight Savings Time). The actual time will vary depending on your location in your time zone. The sunlight reaching the earth will be less when the sun is not directly south, before and after noon; the sunlight has to go through more atmosphere which, like the plastic sheets, is able to absorb the sunlight. The amount of sunlight reaching the earth is also affected by other factors, such as weather conditions and the time of year. More sunlight reaches the earth in the summer than in the winter.

Try It!

★ Try measuring the amount of sunlight reaching the earth at the same time of day once a week for several months. Compare the actual outside temperature to the sunlight intensity readings that you measured.

Name Date

SHIFTING SUNSHINE



What You Want to Know

Does the amount of sunlight reaching the earth change during the day?

What You Think Will Happen

The amount of sunlight reaching the earth is greatest

a. in the early morning.

b. around noon.

c. in the middle of the afternoon.

What Happened

Record the time, weather conditions, and sunlight brightness (in the number of plastic sheets that the sunlight passed through).

Time	Weather conditions	Sunlight brightness

What It Means

What do your observations tell you about how the amount of sunlight reaching the earth changes during the day?

____

What effect does the weather have on the amount of sunlight reaching the earth?

____

What do you think would happen if you measured the sunlight reaching the earth three months from now?

____

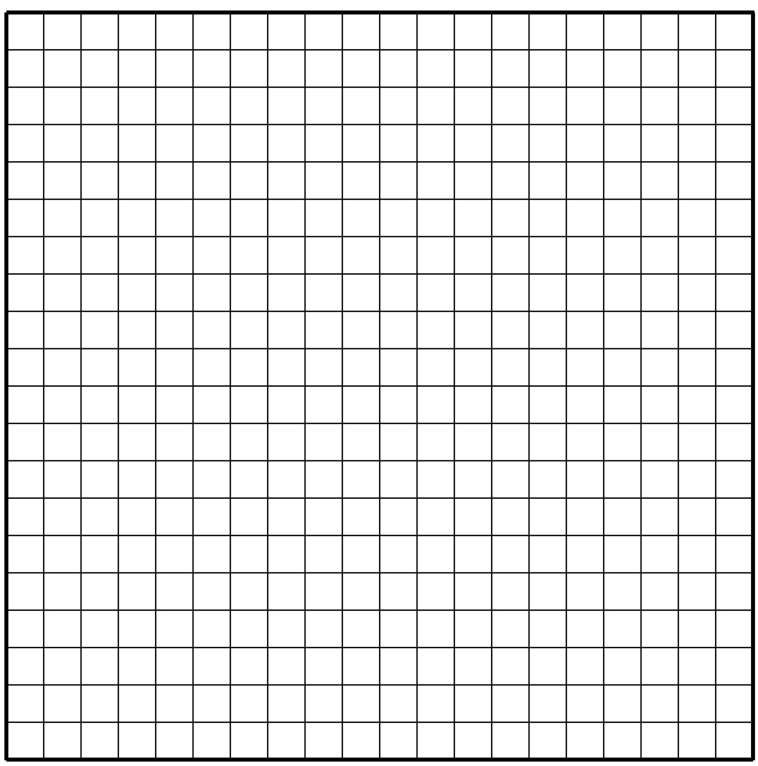
Graph It Next

Name Date

SHIFTING SUNSHINE

GRAPH IT!

1. Label the vertical axis "sunlight brightness in sheets of plastic." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Put a scale on the horizontal axis, too.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



Time of day

Explain one thing that your graph shows.

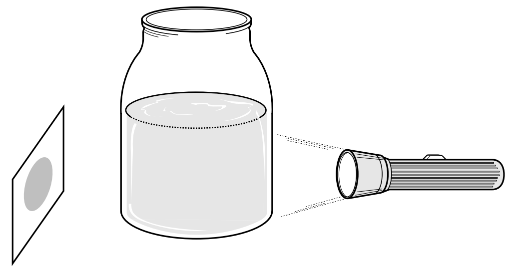
____

____

SIMULATING A SENSATIONAL SUNSET

Science The sun appears orangish-red when it sets and rises due to scattered light.

Stuff Wide-mouth jar; water; flashlight; sheet of white paper; pencil; latex paint (any color)



What to Do

1. Take the label off a wide-mouth jar.
2. Fill the jar about three-fourths with water.
3. Place a flashlight on its side next to the jar, and turn on the light so that it shines through the jar. Hold the white piece of paper a few inches away from the other side of the jar, and observe the color of the light on the piece of paper.
4. Dip the pointed end of a pencil into the latex paint. Stir the small amount of paint on the pencil into the water. Depending on the size of the jar, you may have to adjust the amount of paint you add to the water. If there is too much paint in the water, no light will pass through the jar.
5. Repeat step 3. Also observe the color of the cloudy water on the side of the jar the light is not passing through.

What's Going On Here

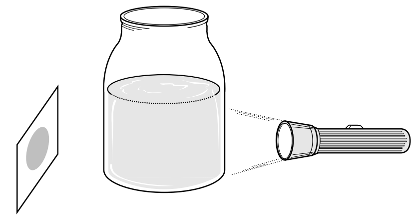
When you shine the flashlight through the plain water, the light on the piece of paper is white. When you shine the flashlight through the cloudy water, the light on the piece of paper is orangish-red. The cloudy water will appear bluish when viewed from the sides where the light is not entering or leaving the jar. This activity demonstrates why the sun appears red at sunset and sunrise. When the sun sets or rises, its light passes through more of the atmosphere than when it is high in the sky at midday. The light from the sun is scattered as it bounces off particles in the air. Blue and green light are scattered more than orange and red light; therefore, the color of light that makes it through the atmosphere (or cloudy water) is orangish-red.

Try It!

- ★ Try holding different colors of transparencies in front of the light beam.
- ★ Try shining the light from the top of the jar and observing the light that passes through the bottom of the jar.
- ★ Try using more or less paint.
- ★ Try using milk instead of latex paint.
- ★ Try using a different size jar.
- ★ Try coloring the cloudy water with food coloring.

Name Date

SIMULATING A SENSATIONAL SUNSET



What You Want to Know

Why does the sun appear orangish-red at sunset and sunrise?

What You Think Will Happen

When the light from a flashlight passes through plain water, it will appear

a. bluish. **b.** whitish. **c.** yellowish. **d.** reddish.

When the light from a flashlight passes through cloudy water, it will appear

a. bluish. **b.** whitish. **c.** yellowish. **d.** reddish.

What Happened

What color was the light from the flashlight after passing through the plain water?

____

What color was the light from the flashlight after passing through the cloudy water?

____

What color did you see when you looked at the sides of the jar where the light was not entering or leaving the jar?

____

What It Means

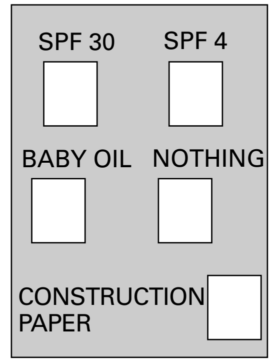
What do your observations tell you about why the sun appears orangish-red at sunset and sunrise?

____

Pollution in the air scatters light from the sun. Explain why the sun might appear redder at sunset than at sunrise due to pollution in the air.

____

SUNSCREEN STUDY



Science Sunscreen lotions are used to protect our skin from the sun's rays.

Stuff Plastic wrap; tape; dark construction paper; 2 kinds of sunscreen; vegetable oil or baby oil

What to Do

1. Cut five 2-inch squares of plastic wrap. Tape the plastic wrap to the construction paper just at the corners of the wrap.
2. Put a drop of sunscreen lotion on one of the squares, and gently rub it around to evenly cover the square. Write the SPF (sun protection factor) of the sunscreen below the square.
3. Repeat step 2 on another square of plastic wrap, using a different sunscreen.
4. Repeat step 2 using baby oil or vegetable oil. Remember to label the square.
5. Place a piece of construction paper over one of the squares. The fifth square should have nothing on it. Label both of these squares.
6. Place the construction paper in the sunlight either outside or next to a window for at least 2 hours. If you place the paper outside, put it on a flat surface, and secure it with rocks at each corner.
7. After 2 hours, remove the plastic wrap and discard it. Compare the squares, and try to order them from least-faded to most-faded.

What's Going On Here

Just as the sun's rays cause your skin to tan or burn, they also cause dark construction paper to fade. Sunscreen helps protect against skin cancer by shielding the skin from the sun's damaging rays. The SPF is a standardized measurement of a sunscreen's ability to protect the skin and prevent sunburn. If, on a particular day, you would normally burn in 10 minutes, using a sunscreen with an SPF of 4 would protect you from sunburn for 40 minutes (SPF of 4×10 minutes). Using sunscreen with an SPF of 15 would protect you from sunburn for 150 minutes, and so on. In this activity, the sunscreen was protecting the paper from fading. A larger SPF should have protected the paper more, so the paper should have faded less. Before sun lotions were popular, vegetable oil and baby oil were used. They did not have chemicals that block the sun's damaging rays. Of course, the best protection from the sun is clothing, as can be seen by looking at the construction paper that was completely covered.

Try It!

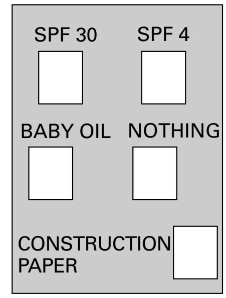
★ Try comparing different brands of sunscreen with the same SPF.

★ Try the activity at different times of the day using the same kind of sunscreen on all the squares.

★ Try varying the amount of time that the construction paper is exposed, using the same kind of sunscreen. Cut the construction paper into 6 sections. Place all 6 in the sun at the same time, and then remove 1 piece every 30 minutes over the course of 3 hours.

Name   Date

SUNSCREEN STUDY



What You Want to Know

What SPF (skin protection factor) level in a sunscreen protects the skin from sunburn the best?

What You Think Will Happen

Small squares of construction paper will be covered with various sunscreens, oil, paper, and nothing and then exposed to the sun for 2 hours. List the squares in the order you expect, from least faded to most faded.

______________________________ (Least faded—most protection)

____

____

____

______________________________ (Most faded—least protection)

What Happened

List the samples in order from least faded to most faded.

______________________________ (Least faded—most protection)

____

____

____

______________________________ (Most faded—least protection)

What It Means

Which of the tested materials would you use to protect your skin? Why?

At the store, you see two sunscreen lotions, one with an SPF 12 and one with an SPF 25. Which provides longer protection from a sunburn? Explain.

HOW HIGH?

Science The length of an object's shadow can be used to determine the object's height.

Stuff 2 pencils
Yardstick (not a meter stick)

What to Do

This activity will work only outside on a sunny day.

1. Push one pencil into the ground to serve as a marker. Hold the yardstick perpendicular to the ground at this marker.
2. While holding the yardstick perpendicular to the ground, have a partner push the other pencil into the ground at the *end* of the shadow of the yardstick.
3. Measure the distance between the 2 pencils in inches. Remove the pencils from the ground.
4. Find a tall object whose height you would like to measure. Push a pencil into the ground at the end of the object's shadow.
5. Measure the distance from the bottom of the object to the pencil, in inches.
6. Repeat steps 4 and 5 for four other objects.

What's Going On Here

There is a simple relationship between the length of the shadow of the yardstick and the height of any other object:

$$\frac{\textbf{Length of yardstick}}{\textbf{Length of yardstick's shadow}} = \frac{\textbf{Height of object}}{\textbf{Length of object's shadow}}$$

If all the measurements are made in inches, the length of the object can be found using the above equation and a little algebra:

$$\textbf{Height of object} = \frac{\textbf{36} \times \textbf{Length of object's shadow}}{\textbf{Length of yardstick's shadow}}$$

Divide the answer by 12 to get the height of the object in feet.

Try It!

- ★ Try measuring the height of objects at some other time during the day.
- ★ Try using a 12-inch ruler instead of a yardstick. How would you have to change the equation that you used?
- ★ If it is practical, measure the actual height of an object using a yardstick, and then compare that to the height you determined using shadows.

Name Date

HOW HIGH?

What You Want to Know

How can you find the height of very tall objects, like trees?

What You Think Will Happen

List the five objects whose height you will find by comparing the shadow length of the object to the shadow length of a yardstick. Then predict how high you think each object is in feet.

Object	Predicted height (in feet)
1	
2	
3	
4	
5	

What Happened

Record the lengths of the shadows of the yardstick and each of the objects. Use the following equation to find the height of the object in inches:

$$\text{Height of object} = \frac{36 \times \text{Length of object's shadow}}{\text{Length of yardstick's shadow}}$$

Divide the height of the object (in inches) by 12 to get the height of the object in feet. Record this number in the last column.

Object	Length of shadow (in inches)	Height of object (in inches)	Height of object (in feet)
Yardstick			
1			
2			
3			
4			
5			

What It Means

Do you think this method of finding height could be used any time of the day or any day of the year? Explain your answer.

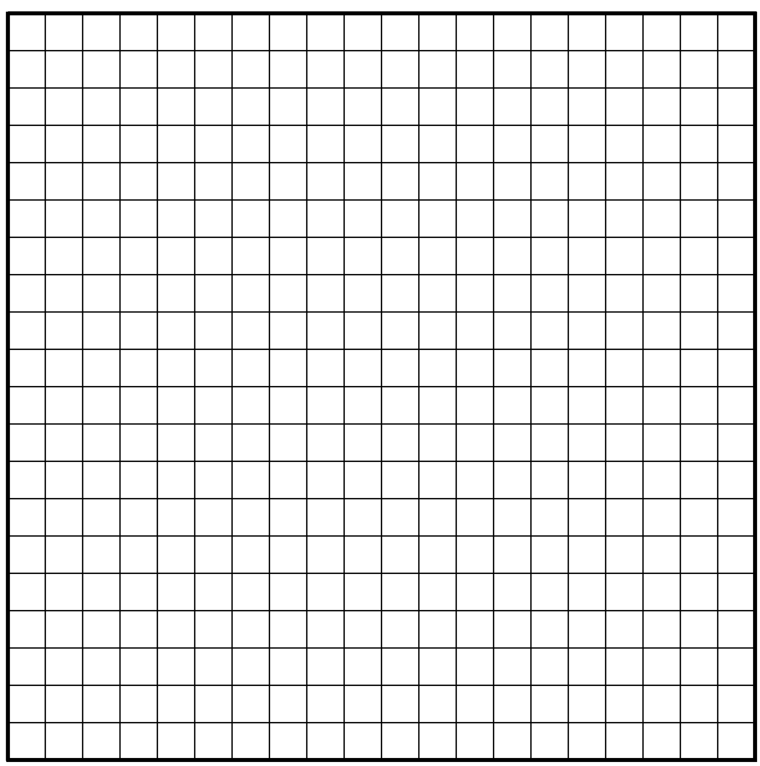
Graph It Next

Name Date

HOW HIGH?

GRAPH IT!

1. Label the vertical axis "object height in inches." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. Your line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



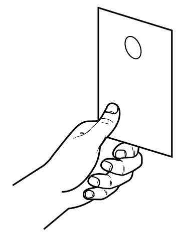
Shadow length in inches

What time of day do you think the line would be the most steep? What time of day would it be the least steep? Explain your answers.

LUNAR ILLUSION

Science The moon appears to be larger when it is rising or setting due to an optical illusion.

Stuff Calendar with moon phases; index card; sharp pencil; yardstick or meter stick



What to Do

Do not do this activity with the sun. Never look at the sun directly.

1. Look at a calendar that shows the phases of the moon to find when the next full moon will occur. Watch the nightly weather forecast to find out which night close to the full moon will be clear.
2. Punch a hole in the index card using the sharp end of a pencil. The diameter of the hole should be $\frac{1}{8}$ inch.
3. The full moon rises at sunset. About one hour after sunset, the full moon should be completely above the horizon. Take the card, the yardstick, and a partner outside at this time.
4. Record your observations about how big the moon appears and what color it is.
5. Hold the card with the punched hole out in front of you, and move it toward and away from your eye until you find a spot where the moon "just fits" inside the hole.
6. Have your partner measure the distance from the card to your eye, using the yardstick.
7. Repeat steps 4 through 6 one hour, two hours, three hours, and four hours later.

What's Going On Here

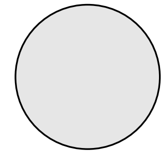
When the moon is rising or setting, it looks much larger than when it is overhead. The actual size of the moon doesn't change, and its distance from the earth stays the same. The reason the moon appears larger when rising or setting is because of perspective; things look smaller when they are farther away than when they are closer. For example, an airplane may look like a speck compared to a bird passing just over your head. The moon looks large on the horizon because you are comparing it to objects on the horizon, such as houses and trees. Your eyes play a trick on you by making you think that the moon is as close as the trees and houses. When the moon is overhead, you compare its size to the background of the stars, which you know to be very distant; you perceive the moon to be at a greater distance, too. When using the card with the hole punched in it to measure the size of the moon, you are measuring its angular diameter. You discovered that the angular diameter is the same when the moon is rising as when the moon is overhead. The sun also appears larger at sunrise and sunset than when it is overhead.

Try It!

★ Some scientists say that the lunar illusion disappears if you stand on your head when you look at the moon. What do you think? Ask several people why they think the moon looks larger when it is rising.

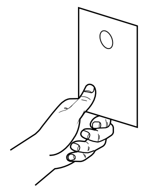
Name Date

LUNAR ILLUSION



What You Want to Know

Why does the moon look larger when it is rising or setting than when it is directly overhead? How can you measure whether the actual size of the moon is different at different times?



What You Think Will Happen

When you measure the size of the moon in the sky,

a. it will be larger when it is rising.

b. it will be larger several hours after rising.

c. it will be the same size when it is rising as it is several hours later.

What Happened

Record your observations about the apparent size and actual size of the moon shortly after the moon has risen, and again several hours later.

Time	Appearance of moon (size and color)	Distance of card from your eye

What It Means

What do your observations tell you about how the actual size of the moon changes from shortly after the moon rises to several hours after it rises?

____

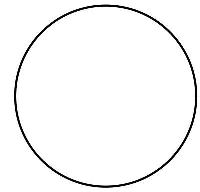
What do your observations tell you about how the apparent size of the moon changes from shortly after the moon rises to several hours after it rises?

____

Why do you think you got different answers to the above two questions?

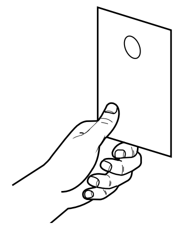
____

MOON MEASUREMENTS



Science The diameter of the moon can be determined without actually going there.

Stuff Index card; small hole punch or sharp pencil; large paper plate; masking tape; meter stick



What to Do

1. Punch a hole in the top of an index card using the sharpened end of a pencil or a small hole punch. The diameter of the hole should be about 0.3 centimeters.
2. Tape the plate on the wall of the room.
3. Stand at a distance of 50 centimeters from the paper plate.
4. Look through the hole in the index card at the paper plate, and move the card back and forth until the edges of the paper plate just match up with the edges of the hole. Have a partner measure the distance from your eye to the index card in centimeters.
5. Measure the diameter of the hole in the index card. Use the following formula to determine the diameter of the plate: **Diameter of plate = (distance to the plate) × (diameter of hole in index card) ÷ distance from index card to eye.**
6. Repeat steps 4 and 5 at distances of 100 centimeters, 150 centimeters, 200 centimeters, and 250 centimeters.
7. Determine the average diameter for the plate by adding the four diameters and dividing by four.
8. On a night when at least half of the moon is visible, use the index card with the punched hole to determine the diameter of the moon. If the moon is not full, make sure that the part of the moon you are looking at lines up with the edges of the hole in your card. The diameter of the moon can be determined using the formula: **(diameter of the moon in miles) = (240,000) × (diameter of hole in index card) ÷ distance from index card to eye.** The diameter of the hole and the distance from the index card to the eye must both be in the same units of measurement.

What's Going On Here

Many astronomical measurements are made indirectly. By using geometry and by knowing that the average distance to the moon is about 240,000 miles, you can determine the diameter of the moon (about 2160 miles) without ever leaving the earth.

A ratio is being used here: the ratio of the diameter of the moon to the distance to the moon is the same as the ratio of the diameter of the hole in the index card to the distance between your eye and the index card.

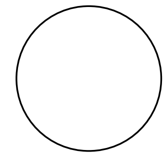
Try It!

★ Try measuring the diameter of moon at moonrise and moonset.

★ Try using this method to measure the height of a tree.

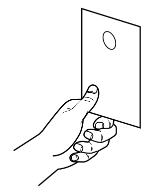
Name Date

MOON MEASUREMENTS



What You Want to Know

How can you measure the diameter of the moon without actually visiting the moon? What is the diameter of the moon?



What You Think Will Happen

You line up the edges of a hole in an index card with the edges of a paper plate hanging on a wall. As you move farther from the plate, the index card will be

a. closer to your eye.

b. farther from your eye.

c. about the same distance no matter where you stand.

The diameter of the moon is about ____________ miles.

What Happened

Record the distance that the index card was from your eye when lined up with the edges of the paper plate. Record the calculated diameter of the plate using the equation:

Distance to plate	Distance from index card to eye	Calculated diameter of plate
50 cm		
100 cm		
150 cm		
200 cm		
250 cm		
		Average:

Distance to moon	Distance from index card to eye	Calculated diameter of moon
240,000 miles		

diameter of plate = (distance to the plate) × (diameter of hole in index card) ÷ distance from index card to eye

Add the four diameters you calculated, and divide by four to get the average.

What It Means

How does your average diameter of the plate compare to the actual diameter?

____

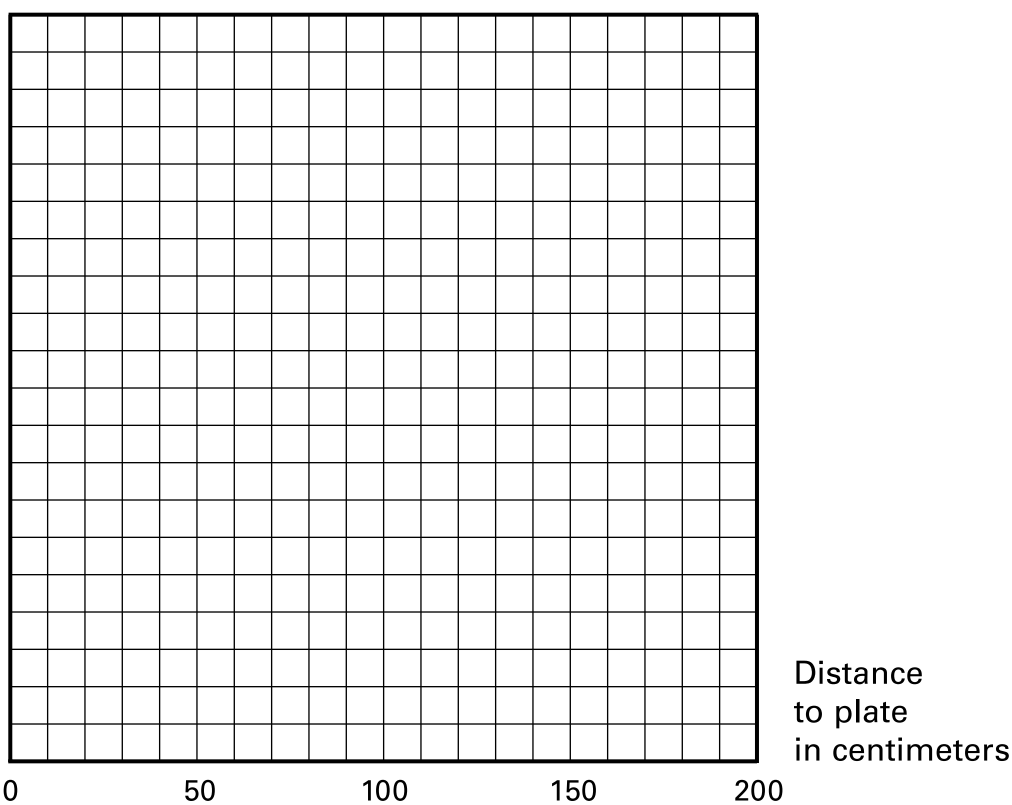
How does your calculated diameter of the moon compare to its actual diameter? ______________________________

Graph It Next

MOON MEASUREMENTS

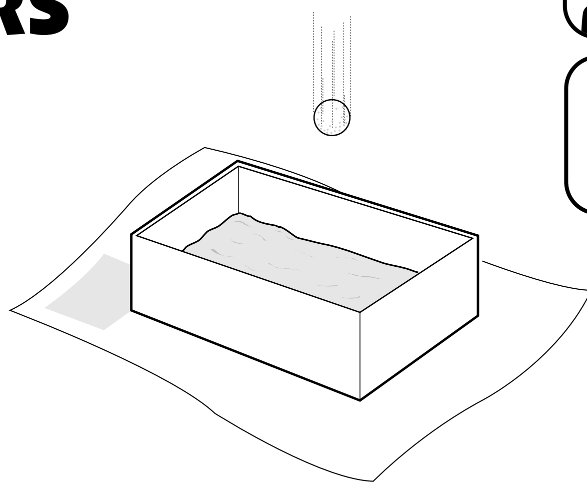
GRAPH IT!

1. Label the vertical axis "index card to eye in centimeters." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the first table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



What happens to the distance from the index card to your eye as the distance to the plate gets larger?

CREATING CRATERS



Science Craters on the moon are the result of large objects colliding with its surface.

Stuff Newspaper; baking pan or shoe box; flour; wooden craft stick; meter stick or ruler with centimeter marks; marble; golf ball; table tennis ball

What to Do

1. Open a sheet of newspaper, and lay it on the floor. Place a baking pan or shoe box in the middle of the opened newspaper.
2. Pour flour in the box to a depth of about two centimeters.
3. Use a wooden craft stick to make the surface of the flour smooth.
4. Hold the meter stick vertically so that it barely touches the surface of the flour. Hold the marble a few inches away from the meter stick at a height of 15 centimeters above the flour. Release the marble.
5. Remove the marble from the flour.
6. Measure the diameter of the hole that the marble makes in the flour right at the surface of the flour.
7. Repeat steps 3 through 6, dropping the marble from 30 centimeters, 45 centimeters, 60 centimeters, 75 centimeters, and 90 centimeters above the flour.
8. Repeat steps 3 through 6 using the golf ball and then the table tennis ball. Drop the balls from 90 centimeters.

What's Going On Here

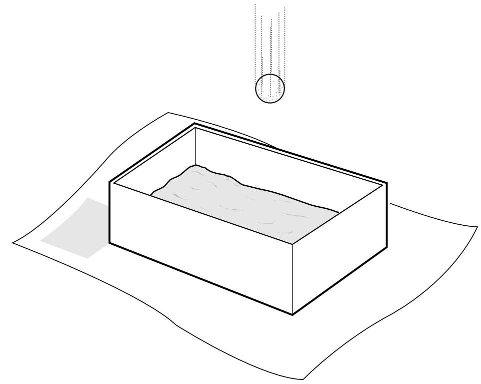
There are craters on our moon, on other planets, and on the earth itself. The craters on the moon range in size from tiny pits called *craterlets* to large basins called *walled plains.* Most craters were probably caused by high-speed meteorites (stony or metallic objects from space) crashing onto the moon. The marble you dropped into the flour represents a meteorite crashing onto the moon. When you dropped the marble from a greater height, it hit the flour at a higher speed and with more energy, causing a larger hole to be formed. The heavier golf ball had more energy and made a larger crater in the flour than did the lighter table tennis ball. Unlike the marble, golf ball, and table tennis ball, high-speed meteorites explode and scatter over a large area, leaving only a large hole behind.

Try It!

★ Try rolling the marble down a paper towel tube held at varying angles to the surface of the flour. You can use the astrolabe from "Angles and Astrolabes" to measure the angle.

Name Date

CREATING CRATERS



What You Want to Know

How does the height from which you drop a marble into a box of flour affect the size of the hole the marble makes? Does the mass of an object affect the size of the hole?

What You Think Will Happen

When you drop a marble into a box of flour, the hole it makes will be

a. larger when it is dropped from a higher spot.

b. smaller when it is dropped from a higher spot.

c. the same size when it is dropped from a higher spot.

When you drop a heavier object into the flour, the hole it makes will be

a. smaller than when you drop a lighter object.

b. the same size as when you drop a lighter object.

c. larger than when you drop a lighter object.

What Happened

Record the diameter of the hole in the flour when the marble was dropped from different heights.

Height	Diameter of hole
15 cm	
30 cm	
45 cm	
75 cm	
90 cm	

Record the diameter of the hole in the flour when the golf ball and table tennis ball were dropped in the flour.

Object dropped	Diameter of hole
Golf ball	
Table tennis ball	

What It Means

What do your observations tell you about how the height from which the marble is dropped changes the size of the hole it makes in the flour?

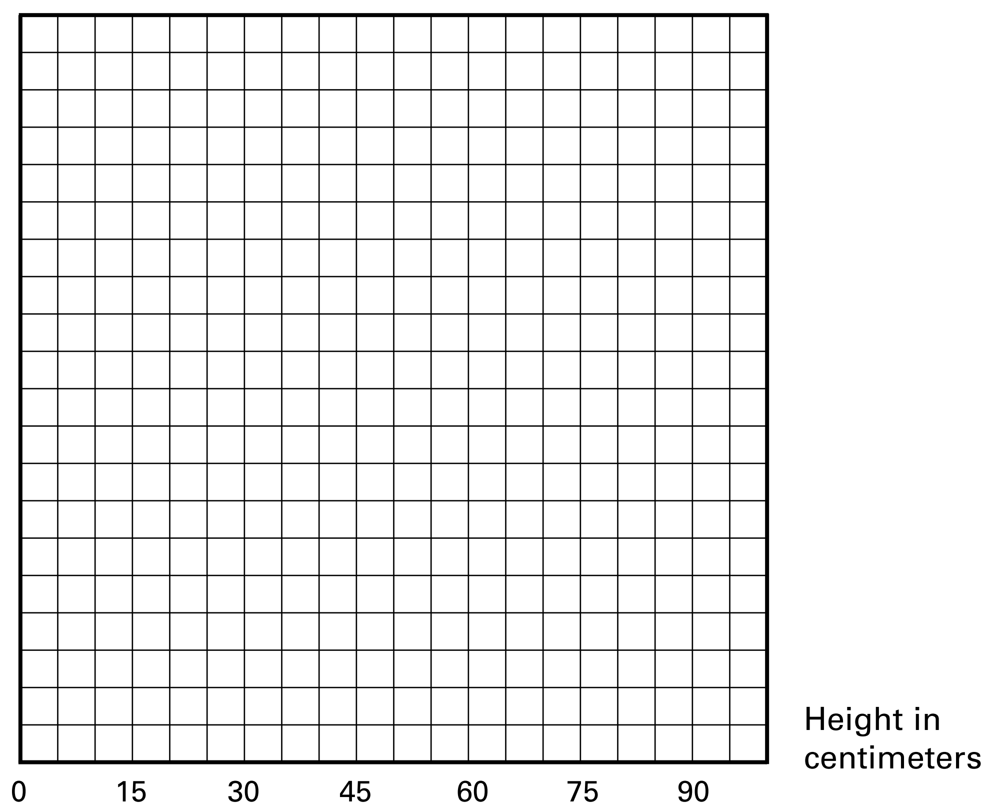
What do your observations tell you about how the mass of the object you drop changes the size of the hole it makes in the flour?

Graph It Next

CREATING CRATERS

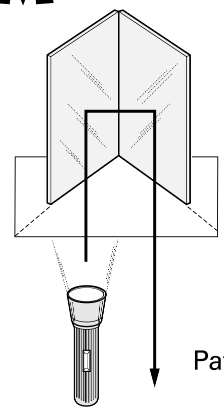
GRAPH IT!

1. Label the vertical axis "diameter in centimeters." Pick a convenient scale and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the first table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



What would the diameter of the hole be if the marble were dropped from a height of 100 centimeters?

BOUNCING-BACK BEAM



Science Light is reflected from a corner reflector parallel to the direction that it hit the reflector.

Stuff Tape; 2 mirrors; protractor; white paper; ruler; scissors; black construction paper or tagboard; flashlight

What to Do

1. Tape two mirrors together along one edge, putting the tape on the unshiny side of the mirrors.
2. Stand the open mirrors upright on the piece of white paper so that the angle between the shiny sides is 90°. On the piece of white paper, carefully draw lines along where the mirrors touch the paper.
3. Cut a circle out of a piece of black construction paper or tagboard that will fit over the lighted end of your flashlight. Cut a vertical slit about $\frac{1}{4}$ inch wide in the middle of the cardboard. The length of the slit should be slightly less than the diameter of the cardboard circle. Tape the circle on the flashlight.
4. Set the flashlight on the piece of paper eight inches away from the mirror. The slit should be vertical.
5. Turn the flashlight on, and shine it toward one of the mirrors. Notice how the beam is reflected.
6. On the piece of white paper, carefully draw lines that trace the path of the beam striking one mirror and the path of the beam reflecting from the other mirror.
7. Move the flashlight to change the angle that light hits the first mirror. Repeat step 6.

What's Going On Here

Light from a corner reflector is reflected parallel to the direction that it strikes the mirror. Light obeys the law of reflection: the angle coming in is equal to the angle reflected. When the angle between the two mirrors is 90°, geometry guarantees that the light reflected from the second mirror will be parallel to the direction that light hit the first mirror. In other words, if you are standing behind the flashlight, the light from the two mirrors is reflected back at you. Apollo astronauts placed a corner reflector on the moon so that scientists could measure the distance to the moon. A laser beam was aimed at the reflector from the earth, and the time that it took to come back to the earth was used to determine the distance to the moon. If the scientists had used a single flat mirror, the laser beam would have been reflected out into space, and the chances of it being sent back to the source of the light would be practically zero.

Try It!

★ Try bouncing a ball off the corner of a wall by rolling it along the floor toward one wall.

Name Date

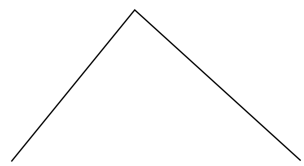
BOUNCING-BACK BEAM

What You Want to Know

What happens to a beam of light that is reflected off of two mirrors that are touching at a 90° angle?

What You Think Will Happen

Two mirrors are touching at a 90° angle. A beam of light is aimed at one of the mirrors. Draw the path that you think the reflected beam will take.



What Happened

Draw the path that the beam of light followed when you aimed it at one of the mirrors. Draw the path the beam followed when you changed the angle that light struck the first mirror.

What It Means

What do your observations tell you about how light is reflected from two mirrors that are touching at 90°?

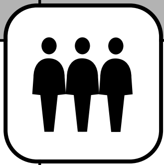
____

Can you think of a way to use two mirrors like these?

____

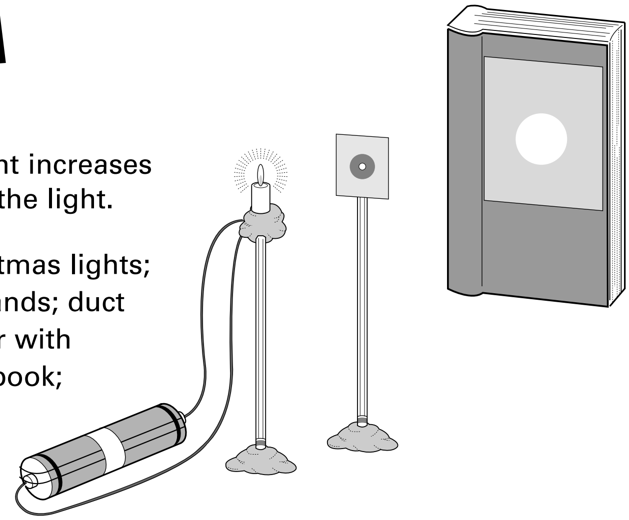
____

BIGGER BEAM



Science The size of a beam of light increases as you move away from the light.

Stuff String of miniature Christmas lights; 2 C batteries; 2 rubber bands; duct tape; clay; 2 pencils; ruler with centimeter marks; large book; scissors; cardboard; aluminum foil



What to Do

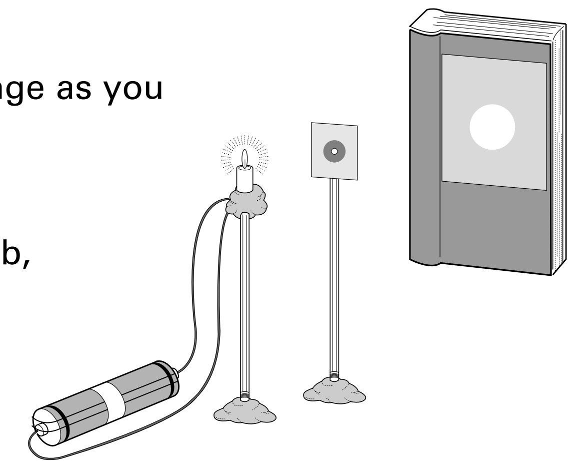
1. From a string of Christmas lights, remove one lightbulb and about six inches of wire on each side. Strip about one inch of insulation from each end of the wire.
2. Line up two batteries so that the positive terminal of one is touching the negative terminal of the other. Wrap two rubber bands around the batteries the long way. Wrap a piece of duct tape around the batteries in the center, where the ends of the batteries meet.
3. Take one lightbulb, and slide the end of one wire under the rubber bands so that it touches one terminal of the battery. Slide the end of the other wire under the rubber bands so that it touches the other terminal. The lightbulb should light. If it doesn't, check your battery connections and the lightbulb.
4. Use a piece of clay to hold one of the pencils upright. Use a small piece of duct tape to attach the light to the top of the pencil. Use a few books to hold the batteries if the pencil is too long or the wires from the light are too short.
5. Cut a one-inch diameter circle out of a four-inch square piece of cardboard. Tape a small piece of aluminum foil over the circle. Punch a small hole in the aluminum foil using the sharpened end of a pencil. Tape the piece of cardboard to the second pencil so that the hole in the foil is above the eraser end of the pencil. Use a piece of clay to hold the pencil upright, and adjust the position of the pencil until the hole in the foil is at the same height as the light on the other pencil. Position the upright pencils about three centimeters apart.
6. Tape the edges of an eight-inch square piece of cardboard to the front of a book. This is the screen. The center of the screen should be at the same height as the light.
7. Darken the room. Place the screen two centimeters from the pencil with the foil. Use the ruler to measure the diameter of the circle of light on the screen.
8. Repeat step 7 with the screen at 4, 6, 8, 10, 12, 14, 16, 18, and 20 centimeters.

What's Going On Here

As the screen is moved away from the light source, the diameter of the beam becomes larger. If you go twice as far from the light, the diameter will be four times as large. As the beam gets larger, the light becomes less bright because the same amount of light energy is spread out over a larger area.

Name Date

BIGGER BEAM



What You Want to Know
How does the size of a beam of light change as you move away from it?

What You Think Will Happen
When you are twice as far from a lightbulb, the diameter of the beam will be

a. twice as big.

b. four times as big.

c. half as big.

d. a quarter as big.

e. the same size.

What Happened
Record the diameter of the beam at different distances.

Distance from lightbulb	Diameter of beam
2 cm	
4 cm	
6 cm	
8 cm	
10 cm	
12 cm	
14 cm	
16 cm	
18 cm	
20 cm	

What It Means
What do your observations tell you about how the size of a beam of light changes as you move away from it?

If you were twice as far from the lightbulb, how much would its size have changed? Explain your answer.

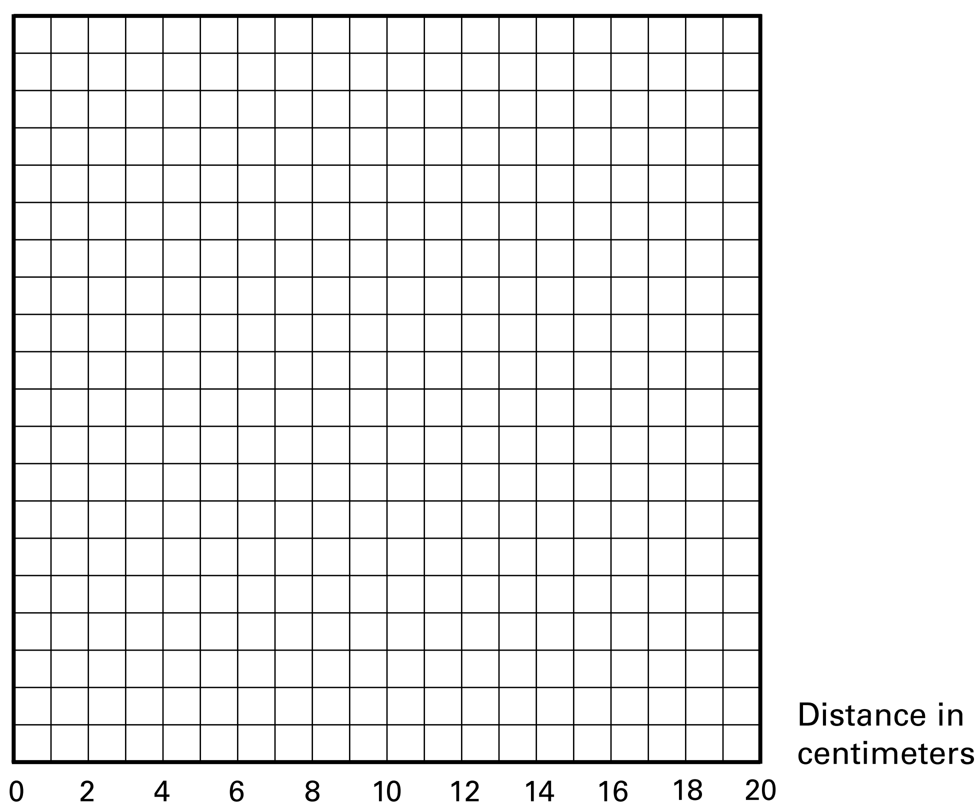
Graph It Next

Name Date

BIGGER BEAM

GRAPH IT!

1. Label the vertical axis “diameter in centimeters.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale you choose the same on the entire vertical axis.
2. Plot the data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

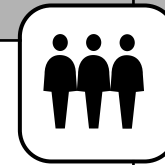


What does the graph show about how the size of a beam of light changes as you move away from it?

____

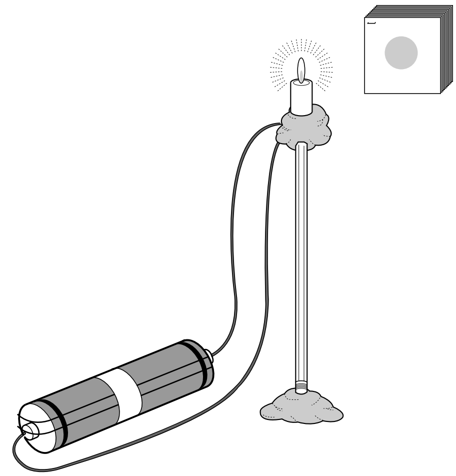
____

BRIGHT BULB



Science The brightness of a light decreases as you move away from the light.

Stuff Scissors; ruler with centimeter marks; white paper; stapler; string of miniature Christmas lights; 2 C batteries; 2 rubber bands; duct tape; clay; pencil



What to Do

1. Cut 12 pieces of white paper so that each is about 8-inches square. Stack the pieces together, and staple them at one edge. This will be your brightness tester.
2. From a string of Christmas lights, remove one light bulb and about six inches of wire on each side. Strip about one inch of insulation from each end of the wire.
3. Line up two batteries so that the positive terminal of one is touching the negative terminal of the other. Wrap two rubber bands around the batteries the long way. Wrap a piece of duct tape around the batteries in the center, where the ends of the batteries meet.
4. Take one lightbulb, and slide the end of one wire under the rubber bands so that it touches one terminal of the battery. Slide the end of the other wire under the rubber bands so that it touches the other terminal. The lightbulb should light. If it doesn't, check your battery connections and the lightbulb.
5. Use a piece of clay to hold one of the pencils upright. Use a small piece of duct tape to attach the light to the top of the pencil. You may need something to hold the batteries if the pencil is too long or the wires from the light are too short. A few books will work.
6. Darken the room. Hold the brightness tester five centimeters from the bulb, and see how many pieces of paper the bulb shines through.
7. Repeat step 6 at 10, 15, 20, 25, 30, 35, 40, 45, and 50 centimeters.

What's Going On Here

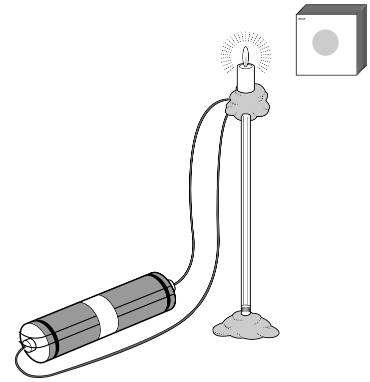
The brightness of a light can be determined by measuring how many pieces of paper the light can pass through; the more pieces of paper it can pass through, the brighter it is. As you move away from a source of light, the brightness decreases. If you go twice as far from the light, the brightness will be one-fourth of what it was. If you go three times as far, the brightness will be one-ninth as much. Move closer and the brightness increases. Go half the distance closer to the light, and the brightness will be four times what it was. Scientists use information about how the brightness of light to determine the distance to stars.

Try It!

★ Try using only one battery.

Name Date

BRIGHT BULB



What You Want to Know
How does the brightness of a lightbulb change as you move away from it?

What You Think Will Happen
When you are twice as far from a lightbulb, it will be

a. twice as bright.
b. four times as bright.
c. half as bright.
d. a quarter as bright.
e. the same brightness.

What Happened
Record the brightness of the light measured in the number of pieces of paper through which it shines.

Distance from lightbulb	Brightness of bulb— pieces of paper
5 cm	
10 cm	
15 cm	
20 cm	
25 cm	
30 cm	
35 cm	
40 cm	
45 cm	
50 cm	

What It Means
What do your observations tell you about how the brightness of a lightbulb changes as you move away from it?

____

If you were twice as far from the lightbulb, how much would its brightness have changed? Explain your answer.

____

Could scientists find out how bright a star is by doing something like you just did? How?

____

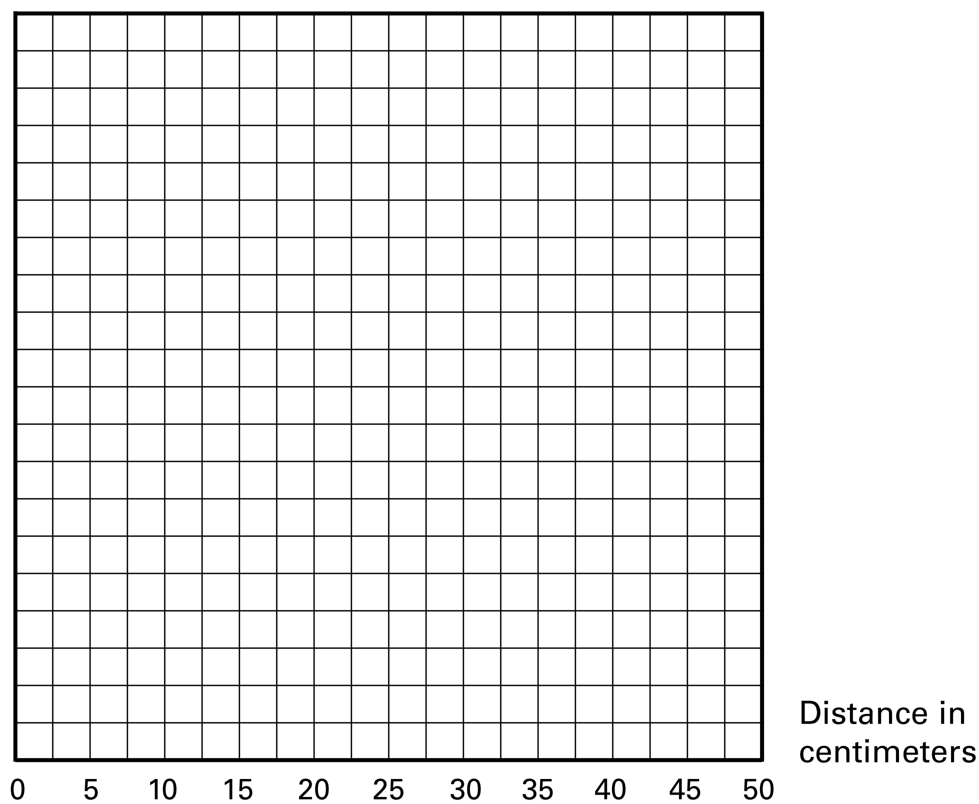
Graph It Next

Name Date

BRIGHT BULB

GRAPH IT!

1. Label the vertical axis "brightness of bulb in pieces of paper." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



What does the graph show about how the brightness of the bulb changes as you move away from the bulb?

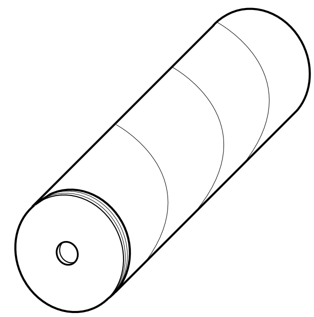
____

____

SPECTACULAR SPECTROSCOPE

Science A spectroscope is a scientific instrument that is used to study the colors of light coming from stars.

Stuff Knife; 2 film-container lids; marker; thin cardboard (6 inches square); tape; diffraction grating (available from science supply catalogs or museums); self-adhesive paper (such as Con-Tac); glue; lamp with 60-watt bulb; overhead transparencies or plastic report covers in various colors



What to Do

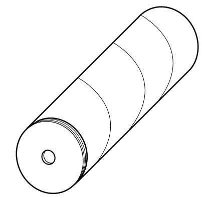
1. Drill or cut a $\frac{1}{4}$-inch hole in one of the film-container lids. Cut a slit that measures $\frac{1}{16}$ inch x one inch in the other lid.
2. Roll the cardboard into a tube that will fit into the groove of the film lid. Secure the tube with tape.
3. Tape the diffraction grating to the inside of the film lid with the hole, making sure that the tape doesn't cover the diffraction grating showing through the hole.
4. Carefully cover the outside of the tube with self-adhesive paper.
5. Place a few drops of glue in the groove of the lid with the slit. Put one end of the tube into the groove.
6. Place the other end of the tube into the groove of the lid with the grating. Don't glue it in place yet.
7. Look into the diffraction-grating end of the tube at the bulb. Rotate the tube so that the slit is vertical. Try to line the bulb up with the slit. You should see spectra (rainbows) on the inside of the tube on either side of the slit.
8. Hold the tube still and rotate the diffraction grating until the spectra on either side of the tube are horizontal. This will give you the best spectra. Glue the diffraction-grating end to the tube in this position.
9. Hold different transparencies or report covers in front of the slit, and look at the bulb.

What's Going On Here

The spectroscope disperses light into its various component wavelengths or colors. The spectroscope you made disperses light using a diffraction grating, a piece of plastic with parallel lines etched into it very close together. When a colored transparency is held in front of the lamp, the spectrum observed in the spectroscope changes, showing which wavelengths or colors are transmitted by the colored transparency. Spectroscopes are used to determine what gases are in stars. The light from stars comes from very hot gases; when this light is studied using a spectroscope, astronomers can tell which gases gave off the light.

Name Date

SPECTACULAR SPECTROSCOPE



What You Want to Know

How can you make a simple spectroscope, something you can look through to see the colors that light has in it? What colors of light pass through different color plastic sheets?

What You Think Will Happen

Different color plastic sheets are placed in front of a spectroscope so that you can see what colors of light pass through the sheets. What colors do you think you will be able to see through each plastic sheet?

Color of plastic sheet	Colors you will see in the spectroscope

What Happened

Describe what you saw when you looked at a light through your spectroscope.

____

Write the colors that you observed in the spectroscope for each plastic sheet.

Color of plastic sheet	Colors you saw in the spectroscope

What It Means

What do your observations tell you about which colors pass through different color plastic sheets?

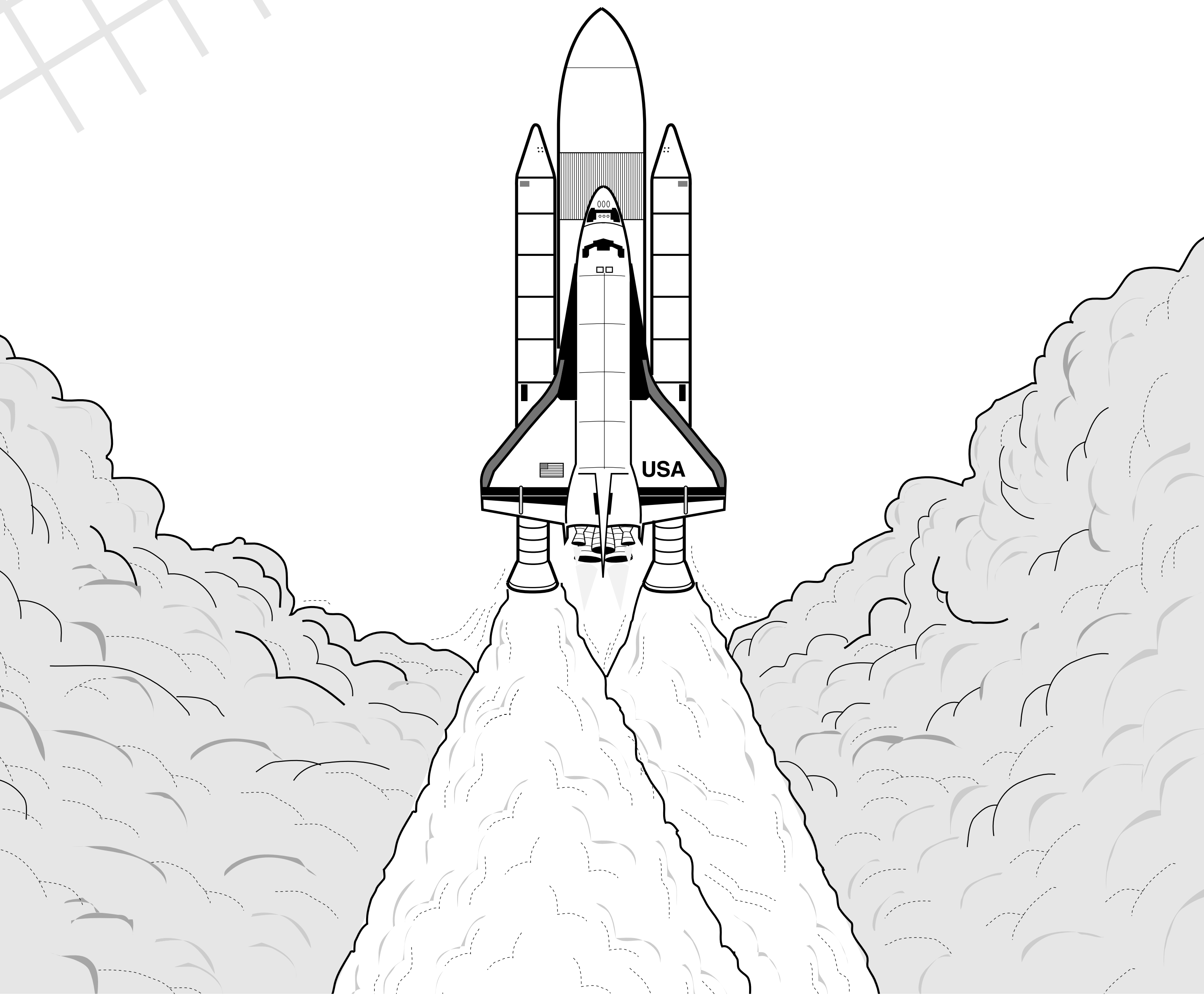
____

Hot gases cause the stars to give off light. Different kinds of gases give off different colors of light. How could a spectroscope be used to tell what gases are in certain stars?

____

CHAPTER

2 ENERGY



EXPERIENCING ENERGY

- *Potential energy* is stored energy. It can be changed to *kinetic energy,* or *energy of motion.* There are many different kinds of potential and kinetic energy, some of which are investigated in this chapter.

- The range of a projectile (horizontal distance it travels from the place it was launched) depends on the angle and the speed of the launch. At a given angle of launch, the greater the speed of projectile when it is launched, the greater the range. At a given speed, the range is greatest at a 45° launch angle. The range is the same for angles that add up to 90°, such as a 30° angle and a 60° angle.

- Potential energy can be changed to kinetic energy, and kinetic energy can be changed back to potential energy, but the total amount of energy *has* to stay the same. That's the law of conservation of energy.

- The higher an object is above the ground, the more potential energy it has at that point, and the more kinetic energy it will have just before it hits the ground when dropped.

- A pendulum is a good example of conservation of energy. As the pendulum swings back and forth, potential energy is constantly being changed to kinetic energy and vice versa. When the pendulum is at the top of its swing, its potential energy is greatest and the kinetic energy is momentarily zero. When the pendulum hits the low point of its swing, its kinetic energy is greatest and its potential energy is momentarily zero.

- Similarly, a vertically oscillating spring changes energy from kinetic to potential and back again. At the top and bottom of its oscillation, its potential energy is greatest; and at the middle, its kinetic energy is greatest.

- Most of the time, energy is associated with the mechanical forms discussed above, but light, heat, and sound are also forms of energy.

- *Heat energy* results from the motion of atoms and molecules. When an object is heated, molecules that make up the object move faster. When an object is cooled, the molecules move more slowly.

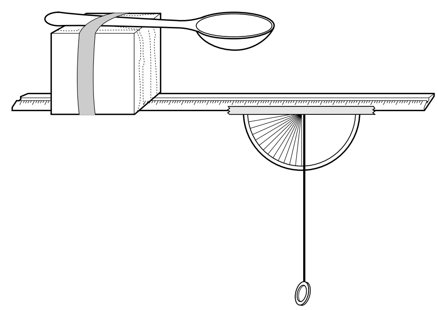
- *Light energy* results from the motion of electrons in the atom. Blue light has greater energy than red light, because blue light has a higher frequency than red light.

- *Sound energy* results from the vibrations of particles in matter. The faster the object vibrates, the higher the frequency, the higher the energy, and the higher the pitch of the sound.

CATAPULT CANNON

Science The range of an object launched from a catapult depends on the launch angle.

Stuff Wooden block (about 1 inch × 1 inch × 2 inches); ruler; masking tape or duct tape; plastic spoon; marker; astrolabe from “Angles and Astrolabes”; paper; meter stick



What to Do

1. Place the block of wood on the flat side of one end of the ruler. Tape the spoon handle to the block, wrapping the tape around the block and the ruler. You have just made a catapult.
2. Place a mark on the bowl of the spoon, close to the middle.
3. Tape the straw of the astrolabe to the bottom flat side of the ruler. You may have to shorten the string on the astrolabe if the washer touches the floor.
4. Tear off a piece of paper about two-inches square, and roll it into a small ball.
5. Place the catapult on the floor so that the ruler is vertical. The reading on the astrolabe should be 90°.
6. Place the ball of paper on the mark on the spoon. Pull the top of the spoon back until it touches the ruler. Release the spoon.
7. Measure the distance from where the paper lands to where the catapult touches the floor. Repeat steps 6 and 7 twice.
8. Change the angle that the catapult makes with the floor, and repeat steps 6 and 7. Launch the paper ball three times at each angle.

What's Going On Here

The launch angle of a projectile determines the distance that it travels horizontally as well as vertically. The horizontal distance traveled is called the *range.* The range is greatest when the launch angle is 45°. The range will be the same for angles that add up to 90°. For example, launch angles of 60° and 30° will have the same range.

