The Everyday Science Sourcebook

Lawrence F. Lowery

Revised 2nd Edition

Ideas for Teaching in Elementary and Middle School

NSTA press
National Science Teachers Association

Chart 1. Science Process/Knowledge and Developmental Stages

Grade Level | **Science Processes** | **Developmental Stages**

9–12 6–9 3–6 K–3

SCIENCE KNOWLEDGE

Applied Knowledge (9–12)

Inferential Knowledge (6–9)

Relational or Interactive Knowledge (3–6)

Organizational Knowledge (K–3)

A OBSERVING — Sensory Motor

- Aa Seeing
- Ab Feeling
- Ac Hearing
- Ad Smelling
- Ae Tasting
- Af Using Several Senses

B COMMUNICATING — Preconceptual

- Ba Describing, Speaking, Sounding
- Bb Formulating Operational Definitions
- Bc Recording, Tabling, Writing
- Bd Researching the Literature, Reading, Referencing
- Be Picturing, Drawing, Illustrating
- Bf Graphing

C COMPARING — Intuitive

- Ca Making General Comparisons or Comparisons From Different Perspectives
- Cb Estimating
- Cc Making Numerical Comparisons
- Cd Measuring Lengths, Angles
- Ce Measuring Temperatures
- Cf Weighing
- Cg Measuring Areas, Volumes, Pressures
- Ch Making Time Comparisons, Measuring Rates

D ORGANIZING — Concrete Operational

- Da Seriating, Sequencing, Ordering
- Db Sorting, Matching, Grouping
- Dc Classifying

E RELATING

- Ea Identifying a Problem, Formulating Questions
- Eb Hypothesizing
- Ec Controlling and Manipulating Variables, Testing

F INFERRING — Formal Operational

- Fa Generalizing, Synthesizing, Evaluating
- Fb Using Indicators, Predicting
- Fc Using Explanatory Models, Theorizing

G APPLYING

- Ga Using Knowledge or Instruments, Identifying Examples
- Gb Inventing, Creating
- Gc Constructing
- Gd Growing, Raising
- Ge Collecting

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Table of Contents

Preface .... **ix**
The Need to Improve Science Instruction .... **ix**
This Sourcebook and National Science Standards .... **x**
Safety .... **xi**

How to Use This Sourcebook .... **xiii**

Features of This Sourcebook .... **xix**

Acknowledgments .... **xxxiii**

References .... **xxxv**

Entry Section

100–199 Inorganic Matter 1

110 Solids **2**
111 Characteristics 2
112 Interactions 14

120 Liquids **17**
121 Characteristics 17
122 Interactions 25

130 Gases **46**
131 Characteristics 46
132 Interactions 55

140 Earth Science **65**
141 Characteristics 65
142 Interactions 77
143 Theory 88

150 Oceans **91**
151 Characteristics 91
152 Interactions 100
153 Theory 107
154 Applications 108

160 Weather **111**
161 Characteristics 111
162 Interactions 118
163 Theory 133
164 Applications 142

200–299 Organic Matter 147

210 Zoology **148**
211 Characteristics 148
212 Interactions 162

220 Botany **166**
221 Characteristics 166
222 Interactions 176

230 Other Organisms **186**
231 Characteristics 186
232 Interactions 193

240 Ecology **197**
241 Characteristics 197
242 Interactions 202
243 Theory 211
244 Applications 214

300–399 Energy 219

310 Motion 220
311 Characteristics 220
312 Interactions 227
313 Theory 234
314 Applications 239

320 Sound 240
321 Characteristics 240
322 Interactions 244
323 Theory 258
324 Applications 263

330 Light 268
331 Characteristics 268
332 Interactions 273
333 Theory 285
334 Applications 290

340 Heat 293
341 Characteristics 293
342 Interactions 296
343 Theory 316
344 Applications 318

350 Electricity 319
351 Characteristics 319
352 Interactions 321
353 Theory 337
354 Applications 341

360 Magnetism 345
361 Characteristics 345
362 Interactions 347
363 Theory 359
364 Applications 360

400–499 Inference Models 363

410 Atoms and Molecules 364
411 Characteristics 364
412 Interactions 369
413 Theory 370

420 Astronomy 377
421 Characteristics 377
422 Interactions 393
423 Theory 399

500–599 Technology and Engineering 403

510 Machines 404
511 Simple Machines 404
512 Complex Machines 424

520 Communications 427
521 Simple Devices 427
522 Complex Devices 430

530 Transportation 435
531 Simple Vehicles 435
532 Complex Vehicles 436

600–699 Instructional Apparatus, Materials, and Systems 447

610 Safety Precautions **448**
611 Guidelines 448

620 General Equipment **451**
621 Heat Sources 451
622 Support Stands 451
623 Glassware 452

630 Measuring Systems and Instruments **453**
631 Measuring Systems 453
632 Measuring Instruments 459

640 Plant and Animal Containers **465**
641 Planters 465
642 Vivariums 472

650 Equipment for Collecting **474**
651 Collections 474

Index Guide **477**

Index **507**

Preface

As a human endeavor, science is a quest for knowledge about the world in which we live. We observe and describe objects; we act upon them to see what happens; we take notes of what takes place. We organize our observations, test what we think we know, and then reorganize our observations. We make inferences about what we cannot determine directly, and some of us apply what we have learned to construct new objects or invent new combinations of ideas.

"Doing" science is not significantly different from normal human behavior. For example, very young children observe the objects of their environment by looking at them, touching them, tasting them, smelling them, and manipulating them. Similarly, the scientist places a space probe on the surface of a distant planet and turns on the TV eye to see what it can see. A mechanical hand touches the surface and explores its composition. Sensors "smell" the atmosphere. With each of these sensory actions, the child and the scientist gather knowledge about our world.

It is important for teachers to realize that science is not solely the accumulation of information over the centuries, but rather it is the simultaneous relationship between the information and the ways by which it is obtained. Science is, at once, the *processes* by which we gather and think about information and the *knowledge* that results from such actions.

The Need to Improve Science Instruction

In April 1983, one of the more important educational reform publications of the last century, *A Nation at Risk*, was released (National Commission on Excellence in Education). It warned that if our educational enterprise continues to develop a citizenry that is illiterate in the areas of mathematics, science, and technology, our nation would lose its influential position among other nations and become a second-rate power in the 21st century.

It was not long before several efforts were initiated to bring about change in science education. Project 2061 under the guidance of the American Association for the Advancement of Science (AAAS) made recommendations for basic learning goals in *Science for All Americans* (1989) and *Benchmarks for Science Literacy* (1993). The *National Science Education Standards* (1996), developed under the auspices of the National Research Council (NRC), outlined the minimal expectations for science programs in schools and described important aspects for curriculum change. Both efforts involved collaboration among scientists, mathematicians, engineers, psychologists, and educators to outline the knowledge and inquiry skills K–12 students needed to understand

and apply to become scientifically literate citizens. Although the documents provided a fundamental set of outcomes for students and educators, they did not, and still do not, prescribe a curriculum. It is expected that states and local districts use the standards as guidelines for planning and implementing science instruction through all grade levels.

The documents emphasize that it is not sufficient to just read about science or demonstrate and lecture in a show-and-tell manner. Rather, they emphasize that learning the essence of the enterprise (the modes of inquiry and the procedures for gathering, organizing, and analyzing data in intellectually honest ways) is more important than memorizing facts. This sourcebook was created because science should be memorable, not memorizable.

This Sourcebook and National Science Standards

The content in this sourcebook was selected to build upon and extend the science standards outlined in the AAAS and NSES documents. All the activities contribute to those standards that can best be learned through direct and indirect observations of natural phenomena. Because the major standards are broad and inclusive, this book restates them in teachable terms that combine the content to be learned with ways by which students can explore and inquire. Since many textbook and kit-centered science programs do not provide engaging activities for all the science standards, the activities in this book can fill gaps in programs and extend and enrich experiences where programs have minimal or shallow activities.

This sourcebook is a thesaurus. It enables the user to quickly locate numerous experiences related to particular scientific standards and thinking processes. Users will be pleased by the many fresh ideas for teaching. The book can make instruction valid, powerful, and enjoyable.

It is important to know that this sourcebook is not a science program, and it is not a methods book. You will not learn from this book how to teach science. As a storehouse of ideas, it will not tell you how to work through activities in a prescribed way. How you instruct depends upon your own training and philosophy about learning. Each activity can be taught didactically or by an inquiry technique. Because this is not a methods book, the activities are intentionally brief. Creative and well-prepared individuals will use the suggestions as springboards for their own ideas and will adapt the activities in many ways to meet the goals of their curriculum and the needs of students.

This book is also not a source of scientific knowledge and not intended to supply all the factual background and explanations for science concepts. However, the entries do supply the generalizations inherent in each activity, and each contributes to a standard and contains sufficient information pertaining to the instructional conditions that enable the teacher to prepare and introduce the activity to students.

Remember: The main purpose for this book is to enable you to easily find hands-on experiences that directly engage students with phenomena in our world.

Safety

With hands-on, process, and inquiry-based activities, today's teaching and learning of science can be both effective and exciting. The challenge of securing this success needs to be met by addressing potential safety issues. Teachers can reinforce safety for students and themselves by adopting, implementing, and enforcing legal standards and best professional practices in the science classroom, laboratory, and out in the field. In this sourcebook, *610 Safety Precautions* (p. 448) includes both recommended basic safety practices and resources for activities. It is designed to help teachers and students become aware of relevant standards and practices that will help make activities safer. Doing science makes the learning come alive; doing science safer makes it a successful experience.

For additional safety regulations and best professional practices, go to:

NSTA: Safety in the Science Classroom:
www.nsta.org/pdfs/SafetyInTheScienceClassroom.pdf

NSTA Safety Portal:
www.nsta.org/portals/safety.aspx

How to Use This Sourcebook

It is easy to use this sourcebook. Look up a topic in the Index Guide, note the entry, or activity number for that topic, and then use that number to find one or more activities in the Entry section.

Let us try an example. Suppose your students have found some rocks that interest them and they bring them to class. You might want to do some activities with rocks to extend their interest.

If you look up the word *Rocks* in the Index Guide, you will see the following:

Rocks
- breakdown of, 141.18
- characteristics of, 141.01–12
- classification of, 141.22–24
- collecting, 651.03
- definition of, operational, 141.10
- identification of
  - color sorting key, 141.14,–15
  - hardness sorting key, 141.22
  - size sorting key, 141.23
- magma, 141.01–04
- minerals in, 141.13–15
- plant growth, effect of, 142.28
- porosity of, 142.27
- in soil formation, 141.16–18
- temperature change, effect of, 142.26–27
- tests for
  - cleavage, 141.11b
  - hardness, 141.10
  - streak, 141.11a
- types of
  - igneous, 141.01–04
  - metamorphic, 141.08–09
  - sedimentary, 141.05–07

From the listing under *Rocks*, you can see that you have a lot of choices. Pick the one that best fits the interest of the students and the resources you have available.

Suppose you decide it would be best for your students to learn something about how rocks can be identified. Note that, in the Index Guide, a set of numbers accompanies the topic *identification of*: *color sorting key, 141.14, 141.15*; *hardness sorting key, 141.22*; and *size sorting key, 141.23*. These numbers mean that in section 141 of this sourcebook, there are several activities related to learning about the identification of rocks.

Suppose you decide to look up *hardness sorting key, 141.22* in the Entry section of this book. The activity numbers are printed at the top of each page for the activities on that page—much in the way that a dictionary and an encyclopedia list entries at the top of their pages. When you look up the *identification of rocks, 141.22* in the Entry section, you will find a page that looks like the following:

Inorganic Matter / Earth Science 141.21–141.23

daily records of what happens. Students will find that the plants in the glass without soil cannot sustain growth, and that the soil must be a contributing factor for continued growth.

b. Fill one flowerpot with sand, another with clay (or subsoil), and a third with loam (or topsoil). Plant five lima beans in each pot and place the pots side by side where they will receive the same amount of sunshine. Add the same amount of water to each pot daily and keep a record of the growth for a month. Decide which kind of soil is best for growth. (The topsoil is usually best.)

Generalization IV. Rocks can be organized by their physical characteristics.

Contributing Idea A. Rocks can be seriated.

Seriating rocks by hardness. Rocks vary in hardness and can be ordered from soft to hard. Table 141.22 is a commonly used hardness key. Students can set up their own hardness scale using the rocks they find by seeing if one will scratch another. (A rock that scratches another rock is harder than that rock.) They can then order their rocks by relative hardness. **22 Ab Da**

Seriating rocks by size. Have students bring to school rocks of different sizes. Line up all the collected rocks in a row from smallest to largest. Table 141.23 shows standard categories for the various **23 Aa Da**

Table 141.22. Hardness Sorting Key—Rocks

Hardness Scale (Soft to Hard)	Hardness Test	Rock Example
1	Scratches easily with a fingernail	talc
2	Scratches with a fingernail	gypsum
3	Scratches with a pin or copper penny	calcite
4	Scratches easily with a knife	fluorite
5	Scratches with a knife	apatite
6	Knife will not scratch rock and rock will not scratch glass.	feldspar
7	Scratches glass easily	quartz
8	Scratches quartz easily	topaz
9	Scratches topaz easily	corundum
10	Scratches all other rocks	diamond

This is one of several pages that list activities related to the identification of rocks. If you skim across the pages in this section, you can choose one or more of the other activities in which to engage your students.

Here is another example. Suppose you are looking for an activity that would help students understand the science content standard that expresses that water washes away topsoil.

If you look up in the Index Guide the word *erosion*, you will find several possible subtopics listed.

Erosion
glacial, 142.24–25
plant, 141.18, 142.28
prevention of, 242.02
temperature, 141.08b, 142.26–27
water, 142.17–23
wave, 142.23, 152.16–17
wind, 142.05–06

The most suitable reference to your idea might be subtopic *water 142.17–23.* Look up the numerical reference in the Entry section, and you will find many activities, one or several of which are applicable to your particular situation and goal.

Observing how rain carries away soil. Fill several flower pots or cans with loose soil until the soil is just level with the edges. Place some small stones or bottle caps on the surface of the soils and set the containers outside or in a sink. Water them with a watering can to represent rain, gradually increasing the flow. When finished, let students notice how the unprotected soil is splashed away, leaving columns of soil under the stones. After a rain, have students look for the same effect in an unplanted area. **17 Aa**

When you locate a numerical reference, you will see that the scientific content is clearly stated as *Contributing Idea*. In the erosion example, you will find *Contributing Idea C: Water carries and deposits materials.* When you look at the subsequent activities 142.18–22, you will find many more ideas concerning erosion by water.

Thus the activities listed for Contributing Idea C relate to the common content that water washes away topsoil. Yet each activity is different in terms of possible experiences for students. Students may observe how rain carries away soil (entry 142.17), collect samples of waterborne materials (entry 142.18), observe how water-carried materials are deposited (entry 142.19), and so forth. Note that the activities are generally sequenced from simple to complex or from directly experienced to abstract. Such sequencing will help you identify the most appropriate activity for your students.

Also note that if you glance over the total structure of this section, other contributing ideas will provide you with additional related activities that might be useful. The other ideas may suggest preliminary experiences that you might not have thought about. Or they might suggest branching experiences for further exploration.

There is another aspect of this book that you will find useful. You probably noticed the letters beneath the activity numbers. These letters indicate the major problem-solving and thinking processes that are part of the activity. The letters are a simple code that is outlined inside the cover of this book. For example, the letter *A* indicates the various sensory observations students will make during the activity:

Aa = looking and seeing
Ab = touching and feeling
Ac = hearing and listening
Ad = smelling
Ae = tasting (within safety guidelines)
Af = multisensory, using several senses

When you use the chart of thinking processes, you will find that each corresponds to the thinking process that researchers have found are the ways by which humans naturally think when given a chance.

The letter codes are easy to remember and use. The sequence of the letters corresponds to developmental stages. The ability to observe begins early in our lives and continues as other abilities are added over time. Inferring (i.e., the thinking about things that are remote in time and space) begins with adolescence and takes many more years to fully develop.

Let us now examine how the thinking processes are a part of an activity. In the erosion example that you looked at earlier, you can see that below the activity numbers, the letter code tells you the major thinking students will do during each activity.

142.17 Aa	Students will observe erosion.
142.18 Ca and Ge	Students will collect and compare samples.
142.19 Ec	Students will test variables.

Contributing Idea C. Water carries and deposits materials.

Observing how rain carries away soil. Fill several flower pots or cans with loose soil until the soil is just level with the edges. Place some small stones or bottle caps on the surface of the soils and set the containers outside or in a sink. Water them with a watering can to represent rain, gradually increasing the flow. When finished, let students notice how the unprotected soil is splashed away, leaving columns of soil under the stones. After a rain, have students look for the same effect in an unplanted area. **17 Aa**

Using this sourcebook is easy! Now enjoy enabling your students to learn science concepts through interesting hands-on experiences.

Features of This Sourcebook

This sourcebook is a thesaurus. In contrast to a dictionary or encyclopedia, which format content alphabetically, a thesaurus is a reference work that arranges its content according to conceptual similarities. Its purpose is to enable readers to find specific ideas and to see how the ideas relate to other ideas.

As a thesaurus of science concepts, this book provides easy access to science activities that teach science concepts that correspond to national standards. And it does much more because of the way the science content is organized.

Organization: Science Content

The Entry section of this book comprises a number of interlocking science content groupings organized by numerical code system. Entries are arranged in broad science categories to match the Standards. These are subdivided into topics, subtopics, and specific activities, all related to the content being taught.

Broad Science Content Categories

Six broad content categories are used to provide a framework for the Entry section—the main body of this book. Each of the content categories is coded by numerals in a decimal system.

100–199: Inorganic Matter

Matter, one of the two great divisions studied by scientists, includes all the materials that occupy space in the world around us. The scientist subdivides the materials into two kinds: inorganic and organic. Inorganic matter is the subdivision that comprises all nonliving materials (e.g., the rocks and minerals above and below the surface of the Earth). This content category includes such directly observable aspects as the physical and chemical properties of matter and the changes in the states of matter (i.e., solid, liquid, gas).

200–299: Organic Matter

The other subdivision of matter studied by scientists is organic matter. Organic matter is found in all living materials (e.g., the various forms of plants and animals). This content category contains entries that pertain to the directly observable physical and chemical properties of living organisms, their growth and response to environmental conditions, and the interrelationships among them.

300–399: Energy

Energy is the second great division studied by scientists. Energy means the ability to do work. This content category includes entries that pertain to the various forms of energy such as light, sound, and heat.

400–499: Inference Models

In scientific terms, a model is a theory that describes or explains a phenomenon that cannot be directly observed (e.g., atomic structures, the solar system). This fourth category contains entries that serve to explain phenomena and pertain to ideas derived through indirect means.

500–599: Technology and Engineering

Technology is the blend of science and invention that aims to increase productivity by rearranging the environment and producing goods. As such, technology is sometimes called *applied science* or *engineering*. This category contains entries pertaining to inventions (e.g., simple machines) developed from the application of scientific principles that, in turn, can be used to further understand basic scientific laws and principles.

600–699: Instructional Apparatus, Materials, and Systems

This sixth category contains entries dealing with the preparation of various materials useful in teaching science that have wide application throughout the content categories. This category includes such topics as techniques for cutting and bending of glass to making certain apparatus and construction plans for the construction of measuring devices (e.g., balance and spring scales).

The content numbering system is presented in the Table of Contents.
100 ← Inorganic Matter
200 ← Organic Matter
300 ← Energy
400 ← Inference Models
500 ← Technology and Engineering
600 ← Instructional Apparatus, Materials, and Systems

Topics

Each of the six broad science categories is divided into specialized topics. For example, the category *100 Inorganic Matter* is subdivided into six topics that are coded by the second numeral in the series of three numerals.

100 Inorganic Matter
- 110 ← Solids
- 120 ← Liquids
- 130 ← Gases
- 140 ← Earth Science
- 150 ← Oceans
- 160 ← Weather

Subtopics

Within the topical categories, scientific knowledge is subdivided into four subtopics.

1. Characteristics: This subtopic contains knowledge that relates to the characteristics or attributes of objects (e.g., size, shape, color, texture, and so on). Generally, this knowledge is descriptive of physical properties of objects.
2. Interactions: This second subtopic contains interactive knowledge. Such knowledge describes causes and effects between and among objects.
3. Theory: The third subtopic contains knowledge that is speculative (e.g., theories and explanations for observed phenomena).
4. Applications: The final subtopic contains activities that are applications of knowledge.

These subtopics are identified by the third numeral in the series of three.

300 Energy
- 340 Heat
  - 341 ← Characteristics
  - 342 ← Interactions
  - 343 ← Theory
  - 344 ← Applications

Knowledge of Characteristics

When we observe, compare, or organize our observations and then describe the results, we make statements such as "insects have three body parts and six legs," "sea water is salty," and "leaves are green." Observing, comparing, and organizing processes always produce information that is largely organizational in character. Objects are described for specific attributes that define them as members of a particular class or function: Fish have fins (class), birds have feathers (class), the flower is the part of the plant where seeds develop (function), and machines are devices that make work easier (function).

Knowledge of Interactions and Relationships

When we observe, compare, or organize objects to determine relationships between and among them, or when we determine the cause and effect of phenomena, we produce knowledge that is largely relational in character: Whales are mammals because they have internal skeletons, hair on their skin, glands that produce milk, and because they bear their young alive (relational); fungi live off animals, dead organic matter, and other plants (relational); adding heat to solids causes them to expand (interactive); and the direction of an object's motion is a straight line unless the object is acted on by other forces (interactive).

Inferential, or Theoretical Knowledge

Inferring is a thinking process that allows us to conceptualize ideas that are not directly observable. This process often leads to explanatory or predictive statements about objects or phenomena: All matter is composed of tiny particles in constant motion (inference); the Earth and other planets revolve around the Sun (inference); cross pollination of particular plants will produce particular results (prediction); and given the rate of water flow from the pipe, we calculate a loss of 4,000 gallons by 7 a.m. (predictive).

Applied Knowledge

Inventing, problem solving, and determining probabilities are ways of using knowledge that leads to further knowledge. To a great extent, usage and invention-technology principles are representative of the knowledge statements obtained from applying knowledge. Some examples are the following: Instruments that are run by heat energy can be built to do work (invention-technology), the electromagnet is an instrument that can be used in the operation of many electrical systems (invention-technology), the principles of sound can be incorporated into instruments to produce music (usage), and selective breeding of plants and animals that have desirable characteristics can cause these characteristics to occur more frequently in offspring (usage).

Applied ideas can also be organizational ideas: The scientist can develop taxonomy, or blueprint based upon a logical rationale, concerning the relationships among the objects or ideas comprising the taxonomy, while at the same time realizing that the arrangement is tentative. That is, the arrangement is one of many possible arrangements that may be changed based upon fresh insights.

Specific Activities

Specific activities are listed for each of the subtopics of knowledge. For example, the Earth Science topic *142 Interactions* includes activities that are listed sequentially and enumerated as decimals:

100 Inorganic Matter
    140 Earth Science

142 Interactions
- 142.**01** ← Observing wind moving across soil
- 142.**02** ← Observing how wind carries and deposits materials
- 142.**03** ← Measuring the distances wind carries and deposits different materials
- 142.**04** ← Collecting and comparing samples of wind-borne materials

Organization: Thinking Processes

An additional feature to the structure of this sourcebook is the identification of the thinking processes by which we derive knowledge. These processes are part of the nature of inquiry and are listed on the chart inside the cover of this book.

The thinking processes have been carefully selected to be appropriate to all fields of science, and they have been sequentially ordered to be compatible with developmental learning theory. In this book, each subsequent process in the listing is built upon and inclusive of the previous process. Thus each process is enhanced and continually used in more advanced and complex ways. Chart 1 inside the front cover of this book shows how the processes correspond with the developmental stages of students. This arrangement matches the suggested order of content outlined as *Benchmarks for Science Literacy* in Project 2061 and as documented in the *National Science Education Standards*.

The organization for the thinking processes uses a letter code system. Capital letters represent broad superordinate thinking-process categories. The first four categories tend to encompass process activities that are most appropriate for young students (preschool through grade three), while the latter three categories tend to be most appropriate for older students (grade four and above). The broad categories of thinking processes are the following:

- A ← Observing
- B ← Communicating
- C ← Comparing
- D ← Organizing
- E ← Relating
- F ← Inferring
- G ← Applying

Lowercase letters are used to represent more specific types of thinking related to the broad categories of processes:

A Observing
- A**a** ← Seeing
- A**b** ← Feeling

A**c** ← Hearing
A**d** ← Smelling
A**e** ← Tasting
A**f** ← Using Several Senses

Each activity in the Entry section is accompanied by the coded capital and lowercase letters indicating, respectively, the general thinking process and the specific thinking expected in the activity. For example, the letter code *Ec* indicates that the main purpose of the activity involves relating (*E*) and specifically requires the student to control and manipulate variables (*c*). Naturally, other science thinking processes and actions are required in any given activity. This code simply indicates the processes of greatest emphasis in an activity.

Every activity relates thinking processes to scientific knowledge. The arrangement of the processes suggests the best age levels at which to introduce particular scientific knowledge so that it can be learned in a meaningful way.

The following examples provide another view of the content and process structure of this sourcebook. The following section shows several pages from the Entry section. The topic for the examples is *350 Electricity*. Pages xxiv–xxvii show the content structure for the topic *without* the activities. From this you can see the logic to the Generalizations and Contributing Ideas that correspond to standards related to Electricity. Pages xxvii–xxxi show the content structure again but with the *thinking processes* added. These labels indicate what the activity is about. From this, you can see the relationship between how humans come to know something and the content that is derived from that experience.

Example 1
Content Organization Without Activities
Topic: Electricity

350 Electricity

351 Characteristics

Generalization: Electricity has identifiable characteristics.

Contributing Idea A: Electrical energy can be stationary (static electricity).

Contributing Idea B: Electrical energy can move (current electricity).

352 Interactions

Generalization I: Electricity is a form of energy produced by different sources.

Contributing Idea A: Chemical reactions can be a source of electricity (electrochemical propagation).

Contributing Idea B: Motion can be a source of electricity (mechanical propagation).

Generalization II: Current electricity produces a magnetic field.

Contributing Idea A: An electric current carried by a wire produces a magnetic field around it.

Contributing Idea B: A compass is an instrument that can be used to detect magnetic fields.

Generalization III: Current electricity moves when there is a complete circuit.

Contributing Idea A: Current electricity can be detected.

Contributing Idea B: A circuit is a continuous path through which electricity can move.

Contributing Idea C: Current electricity takes the shortest and easiest circuit back to the place where it started.

Contributing Idea D: Switches are used to open and close circuits.

Generalization IV: Current electricity travels through some materials better than others.

Contributing Idea A: Some materials allow electricity to pass through them easily (conductors); other materials tend to block the movement of electricity (insulators).

Contributing Idea B: Thinner wires have more resistance than thicker wires of the same material; longer wires have more resistance than shorter wires of the same material.

Contributing Idea C: Some metals have more resistance to electricity than others.

Contributing Idea D: Overloading a circuit with too many resistors can overheat the wires.

Generalization V: Current electricity can be controlled.

Contributing Idea A: Series circuits channel all the electricity through a single pathway; parallel circuits channel all the electricity through a main pathway and branching pathways.

Contributing Idea B: Electric cells can be arranged to produce different voltages.

Contributing Idea C: Switches can be used to control circuits and voltages easily and safely.

353 Theory

Generalization I: According to theory, all matter is made up of atoms that contain tiny particles of electricity.

Contributing Idea A: Atomic particles can be accumulated into electrical charges.

Contributing Idea B: Unlike electric charges attract; like electric charges repel.

Contributing Idea C: Models can be used to explain the movement of electrons.

Generalization II: Electrical energy can produce electromagnetic radiation.

Contributing Idea A: Electrical energy can produce heat and light.

Contributing Idea B: Electrical energy can produce radio waves.

354 Applications

Generalization I: A magnetic field is generated around a wire carrying electricity; the strength of the magnetic field can be increased or decreased several ways.

Contributing Idea A: The electromagnet is an instrument used in the operation of many electrical systems.

Contributing Idea B: Electric circuit breakers and door chimes can operate using electromagnets.

Generalization II: Many household appliances use highly resistant wires to produce heat and to control electric currents.

Contributing Idea: Highly resistant metal wires are commonly used to produce heat in such appliances as electric irons, toasters, and heaters.

The following example provides more detail about the features of this book. The example repeats a portion of the previous example but adds the descriptors for each of the content statements.

Example 2
Content–Process Organization
Topic: Electricity

350 Electricity

351 Characteristics

Generalization: Electricity has identifiable characteristics.

Contributing Idea A: Electrical energy can be stationary (static electricity).

01 Seeing, feeling, and hearing evidence of electrical charges
02 Observing that rubbing charges some materials
03 Determining what materials can produce electrical charges
04 Determining that not all electrical charges are alike

Contributing Idea B: Electrical energy can move (current electricity).

05 Generating a direct current
06 Generating an alternating current

352 Interactions

Generalization I: Electricity is a form of energy produced by different sources.

Contributing Idea A: Chemical reactions can be a source of electricity (electrochemical propagation).

01 Making an electric cell
02 Producing electricity from a “wet” cell
03 Producing electricity from a “dry” cell

04 Testing materials to make "dry" cells
05 Examining a "dry" cell
06 Making a battery

Contributing Idea B: Motion can be a source of electricity (mechanical propagation).

07 Producing electricity by rubbing objects
08 Producing electricity by moving a magnetic field

Generalization II: Current electricity produces a magnetic field.

Contributing Idea A: An electric current carried by a wire produces a magnetic field around it.

09 Observing that an electric current produces a magnetic field
10 Comparing magnetic and electric fields
11 Testing the effect of magnetic and electric fields on different materials

Contributing Idea B: A compass is an instrument that can be used to detect magnetic fields.

12 Detecting the magnetic field produced by an electric current

Generalization III: Current electricity moves when there is a complete circuit.

Contributing Idea A: Current electricity can be detected.

13 Detecting electric currents
14 Using a radio to detect electric currents
15 Building a galvanometer

Contributing Idea B: A circuit is a continuous path through which electricity can move.

16 Arranging a circuit to light a bulb
17 Making a holder for D-cell battery and preparing wires for use in a circuit
18 Making a holder for a small (flashlight) bulb
19 Exploring electric circuits

20 Making a circuit tester
21 Locating hidden circuits

Contributing Idea C: Current electricity takes the shortest and easiest circuit back to the place where it started.

22 Observing a short circuit
23 Observing a grounded circuit

Contributing Idea D: Switches are used to open and close circuits.

24 Making a switch

Generalization IV: Current electricity travels through some materials better than others.

Contributing Idea A: Some materials allow electricity to pass through them easily (conductors); other materials tend to block the movement of electricity (insulators).

25 Identifying conductors and insulators

Contributing Idea B: Thinner wires have more resistance than thicker wires of the same material; longer wires have more resistance than shorter wires of the same material.

26 Examining the influence of size factors on the conductivity of wires
27 Making a rheostat

Contributing Idea C: Some metals have more resistance to electricity than others.

28 Examining resistance in metals
29 Using resistances in metals to make a model lightbulb

Contributing Idea D: Overloading a circuit with too many resistors can overheat the wires.

30 Making a fuse
30 Using fuses

Generalization V: Current electricity can be controlled.

Contributing Idea A: Series circuits channel all the electricity through a single pathway; parallel circuits channel all the electricity through a main pathway and branching pathways.

31 Comparing series and parallel circuits
32 Testing one electric cell and several bulbs

Contributing Idea B: Electric cells can be arranged to produce different voltages.

34 Testing several electric cells and one bulb

35 Testing several electric cells and several bulbs

Contributing Idea C: Switches can be used to control circuits and voltages easily and safely.

36 Turning an appliance on and off from two or more switches

37 Making a reversible switch

38 Making a dimmer switch

39 Listing safety precautions for use of electricity

353 Theory

Generalization I: According to theory, all matter is made up of atoms that contain tiny particles of electricity.

Contributing Idea A: Atomic particles can be accumulated into electrical charges.

01 Using drawings to explain the electrical components of atoms

Contributing Idea B: Unlike electric charges attract; like electric charges repel.

02 Building an electroscope

Contributing Idea C: Models can be used to explain the movement of electrons.

03 Using a marble model to explain the movement of electrons through materials

04 Using a water-hose model to explain the movement of electrons

Generalization II: Electrical energy can produce electromagnetic radiation.

Contributing Idea A: Electrical energy can produce heat and light.

05 Producing heat and light from electricity

Contributing Idea B: Electrical energy can produce radio waves.

06 Producing radio waves from electricity

354 Applications

Generalization I: A magnetic field is generated around a wire carrying electricity; the strength of the magnetic field can be increased or decreased several ways.

Contributing Idea A: The electromagnet is an instrument used in the operation of many electrical systems.

01 Studying the presence of a magnetic field produced by an electric current

02 Making an electromagnet

Contributing Idea B: Electric circuit breakers and door chimes can operate using electromagnets.

03 Building a simple circuit breaker

04 Building a simple electric bell

Generalization II: Many household appliances use highly resistant wires to produce heat and to control electric currents.

Contributing Idea: Highly resistant metal wires are commonly used to produce heat in such appliances as electric irons, toasters, and heaters.

05 Observing the application of the idea that a greater electrical resistance results in a greater production of heat

It is hoped that these features will be useful to researchers, curriculum developers, and others interested in not only the relationships among scientific knowledge but also how that knowledge can be learned.

Acknowledgments

In various ways, many friends and colleagues have contributed throughout the years to the gradual collection and classification of appropriate activities in this sourcebook. Countless teachers and classroom students have added to the collection by suggesting activities, testing activities, and providing refinements. A very loud thank you goes to those scores of individuals who contributed directly and indirectly in so many different ways.

Mathematicians have contributed to the metric measures in the activities in this book. Following their advice, some activities purposely do not give precise conversions to metric measures due to the intent of the activity. For example, sometimes the metric measure is rounded to an easily measured unit. Sometimes the ratios of sequential units are more important than precise equivalents. Another example: If an activity requires the measurement of 5 in., 10 in., and 15 in., the suggested metric measurements might be 10 cm, 20 cm, and 30 cm, because the second unit must be twice the first and the third unit must be three times the first. In addition, many industrial conversions are not yet clear. Although liter containers can substitute well for quart containers, gallon equivalents are not established among different industries. Thus a 10-gallon aquarium remains so until an industrial decision is made on an equivalent size. Finally, some of the activities have no metric equivalents because they would make the activities awkward and confusing. This is especially apparent for graphs and certain tables. Hopefully, all activities will eventually be presented in the metric system. Until then, this book tries to help the reader toward this end as much as possible.

Much appreciation also goes to the specialists who submitted activities and kept information scientifically accurate and classroom related. To the following science educators, thanks for years of fruitful professional interactions: Carl Berger, dean of education, University of Michigan; Jane Bowyer, dean of education, Mills College, California; Diane Conradson, professor of science education, California State University at San Jose; Lawrence Hovey, professor emeritus of science education, Texas Tech University; Professor Roger Johnson, University of Minnesota; Bill Leonard, professor emeritus of science education, Clemson University; Vince Mahoney, professor emeritus of science education, Iowa Wesleyan; Richard Merrill, director emeritus of science education, Mt. Diablo Unified School District, California.

