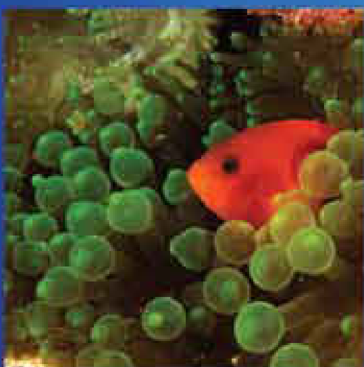
Project Earth Science

PHYSICAL OCEANOGRAPHY

REVISED SECOND EDITION



By Alfredo L. Aretxabaleta,
Gregg R. Brooks,
and Nancy W. West

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National Science Teachers Association

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Readings

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Project Earth Science provided inservice education for and by middle school Earth science teachers in North Carolina. Activities and Reading in this book underwent several revisions as a result of suggestions provided by PES teacher-leaders, principal investigators, and the project staff and consultants. PES leaders made this book possible through their creativity and commitment to the needs of students and classroom teachers. Brent A. Ford and P. Sean Smith were the authors of the first edition and were part of the PES team.

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Introduction

Project Earth Science: Physical Oceanography is one of the four-volume Project Earth Science series. The other three volumes in the series are *Astronomy, Geology,* and *Meteorology.* Each volume contains a collection of hands-on Activities developed for middle-level students plus a series of Readings intended primarily for teachers, but that could also be useful to interested students.

Additions and Changes to Revised 2nd Edition

The Activities and Readings sections have been rewritten to improve clarity and scientific currency, and to suggest additional teaching and learning strategies. The Resources section at the back of this book has been updated. At the beginning of each Activity, there is now a Planner to quickly provide information about that Activity. Material specifically for students, and material specifically for teachers, is more clearly delineated. There are new sections for students within Activities entitled What Can I Do? and Fast Fact. Additional new sections included for teachers are How Do We Know This?, Safety Alert!, Connections, Differentiated Learning, and Assessment.

Within each Activity, there now is a section for teachers titled Preconceptions. A preconception is an opinion or view that a student might have prior to studying a particular topic. These opinions may not be accurate because the student does not have the correct information or does not understand that information. Each possible preconception that we list with each Activity actually is a misconception. Asking students about their preconceptions at the outset of a new instructional topic can provide useful information about what students already know and what misinformation needs to be corrected so they can have a good understanding of the topic. The preconceptions we list are, of course, only examples of incorrect ideas that some students might have. Most groups of students are imaginative enough to come up with many other preconceptions!

About *Project Earth Science: Physical Oceanography*

This book is divided into three sections: Activities, Readings, and Resources. The Activities in this volume are organized under three broad concepts. First, students investigate the unique properties of water and how these properties shape the ocean and the global environment. Second, students perform Activities investigating the complex systems that lead to the development of currents, waves, and tides. This section focuses on the interactions of wind, water, gravity, and inertia. In the third section, students study the impacts that humans have on the ocean and the marine environment, particularly the effects of pollutants.

An understanding of the concept of density is required for several of the Activities contained in this volume. The Activities are written with the assumption that students have this understanding. The Preconceptions sections are designed to reveal what students actually do understand about density. If their responses indicate a shaky grasp of density, Differentiated Learning offers suggestions for consolidating their knowledge. The series of Activities also provides additional concrete experiences for students to gain mastery in an intuitive way.

At the back of this book, there is also a section on how to construct a wave tank.

A series of overview Readings supports the Activities. By elaborating on concepts presented in the Activities, the Readings are intended to enhance teacher preparation and serve as additional resources for students. The Readings also introduce supplemental topics so that you can link contemporary science to broader subjects and other disciplines.

The Resources provide supplemental materials. The Resources section includes government agencies, organizations, aquaria, coastal reserves, and media. These are annotated and contain the necessary information for gaining access to them.

Creating Scientific Knowledge

Project Earth Science: Physical Oceanography presents a variety of opportunities for you to discuss the creation and evolution of scientific knowledge. For example, students might consider

- how models help develop—yet sometimes restrict—our conceptions of nature
- how scientific knowledge changes over time
- how our choice of measurement scale affects our perceptions of nature and of change

Models and analogies are extremely effective tools in scientific investigation, especially when the subject under study proves to be too large, too small, or too inaccessible for direct study. Although Earth scientists often use models, students must be reminded that models are not perfect representations of the object or phenomenon under study. It is essential that students learn to evaluate models for strengths and weaknesses, such as which phenomena are accurately represented and which are not. When using models, it is good to discuss both their advantages *and* their limitations.

As students learn science, it is easy for them to lose sight of the fact that scientific knowledge evolves. As scientists gather more data, test hypotheses, and develop more sophisticated means of investigation, their understanding of natural phenomena often changes.

With growing information from new technology and expanded understanding, scientific knowledge changes: what seemed impossible to many at the start of the 20th century is accepted in the 21st century. You should emphasize this changing nature of science—it is what makes scientific inquiry special as a form of knowledge—and encourage students to investigate in more detail how scientific knowledge evolves.

Observing and the Problem of Scale

Central to understanding how science evolves is appreciating the limits of our perceptions of change. We observe the world as it *is*, and our thoughts about how it *was* and how it *could be* tend to be quite restricted. That our world is changing constantly can be a difficult concept for students to accept. In several respects, this is a function of the rate at which change sometimes occurs compared to the length of time available to humans for direct observation.

To illustrate this point, ask students to consider the life of an insect that spends its entire existence—from June to August of a single year—in an oak tree. As outside observers, humans can observe seasonal and annual changes in the tree's biology. Due to the relatively short duration of its life, the insect cannot observe these changes.