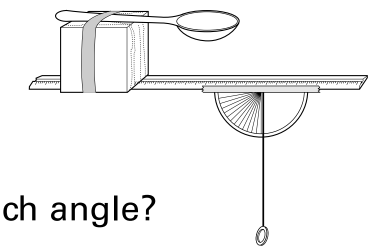
Try It!

★ Try measuring the height the paper ball travels at different launch angles.

★ Try placing the top end of the catapult against a wall and the bottom edge on the floor. Change the angle of launch by sliding the top end of the catapult up and down the wall.

Name Date

CATAPULT CANNON



What You Want to Know

How does the distance traveled by a paper ball launched from a catapult depend on the launch angle?

What You Think Will Happen

The paper ball launched from the catapult will travel the greatest distance horizontally when it is launched at an angle of

a. 90°. **b.** 0°. **c.** 45°. **d.** 30° or 60°.

What Happened

Record the launch angle and the *range,* or distance that the paper ball traveled horizontally. For each launch angle, add the three range numbers, and then divide by three to get the average range. Record the average range in the third column.

Launch angle	Range			Average range
0°				
15°				
30°				
45°				
60°				
75°				
90°				

What It Means

What do your observations tell you about which launch angle has the greatest range?

____

Are there any pairs of launch angles that have about the same average range?

____

If you want to throw a baseball the greatest distance forward, what angle do you think you should throw it at, and why?

____

____

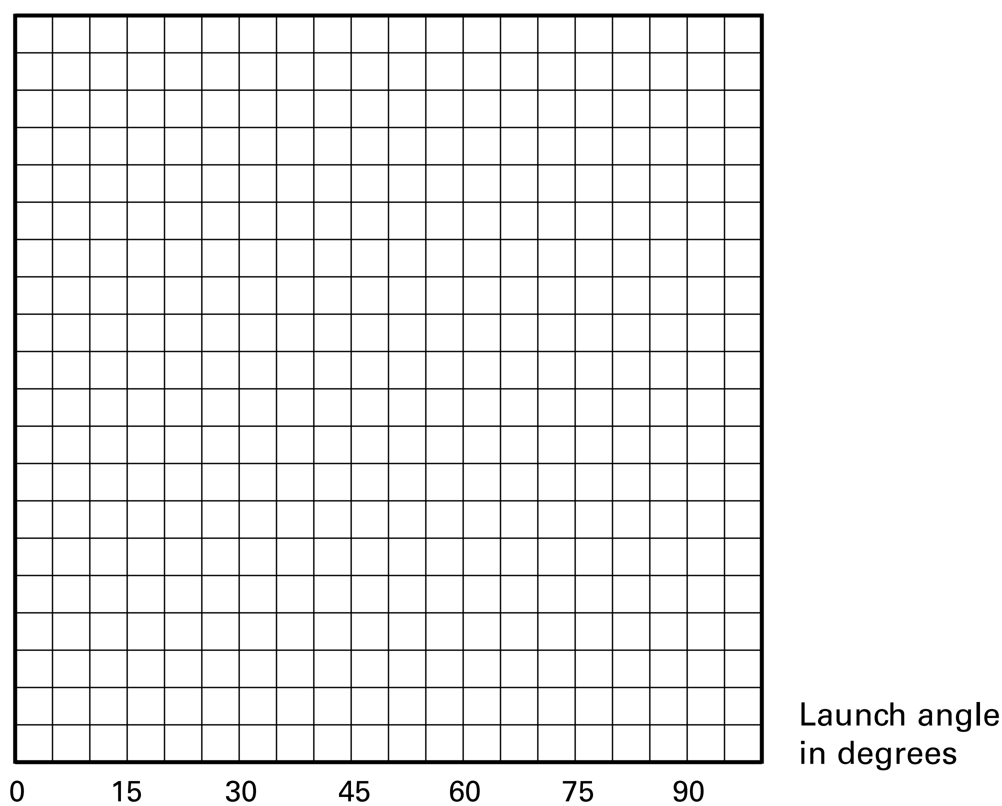
Graph It Next

Name Date

CATAPULT CANNON

GRAPH IT!

1. Label the vertical axis "average range in centimeters." Pick a convenient scale and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened." Use the average range values.
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

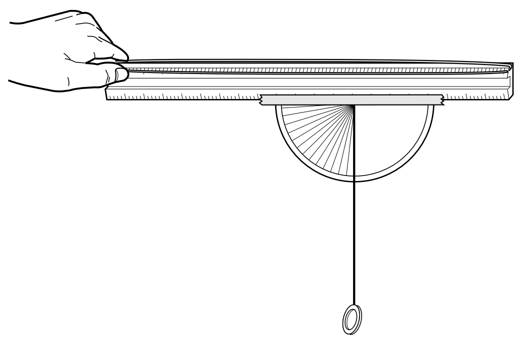


If you launched the paper ball at 35°, what do you think the range would be? Is there another angle that would have the same range? Explain.

RUBBER BAND BLAST

Science The range of a rubber band depends on its launch angle.

Stuff Tape; astrolabe from "Astrolabes and Angles"; ruler with centimeter marks; rubber band



What to Do

1. Tape the straw of the astrolabe to the edge of the ruler.
2. Hold the ruler away from your body at shoulder height so that it is horizontal and the astrolabe reads 0°.
3. Wrap the rubber band around the end of the ruler farthest from your body, and pull it back five centimeters. Look at the mark on the ruler to which the rubber band has been pulled back. Remember this location.
4. Release the rubber band.
5. Record the horizontal distance (the range) from where the rubber band landed to where you were standing when you launched it. Repeat this step twice.
6. Change the angle that the ruler makes with the floor; repeat steps 3, 4, and 5. Launch the rubber band three times at each angle. Make sure that you hold the ruler at shoulder height and that you pull the rubber band back the same distance each time.

What's Going On Here

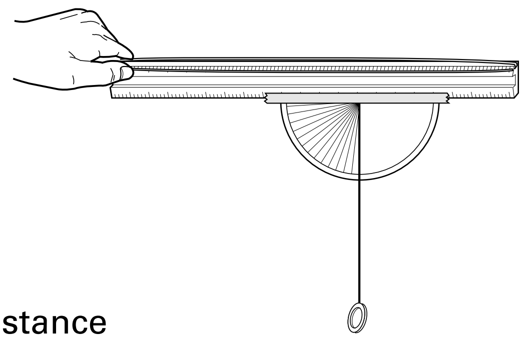
The launch angle of the rubber band determines the distance that it travels horizontally (the range) as well as vertically. The range is greatest when the launch angle is 45°. The range will be the same for angles that add up to 90°. For example, launch angles of 60° and 30° will have the same range.

Try It!

- ★ Try different sizes of rubber bands.
- ★ Place a target on the floor, and try to hit it with the rubber band by changing the launch angle.

Name Date

RUBBER BAND BLAST



What You Want to Know

How does the distance a rubber band travels depend on the launch angle?

What You Think Will Happen

The rubber band will travel the greatest distance horizontally when it is launched at an angle of

a. 90°. **b.** 0°. **c.** 45°. **d.** 30° or 60°.

What Happened

Record the launch angle and the distance that the rubber band traveled horizontally (the *range*). For each launch angle, add the three range numbers, and then divide by three to get the average range. Record the average range in the third column.

Launch angle	Range			Average range
0°				
15°				
30°				
45°				
60°				
75°				
90°				

What It Means

What do your observations tell you about which launch angle has the greatest range?

Are there any pairs of launch angles that have about the same average range?

If you want to spray water with a hose, at what angle do you think you should spray the water to have it go the farthest horizontal distance?

Graph It Next

Name Date

RUBBER BAND BLAST

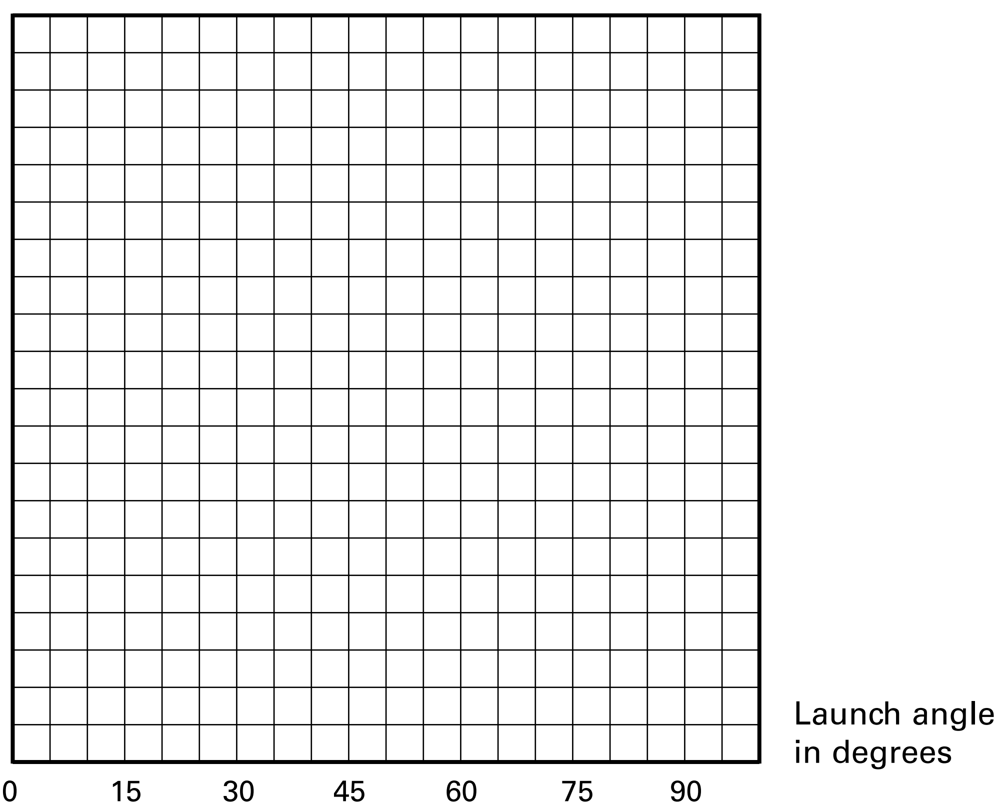
GRAPH IT!

1. Label the vertical axis “average range in centimeters.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the data from the table in “What Happened.” Use the average range values.

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.

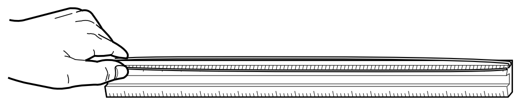


What does your graph show about how the range changes as the angle of launch increases?

____

RUBBER BAND BARRAGE

Science The range of a rubber band depends upon how far the rubber band is stretched.



Stuff Ruler with centimeter marks; rubber band

What to Do

1. Hold the ruler out away from your body at shoulder height so that it is horizontal.
2. Wrap the rubber band around the end of the ruler farthest from your body, and pull it back to the nearest centimeter mark on the ruler after it has begun to stretch.
3. Release the rubber band.
4. Record the horizontal distance (the range) that the rubber band traveled from where it landed on the floor to where you were standing when you launched it. Repeat this step twice.
5. Repeat steps 2 to 4 at one-centimeter intervals until you reach the end of the ruler.

What's Going On Here

When you pull the rubber band back, you are doing work on it; the work that you do is stored in the rubber band as elastic potential energy. When you release the rubber band, the potential energy is changed to kinetic energy, the energy of motion. The rubber band moves a distance (the range). The farther back you pull the rubber band, the more work you do on it, and the more potential energy is stored in it; therefore, it has more kinetic energy on its release and travels farther. If you place a small target in front of the rubber band, you knock it over. The kinetic energy of the moving rubber band is able to do work on the target, providing a force to knock it over. There is a lot of physics involved in this simple science activity.

Try It!

- ★ Try different sizes of rubber bands.
- ★ Place a target on the floor, and try to hit it with the rubber band.
- ★ Try the activity at a different launch angle.

Name Date

RUBBER BAND BARRAGE

What You Want to Know

How does the distance that a rubber band travels depend on how far back it is pulled before it is launched?

What You Think Will Happen

As you pull the rubber band farther back before releasing it, it will travel a farther horizontal distance

a. each time.

b. up to a certain point; after that point it will travel the same distance each time.

c. up to a certain point; after that point it will travel a shorter distance each time.

What Happened

For each distance that the rubber band was pulled back (stretched distance), record the distance that the rubber band traveled horizontally (the *range*). For stretched distance, add the three range numbers, and then divide by three to get the average range. Record the average range in the third column.

Stretched distance	Range			Average range
1 cm				
2 cm				
3 cm				
4 cm				
5 cm				
6 cm				

What It Means

What do your observations tell you about how the range of a rubber band depends on how far it is pulled back before it is fired?

If you were to do this activity again, what would you change? What would you keep the same?

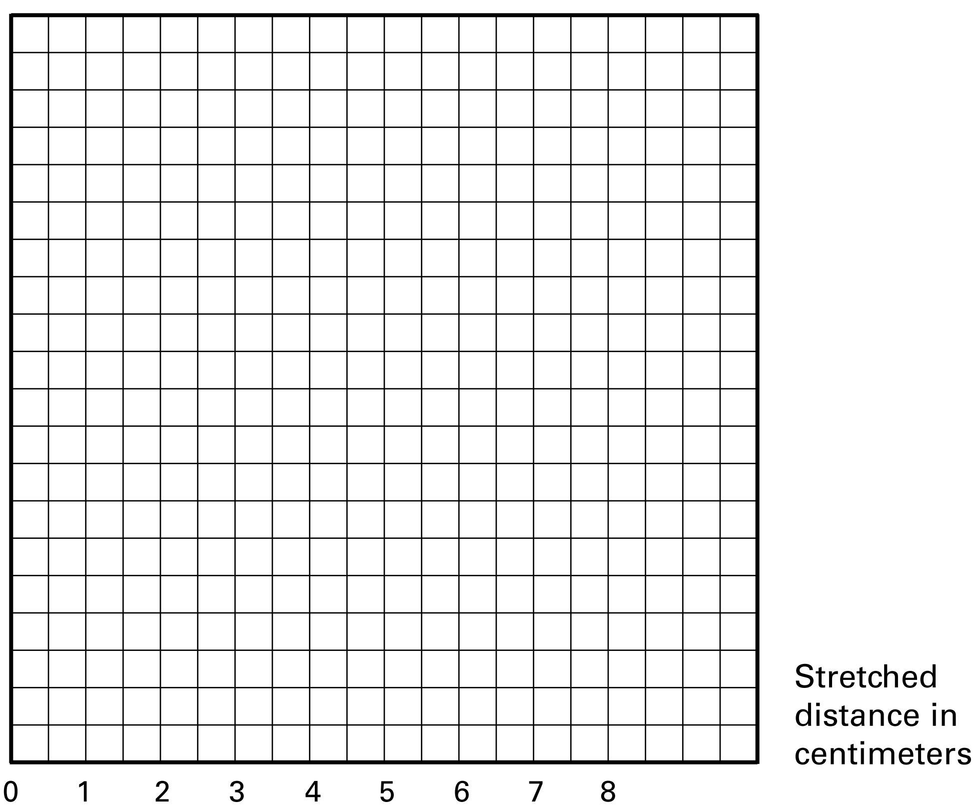
Graph It Next

Name Date

RUBBER BAND BARRAGE

GRAPH IT!

1. Label the vertical axis “average range in centimeters.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in “What Happened.” Use the average range values.
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



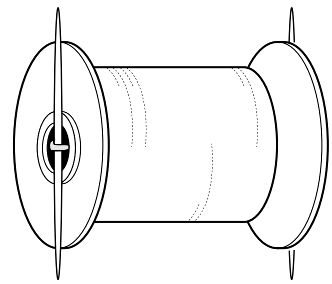
What does your graph show about how the range changes when the stretched distance is increased?

____

SPEEDY SPOOL

Science Potential energy can be changed to kinetic energy.

Stuff 2 toothpicks; rubber band (a little longer than the spool); empty spool; masking tape; washer (smaller than spool diameter); ruler with centimeter marks



What to Do

1. Put one toothpick through one loop of the rubber band.
2. Insert the rubber band into the hole in the spool. Tape the toothpick flat across the bottom of the spool, making sure that it is centered with equal amounts protruding.
3. Put the washer on the top of the spool, so that the hole in the washer lines up with the hole in the spool.
4. Use the second toothpick to reach through the washer into the spool to grab the free loop of the rubber band. Pull the loop of the rubber band out of the spool, and place the toothpick through the loop.
5. Adjust the second toothpick on the top of the spool, so that equal amounts of the toothpick are protruding on each side of the spool. Do **not** tape the toothpick.
6. Place a small piece of tape on the floor. This is your starting line.
7. Hold the spool with one hand, and wind the unattached toothpick with the index finger of your other hand. Wind the rubber band three complete turns.
8. Place the spool on the starting line, and let it go.
9. Measure the distance the spool travels on the floor.
10. Repeat steps 7 through 9, using 6, 9, 12, 15, and 18 complete turns of the unattached toothpick. If possible, try even more turns.

What's Going On Here

When you wind the rubber band, you are doing work on it by moving your index finger around. The work you do on the rubber band is stored in the rubber band as potential energy. When you let the spool go on the floor, the potential energy is changed to kinetic energy, the energy of motion.

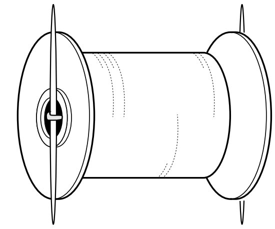
Friction between the spool and the floor slows the spool down. Some of the kinetic energy of the spool is changed to heat energy (produced by the friction). There may also be some kinetic energy that is changed to sound energy; listen for it as the spool moves.

Try It!

- ★ Try a larger or smaller spool.
- ★ Try longer or shorter toothpicks.

Name Date

SPEEDY SPOOL



What You Want to Know

How far will a spool that is powered by a rubber band travel on the floor?

What You Think Will Happen

How far do you think the spool will travel when you wind the toothpick three turns?

____

How far do you think the spool will travel when you wind the toothpick 15 turns?

____

What Happened

Record the distance that the spool traveled for each number of toothpick turns.

Toothpick turns	Distance traveled
3	
6	
9	
12	
15	
18	

What It Means

In this activity, potential energy in the wound-up rubber band is changed to kinetic energy when the spool rolls across the floor. Where do you think the potential energy in the rubber band came from?

____

If you could redesign the spool, what changes would you make so that it would roll even farther?

____

____

Graph It Next

Name Date

SPEEDY SPOOL

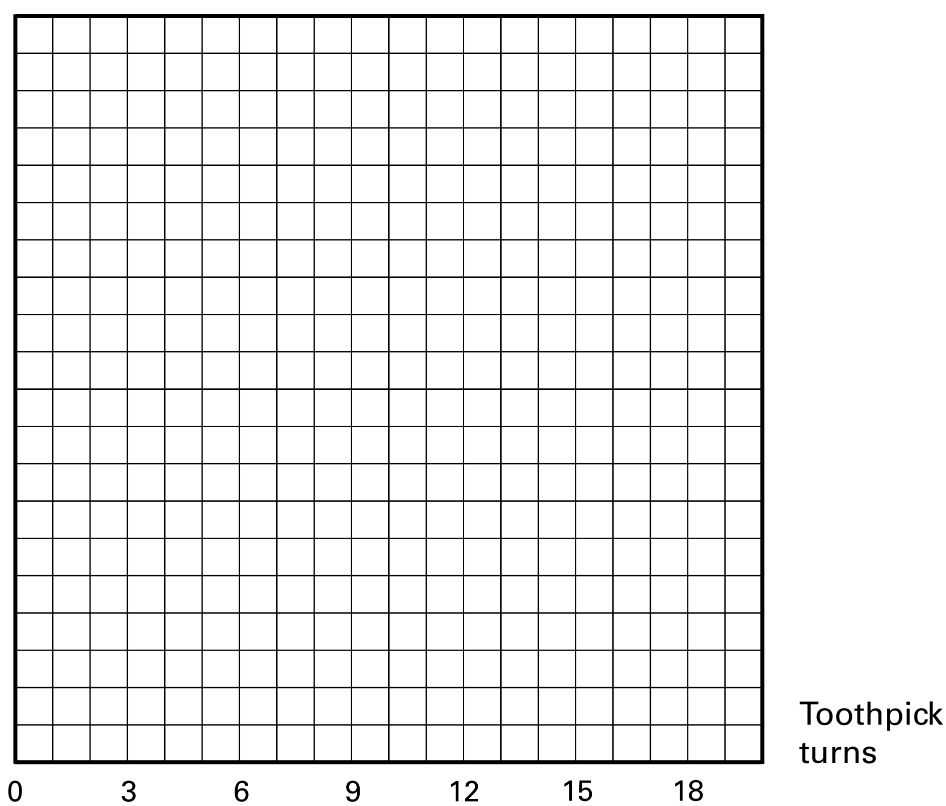
GRAPH IT!

1. Label the vertical axis "distance traveled in inches." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the data from the table in "What Happened."

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.

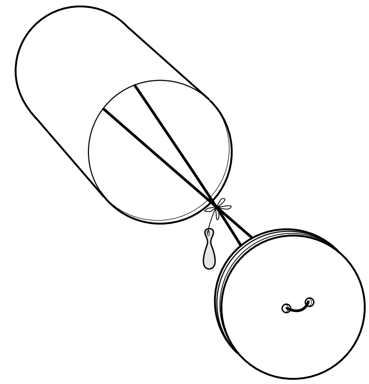


How far would the spool travel with 20 toothpick turns? Explain your answer using the graph.

____

____

CHANGING-COURSE CAN



Science Potential energy in a rubber band can be changed into kinetic energy, and vice versa.

Stuff Nail and hammer; small can with plastic lid; 2 rubber bands (each about the length of the can); string; small fishing weight or several washers

What to Do

1. Use the hammer and nail to punch two holes $\frac{1}{2}$ inch apart in the middle of both the bottom of the can and the lid.
2. Thread one rubber band through the two holes in the bottom of the can, leaving the ends of the rubber band inside the can. Thread the other rubber band through the lid the same way.
3. Use a piece of string to tie all four loops of the rubber bands together in the middle of the can.
4. Use another piece of string to tie the fishing weight to the place where the rubber bands are connected. Allow the fishing weight to hang down from the string by about an inch.
5. Place the top on the can. The rubber bands should pull the lid tightly onto the can. If the rubber band is loose, tighten it by sliding rolled-up paper under the rubber band outside of the can on the bottom.
6. Roll the can gently on the floor. If the fishing weight is dragging on the side of the can, remove the lid, and shorten the string attaching the weight to the rubber bands.
7. Roll the can gently across the floor. When it appear to come to a stop, coax it back to you by calling, "Here can, here can." The can should respond. Count the number of times the can reverses direction before it stops completely.

What's Going On Here

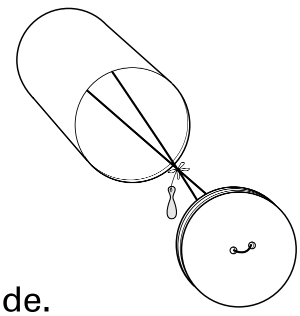
The changing-course can is an excellent example of energy changing from potential to kinetic and back again. When you roll the can across the floor, it has kinetic energy due to its motion. As the can rolls across the floor, the rubber bands twist inside the can as the kinetic energy of the rolling can is changed to potential energy in the rubber bands. As the potential energy increases, the kinetic energy decreases until the can completely stops. Then the potential energy changes to kinetic energy as the rubber bands unwind, and the can begins to roll in the opposite direction. This changing of kinetic energy to potential energy and then back to kinetic energy continues until the forces of friction between the can and the floor cause the can to stop completely.

Try It!

- ★ Try other sizes of cans.
- ★ Try tighter or looser rubber bands. Then try more or less weight hanging from the rubber bands.

Name Date

CHANGING-COURSE CAN



What You Want to Know

How can you make a can that will change direction when rolled across the floor?

What You Think Will Happen

Draw a picture of the inside of the can that you made.

When you roll the can across the floor, it will

a. continue to roll in a straight line.

b. come back and then stop right away.

c. come back and then roll away again.

What Happened

Describe the motion of the changing-course can when you rolled it across the floor.

____

____

Did the can change directions? If so, how many times did it change?

____

What It Means

Use the word *energy* to describe the motion of the can when you rolled it across the floor.

____

____

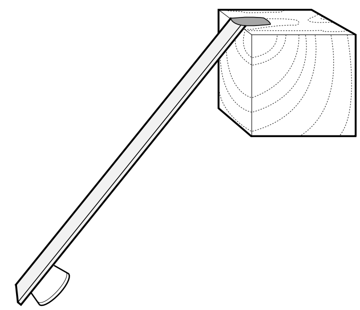
How would you redesign the can to make it change course even better?

____

PENNY PENDULUM

Science The farther back a pendulum is pulled, the more potential energy it has, and the more kinetic energy it will have at the bottom of its swing.

Stuff Duct tape; ruler or paint stick; small block of wood; scissors; small paper cup; penny; yardstick



What to Do

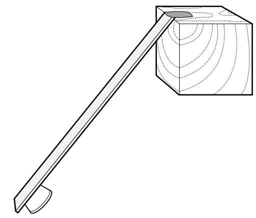
1. Tape the bottom of a ruler or paint stick to the top edge of a block. (If you have a table with a vertical edge along the top, you can tape the ruler directly to the table.) The ruler should be able to swing back freely, and when released it should swing until it hits the block of wood.
2. Cut the paper cup down so that it is about as high as the width of a penny.
3. Tape the paper cup to the bottom of the ruler so that the bottom of the cup is against the ruler.
4. Tape the block of wood to the top of a table, on the edge, so that when the ruler is pulled back and then released, the paper cup is below the top of table.
5. Test the pendulum by putting a penny, flat side down, in the cup. Holding the edge of the penny with your forefinger, pull the ruler back, and then release it. The ruler should stop when it hits the block, and the penny should fly out of the cup onto the floor.
6. Put a small piece of tape on the floor directly under the cup when it is in the stopped position.
7. Put the penny back in the cup. Pull the ruler back, and measure the distance from the bottom of the ruler to the floor using the yardstick. Release the ruler.
8. Measure the distance from the piece of tape you placed on the floor in step 6 to where the penny landed on the floor. If the penny rolls along the floor, do not measure the distance; instead repeat this step.
9. Repeat steps 7 and 8 five times, pulling the ruler back different amounts each time.

What's Going On Here

When you pull the ruler back, you are doing work against gravity: Gravity is pulling the ruler and cup downward, and you are pulling them upward. Because of the work that you have done on the ruler by moving it back, the ruler has potential energy and is able to do work. When you released the ruler, its potential energy was changed to kinetic energy, the energy of motion. At the bottom of its swing, the ruler had its greatest kinetic energy and its greatest speed. The ruler hit the block of wood and stopped. The penny kept moving due to *inertia*, the tendency of an object to keep moving once it is moving. The more kinetic energy the penny had, the greater its speed at the bottom of its swing and the farther it was able to travel before it hit the floor.

Name Date

PENNY PENDULUM



What You Want to Know

How does the amount that you pull a pendulum back affect how much speed it has at the bottom of its swing?

What You Think Will Happen

If you pull the pendulum farther back each time, it will have

a. more speed at the bottom of its swing.

b. less speed at the bottom of its swing.

c. the same speed at the bottom of its swing.

What Happened

Record the height of the pendulum from the floor and the distance that the penny traveled.

Height of pendulum	Distance penny traveled

At what part of its swing was the pendulum moving fastest?

____

What It Means

What do your observations tell you about how the amount that the pendulum was pulled back affects how far the penny will travel?

____

____

The faster an object is moving, the more kinetic energy it has. At what point in the ruler's swing did it have the greatest kinetic energy?

____

At which distance from the floor was the ruler's kinetic energy the greatest?

____

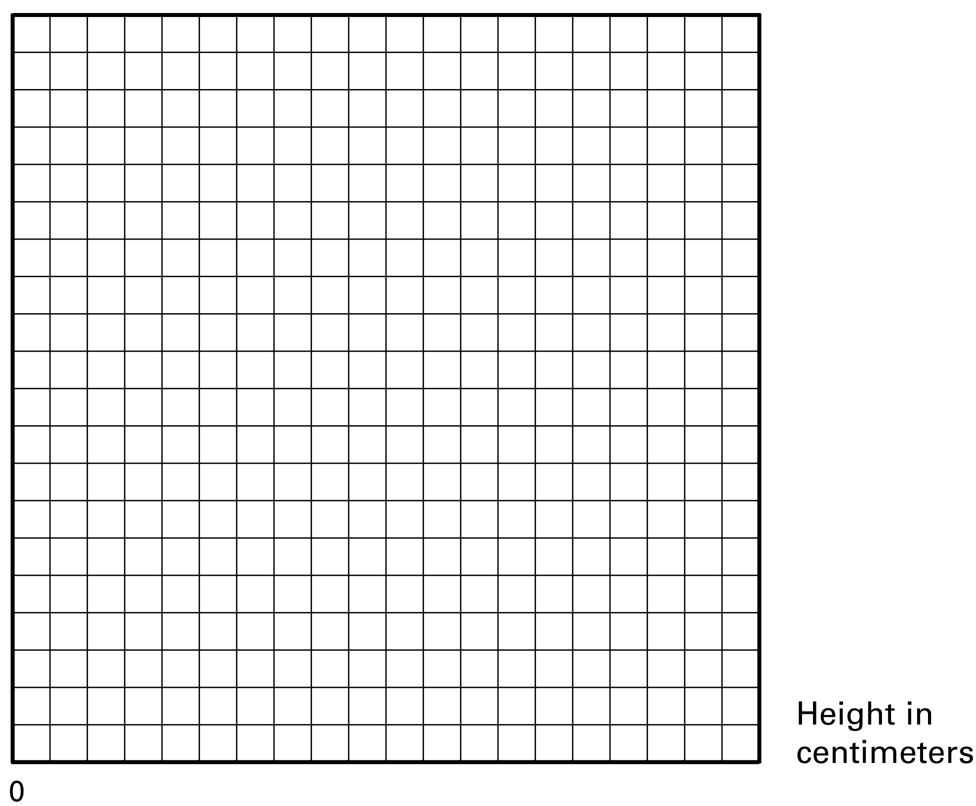
Graph It Next

Name Date

PENNY PENDULUM

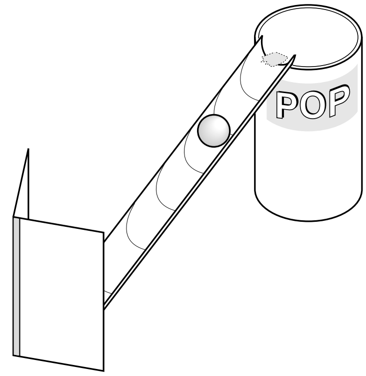
GRAPH IT!

1. Label the vertical axis "distance traveled in centimeters." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Put numbers on the horizontal axis, too.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



What does the graph show about how the height of the pendulum affects the distance that the penny will travel?

TUBE TARGET



Science The kinetic energy of an object rolling down a ramp depends on the height of the ramp.

Stuff Scissors; paper towel tube; marker; ruler with centimeter marks; marble; tape; pop can; two 3 inch × 5 inch index cards

What to Do

You will need a relatively flat surface to do this activity, such as a long table or the floor.

1. Cut the paper towel tube in half along the long edge to form a trough.
2. Make a mark in the trough about an inch from one end of the tube. This will be the starting line for the marble.
3. Tape the tube to the top of the pop can and to the table, so that the trough is clear and the tube is secure.
4. Fold both index cards in half along the short side, and tape them together to make a thicker card. Open the taped cards halfway to make a target. The target will resemble a greeting card.
5. Place the target almost touching the end of the tube, so that when the marble is rolled down the tube, it will hit the inside of the folded index cards and move them some distance.
6. Place the marble at the mark on the towel tube, and allow it to roll down the tube.
7. Measure the distance that the target moved from the end of the tube. Measure the height of the top of the tube from the table.
8. Move the top of the tube down about one centimeter, and repeat steps 6 and 7. Continue to move the tube down the side of the can until you reach the bottom.

What's Going On Here

The marble has potential energy at the top of the tube. As the marble rolls down the tube, the force of gravity increases it speed. The marble has kinetic energy due to its speed, and it is able to do work by moving the target at the bottom of the trough. The greater the height from which the marble is rolled, the more speed it has, and thus the more energy it has to do work on the target by moving it.

Try It!

- ★ Try using a longer tube, such as a wrapping paper tube.
- ★ Try using two pop cans taped together to get more height.
- ★ Try a larger or smaller marble or ball.

Name Date

TUBE TARGET

What You Want to Know

When a marble is rolled down a ramp, how does the height it is rolled from affect how far it can move a target at the bottom of the ramp?

What You Think Will Happen

A marble is rolled down a ramp and strikes a target at the bottom of the ramp, moving the target some distance. How does the height from which the marble is rolled affect the distance the target is moved?

a. If you roll the marble from a higher point, the target will move the same amount as from a lower point.

b. If you roll the marble from a higher point, the target will move less than it moves from a lower point.

c. If you roll the marble from a higher point, the target will move more than it does from a lower point.

What Happened

Record the distance that the target moved when the tube was at different heights.

Height of tube	Distance that target moved

What It Means

What do your observations tell you about how the height from which a marble rolls down a ramp affects the distance that it can move a target at the bottom of the ramp?

____

____

Graph It Next

Name Date

TUBE TARGET

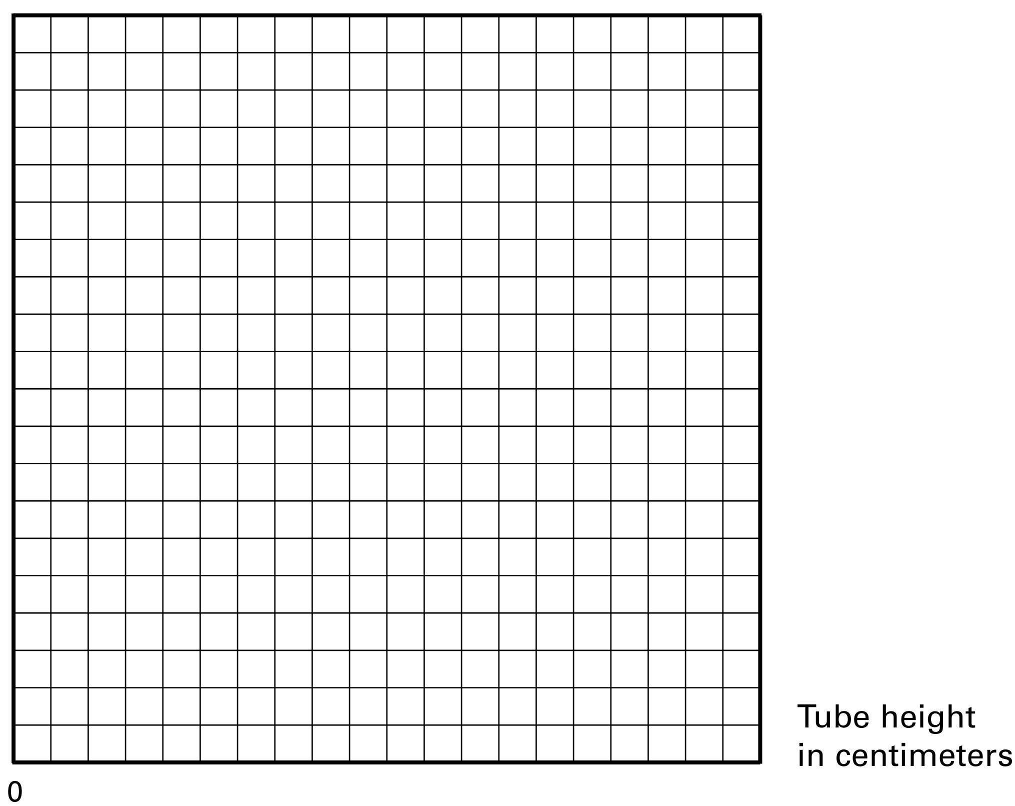
GRAPH IT!

1. Label the vertical axis “distance target moved in centimeters.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Put numbers on the horizontal axis, too.

2. Plot the data from the table in “What Happened.”

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.



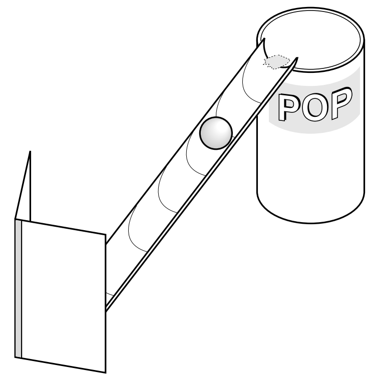
What factors beside tube height affect how far the target is moved?

____

____

TUBE TARGET TWO

Science The kinetic energy of an object rolling down a ramp depends on the forces that act on the object to increase or decrease its speed.



Stuff Scissors; paper towel tube; marker; ruler; marble; tape; pop can; two 3 inch × 5 inch index cards; smooth and rough surfaces, such as fabric, sandpaper, waxed paper, aluminum foil, crepe paper

What to Do

You will need a relatively flat surface to do this activity, such as a long table or the floor.

1. Cut the paper towel tube in half along the long edge to form a trough.
2. Make a mark in the trough about an inch from one end of the tube. This will be the starting line for the marble.
3. Tape the tube to the top of the pop can and to the table, so that the trough is clear and the tube is secure.
4. Fold both index cards in half along the short side and tape them together to make a thicker card. Open the taped cards halfway to make a target. The target will resemble a greeting card.
5. Place the target almost touching the end of the tube so that when the marble is rolled down the tube, it will hit the inside of the folded index cards and move them some distance.
6. Place the marble at the mark on the towel tube, and allow it to roll down the tube.
7. Measure the distance that the target moved from the end of the tube. Measure the height of the top of the tube from the table.
8. Line the bottom of the trough with one of the smooth or rough surfaces. Trim the excess material if necessary. Repeat steps 5, 6, and 7.
9. Try all the other surfaces, one at a time.

What's Going On Here

The marble has potential energy at the top of the tube. As the marble rolls down the tube, the force of gravity increases its speed. Friction between the marble and the surface that lines the tube opposes the force of gravity. Rough surfaces introduce more friction than smooth surfaces. The marble has kinetic energy due to its speed, and it is able to do work by moving the target at the bottom of the trough. The less friction the marble encounters as it rolls down the trough, the more speed it has at the bottom and thus the more energy it has to do work on the target by moving it.

TUBE TARGET TWO

What You Want to Know

When a marble is rolled down a ramp, how does the type of surface that it is rolling on affect how far it can move a target at the bottom of the ramp?

What You Think Will Happen

A marble is rolled down a ramp and strikes a target at the bottom of the ramp, moving the target some distance. The marble will move the target the farthest

a. on a rough surface.

b. on a smooth surface.

c. on any kind of surface (the target will always be moved the same distance).

What Happened

Record the distance that the target moved when the tube was lined with different materials.

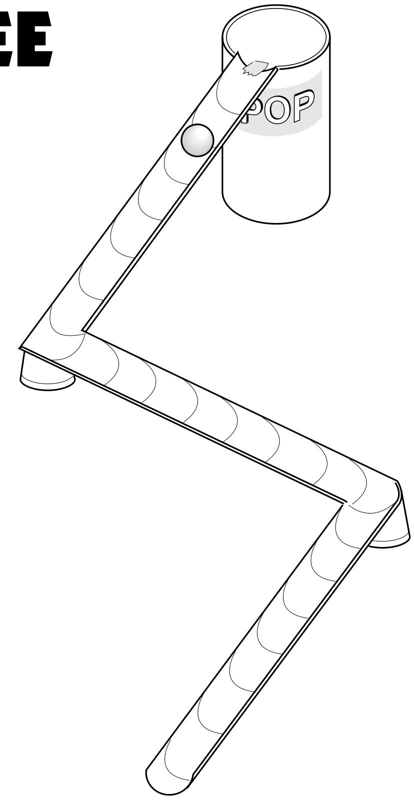
Material lining the tube	Distance that target moved
none	

What It Means

What do your observations tell you about how the surface of the tube affects how far the marble can move a target at the bottom of the tube?

What other material would you like to try for the tube's surface? How far do you think the marble would move the target with this material? Explain.

TUBE TARGET THREE



Science The energy of an object rolling down a ramp depends on the forces that act on the object to increase or decrease its speed.

Stuff 2 paper towel tubes; marble; pop can; scissors; 36 inches of masking tape; 12 inch squares each of fabric, waxed paper, and aluminum foil; 4 index cards; 4 small paper cups; stop watch or watch with a timer; marker

What to Do

This is an open-ended activity that allows students to experiment with what they observed and learned in the two previous activities.

1. Using only the materials in the above list, design a device that meets the following criteria:
   - **a.** The pop can must stand upright on the floor, and the marble must move from the top of the can to the floor, taking as much time as possible.
   - **b.** You may use all or some of the materials.
   - **c.** Time will start when the marble starts rolling, and time will stop when the marble stops moving, whether on the floor or somewhere on the way down.
   - **d.** You cannot touch the marble or move air toward it after you start it rolling.
2. Once you have designed, tested, and redesigned the device, time how long it takes for the marble to roll from the top of the can to the floor.

What's Going On Here

The marble has potential energy at the top of the tube. As the marble rolls down the tube, the force of gravity increases it speed. Friction between the marble and the surfaces that it rolls on or comes into contact with opposes the force of gravity. The marble has kinetic energy as it moves toward the floor. The more kinetic energy it has, the faster it moves. Since you want the kinetic energy to be small, you need to design the tube so that the potential energy the marble has at the top of the tube is changed to heat energy instead of kinetic energy of motion. You can do this by making sure that the marble encounters as much friction as possible, but not so much that it stops moving altogether.

TUBE TARGET THREE

What You Want to Know

What kind of device will make a marble take the greatest amount of time to travel from the top of a pop can to the floor?

What You Think Will Happen

Draw a sketch of your design in the space below. Identify all the materials you will be using.

What Happened

How long did it take the marble to travel from the top of the can to the floor?

____

Describe the motion of the marble as it moved down the ramp. When did it move slowest? When did it move fastest?

____

____

What It Means

What changes would you make to your design so that the marble could move even more slowly?

____

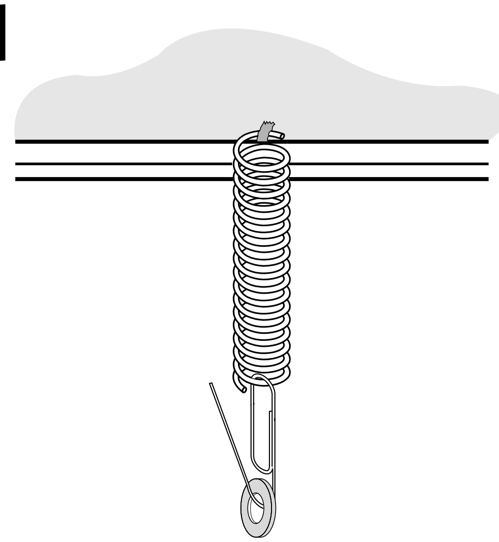
____

What other materials would you like to use in your design? How would the materials be used to make the marble move even more slowly?

____

____

SPRING STRETCH



Science A spring will stretch when mass is suspended from it. As more mass is added, the spring will stretch more.

Stuff Tape; several springs (available at hardware stores); large paper clip; ruler with centimeter marks; 6 large washers

What to Do

1. Tape one end of a spring to the side of a table so that the spring hangs freely.
2. Hang a large paper clip on the free end of the spring. Bend one free end of the paper clip slightly, so that washers can be hung from the paper clip.
3. With the ruler, measure the distance from the top of the spring to the bottom of the spring.
4. Place a washer on the paper clip, and measure the distance from the top of the spring to the bottom of the spring. Subtract the distance you got in step 3 from this distance to find the amount of "stretch."
5. Place one additional washer at a time on the paper clip, repeating step 4 each time, until all the washers have been used.
6. Repeat steps 1 through 5 using the other springs.

What's Going On Here

When mass is suspended from the spring, the force of gravity pulls the spring downward. A force in the spring, called the *restoring force,* pulls back on the mass. The force of gravity and the restoring force are equal in size and opposite in direction. The more mass suspended from the spring, the more the spring will be stretched. In fact, if you double the mass, you will double the amount that the spring is stretched. A stiffer spring will not stretch as much as a loose spring. A simple experiment like the one you just performed can be used to determine the "spring constant" of a spring, which gives an indication of how "stretchy" a spring is.

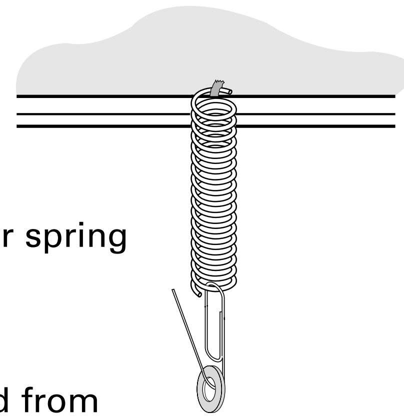
Try It!

★ Try hooking two or three springs together in a long chain.

★ Try hanging several springs of the same length side by side. Slide a pencil through the free ends so that they are joined together. Then suspend masses from a paper clip attached to the pencil. Which spring determines how much stretch occurs when mass is suspended from the group?

Name Date

SPRING STRETCH



What You Want to Know

How does the amount of mass attached to a spring affect how far it stretches? Will a stiffer spring stretch more or less than a looser spring?

What You Think Will Happen

If you double the amount of mass suspended from a spring

- **a.** the spring will stretch about twice as far.
- **b.** the spring will stretch about the same.
- **c.** the spring will stretch quite a bit less than twice as far.
- **d.** the spring will stretch quite a bit more than twice as far.

What Happened

For each spring you tested, record the amount of "stretch" of the spring when mass was suspended from it.

Number of washers	Amount of stretch		
	Spring #1	Spring #2	Spring #3
1			
2			
3			
4			
5			
6			

What It Means

What do your observations tell you about how the "stretch" changes when you double the mass that is suspended from the spring? Is this true for all the springs you tested?

____

____

Which of the springs seems to be the stiffest? Explain your answer.

____

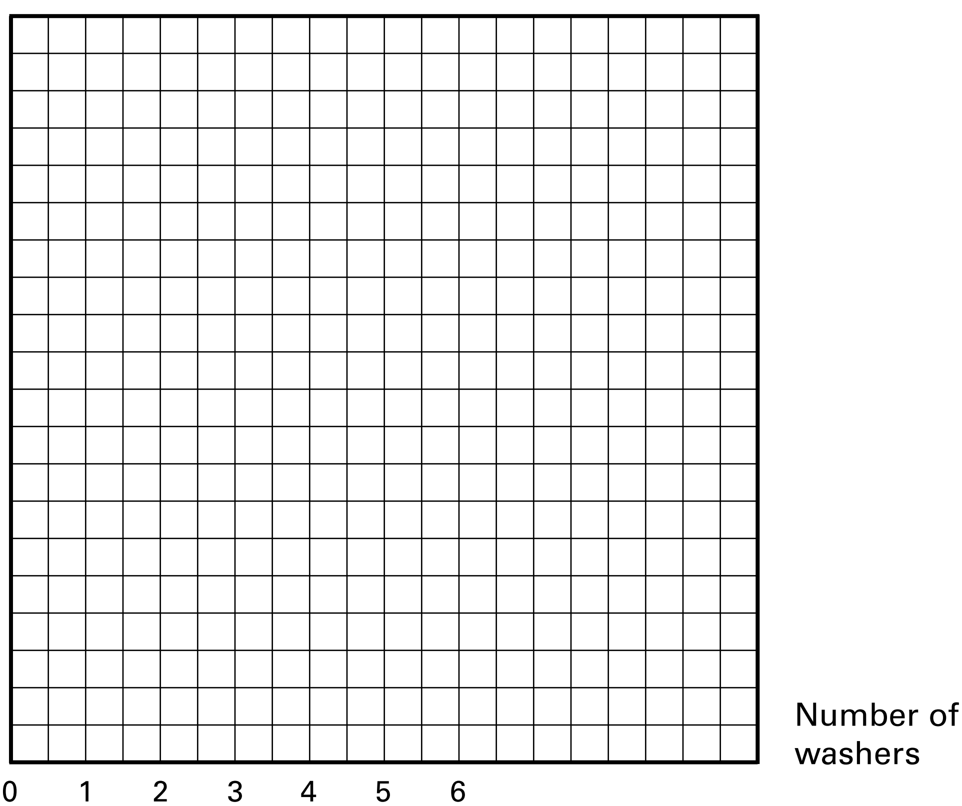
____

Graph It Next

Name Date

SPRING STRETCH
GRAPH IT!

1. Label the vertical axis "stretch in centimeters." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened." Use a different color for each spring.
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot. Label each line with the spring number.
4. Put a descriptive title at the top of your graph.

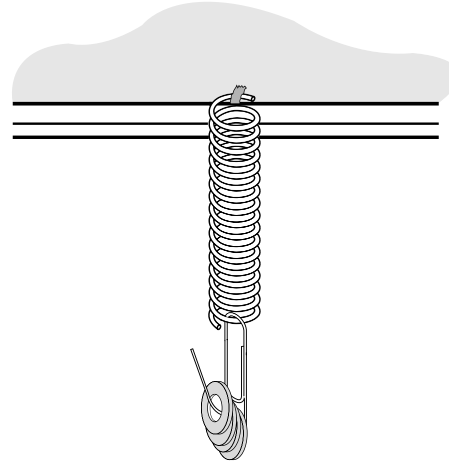


What does the graph show about which spring is the stiffest?

____

____

SPRING SWING



Science The time it takes for a mass suspended on a spring to swing up and down depends on the amount of mass and the stiffness of the spring.

Stuff Tape; 2 different springs; large paper clip; 6 large washers; stop watch or watch with a timer

What to Do

1. Tape one end of a spring to the side of a table, so that the spring hangs freely.
2. Hang a large paper clip on the free end of the spring. Bend one free end of the paper clip slightly, so that washers can be hung from the paper clip.
3. Place two washers on the paper clip. Bend the free end of the paper clip back in place, so that the washers do not slip off.
4. Pull the washers down a few inches, and let go. Time ten complete swings of the washers. (A complete swing is the motion of the washers starting from where you released them and ending at the same point.)
5. Place four washers on the paper clip, and time ten complete swings. Now try six washers. Try to pull the washers down the same distance each time before releasing them.
6. Repeat steps 1 through 5 using the other spring.

What's Going On Here

When you initially release the washers, the restoring force of the spring pulls them upward, increasing their speed. The washers have energy due to this speed and are able to use this energy to compress the spring. Potential energy in the compressed spring is changed to kinetic energy when the spring moves downward again. Gravity is a force that is constantly acting to pull the mass downward. The swinging back and forth of the mass on the end of the spring is an excellent example of how energy is changed from one kind (kinetic) to another kind (potential). The time it takes to complete a full swing back and forth depends on the mass on the end of the spring and the stiffness of the spring. If more mass is suspended from the spring, the time for a complete swing will be longer. In fact, the time will be doubled when the mass is four times the initial mass. A stiffer spring will take a shorter time to complete a swing.

Try It!

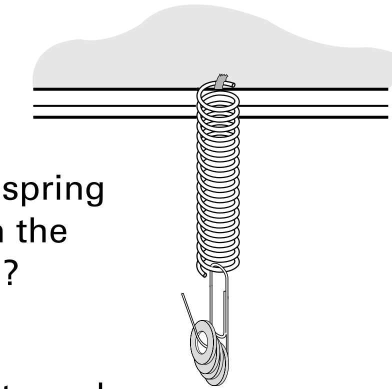
★ Try the activity with a chain of two or more springs.

★ Try to make a combination of springs and washers that will make one complete swing in one second.

★ Change how far down you pull the washers, and time 10 complete swings.

Name Date

SPRING SWING



What You Want to Know

Does the time it takes for the mass on the end of a spring to make a complete swing up and down depend on the mass? Does it depend on the stiffness of the spring?

What You Think Will Happen

If you put more mass on a spring, the time it takes to make one complete swing up and down

a. will be longer. **b.** will be shorter. **c.** will stay about the same.

Compared to a looser spring, the time it takes the mass on the end of a stiff spring to make one complete swing up and down

a. will be longer. **b.** will be shorter. **c.** will stay about the same.

What Happened

Record your observations in the tables. (To calculate the time for one swing, divide by the time it took for 10 swings.)

Spring #1

Number of washers	Time for 10 swings	Time for one swing
2		
4		
6		

Spring #2

Number of washers	Time for 10 swings	Time for one swing
2		
4		
6		

What It Means

What do your observations tell you about how the time it takes for the mass on the end of a spring to make one complete swing depends on the mass?

____

____

What effect does the stiffness of the spring have on the amount of time it takes for the mass to make one complete swing?

____

____

Graph It Next

Name Date

SPRING SWING

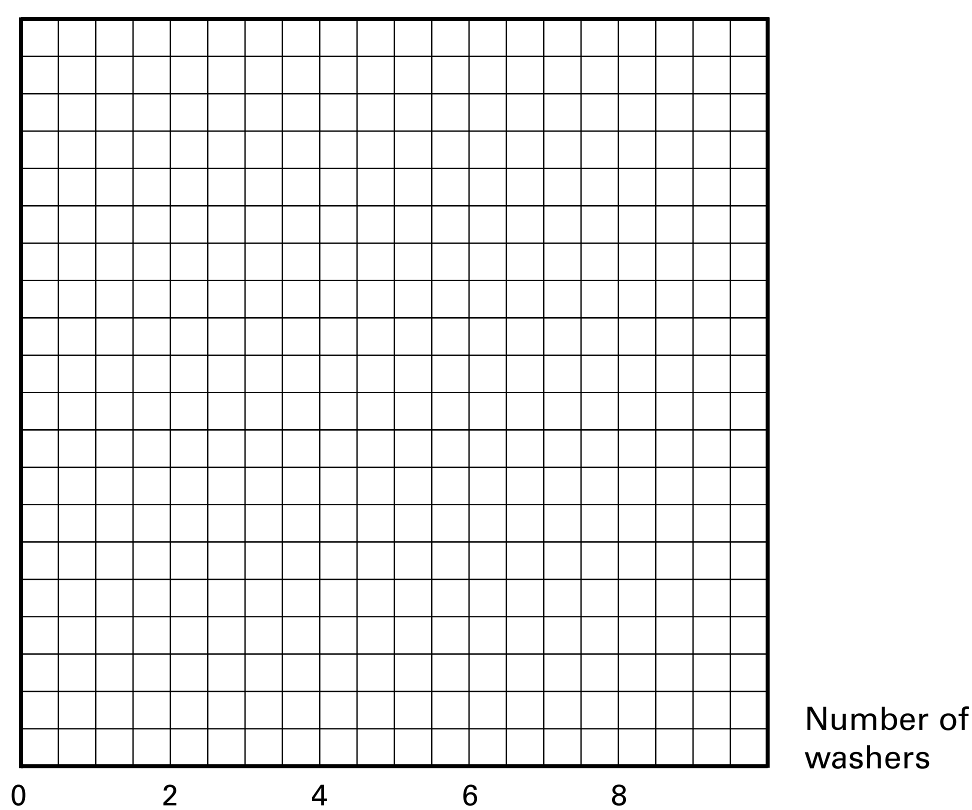
GRAPH IT!

1. Label the vertical axis "time for one swing in seconds." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the data from the table in "What Happened." Use a different color for each spring.

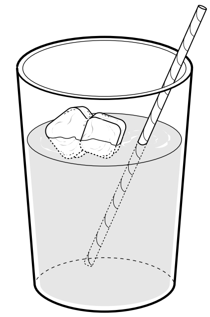
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot. Label each line with the spring number.

4. Put a descriptive title at the top of your graph.



Using the graph, determine what the time for one swing would be using 10 washers. Do this for both springs. Be sure to label your answers.

WARMING WATER



Science A cup of ice water warms up steadily at room temperature after the ice has melted.

Stuff Cold water; plastic cup or glass; ice cubes; spoon or other stirrer; thermometer; clock or watch

What to Do

1. Pour cold water into the plastic cup or glass.
2. Put four ice cubes into the water. Stir the water for a few minutes.
3. Record the temperature of the water every two minutes, making sure to stir the water between readings. Continue to record the temperature until the water seems to stay at the same temperature for several minutes.
4. Dump the water out of the cup. Pour hot tap water into the cup. Record the temperature of the water. Add four ice cubes to the water, and stir.
5. Record the temperature of the water every two minutes, making sure to stir the water between readings. Continue to record the temperature until the water seems to stay at the same temperature for several minutes.

What's Going On Here

When you started with ice water and took the temperature of the water every two minutes, the temperature stayed the same until the ice melted, and then steadily rose. The air surrounding the cup of ice water was a source of heat energy. Heat energy flowed from the warm air to the cold water, and the water responded by warming up until it reached room temperature. Before the ice melted, the temperature stayed at about 32°F or 0°C. Heat energy was being supplied by the surrounding warm air, but that energy did not go to heating up the water; it went to melting the ice. When you added ice to hot water and took the temperature every two minutes, you noticed a decrease in temperature, but it was not a steady decrease. Instead, the temperature decreased more rapidly at the beginning and more slowly at the end. This is because the hot water was the main source of energy to melt the ice. As the hot water lost energy to melt the ice and warm the colder water, there was less heat energy available to warm up the water. The air surrounding the cup also affected the cooling of the water, but it was a constant supplier of energy, as compared to the variable water.

Try It!

- ★ Try cooling hot water in the freezer. Take the temperature every two minutes.
- ★ Try to determine which freezes faster, hot water or cold water.
- ★ Try to determine which freezes faster, a thin layer of water or the same amount of water in a deep cup.

Name Date

WARMING WATER

What You Want to Know
How does the temperature of ice water change as it warms up? How does the temperature of hot water change when ice is added to it?

What You Think Will Happen
When ice water stands at room temperature,

a. the temperature will go up right away and will continue to rise about the same amount every two minutes.

b. the temperature will stay the same for a while and then go up about the same amount every two minutes.

c. the temperature will stay the same for a while and then go up, but not by the same amount every two minutes.

When ice is added to hot water and the water stands at room temperature,

a. the temperature will stay the same and then go down about the same amount every two minutes.

b. the temperature will go down about the same amount every two minutes.

c. the temperature will go down but not by about the same amount every two minutes.

What Happened
Record the temperature of water every two minutes.

Time	Ice water	Hot water
2 minutes		
4 minutes		
6 minutes		
8 minutes		
10 minutes		
12 minutes		
14 minutes		
16 minutes		
18 minutes		
20 minutes		

What It Means
Is the change in temperature more steady when ice water is warmed or when hot water is cooled? Explain your answer.