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160 Weather

161 Characteristics

Generalization I. Temperatures on Earth vary from time to time and place to place.

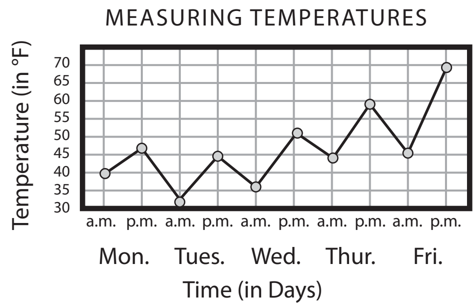
Contributing Idea A. The thermometer is an instrument used to measure temperatures.

01 Gc **Making a liquid thermometer.** Put a length of glass tubing (approximately 1 ft. or 30 cm long) through a one-hole stopper using a twisting, rotary motion. Fill a bottle or flask to the top with water and add a drop of red ink to make the water more visible. Force the stopper into the bottle so that the water rises into the tube approximately 3 in. (10 cm). Mark the position of the water, then let a student warm the bottle with his or her hands. Students will note that the colored water rises in the tube. Now cool the bottle with an ice cube or a sponge soaked in cold water and note that the water level drops. To calibrate this instrument, place the bottle into a deep bowl filled with ice cubes. When the liquid in the tube stops descending, tie a string or slip a rubber band around the tube to mark the level of the liquid. Next, place the bottle in a pan of water and heat it. Boil the water in the pan until the level of the colored liquid stops rising. Mark the level with another piece of string or rubber band. The two marks represent the high and low points. A card divided into tenths and hundredths can be placed behind the tube for a scale. This instrument works similarly to commercial liquid thermometers; the liquid expands when heated, contracts when cooled. Commercial liquid thermometers use alcohol or mercury instead of water, since these liquids respond uniformly to temperature changes and do not freeze at temperatures below 32°F (0°C). Other types of thermometers can be compared to this one.

Measuring and graphing air temperatures. Attach a thermometer outside a classroom window. Be sure it is shielded from direct sunlight. (A thermometer will show a higher temperature than the air if it is placed in sunlight.) Have students record the temperature twice each day by checking it at the same time each morning and each afternoon. A record can be kept on a table similar to Table 161.02. The information can be graphed (see Graph 161.02, p. 112) to represent the general directions of temperature change throughout the week. Several interesting variations of this activity can be explored: One student can record the temperature every hour for one day to see how the temperature changes; a 02 Bf Ce Ch

Table 161.02. Measuring Temperatures

Week of ____________	Morning	Afternoon
Monday	41°F (5°C)	48°F (9°C)
Tuesday	32°F (0°C)	45°F (7°C)
Wednesday	43°F (6°C)	50°F (10°C)
Thursday	45°F (7°C)	59°F (15°C)
Friday	48°F (9°C)	68°F (20°C)



Graph 161.02

group of students can keep records for several months to note temperature changes during the year—weekly or monthly averages can also be computed; individuals or groups can study contrasting temperatures in (a) sun and shade, (b) moving wind and calm air, (c) surface soil and subsoil, (d) shallow water and deep water, (e) shallow snow and deep snow, and so on.

Measuring the temperature of air at different altitudes. Record the temperature of a thermometer outdoors, then tie the thermometer to a large kite. Let students sail the kite as high as they can. In about 30 minutes, pull the kite in as quickly as possible and record the temperature. Compare the two temperatures. 03 Ce

Contributing Idea B. The Sun's radiant energy is converted to heat energy when it reaches the Earth.

Observing that the Sun is a source of heat energy. Put equal amounts of ice in two glasses. Place one in the shade and one in the sunlight. Let students observe in which glass the ice melts more quickly. They will realize that the deciding factor is the heat from the Sun. 04 Aa

Measuring the conversion of solar energy to heat energy. Obtain two small identical flasks and coat one with candle soot or cover it with aluminum foil to prevent sunlight from entering. Insert thermometers into one-hole stoppers, and place them into the flasks. Set the flasks in a place that is shaded from direct sunlight until they become cool, and then record the thermometer readings. Next, set both flasks in the direct rays of sunlight, and record the thermometer readings every minute until the same reading appears at least three times in a row for each thermometer. The results can be plotted on a graph. Students will readily realize that the Sun's radiant energy easily enters the uncovered flask and is converted into heat energy that is measured by the thermometer. The experimental flask remains cool because the radiant energy could not enter. You can make an analogy to the radiant energy that penetrates the Earth's atmosphere, strikes the Earth, and is converted into heat energy. As a supplementary activity, let students repeat the above procedure after covering the experimental flask with various materials such as colored cellophanes or paint or by filling it with various solid or liquid substances such as soil or water. 05 Ce Ec

Generalization II. Air pressures vary from time to time and place to place.

Contributing Idea A. The barometer is an instrument used to measure air pressure.

Making an air pressure indicator (barometer). Remove the cork from a small thermos bottle and drill a hole through the cork just large enough to insert a plastic straw or glass tube. Seal the cork in the thermos by dripping candle wax on all connections, and then mount the thermos upside down on a stand so that the end of the tube is approximately ¼ in. (1 cm) from the base. Wrap the thermos in some insulating material, and fit a cardboard box snugly around it. The insulation will help to keep the instrument from acting more like a thermometer than a barometer. Now have students color some mineral oil with food coloring. Set a cup of mineral oil beneath the tube on a day that the air pressure is low (listen to weather forecasts; the low should be below 29.90 in. or 76 cm). Have students observe that whenever the air pressure rises, the mineral oil is pushed up the tube. A scale can be placed behind the tube to note changes (see Figure 161.06). Barometers will work indoors as well as outdoors since the air pressures are about the same. 06 Bb Gc

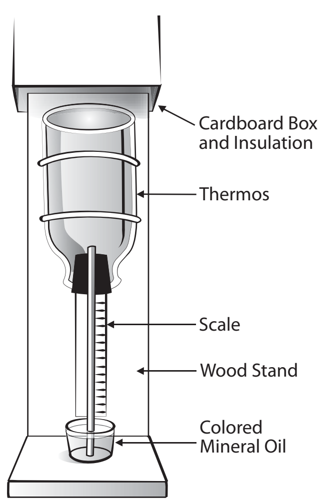


Figure 161.06

Measuring and recording the pressure of air. Use a commercial or homemade barometer to keep twice-daily records of changes in air pressure. Note what weather changes take place outdoors with each recording on a table similar to Table 161.07 (p. 114). Some weather predictions can be made if wind direction and wind speed information are also obtained. 07 Bc Cd Fb

Contributing Idea B. The movement of air affects air pressures.

Observing that low pressure areas can be created when air flows swiftly. There are several activities that will help students realize that air pressure can be reduced by rapidly moving air. 08 Aa

a. Place a table tennis ball in a funnel, hold it stem downward, and blow up through the stem. Students will be surprised to find that they cannot blow the ball out of the funnel. Next, turn the funnel stem upward while holding the ball inside with one hand. While blowing, release the ball. (The ball should not fall as long as the student is blowing.) Students

Table 161.07. Measuring Air Pressure

Week of ______________________________			
	a.m.	p.m.	Observations
Monday	rising	falling	
Tuesday			
Wednesday			
Thursday			
Friday			

can realize that the quickly moving air over the ball creates a low pressure area behind it, and the normal air pressure is enough to hold the ball in place. Explain that when air moves rapidly across the surface of the Earth, low pressure areas result in a similar way.

b. Put a pin through the center of a 3 in. (8 cm) square of cardboard. Insert the pin into the hole of a spool of thread, and hold the cardboard beneath and flat against the spool. Blow through the spool and remove the hand holding the cardboard. (The card is held in place due to the decreased pressure above the card; the normal air pressure is sufficient to hold the card to the spool.)

Generalization III. Water on Earth evaporates into the atmosphere as moisture.

Contributing Idea A. The hygrometer is an instrument used to measure the relative amount of water in the air (humidity).

Making a humidity indicator (hygrometer). There are two basic ways to build an instrument that can measure the amount of moisture in the air. **09 Gc**

a. Open two paper clips partway (Figure 161.09a) and press them approximately ½ in. (1 cm) apart into a block of soft wood about halfway down one side (Figure 161.09b). The block of wood should be approximately 10 in. (25 cm) high and sturdy enough so that it will not tip over easily. Glue a fine wire or piece of straw into the eye of a needle (Figure 161.09c), then set the needle on the two paper clips so that the straw or wire sticks out past the edge of the block (Figure 161.09d). Wash a long strand of hair in hot soapy water to remove the natural oils. When dry, tie the hair to a pin placed at the top of the block (Figure 161.09e). Wrap the free end once around the needle in a counterclockwise loop (Figure 161.09f), and then tie a

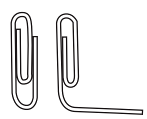


Figure 161.09a

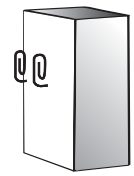


Figure 161.09b

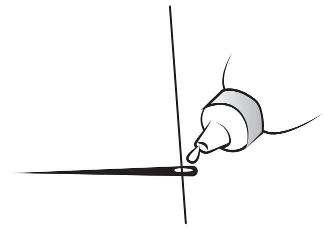


Figure 161.09c

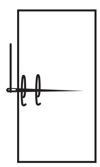


Figure 161.09d

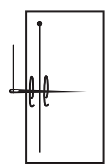


Figure 161.09e

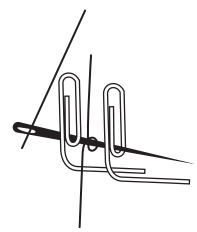


Figure 161.09f

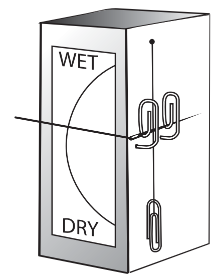


Figure 161.09g

paper clip onto the end of the hair so that it pulls tightly around the needle. Make a measuring scale on a card and mount it on the side of the block (Figure 161.09g). Set the straw so that it is at the center of the card. The scale can be calibrated by draping the hygrometer with a cloth soaked in very hot water. Hair stretches when wet and contracts when dry. This action is at an exact rate and is proportional to the amount of water in the air. The humidity under the cloth will cause the hair to stretch and the pointer to rise. When it stops rising, the humidity will be very close to 100%. This position can be marked on the card. Other positions can be calibrated by comparing this hygrometer with a commercial one.

b. Mount two identical thermometers on a milk carton or side by side on a board. Cut the tips from a clean white cotton shoestring and slip the loose fibers of one end over the bulb of one thermometer. Tie it in place with a piece of thread, then place the other end into a small container of water. In operation, the two thermometers will produce two different readings. The wet bulb thermometer will give a reading based upon the evaporation of the water from the shoestring. Evaporation has a cooling effect; the reading will

Table 161.09. Relative Humidity Table

Dry Bulb Temperature Degrees Fahrenheit	Difference Between Dry Bulb and Wet Bulb Temperatures in Degrees Fahrenheit																					
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	18	20	22	24	26	28	30	32	34
10	78	56	34	13																			
15	82	64	46	29	11																		
20	85	70	55	40	26	12																	
25	87	74	62	49	37	25	13	1															
30	89	78	67	56	46	36	26	16	6														
35	91	81	72	63	54	45	36	27	19	10	2												
40	92	83	75	68	60	52	45	37	29	22	15	7											
45	93	86	78	71	64	57	51	44	38	31	25	18	6										
50	93	87	80	74	67	61	55	49	43	38	32	27	16	5									
55	94	88	82	76	70	65	59	54	49	43	38	33	23	14	5								
60	94	89	83	78	73	68	63	58	53	48	43	39	30	21	13	5							
65	95	90	85	80	75	70	66	61	56	52	48	44	35	27	20	12	5						
70	95	90	86	81	77	72	68	64	59	55	51	48	40	33	25	19	12	6					
75	96	91	86	82	78	74	70	66	62	58	54	51	44	37	30	24	18	12	7	1			
80	96	91	87	83	79	75	72	68	64	61	57	54	47	41	35	29	23	18	12	7	3		
90	96	92	89	85	81	78	74	71	68	65	61	58	52	47	41	36	31	26	22	17	13	9	5
100	96	93	89	86	83	80	77	73	70	68	65	62	56	51	46	41	37	33	28	24	21	17	13

be lower than that of the dry bulb thermometer. The rate of evaporation depends upon the amount of water already in the air. When there is a great deal of water in the air, the evaporation is slowed down; thus the temperature reading is higher and closer to that of the dry bulb thermometer. By comparing the readings of the two thermometers, students can determine the relative humidity of the air. Generally a difference in temperature of 15°F (9°C) or more is considered to be an indication of low humidity while a difference of less than 15°F (9°C) indicates high humidity. Table 161.09 can be used to determine the relative humidity more precisely. For example, if the dry bulb thermometer reading is 65°F and the wet bulb thermometer reading is 56°F, the difference in temperature would be 9°F. By reading down the left-hand side of Table 161.09 to 65°F and across the top of 9°F, the intersection of the two columns is at 56. The numeral in the intersection indicates that the relative humidity is 56%.

Measuring and recording the amount of moisture in the air. Have students use hygrometers to measure the amount of moisture in the air. Have them use Table 161.10 to keep a weekly record of their measurements. 10 Bc Cg

Contributing Idea B. Water evaporates.

Observing that water evaporates. Have students observe saucers filled with water over a period of several days. Discuss what happens to the water. 11 Aa

Measuring the amount of water that evaporates from soil. Fill a flower pot with soil and pour some water into the soil until it begins to drip from the bottom. Weigh the pot, and then do not water 12 Cf

Table 161.10. Measuring Humidity (Wet and Dry Bulb Hygrometer)

	Week of ______________		
	Wet Bulb	Dry Bulb	Humidity
Monday	58°F (15°C)	65°F (19°C)	High
Tuesday	49°F (9°C)	65°F (19°C)	Low
Wednesday			
Thursday			
Friday			

it again for a week. After a week, weigh the pot again. Students can compare the before and after weights and infer what caused the difference.

Experimenting to see how different factors affect evaporation. Challenge students to design tests to find out how each of the following factors affects the rate at which water evaporates: temperature, movement of the air, amount of liquid exposed to the air, type of liquid, amount of moisture in the air (humidity). If needed, help students prepare at least two conditions for each test so that results can be compared (e.g., to test the effect of air movement, place some liquid in front of an electric fan and an equal amount in another place where the temperature and humidity are the same, but where there is no wind). **13 Ec**

162 Interactions

Generalization I. As land and water are warmed by the Sun, the air above them is heated, becomes lighter, and rises; cooler air, being heavier, moves to replace the warm air.

> *Contributing Idea A.* The wind vane and the nephoscope are instruments used to determine wind direction.

Making a wind direction indicator (wind vane). There are several kinds of instruments that can be made to indicate wind direction. **01 Gc**

a. Cut a notch approximately 1 in. (2.5 cm) deep in each end of a 1 ft. (30 cm) long piece of wood. Cut a small arrow head and a large tail piece from aluminum pie plates. Insert them into the slits, and nail them into place (Figure 162.01a). Find the point along the stick where it balances, then drill a hole at that spot just large enough for a small test tube or medicine dropper tubing to fit through. The medicine dropper tubing can be prepared by holding it by the rubber bulb, placing the tip of the dropper into a flame, and rotating it slowly until the opening is completely closed and rounded (Figure 162.01b). When the glass is cool, remove the rubber and insert the tubing through the wood. You might need to use some friction tape to keep the wood from slipping off the tubing (Figure 162.01c). Now bend a coat hanger to form a bracket (Figure 162.01d), and mount the wind vane on a post or fence where winds blowing from many directions will strike it (Figure 162.01e). Be sure students note that the arrow points in the direction *from* which the wind comes. Tell them that winds are named for the direction *from* which they come (e.g., a north wind comes from the north, and the arrow will point north). Students can use a compass to determine from which direction the winds come.

b. The wind sock is another instrument that is used at airports as a wind direction indicator. It can be made by bending a section of light wire into a circle and attaching some thin cloth to it. It can then be attached to a stick with strings and placed outdoors where the wind will blow freely into it. (See Figure 162.01f.)

Making a cloud direction indicator 02 Gc
(nephoscope). The lower part of a moving air mass is usually obstructed and influenced by trees, houses, and other objects; thus, wind vanes (usually near the ground) do not always indicate the true direction of the moving air. To observe movement higher in the atmosphere, have students glue a round mirror to a piece of cardboard, and mark the points of the compass around the mirror. Paste a small paper circle about the size of a dime in the center of the mirror. Set the cardboard on a level spot outdoors with the *N* pointing north (a compass can be used to orient the mirror). Have students look down into the

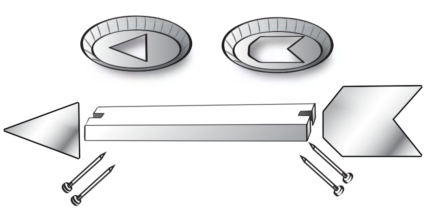


Figure 162.01a

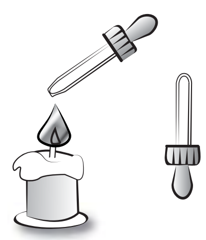


Figure 162.01b

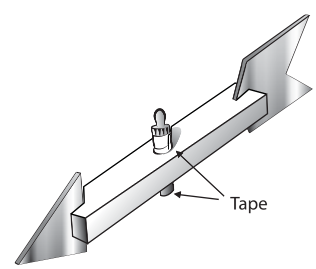


Figure 162.01c

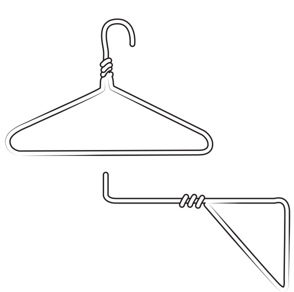


Figure 162.01d

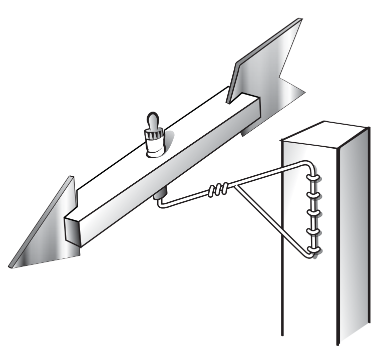


Figure 162.01e

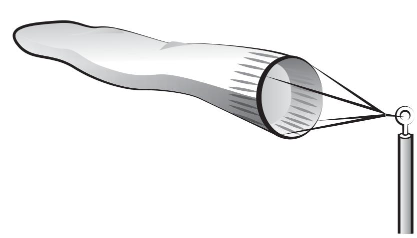


Figure 162.01f

mirror. When they see a cloud passing over the dime-sized circle, have them follow it with their eyes until it reaches the edge of the mirror. At that point they will see a wind direction indicated on the cardboard. This is the direction *toward* which the wind is blowing. You might remind them that winds are named for the direction *from* which they come.

Recording wind directions. Use a commercial or homemade wind vane or nephoscope and record the wind direction twice a day at the same times each day as shown in Table 162.03. Note if there seems to be any relationship between the direction of the wind and the kind of weather that follows. 03 Bc Fb

Table 162.03. Recording Wind Direction

Week of ______________________	a.m.	p.m.	Observations
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			

Contributing Idea B. The anemometer is an instrument used to measure wind speed.

Making a wind speed indicator (anemometer). There are two basic kinds of instrument designs used to measure the speed of winds. 04 Gc

a. The first design requires the student to turn the instrument into the wind. To make such an instrument, clean a milk carton and remove both ends. Thumbtack it to a block of wood to hold it steady. Cut an *H* in the middle section of the top side and open the flaps (Figure 162.04a) Push a cork to the center of a long knitting needle; then push the needle through the flaps (Figure 162.04b). Mount a small needle vertically into the cork to serve as a pointer. Cut a square piece of cardboard so that it fits inside the carton. Attach a second, smaller needle to it with tape or glue and stick the needle into the bottom of the cork (Figure 162.04c). Students may have to adjust the cork, knitting needle, or the card so that the card swings smoothly within the box. When the wind is blowing, point the indicator into the wind so that it blows through the box. The wind will push against the square card, tilting the cork and moving the needle pointer. The distance the needle tilts indicates how fast the wind flows through the carton. A card can be attached to the carton to make a gauge. When attached, draw a line on it parallel to the needle when it is straight up (Figure 162.04d). The gauge can be calibrated using the Beaufort scale (see entry 162.06).

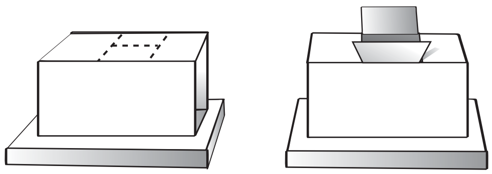


Figure 162.04a

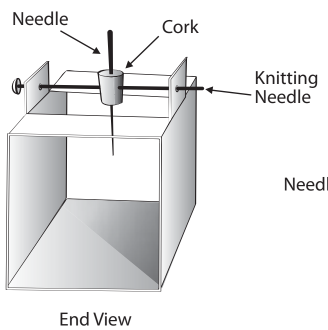


Figure 162.04b

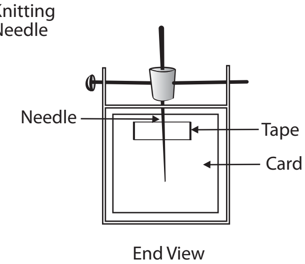


Figure 162.04c

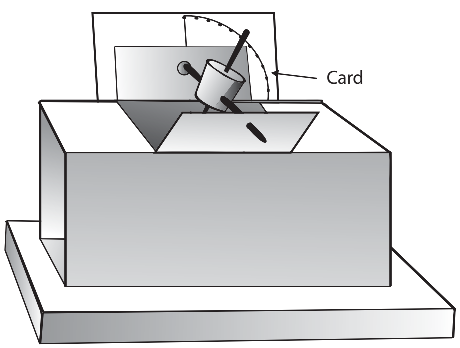


Figure 162.04d

b. A second type of anemometer rotates as the wind strikes it. To make this type, attach two 1½ in. (4 cm) square sticks, 18 in. (½ m) long (Figure 162.04e, p. 122). After the sticks have been nailed together (leaving room for a hole in the middle), drill through their centers so that a small test tube or medicine dropper will fit snugly into their holes (see entry 162.01a, for the preparation of a medicine dropper) (Figure 162.04f, p. 122). Attach four paper cups, halved rubber balls, tin cans, or other cupped objects to the ends of the sticks (Figure 162.04g, p. 122). The instrument can be mounted on a coat hanger (Figure 162.04h, p. 122) or a hole can be drilled into a block of wood, a pencil placed in the hole, and the instrument set over the pencil (Figure 162.04i, p. 122). Paint one of the cups so that students can easily count the number of times it goes around in one minute. The instrument can be calibrated by comparing the number of turns with observations on the Beaufort scale (see entry 162.06). Another way to calibrate the instrument is to hold it out the window of a moving car on a calm day. This is done by sitting next to the front right window while the driver drives the car at a steady 5 miles (kilometers) per hour. The number of turns is counted for one minute. (This should be done several times and an average taken.) Repeat for 10 mph (kph), 15 mph (kph), etc. The information can be graphed (see Graph 162.04, p. 122). When the instrument is

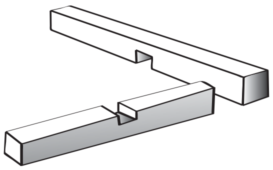


Figure 162.04e

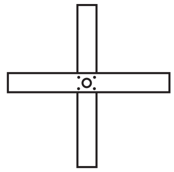


Figure 162.04f

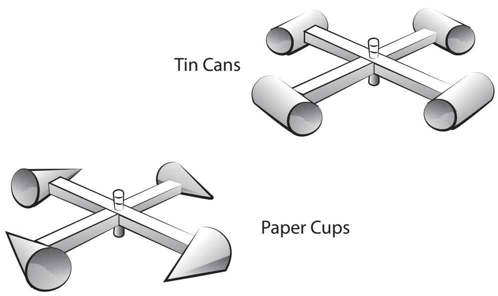


Figure 162.04g

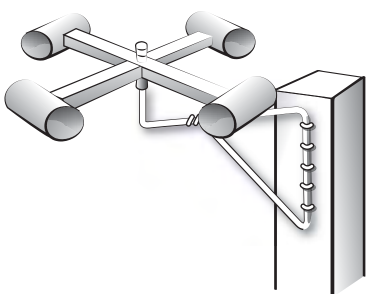


Figure 162.04h

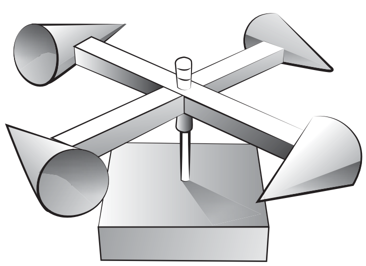
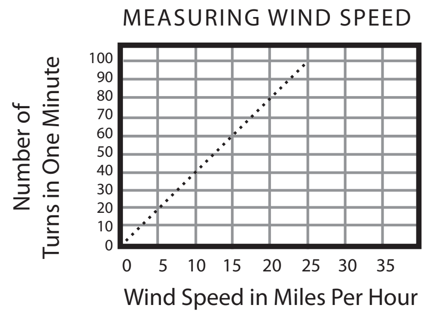


Figure 162.04i



Graph 162.04

mounted on the school grounds, the speed can be determined by counting the number of turns in one minute.

Measuring and recording the speed of wind. Students can keep a daily record of wind speed on a table similar to Table 162.05. Measurements should be made at the same time each day, and students should note whether the sky is sunny, cloudy, rainy, and so on. Have them study their table after several weeks to see if there is any relationship between the speed and direction of the wind and the kind of weather that follows. **05 Bc Ch Fb**

Table 162.05. Measuring Wind Speed (Rotary Anemometer)

Week of ______________________			
	a.m.	p.m.	Observations
Monday			
Tuesday			
Wednesday			
Thursday			
Friday			

Estimating wind speed without an anemometer. The speed of the wind can be estimated without complex instruments simply by using the Beaufort scale (see Table 162.06). The scale allows students to estimate fairly accurately the speed of wind by observing the motions of leaves on trees, chimney smoke, etc. **06 Cb**

Contributing Idea C. Air is heated primarily by contact with the ground.

Measuring the temperature of air near the ground. On a windless day, have students find a place in direct sunlight and drive a 6 ft. (2 m) stake into the ground. On the shadow side of the stake, let them place one thermometer on the ground so that the bulb is in direct contact with the ground. Place a second thermometer on the stake near the ground and directly above the first thermometer. Attach a third thermometer at least 5 ft. (1.5 m) above the second. Be sure that each thermometer is on the shadow side so that it is not in the direct rays of the Sun. At 10-minute intervals, check the readings on the thermometers. Students will find that the temperatures are higher nearer the ground. Explain that when cold air moves near the warm land or water, it becomes warmer and begins to rise. **07 Ce**

Table 162.06. The Beaufort Scale of the Speed of Wind

Scale Number	Observation	Name of Wind	Miles Per Hour
0	Smoke goes straight up	Calm	Less than 1
1	Direction shown by smoke but not by wind vanes	Light Air	1–3
2	Wind vane moves; leaves rustle	Light Breeze	4–7
3	Flag flutters; leaves move constantly	Gentle Breeze	8–12
4	Raises dirt, paper; flags flap	Moderate Breeze	13–18
5	Small trees sway; flags ripple	Fresh Breeze	19–24
6	Large branches move; flags beat	Strong Breeze	25–31
7	Whole trees sway; flags are extended	Moderate Gale	32–38
8	Twigs break off; hard to walk against	Fresh Gale	39–46
9	Slight damage to buildings	Strong Gale	47–54
10	Trees uprooted; windows break	Full Gale	55–63
11	Widespread damage to buildings	Violent Storm	64–75
12	General destruction	Hurricane	Over 75

As the air rises, it becomes cooler and heavier, and then moves down toward the land and water again.

> *Contributing Idea D.* Winds are caused by unequal heating of the Earth's surface.

08 Ce **Comparing the absorption and release of heat by soil and water.** Fill one coffee can with dry soil and another with water. Let each remain in the classroom overnight so that they will be equal in temperature. Students can then put thermometers to the same depth in each and place both cans outdoors in the sunlight. After two hours, check the temperatures to see which is warmer and which is cooler. (The water should be cooler.) Have students share experiences they have had walking barefoot from hot pavement or land to a puddle or from a sandy beach to the water. They should deduce that soil heats up more rapidly than water. If they next set a can of soil and a can of water of equal temperatures in a refrigerator and check the temperatures every 10 minutes, they will find that the soil cools more quickly than the water. Such data can be easily graphed. Explain that soil or water temperatures influence the air above them. That is, land areas generally warm more rapidly during the day than water areas; thus the air above the land tends to be heated and rise while the cooler, heavier air over the water areas pushes inland to replace it. At night the land areas generally cool more quickly, thus the exchange of air is reversed.

09 Aa **Detecting warm and cool air currents.** Small wind currents in the classroom can be detected using simple wind current detectors. The detector in Figure 162.09 can be made by folding a square piece of paper up on the solid lines and down on the dotted lines, then attaching a thread to the center. If held by the thread over a radiator or lightbulb, the device will move and indicate the direction of the current. If temperature readings are taken in different places in the room (e.g., at the ceiling and the floor; at the bottom and top of an open window), students will see that the movement corresponds to the exchange of warm and cool air. Explain that warm air weighs less than cold air, exerts less pressure—thus creating an area of low pressure. The heavier cold air creates an area of high pressure and pushes the warm air upward.

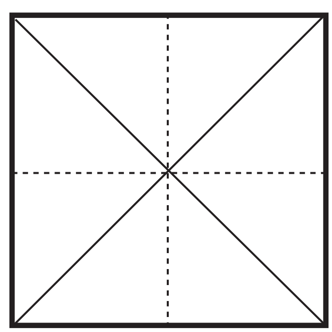


Figure 162.09

Generalization II. Water on Earth evaporates into the atmosphere as moisture.

Contributing Idea A. Temperature change affects evaporation.

Testing to see if an increase in temperature affects evaporation. Pour ½ c. (100 ml) of water into each of two identical shallow pans. Place one in a warm location and the other in a cool place away from any breeze. Compare the time required for the water to evaporate from each pan. Students can make some judgment about the relationship of heat to evaporation. The test can be repeated and speeded up by placing the experimental pan over a heat source such as a hot plate or radiator. Similarly, two cloths of the same size and same material can be substituted for the pans. Soak each thoroughly in water. Set one in a cool location and one in a warm location. An analogy can be made to clothes on a line on a sunny day and on a cloudy day. In each of the above tests, be sure that the heat factor is the only influence. 10 Ec

Testing to see if a great reduction in temperature affects evaporation. Thoroughly wet a cloth on a sunny day when the temperature outside is below freezing. Suspend the cloth and observe it every half hour until it is frozen stiff. After several hours, bring the cloth indoors and let students examine it. They will find that the cloth is dry. The time required for the frozen water to leave the cloth will depend upon the relative humidity of the air, the wind, and the temperature. (Note: The water in the cloth actually sublimes from a solid state to a gaseous state.) 11 Ec

Contributing Idea B. Moving air affects evaporation.

Testing to see if moving air affects evaporation. If you have access to a chalkboard or one in the classroom, wet two identical areas of a chalkboard and fan one with a piece of cardboard or an electric fan. Students will realize that the moving air was the influencing factor in making one area dry faster. Similarly, they can thoroughly wet two cloths of the same size and material, and hang one outdoors in a windy location and the other in a sheltered spot. If students touch the cloths periodically, they will find that the water evaporates from the cloth in the wind more quickly. Let them discuss how clothes dry on windy days. **Caution: Follow safety guidelines when using the electric fan.** 12 Ec

Testing to see if moving moist air affects temperature. Have students use thermometers to find the temperature of moving air (outside when the wind is blowing or in front of an electric fan). Hang some wet straw, newspaper, or cloth strips in the breeze. Leave a little space between the strips so the air can pass between them. Use thermometers to find out what happens to the temperature of the air after 13 Ec it passes through the wet material. An analogy can be made to air conditioners and how they work.

Contributing Idea C. Surface area affects evaporation.

Testing to see if surface area affects evaporation. Pour 1 c. of water into a wide, shallow dish and another cup into a tall, narrow jar. Place both in direct sunlight. Students will see that the one with the wide mouth evaporates faster than the other. Discuss the differences in evaporation from small puddles and large lakes. 14 Ec

Generalization III. Moisture in the atmosphere can condense into various forms that return to the Earth.

Contributing Idea A. The rain gauge is an instrument used to measure rainfall.

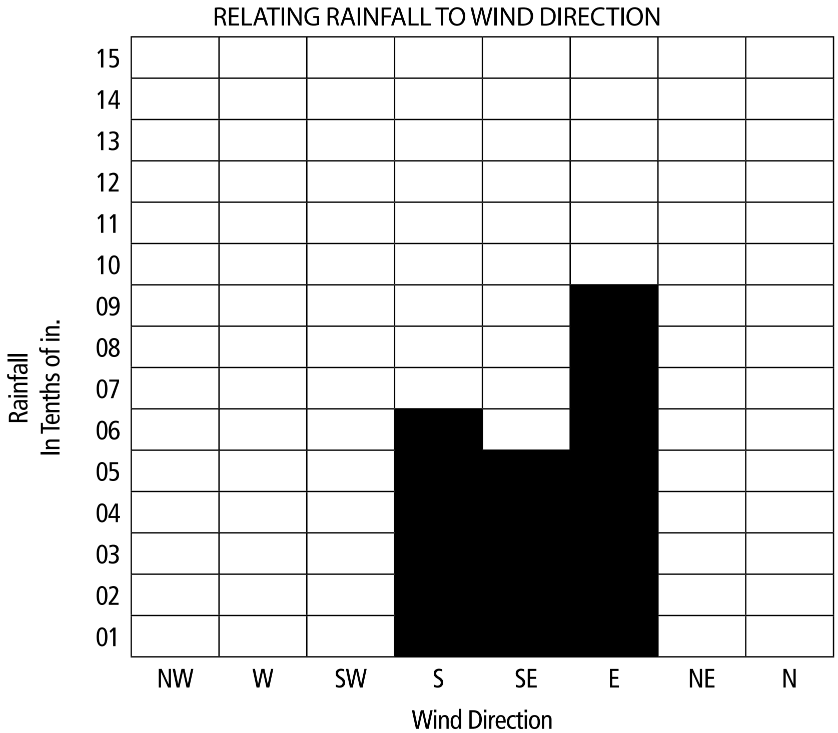
Making a rainfall indicator (rain gauge). Any open container with straight sides can be used to measure amounts of rainfall. When the rain is collected, simply have students stick a ruler into the container to see how deep the water is. If the water is 1 in. (3 cm) deep, then 1 in. (3 cm) of rain has fallen. Since most rainfall is less than an inch, a true rain gauge is designed to catch a relatively wide area of rainfall and to funnel it into a narrow area so that it will be deeper and can be measured more easily. (Note: Measurements must be taken very soon after a rainfall or evaporation will give inaccurate readings.) Attach a test tube beside a strip of paper on a block of wood. Fill a widemouthed, straight-sided jar with 1 in. (3 cm) of water. Pour this water into the test tube and mark the height on the strip of paper. Repeat this procedure using ¾ in., ½ in., and ¼ in. (or 2.5 cm, 2 cm, 1.5 cm, 1 cm, and 0.5 cm) of water. Now the jar can be placed outdoors in the open. When rain is collected in the jar, pour it into the test tube to measure how much rain fell. 15 Gc

Measuring and recording rainfall. Use a rain gauge in conjunction with a wind vane. Information can be recorded on Table 162.16. A graph of the data (Graph 162.16) will reveal how much rain falls in your area in a month and which winds bring rain. 16 Bc Bf Cd

Contributing Idea B. Water condenses.

