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Grade Two

Buoyancy and Boats

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Buoyancy and Boats

Before You Begin

What grade 2 child hasn't played with a variety of objects in the water? The activities in this unit are designed to extend the students' understanding of floating and sinking, and how objects move on and in the water. Through building and testing water-borne objects, they learn about balance and stability, and develop a preliminary understanding of the concept of density. They also come to appreciate the importance of appropriate materials selection and workmanship in the production of successful watercraft.

Topic B: Buoyancy and Boats

(Suggested time: 4-6 weeks)

The materials listed with each key activity should be reviewed in detail at least two weeks prior to the start of this unit. Water is a critical component. Careful arrangements need to be made to ensure maximum student participation and minimal disruption to the classroom scene. Old shower curtains or large plastic tarpaulins are effective aids in waterproofing some areas of the classroom. Borrowing the water table from the kindergarten classroom may be an option. Other large containers may be borrowed from members of the school community. Watercraft construction can be enhanced through the use of wooden materials or a number of recyclable materials. A letter to a local business or to parents might generate enough supplies for each student to create his or her own watercraft. Ask students to also collect a variety of small objects that sink or float.

This unit can be done at any time of the year. **Connecting it with the Grade 2 Exploration of Liquids unit may be logical, as the procedures established for handling liquids can be used for both units.** Consider moving the activities outside, where spills are not so much of a concern. In that case, early fall or spring would be the best time. Explorations take time, as does setting up water experiences. Some consideration should be given to establishing a block of time for this unit, for example, an hour every day.

Some children may have visited boat museums and can share their experiences with the class. People who have occupations in the boating industry can provide another dimension to the study of boats. Communities may hold boat shows or hobby shows. If not, a school boat show can be held where student-made boats are exhibited. The inclusion of activities such as these need to be explored well before the unit begins.

If the students have a swim program, consider teaching this unit at the same time.

Background Information

In the third century BC, the Greek natural philosopher Archimedes formulated the basic principle of buoyancy, which applies equally to boats, swimmers, fish, beach balls, logs or any other objects immersed in a fluid. And because gases are fluids, it even applies to objects such as hot-air balloons. (See the grade 6 unit Air and Aerodynamics.)

Known today as *Archimedes' Principle*, it can be stated as follows:

> *An object partially or completely submerged in a fluid is acted upon by an upward force equal to the weight of the fluid displaced by the object.*

This phenomenon is easily comprehended by anyone who has tried to submerge an inflated beach ball. The force it takes to push a ball below water increases with the size of the ball (for example, the volume of water that is being displaced). Left alone, a beach ball will float with only a portion of its volume submerged, as will any object less dense than water.

You can alter the density of an object, and hence its ability to float, by altering either its mass or its volume. The more mass you add, the more dense it becomes. The more volume you add, the less dense it becomes. For example, imagine you have a small canoe floating partially submerged at dockside. One person gets in and the canoe descends a little farther into the water. A second person comes aboard and more of the canoe submerges. A third person sets foot in the canoe, but as he gets in the canoe sinks low enough to allow water to rush over the sides. The mass of the cargo (people in this case) increases to the point where the average density of the canoe plus cargo exceeds the density of water. The buoyant force is no longer sufficient to counter the force of gravity and the canoe sinks to the bottom of the lake, all hands aboard. Now imagine you have a larger canoe. It can accommodate three people and all their camping gear, because the average density of the more voluminous craft plus cargo is still less than the density of water.

An object denser than water sinks to the bottom of the fluid, as the overloaded canoe in our example sinks to the bottom of the lake. If you weigh this submerged object, you will find it lighter than its original weight by an amount equal to the mass of the volume of water it displaces.

The practical consequences of Archimedes' Principle become apparent if you consider the three common scenarios in which buoyant force applies.

1. A solid object lighter than an equal volume of water sinks only far enough to displace a volume of water equal in weight to the object. At this point, the upward force of buoyancy equals the downward pull of gravity. For example, if you have a bar of soap that weights only half as much as an equal volume of water, the soap will float with half its volume below water level and half above.

2. A solid object equal in weight to the volume of water it displaces floats but with its upper surface just at water level. The buoyant force equals the weight of the water displaced by the entire volume of the object. This aspect of Archimedes' Principle is important to keep in mind when determining how much cargo (extra weight) a vessel can carry without sinking. For example, the bar of soap in the previous example can take on weight and still remain afloat up to the point where the extra weight matches the weight of the bar of soap. (Remember, our bar of soap weighs only half as much as an equal volume of water, so twice as much weight is needed to match the buoyant force).
3. Finally, a solid object heavier than water of equal volume sinks to the bottom of the fluid. If you weigh this submerged object, you will find it lighter than its original weight by an amount equal to the weight of the volume of water it displaces. If an object weighing five kilograms displaces a volume of water weighing three kilograms, it will have an apparent weight of two kilograms when submerged.