____

____

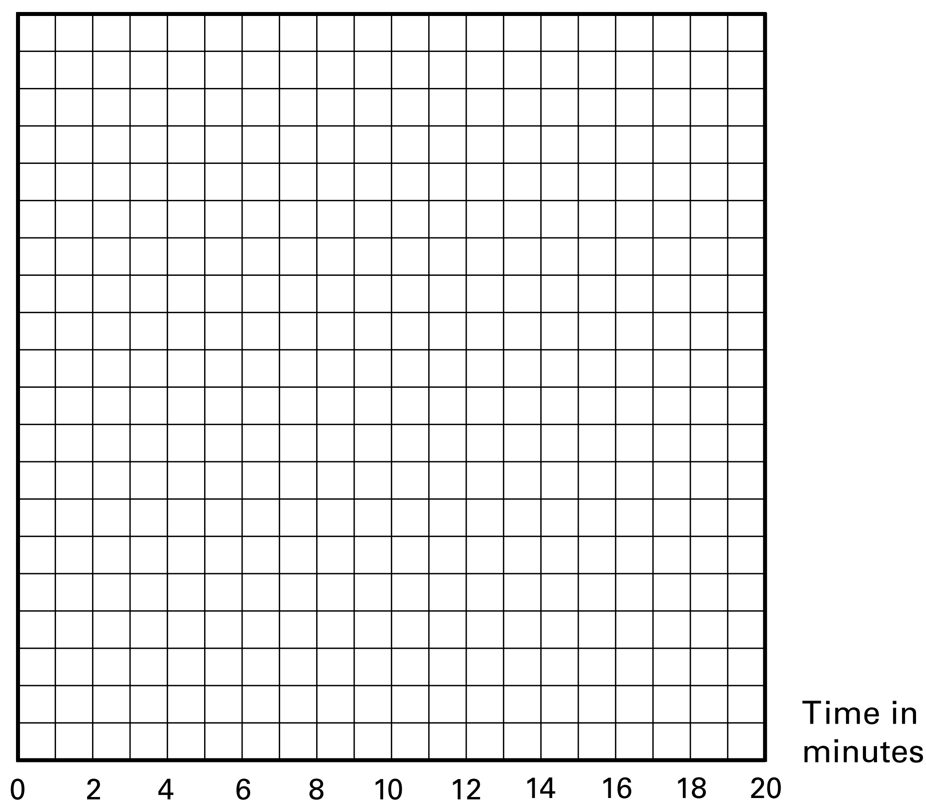
Graph It Next

Name Date

WARMING WATER (ICE)

GRAPH IT!

1. Label the vertical axis “temperature in degrees F” or “temperature in degrees C” (whichever you used). Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the ice water data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



How long did the temperature of the water stay the same? Explain how you got your answer.

____

____

Name Date

WARMING WATER (HOT)

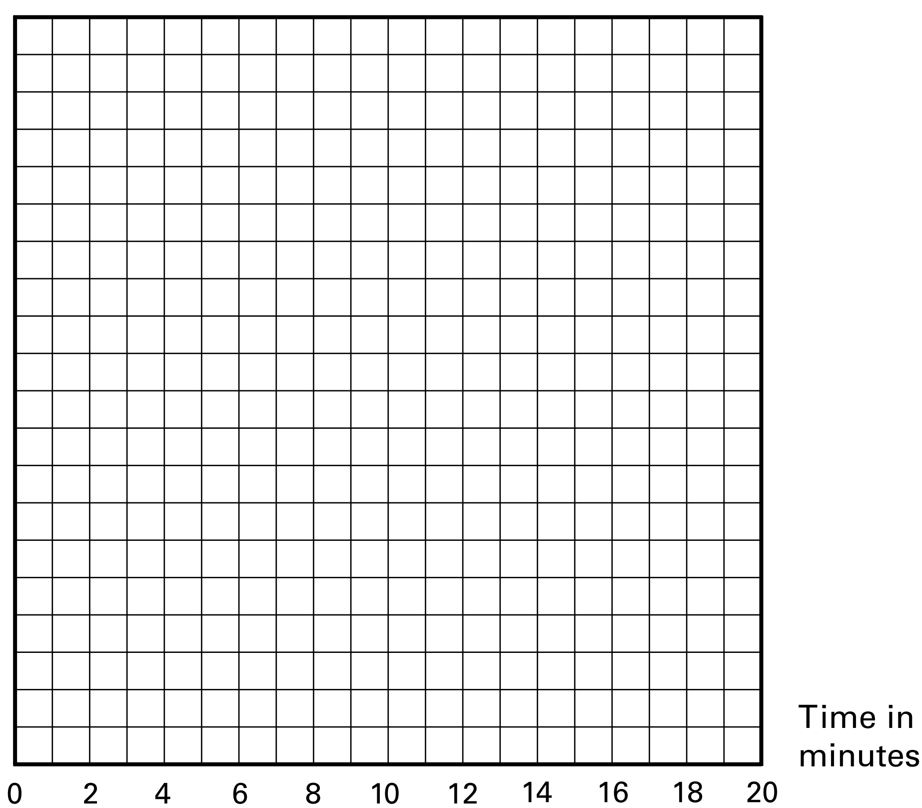
GRAPH IT!

1. Label the vertical axis "temperature in degrees F" or "temperature in degrees C" (whichever you used). Pick a convenient scale and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the hot water data from the table in "What Happened."

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.

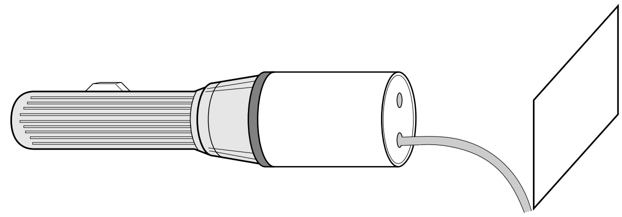


When did the temperature of the water seem to change the fastest? Explain how you got your answer.

SHIMMERING STREAM

Science Light can be totally reflected inside a stream of water.

Stuff Hammer and nail; empty cylindrical bottle with screw-on cap; duct tape; flashlight; piece of paper; water; bucket



What to Do

1. Punch two holes into the lid of a cylindrical bottle. The holes should be close to the edge of the lid and on opposite sides.
2. Wrap duct tape around the sides of the bottle. Place the bottom of the bottle on top of the flashlight, and use duct tape to attach the top of the flashlight to the bottle.
3. Turn the flashlight on, and make sure that no light is leaking from the sides of the bottle; light should be coming through the open top only. Darken the room. Hold the flashlight and bottle horizontally about six inches from a piece of paper, and observe the light hitting the paper.
4. Fill the bottle with water. Screw the lid on, and secure the edge with duct tape.
5. Darken the room. Cover the holes in the lid with your fingers, and hold the flashlight and bottle horizontally over the bucket. Have a partner hold the piece of paper about six inches from the flashlight and bottle.
6. Turn the flashlight on, and pull your fingers away from the holes. Observe the light hitting the paper and the stream of water coming from the bottle.

What's Going On Here

The bending of light as it travels from one material into another is called refraction. As light travels from a less dense material, like air, into a more dense material, like water, it is bent inward. As light travels from a more dense material to a less dense material, it is bent outward. When light travels from a more dense material, like water, into a less dense material, like air, if it strikes the surface between the two materials at a large enough angle, it is not refracted but instead is totally reflected in the denser material. The light cannot get out of the denser material but in a sense is trapped inside it by being reflected each time it tries to escape. This property is used in fiber optics.

Name Date

SHIMMERING STREAM

What You Want to Know

How does light travel through a stream of water?

What You Think Will Happen

A flashlight is taped to the bottom of a bottle. Two holes are punched in the lid of the bottle. In the two squares below, show what you think you will see when the bottle is held in front of a piece of paper and the flashlight is turned on.

No water in the bottle.

Water flowing from the bottle.

What Happened

In the two squares below, show what you saw when the bottle was held in front of a piece of paper and the flashlight was turned on.

No water in the bottle.

Water flowing from the bottle.

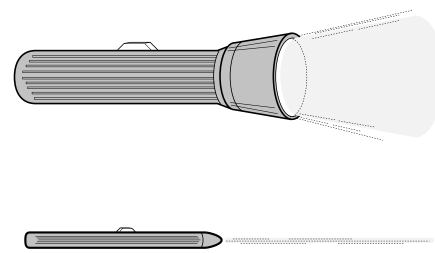
What did the water flowing from the bottle look like?

What It Means

What do your observations tell you about how light travels through a stream of water?

How do you think light would travel through a bent piece of clear plastic?

LASER LIGHT



Science Laser light is different from the white light of flashlights both in its color and in the narrowness of its beam.

Stuff Flashlight; stool or chair; 3 different color sheets of plastic or plastic wrap; low wattage helium-neon laser (e.g., laser pointer); meter stick

What to Do

Do not look directly into the laser light or at any reflected laser light. Do not shine the laser light toward anyone's eyes.

1. Darken the room.
2. Set the flashlight on a stool or chair, and aim it at a screen or the wall. Record the color of light you see. Hold the sheets of colored plastic in front of the flashlight one at a time, and record the color of light you see on the screen or wall. Turn the flashlight off.
3. Repeat step 1 using the laser.
4. Set the flashlight on a stool or chair. Position the flashlight and chair so that the front of the flashlight is 50 centimeters from the wall. Measure the diameter of the light beam on the wall. The diameter is the distance from one side of the beam to the other, measured through the center of the beam.
5. Move the stool and flashlight so that the front of the flashlight is one meter from the wall. Measure the diameter of the beam. Continue to move the flashlight back from the wall, 50 centimeters at a time, until you run out of room or can no longer see the beam on the wall.
6. Repeat step 5 using the laser light.

What's Going On Here

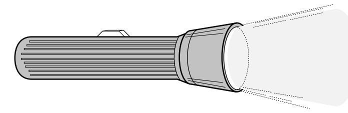
There are two major differences between laser light and the white light from a flashlight. First, the white light from the flashlight is made up of many colors, so when you hold plastic sheets of different colors in front of it, the beam appears to be the same color as the plastic. Laser light is a single wavelength (or color), so no matter what color of plastic is held in front of it, the beam appears red. The second major difference is in the divergence or spreading out of the beam. The flashlight beam spreads out greatly compared to the laser beam. The reason that laser beams are used for pointers is that the beam stays narrow over a long distance. If the divergence was zero, the beam would not increase in size at all. In fact, there is a small *divergence,* so the laser beam increases somewhat over a large distance. You may have been able to measure this small increase in size of the laser beam.

Try It!

★ Try to find a combination of colored plastic sheets that will block the laser light from passing through.

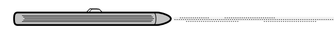
Name Date

LASER LIGHT



What You Want to Know

How does a laser light differ from a flashlight?



What You Think Will Happen

In the table, list two colors of plastic that you will be using and what color you think you will see when you shine the laser light or a flashlight through it.

Plastic color	Color when using flashlight	Color when using laser

When you shine a flashlight at a wall, the size of the beam will

a. get larger the farther the light is from the wall.

b. get smaller the farther the light is from the wall.

c. stay about the same size the farther the light gets from the wall.

When you shine a laser light at a wall, the size of the beam will

a. get larger the farther the light is from the wall.

b. get smaller the farther the light is from the wall.

c. stay about the same size the farther the light is from the wall.

What Happened

Record the color that you saw on the wall using the colored plastic sheets.

Plastic color	Color when using flashlight	Color when using laser

Record the size of the beam at the various distances from the wall.

Distance from wall	Size of flashlight beam	Size of laser beam
50 cm		
100 cm		
150 cm		
200 cm		
250 cm		

What It Means

What can you now say about the difference between a flashlight and a laser light?

____

____

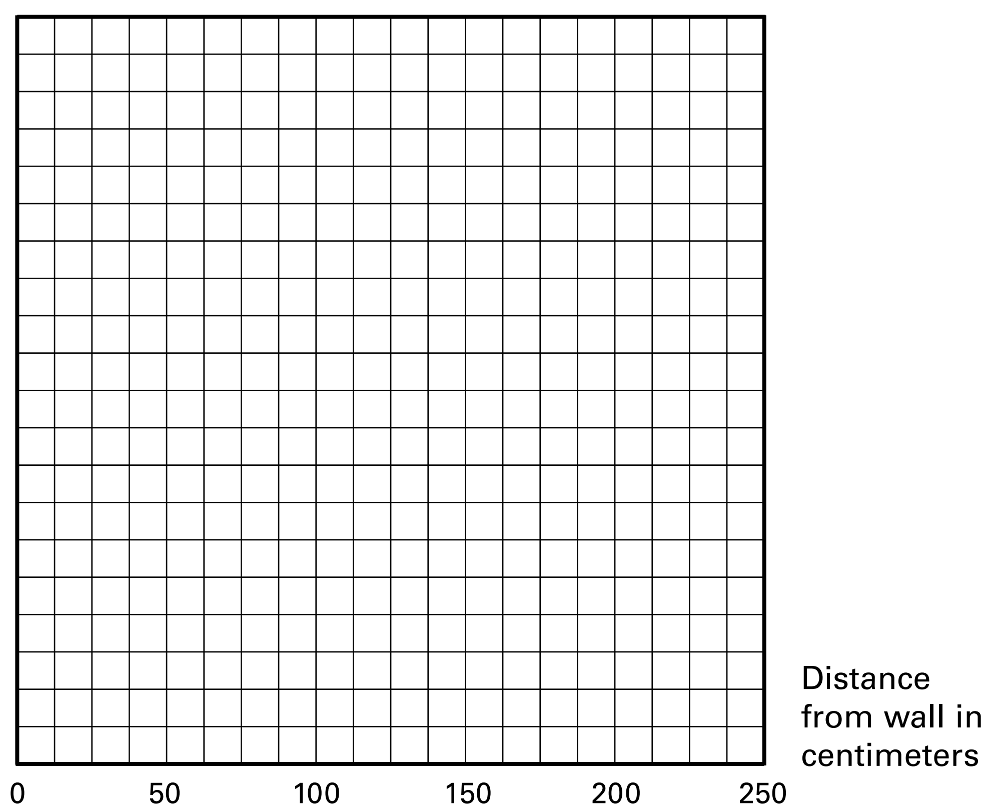
Graph It Next

Name Date

LASER LIGHT

GRAPH IT!

1. Label the vertical axis "size of beam in centimeters." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened." Use a different color for the laser light and the flashlight.
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot. Label each line as "flashlight" or "laser light."
4. Put a descriptive title at the top of your graph.



What does the graph show about which light changes its beam size most rapidly?

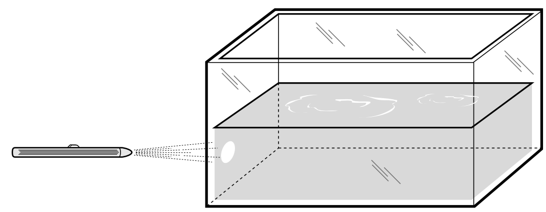
____

____

LIGHT IN A LIQUID

Science Some basic properties of light can be demonstrated with a laser beam.

Stuff Small rectangular fish tank; water; low wattage helium-neon laser (e.g., laser pointer); dirty chalkboard erasers (or pieces of felt sprinkled with cornstarch); sharpened pencil; 1 teaspoon of latex paint (any color)



What to Do

Do not look directly into the laser light or at any reflected laser light. Do not shine the laser light toward anyone's eyes.

1. Fill the an empty fish tank $\frac{1}{2}$ full with water. Darken the room.
2. Stand about six feet from a wall, and aim the laser at the wall. Observe the air between the wall and the laser. Now have a partner clap erasers together directly above the beam and midway between the wall and the flashlight. Observe the beam of light.
3. Hold the laser above the fish tank, and shine it straight down at the water. Observe the reflection of the laser light on the ceiling. Jiggle the fish tank, and watch the reflection.
4. Aim the laser in the water from one side of the fish tank to the other. Use the pencil tip to add a few drops of latex paint to the water. Stir the water with the pencil. Observe the beam.
5. Hold the laser light above the water, and shine it in at an angle. Have a partner clap erasers just above the beam. Ask your partner to observe the beam in the air and in the water. Switch places with your partner.
6. Hold the laser at one side of the fish tank, and direct the beam up at an angle, so that it hits the top of the water. Observe the light beam in the water. Have a partner clap erasers just above the water and the beam. Observe the air above the water.

What's Going On Here

You observed three basic properties of light using the laser beam: scattering, refraction, and reflection. The beam scattered off the chalk dust in the air and the small particles of latex paint in the water. The beam reflected off the top of the water and off the bottom of tank, making two spots that danced on the ceiling when you jiggled the tank. When you held the laser above the water at an angle, you were able to see how light was refracted, or bent, as it passed from air into water. In the last part of the activity, you observed how light is totally internally reflected. When the laser light hit the top surface of the water, it could not refract into the air. All the light was reflected, which you could observe by the lack of light scattered in the chalk dust above the water.

Try It!

★ Try using a flashlight instead of a laser.

Name Date

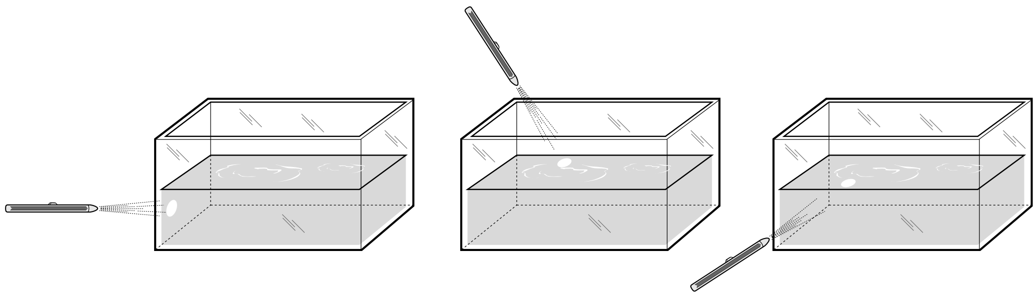
LIGHT IN A LIQUID

What You Want to Know

What happens when a light shines into a liquid at different angles?

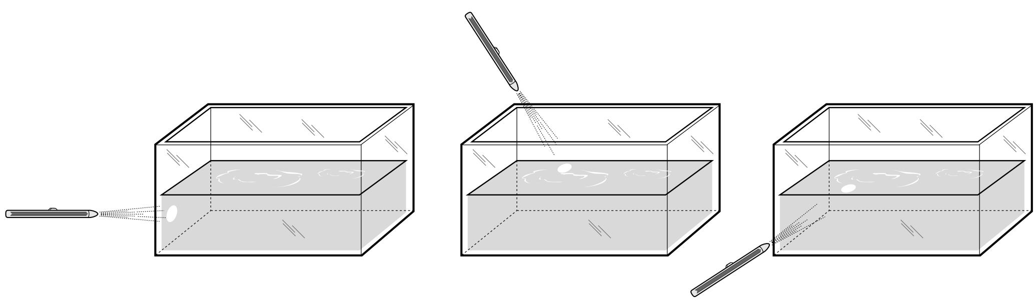
What You Think Will Happen

In the drawings below, a laser beam is aimed into water. With a straight line, show where you think the beam will go next.



What Happened

In the drawings below, a laser beam is aimed into water. With a straight line, show the path of the beam you observed.



What It Means

What did you learn about light in this activity?

____

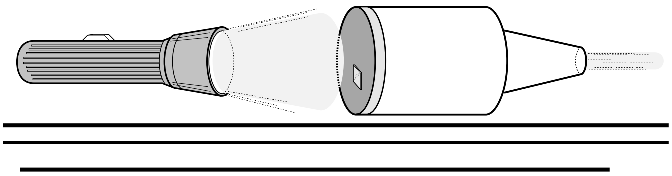
What would you like to investigate about light? How would you use the laser to do it?

____

____

SEEING SOUND

Science A beam of light reflected from a vibrating mirror will move about. Sound waves can make the mirror vibrate so that you can "see sound."



Stuff Can opener; empty soup can or coffee can; scissors; large balloon; duct tape; double-sided tape; small mirror; flashlight; sheet of paper; radio and various musical instruments

What to Do

1. Use the can opener to carefully remove the bottom of the can.
2. Cut off the part of the balloon you blow into.
3. Stretch the balloon around one open end of the can to form a drumlike surface. Secure the balloon to the sides of the can with duct tape.
4. Use the double-sided tape to attach the small mirror to the balloon. Make sure that the mirror is not in the balloon center.
5. Place the can on a table, and tape it in place with the duct tape.
6. Place the flashlight on the table, and shine it at the mirror. Adjust the position of the flashlight until you can see the reflection from the mirror on a wall in the room.
7. Roll the sheet of paper into a cone. Place the cone inside the can with its wide end very close to, but not touching, the balloon. Speak loudly into the cone.
8. Observe the movement of the beam on the wall.
9. Try varying the pitch of a note that you sing loudly into the can. Try playing various musical instruments or a radio near the opening in the can. Vary the volume of the radio.

What's Going On Here

When the light beam is aimed at the mirror, the beam is reflected on the wall. As long as the mirror does not move, the light beam does not move. But if the mirror starts moving, the light beam will move as well. One way to make the mirror move is to use sound waves to cause it to vibrate. When you shout into the can, vibrations from the sound wave make the balloon vibrate, which in turn makes the mirror vibrate. When the mirror vibrates, the light beam will move on the wall. Tones with higher pitch will cause the mirror to vibrate faster than tones with low pitch, and the light beam will also vibrate faster.

Try It!

★ Try using a laser instead of the flashlight.

Name Date

SEEING SOUND

What You Want to Know
How can you "see" sound waves?

What You Think Will Happen
Light is reflected from a mirror that is vibrated by sound waves. Draw a picture of what you think the reflected light looks like.

What Happened
Draw a picture of what the reflected light looked like when the radio was played.

What happened to the reflected light pattern when you changed the volume of the radio?

____

____

What It Means
What was your favorite pattern of light?

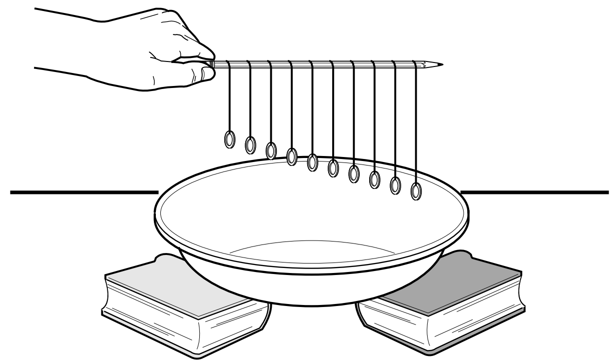
____

What other kinds of sound would you like to "see"? What do you think the sound would look like?

____

____

SUPERIOR SOUNDS



Science The volume of sound depends on the energy of the object making the sound.

Stuff 20 washers; string; 2 pencils; cookie pan or aluminum pie plate; 2 books; ruler; tape

What to Do

1. Place two books on a table far enough apart to support the cookie pan or aluminum pie plate at its edges. Place the cookie pan on the books.
2. Cut 10 pieces of string that start at 12 inches long and are each 1 inch longer, up to 21 inches. Tie the end of each string to a washer and then to a pencil. When the pencil is held horizontally, each washer should be 1 inch longer or shorter than the one next to it.
3. Cut ten pieces of string that are each 15 inches long. Tie the end of each string to a washer and then to the other pencil. When the pencil is held horizontally, the washers should line up horizontally. If any washer is not lined up, roll it up or down around the pencil, and secure it in place with a small piece of tape.
4. Hold the pencil that has strings of unequal length horizontally about one foot above the pan. Drop the pencil so that it falls horizontally into the pan. Listen to the sound of the washers. Drop the pencil from two feet and then three feet, listening to the sound each time and comparing it to the sounds you heard previously. Untangle the strings.
5. Repeat step 4 using the pencil that has strings of equal length.
6. Drop the first pencil from a height of three feet. Drop the second pencil from the same height. Repeat several times with both until you can distinguish which makes the louder sound.

What's Going On Here

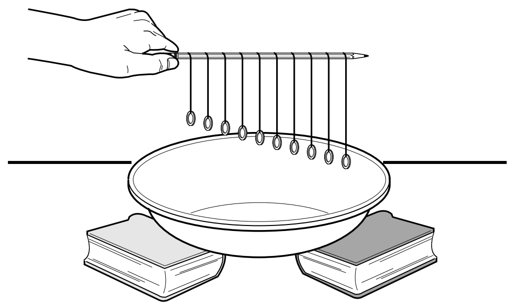
As the washers are dropped from a greater height, they have a greater speed and thus more energy when they hit. The washers have kinetic energy due to their motion. This kinetic energy is changed to sound energy when the washers hit the pan. The greater the height, the more energy they have and the louder the sound, no matter which pencil you are using. When you compare the sound of washers of equal length to those of unequal length dropped from the same height, the washers of equal length will make a louder sound because all the washers are expending their energy at the same time. When the washers of unequal length fall, they hit the pan at different times, and their energy is expended one at a time. The net effect is that the sound is not as loud as that of the washers of equal length.

Try It!

- ★ Try varying the length of the washers.
- ★ Try using more or fewer washers.

Name Date

SUPERIOR SOUNDS



What You Want to Know

Does the volume of the sound of a falling object hitting a metal pan depend on its height? Do 10 objects falling at the same time make a louder noise when they hit a pan than if they fell separately?

What You Think Will Happen

As the height of an object increases, the volume of the sound it makes when it hits a metal pan

a. decreases. **b.** increases. **c.** stays about the same.

What Happened

Describe the difference in the sound when you dropped the washers of unequal length from different heights above the pan.

Describe the difference in the sound when you dropped the washers of equal length from different heights above the pan.

Describe the difference in the sound when you dropped the washers of unequal length and equal length from the same height, one after the other.

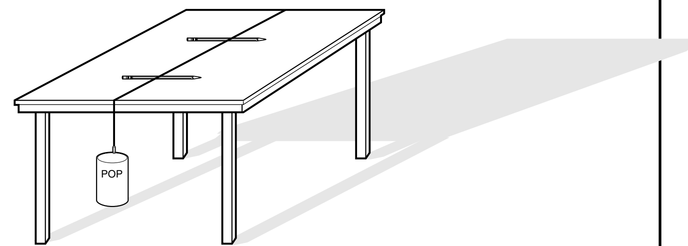
What It Means

What do you think would make more noise: a bunch of students jumping up and down in a room randomly, or the same group jumping up and down on the count of "one, two, three, jump"? Explain your answer. Try it.

STRING SOUNDS

Science The pitch of a string depends on its length, thickness, and tension.

Stuff Measuring cup; water; 6 empty pop cans; ruler; thin string (e.g., kite string); scissors; 2 pencils; thick string (e.g., cotton twine)



What to Do

1. Put one cup of water into each can. Cut a piece of thin string about two feet longer than the table or desk. Tie each end of the string to a can, using the tabs on the tops of the cans.
2. Place the pencils on the table parallel to each other and separated by two inches. Place the string over the pencils, allowing the cans to hang over the edges of the table. Have a partner place a finger on the string in each of the places it touches the pencils.
3. Put your ear against the table, and pluck the string between the two pencils. Listen to the pitch. Move the pencils farther apart, and listen to the pitch again. Remove the string and cans from the table.
4. Cut a piece of the thick string that is two feet longer than the table or desk. Tie each end of the string to a can, using the tabs on the top of the cans.
5. Place the pencils on the table parallel to each other and separated by 12 inches. Place the thick string over the pencils, allowing the cans to hang over the edges of the table. Place the thin string about one inch away from the thick string in the same manner. Have a partner place a finger on the strings in all the places they touch the pencils.
6. Put your ear against the table, and pluck each string between the two pencils. Listen to the pitch. Remove the string and cans from the table.
7. Cut a piece of thin string about 12 inches longer than the table or desk. Tie each end of the string to two pop cans using the tabs on the top of the cans. With the pencils 12 inches apart, place the thin string with two cans and the thin string with four cans over the pencils. Compare the pitch of the two strings.

What's Going On Here

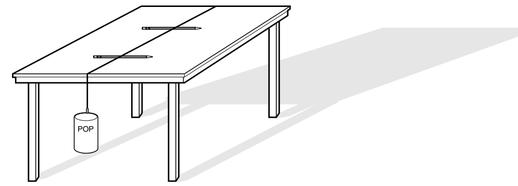
Length, tension, and thickness are factors that affect the pitch produced by a vibrating string. The faster the string vibrates, the higher the pitch. Moving the pencils closer together shortened the length of the string, causing it to vibrate faster and resulting in a higher pitch. A thinner string vibrates faster than a thicker string of the same length and under the same tension, resulting in a higher pitch. Likewise, adding tension to the string by having two cans on each end instead of just one increased the pitch.

Try It!

- ★ Try to play a song by plucking a string while varying its length by moving one pencil back and forth.
- ★ Place the string over an open box to increase the volume of the sound.

Name Date

STRING SOUNDS



What You Want to Know

How will a plucked string sound when you change its length, thickness, or tightness (tension)?

What You Think Will Happen

Compared to a shorter string, the pitch of a longer string will be
a. higher. **b.** lower. **c.** the same.

Compared to a thinner string, the pitch of a thicker string will be
a. higher. **b.** lower. **c.** the same.

Compared to a looser string, the pitch of a tighter string will be
a. higher. **b.** lower. **c.** the same.

What Happened

For each pair of choices below, circle the one that results in a higher pitch.

Long string or Short string

Thin string or Thick string

Loose string or Tight string

What It Means

Can you think of an instrument that uses strings to make music? How does that instrument use the thickness, length, or tightness of the strings to change the pitch?

____

____

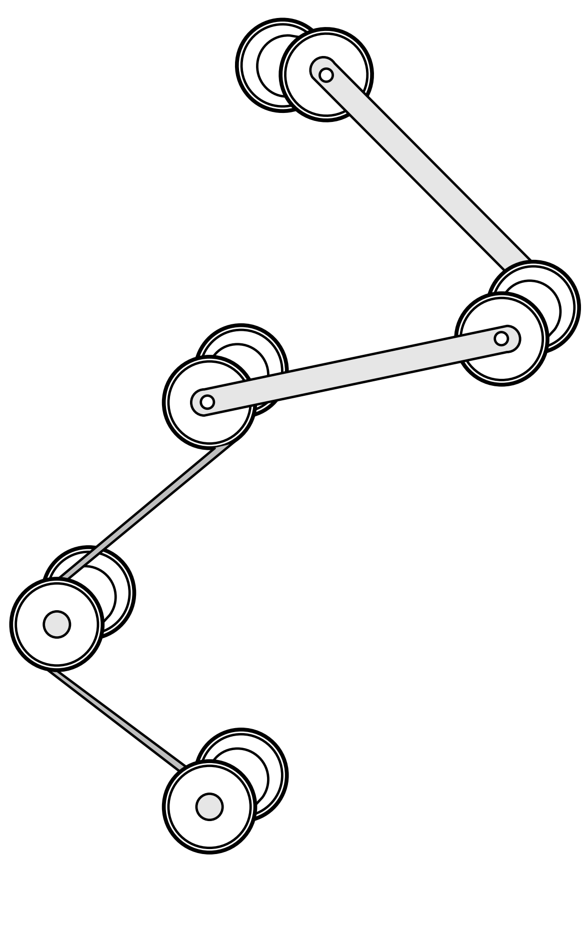
What other kind of string could you use? Do you think its pitch would be higher or lower than the thin string you used? Explain your answer.

____

____

CHAPTER

3 MACHINES



MACHINE MATERIAL

- Machines are designed and used to make work easier. The amount of work doesn't change; the machine makes it easier to do the work by requiring the operator to use less effort or force. But there is a trade-off. Even though the operator uses less force, he or she has to apply the force over a greater distance.

- Levers are simple machines that trade force for distance and make it easier to do work.

- In a first-class lever, the *fulcrum* (lever's support) is located between the *load* (the weight to be lifted) and *effort* (the force that is applied). As long as the distance from the fulcrum to the effort is greater than the distance from the load to the effort, less effort will be needed to lift the load. Seesaws and balance scales are examples of first-class levers.

- In a second-class lever, the load is located between the fulcrum and the effort. As long as the distance from the fulcrum to the effort is greater than the distance from the load to the effort, less effort will be needed to lift the load. A wheelbarrow is an example of a second-class lever.

- A third-class lever has the effort located between the fulcrum and the load. It is not possible for the distance to the effort to be greater than the distance to the load in a third-class lever. So these levers can't be used to make work easier. They are still useful machines, however. Hammers, fishing rods, and tweezers are examples of third-class levers.

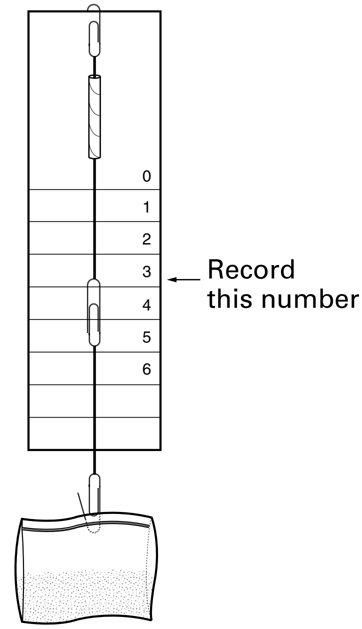
- It takes less effort to move an object up an inclined plane than to pull it straight up the same vertical distance.

- A screw is a simple machine that is really an inclined plane. If you follow the groove in a screw, you can see that it winds its way up from the bottom to the top in the same way that an inclined plane starts at the bottom and goes to the top.

- Pulleys are used to make it easier to do work, too. A single pulley, like the one on a flagpole, makes it easier to lift the flag to the top by changing the direction of the force: You pull down on the rope, and the flag moves upward. The amount of effort isn't less; the pulley just changes the direction of the effort.

- *Friction* is a force that always opposes the direction of an object's motion. Machines are designed to minimize friction. They can never entirely eliminate it.

SIMPLE SPRING SCALE



Science The mass of an object can be found by measuring how much it stretches a rubber band.

Stuff Straw; ruler; 3 large paper clips; stiff cardboard (cut to 3 inches × 11 inches); rubber band; tape; string (4 inches long); marker; sandwich bag; various objects to place in bag, such as paper clips, pennies, sand, marbles, toy balls

What to Do

The spring scale made in this activity is used in several other activities in this book.

1. Cut the straw to a length of two inches.
2. Place a paper clip on the top middle of the cardboard. Loop one end of the rubber band into the paper clip.
3. Pull the rubber band through the straw, and tape the straw to the cardboard so it is barely touching the paper clip.
4. Unbend the second paper clip, and attach it to the free end of the rubber band.
5. Tie the string to the second paper clip and then to the third paper clip.
6. Make horizontal marks on the cardboard every $\frac{1}{2}$ inch, starting next to the straw. Number the marks 0, 1, 2, . . . starting at the straw.
7. Fill the sandwich bag halfway with sand. Attach the bag to the bottom paper clip on your scale. Holding the top part of the scale, lift the bag vertically. Record the position of the top part of the second paper clip. This number corresponds to the force that is needed to lift the bag. Empty the bag.
8. Repeat step 7 using other objects.

What's Going On Here

Mass is a measure of the amount of matter in an object. Consequently, it is also a measure of how difficult it is to move the object. The difficulty you encounter moving an object horizontally in the absence of friction is called *inertia;* the more mass an object has, the more work you need to do to overcome its inertia in order to move it. Even in outer space where there is no air resistance, astronauts must do work to move an object. When you move an object vertically, you need to do work against gravity; the more mass an object has, the more weight it has, and the more work you must do to lift it. The simple spring scale measures the amount of mass for objects that are not so heavy that they break the rubber band and not so light that they don't noticeably stretch the rubber band. The more mass an object has, the more weight it has, and the more it stretches the rubber band.

Name _______________ Date _______________

SIMPLE SPRING SCALE

What You Want to Know

How can the mass of objects be found using a simple rubber band scale?

What You Think Will Happen

List the objects whose mass you will measure in order from the one you think has the least mass to the one you think has the greatest mass.

_______________ (least mass)

____

____

____

____

_______________ (greatest mass)

What Happened

Record the number from your spring scale in the table.

Contents of bag	Amount of mass (number from scale)

What It Means

Do you think the scale you made could be used to find the mass of a feather? Why?

____

____

Do you think the scale you made could be used to find your own mass? Why?

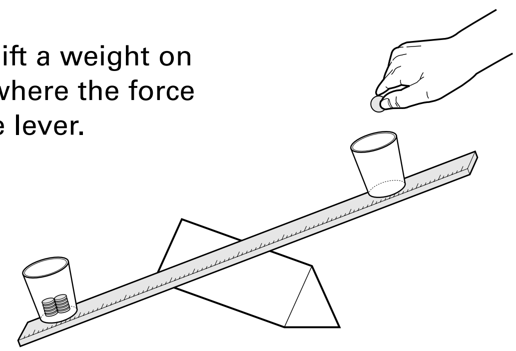
____

____

LIFTING LEVER

Science The amount of force needed to lift a weight on one end of a lever depends on where the force is placed on the other end of the lever.

Stuff Heavy cardboard (6 inches × 6 inches); yardstick; sharp knife or scissors; masking tape; two 3-ounce paper cups; scrap of paper; 100 pennies



What to Do

1. Measure two inches in from one edge of the cardboard, and draw a line parallel to that edge. Measure two inches from the line you just drew, and draw another line parallel to the first. Use a knife or scissors to score the lines.
2. Bend the cardboard away from the scored lines to form a triangle. Tape the triangle along the top edge. You have made a *fulcrum*. Place the fulcrum on the table, taped edge up.
3. Tape one of the paper cups to the yard-stick, so that the center of the bottom of the cup is positioned on the two-inch mark of the yardstick.
4. Cut a piece of masking tape four inches long. Stick a piece of paper that is two inches long and a little wider than the tape in the middle of the tape, so that about one inch of sticky tape is exposed on each end.
5. Place the tape under the yardstick at the 34-inch mark, with the sticky side facing up. Place the second paper cup on the yardstick, and attach the sticky ends of the tape to the sides of the cup. The cup should be able to slide on the yardstick but should not fall off of it.
6. Place the yardstick on the fulcrum so that the 18-inch mark is directly over the top edge.
7. Place ten pennies in the first cup (the cup at the two-inch mark); this is called the *load.* Count how many inches the load is from the center of the yardstick. Place pennies in the second cup, one at a time, until the first cup begins to lift off the table. The number of pennies needed to lift the load is called the *effort.* Count how many inches the effort is from the center of the yardstick.
8. Repeat step 7 with the movable paper cup at 32 inches, 30 inches, 28 inches, 26 inches, 24 inches, 22 inches, and 20 inches.

What's Going On Here

As the effort is moved toward the fulcrum, more pennies are needed to lift the load. The distance from the fulcrum to the load multiplied by the number of pennies in the load is equal to the distance from the fulcrum to the effort multiplied by the number of pennies in the effort.

Try It!

★ Try changing the position of the yardstick on the fulcrum, the number pennies in the load, or the location of the load.

Name Date

LIFTING LEVER

What You Want to Know

How much effort on one end of a yardstick is needed to lift a weight or load on the other end of the yardstick?

What You Think Will Happen

The center of a yardstick is placed on a triangular cardboard stand called a *fulcrum*. A cup of pennies (the *load*) is placed at one end of the yardstick. A cup of pennies on the other end of the yardstick is used to lift the load. As the cup is moved closer to the fulcrum, the number of pennies needed to lift the load

a. increases. **b.** decreases. **c.** does not change.

What Happened

Distance from fulcrum to load = ______

Number of pennies in load = ______

(Distance to load) × (pennies in load) = ______ Record your observations in the table.

Distance from fulcrum to effort	Number of pennies needed to lift load	(Distance to effort) × (pennies in effort)

What It Means

What do your observations tell you about how the effort changes as it is moved closer to the fulcrum?

____

What do you notice about how the numbers in the third column of the table compared to the distance to the load multiplied by the number of pennies in the load?

____

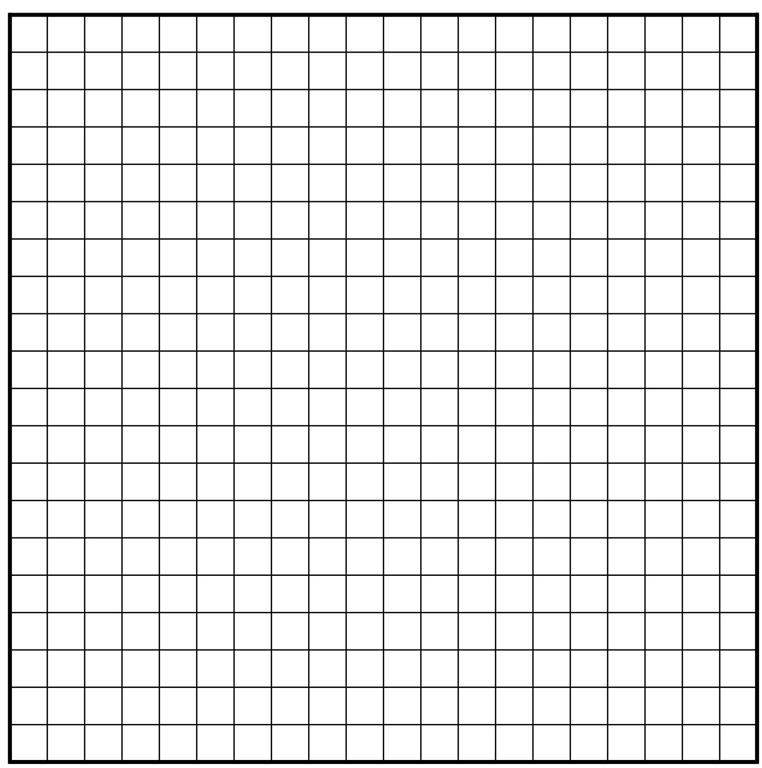
Graph It Next

Name Date

LIFTING LEVER

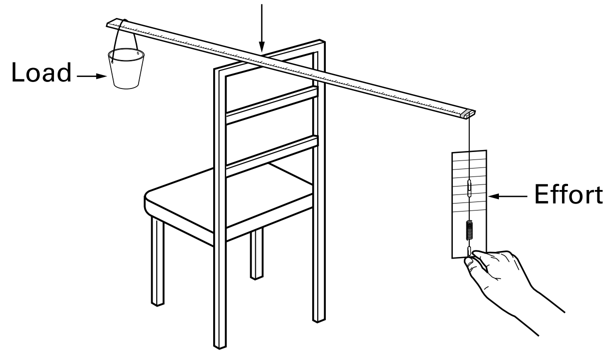
GRAPH IT!

1. Label the vertical axis "number of pennies." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data from the first two columns of the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



What does the graph show about how the number of pennies needed to lift the load changes as the distance to the effort increases?

FIRST-CLASS LEVER LIFT



Science In a first-class lever, the fulcrum (lever's support) is located between the load (weight to be lifted) and effort (force to lift the load).

Stuff Pencil; paper cup; string; 50 pennies; yardstick; chair; tape; spring scale from "Simple Spring Scale"

What to Do

1. With a pencil, poke holes in opposite sides of a paper cup just below the rim. Tie an end of a 12-inch piece of string through each of the holes to make a handle. Put all the pennies in the cup.
2. Place the yardstick on the edge of the back of a chair so that 12 inches hangs over the edge of the chair. Hang the cup at the edge of the yardstick, and tape it in place. The distance from the fulcrum to the cup (load) is called the *load arm*; it should be 12 inches.
3. Attach a piece of string to the top of the spring scale, and then make a loop in the free end of the string to attach to the yardstick. Tape the string on the end of the yardstick. The distance from the fulcrum to the spring scale (effort) is called the *effort arm*; it should be 24 inches.
4. Pull down on the spring scale to raise the load. Record the measurement on the spring scale when the load is balanced (the yardstick is level). You may have to add more weight or change the kind of rubber band on the spring scale to get a good measurement.
5. Move the spring scale so that it is 18 inches from the fulcrum, and raise the load. Also, raise the load at 12 inches and 6 inches.
6. Remove the load from the lever, and use the spring scale to lift it directly upward. Record the measurement on the spring scale. This is a measure of the weight of the load.

What's Going On Here

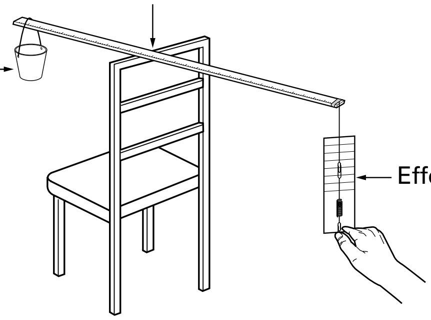
The lever in this activity is a first-class lever. The fulcrum (support for the lever) is located between the load (the object you want to lift) and the effort (whatever is used to lift the load). In this activity, the cup of pennies provided the load, the edge of the chair was the fulcrum, and your hand provided the effort. When you raised the load from the end of the yardstick, you needed less force than when you raised it closer to the fulcrum. In fact, when you were closer to the fulcrum than the load, it actually took more force to raise the load than the load itself weighs.

Try It!

★ Try changing the distance of the load arm.

★ Try changing the amount of weight in the cup.

FIRST-CLASS LEVER LIFT



What You Want to Know

Does a first-class lever always make it easier to lift something?

What You Think Will Happen

When you use a first-class lever to lift something,

- **a.** it will always be easier than lifting the object without the lever.
- **b.** it will sometimes be easier than lifting the object without the lever.
- **c.** it will always be harder than lifting the object without the lever.
- **d.** it will take about the same force as lifting the object without a lever.

What Happened

Record the reading on the spring scale when you used the first-class lever to raise the load.

Load arm	Effort arm	Amount of effort (spring scale)
12 inches	24 inches	
12 inches	18 inches	
12 inches	12 inches	
12 inches	6 inches	

How much effort was needed to lift the cup of pennies without the lever?

____

What It Means

Does the first-class lever always make it easier to lift a load? Explain your answer using the measurements that you made.

____

____

If the load arm were 2 inches and the effort arm were 34 inches, how much effort do you think it would take to raise the load? Try it.

____

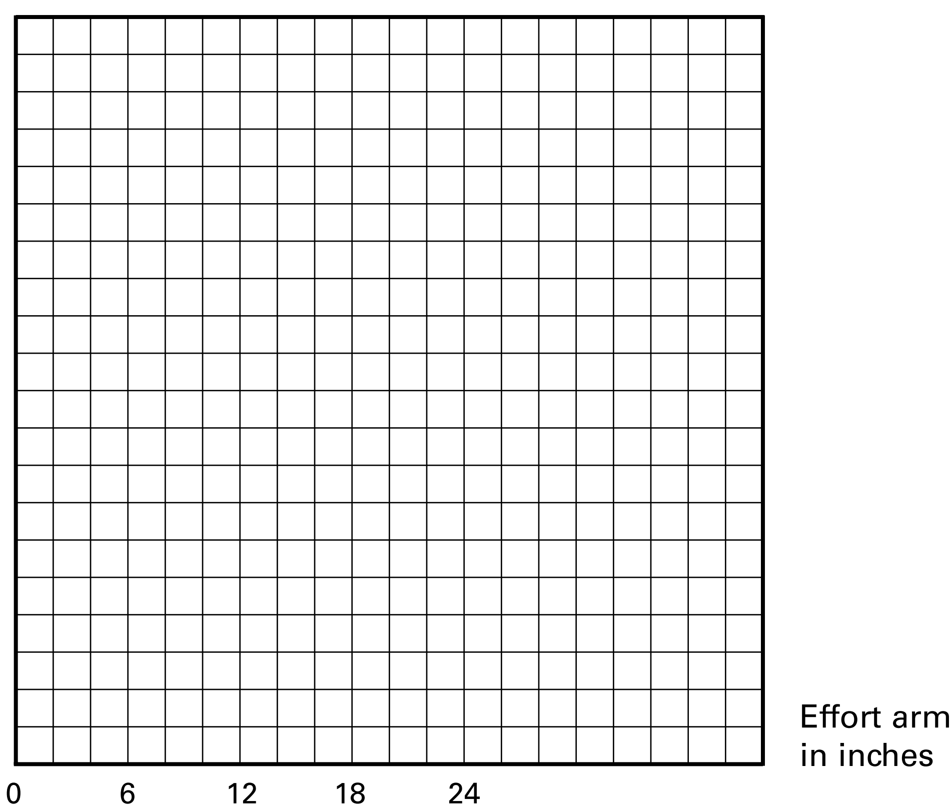
Graph It Next

Name Date

FIRST-CLASS LEVER LIFT

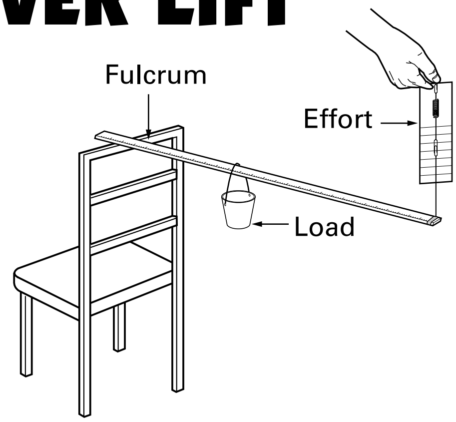
GRAPH IT!

1. Label the vertical axis “effort from spring scale.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph



How much effort would it take to lift the load if the effort arm were 30 inches? Mark that data point on the graph with an X.

SECOND-CLASS LEVER LIFT



Science In a second-class lever, the load (weight to be lifted) is located between the fulcrum (lever's support) and effort (force to lift the load).

Stuff Pencil; paper cup; string; 50 pennies; yardstick; chair; tape; spring scale from "Simple Spring Scale"

What to Do

1. With a pencil, poke holes in opposite sides of a paper cup just below the rim. Tie an end of a 12-inch piece of string through each of the holes to make a handle. Put all the pennies in the cup.
2. Place the yardstick on the edge of the back of a chair so that about 12 inches hangs over the edge of the chair. Hang the cup 6 inches from the fulcrum, and tape it in place. The distance from the fulcrum to the cup (load) is called the *load arm*; it should be 6 inches.
3. Attach a piece of string to the end of the spring scale, and then make a loop in the free end of the string to attach to the yardstick. Tape the string on the end of the yardstick. The distance from the fulcrum to the spring scale (effort) is called the *effort arm*; it should be 24 inches.
4. Pull up on the spring scale to raise the load. Record the measurement on the spring scale when the load is balanced (the yardstick is level). You may have to add more weight or change the kind of rubber band on the spring scale to get a good measurement.
5. Move the spring scale so that it is 18 inches from the fulcrum, and raise the load. Also, raise the load at 12 inches and 6 inches. When the spring scale is 6 inches from the fulcrum, it is right next to the cup of pennies.
6. Remove the load from the lever, and use the spring scale to lift it directly upward. Record the measurement on the spring scale. This is a measure of the weight of the load.

What's Going On Here

The lever in this activity is a second-class lever. The load (the object you want to lift) is located between the fulcrum (support for the lever) and the effort (whatever is used to lift the load). In this activity, the cup of pennies provided the load, the edge of the chair was the fulcrum, and your hand provided the effort. When you raised the load from the end of the yardstick, you needed less force than when you raised it closer to the fulcrum. When the effort was right next to the load, the force required to raise the pennies was about the same as the force needed to lift the pennies without the lever. With a second-class lever, you never need more force to lift a load than you need without the lever.

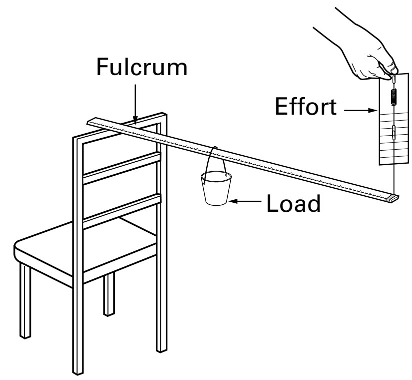
Try It!

★ Try changing the distance of the load arm.

★ Try changing the amount of weight in the cup.

Name Date

SECOND-CLASS LEVER LIFT



What You Want to Know

Does a second-class lever always make it easier to lift something?

What You Think Will Happen

When you use a second-class lever to lift something,

a. it will always be easier than lifting the object without the lever.

b. it will sometimes be easier than lifting the object without the lever.

c. it will always be harder than lifting the object without the lever.

d. it will take about the same force as lifting the object without a lever.

What Happened

Record the reading on the spring scale when you used the second-class lever to raise the load.

Load arm	Effort arm	Amount of effort (spring scale)
12 inches	24 inches	
12 inches	18 inches	
12 inches	12 inches	
12 inches	6 inches	

How much effort was needed to lift the cup of pennies without the lever?

____

What It Means

Does the second-class lever always make it easier to lift a load? Explain your answer using the measurements that you made.

____

____

If the load arm were 2 inches and the effort arm were 24 inches, how much effort do you think it would take to raise the load? Try it.

____

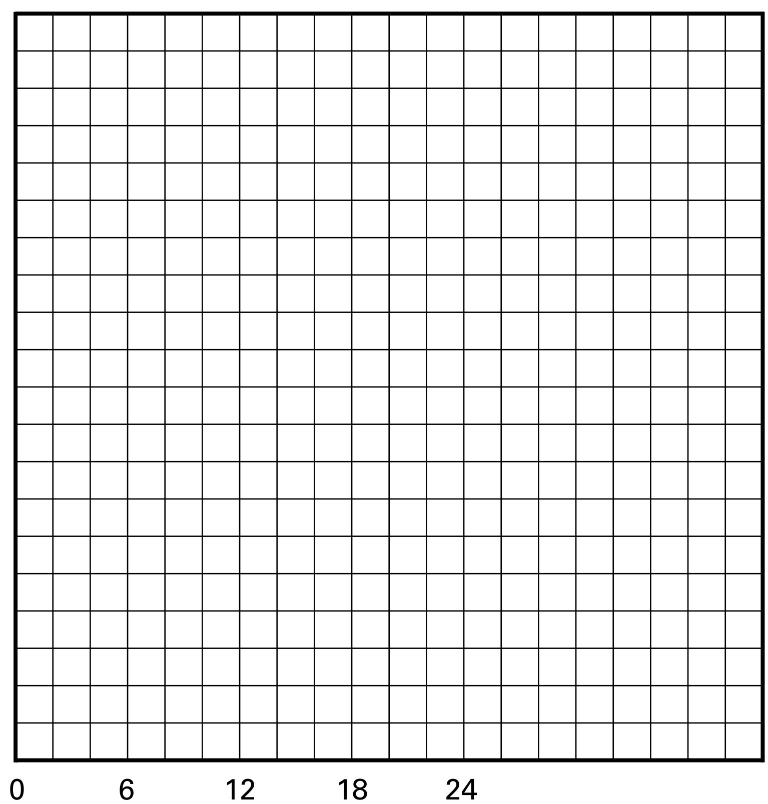
Graph It Next

Name Date

SECOND-CLASS LEVER LIFT

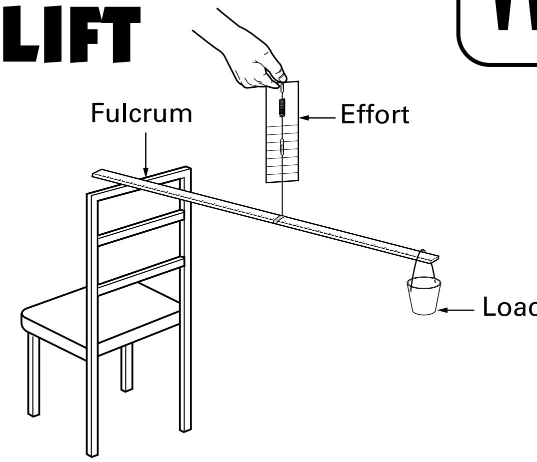
GRAPH IT!

1. Label the vertical axis "effort from spring scale." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



How much effort would it take to lift the load if the effort arm was 30 inches? Mark that data point on the graph with an X.

THIRD-CLASS LEVER LIFT



Science In a third-class lever, the effort (force to lift the load) is located between the fulcrum (lever's support) and load (weight to be lifted).

Stuff Pencil; paper cup; string; 50 pennies; yardstick; chair; tape; spring scale from "Simple Spring Scale"

What to Do

1. With a pencil, poke holes in opposite sides of a paper cup just below the rim. Tie an end of a 12-inch piece of string through each of the holes to make a handle for the cup. Put all the pennies in the cup.
2. Place the yardstick on the edge of the back of a chair so that 12 inches hangs over the edge of the chair. Attach a piece of string to the end of the spring scale, and then make a loop in the free end of the string to attach to the yardstick. Tape the string on the yardstick, 6 inches from the fulcrum. The distance from the fulcrum to the spring scale (effort) is called the *effort arm*; it should be 6 inches.
3. Hang the cup at the end of the yardstick, and tape it in place. The distance from the fulcrum to the cup (load) is called the *load arm*; it should be 24 inches.
4. Pull up on the spring scale to raise the load. Record the measurement on the spring scale when the load is balanced (the yardstick is level). You may have to add more weight or change the kind of rubber band on the spring scale to get a good measurement.
5. Move the spring scale so that it is 12 inches from the fulcrum, and raise the load. Also raise the load at 18 inches and 24 inches. When the spring scale is 24 inches from the fulcrum, it is right next to the cup of pennies.
6. Remove the load from the lever, and use the spring scale to lift it directly upward. Record the measurement from the spring scale. This is a measure of the weight of the load.

What's Going On Here

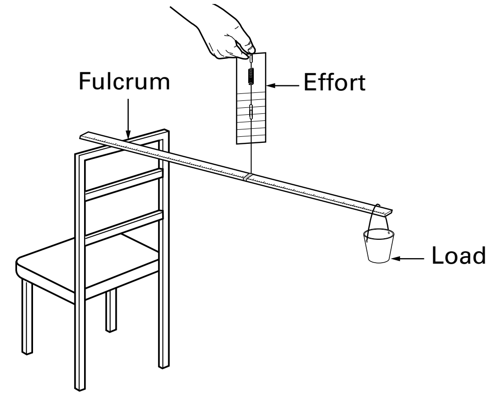
The lever in this activity is a third-class lever. The effort (whatever is used to lift the load) is located between the fulcrum (support for the lever) and the load (the object you want to lift). In this activity, the cup of pennies provided the load, the edge of the chair was the fulcrum, and your hand provided the effort. No matter where the effort is located in a third-class lever, more force is needed to lift the load than if no lever is used. It may seem that third-class levers would not be very useful machines, but they do have practical applications.

Try It!

- ★ Try changing the distance of the load arm.
- ★ Try changing the amount of weight in the cup.

Name Date

THIRD-CLASS LEVER LIFT



What You Want to Know

Does a third-class lever always make it easier to lift something?

What You Think Will Happen

When you use a third-class lever to lift something,

- **a.** it will always be easier than lifting the object without the lever.
- **b.** it will sometimes be easier than lifting the object without the lever.
- **c.** it will always be harder than lifting the object without the lever.
- **d.** it will take about the same force as lifting the object without a lever.

What Happened

Record the reading on the spring scale when you used the third-class lever to raise the load.

Load arm	Effort arm	Amount of effort (spring scale)
24 inches	6 inches	
24 inches	12 inches	
24 inches	18 inches	
24 inches	24 inches	

How much effort was needed to lift the cup of pennies without the lever?

____

What It Means

Does the third-class lever always make it easier to lift a load? Explain your answer using the measurements that you made.

____

____

If the load arm were 12 inches and the effort arm were 24 inches, how much effort do you think it would take to raise the load? Try it.