Table 162.16 Measuring Rainfall

Date	Direction of Wind During Rainfall	Amount of Rainfall



Graph 162.16

Observing condensation. Have students observe the condensation of water on glasses of ice water. Let them discuss where the droplets come from. Let them also describe personal experiences that are examples of condensation (e.g., moisture on a mirror in bathroom, moisture on windows inside a closed automobile). **17 Aa Ga**

Contributing Idea C. Temperature change affects condensation.

Observing condensation by cooling through contact. On a very cold day, have students go outside and notice how the moisture from their breath can be seen when it comes in contact with the cold air. Similarly, have them exhale across an ice cube tray or into an open freezer compartment and observe the condensation in the air. They will realize that this phenomenon takes place when moist air comes in contact with cooler air or a cooler surface. **18 Aa**

Observing condensation by cooling through rising. Boil some water in a pot, beaker, or tea kettle on a hot plate. When it is boiling, let students describe what they see. **Caution: Be careful of the steam.** Students will see clouds of moisture forming as the heated moist air rises into the cooler air of the room. Encourage them to imagine how warm moist air near the Earth may rise and cool in the **19 Aa Fa**

atmosphere in a similar way. (Note: Rising air cools at the rate of 1°F every 300 ft. in the atmosphere.)

Observing condensation by cooling through expansion. Pour a cup of hot water into a transparent widemouthed gallon (4 L) jar. Put a plastic bag inside the jar and fold its edge over the rim, fastening it tightly with rubber bands. Have one student hold the jar firmly on the table, and let another pull upward on the bag quickly. Have them describe what they see inside the jar. (When the bag is pulled upward, the pressure inside the jar is reduced and the warm moist air inside expands. It cools with expansion and a cloud forms inside. When the bag is released, the cloud disappears.) This activity can be repeated several times. The cloud is best seen when the light source is behind the viewer. Students should be able to generalize that clouds can form in a similar way. **20 Aa Fa**

> *Contributing Idea D.* Dew and frost are formed by the condensation of water vapor on the surface of the Earth.

Observing how dew is formed. Remove the label from a tin can. Take some water that has been allowed to stand until it has reached room temperature, and fill the can about halfway. Add a few ice cubes to cool the water. After several minutes, students will see droplets of water forming on the outside of the can. Tell them that the formation is called dew. Explain the parallel formation of early morning dew that they may have seen. They will realize that when moist air contacts a cooler surface, such as the side of the can or blades of grass, the moisture in the air condenses on the surface. (Note: In very dry areas, this activity may not work because there may not be enough water vapor in the air for droplets to form.) **21 Aa Bb Fa**

Measuring dew points. Remove the label from a tin can, and half-fill it with water. Place a thermometer in the water, and record the temperature. Add chips of ice, stir, and record the temperature again when droplets form on the outside of the can. Tell students that the temperature reading when the droplets form is called the dew point for the temperature of the air in the room. Explain that water droplets or dew on blades of grass or flowers in the morning is formed in a similar way, and the temperature at which it forms is the *dew point*. Let students repeat this activity in different locations and on different days to compare dew points. If other observations are recorded (e.g., room temperature, humidity), factors influencing dew point will be discovered. After several tests, ask students what conclusion they would make if the temperature of the room and the dew point were within a few degrees of each other. (There would be a very high relative humidity.) **22 Bb Ce**

Observing how frost is formed. Remove the labels from two tin cans and half-fill one can with water, chips of ice, and a handful of salt to make it very cold. Half-fill the second can with water only. Use two thermometers to record the temperature of each can, and then stir the contents of both rapidly. Students can observe the outside of the cans. Tell them that the formation they observe on the first can is called frost. Explain the parallel formation of early morning frost on the ground. They can then compare the two temperature readings and realize that when the surface of an object (e.g., the ground) is below the freezing temperature of water, the water vapor in the air condenses on the surface as frost. 23 Aa Bb Fa

Contributing Idea E. Fog is formed by the condensation of water vapor near the surface of the Earth.

Observing how fog is formed. Fog is the condensation of moisture in the atmosphere near the surface of the Earth. For any of the following experiences, help students realize that real fog is formed in an analogous way through the rapid cooling and condensation of water vapor in the air near the Earth's surface. 24 Aa Fa

a. Heat some water in a container until it boils, and then fill a beaker slowly to prevent it from breaking. Next, empty all but 1 in. (3 cm) of water from the bottle and hold it so the light source (e.g., window, electric light) comes from behind the viewers. Now, set the bottle on a tray of ice cubes, and let students describe and discuss what happens inside. They will realize that in a similar way fog forms at night when the Earth cools rapidly (represented by the ice tray) and the air next to it cools in turn and comes in contact with the warmer moist air above.

b. Take a large fruit juice can, put some ice in it, and add a handful of salt to make it very cold. Set a smaller can on the ice so that the tops of both cans are even. Pack more ice and salt into the space between the two cans and let a student exhale into the smaller one. The class will see fog form and remain in the smaller can. Point out the parallel to real fog that clings in valleys when the ground is cooled.

Contributing Idea F. Clouds are formed by the condensation of water vapor in the atmosphere.

Observing how clouds are formed. Clouds are condensations of moisture in the atmosphere. For any of the following experiences, help students realize that real clouds are formed similarly through the cooling and condensation brought about by the expansion of rising air. 25 Aa Fa

a. Pour 1 c. (200 ml) of warm water into a transparent widemouthed gallon (4 L) jar. Hold a lighted match in the jar, blow it out, and let it remain briefly. Now place a plastic bag inside the jar, turn its edge down over the rim of the jar, and fasten it securely with rubber bands. Have a student hold the jar firmly on the table, and let another quickly pull upward on the plastic bag. They will see a cloud form inside; when the bag is released, it will disappear. The cloud forms for several reasons: (1) the air in the jar contains invisible water vapor; (2) the air pressure inside the jar is reduced; (3) there are many small particles from the match in the air. As the air inside the jar expands, it cools, and the water vapor condenses as liquid around the smoke particles form the minute droplets that make up the cloud. Students can test to see if a cloud can be made: (1) without putting water in the jar; (2) with cold water instead of warm water; (3) with water but without smoke, and so on.

b. Obtain two identical widemouthed jars. Line half the inside of each with soft, black cloth. Add glue to hold the cloths in place, and then soak the cloths with water. Cover each jar with a square of glass and set them upright, one in a pan of cold water, the other in a pan of very hot water. Leave the jars for 15 minutes. Remove them from the pans and set the cold jar upside down over the warm jar leaving the glass squares over the openings (see Figure 162.25). Hold a flashlight to shine down through both jars, and then carefully remove the glass squares. A cloud will form as the warm moist air rises and comes in contact with the cooler air above. Students can experiment by repeating the activity and reversing the positions of the jars. Tiny tissue paper streamers can be placed inside the jars to indicate the direction the air flows. If possible, observe cloud formations outdoors, and let students judge the relationship of hot and cold air masses based upon their experimental models.

Identifying cloud types. Have students keep records for a week of the kinds of clouds that they see. Help them recognize some of the common types. 26 Ba Bb

a. *Cirrus*, *cumulus*, and *stratus* are the basic types of clouds. Cirrus are very high in the atmosphere. They generally look feathery and are composed of tiny ice crystals. They are usually a sign of clear weather. Cumulus clouds are

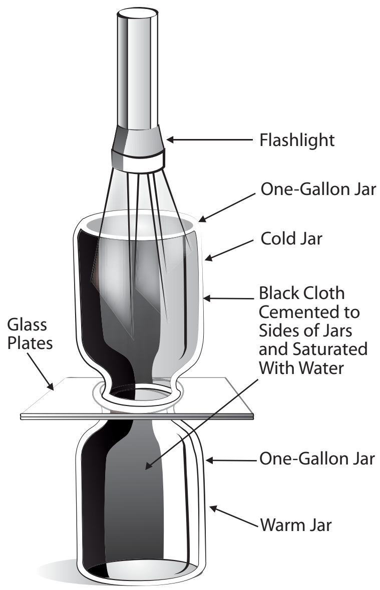


Figure 162.25

lower than cirrus clouds, and airplanes often fly above them. They look like white puffs in the sky and usually indicate fair weather. Stratus clouds are much lower and foglike. They form gray layers across the sky.

b. *Nimbus* describes basic clouds containing a great amount of water. They are usually very low in the sky and look thick and black. They generally bring rain, snow, sleet, or hail.

c. *Alto* is a prefix meaning "high." It is used to describe high forms of basic clouds.

Students can study events that bring about the formation of each type of cloud. They might group cloud types on the basis of the events (clouds that usually follow in sequence with an approaching cold front: altocumulus, cumulonimbus, stratus, stratocumulus; clouds that usually follow in sequence with an approaching warm front: cirrus, cirrostratus, altostratus, nimbostratus, stratus).

Contributing Idea G. When the moisture in clouds continues to condense, it may fall as rain or snow.

Observing how rain is formed. After students have seen how clouds can be formed, have them hold the flat bottom of an ice cube tray slightly tilted but close to steam escaping from a boiling teakettle. **Caution: The steam is very hot.** Be sure they observe how the water droplets collect, enlarge, and drip off the edge of the tray because of their increasing weight. It should be noted that although the formation of rain is not fully understood, scientists believe that droplets form upon minute particles in the air and continue to increase in size as water vapor cools. Students can try this activity again using two ice cube trays—one empty and one filled with ice cubes. Explain that as the moist air rises (from the teakettle), it cools rapidly against the filled tray and less rapidly against the empty tray. Take care to hold the trays at equal distances from the spout of the teakettle and record the time taken for drops of "rain" to fall **27 Aa Fa**

from each. They can compare the times. Students can relate their findings to actual events in the atmosphere.

28 Cd Da **Measuring the size of raindrops.** On a rainy day, pour some flour through a sifter into a pie pan until it is ½ in. (1 cm) deep. Cover the pan with a large plate and take it outdoors. Hold it in the rain, uncover it, and let the rain fall into the flour for three seconds. Cover the pan with the plate and return indoors. When the pan is uncovered again, students will see wet round lumps where the raindrops fell. Let the lumps dry for about three hours, and then use the sifter to separate the lumps from the flour. Measure the lumps with a ruler or seriate them by size to learn something about the relative size of raindrops. (Note: The lumps are slightly larger than the actual raindrops.) If records are kept (Table 162.28), the sizes of raindrops can be compared during different parts of a storm or between different storms. Another way to measure the size of raindrops is to prepare hoop screens by stretching pieces of discarded nylon stockings over embroidery hoops. When each screen is stretched tightly, staple or tack it in place, then trim away the excess stocking. On a rainy day, press the screens into a large pan with some sprinkled powdered sugar. Tap off any excess sugar, cover the screens, take them outdoors, and hold them horizontally in the rain. When ready, uncover the screens and allow raindrops to fall on them for a timed period (e.g., 30 seconds). Cover the screens again and bring them into the classroom. If the screens are held up against a dark background, students will see darkened spots where each drop removed the sugar as it fell through the screen. Diameters can be compared with a ruler. Samples taken from different locales or at different times during the rainfall can also be compared.

Observing how snow is formed. Obtain some dry ice. **Caution: Do not touch dry ice with bare hands. Keep it in a closed container when not in use.** Prepare a cloud as in entry 162.24b, and then chip a few small pieces from the dry ice, and 29 Aa Bb Fa

Table 162.28. Seriating Raindrops by Size

	Small Drops	Medium Drops	Large Drops
Number of drops in 3 seconds at the beginning of the storm.			
Number of drops in 3 seconds in the middle of the storm.			
Number of drops in 3 seconds near the end of the storm.			

drop them into the cloud. Hold a flashlight into the small can and exhale gently into the cloud at two-minute intervals. Have students describe what happens. Explain that snow is formed directly from water vapor to ice crystals in a similar way (no liquid state between the two), and that the crystals may fall to the ground as snowflakes. You might explain that if rain freezes when it contacts an object or the ground, the result is called *sleet*, and when frozen particles in the air have additional layers of water frozen to them before they fall to the ground, the result is called *hail*.

Observing how obstacles affect snow-drifts. On a snowy day, prop some cardboard sheets upright on old snow. Set the sheets so they face in different directions. When it stops snowing, students can examine the distribution of the snow around each sheet. They will be able to describe where the drifting takes place. On the basis of their observations, ask them how they would place a snow fence if they wanted to keep snow from a walkway. 30 Aa

Measuring snowfall. Although snowfall depth is reported on newscasts and is important to skiers, the snowfall measurement by weather bureaus has more meaning when the water content of the snow is determined. To do this, remove the top and bottom from a straight-sided can and push the can straight down into the snow until its rim is even with the Earth's surface. Let one student reach under the can and cut the snow even with the bottom edge with a piece of cardboard. Remove the cylinder of snow and dump it into a second can of the same size but that has only one end removed. Melt the snow slowly to avoid too much loss of water by evaporation. Measure the depth of the water that remains. Compare the depth of the water to the depth of the snow that produced it. Since snows are different, students can try this activity with dry, light, fluffy, and packed snows. They will find that some snows are drier than others (the ratio of water to snow depth is less). They can seriate or rank the snows by the amount of water each produces; and if temperature measurements are taken during snowfalls, a relationship between temperature, the type of snow that is formed, and the water content will be discovered. 31 Cd

163 Theory

Generalization I. Many factors act together in complex ways to keep the forces that control weather constantly out of balance.

> *Contributing Idea A.* The tilt of the Earth affects the balance of temperatures.

Making a model to show how solar energy strikes the Earth's surface. On lined paper, have students trace and cut out a large circle. Have them print *North* 01 Fc

Pole on the top of the circle and *South Pole* on the bottom. Draw a heavy horizontal line through the middle of the circle to represent the equator. Place two sheets of lined paper on a flat surface, and mark an *S* in the center between the two sheets to represent the placement of the Sun. Tell students that the lines on the paper represent rays of solar energy, some of which become converted into heat. Place the cut-out Earth on the left-hand lined sheet so that the North Pole is at the top and the lines on the circle match those on the sheet. Ask students which part of the Earth receives the most radiation from the Sun when in this position, then move the North Pole to the right as if the Earth were tilted toward the Sun (the Earth tilts 23½°), and ask which part of the Earth now receives the most radiation from the Sun. They will see that more rays strike the northern regions than the southern. (Arrow heads can be added to the parallel lines to emphasize how the rays strike the Earth.) Next, move the Earth so that it travels around the Sun to the other side (place it on the right-hand sheet of lined paper). Be sure the Earth remains in the same tilted position. Again ask which areas on the Earth receive more and less solar energy. Students will see that the polar regions alternate in receiving more or less solar energy due to the tilt of the Earth and realize the angle of the Sun's rays cause the changing seasons. In winter (in the Northern Hemisphere) the Sun is low in the sky. In the summer it is more directly overhead.

Contributing Idea B. The curved surface of the Earth affects the balance of temperatures.

Using a model to observe the effect of solar energy upon a curved surface. Shine a flashlight through a cardboard tube (to keep the rays from spreading outward). Aim the tube horizontally at the equator of a globe, and let students describe the spot of light that is projected. Move the flashlight gradually toward the North Pole while holding the tube horizontally. (Note: The parallel lines in entry 163.01 can be used to supplement this experience.) Students can describe the spot of light that is now projected. (It is larger because the rays strike the surface at more and more of a slant as the light is moved toward the pole.) They can make the analogy to the radiant energy reaching the Earth from the Sun. Now attach several small thermometers to the globe. Place a lamp 8 in. (20 cm) from the globe so that the thermometer on the equator is in the center of the lighted half of the globe. After three minutes, compare the thermometer readings. Students will find that the temperature readings decrease toward the poles. **02 Ce Fc**

Comparing temperature differences of soils receiving direct and slanted solar energy. Fill identical cardboard boxes or milk cartons with equal amounts of soil **03 Bc Ce**

or sand. Insert thermometers into each box to equal depths. Set both boxes in the sunlight, but prop one so that the Sun's rays strike it directly. Record temperature readings every 10 or 15 minutes. Results can be graphed. Students will see that the temperature rises more quickly and higher where the Sun's rays strike the soil directly. Analogies can be made to various places on Earth.

Contributing Idea C. Some materials absorb more heat energy than others.

Comparing differences in heat energy absorbed by differently colored materials. Obtain two dowel sticks of the same diameter and length. Sharpen one end of each so that it can be driven or pressed into packed snow. Paint one stick black and the other white. On a sunny day, when there is a good snow cover, press the two sticks upright into the snow to the same depth, and check them every few hours while observing the snow around each. Students will observe that the snow area around the black stick melted more than the snow area around the white stick. Have them look for everyday examples of the same phenomenon (e.g., the area around tree trunks, weeds, and posts sticking through the snow and around various objects that people drop onto the snow). Students can also cut several identical squares from different colors of construction paper. On a sunny day, place the papers on a clean snow surface and observe every hour to see which shows the least effect from exposure to the Sun. **04 Ca**

Measuring the heat energy absorbed by differently colored materials. Fill two glasses with equal volumes of water. Wrap a sheet of white paper around one glass and a black sheet around the other. Set identical thermometers in each, and place the glasses in direct sunlight. Have students take temperature readings every 10 minutes. The data can be graphed. Students will find that the water in the glass wrapped in black paper warms more quickly. Next, let them try papers of various colors and compare the results. They may wish to discuss the advantages and disadvantages of wearing certain color clothes at different times of the year. **05 Bf Ce**

Contributing Idea D. The atmosphere affects temperatures by shielding the Earth from solar radiation and by trapping heat energy that is reradiated from the Earth's surface.

Using a model to observe that solar energy can be shielded from a surface. Hold a thermometer directly beneath a lighted bulb at a distance of 8 in. (20 cm) for three minutes. Record the temperature, then let the thermometer return to room temperature. Next, repeat this procedure after inserting a sheet of paper between the bulb and the thermometer. After three **06 Ce Fc**

minutes, record the temperature and compare readings. Let students feel the paper and ask them how the atmosphere might affect heat and light from the Sun in a similar way. Explain that clouds, dust, and other impurities in the air reflect and absorb some solar energy much like the sheet of paper and that some of the Sun's energy is turned back by the atmosphere, some is absorbed by the atmosphere, and some goes clear through the atmosphere and warms the Earth. As a supplemental or alternative activity, tape two thermometers on directly opposite sides on a globe at the equator. Hold a lamp about 8 in. (20 cm) from the globe so that one thermometer is in the center of the lighted half of the globe. After three minutes compare the two thermometer readings. Students can discuss the temperature differences between night and day and relate their finding to personal experiences. Next, have them hold a piece of paper between the bulb and the thermometer for another three minutes and compare the readings. They can make analogies between this experience and days that are overcast, foggy, or smoggy.

Using a model to observe that heat can be trapped in the atmosphere. Fill a plastic bag with soil, and place a small thermometer on top of the soil. Tie the bag securely. Place another thermometer on an identical type of soil outside the bag. Leave both in the bright sunlight and record the temperature readings every 10 minutes for an hour. Compare the readings of the two thermometers. The data can be graphed. Ask why one reading is higher than the other. (Although both received the same amount of solar energy, the energy absorbed by the soil in the bag heated the air confined in the bag. The trapped air, in turn, kept the soil warm.) Similarly, the students can fill two pans with equal quantities of soil or sand and set them in a warm place for several hours. Let them insert thermometers, each one-half inch (1 cm) beneath the surface of the soil or sand in each pan. Place both pans outdoors and away from any buildings on a sunless, windless day. Place a cloth or canvas covering a few in. over one of the pans and take temperature readings of the soil every 10 minutes for an hour. The data may be graphed. The students should see that the uncovered pan cools more rapidly, as heat energy strikes the canvas over the covered pan and reflects some back, retaining some of the heat. 07 Ce Fc

Contributing Idea E. Air moves because of unbalanced temperatures.

Observing that warm air rises and cooler air moves in to replace it. Make a tube of lightweight cardboard, and fit it loosely around an uncovered lightbulb (Figure 163.08a). If you have access to chalk and chalkboard erasers, rub chalk or erase chalk to create dusty erasers. 08 Aa

Turn the bulb on and darken the room. Have one student clap together two dusty chalkboard erasers near the bottom of the tube (Figure 163.08b), and let others observe what happens. (The chalk dust will rise through the tube and out the top.) Ask what happens to the air that is warmed. (It rises.) Ask what happens to the air over warm parts of the Earth. (Warm air creates a low pressure area.) Next, hold the tube under a tray of ice cubes, shine a flashlight at the bottom of the cubes, and hold a smoking piece of clothesline rope or string near the top. Ask what happens to the air as it is cooled. (It falls.) Ask what happens to the air over cold parts of the Earth. (Cooler air forms a high pressure area and replaces warmer air as the warmer air rises.)

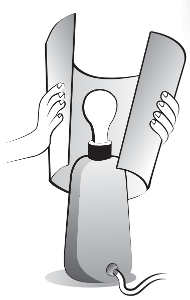


Figure 163.08a

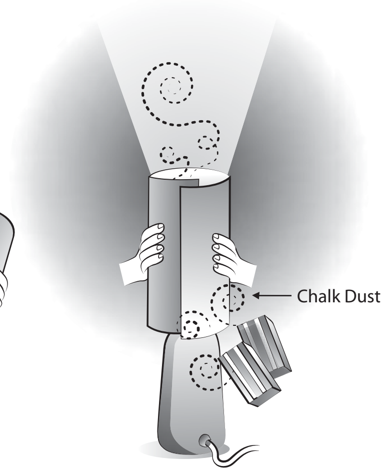


Figure 163.08b

Making a model tornado. Find a cardboard box that is at least 1 ft. (30 cm) high and just slightly larger than a square-shaped hot plate. Cut the bottom from the box so that it can be set over the hot plate. Next, cut out large openings on two adjacent sides of the box, cover them with heavy clear plastic, and paint the inside of the box black. Next, cut a 4 in. (10 cm) hole in the top and insert a 3 ft. (1 m) long cardboard chimney. Be sure to tape the chimney securely and seal it with melted wax so that no air can leak into the box. Now, cut ½ in. (2 cm) slots in the four corners, starting 1 in. (3 cm) from the top and extending to within 1 in (3 cm) from the bottom. Place on the hot plate a shallow square tray of water that is about the same size as the hot plate. Cover them with the box. Shine a flashlight through one window, and let the class observe (Figure 163.09). They will see the formation of a vortex, like a miniature tornado, 09 Fc

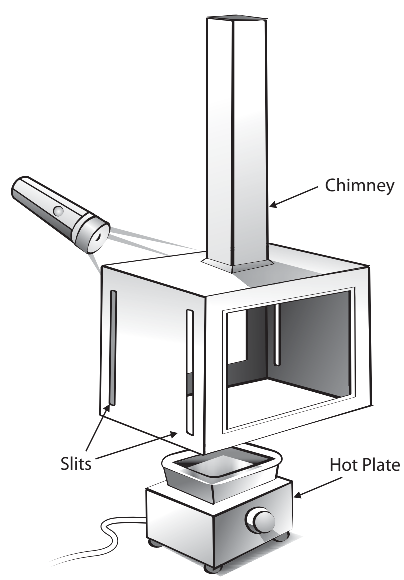


Figure 163.09

above the boiling water. (A real tornado is formed similarly due to convection currents.)

10 Aa Bb

Observing that high pressure areas move into low pressure areas. Air generally moves from a high pressure area to a low pressure area; thus, winds blow from high to low. There are several activities that help students realize this.

- **a.** Students can hold two sheets of typing paper approximately 3 in. (10 cm) apart and blow between them. As long as the students blows, the sheets of paper will be forced together. (The rapidly moving air current between the papers creates a low pressure area as the greater surrounding pressure outside forces the papers together.)
- **b.** Students can attach threads to two table tennis balls with cellophane tape or drops of glue. Suspend the balls about an inch apart and, using a soda straw, blow between them. Students will realize that as the stream of air passes between them, a low pressure area results as indicated by the balls being pushed together. Tell them that weather forecasters call low-pressure areas *lows* and high-pressure areas *highs*. If possible, show weather maps, indicate the high and low symbols, and discuss what they mean in terms of moving air masses.

11 Fc

Using a model to observe how winds are affected by the rotation of the Earth. Spin a globe in a counterclockwise direction (west to east) as viewed from above the North Pole. Let one student try to draw a straight line on the spinning globe by pressing lightly on it with a piece of chalk or wax pencil. The line drawn should extend from about 35°N latitude to the equator (Figure 163.11a). When the globe stops spinning, students can observe the line that was made. Tell them that the line could represent a wind blowing from the north. Explain that such winds are twisted to their right (west) as was the drawn line. Because winds from the north constantly come in contact with the Earth's surface, whose speed of rotation is greater than the winds' speed, the wind currents lag behind, causing them to turn a little from their straight course. Students will realize that the Earth's rotation influences all winds in the Northern Hemisphere to shift to their right (i.e., north winds become easterly and south winds become westerly) (Figure 163.11b). Explain that winds that push toward a low pressure area are also twisted to the right, creating a counterclockwise swirl of air, while winds pushing out from a high pressure area are all twisted to their right, creating a clockwise spiral of air (Figure 163.11c). This can be demonstrated three-dimensionally by cutting

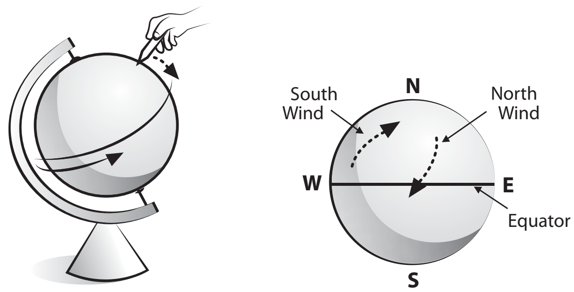


Figure 163.11a Figure 163.11b

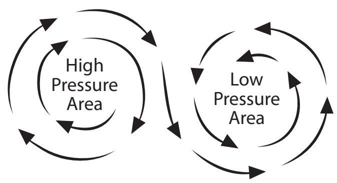


Figure 163.11c

a rubber ball in half and painting rings around the outside of each half. Place one cup of the ball open-side down on a map at a place where a high pressure area might be indicated. Place the other cup open-side up where a low might be. Explain that the cups represent the pressure areas, and then trace with a pencil how the air will spiral up one cup and spiral downward into the other.

Generalization II. According to theory, the air above the Earth can be thought of as masses that are separated by zones of rapidly changing conditions.

Contributing Idea. Air masses transport complete sets of weather conditions that change as the air masses move over the Earth's surface.

Using models to demonstrate weather fronts. An aquarium can be structured to show what generally takes place when differently heated air masses come in contact. To do this, use plastic-model cement or contact cement to glue plastic rib binders, such as the type used by students to hold report papers together, along the bottom and sides of the aquarium (Figure 163.12a). Be sure the ribs are glued securely to form a watertight guide for a glass partition. Now make a parti- 12 Bb Fc

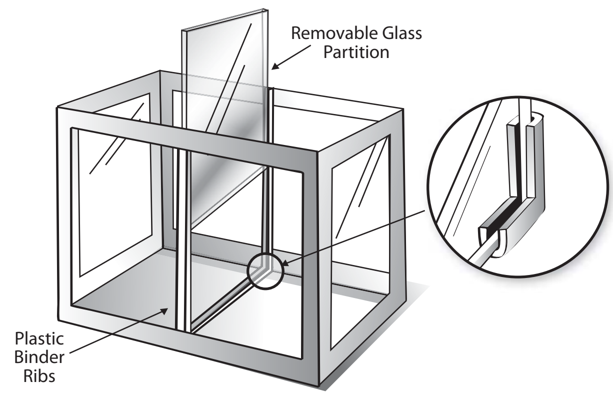


Figure 163.12a

tion from a sheet of glass. Cut it so it will just slide in the plastic guides, but higher than the top edge of the aquarium. Several different demonstrations pertaining to the contact of warm and cold air masses (weather fronts) can be observed.

a. *Warm and Cold Fronts.* Place warm water in one side of the aquarium and cool water in the other. Use food coloring to color the warm water red and the cool water blue. Add half a spoonful of salt to the cool water. Explain to students that the red water represents a warm air mass and the blue represents a cool air mass (Figure 163.12b). Such air masses are like huge invisible flat bubbles—often over 10 miles high and hundreds of miles across. Now remove the partition and let students describe what they see. Tell them that the dividing line between the masses is called a front. When a cold mass (blue water) moves against a warm mass there is a *cold front*. Students will see that the warm mass is forced upward over the cold mass (Figure 163.12c).

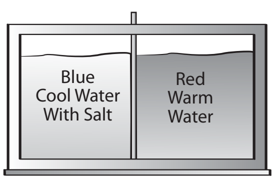


Figure 163.12b

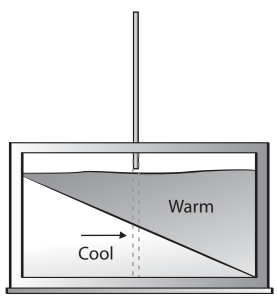


Figure 163.12c

Let them predict what warm moist air would do under such circumstances. Generally a sequence of cloud types progress along the front bringing a sequence of weather events (Figure 163.12d). (1) A general haziness, light fog, or fairly low clouds appear due to the chilling of the warmer moist air near the ground. Near the ground the air

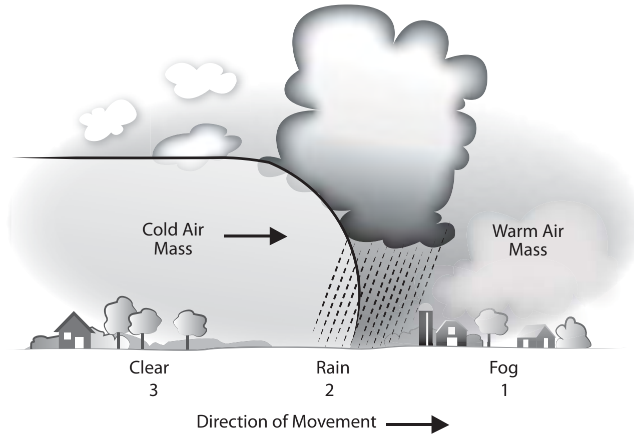


Figure 163.12d

is warmer than it will be as the cold front progresses. (2) Somewhat higher thunderclouds (cumulonimbus) appear due to the rapid rising and cooling of the warm moist air over the cold mass front. Heavy rains fall and on the ground strong winds blow. (3) Diminishing numbers of cumulus clouds can be seen high in the sky. On the ground, the wind is calmer and the air is cooler or cold. Some variations take place in this sequence, depending upon the degree of difference in temperatures between the cold and warm masses. If the difference is slight, the stormy portion is less violent—possibly just changing from mild to light rains and to slightly cooler temperatures. In the winter, the cold front may bring snow or sleet instead of rain.

When a warm mass (red water) moves against a cold mass there is a *warm front*. In the same demonstration students can imagine (Figure 163.12e) how the warm mass can advance over the cold mass and bring a sequence of weather events (Figure 163.12f):

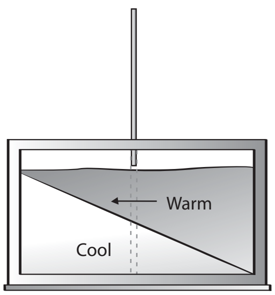


Figure 163.12e

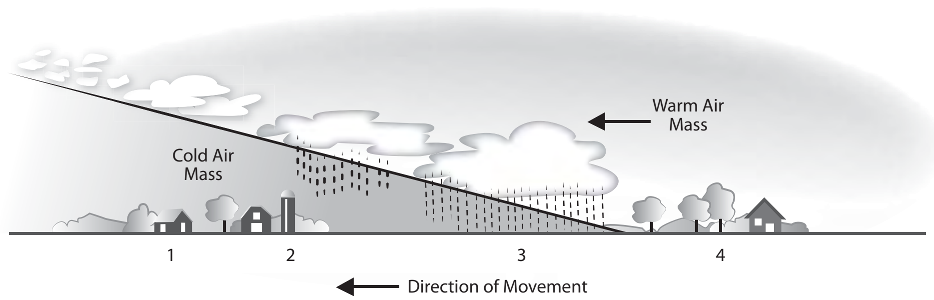


Figure 163.12f

(1) Feathery bands or rows of cirrus clouds appear approximately 8 miles (13 km) up where the air is so cold that water vapor freezes. The clouds are made up of ice crystals due to the warm mass being chilled by the cold mass. (2) Thin sheets of altostratus clouds appear at a lower altitude. (3) Nimbostratus clouds appear and steady rains fall. The clouds seem to come lower and lower as the front progresses, and may touch the ground as fog. (4) The sky clears and the air is warmer and damp. Many variables can affect this general sequence. Students should note that when a cold front advances, the progression of clouds increases in altitude. They decrease in altitude when a warm front progresses. By knowing what type of air mass is approaching and how fast, the meteorologist can generally predict the type of weather and when it will arrive.

b. *Occluded Fronts.* Insert the glass partition after finishing the previous activity. Stir one side, and then remove the partition (Figure 163.12g). Explain that the three colors of water now represent three different air masses: warm, cold, and colder (Figure 163.12h) Students will see the air mass of the intermediate

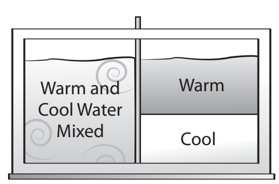


Figure 163.12g

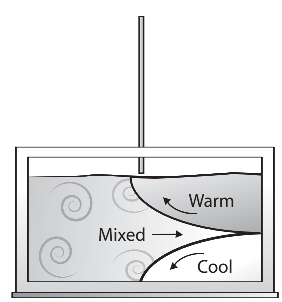


Figure 163.12h

temperature forcing its way between the warmer and colder layers to form three distinct layers. Tell them that this relationship forms an *occluded front*. In a sequence of events, this triple-mass system passes high above the ground, the clouds move downward (e.g., cumulus, stratus, nimbostratus), then back up again (e.g., nimbostratus, altostratus, cirrus). The lowest clouds are almost always some distance above the ground. The weather changes from clear and cool to stormy, to clear and cool again (Figure 163.12i).