Likewise, due to the relatively short span of our lifetimes compared to geologic time, people have difficulty appreciating the changes taking place on a million-year scale. The shape of ocean basins change as continents move centimeters per year; average global temperatures may change only a few degrees over thousands of years; sea level changes by millimeters per year. Changes such as these may be imperceptible during a single human life span. It is important for students to understand that while observing these changes may be difficult, Earth is continually changing. Comparing events and changes on different scales can be a difficult concept for students to grasp.

Also, diagrams and models often exaggerate or compress relative sizes to make a certain point more obvious or to make the model small enough to be practical. Sometimes one scale is changed, but others are not. For example, displays of our solar system often accurately depict the relative *distances* between planets but misrepresent planets' relative *sizes*. In oceanography, physical models that are built with an exaggerated vertical scale distort features such as the slope of the continental shelf. It is important for you to discuss the concept of scale and encourage students to raise questions about the various measurement scales used in these Activities.

Getting Ready for Classroom Instruction

The Activities in this volume are designed to be hands-on. In developing them, we tried to use materials that are either readily available in the classroom or inexpensive to purchase. Note that many of the Activities also could be done as demonstrations.

Each Activity has two sections: a Student section and a Teachers' Guide. Each student section begins with Background information to explain briefly, in nontechnical terms, what the Activity is about; the Objective states what students will learn. Then there is Vocabulary, which includes important oceanographic terms students should know. This is followed by a list of the Materials needed and an estimate of the amount of Time that the Activity will take. Following this introduction is a step-by-step Procedure outline and a set of Questions and Conclusions to facilitate student understanding, encourage constructive thinking, and advance the drawing of scientific conclusions.

Each Student section concludes with additional activities for students in What Can I Do? Safety Alert! appears throughout to warn students about dangers in given Activities. Fast Facts, which also appear throughout, are tidbits of information to intrigue students or to provide particulars that will support the Activities. At the end of most Student sections, there are one or more reproducible BLMs (Black Line Masters) for students to fill out.

The Teachers' Guide contains a What Is Happening? section—a more thorough version of the background information given to students. The How Do We Know This? section explains techniques or research methods that oceanographers currently use to generate knowledge related to the Activity. This is followed by a section of possible student Preconceptions, which can be used to initiate classroom discussions. Next comes a summary of What Students Need to Understand, and Time Management discusses the estimated amount of time the Activity will take. The Objective section spells out what students do and learn, while Key Concepts ties the content of the Activity to categories of oceanographic content described on page xii. Preparation and Procedure describes the setup for the Activity. In some cases, we suggest other ways to do the Activity in a section titled Alternative Preparation. Some Activities could be done as a demonstration, for instance, although we advocate giving students the opportunity and responsibility for doing the Activities. Activity 13, on the other hand, involves a large wave tank and is only practical to do as a demonstration.

To challenge students to extend their study of each topic, a section on Extended Learning is provided. For relating the science in each Activity to other disciplines, such as language arts, history, and social sciences, there is a section on Interdisciplinary Study. Connections is a margin feature that links physical oceanography to a similar process or concept in astronomy, geology, or meteorology. The final portion of each Teachers' Guide includes possibilities for Differentiated Learning, Answers to Student Questions, and suggestions for Assessment.

Although the scientific method often is presented as a "cookbook" recipe—state the problem, gather information, form a hypothesis, perform experiments, record and analyze data, and state conclusions—students should be made aware that the scientific method provides an approach to understanding the world around us, an approach that is rarely so straightforward.

For instance, many factors can influence experimental outcomes, measurement precision, and the reliability of results. Such variables must be taken into consideration throughout the course of an investigation.

As students work through the Activities in this volume, make them aware that experimental outcomes can vary and that repetition of trials is important for developing an accurate picture of concepts they are studying. By repeating experimental procedures, students can learn to distinguish between significant and insignificant variations in outcomes. Regardless of how carefully they conduct an experiment, they can never entirely eliminate error. As a matter of course, students should be encouraged to look for ways to eliminate sources of error. However, they also must be made aware of the inherent variation possible in all experimentation.

Finally, controlling variables is important in maintaining the integrity of an experiment. Misleading results and incorrect conclusions often can be traced to experimentation where important variables were not rigorously controlled. You should encourage students to identify experimental controls and consider the relationships between the variables under study and the factors held under control.

Key Concepts

The Activities are organized around three key concepts: the investigation of water and its properties; how the ocean varies spatially and processes that move water vertically and horizontally; and the human impact on Earth's ocean.

Key Concept I: Properties of water
Although water is a common substance, many of its familiar characteristics make it unique among molecules. Its special properties lead to the characteristics of Earth's ocean that make the planet uniquely life-bearing among its neighbors in the solar system. An awareness of the chemical structure and physical characteristics of water underlies an understanding of its importance on Earth.

Key Concept II: Ocean structure and water movement
Movement of water within the ocean occurs through the development of currents, waves, and tides. Deep ocean currents are caused by variations in ocean water density; surface currents result mainly from wind. Waves represent energy in motion and result primarily from the wind as well. Tides are produced by the interaction of forces involving Earth, the Sun, and the Moon.

Key Concept III: Impact of human activities on the ocean
Human activities have an impact on Earth's ocean. The effects are long-lasting and sometimes irreversible.

Project Earth Science: Physical Oceanography and the *National Science Education Standards*

An organizational matrix for the Activities in *Project Earth Science: Physical Oceanography, Revised 2nd Edition*, appears on pages xvi–xvii. The categories listed along the *x*-axis of the matrix, listed below, correspond to the categories of performing and understanding scientific activity identified as appropriate by the National Research Council's 1996 *National Science Education Standards*.

Subject and Content: Specifies the topic covered by an Activity.

Scientific Inquiry: Identifies the "process of science" (i.e., scientific reasoning, critical thinking, conducting investigations, formulating hypotheses) employed by an Activity.

Unifying Concepts and Processes: Links an Activity's specific subject topic with "the big picture" of scientific ideas (i.e., how data collection techniques inform interpretation and analysis).