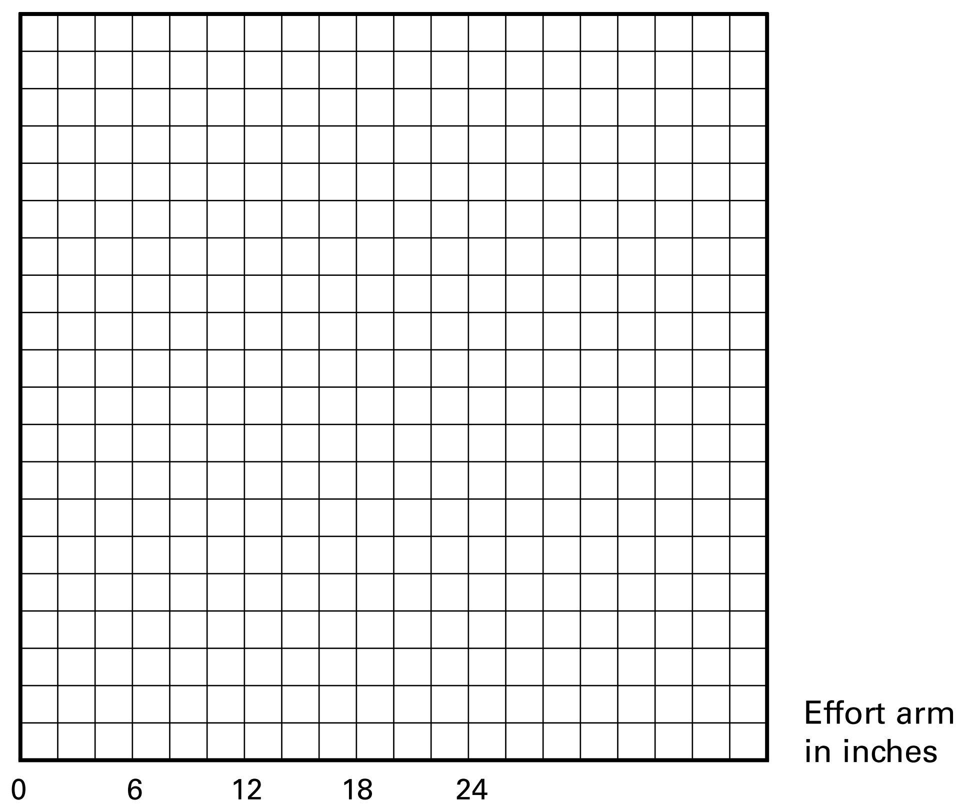
____

Graph It Next

THIRD-CLASS LEVER LIFT

GRAPH IT!

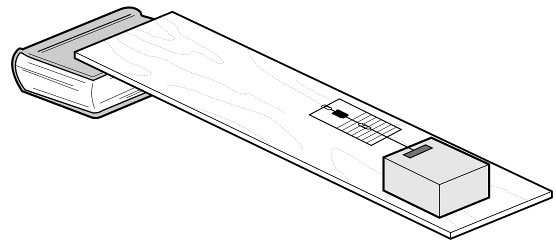
1. Label the vertical axis “effort from spring scale.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



How much effort would it take to lift the load if the effort arm were 30 inches? Mark that data point on the graph with an X.

PULLING UP A PLANE

Science It takes less effort to pull an object up an incline than to lift the object vertically.



Stuff Several small rocks; small box with cover; duct tape; scale from "Simple Spring Scale;" bookshelf board (about 3 feet × 1 foot); books

What to Do

1. Place several rocks inside a small box. Cover the box, and tape it shut.
2. Tape the lower paper clip from the spring scale to one of the top edges of the small box.
3. Prop the board on one book. Measure the height of the board from the top of the table.
4. Holding the top of the spring scale, lift the box straight up to the height of the bookshelf. Record the position of the upper paper clip.
5. Place the box on the lower end of the board. Hold the top of the spring scale level with the board, and slowly and steadily pull the box up the board. Record the position of the upper paper clip as you move the box.
6. Repeat steps 3, 4, and 5 using two, three, four, and five books to prop up the board.

What's Going On Here

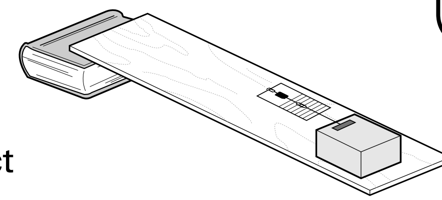
When you lift the box with the spring scale, you are doing work against gravity; gravity is pulling the box down, and you are pulling it up. When you lift the box vertically a given distance, you must use a force equal to the weight of the box itself. The work done on the box is equal to the force times the vertical distance the box moved. You need less force to move the same box up a ramp. But you need to move the box a longer distance on the ramp to get it to the same height than when you lifted it straight up.

Try It!

- ★ Try pulling other objects up the ramp.
- ★ Try a longer ramp or a shorter ramp.

Name Date

PULLING UP A PLANE



What You Want to Know
How much force does it take to move an object up a ramp?

What You Think Will Happen
Compared to the amount of force needed to lift an object straight up, the amount of force needed to drag it up a ramp is

a. about the same.

b. more.

c. less.

What Happened
Record the numbers from your spring scale in the table.

Height of board	Force (number on spring scale)

What It Means
What do your observations tell you about how the amount of force to pull something up a plane changes when the height of the plane is changed?

____

____

Can you think of any places where you have seen people move things up ramps?

____

____

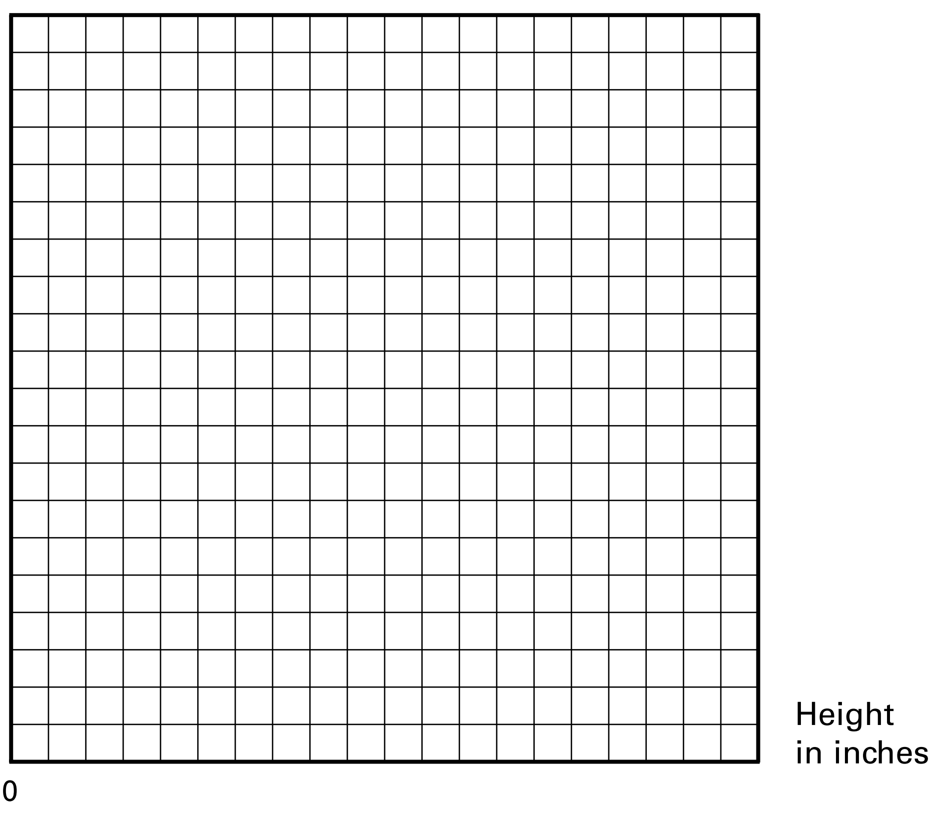
Graph It Next

Name Date

PULLING UP A PLANE

GRAPH IT!

1. Label the vertical axis “force on spring scale.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straight-edge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



What does the graph show about how the height of the board affects the force needed to pull something up the plane?

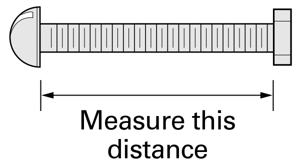
____

____

PLANE PRETENDERS

Science Screws (or nuts and bolts) are really inclined planes in disguise.

Stuff 3 nuts and matching bolts; sharp pencil; ruler (preferably with millimeter marks); marker



What to Do

1. Take one of the bolts and a sharp pencil. Place the bolt on the table, and put the tip of the pencil in the groove of the bolt near the top. Rotate the head of the bolt while holding the pencil point firmly in the groove. Continue to rotate the head of the bolt, and observe the motion of the pencil. Determine how many grooves the bolt has.
2. In the first step, you determined that the bolt has one continuous groove. Now look at the bolt from the side. Count the number of raised ridges in the entire bolt (these are called crests). Measure the length of the bolt (where the ridges are) in millimeters. Divide the number of ridges by the length of the bolt to get the "threads per millimeter" for the bolt. This is called the pitch.
3. Find the matching nut. Screw the nut onto the bolt all the way to the head of the bolt. With the marker, draw a line on the edge of the head of the bolt and the nut where the two meet.
4. Unscrew the nut five complete turns. The marker lines will help you keep track of the turns.
5. Measure the distance from the bottom of the head of the bolt to the top of the nut in millimeters.
6. Unscrew the nut five more complete turns. Measure the distance between the head of the bolt and the nut. Continue making five turns and then measuring the distance until the nut is off of the bolt.
7. Repeat the entire activity using the other two matching nuts and bolts.

What's Going On Here

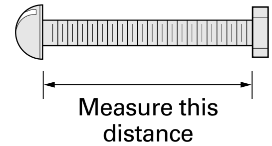
Imagine that you are a tiny flea climbing up the side of the bolt. You would be climbing up a winding hill with a constant slope. If you could flatten out the winding hill, it would look just like an inclined plane or ramp. The flea has an easier time climbing the screw by winding around it than walking straight up its side. So a screw or bolt is really an inclined plane. When the nut is screwed off the bolt, it moves a much greater circular distance around the bolt compared to the actual length of the bolt. Bolts or screws have different numbers of threads per millimeter. Bolts that have a smaller number of threads per millimeter can be compared to inclined planes with larger slopes.

Try It!

★ Try screwing screws with different numbers of threads per inch into a board. Determine which screw requires more turns to move a certain distance into the board.

Name Date

PLANE PRETENDERS



What You Want to Know

What kind of measurements can you make using nuts and bolts?
What can you find out about how nuts and bolts work together?

What You Think Will Happen

As you unwind a nut from a bolt, the distance from the head of the bolt to the nut

a. will increase steadily. **b.** will increase, but not very steadily.

The *pitch* of the bolt is the number of threads in a millimeter. Compared to a bolt with a smaller pitch, the distance the nut will move down the bolt for each turn on a larger pitch bolt will be

a. larger. **b.** smaller. **c.** about the same.

What Happened

Record the distance between the head of the bolt and the nut. Also record the pitch.

Number of turns	Bolt #1 Pitch = ____________	Bolt #2 Pitch = ____________	Bolt #3 Pitch = ____________
5			
10			
15			
20			
25			
30			

What It Means

Is there a relationship between the pitch of the bolt and the distance the nut moves down the bolt for each five turns? Explain your answer.

____

If three fleas started at the same distance from the head of each bolt and crawled around the bolt on the ridges to get to the top, the flea on which bolt would get to the top first? Explain your answer.

____

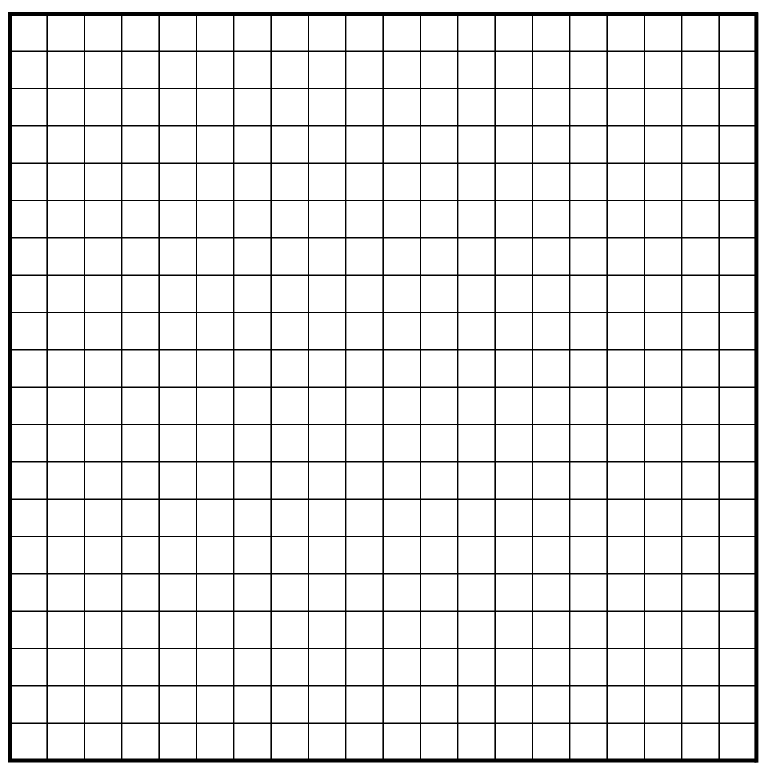
____

Graph It Next

PLANE PRETENDERS

GRAPH IT!

1. Label the vertical axis "distance in mm." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened." Use a different color for each bolt.
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot. Label each line.
4. Put a descriptive title at the top of your graph.

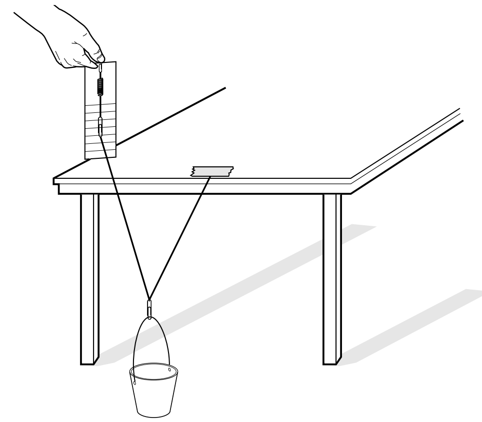


Number of turns

0 5 10 15 20 25 30 35 40

Which line is the steepest? Which bolt has the largest pitch? Are your answers the same? Explain why.

PAPER CLIP PULLEY



Science Pulleys are used to reduce the amount of effort required to lift something.

Stuff 3 paper clips; paper cup; string; yardstick; tape; table; scale from "Simple Spring Scale"; 100 pennies

What to Do

1. Poke the sharp end of one paper clip through the upper lip of the paper cup. On the opposite side of the cup, poke another paper clip through the lip.
2. Join the paper clips together to form a handle for the cup, and tie the clips together with a 12-inch piece of string. Tie the other end of the string onto the third paper clip (the pulley).
3. Tape one end of a 36-inch piece of string to the edge of a table. Loop the free end through the rounded end of the paper clip pulley. Tie the free end of the string to the spring scale's paper clip.
4. Put 20 pennies into the paper cup. Use the spring scale to lift the pennies to the height of the table. Record the reading on the spring scale.
5. Repeat step 4 with 40, 60, 80, and 100 pennies in the cup.
6. Starting with the cup on the floor, have a partner measure the distance that your hand moves as you lift the pennies to the height of the table.
7. Remove the paper clip pulley from the string attached to the cup handle. Attach the string to the spring scale's paper clip.
8. Put 20 pennies in the cup. Use the spring scale to lift the pennies to the height of the table. Record the reading on the spring scale.
9. Repeat step 8 with 40, 60, 80, and 100 pennies.
10. Starting with the paper cup on the floor, have a partner measure the distance that your hand moves as you lift the pennies to the height of the table.

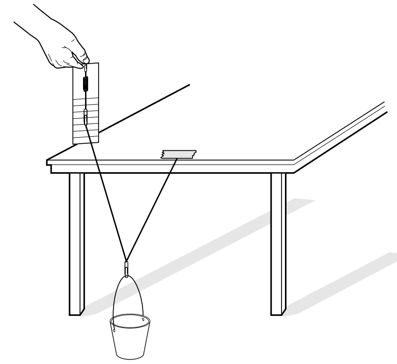
What's Going On Here

A pulley is a simple machine that trades distance for effort. In this activity, a single movable pulley is used to reduce the effort needed to lift the load by one-half. The string must be pulled through twice the distance that the load is actually lifted. Work is the product of effort (or force) and distance. The total work done to lift the load is the same whether or not a pulley is used.

Try It!

- ★ Try measuring the amount of string that is used to lift the load through a certain distance using the movable pulley.
- ★ Try other combinations of pulleys, both movable and fixed.

PAPER CLIP PULLEY



What You Want to Know

What effect does a single movable pulley have on the amount of effort that is needed to lift a load?

What You Think Will Happen

The amount of effort needed to lift a load to a certain height using a single movable pulley is

- **a.** half of the effort needed to lift it without the pulley.
- **b.** the same amount of effort needed to lift it without a pulley.
- **c.** double the effort needed to lift it without a pulley.

What Happened

Record the effort measured on the spring scale that was needed to lift a certain amount of pennies without the movable pulley and with the movable pulley.

Number of pennies in load	Effort needed to lift the load without pulley	Effort needed to lift the load using movable pulley
20		
40		
60		
80		
100		

What It Means

What do your observations tell you about how using the movable pulley affects the amount of effort needed to lift the load?

Pulleys are often used on flagpoles to raise and lower flags. Can you think of other places that pulleys are used? How do they make the job easier?

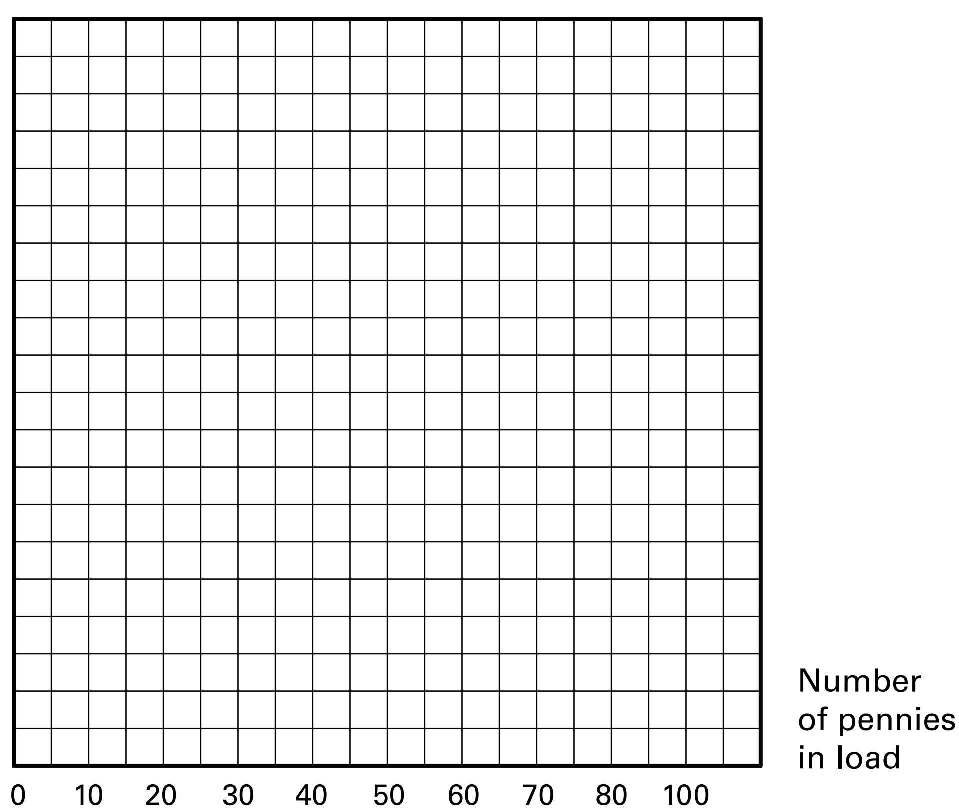
Graph It Next

Name Date

PAPER CLIP PULLEY

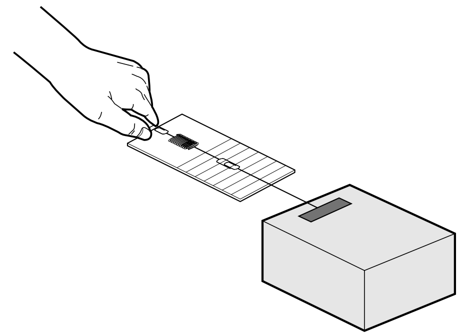
GRAPH IT!

1. Label the vertical axis “effort from spring scale.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in “What Happened.” Use a different color for “lifting the load without the pulley” and “lifting it with a pulley.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot. Label each line.
4. Put a descriptive title at the top of your graph.



Which of the lines is steeper? If you were to design a pulley system that required even less effort for each load, what would the line look like in this graph? Sketch in the line in a different color.

FRICTIONAL FORCE



Science The force needed to start an object moving over a surface is greater than the force needed to keep the object moving at a constant speed.

Stuff Several small rocks; small box with cover; tape; scale from "Simple Spring Scale"; waxed paper (3 feet); sandpaper (4 large pieces)

What to Do

1. Place several rocks inside a small box. Cover the box, and tape it shut.
2. Tape the lower paper clip from the spring scale to the top edge of the small box.
3. Hold the top of the spring scale level with the table and slowly pull the box until it *just begins to move.* Record the position of the upper paper clip on the spring scale just before the box moves.
4. Continue pulling on the box slowly and steadily, so that it is moving at a fairly constant speed. Record the reading on the spring scale when the box is being pulled along at a constant speed.
5. Tape the waxed paper to the table; repeat steps 3 and 4, pulling the box over the waxed paper.
6. Tape a piece of waxed paper to the bottom of the box; repeat steps 3 and 4 pulling the box over the waxed paper.
7. Remove the waxed paper from the box and from the table or floor. Tape the sandpaper end to end on the table; repeat steps 3 and 4.
8. Tape a piece of sandpaper to the bottom of the box; repeat steps 3 and 4, pulling the box over the sandpaper on the table.

What's Going On Here

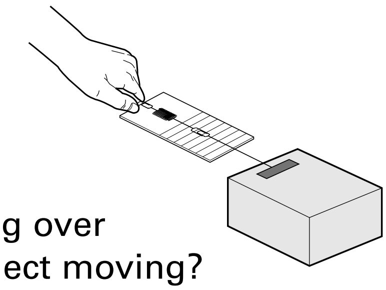
Friction is a force that opposes the motion of objects. It is caused by the irregularities in the surfaces of objects that slide over each other. Even very smooth surfaces appear rough when viewed under a microscope. Friction can be troublesome. Engineers had to develop new materials so that the space shuttle could withstand enormous heating caused by friction between the shuttle and the atmosphere on reentry. Friction can also be helpful. We want to have friction between our car's tires and the road so that the car won't skid. In this activity, you measured two kinds of friction. *Static friction* is the amount of force needed to get an object moving over a surface. *Sliding friction* is the force that is needed to keep the object moving at a constant speed over a surface. In general, static friction is greater than sliding friction. It takes more force to start an object moving over a surface than to keep it moving at a constant speed.

Try It!

★ Try using other materials on the table and on the box.

Name Date

FRICTIONAL FORCE



What You Want to Know
How much force does it take to start an object moving over a surface? How much force is needed to keep the object moving?

What You Think Will Happen
Compared to the amount of force needed to start an object moving over a flat surface, the force needed to keep the object moving will be

a. about the same. **b.** greater. **c.** smaller.

The greatest force to start the box moving will be required when there is

a. sandpaper on the box and table.

b. waxed paper on the box and table.

c. waxed paper on the table and nothing on the box.

d. sandpaper on the table and nothing on the box.

e. nothing on the table or the box.

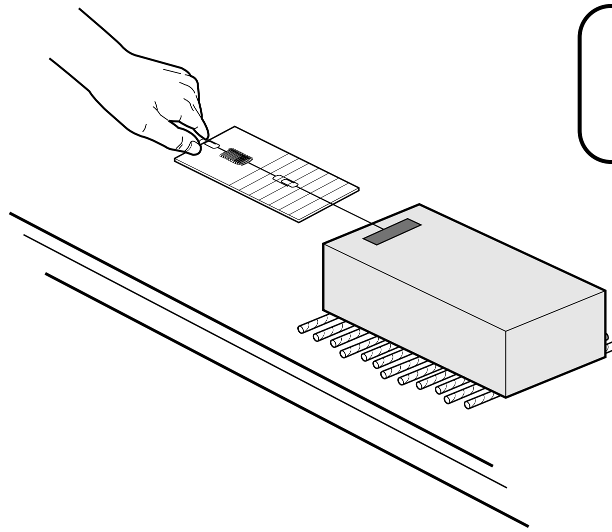
What Happened
Record the number from your spring scale in the table.

Material used		Force (number on spring scale)	
On table	On box	To get box moving	To keep box moving
Nothing	Nothing		
Waxed paper	Nothing		
Waxed paper	Waxed paper		
Sandpaper	Nothing		
Sandpaper	Sandpaper		

What It Means
What other kind of material would you like to try? Do you think the force to keep the box moving will be greater or smaller than it was for the waxed paper?

Give an example of where you have seen friction. Was it a good thing to have friction in the example you chose?

FIGHTING FRICTION



Science The force needed to start an object moving over a surface can be reduced by using rollers.

Stuff Several small rocks; small box with cover; tape; scale from "Simple Spring Scale;" 12 nonflexible straws

What to Do

1. Place several rocks inside a small box. Cover the box, and tape it shut.
2. Tape the lower paper clip from the spring scale to the top edge of the small box.
3. Hold the top of the spring scale level with the table or floor, and slowly pull the box until it *just begins to move.* Record the position of the upper paper clip on the spring scale just before the box begins to move.
4. Continue pulling on the box slowly and steadily, so that it is moving at a fairly constant speed. Record the reading on the spring scale when the box is being pulled along at a constant speed.
5. Place the straws on the table about $\frac{1}{2}$-inch apart. Place the box on top of the straws toward one end, so that as you pull the box it will ride on top of the straws. Repeat steps 3 and 4.

What's Going On Here

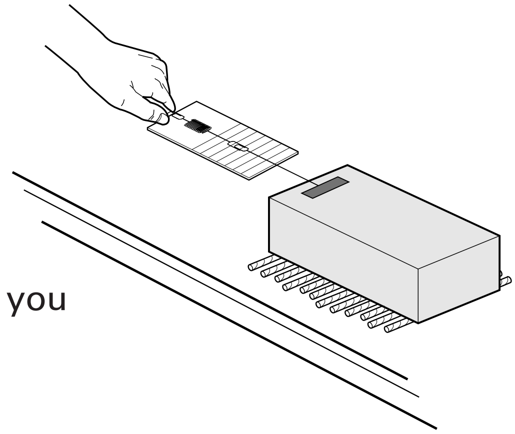
Friction is a force that opposes the motion of objects. It is caused by irregularities in the surfaces of objects that slide over each other. Even very smooth surfaces appear rough when viewed under a microscope. Friction can be very troublesome. *Static friction* is the amount of force that is needed to start an object moving. When you moved the box over the flat surface, you measured *sliding friction,* which is the amount of force that is needed to keep an object moving at a constant speed over a surface. In the previous activity, you attempted to minimize static and sliding friction by having the box slide on smooth surfaces. In this activity, you minimized friction by using wheels.

Try It!

★ Try using other rollers, such as towel tubes.
★ Try using a larger box with more weight.
★ Try using more rollers or fewer rollers.

Name Date

FIGHTING FRICTION



What You Want to Know

Will you use less force to start an object moving over a flat surface or over rollers? Will you use less force to keep it moving if you place rollers under it?

What You Think Will Happen

Compared to the amount of force needed to start an object moving over a flat surface, the force needed to start it moving using rollers will be

a. about the same. **b.** greater. **c.** smaller.

Compared to the amount of force needed to keep an object moving over a flat surface, the force needed to keep it moving using rollers will be

a. about the same. **b.** greater. **c.** smaller.

What Happened

Record the number on your spring scale in the table.

What's under the box	Force (number on spring scale)	
	To start box moving	To keep box moving
Flat surface		
Rollers		

What It Means

Did the rollers make it easier to start the box moving and keep it moving? Explain your answer using the observations you made.

Give two examples of where you have seen wheels used to make friction less.

CHAPTER

4 NEWTON'S LAWS

NEWTON KNOWLEDGE

- In this chapter you will explore some interesting concepts about motion that were discovered by Sir Isaac Newton (1642–1727). Newton was an English astronomer, scientist, and mathematician who made many important discoveries about motion and light.

- Newton's first law of motion (also called the law of inertia): An object moves in a straight line at a constant speed unless some force (a push or a pull) changes its direction or speed. An object will also stay still unless something moves it.

- A consequence of Newton's first law is that a force is needed to make an object move in a circle. When an object moves in a circle, its direction is constantly changing. The force needed to change the object's direction is called a *centripetal force.*

- Another consequence of Newton's first law is the motion of a projectile, where the vertical component of its motion is independent of the horizontal motion. In other words, how fast a thrown object falls to the ground does not depend on how fast it was thrown.

- One application of Newton's first law of motion is the design and use of seat belts. When a car stops abruptly, the passengers continue moving, unless they are somehow restrained.

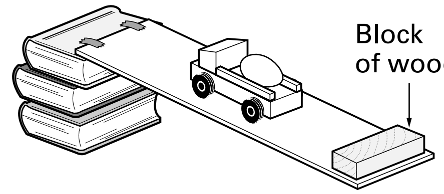
- Newton's second law of motion: The more you push or pull an object, the greater effect you have on changing its speed or direction of motion. The object will move in the direction you pushed or pulled it.

- An application of Newton's second law of motion is the design of packaging. Egg cartons and lightbulb packages are designed to lessen the impact if the cartons or packages are dropped. The packaging is designed to bring the eggs or lightbulbs to a stop more slowly so that the force on the objects is less.

- Newton's third law of motion: For every force on an object, there is an equal (in size) and opposite (in direction) force on another object.

- Newton's third law of motion is used in the design of rockets. Rockets expend fuel in one direction and move in the opposite direction.

SEAT BELT SAFETY



Science Seat belts and air bags protect the driver and passengers when a car stops abruptly.

Stuff Cardboard ramp (about 1 foot × 4 feet); several books; masking tape; small toy car; block of wood; hard boiled egg (or small doll) that fits inside car; cotton balls

What to Do

1. Tape a cardboard ramp to the top of the pile of books.
2. Tape a block of wood at the lower end of the ramp. The block of wood should be almost the same height as the front of the car.
3. Take a test run without the egg in the car by starting the car from the top of the ramp. Allow it to roll down the ramp and hit the block of wood. The car should hit the block of wood and stop. If it pitches over the wood, you will have to adjust the height of the wood stop.
4. Place the egg in the car.
5. Start the car from the top of the ramp. Observe what happens to the egg when the car hits the block of wood at the end of the ramp.
6. Use tape to secure the egg inside the car, and repeat step 5.
7. Tape cotton balls to the front of the egg that is taped in the car. Repeat step 5.
8. Remove the tape that was used to secure the egg inside the car. Tape the cotton balls to the front of the egg. Repeat step 5.

What's Going On Here

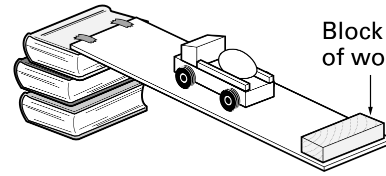
Newton's first law of motion says that an object in motion stays in motion unless some outside force acts on it. This law is also called the law of inertia. When the car with the egg in it rolls down the ramp, they are both in motion. At the end of the ramp, the car hits the block of wood and stops abruptly. If the egg is not fastened securely in the car, it continues moving, right over the top of the block of wood, and may even crack on the table or floor. This shows what can happen if you are not wearing seat belts and your car stops suddenly, as it would in an accident. When the egg is taped securely in the car, it stops along with the car at the end of the ramp. It may pitch forward a little bit, and the egg may actually hit the block of wood at the end of the ramp. Similarly, when you wear your seat belt, you may be injured in an accident, but you generally stay inside the car. The cotton balls attached to the front of the egg cushioned the egg when the car hit the block of wood, just as air bags do in real cars.

Try It!

- ★ Try using a raw egg for a more dramatic effect. Place newspapers under the end of the ramp to minimize the mess.
- ★ Try a small balloon instead of the cotton balls.

Name Date

SEAT BELT SAFETY



What You Want to Know

How do seat belts and air bags keep you safe in cars?

What You Think Will Happen

When you roll a car with an egg in it down a ramp and the car hits a block of wood at the end of the ramp, the egg will be the safest if

a. it is taped inside the car.

b. it has cotton balls taped to its front.

c. neither (a) nor (b).

d. both (a) and (b).

What Happened

Record what happened each time you rolled the car down the ramp.

Egg inside the car	What you observed
No tape or cotton balls	
Tape only on egg	
Tape and cotton balls on egg	
Cotton balls only on front of egg	

What It Means

What do you think the tape that holds the egg inside the toy car is like in a real car?

____

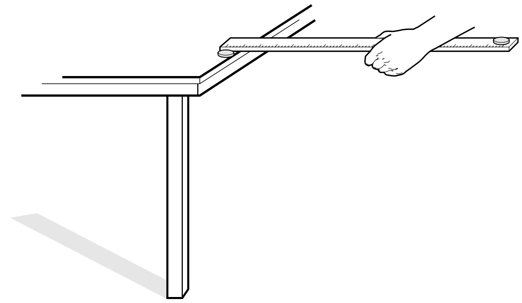
What do you think the cotton balls in the toy car are like in a real car?

____

What do your observations tell you about why you should wear seat belts when riding in a car?

____

PLUNGING PENNIES



Science An object that is thrown straight out will hit the floor at the same time as an object that is dropped from the same height.

Stuff 2 pennies; table; flat ruler

What to Do

Because you need to hear the sound of the pennies hitting the floor, this activity should be done over a hard floor.

1. Hold one penny in each hand, and drop both pennies from the same height at the same time. Listen to the sound as they hit the floor.
2. Hold one penny in each hand, and drop the pennies from different heights at the same time. Listen to the sound as they hit the floor.
3. Place one penny at the edge of a table.
4. Place one end of the flat ruler just behind the penny, with the other end of the ruler extending out from the table at an angle.
5. Place the second penny on the end of the ruler that is beyond the table's edge.
6. With your thumb and forefinger on either side of the middle of the ruler, twist the ruler abruptly, so that the penny on the edge of the table flies out and the penny on the ruler falls straight down.
7. Listen for the sound of the pennies as they hit the floor.
8. Measure the distance from the floor just below the edge of the table to where each penny hit the floor.
9. Repeat steps 3 through 8 two times.

What's Going On Here

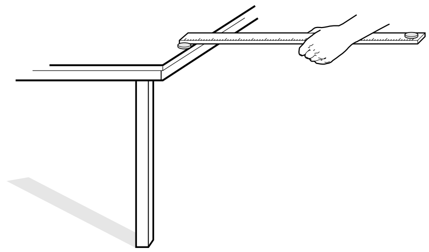
When you abruptly twist the ruler, the penny that is on the ruler falls straight down. The penny that is on the table also falls down, but it is also moving out in a horizontal direction. The penny that was on the ruler will land almost next to the table. The other penny will land some distance away from the table because of its horizontal motion. Both pennies hit the floor at the same time because the vertical motion of the pennies is independent of their horizontal motion. They fall to the floor at the same rate no matter how much horizontal speed they begin with. If you could snap the ruler so that the flying penny had a speed of 100 miles per hour, it would still hit the floor at the same time as the penny that fell straight down. Of course, the flying penny would land very far away from the table.

Try It!

- ★ Try other coins.
- ★ Place a target on the floor, and see how close you can get to it with the flying penny.

Name Date

PLUNGING PENNIES



What You Want to Know

Which will hit the floor first, a flying penny or a penny dropped straight down from the same height?

What You Think Will Happen

When you drop two pennies from the same height at the same time,

a. they both hit the floor at the same time.

b. they hit the floor at different times.

When you drop two pennies from different heights at the same time,

a. they both hit the floor at the same time.

b. they hit the floor at different times.

When one penny drops straight to the floor and another one drops from the same height but also flies outward,

a. they both hit the floor at the same time.

b. they hit the floor at different times.

What Happened

Indicate whether the pennies hit the floor at the same time or at different times.

Pennies dropped	How they hit the floor
From the same height	
From different heights	
From ruler	

Record the distance the pennies traveled from the table when they were pushed by the ruler.

Trial number	Distance from the table
1	
2	
3	

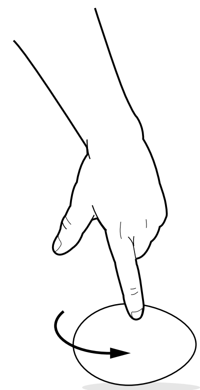
What It Means

What do your observations tell you about how the outward motion of an object affects how fast it falls to the floor and how far it travels?

ENERGETIC EGGS

Science Newton's first law can be used to determine if an egg is raw or cooked.

Stuff Paper; hard-boiled eggs; raw eggs



What to Do

1. On a piece of paper, write down as many ways as you can think of to tell if an egg is raw or cooked, without breaking the egg.
2. Spin the cooked egg on its side. Touch the egg momentarily in the middle with your forefinger. Pull your finger away. The egg should stop spinning.
3. Spin the raw egg on its side. Touch the egg momentarily in the middle with your forefinger. Pull your finger away. The egg should start spinning again.
4. Repeat steps 2 and 3, this time counting slowly to five before pulling your finger away.

What's Going On Here

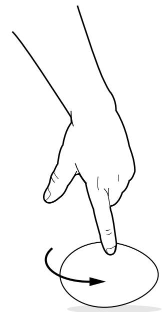
The hard-cooked egg is one solid mass. When you momentarily stop the outside shell you also are stopping the inside yolk and white. So when you pull your finger away, the hard-cooked egg stays still; there is no force to get it spinning again. Remember that by Newton's first law, a force is needed to get an object moving. The raw egg is solid on the outside and liquid on the inside. When you momentarily stop the raw egg, the inside liquid continues to move. When you pull your finger away, the egg starts spinning again; the moving yolk and white rub against the egg shell to get it spinning again. Of course, if you stop the raw egg for longer than a second or two, friction between the liquid inside and the shell will stop the yolk and white, and when you pull your finger away the entire egg will be still.

Try It!

- ★ Try your own ideas for finding out if an egg is raw or cooked, without breaking the eggs.
- ★ Try spinning and stopping other round objects.

Name Date

ENERGETIC EGGS



What You Want to Know

How can you tell if an egg is raw or cooked? Make a list of all the ways you can tell whether an egg is raw or cooked.

What You Think Will Happen

When you touch a spinning egg for just a second, and then pull your finger away, the egg will stay still if

a. it is raw.

b. it is cooked.

c. both (a) and (b).

d. neither (a) nor (b).

What Happened

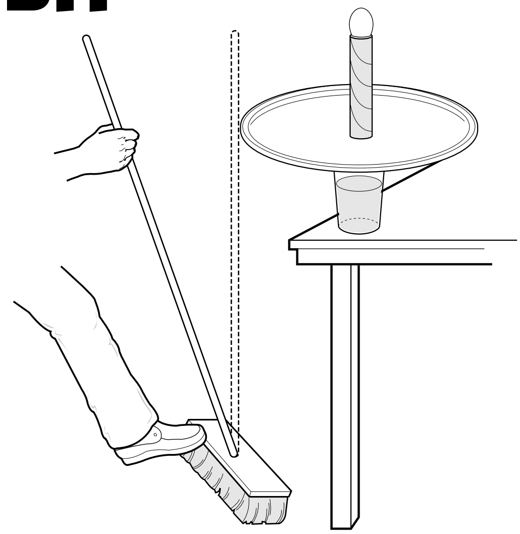
Record what happened to the spinning eggs when you removed your finger from the top of the egg.

Spinning egg	Spinning egg was touched for just a second	Spinning egg was touched for five seconds
Raw		
Cooked		

What It Means

Why do you think it is important to know whether an egg is raw or cooked?

EASY EGG EXHIBIT



Science According to the law of inertia, an object at rest stays at rest, unless a force acts on it.

Stuff Drinking glass; water; pizza pan or cardboard circle; toilet paper tube; raw egg; broom; paper towel

What to Do

Before doing this activity, make sure that no one is in front of the table, so that they do not get hit by the pizza pan. You may want to practice this activity with a cooked egg before trying it with a raw egg.

1. Fill the drinking glass about three-quarters with water.
2. Place the pan on top of the glass.
3. Stand the tube on the pan so that it is directly over the drinking glass.
4. Place the egg on top of the tube.
5. Move the entire set-up so that the edge of the pan overhangs the table top by a few inches.
6. Hold the broom directly in front of the set-up. Push down on it so the fiber bends. Place one foot on the fiber, and pull back on the upper part of the handle with your hand. Release the handle, and allow it to strike the edge of the pan.
7. Use the paper towels to clean up the mess!

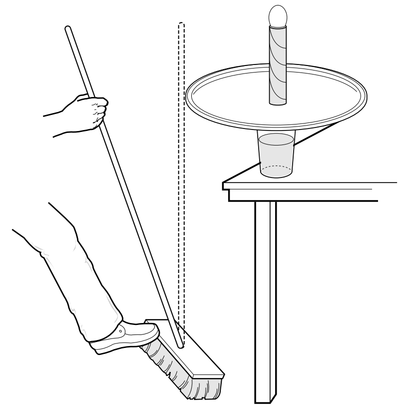
What's Going On Here

When the broom handle strikes the edge of the pan, the pan flies out from under the paper tube, and the egg drops directly into the glass of water. The egg was at rest and stayed at rest, following Newton's first law; it did not move forward as the pan did because there was no force on the egg to move it forward. The downward force of gravity on the egg allowed it to fall into the glass of water. If the pizza pan has a rim, the cardboard tube gets caught on it and sails across the room. Otherwise, the cardboard tube will probably fall into the water along with the egg.

Try It!

- ★ Try the activity with a paper cup, index card, penny, and pencil in place of the drinking glass, pan, egg, and broom.
- ★ Try the activity with three eggs, tubes, and glasses of water. What kind of record can you set for the number of eggs you can dunk?

EASY EGG EXHIBIT



What You Want to Know

What happens to an egg placed directly above a glass of water on a pizza pan when the pizza pan is quickly knocked away from under the egg?

What You Think Will Happen

Draw a picture of where you think the pizza pan, toilet paper tube, glass of water, and egg will be after the pizza pan is knocked away from under the egg.

What Happened

Draw a picture of where the pizza pan, toilet paper tube, glass of water, and egg actually were after the pizza pan was knocked away.

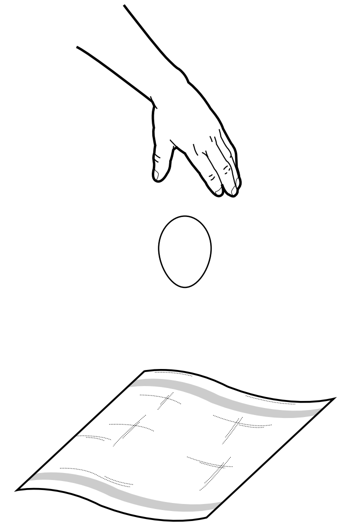
What It Means

The law of inertia says that an object at rest stays at rest unless it is acted on by a force. What stuff did the force from the broom act on?

What stuff did not have the force from the broom acting on it?

All the stuff in the activity had the force of gravity acting on it. How did gravity affect what happened to the egg?

FOWL FORCES



Science An object that stops slowly has less force on it than if it is abruptly stopped.

Stuff 3 hard-boiled eggs; paper towels

What to Do

This activity should be done outdoors.

1. Stand on a sidewalk or driveway. Hold one egg in your hand as high as your arm will reach. Drop the egg on the sidewalk or driveway. Pick up the egg, and observe it.
2. Stand on grass. Hold one egg in your hand as high as your arm will reach. Drop the egg on the grass. Pick up the egg, and observe it.
3. Have a partner hold the paper towel a few inches above the grass so that it is stretched out in a rectangle. Hold one egg in your hand as high as your arm will reach. Drop the egg on the paper towel. Pick up the egg, and observe it.
4. Drop the egg in a similar way on two other surfaces.

What's Going On Here

When you dropped the egg on the sidewalk, it cracked on impact. The egg probably did not crack when you dropped it in the grass, and it most certainly didn't crack when you dropped it on the paper towel. This activity demonstrates Newton's second law: the force on a stopping object depends on how quickly it stops. If an object comes to an abrupt stop, the force on it is greater than if it comes to a stop more slowly. A practical example of Newton's second law is when you catch a baseball. You should move your hand back as the ball enters your glove; this brings the ball to a stop slower than if your hand is stationary and the ball abruptly stops in the glove. Bringing the ball to a stop more slowly makes the force—and thus the sting on your hand—less.

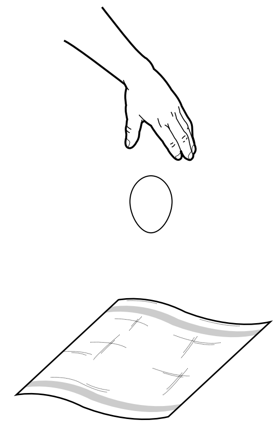
Try It!

★ Try dropping the egg on other surfaces and from other heights.

★ Try determining how high you could throw the egg upward and not have it break when it hits the towel.

Name Date

FOWL FORCES



What You Want to Know

Will an egg break when you drop it on the sidewalk, the grass, or a paper towel?

What You Think Will Happen

If you hold an egg in your hand as high as your arm will reach and then let it fall, it will crack when it hits the (you may choose more than one answer)

a. sidewalk.

b. grass.

c. paper towel.

What Happened

Record what happened to the egg when it fell on the different surfaces.

Egg dropped on	Observation
Sidewalk	
Grass	
Paper towel	

What It Means

What do your observations tell you about what type of surface is best to drop an egg on so that it won't crack?

Give an example of where you might want something to stop slowly so that the force on it is small.

Give an example of where you might want something to stop quickly so that the force on it is large.

PRECARIOUS PACKAGE

Science An object that stops slowly has less force on it than if it is abruptly stopped.

Stuff 1 raw egg; clean, empty half-pint milk carton; various packing materials (small marshmallows, tissues, paper, styrofoam cups, etc.); masking tape; paper towels

What to Do

This activity should be done outdoors. To minimize clean-up, you may want to place the egg in a plastic sandwich bag before putting it in the milk carton.

1. Design packing for a raw egg that will be placed in a half-pint milk carton and dropped from as high as your arm can reach.
2. Completely open the top of the empty milk carton so that you can easily put the packing material in it.
3. Put the packing material and the egg into the milk carton.
4. Tape the top of the milk carton shut.
5. Hold the milk carton in your hand as high as your arm will reach. Drop the carton on the sidewalk.
6. Carefully open the milk carton, and inspect the raw egg for damage.

What's Going On Here

When designing the packing for the egg inside the milk carton, the goal is to bring the egg to a stop slowly, so that the force on it is not great enough to break it. This is an application of Newton's second law, which states that the force on an object is greater when it is stopped quickly than when it is stopped slowly. The egg has a certain speed when it hits the ground. When the egg stops, there is a force on it. The more quickly it comes to a stop, the greater the force on the egg. Placing the egg in packing material makes the egg stop more slowly than the milk carton. The packing material "gives," allowing the egg to come to a stop more slowly than the milk carton. Engineers design packaging for delicate objects like eggs and lightbulbs to be lightweight and efficient.

Try It!

★ Try designing a way to drop the egg using only two pieces of notebook paper and two yards of masking tape.

★ Try dropping the egg from a greater height.

Name Date

PRECARIOUS PACKAGE

What You Want to Know

How can you design a package for an egg so that it will not break when it is placed in a milk carton and dropped from as high as your arm will reach?

What You Think Will Happen

Design packing for an egg that will be placed inside a milk carton. The milk carton will be dropped from as high as your arm will reach. The idea is that the egg should not break or crack. Draw a sketch of your design in the space below. Identify all materials you will be using.

What Happened

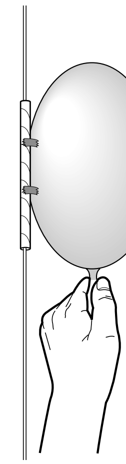
Record what happened to the egg after the milk carton was dropped on the sidewalk.

What It Means

What other packing material would you like to use? Why do you think it would be better?

Describe the packing material that is used for eggs you buy at the store. How is it better than what you used? How is it worse than what you used?

BALLOON BLAST-OFF



Science Newton's third law of motion says that if you push an object, the object pushes you back with the same force.

Stuff String; scissors; yardstick or meter stick; marker; tape; paper; balloon; straw

What to Do

1. Cut a piece of string about the same height as the room. Mark the string at six-inch intervals. Use a piece of tape to attach one end of the string to the ceiling, making sure that one of the marks on the string exactly touches the floor.
2. Cut a piece of paper into three one-inch strips the long way. Tape the strips together to make one long strip. Mark the strip at half-inch intervals from one end to the other. Label every other mark with numbers, starting with 0 at one end.
3. Inflate the balloon, but do not tie it shut. While pinching the end of the balloon, tape a straw to it at two spots about two inches apart. The open ends of the straw should be pointing to the open end of the balloon and its top.
4. Slide the string through the straw, making sure that the open end of the balloon is facing downward. If you have trouble getting the string through the straw, put a little of the string through one end of the straw and carefully suck on the other end of the straw.
5. Using the paper strip that you made in step 2, measure around the widest part of the balloon.
6. Hold the free end of the string taut on the floor. Move the balloon down the string until the pinched end is just touching the floor. Count backwards from 10. When you get to 0, release the balloon.
7. Measure the distance that the balloon moved upward on the string by noting the closest mark on the string.
8. Repeat steps 3 through 7 four times, using different amounts of air in the balloon.

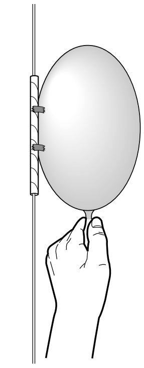
What's Going On Here

The balloon rocket is an excellent example of Newton's third law of motion, which states that for every action there is an equal and opposite reaction. When something pushes on something else, the something else pushes back on the something. In the case of the balloon rocket, the balloon pushes on the air inside to expel it. The air in turn pushes on the balloon. This force on the balloon is called *thrust;* it provides the upward force on the balloon.

Try It!

★ Try attaching some weight to the balloon.

BALLOON BLAST-OFF



What You Want to Know
How does the amount of air in a balloon rocket affect how high it can travel?

What You Think Will Happen
When a balloon rocket is almost fully inflated, it can travel upward

a. less than four feet.

b. about four feet.

c. about six feet.

d. more than six feet.

When a balloon rocket is only half inflated, it can travel upward

a. less than four feet.

b. about four feet.

c. about six feet.

d. more than six feet.

What Happened
Record the circumference (distance around) of the balloon and the height that it traveled up the string.

Circumference	Height

What It Means
What do your observations tell you about how the amount of air in the balloon affects how high the balloon can travel?

____

What could you change in this activity to make the balloon travel even farther up the string?

____

Graph It Next

Name Date

BALLOON BLAST-OFF

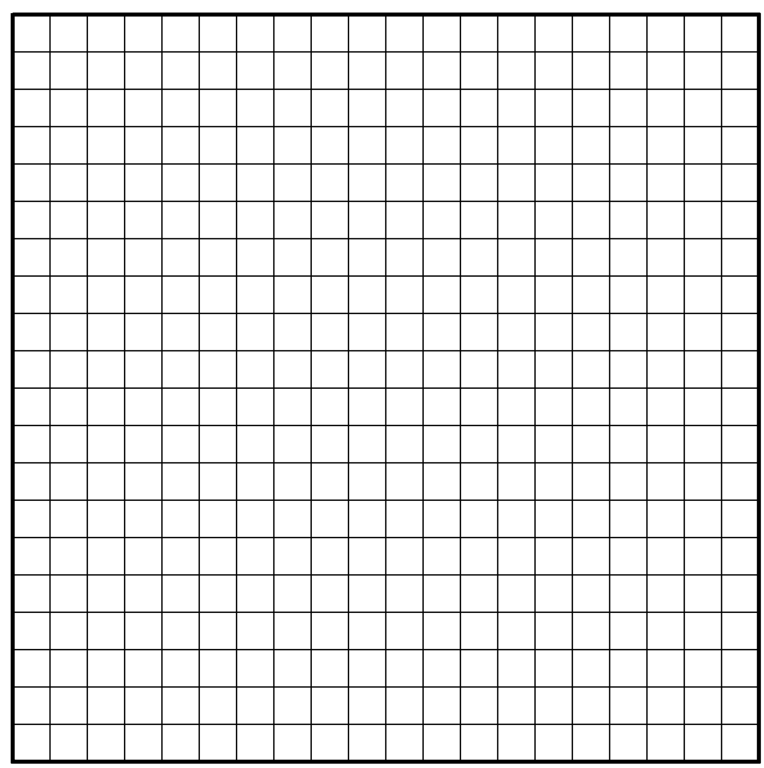
GRAPH IT!

1. Label the vertical axis "height traveled in inches." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.

2. Plot the data from the table in "What Happened."

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.

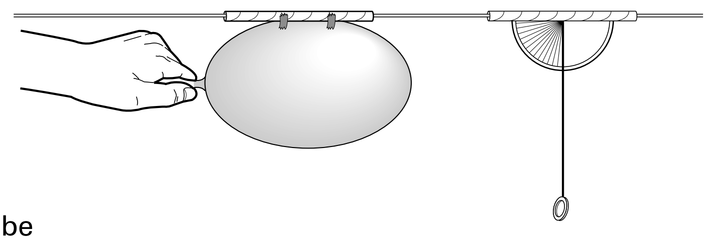


0

Circumference in inches

What are two things that limit how far the balloon can travel up the string? Explain your answer.

BETTER BALLOON BLAST-OFF



Science The forces of gravity and friction oppose the thrust of a rocket.

Stuff String; scissors; marker; yardstick or meter stick; tape; paper; balloon; straw; astrolabe from “Angles and Astrolabes”

What to Do

1. Cut a piece of string about the same height as the room. Mark the string at six-inch intervals. Use a piece of tape to attach one end of the string to the ceiling, making sure that one of the marks on the string exactly touches the floor.
2. Cut a piece of paper into three one-inch strips the long way. Tape the strips together to make one long strip. Mark the strip at half-inch intervals, and label every other mark.
3. Inflate the balloon about half way, but do not tie it shut. While pinching the end of the balloon, tape a straw to it at two spots about two inches apart. The open ends of the straw should be pointing to the open end of the balloon and its top.
4. Slide the string through the straw, making sure that the open end of the balloon is facing downward. If you have trouble getting the string through the straw, put a little of the string through one end of the straw, and carefully suck on the other end of the straw.
5. Use the long paper strip you made in step 2 to measure around the widest part of the balloon. Record this number.
6. Hold the free end of the string taut on the floor. Move the balloon down the string until the pinched end is just touching the floor. Release the balloon
7. Measure the distance that the balloon moved upward on the string by noting the closest mark on the string.
8. Repeat steps 3 through 7 using four different angles of the string. Change the angle by holding the free end of the string at different heights above the floor. Measure the angle of the string by holding the straw of the astrolabe against the string. Make sure that the balloon is inflated the same amount each time by releasing a little air or adding a little more air before you launch it. Release the balloon from the same mark on the string each time.

What’s Going On Here

Thrust is the force on the balloon caused by the air rushing out of it. Thrust causes the balloon to move in a forward or upward direction. *Gravity* is the force acting downward on the balloon; it opposes the balloon’s upward motion. *Friction* is the force between the straw and the string that the balloon is moving on; it opposes the balloon’s forward direction. Depending on the strength of these forces, the balloon will move different distances at different angles of the string.

Name Date

BETTER BALLOON BLAST-OFF

What You Want to Know

How does changing the angle of a balloon launch affect how far it can travel?

What You Think Will Happen

Compared to the distance the balloon travels when the string is straight up and down, the amount it will travel when the string is at an angle is

- **a.** about the same distance.
- **b.** farther.
- **c.** not as far.

The balloon will travel the farthest when the angle is

- **a.** 90° (straight up and down).
- **b.** at about 30°.
- **c.** at about 60°.

What Happened

Record the launch angle and the distance the balloon traveled on the string.

Launch angle	Distance

What It Means

What do your observations tell you about how the launch angle affects how far the balloon can travel?

____

What things affected how far the balloon traveled on the string?

____

____

Graph It Next

Name Date

BETTER BALLOON BLAST-OFF

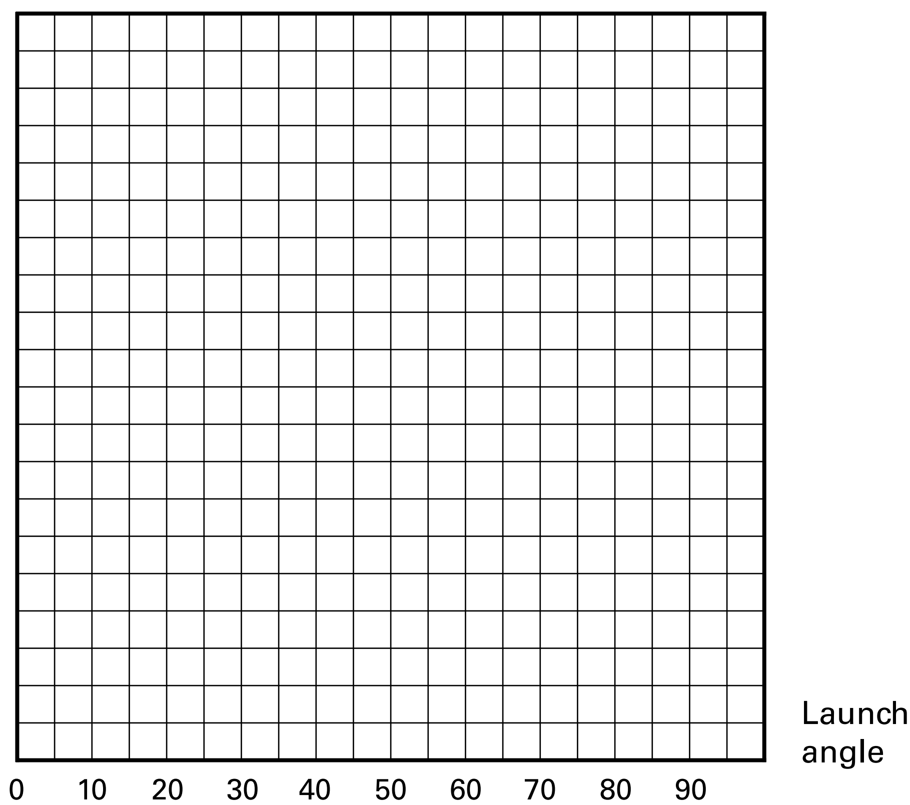
GRAPH IT!

1. Label the vertical axis “distance traveled in inches.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.

2. Plot the data from the table in “What Happened.”

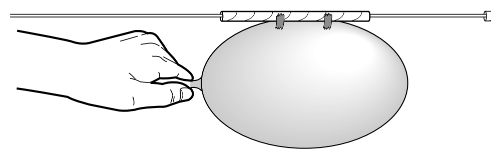
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.



At what angle did the balloon travel the farthest? __________ Put an X on this point on the graph. Draw a line that shows how far the balloon might travel at each angle if you put more air into the balloon.

BEST BALLOON BLAST-OFF



Science You can change the motion of a rocket by changing the forces on it.