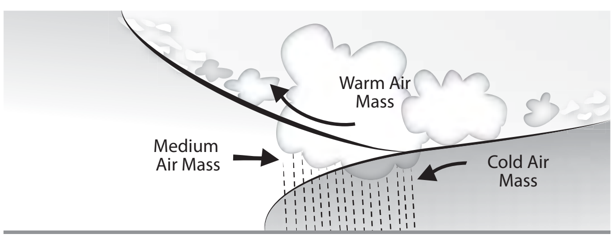


Figure 163.12i

Let students use the aquarium to see what would happen if no salt was used in the beginning or if the two compartments contained water of the same temperature. They might find the temperature differences among the three layers in an occluded front. Other liquids, such as white syrup or glycerin, might be tried to slow down the changes that take place.

164 Applications

Generalization. Changes in weather can be predicted.

Contributing Idea A. Weather is the temporary condition of temperature, wind, and moisture of the atmosphere in a given place at a given time.

Using instruments to predict changes in weather. Many factors such as temperature, wind, air pressure, and moisture make up what is called weather. The following are a few very general suggestions for obtaining information and making predictions from some of the factors. **01 Fb Ga**

a. *Wind.* Students can use a wind vane to find patterns of wind direction and the subsequent changes in weather (see entry 162.01). For example, on the west coast of the United States, winds from the south, southwest, west, and northwest usually bring rain because they blow from the ocean; winds from the northwest, north, northeast, and east usually bring fair and cooler weather because they come from cooler land areas; winds from the east, southeast, and south usually bring fair and warmer weather because they come from warmer land areas; winds coming from the west, northwest, or north usually bring fair and cooler weather

Table 164.01. Relating Humidity to Weather Changes

	Before Front	During Front	After Front
Warm Front	Increasing	very moist	slight decrease
Cold Front	Steady	very moist	rapid decrease

because they come from cooler land farther north or from dryer land farther west; winds from the northeast, east, southeast, and south usually bring rain because they blow from the ocean. Students might also use an anemometer to determine how long it takes for certain types of weather to move into their locale (see entries 162.04, 162.05).

b. *Air Pressure.* Until weather satellite photos became available, the barometer was the major instrument to forecast changes in the weather days in advance. Students can use a barometer to identify patterns between readings and subsequent weather changes (see entries 161.06, 161.07). Students will find that a rising barometer usually means the approach of a high pressure air mass that generally brings increasingly cool, heavy air and better weather. A falling barometer usually means the approach of a low pressure air mass that generally brings increasingly warm, light air, and stormy weather.

c. *Moisture.* Students can use a hygrometer to measure the amount of water (humidity) found in the air (see entries 161.09, 161.10) In general they will find that the humidity of the air increases before a rain and decreases afterward. In terms of approaching weather fronts, the humidity will usually change as shown in Table 164.01.

Preparing a weather station. Several instruments are important in a weather station: thermometer, barometer, anemometer, hygrometer, rain gauge. Such instruments should be placed outdoors in a protected and shaded location for best results. The instruments may be sheltered in an open box; or a station can be built (Figure 164.02). This station can house **02 Gc**

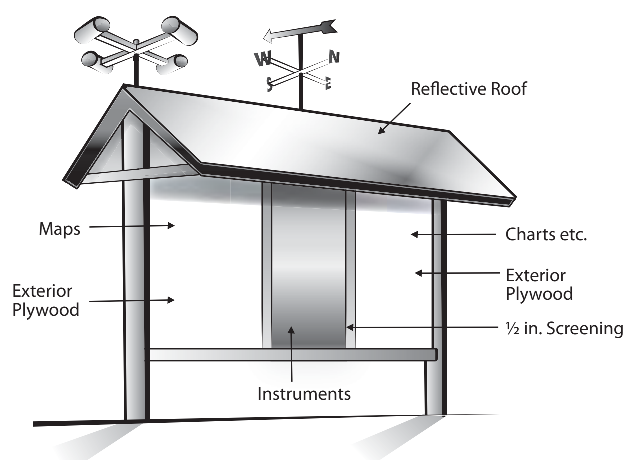
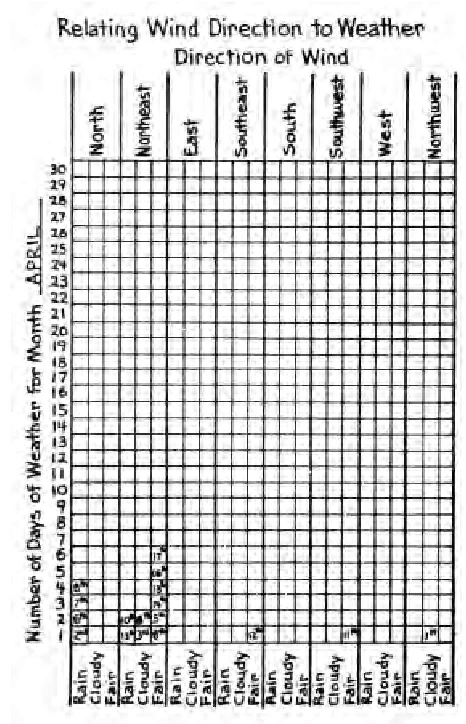


Figure 164.02

both the instruments and several visual aids to provide easy access as well as protection. If the central panel is constructed of ½ in. (1 cm) hardware screening, various weather instruments can be mounted to it. The opening will allow the air to circulate around the instruments. The two panels on either side can be used as bulletin boards and data recording boards. One board might hold a map of the local area or the United States, covered with acetate so that students can sketch weather fronts on it with grease pencils. It might also hold pictures of cloud types, relative humidity tables, or wind speed scales. The other board might hold data sheets, tables, charts, and graphs that the students prepare. Data tables should be kept current by recording instrument readings twice a day at the same hours.

Table 164.03a



03 Bc Bf Fb

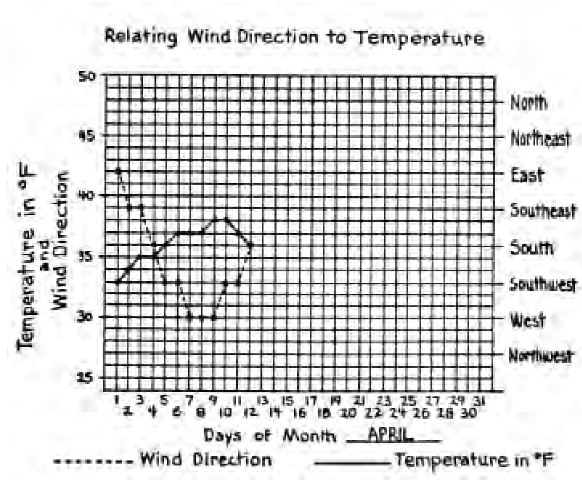
Recording data and predicting weather changes. There is a great variety of forms that can be used to record data. The selection depends upon what information is sought. A few examples are given here in hope that they will stimulate other ideas (e.g., each activity can be altered by substituting an hygrometer or barometer for the wind vane). All of these data sheets may be similarly prepared using the metric and Celsius systems.

a. *Determining the relationship of wind direction to weather.* Make or obtain a wind vane. Using the instrument, keep a record for a month on a table similar to Table 164.03a. On a daily basis, mark the wind direction and the type of weather observed by using symbols. Next, label the mark with the day of the month (e.g., on the third day the wind was from the northeast, and the sky was cloudy; on the tenth day the wind was from the northeast, and it rained). When completed, students will have a graph representing one month of data. Let them decide what winds brought what weather into their locale. Using the knowledge gained from the patterns, they will be able to make more rational predictions in subsequent months.

b. *Determining the relationship of wind direction to temperature.* Make or obtain thermometers and wind vanes. A graph similar to Graph 164.03a can be used to compare wind direction and temperature simultaneously. Students can thus determine that winds from particular directions generally bring certain temperatures.

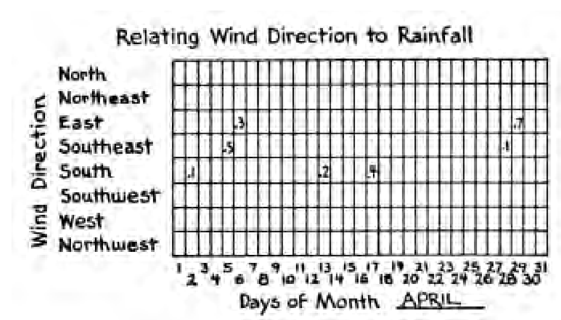
c. *Determining the relationship of wind direction to rainfall.* Use a rain gauge and wind vane to gather data for a table like Table 164.03b. Amount of rainfall can be recorded in tenths of in. in relation to wind direction. At the end of one month, students can determine which direction brought the most rain.

d. *Comprehensive weather table.* Using all the instruments important to a weather station, students can take readings twice daily and record them on a table like Table 164.03c.



Graph 164.03a

Table 164.03b



From the data, predictions can be made as to what weather to expect. The predictions can be compared with those made by weather forecasters. From such data, students will realize that

Table 164.03c. Collecting Weather Information

Date	Time	Temperatture	Barometer Reading (air pressure)	Hygrometer Reading (humidity)	Air Direction	Air Speed	Rainfall	Types of Clouds	Weather Prediction

today's weather was brought on by something that took place earlier and that today's weather, in turn, will be an influence upon the future weather. Students can also discuss the importance of predicting weather (e.g., hurricane warnings, frost warnings).

Contributing Idea B. Climate is the long range condition of temperature, wind, and moisture of the atmosphere in a given place over a long period of time.

Determining local climate. Students can keep monthly graphs of weather conditions in their locale. Averages may be kept on a table like Table 164.04. After several months, students can make some judgments about trends in the weather conditions. Have students recall what the weather was like during the same periods of time in previous years to see if they can determine some pattern. Explain that similar weather conditions over long periods of time are called climate. If graphs of data are kept for subsequent classes, in a few years students will have much data to help them determine climatic conditions for their area. **04 Bb Bc Fa**

Determining climates in other parts of the world. Find maps showing the principal climatic conditions found in various countries of the world. Students can infer what factors may cause the conditions (e.g., they can use their knowledge of wind systems and precipitation to explain the climate of certain geographic regions). Have students also infer how the conditions might affect people (e.g., in terms of where they can live or how they must adjust their clothing and shelters to live in certain areas; where they can grow certain food crops). **05 Fa**

Table 164.04. Collecting Monthly Averages of Weather Factors

Month ____________________	
Average Temperature	
Average Humidity______________________	How many times "high"
	How many times "low"
Average Rainfall	Number of days it rained
Average Snowfall	Number of days it snowed
Sunny Days	Number
Cloudy Days	Number
Windy Days	Number

Index Guide

Absorption
- of heat, 163.04–05
- of light, 331.12, 332.33–34
- of liquids, 122.34–35, 632.06e
- of sound, 321.10, 322.25–26

Acceleration (*see also* Deceleration)
- definition of, operational, 312.11–12
- influence on mass, 312.22

Action/reaction
- applications of
  - in aircraft, 531.03, 512.16–21
  - in everyday use, 313.10
  - in seacraft, 314.02, 531.02
- measurement of, 313.08–09

Ailerons on aircraft, 532.13

Air (*see also* Air pressure; Wind)
- characteristics of, 131.05–07, 162.07
- currents
  - detection of, 132.17–18
  - heat influence, 342.36–39
  - pressure influence, 163.08–11
- measurement of
  - movement, 162.04–05, 09
  - pressure, 163.08–11
  - temperature, 162.07–09
  - weight, 131.17

Air barometer
- construction and use of, 132.15

Air conditioner, 162.13

Aircraft
- airplane
  - directional movements of, 532.09–15
  - parts of, 532.02–17, 532.20
- jets/rockets, 532.18–21
- parachutes, 532.22–23
- space vehicles, 532.24–26
- wind tunnel for testing, 532.01

Air pressure
- changes in, 132.11–12
- definition of, operational, 132.06
- effect upon
  - aircraft, 532.04–06
  - ears, 132.06
  - weather, 161.08, 161.13
- measurement
  - at altitudes, 132.07–08
  - by barometers, 132.13–15, 161.06–07

Algae
- characteristics of, 231.19
- classification of, 151.23
- culturing, 231.18
- measurement of growth, 231.02
- observations of, 151.10
- reproduction of, 232.01

Alligators, 211.37

Alternating current (electricity), 351.06

Altimeter
- construction and use of, 132.07

Altitude
- pressure differences, 132.07–08
- temperature differences, 161.03

Amoeba
- observations of, 231.12

Amphibians
- characteristics of, 211.31–36
- definition of, operational, 211.30

Amplitude
- of sound waves, 323.07

Anemometer
- Construction and use of, 162.04–05

Angular diameter
- measurement technique, 421.16–18

ANIMALS, 210 (*see* Zoology; *see also* names of specific animals)

Anthers in flowers, 242.12

Ants, 211.23

Apple, 221.24

Applied force in machines
- definition of, operational, 511.03–04
- in gears, 511.37–38
- in levers, 511.10, 511.13, 511.16
- in pulleys, 511.24, 511.30–34
- in wheels and axles, 511.19

Aquariums
- construction of, 241.01, 642.01

Arthropods, 211.12–14

Ash tree, 221.19

ASTRONOMY, 420
- characteristics of the universe, 421.01–21
- classification of objects, 421.22–23
- eclipses, 422.13–18
- measurement in
  - distances, 421.12–13, 421.19–20
  - sizes, 421.14–19, 421.22
- moon, 421.14, 422.03–04, 422.13–18

motions, 422.01–18
planets, 421.09, 421.22–23
solar system, 423.01–04
stars, 421.02–11, 422.05–06
sun, 421.07–09, 422.01–02, 422.16–18
telescope, 421.01
time/seasons, 422.07–12
Atmosphere (*see also* Weather)
as a shield from solar radiation, 163.06
as a trap for heat energy, 163.07
ATOMS, 410
characteristics of, 363.01–04, 411.01–13
chemical symbols for, 411.08
classification of, 411.12–13
definition of, theoretical, 353.01, 411.05
electrical charges in, 353.01–02, 413.04–05
evidence of, 411.01–04
models of, 353.01, 411.06, 413.01–06
motion in, 412.01–04
and radiation, 413.06
Attraction/repulsion
electrical charges, 353.01–02
magnetic fields, 361.04, 362.10–13
Axles and wheels
definition of, operational, 511.19
examples of, 511.20
mechanical advantages of, 511.21–22

Bacteria
fermentation/putrefaction by, 232.04
in foods, 232.04
Baking soda
in test for electrical conductivity, 352.25
in test for presence of a carbonate, 111.09
Balance scales
construction and use of, 511.11, 632.05–06
Ball bearings in machines
construction of, 511.08–09
Bar graphs
techniques for, 631.02
Barium
test for, 411.10
Barometer
construction and use of
air, 132.15
liquid, 132.15, 161.06–07
Basalt, 141.03–04
Battery
construction and use of, 352.01–05
definition of, operational, 352.06
Beaks of birds (*see* Bills of birds)
Beaufort wind speed scale, 162.06
Beetles, 211.23
Bell, electric
construction of, 354.04
Bell, musical percussion instrument
construction of, 324.02c
Benedict's solution
as an indicator for simple sugars, 111.09
Berzelius, Jöns, 411.12
Beta particles
observations of, 413.06
Big Dipper
location of, 421.03, 421.05
Bills of birds
adaptations of, 242.20
Binoculars, 332.19, 332.21
Birch tree, 221.15, 221.19
Birds
adaptations of, 211.07, 242.20
care of, 211.45
characteristics of, 211.44
feeders for, 211.46
Block and tackle
definition of, operational, 511.32
mechanical advantages of, 511.33
Blueprint paper
prints of magnetic fields, 361.03d
prints of plant parts, 332.10
Boiling
boiling point, effect of solutions upon, 122.44
graphing technique for, 631.02c
Boron
test for, 411.10
BOTANY, 220
adaptations of, 242.01–18
aquarium habitats, 241.01, 642.01
characteristics of, 221.01–07, 243.01, 243.03–04
classification of, 221.14, 221.20, 221.22–26
collecting, 651.02
dissection of, 221.13
and erosion, 141.18, 142.28, 242.02
fossils, 243.06
germination, 221.03, 222.01–16, 641.02
growth of, 221.03–06, 631.02b–02c

in mud samples, 151.20–21
natural selection of, 243.03
in ocean samples, 151.22–23
outdoor gardening, 641.04
parts of
cotyledons, 221.14
flowers, 221.21–22, 242.11–16
leaves, 221.20, 242.10
roots, 221.14, 242.01–06
stems, 221.15–19, 242.07–09
pollination of, 242.11–16
reproduction of, 221.01–02, 242.11–16
responses to environmental conditions, 141.21, 221.05–07, 221.17–31, 332.11
safety precautions in handling, 611.06
soil containers for, 641.01
soilless containers for, 641.01
spores, 221.08–09
terrarium habitats, 241.02, 642.02
theory of evolution, 243.01, 243.03–04
types with seeds, 221.01, 221.03, 221.12, 221.26, 222.01, 242.17–18
types without seeds
ferns, 221.10–11
fungi, 221.08–09
mosses, 221.10–11
mushrooms, 221.08–09
use of, 244.01–04
Bread making, 231.17–22
Brown, Robert, 412.01
Brownian movement
observations of, 412.01
Budding of yeast cells, 232.02
Buds of plants
arrangements on stems, 221.20
Building (*see* Models, making; Science equipment)
Buoyancy
characteristics of, 122.18–21
definition of, operational, 122.17
of ice, 151.06
ocean vs. freshwater, 151.05–06
Burning
heat, as a source of, 342.08
kindling point, 342.09–10
light, as a source of, 332.04–05
Butterflies, 211.23
Butterwort, 242.10b
Calcium
test for, 411.10
spectrum analysis of, 421.11
Camera, pinhole
construction and use of, 334.01, 421.07–08
Canary, 242.20b
Candles
graphing burning times of, 631.02
Capillary action
characteristics of, 122.35
definition of, operational, 122.34
in soils, 641.03c
Carbon
in compounds, 411.11, 413.07–10
model of, atomic, 411.06a
Carbonate
test for, 111.09
Carbon dioxide
applications of, 131.19–21, 132.10
collecting, 131.11
measurement of, 131.18–20
model of, molecular, 413.07c–10c
production of, 131.10
yeast, as an action of, 232.07–08
Carrots, 221.23
Catfish, 242.19
Cedar waxwings, 211.46
Cell division, 232.01
Celsius, Anders, 341.06
Celsius/centigrade temperature scale, 341.06, 631.04
Changes of state
of gases, 121.01–03, 131.01–04
of liquids, 111.01–03, 121.01–03, 131.03
model of, theoretical, 343.03
phases, 342.21–29
of solids, 111.01–03, 131.04
Chemical symbols
for elements, 411.08
Cherry tree, 221.15
Chickadees, 211.46
Chimes, musical percussion instrument
construction of, 324.02d
Chlorine
model of, atomic, 411.06b
Circuit, electrical
breaker, 354.03
characteristics of, 352.16–24

definition of, operational, 352.16
definition of, theoretical, 353.01
grounded, 352.23
in parallel/series arrangements, 352.32–33
short, 352.22
tester for, 352.20
Circumferentor
construction and use of, 421.17
Classifying
animals, 211.07, 211.49–50
atoms, 411.12–13
birds, 242.20
color sorting key, 141.14–15
elements, 411.13
flower pattern key, 221.22
hardness sorting key, 141.22
leaf pattern key, 221.20
light, 331.13–15
liquids, 121.21–24, 122.06–07, 122.26–28, 122.42, 151.16–19
magnets, 362.26
materials
by kindling points, 342.09
by magnetic properties, 361.04–05, 362.13
by sounds they make, 321.10, 322.26
by transmission of light, 331.16, 332.09, 332.30
microorganisms, 231.21
mineral sorting key, 141.13–15
motions, 311.14–16
mud samples, contents of, 151.20–21
objects in the universe, 421.22–24
ocean samples, contents of, 151.19, 151.22–23
pollen, 242.15
raindrops by size, 162.28
rocks, 141.10–12, 141.22–24
root pattern key, 221.14
sand, 152.17
seeds, 221.23–26, 222.04
size sorting key, 141.23
soils, 141.17
solids, 111.02, 111.11, 111.19–23
sounds, 321.10–15
Classroom equipment (*see* Measuring instruments; Science equipment)
Climate
local, 164.04
ocean effect upon, 142.18–20
predictions of, 164.04–05
world, 164.05
Clinometer, 142.15
Clocks
Sun clock, 422.09
sundials, 422.07–08
timers, 632.08–09
Cloud chamber
construction of, 413.06
Clouds, 162.25–26
Clover, 222.23
Coconuts, 221.13
Codes/ciphers
invention and use of, 521.05–06, 521.08–10
Coleus, 222.22
Collecting
animals, 651.01
plants, 651.02
rocks, 651.03
Colors, spectrum
observations of, 331.05, 331.09, 331.13
plant growth, effect upon, 222.24
Combustion
as a source of light, 332.04
COMMUNICATIONS, 520
electrical devices
radio, 522.04
telegraph, 522.01
telephone, 522.02–03
mechanical devices
codes/ciphers, 521.08–09
heliograph, 521.10
signal devices
flags, 521.02
light, 332.28, 521.03
nonverbal, 521.01
sound devices
telegraph, 521.06
telephone, 322.11d, 322.14, 521.07
whistle, 521.05
Compaction gauge
construction and use of, 142.11
Compaction of soil, 142.10–11
Compass
construction and use of, 362.15–17
electric current, as an indicator for, 352.12
Complex machines (*see* Machines)

Compounds
definition of, operational, 411.11
definition of, theoretical, 411.06b
models of, theoretical, 411.06, 413.07
Compression
of sound waves, 323.03
strength of solids, 111.23a
Computer, 522.05–07
Concave lens (*see also* Lenses)
definition of, operational, 332.18
refraction by, 332.24
Condensation (*see also* Evaporation)
change of state, 131.01, 131.03–04
definition of, operational, 121.03, 131.01
definition of, theoretical, 412.03
forms of
clouds, 163.20, 163.25–26
dew, 163.21–22
fog, 162.24
frost, 162.23
rain, 162.15–16, 162.27–28
snow, 162.29–31
heat energy effect upon, 162.18–20, 342.27
observations of, 162.17–20, 342.26–27
in water cycle, 152.18
Conduction
of electricity
definition of, operational, 352.25
materials, characteristics of, 352.26–29
tester for, 352.20
of heat
definition of, operational, 342.32
in gases, 342.35
in liquids, 342.34
in solids, 111.15, 342.33, 342.46
Conglomerate, 141.07
Constellations
maps of, 421.05
projection of, 421.06
Constructing (*see* Measurement instruments; Science equipment)
Contraction (*see also* Expansion)
definition of, operational, 342.13
definition of, theoretical, 343.02–03, 412.04
of gases, 131.20–21, 132.09, 342.19–20
of liquids, 142.27, 342.18, 342.22
measurement of, 131.21, 342.14–15, 342.18
observations of, 342.16–17, 342.19–20
of solids, 111.14, 141.18b, 142.26, 342.13–17
Convection currents
definition of, operational, 342.39
in gases, 163.09, 342.36–39
in liquids, 152.01–07, 342.40
Convection, heat, 342.36–40
Convex lens (*see also* Lenses)
definition of, operational, 332.18
focal point of, 332.24
measurement of power, 332.22
refraction of, 332.20–23
Copernicus, Nicolaus, 423.03
Copper
test for, 411.10
Corn, 221.13
Counter force, in machines
definition of, operational, 511.03–04
in gears, 511.37–38
in levers, 511.10, 511.13, 511.16
in pulleys, 511.24, 511.30–34
in wheels and axles, 511.19
Crabs, 211.13
Cranks
construction and use of, 511.22
Crayfish, 211.14–15
Creepers, 211.46
Crickets, 211.23, 212.10
Crocodiles, 211.37
Crustaceans, 211.13
Crystal set (radio)
construction and use of, 522.04
Crystals
characteristics of, 111.10
cooling rate, effect upon, 141.04
growing, 122.46–47
in rocks, 141.04, 141.11b
snowflake, 162.29
Currents, air (*see* Weather)
Currents, electrical
alternating, 351.06
direct, 351.05
Currents, water (*see* Oceans)

Dandelion, 242.18c
Daphnia, 211.16–17
Darwin, Charles, 243.01–07
Day and night
model of, 422.11

temperature difference, 163.06
Decay, 141.19–20
Deceleration (*see also* Acceleration)
definition of, operational, 312.11
factors that influence, 311.12
Decibels, sound, 321.11
Density, of liquids, 122.07, 122.20–21
Deposition
chemical, 142.29
sedimentary rocks, in formation of, 141.05
shoreline, 152.15
water, 142.18–20
wind, 142.02–04
Desalination, ocean water, 154.03–04
Dew, 162.21–22
Dew point, 162.22
Diatoms, 151.10
Diffraction
definition of, operational, 331.06
definition of, theoretical, 333.06
spectroscope, 331.07
in spectrum analysis, 331.05, 411.10, 421.11
Diffraction grating
astronomy, use in, 412.11
Diffusion
definition of, operational, 132.16
in gases, 131.09, 343.01, 421.01
heat, influence of, 412.01–02, 412.04
in liquids, 412.01
Direct current (electricity), 351.05
Displacement (water), 122.22–24
Dissolving, 112.01–03, 121.09
Diving bell
construction of, 154.01
Drawing/picturing
contour maps, 152.03
convection currents
air, 342.36, 342.38, 342.40
water, 152.01–02
Earth's magnetic lines of force, 362.03
electric circuits, 352.21
germination of seeds, 222.05
maps of volcanic activity, 152.04
models of atomic particles, 413.01
phases of the Moon, 422.13
surface tension, characteristics of, 121.12–13
Drive belts
construction and use of, 511.35
Drums, musical percussion instruments
construction of, 324.02a
Dry cell
construction of, 352.04, 352.06
definition of, operational, 352.03
Duck, 242.20d, 242.20h

Eagle, 242.20g
Earth
axis, tilt of, 163.01, 422.12
curved surface of, 163.02–03
interior, model of, 143.02, 363.04
magnetic lines of force around, 362.01–04
revolution of, 423.04
rotation of, 422.10–11
surface formation of, 143.01
Earthquakes
definition of, theoretical, 143.04
plate tectonics, 153.02, 153.04
seismograph, 143.05, 332.29
sensing, 143.05
water waves caused by, 152.10
Earthworms
care of, 211.11
collecting, 211.10
respiration of, 242.22
responses to environmental conditions, 212.03, 212.06, 212.09–10, 332.12
training, 244.07
EARTH SCIENCE, 140
Earth formation, models of, 143.01–08, 153.01–04
erosion/deposition
by chemicals, 142.29
by heat, 142.26
by plants, 142.28
by water, 142.07–28
by wind, 142.01–06
minerals, 141.13–15
rocks, 141.01–12, 141.22–24
soils, 141.16–21
Earwigs, 211.23
Easter lily, 242.11
Echoes
definition of, operational, 321.09, 322.24
definition of, theoretical, 323.04
Eclipses
definition of, theoretical, 422.16

lunar/solar, models of, 422.16–17
observations of, 421.07, 422.07, 422.18
ECOLOGY, 240
adaptations
of animals, 242.01–02
of plants, 242.02–18
environmental habitats, 241.01–02
extinction of species, 243.06–07
natural selection, 243.01–05
plants and animals, use of, 244.01–09
Edison, Thomas, 352.29
Effort (*see also* Force)
in machines, 511.03–04
Electrical equipment
battery, 352.01–06
battery holder, 352.17
bell, 354.04
bulb, 352.29
bulb holder, 352.18
electromagnet, 354.02
electroscope, 353.02
fuse, 352.30–31, 354.03
galvanometer, 352.15
motor, 364.02
radio, 522.04
rheostat, 352.27
switches, 352.27
telegraph, 522.01
telephone, 522.02–03
ELECTRICITY, 350
applications of (*see also* Electrical equipment)
heat, production of, 342.11–12, 353.05, 354.05
light, production of, 332.06, 353.05
magnetism, production of, 354.01–04, 362.07–08, 362.19
radio waves, production of, 353.06
characteristics of, 351.01–06
charges, 351.02–04, 413.04–05
circuits
breaks in, 352.22–24
completion of, 352.16–21
detection of, 352.13–15
grounded, 352.23
series/parallel arrangements, 352.32–33
short, 352.22
conduction/insulation
definition of, operational, 352.25
materials, characteristics of, 352.26–29
tester for, 352.20
control of, 352.32–39
current
alternating, 351.06
detecting, 352.13–15, 352.20
direct, 351.05
and magnetism, 352.09–12, 354.02, 364.01–02
models of, theoretical
electrical charges, 351.04, 353.01, 413.04–05
electron, 353.01, 353.03–04
proton, 353.01
resistance to, 352.26–29, 354.05
safety precautions in handling, 352.23, 352.39, 611.03
sources of
chemical, 352.01–06
mechanical, 352.07–08
static
charges, 351.03–04
detecting, 351.01–02
voltage of, 352.34–35
Electroconductivity of water, 151.09
Electrodes, 352.01
Electrolyte, 352.01
Electromagnet
construction and use of, 354.02
Electromagnetic spectrum
chart of, 333.12
components of, 333.13–15
Electronic devices, 522.05
Electrons
charge of, 413.04–05
definition of, theoretical, 353.01
models of, theoretical, 353.03–04
movement of, 413.03
Electroscope
construction and use of, 353.02
Elements
characteristics of, 411.07–10
chemical symbols for, 411.08
definition of, theoretical, 411.07
metallic, identification of, 411.10
number of, 411.06a
periodic table of, 411.13
ENERGY, 300

electrical, 351.01–354.05
heat, 341.01–344.02
light, 331.01–334.05
magnetic, 361.01–364.05
motion, 311.01–314.02
sound, 321.01–324.06
ENGINEERING, 500 (*see* Technology)
Environmental conditions
aquarium, 241.01, 642.01
animals, effect upon, 212.03–13, 242.19–26, 243.02, 243.05, 244.06–07
microorganisms, effect upon, 231.06–07
plants, effect upon, 221.07, 221.17–31, 242.01–18, 243.01, 243.03–04
terrariums, 221.11, 241.02, 642.02
EQUIPMENT, 650 (*see* Measuring instruments; Science equipment)
Erosion
glacial, 142.24–25
plant, 141.18, 142.28
prevention of, 242.02
temperature, 141.08b, 142.26–27
water, 142.17–23
wave, 142.23, 152.16–17
wind, 142.05–06
Estimating
absorption rates, 142.12
speed of sound/speed of light, 322.19
techniques for, 631.01, 632.06b
tide changes, 152.11
wind speed, 162.06
yeast growth, 231.02c
Evaporation (*see also* Condensation)
change of state, 131.02–04, 161.11
definition of, operational, 121.01, 131.02
definition of, theoretical, 412.03
factors that influence, 161.13, 162.10–14, 342.24
from soil, 161.12
humidity indicator (hygrometer), 161.09–10
measurement of rate, 121.02, 342.25, 631.02c, 632.06d
observations of, 342.23
solids from liquids, separation of, 122.52
Evolution, theory of, 243.01–07
Expansion (*see also* Contraction)
definition of, operational, 342.13
definition of, theoretical, 343.04–05, 412.04
of gases, 131.20–21, 132.09, 162.20, 342.19–20
of liquids, 121.11, 142.27, 342.18, 342.22
measurement of, 131.21, 342.14–15, 342.18
observations of, 342.16–17, 342.19–20
of solids, 111.14, 141.18b, 142.26, 342.16–17
Experimenting
controlling and manipulating variables that affect
animal behaviors, 212.01–13, 332.12, 342.31
decay, 141.20
electricity, 351.03–04, 352.08, 352.11, 352.20–21, 352.25–26, 352.29–30
evaporation/condensation, 161.13, 162.10–14
expansion/contraction, 142.26–27
heat, 1161.05, 342.39, 342.48, 342.50, 532.25–26
light, 331.12, 332.03, 332.08, 332.20, 332.32–33, 333.26–30
magnetism, 362.06, 362.09
microorganism growth, 231.05–05, 231.16, 232.05–09
motion, 311.06–07, 311.12, 312.14, 313.06
ocean waves and currents, 151.13–14, 152.06, 152.08
plant growth, 141.21, 221.05–07, 222.08–18, 222.24, 222.32, 242.09, 243.04, 332.11, 342.30
pollination, 242.11
respiration, 242.22–26
solubility, 111.11
sounds, 321.04–10, 322.08, 322.10, 322.26
surface tension, 121.13, 121.18
water deposition, 142.19–20
wind deposition, 142.03

Fahrenheit, Gabriel, 341.06
Fahrenheit temperature scale, 631.04
Farsightedness, 332.19
Fault line
definition of, theoretical, 143.03
eruption, model of, 143.07
Feeling/touching, using the sense of touch
buoyancy, 122.17–18
characteristics of
gases, 131.06, 131.08, 132.05

liquids, 121.04–05, 121.23, 122.04, 122.17–18, 122.32
solids, 111.05, 111.15, 111.20, 111.22
counter force, 511.03–04
directional movements of aircraft, 532.09
deposition, 141.06
electrical charges, 351.01
evaporation, 131.02
feely box, 111.05
force, 312.01–02, 511.01–04
friction, 312.13, 511.05
gravity, 312.04
heat/temperature, 341.01, 342.01–12, 342.32, 342.41–42
liquids, pollution of, 112.03
magnetic fields, 361.02
mass, 312.09
mechanical advantages, 511.10, 511.13, 511.16, 511.19, 511.22–23, 511.27, 511.30, 511.40, 511.45
moving air, 132.19
moving water, 122.32
pressure on parachute, 532.22
safety precautions in
handling electricity, 352.39, 611.03
handling glassware, 611.04
handling hot objects, 611.02
soil, compaction of, 141.16
sound vibrations, 322.01–02, 323.01
weight of
air, 132.05
water, 122.04
Feet of birds
adaptations of, 242.20
Fehling's solution
as an indicator for simple sugars, 111.09
Fermentation
by bacteria, 232.04
by yeast, 232.07
Ferns, 221.02, 221.10–11
Filter
for ocean water, 151.03
for surface water, 122.49–51
Filter paper, 122.51
Fire extinguishers
construction and use of, 131.19, 132.10
First-class lever (*see also* Levers)
definition of, operational, 511.10
examples of, 511.12
mechanical advantages of, 511.11
Fish
adaptations of, 242.19
care of, 211.29, 241.01, 642.01
characteristics of, 211.28
respiration of, 242.24
responses to environmental conditions, 212.05, 212.11–12
training, 244.08
Fixed pulley (*see* Single-fixed pulley)
Flame test
metallic elements, identification of, 411.10
spectroscope, use with, 421.11
Flashlight
preparation for thin beam, 332.31
Flight (*see* Aircraft)
Floating/sinking, 122.17–24
Flowers
arrangement on stems, 221.21
classification key, 221.22
collecting and preserving, 651.02c
pollination of, 242.13–16
reproduction of, 242.11–12
responses to environmental conditions, 222.24
use of, 244.02–03
Fluorescent tubes
safety precautions in handling, 332.06
Flute, musical wind instrument
construction of, 324.06a
Fly (insect), 211.23, 332.12
Focal point, 332.24
Focus, 332.23–24, 342.03
Fog, 162.24
Food
bacteria on, 232.04
mold on, 232.05
Food chain, 151.10
Foot-candle, 332.05
Foot-pound, 512.01–02
Force
action/reaction, 313.08–10
of air, 132.19–20
applied, 511.03
centrifugal/centripetal, 312.17–19
characteristics of, 511.01
counter force, 511.03–04
definition of, operational, 312.01, 511.01–03

effort, 511.03–04
friction, 312.13–16, 511.05–09
gravity, 312.04–05
inertia, 313.01–03
in machines, 511.01–04
magnetism, 312.06
momentum, 313.04–27
and motion, 312.01–03, 331.16
Forced vibrations (sound waves), 322.20
Fossils
of animal tracks, 243.06
models of, 151.15
plant, 24306
in sedimentary rocks, 141.06
Frames of reference, 311.13
Freezing
change of state, 11.01, 11.03
definition of, operational, 11.01, 342.22
definition of, theoretical, 343.03
factors that influence, 122.42–43, 342.22
Frequency (sound vibrations)
definition of, operational, 322.04, 322.09
definition of, theoretical, 323.06
scale, 321.12
wave model, 33.04
Friction
definition of, operational, 312.13, 511.05–06
to generate electricity, 413.04
in machines, 511.05–09
motion, effect upon, 312.13–14
reduction of, 312.15–16, 511.07–09
surfaces, influence of, 312.14
Frogs
collecting and care of, 2111.35–36
eggs, 211.33–34
hibernation of, 212.13
respiration of, 242.25
Fronts, weather (*see* Weather)
Frost, 162.23
Frosting/subliming, 342.28–29
Fuels
heat, in the production of, 342.08
kindling point of, 342.09–10
light, in the production of, 332.04–05
Fulcrum, 511.10
Fungi
life functions of, 232.05, 232.06–07
mold, 231.13–14
mushrooms, 211.08–09
reproduction of, 232.02–03
responses to environmental conditions, 232.09
yeast, 231.15–16
Fuses
applications of, 352.31, 354.03
definition of, operational, 352.20