Technology: Establishes a connection between the natural and designed worlds.

Personal/Social Perspectives: Locates the specific oceanography topic covered by an Activity within a framework that relates directly to students' lives.

Historical Context: Portrays scientific endeavor as an ongoing human enterprise by linking an Activity's topic with the evolution of its underlying principle.

Project Earth Science: Physical Oceanography hopes to address the need for making science—in this case, physical oceanography—something students do, not something that is done to students. The Standards Organizational Matrix on pages xvi–xvii provides a tool to assist you in realizing this goal.

Safety in the Classroom Practices

The teaching and learning of science today through hands-on, process, and inquiry-based activities make classroom and laboratory experiences effective. Addressing potential safety issues is critical to securing this success. Although total safety cannot be guaranteed, teachers can make science safer by adopting, implementing, and enforcing legal standards and best professional practices in the science classroom and laboratory. Safety in the Classroom Practices includes both basic safety practices and resources. It is designed to help teachers and students become aware of relevant standards and practices that will help make activities safer.

1. When working with glassware, wires, projectiles, or other solid hazards, students should use appropriate personal protective equipment, including safety glasses or goggles, gloves, and aprons.
2. When working with hazardous liquids, indirectly vented chemical splash goggles, gloves, and aprons must be used.
3. Always review Material Safety Data Sheets (MSDSs) with students relative to safety precautions when working with hazardous chemicals.
4. When dealing with hazardous chemicals, an eyewash station within 10-second access is required because of the possibility of a splash accident in the eyes. If there is potential for a body splash, an emergency shower is required within 10-second access.
5. Make sure appropriate laboratory ventilation is used when working with hazardous vapors, fumes, or particulates.
6. Use caution when working with flammables like alcohol. Keep away from flames or sources of sparks. An explosion can occur.
7. When heating liquids other than water, use only heat-resistant glassware (Pyrex- or Kimax-type equipment). Remember that glass labware is never to be placed directly on heating surfaces. Also remember that hot containers are potential hazards. Water may be heated in glassware, but teapots or other types of pans also may be used.
8. When heating liquids on electrical equipment such as hot plates, use ground-fault-protected circuits (GFI). Keep electrical equipment away from water or other liquids—electrical shock hazard.
9. Always remind students of heat and burn hazards when working with heat sources such as hot plates for melting wax, heating water, and more. Remember that it takes time for the hot plate and the objects heated on the hot plate to cool.
10. Lightbulbs can get hot and burn skin. Handle with care.
11. Use caution when working with hot water—it can burn skin.
12. Use caution when working with scissors, wire, or other sharp objects—cut or puncture hazards.
13. If a relatively harmless liquid (e.g., water, dilute chemical) is spilled on the floor, always wipe it up immediately to prevent slip and fall hazards. However, if a spilled liquid (e.g., concentrated acid) is causing, or has the potential to produce toxic fumes, the classroom or lab must be vacated and appropriate emergency authorities called immediately. Teachers must know in advance what to do in this type of emergency.
14. Never consume food or drink that has been either brought into or used in the laboratory.
15. Make sure that all food (e.g., sugar) is disposed of properly so that it does not attract rodents and insects in the lab or classroom.

16. Teachers should always model appropriate techniques before requiring students to cut, puncture, or dissect, and so on.
17. Wash hands with soap and water after doing activities dealing with hazardous chemicals.
18. Markers can have volatile organic compounds (VOCs) that can irritate the eyes, nose, and throat. Use in well-ventilated areas, or use only low-VOC markers.
19. Clear the area of falling or tripping hazards such as desks, other furniture, or equipment before conducting activities that require open floor space (e.g., Activity 11).
20. Know the source for any materials used in this Activity. Never use garbage or other refuse. Also check for mold or fungi. Some students are allergic to these organisms.

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*

Standards Organizational Matrix

Activity	Subject and Content	Scientific Inquiry	Unifying Concepts and Processes
Activity 1 A Pile of Water	Surface tension and cohesion of water	Exploring, estimating, and predicting	Predicting based on an ordered universe
Activity 2 A Sticky Molecule	Structure of water molecules, and ensuing polarity	Modeling, visualizing	Structure and properties of matter
Activity 3 Over and Under—Why Water's Weird	Density of solid versus liquid states of matter	Observing	Structure and properties of matter
Activity 4 How Water Holds Heat	Specific heat of sand and water	Measuring and graphing data	Measuring relative rate of change
Activity 5 Water—The Universal Solvent	Solubility	Observing and recording data in an organized way	Structure and properties of matter
Activity 6 Won't You BB My Hydrometer?	Measuring density of freshwater and salt water	Measuring	Measuring and instrumentation
Activity 7 Ocean Layers	Salinity/density layers in water	Modeling and observing	Change within open systems
Activity 8 The Myth of Davy Jones's Locker	Density layering of ocean	Modeling and observing	Effect of density on ocean's vertical structure
Activity 9 Estuaries—Where the Rivers Meet the Sea	Mixing of estuaries	Modeling and observing	Modeling change within estuaries
Activity 10 Current Events in the Ocean	Surface ocean currents	Modeling and observing	Change due to atmosphere/ocean interactions
Activity 11 Body Waves	Wave motion and energy	Modeling and observing	Energy flow via waves
Activity 12 Waves and Wind in a Box	Wind's influence on waves	Modeling, observing, and experimenting	Energy flow in open systems
Activity 13 Tanks a Lot—Activities for a Wave Tank (Teacher Demonstration)	Modeling wave formation, properties, and behavior	Modeling, observing, measuring, and experimenting	Energy flow in open systems
Activity 14 Plotting Tidal Curves	Tidal patterns	Graphing, analyzing data	Patterns of change within systems
Activity 15 Tides Mobile	Why tides form	Modeling and explaining	Modeling to explain patterns of change within systems
Activity 16 The Bulge on the Other Side of Earth	Inertia as a factor in tides	Modeling and explaining	Modeling to explain patterns of change within systems
Activity 17 Oily Spills	Oil spills and their mitigation	Modeling, experimenting, observing, and analyzing	Modeling to explore systems
Activity 18 Forever Trash	Decomposition of ocean pollutants	Experimenting, observing, and analyzing	Experimenting with conditions to explore changes in a system