Stuff String; scissors; yardstick or meter stick; straws; balloon; tape; marker; paper; small paper cups; paper clips

What to Do

This is an open-ended activity that allows students to experiment with what they observed and learned in the previous activities.

1. Cut a piece of string about 10 feet long.
2. Tie one end of the string to the back of a chair, or tape it to the end of a table.
3. Slide the string through the straw. Tie the loose end of the string to the back of another chair, or tape it to another table. The string should be almost horizontal.
4. Inflate the balloon about half way, but do not tie it shut. While pinching the end of the balloon, tape the straw to it at two spots about two inches apart. The open ends of the straw should be pointing to the open end of the balloon and its top.
5. Release the balloon, and observe its motion.
6. Using only the materials in the supply list, design a balloon rocket that will spin while moving horizontally on the string.
7. Design a balloon rocket that will move very slowly horizontally on the string.
8. Design a balloon rocket that will move very fast horizontally on the string.
9. Design a balloon rocket that uses more than one balloon.

What's Going On Here

This activity combines the concepts from previous activities while introducing opportunities for new observations. There are still three forces on the balloon rocket: thrust, gravity, and friction. Thrust, caused by the air rushing out, causes the balloon to move in a forward or upward direction. Gravity opposes the balloon's upward motion. Friction, the force between the straw and the string, opposes the balloon's forward direction. By adding other components to the balloon rocket, the interaction of these forces changes, causing the balloon to spin, move slowly, or move rapidly on the string, depending on how the rocket is designed.

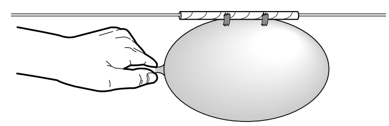
Try It!

★ Try using other materials on the balloon rocket.

★ Invent your own challenges for the balloon rocket.

Name Date

BEST BALLOON BLAST-OFF



What You Want to Know

How can you change the motion of a balloon rocket?

What You Think Will Happen

Choose one of the challenges below by drawing a circle around it.

Make the balloon rocket spin.

Make the balloon rocket move very slowly.

Make the balloon rocket move very rapidly.

Use more than one balloon on the balloon rocket.

Using the materials provided, design a balloon rocket that will perform the challenge you have chosen. Draw a sketch of your design in the space below. Identify all the materials you will be using.

What Happened

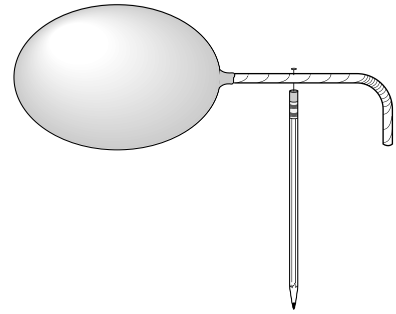
Describe the motion of your balloon rocket. How well did it perform the challenge you selected? Did you make any changes from your sketch?

What It Means

What changes would you make to your balloon rocket so that it would perform its challenge even better?

What other materials would you like to use with your balloon rocket? How would the materials be used to make the rocket meet its challenge?

BALLOON BLAST



Science For every action there is a reaction; this is Newton's third law of motion.

Stuff Balloon; flexible straw; rubber band; stick pin; small plastic bead with a hole in it; pencil with an eraser on one end

What to Do

1. Inflate a balloon, and let the air out several times. Attach the uninflated balloon to the short end of a flexible straw. Hold it in place with a rubber band.
2. Move your finger along the straw until you find a point where the straw balances well. Stick a pin through the straw at this point. Bend the straw at a right angle. Rotate the straw on the pin until it becomes fairly loose.
3. Stick the pin through the plastic bead and then into the eraser on top of the pencil. Spin the straw around the top of the pencil to make sure it turns freely.
4. Blow air into the balloon through the open end of the straw until the balloon is fully inflated. Release the straw, and watch it spin in a circle.
5. Change the angle on the straw and repeat step 4. Do this for several angles of the straw. Determine which angle provides the greatest speed.

What's Going On Here

As the balloon pushes the air out of the straw, the straw moves in a circle around the top of the pin. The straw and balloon move fastest when the straw is bent at a right angle. The movement of the straw is an example of Newton's third law of motion: for every action, there is an equal (in size) and opposite (in direction) reaction. The action here is the air being pushed backwards out of the straw. The reaction is the straw being pushed in the opposite direction.

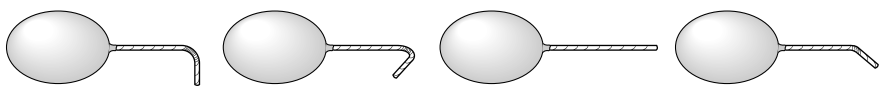
Try It!

- ★ Try inflating the balloon different amounts.
- ★ Try using several straws and several balloons.
- ★ Try bending the straw downward at an angle.

BALLOON BLAST

What You Want to Know
How can a balloon attached to a straw be made to move in a circle? How can you change the speed of the balloon?

What You Think Will Happen
Circle the drawing that shows the bend in the straw that will make the balloon move the fastest.



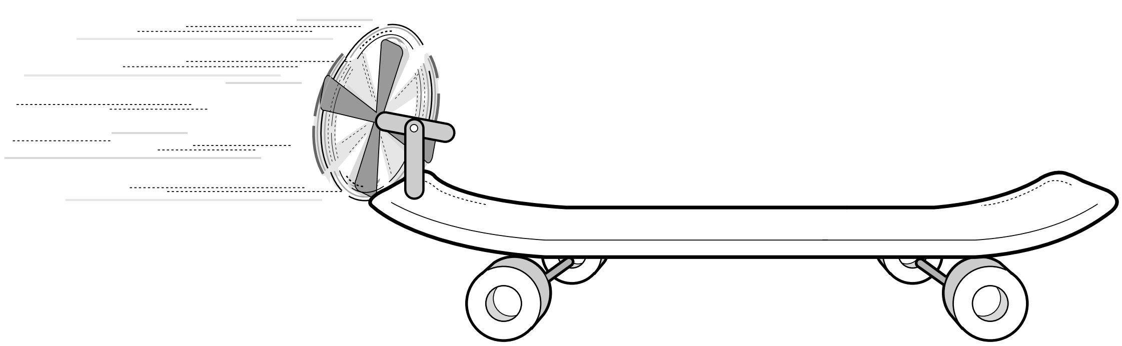
What Happened
Draw a picture of the "balloon blast" that had the greatest speed. Place the straw on the paper so that you can trace the bend in the straw.

What It Means
What could you do to the "balloon blast" to make it move even faster? What other materials would you need?

How would you attach another "balloon blast" to the first one so that, when air came out of both balloons, they would not move?

CHAPTER 5

PLAYGROUND PHYSICS



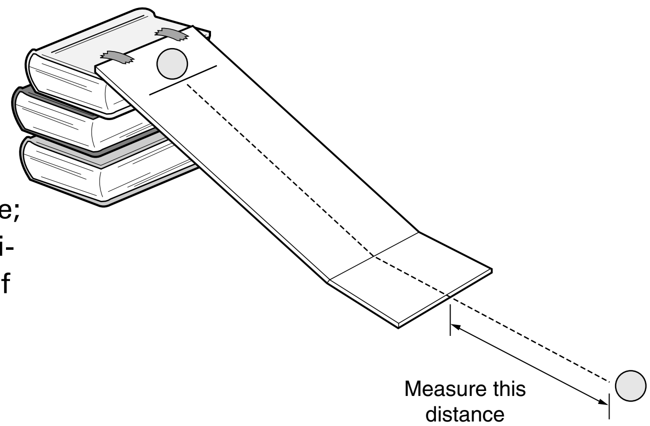
PRINCIPLES OF PLAYGROUND PHYSICS

- Many principles of physics can be explored at the playground. It doesn't take an elaborate play area, either. A swing, slide, sand box, and monkey bars will do just fine. If your playground is sparse, you can improvise by making smaller desktop versions of playground equipment and explore the same science concepts. You may want to do this anyway, as an extension of the outdoor activities.
- Friction is a force that opposes the motion of things. You can feel friction when you slide down a slide, and you can observe it by watching different objects slide down.
- An object has potential energy (stored energy) at the top of a slide. That potential energy is changed to kinetic energy (energy due to motion), which is greatest just at the bottom of the slide. In theory, the height of the slide, not the slope, determines the speed at the bottom. But in practice, friction creeps in, and the slope is very important.
- The time for a swing to go back and forth depends on the length of the swing. It doesn't depend on how many people sit on the swing or the weight of the single swinger. It depends on how far back the swing is pulled before letting go. For small angles the time doesn't change too much.
- A bouncing ball has both kinetic and potential energy. The potential energy is greatest at the top of its bounce and zero just as it hits the ground. The kinetic energy is zero at the very top of its bounce and greatest just as it hits the ground. The values for both potential and kinetic energy are in the intermediate range at the points in between the top and bottom of the bounce.
- When a ball is dropped and bounces back up, it doesn't make it back to its original height because some of its energy is changed to heat and sound energy. On each successive bounce, it will get to a smaller height until soon it will be rolling along the ground.
- You can find out the height of objects outdoors by measuring the length of their shadows on a sunny day and then using a little mathematics.
- The sandbox at the playground is a source of magnetic material. The sand comes from the earth, which has a large content of iron, which is attracted by magnets. You may be able to find other magnetic material in the sand, too.
- The force on an object moving in a circle is always directed toward the center of the circle. This is one of the least intuitive concepts in physics, but it is easily seen with the use of a bucket of water taped to a skateboard moving in a circle.

SLIPPING, SLIDING STUFF

Science Friction is a force that keeps things from moving or from moving as fast as they could.

Stuff Slide; yardstick or tape measure; small rocks; tape; 3 balls of various sizes; 3 toy cars or trucks of various sizes; 3 wood blocks of various sizes; empty shoe box



What to Do

If your playground does not have a slide, you can make a smaller desktop version of the slide by using books to prop up a bookshelf board. Make sure that the bottom of the slide is horizontal so that the objects going down the slide are able to travel horizontally for a short distance.

1. Hold the yardstick vertically against the end of the bottom of the slide, and mark the place just below the bottom of the slide with a rock or other marker. This is the point from which all measurements will be taken, so mark it carefully.
2. Pick a starting point near the top of the slide, and place a piece of tape at this point. This will be the starting point for all of the sliding stuff.
3. Release one of the balls from the starting point at the top of the slide. Make sure that as it travels down the slide, it doesn't touch any edges.
4. Measure the distance that the object travels from the point you marked in step 1.
5. Repeat steps 3 and 4 with the other balls. Repeat steps 3 and 4 with the toy cars or trucks, and with the blocks.
6. Repeat steps 3 and 4 using an empty shoe box, then the shoe box with 10 small rocks inside of it, and finally the shoe box with 20 small rocks. Tape the box shut when it has rocks in it.

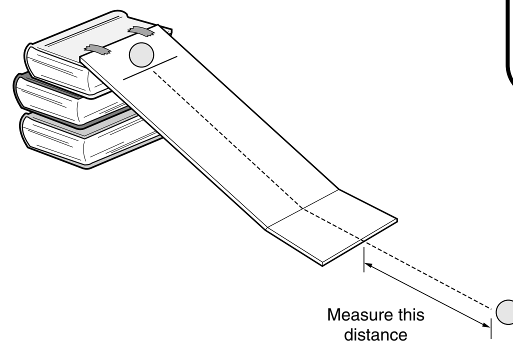
What's Going On Here

Different objects travel different distances depending on the amount of *friction* between the objects and the slide. *Friction* is a force that opposes the motion of an object. In this case, friction is caused by the irregularities in the surfaces of the slide and the sliding objects. There are two kinds of friction. *Static friction* is the friction when the object is at rest; it takes a certain amount of force to overcome this friction to get the object moving. Once the object is moving, the friction between the object and the surface it is moving on is called *sliding friction.* Sliding friction is less than static friction; it takes more force to get an object moving than to keep it moving.

In this activity, the force that overcomes static friction and sliding friction is the force of gravity. Different objects travel different distances after leaving the slide because they have different speeds at the bottom. The objects with less friction speed up more as a result of gravity and have a greater speed at the bottom than those objects with a greater amount of friction. By using different objects and also different weight in the same object (shoe box), you are able to see what variables affect friction.

Name Date

SLIPPING, SLIDING STUFF



What You Want to Know

Does the size or shape of an object affect how fast it moves down a slide?

What You Think Will Happen

In each of the four groups of objects below, write a **1** on the line next to the object that you think will travel the farthest after sliding down the slide. Write a **2** on the line next to the object that you think will travel the second farthest, and a **3** on the line for the third farthest.

Group 1

____ Small ball

____ Medium-sized ball

____ Large ball

Group 2

____ Small truck

____ Medium-sized truck

____ Large truck

Group 3

____ Small wood block

____ Medium-sized wood block

____ Large wood block

Group 4

____ Empty shoe box

____ Shoe box with 10 rocks

____ Shoe box with 20 rocks

What Happened

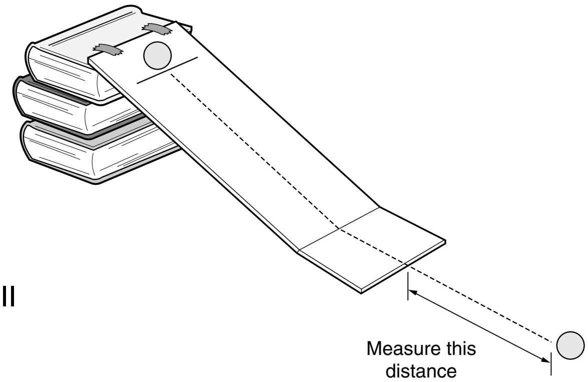
Record the objects that slid down the slide and the distance that they traveled from the end of the slide.

Object	Distance traveled

What It Means

What things affected how fast an object moved down a slide?

SLIPPING, SLIDING STUFF SEQUEL



Science Friction is a force that keeps things from moving or from moving as fast as they could.

Stuff Meter stick; slide; tape; tennis ball

What to Do

If your playground does not have a slide, you can make a smaller desktop version of the slide by using books to prop up a bookshelf board. Make sure that the bottom of the slide is horizontal so that the objects going down the slide are able to travel horizontally for a short distance.

1. Hold the meter stick vertically against the end of the bottom of the slide, and mark the place just below the bottom of the slide with a rock or other marker.
2. Place a piece of tape near the bottom of the slide where it becomes horizontal. Place a piece of tape near the top of the slide; this is the starting point.
3. Release the tennis ball from the starting point. Measure the distance that the ball traveled from the point you marked in step 1.
4. Measure the distance between the pieces of tape on the slide.
5. Place the piece of tape used for the starting point 10 centimeters closer to the bottom of the slide, and repeat steps 3 and 4.
6. Repeat steps 3 and 4, moving the starting point 10 centimeters closer to the bottom of the slide each time.

What's Going On Here

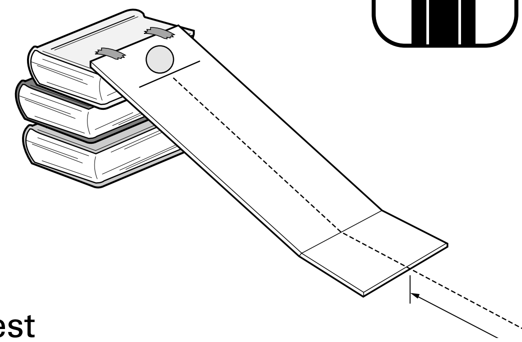
The tennis ball traveled farther after it left the slide when it was released from a point farther up the slide. When the tennis ball is released near the top of the slide, it has a greater speed at the bottom than when it was released from a point closer to the bottom of the slide. Because the ball is traveling a greater distance down the slide, gravity can act on it for a longer time, speeding it up more than when it is released nearer the bottom of the slide. Galileo performed experiments similar to this one to study the motion of falling objects. He discovered that it was much easier to measure the acceleration of an object moving down an inclined plane (slide) than to measure the acceleration of an object falling vertically. He later made inferences about what happens when an object falls vertically based on the motion of objects down inclined planes.

Try It!

★ Try other rolling or sliding objects, like golf balls, basketballs, or small dolls.

Name Date

SLIPPING, SLIDING STUFF SEQUEL



What You Want to Know

Does the point from where you release a ball affect how far it travels after sliding down a slide?

What You Think Will Happen

A ball that slides down a slide will travel the farthest after leaving the slide when its starting point is

- **a.** near the top of the slide.
- **b.** near the middle of the slide.
- **c.** near the bottom of the slide.

What Happened

Record the distance from the starting point to the bottom of the slide and the distance that the ball traveled after leaving the slide.

Distance of starting point from bottom of slide	Distance the ball traveled after leaving slide

What It Means

What advice would you give a young child who is afraid of going too far off the end of the slide after sliding down? What would you tell the child about how fast he or she would be going if he or she followed your advice?

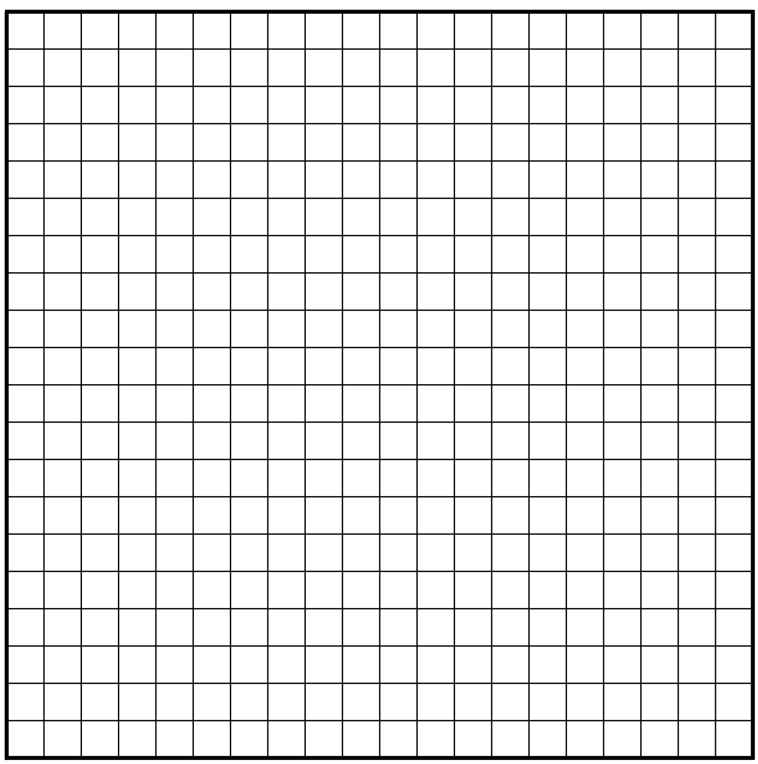
Graph It Next

Name Date

SLIPPING, SLIDING STUFF SEQUEL

GRAPH IT!

1. Label the vertical axis "distance traveled in centimeters." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

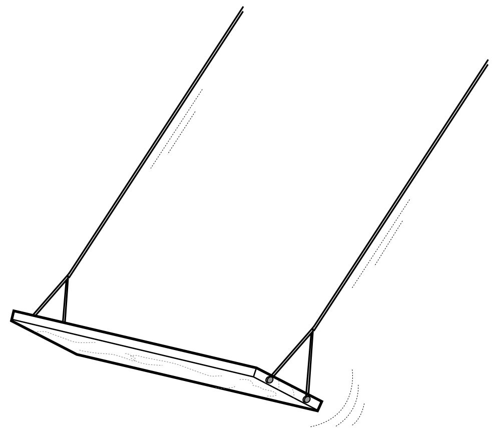


Starting point distance in centimeters

0

Use a colored pencil to draw what you think the graph would look like if you used a steeper slide. Use a different color to draw what the graph would look like if you used a slide that was less steep. Label your lines.

SUPER SWINGS



Science The time it takes a swing to go back and forth does not depend on how far you pull the swing back (as long as you don't pull it too far) or how much weight is on the swing.

Stuff Swing; meter stick or yardstick; stopwatch

What to Do

In this activity you will be timing swings. A *swing* is defined as going from one high point, passing through the low point, going up to the other high point, going back through the low point, and then reaching the original high point. You will be timing 10 swings and then dividing by 10 to determine the time for 1 swing.

1. Pull the swing back to a certain height.
2. Measure the height from the bottom of the swing straight down to the ground.
3. Release the swing, and time 10 swings. Don't push the swing—that introduces another variable, which you will be exploring in the next activity.
4. Pull the swing back to a different height, and repeat steps 2 and 3. Do this for five different heights of the swing.
5. Pull the swing back to another height. Measure the height from the bottom of the swing. Release the swing, and time 10 swings.
6. Repeat step 5 with a person in the swing. Make sure that you pull the swing back to the same height you used in step 5.
7. Repeat step 5 with two people in the swing, if possible and safe!

What's Going On Here

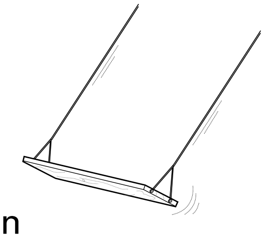
A swing is like a giant pendulum. The time that it takes the swing or pendulum to make one complete swing is called the *period* of the swing or pendulum. The period of a pendulum does not depend on the weight of the pendulum. It does depend on the height from which the pendulum is released. For small angles (height above the bottom point of the swing), the period doesn't vary much.

Try It!

★ Try to find the height where the period starts to change noticeably.

Name Date

SUPER SWINGS



What You Want to Know

Does the time it takes a swing to go back and forth depend on how high the swing starts or on how much weight is on the swing?

What You Think Will Happen

If you release the swing from a greater height, the time for a complete swing will be

a. shorter than when you release it from a lesser height.

b. longer than when you release it from a lesser height.

c. about the same as when you release it from a lesser height.

If someone sits in the swing, the time for a complete swing will be

a. shorter than when the swing was empty.

b. longer than when the swing was empty.

c. about the same as when the swing was empty.

What Happened

Record the height of the swing from the ground and the time for 10 swings. Divide the time for 10 swings by 10 to get the time for 1 swing, and record that in the table. Fill in the second table the same way.

Height of swing	Time for 10 swings	Time for 1 swing

Number of people in swing	Time for 10 swings	Time for 1 swing
0		
1		
2		

What It Means

How does the height of the swing affects the time for one swing?

____

How does the weight on the swing affects the time for one swing?

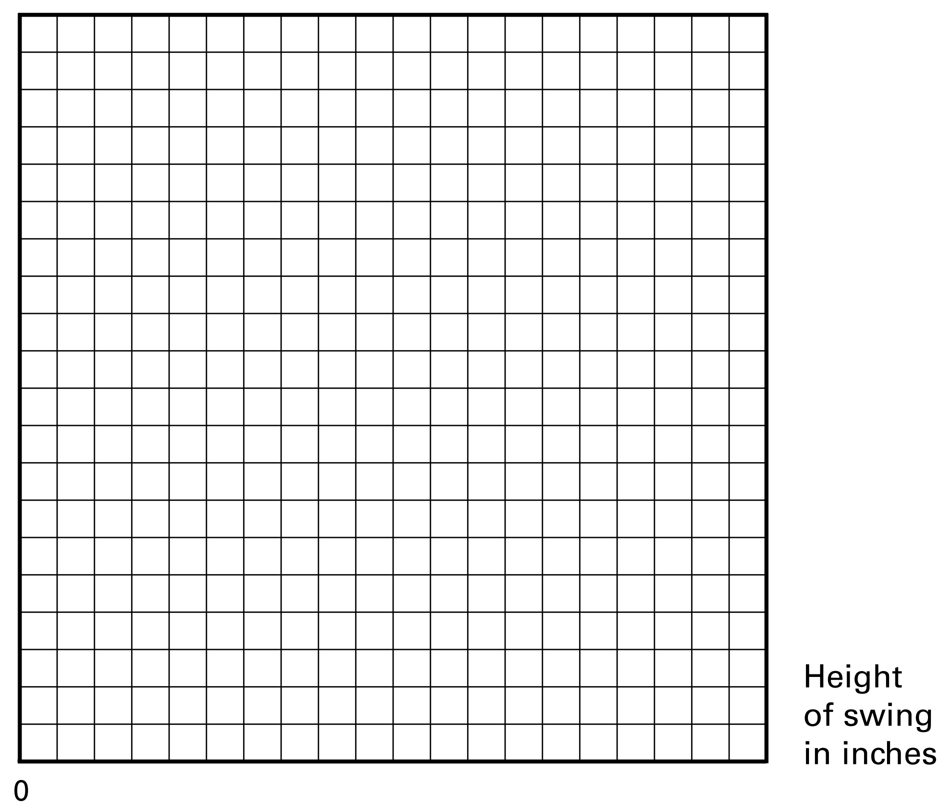
____

Graph It Next

SUPER SWINGS

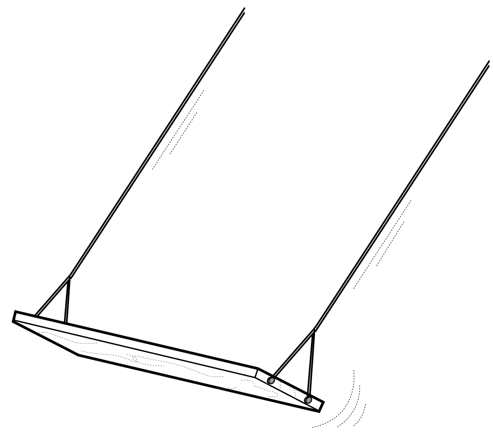
GRAPH IT!

1. Label the vertical axis "time for one swing in seconds." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data from the first table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



Use a colored pencil to draw what the graph would look like if two people were on the swing instead of one. You will need to look at the second table in "What Happened" and this graph to help you draw the line.

S'MORE SWINGS



Science The time it takes a swing to go back and forth depends on the length of the swing's chain. When you push a swing, you have to push at just the right time to keep it going.

Stuff Swing; meter stick or yardstick; stopwatch

What to Do

In this activity you will be timing swings. A *swing* is defined as going from one high point, passing through the low point, going up to the other high point, back through the low point, and then reaching the original high point. You will be timing 10 swings and then dividing by 10 to determine the time for 1 swing.

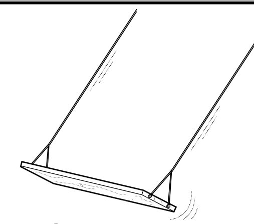
1. Measure the length of the swing from the top of the point where it is suspend-ed to the seat of the swing.
2. Pull the swing back to a certain height. Measure the height from the bottom of the swing straight down to the ground.
3. Release the swing, and time 10 swings. Don't push the swing—that introduces another variable, which you will be exploring later.
4. Have two people hold the swing's chains on each side at a point midway between the seat and the top of the chain. Measure the length from where the chain is being held to the seat at of the swing.
5. Pull the swing back to the same height as in step 2. Repeat step 3.
6. Repeat steps 4 and 5 two times with the chains held at some other point between the top and the seat.
7. Using the same length of the swing as in step 1, pull the swing back to about the same height above the ground, and give it a gentle push. Time 10 swings.
8. After timing 10 swings, push the swing *gently* each time it is at the high point of its swing back to you. Now, close your eyes and try to continue pushing the swing.

What's Going On Here

A swing is like a giant pendulum. The time that it takes the swing or pendulum to make one complete swing is called the *period* of the swing or pendulum. The period of a pendulum depends on the length of the pendulum. When the pendulum's length is one-fourth of its original value, its period is half of its original value. Giving the swing a push does not change its period. Pushing the swing with your eyes closed might seem trivial, but it demonstrates a very important concept in physics called *resonance*. This concept permeates many different topic areas of physical science. In order for the swing to keep going, the person pushing must push at just the right time. If the swing makes a complete swing in two seconds, the pusher must push every two seconds, when the swing is exactly at the top.

Name Date

S'MORE SWINGS



What You Want to Know

Does the time it takes a swing to go back and forth depend on the length of the swing or on how much of a push you give it?

What You Think Will Happen

If you shorten the chains on a swing, the time it takes to go back and forth will

a. also be shortened.

b. be lengthened.

c. not change much at all.

If you give the swing a push, the time it takes to go back and forth will

a. be about the same as when you don't push it.

b. be longer than when you push it.

c. be shorter than when you push it.

What Happened

Record the length of the swing and the time for 10 swings. Divide the time for 10 swings by 10 to get the time for 1 swing, and record that in the table.

Length of swing	Time for 10 swings	Time for 1 swing

What happened when you tried to push the swing with your eyes closed?

____

What It Means

How does the length of the swing affect the time for one swing?

____

How does pushing the swing affect the time for one swing?

____

If a swing takes a half second to make a complete swing back and forth, how often would you need to push the swing to keep it going?

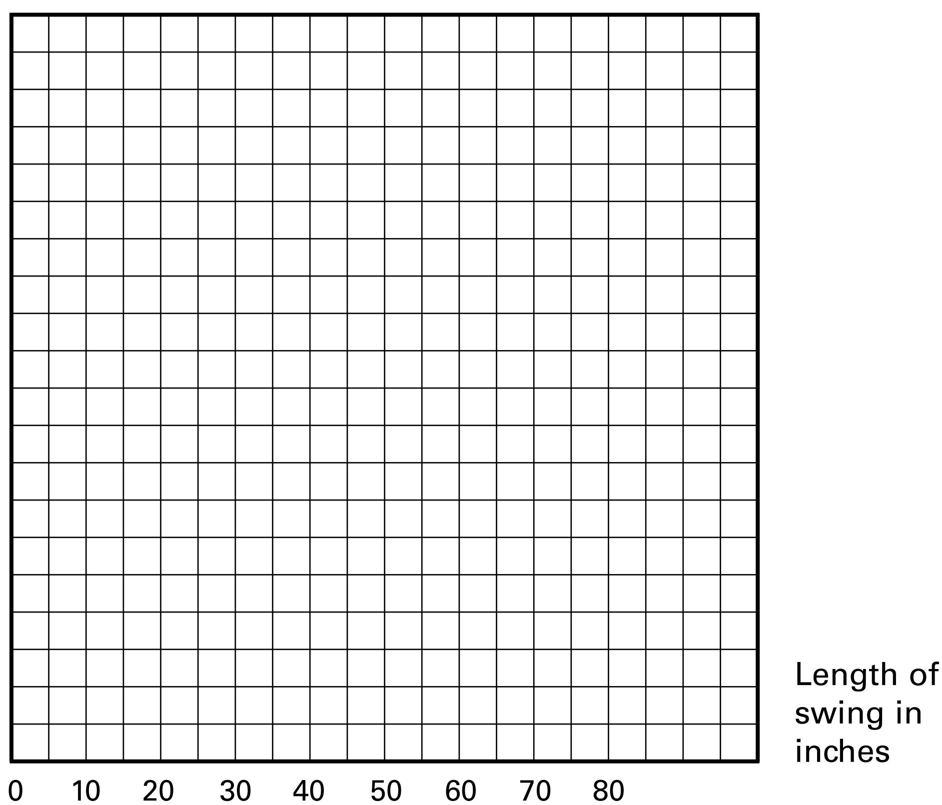
____

Graph It Next

S'MORE SWINGS

GRAPH IT!

1. Label the vertical axis "time for one swing in seconds." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

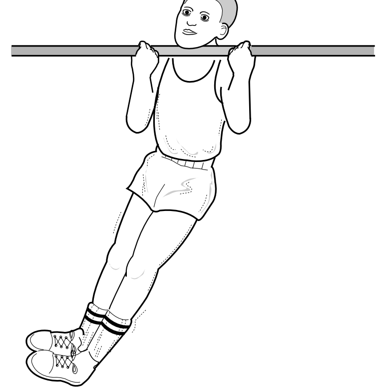


What does the graph show about how the length of the swing affects how long it takes to make one complete swing back and forth?

____

____

SWELL SWINGERS



Science The time it takes a person to swing back and forth while hanging from a bar depends on the person's height.

Stuff Bar that is at a height slightly greater than the swinger's height; stopwatch; tape; yardstick

What to Do

A *swing* is defined as going from one high point, passing through the low point, going up to the other high point, going back through the low point, and then reaching the original high point. You will be timing 10 swings and then dividing by 10 to determine the time for 1 swing.

1. Jump up to the bar, grab it with both hands, and start swinging. Once you have reached a good, safe swing, stop pumping and have a partner use the stopwatch to time 10 complete swings.
2. Repeat step 1 two times. Add the times for each set of 10 swings, and divide by 30 to get the average time for 1 complete swing.
3. Stand against a wall. Put the tape on the wall where the top of your head touches the wall. Measure the distance from the floor to the tape to get your height.
4. Have a shorter person swing from the bar and time 10 swings. Do this three times, and calculate the average time for one complete swing. Measure the height of the shorter person.
5. Have a taller person swing from the bar and time 10 swings. Do this three times and calculate the average time for one complete swing. Measure the height of the taller person.

What's Going On Here

A person swinging from a bar is actually a pendulum. The time it takes the person to make one complete swing is called the period of the pendulum. The period of a pendulum does not depend on the weight on the pendulum. The period does depend on the length of the pendulum. The time it takes for one complete swing is less for a shorter pendulum. Therefore, the shorter person should take less time to make one complete swing than the taller person. It turns out that the period depends on the height from which the pendulum is released, or in the case of the person pendulum, how far back she or he swings. But for small angles (height above the bottom point of the swing), the period doesn't vary much.

Try It!

- ★ Try continuing to pump while your partner measures the time for 10 complete swings.
- ★ Try pulling your legs up toward your chest while you are swinging to see if the time for a swing changes.

Name Date

SWELL SWINGERS

What You Want to Know

How long does it take a person to swing back and forth on a bar? Does the time it takes to swing back and forth depend on how tall the person is?

What You Think Will Happen

Record the names of three people who will be swinging from a bar and how long you think it will take each person to make one complete swing.

Person	Time to make 1 complete swing on the bar

What Happened

Record the height of each person and the amount of time it took for 10 complete swings on each of 3 trials. Add the times together, and divide by 30 to get the average time for 1 complete swing.

Person	Person's height	Time for 10 swings			Average time for 1 complete swing

What It Means

What do your observations tell you about how the height of the person affects the time for one swing?

____

____

What do you think would happen to your speed if you pulled your legs up to your chest while you were swinging? Try it.

____

____

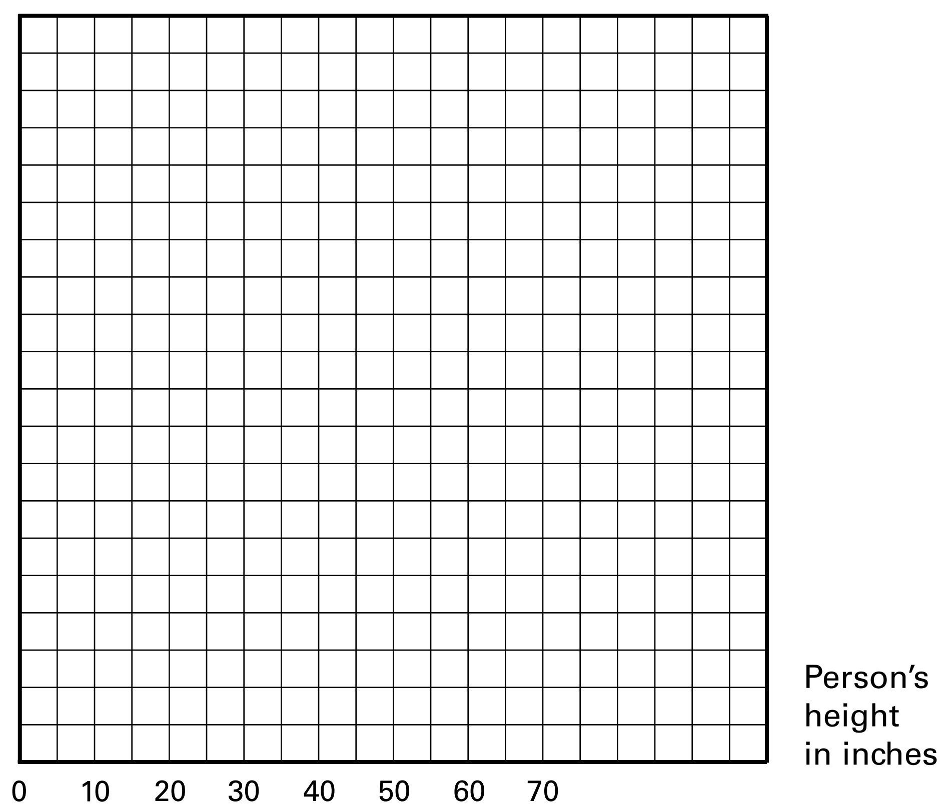
Graph It Next

Name Date

SWELL SWINGERS

GRAPH IT!

1. **1.** Label the vertical axis “time for one swing in seconds.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. **2.** Plot the data from the table in “What Happened.”
3. **3.** If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.



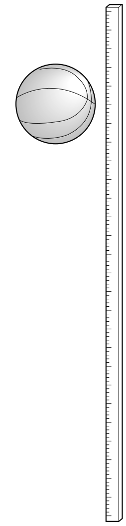
4. **4.** Put a descriptive title at the top of your graph.

What happens to the time to make one swing as the person’s height increases?

____

____

BALL BOUNCE



Science Potential energy is changed to kinetic energy when a ball bounces.

Stuff Basketball; yardstick; tennis ball; golf ball; baseball; soccer ball

What to Do

1. Hold a basketball so that the top of the basketball is 36 inches above an asphalt or cement surface. Drop the basketball. Have a partner measure how high the top of the basketball reaches after it bounces one time. Repeat this step two times, and find the average height that the basketball reaches after one bounce.
2. Repeat step 1 using the tennis ball, golf ball, baseball, and soccer ball.
3. Repeat the entire activity on grass.

What's Going On Here

When you hold the basketball above the ground, it has potential energy due to its height. That potential energy is changed to kinetic energy (energy of motion) as the ball speeds up when it falls to the ground. The potential energy is greatest when you are holding the ball above the ground. The kinetic energy is greatest just before it hits the ground. When the ball hits the ground, the ball is compressed at the point of impact. The ball then has *elastic potential energy.* That elastic potential energy is changed to kinetic energy when the ball bounces back up. The kinetic energy of the ball changes to potential energy and is greatest when the ball is at the highest point of its first bounce. The ball doesn't reach its initial height because some energy has been dissipated as sound energy (when you hear the ball's impact on the surface) and heat energy (when the ball comes in contact with the surface, friction causes the surface and the ball to become heated). Different balls will bounce to different heights because of the way they were made. When you bounce the balls in the grass, they do not bounce as high. The balls are not as easily compressed on a soft surface, so they do not acquire as much elastic potential energy.

Try It!

★ Try using other balls.

★ Try bouncing the balls on other surfaces.

Name Date

BALL BOUNCE

What You Want to Know
Which ball bounces the highest?

What You Think Will Happen
Order the falling balls from the one you think will bounce the highest to the one you think will bounce the least high.

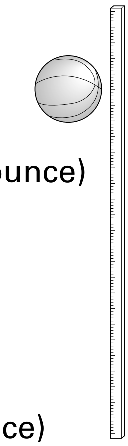
_______________ (highest bounce)

____

____

____

_______________ (least bounce)



What Happened
Record the height of the ball after its first bounce on asphalt or cement. The average height is the sum of the three heights for each ball divided by three.

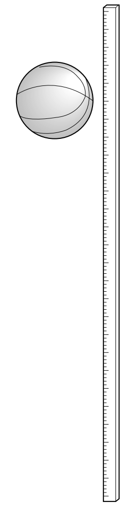
Ball	Height			Average height
Basketball				
Tennis ball				
Golf ball				
Baseball				
Soccer ball				

Record the height of the ball after its first bounce on grass.

Ball	Height			Average height
Basketball				
Tennis ball				
Golf ball				
Baseball				
Soccer ball				

What It Means
What other kind of ball could you try? How high do you think it would bounce on asphalt or cement? On grass? Explain your answers.

ANOTHER BALL BOUNCE



Science Potential energy is changed to kinetic energy when a ball bounces.

Stuff Basketball; yardstick; tennis ball; golf ball

What to Do

1. Hold a basketball so that the top of the basketball is 36 inches above an asphalt or cement surface. Drop the basketball. Have a partner measure how high the top of the basketball reaches after it bounces one time. Repeat this step two times, and find the average height that the basketball reaches after one bounce.
2. Repeat step one, but this time have a partner measure how high the top of the basketball reaches after the *second* bounce. Measure the height, and find the average height the basketball reaches after the second bounce. Do the same thing for three bounces, and if possible, for four bounces.
3. Repeat the activity using the tennis ball and golf ball.

What's Going On Here

When you hold the basketball above the ground, it has potential energy due to its height. That potential energy is changed to kinetic energy (energy of motion) as the ball speeds up when it falls to the ground. The potential energy is greatest when you are holding the ball above the ground. Its kinetic energy is greatest just before it hits the ground. When the ball hits the ground, the ball is compressed at the point of impact. The ball then has elastic potential energy. That elastic potential energy is changed to kinetic energy when the ball bounces back up. The kinetic energy of the ball changes to potential energy and is greatest when the ball is at the highest point of its first bounce. The ball doesn't reach its initial height because some energy has been dissipated as sound energy (when you hear the ball's impact on the surface) and heat energy (when the ball comes in contact with the surface, friction causes the surface and the ball to become heated). On successive bounces, the ball will reach lower and lower heights until finally it rests on the ground, all of its potential energy having been changed to heat and sound energy. When you dribble a basketball, you have to give the ball a push with your hand so that it comes back up to the same height as your hand for the second dribble.

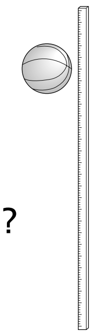
Try It!

★ Try bouncing the balls on other surfaces.

★ Try dribbling a basketball without pushing the ball downward each time. Or try pushing the ball with less or more force than you usually use.

Name Date

ANOTHER BALL BOUNCE



What You Want to Know

Will a ball bounce back up to its starting height when you drop it? How high will it bounce on its second or third bounce?

What You Think Will Happen

Fill in the table with your predictions about how high a ball will bounce on its first, second, and third bounce, after being dropped from a height of 36 inches.

Ball used	First Bounce	Second Bounce	Third Bounce
Basketball			
Tennis ball			
Golf ball			

What Happened

Record the height of the basketball after its first, second, and third bounce. The average height is the sum of the three heights for each ball divided by three.

Basketball	Height			Average height
First bounce				
Second bounce				
Third bounce				

Record the height of the tennis ball after its first, second, and third bounce.

Tennis ball	Height			Average height
First bounce				
Second bounce				
Third bounce				

Record the height of the golf ball after its first, second, and third bounce.

Golf ball	Height			Average height
First bounce				
Second bounce				
Third bounce				

What It Means

What did you notice about the height of the basketball after each bounce?

____

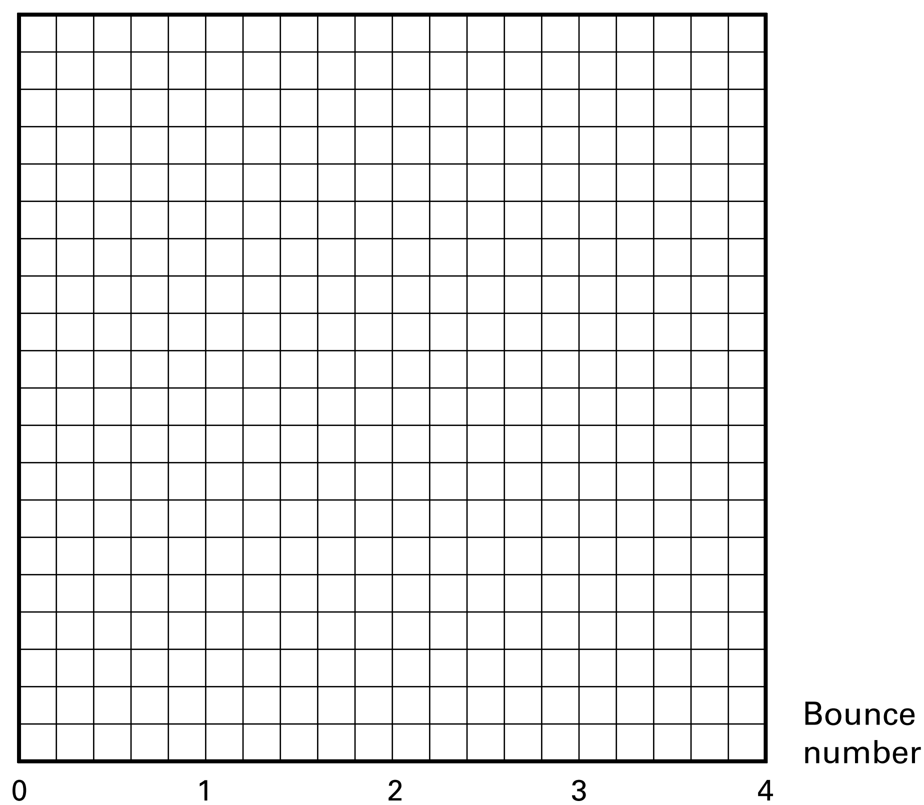
Graph It Next

Name Date

ANOTHER BALL BOUNCE

GRAPH IT!

1. Label the vertical axis “average height in inches.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the tables in “What Happened.” Use a different color for each ball.
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot. Label the lines.
4. Put a descriptive title at the top of your graph.



Use a different color to draw what you think the graph will look like for a softball. Explain why you think the graph will look that way.

SIZES OF SHADOWS

Science The length of an object's shadow changes over the course of a day as the sun's position in the sky changes.

Stuff Meter stick; clock

What to Do

1. Go outside in the middle of the morning on a sunny day, and find any stationary object. A tree, fire hydrant, sign, or basketball post will work very well. The object you choose should be upright, and its shadow should be on the flat ground, not on a slope.
2. Measure the length of the shadow of the object, starting at the base of the object and measuring to the end of the shadow. Record the time of day and the length of the shadow.
3. Repeat step 2 every 30 minutes until the middle of the afternoon.

What's Going On Here

The length of an object's shadow outside depends on the sun's location in the sky. When the sun is lower in the sky, the shadow will be longer than when the sun is higher in the sky. The length of an object's shadow changes over the course of a day. In the early morning and late afternoon, the shadow is relatively long compared to its shorter length at midday. Midday may occur at different times depending on several factors. If Daylight Savings Time (DST) is in effect, the shortest shadow will be closer to 11:00 A.M. than noon. Depending on your location in your time zone, the shortest shadow may occur earlier or later than noon. The time of year will also affect the length of the shadow.

Try It!

- ★ Try measuring the length of an object's shadow at the same time once a week for several months.
- ★ Try measuring the shadows of various objects, including yourself.
- ★ Try comparing the length of your shadow on flat ground and your shadow on a slope at the same time of the day.

Name Date

SIZES OF SHADOWS

What You Want to Know

At what time of the day are outside shadows longest? At what time of the day are outside shadows shortest?

What You Think Will Happen

At what time of day are outside shadows the longest? ____________________

At what time of day are outside shadows the shortest? ____________________

What Happened

What object did you use to measure the length of the shadows? __________

Record the time of day and the length of the shadow.

Time	Length of shadow

What It Means

What did you notice about how the length of the shadow changes over the course of a day?

____

____

Do you think the length of the shadow would be different if you repeated this activity three months from now? Explain your answer.

____

____

Graph It Next

Name Date

SIZES OF SHADOWS

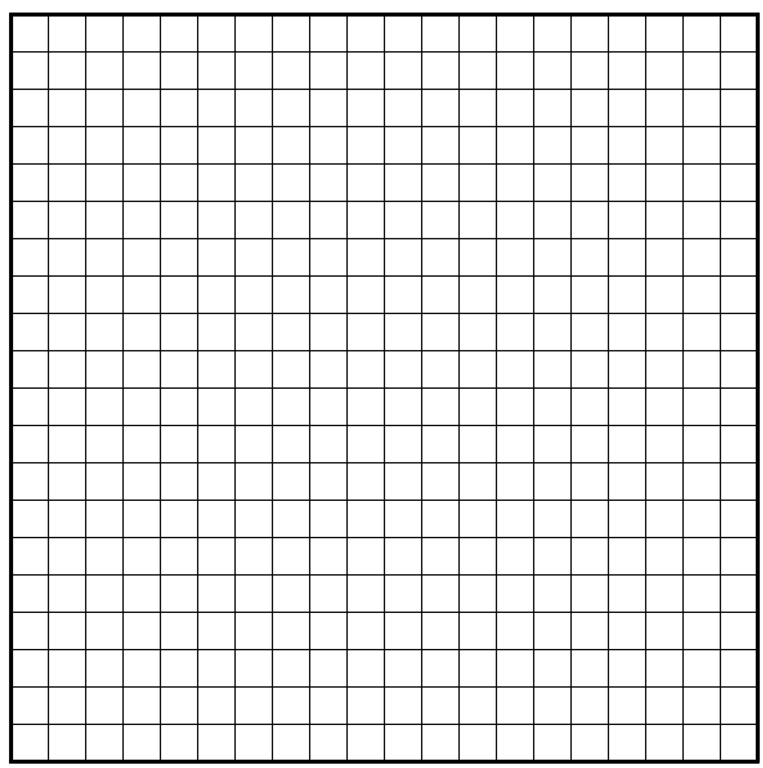
GRAPH IT!

1. Label the vertical axis "shadow length in centimeters." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.

2. Plot the data from the table in "What Happened."

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.

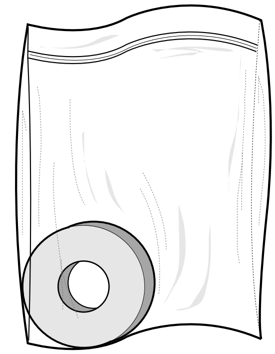


Use a colored pencil to draw what the graph might look like three months from now. Explain why you think the graph will look that way.

____

____

SORTING SAND SCRAPS



Science A magnet can be used to remove iron from playground sand.

Stuff Strong magnet; sealable clear plastic sandwich bag; playground sandbox; sheet of paper; paper cup; coins (nickel, dime, and penny); paper clips

What to Do

1. Put a strong magnet inside an empty plastic sandwich bag, and seal the top. Stick the magnet to something that is magnetic, such as a slide or the metal chains on the swings, to confirm that the magnetic force goes through the plastic.
2. Gently drag the sandwich bag through the sandbox sand for a few minutes. As you are dragging the bag through the sand, watch out for other objects that you might not want to touch.
3. Pull the bag out of the sand, and gently shake it to remove any nonmagnetic particles.
4. Hold the bag over the sheet of paper, and carefully remove the magnet from the bag so that the magnetic particles fall on the piece of paper.
5. Put a small crease down the middle of the paper, and pour the magnetic particles into the paper cup.
6. Repeat steps 1 through 5 several times to accumulate a collection of particles.
7. Bury the paper clips and coins about one-half inch below the surface. Drag the plastic bag with the magnet through the area to see if you can find the hidden stuff.

What's Going On Here

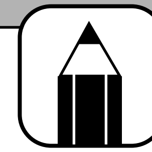
Iron particles in the sand are magnetic and will stick to the magnet even through the plastic bag. This shows that magnetic force can go through materials. Magnets are often used in industry to sort materials. In this activity, the magnet was used to sort small pieces of iron from playground sand. Much of the earth is composed of iron, so iron particles are naturally found in the soil. The sandbox sand may not have much iron in it, depending on the source of the sand. You may have noticed sandbanks along the highway or at construction sites. Generally, the sand toward the bottom of a bank has more iron in it than sand at the top of the bank, because the heavier iron sinks down toward the bottom. Soil also has bits of iron particles in it, but its harder to see because the iron is the same color as the soil.

Try It!

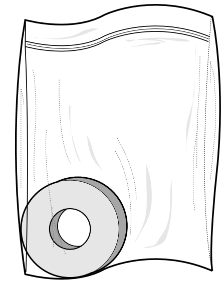
★ Try dragging the magnet through some loose soil.

★ Try dragging the magnet through the grass or other playground material.

Name Date



SORTING SAND SCRAPS



What You Want to Know

How can a magnet be used to sort material from sand?
What kinds of magnetic material are found in sand?

What You Think Will Happen

A plastic bag with a magnet in it is pulled through the sand. What do you think will stick to the magnet?

_______________ _______________ _______________

Circle the items that you think you will be able to find in the sand using the magnet.

Nickel   Dime   Penny   Paper clip

What Happened

Describe the materials that you found in the sand that were magnetic.

____

____

Which of the items that you buried in the sand were you able to find with the magnet?

____

____

What It Means

What could you find on the beach by dragging a magnet through the sand?

____

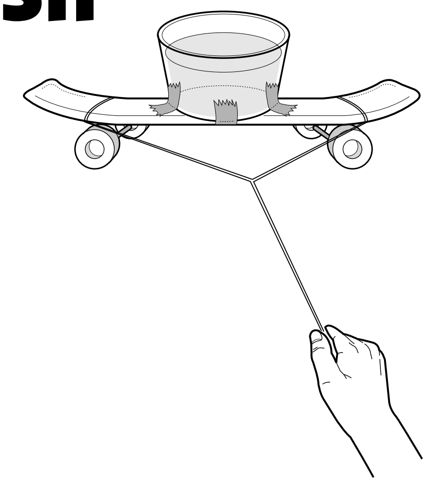
____

What could you do to make it easier to collect magnetic materials from the sand?

____

____

SKATEBOARD SLOSH



Science Water in a bucket will "slosh" in the opposite direction as the force on the bucket. The direction of the force on an object moving in a circle is toward the center of the circle.

Stuff 2 plastic buckets; water; yardstick; skateboard or small wagon; duct tape; thick string

What to Do

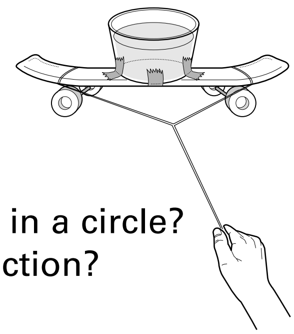
1. Fill a bucket with water to within two inches of the top. Fasten the bucket to the middle of the skateboard using generous amounts of duct tape. Fill the other bucket with water; this is the refill bucket, which you will use to add water to the bucket on the skateboard as the need arises.
2. Place the skateboard on a level surface outdoors. Push the skateboard in a forward direction. Observe the direction that the water in the bucket moves, or sloshes, at the moment you pushed the skateboard. You may have to do this step a few times to get used to watching the water slosh.
3. Add water to the bucket if too much sloshed out. This time, push the skateboard in a forward direction, and stop it suddenly. Observe the direction that the water sloshes at the moment that the skateboard is abruptly stopped.
4. Tie a three-foot length of heavy string to the skateboard near one set of wheels. Tie another three-foot length of string to the other end of the skateboard near the other set of wheels. Join the loose ends of the string with the end of another three-foot length of string.
5. Grab the loose end of the string, and standing in one spot, spin around slowly so that the skateboard moves in a circle. Observe the direction that the water sloshes in the bucket.

What's Going On Here

When you pushed the skateboard in a forward direction, you were applying a force in the forward direction, and the water sloshed backward. So the "slosh direction" was opposite to the direction of the force on the skateboard. To stop the skateboard abruptly, you had to apply a force in a direction opposite to the skateboard's motion, in other words, a backwards force and the water in the bucket sloshed in a forward direction. So again, the slosh direction is opposite to the direction of the force. Maybe it's time for a rule here: The slosh direction is opposite to the direction of the force. When you got the skateboard moving in a circle, the water sloshed away from you, and you were at the center of the circle in which the skateboard was moving. So you could say that the water sloshed away from the center of the circle. Using the rule we just deduced, the direction of the force on the skateboard must be opposite to the slosh direction. The direction of the force on the skateboard is toward the center of the circle. This force is called the *centripetal force,* or center-seeking force.

Name Date

SKATEBOARD SLOSH



What You Want to Know

What is the direction of the force on an object moving in a circle? How can you use sloshing water to determine the direction?

What You Think Will Happen

In what direction do you think the water will slosh when you move the skateboard in a circle?

____

What Happened

Record your observations of the sloshed water in the table. In the last row, determine the direction of the force on an object moving in a circle after observing the direction the water sloshed.

Direction of force on the skateboard	Direction that the water sloshed
Forward (getting a skateboard moving)	
Backward (stopping a moving skateboard)	
____________ (moving a skateboard in a circle)	

What It Means

Write a "slosh rule" that states how the direction of the force and the direction of the slosh are related?

____

In what direction does your body move when the car you are riding in abruptly stops? Explain your answer by comparing this example to one in the activity.

____

____

____

SOCCER SKILLS

Science A soccer ball will travel farther if the player's foot stays in contact with the ball for a longer time. The ball will also travel farther if the player runs toward the ball and then kicks it.

Stuff 2 cones (or other type of ground marker); soccer ball (or other type of kick ball); yardstick

What to Do

1. Place a cone on the ground at a location from which you can kick the ball.
2. Kick the ball as far as you can by standing next to the ball, pulling your leg back, and striking the ball with your foot, stopping your foot just as it touches the ball. You may have to practice this a few times. This method of kicking the ball will be called a "quick kick."
3. Quick kick the ball. Have a partner place a cone where the ball stops rolling. Measure the distance between the two cones. Repeat this step two times.
4. Now kick the ball as far as you can by standing next to it, pulling your leg back, and striking the ball with your foot, allowing your foot to remain in contact with the ball as long as it can. This is called the "follow-through kick."
5. Follow-through kick the ball. Have a partner place a cone where the ball stops rolling. Measure the distance between the two cones. Repeat this step two times.
6. Step about 10 yards from the ball. Run towards the ball, and kick it as hard as you can, keeping your foot in contact with the ball for as long as you can. This is called the "running kick."
7. Running kick the ball. Have a partner place a cone where the ball stops rolling. Measure the distance between the two cones. Repeat this step two times.

What's Going On Here

A lot of science is involved in kicking a soccer ball well. When you quick kick the ball, your foot is in contact with it for a very short time. The force that your foot exerts on the ball acts for a short time, and the ball does not accelerate (increase its speed) much; this is an application of Newton's second law. When you follow-through kick the ball, the force that you exert on the ball is about the same as in the quick kick, but since the force (your moving foot) is in contact with the ball for a longer time, the ball accelerates more. When you run toward the ball before kicking it, you have momentum. When you kick the ball, you share your momentum with the ball, and it is able to go farther than when you kick standing still. Follow through and momentum are used in every contact sport.

Try It!

★ Use the three methods to kick the ball *in the air.* Measure to where it hits the ground, not to where it rolls.

★ Compare kicking the ball as hard as you can with your toes and with the inside of your foot.

★ Compare the distances that the ball travels when you kick it with your left foot and with your right foot.

Name Date

SOCCER SKILLS

What You Want to Know

How does the way you kick a soccer ball determine how far it will travel?

What You Think Will Happen

A soccer ball will travel the farthest when you kick it

a. standing still, but stopping your foot when it touches the ball (the "quick kick").

b. standing still, but keeping your foot in contact with the ball as long as you can (the "follow-through" kick).

c. running toward the ball and kicking it (the "running kick").

What Happened

Record the distances that the soccer ball traveled when you kicked it using the different methods. Record the average of the three kicks for each method by adding the three distances together and then dividing the result by three.

Method	Distance ball traveled			Average distance
Quick kick				
Follow-through kick				
Running kick				

What It Means

What do your observations tell you about what kind of kick works best to make a soccer ball travel the farthest?