Galaxy, 421.21
Galvanometer
construction and use of, 352.05–06, 352.15
Gardening techniques, 641.04
Garter snake, 211.38
GASES, 130
changes of state
evaporation/condensation, 121.01–03, 131.02–03, 342.28–29
frosting/subliming, 131.04, 342.28–29
characteristics of, 131.05–21
definition of, operational, 131.02–03
definition of, theoretical, 343.03, 412.04
diffusion of, 131.09, 343.01
heat energy effect upon
changes of state, 342.23–29
contraction/expansion, 132.09, 342.19–20
convection currents, 132.16–18, 342.36–39
measurement of
pressure, 132.05–15
volume, 132.01–02, 132.04
weight, 131.17–18, 132.03–06
in ocean water, 151.01
penetration by magnetic fields, 362.22
production and identification of
carbon dioxide, 131.10–12
oxygen, 131.13–14
transmission of
heat through, 342.35
light through, 332.31
sound through, 322.13–17, 323.08
Gears
compared to levers, 511.37–38
definition of, operational, 511.36
mechanical advantages of, 511.38–39
GENERAL EQUIPMENT, 620
Geological periods
evidence of, 141.06, 151.15
Mesozoic era, 153.01
GEOLOGY, 140

Earth formation, models of, 143.01–08, 153.01–04
erosion/deposition
by chemicals, 142.29
by heat, 142.26
by plants, 142.28
by water, 142.07–28
by wind, 142.01–06
minerals, 141.13–15
rocks, 141.01–12, 141.22–24
soils, 141.16–21
Geotropism, 22.17–19
Geranium, 221.22, 222.22
Germination
environmental conditions' effect upon, 22.08–16
observations of, 221.08–16
ratios of, 221.02–03
table of wait-time for, 641.02
Glaciers
erosion by, 142.24–25
icebergs from, 151.06
Glassware, construction techniques
bending tubing, 623.02
cutting tubing, 623.01
making containers, 632.03
safety in handling, 611.04
Gneiss, 141.08
Goldfish, 242.19
Graduated cylinders
construction and use of, 632.03
Graphing techniques
bar graphs
definition of, operational, 631.02b
examples of, 222.06, 332.09
curved-line graphs
definition of, operational, 631.02c
examples of, 211.05, 221.05, 222.24, 631.02a
histograms
definition of, operational, 631.02a
examples of, 121.17, 221.17, 221.24, 222.03, 631.02
straight-line graphs
definition of, operational, 632.02c
examples of, 121.02, 311.07, 311.10–11, 342.06, 342.25, 362.26–27, 631.02b
Grasses, 221.20
Grasshoppers, 211.23, 212.10
Gravity
motion, as a source of, 312.05
plant growth, effect upon, 222.17–19
sensing, 312.04
tides, as a source of, 152.12–13
Greenhouses
construction and use of, 641.02f
Growth
of animals, 211.04–05
measurements of, 211.05
of microorganisms, 231.02–06
rings of trees, 221.18–19
Guinea pigs, 211.48
Guitars, musical string instruments
construction of, 324.04b
Guppies, 211.02

Hail, 162.29
Hamster, 211.05, 211.48
Hard water, 122.39–41
Harpsichord, musical string instrument
construction of, 324.04c
Hawk, 242.20c, 242.20g
Hearing, using the sense of hearing
characteristics of
liquids, 121.25
solids, 111.04, 111.06, 111.16
communication messages, 521.01–05, 522.01–03
echoes, 321.09, 322.24
electricity, 351.01, 352.14
moving water, 122.25–26
sounds, 321.01–15, 322.07, 323.11–16, 522.02
sounds through materials, 322.11–15, 323.01, 323.08
HEAT, 340
applications of, 344.01–02
behavior of
absorption, 161.05, 163.04–05, 342.51
reflection, 342.50
refraction, 342.49
changes of state, effect upon
gases, 131.02–04, 132.16–18, 342.19–20, 342.28–29
liquids, 121.01–03, 342.18, 342.23–27

solids, 111.14, 342.13–17, 342.21–22, 342.28–29
characteristics of, 341.01–10, 342.49–50
control of, 342.47–51
definition of, operational, 341.09–10
definition of, theoretical, 343.01–05
expansion/contraction, effect upon
gases, 131.20–21, 132.09, 162.20, 342.19–20
liquids, 121.11, 142.27, 342.18, 342.22
solids, 111.14, 141.18b, 142.26, 342.13–17
as an indicator, 111.09
insulation for, 342.47–48
kindling point, 342.09–10
magnetism, effect upon, 362.21, 363.03
models of, 343.01–05
movement of
by conduction, 111.15, 342.32–35, 342.46
by convection, 342.36–40
by radiation, 342.41–45
organisms, effect upon
animals, 212.10–13, 342.31
plants, 222.29–30, 342.30
safety precautions in handling, 611.02
source of
chemical, 342.08–10
for classrooms, 621.01, 622.02
electrical, 342.11–12, 353.05
motion, 342.04–07
Sun, 342.01–03
temperature comparison, 343.04–05
Heating sources (classroom)
materials, 621.01, 622.02
safety precautions in handling, 611.02
Heliocentric theory, 423.01–02
Helium
model of, atomic, 413.02b
Hibernation, frog, 212.13
Hognosed snake, 211.38
Horse chestnut, 221.15
Humidity
indicator (hygrometer) for, 161.09
measurement of, 161.10
scale, 161.09
Humus, 141.16
Hurricanes, 152.19
Huygens, Christian, 333.02
Hydrogen
in compounds, 411.11, 413.07
model of, atomic, 413.02a
Hydrogen peroxide
as a source of oxygen, 131.13
Hydrometer
construction and use of, 122.08–09
Hygrometer
construction and use of, 161.0–10

Ice, 111.03, 342.47
Iceberg, 151.06
Igneous rocks
characteristics of, 141.01–04
crystal formations in, 141.04
definition of, operational, 141.03
model of source, 141.02
Impurities
removal from water, 122.49–52, 151.03
Incandescent light, 332.02
Inclined plane
definition of, operational, 511.40
examples of, 511.41
mechanical advantages of, 511.43
screws, 511.46–47
wedges, 511.43–45
Indicators
for gases, 131.10–14
for liquids, 121.07, 121.24
for solids, 111.09, 141.08e, 141.12, 411.10
Inertia
definition of, operational, 313.02–03
motion, effect upon, 312.19, 313.02–03
INFERENCE MODELS, 400
atoms, 411.01–413.08
astronomy, 421.01–423.04
Inferring (*see also* Predicting)
existence of
air, 131.05
atoms, 411.01–03, 411.05, 412.02–03
functions of plant parts, 221.12–18, 221.25, 242.02, 242.06, 242.11, 242.14
principles of
how clouds, dew, fog, frost, rain, and snow are formed, 162.19–29
solubility, 122.38
relationship between
expansion/contraction and gas pressure, 132.09

mass and momentum, 313.05
Infrared energy, 333.14
Inheritance
physical characteristics in animals, 211.03–07
INORGANIC MATTER, 100
gases, 131.01–132.20
geology, 141.01–143.07
liquids, 121.01–122.52
weather, 161.01–164.05
oceans, 151.01–154.04
solids, 111.01–112.05
Insects
care of, 211.24
collecting, 211.23
respiration of, 242.23
responses to environmental conditions, 212.05, 342.31
INSTRUCTIONAL APPARATUS, MATERIALS, AND SYSTEMS, 600
Insulation
from electricity
definition of, operational, 352.25
materials, characteristics of, 352.26–29
tester for, 352.20
from heat
in space vehicles, 332.25–26
testing materials, 342.47–48
Internodes, 221.15
Invisible ink, 521.04
Iodine
as an indicator for starch, 111.09
safety precautions in handling, 111.09
Iron
as an indicator for oxygen, 131.14b

Jays, 211.26
Jets/rockets, 313.10, 531.03, 532.18–21

Kindling point
definition of, operational, 342.09
measurement of, 342.10

Ladybug, 211.13
Lateral bud, 221.15
Lava, 141.02
Leaves
classification key, 221.20
collecting and preserving, 651.02b
as insect traps, 242.10
responses to environmental conditions, 222.22–24, 222.29–30
Leeuwenhoek, Anton, 231.08
Lenses (*see also* Concave lenses; Convex lenses)
applications of
binoculars, 332.19, 332.21
microscopes, 231.08, 332.19, 332.21
telescopes, 332.19, 332.21, 421.01
characteristics of, 332.18
focal points of, 332.24
focus, 332.23–24
magnification by, 332.20–22
to produce high temperatures, 342.03
Lenticels, 221.15
Levers
compared to
gears, 511.37–38
pulleys, 511.24
types of
first-class, 511.10–12
second-class, 511.13–15
third-class, 511.16–18
LIGHT, 330
applications of
pinhole camera, 334.01
projector, 334.02–03, 334.05
behavior of
absorption, 331.12, 332.33–34
diffraction, 331.05–07
reflection, 331.11–12, 332.27–32
refraction, 151.07, 331.08–10, 332.16–26
characteristics of, 331.01–16
control of, 332.18–34
definition of, theoretical, 331.01–11
intensity, 331.14, 332.05, 332.07–08
and lenses
focus of, 332.23–24
magnification of, 332.20–22
optical instruments, 332.18–32
materials, effect upon
blueprint paper, 332.10, 361.03d
fading colors, 332.09–10
measurement of
intensity, 332.05
speed, 322.18–19, 333.11, 421.20
organisms, effect upon
animals, 212.09, 332.12

microorganisms, 231.06
plants, 222.21–24, 332.11
sources of
chemical, 332.04–05
electrical, 332.06–08, 353.05
heat, 332.02–03
Moon, 331.15
Sun, 332.01
transmission of
through liquids, 151.07–08, 332.31
through solids, 331.11–17, 332.13–15
Lightning, 322.19, 333.11, 351.01, 353.06
Light-year, 421.20
Limestone, 141.07, 142.07, 142.27
Limewater
as an indicator for carbon dioxide, 232.06
LIQUIDS, 120 (*see also* Oceans; Water)
changes of state
evaporation/condensation, 121.01–03, 131.02–03, 342.23–27
melting/freezing, 111.01, 111.03, 122.42–43, 342.21–22
characteristics of
buoyancy, 122.17–21
capillary action, 122.34–35
density, 122.07, 122.20–21
specific gravity, 122.07
surface tension, 121.12–20, 121.22
viscosity, 122.27–28
definition of, operational, 121.01–03
definition of, theoretical, 343.03, 412.04
floating/sinking, 122.21–24
heat energy effect upon
changes of state, 111.01, 111.03, 121.01–03
contraction/expansion, 121.11, 342.18
convection currents, 342.40
measurement of
pressure, 122.11–16
volume, 122.01–03, 122.21
weight, 122.04–06, 122.11, 122.21
penetration by magnetic fields, 362.25
siphoning technique, 122.30
solubility, 122.36–43
transmission of
heat through, 342.34
light through, 331.11–12, 331.16, 332.14, 332.31
sound through, 111.16, 322.12
Lithium
test for, 411.10
Litmus paper
as an indicator for acids and bases, 121.07, 121.24
Lizards, 211.40–41
Load, 511.10
Lobsters, 211.13
Lodestone, 362.05
Longitudinal waves
compared to transverse waves, 323.05
compression/rarefaction, 323.03
measurement for frequencies, 323.06
models of
for light, 333.04
for sound, 232.03–04
Lunar eclipse, 422.16–18

MACHINES, 510
complex, 512.01–04
force/counter force in, 511.01–04
friction and efficiency of, 511.05–09
simple
ball bearings, 511.08–09
block and tackles, 511.33
drive belts, 511.35
gears, 511.36–39
inclined planes, 511.40–47
levers, 511.10–18
pulleys, 511.23–35
screws, 511.46–47
wedges, 511.43–45
wheels and axles, 511.19–22
Magma
characteristics of, 143.06
definition of, operational, 141.01
in Earth formations, 143.01
model of flow, 141.02
Magnetic equipment
compass, 362.15–17
electromagnet, 354.02
lines of force indicator, 362.01–03
Magnetic fields
applications of
in appliances, 364.02–05
in electrical systems, 354.01–02
electricity, as a source of, 364.01

motion, as a source of, 312.06
attraction/repulsion, 361.04, 362.09, 362.11–12
characteristics of, 362.09–13
definition of, operational, 361.01–02
definition of, theoretical, 363.01–04
detection of, 362.15–17
Earth, model of, 362.03–04
materials, effect on, 361.04–05, 362.13
measurement of
penetration through materials, 362.22–25, 362.27
strength, 362.26–28
patterns of, 361.01, 361.03
MAGNETISM, 360 (*see also* Magnetic equipment; Magnetic fields, Magnets)
applications of, 364.01–05
characteristics of, 361.01–05
magnetizing objects, 111.17, 362.18–21
models of, theoretical, 363.01–04
and polarity, 362.09–12, 362.16
sources of
the Earth, 362.01–06
electricity, 352.09–15, 354.01, 362.07–08
Magnetizing objects, 111.17, 362.18–21
Magnets
characteristics of, 363.01
making, 111.17, 362.18–21
permanent, 362.20
polarity of, 362.10–12, 362.16
temporary, 362.14, 362.20–21
Magnification, 332.20–22 (*see also* Lenses)
Mammals
adaptations of, 211.07
care of (small), 211.48
characteristics of, 211.47
growth of, 211.05
training, 244.09
Manometer
construction and use of, 122.13–16
Maple tree, 222.31
Maracas, musical percussion instruments construction of, 324.02g
Marble, 141.08, 142.07
Marimbas, musical percussion instruments, construction of, 324.02b
Mass
acceleration/deceleration, effect upon, 312.11–12
definition of, operational, 312.09
measurement of, 312.10
momentum, effect upon, 313.04–05
size, relationship to, 312.09
weight, relationship to, 122.05
Matter (*see* Inorganic matter; Organic matter)
Meadowlark, 212.20b
Measuring instruments
altimeter (altitude pressure indicator), 132.07
anemometer (wind speed indicator), 162.04
barometer (air pressure indicator), 132.14–15, 161.06
circumferentor (size indicator), 421.17
clinometer (steepness of slope indicator), 142.15
clocks, 422.07–09, 632.08–09
compaction gauge, soil, 142.11
hydrometer (specific gravity indicator), 122.08
hygrometer (humidity indicator), 161.09
liquid capacity containers, 122.02, 632.03
manometer (liquid pressure indicator), 122.13–14
overflow container, 122.23
rain gauge, 162.15
range finder, 632.02
scales, 632.04–05
Secchi disk (water cloudiness indicator), 151.17
sextant, 632.01
tensiometer (surface tension indicator), 121.17
thermometer, 161.01, 341.05, 341.07–08, 632.07
MEASURING SYSTEMS AND INSTRUMENTS, 630
Measuring techniques
for absorption, 142.12, 632.06e
for action/reaction, 312.08–09, 532.19
for angles of reflection, 332.32
for boiling/freezing, 122.42–44
for buoyancy, 122.19, 122.21
calibrating
anemometers, 162.04
graduated cylinders, 632.02
spring scales, 632.04

thermometer, 341.06
compaction of soil, 142.11
condensation, 162.22
density, 122.07
diameters of Sun and Moon, 421.08, 421.14–18
distances
short, 142.03, 311.03, 311.15, 632.01–02
vast, 421.12–13
electroconductivity, 151.09
erosion, 142.21–22
estimating
distance from lightning, 322.19
from samples, 231.02c, 631.01, 632.06b
wind speed, 162.06
evaporation, 161.02, 632.06d
expansion/contraction in
gases, 131.21
liquids, 342.18
solids, 342.14–15
flow of liquids, 122.28, 122.31, 142.14
graphing (*see* Graphing techniques)
growth
animals, 211.05
microorganisms, 231.02
plants, 221.03, 221.06–07
humidity, 161.09–10
magnetism, 362.24, 362.26, 362.28
magnification, 332.22
mechanical advantage
block and tackles, 511.33
gears, 511.36–39
inclined planes, 511.42
levers, 511.11, 511.14, 511.17
pulleys, 511.31
screws, 511.46
wedges, 511.43–45
wheels and axles, 511.21
motion
and heat, 342.06–07
and mass, 312.10
periodic, 311.07
rotary, 311.09
time/distance, 311.03
parallax, 421.13
pressure of
gases, 132.06–08, 132.14–15, 161.06–07
liquids, 122.13–16
quantity, 221.24, 222.03
rainfall, 162.15–16
rates, 311.10, 311.12, 311.14, 342.25
sampling, 231.02c, 631.01, 632.06b
slopes, 142.15–16
snowfall, 162.31
specific gravity, 122.08–09
surface tension, 121.17–18, 121.22
temperature of
air, 161.01–03, 161.05, 162.07, 341.03–04, 343.05
liquids, 152.04, 342.24
solids, 111.02, 163.03–05
stars, 421.10
tensile strength, 111.23b
time, 222.04, 311.03, 311.10, 311.12, 311.14, 422.07–09, 632.08–09
triangulation, 421.12
turbidity, 151.16–18
units of measure
creative, 122.02–03, 631.03
foot-candle, 332.05
foot-pound, 512.01–02
metric/standard, 631.03
temperature, 341.03
work, 512.02
volume of
gases, 131.21, 132.02, 132.04, 142.08
liquids, 122.01–03, 122.22–24, 142.09, 151.04, 162.28, 222.09, 632.03
solids, 111.13, 122.19, 122.21–22, 122.24, 151.05, 163.06a
Mechanical advantage
of block and tackles, 511.33
of gears, 511.38
of inclined planes, 511.42
of levers, 511.11, 511.14, 511.17
of pulleys, 511.28, 511.31, 511.34
of screws, 511.46
of wedges, 511.45
Melting
change of state, 11.02–03, 342.22
definition of, operational, 111.01
definition of, theoretical, 343.03
Melting point, 111.02–03
Mendeleev, Demitri, 411.13
Metamorphic rocks
characteristics of, 141.08

definition of, operational, 141.08
model of formation, 141.09
Metamorphosis, 342.31
METEOROLOGY, 160 (*see* Weather)
Metric system
Celsius/centigrade scale, 341.06
conversion tables, 631.04
standardization techniques, 341.03, 631.03
MICROORGANISMS, 230
characteristics of, 231.01–08, 231.13, 231.15, 231.19, 231.24–26
budding of yeast, 232.03
in food chain, 151.10
growth of, 231.02–06
life functions of, 232.04–07
reproduction of, 231.01–14
responses to environmental conditions, 231.03–08
spores, 232.02
types of
algae, 232.01
bacteria, 232.04
fungi, 231.18–22, 232.06
molds, 231.18–19, 232.02, 232.05, 232.06, 232.09
paramecium, 232.01
protozoa, 231.11–13, 232.01, 232.08
yeasts, 231.20–22, 232.03, 232.06
Microscope (*see also* Lenses)
parts of, 231.09
preparation of slides, 231.10
use of, 231.09, 231.13, 231.15, 231.19–20, 231.34
Mildew, 221.08
Milky Way, 421.21
Mimosa, 222.27, 222.29–30
Minerals
characteristics of, 141.13–15
color sorting keys, 141.14–15
definition of, operational, 141.13
identification of, 141.15
Mirrors, 332.27–28
Models, making
aircraft parts, function of, 532.10–14
atomic structures, 353.03–04, 362.02–03, 412.04, 413.01–05
ball bearings, 511.09
chemical disposition, 142.29
city water system, 122.29
clothes dryers, 314.01
continental drift, 153.01–02
crystals in rocks, formation of, 141.04
Earth's magnetic fields, 362.04
earthquakes, 143.03–04
eclipses, 422.16–17
electric motors, 364.02
fire extinguishers, 132.10
fossils in sedimentary rocks, 151.15, 243.06
glaciers, erosion of land by, 142.24–25
heat, effects on Earth's atmosphere by, 163.06–07
light, particle theory of, 333.01–02
light, wave theory of, 333.03–09
metamorphic rocks, formation of, 141.09
molecular structures, 411.06, 413.07–08
Moon phases, 422.14–15
ocean tides, 152.12–14
ocean waves, caused by earthquakes, 152.10
pollination process, 342.14
raindrops, erosion of the land by, 142.21
rainwater, dissolving of materials by, 151.02
rocks, effect of temperature changes upon, 141.18, 142.26–27
salt, recovery from water of, 154.03
sediments, deposition of, 141.06–07, 142.02, 152.15
solar energy, relationship to Earth's surface, 163.01–02
solar system, 421.09–10, 421.19, 423.01–04
sound waves, 322.22, 323.02, 323.09
steam turbines, 344.02
tornadoes, 163.09
water currents, cause of, 152.01–05, 152.07
water cycle, 152.18
water flow, 142.13–14
water spout, 152.20
water wheel, 122.52
waves, erosion of shorelines, 142.23, 152.16
weather fronts, 163.12
volcanic eruptions, 141.02, 143.03–04
Molds
characteristics of, 231.19, 231.25
culturing, 231.18
in foods, 232.05
life functions of, 232.06
measurement of growth, 231.02, 231.06

reproduction of, 232.02
responses to environmental conditions, 232.09
spores of, 232.02
Molecules
chemical symbols for, 411.08
definition of, theoretical, 343.01, 411.06
heat, effect upon, 343.01
models of, 343.02–03, 413.07–08
in transmission of sound, 323.08–09
Mollusks, 211.25
Momentum
definition of, operational, 313.04, 313.06
relationship to mass, 313.05–06
transference of, 131.07
Moon
definition of, operational, 421.13
distance to, 421.13
eclipse of, 422.16–18
motion of, 422.03–04, 422.15
phases of, 422.13–14
size of, 421.15–15, 421.18–19
tides, effect upon, 152.12–14
Moon flower, 222.28
Morning glory, 222.28
Morse, Samuel, 522.01
Mosquitos, 332.12
Mosses, 221.10–11
Moths, 211.23
MOTION, 310
action/reaction, 313.08–10
applications of
electricity, production of, 352.07–08
heat, production of, 342.04–07, 343.01–05
in vehicles, 531.02–03
characteristics of, 311.01–16
control of, 312.15–16, 312.19, 313.01–10
definition of, operational, 311.01
definition of, theoretical, 311.13, 313.01–10
factors that affect
forces, 312.01–03
friction, 312.13–16
gravity, 312.04–05
inertia, 312.19, 313.01–03
magnetism, 312.06
mass, 312.09–12
measurement of, 311.03, 311.10–12, 311.14–15
momentum, 313.04–07
Newton's laws of, 313.01–10
sources of, 311.16, 312.01–08
types of
circular, 312.17–19
periodic, 311.06–07
rolling, 312.16
rotary, 311.08–09
sliding, 312.16
straight-line, 311.04–05
uniform, 311.10–11
Motion pictures
making, 334.02–05
Mountain formation, 153.04
Mouse, 211.05
Movable pulley (*see* Single-movable pulley)
Mud sampler
construction and use of, 151.21
Mud sorter
construction and use of, 151.20
Mushrooms, 221.08–09
Musical instruments
percussion, 324.01–02
sounding board, 321.05
string, 324.03–04
wind, 324.05–06

Nearsightedness, 332.19
Nephoscope
construction and use of, 162.02
Newton, Sir Isaac, 312.05, 333.01
Newton's Laws, 313.01–10
Newts, 211.30
Night and day
model of, 422.11
temperature difference, 163.06
Nodes, 221.15
North Pole, 362.05, 362.10
North star
location of, 422.05
Nucleus
of atoms, 353.01, 413.03
in protozoa, 231.13
in yeast, 232.02

Oats, 221.13
Observing (*see* individual senses: Seeing, Hearing, etc.)
Obsidian, 141.03–04

OCEANS, 150 (*see also* Liquids; Water)
applications/exploration of oceans
diving bell, 154.01
recovery of dissolved materials, 151.03, 154.03–04
sampling, 151.20–23
submarine, 154.02
characteristics of ocean water
buoyancy, 151.05–06
conduction of electricity, 151.09
dissolved materials, 151.01–03
organisms, 151.10, 151.22–23
pressure, 151.05
transmission of solar radiation through, 151.07–08
waves, 151.11–14
continental drift, 153.01–04
currents
heat, effect of, 152.01–04, 342.40
salinity, effect of, 152.07
wind, effect of, 152.05–06, 152.08–09
measurements of ocean water
pressure, 151.04
temperature, 152.01–04
turbidity, 152.16–18
ocean water, simulation of, 151.04, 241.01
shorelines
deposition along, 152.15
erosion of, 152.16–17
sediments, 151.20–21
tides, 152.11–14
weather/climate, ocean's effect upon
storms, 152.18–20
water cycle, 152.18
Opaque objects, 332.15
Optical instruments (*see also* Lenses)
binoculars, 322.19, 322.21
lenses, 332.18–26
microscope, 231.09, 332.19, 332.21
mirrors, 332.27–32
telescope, 332.19, 332.21, 421.01
ORGANIC MATTER, 200
animals, 211.01–212.13
botany, 221.01–222.31
ecology, 241.1–244.09
other organisms, 231.01–232.09
plants, 221.01–222.31
zoology, 211.01–212.13
Organisms (*see* Animals; Botany; Microorganisms; Plants; Zoology)
Ovary, in plants, 242.12
Overflow container, 122.23
Owl, 242.20c
Oxygen
in compounds, 411.11, 413.07
production of, 131.13
test for, 131.14

Parachutes, 532.22–23
Parallax effect
measurement techniques, 421.13
Paramecia, 231.11, 231.13, 232.01
Pasteur, Louis, 232.04
Peanuts, 221.13
Peas, 221.13, 221.23–24
Pelican, 242.20h
Pendulum clock
construction and use of, 632.09
Penumbra, 422.17
Periodic motion, 311.06–07
Periodic table of elements, 411.13
Petiole, 221.20
Phase transformations, 342.21–29, 343.03
Phonograph, 322.21
Phototropism, 222.21
Pill bugs, 211.18
Pinecones, 242.18d
Pinhole camera
construction and use of, 344.01, 421.07–08
Pistil, 242.12–13
Pitch (sound)
definition of, operational, 322.09
factors that influence, 321.06–07, 322.10, 323.06
scale, 321.12
Pitcher plant, 242.10c
Pivot point, 511.10–18
Planck, Max, 333.10
Plane, inclined (*see* Inclined plane)
Planets
characteristics of, 421.22–23
definition of, operational, 421.0
diameters of, 421.19
distances from Sun, 421.09, 421.19, 421.23
motion of, 423.02
revolution periods of, 423.04

sizes of, 421.09, 421.19, 421.22–23
solar system, model of, 423.03–04
temperatures of, 421.23
Plankton, 151.10
PLANT AND ANIMAL CONTAINERS, 640
Plants (*see* Botany)
Plate tectonics, 153.01–04
Poinsettia, 242.18c
Poles, magnetic
attraction/repulsion, 362.10–13, 362.16
definition of, operational, 362.10
definition of, theoretical, 363.01–03
on Earth, 362.16
Pollen, 242.14–15
Pollination, 221.22, 242.11–16
Pollution
air, 112.04–05, 142.04
detection of, 112.01–05
land, 141.19
water, 112.01–03, 122.48–52, 151.17–18
Poplar tree, 222.31
Poppy, 221.22, 242.18
Porosity
definition of, operational, 142.07
of rocks, 141.03d, 142.27
of soils, 142.08–12
Positive/negative electrical charges
model of, 413.04
Potassium
test for, 411.10
Precipitation
measurement of, 162.15
Predicting
behaviors of animals, 212.05–13
behaviors of microorganisms, 231.01–07, 232.03–12
inheritance characteristics of animals, 211.03–08
mechanical advantages, 511.11, 511.14, 511.17, 511.21, 511.31, 511.33–34, 511.39, 511.42, 512.03
momentum, transfer of, 313.07
plant parts by arrangements, 221.20
sizes of projected images, 333.02
sound transmissions, 323.08
weather, 161.07, 162.03, 162.05, 164.01, 164.03–05
Pressure (*see* Air pressure; Water pressure)
Prism, 331.09
Propellers on airplanes, 532.16–17
Prothallia, 221.01–02
Protons
charge of, 413.04–05
definition of, theoretical, 353.01
models of, 353.03–04
movement of, 413.03
Protozoa
characteristics of, 231.12
collecting, 231.10
culturing, 231.11
reproduction of, 232.01
responses to environmental conditions, 232.09
Ptolemy, Claudium, 423.03
Pulleys
compared to levers, 511.24
in complex machines, 512.04
definition of, operational, 511.23
and drive belts, 511.35
examples of, 511.25
making, 511.26
types of
block and tackle, 511.32–33
single-fixed, 511.27–29
single-movable, 511.30–31
Pumice, 141.03d, 142.27
Putrefaction, by bacteria, 232.04

Quality, characteristic of sound, 321.08
Quartzite, 141.08

Rabbits, 211.48
Radiant energy
heat, 333.14, 342.41–45, 342.49
light, 333.10–12
radio, 333.15
source of, 161.04–05
ultraviolet, 333.13
Radiation, heat, 342.41–45
Radio, crystal set
construction of, 522.04
Radioactivity
detection of, 413.06
Radio waves
definition of, theoretical, 333.15
detection of, 333.15
production of, 353.06

Radium, 413.06
Rain
  content of, 151.02, 162.27
  erosion by, 142.17–18, 142.21–22
  measurements of, 162.15–16, 162.28
Rain gauge
  construction and use of, 162.15
Rainbows, 331.09
Raindrop
  formation of, 162.27
  measurement of, 162.28
Rainfall
  measurement of, 162.15–16
  raindrops, formation of, 162.27–28
Rangefinder
  construction and use of, 632.01
Rarefaction/compression
  of sound waves, 323.03
Rats, 211.48
Rattles, musical percussion instrument
  construction of, 324.02g
Recording data (*see* Tabling data)
Redwood, 221.19
Reflection
  heat, 342.50, 532.26
  light, 331.11–12, 332.27–32, 333.07
  sound, 321.09, 322.24
Refracting telescope
  construction of, 421.01
Refraction
  definition of, operational, 332.16
  density of medium, effect upon, 332.17
  heat, 342.49
  through lenses, 332.18–26
  light, 151.07, 331.08–10, 332.16–26
  measurement of, 332.24
  spectrum observations of, 331.08–10
  through water, 151.07
Relative humidity table, 161.09
Relativity of positions, 311.13
Reproduction
  animal, 211.01–02, 212.01–02
  microorganism, 231.01–14, 232.01–03
  plant, 221.01–02, 242.11–16
Reptiles, 211.37–43
Repulsion/attraction
  electrical charges, 353.01–02
  magnetic fields, 361.04, 362.10–13
Resistance (*see also* Insulation)
  electrical, 352.28, 354.05
  heat, 342.47–48
Resonance, 322.22
Respiration
  in amphibians, 242.25
  characteristic in animals, 211.08
  exercise, effect of, 211.08
  in fish, 242.24
  in insects, 242.23
  in people, 242.26
  in worms, 242.22
Revolution
  Earth, 422.12
  planetary, 423.04
Rheostat
  construction and use of, 352.27
Rhizoids, 221.10
Ringnecked snake, 211.38
Ripple tank
  construction and use of, 333.08
Robins, 211.46, 242.20f
Rockets/jets, 313.10, 531.03, 532.18–21
Rocks
  breakdown of, 141.18
  characteristics of, 141.01–12
  classification of, 141.22–24
  collecting, 651.03
  definition of, operational, 141.10
  identification of
    color sorting key, 141.14–15
    hardness sorting key, 141.22
    size sorting key, 141.23
  magma, 141.01–04
  minerals in, 141.13–15
  plant growth, effect of, 142.28
  porosity of, 142.27
  in soil formation, 141.16–18
  temperature change, effect of, 142.26–27
  tests for
    cleavage, 141.11b
    hardness, 141.10
    streak, 141.11a
  types of
    igneous, 141.01–04
    metamorphic, 141.08–09
    sedimentary, 141.05–07
Roots

classification key, 221.14
conduction tubes in, 242.05
function of, 242.01–06
growth of, 222.06
responses to environmental conditions, 222.17–19, 222.22, 222.25
use of, 244.01
Rotary motion, 311.08–09
Rotation
Earth, 422.11
Moon, 422.15