The ability of a solid object to remain in a stable, upright position in the water depends on the position of its *centre of buoyancy* in relation to the position of its *centre of gravity*. Buoyant force acts upward through a point called the centre of buoyancy located in the centre of the volume of water displaced by the object (Fig. 1). Gravity, on the other hand, pulls downward through a point in the object called the centre of gravity. (An object that is top heavy has a high centre of gravity.)

In order for a completely submerged object to remain upright, the buoyant force must push up directly below the object's centre of gravity: the centre of gravity and centre of buoyancy must be in vertical alignment. Harkening back to the example of a beach ball pushed below water, consider how you must balance your weight directly above the ball or it shifts to one side, pops out of the water and knocks you over in the process.

A floating object has some leeway in the distance its centre of buoyancy can shift from beneath its centre of gravity and still remain upright. Consider the diagrams depicting a floating boat in Figure 1. In the first diagram, the boat is sitting still on the water with its centre of gravity poised directly above its centre of buoyancy in vertical alignment. The next diagram depicts the situation if the boat tips to one side (perhaps due to wind or wave action). The boat will remain rotationally stable (i.e., it won't tip over) if the vertical line through the new centre of buoyancy intersects the original vertical above the centre of gravity. The point where these two lines meet is called the *metacentre*. If the metacentre falls beneath the centre of gravity, the boat becomes rotationally unstable and tips over. In general, the greater the height of the metacentre above the centre of gravity, the more stability the boat has.

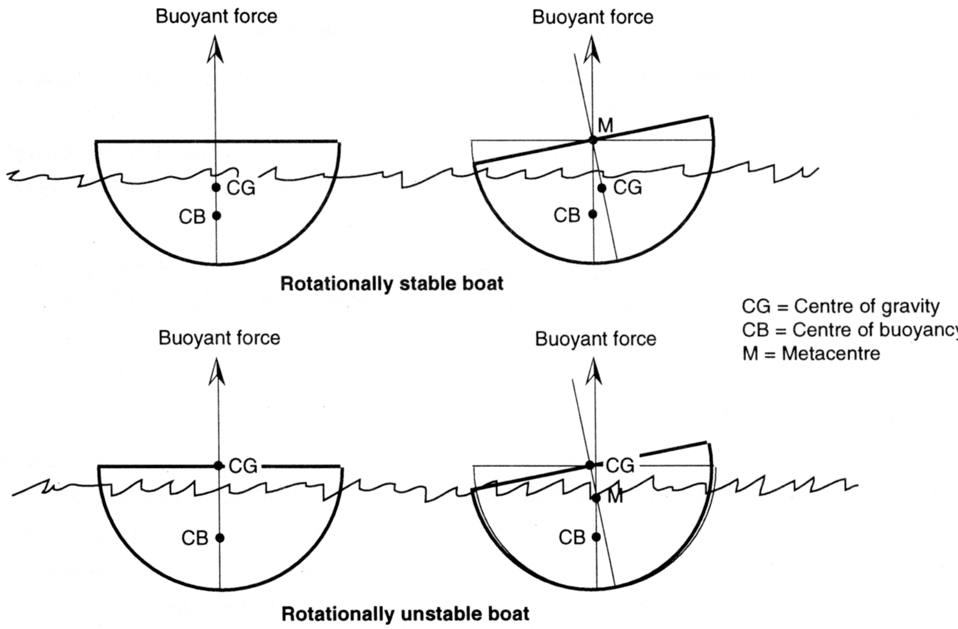

Figure 1. The relationship between the centre of gravity in a stable and unstable boat.

As Figure 1 suggests, the lower the centre of gravity, the greater the stability of the watercraft (assuming the centre of gravity does not descend below the centre of buoyancy). In practical terms this means the lower you situate the majority of the weight and cargo in your boat, the less likely your boat is to capsize. If you've ever tried standing in a canoe, you doubtless have an excellent appreciation of this concept! You can also see the importance of securing your cargo. If cargo gets loose it will move toward the lowest side of the craft and shift the centre of gravity in that direction as well. The height of the metacentre decreases and, if it descends below the centre of gravity, the boat goes over. This is exactly what happened when the ferry *Estonia* went down in the Baltic Sea. Unsecured weight moved to one side of the ferry, shifting its centre of gravity and tipping the open cargo doors below water level. As the water rushed in, the centre of gravity continued to shift until the ferry flipped.