Technology	Personal/Social Perspectives	Historical Context	Key Concept
			I
			I
			I
			I
			I
Building a hydrometer	Improvements in measuring devices allow science to advance		I
			II
	Science in society	Seafaring mythology	I, II
	Influence of human activity on estuaries		II, III
			II
			II
Building a wave tank			II
Measuring waves using a wave tank			II
	Waves as a natural hazard	Historic wave events	II
Building a planet/tide model			II
Building an inertia/tide model			II
Testing technology to clean up spills	Risks and benefits of using oil	Historic oil spills	III
	Risks of designing synthetic materials		III

Activities at a Glance Matrix

Activity	Pages	Subject and Content	Objective	Materials
Activity 1 A Pile of Water	1–11	Surface tension and cohesion of water	Investigate a specific property of water: its ability to "stick" to itself.	The teacher will need (for preparation ahead of Activity): food coloring, water Each group (of five groups) will need: one of five containers varying in shape and size of opening, several rolls of pennies Each student will need: penny, eyedropper, small beaker or clear plastic cup (may be shared), paper towel, other assorted coins (quarters, nickels, etc.)
Activity 2 A Sticky Molecule	13–21	Structure of water molecules and ensuing polarity	Construct a model of the water molecule to explore the concepts of polarity and hydrogen bonding.	Each student will need: paper molecule pattern, scissors, glue, crayons or markers (red and blue), blank paper
Activity 3 Over and Under—Why Water's Weird	23–31	Density of solid versus liquid states of matter	Observe the behavior of different substances, including water, in their solid and liquid states.	Each group will need: several cups of ice cubes, several cups of unflavored gelatin cubes—clear and colored, vegetable shortening, teaspoon, spoon or tongs, hot plate with wire gauze screen, three 250 ml beakers, indirectly vented chemical splash goggles, gloves, aprons
Activity 4 How Water Holds Heat	33–43	Specific heat of sand and water	Compare the specific heat of sand and water.	Each group will need: two thermometers (nonmercury), ring stand, two utility clamps, two 240 ml (8 oz.) polystyrene foam cups, sand, water, string, lamp with reflector and 200-watt bulb, clock or watch with a second hand, balance, graduated cylinder, ruler or meter stick, GFI-protected circuit
Activity 5 Water—The Universal Solvent	45–55	Solubility	Explore the solubility of various substances in water as compared with other liquids.	Each group will need: water, mineral oil (or baby oil), isopropyl alcohol (70%), Epsom salts (Mg_2SO_4), baking soda ($NaHCO_3$), table salt (NaCl), granular sugar, red wax marking pencil, five test tubes with rubber stoppers, small spoon (1/8 teaspoon will work), test tube rack, graduated cylinder, black construction paper, indirectly vented chemical splash goggles, gloves, aprons, MSDSs for all hazardous materials

Time	Vocabulary	Key Concepts	Margin Features
50 minutes	Atom, Molecule, Molecular structure	I	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resource
50 minutes	Molecule, Atom, Chemical bonds	I	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
30–50 minutes	Density	I	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes	Specific heat, Calorie	I	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes	Solvent, Solubility	I	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources

Activity	Pages	Subject and Content	Objective	Materials
Activity 6 Won't You BB My Hydrometer?	57–69	Measuring density of freshwater and salt water	Understand the implications of water density by building and using a hydrometer to measure the densities of freshwater and saltwater samples.	For Part 1, each group will need: plastic transfer pipette, sharp scissors, fine-tip permanent marking pen, metric ruler, 20 BBs, 500 ml beaker, masking tape, modeling clay, food coloring, pickling salt, waste container, towels or rags for cleanup, teaspoon (5 ml) or tablespoon (15 ml) For Part 2, each group will need: large jar or beaker, pickling salt, soupspoon (large enough to hold an egg), 100 ml graduated cylinder, hard-boiled egg, ruler or straightedge, 5 ml metric measuring spoon (a teaspoon), hydrometer (from Part 1)
Activity 7 Ocean Layers	71–79	Salinity/density layers in water	Investigate what happens when ocean water, brackish water, and river water contact one another.	Each group will need: cafeteria tray, slice of clay 3 cm thick, clear plastic straw (about 10 cm long), three 250 ml clear plastic cups containing 25 ml each of the colored solutions, 250 ml clear plastic cup (waste container for used solutions), three medicine droppers or plastic pipettes, one or two sheets of white paper, towels or rags for cleanup
Activity 8 The Myth of Davy Jones's Locker	81–91	Density layering of ocean	Investigate some of the properties of water that could explain the myth of Davy Jones's Locker.	For the demonstration, the teacher will need: three buckets (4 L or 1 gal. size), eight small screw-top vials (or eight test tubes and stoppers), plastic cylinder with an end cap (122 cm [4 ft.] tall and 4 cm [1.5 in.] in diameter), ring stand with clamp to hold cylinder, large funnel, 1 to 2 m length of rubber tubing with U-shaped glass tubing in one end, package of BBs, hot plate and pan or coffee heater, pickling salt (produces a clear brine), ice, water, red wax marking pencil, optional: food coloring For the Activity, each student or group will need: three 600 ml beakers, eight small screw-top vials (or eight test tubes and stoppers), plastic cylinder with an end cap (122 cm [4 ft.] tall and 4 cm [1.5 in.] in diameter), ring stand with clamp to hold cylinder, large funnel, 0.5 m length of rubber tubing with U-shaped glass tubing in one end, package of BBs, pickling salt, water, red wax marking pencil