SAFETY PRECAUTIONS, 610
classroom science, 611.01
handling
animals, 611.05
fluorescent tubes, 332.06
plants, 611.06
observing the Sun, 421.07–08
using
alcohol, 111.12
electricity, 611.03
glassware, 611.04
heat, 611.02
iodine, 111.09
Salamanders, 211.31–32
Salinity
ocean currents, as a source of, 152.07
Salt
flame test for, 411.10
model of, molecular, 411.06b
Sampling techniques, 231.02c, 631.01, 632.06b
Sand, 152.17
Sand dunes, 142.03
Sand fleas, 211.13
Sandstone, 141.07, 142.07, 142.27
Saturation, 122.37
Saxophone, musical wind instrument
construction of, 324.06c
Scales (*see* Balance of scales)
Scaling
distances
by parallax, 421.13
plants from Sun, 421.09
by triangulation, 421.12
sizes
by angular diameter, 421.16–18
Schist, 141.08
Science equipment (*see also* Measuring instruments)
classroom safety, 611.01–06
cloud chamber, 413.06
filters, 122.49–52
glassware, 623.01–02
heat sources, 621.01
refracting telescope, 421.01
ripple tank, 333.08
seismograph, 143.05, 332.29
spectroscope, 331.07, 421.11
support stands, 622.01–02
wind tunnel, 532.01–03
Scotch broom, 242.18a
Screws
definition of, operational, 511.46
examples of, 511.47
friction in using, 511.06
Seasons
planets, effect upon, 222.31
Sun/Earth relationship, 422.01–02, 422.10–12
and weather, 162.01
Secchi disk
construction and use of, 151.16–17
Second-class lever
definition of, operational, 511.13
examples of, 511.15
mechanical advantages of, 511.14
Sedimentary rocks
characteristics of, 141.07
definition of, operational, 141.06–07
fossils in, 141.06, 151.15
model of deposition, 141.05
Sediments
buildup of land forms, 142.20
definition of, operational, 142.20
deposition of, 142.18–19, 152.15
mud sampling, 151.20–21
Seed crystal, 122.47
Seedless plants, 221.08–11
Seeds
absorption of water by, 222.09
characteristics of, 221.12–13
classification of, 221.23–26, 222.14
collecting, 651.02a
dicotyledon, 221.13
dispersion of, 221.26, 242.17–18
germination of, 221.03, 222.01–16, 641.02

micropyle, 221.12
monocotyledon, 221.13
planting techniques, 641.02d
Seeing, using the sense of sight
acceleration/deceleration, 311.12, 312.11–12
action/reaction, 313.08–10
atoms, evidence of, 411.03
battery, composition of a, 352.05
capillary action, 122.34
changes of state, 342.21
characteristics of
airplane parts, 532.02–07, 532.16, 532.18
animals, 211.01–02, 211.09, 211.12–13, 211.23, 211.25–26, 211.28, 211.30, 211.37, 211.44, 211.47, 212.03–13, 242.22–26
electricity, 351.01–06
gases, 131.07, 131.15–16, 132.11–12
heat, 341.02–03, 342.33–34, 342.37–41, 342.49
igneous rocks, 141.03
lenses, 332.18, 332.20–21
light, 331.01–06, 331.08, 331.10–12
liquids, 121.04, 121.14–16, 121.19, 121.23, 122.27
magma, 141.01
magnetism, 352.09, 352.12, 354.01, 361.01, 361.03, 362.01–04, 362.07, 362.10, 362.22
metamorphic rocks, 141.08
microorganisms, 231.12, 231.14, 231.19
minerals, 141.14–15
motion, 311.04–05, 311.08, 312.17–19, 313.01–03, 313.07
plants, 221.12, 221.14–15
sedimentary rocks, 141.07
simple machines, 511.32, 511.36, 511.43–44, 511.46
snowdrifts, 162.30
soil, 141.16–17, 142.07
solids, 111.01, 111.03–04, 111.10, 111.12, 111.14, 111.19, 111.21, 332.13–15
condensation, 121.03, 131.01, 162.17–29, 342.26–27
contraction, 131.20, 132.09
convection currents, 152.01–03, 152.09, 162.09, 163.08, 163.10
crystal growing, 122.45
decay, 141.19
deposition, 141.06, 142.29, 152.15
diffusion of gases, 132.16
dissolving materials, 112.01–02, 121.09, 122.36
erosion, 142.06, 142.17, 152.16–17
evaporation, 121.01, 131.02, 161.11, 342.23
expansion, 131.20, 132.09, 342.13, 342.16–17, 342.19–20
melting/freezing, 342.22
minerals in rocks, 141.13
North star, 421.03
ocean water, contents of, 151.01, 151.10
plant parts, 221.20–22, 242.01–05, 242.08, 242.10, 242.12, 242.18
radioactivity, evidence of, 413.06
reflections, 332.27–28, 332.31
safety precautions in, 421.07–08, 611.01e
sound vibrations, 323.01
stars, motions of, 422.02, 422.06
subliming/frosting, 342.28–29
Sun, 421.07
surface currents in water, 152.05–06
surface, effect upon motion, 312.14
tree rings, 221.18
water waves, 151.11, 152.08–10
through water, 151.08
wind, 132.18, 142.01
Seismograph
construction of, 143.05, 332.29
Senses (*see* individual senses; Seeing, Hearing, etc.)
Sextant
construction and use of, 421.04, 632.01
North star, location of, 421.04
Shale, 141.07
Shorelines
continental drift theory, 153.02
tides, effect of, 152.11
waves, effect of, 142.23, 152.15–17
Short circuit, 352.22
Shrimp, 211.13
Simple machines (*see* Machines)
Single-fixed pulley (*see also* Pulleys)
definition of, operational, 511.27
examples of, 511.23
use of, 511.28, 511.32
Single-movable pulley (*see also* Pulleys)

definition of, operational, 511.30
mechanical advantage of, 511.31
use of, 511.32
Sinking/floating, 122.17–24
Siphoning techniques, 122.30
Slate, 141.08
Sleet, 162.29
Smelling, using the sense of smell
atoms, evidence of, 4141.03, 412.02
characteristics of
gases, 131.07, 131.09
liquids, 121.04, 121.23, 122.49
solids, 111.04, 111.07
liquids, pollution of, 112.03, 122.48
scent trails, 212.07
Snails, 211.26–27, 212.04–05, 212.08, 212.11
Snakes, 211.38–39
Snowdrifts, 162.30
Snowfall, 162.29–31
Sodium
flame test for, 411.10, 421.11
model of, molecular compound (salt), 411.06b
Soft water, 122.41
Soil containers (for plants), 641.02–03
Soilless containers (for plants), 641.01
Soils
characteristics of, 141.16–17
compaction of, 142.10–11
composition of, 141.10–11
contribution to plant growth, 141.21, 221.05
definition of, operational, 141.16
erosion by rain, 142.17–18, 142.21–22
formation of, 141.18–20
porosity of, 142.07, 12
Soils, planting
in gardens, 641.04b
germination, influence on, 222.14
in terrariums, 641.02c
Solar eclipse, 421.07, 422.07, 422.16–17
Solar energy
Earth, effect upon, 163.01–03
heat, conversion to, 161.05
Solar system
composition of, 421.02, 421.07–09
definition of, theoretical, 421.02
distances between objects, 421.19
models of, 423.01–04
observations of, 421.07
scaling, distances and sizes, 421.09, 421.14–19
SOLIDS, 110
changes of state
frosting/subliming, 131.04, 342.28–29
melting/freezing, 111.01, 111.03, 122.42–43, 342.21–24
characteristics of, operational, 111.04–23
crystals, 111.10, 122.46–47
definition of, operational, 111.04–18
definition of, theoretical, 343.03, 412.04
floating/sinking, 111.12, 122.21–24
heat energy effect upon
changes of state, 111.01–03, 342.21–23, 342.28–29
contraction/expansion, 342.13–17
light energy effect upon, 332.09–10
magnetic properties of, 111.17–18
measurement of
compression strength, 111.23a
penetration by magnetic fields, 362.23–24
size and weight, 111.13
volume, 122.23
pollution of
air by, 112.04–05
water by, 112.01–03
solubility of, 111.11, 112.01–03, 121.09
transmission of
electricity through, 352.38
heat through, 342.32–33, 342.46
light through, 331.11–17
sound through, 111.16, 322.11, 521.07
Solubility
making crystals, 122.46–47
temperature, effect of, 122.44
of solids, 111.11, 122.36–41
Solutions
characteristics of, 122.36–43
electroconductivity, effect upon, 151.09
freezing/boiling, effect upon, 122.42–43
making crystals, 122.46–47
ocean water, 151.01
Solvents, 122.38
SOUND, 320
absorption of, 321.10, 322.25–26
amplitudes, 323.07
applications of
telegraph, 521.06, 522.01

telephone, 521.07, 522.02–03
characteristics of, 321.01–10
classifying, 321.11–15
control of, 322.22–24
decibels, 321.11
definition of, operational, 321.01–10
definition of, theoretical, 323.01–09
echoes, 321.09, 322.24, 323.04
effects, 322.06
frequency, 322.04, 322.09, 323.06
longitudinal waves, 323.01–07
loudness, 322.07
musical instruments, 324.01–06
pitch, 321.03–05, 321.11–12, 322.09–10
quality, 321.08
radio waves, 333.15
reflection of, 321.09
sensing, 322.01–04
sources of, 322.01–06, 324.01, 324.03, 324.05
speed of, 322.15–19, 333.10–11
thunder, 322.19
transmission through
gases, 322.13–14, 322.23
liquids, 322.12
model of, 323.09
solids, 111.16, 322.11, 521.07
types of, 321.01–02
vibrations, 322.20–22
volume, 321.03–05, 321.11, 322.07–08
Sounding board, 321.05
South pole, 362.10
Sowbugs, 211.13, 211.18–19
Sparrows, 211.46
Specific gravity
definition of, operational, 122.07
measurement of, 122.08–09
Spectroscope
construction and use of, 331.07, 421.11
Spectrum
analysis of, 421.11
electromagnetic, 333.12–15
Speed
changes in, 311.12
definition of, operational, 311.03
uniform, 311.10–11, 311.14
Spiders, 211.21–22, 332.12
Spores
definition of, operational, 232.02
growth from, 221.02, 221.04
in molds, 231.14
on mushrooms, 221.08–09
prints from, 221.09
Spring scale
construction and use of, 632.04
Stalactites/stalagmites, 142.29b
Stamens, 242.11–14
Starch
test for, 111.09
Star maps, 421.05
Stars
definition of, operational, 421.02
composition of, 421.11
constellations, 421.05–06
distances between, 421.20
motion of, 422.05–06
North Star, 421.03–04
Static electricity, 351.01–04
Steam turbine, 344.02
Stems
characteristics of, 221.15–19
conduction tubes in, 242.08
function of, 242.07–09
growth of, 222.06
responses to environmental conditions, 222.17–19, 222.21, 222.26
uses of, 244.04
Stigma, 242.12–13
Stipules, 221.20
Storms, 152.19
Straight-line motion, 311.04–05
String telephone
construction and use of, 521.07
Strontium
test for, 411.10
Subliming/frosting, 131.04, 162.11, 342.28–29
Submarine
construction of, 152.02
Sugar
as a compound, 411.11, 413.07
model of, molecular, 413.07e
test for simple, 111.09
Sun
definition of, operational, 421.02
distance to, 421.09, 421.19
heat energy, as a source of, 161.04–05, 342.01–03

light energy, as a source of, 332.01, 342.01–03
motion of, 422.01–02, 422.08–09
observation of, 421.07
safety precautions in observing, 421.07–08
size of, 421.08, 421.19
Sun clock
construction and use of, 422.09
Sundew plant, 242.10a
Sundials
construction and use of, 421.07–08
Support stands
construction and use of, 622.01–02
Surf, 152.10
Surface tension
characteristics of, 121.13–16
definition of, operational, 121.12
measurement of, 121.17–18, 121.22
reduction of, 121.19–20
Swallow, 242.20f
Swan, 242.20d
Sweetpea, 222.28
Swells, 152.10
Switches, electric
arrangements, 352.36–38
dimmer, 352.38
reversible, 353.37
Sympathetic vibrations, 322.22

Tabling data
descriptive
air, impurities in, 112.04
animals, 311.02
elements, 411.10
friction and surfaces, 312.14
magnetic properties, 362.12, 362.14
marine organisms, location of, 151.22
materials that dissolve, 121.09
meals, heat held by, 341.10
motion, 311.02
solids, 111.09
sounds, pitch of, 322.10
numerical
air pressures, 161.07
block and tackle, 5111.33
boiling water and solutions, 631.02b
burning candles, 631.02a
electricity, 352.04, 352.11, 352.25
evaporation, 342.25
friction and motion, 312.14
gears, 511.39
heat produced by motion, 342.06
humidity, 161.10, 164.01
inclined planes, 511.42
levers, 511.11, 511.14, 511.17
magnets, strength of, 362.26
mass and motion, 312.09, 313.06
momentum, 313.04
plant growth, 631.02
pulleys, 511.31, 511.34
raindrops, sizes of, 162.28
temperatures, 163.03, 343.05
water pressure, 122.11, 122.14
weather conditions, 164.03, 164.05
wheels and axles, 511.21
wind, 162.03, 162.05
Tadpoles, 211.33–34
Tambourines, musical percussion instruments
construction of, 342.02f
Tasting, using the sense of taste
atoms, evidence of, 411.03
characteristics of
liquids, 121.06, 121.23
solids, 111.04, 111.08
electricity, 352.13
flowers, edible, 244.02
rainwater, 151.02
roots, edible, 244.01
safety precautions in, 121.06, 121.23
TECHNOLOGY AND ENGINEERING, 500
communications, 521.01–522.04
electric devices, 522.05
machines, 511.01–512.04
transportation, 531.01–532.26
Telegraph
key, 521.06
system, 522.01
Telephone
receiver, 522.02
string, 521.07
system, 522.03
Telescope
lenses, applications of, 332.19, 332.21
refracting, construction of, 421.01
Temperature
Celsius/centigrade scale, 341.06, 631.04

definition of, operational, 341.09
  effect of
    altitude upon, 161.03
    Earth's axis upon, 163.01
    Earth's curved surface upon, 163.02–03
  effect upon
    air movement, 163.08–11
    animals, 212.10–13
    condensation, 162.18–20
    evaporation, 162.10–11
    microorganisms, 231.07, 232.09–14
    plants, 222.10–11, 222.29–31
    rocks, 141.18b, 142.26–27
    solubility, 122.44
  feeling, 341.01
  heat, compared to, 341.09–10, 343.04–05
  measurement of
    atmosphere, 161.02–03, 163.06–07
    planets, 421.23
    stars, 421.10
  Sun as a source of, 161.04–05
  thermometers, 161.01, 341.05–08
Tensile strength, 111.23b
Tensiometer
  construction and use of, 121.17
Terminal bud, 221.15
Termites, 211.23
Terrariums, preparation of
  desert environment, 241.02c
  for ferns and mosses, 221.11
  swamp environment, 241.02b
  woodland environment, 241.02a
Testing
  air pressures, 132.08
  aircraft parts, 532.03, 532.08, 532.15, 532.20
  to amplify and mute sounds, 322.21, 322.26
  for colors animals can see, 243.04
  for compass markings, 362.11–12, 362.14, 362.16
  for electrical charges, 413.05
  electric circuit arrangements, 352.16, 352.19–21, 352.25–26, 352.29–30, 352.32–35
  objects for effect
    by electric fields, 352.11
    by heat, 142.26–27, 342.30–31, 412.04
    by light, 333.09–12
  optical equipment, 332.06
  parachute designs, 532.23
  for the presence of
    carbonates, 111.09
    carbon dioxide, 131.12
    metallic elements, 411.10
    oxygen, 131.14
    starch, 111.09
    simple sugars, 111.09
  pulley arrangements, 511.34
  for root functions, 242.04, 242.06
  soap powders, 122.41
  soil compaction, 142.10
  for stem functions, 242.09
  trained animals, 244.07–09
  types of food to attract birds, 211.46
  water pressures, 122.13–14
Test tube stands
  construction and use of, 622.01c
Thermometer
  air, 341.07
  copper-wire, 341.08
  liquid, 161.01, 341.05–06, 632.07
  use of, 341.02–04
Third-class lever (*see also* Levers)
  definition of, operational, 511.10–16
  examples of, 511.18
  mechanical advantages of, 511.17
Thistle, 242.18c
Thunder, 322.19, 351.01
Tidal basin, 152.14
Tidal wave, 152.10
Tides
  definition of, operational, 152.11
  source of, 152.12–14
Time
  measurement of, 422.07–09, 632.08–09
Tines, musical percussion instruments
  construction of, 324.02e
Toads, 211.33–36
Tobacco seeds, 221.23
Tornado
  model of, 152.19, 163.09
Tortoise, 211.42–43
Touching (*see* Feeling)
Translucent objects, 332.14
Transmission
  light, 221.11–12, 331.16, 332.14, 332.31
  sound, 111.16, 322.23
Transparent objects, 332.13

Transplanting techniques, 641.04f
TRANSPORTATION, 530
complex vehicles
air, 532.01–21
space, 532.24–26
simple vehicles
air, 531.03
land, 531.01
water, 531.02
Transverse waves
compared to longitudinal waves, 323.05
definition of, theoretical, 333.03–04
model of, 333.03–04
in water, 333.05
Tree rings, 221.18–19
Triangulation
measurement technique for distances, 421.12
Trombone, musical wind instrument
construction of, 324.06b
Tsunami, 152.10
Tulip, 242.11
Turbidity, 151.16–19
Turbine, steam
model of, 344.02
Turtles, 211.42–43
Twining plants, 222.19, 222.28
Typhoon (*see* Waterspout)

Ultraviolet energy, 333.13
Umbra, 422.17
Units of measure (*see* Measuring techniques)
Universe
composition of, 421.02–09, 421.11
distances between and sizes of objects in, 421.12–13, 421.19–21
viewing of, 421.01
Uranium, 413.02b

Vapor trails (atomic particles)
observations of, 413.06
Vehicles
air, 531.03, 532.02–21
land, 531.01
space, 532.24–26
water, 531.01–02
Vibrations
earthquake, 143.04
sound, 322.20–22
Vinegar
as an indicator for a carbonate, 111.09, 141.08e, 141.12
to produce carbon dioxide, 121.10–11
Violins, musical string instruments
construction of, 324.04a
Viscosity, 122.27–28
Vivarium (*see* Aquariums; Terrariums)
Volcanoes
in Earth formations, 143.01, 143.06
fault line eruption, 143.07
model of, 141.02
locations, 153.04
Voltage, 352.34–35
Volume
matter
displacement, 111.12
measurement of, 122.01–06, 122.21, 122.23, 132.01–02, 132.04
sound
characteristics of, 321.03–05, 322.07–08
scale, 321.11

Wasps, 211.23
Water (*see also* Liquids; Oceans)
absorption of, 122.34–35, 631.02c, 632.06e
applications of force, 344.01–02
as an indicator, 111.09
in aquariums, 641.02e
buoyancy, 151.05–06
capillary action of, 122.34–35
currents in, 152.01–09
definition of, theoretical, 413.07a
deposition in, 142.18–20, 152.15
electroconductivity of, 151.09
erosion by, 142.17–25, 152.16–17
evaporation/condensation of, 161.09–12
flow of, 142.13–25
fresh, 151.04
germination, effect upon, 222.08–09
glacier, 142.24–25
measuring flow of, 142.14, 142.16
microorganism growth, effect upon, 231.02
ocean, 151.01–23
plant growth, effect upon, 221.06, 222.20
pollution of, 112.01–03, 122.48–52, 151.17–18
pressure of, 122.11–14, 151.04

rocks, effect upon, 141.18a, 142.26–27, 142.29
in soils, 142.07–12
in terrariums, 641.02e
transparency of, 151.07–08, 151.16–19
waterborne materials, 142.17–20
waves, 151.11–14, 152.08–10
Water barometer
construction and use of, 632.08
Water clock, 632.08
Water cycle, 152.18
Water sampler
construction and use of, 151.19
Waterspout
model of, 152.20
Waterwheel
construction and use of, 122.34–35, 512.04
Wave theory
amplitude, 323.07
frequency, 323.06
light, 333.01–15
longitudinal wave, 323.01–07
sound, 323.01–09
transverse wave, 333.05
Waves, water
characteristics of, 151.12, 152.08
determining velocity, 151.12
earthquakes, as a source of, 152.10
relationship to depth, 151.13
shoreline erosion, 142.23, 151.11, 151.14
wind, as a source of, 152.10
WEATHER, 160
characteristics of, 161.01–13
measurement of factors
air pressure, 161.06–08
humidity, 161.09–13
temperature, 161.01–05, 162.07
wind, 162.01–06
measuring instruments for
anemometer, 162.04
barometer, 132.14–15, 161.06–07
hygrometer, 161.09
nephoscope, 162.02
rain gauge, 162.15
thermometer, 161.01, 341.05–08, 632.07
wind vane, 162.01
predictions of weather and climate, 164.01–05
water cycle
model of, 152.18, 163.01–12
temperature, effect of, 162.07–09
water, effect of, 162.10–31
wind, effect of, 162.01–06
Wedges
definition of, operational, 511.43
examples of, 511.44
mechanical advantages of, 511.45
Weighing (*see* Measuring techniques)
Wet cell
construction and use of, 352.01–02
Wheels
with drive belts, 511.35
friction in, 511.05–07
as pulleys, 511.23–24
and rotary motion, 311.08–09
Wheels and axles
in complex machines, 512.04
cranks, 511.22
definition of, operational, 511.19
examples of, 511.20
mechanical advantages of, 511.21–22
pulley, compared to, 511.24
Willow, 221.16
Wilson, Charles, 413.06
Wind (*see also* Air)
air movement indicator, 162.09, 342.38
applications of, 132.19–20
Beaufort wind scale, 162.06
cloud direction indicator, 163.02–03
definition of, operational, 132.17
deposition by, 142.02–04
Earth's rotation, effect of, 163.11
erosion by, 142.04–06
ocean currents, as a source of, 152.05–06
rocks, effect upon, 152.16–17
shorelines, effect upon, 156.16–17
temperature/pressure, effect of, 163.08–11
tornado, 163.09
windborne materials, 142.01–04
windsock, 162.01
wind speed indicator, 162.04–05
wind vane, 162.01, 162.03
Wind tunnel
construction and use of, 532.01, 532.03
testing aircraft in, 532.10–12
Wings (on aircraft), 532.10–12
Witch hazel fruit, 242.18b

Woodpecker, 242.20a. 242.20e
Work
  definition of, operational, 512.01
  machines to do, 512.03–04
  measurement of, 512.02
  by moving water, 122.32–33
Worms, 211.09–11

Xylophones, musical percussion instruments
  construction of, 324.02b

Yeast
  budding of cells, 232.03
  fermentation, 232.08
  life functions, 232.07
  measurement of growth, 232.02d
  reproduction of, 232.03

Zither, musical string instrument
  construction of, 324.04d
ZOOLOGY, 210 (*see also* names of specific animals)
  adaptations of, 242.19–26
  aquarium habitats, 24.01, 642.01
  characteristics of, 211.01–50, 342.02–03
  classification of, 211.13–19
  collecting, 651.01
  coloration of, 243.02–05
  endangered species, 243.07
  fossils, 243.06
  growth of, 211.04–05
  in mud samples, 151.20–21
  natural selection of, 243.01–02
  needs of, 211.06–08
  in ocean samples, 151.22–23
  reproduction of, 211.01–03, 212.01
  responses to environmental conditions, 212.03–13, 332.12, 342.31
  safety precautions in handling, 611.05
  terrarium habitats, 241.02, 642.02
  theory of evolution, 243.02, 243.04–07
  tracks of, 243.02–07
  training, 244.06–09
  types with backbones
    amphibians, 211.30–36
    birds, 211.44–46, 242.20
    fish, 211.28–29, 242.19, 244.08
    mammals, 211.47–48
    reptiles, 211.37–43
  types without backbones
    arthropods, 211.12–24
    crustaceans, 211.13–19
    insects, 211.23–24
    mollusks, 211.25–27
    worms, segmented, 211.09–11, 244.07

Index

*Page numbers printed in **boldface** type refer to figures and tables.*

A

A Nation at Risk, ix
Absorption
of heat, 135, 315, **315**
of light, 272, 284, **284**
of sound, 242, 257–258
of water
by plant roots, 202–203, **203**
by soil and rocks, 79–82, **80–81**
Acceleration, 230, **230**
Acids, 25
Action and reaction
building a model action/reaction engine, 444, **444**
caused by steam pressure, 443
measuring reaction to an action, 443
motion caused by, 238, 239, **239**
opposing forces of, 237–238, **238**
pulling, 237–238, 404
pushing, 238, 404
Adaptations for survival, 202–211
of animals, 208–211
of plants, 202–207
Air. *See also* Gases
air masses above Earth, 139–142, **139–142**
conduction of heat by, 308
detecting solids in, 15–16, **15–16**
expansion and contraction of, 301–302
feeling characteristics of, 48
inferring presence of, 47, **47**
light reflected by particles in, 283
movement of, 62–64 (*See also* Wind)
air pressure and, 113–114, 138
devices for detection of, 62–64, **63**
effect on evaporation, 125
force due to, 64
hurricanes, 106
lift of aircraft wings due to, 438
temperature and, 64, 124, **124,** 125–126, 136–138, **137**
tornadoes, 106, **137,** 137–138
using to do work, 64
observing physical characteristics of, 47–48
relative humidity of, 114–118
hygrometer for measurement of, 114–117, **115–117,** 143
for weather prediction, 143
temperature of
air currents and, 64, 124, **124**
conversion of solar energy to heat energy, 112
measuring and graphing, 111–112, **111–112**
near the ground, 123–124
relationship of wind direction to, 145, **145**
travel of sounds through, 253–254
estimating distance of a flash of lightening, 255
measuring speed of, 254–255
speed of light compared to speed of, 255
volume of, 55, **55**
in relation to burning times, 55–56, **56**
weight of, 53, 56–57
weight of object suspended in water vs., 92
Air barometer, making and using, 62, **62,** 113, **113,** 143
Air pollution, 15–16, **16**
Air pressure, 56–62, 113–114
air movement and, 113–114, 138
in all directions, 58–59, **59**
effect of expansion and contraction on, 59
measurement of, 61–62, 113
altimeter for, 57–58, **58**
barometer for, 62, **62,** 113, **113,** 143
upon a surface, 57
water barometer for, 61, **61**
for weather prediction, 143
observing effects of changes in, 60–61
Air thermometer, making and using, 294–295, **295**
Aircraft, 437–445
building a simple vehicle, 435–436, **436**
controlling directional movements of, **440,** 440–442
ailerons, **441,** 441–442
effect of movable parts of aircraft on flight, 442
elevators, 442
fin, 440–441, **441**
rudder, 441, **441**
stabilizers, 440, **440**
driven by reaction engines, 443–444

building a model action/reaction engine, 444, **444**
stabilization of jets and rockets, 443–444
parachute for safe descent from, 444–445
propellers for, 442–443, **443**
wings of, 437–438
air movement causing lift of, 438
shapes of, **437,** 437–438
Algae, 151
on aquarium walls, 155, 157, 186, 192, 199, 200
culturing of, 192
growth of, 186
in ocean water, 94, 100
physical characteristics of, 192
reproduction of, 193
Alkalinity, 25
Alligators, 201
Alpha Centauri, 390
Alternating current, 321
Altimeter, making and using, 57–58, **58**
Altitude
air temperature and, 112
of the North Star, 378, **378**
American Association for the Advancement of Science (AAAS), ix, x
Amphibians, 156–157, **157**
respiration in, 210–211
response to sound, 163
Anemometer, making and using, 120–122, **121–122**
Angles of reflection, **283,** 283–284
Angular diameter of an object, 388, **388**
to calculate diameter of the Moon, 389
circumferentor for measurement of, 388–389, **389**
Animals, 148–165
adaptations for survival, 208–211
advertising coloration of, 213–214
in aquariums, 148, 150, 154–159, 198, 199, 200, 208, 210, 216, 472
attraction to particular flower colors, 213
breathing by, 149, 208–211
amphibians, 210–211
earthworms, 208, 210
fish, 210
insects, 210
people, 211
caring for (*See* Housing and caring for animals)
characteristics of, 148–162
amphibians, 156–157, **157**
animals without backbones, 149–150
arthropods, 150–154
birds, 159–161
classification by, 162
fish, 155–156
inheritance of, 148
mammals, 161
mollusks, 155
reptiles, 158–159
collecting and preserving, 474
domesticated, 215
effect of light on, 276
extinct and endangered species, 214
food and eating habits of, 149
physical characteristics related to, 208, **209**
fossils of, 214
growth of, 148–149
hibernation of, 165
interactions of, 162
reproduction, 148, 162
response to gravity, 164
response to light, 164, **164**
response to smell, 163–164
response to sound, 163
response to temperature changes, 164–165
response to touch, 162–163
lenses in eyes of, 279
making impressions of tracks of, 214
natural selection of, 211–214
advertising coloration, 213–214
camouflage characteristics, 212
pollination by, 206–207, 212–213
safety precautions for study of, 449–450
seriating characteristics of, 161–162
in terrariums, 153, 155–159, 162, 165, 210, 162, 201–202
training of, 215–217, **216**
Annual rings in woody stems, 172–173
Apatite, **72**
Applied science, xx
Aquariums, 46, 53, 93, 100, 182
algae on walls of, 155, 157, 186, 192, 199, 200
animals in, 148, 150, 154–159, 198, 199, 200, 472

building, 197–200, 472
containers for, 197
equipment for, 200
aerating pumps, 151
heaters, 100, 101
plants in, 155, 156, 199–200, 472
problems with, 200
sand in, 9, 197–198
water in, 198–199
comparing and sorting floating objects by weight and volume in, 34
comparing weight of other liquids to, 26–27
to demonstrate water cycle, 106, **106**
to demonstrate weather fronts, 139, 142
evaporation of, 17
hearing sounds through, 252
light penetration through, 92
measuring pressure of, 31–32
measuring transparency of, 96
observing flow of, 37
observing waves in, 94–95, 103, 286–287
refraction of light through, 278
"seeing" air in, 47–48
temperature of, 101, 198, 199, 295–296
travel of radio waves through, 290
Arachnids, 150, 152–153
Arthropods, 150–154
arachnids, 150, 152–153
characteristics of, 150–151
crustaceans, 151–152
insects, 153–154, **154**
Aspergillus elegans, 186
Asteroids, 378, 393
Astronomy, 377–401
apparent motion of the Moon, 393–394
apparent motion of the Sun, 393
apparent movement of stars, **394,** 394–395
calculating diameter of the Moon, 387
angular diameter, 389
calculating distance to objects by triangulation, 385–386, **386**
characteristics of, 377–393
constructing a spectroscope to determine composition of stars, 385
constructing a telescope, 377, **377**
defining a light-year, 390
defining types of objects in the universe, 377–378
determining difference between real size and apparent size, 387–388
determining temperatures of stars, 384
distances between planets and Sun, 383–384, **384**
eclipses, 398–399, **399**
interactions of, 393–399
locating the North Star, 378
instruments to determine its altitude, 378.**378**
making a constellation projector, 383
making and using a circumferentor, 388–389, **389**
making and using a sundial, **395,** 395–396
measuring angular diameter of an object, 388, **388**
measuring size of the Sun, 383, **383**
model to compare sizes and distances between objects in solar system, 389–390, **391**
Moon phases, 397–398
observing the Sun, 383
orienting a model of the Earth to the Sun, 396
seriating planets by size, 390
seriating planets by temperatures, 392, **392**
star maps to locate constellations, 379, **379–382**
theory of, 399–401
different models of the solar system, 400
heliocentric theory of the solar system, 399–400, **400**
Sun-centered model of the solar system, 400–401, **401**
using a model to depict day and night, 396
using a model to depict seasonal changes, 396
using parallax effect to calculate distance to objects, 386–387
Atmosphere
condensation in, 126–133
heat trapping in, 136
solar radiation shielded from Earth's surface by, 135–136
Atomic weights, 368
Atoms, 364–376
atomic particles in Earth produce electricity and magnetism, 360, **360**
characteristics of, 364–369
classification of, 368–369
definition of, 365

electrical components of, 337–338, **338**
formation of molecules by, 365
compounds, 365, 366, **366,** 368
elements, 365–368, **366–367**
helium, 372, **372**
hydrogen, 371–372, **372**
inferring existence of, 364–365
interactions of, 369–370
magnetic properties within, 359, **359**
movement of, 369
effect of heat on, 369–370
number of kinds of, 366
seriating characteristics of, 368
theory of, 370–376
atomic models, **371,** 371–373, **372**
constructing and using a cloud chamber, 374, **374**
molecular models, 374–376, **375–376**
Axles and wheels, **411–412,** 411–413
characteristics of, 411–412, **411–412**
determining numerical patterns using, 412–413
finding examples of, 412

B

Bacteria, 186, 194
growth of, 187
Balance scale, making and using, **461,** 461–463
Ball bearing, making a model, 406
Bar graphs, 454, **454**
Barometer
air, 62, **62,** 113, **113,** 143
water, 61, **61**
Basalt, 65–66
Bases, 25
Battery, making, 323–324, **324**
Bearings to reduce friction, 406
making a model ball bearing, 406
Beaufort scale of wind speed, 123, **123**
Bees, attraction to particular flower colors, 213
Bells, 264, **264**
building an electric bell, 343–344, **344**
Benchmarks for Science Literacy, ix, xxiii
Bending glass tubing, 452
Benedict's solution, 7
Berzelius, Jöns, 368
Big Dipper, 394
Binary system for computers, 432
Bird feeders, **160,** 160–161
Birds, 159–161
advertising coloration of, 213
physical characteristics related to food of, 208, **209**
Block and tackle, 416–418, **417**
determining numerical patterns using, **417,** 417–418
Blueprint paper, 275
Botany, 166–185. *See also* Plants
Bread making, 192, 195
Bread mold, 191
Breathing, 149, 208–211. *See also* Respiration
Brown, Robert, 369
Budding of yeasts, 193–194, **194**
Buoyancy, 32–35, **33**
of ocean water vs. freshwater, 92
Burning
fuels produced by, 298
kindling points for, 298–299
as source of heat, 298–299
as source of light, 274
Butterworts, 205

C

Calcite, **72, 76**
Cameras, 290–291, **291**
Camouflage characteristics, 211–212
of animals, 212
of plants, 211–212
Candles
candlelight compared to sunlight, 274
heat produced by burning of, 298
Capillarity of liquids, **39,** 39–40
Carbon dioxide
collection of, **49,** 49–50
dry ice as solid form of, 49, 50 (*See also* Dry ice)
molecular model of, 375, **375**
production of, 48–49
by microorganisms, 195
using to extinguish a fire, 59–60, **60**
testing for presence of, 50
weight of, 53–54, **53–54**
Carbon molecule, 365–366, **366**
Cats, 148, 161, 215
Caves, stalactites and stalagmites in, 88
Celsius scale, 294