____

When you did the running kick, did you use the quick kick or the follow-through kick when you kicked the ball? Why?

____

Explain how follow-through could be used in some other sport.

____

____

CHAPTER

6

PROPERTIES OF MATTER

MATTER MEASUREMENTS

- *Mass* is the amount of matter an object has. It is measured in grams in the metric system and slugs (yes, that is right) in the English system. The reason you may not have heard of the word *slugs* is that in the United States we generally specify the amount of matter an object has by its weight (in pounds), which is the force of gravity acting on an object.

- The mass of an object doesn't change unless it loses or gains matter or travels close to the speed of light, but its weight does change depending on where the object is located on or above the earth. A pound of butter weighs a little more at sea level than it weighs at the top of a mountain and a little more at the North Pole than at the equator, but its mass is the same no matter where it travels.

- *Volume* is the amount of space an object occupies. It is measured in cubic feet, cubic centimeters, cups, gallons, milliliters, and so on.

- *Density* is the mass of an object per a given volume. Imagine a box filled with books and the same size box filled with air. They each have the same volume, but the box with the books has a much greater mass and therefore a much greater density.

- One important application of density is determining whether an object will sink or float. If a solid object is more dense than the material it is in, it will sink. If it is less dense, it will float. If its density is exactly the same, it will hover, which means that it will stay wherever you place it in the material, neither sinking nor floating.

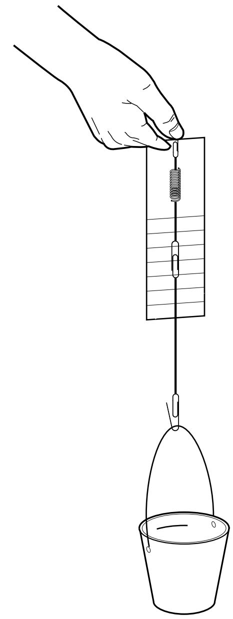
- Objects weigh less in water than in air because the force of water, called the *buoyant* force, acts in the opposite direction of gravity.

- Water changes from a liquid to a solid (ice) at 0°C or 32°F. Adding salt to water lowers its freezing temperature.

- *Surface tension* is the piling up of a liquid when the molecules of the liquid are attracted to each other in such a way that the liquid seems to defy gravity. Water has the highest surface tension of any liquid.

- The strength of a material depends on many factors, including the material itself, its thickness, its length, and how it is supported. Engineers must take these factors and others into account when they design buildings and bridges.

MEASURING MASS



Science Soil is heavier than water, and water is heavier than air.

Stuff Pencil; paper cup (5–8 oz); marker; ruler; string; scale from "Simple Spring Scale;" soil; water

What to Do

1. Use the pencil point to carefully poke two holes in the paper cup near the top, on opposite sides.
2. Make a small mark on the inside of the cup one inch from the top of the cup; this is the *fill line.*
3. Cut a piece of string about eight inches long. Tie one end of the string through one hole and the other end through the other hole.
4. Place the string handle on the lower paper clip of the spring scale, and lift the cup upward. Record the position of the top part of the middle paper clip.
5. Put soil in the cup to the fill line, and repeat step 4. Empty the cup.
6. Put water in the cup to the fill line, and repeat step 4. Empty the cup.
7. Put half water and half soil in the cup to the fill line, and repeat step 4.

What's Going On Here

The earth is made up of soil, water, and air. The measure of mass in a given volume is called *density.* In this activity, the given volume was always the same—the cup filled to the fill line. Since the volume was always the same, densities of different materials could be compared by measuring the mass of each material using the spring scale. Soil is the most dense material, a mixture of water and soil is the second most dense, water is the third most dense, and air is the least dense.

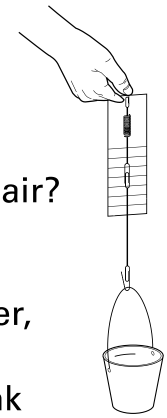
Try It!

★ Try measuring the mass of different soil samples, such as sand, topsoil, and clay.

★ Try measuring the mass of different liquids.

Name Date

MEASURING MASS



What You Want to Know

How does the mass of soil compare to the mass of water and air?

What You Think Will Happen

You will be measuring the mass of a given amount of air, water, soil, and water and soil mixed. List these four items in order from what you think will have the most mass to what you think will have the least mass.

_______________________ (most mass)

____

____

_______________________ (least mass)

What Happened

Record the number from your spring scale in the table.

Content of cup	Amount of mass (number from scale)
Air	
Soil	
Water	
Soil and water	

What It Means

What do your observations tell you about how the mass of a given amount of air compares to the mass of the same amount of water or soil?

____

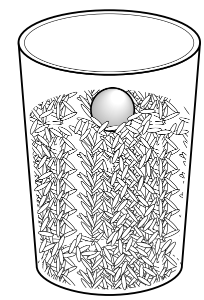
____

Which do you think has more mass: a cup of water from a clear lake or from a polluted lake? Explain your answer.

____

____

DENSITY DISCOVERIES



Science Materials placed in solids will rise or sink if the solid is broken into small bits.

Stuff 2 large plastic cups; 1 cup of white uncooked rice; marble; small plastic toy (about the size of the marble); M&M® candy; small pebble or stone; other small objects that fit inside cup (avoid flat objects like coins); 1 cup of dry dirt from outside; small box of cereal

What to Do

1. Pour one cup of uncooked rice into the plastic cup.
2. Bury the marble about $\frac{1}{2}$-inch below the top of the rice. Cover it so that you can't see the marble. Shake the cup back and forth (not up and down) on the table for about 30 seconds. If the marble is on top of the rice, just reach in and remove it. If it is not on top, dig through the rice to retrieve it, and observe how far it has sunk in the rice.
3. Repeat step 2 using the plastic toy, candy, small pebble, and any other small objects you would like to test.
4. Pour the rice out, and put one cup of dirt in the cup. Repeat step 2 using the marble, plastic toy, candy, small pebble, and any other objects you would like to test.
5. Pour the contents of the almost-empty box of cereal into one of the cups. You should have mostly cereal with some fine crumbs mixed in. Shake the cup back and forth for about a minute, and observe what has happened to the crumbs. Pour the cup of cereal into another cup, and again shake the cup back and forth for a minute. Observe what has happened to the crumbs.

What's Going On Here

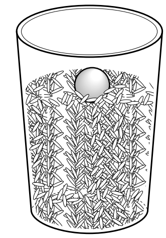
Density is the amount of mass an object has in a given volume. A common activity is to compare an object's density to that of water by determining if the object sinks or floats. In this activity, you determined whether an object sinks or floats in a solid. As you shook the cup of rice back and forth, the grains of rice settled into spaces that were unoccupied, pushing less dense objects or objects of similar density upward to the top of the rice. Objects that were noticeably denser than the rice worked their way down in the rice. Farmers deal with this phenomenon every spring in the colder climates: As the dirt in their fields settles, rocks are pushed upward toward the surface, and they have to remove these rocks before plowing the fields for planting. Anyone who has ever poured the last bowl of cereal from a box, or the last bowl of chips, knows that the crumbs are always at the bottom and the larger whole pieces are at the top.

Try It!

★ Try using salt instead of rice or dirt.

Name Date

DENSITY DISCOVERIES



What You Want to Know

What objects will rise to the surface when placed in a cup of rice that is shaken back and forth? What objects will rise to the surface of dirt?

What You Think Will Happen

Circle the objects that you think will rise to the surface when a cup of rice is shaken back and forth.

marble toy M&M® candy pebble

Circle the objects that you think will rise to the surface when a cup of dirt is shaken back and forth.

marble toy M&M® candy pebble

What Happened

Record which objects rose to the surface and which sank lower in the rice and in the dirt.

Object	In rice		In dirt	
	Rose	Sank	Rose	Sank
Marble				
Toy				
M&M® candy				
Pebble				

What happened to the crumbs when you shook the cup of cereal back and forth?

____

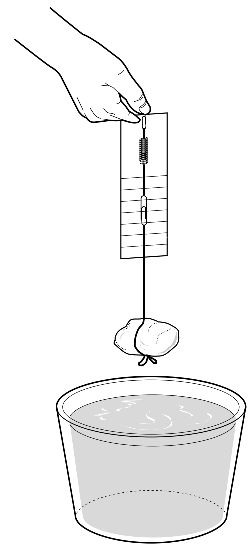
What It Means

What other stuff would you like to try in the cup of rice or dirt? Do you think it would rise to the surface or sink? Explain your answer.

____

____

WATER WEIGHT



Science Things weigh less in water than in air.

Stuff Bowl; water; string; rock; scale from “Simple Spring Scale”; golf ball; small block of wood; other small objects

What to Do

1. Fill the bowl almost to the top with water.
2. Tie the string around the rock, and then attach the string to the paper clip on the spring scale. Use the spring scale to measure the weight of a small rock in the air. Change the rubber band in the scale if it does not stretch enough to measure the mass.
3. While holding the spring scale, slowly lower the rock into the water until the rock is entirely immersed, but not touching the sides or bottom. Measure the weight of the rock in the water using the spring scale.
4. Repeat steps 2 and 3 using the golf ball, the block of wood, and other small objects. When the object floats on top of the water, the spring scale should indicate that it has no weight in the water.

What’s Going On Here

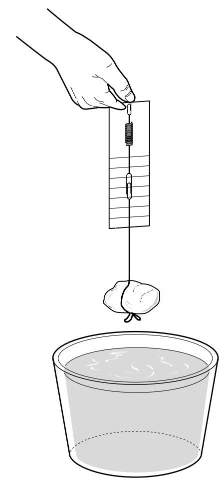
When an object is placed in water, the water exerts a force on the object, called the *buoyant force.* The buoyant force is equal to the weight of the water that the object pushes aside. When the object sinks in water, it is because the buoyant force of the water is less than the weight of the object; in other words, the weight of the water that the object has pushed aside is less than the weight of the object. When an object floats in water, its weight is equal to the buoyant force; the weight of the water that the object has pushed aside is equal to its own weight. An object that sinks in water will still weigh less in water than in air because the water is still pushing up on it with a force equal to the weight of the water it pushed aside. The difference between the object’s weight in air and its weight in water is the buoyant force on the object. When an object floats on water, its weight in water is zero; the rubber band on the spring scale is not pulled at all.

Try It!

- ★ Try finding the weight of objects in other liquids.
- ★ Try finding the weight of objects in salt water.
- ★ Try finding the weight of objects in sugar water.

Name Date

WATER WEIGHT



What You Want to Know
Do things weigh the same in water as they do in air?

What You Think Will Happen
An object's weight in water will be

a. less than it is in air.

b. more than it is in air.

c. the same as it is in air.

What Happened
Record the weight of each object in air and in water. Indicate whether the object sank or floated in the water.

Object	Sink or float	Weight in air	Weight in water
Rock			
Golf ball			
Wood			

What It Means
How did the weight of each object in water compare to the weight of each object in air?

____

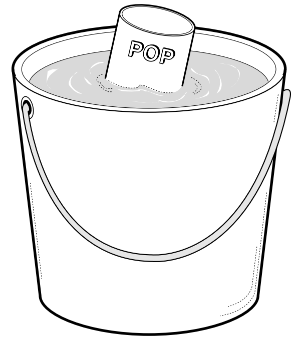
____

If you stood on a scale in a pool, do you think you would weigh more in shallow water or in deep water? Explain your answer. How could you test your answer using the rock, the spring scale, and a bowl of water? Try it.

____

____

BUOYANT BEVERAGES



Science Most cans filled with diet soft drinks float and most cans filled with regular soft drinks sink.

Stuff Bucket; water; various kinds of regular soft drinks in cans; various kinds of diet soft drinks in cans; balance; paper towels

What to Do

1. Fill the bucket about three-fourths full of water. Let the water stand for about 20 minutes so that it is at room temperature.
2. At the same time, let the cans of soft drinks come to room temperature.
3. Pick one of the soft drink cans, and determine its mass in grams using the balance. Find the volume of the can marked on the side in milliliters (ml). Calculate the density by dividing the mass of the can by its volume. The density will be measured in grams per milliliter.
4. Place the can in the water to determine if it sinks or floats.
5. Repeat steps 3 and 4 for all the soft drink cans.

What's Going On Here

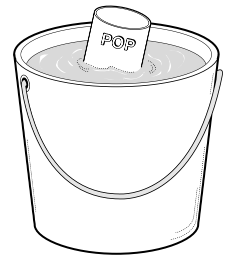
Usually the regular soft drink cans sink and the diet soft drink cans float. Regular soft drinks are sweetened with sugar or high-fructose corn syrup. Diet soft drinks are sweetened with artificial sweeteners. It takes a much greater quantity of sugar or syrup than of artificial sweeteners to sweeten soft drinks. Therefore, cans of regular soft drinks have greater mass than cans of diet soft drinks. There is some variation in the actual mass due to the filling process at the beverage factory. You may find a regular soft drink can that floats because it isn't filled as much as another. Similarly, a certain diet soft drink can may sink because it is overfilled. *Density* is the mass of something divided by its volume. The density of water at room temperature is about one gram per milliliter (1 gm/ml). Objects that have a density greater than one gm/ml will sink in the water, and objects that have a density less than one gm/ml will float in the water. In this activity, all the densities are very close to that of water and the volume measurements are only approximate, so the density readings may not be consistent with your results.

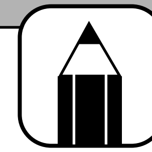
Try It!

- ★ Try other kinds of canned beverages.
- ★ Try using bottles of soda.
- ★ Try using salt water in the bucket.

Name Date

BUOYANT BEVERAGES





What You Want to Know

What kinds of canned soft drinks will sink in water? What kinds will float in water?

What You Think Will Happen

List all of the beverages that you will be using in this activity. Indicate which you think will sink and which you think will float.

Beverage	Sink	Float

What Happened

Record the mass, volume, and density for each can, and indicate whether it sank or floated. Density is mass divided by volume **(density = mass ÷ volume)**.

Beverage	Mass (grams)	Volume (mL)	Density (grams/mL)	Sank or floated

What It Means

Do you see any connection between the density of the can and whether it sank or floated? Explain your answer using numbers from the table.

____

____

How do you think you could find the density of water using the materials from this activity?

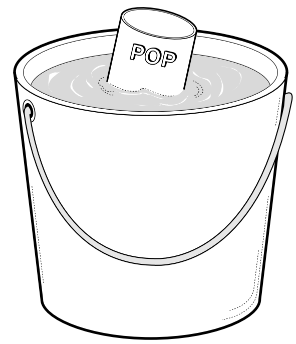
____

____

BOBBING BEVERAGES

Science When the buoyant force on an object in water is exactly equal to the weight of the object, the object will hover in the water.

Stuff Bucket; water; can of diet soft drink that floats in water; can of regular soft drink that sinks in water; empty soft drink can; 50 pennies; duct tape; Styrofoam® cups; scissors; paper towels



What to Do

This is an open-ended activity for students to experiment with what they observed and learned in the previous activity.

1. Fill the bucket almost to the top with water. Let the water stand for about 20 minutes so that it is at room temperature.
2. At the same time, let the cans of soft drinks come to room temperature.
3. Using only the materials listed above, figure out a way to make the can of diet soft drink hover in the middle of the bucket of water. When it is hovering, the can should neither sink nor float. Use the scissors to cut pieces of Styrofoam® from the cup if needed.
4. Repeat step 3 with the can of regular soft drink and with the empty soft drink can.

What's Going On Here

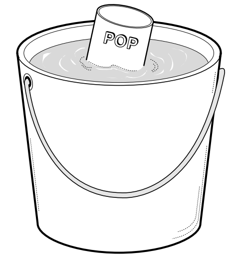
The buoyant force on an object in water is equal to the weight of the water the object pushes aside. If the buoyant force is less than the weight of the object, the object will sink. If the buoyant force is greater than the weight of the object, it will float. If the buoyant force is exactly equal to the weight of the object, the object will hover, neither floating nor sinking. Underwater exploratory vehicles are often designed to hover. It takes less energy to move a hovering vehicle in the water, because no extra energy is needed to make the object stay at the level where the exploration is being done. A hovering vehicle is a lot more maneuverable underwater than one that tends to sink or float.

Try It!

★ Try using other materials to add to the cans to make them sink or float.
★ Try using salt water in the bucket.
★ Try using plastic or glass bottles filled with beverages or that are empty.

Name Date

BOBBING BEVERAGES



What You Want to Know

What changes can you make to soft drink cans so that they will hover in the middle of a bucket of water?

What You Think Will Happen

Draw a sketch of what you think you can add to the soft drink cans to make them hover in the middle of a bucket of water. Label all the materials you will be using.

Empty can Regular soft drink Diet soft drink

What Happened

For each kind of can, describe what changes you made so that the can would hover in the middle of the bucket of water.

Can used	Changes you made to the can
Empty can	
Regular soft drink	
Diet soft drink	

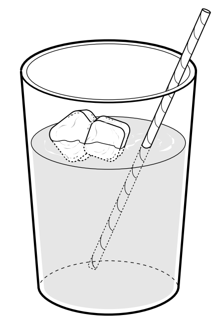
What It Means

What other materials would you like to use to make the cans hover? How would the materials be used?

FREEZING FLUIDS

Science Salt lowers the temperature at which water freezes.

Stuff Marker; 5 Styrofoam® cups; $\frac{1}{2}$ cup measuring cup: water; teaspoon; salt; 4 spoons or stirring sticks; 20 ice cubes; thermometer; watch or clock; paper towel



1 teaspoon

What to Do

1. With the marker, label the cups "2 teaspoons," "$1\frac{1}{2}$ teaspoons," "1 teaspoon," "$\frac{1}{2}$ teaspoon," and "none." Pour $\frac{1}{2}$ cup of cool water into each cup.
2. Into each cup pour the labeled number of teaspoons of salt. Do not put any salt in the "none" cup. Place a spoon or stirring stick in each cup. Stir the water in each cup until the salt is dissolved.
3. Put four ice cubes into each cup. You may have to break the ice cubes if they are too big for the cup. The ice cubes should be crowded and may even be above the water level.
4. Stir the water in each cup for one minute, alternating stirs among the cups. Record the temperature of the water in each cup, starting with the "none" cup. Dry the thermometer with a paper towel. Wait another minute, and record the temperatures again. Continue to record the temperature every minute until it seems to stay the same.

What's Going On Here

Adding salt to water lowers the freezing temperature of the water. When you add ice to regular water, the coldest the water can get is 32°F or 0°C. The ice continues to melt as the cold water warms up from the air surrounding the cup. Since salt water lowers the freezing temperature of water, the salt water solution gets lower than 32°F or 0°C. In fact, the more salt that is in the water, the lower the temperature. Salt is used to keep water from freezing on roads when the temperature dips below the freezing point of water. The more salt that is put on the road, the lower the outside temperature can drop before water freezes to ice on the roads. But salt damages cars, and used in large quantities it is not cheap, so road workers can't put too much on the road.

Try It!

- ★ Try other concentrations of salt.
- ★ Try using sugar or baking soda instead of salt.
- ★ Try pouring a little salt on an ice cube, and observe what happens.

Name Date

FREEZING FLUIDS

What You Want to Know
How does the temperature of salt water change when ice cubes are added?

What You Think Will Happen
When ice cubes are added to salt water, the solution that will reach the coldest temperature is

a. the one with the least salt.

b. the one with the most salt.

c. all of them.

What Happened
Record the temperature of each cup of salt water. Circle the lowest temperature for each cup.

Time	Temperature of salt water				
	None	$\frac{1}{2}$ teaspoon	1 teaspoon	$1\frac{1}{2}$ teaspoons	2 teaspoons
1 minute					
2 minutes					
3 minutes					
4 minutes					
5 minutes					
6 minutes					
7 minutes					
8 minutes					
9 minutes					
10 minutes					

Which solution reached its lowest temperature in the least amount of time?

____

What It Means
What do your observations tell you about how the amount of salt in water affects the temperature when ice is added to the water?

____

Graph It Next

Name Date

FREEZING FLUIDS

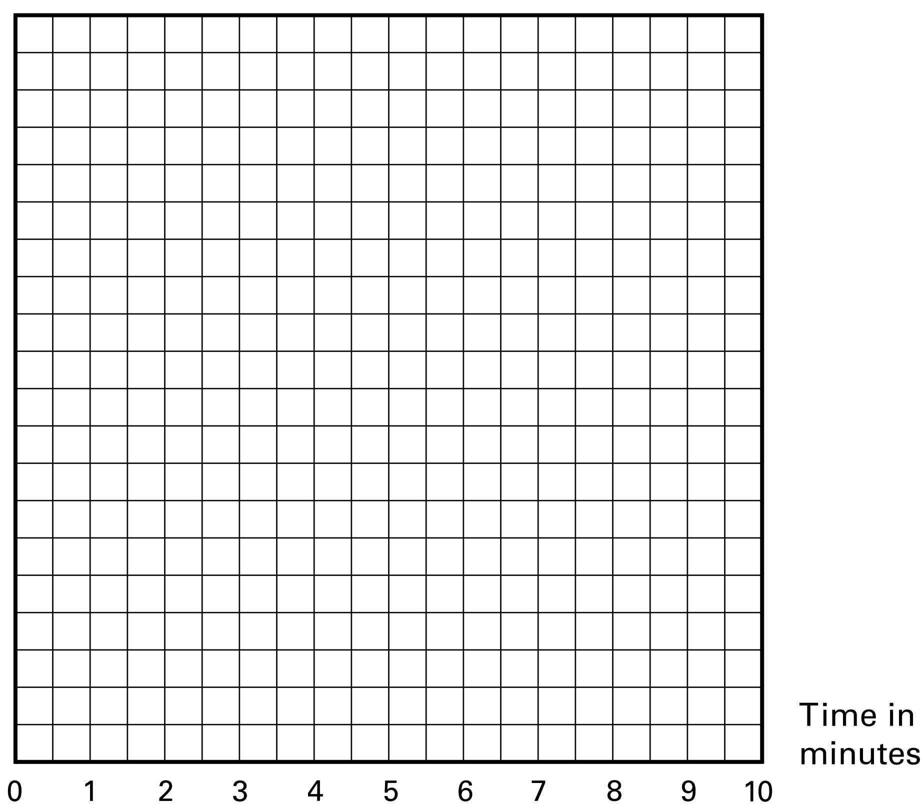
GRAPH IT!

1. Label the vertical axis “temperature in degrees F or C” (whichever you used). Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the circled data from the table in “What Happened.”

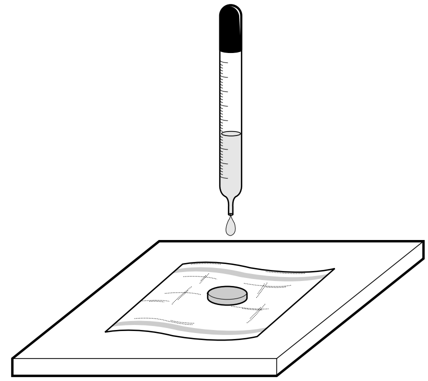
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.



How could you use this graph to give someone advice on how much salt to use to melt ice on a sidewalk?

PENNY PUDDLE



Science Surface tension allows a penny to hold more drops of water than one might expect.

Stuff 50 pennies; paper towel; eyedropper; water; nickel; dime; quarter; small paper cup

What to Do

1. Place a penny on the paper towel with the head facing up. Fill the eyedropper with water.
2. Hold the eyedropper close to the penny, and very slowly deposit drops of water on the coin. Observe the shape of the mound of water on the penny as you add more water. Count the number of drops the penny will hold before the water spills over the edge.
3. Repeat the activity with three other pennies, making sure that each one has a different year stamped on it.
4. Repeat the activity with a nickel, a dime, and a quarter.
5. Pour water into the cup so that the cup is completely filled to the brim. Add pennies to the cup until the water just starts to pour over the sides. Observe the top of the water as you add the pennies.

What's Going On Here

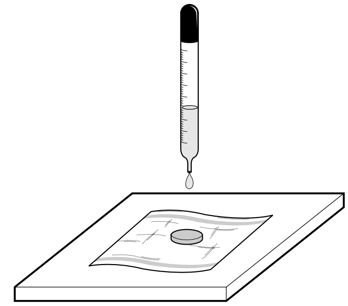
Water molecules are attracted to themselves more than they are to the surface of the penny, so the water mounds to form a curved (convex) surface on top of the penny. The name for this effect is surface tension. The number of drops of water a coin can hold is affected by several factors, including the size and age of the coin. Both of these factors were investigated in this activity. In general, older coins have been in circulation longer and have worn edges. Newer coins have higher edges that are able to hold more water. Larger coins should hold more water, but since the height of the edges is also a factor, you may find a smaller coin that holds more water than a larger coin. Water has the highest surface tension of any liquid, so you should be able to fit more drops of water on a given coin than, say, cooking oil.

Try It!

- ★ Try the activity again with a few drops of detergent in the water. Detergent decreases the surface tension.
- ★ Try nickels, dimes, or quarters that have different years stamped on them.
- ★ Try adding salt to the water.

Name Date

PENNY PUDDLE



What You Want to Know

How many drops of water can you fit on the top of various coins? How many pennies will fit into a full cup of water?

What You Think Will Happen

How many drops of water do you think can fit on the head of a

a. penny? ________ **b.** nickel? ________

c. dime? ________ **d.** quarter? ________

How many pennies do you think you could add to a full cup before the water spills? ____________________

What Happened

Draw pictures of what the water looked like on top of the penny and on top of the cup just before it spilled.

Record how many drops of water each coin held.

Coin	Drops of water
Penny (year:)	
Penny (year:)	
Penny (year:)	
Penny (year:)	
Nickel	
Dime	
Quarter	

What It Means

What factors seemed to affect how much water a coin could hold?

____

____

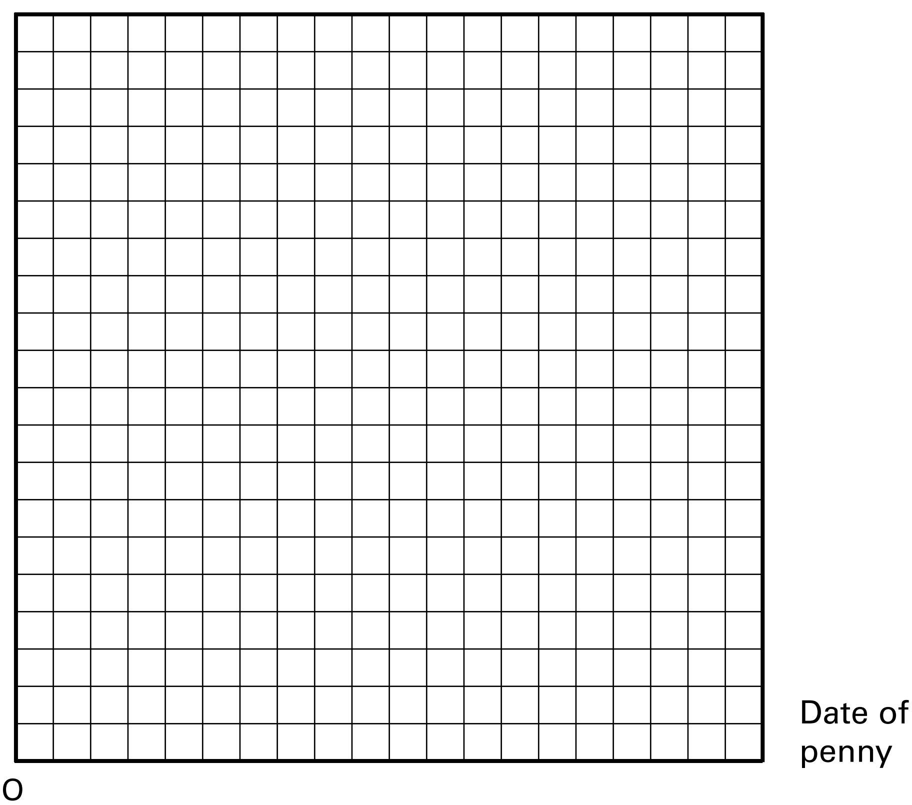
Graph It Next

Name Date

PENNY PUDDLE

GRAPH IT!

1. Label the vertical axis "drops of water." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data for the pennies from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

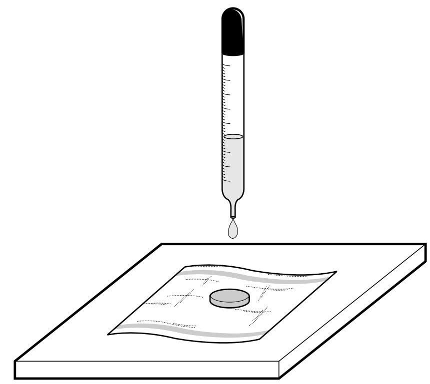


Put an X on the graph to show how many drops a brand new penny might hold. Explain why you put the X where you did.

PENNY PUDDLE PRACTICE

Science Liquids other than water exhibit a lesser degree of surface tension.

Stuff Marker; 5 small paper cups; water; salt; vinegar; spoon; rubbing alcohol; liquid detergent; 50 pennies; paper towel; eyedropper



What to Do

1. Label the five cups with the words: "water," "salt," "vinegar," "alcohol," and "detergent." Fill each glass about $\frac{3}{4}$ full of water. In the cup marked "salt," add salt and stir with a spoon until no more dissolves. In the cup marked "vinegar," fill the cup to almost to the top with vinegar and stir. In the cup marked "alcohol," fill the cup almost to the top with rubbing alcohol and stir. In the cup marked "detergent," add about 10 drops of detergent and stir. Clean and dry the spoon thoroughly after mixing each cup.
2. Place a penny with the head facing up on the paper towel. Fill the eyedropper from the cup marked "water." Holding the eyedropper close to the penny, very slowly deposit drops of water on the coin. Count the number of drops the penny will hold before the water spills over the edge.
3. Use a paper towel to dry the penny.
4. Repeat the activity with liquid from the other cups, making sure to clean the penny and eyedropper with clear water each time. Use liquid from the detergent cup last.
5. Pour water into each of the five cups until they are filled to the brim.
6. Place the cup marked "water" on a paper towel. Add pennies to the water cup until the water just starts to pour over the sides. Count the number of pennies that fit in the cup just before it spilled. Pour the water out, and carefully dry the pennies.
7. Repeat steps 5 and 6 using the cups containing salt, vinegar, alcohol, and detergent.

What's Going On Here

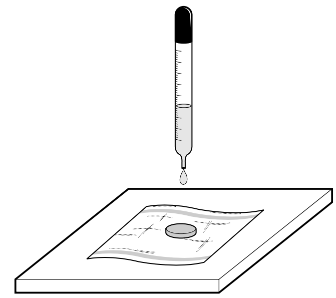
Surface tension is a property of liquids in which the molecules are attracted to each other so that the liquid mounds to form a curved (convex) surface on top of the penny. Water has the greatest surface tension of any liquid. When you dilute water with other liquids, its surface tension is less so that you can't fit as many drops of the diluted water on a penny, nor can a cup filled to the brim hold as many pennies.

Try It!

★ Try various concentrations of salt, vinegar, alcohol, or detergent in the water.

Name Date

PENNY PUDDLE PRACTICE



What You Want to Know

How many drops of different kinds of liquid can you fit on the top of a penny? How many pennies will fit into a full cup of different liquids?

What You Think Will Happen

Rank the solutions listed in the table below from 1 (most) to 5 (least) according to how many drops you think will fit on the head of a penny.

Solution	Ranked by drops that you think will fit on the head of a penny
Plain water	
Vinegar and water	
Alcohol and water	
Salt and water	
Detergent and water	

What Happened

Record how many drops of each kind of water fit on the head of a penny.

Solution	Drops that fit on the head of a penny
Plain water	
Vinegar and water	
Alcohol and water	
Salt and water	
Detergent and water	

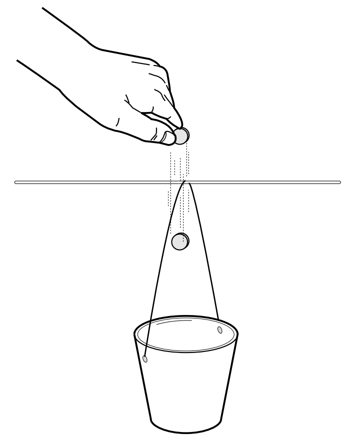
Record how many pennies fit inside a full cup of each of the solutions before the cup spilled over.

Solution	Pennies that fit in a full cup
Plain water	
Vinegar and water	
Alcohol and water	
Salt and water	
Detergent and water	

What It Means

What other liquid could you add to the water? How many drops do you think the penny would hold with this new solution? How many pennies would fit in the filled cup? Explain your answers.

STURDY SPAGHETTI



Science The amount of weight a span made of spaghetti can support depends on the thickness of the spaghetti and the number of strands used.

Stuff Pencil; small paper cup; 12 inches of string; ruler; 15 strands of thick spaghetti; 100 pennies; 15 strands of thin spaghetti; 15 strands of vermicelli

What to Do

1. With a pencil, poke holes in opposite sides of a paper cup just below the rim. Tie each end of the string through one of the holes to make a handle for the cup.
2. Adjust the distance between two chairs (or tables or desks) so that they are five inches apart.
3. Slide the handle of the cup through one piece of thick spaghetti so that the cup hangs straight down from a point in the middle of the pasta. Place the spaghetti across the five-inch gap.
4. While gently supporting the bottom of the cup, drop a penny into it, and gently lower the cup to see if the spaghetti will support that amount of weight without breaking. Continue to add pennies to the cup until the spaghetti breaks. Count the number of pennies the spaghetti supported just before it broke.
5. Repeat steps 3 and 4 using two strands of spaghetti to span the five-inch gap. The strands should be touching. Then try three strands, four strands, and so on until you run out of pennies.
6. Repeat steps 3, 4, and 5 using thin spaghetti.
7. Repeat steps 3, 4, and 5 using vermicelli.

What's Going On Here

The amount of weight that can be supported by a bridge made of spaghetti depends on the thickness of the strands and on the number used to make the bridge. If more strands are used to make the bridge, it will support more weight. As you add more pasta to the bridge, each strand is able to support as much weight as it could by itself. Therefore, if you use twice as many strands, the bridge should support twice as much weight. The thicker spaghetti will support more weight than the thinner. Using a thicker pasta can be compared to using more than one strand of thinner pasta.

Try It!

- ★ Try taping the ends of the pasta on the chairs before doing the activity.
- ★ Try different kinds of pasta.

Name Date

STURDY SPAGHETTI

What You Want to Know

How much weight will a spaghetti bridge support before it breaks? Will the thickness of the pasta affect how much weight it can support? How about the number of strands that are used to make the bridge?

What You Think Will Happen

How many pennies do you think each of the bridges described on the right will hold when the bridge is five inches long?

Bridge	Number of pennies
1 thick spaghetti strand	
1 thin spaghetti strand	
1 vermicelli strand	
2 thin spaghetti strands	
3 thin spaghetti strands	
4 thin spaghetti strands	

What Happened

Record the number of pennies that each five-inch bridge supported.

Number of strands	Thick spaghetti	Thin spaghetti	Vermicelli
1			
2			
3			
4			
5			
6			

What It Means

What do your observations tell you about how the thickness of the spaghetti affects how much weight a bridge can hold?

____

What do your observations tell you about how the number of strands used for the thin spaghetti bridge affects how much weight it can hold? Is the same thing true for the vermicelli bridge and for the thick spaghetti bridge?

____

____

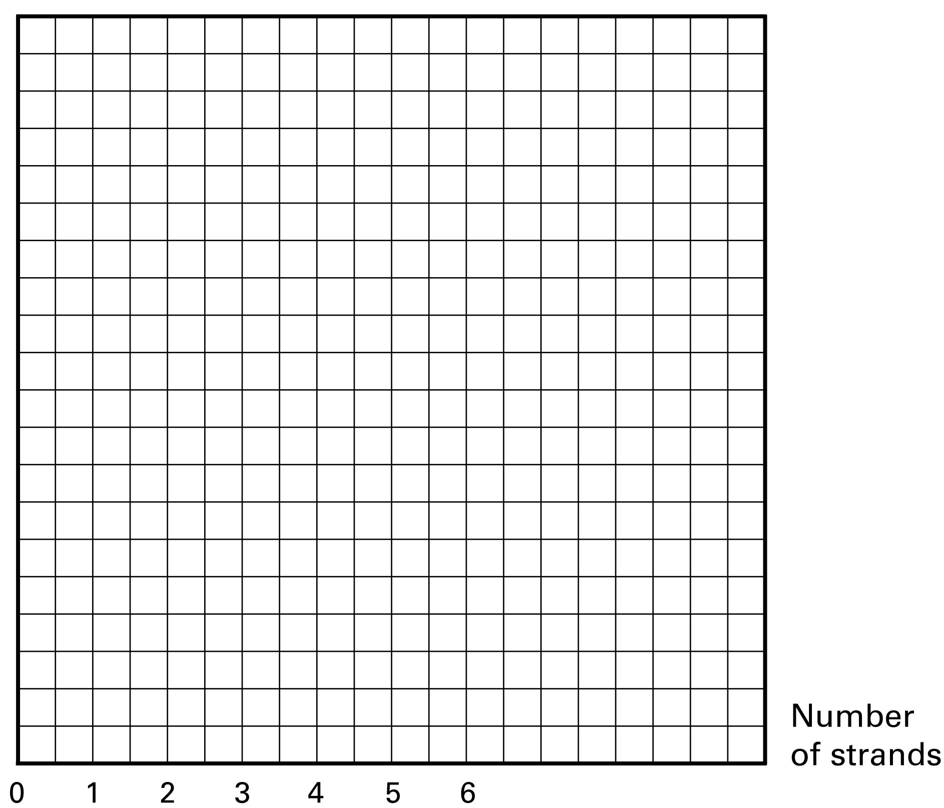
Graph It Next

Name Date

STURDY SPAGHETTI

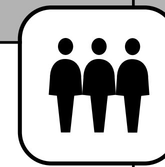
GRAPH IT!

1. Label the vertical axis "number of pennies supported." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened." Use a different color for each kind of pasta.
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot. Label each line.
4. Put a descriptive title at the top of your graph.



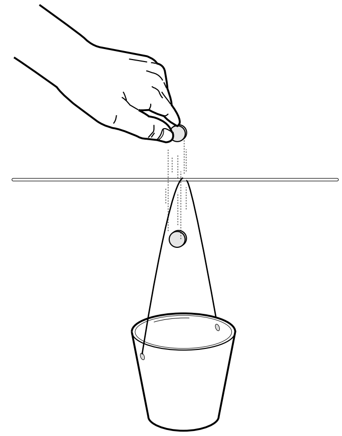
Why don't all the data points lie exactly on a line for each kind of pasta?

SPAGHETTI SCAFFOLD



Science The amount of weight a span made of spaghetti can support depends on the length of the span.

Stuff Pencil; small paper cup; 12 inches of string; ruler; 10 strands of thin spaghetti; 100 pennies



What to Do

1. With a pencil, poke holes in opposite sides of a paper cup just below the rim. Tie each end of the string through one of the holes to make a handle for the cup.
2. Adjust the distance between two chairs (or tables or desks) so that they are two inches apart.
3. Slide the handle of the cup through one piece of thin spaghetti so that the cup hangs straight down from a point in the middle of the pasta. Place the spaghetti across the two-inch gap.
4. While gently supporting the bottom of the cup, drop a penny into it, and gently lower the cup to see if the spaghetti will support that amount of weight without breaking. Continue to add pennies to the cup until the spaghetti breaks. Count the number of pennies the spaghetti supported before it broke.
5. Repeat steps 3 and 4 for bridge spans of $2\frac{1}{2}$, 3, $3\frac{1}{2}$, 4, $4\frac{1}{2}$, 5, $5\frac{1}{2}$, and 6 inches.

What's Going On Here

The amount of weight that can be supported by a bridge made of spaghetti depends on the length of the bridge. A longer bridge will support less weight than a shorter bridge made of the same material. The relationship between the amount of weight that can be supported and the length of the bridge is an *inverse relationship,* which means that as one quantity increases, the other decreases. In this case, as the bridge length increases, the amount of weight that can be supported decreases. Bridge designers use their knowledge of how much weight spans of different materials can support in order to design supports that give their bridges added strength.

Try It!

★ Try taping the ends of the spaghetti to the chairs before doing the activity.

★ Try different kinds of pasta.

Name Date

SPAGHETTI SCAFFOLD

What You Want to Know

How much weight will a spaghetti bridge support before it breaks? Will the length of the bridge affect how much weight it can support?

What You Think Will Happen

How many pennies do you think each of the bridges described on the right will hold?

Span of bridge	Number of pennies
2 inches long	
3 inches long	
4 inches long	
5 inches long	
6 inches long	

What Happened

Record the number of pennies that each bridge supported.

Span of bridge	Number of pennies
2 inches long	
$2\frac{1}{2}$ inches long	
3 inches long	
$3\frac{1}{2}$ inches long	
4 inches long	
$4\frac{1}{2}$ inches long	
5 inches long	
$5\frac{1}{2}$ inches long	
6 inches long	
$6\frac{1}{2}$ inches long	

What It Means

What do your observations tell you about how the length of the bridge affects how much weight it can hold?

What could you do to the bridge to make it support more weight when the span is fixed at five inches?

Graph It Next

SPAGHETTI SCAFFOLD

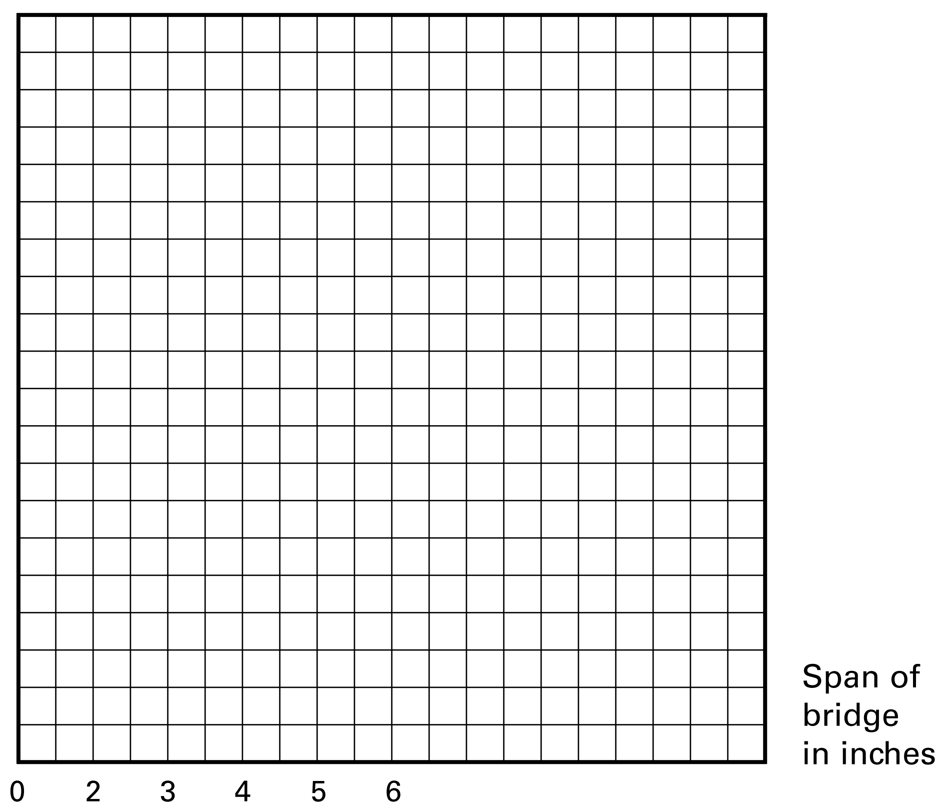
GRAPH IT!

1. Label the vertical axis "number of pennies supported." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the data from the table in "What Happened."

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.



Use a different color to draw what you think the graph would look like if vermicelli (very thin spaghetti) were used. Explain why you think the graph would look that way.

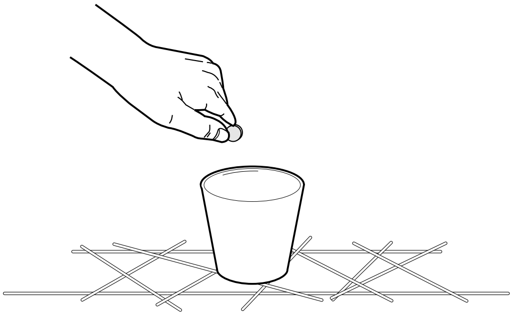
____

____

BRIDGE BUILDING

Science You can build a bridge of spaghetti that will support more weight than you might expect.

Stuff 12 strands of thin spaghetti; 1 yard of masking tape; ruler; small paper cup; 100 pennies



What to Do

This is an open-ended activity for students to experiment with what they observed and learned in the two previous activities.

1. Using only 12 strands of thin spaghetti and 1 yard of masking tape, design a bridge that meets the following specifications:
   - **a.** The bridge must span six inches between two chairs (or tables or desks).
   - **b.** You may use all or some of the materials.
   - **c.** You may break the noodles and tear the tape into smaller pieces.
   - **d.** The cup must be supported on top of the bridge in the middle. It should not hang below the bridge.
   - **e.** Pennies will be placed in the cup to see how much weight the bridge will support.
   - **f.** If more cups are needed to hold pennies, the cups must be stacked on top of each other.
   - **g.** The amount of weight that the bridge supports will be determined by counting the number of pennies it held just before it broke or the cup tipped over.

2. Design, build, and test your bridge. Count the number of pennies that the bridge supports.

What's Going On Here

As you discovered in the two previous activities, the amount of weight a spaghetti bridge can support depends on the thickness of the pasta, the number of strands in a bundle, and the length of the bridge. There are many ways of making a bridge stronger. Adding support at the potential breaking points is one way. Making the materials stronger by binding them together is another way. By designing, building, and testing your own bridge, you will likely discover many other ways. A penny has a mass of about 2.5 grams, so you can determine the actual mass that the bridge supported before it broke by multiplying the number of pennies by 2.5 grams.

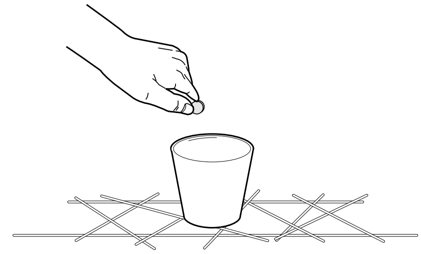
Try It!

★ Try using other materials to make your bridge even stronger.

★ Try designing a bridge that will support weight hanging from it.

Name Date

BRIDGE BUILDING



What You Want to Know

What kind of bridge can you design using 12 strands of spaghetti and 1 yard of tape?

What You Think Will Happen

Draw a sketch of your design in the space below. Identify all the materials you will be using.

How many pennies do you think your bridge will support? ______________

What Happened

How many pennies did your bridge support? ______________

Describe the way in which the bridge broke or the cup tipped over. What part of the bridge gave way first?

____

____

What It Means

What changes could you make to your bridge to so that it would hold more pennies?

____

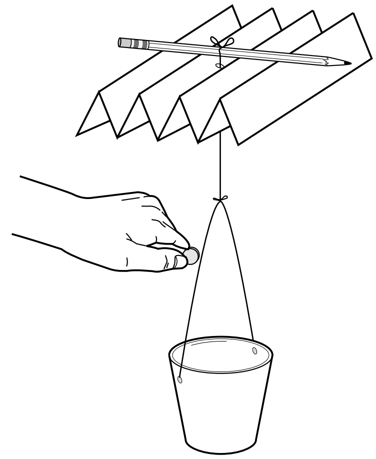
____

What other materials would you like to use in your design? How would the materials be used to make the bridge hold more pennies?

____

____

PLEATED PAPER



Science The strength of paper can be increased by changing its shape.

Stuff Pencil; paper cup; string; ruler; scissors; 5 sheets of paper; masking tape; 100 pennies

What to Do

1. With a pencil, poke holes in opposite sides of a paper cup just below the rim. Tie each end of a piece of string 12 inches long through one of the holes to make a handle for the cup.
2. Take a sheet of paper; fold it back and forth along the short side to make pleats that are $\frac{1}{4}$-inch wide and $8\frac{1}{2}$ inches long. The entire sheet should be pleated.
3. Cut two pieces of tape that are each exactly two inches long. Put one piece on the table, sticky side up. Take the pleated piece of paper and adjust its width so that it is two inches wide, and place one edge of it on the piece of tape. Do the same thing with the other end of the pleated paper. The tape should hold the pleated paper in a 2-inch by $8\frac{1}{2}$ inch rectangle.
4. Adjust the distance between two chairs (or tables or desks) so that they are six inches apart. Place the pleated paper across the gap the long way. This will be your bridge.
5. Cut a small hole in the middle of your bridge. Place a pencil across the bridge, and tie a piece of string about eight inches long to the middle of the pencil. Poke the string through the hole in the paper, and tie it to the string handle of the cup.
6. Put pennies into the cup, one at a time, until the bridge collapses. Record the number of pennies that the bridge held just before it collapsed.
7. Repeat steps 2 though 6 for pleat sizes of $\frac{1}{2}$, 1, 2, and 3 inches.

What's Going On Here

If you have ever taken a close look at a piece of corrugated cardboard, you may have noticed that it looks similar to the bridges you built in this activity. Corrugated cardboard consists of pleated paper sandwiched between flat paper. It is designed to be very strong, lightweight, and inexpensive. The strength of materials can be increased by changing their shape. For a given height, a triangle will support the most weight. Corrugated cardboard has triangle shapes in the pleats so that it has added strength and can support more weight.

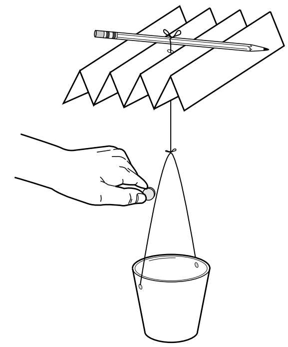
Try It!

★ Try paper that is thinner, such as tracing paper, or thicker, such as construction paper.

★ Try changing the length or width of the bridge.

★ Try making pleats that are shaped like rectangles rather than triangles.

PLEATED PAPER



What You Want to Know

How much weight will a bridge made of a piece of pleated paper support?

What You Think Will Happen

A 2-inch by $8\frac{1}{2}$-inch bridge is made by folding paper back and forth to make pleats of the widths shown in the table. The bridge is then placed across a six-inch gap. How many pennies do you think each bridge will support?

Width of pleat	Number of pennies you think the bridge will support
$\frac{1}{4}$ inch	
$\frac{1}{2}$ inch	
1 inch	
2 inches	
3 inches	

What Happened

Record the number of pennies that each bridge supported.

Width of pleat	Number of pennies the bridge supported
$\frac{1}{4}$ inch	
$\frac{1}{2}$ inch	
1 inch	
2 inches	
3 inches	

What It Means

How many pennies do you think a bridge made with four-inch pleats would support? Explain your answer.

How many pennies do you think a bridge made with $\frac{1}{8}$ inch pleats would support? Explain your answer.

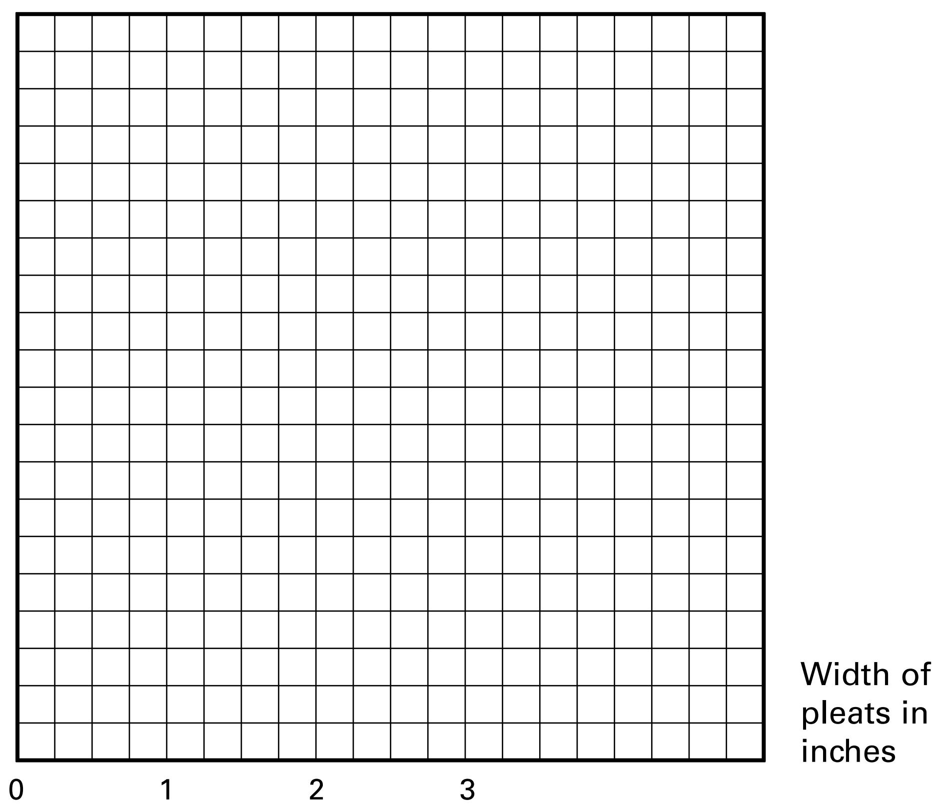
Graph It Next

Name Date

PLEATED PAPER

GRAPH IT!

1. Label the vertical axis “number of pennies supported.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

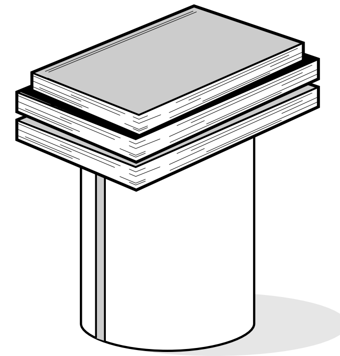


Draw what you think the graph would look like if the bridge were placed across a four-inch gap. Explain why you think the graph would look like that.

____

____

PAPER PILLARS



Science The strength of a paper tube depends on its height, thickness, and diameter, the kind of paper used, and whether the tube is vertical or horizontal.

Stuff Used copy paper; ruler; scissors; tape; paperback books of the same size and shape

What to Do

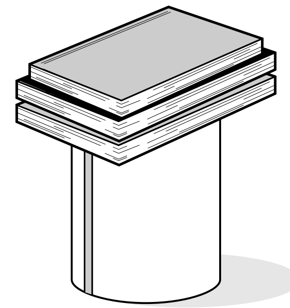
1. Cut a piece of paper that is 2 inches wide and 11 inches long. Roll the paper into a tube that is two inches high. Tape the tube all the way along the edge where the two pieces of paper touch, being careful not to crease the paper. Do not overlap the paper.
2. Stand the tube upright, and place one book carefully on top of the tube so that it balances. Add books, one at a time, until the tube collapses. Record the number of books the tube supported just before it collapsed.
3. Repeat steps 1 and 2 using pieces of paper that are 4, 6, and 8 inches wide to make tubes that are 4, 6, and 8 inches high. The tubes should always have the same diameter.
4. Roll a piece of uncut paper into a tube that is $8\frac{1}{2}$ inches tall. Tape the tube as before.
5. Repeat step 2.
6. Repeat steps 4 and 5 making the tube 2, 3, 4, and 5 pieces of paper thick.
7. Cut a piece of paper that is 2 inches wide and 3 inches long. Roll the paper into a tube that is 2 inches high. Tape the tube as before. Measure the diameter of the tube.
8. Repeat step 2.
9. Repeat steps 7 and 8 using pieces of paper that are 2 inches wide and 5, 7, 9, and 11 inches long to make tubes that are all 2 inches tall.

What's Going On Here

The strength of a paper tube depends on its height, thickness, and diameter, the kind of paper used, and whether the tube is vertical or horizontal. In this activity, the kind of paper used and the position (vertical) was not changed. You investigated the effect of the height, thickness, and diameter of the tube. In theory, a given tube should be able to support the same weight no matter how high it is. But it is impossible to keep the tube exactly vertical, and the higher tubes tend to be more tilted than the shorter ones. Thus the higher tubes generally don't support as much weight as the shorter ones. A tube with thicker walls will support more weight than one with thinner walls because the added paper adds strength to the wall. As the diameter of the tube is increased, the tube is able to support more weight because the weight is spread over a larger area.

Name Date

PAPER PILLARS



What You Want to Know

How does the thickness, diameter, and height of a paper pillar affect how much weight it can support when standing upright?

What You Think Will Happen

For each pair listed below, circle the kind of paper tube that you think will support more weight. If you think both will support the same weight, don't circle either one.

taller tube	thinner tube	bigger diameter
or	*or*	*or*
shorter tube	thicker tube	smaller diameter

What Happened

Record the number of books each tube held.

Height of tube	Number of books
2 inches	
4 inches	
6 inches	
8 inches	

Thickness of tube	Number of books
1 piece of paper	
2 pieces of paper	
3 pieces of paper	
4 pieces of paper	
5 pieces of paper	

Diameter of tube	Number of books

What It Means

If someone gave you eight pieces of paper and a roll of tape, what kind of tube would you build to support the most weight?

Graph It Next

Name Date

PAPER PILLARS (HEIGHT)

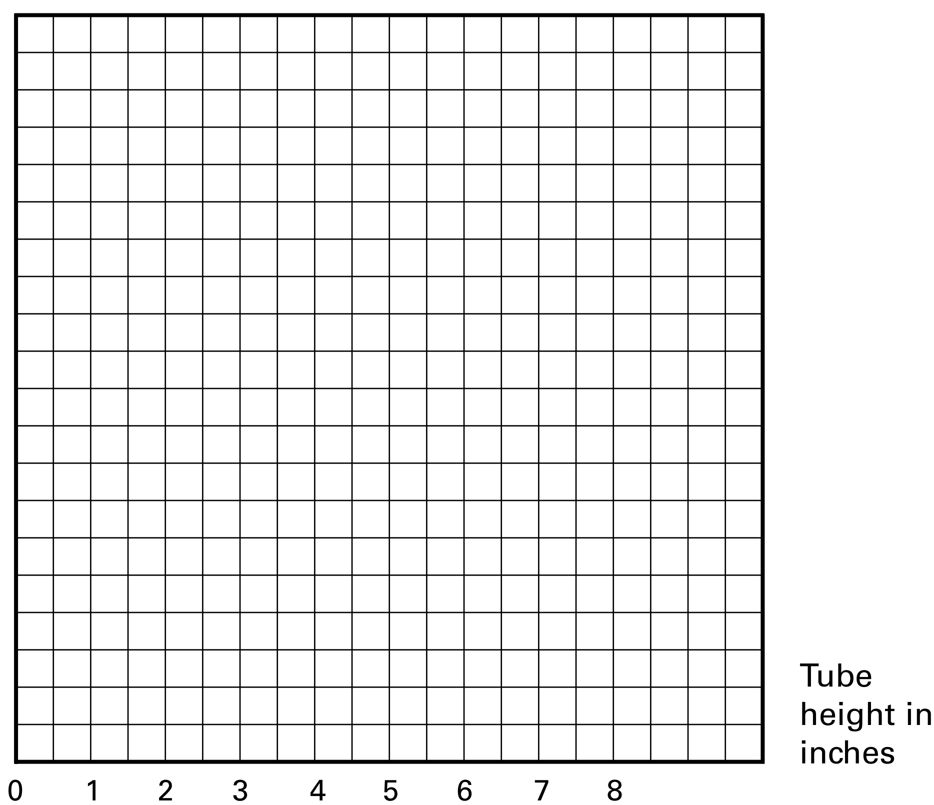
GRAPH IT!