Time	Vocabulary	Key Concepts	Margin Features
90–100 minutes (45–50 minutes for each part)	Hydrometer, Density	I	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes	Estuary, Brackish water	II	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
Demonstration: 25–30 minutes Activity: 50 minutes		I, II	Safety Alert!, Fast Fact, What Can I Do?, Connections

Activity	Pages	Subject and Content	Objective	Materials
Activity 9 Estuaries—Where the Rivers Meet the Sea	93–101	Mixing of estuaries	Investigate how water mixes in estuaries.	Each group of students will need: clear Pyrex glass loaf pans, 500 ml "ocean water" (see Preparation section), 500 ml "river water" (see Preparation section), pickling salt, blue and yellow food coloring, graduated cylinder, pencil or pen, 20 cm masking tape, spoon, waste container for used solutions, towels or rags for cleanup
Activity 10 Current Events in the Ocean	103–115	Surface ocean currents	Model how landforms and wind affect ocean surface currents.	Each group of three to four students will need: indirectly vented chemical splash goggles and aprons; baking pan, 30 cm × 45 cm × 3 cm (12 in. × 18 in. × 1.5 in.) deep, painted black inside; white chalk; modeling clay; colored pencils; a plastic drinking straw with a flexible elbow for each student; black permanent marker (no or low VOC); 400 ml rheoscopic fluid; towels or rags for cleanup
Activity 11 Body Waves	117–125	Wave motion and energy	Investigate the energy of a wave and the motion of the medium through which a wave travels.	None
Activity 12 Waves and Wind in a Box	127–135	Wind's influence on waves	Investigate the relationship between wind and waves.	Each group will need: one or two large plastic trash bags (preferably white), 2 kg sand (optional), two sturdy cardboard boxes (75 cm × 28 cm × 5 cm or comparable size), two-speed fan or hair dryer, scissors, packing or duct tape, stopwatch or watch with second hand
Activity 13 Tanks a Lot—Activities for a Wave Tank (Teacher Demonstration)	137–147	Modeling wave formation, properties, and behavior	A: Teach students about selected wave characteristics and properties. B: Show the effect of water depth on wave speed. C: Show the orbital motion of particles in an ocean wave, and two aspects of wave–coast interactions: breakers and sand transport.	For demonstration, teacher will need: water, wave tank, stopwatch, pebbles, floating objects (e.g., Ping-Pong balls, eyedroppers, corks)
Activity 14 Plotting Tidal Curves	149–159	Tidal patterns	Plot tide data for a period of one month and draw the tidal curve for this data.	Each student will need: pencil with eraser, red pen or a bright color crayon, scissors, clear tape, ruler

Time	Vocabulary	Key Concepts	Margin Features
Preparation 25–30 minutes Activity 50 minutes		II, III	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes	Ocean currents, Gulf Stream, California Current, Rheoscopic fluid	II	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
30 minutes or less	Oscillate	II	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
100 minutes		II	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes, more time optional	Crest, Trough	II	Safety Alert!, Fast Fact, Connections, Resources
100 minutes	Bathymetry, Global forcing	II	Fast Fact, What Can I Do?, Connections, Resources

Activity	Pages	Subject and Content	Objective	Materials
Activity 15 Tides Mobile	161–169	Why tides form	Construct a mobile that shows the relationship among the Sun, Moon, and Earth, and use this mobile to investigate how tides are created.	Each group will need: scissors, coat hanger, string, meter stick or dowel, modeling clay, tape, yellow construction paper, pencil, paper clip
Activity 16 The Bulge on the Other Side of Earth	171–181	Inertia as a factor in tides	Demonstrate how the rotation of the Earth–Moon system accounts for the bulge of water on the side of Earth facing away from the Moon.	Each group will need: safety glasses or goggles for each student, Styrofoam ball (15 cm diameter), Styrofoam ball (6 cm diameter), string, dowel (1 m long and 0.5 cm diameter), dowel (0.5 m long and 0.5 cm diameter), masking tape, two weights (about 15 g each), 473 ml (16 oz.) drink bottle, ruler
Activity 17 Oily Spills	183–191	Oil spills and their mitigation	Explore the effectiveness of different methods for cleaning up oil spills.	Each group of four or more students will need: dish pan or plastic tub, tap water, vegetable oil or heavy olive oil (500 ml), cotton string (approximately 1 m long), several drinking straws (cut in half), paper towels, several small pieces of polystyrene foam (such as packing material), 10 ml liquid detergent, sand (125 g), diatomaceous earth (125 g), feather
Activity 18 Forever Trash	193–204	Decomposition of ocean pollutants	Observe the breakdown of various materials in water and in sand.	Each group will need: small piece of paper (10 cm × 10 cm); 10 cm × 10 cm scraps of cloth (cotton, rayon, wool, polyester, nylon, etc.); small sheets of aluminum foil, waxed paper, plastic wrap; aluminum soda can tabs; plastic bag (sandwich size); pieces of a plastic grocery bag; plastic six-pack holder; plastic bottle cap; hard candy in a plastic wrapper; unwrapped hard candy; rubber balloon; polystyrene foam packing peanuts; starch-based packing peanuts; sand containing organic matter; shoe box or small individual containers; beaker; salt (for salt water)

Time	Vocabulary	Key Concepts	Margin Features
50 minutes	Gravitational forces, spring tides, neap tides	II	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes	Inertia, Axis of rotation, Center of gravity	II	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes	Dispersant	III	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources
50 minutes twice, with at least a week between	Biodegradable	III	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resources

Activity 1 Planner

Activity 1 Summary

Students count the number of drops of water they can add onto coins before the water spills over. They then apply what they learn by predicting and then testing the number of coins they can add to different containers filled with water before the water overflows. These exercises teach students about the ability of water to "stick" to itself.