Centripetal force, 234
Chalcopyrite, 72, **72**
Chemical propagation, 298
Chemical reactions as source of electricity, 321–324
  examining a "dry" cell, 323, **323**
  making a battery, 323–324, **324**
  making an electric cell, 321–322
  producing electricity from a "dry" cell, 322, **322**
  producing electricity from a "wet" cell, 322, **322**
  testing materials to make "dry" cells, 323
Chemical symbols for elements, 366–367
Chimes, 264
Circuit breaker, building, 343, **343**
Circuit tester, making and using, 329, **329,** 331
Circuits. *See* Electric circuits
Circumferentor, making and using, 388–389, **389**
Clams, 155
Classroom safety, xi, 448–450
Climate, 146, **146**. *See also* Weather
  ocean effects on, 106–107
Clinometer, making and using, 83, **83**
Clocks
  pendulum, 464, **464**
  water, 464
Clothes dryer, 239
Cloud chamber, constructing and using, 374, **374**
Cloud direction indicator, making and using, 118–120, **120**
Cloudiness indicator for water, making and using, **97,** 97–98
Clouds, 129–131
  alto, 130
  cirrus, 129–130
  cumulus, 129–130
  formation of, 129–130
  nimbus, 130, 131
  stratus, 129–130
  thunderclouds, 140
  weather fronts and, 140–142
Coding and decoding written messages, 429, **429**
Cold/cooling
  air movement due to, 64
  animals' responses to, 164, 165
    hibernation, 165
  breaking of rocks by, 86
  condensation and, 127–128, 304–305
  contraction of materials when cooled, 299–302
    gases, 54, 59, 301–302
    liquids, 19, 301
    solids, 11, 299–301, **300**
  effect on seed germination, 179–180
  evaporation and, 125, 303
  plant responses to, 184–185
  sensitivity of microorganisms to, 187–188
Cold fronts, 139–141, **140–141**
Collection(s), 474–475
  of animals, 474
    crayfish, 151
    daphnia, 151
    earthworms, 150
    frogs and toads, 156–157
    lizards, 158
    protozoa, 189–190
    salamanders, 156
    snails, 155
    snakes, 158
    sow bugs, 152
    spiders, 152
    turtles and tortoises, 159
  of plants, 474–475
    ferns and mosses, 168–169
    flowers, 475
    leaves, 3, 474–475
    from ocean water, 99
    seeds, 205, 474
  of rocks, 3, 475
  seriating, 12
Colors
  absorption of heat energy by differently colored materials, 135
  absorption of light by colored materials, 284
  advertising characteristics
    of animals, 213–214
    of plants, 212–213
  advertising coloration of animals, 213–214
  animal attraction to particular flower colors, 213
  camouflage characteristics
    of animals, 212
    of plants, 211–212
  to estimate temperatures of stars, 384
  flame test to determine color characteristics of some elements, **367,** 367–368

heat radiation and, 312–313
influence on plant growth, 183
of light
combining to make white light, 271
electromagnetic spectrum, 288–289, **289**
in neon lighting tubes, 274
separating white light into colors, 269–270
seriating by, 272
transmission, reflection, and absorption of, 271–272
of rocks, 70–71
seasonal color changes of leaves, 185
testing effect of light on colored materials, 275
Comets, 378
Communications, 427–434
complex devices for, 430–434
computers, 432–434
model telegraph system, 430–431, **431**
radio, 432
telephone system, **431,** 431–432
simple devices for, 427–430
to code and decode written messages, 429, **429**
flags, 427
heliograph, 429–430, **430**
light, 427
telegraph key, 428, **428**
telephone, 428
whistles, 427–428, **428**
writing invisible messages, 427
without language, 427
Compact fluorescent lights (CFLs), 275
Compass, making and using, 326, 352–354, **353**
Compounds, 365, 366, **366,** 368
Compression, 259
Computers, 432–434
how a simple binary system works in, 432
uses of, 432–434
Concave lens, 278–279
refraction of light by, 280
Condensation, 17, 46, 304–305
in atmosphere, 126–133
clouds formed by, 129–131, **131**
dew formed by, 128
fog formed by, 129
frost formed by, 129, 303
rainfall due to, 126–127, **126–127,** 131–132, **132**
temperature changes affecting, 127–128
observation of, 304–305
temperature changes affecting, 127–128, 303, 305
Conduction of electricity, 331–334
fuses and, 334, **334**
influence of wire size on, 332–333, **332–333**
making a rheostat, 333
by ocean water vs. freshwater, 93, **93**
resistance in metals and, 333, **333**
testing, 331–332, **332**
Conduction of heat, 306–308
by gases (air), 308
by liquids, 307
poor conductors make good heat insulators, 313–314, **314**
by solids, 11, 306–307
Conglomerate, 67–68
Constellations
Big Dipper, 394
making a constellation projector, 383
using a star maps to locate, 379, **379–382**
Continental drift theory, 107–108
Contraction of materials when cooled, 299–302
gases, 54, 301–302
effect on pressure, 59
liquids, 19, 301
solids, 11, 299–301, **300**
Copper-wire thermometer, making and using, 295, **295**
Corundum, **76**
Cranks, 413, **413**
Crayfish, 151
Cross-pollination, 206
Crustaceans, 151–152
Crystals
in igneous rocks, 66
iodine, 305
made from solutions, 42–43, **42–43**
shapes of, 7, **8–10**
solubility of, 40
Cubic crystalline shape, **8, 10**
Current detector, 325
Cutting glass tubing, 452

D

Daphnia, 151
Darwin's theory, 211, 214
Day and night, model of, 396
Decay of organic matter, 74–75, **75**
Deceleration, 230
Decoding written messages, 429, **429**
Density of liquids, 26
  buoyancy related to, 33–34
Developmental learning theory, xxiii
Dew formation and dew points, 128
Dextrose molecule, 375–376, **376**
Diamond, **76**
Diatoms, 94
Dicotyledons, 170, **170**
Diffraction of light, 269–270
  making a spectroscope for, 270
  separating white light into colors, 269
  water wave model of, 287
Diffusion of gases, 62
Dimmer switch, making, 336, **336**
Dinosaurs, 214
Direct current, 321
Distance
  calculating distance to objects by triangulation, 385–386, **386**
  constructing instruments for measurement of, 459–460
    range finder, 459–460
    sextant, 459, **459**
  effect on volume of sound, 248–249
  estimating distance of a flash of lightening, 255
  light-years to measure distance to stars, 390
  model to compare sizes and distances between objects in solar system, 389–390, **391**
  model to represent distances between planets and the Sun, 383–384, **384**
  relationship of light intensity to, 275
  seriating motions by distances traveled, 226
  and time, as characteristics of motion, 220
  using parallax effect to calculate distance to objects, 386–387
Diving bells, 108–109
Dogs, 148, 161, 215
Drive belts, 418–419
Drums, 263
Dry ice, 46–47, 49, 50, 53, 132
  in construction of cloud chamber, 374
  in construction of model action/reaction engine, 444, **444**
  in construction of wind tunnel, **436,** 437
  germinating seeds in, 180, 305
  subliming of, 305

E

Earth
  air masses above, 139–142, **139–142**
  atmospheric shielding from solar radiation, 135–136
  Earth-centered theory of the solar system, 399–400, **400**
  effect of Earth's tilt on balance of temperatures, 133–135
  magnetic field of, 347–348, **347–348,** 360, **360**
  magnetic poles of, 348, 360
  model to compare sizes and distances between objects in the solar system, 389–390, **391**
  Moon revolving around, 378
  Moon's orbit around, 398
  orienting a model of the Earth to the Sun, 396
  revolution period of, **401**
  temperature and distance from Sun, **392**
Earth science, 65–90
  characteristics of, 65–77
  composition of Earth's interior, 88–89, **89**
  erosion, xv–xvii
    glacial, 86
    water, 84–85, **85**
    wind, 79
  formation of Earth's surface, 88
  glaciers, 85–86
  interactions of, 77–88
    with plants, 74, 87
    with temperature changes, 86–87
    with water, 73, 79–88
    with wind, 77–79
  pressure and heat sources in Earth, 69–70
    fault lines and earthquakes due to, 89–90, **90**
    magma and volcanoes formed by, 65, 90
  rocks (*See also* Rocks)
    igneous, 65–66
    metamorphic, 68–69
    minerals in, 71–72, **72**
    physical characteristics of, 70–71, 76–77, **76–77**

sedimentary, 67–68
soils, 72–76
stalactites and stalagmites in caves, 88
theory of, 88–90
Earthquakes, 89–90
continental drift and, 107, 108
ocean waves produced by, **103,** 103–104
seismograph for measurement of, 89–90, **90,** 282
Earthworms, 149–150, **150**
respiration in, 208, 210
response to smell, 163
response to touch, 162–163
training of, 215–217, **216**
Eating habits of animals, 149
physical characteristics related to foods, 208, **209**
Echoes, 260
Eclipses, 395, 398–399, **399**
Ecology, 197–217. *See also* Animals; Plants
applications related to, 214–217
domestication and training of animals, 215–217
uses of plants, 214–215
building a terrarium, 201–202, 472–473
building an aquarium, 197–200, 472
characteristics of, 197–202
interactions of, 202–211
animal adaptations for survival, 208–211
plant adaptations for survival, 202–207
theory of evolution, 211–214
extinct and endangered species, 214
natural selection, 211–214
Egg drop contest, 444–445
Eggs, 162
amphibian, 156
arachnid, 152
arthropod, 151
bird, 159
crustacean, 150
fish, 155
frog and toad, 156–157, **157**
hatching of, 162
insect, 153
mollusk, 155
reptile, 158
Electric bell, building, 343–344, **344**
Electric circuits, 327–335
arranging a circuit to light a bulb, 327
building a circuit breaker, 343, **343**
conductors and insulators for, 331–332, **332**
exploration of, 329
fuses for, 334, **334**
grounded, 330–331, **331**
influence of size on conductivity of wires, 332–333, **332–333**
locating hidden circuits, 329–330, **330**
making a circuit tester, 329, **329**
making a holder for a D-cell battery and preparing wires for use in, 327–328, **328**
making a holder for a flashlight bulb, 328–329, **329**
making a rheostat, 333
parallel, 334–335
resistance and heat production, 344
resistance in metals, 333, **333**
series, 334–335
short, 330
switches for opening and closing of, 330, **330,** 335–336
making a dimmer switch, 336, **336**
making a reversible switch, 335, **335**
Electric current, 321
building a galvanometer, 326–327, **327**
conductors and insulators for, 331–333, **332–333**
detection of, 326–327
generating a direct current, 321
generating an alternating current, 321
magnetic field produced by, 325–326, **325–326,** 341–342, **342**
moving through a circuit, 327–331 (*See also* Electric circuits)
Electrical propagation, 299
Electricity, xxiv–xxxi, 319–344
applications related to, 341–344
building a circuit breaker, 343, **343**
building an electric bell, 343–344, **344**
electrical resistance and heat production, 344
magnetic field produced by electric current, 341–342, **342**
making and testing an electromagnet, 342–343, **342–343**
characteristics of, 319–321
chemical reactions as source of, 321–324

examining a "dry" cell, 323, **323**
making a battery, 323–324, **324**
making an electric cell, 321–322
producing electricity from a "dry" cell, 322, **322**
producing electricity from a "wet" cell, 322, **322**
testing materials to make "dry" cells, 323
conduction of, 331–334
fuses and, 334, **334**
influence of wire size on, 332–333, **332–333**
making a rheostat, 333
by ocean water vs. freshwater, 93, **93**
resistance in metals and, 333, **333**
testing, 331–332, **332**
determining that not all electrical charges are alike, 320–321
determining what materials can produce electrical charges, 320
electrical charges of atoms, 372–374
interactions of, 321–337
making a magnet using, 355, **355**
motion as source of, 324–325
observing that rubbing charges some materials, 319–320
producing by using a magnet, 324–325, 360–361
safety precautions for use of, 337, 449
seeing, feeling, and hearing evidence of electrical charges, 319
as source of heat, 299, 340, 344
as source of light, 274–275, 340
as source of magnetism, 325, **325,** 341–342, **342,** 349–350, **350**
static, 319–320
theory of, 337–341
building an electroscope, 338–339, **339**
electrical components of atoms, 337–338, **338**
models to explain movement of electrons, 339–340
producing heat and light from electricity, 340, **340**
producing radio waves from electricity, 341, **341**
use of ground fault interrupter (GFI) circuits, 100–102, 103
voltage produced by electric cells, 335–336
switches to control circuits and, 336–337
Electro-chemical propagation, 321–324
Electromagnet, making and testing, 342–343, **342–343**
Electromagnetic spectrum, 288–290
infrared energy as part of, 289–290, **290**
light energy as part of, 288–289, **289**
ultraviolet energy as part of, 289
Electronic devices, 432
Electrons, 337–338, **338,** 372
models to explain movement of, 339–340
Electroscope, building and using, 338–339, **339**
Elements, 365–368
characteristics and uses of, 367
definition of, 366
learning chemical symbols for, 366–367
metallic, flame test for identification of, **367,** 367–368
number of, 366, 368
periodic table of, 370
Endangered species, 214
Energy, xx, xxi, 220–362
electricity, 319–344
heat, 293–318
light, 268–292
magnetism, 345–362
motion, 220–239
sound, 240–267
Engineering. *See* Technology and engineering
Equipment, 451–452
glassware, 452
heat sources, 451
support stands, **451,** 451–452
Erosion, xv–xvii
glacial, 86
water, 84–85, **85**
wind, 79
Estimating, 453
Ethyl alcohol molecule, 375, **375**
Evaporation, 17, 46, 117–118
factors affecting, 118, 125–126
air movement, 125–126
surface area, 126
temperature changes, 125, 303–304, **304**
graphing rates for different liquids, 303–304, **304**
measuring cooling effect of, 303

observation of, 303
of ocean water, 106
salt deposits on Earth's surface due to, 88
separating materials from water by, 45
from soil, 117–118
Evolution
Darwin's theory of, 211, 214
extinct and endangered species, 214
natural selection, 211–214
Expansion of materials when heated, 299–302, 316
gases, 54, 301–302
effect on pressure, 59
liquids, 19, 301
breaking of rocks by freezing water, 86–87
solids, 11, 299–301
breakage due to, 301
making adjustments for, 301
measurement of, 300, **300**
wires, 300
Extinct species, 214
Eyeglasses, 279

F

Fahrenheit scale, 294
Fault lines and earthquakes, 89–90, **90**
Feely Box, 12, 13
Fehling's solution, 7
Feldspar, 71, **72, 76**
Fermentation of yeast, 195
Ferns, 166, 167, 168–169
Fertilizers, 167
Fire extinguisher, 59–60, **60**
First-class levers, 407–408
characteristics of, 407, **407**
determining numerical patterns using, 407–408, **408**
finding examples of, 408
Fish, 155–156
in aquariums, 155–156, 198, 199, 200, 208, 210, 216
feeding habits of, 208
respiration in, 210
response to sound, 163
response to temperature changes, 165
training of, 216
Flags, communicating with, 427
Flies, 276
"Flip" movies, 292
Floating
buoyancy, 32–35, **33**
of ocean water vs. freshwater, 92
ice, 92
Flowers/flowering plants, 174, **174**
animal attraction to particular flower colors, 213
collecting and preserving, 475
edible flowers, 215
parts of flowers, 205
pollination of, 205–207, 212–213
researching information about use of, 215
responses to light, 182–183
Fluorescent lights, 275
Fluorite, **72, 76**
Flutes, 267
Fog formation, 129
Foods, 194–195
for animals, 149 (*See also specific animals*)
physical characteristics related to, 208, **209**
growth of mold on, 194–195
Force(s)
of action and reaction, 237–238, **238**
building a model action/reaction engine, 444, **444**
caused by steam pressure, 443
measuring reaction to an action, 443
motion caused by, 238, 239, **239**
pulling, 237–238, 404
pushing, 238, 404
applied, 404
centripetal, 234
characteristics of, 404
counter, 404
feeling, 404
of moving water, 38–39, **38–39**
work as product of, 424–425
Forced vibrations, 255–256
Fossils, 214
in ocean sediments, 95–96
Freezing, 2, 41–42, 302–303
removing dissolved materials from ocean water by, 91
Friction
effect on machines, 404–406
reduced by bearings, 406
reduced by lubrication, 405–406

feeling, 404–405
finding evidence of, 405
impedance of motion by, 230–232, **231**
comparing rolling and sliding motion, 232
reducing friction, 232
testing effects of different surfaces, 231, **231–232**
Frogs, 156–157, **157,** 201
hibernation of, 165
respiration in, 210–211
Frost formation, 129, 303
Fungi, 168, 186, 191–192
culturing of, 191
molds, 186, 191, 192–196, **193**
yeasts, 186, 187, 191–195, **194**
Fuses, 334, **334**

G

Galena, **72**
Galvanometer, building and using, 326–327, **327**
Gases, 46–64
atomic particles making up, 370
characteristics of, 46–54
conduction of heat by, 308
detecting diffusion of, 62
expansion and contraction of, 54, 301–302
effect on pressure, 59
indicators for identification of, 48–52
carbon dioxide, 48–50, **49**
oxygen, 50–52
interactions of, 55–64
movement of, 62–64
detecting gas diffusion, 62
devices for detection of, 62–64, **63**
force of, 64
temperature and, 64
using to do work, 64
observing convection currents in, **310,** 310–311
in ocean water, 91
pressure exerted by, 56–62 (*See also* Air pressure)
in all directions, 58–59, **59**
altimeter for measurement of, 57–58, **58**
effect of expansion and contraction on, 59
measuring air pressure upon a surface, 57
measuring changes in air pressure, 61–62, **61–62**
observing effects of changes in, 60–61
using to extinguish a fire, 59–60, **60**
sensory identification of, 47–48
feeling characteristics of air, 48
inferring presence of air, 47, **47**
observing physical characteristics of air, 47–48
smell, 48
shape of, 52
space occupied by, 52–53, 55, **55**
transformation of solids to, 305
travel of sounds through, 253–254
volume of, 55, **55**
air volumes in relation to burning times, 55–56, **56**
comparing gases by weight and, 56
weight of, 53–54, 56
air, 53
carbon dioxide, 53–54, **53–54**
comparing gases by, 56
Gears, 419–421
characteristics of, 419, **419**
compared to a lever, 419, **419**
comparing interactions of two gears to two levers, 420
determining numerical patterns using, 420–421, **420–421**
Germination of seeds, 166, 176–181
drawing pictures of, 178, **178**
growth rate of germinating seed, 178
light and, 180
percentage or ratio of, 176–177, **177**
planting depth and, 180–181
seed position in soil and, 181
soaking seeds to speed process of, 467–468
soil and, 180
strength of germinating seed, 179
temperature effects on, 179–180, 305
time required for, 177–178, 468, **468**
water for, 179
Glaciers, 85–86
Glassware, 452
bending glass tubing, 452
cutting glass tubing, 452
safety precautions for use of, 449
Gneiss, 68–69
Goldfish, 155
Graduated cylinder, making, 460
Granite, 65–66

Graphing, 453–456
bar graphs, 454, **454**
histograms, 454, **454**
line graphs, 454–456, **455**
Gravity
animals' responses to, 164
effects on plant growth, 181–182
feeling force of, 228
motion produced by, 228
Ground fault interrupter (GFI) circuits, 100–102, 103
Growth
of animals, 148–149
of microorganisms, 186–187
of plants, 166–167
Guinea pigs, 161
Guitars, 265–266, **266**
Guppies, 148, 155
Gypsum, **76**

H

Hamsters, 148, 149, 161
Hard water, 41
Harpsichords, 266
Heat, 293–318
absorption of, 135, 315, **315**
animals' responses to, 165
applications related to, 318
heated water can move objects, 318, **318**
making a model steam turbine, 318, **318**
breaking of rocks by, 86
burning as source of, 298–299
characteristics of, 293–296
condensation and, 127–128, 303, 305
conduction of, 306–308
by gases (air), 308
by liquids, 307
poor conductors make good heat insulators, 313–314, **314**
by solids, 11, 306–307
convection of, 308–311
cooler air falls and pushes heated air upward, 308–309
locating air currents, 309, **309**
locations of heated and cooler air in classroom, 308
observing convection currents in gases, **310,** 310–311
observing convection currents in liquids, 311
conversion of solar energy to heat energy, 112
differences between temperature and, 295–296, 317, **317**
effect on insect metamorphosis, 306
effect on motion of atomic particles, 369–370
effect on movement of molecules, 316
effect on seed germination, 179–180
effect on solubility, 42
electricity as source of, 299, 340, 344
evaporation and, 125, 303–304, **304**
expansion of materials when heated, 299–302, 316
gases, 54, 59, 301–302
liquids, 19, 301
solids, 11, 299–301, **300**
gas movement due to, 62–64, **63**
heat trapping in atmosphere, 136
as indicator for solids, 6
interactions of, 296–315
measuring heat held by metals, 296, **296**
motion as source of, 297–298, **298**
phase transformations due to addition or removal of, 2, 41–42, 302–303
plant responses to, 184
radiant, 291, 311–313
focusing and reflection of, 314–315
reflection of, 315, **315**
safety precautions for use of, 448
sensitivity of microorganisms to, 187–188
as source of light, 273–274
as source of ocean currents, 100–102
sources in the Earth, 69–70
Sun as source of, 296–297
theory of, 316–317
Heat sources, 451
Heating stands, construction of, 452
Heliocentric theory of solar system, 399–400, **400**
Heliograph, building and using, 429–430, **430**
Helium atom, 372, **372**
Hematite, **72**
Hexagonal crystalline shape, **9, 10**
Hibernation, 165
Histograms, 454, **454**
Horn-type instruments, 267
Hornblend, **72**
Housing and caring for animals

birds, 159–160
crayfish, 151
daphnia, 151
earthworms, 150, **150**
fish, 156
frogs and toads, 157
insects, 153–154, **154**
lizards, 158–159
salamanders, 156
small mammals, 161
snails, 155
snakes, 158
sow bugs, 152
spiders, 152–153
turtles and tortoises, 159
Humidity, 114–118
hygrometer for measurement of, 114–117, **115–117,** 143
in weather prediction, 143
Humus, 73
Hurricanes, 106
Huygens, Christian, 285
Hydrogen atom, 371–372, **372**
Hydrogen peroxide molecule, 375, **375**
Hydrometer, making and using, 27–28, **28**
Hygrometer, making and using, 114–117, **115–117,** 143

I

Ice
dry, 46–47, 49, 50, 53, 132
in construction of cloud chamber, 374
in construction of model action/reaction engine, 444, **444**
in construction of wind tunnel, **436,** 437
germinating seeds in, 180, 305
subliming of, 305
melting and freezing of, 2, 302–303
Igneous rocks, 65–66
Incandescence, 273
Incandescent light bulbs, 275
Inclined planes, 421–424
characteristics of, 421
determining numerical patterns using, 422
finding examples of, 421–422
screws, 424
wedges, 422–424
Indoor sundial, making and using, 395
Inertia, 233–235
in an object in motion, 235
controlling inertial tendency of an object to travel in a straight line, 233–234
observing presence of, **234,** 234–235
Inference models, xx, 364–401
astronomy, 377–401
atoms and molecules, 364–376
Infrared radiation, 289–290, **290**
Inheritance of physical characteristics, 148
Inorganic matter, xix, xxi, 1–146
Earth science, 65–90
gases, 46–64
liquids, 17–45
oceans, 91–109
solids, 2–16
weather, 111–146
Inquiry-based teaching, ix, x
Insects, 150, 153–154, **154**
metamorphosis of, 306
respiration in, 210
response to sound, 163
trapped by plants, 204–205
Insulation
by poor heat conductors, 313–314, **314**
qualities of dark and light surfaces, 315, **315**
for space vehicles, 445
International Code, 427, 430
Invertebrates, 149–150
“Invisible ink,” 427
Iodine
forming crystals of, 305
as indicator for solids, 6
Iron, as indicator for presence of oxygen, 51–52

J

Jupiter, 393
moons revolving around, 378
revolution period of, **401**
scaling diameter and distance from Sun, **391**
temperature and distance from Sun, **392**

K

Kindling points, 298–299

L

Leaves
collection of, 3, 474–475

locations and patterns on stems, **173,** 173–174
making molds of, 214
responses to light, 182–183
seasonal color changes of, 185
trapping of insects by, 204–205
Lenses, 278–281
in animals' eyes, 279
concave, 278–279
refraction of light by, 280
convex, 278–280
locating focal point of, 280
refraction of light and magnification by, 279–280
observing shapes of, 278–279
testing of, 280–281, **281**
uses of, 279
Levers, 407–411
compared to gears, 419, **419**
compared with pulleys, 414
comparing interactions of two gears to two levers, 420
first-class, 407–408, **407–408**
second-class, **409,** 409–410
third-class, **410,** 410–411
Light, 268–292
absorption of, 272, 284, **284**
animals' responses to, 164, **164**
applications related to, 290–292
cameras, 290–291, **291**
projectors, 291–292
burning as source of, 274
categorizing luminous and nonluminous sources of, 272–273
characteristics of, 268–273
classifying materials by transmission of, 273
colors of
combining to make white light, 271
in neon lighting tubes, 274
separating white light into colors, 269–270
seriating by, 272
transmission, reflection, and absorption of, 271–272
communicating with, 427
building and using a heliograph for, 429–430, **430**
diffraction and refraction of, 269–271, 277–278
making a prism, 271
making a spectroscope, 270
observing diffraction, 269–270
observing refraction, 270–271, 277–278
refraction by lenses in optical instruments, 278–281, **281**
water wave model of diffraction, 287
effect on animals, 276
effect on plants, 182–183, 276
seed germination, 180
electricity as source of, 274–275, 340
heating as source of, 273–274
intensity of
factors influencing, 275
foot-candle as measure of, 274
relationship to distance, 275
seriating by, 272
interactions of, 273–284
penetration through ocean water, 92
produced by stars, 377
reflection of, 281–284
by different surfaces, 282, **282**
making a seismograph using, 282
measuring angles of, **283,** 283–284
in a mirror, 282
by particles in gases and liquids, 283
by planets, 377
signaling by, 282
water wave model of, 287
sensitivity of microorganisms to, 187
seriating characteristics of, 272
speed of, 276, 288
compared to speed of sound, 255
Sun as source of, 273
testing effect of light on colored materials, 275
theory of, 285–290
particle theory, 285
wave-particle theory, 288–290, **289–290**
wave theory, 285–288, **287** (*See also* Waves: light)
travel in a straight line, 268
travel in all directions from a source, 268
travel through a narrow opening, 268–269, **269**
travel through different materials, 276–277
opaque materials, 277
translucent materials, 276–277
transparent materials, 276

using blueprint paper, 275
Light-year, 390
Lightening, estimating distance of a flash of, 255
Limestone, 67–68
Limonite, **72**
Limpets, 155
Line graphs, 454–456, **455**
Liquid thermometer
calibration of, 294
making and using, 111, 294
Liquids, 2, 17–45. *See also* Water
atomic particles making up, 370
buoyancy of, 32–35, **33**
capillarity of, **39,** 39–40
characteristics of, 17–25
classifying characteristics of, 24–25
acidity or alkalinity, 25
by sight, smell, and taste, 24–25
condensation of, 17, 46, 126–133, 304–305
conduction of heat by, 307
density of, 26
evaporation of, 17, 46, 117–118, 303–304, **304**
expansion and contraction of, 19, 301
freezing of, 2, 41–42, 302–303
identifying materials that dissolve in, 18–19
indicators for identification of, 18
interactions of, 25–45
making a graduated cylinder for measurement of, 460
measuring heat produced by motion in, 298
moving/falling, 35–36, **36**
flowing from higher to lower levels, **37,** 37–38
using force to do work, 38–39, **38–39**
viscosity of, 36–37, **37**
observing convection currents in, 311
penetration of magnetic fields through, 357–358
pollution of, 43–45, **44–45**
pressure exerted by, 29–32, **29–32**
manometer for measurement of, 30–31, **31**
sensory identification of, 17–18
sight, 17–18
taste, 18
touch, 18
seriating characteristics of, 24
shape of, 18
solutions, 40–45
space occupied by, 19, 25–26
specific gravity of, 26–28
hydrometer for measurement of, 27–28, **28**
surface tension of, 19–24, **20–22**
travel of sounds through, 252–253
using heat to break liquids into particles that are too small to be seen, 369–370
volume of, 25–26
weight of, 19, 26–27
Lithium atom, 372
Litmus paper, 18
Lizards, 158–159
Lodestones, 348–349
Lubrication, to reduce friction, 405–406
Lunar eclipse, 398–399

M

Machines, 404–426
complex, 424–426
components of, 425
defining work, 424–425
making a water-powered machine that will do work, 425–426, **425–426**
measuring work, 425
simple, 404–424
cranks, 413, **413**
drive belts, 418–419
effect of friction on, 404–406
first-class levers, 407–408, **407–408**
force and, 404
gears, 419–421, **419–421**
inclined planes, 421–424
pulleys, 413–418, **414–418**
second-class levers, **409,** 409–410
third-class levers, **410,** 410–411
wheels and axles, **411–412,** 411–413
Magma, 65, 90
Magnetism, 345–362
applications related to, 360–362
magnetic fields in electrical appliances, 362
magnetic fields in toys and tools, 361–362, **362**
making a model to represent the motion within an electric motor, 361, **361**
producing electricity using a magnet, 324–325, 360–361

artificial magnets, 349
characteristics of, 345–346
classifying materials by their ability to be magnetized, 346
comparing permanent and temporary magnets, 355
compass for detection of magnetic fields, 326, 352–354, **353**
differentiating among magnetic, magnetized, and nonmagnetic objects, 352
Earth as source of, 347–348, **347–348,** 360, **360**
feeling magnetic fields, 345
inducing magnetic fields in some materials, 352
interactions between magnetic fields, 350
interactions of, 347–359
magnetic fields compared with electric fields, 325
magnetic fields produced by electric current, 325, **325,** 341–342, **342,** 349–350, **350**
making a magnet using another magnet, 354
making a magnet using electricity, 355, **355**
making permanent pictures of magnetic fields, 345–346
measuring strength of magnetic fields, **358,** 358–359
motion produced by, 228
natural magnets, 348–349
observing magnetic fields, 345
penetration of magnetic fields through various materials, 357, **357**
liquids, 357–358
polarity of magnets, 350–351, **351**
of solids, 12
sorting objects by how they are affected by, 346
testing effects of magnetic and electric fields on different materials, 325–326, **326**
theory of, 359–360
Earth's magnetic interior, 360, **360**
magnetic properties within atoms, 359, **359**
observing a model of magnetic domains, 359–360
travel of magnetic fields through space, 356–357, **356–357**
Magnetite, **72**
Malachite, **72**
Mammals, small, 161
training of, 216–217
Manometer, making and using, 30–31, **31**
Maracas, 264
Marble, 68–69
Marimbas, 263
Mars, 393
moons revolving around, 378
revolution period of, **401**
scaling diameter and distance from Sun, **391**
temperature and distance from Sun, **392**
Mass
effect on motion, **229,** 229–230
acceleration, 230, **230**
independent of size, 229
momentum related to speed and, 235–237, **236, 237**
Measuring instruments, making and using, 459–464
for distance, 459–460
range finder, 459–460
sextant, 459, **459**
for liquid capacity: graduated cylinder, 460
for temperature: thermometer, 463, **463**
for time, 464
pendulum clock, 464, **464**
water clock, 464
for weight, 460–463
balance scale, **461,** 461–463
spring scale, 460–461, **461**
Measuring systems, 453–458
creation of, 456
depicting measurements pictorially, 453–456
estimating, 453
graphing, 453–456
metric system, 456, **457**
metric → U.S. conversion table, **458**
Mechanical propagation, 297, 324–325
Melting, 2, 302–303
Melting point, 2
Mendeleev, Demitri, 369
Mercury, 389
revolution period of, **401**
scaling diameter and distance from Sun, **391**
temperature and distance from Sun, **392**
Mercury-vapor lights, 275
Metals
measuring heat held by, 296, **296**

resistance to electricity in, 333
to make a model lightbulb, 333, **333**
Metamorphic rocks, 68–69
Metamorphosis, effect of heat on, 306
Meteors, 378
Metric system, 456, **457**
metric → U.S. conversion table, **458**
Mica, 71, **72**
Mice, 148, 161
Microorganisms, 186–196
algae, 94, 100, 151, 155, 157, 186, 192, 193, 199, 200
characteristics of, 186–193
classification of, 193
fungi, 186, 191–192
growth of, 186–187
food and water for, 187
on foods, 194–195
temperature effects on, 195–196
interactions of, 193–196
bacterial growth on foods, 194
carbon dioxide production, 195
mold growth on foods, 194–195
reproduction, 186, 193–194, **193–194**
microscope for viewing of, **188,** 188–189
preparing microscopic slides, 189, **189**
protozoa, 189–191, **190**
sensitivity to light, 187
sensitivity to temperature changes, 187–188
seriating characteristics of, 192–193
Microscope, 188–189
parts of, **188,** 188–189
preparing microscopic slides, 189, **189**
Minerals
in rocks, 71–72, **72**
stalactites and stalagmites due to deposition of, 88
streak test for identification of, 72
Mirrors, 282
Molds, 191
classification of, 193
growth of, 186
on foods, 194–195
moisture effects on, 187
temperature effects on, 196
penicillin, 191
reproduction of, 193, **193**
seriating characteristics of, 192–193
Molecules
carbon, 365–366, **366**
carbon dioxide, 375, **375**
compounds, 365, 366, **366,** 368
constructing models of, 374–376, **375–376**
definition of, 365
dextrose, 375–376, **376**
elements, 365–368, **366–367**
ethyl alcohol, 375, **375**
hydrogen peroxide, 375, **375**
motion of
expansion and contraction of materials and, 316
heat effects on, 316
sound transmission by, 261–262, **261–262**
spaces between, 376
water, 375, **375**
Mollusks, 155
Momentum, 235–237, **236**
definition of, 235–236
relationship between mass and, 236, **237**
relationship between speed and, 236–237, **237**
transfer from one object to another, 237
Monoclinic crystalline shape, **9, 10**
Monocotyledons, 170, **170**
Moon
apparent motion of, 393–394
calculating diameter of, 387
angular diameter, 389
eclipse of, 398–399
model to compare sizes and distances between Sun, planets and, 389–390, **391**
orbit around Earth, 398
phases of, 397–398
tides produced by, **104,** 104–105
using parallax effect to calculate distance to, 387
Moons revolving around planets, 377–378
Morse, Samuel, 431
Morse Code, 427, 430
Mosquitoes, 210, 276
Mosses, 168–169
Motion(s), 220–239
applications related to, 239
clothes dryer, 239
using forces of action and reaction to move objects, 239, **239**
of atomic particles, 369

effect of heat on, 369–370
characteristics of, 220–226
circular, 232–234
controlling some effects of, 233–234
observing effects of, 232–233
tendency of objects to break away from, 233, **233**
classification of, 226
definition of, 220
direction of, 220–222
periodic motion, 221–222, **222**
rotary motion, 222
straight-line motion, 220–221
distance and time as characteristics of, 220
effect of mass on, **229,** 229–230
acceleration, 230, **230**
independent of size, 229
forces causing, 226–229
gravity, 228
magnetism, 228
mechanical activity, 229
muscular activity, 228–229
heat produced by, 297–298, **298**
heated water can move objects, 318, **318**
impedance by friction, 230–232, **231**
comparing rolling and sliding motions, 232
reducing friction, 232
testing effects of different surfaces, 231, **231–232**
interactions of, 227–234
of molecules
heat effects on, 316
sound transmission by, 261–262, **261–262**
observing from different positions, 225–226
seriating characteristics of, 226
as source of electricity, 324–325
speed of, 220, 223–225
defining uniform motion, 224–225, **224–225**
graphing uniform rates of motion, **223,** 223–224
increasing and decreasing rates of, 225, **225**
seriating motion by rates of, 226
theory of, 234–238
inertia, **234,** 233–235
momentum, 235–237, **236, 237**
opposing forces of action and reaction, 237–238, **238**

Mountain formation, 69, 88–90
Movies
"flip," 292
making on film, 292
projectors for, 291–292
Mud samples of ocean sediments, 99, **99**
Muscular activity, motion produced by, 228–229
Mushrooms, 168
spore prints of, 168
Musical instruments, 263–267
percussion, 263–264, **264**
stringed, 264–266, **265–266**
wind, 266–267
Musical tines, 264
Mussels, 155