1. Label the vertical axis "number of books supported." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the data from the first table in "What Happened."

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

4. Put a descriptive title at the top of your graph.



Use the graph to predict how many books a tube that is one inch tall would support. Explain how you got your answer.

____

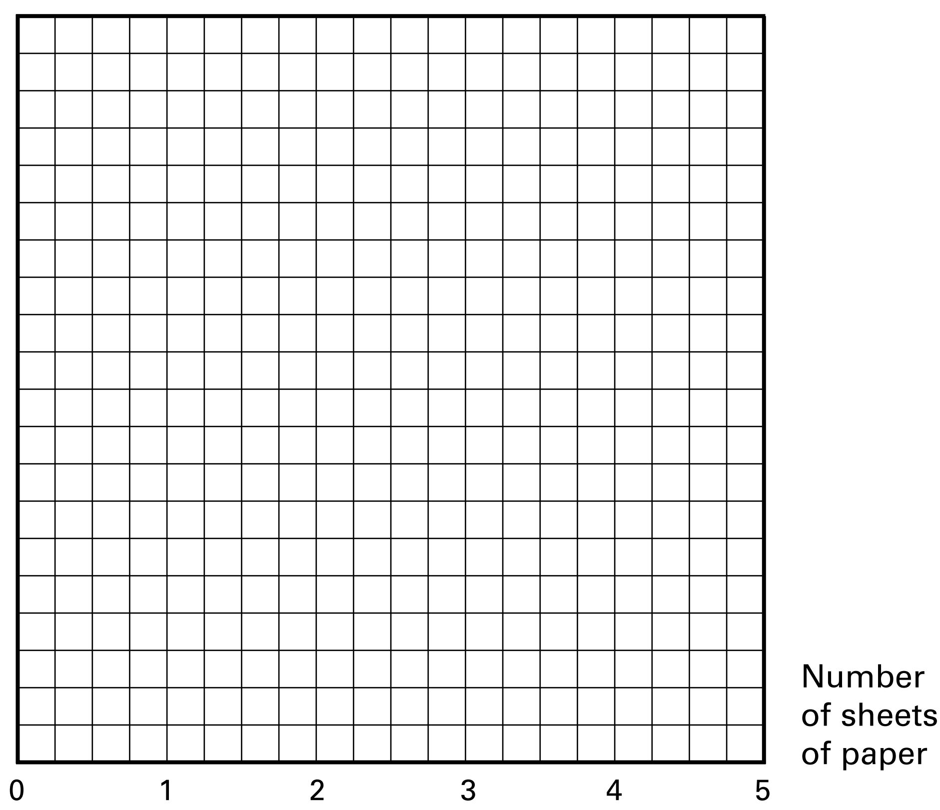
____

Name Date

PAPER PILLARS (THICKNESS)

GRAPH IT!

1. Label the vertical axis "number of books supported." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the first table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



Use a colored pencil to draw what you think the graph would look like if the tube were taller. Explain why you think the graph would look that way.

Name Date

PAPER PILLARS (DIAMETER)

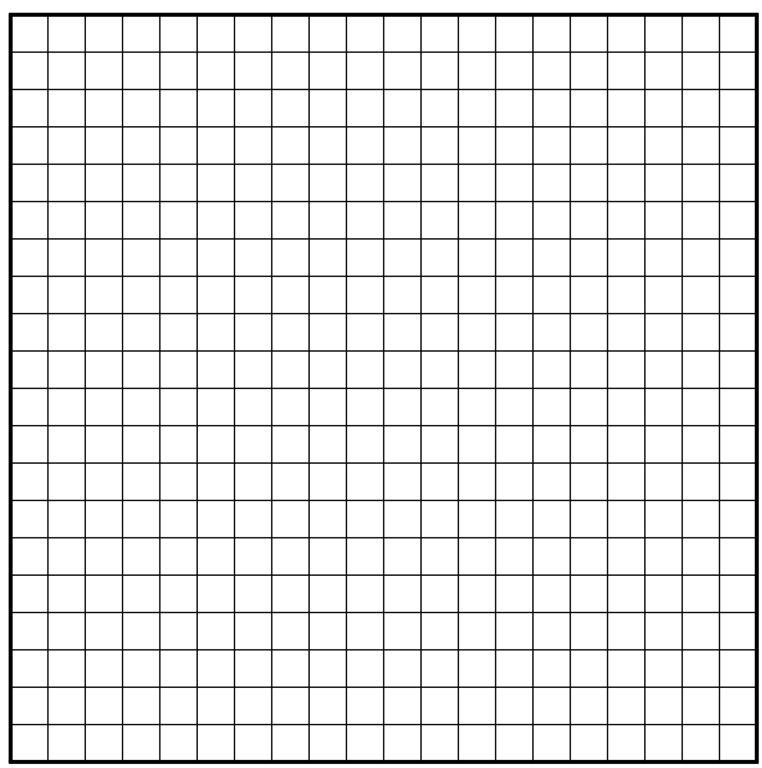
GRAPH IT!

1. Label the vertical axis "number of books supported." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.

2. Plot the data from the first table in "What Happened."

3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.

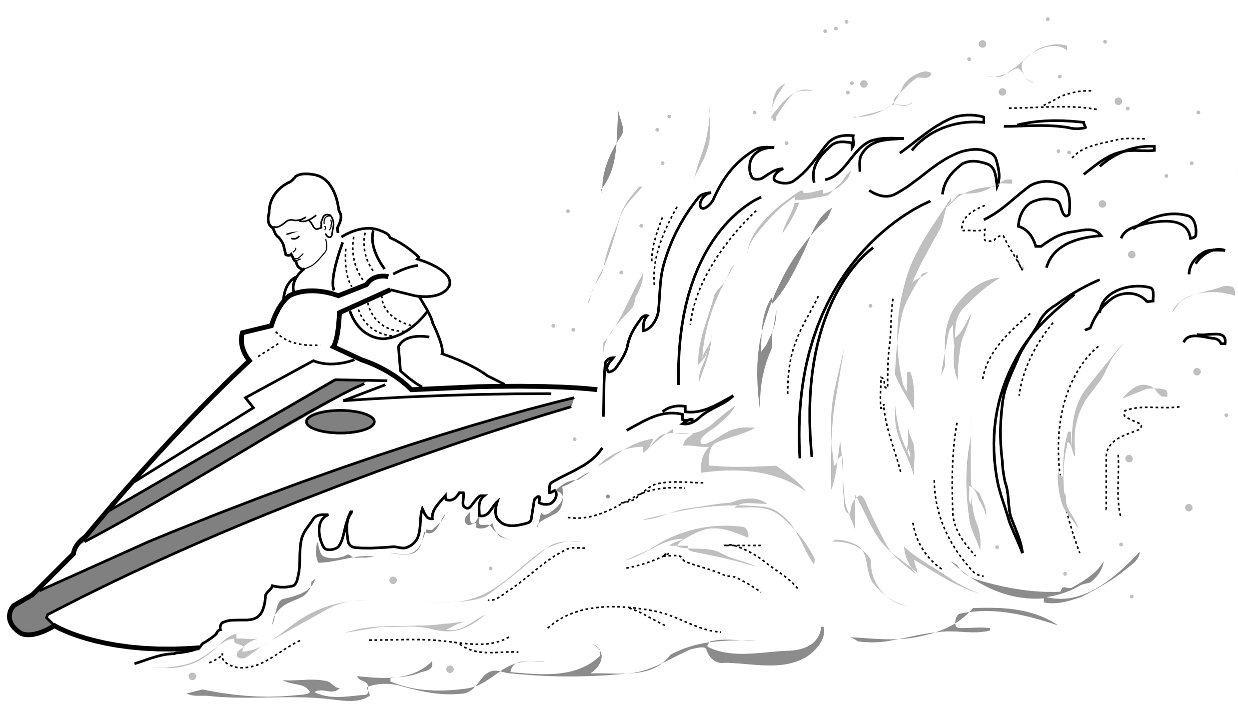
4. Put a descriptive title at the top of your graph.



Use a colored pencil to draw what you think the graph would look like if the tube were thicker. Explain why you think the graph would look that way.

CHAPTER

7 SPEED



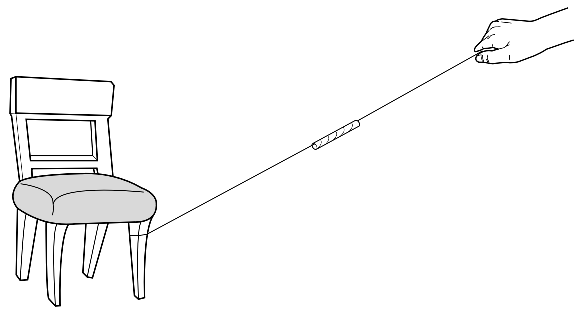
SPEED STUFF

- The *average speed* of an object is the total distance it travels divided by the time it took to travel that distance.
- When you travel somewhere in a car, you may stop at stop signs or to take a break from traveling. You will probably travel faster on the highway than on single-lane country roads, so your speed will vary. But your average speed can be found by dividing the distance you traveled by the total time it took, including the time you weren't moving at all.
- Different factors affect an object's speed. These factors include friction, air resistance, height from which an object is dropped, the shape of the object, and the weight of the object.
- Friction always opposes the motion of objects, making them move more slowly. Air resistance, which is just another kind of friction, is encountered whenever an object moves where there is air (practically everywhere).
- The height from which an object falls determines its speed just before it hits the ground. As an object falls to the ground, its speed increases.
- The weight and shape of an object affect its speed. The heavier an object, the more quickly it will fall. An object that is wide will fall more slowly than one that is compact.
- The speed of a rolling object depends on all the factors mentioned plus how the mass of the rolling object is distributed. With all the other factors being equal, a can with its mass distributed evenly will roll faster than a can whose mass is concentrated toward the outside.
- A pendulum has a natural *frequency* (number of times it swings back and forth in a second). You can't change the frequency of the pendulum by pushing it, but if you push at the right time, you can make the pendulum go higher, which increases its speed at the lowest point of its swing.
- The frequency of a pendulum depends on its length; it will be greater for a shorter pendulum than for a longer one.

SPEEDY STRAW

Science The average speed of an object is the total distance that it travels divided by the time it took to travel that distance.

Stuff Thread; yardstick; scissors; chair; straw; marker; stopwatch



What to Do

1. Cut a piece of thread about 10 feet long. Tie one end securely to the leg of a chair.
2. Cut a piece of straw two inches long. Slide the thread through the straw.
3. Slide the straw to the loose end of the thread, and mark the thread where you are holding it. Measure the distance from the mark to the chair leg, holding the thread taut.
4. Hold the thread taut, and raise it to a height above the floor, so that the straw moves slowly down the thread.
5. Measure the distance from the floor to where you are holding the thread.
6. Slide the straw to the top of the mark on the thread, and raise the end to the height you measured in step 5. Have a partner with a stopwatch tell you when to release the straw.
7. Your partner should time how long it takes the straw to travel to the chair leg.
8. Repeat steps 6 and 7 two times, making sure that the thread is always the same distance above the floor and that the straw is always released from the mark on the thread.
9. Repeat steps 5, 6, 7, and 8 for three different heights of thread.

What's Going On Here

The straw gains speed as it moves down the thread. At the top it has no speed; by the time it reaches the chair leg it has its greatest speed. The average speed of the straw is the total distance that it travels down the thread divided by the time it took to make the trip. The speed increases at a steady pace. The maximum speed that the straw reaches at the end of its trip depends on how high the thread is held; the higher it is held, the greater speed the straw will have. Friction between the straw and the string also affects how fast the straw will travel. Galileo used inclined planes in the early 1600s to study the motion of falling objects. He could just as easily have used thread and straws as you did in this activity.

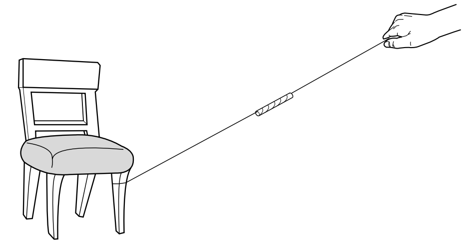
Try It!

★ Try different lengths of straws.

★ Try different kinds of thread or string.

Name Date

SPEEDY STRAW



What You Want to Know
How does the speed of a straw moving on a thread depend on how high the thread is held?

What You Think Will Happen
As you raise the thread upward, the speed the straw has at the bottom will
a. increase. **b.** decrease. **c.** remain the same.

The straw moves fastest on the string
a. right at the top. **b.** in the middle of the thread.
c. just before it stops at the end of the thread.

What Happened
For each height above the floor, record the time it took the straw to travel the length of the thread. Add the three times together, and divide by three to get the average time. Divide the length of the thread by the average time to get the average speed. Length of thread: __________

Average speed = Length of thread ÷ Average time

Height of thread above the floor	Time			Average time	Average speed

What It Means
What do your observations tell you about how the average speed changes when the thread is held higher above the floor?

____

What did you observe about the motion of the straw? When was it going slowest? When was it going fastest?

____

____

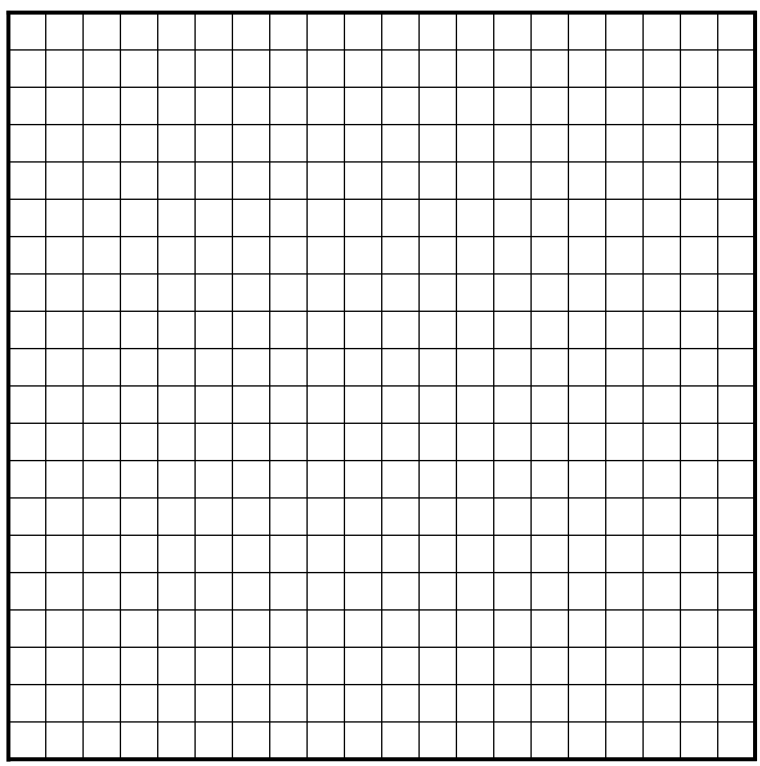
Graph It Next

Name Date

SPEEDY STRAW

GRAPH IT!

1. Label the vertical axis "average speed in inches per second." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

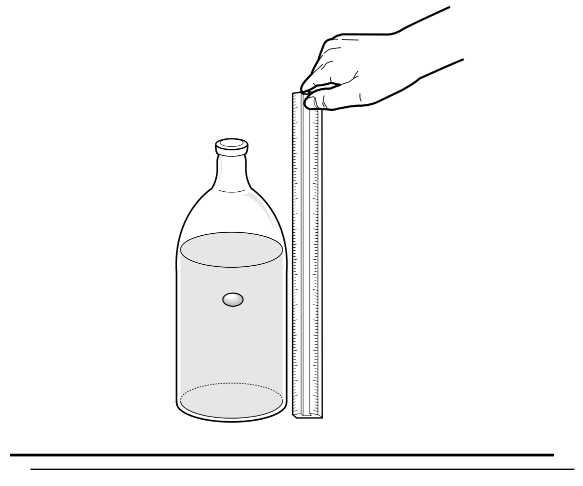


What variables other than height affect how fast the straw moves down the string?

____

____

FALLING FRUIT



Science The size of an object determines how fast it falls in water.

Stuff 2-liter plastic bottle; water; ruler with centimeter marks; two large grapes; knife; stopwatch

What to Do

1. Fill the two-liter bottle with water. Use the ruler to measure the height of the water from the table.
2. Carefully peel the skin off all the grapes.
3. Drop one grape into the bottle. Using the stopwatch, time how long it takes the grape to fall to the bottom of the bottle.
4. Cut one of the grapes in half, and repeat step 3 with half the grape.
5. Cut the grape in half again, and repeat step 3 with a quarter of the grape.
6. Cut the grape in half one more time, and repeat step 3 with an eighth of the grape.

What's Going On Here

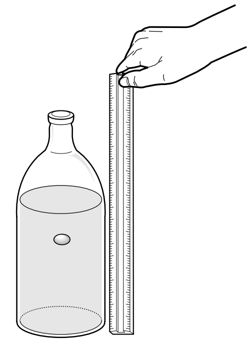
The smaller and larger pieces of grape sink in the water. If the grape is cut too small, surface tension will cause it to float. The average speed of the grape as it falls in the water is the total distance it falls divided by the total time it took. The average speed depends on the size of the grape. There are two forces on the grape as it falls, the force of gravity pulling the grape down and the buoyant force of the water pushing the grape up. The *total force* is the sum of gravity and the buoyant force and is different for the different sizes of grape. Generally speaking, the larger pieces of grape will fall faster than the smaller pieces of grape. The same thing happens when things fall in air; larger objects fall faster than smaller objects of the same material. In a vacuum, things fall at the same rate no matter what their size.

Try It!

- ★ Try other fruits or other objects.
- ★ Try other liquids, such as oil or salt water.

Name Date

FALLING FRUIT



What You Want to Know
How does the size an object affect how fast it falls in water?

What You Think Will Happen
When you drop pieces of fruit into water,

a. smaller pieces will fall faster than larger pieces.

b. smaller pieces will fall slower than larger pieces.

c. smaller pieces will fall as fast as larger pieces.

d. other (fill in) ______________________.

What Happened
Record the amount of time it took the pieces of fruit to fall to the bottom of the two-liter bottle of water. The average speed of the fruit is equal to the height of the water in the bottle divided by the time it took the fruit to fall. Record the average speed in the third column.

Height of water in bottle: ______________

Size of grape	Time to fall	Average speed
Whole		
Half		
Quarter		
Eighth		

What It Means
What do your observations tell you about how the size of the grape affects how fast it falls in the water?

____

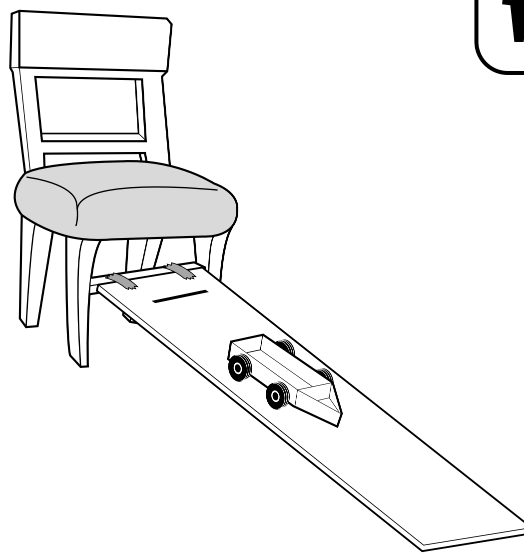
____

Do you think you could cut the grape small enough so that it would float on the water? Explain your answer.

____

____

CARTON CARS



Science The amount of weight in a milk carton car affects how far it travels after moving down a ramp.

Stuff 2 straws; scissors; clean, empty half-pint milk carton; tape; yardstick (or meter stick); 4 plastic inserts from "Push-Up" sherbet treats, (disk with attached stick); cardboard ramp (about 2 feet × 3 feet); chair or table; 50 washers or pennies

What to Do

1. Cut two straws exactly the width of the side of the milk carton. Tape one straw about $\frac{1}{2}$-inch from the top of the milk carton and the other straw about $\frac{1}{2}$-inch from the bottom.
2. Take the stick off two of the plastic sherbet inserts, and put the two plastic disks aside. Put one of the other plastic inserts through the top straw, and attach a plastic disk to the stick.
3. Repeat step 2 with the other straw.
4. Tape the cardboard ramp to a chair or table leg so that it is about a foot off the floor. Put a piece of tape about six inches from the top of the ramp; this is the starting line. Place the front of the car at the starting line, and release the car.
5. Make adjustments to the car so that it travels in a straight line down the ramp.
6. Release the car from the top of the ramp. Measure the distance it travels from the bottom of the ramp to where it stops.
7. Put 10 washers or pennies inside the car, and repeat step 6.
8. Repeat step 6 with 20, 30, 40, and 50 pennies.

What's Going On Here

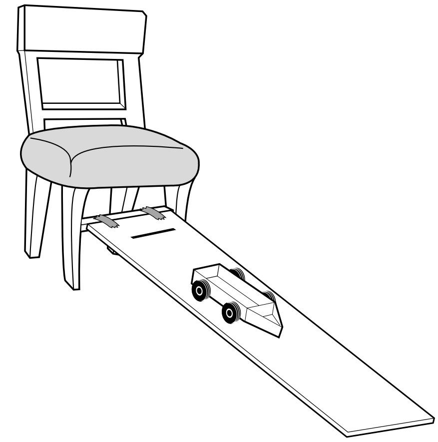
There are several forces that act on the car when it moves down the ramp. The force of gravity is pulling the car down, making it go faster. The force of air resistance is pushing against the car, slowing it. The force of friction between the car and the ramp is also slowing it. These three forces acting together account for the motion of the car down the ramp. As you add weight to the car, you are changing the effect of the three forces. When the car is feather-light, it will barely move down the ramp at all because of air resistance. When it is too heavy, the force of friction between the car's tires and the ramp may become so great that the car cannot move at all. In between the extremes, the car will have varying degrees of success attaining speed as it moves down the ramp.

Try It!

★ Try placing washers inside the disks (wheels) of the car.

Name Date

CARTON CARS



What You Want to Know

How does the amount of weight in a car affect how far it can travel after moving down a ramp?

What You Think Will Happen

When you add more weight to the car,

- **a.** it will travel farther after leaving the ramp.
- **b.** it will travel less far after leaving the ramp.
- **c.** it will travel about the same distance after leaving the ramp.
- **d.** other (fill in) ___________________________.

What Happened

Record the distance the car traveled after leaving the ramp.

Weight in the car	Distance traveled after leaving the ramp
0 pennies	
10 pennies	
20 pennies	
30 pennies	
40 pennies	
50 pennies	

What It Means

What do your observations tell you about how the amount of weight in the car affects how far it can travel after leaving the ramp?

____

____

Which takes more force to stop, a bike moving 25 miles an hour or a large truck moving 25 miles an hour? How does this activity help explain your answer?

____

____

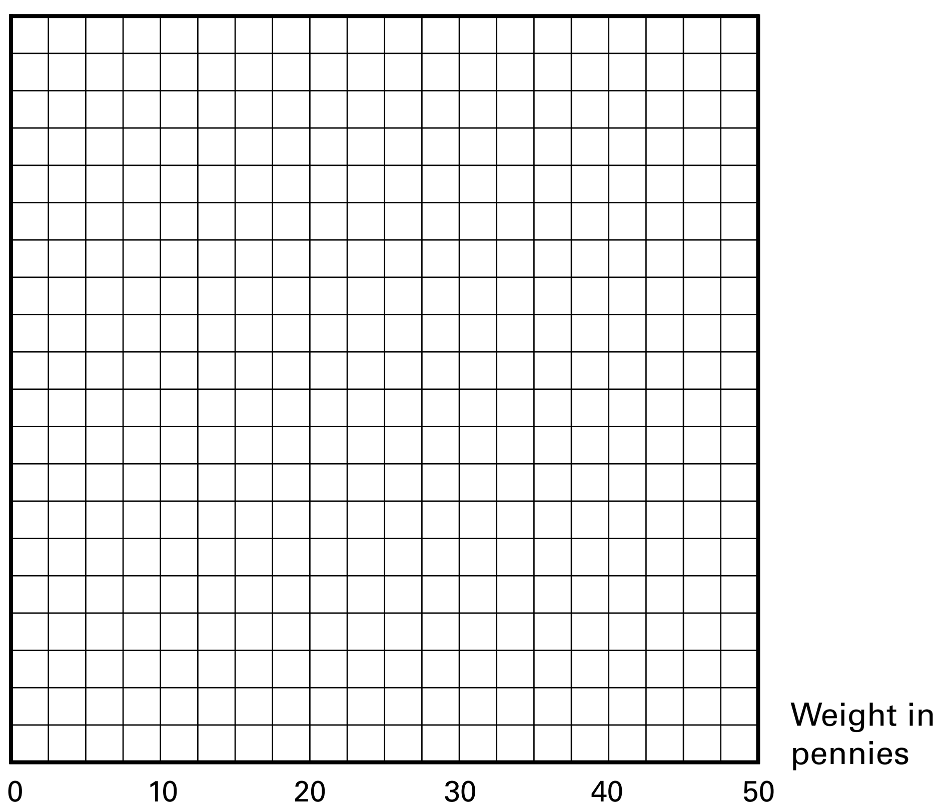
Graph It Next

Name Date

CARTON CARS

GRAPH IT!

1. Label the vertical axis "distance traveled in inches (or centimeters)." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.

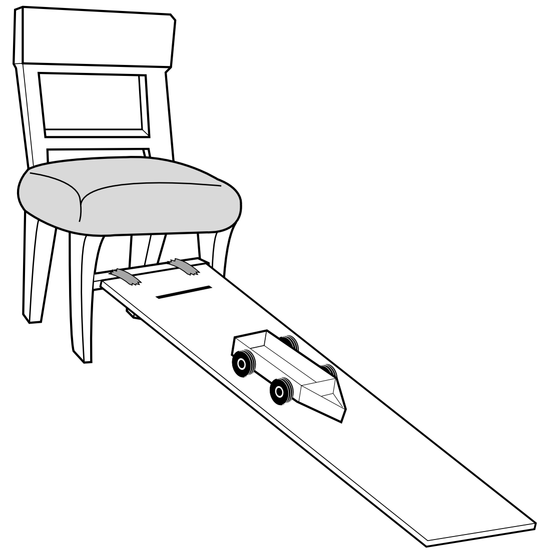


Use the graph to predict how far you think the car would travel with 100 pennies. Explain how you got your answer.

QUICK CARTON CARS

Science You can change the motion of a car by changing the forces acting on it.

Stuff 2 straws; scissors; clean, empty half-pint milk carton; tape; yardstick (or meter stick); 4 plastic inserts from "Push-Up" sherbet treats (disk with attached stick); cardboard ramp (about 2 feet × 3 feet); chair or table; rubber bands; balloons; index cards; string



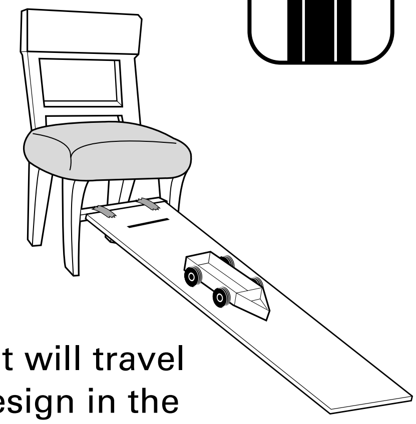
What to Do

1. Cut two straws exactly the width of the side of the milk carton. Tape one straw about $\frac{1}{2}$-inch from the top of the milk carton and the other straw about $\frac{1}{2}$-inch from the bottom.
2. Take the stick off two of the plastic inserts, and put the two plastic disks aside. Put one of the other plastic inserts through the top straw, and attach a plastic disk to the stick.
3. Repeat step 2 with the other straw.
4. Tape the cardboard ramp to a chair or table leg so that it is about a foot off the floor. Put a piece of tape about six inches from the top of the ramp; this is the starting line. Place the front of the car at the starting line, and release the car.
5. Make any needed adjustments to the car so that it travels in a straight line down the ramp and after it leaves the ramp
6. Release the car from the top of the ramp three times. Each time, measure the distance it travels from the bottom of the ramp to where it stops on the floor.
7. Using rubber bands, balloons, index cards, straws, and string, make changes to the design of your car so that it will travel the farthest distance after rolling down the ramp.
8. Repeat step 6 with your newly designed car.
9. Make additional changes to the design of your car, and repeat step 6. Make some more changes, and repeat step 6.

What's Going On Here

There are several forces that act on the car as it moves down the ramp. The force of gravity is pulling the car down, making it go faster. The force of air resistance is pushing against the car, slowing it. The force of friction between the car and the ramp is also slowing it. These forces acting together account for the motion of the car down the ramp. As you make design changes to the car, you change the net effect of the forces on the car, causing it to have a greater speed at the bottom of the ramp and to travel farther on the floor.

QUICK CARTON CARS



What You Want to Know
How can you change the motion of a milk carton car to make it travel the farthest distance after leaving a ramp?

What You Think Will Happen
Using the materials provided, design a milk carton car that will travel the farthest after leaving a ramp. Draw a sketch of your design in the space below. Identify all materials that you will be using.

What Happened
Record the distance the car traveled after leaving the ramp.

What was changed on car	Trial 1	Trial 2	Trial 3	Best distance
Nothing—basic car				

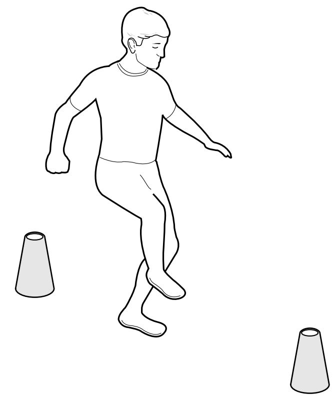
What It Means
What would you do to your car to make it travel the least distance after it leaves the ramp?

What would you change in the design of your car to make it go even farther? What materials would you use that were not available to you today?

MEASURING MANY MOVES

Science The average speed of an object is equal to the total distance it travels divided by the time it takes to travel that distance.

Stuff Yardstick (or meter stick); stopwatch (or seconds timer on a wristwatch); soccer ball; 2 plastic playground cones



What to Do

1. Find a flat grassy area outside. Place a cone (or other marker) on the ground. Measure 25 yards (or 25 meters) on the ground, and place another cone on the ground.
2. Have a partner time how long it takes you to run from one cone to the other and back.
3. After you have rested for a few minutes, have a partner time how long it takes you to walk quickly from one cone to the other and back.
4. Have a partner time how long it takes you to walk from one cone to the other and back when you walk heel-to-toe, placing one foot in front of the other so that the heel of that foot touches the toe of the foot already on the ground.
5. Have a partner time how long it takes you to dribble a soccer ball from one cone to the other and back.
6. Determine your average speed (in yards per second or meters per second) in each case by dividing the total distance (in yards or meters) by the total time (in seconds).

What's Going On Here

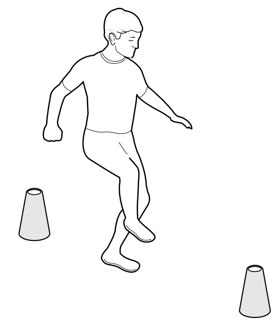
The average speed of an object is the total distance the object travels divided by the time it takes to travel that distance. The speed at any instant during the object's travel may be different; the object may speed up or slow down during the course of its travel. The less time it takes you to travel a given distance, the greater average speed you will have. When you ran the course, your speed was probably the greatest. Your average speed was probably least when you walked heel-to-toe. Dribbling a soccer ball and briskly walking the course will give speeds that are between the running speed and the heel-to-toe speed. During a race, runners generally vary their speed. A runner may start out very fast, slow down in the middle, and sprint at the end. The average speed is the total distance divided by the time it took to run that distance, no matter how fast the runner was going at any moment during the race.

Try It!

- ★ Time how long it takes to throw a basketball as far as you can.
- ★ Try the activity with the cones 50 yards apart, but this time run, walk, or dribble from one cone to the other without making a turn and returning to the starting cone.
- ★ Try to determine your average speed the next time you take a long car trip.

Name Date

MEASURING MANY MOVES



What You Want to Know

How can you measure your average speed as you walk, run, or dribble a soccer ball?

What You Think Will Happen

List in order the following movements from greatest average speed to smallest average speed: running, walking fast, walking heel-to-toe, and dribbling a soccer ball.

__________ __________ __________ __________

(greatest average speed) (smallest average speed)

What Happened

Record the amount of time and the average speed for each type of movement. The average speed is the distance divided by the time.

Distance = ____________________

Move	Time (in seconds)	Average speed (circle one: meters per seconds or yards per second)
Run		
Walk quickly		
Walk heel-to-toe		
Dribble soccer ball		

What It Means

If you were to run a long race, when do you think you would run slowest during the race? When do you think you would run fastest? Explain your answer.

____

____

What other way could you move between the two cones? What do you think your average speed would be? Explain your answer.

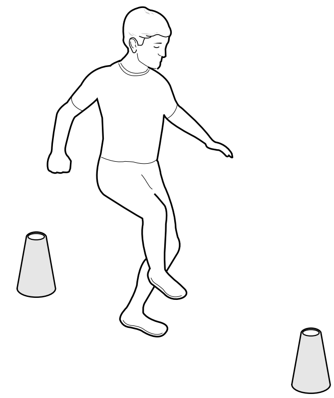
____

____

MANY MORE MOVES

Science The average speed of an object is equal to the total distance it travels divided by the time it takes to travel that distance.

Stuff 2 plastic playground cones; yardstick (or meter stick); stopwatch (or seconds timer on a wristwatch)



What to Do

1. Find a flat grassy area outside. Place a cone (or other marker) on the ground. Measure five yards (or five meters) on the ground, and place another cone on the ground.
2. Have a partner time how long it takes you to walk heel-to-toe from one cone to the other. A heel-to-toe walk consists of placing one foot in front of the other so that the heel of that foot touches the toe of the foot already on the ground.
3. Repeat step 2 after placing the cones 10 yards (or 10 meters) apart. Continue to move the cones at 5 yard (or 5 meter) increments until they are 40 yards (or meters) apart.
4. Determine your average speed (in yards per second or meters per second) in each case by dividing the total distance (in yards or meters) by the total time (in seconds).

What's Going On Here

The average speed of an object is the total distance the object travels divided by the time it takes to travel that distance. If the average speed is fairly constant, it should take a longer time to travel a greater distance and a shorter time to travel a lesser distance. In fact, it should take twice as long to walk 10 yards as it takes to walk 5 yards, and it should take half as long to walk 10 yards as it takes to walk 20 yards. But whatever the distance, the average speed should be the same. A heel-to-toe walk was chosen for this activity because it is a movement with relatively constant speed, in which the walker will not tire easily. The speed at any time during the walk is approximately the same as the average speed. Heel-to-toe walking is somewhat similar to cruise control in a car, where the car can be set to drive a constant speed.

Try It!

★ Try the activity by walking quickly between the cones.

★ Try the activity with a bicycle.

★ Try to determine your average walking speed in miles per hour.

Name Date

MANY MORE MOVES

What You Want to Know

As the distance increases, how is the time it takes to walk the distance affected? How is the average speed affected?

What You Think Will Happen

As the distance increases, the time it takes to walk the distance

- **a.** also increases.
- **b.** decreases.
- **c.** stays about the same.

As the distance increases, the average walking speed

- **a.** also increases.
- **b.** decreases.
- **c.** stays about the same.

What Happened

Record the distances and the amount of time it took to walk each distance. Then record the average speed, which is the distance divided by the time.

Distance	Time (in seconds)	Average speed (circle one: meters per seconds or yards per second)

What It Means

What do you notice about the time it takes to walk 10 yards compared to the time it takes to walk 5 yards? What do you notice about the average speed for these distances?

____

How long do you think it would take to walk 80 yards heel-to-toe? What would your average speed be? Explain your answers.

____

____

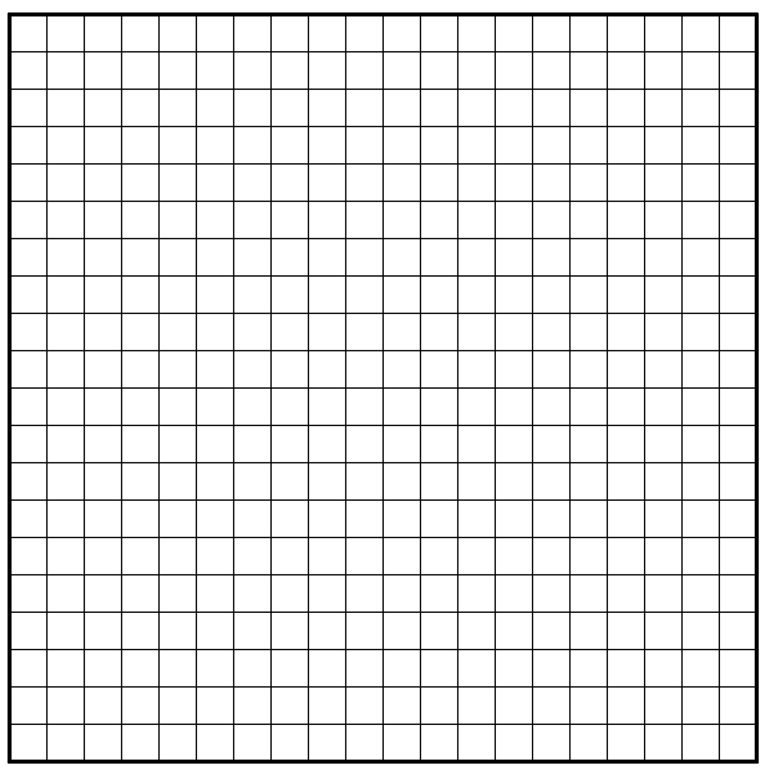
Graph It Next

Name Date

MANY MORE MOVES (SPEED)

GRAPH IT!

1. Label the vertical axis "average speed in meters per second (or yards per second)." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too, and write whether you are measuring distance in meters or yards.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



0

Distance in _______

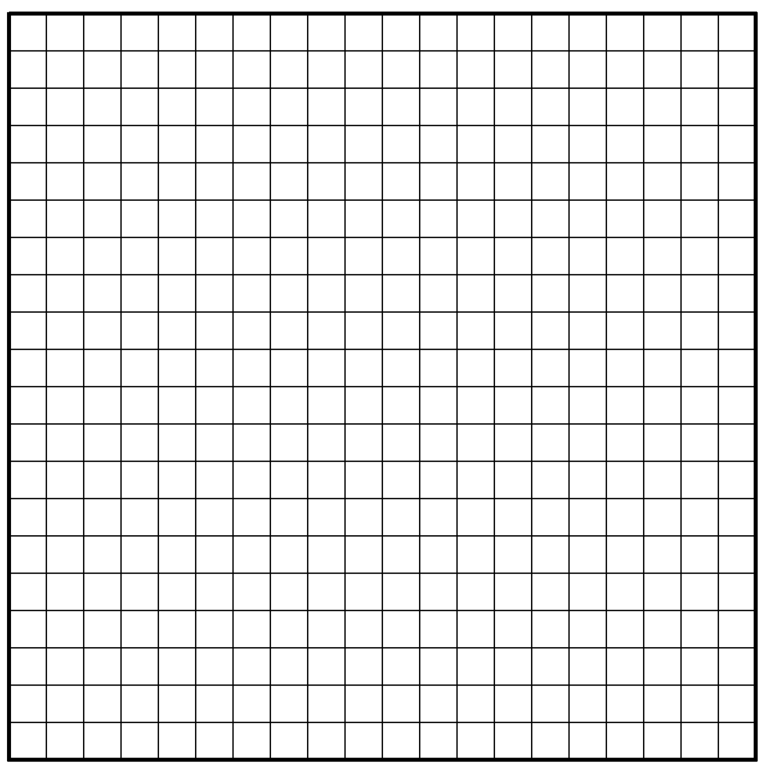
Draw what you think the line would look like if you ran instead of walked. Label the new line. Explain why you think it looks the way it does.

____

MANY MORE MOVES (TIME)

GRAPH IT!

1. Label the vertical axis "time in seconds." Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write numbers on the horizontal axis, too, and write whether you are measuring distance in meters or yards.
2. Plot the data from the table in "What Happened."
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



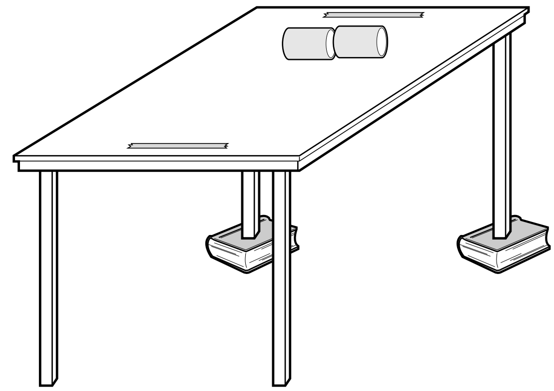
Draw what you think the line would look like if a person with bigger feet did the same activity. Label the new line. Explain why you think it looks the way it does.

____

____

CIRCLING CANS

Science The speed of a can rolling down an incline depends on several factors.



Stuff Table; 2 books; 1 can of cream of mushroom soup; 1 can of chicken noodle soup; ruler; 2 other cans of soup (same size); 1 empty soup can

What to Do

1. Prop up two legs of the narrow end of the table by placing a book under each leg.
2. Place the can of mushroom soup and the can of chicken noodle soup at the top of the incline on their sides, next to each other. Put the ruler sideways in front of the cans to serve as the "starter" for the race.
3. Lift up the ruler so that the cans start to roll at the same time. Be prepared to catch them at the end of the table. Record which can won the race.
4. Repeat steps 2 and 3 using other pairings of the cans. Continue racing cans in pairs until you determine which can is the fastest, second fastest, and so on.

What's Going On Here

Several factors affect the speed of a can rolling down a table. One factor is the distribution of the can's mass. If the mass if concentrated at the center, an object will roll faster than if the mass is evenly distributed; if the mass is evenly distributed, an object will roll faster than if the mass is concentrated on the outer edge. So, for the racing cans, the can of cream of mushroom soup should roll faster than the can of chicken noodle because its mass is evenly distributed throughout the can, whereas once the chicken noodle soup is rotating, the noodles go to the outside of the can, which makes that can roll more slowly. Another factor that affects the speed of the can is friction. There is friction between the table and the can, and between the can's contents and the can itself. Noodles inside a can of chicken noodle soup are rubbing against the inside of the can, creating friction, which will slow the can down. A full can will have more friction with the table than an empty can, but it will also roll easier because of the way its mass is distributed. So three different factors affect the speed of the can rolling down the incline—mass of the can, distribution of the mass, and friction. The speed of each can depends on how these factors interact and the net effect each one has on the can.

Try It!

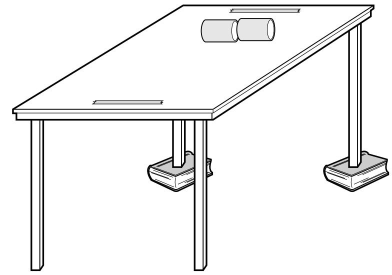
★ If you are really brave and/or have quick reaction time for catching things, try racing a raw egg and a cooked egg.

★ Try cans of soft drinks: diet, regular, and empty.

★ Try cans of vegetables.

Name Date

CIRCLING CANS



What You Want to Know

What kind of soup can rolls the fastest, and what kind rolls the slowest?

What You Think Will Happen

List the soup cans (including the empty one) in order, from the one you think will be the fastest to the one you think will be the slowest.

____________________ (fastest)

____

____

____

____________________ (slowest)

What Happened

Record each race you ran and the winner.

Race Contestants		Winner

What It Means

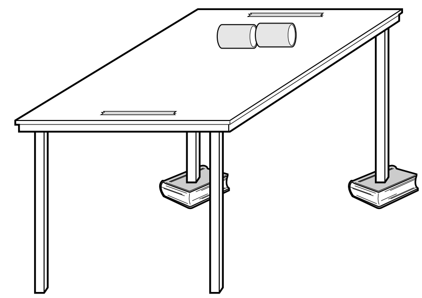
List the cans in order from fastest to slowest.

What other two cans would you like to race? Which do you think would win? Explain your answer.

CIRCLING CAN CONTEST

Science You can change the speed of a can rolling down a ramp by changing its mass and where the mass is distributed.

Stuff Masking tape; 2 empty soup cans (same size); scissors; table; book; duct tape; 20 washers; 1 sheet of newspaper; 1 balloon; tap water; pieces of packaging material; stopwatch



What to Do

This is an open-ended activity that expands on the concepts investigated in the previous activity.

1. Use a piece of masking tape on each can to cover the sharp edge where the lid was removed. Trim the tape so that it does not affect the rolling motion of the can.
2. Prop up two legs of the narrow end of the table by placing a book under each leg. Stick a piece of masking tape near the top end of the table to serve as the starting line and another piece at the other end for the finish line.
3. Using only the materials listed above, make a can that will roll quickly down the table.
4. Place the can sideways on the starting line. Release the can, and time how long it takes to get to the finish line. You may have to adjust the height of the table if the can moves too fast, but once you pick a height do not change it during the rest of the activity.
5. Make one change to the can to see if you can make it roll faster. Repeat step 4. Make another change to the can, and repeat step 4. When you make changes, you should change one thing at a time.
6. Repeat steps 4 and 5, this time designing and making changes to a can so that it will roll slowly down the ramp. Taping the can to the top of the ramp or changing its outside shape so it doesn't roll is not allowed. Your goal is to have a can that moves, but moves slowly.

What's Going On Here

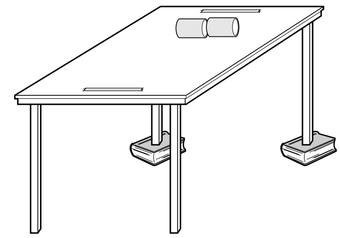
Three different factors affect the speed of the can rolling down the incline: mass of the can, distribution of the mass, and friction. The speed of the can depends on how these factors interact and the net effect each one has on the can. When you designed the inside of the can to make it move fast, the mass needed to be concentrated toward the center (hard to do with your materials) or evenly distributed. The friction between the can and the table and between the can itself and its contents needed to be minimized. Designing the slow-moving can was just the opposite; you wanted to maximize friction and distribute the mass in the can away from its center.

Try It!

★ Try soup can races with a partner. Have a slow race and a fast race.

Name Date

CIRCLING CAN CONTEST



What You Want to Know

How can you change the inside of an empty soup can so that it will roll quickly down a ramp? How can you change it to roll slowly down the ramp?

What You Think Will Happen

Draw a sketch of your design for a quick can and a slow can. Label all of your materials.

What Happened

Record the amount of time it took each can to roll down the ramp. Identify each can by what materials it had in it and how they were attached.

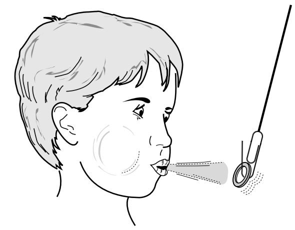
Quick cans		Slow cans	
Description	Time to roll down ramp	Description	Time to roll down ramp

What It Means

What other materials would you like to use to make your fast can roll even faster? How would you use the materials inside the can?

What other materials would you like to use to make your slow can roll even slower? How would you use the materials inside the can?

PUMPING A PENDULUM



Science A pendulum has a natural frequency. If you give it a push at just the right time, it will swing higher.

Stuff Paper clip; 20 inches of string; tape; table or desk; washer

What to Do

1. Tie the paper clip to one end of the string. Tape the other end of the string to the corner of a table or desk so that the paper clip can swing freely when it is pulled back.
2. Open the paper clip so the washer can be slid onto it. Place the washer on the paper clip. Pull the washer back a few inches and let it go. Observe the motion of the pendulum.
3. While the pendulum is swinging, blow a steady stream of air horizontally towards the washer. Observe the motion of the pendulum.
4. Now blow several small puffs of air toward the washer randomly. That is, sometimes blow the air on one side or the other side when the washer is at the top of its swing or at it lowest point in the swing. Observe the motion of the pendulum.
5. Blow several small puffs of air at the washer when it is at its highest point on the other side of the swing away from you, and observe its motion.
6. Blow puffs of air when the pendulum is at its lowest point in its swing, and observe its motion.
7. Blow small puffs of air at the pendulum when it is closest to you. Watch the pendulum carefully, because you may have to duck!

What's Going On Here

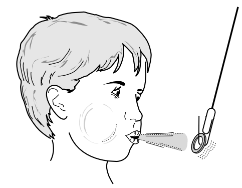
The pendulum has a natural frequency; if you give it a push at just the right time, it will swing higher. Young children who are learning how to "pump" playground swings experience the same effect. They have to pull back with their arms and legs and then push forward at just the right time if they want the swing to go higher. In this activity, you were mimicking a young child learning how to swing. Blowing puffs of air on the washer was the same as "pumping" it. The best way to pump a washer is to blow puffs of air on it when it is at the highest point of its swing, closest to you. When you blew a steady stream of air at the washer, it did not have much effect on its motion. Neither did blowing random puffs of air. What works the best is blowing puffs of air at just the right frequency and time.

Try It!

- ★ Try using more washers or a longer string.
- ★ Try changing the direction that you blow on the washer.
- ★ Try using some object other than a washer for the pendulum.

Name Date

PUMPING A PENDULUM



What You Want to Know

What is the best way to blow air on a washer pendulum ("pump" the pendulum) to make it go higher?

What You Think Will Happen

The washer pendulum will go higher if

- **a.** one steady stream of air is blown at the washer.
- **b.** several short puffs are blown at random times.
- **c.** several puffs are blown when the washer is at the top of its swing away from you.
- **d.** several puffs are blown when the washer is at the top of its swing closest to you.
- **e.** several puffs are blown when the washer is at the bottom of its swing.

What Happened

Record your observations for each type of "pump."

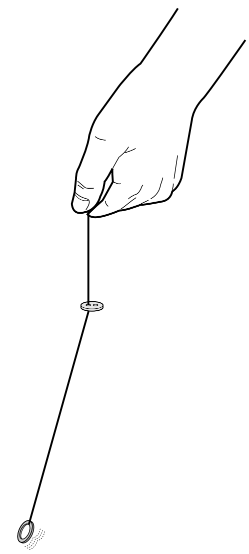
Pump	Observed motion of pendulum
One steady stream of air	
Several puffs at random times	
Several puffs at high point away from you	
Several puffs at low point	
Several puffs at high point closest to you	

What It Means

What advice could you give a young child who is trying to learn how to "pump" a swing?

Do you think you would have to use shorter puffs or longer puffs if the pendulum string was made longer? Explain your answer. Try it.

FINDING FREQUENCY



Science The frequency of a pendulum is the number of times it moves back and forth in one second. Frequency is greater for a shorter pendulum than for a longer one.

Stuff Washer; 40 inches of string; ruler; marker; button; stopwatch

What to Do

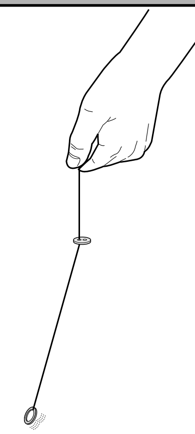
1. Tie the washer to one end of the string. Hold the string taut . Measure 10 inches from the center of the washer toward the top of the string, and mark the string. Measure 20 inches from the center of the washer, and make another mark. Measure 30 inches, and make another mark.
2. Thread the loose end of the string through a hole in the button. Line up the 30-inch mark on the string with the top of the button. Move both of your hands to start the washer swinging. Count how many complete swings the pendulum makes in 10 seconds. A complete swing is the motion of the pendulum from the top of its swing on one side back to that same point.
3. While the pendulum is still swinging, pull the string up through the buttonhole to the 20-inch mark, and count the number of complete swings in 10 seconds.
4. While the pendulum is still swinging, pull the string up through the buttonhole to the 10-inch mark, and count the number of complete swings in 10 seconds.
5. In each case, you counted the number of complete swings in 10 seconds, so divide each number by 10 to get the number of swings in 1 second for each of the lengths.
6. Line up the 30-inch mark with the button, and start the pendulum swinging. Slowly and smoothly pull the string upward, and observe the motion of the pendulum. Slowly and smoothly let the string back down through the buttonhole, and observe the motion of the pendulum.

What's Going On Here

As the pendulum is shortened, the period of the pendulum (time it takes to go back and forth) decreases, but the frequency (the number of swings in one second) increases. When you observed the pendulum motion, you may have thought the pendulum was moving faster when the string was shortened, but it depends on how you define the word *faster.* The pendulum is moving back and forth more times in a second since its frequency is greater, but its speed is actually less. The speed of the pendulum is greatest at the bottom of the swing and depends on the height that it rises to above the low level of the swing. The pendulum does not rise as high when it is shortened, so its speed at the low point is actually less.

Name Date

FINDING FREQUENCY



What You Want to Know

What is *frequency,* and how can you measure it using a pendulum? How does the frequency change with the length of the pendulum?

What You Think Will Happen

The frequency of a pendulum is the number of times it moves back and forth in a second. As the pendulum length is shortened, the frequency will

a. increase. **b.** decrease. **c.** stay about the same.

What Happened

Record the number of complete swings in 10 seconds at each length. Divide each number by 10 to get the number of swings in 1 second; this is the frequency of the pendulum.

Length	Swings in 10 seconds	Swings in 1 second (frequency)
10 inches		
20 inches		
30 inches		

Describe the motion of the pendulum when you started it swinging and then slowly pulled up the swing and let it down?

____

____

What It Means

What do you think the frequency would be for a pendulum having a length of 40 inches? Explain your answer. Try it.

____

____

What do you think the frequency would be for a pendulum having a length of 5 inches? Explain your answer. Try it.

____

____

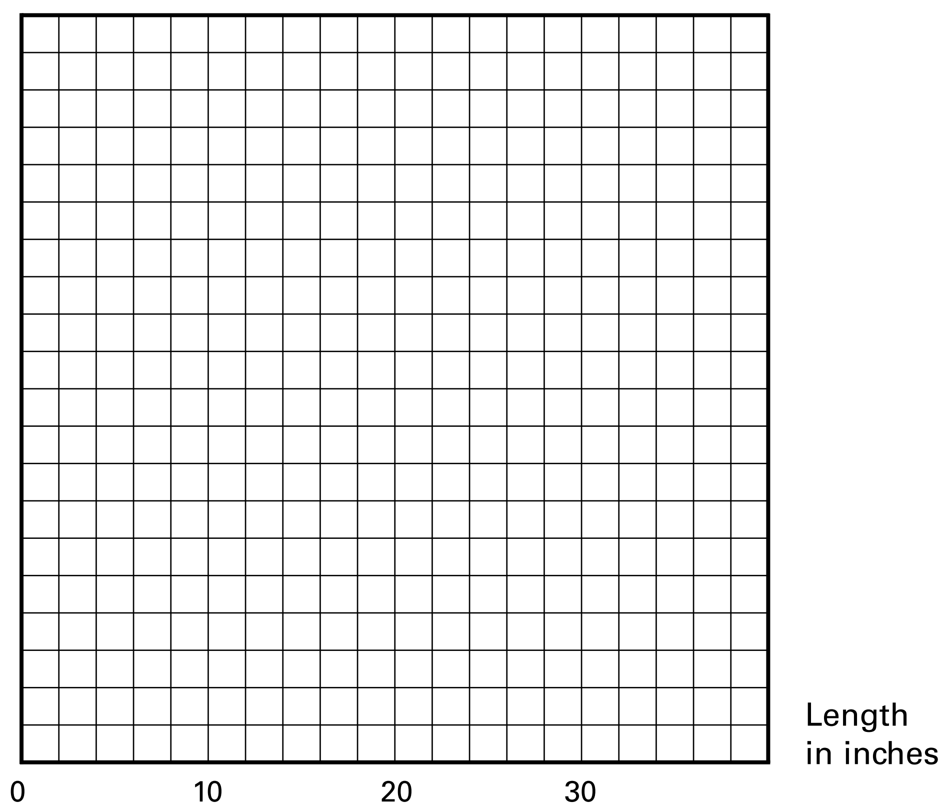
Graph It Next

Name Date

FINDING FREQUENCY

GRAPH IT!

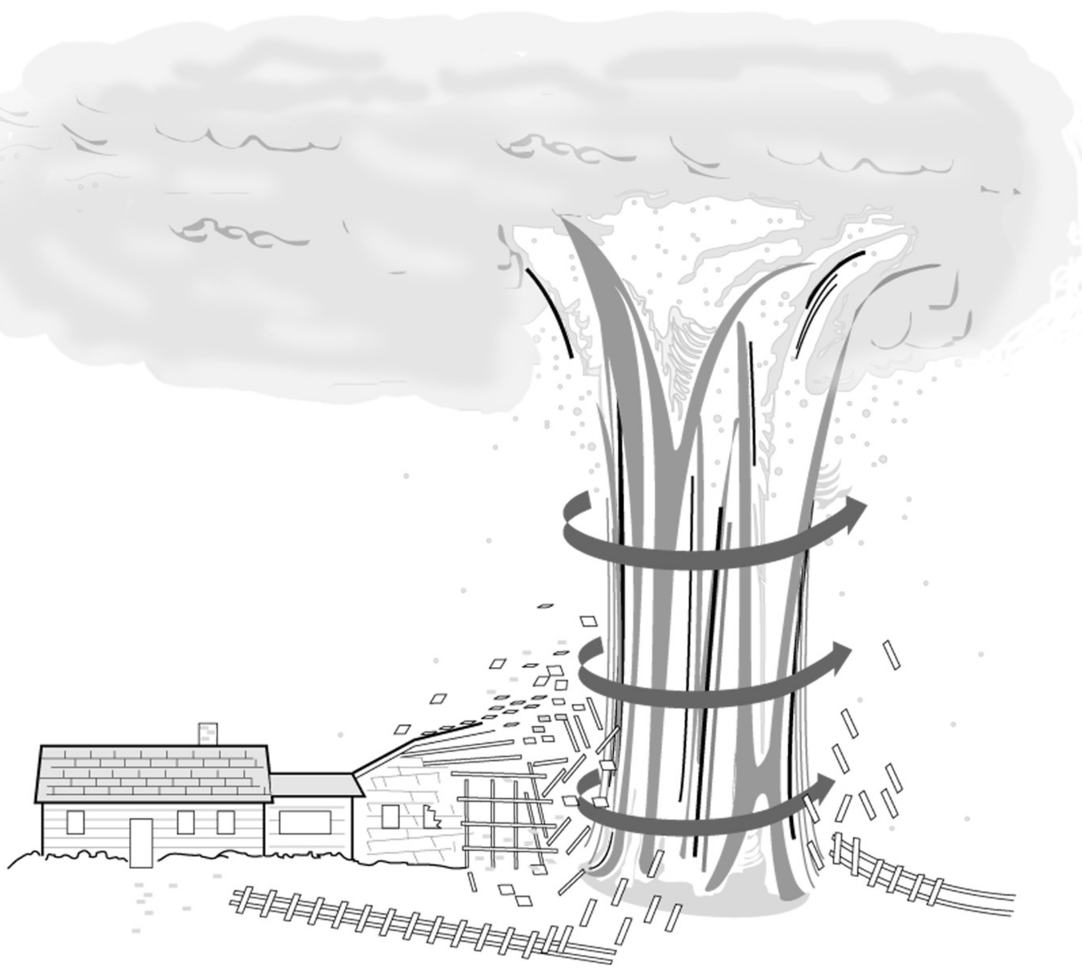
1. Label the vertical axis “frequency in swings per second.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis.
2. Plot the frequency and length data from the table in “What Happened.”
3. If your points look like they are on a straight line, use a straightedge to draw a line. The line should touch most of the points; those that it misses, it should miss by just a little bit. If your points look like they are on a curve, draw a smooth curved line through the points. Do not connect the points dot-to-dot.
4. Put a descriptive title at the top of your graph.