Activity	Subject and Content	Objective	Materials
A Pile of Water	Surface tension and cohesion of water	Investigate a specific property of water: its ability to "stick" to itself.	The teacher will need (for preparation ahead of Activity): food coloring, water Each group will need (class will be divided into five groups): one of five containers varying in shape and size of opening, several rolls of pennies Each student will need: penny, eyedropper, small beaker or clear plastic cup (may be shared), paper towel, other assorted coins (quarters, nickels, etc.)

Time	Vocabulary	Key Concept	Margin Features
50 minutes	Atom, Molecule, Molecular structure	I: Properties of water	Safety Alert!, Fast Fact, What Can I Do?, Connections, Resource

Scientific Inquiry	Unifying Concepts and Processes
Exploring, estimating, and predicting	Predicting based on an ordered universe

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A Pile of Water

Activity 1

Background

We observe and use water every day. It makes life on Earth possible. Water covers nearly three-fourths of Earth's surface and affects almost all living and nonliving things. Because it is so abundant, it may not seem unusual, but water is unique when compared to other substances in the universe. In fact, its properties are quite different from those of other substances even here on Earth. For instance, it is the only substance on Earth that occurs naturally in all three states—solid (e.g., an iceberg), liquid (e.g., ocean water), and gas (e.g., steam or vapor in a cloud). (See **Figure 1.1**.)

Most substances (water, air, dirt, etc.) are made up of **atoms**. Atoms are arranged in a specific way, often forming a **molecule.** The makeup of a water molecule—or any molecule—is called **molecular structure**. A substance's molecular structure is responsible for its properties and governs how it interacts with other things on Earth. This Activity introduces and explores one specific property of liquid water.

Vocabulary

Atom: The basic unit of matter.

Molecule: The most basic unit of many substances; it has a specific arrangement of atoms.

Molecular structure: The arrangement of atoms in a specific molecule.

Objective

Investigate a specific property of water: its ability to "stick" to itself.

SCILINKS
THE WORLD'S A CLICK AWAY

Topic: water cycle
Go to: *www.scilinks.org*
Code: PESO 001

Activity 1

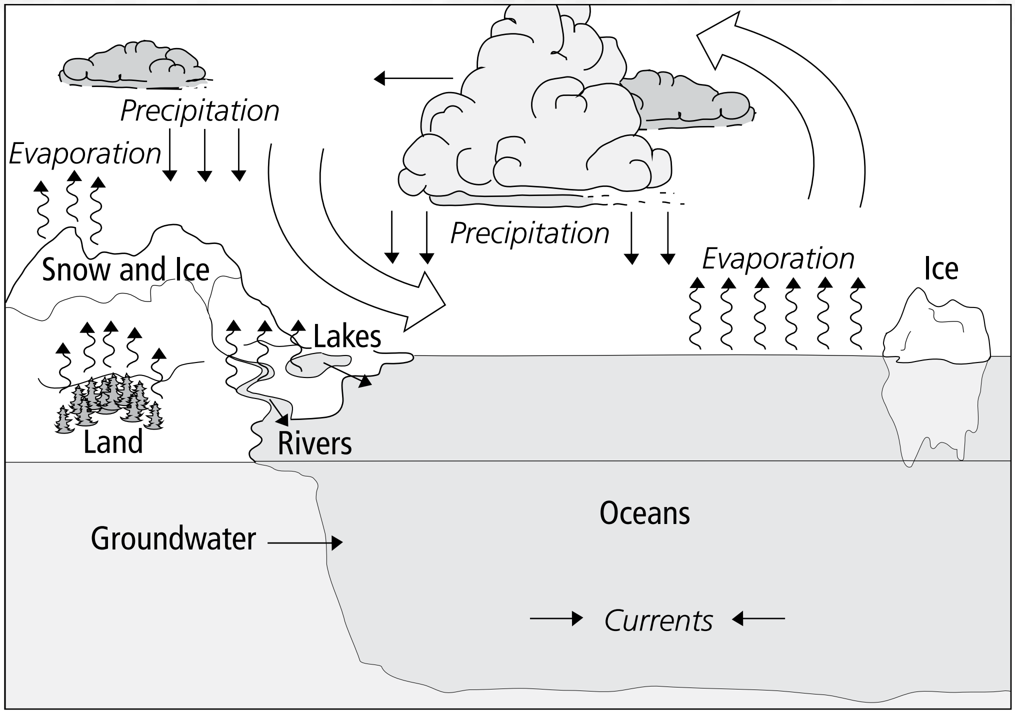

Figure 1.1
Global Water Cycle
Water is the only substance that occurs naturally on Earth in all three states: solid (ice and snow), liquid (ocean, river, and lake water), and gas (clouds, steam, and vapor). The natural circulation or pathway that Earth's water follows as it changes between liquid, solid, and gas states is called the global water cycle.

Materials

Each group will need (class will be divided into five groups):

- one of five containers varying in shape and size of opening
- several rolls of pennies

Each student will need

- penny
- eyedropper
- small beaker or clear plastic cup (may be shared)
- paper towel
- other assorted coins (quarters, nickels, etc.)

Time

50 minutes

SAFETY ALERT !

1. Be careful to quickly wipe up any spilled water on the floor—slip and fall hazard.

2. Wash hands with soap and water upon completing the lab.

Procedure

Part 1

1. Explore the behavior of water with a single coin by placing a penny on a piece of paper towel.
2. Estimate the number of water drops you can pile on the penny before the water runs over its edge. Record your estimate in the table on **BLM 1.1**.
3. Place water on the penny drop by drop. Working with the other members of your group, develop a technique that allows you to put the most drops on your penny. You may want to put the drops on in different areas of the penny or from different heights. Count each drop until the water spills over. Record your results in the table on **BLM 1.1**.
4. Make a sketch of the water on the surface of the penny just before the water spilled over.
5. Based on what you observed with the penny, make a prediction comparing the number of drops you could pile on a nickel, dime, or quarter. Remember that the area of the different-size coins is important to your predictions. Record these predictions in the table on **BLM 1.1**.
6. Repeat steps 2, 3, and 4 with each coin to test your hypothesis.
7. Compare the techniques you used that allowed you to put the most drops on a coin.