N

National Research Council, ix
National Science Education Standards, ix, x, xxiii
Natural resources in ocean water, 109
Natural selection, 211–214
Neon lighting tubes, 274
Neptune
moons revolving around, 378
revolution period of, **401**
scaling diameter and distance from Sun, **391**
temperature and distance from Sun, **392**
Newton's theory
of inertia, 234
of momentum, 235
of opposing forces of action and reaction, 237
of particle model of light, 285
Newts, 156, 201
Night sky, star maps of, 379, **379–382**
North Pole, 133–134, 349
North Star (Polaris), 390, 394
instruments to determine altitude of, 378, **378**
locating, 378

O

Obsidian, 65–66
Occluded fronts, 141–142, **141–142**
Oceans and ocean water, 91–109
applications related to, 108–109
diving bells, 108–109
natural resources, 109
submarines, 109, **109**

buoyancy of, 92
characteristics of, 91–100
classifying ocean sediments, 98–99
mud samples for, 99, **99**
sorting screens for, 98–99
dissolved materials in, 91
effect on depth perception, 93
effects on climate and weather, 106–107
electroconductivity of, 93, **93**
extracting pure water from, 109, **109**
fossils in ocean sediments, 95–96
interactions of, 100–107
light penetration through, 92–93
living organisms in, 93–94
identification and classification of, 99–100
pressure exerted by, 91–92
recovering salt from, 109
seriating characteristics of, 96–98
cloudiness indicator, **97,** 97–98
Secchi disk to measure transparency, **96,** 96–97
water sampler, 98, **98**
sources of currents in, 100–102
heat, 100–102
salinity, 102, **102**
wind, 102
theory of: continental drift, 107–108
tides in, **104,** 104–105
waves on surface of, 94–95
measuring characteristics of, 94
observation of, 103
observing action of, 85, **85,** 94
produced by earthquakes, **103,** 103–104
produced by wind, 103
water depth and, 94–95
Opaque materials, 277
Optical instruments, 278–282
reflection of light by mirrors in, 282
refraction of light by lenses of, 278–281, **281**
Organic matter, xix–xx, 147–217
botany, 166–185
decay of, 74–75, **75**
ecology, 197–217
other organisms, 186–196
in soils, 72–73
zoology, 148–165
Orthorhombic crystalline shape, **8, 10**
Outdoor planting areas, 469–472, **470**
choice of seeds for, 471
location of, 470
planning of, 469–470, **470**
soil for, 470–471
transplanting in, 471–472
watering of, 471
weeding of, 471
Outdoor sundial, making and using, **395,** 395–396
Oxygen
animals' need for, 149
amphibians, 210–211
earthworms, 208, 210
fish, 210
insects, 210
people, 211
production of, 50–51
testing for presence of, 51–52

P

Parachutes, 444–445
Parallax effect to calculate distance to objects, 386–387
Particle theory of light, 285
Pasteur, Louis, 194
Pendulum, 221–222, **222**
Pendulum clock, making, 464, **464**
Penicillin mold, 191
Percussion instruments, 263–264, **264**
Periodic motion, 221–222, **222**
Periodic table of the elements, 370
Pets in classroom, 148–149. *See also* Animals
Phase transformations, 2, 41–42, 302–303. *See also* States of matter
Phototropism, 182–183
Pinhole camera, making and using, 290–291, **291**
Pitch, 241, 243, **243,** 250–251
comparing differences in, 250, **250**
frequency and, 250, 260
testing factors that influence, 250–251, **251**
Pitcher plant, 205
Planarian, 186
Planck, Max, 288
Planets, 377–378
difference from stars, 377
Earth-centered model of the solar system to explain movement of, 400, **400**
inner and outer, 393

model to compare sizes and distances from Sun, 389–390, **391**
model to represent distances between Sun, 383–384, **384**
moons revolving around, 377–378
revolution periods of, 401, **401**
seriating by size of, 390
seriating by temperatures, 392, **392**
Plankton, 94, 99, 186
Plants, 166–185
adaptations for survival, 202–207
advertising characteristics of, 212–213
in aquariums, 155, 156, 199–200, 472
breaking down of rocks by, 74, 87
characteristics of, 166–176
collecting and preserving, 474–475
constructing containers for, 465–472, 466–469
large soil containers, 469, **469**
small soil containers, 466–469
decay of, in soil formation, 74–75
flowering, 174, **174**
animal attraction to particular flower colors, 213
collecting and preserving flowers, 475
edible flowers, 215
parts of flowers, 205
pollination of, 205–207, 212–213
researching information about use of, 215
responses to light, 182–183
fossils of, 214
fungi, 168, 186, 191–192
growth of, 166–167
colors influencing, 183
fertilizers for, 167
measuring rate of, 178, **178**
from seeds, 166, 176
soil nutrients for, **75,** 75–76, 167
from spores, 166, 167
water for, 167
interactions of, 176–185
leaves of
collection of, 3, 474–475
locations and patterns on stems, **173,** 173–174
making molds of, 214
responses to light, 182–183
seasonal color changes of, 185
trapping of insects by, 204–205
microscopic, 186
natural selection of, 211–214
advertising characteristics, 212–213
camouflage characteristics, 211–212
preparing outdoor planting areas for, 469–472, **470**
reproduction of, 166
pollination, 205–207, 212–213
response to environmental conditions, 181–185
gravity, 181–182
heat and cold, 184–185
light, 180, 182–183, 276
root growth in presence of water, 182
seasonal changes, 185
touch, 183–184, **184**
roots of
absorption of water and dissolved substances by, 202–203, **203**
anchoring power of, 202
edible, 214
effect of gravity on, 181
growth in the presence of water, 182
location on stems, 170–171, **171**
prop root systems, 202
safety precautions for study of, 450
seedless, 168–169
ferns and mosses, 168–169
fungi/mushrooms, 168
seeds of, 166, 169–170, 176
classification of, 175–176
collecting, 207, 474–475
external parts of, 169
germination of, 166, 176–181
histogram of numbers of seeds in pods, 175, **175**
internal parts of, 170, **170**
methods of dispersion of, 176, 207
seriating characteristics of, 174–175
sensitivity to environmental factors, 167–168
seriating characteristics of, 174–175
stems of, **171,** 171–172, 203
annual rings in woody stems, 172–173
arrangements of flowers on, 174, **174**
comparing grains in woody stems, 173
effect of gravity on, 181
external characteristics of, 171–172, **171–172**

internal characteristics of, 172–173
leaf locations and patterns on, **173,** 173–174
location of root growth on, 170–171, **171**
researching how people use, 215
response to light, 182–183
in terrariums, 168, 169, 201–202, 169
that live in water
algae, 94, 100, 151, 155, 157, 186.192, 193, 199, 200
building aquariums for, 197–200
choice of, 199–200
ocean water, 94, 99–100, **100**
twining, 181–182, 184
uses by people, 214–215
yeasts, 186, 191–192, 193–195, **194**
Pluto, 379
Polaris (North Star), 390, 394
instruments to determine altitude of, 378, **378**
locating, 378
Polarity of magnets, 350–351, **351**
Pollination, 205–207, 212–213
Pollution
air, 15–16, **16**
water, 15, 43–45, **44–45**
Porosity of soil and rocks, 79–82, **80–81**
Pressure
exerted by gases, 56–62 (*See also* Air pressure)
exerted by liquids, 29–32, **29–32**
manometer for measurement of, 30–31, **31**
ocean water vs. fresh water, 91–92
melting of glaciers by, 86
sources in the Earth, 69–70
fault lines and earthquakes due to, 89–90, **90**
volcanoes formed by, 65, 90
Prism, making and using, 271
Project 2061, ix, xxiii
Projectors, 291–292
Propagation
chemical, 298
electrical, 299
electro-chemical, 321–324
mechanical, 297, 324–325
Protists, 186
Protons, 337–338, **338,** 372
Protozoa, 189–191
collection of, 189–190
culturing of, 190
growth of, 186
temperature effects on, 196
physical characteristics of, **190,** 190–191
reproduction of, 193
sensitivity to temperature changes, 187–188
Protractor, determining altitude of the North Star with, 378, **378**
Pulleys, 413–418
characteristics of, 413
compared with levers, 414
finding examples of, 414
making a simple pulley, 414, **414**
simple block and tackle, 416–418, **417**
single fixed, 414–415, **415**
single movable, 415–416, **416**
testing pulley systems, 418, **418**
Pulling, 237–238, **238,** 404
Pumice, 65–66
Pushing, 238, **238,** 404
Pyrite, 72, **72**

Q
Quartz, 71, **72, 76,** 86
Quartzite, 68–69

R
Rabbits, 161
Radio, building and using, 432
Radio waves
produced from electricity, 341, **341**
travel through water, 290
Rain gauge, making and using, 126
Rainbow, 270
Rainfall
erosion due to, 84–85, **85**
how rain is formed, 131–132
materials carried and deposited by, 83–84
materials dissolved in Earth by, 91
measurement of, 126–127
rain gauge for, 126
relationship of wind direction to, **126–127,** 145, **145**
seriating raindrops by size, 132, **132**
Range finder, constructing, 459–460
Rarefaction, 259
Rats, 161, 217

Rattles, 264
Reflection
of heat, 314–315, **315**
of light, 271–272, 281–284
by different surfaces, 282, **282**
making a seismograph using, 282
measuring angles of, **283,** 283–284
in a mirror, 282
by particles in gases and liquids, 283
by planets, 377
signaling by, 282
water wave model of, 287
of sound, 241–242, 257
Refraction of light, 270–271, 277–278
combine a spectrum of colors to make white light, 271
by lenses, 278–281, **281**
making a prism for, 271
as rays move from denser to less dense medium, 278
Relative humidity, 114–118
hygrometer for measurement of, 114–117, **115–117,** 143
in weather prediction, 143
Reproduction
of animals, 148, 162
of microorganisms, 186, 193–194, **193–194**
of plants, 166
pollination, 205–207
Reptiles, 158–159
Respiration in animals, 149, 208–211
amphibians, 210–211
earthworms, 208, 210
fish, 210
insects, 210
people, 211
Reversible switch, making, 335, **335**
Rheostat, making and using, 333
Rhizoids, 169
Rhombohedral crystalline shape, **8, 10**
Rhythm, 240
Ripple tank, making and using, **287,** 287–288
Rocks, xiii–xiv, 65–77
breaking down of
into soil, 72–74 (*See also* Soil(s))
by water, 73, 86–87
collecting, 3, 475
effects of temperature changes on, 86
igneous (“fire”), 65–66
indicators for identification of, 71
lodestones, 348–349
metamorphic, 68–70
minerals in, 71–72, **72**
physical characteristics of, 70–71, 76–77
color, 70–71
composition, 71
hardness, 70, 76, **76**
organizing by, 76–77
size, 70, 76–77, **77**
weight, 70
porosity of, 79
sedimentary, 67–68
seriating characteristics of, 76–77, **76–77**
sorting and classification of, 77
Roots of plants
absorption of water and dissolved substances by, 202–203, **203**
anchoring power of, 202
edible, 214
effect of gravity on, 181
growth in the presence of water, 182
location on stems, 170–171, **171**
prop root systems, 202
Rotary motion, 222
Rubbing objects
electrical charging caused by, 319–320, 324, 337
to produce heat, 297

S

Safety precautions, xi, 448–450
ground fault interrupter (GFI) circuits, 100–102, 103
warning against looking directly at Sun, 270, 377, 383
Salamanders, 156, 201
Salinity, as source of ocean currents, 102, **102**
Salt
deposits on Earth’s surface, 87
recovering from ocean water, 109
Saltwater, 91. *See also* Oceans and ocean water
Sand
in aquariums, 9, 197–198
measuring heat produced by motion in, 297–298, **298**
minerals in, 72, **72**

on seashore, 105–106
Sandstone, 67–68, 72, 73
Saturation, 40
Saturn
moons revolving around, 378
revolution period of, **401**
scaling diameter and distance from Sun, **391**
temperature and distance from Sun, **392**
Saxophones, 267
Schist, 68–69
Science for All Americans, ix
Scientific literacy, ix–x
Screws, 424
Seasonal changes, 396–397
leaf colors, 185
Secchi disk, making and using, **96,** 96–97
Second-class levers, 409–410
characteristics of, 409, **409**
determining numerical patterns using, 409, **409**
finding examples of, 409–410
Sedimentary rocks, 66–67
Seeds, 166, 169–170
classification of, 175–176
by methods of dispersion, 176, 207
collection of, 207, 474
dicotyledons, 170, **170**
external parts of, 169
germination of, 166, 176–181
drawing pictures of, 178, **178**
growth rate of germinating seed, 178
light and, 180
percentage or ratio of, 176–177, **177**
planting depth and, 180–181
seed position in soil and, 181
soaking seeds to speed process of, 467–468
soil and, 180
strength of germinating seed, 179
temperature effects on, 179–180, 305
time required for, 177–178, 468, **468**
water for, 179
internal parts of, 170, **170**
monocotyledons, 170, **170**
numbers of seeds in pods, 175, **175**
for outdoor planting areas, 471
for planters, 467–468
planting of, 468
seriating characteristics of, 174–175
watering of, 468–469
Seismograph, making and using, 89–90, **90,** 282
Self-pollination, 206
Serpentine, **72**
Sextant, constructing, 459, **459**
Shadows, 395–396
Shale, 67–68
610 Safety Precautions, xi
Slate, 68–69
Slope, clinometer for measurement of, 83, **83**
Smell (odors), 48
animals' responses to, 163–164
classifying liquids by, 24–25
human detection of, 163–164
identification of gases by, 48
identification of solids by, 4
Snails, 155
in aquariums, 199
response to gravity, 164
response to sound, 163
response to touch, 163
responses to heat, 165
Snakes, 158, 201
Snowfall, 132–133
Soft water, 41
Soil(s), 72–74
amounts of airspace in, 79–80, **80**
breaking down of rocks into, 73–74
carried and deposited by water, 83–84
erosion due to, 84–85, **85**
decay of organic materials in formation of, 74–75, **75**
effect on seed germination, 180
nonorganic and organic components of, 72–73
nutrients for plant growth in, **75,** 75–76, 167
observing wind movement across, 77
for outdoor planting areas, 470–471
for planters, 467
porosity of, 79–82, **80–81**
position of seed in, 181
roots holding plants in, 202
temperature differences of soils receiving direct and slanted solar energy, 134–135
testing compaction of, 81, **81**
water absorption by, 80–82
water evaporation from, 117–118
Soil containers for plants, preparing, 466–469
large containers, 469, **469**
small containers, 466–469

Soilless containers for plants, constructing, 465–466
Solar eclipse, 395, 398–399
Solar radiation. *See* Sun
Solar system, 378. *See also* Astronomy
  different theoretical models of, 400
  heliocentric theory of, 399–400, **400**
  model to compare sizes and distances between objects in, 389–390, **391**
  Sun-centered model of, 400–401, **401**
Solids, 2–16
  atomic particles making up, 370
  characteristics of, 2–14
  classifying characteristics of, 12
    by sight, 12
    tests for, 13–14, **13–14**
    by touch, 12, 13
  conduction of heat by, 11, 306–307
  expansion and contraction of, 11, 299–301
    breakage due to, 301
    making adjustments for, 301
    measurement of, 300, **300**
    wires, 300
  identification by shape, 7
    crystals, 7, **8–10**
  indicators for identification of, 5–7, **6**
  interactions of, 14–16
    dissolving in water, 14–15
    polluting air, 15–16, **15–16**
    polluting water, 15
  magnetizing of, 12
  measuring heat produced by motion in, 297–298, **298**
  measuring size and weight of, 9, 11
  in ocean water, 91
  sensory identification of, 2–5
    hearing, 4
    seeing, 2–3
    smelling, 4
    tasting, 4–5
    touch, 3, **3**
  seriating by physical characteristics of, 12
  solubility of, 5–6, 7, 14–15
  space occupied by, 9
  as state of matter, 2
  travel of sounds through, 11, 251–252, **252**
  using heat to break materials into particles that are too small to be seen, 369
Solubility, 7
Solutions, 40–45
  freezing and boiling temperatures of, 41–42
  making crystals from, 42–43, **42–43**
  ocean water, 91
Solvents, 40–41
Sorting screens for ocean sediments, making and using, 98–99
Sound(s), 240–267
  absorption of, 242, 257–258
  applications related to, 263–267
    percussion instruments, 263–264, **264**
    stringed instruments, 264–266, **265–266**
    wind instruments, 266–267
  causing objects to vibrate, 255–256
    forced vibrations, 255–256
    sympathetic vibrations, 256, **256**
  characteristics of, 240–244
  classification of, 244, **245**
  communicating nonverbally with, 427–428
  controlling direction of, 256–257, **257**
  creating sound effects, 248
  grouping of, 244
  hearing through a telephone receiver, 431
  hearing through air, 253–254
  hearing through solid materials, 11, 251–252, **252**
  hearing through water, 252–253
  household, 240
  interactions of, 244–258
  outdoor, 240
  pitch of, 241, 243, **243,** 250–251
    comparing differences in, 250, **250**
    frequency and, 250, 260
    testing factors that influence, 250–251, **251**
  producing different types of, 248
  reflection of, 241–242, 257
  rhythm of, 240
  seriating characteristics of, 242–243, **242–243**
  speed of, 254–255
    compared to speed of light, 255
    estimating distance of a flash of lightening, 255
    measuring speed in air, 254–255
    through different materials, 254
  theory of, 258–262
  transmission by motion of molecules, 261–262, **261–262**

variations in quality of, 241
vibrations causing, 244–251
feeling, 246
making visible, 246, **246,** 258–259, **259**
sensing, 244–246, 258
wavelike patterns of, 246–248, 258–262 (*See also* Waves: sound)
volume of, 240–241, 242, **242,** 248–250
effect of distance on, 248–249
testing factors that influence, **249,** 249–250
South Pole, 134
Sow bugs, 150, 152
Space science. *See* Astronomy
Space vehicles, **445,** 445–446
insulating and reflective materials for protection of, 445–446
making a model of an orbiting vehicle, 445, **445**
Specific gravity, 26–28
comparing liquids by, 28–29
hydrometer for measurement of, 27–28, **28**
Spectroscope, making and using, 270, 385
Speed
of flowing water, 82
of light, 276, 288
compared to speed of sound, 255
of moving object, 220, 223–225
defining uniform motion, 224–225, **224–225**
graphing uniform rates of motion, **223,** 223–224
increasing and decreasing rates of, 225, **225**
momentum related to mass and, 235–237, **236, 237**
seriating motions by rate of, 226
of sound, 254–255
compared to speed of light, 255
estimating distance of a flash of lightening, 255
measuring speed in air, 254–255
through different materials, 254
of wind, 120–123, **121–123**
Spiders, 150, 152–153, 276
Spore prints, 168
Spores
fern, 166, 167
mold, 191, 193, **193**
mushroom, 168
Spring scale, making, 460–461, **461**
Stalactites and stalagmites, 88
Standards for science education, ix–x
Stars
Alpha Centauri, 390
apparent movement of, **394,** 394–395
constructing a spectroscope to determine composition of, 385
determining temperatures of, 384
difference from planets, 377
light-years to measure distance to, 390
making a constellation projector, 383
North Star (Polaris), 390, 394
instruments to determine altitude of, 378.**378**
locating, 378
star maps to locate constellations, 379, **379–382**
States of matter, 302
liquids, 17–45
model to explain changes of, 316–317
observing changes of, 2, 17, 46–47
phase transformations due to addition or removal of heat, 302–303
solids, 2–16
Steam pressure, action and reaction caused by, 43
Steam turbine, making a model, 318, **318**
Stems of plants, **171,** 171–172, 203
annual rings in woody stems, 172–173
arrangements of flowers on, 174, **174**
comparing grains in woody stems, 173
effect of gravity on, 181
external characteristics of, 171–172, **171–172**
internal characteristics of, 172–173
leaf locations and patterns on, **173,** 173–174
location of root growth on, 170–171, **171**
researching how people use, 215
response to light, 182–183
Stethoscope, 257
Straight-line motion, 220–221
Streak test to identify minerals, 72
Stringed instruments, 264–266, **265–266**
Subliming, 303, 305
Submarines, 109, **109**
Sun
apparent motion of, 393
atmospheric shielding of Earth's surface from solar radiation, 135–136

conversion of solar energy to heat energy, 112
eclipse of, 395, 398–399
effect of solar energy upon a curved surface, 134
how solar energy strikes Earth's surface, 133–134
measuring size of, 383, **383**
model to compare sizes and distances between planets, Moon and, 389–390, **391**
model to represent distances between planets and, 383–384, **384**
observing, 383
orienting a model of the Earth to, 396
revolution of planets around, 377
as source of heat, 296–297
comparing differences in temperatures from the Sun, 297
focusing and reflection of radiant heat energy, 314–315
focusing Sun's rays to produce high temperatures, 297
as source of light, 273
comparing candlelight to sunlight, 274
making an using a sundial, **395,** 395–396
making and using a Sun clock, 396, **396**
Sun-centered model of the solar system, 400–401, **401**
warning against looking directly at, 270, 377, 383
Sun clock, making and using, 396, **396**
Sunburn, 296
Sundew plant, 205
Sundial, making and using, **395,** 395–396
Support stands, construction of, 451–452, **451–452**
Surface tension of liquids, 19–24, **20–22**
Sympathetic vibrations, 256, **256**

T

Tadpoles, 156–157
Talc, **72, 76**
Tambourines, 264
Technology and engineering, xx, 404–434
communications, 427–434
machines, 404–426
transportation, 435–446
Telegraph
building and using a model system, 430–431, **431**
building and using a simple telegraph key, 428, **428**
Telephone
building and using a model system, **431,** 431–432
hearing sounds through a telephone receiver, 431
simple, making and using, 428
Telescope, constructing and using, 377, **377**
Temperature(s)
of air
conversion of solar energy to heat energy, 112
at different altitudes, 112
measurement and graphing of, 111–112, **111–112**
relationship of wind direction to, 145, **145**
differences between heat and, 295–296, 317, **317**
effect of Earth's tilt on balance of, 133–135
effect of moving moist air on, 125–126
effect on insect metamorphosis, 306
effect on seed germination, 179–180, 305
freezing and boiling temperatures of solutions, 41–42
insulating and reflective materials to protect space vehicles from, 445–446
measurement of, 293–295
air thermometer for, 294–295, **295**
copper-wire thermometer for, 295, **295**
liquid thermometer for, 111, 294
making thermometer for, 460
standardization of, 293
seriating planets by, 392, **392**
of stars, 384
from the Sun, 297
of water
in aquarium, 101, 198, 199, 295–296
water currents and layers of water, 101
water weight and, 100
Temperature changes
animals' responses to, 164–165
hibernation, 165
breaking down of rocks by, 73–74, 86
effect on air movement, 64, 124, **124,** 125–126, 136–138, **137**
effect on condensation, 127–128, 303, 305
effect on evaporation, 125, 303–304, **304**

effect on growth of microorganisms, 195–196
effects on growth of yeast, 192
expansion and contraction of materials due to, 299–302, 316
gases, 54, 59, 301–302
liquids, 19, 301
solids, 11, 299–301, **300**
sensitivity of microorganisms to, 187–188
Tensiometer, making and using, **20–21,** 20–22
Terrariums
animals in, 153, 155–159, 162, 165, 210, 201–202
building, 201–202, 472–473
desert environment, 201–202
heat source in, 165
plants in, 168, 169, 201–202
swamp environment, 201
woodland environment, 201
Test-tube stands, construction of, 452, **452**
Tetragonal crystalline shape, **8, 10**
Thermometers
Celsius, 294
Fahrenheit, 294
making and using, 460
air thermometer, 294–295, **295**
copper-wire thermometer, 295, **295**
liquid thermometer, 111, 294
measuring temperatures with, 293–294
observing how temperatures affect, 293
Third-class levers, 410–411
characteristics of, 410, **410**
determining numerical patterns using, 410
Tidal basin, 105
Tides, 104–105
determining changes in water levels at shorelines, 104
produced by the Moon, **104,** 104–105
Time
and distance, as characteristics of motion, 220
making and using a sundial, **395,** 395–396
making instruments for measurement of, 464
pendulum clock, 464, **464**
water clock, 464
required for seed germination, 177–178
Toads, 156–157, **157,** 201
Topaz, **76**
Tornadoes, 106, **137,** 137–138
Tortoises, 158, 159
Touch
animals' responses to, 162–163
classifying solids by, 12, 13
identification of liquids by, 18
identification of solids by, 3, **3**
plants' responses to, 183–184, **184**
Translucent materials, 276–277
Transparent materials, 276
travel of radiant heat through, 312
Transportation, 435–446
complex vehicles, 436–446
aircraft, 437–445, **437, 439–441, 443–444**
space vehicles, **445,** 445–446
simple vehicles, 435–436
building a vehicle to travel in air, 435–436, **436**
building a vehicle to travel on land, 435, **435**
building a vehicle to travel on water, 435, **435**
Triclinic crystalline shape, **9, 10**
Trombones, 267
Tsunami, 104
Tuning fork, **247,** 247–248, 255, 256, **256**
Turtles, 158, 159, 201

U

Ultraviolet radiation, 289
Uniform motion, 223–225
defining, 224–225, **224–225**
graphing, **223,** 223–224
Universe. *See also* Astronomy
constructing a telescope to view objects in, 377, **377**
defining types of objects in, 377–378
making a constellation projector, 383
seriating objects in, 390–393, **392**
solar system, 378
different theoretical models of, 400
heliocentric theory of, 399–400, **400**
model to compare sizes and distances between objects in, 389–390, **391**
Sun-centered model of, 400–401, **401**
star maps to locate constellations, 379, **379–382**
Uranus
moons revolving around, 378
revolution period of, **401**

scaling diameter and distance from Sun, **391**
temperature and distance from Sun, **392**

V

Vehicles. *See* Transportation
Venus, 389
revolution period of, **401**
scaling diameter and distance from Sun, **391**
temperature and distance from Sun, **392**
Venus flytrap, 205
Vibrations
causing sound, 244–251
changing vibrations into wave pictures, 247, **247**
feeling, 246
making vibrations visible, 246, **246,** 258–259, **259**
seismograph for detection of, 89–90, **90,** 282
sensing, 244–246, 258
wavelike patterns of, **246,** 246–248, **247,** 258–262
forced, 255–256
sympathetic, 256, **256**
Violins, 265, **265**
Viscosity of liquids, 36–37, **37**
Vivariums, 472. *See also* Aquariums; Terrariums
Volcanoes, 65, 90, 108
Voltage produced by electric cells, 335–336
switches to control circuits and, 336–337
Volume
of gases, 55, **55**
air volumes in relation to burning times, 55–56, **56**
comparing gases by weight and, 56
of liquids, 25–26
of sound, 240–241, 248–250
effect of distance on, 248–249
testing factors that influence, **249,** 249–250
von Leeuwenhoek, Anton, 189

W

Warm fronts, 139–141, **140–141**
Water. *See also* Liquids
absorption of
by plant roots, 202–203, **203**
by soil and rocks, 79–82, **80–81**
breaking down of rocks by, 73, 86–87
building a vehicle to travel on, 435, **435**
buoyancy of, 32–35, **33**
ocean water vs. freshwater, 92
changes in materials on Earth's surface by, 87–88
condensation of, 17, 46, 126–133, 304–305
detecting solids in, 15
effect on mold growth, 187
evaporation of, 17, 45, 46, 117–118, 303–304, **304**
extracting pure water from ocean water, 109, **109**
flowing, 82–86
erosion due to, 84–85, **85**
from high to lower places on Earth's surface, 82–83
materials carried and deposited by, 83–84
measuring speed of, 82
wave action along a shoreline, 85, **85**
freezing of, 2, 41–42, 302–303
breaking of rocks by, 86–87
hard, 41
light reflected by particles in, 283
living organisms in
amphibians, 156–157, **157**
crustaceans, 151
fish, 155–156
insects, 154
mollusks, 155
in ocean water, 93–94, 99–100
protozoa, 189–191, **190**
materials that dissolve in, 40
solids, 5–6, 7, 14–15
measuring transparency of, 96–97
molecular model of, 375, **375**
in nimbus clouds, 131
in oceans, 91–109 (*See also* Oceans and ocean water)
for plant growth, 167
in outdoor planting areas, 471
in planters, 468–469
root growth in the presence of water, 182
seed germination, 179
removing impurities from, 44–45, **44–45**
soft, 41
sounds traveling through, 252–253
surface tension of, 20–21, 23
temperature of
in aquarium, 101, 198, 199, 295–296

feeling and describing, 293
water currents and layers of water, 101
water weight and, 100
weighing objects in, 33, **33**
weight of, 26–27
temperature and, 100
weight of object suspended in air vs., 92
Water barometer, making and using, 61, **61**
Water clock, making, 464
Water cycle model, 106, **106**
Water filters, 44, **44–45**
Water pollution, 15, 43–45, **44–45**
Water-powered machine that will do work, making, 425–426, **425–426**
Water pressure, 29–32, **29–32**
manometer for measurement of, 30–31, **31**
Water sampler, making and using, 98, **98**
Waterspout, 107
Waterwheel, 38–39, **38–39**
Wave-particle theory of light, 288–290, **289–290**
infrared energy as part of electromagnetic spectrum, 289–290, **290**
light energy as part of electromagnetic spectrum, 288–289, **289**
research on, 288
speed of light, 288
ultraviolet energy as part of electromagnetic spectrum, 289
Waves: light, 285–286, 285–288
travel in transverse waves, 285–286
observing in water, 286–287
water wave model, 286–288
discrepancies in, 288
to explain diffraction, 287
to explain reflection, 287
making and using a ripple tank, **287,** 287–288
Waves: radio
produced from electricity, 341, **341**
travel through water, 290
Waves: sound, 246–248, 258–262
amplitude of, 261, **261**
changing sound vibrations into wave pictures, 247, **247**
comparing longitudinal and transverse waves in a coil, 260, **260**
frequency of, 250, 260
making sound vibrations visible, 246, **246,** 258–259, **259**
producing longitudinal waves of various amplitudes, 261, **261**
producing longitudinal waves of various frequencies, 260
transmission by motion of molecules, 261–262, **261–262**
using spring model to explain echoes, 260
using spring model to represent vibrations as longitudinal waves, **259,** 259–260
Waves on surface of water, 94–95
measuring characteristics of, 94
observation of, 103
observing action of, 85, **85,** 94
produced by earthquakes, **103,** 103–104
produced by wind, 103
water depth and, 94–95
Weather, 111–146
air pressure, 112–114, 113, **113,** 143
air movement and, 113–114, 138
measurement of, 113, **113–114**
air temperature
air currents and, 64, 124, **124**
conversion of solar energy to heat energy, 112
measuring and graphing, 111–112, **111–112**
near the ground, 123–124
relationship of wind direction to, 145, **145**
applications related to, 142–146
climate, 146, **146**
predicting weather changes, 142–146
characteristics of, 111–118
condensation in atmosphere, 126–133
clouds, 129–132
dew, 128
fog, 129
frost, 129, 303
observation of, 127
rainfall, 126–127, **126–127,** 131–132
snowfall, 132–133
temperature changes affecting, 127–128
interactions of, 118–133
air temperature near the ground, 123–124
conditions affecting evaporation, 125–126, 303–304, **304**
return to Earth of condensation in atmosphere, 126–133

wind caused by unequal heating of Earth's surface, 124, **124**
wind direction, 118–120, **119–120**
wind speed, 120–123, **121–123**
ocean effects on, **106,** 106–107
relative humidity, 114–117, **115–117,** 143, 114–118
hygrometer for measurement of, 114–117, **115–117,** 143
theory of, 133–142
air pressure and air movement, 138
atmospheric shielding of Earth's surface from solar radiation, 135–136
differences in heat energy absorption by differently colored materials, 135
effect of Earth's rotation on winds, 138–139
effect of Earth's tilt on balance of temperatures, 133–135
heat trapping in atmosphere, 136
temperature effects on air movement, 64, 124, **124,** 125–126, 136–138, **137**
weather fronts and air masses above Earth, 139–142, **139–142**
Weather prediction, 142–146
air pressure, 143
data collection and recording for, **144–145,** 144–146
preparing a weather station for, **143,** 143–144
wind patterns, 142–143
Weather station, **143,** 143–144
Wedges, 422–424
characteristics of, 422
sensing advantage of, 423–424
varieties of, 422–423
Weeding of outdoor planting areas, 471
Weight(s)
atomic, 368
constructing instruments for measurement of, 460–463
balance scale, **461,** 461–463
spring scale, 460–461, **461**
of gases, 53–54, 56
air, 53
carbon dioxide, 53–54, **53–54**
comparing gases by, 56
of liquids, 19, 26–27
ocean water vs. fresh water, 91–92
making instruments for measurement of, 460–463
of object suspended in air vs. water, 92
of rocks, 70
of solids, 9.11
weighing objects in water, 33, **33**
Wheels and axles, 411–413
characteristics of, 411–412, **411–412**
determining numerical patterns using, 412–413
finding examples of, 412
Whistles, signaling with, 427–428, **428**
Wind. *See also* Air, movement of
breaking down of rocks by, 73
direction of, 118–120, **119–120**
relationship to rainfall, **126–127,** 145, **145**
relationship to temperature, 145, **145**
relationship to weather, **144,** 144–145
effect of Earth's rotation on, 138–139, **139**
effect on evaporation, 125
hurricanes, 106
materials carried and deposited by, 77–78
land surfaces carved and eroded by, 79
measuring speed of, 120–123
anemometer for, 120–122, **121–122**
Beaufort scale of, 123, **123**
observing movement across soil, 77
ocean currents produced by, 102
ocean waves produced by, 103
role in pollination, 206–207
tornadoes, 106, **137,** 137–138
weather changes and patterns of, 142–143
Wind instruments, 266–267
Wind sock, making and using, 119, **119**
Wind tunnel, building and using, **436,** 436–437
Wind vane, 142
making and using, 118–119, **119**
Wires
copper-wire thermometer, 295, **295**
examining resistance to electricity in, 333
expansion when heated, 300
glowing, as light source, 273–274
influence of wire size on electrical conductivity, 332–333, **332–333**
making a holder for a D-cell battery and preparing wires for use in a circuit, 327–328, **328**

overheating due to overloading a circuit with too many resistors, 334, **334**
Work, 424–425
complex machines to do, 425–426
definition of, 424–425
measurement of, 425
Worms
camouflage characteristics of, 212
respiration in, 208, 210
response to light, 164, 276
response to smell, 163
response to touch, 162–163
responses to cold, 164
segmented, 149–150, **150**
training of, 215–217, **216**
Written messages
devices for coding and decoding, 429, **429**
in "invisible ink," 427

X
Xylophones, 263, **264**

Y
Yeast(s), 186, 191–192
for bread making, 192, 195
budding of, 193–194, **194**
culture of, 187
culturing of, 191–192
fermentation of, 195
growth of, 186
effect of temperature changes on, 192
food for, 187

Z
Zither, 266
Zoology, 148–165. *See also* Animals

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