What does the graph predict the frequency would be for a length of five inches? Does that number agree with your estimate?

CHAPTER

8 WEATHER



WEATHER WONDERS

- Weather instruments are used to measure the many attributes of the weather. Some instruments are very sophisticated, and some are rather crude.

- Weather vanes are used to measure the direction in which the wind is blowing.

- Barometers are used to measure air pressure. Major changes in air pressure usually precede a change in the weather. When the air pressure drops significantly, you can expect wind and perhaps a storm.

- Thermometers are used to measure the temperature of the air. There are many kinds of thermometers that work on different principles. One type uses the rise and fall of a liquid inside a tube to indicate when the temperature is rising and falling.

- An *anemometer* is used to measure the speed of air, or wind speed.

- Despite advances in technology, snowfall is still measured the old-fashioned way. Measurements are taken with a ruler at several places after a snowfall and then averaged.

- The dew point is the temperature at which the air can no longer hold water. At this temperature, the water condenses out of the air.

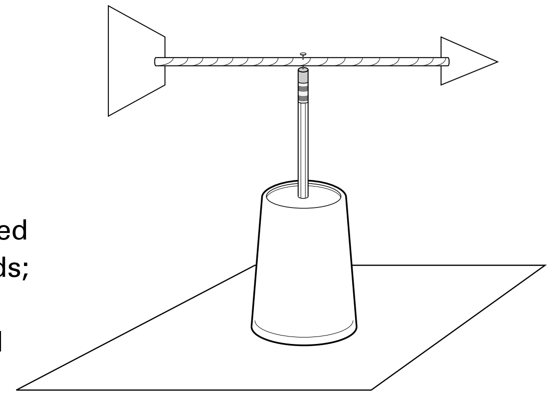
- When snow melts, it take up less space, so weather forecasters often say that 10 inches of snow is equivalent to 1 inch of rain. This is a rule of thumb; the water equivalent of snow varies depending on whether the snow is heavy and wet or light and fluffy.

- Clouds appear when water vapor condenses on particles in the air.

- Since many factors affect air temperature, it can change unpredictably over the course of a day. On most days, however, the temperature is lowest in the morning and evening and higher during the day. Interestingly, the highest temperature for the day usually occurs in the late afternoon. This is because the earth takes a while to warm up from the night before, a phenomenon called *thermal lag.*

- On cloudy days, the clouds insulate the earth from changes in temperature. In general, there is not as much difference between the high and low temperatures on cloudy days as there is on sunny days. Weather being as unpredictable as it is, there are many exceptions to this generalization.

WHICH WAY, WIND?



Science A weather vane is used to measure the direction in which the wind is moving.

Stuff Sharpened pencil; paper cup (5 ounce or larger); unsharpened pencil with eraser; 3 index cards; scissors; ruler; straw; tape; darning needle; stick pin; small plastic bead; clay

What to Do

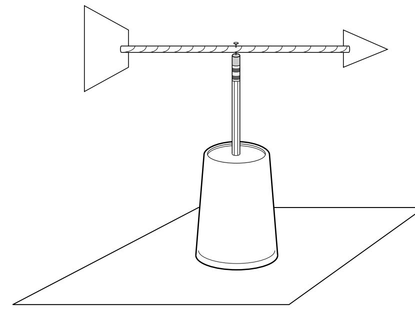
1. Using the sharpened pencil, poke a hole in the middle of the bottom of the paper cup so that the hole is large enough to fit the unsharpened pencil.
2. From an index card, cut a triangle with sides that measure one inch. From another index card, cut a trapezoid with a base of $4\frac{1}{2}$, a top of $1\frac{1}{2}$ inches, and sides measuring $3\frac{1}{4}$ inches. The top should be about $2\frac{3}{4}$ inches from the base.
3. Cut small slits in the top and bottom of the straw at each end of the straw. The slits should line up with each other and should be about $\frac{1}{2}$ inch long. Slide the triangle into the slits at one end of the straw and use a small piece of tape to hold it in place. Attach the $1\frac{1}{2}$ inch top of the trapezoid to the other end of the straw the same way.
4. Find the balancing point of the straw with the triangle and trapezoid attached by balancing the straw on your finger. Carefully push the darning needle through the straw at its balancing point. Remove the darning needle; push the stick pin through the hole in the straw, through the small plastic bead, and then into the eraser of the unsharpened pencil. Move the straw around the stick pin several times so that it moves freely.
5. Push the pencil through the hole in the bottom of the cup.
6. Put a small amount of clay on the writing end of the pencil. While holding the cup up, attach the clay to the middle of the third index card so that the pencil will stand upright. Put the cup flat on the index card, and tape it in place.
7. Take the weather vane outside, and observe the wind direction at several locations.
8. Place the weather vane on the ground and use your hand to move the arrow to the direction it would point if the wind were coming directly from the west. Write a W (for west) directly under the arrow on the index card. Repeat this step for the other directions; E (for east), N (for north), and S (for south).

What's Going On Here

Weather vanes are used to determine the direction of the wind. They do not measure speed, only direction. The arrow on the weather vane that you made will point into the wind when the other end of the weather vane catches the wind equally on both sides. Wind direction is usually given as the direction the wind is coming from, which for your weather vane is the direction that the arrow is pointing.

Name Date

WHICH WAY, WIND?



What You Want to Know

Which direction does the arrow on a weather vane point? Does a weather vane measure wind speed, direction, or both?

What You Think Will Happen

When the weather vane is placed in a breeze, the arrow will point

a. in the direction that the wind is coming from.

b. in the direction that the wind is moving toward.

Weather vanes can measure

a. wind speed.

b. wind direction.

c. both a and b.

What Happened

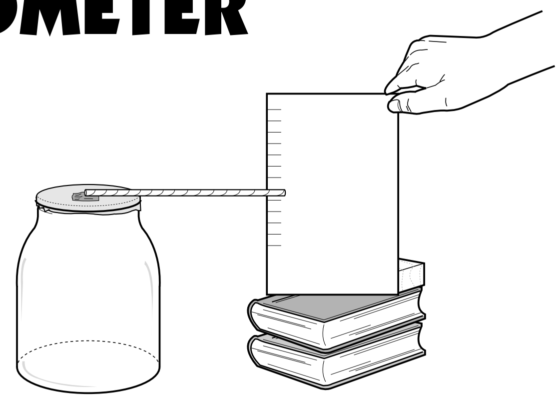
Draw a picture showing what your weather vane looked like when it was placed outside in the wind. Also show the direction in which the wind was blowing.

What It Means

Does a weather vane measure wind speed, wind direction, or both? What did you observe to help explain your answer?

What do your observations tell you about what direction the arrow on a weather vane will point?

BALLOON BAROMETER



Science A barometer measures air pressure.

Stuff Scissors; large balloon; wide-mouth jar; rubber band; double-sided tape; straw; index card; ruler; small block of wood

What to Do

1. Cut off the top part of a large balloon. Stretch the balloon over the opening of the top of a wide-mouth jar, and use a rubber band to secure the balloon in place. The balloon should be taut.
2. Put a small piece of double-sided tape in the middle of the balloon.
3. Attach one end of the straw to the double-sided tape on the balloon.
4. On the long edge of the index card, make small marks $\frac{1}{4}$ of an inch apart. Start at the bottom, and label the marks 1, 2, 3, 4, and so on. Use double-sided tape to attach the card to a small block of wood so that it stands upright.
5. Position the jar so that the straw points to the middle mark on the index card. You may have to place the index card on top of a few books. Record the number of the mark at the top of the straw.
6. Call a local weather station, check a weather site on the Internet, or listen to the weather report on television to find out the actual barometric pressure, and record it in a table.
7. Repeat steps 5 and 6 at the same time every day for a week. Do not move the card or jar between readings. Keep the jar in a protected area away from windows or heat sources.

What's Going On Here

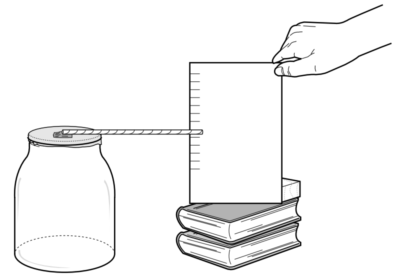
When the air pressure outside of the jar increases, the air pushes down on the balloon, and the straw moves upward, reflecting an increase in air pressure. The opposite thing happens when the air pressure decreases; then the air inside the jar pushes up on the balloon, and the straw moves downward, reflecting a decrease in the air pressure.

Try It!

★ Make a small version of the barometer using a small jar and a toothpick instead of the straw. Place the small jar inside a large jar. Cover the top of the large jar with a large balloon. Pull up on the balloon to simulate low pressure, and observe the movement of the toothpick. Push down on the balloon to simulate high pressure.

Name Date

BALLOON BAROMETER



What You Want to Know

What happens to the pointer on a barometer when the air pressure increases? Will a barometer measure changes in air pressure?

What You Think Will Happen

When the air pressure increases, the pointer on the barometer will move

a. up.

b. down.

What Happened

Record the barometric pressure at the same time for a week using your barometer. Record the barometric pressure from the local weather station for each day.

Date	Reading on your barometer	Reading on the local weather station barometer

What It Means

What do your observations tell you about how the pointer on the barometer moves when the air pressure increases? Explain why the pointer moves in that direction.

____

____

How do the readings made with your barometer compare to those from the local weather station?

____

____

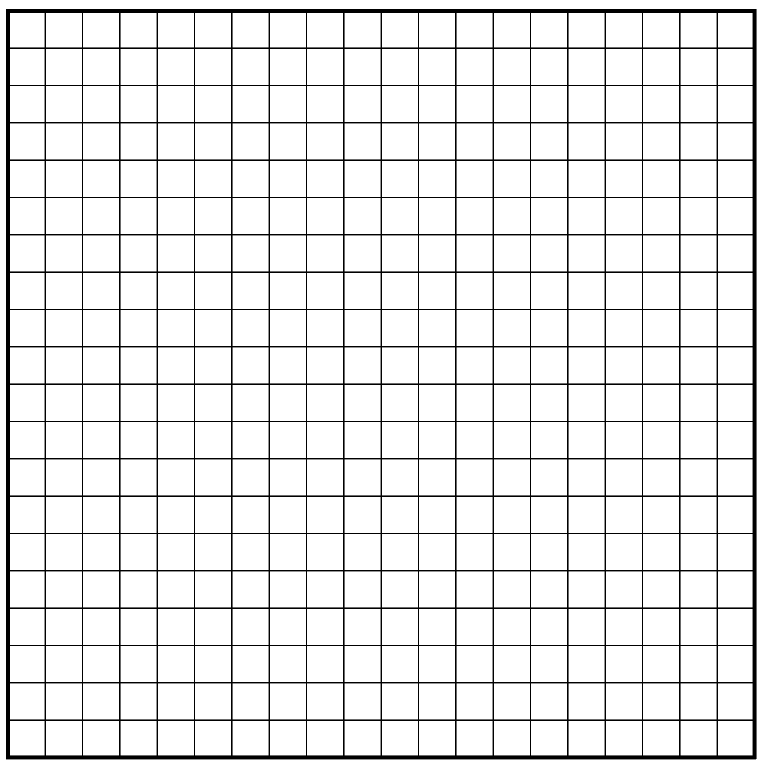
Graph It Next

Name Date

BALLOON BAROMETER

GRAPH IT!

1. Label the vertical axis “barometer reading.” Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write dates on the horizontal axis.
2. Plot your barometer data from the table in “What Happened.”
3. Connect each point, dot-to-dot, with the one before and after it using a straightedge or ruler.
4. Put a descriptive title at the top of your graph.



0 Date

On what date did the barometer have the lowest reading? __________

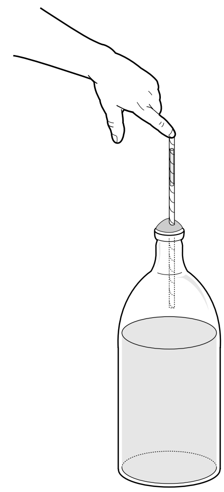
Put an L on this point on the graph.

On what date did the barometer have the highest reading? __________

Put an H on this point on the graph.

THRIFTY THERMOMETER

Science As air is heated, it expands. The more it expands, the more room it needs. This concept can be used to make an inexpensive thermometer.



Stuff Water; small cup; food coloring; clear straw (available from restaurants); small glass bottle; clay; large dish of hot water; large dish of ice water

What to Do

1. Put some water in a small cup, and add food coloring.
2. Place the straw in the cup of water to a depth of about an inch. Put your index finger over the top of the straw, and remove the straw from the water.
3. Keep your index finger over the top of the straw, and place the other end of the straw into the glass bottle. Place the straw about halfway into the bottle, and mold the clay around the top of the bottle, sealing it to the straw.
4. Take your finger off the top of the straw. The water should rise in the straw a little bit, but it shouldn't go over the top.
5. Wrap your hands around the lower part of the bottle, and hold on to it for a few minutes. The water in the straw should rise.
6. Place the bottle in a dish of warm water. If the water is warmer than your hands, the water in the straw should rise even more. If the water starts to go out of the straw, very quickly move the bottle into the ice water.
7. Place the bottle in a dish of ice water. The water in the straw should go down.

What's Going On Here

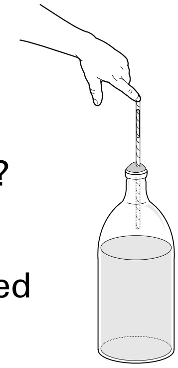
As the air inside the bottle is heated by your hands or by the warm water, the air molecules move faster and need to take up more space. There is space available in the straw if the air could just push the water up a bit. It gladly does this! When the bottle is placed in ice water, the opposite happens. The air molecules slow down, get closer together, and take up less space. The water in the straw is delighted to take up the space vacated by the air molecules, and it moves down to do just that.

Try It!

★ Try calibrating your straw thermometer by making marks on the straw and comparing the actual temperature of the water in the dish to the water level in the straw.

Name Date

THRIFTY THERMOMETER



What You Want to Know

What happens when air is heated? What happens when air is cooled?

What You Think Will Happen

A thermometer is made with a glass bottle. A straw containing colored water is attached to the top of the bottle with clay. When the bottle is heated by your hands or by placing the bottle in warm water,

a. the water inside the straw will rise.

b. the water inside the straw will drop.

c. the water inside the straw will not move at all.

When the bottle is placed in ice water,

a. the water inside the straw will rise.

b. the water inside the straw will drop.

c. the water inside the straw will not move at all.

What Happened

What happened when you wrapped your hands around the bottle?

___

What happened when you placed the bottle in warm water?

___

What happened when you placed the bottle in ice water?

___

What It Means

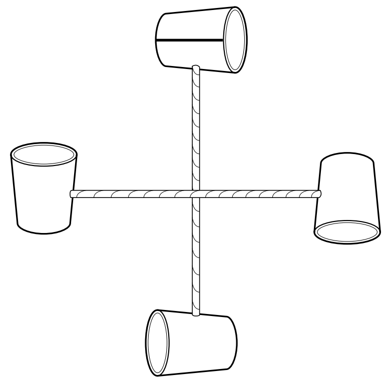
What do your observations tell you about how the temperature of the air in the bottle affects the movement of the water in the straw?

___

What do your observations tell you about how the temperature of the air affects how much space the air takes up?

___

BRISK BREEZE



Science An anemometer is used to measure the speed of the wind.

Stuff 2 straws; darning needle; stick pin; small plastic bead; pencil; 4 3-ounce paper cups; double-sided tape; masking tape; marker; ruler; stopwatch or clock with a seconds hand

What to Do

This activity works well on windy days.

1. Tape a cup to each end of each straw so that the opening of the cup is parallel to the straw. The cups should be pointed in opposite directions. Mark the outside of one of the four cups very clearly with a line down the middle.
2. Use the double-sided tape to tape the centers of the straws together. The opening of each cup should be facing the bottom of the adjacent cup.
3. Use the darning needle to poke a hole through the center of both straws.
4. Push the stick pin through the hole made by the darning needle, through the plastic bead, and into the eraser end of the pencil. You have now made an anemometer.
5. Take the anemometer outdoors. Watch the cups rotate in the wind. Count how many times the cup with the line on it passes in front of you in one minute.
6. Repeat step 5 at several different locations outdoors (for example on top of hill, next to a building, or under a tree.)

What's Going On Here

The faster the wind is blowing, the faster the cups will rotate. There is some friction between the parts of the anemometer, so the wind speed that you measure will be less than the actual wind speed. The wind speed will be different at different locations outdoors. For example, if the wind is coming from the west, then the wind speed on the east side of a building will be small, whereas the speed on top of a hill will be large.

Try It!

★ Try measuring the speed of air coming from a fan. Change the speed on the fan and also change the distance from the fan to the anemometer.

★ Measure the wind speed, and then call the local weather station to find out what the actual wind speed is.

Name Date

BRISK BREEZE

What You Want to Know
How can you measure wind speed?

What You Think Will Happen
List three locations where you will measure the wind speed with an anemometer.

____

____

____

At which location do you think the wind speed will be the greatest?

____

What Happened
Record the locations where you measured the wind speed and the number of times the cups completed a circle in one minute.

Location	Wind speed in number of circles per minute

What It Means
What do your observations tell you about the wind speed at different locations outdoors?

____

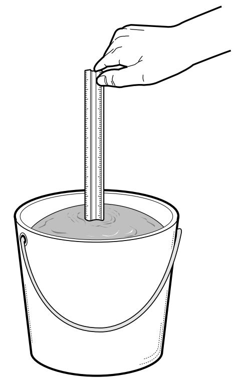
Where outdoors could you get warm on a cold windy day?

____

Where would you go outdoors on a hot windy day to get cool?

____

SNOW SCALE



Science When snow melts, it takes up less space.

Stuff Ice cream pail or small bucket; snow; ruler; clock or stopwatch

What to Do

1. An easy way to get snow is to live where it snows a lot and just wait. Ice shaving machines are available in toy stores and can be used to make snow from ice. If you use ice shavings, put them in a paper cup instead of a bucket.
2. Fill the bucket (or cup) with snow—the real stuff or the kind you made with the ice shaver.
3. Measure the depth of the snow in the bucket (or cup) using the ruler.
4. Allow the snow to melt naturally at room temperature. Time how long it takes to melt. Look at the melted snow carefully to see if there are any particles of dirt in it.
5. Measure the depth of the melted snow.
6. If you are using real snow, repeat steps 3 through 5, gathering snow from two other locations.

What's Going On Here

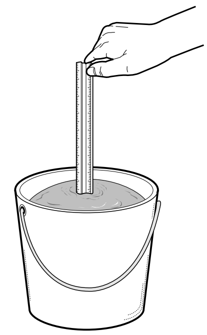
Snow contains crystals of ice, water, and often dirt from the air. When snow melts, it takes up a lot less space because the air trapped in the snow rejoins the atmosphere. A rule of thumb is that 10 inches of snow equals 1 inch of water, but the exact ratio depends on the water and air mixture of the snow. A "dry snow" will have less water in it and will melt down to a smaller volume of water, whereas a "wet snow" will have more water in it and melt down to a larger volume of water. Snow that has been on the ground for several days becomes compacted and will have more water in a given volume than it had when it was "fresh." The amount of water in snow is important in predicting how much water will be in the rivers when the snow melts in the spring.

Try It!

- ★ Try comparing the amount of water in snow taken on several different days from the same spot after a fresh snowfall.
- ★ Compare the amount of water in snow from a snowfall when the temperature is close to freezing (a "wet snow") to that from a snowfall when the temperature is significantly below freezing (a "dry snow").
- ★ Use an ice shaving machine to measure the amount of melted liquid using frozen liquids other than water, such as milk or juice.

Name Date

SNOW SCALE



What You Want to Know

How much water is in snow? How long does it take for snow to melt at room temperature?

What You Think Will Happen

About how long will it take for the snow you gathered to melt? ______________________

How many inches of water will you have after the snow has melted? ______________________

What Happened

Record the location at which you gathered the snow, the amount of snow in the bucket, the time it took it to melt, and the amount of water remaining.

Location	Amount of snow	Time to melt	Amount of water

What did you observe when you looked at the melted snow?

____

What It Means

What do your observations tell you about how long it takes for snow to melt at room temperature?

____

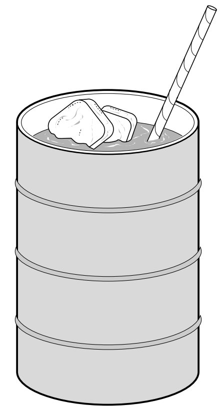
What do your observations tell you about how much water is in melted snow?

____

What could cause the difference in the amount of snow you measured and the amount of water in the melted snow?

____

DOING DEW POINTS



Science The dew point is the temperature at which the air can no longer hold water. The water condenses out of the air in the form of dew.

Stuff Empty soup or vegetable can; water at room temperature; thermometer; ice cubes; straw

What to Do

1. Take the label off the can. Fill the can three-fourths full of water that is at room temperature.
2. Using the thermometer, record the air temperature in the room.
3. Place the thermometer in the water against the bottom of the can. Record the temperature.
4. Add two ice cubes to the water. Gently stir the water with the straw. If the room temperature is above 80°F, use cold tap water instead of ice, adding it very slowly to the can.
5. Watch the can very carefully as you stir the water. Record the temperature when you first notice the can begin to fog up with moisture beginning to appear on the outside of the can. This is the *dew point.* If you are unsure whether the can has fogged up, just wipe your finger on the can near the bottom to see if there is water on the can. If the dew point is below 32°F, dew will not form on the can, and you will have to try this activity on a more humid day.
6. Repeat steps 1 through 5 outdoors. This will give you the outdoor dew point.
7. Repeat steps 1 through 5 indoors using hot tap water in the can. Blow on the can while slowly adding and stirring cold tap water into the can. This will give you the dew point of your breath.

What's Going On Here

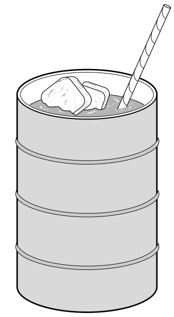
The *dew point* is the temperature at which the air is saturated and can hold no more water. At this temperature, moisture in the air will condense. If the dew point is very close to the air temperature, the humidity is high. If the dew point is not close to the air temperature, then the humidity is low. Dew point is often used to determine how comfortable the air is. When the dew point reaches 60°F, the air is considered to be uncomfortable. In this activity, the thin layer of air surrounding the outside of the can is cooled to the same temperature as the can. When the air surrounding the can is lowered to the dew point, water in the air condenses on the can. The dew point of your breath is high because your breath contains a lot of moisture. The high dew point of your breath is why windows in your car become fogged up in the winter.

Try It!

- ★ Listen to the weather report, and compare the dew point on a particular day to the dew point you measured.
- ★ Measure the dew point in your bathroom after taking a bath or shower.

Name Date

DOING DEW POINTS



What You Want to Know
What is the dew point, and how can it be measured?

What You Think Will Happen
The dew point is the temperature at which the air can no longer hold water. The higher the dew point, the higher the humidity.

The dew point of the room will be ______ °F.

The dew point outside will be ______ °F.

The dew point of your breath will be ______ °F.

What Happened
Record the air temperature and dew point inside, outside, and using your breath.

	Temperature	Dew point
Inside		
Outside		
Your breath		

What It Means
What do your observations tell you about how the dew point is measured?

____

Does cool air hold more or less water than warm air? Explain your answer.

____

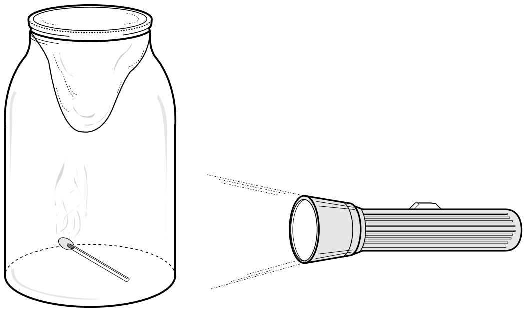
How do you think dew point and humidity (a measure of the amount of water in the air) are related?

____

Why might the dew point be different inside than outside?

____

CLOUD CHAMBER



Science Clouds appear when water vapor condenses on particles in the air.

Stuff Wide-mouth jar; water; matches; plastic sandwich bag; 2 rubber bands; flashlight

What to Do

1. Make sure that your forefinger and thumb can fit through the opening of the wide-mouth jar. Take the label off the jar.
2. Fill the jar halfway with warm water. Swirl the water around the jar, and then pour it out. Do not dry the jar.
3. Light a match, and drop it into the jar. When the match has been extinguished, quickly put your hand inside the plastic bag, and place the bag inside the jar. Wrap the top of the plastic bag around the top of the jar, and secure it tightly with two rubber bands.
4. Place a flashlight on its side next to the jar, and turn on the light so that it shines through the jar.
5. Darken the room.
6. Put your fingers inside the jar, grasp the plastic bag, and pull it quickly upward from the jar. You will see a cloud form.
7. Slowly push the sandwich bag back into the jar, and repeat step 6.

What's Going On Here

Three things are required for clouds to form: water vapor in the air; dust, smoke, or ice particles in the air; and cooling so that the water vapor can condense out of the air on to the dust, smoke, or ice particles. In this activity, the swirling water around the jar provided the water vapor. The extinguished match provided the smoke particles on which the water vapor could condense. The air inside the jar was cooled when the plastic bag was pulled upward. Pulling up on the plastic bag increased the volume of the jar and reduced the air pressure, thus cooling the air inside the jar.

Try It!

★ Try using a larger or smaller jar.

★ Try dropping several matches into the jar. Make sure all the matches are extinguished before you put the plastic bag over the jar.

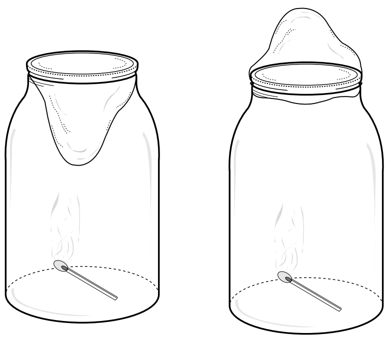
★ Try the activity in a room with the lights on.

Name Date

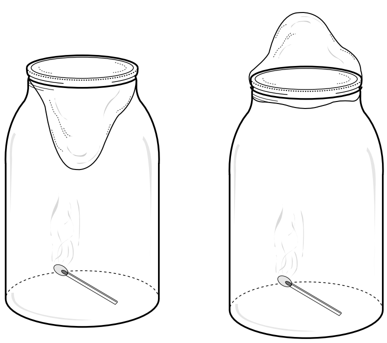
CLOUD CHAMBER

What You Want to Know
How do clouds form?

What You Think Will Happen
Draw a picture of what you think the inside of the jar will look like when you push in on the plastic bag and when you pull up on the plastic bag.



What Happened
Record what the inside of the jar looked like when the bag was pushed into the jar and when the bag was pulled up from the jar.

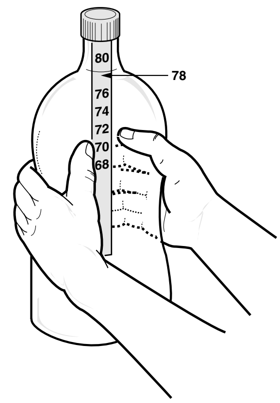


What It Means
What do your observations tell you about how clouds are formed?

What three things are needed for clouds to form?

How do you think the three things needed for clouds to form happen outdoors naturally?

PACKED PARTICLES



Science When air is squeezed into a smaller space, its temperature increases.

Stuff Adhesive thermometer for aquarium (liquid crystal type); empty 20-ounce pop bottle with cap; empty 64-ounce pop bottle with cap

What to Do

1. Bend about a half inch of the top of the thermometer downward so that the adhesive backing is on the outside of the fold. Peel the top half inch of the adhesive backing off the top of the thermometer.
2. Attach the thermometer to the inside of the cap of the 20-ounce plastic bottle using the adhesive backing.
3. Place the cap tightly on the bottle.
4. Record the temperature from the thermometer strip. If two of the numbers seem to be showing, record the number between them.
5. Squeeze the bottle as tightly as you can, and keep the bottle squished for about a minute. Record the temperature on the thermometer as you did in step 4.
6. Release your grip on the bottle. Wait about a minute, and record the temperature on the strip.
7. Repeat steps 2 through 6 using the larger bottle.

What's Going On Here

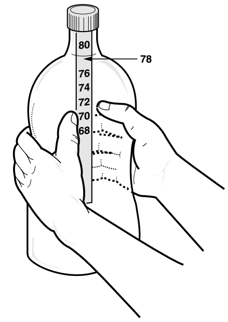
The temperature inside the bottle is a result of the movement of the particles of air inside the bottle. When you squeeze the bottle, the particles of air move around in a smaller space and collide more often with other particles of air. The additional collisions cause friction between the air molecules, which causes the temperature in the bottle to increase. When you release your grasp on the bottle, the temperature in the bottle decreases because the air particles in the bottle do not collide as often and thus produce less heat. Compared to the smaller bottle, there is not much increase in temperature when you squeeze the larger bottle. You can squeeze the larger bottle more, but it has a much larger volume of air. The atmosphere is very similar to the air inside the bottle. When the atmosphere is pushed into a smaller space, the temperature increases; when the atmosphere takes up a larger space, it cools down.

Try It!

- ★ Try using a bottle that has been stored in the refrigerator for 20 minutes.
- ★ Try using a bottle that has had hot water poured into it, swished around, and then poured out.

Name Date

PACKED PARTICLES



What You Want to Know

What happens to the temperature inside a closed plastic bottle when you squeeze the bottle very tightly?

What You Think Will Happen

When you squeeze a closed plastic bottle very tightly, the temperature inside the bottle will

a. increase. **b.** decrease. **c.** stay the same.

If you use a larger bottle, the results will be

a. noticeably different. **b.** about the same.

What Happened

For each bottle, record the temperature before squeezing, while squeezing, and after you have stopped squeezing the bottle.

Bottle size	Temperature before squeezing	Temperature while squeezing	Temperature after squeezing

What It Means

What do your observations tell you about how the temperature inside a bottle changes when you squeeze the bottle very tightly?

When you squeeze the bottle very tightly, what happens to the amount of space that the air particles have? Will the amount of space that the particles have cause them to bump together more or less often? Explain how the bumping together of the particles could change the temperature inside the bottle.

TRAILING TEMPERATURES

Science The highest temperature of the day usually occurs in the late afternoon, after the sun has been highest in the sky.

Stuff Nightly weather report

Day	High	Time	Low	Time	Kind of day

What to Do

1. Watch the nightly weather report for one week, or check a weather site on the Internet. Check at the same time every night.
2. Record the high temperature, the low temperature, and the time at which each occurred. You may need someone to help you record the numbers because weather reporters generally talk very fast. Also record the kind of day it was: sunny, cloudy, partly sunny, or partly cloudy.
3. Look at the high temperature and the time it occurred each day to see if there is a pattern. Do the same thing for the low temperature.

What's Going On Here

The high temperature for the day usually occurs in the late afternoon, several hours after the sun has been at its highest point in the sky. One might expect the high temperature to be at midday when the sun is highest in the sky, but this is generally not the case. The earth heats the atmosphere, and it takes a while for the earth to warm up after cooling down at night. This phenomenon is called *thermal lag*. The low temperature for the day usually occurs after midnight because the earth takes a while to cool down after it has been warming up all day. Other factors affect the time that the high and low temperature occur, such as a front moving in and cloud cover. Thermal lag affects seasonal temperatures, too. Even though the sun is at its lowest point in the Northern Hemisphere around December 21, the coldest day of the year is generally around the middle of January. The hottest day of the year is around the middle of July even though the sun is highest in the sky in the Northern Hemisphere around June 21.

Try It!

- ★ Look in an almanac or use the Internet to find historical information on weather. Determine when the coldest day of the year generally occurs and when the hottest day of the year generally occurs.
- ★ Watch the weather report every hour during the day, or call the local weather station to get the current temperature. Make a graph of the temperature over the course of a day to see how it changes.

Name Date

TRAILING TEMPERATURES

What You Want to Know

What time of the day does the highest temperature usually occur? What time of the day does the lowest temperature usually occur?

What You Think Will Happen

The highest temperature of the day will usually occur

a. at midday when the sun is highest in the sky.

b. a few hours after midday.

c. a few hours before midday.

d. in the morning right after the sun rises.

The coldest temperature of the day will usually occur

a. around midnight.

b. a few hours after midnight.

c. a few hours before midnight.

d. in the evening right after the sun sets.

What Happened

Record the day, high temperature and time it occurred, low temperature and time it occurred, and weather conditions.

Day	High temperature	Time	Low temperature	Time	Kind of day

What It Means

What do your observations tell you about when the highest temperature of the day occurs and when the lowest temperature of the day occurs?

____

____

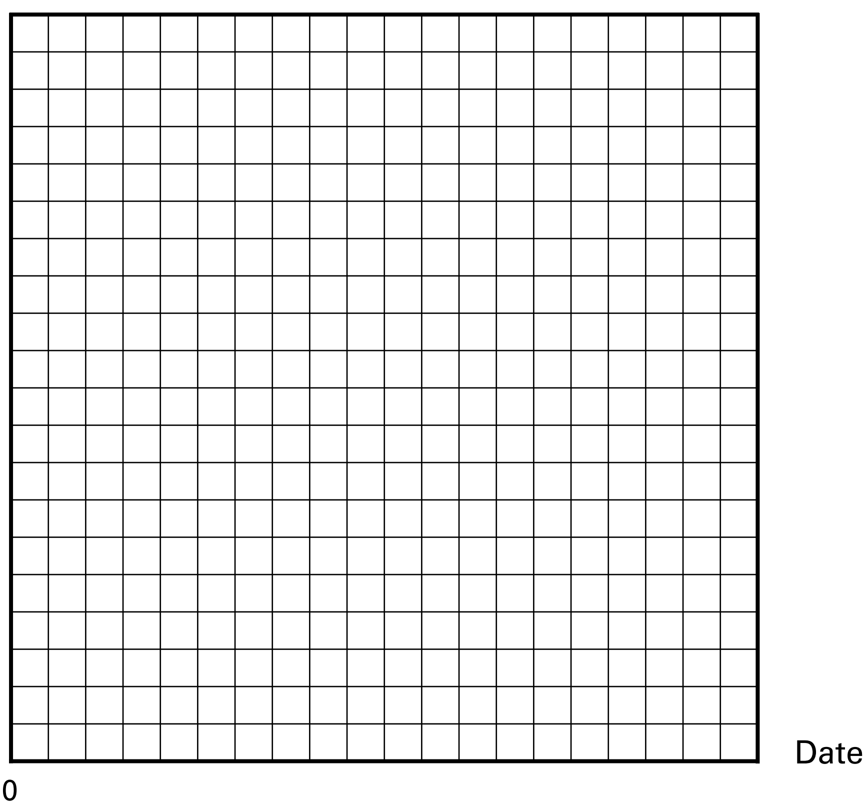
Graph It Next

Name Date

TRAILING TEMPERATURES (HIGH)

GRAPH IT!

1. Label the vertical axis "high temperature in degrees F or C" (whichever you used). Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write dates on the horizontal axis, too.
2. Plot the high temperature data from the table in "What Happened."
3. Connect each point, dot-to-dot, with the one before and after it using a straightedge or ruler.
4. Put a descriptive title at the top of your graph.



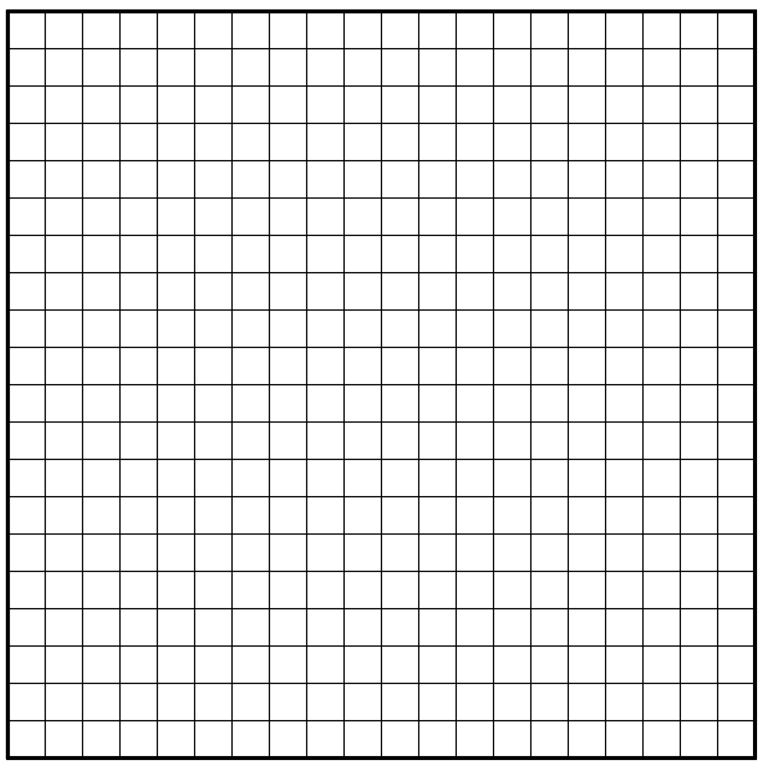
Use a colored pencil to show what this graph might look like three months from now. Explain why you think the graph would look that way.

Name Date

TRAILING TEMPERATURES (LOW)

GRAPH IT!

1. Label the vertical axis "low temperature in degrees F or C" (whichever you used). Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write dates on the horizontal axis, too.
2. Plot the low temperature data from the table in "What Happened."
3. Connect each point, dot-to-dot, with the one before and after it using a straightedge or ruler.
4. Put a descriptive title at the top of your graph.



0

Date

Use a colored pencil to show what this graph might look like three months from now. Explain why you think the graph would look that way.

MINIMUMS AND MAXIMUMS

Science On cloudy days there is usually less of a difference in the high and low temperatures than there is on a sunny day.

Stuff Nightly weather report

Day	High	Low	Difference	Kind of day

What to Do

1. Watch the nightly weather report for one week, or check a weather site on the Internet. Check it at the same time every night.
2. Record the high temperature and the low temperature. You may need someone to help you record the numbers because weather reporters talk really fast. Also, record the kind of day it was: sunny, cloudy, partly sunny, or partly cloudy.
3. For each day, subtract the low temperature from the high temperature. Look at the difference between the high and low temperatures for each day and the kind of day it was to see if there is a pattern.

What's Going On Here

The difference between the daily high and low temperatures depends on the cloud cover. On sunny days, the earth absorbs more of the sun's energy and the air gets warmer. If the evening is clear with no clouds, the warm air from the earth can escape, and the evening becomes cooler. With no cloud cover, there is a big difference between the high and low temperatures. When there is significant cloud cover, the earth does not have much of a chance to heat up during the day. The clouds keep the sunlight out. In the evening, the clouds keep the warm air from escaping. There is usually a smaller difference between the high and low temperatures on a cloudy day than on a clear one. Other factors such as a front moving in can affect the difference between the daily high and low temperatures.

Try It!

★ Try the activity at different times during the year.

★ Make a graph of the daily high and low temperatures for a week.

★ Look in an almanac or use the Internet to find historical information on weather. Find the difference between the daily high and low temperatures at different times of the year. Is the difference greater in the spring on a sunny day than it is in the summer on a sunny day?

Name Date

MINIMUMS AND MAXIMUMS

What You Want to Know

If you subtract the daily low temperature from the daily high temperature each day for a week, will the difference always be about the same?

What You Think Will Happen

If you subtract the daily low temperature from the daily high temperature each day for a week, the difference will be

a. greater on cloudy days. **b.** greater on sunny days.

c. about the same throughout the week.

What Happened

Record the daily high temperature, low temperature, the difference between the high and low temperatures, and the weather conditions (sunny, cloudy, partly sunny, or partly cloudy) for one week.

Day	High temperature	Low temperature	Difference	Kind of day

What It Means

How does the difference in the high and low temperature change over a week?

Does the difference between the high and low temperature seem to be greater on sunny days or cloudy days?

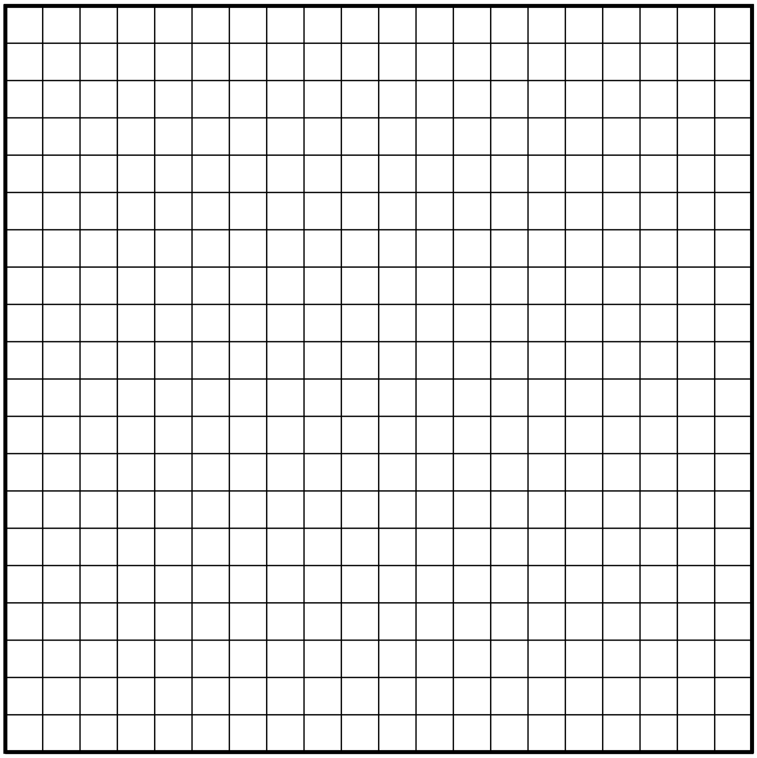
What other factors could affect the difference between the daily high and low temperature?

Graph It Next

MINIMUMS AND MAXIMUMS

GRAPH IT!

1. Label the vertical axis "temperature difference in degrees F or C" (whichever you used). Pick a convenient scale, and write numbers on the vertical axis starting at 0. Keep the scale the same on the entire vertical axis. Write dates on the horizontal axis, too.
2. Plot the temperature difference data from the table in "What Happened."
3. Connect each point, dot-to-dot, with the one before and after it using a straightedge or ruler.
4. Put a descriptive title at the top of your graph.



0 Date

On what day was the temperature difference the greatest? ________________

Put a G on this point on the graph.

On what day was the temperature difference the least? ___________________

Put a L on this point on the graph.

Glossary

Accelerate To increase an object's speed, change its direction of motion, or both.

Air pressure The weight of the air pushing down on us; the force of air molecules bouncing off something.

Air resistance A force that opposes the motion of objects through air. As an object moves through air, it is constantly bumping into air molecules that resist the object's motion.

Anemometer An instrument used to measure wind speed.

Angle The opening between two lines that meet at a point.

Angle of incidence The angle that light strikes a surface.

Angle of reflection The angle that light bounces off of a surface.

Angular distance The distance between two objects (or two sides of a single object) using an angle. One of the rays of the angle goes from your eye to one object (or side of a single object), and the other ray goes from your eye to the other object (or other side of a single object).

Angular momentum The momentum of an object moving in a circular path. It is the product of the object's mass, speed, and radius of motion.

Archimedes' principle An object will float if the weight of the water it displaces is equal to the weight of the object; an object will sink if the weight of the displaced water is less than the weight of the object. Named after its discoverer, Greek mathematician and inventor Archimedes (287–212 B.C.).

Astrolabe An instrument that measures the angular separation of objects. It is used to measure the height of objects, the angle an object is above the horizon, and the angular distance between objects.

Barometer An instrument used to measure air pressure.

Buoyant force The force of water pushing up on an object. It is equal to the weight of the water that is displaced by the object.

Centripetal force The force on an object that is moving in a circular path. The direction of this force is toward the center of the circle.

Condense To change from a gas to a liquid when cooling occurs. Water vapor condenses to water droplets when cooled.

Convex An outward curve.

Compressed Pushed tightly together.

Conservation of energy, law of Energy cannot be created or destroyed. It can be changed from one form to another, for example, from potential to kinetic, but the total amount of energy stays the same.

Crater A depression in the moon's surface caused by the collision of a high-speed meteorite after the moon was formed.

Density How much matter there is within a given space; or mass per volume. A box filled with feathers is less dense than the same box filled with books.

Dew point The temperature at which the air can no longer hold water. At this temperature, the water condenses out of the air.

Diameter The distance from one edge of a circle to the opposite edge, measured through the center of the circle.

Diffraction The spreading out of waves as they go around an obstacle or through an opening.

Diffraction grating A piece of plastic with parallel lines etched into it very close together. It is used to disperse light.

Direct relationship When one measured quantity increases, the other measured quantity increases.

Disperse To break up. A prism disperses white light into its component colors of red, orange, yellow, green, blue, indigo, and violet.

Displace To push aside.

Divergence The spreading out of a beam of light.

Effort The force that is applied to do work.

Effort distance The distance from the fulcrum to the effort location on a lever. Also called the *effort arm.*

Energy The ability to do work.

First-class lever Lever with the fulcrum located between the effort force and the load.

Force A push or a pull.

Frequency The number of times in 1 second that a vibrating object moves back and forth; the number of waves that pass a point in 1 second.

Friction A force caused by irregularities in the surfaces of objects that are moving over each other. The direction of the force of friction is always opposite to the motion of an object.

Fulcrum The support for a lever.

Gravity The force of attraction between two objects due to their masses. The force of gravity that attracts a person toward the earth is the person's weight.

Gravity, law of Every object in the universe attracts every other object in the universe with a force. This force is greater for greater masses, and it decreases as the distance between the objects increases.

Heat The energy that flows from one object to another because of a difference in temperature; the energy caused by the motion of molecules and atoms. When an object is heated, the molecules move faster. When an object is cooled, the molecules move slower.

Inertia The measure of an object's resistance to a change in its motion, in either direction or speed.

Intensity Brightness of light; loudness of sound.

Inverse relationship When one measured quantity increases, the other measured quantity decreases.

Kinetic energy The energy of motion. The kinetic energy of an object increases as its mass or speed increases.

Load The weight that is lifted using a machine.

Load distance The distance from the fulcrum to the load location on a lever. Also called the *load arm*.

Lunar illusion The moon appears to be larger when it is rising or setting than when it is high in the sky.

Mass A measure of the amount of matter in an object.

Matter Anything that has mass and occupies space.

Meteorite Stony or metallic object from space that lands on a planet or moon.

Momentum The short form for *linear momentum,* the product of an object's mass and speed.

Newton's first law of motion An object stays at rest or in motion at a constant speed in a straight line unless it is acted upon by a force. The law is named after its discoverer, English astronomer, scientist, and mathematician Sir Isaac Newton (1642–1727).

Newton's second law of motion The more you push or pull on an object, the greater effect you will have on changing its speed or direction of motion. The object will move in the same direction that you pushed or pulled it. The law is named after its discoverer, English astronomer, scientist, and mathematician Sir Isaac Newton (1642–1727).

Newton's third law of motion For every force on one object, there is an equal (in size) and opposite (in direction) force on another object. The law is named after its discoverer, English astronomer, scientist, and mathematician Sir Isaac Newton (1642–1727).

Pendulum An object that swings back and forth. An example is a washer attached to a string.

Period The time it takes a pendulum to make a complete swing. A complete swing is going from a high point, passing through the low point, going up to the other high point, back through the low point, and up to the original high point.

Pitch Highness or lowness in the tone of a sound. The higher the frequency, the higher the pitch.

Potential energy Stored energy that may be changed to kinetic energy. One kind of potential energy is the result of an object's position—for example, its height above the ground. If the object falls to the ground, the potential energy changes to kinetic energy as it falls.

Pressure The ratio of force to the area that the force is acting on.

Projectile An object that is launched or thrown at any angle between 0° (straight up or vertical) and 90° (straight out, or horizontal). The vertical motion of a projectile is independent of its horizontal motion. In other words, a projectile falls to the ground in the same amount of time no matter what its horizontal speed.

Range The horizontal distance that a projectile travels from the place it was launched to the place it lands on the ground. For a given speed, the range is greatest at a 45° launch angle.

Reflection The bouncing back of light from a surface.

Reflection, law of The angle that light strikes a surface is the same as the angle that it is reflected off the surface. The angle of incidence equals the angle of reflection.

Refraction The bending of light as it passes from one material to another, as from glass to air or glass to water.

Resonance The condition that exists when an object is pushed at the same frequency as the object's own frequency. In the case of a pendulum, it simply means giving the pendulum a push when it is at the top of its swing.

Restoring force The force that pulls a stretched spring back to its original unstretched form or pushes a compressed spring back to its uncompressed form.

Scatter To send off in many different directions.

Second-class lever Lever with the load located between the fulcrum and the effort.

Sliding friction The amount of force needed to keep an object moving over a surface.

Spectroscope A scientific instrument that is used to view a visible light spectrum.

Spectrum All the colors that are in white light: red, orange, yellow, green, blue, indigo, and violet.

Speed A measure of how fast an object is moving. Average speed is determined by dividing the distance an object travels by the elapsed time.

Spring constant The measure of how stiff a spring is or how easily it can be stretched. A spring with a large spring constant can be easily stretched.

Static friction The amount of force needed to start an object moving over a surface.

Sun protection factor (SPF) A standardized measurement of a sunscreen's ability to protect the skin and prevent sunburn. If on a particular day, your skin would burn in 10 minutes without protection, using a sunscreen with an SPF of 4 would protect you from a sunburn for 40 minutes (SPF of 4 $\times$ 10 minutes).

Surface tension The attraction of the molecules of some materials to one another. Surface tension in water allows you to fill a glass slightly over the top.

Third-class lever Lever with the effort located between the fulcrum and the load.

Thrust The force on an object that is in the direction of its motion or intended motion.

Total internal reflection Trapping light inside a material. When light travels from a more dense material like glass into a less dense material like air at a certain angle, none of the light is bent into the less dense material; it is all reflected back into the more dense material.

Transmission The passing of light through an object. For example, glass and clear plastics transmit light well.

Vacuum Space that has no matter in it.

Vibration Moving back and forth.

Volume The amount of space that an object occupies; the loudness or softness of sound.

Water pressure The weight of water pushing on an object.

Water vapor The gaseous state of water.

Wavelength The distance between two adjacent peaks in a wave. The wavelength of light determines its color; red light has a longer wavelength than violet light.

Weight The force of gravity on an object.

Work What is done when a force is applied to an object and the object moves in the direction of the force.

Selected Bibliography

Allison, Linda, and David Katz. *Gee Whiz: How to Mix Art and Science, or the Art of Thinking Scientifically.* Boston: Little, Brown, 1983.

Bentley, Joan, and Linda Hobbs. *How to Do Science Experiments with Children.* Monterey, CA: Evan-Moor, 1994.

Herbert, Don. *Mr. Wizard's Supermarket Science.* New York: Random House, 1980.

Hoover, Evalyn, et al. *Principally Physics.* Fresno, CA: AIMS Education Foundation, 1991.

Levenson, Elaine. *Teaching Children About Science Ideas and Activities Every Teacher and Parent Can Use.* Englewood Cliffs, NJ: Prentice-Hall, 1985

Liem, Tik L. *Invitations to Science Inquiry.* Chino Hills, CA: Science Inquiry Enterprises, 1987.

Murphy, Pat, and Suzanne Shimek. *Exploratorium Science Snackbook*. San Francisco: Exploratorium Teacher Institute, 1991.

Popelka, Susan. *Super Science with Simple Stuff!* Palo Alto, CA: Dale Seymour, 1997.

Smith, Robert. *Hands-On Science: The Science Series.* Grand Rapids, MI: Instructional Fair, 1989.

VanCleave, Janice. *Physics for Every Kid: 101 Easy Experiments in Motion, Heat, Light, Machines, and Sound.* New York: John Wiley, 1991.

VanCleave, Janice. *200 Gooey, Slippery, Slimy, Weird, and Fun Experiments.* New York: John Wiley, 1993.

VanCleave, Janice. *201 Awesome, Magical, Bizarre, and Incredible Experiments.* New York: John Wiley, 1994.

Walpole, Brenda. *175 Science Experiments to Amuse and Amaze Your Friends.* New York: Random House, 1988.

Walpole, Brenda. *175 More Science Experiments to Amuse and Amaze Your Friends.* New York: Random House, 1990.

Index

acceleration 160. 184
air pressure 250, 254, 265
air resistance. 104, 223, 229, 232
air speed 250, 259
anemometer 250, 259
angle. 13, 14, 16, 18, 21, 42, 53, 54, 57, 60, 88, 93, 149, 154, 157, 163, 169
angular diameter 13, 14, 34
astrolabe. 13, 14, 16
astronomy 13–51
atmosphere . . 13, 24, 27, 127, 261, 267, 269
average speed 223, 224, 227, 234, 236
balloon rocket. 146, 149, 152
barometer. 250, 254
buoyant force. 187, 192, 196, 227
centripetal force 132, 157, 182,
clouds 251, 265, 269, 273
color 50, 53, 90
condensation 251, 263, 265
corrugated paper 214
craterlets 39
craters 13, 39
density 187, 188, 190, 194
dew point 251, 263
dispersion 50
divergence 90
elastic potential energy 172, 174
energy 53–100
energy, elastic potential. 172, 174
energy, heat 53, 63, 76, 84, 127, 157, 172, 174, 257, 267
energy, kinetic 39, 53, 60, 63, 66, 68, 71, 74, 76, 81, 97, 157, 172, 174
energy, law of conservation 53
energy, light 53, 88, 90, 93, 95
energy, potential 53, 60, 63, 66, 68, 71, 74, 76, 81, 157, 172, 174
energy, sound. 53, 63, 95, 97, 99, 157, 172, 174
fiber optics 88
force 71, 74, 76, 78, 81, 102, 106, 109, 112, 115, 118, 127, 129, 132, 133, 134, 138, 140, 142, 144, 146, 149, 152, 154, 157, 158, 160, 180, 182, 184, 187, 192, 196, 227, 229, 232
force, buoyant 187, 192, 196, 227
force, centripetal 132, 157, 182
force, restoring. 78, 81
freezing water 84, 187, 198
frequency 53, 223, 244, 246
friction. 63, 66, 74, 76, 103, 104, 127, 129, 138, 139, 149, 152, 157, 158, 160, 223, 224, 229, 232, 240, 242, 250, 259, 267
friction, sliding 127, 129, 158
friction, static 127, 129, 158
fulcrum 103, 106, 109, 112, 115
gravity. 10, 68, 71, 74, 76, 81, 104, 118, 140, 149, 152, 158, 160, 187, 227, 229, 232
heat energy. 53, 63, 76, 84, 127, 157, 172, 174, 257, 267
humidity 263
inclined plane 103, 118, 121, 134, 158, 160, 224, 229, 232, 240, 242
inertia. 68, 104, 132, 134, 138, 140
inverse relationship 209
kinetic energy 39, 53, 60, 63, 66, 68, 71, 74, 76, 81, 97, 157, 172, 174
laser 42, 90, 93, 95

latitude 14
law of conservation of energy. 53
law of reflection 42
lever. 102, 103, 106, 109, 112, 115
lever, first-class 102, 106, 109
lever, second-class 102, 112
lever, third-class 102, 115
light, brightness 13, 24, 44, 47
light, color 50, 53, 90
light, divergence 90
light, energy 53, 88, 90, 93, 95
light, intensity 13, 24, 44, 47
light, reflection 42, 88, 93, 95
light, refraction 88, 93
light, scattered 13, 27, 93
lunar illusion 13, 34
machines. 102–130
magnet 157, 180
mass 78, 81, 104, 138, 187, 188, 190, 194, 212, 223, 240, 242
matter 187–221
meteorites 39
momentum 184
moon, craters 13, 39
moon, diameter 13, 34, 36
moon, distance 36
Newton's first law of motion . . . 132, 134, 138, 140
Newton's second law of motion 133, 142, 144, 184
Newton's third law of motion. . . 133, 146, 149, 152, 154
Newton, laws of motion 132–155
pendulum. 53, 68, 163, 166, 169, 223, 244, 246
pendulum, frequency 223, 244, 246
pendulum, period 163, 166, 169, 246
period 163, 166, 169, 246
pitch 53, 95, 99
potential energy 53, 60, 63, 66, 68, 71, 74, 76, 81, 157, 172, 174
prediction 9, 10
pressure, air 250, 254, 265
projectile 53, 54, 57, 60, 132, 136
projectile, range 53, 54, 57, 60
pulley 103, 124
ramp 103, 118, 121, 134, 158, 160, 224, 229, 232, 240, 242
range 53, 54, 57, 60
reflection 42, 88, 93, 95
refraction 88, 93
resistance, air 104, 223, 229, 232
resonance 166
restoring force 78, 81
rocket. 133, 146, 149, 152
salt water 198
scale, spring 104
scattered light. 13, 27, 93
scientific method 9, 10
screw 103, 121
seat belts 132, 134
shadow 18, 21, 31, 157, 177
slides 158, 160
sliding function 127, 129, 158
snow 250, 251, 261
sound energy 53, 63, 95, 97, 99, 157, 172, 174
sound, frequency 53
sound, pitch 53, 95, 99

sound, volume 97
sprectroscope. 13, 50
speed 53, 68, 71, 74, 76, 81, 97, 127, 129, 132, 133, 136, 144, 154, 157, 158, 160, 172, 174, 184, 187, 223–248, 250, 252, 259
speed, average. . . . 223, 224, 227, 234, 236
spring 53, 78, 81
spring constant 78
spring scale 104
stars 13, 47, 50
static friction 127, 129, 158
strength of materials 187, 206, 209, 212, 214, 217
sunrise. 13, 18, 27, 34
sunscreen. 13, 29
sunset 13, 18, 27, 34
surface tension 187, 201, 204, 227
swings 163, 166
temperature 84, 187, 198, 250, 251, 257, 263, 265, 267, 269, 273
thermal lag 251, 269
thermometer 250, 257, 267
thrust 146, 149, 152
total internal reflection 88, 93
ultraviolet light 13
volume . 97, 187, 188, 190, 194, 261, 265, 267
walled plains 39
water. 84, 201, 204
water vapor 251, 263, 265
water, freezing. 84, 187, 198
water, salt. 198
wavelength 50
weather 250–275
weather vane 250, 252
weight 104, 106, 109, 112, 115, 118, 157, 158, 163, 169, 187, 192, 196, 206, 209, 212, 214, 217, 223, 227, 229
wind direction 250, 252
wind speed. 250, 259
work 60, 63, 68, 71, 74, 102, 104, 118, 124