Part 2

1. Your teacher has filled five different containers with colored water. (See **Figure 1.2**.) Observe the containers closely. Record brief descriptions of the size, shape, and other characteristics of the containers that help you distinguish among them.
2. Predict which of the five containers will hold the greatest number of pennies without spilling over. Record your prediction in the table on **BLM 1.2**.
3. Estimate the number of pennies that would have to be added to each container to make it spill over. Record your estimates in the table on **BLM 1.2**. You will have a chance to revise these estimates in step 5 below.

Figure 1.2
Five possible types of containers to be used in Activity 1

4. You will add pennies to a container, one at a time, counting how many you add before water spills over the lip. Add them this way:
   (a) Hold the penny so its edge will enter the water first (not flat).
   (b) Hold the penny over the center of the container opening, no more than 5 cm above the surface of the water.
   (c) Release the penny and let it drop into the water.
5. Based on what you learned by adding pennies to one container, revise your predictions about how many pennies the other container can hold before overflowing. Record your predictions in the table on **BLM 1.3**.

Fast Fact

One milliliter of water has 3.34×10^{22} molecules in it. This is the shorthand way of writing a long number with many zeros: 3.34×10^{22} means that the decimal point in 3.34 actually goes 22 places to the right, so that the long version of the number is 33,400,000,000,000,000,000,000!

Questions and Conclusions

1. Describe the way water “sits” on the penny.
2. Why do some pennies hold more water droplets than others?
3. Why do you think water piles up on the penny, rather than spilling over the edges immediately?
4. Suggest reasons why the five containers hold a different number of pennies before spilling over.
5. In Part 2, step 5, did you change your predictions from step 3 before testing your original prediction? Describe how this is consistent with the way scientists test their ideas.

What Can I Do?

You could figure out how many milliliters of water, on average, you put on a penny, and work out how many molecules that is. (How could you determine how many milliliters are in each drop of water?)

BLM 1.1: Predicted and Observed Results

Date ____________________________

Data Table: Predicted and Observed Results		
Item	Number of Drops	
	Prediction	Observation
Penny		
Nickel		
Dime		
Quarter		

Data Table: Initial Predictions		
Container Predicted to Hold the Most Pennies Before Overflowing:		
Container Number	Description	Number of Pennies Predicted to Cause Overflow
1		
2		
3		
4		
5		

Data Table: Revised Predictions and Observed Results		
Container Predicted to Hold the Most Pennies Before Overflowing:		
Container Number	Number of Pennies Predicted to Cause Overflow	Number of Pennies Required to Cause Overflow
1		
2		
3		
4		
5		

A Pile of Water

What Is Happening?

The properties of water play an integral role in the development and maintenance of Earth's environment and its ability to sustain life. Although water is a unique substance in the universe, it is so common on Earth that many students may expect other substances to have similar properties.

Water exhibits characteristics that are unusual. For instance, solid water floats in liquid water (unlike most solids, which are denser than their liquid and therefore sink); large amounts of energy must be added to water to achieve relatively small changes in temperature (heat capacity); and water molecules tend to "stick" to each other (cohesion) and to other molecules (adhesion). Later Activities will explore the first two properties, while this Activity introduces students to liquid water's ability to "stick" to itself.

Water molecules "stick," or are attracted to one another, because water has an uneven distribution of electrical charge. (It is a "polar molecule.") Each molecule has a positive end, or "pole," and a negative pole. The positive end of one molecule and the negative end of another molecule attract each other. This attraction, called hydrogen bonding, is strong enough to hold water molecules together. The force of hydrogen bonds causes water to fall in drops and to dome up on flat surfaces or containers full of water.

When placed on coins, the molecules of water form flexible piles that stay together because of hydrogen bonding. This phenomenon—of water "piling up"—is due to surface tension. Liquid water has an extremely high surface tension because of its molecular structure and the hydrogen bonding between molecules.

How Do We Know This?

How do we measure surface tension in liquids?

The traditional way to measure tension in liquids is by slowly pulling out a ring (called a Du Nouy ring, often made of platinum) from the surface of the liquid. We measure the force required to raise the ring from the liquid's surface; this force is a direct measure of the surface tension. Another method uses a vertical plate (known as a Wilhelmy plate) and a precision balance to measure the force caused by placing the plate in contact with the liquid surface.

Objective

Investigate a specific property of water: its ability to "stick" to itself.

Key Concept

I: Properties of water

Materials

The teacher will need (for preparation ahead of Activity):
- food coloring
- water

Each group will need (class will be divided into five groups):
- one of five containers varying in shape and size of opening
- several rolls of pennies

Each student will need
- penny
- eyedropper
- small beaker or clear plastic cup (may be shared)
- paper towel
- other assorted coins (quarters, nickels, etc.)

Time

50 minutes

SAFETY ALERT

1. Be careful to quickly wipe up any spilled water on the floor—slip and fall hazard.

2. Wash hands with soap and water upon completing the lab.

Preconceptions

Explain to students, "Physical properties are descriptions of a substance by itself, like its boiling point and melting point. Chemical properties are descriptions of how a substance reacts in the presence of another, like the way iron rusts in the presence of oxygen." Then ask students, "What do you think you know about physical and chemical properties of water?" You could ask them as a Think-Pair-Share, a journal entry, a concept map, or a class discussion. You can also ask if students have watched insects walking on water. What did they see? Did they have any questions about it? Some preconceptions that students may have are as follows:

- What is the shape of a raindrop? Most people think raindrops have a teardrop shape when in reality they are spherical due to surface tension.
- Because water is such a part of our everyday lives, it is typical of compounds.
- All liquids mound the same way that water does on a penny.

