### Chart 1. Science Process/Knowledge and Developmental Stages

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<td>6–9</td>
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<td>Ba Describing, Speaking, Sounding</td>
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<td>Bb Formulating Operational Definitions</td>
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<td></td>
<td>Bc Recording, Tabling, Writing</td>
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<td>Bd Researching the Literature, Reading, Referencing</td>
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<td></td>
<td>Be Picturing, Drawing, Illustrating</td>
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<td>C COMPARING</td>
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<td></td>
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<td>F INFERRING</td>
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<td></td>
<td>Fa Generalizing, Synthesizing, Evaluating</td>
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<td>Fb Using Indicators, Predicting</td>
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<td>G APPLYING</td>
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<td>Ga Using Knowledge or Instruments, Identifying Examples</td>
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<td>Gb Inventing, Creating</td>
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<td>Gc Constructing</td>
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<td></td>
<td>Gd Growing, Raising</td>
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<td></td>
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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

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.

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

Table 141.22. Hardness Sorting Key—Rocks

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

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.

<table>
<thead>
<tr>
<th>100 Inorganic Matter</th>
</tr>
</thead>
<tbody>
<tr>
<td>110 Solids</td>
</tr>
<tr>
<td>120 Liquids</td>
</tr>
<tr>
<td>130 Gases</td>
</tr>
<tr>
<td>140 Earth Science</td>
</tr>
<tr>
<td>150 Oceans</td>
</tr>
<tr>
<td>160 Weather</td>
</tr>
</tbody>
</table>

### 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:

<table>
<thead>
<tr>
<th>300 Energy</th>
</tr>
</thead>
<tbody>
<tr>
<td>340 Heat</td>
</tr>
<tr>
<td>341 Characteristics</td>
</tr>
<tr>
<td>342 Interactions</td>
</tr>
<tr>
<td>343 Theory</td>
</tr>
<tr>
<td>344 Applications</td>
</tr>
</tbody>
</table>

### 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
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
   Aa ← Seeing
   Ab ← Feeling
Ae ← Hearing
Ad ← Smelling
Af ← 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.

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

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

Generalization II:  Current electricity produces a magnetic field.

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

Contribution 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.

Contribution Idea A:  Current electricity can be detected.

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

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

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

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

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

Contribution 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.

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

Contribution 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
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
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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References


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.

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

<table>
<thead>
<tr>
<th>Week of _____________________________</th>
<th>Morning</th>
<th>Afternoon</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>41°F (5°C)</td>
<td>48°F (9°C)</td>
</tr>
<tr>
<td>Tuesday</td>
<td>32°F (0°C)</td>
<td>45°F (7°C)</td>
</tr>
<tr>
<td>Wednesday</td>
<td>43°F (6°C)</td>
<td>50°F (10°C)</td>
</tr>
<tr>
<td>Thursday</td>
<td>45°F (7°C)</td>
<td>59°F (15°C)</td>
</tr>
<tr>
<td>Friday</td>
<td>48°F (9°C)</td>
<td>68°F (20°C)</td>
</tr>
</tbody>
</table>
A 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.

**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.

**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.

**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.

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.

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.

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

Figure 161.06
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.

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

---

**Table 161.07. Measuring Air Pressure**

<table>
<thead>
<tr>
<th>Week of</th>
<th>a.m.</th>
<th>p.m.</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td>rising</td>
<td>falling</td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wednesday</td>
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<tr>
<td>Thursday</td>
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<tr>
<td>Friday</td>
<td></td>
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</tr>
</tbody>
</table>

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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

| Difference Between Dry Bulb and Wet Bulb Temperatures in Degrees Fahrenheit |
| 10 | 56 | 34 | 13 |
| 15 | 78 | 56 | 34 | 13 |
| 20 | 82 | 64 | 46 | 29 | 11 |
| 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.

**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.

**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

<table>
<thead>
<tr>
<th>Table 161.10. Measuring Humidity (Wet and Dry Bulb Hygrometer)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Week of</strong></td>
</tr>
<tr>
<td>Monday</td>
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<tr>
<td>Tuesday</td>
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<td>Wednesday</td>
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<tr>
<td>Thursday</td>
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<tr>
<td>Friday</td>
</tr>
</tbody>
</table>
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).

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.

**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 (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
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.

*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.

- **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).

<table>
<thead>
<tr>
<th>Table 162.03. Recording Wind Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Week of _____________________________</td>
</tr>
<tr>
<td>Monday</td>
</tr>
<tr>
<td>Tuesday</td>
</tr>
<tr>
<td>Wednesday</td>
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<td>Thursday</td>
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<tr>
<td>Friday</td>
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</tbody>
</table>

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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
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.

<table>
<thead>
<tr>
<th>Week of</th>
<th>a.m.</th>
<th>p.m.</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monday</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tuesday</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Friday</td>
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</tr>
</tbody>
</table>
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.

Contribution 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.

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

**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.

**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.
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.

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.)

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.

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...
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.

**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.

**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.

*Contributing Idea B. Water condenses.*

<table>
<thead>
<tr>
<th>Date</th>
<th>Direction of Wind During Rainfall</th>
<th>Amount of Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
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</table>
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).

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.

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
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.

*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, 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.)
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.

Contribution 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.

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.

Contribution 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.
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.

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
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
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

<table>
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<th>Table 162.28. Seriating Raindrops by Size</th>
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<tr>
<td>Small Drops</td>
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<td>Number of drops in 3 seconds at the beginning of the storm.</td>
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<tr>
<td>Number of drops in 3 seconds in the middle of the storm.</td>
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<tr>
<td>Number of drops in 3 seconds near the end of the storm.</td>
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Copyright © 2012 NSTA. All rights reserved. For more information, go to www.nsta.org/permissions.
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.

**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.

**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*
**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.

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

**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.

*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
Inorganic Matter / Weather

Inorganic Matter / Weather

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 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.

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.
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.)

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. Place the hot plate on the tray. 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,
above the boiling water. (A real tornado is formed similarly due to convection currents.)

**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.

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
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-
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).

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 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):

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
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).

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.

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.
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.

Preparation of 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

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**Table 164.01.** Relating Humidity to Weather Changes

<table>
<thead>
<tr>
<th>Condition</th>
<th>Before Front</th>
<th>During Front</th>
<th>After Front</th>
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<tbody>
<tr>
<td>Warm Front</td>
<td>Increasing</td>
<td>very moist</td>
<td>slight decrease</td>
</tr>
<tr>
<td>Cold Front</td>
<td>Steady</td>
<td>very moist</td>
<td>rapid decrease</td>
</tr>
</tbody>
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![Figure 164.02](Figure_164.02.png)
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.

**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.

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>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Temperature</th>
<th>Barometer Reading (air pressure)</th>
<th>Hygrometer Reading (humidity)</th>
<th>Air Direction</th>
<th>Air Speed</th>
<th>Rainfall</th>
<th>Types of Clouds</th>
<th>Weather Prediction</th>
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</table>
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.

**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).

### Table 164.04. Collecting Monthly Averages of Weather Factors

<table>
<thead>
<tr>
<th>Month</th>
<th>Average Temperature</th>
<th>Average Humidity</th>
<th>Average Rainfall</th>
<th>Average Snowfall</th>
<th>Sunny Days</th>
<th>Cloudy Days</th>
<th>Windy Days</th>
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<td>How many times “high”</td>
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