What Students Need to Understand

- Water is unique among substances.
- The high surface tension of water, which results in water "piling up" on a flat surface, is just one of the unusual properties of water. Water's characteristics are important in determining how water interacts with other substances.
- The characteristics of water make life possible on Earth. One of these characteristics, surface tension, is investigated in this Activity. It allows water striders to "walk" on the surface of water. It also aids in capillary action, which allows groundwater to move through soil, wells to function, and plants to transport water from their roots upward.

Time Management

Students can do both parts of this Activity in 50 minutes. Be sure to leave at least 5 minutes at the end of class for them to compare their predictions for Part 2 to their classmates' results.

Preparation and Procedure

Choose five containers, each differing in volume and mouth shape and size. The containers may be of like or different materials (plastic, glass, etc.). The material used affects the surface tension to a much smaller degree than the diameter of the opening. Possible containers might include an apple juice jar, a wide-mouthed plastic cup, a petri dish, a two-liter plastic drink bottle, and a canning jar. It is important that the containers chosen for the Activity have a variety of opening sizes, from small to large. *The success of the Activity depends on using a wide variety of containers*. All containers should be transparent.

Fill each container with water and add a different color of food coloring to each. Be sure all containers are filled to the point where the water is exactly level with the opening of the container. The water should not form a depression (meniscus) or be domed up in the center of the opening. You might want to do this part of the Activity ahead of time. Also, check the water level after each group has used a container.

Give students an opportunity to record their results on the board and make comparisons with other groups in the class. Ask students to compute a class average for the results from the table on **BLM 1.1**, then construct two bar charts: one tallying students' predictions, and the other tallying the actual number of drops that fit on each coin. What conclusions emerge from looking at the data in this way? (Did most students predict too many drops or too few?)

Extended Learning

- Challenge students to float a paper clip on a petri dish full of water. With the paper clip floating, add a drop or two of liquid detergent or soap. Watch what happens and ask students to try to refloat the paper clip. Soap reduces the surface tension of the water, making the paper clip sink. (Explain this *after* students have watched the paper clip sink).
- Compare the surface tension of tap water and salt water. Although the addition of impurities—like salt—decreases the cohesion between water molecules, it also increases the density of water (density will be explored in Activity 3). For example, the presence of large quantities of salt allows objects that would sink in freshwater to float on the surface of water in the Dead Sea and in the Great Salt Lake. This may be confusing to students. The ability to float is the result of a difference in density, rather than an increase in surface tension.
- Ask students why water forms drops. What factors affect the size of a water drop? How would that compare with drops from other liquids?
- Challenge students to repeat Part 2 using liquids other than water. Their predictions before testing will expose any misconceptions that all liquids behave as water does. Rubbing alcohol, white vinegar, and vegetable oil make good alternatives.
- Students should not try to experiment with mercury, but they can read about the differences between water and mercury. Which one has more surface tension? What are the effects on the formation of drops? What shape (concave or convex) does the surface of each liquid have when in a glass container?

Connections

In the absence of any other forces, liquids will take on a spherical shape. In reality, this is true for any fluid (both liquids and gases are fluids). This tendency toward a spherical shape holds whether fluids are the size of raindrops, planets, or stars. Solid planets like Earth are spherical because they were once fluid. Stars like the Sun and the large giant planets in our solar system (Jupiter, Saturn, Uranus, Neptune) are mostly spherical because they are formed of gas. The surface tension on a fluid tries to minimize its surface area. The shape resulting from this minimization is a sphere. See *www.haydenplanetarium.org/tyson/read/1997/03/01/on-being-round.*

Interdisciplinary Study

Explore either capillary action, the mechanism by which groundwater moves and trees and plants transport water from their roots throughout the plant, or "water striders"—animals that take advantage of water's surface tension to live on the surface of the water.

Differentiated Learning

This is a concrete Activity with which many students will be successful. Ask students who are skilled in mathematics or who enjoy math challenges to work out the number of molecules they added to the pennies using scientific notation, as described in How Do You Know This?

Answers to Student Questions

1. The water forms a dome on the surface of the penny. (Note: The hydrogen bonds hold the water molecules together, allowing many more drops than would be expected to pile on the penny.)
2. Pennies hold different numbers of drops because they are not all exactly the same. Some pennies have worn edges, while others are dirty or dented. There may also be a difference between the head and tail sides of the pennies. (Note: There also may be differences in the size of the drops. Encourage students to develop techniques that "standardize" their drop size.)
3. Answers will vary since students have not yet been introduced to hydrogen bonding. Students may create explanations, though, that are fairly accurate. Encourage students to formulate hypotheses explaining why the water piled up. Address these hypotheses through discussion. The answer: The hydrogen bonding between water molecules holds the molecules together. When the number of water molecules gets too large for the cohesive forces to hold together, the water spills over the side.
4. Again, answers will vary. Ask students to formulate and discuss their hypotheses. The openings or mouths of the containers differ in surface area and shape. Containers with large round openings will hold a greater number of pennies than those with small round openings. There may also be differences in the adhesive forces between water and the material from which the containers are made.
5. Answers will vary. (Note: Most students greatly underestimate the number of pennies it takes to make the water spill over the sides of the containers. Therefore, after observing the water dome up on the coins, most students will increase their estimates.) Scientists often form their initial ideas based on intuition or initial observations. Hypotheses are revised as additional data are collected through experimentation or further observations.

Assessment

- Ask students to revisit their responses to your questions in Preconceptions. What have they learned about the properties of water? How would they respond now?
- You can also grade student answers to questions.

Resource

www.haydenplanetarium.org/tyson/read/1997/03/01/on-being-round

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