If all you wish to do is float a craft in a stationary position, it doesn't matter a great deal whether it's round like an inner tube or square like a raft. However, if you want your craft to move easily through the water it is best to give it a streamlined shape that minimizes drag. (See the grade 6 unit Air and Aerodynamics for a detailed discussion of drag and streamlining.)

Finally, regardless of the shape of your boat, you will want the surface of all building components, and the boat's structure as a whole, to be watertight. Some boats are made of lighter-than-water materials that are riddled with air-filled pores, like wood. It is essential to apply a watertight sealant that prevents these pores from absorbing water, otherwise the boat eventually becomes waterlogged and loses its buoyancy. (For a discussion of absorbency, see the grade 2 unit Exploration of Liquids.) Other boats are buoyant even though they are made of heavier-than-water materials, such as steel, because their total volume incorporates open spaces of lighter-than-water air. When water comes onboard, it displaces the air and the weight of the boat increases until it exceeds the buoyant force, at which point the whole thing sinks.

Elementary Science Program of Studies

General and Specific Learner Expectations

The following general and specific learner expectations have been taken directly from the 1996 Elementary Science Program of Studies. The specific learner expectations (SLEs) are referred to by number in the second column of the activities table.

General Learner Expectation

Students will be able to:

Construct objects that will float on and move through water, and evaluate various designs for watercraft.

Specific Learner Expectations

Students will be able to:

1. Describe, classify and order materials on the basis of their buoyancy. Students who have achieved this expectation will distinguish between materials that sink in water and those that float. They will also be aware that some "floaters" sit mostly above water, while others sit mostly below water. The terms *buoyancy* and *density* may be introduced, but are not required as part of this learning expectation.
2. Alter or add to a floating object so that it will sink, and alter or add to a non-floating object so that it will float.
3. Assemble materials so that they will float, carry a load and be stable in water.
4. Modify a watercraft to increase the load it will carry.
5. Modify a watercraft to increase its stability in water.
6. Evaluate the appropriateness of various materials to the construction of watercraft, in particular:
   - the degree to which the material is waterproof (not porous)
   - the ability to form waterproof joints between parts
   - the stiffness or rigidity of the material
   - the buoyancy of the material
7. Develop or adapt methods of construction that are appropriate to the design task.
8. Adapt the design of a watercraft so it can be propelled through water.
9. Explain why a given material, design or component is appropriate to the design task.

Cross-curricular Connections

Mathematics

- Compare weights of floating and non-floating objects and count items used as loads in the boats.

Language Arts

- Write stories based on travels of a watercraft.

Art

- Design postcards of possible destinations on a boat trip.

Social Studies

- Read maps that show where the boat may go.

Children's Alternative Frameworks

Children sometimes hold beliefs about buoyancy and boats that are not consistent with current scientific knowledge, for example:

- large things always sink, small things float;
- changing the shape of a boat changes its weight; and
- things with holes always sink.

Activities

Classroom teachers have identified the following activities that address the Specific Learner Expectations (SLEs) in the Program of Studies. The list is not prescriptive and teachers may select activities that are most appropriate for their students.

Activities have been listed under two headings. Key Activities and Extension Activities. Key activities are supported by authorized resources and identify "powerful and practical" means for achieving learner expectations. Extension activities represent alternative ways of achieving or supporting learner expectations.

Key Activities

Key Activity	SLE	Print Resources	Essential Materials	Comments
Exploring objects and their interactions with water		*Explorations in Science, Level 2, On the Water (Free Exploration)*, p. 6	a collection of floatable containers such as empty cartons, detergent bottles, empty plastic bottles, waxed paper, aluminum foil, a collection of sails of different sizes and shapes, a collection of items that float or sink	This activity can provide informal opportunities for teachers to assess students' concept and skill development. At this time, the teacher can establish routines for the handling of water and other materials that will be used during this unit. Opportunity should be available for the students to share their discoveries using appropriate oral language (for example, sinkers or floaters; high floating or low floating, etc.)
Testing and sorting a collection of objects to discover which sink and which float	1	*Explorations in Science, Level 2, Wet and Wonderful (Float or Sink?)*, p. 15 *Explorations in Science, Level 2, Wet and Wonderful (Looking at Floaters and Sinkers)*, p. 16 *Innovations in Science, Level 2, Waterways (Floaters and Sinkers)*, p. 12 *Windows on Beginning Science: Water and Ice* (Westley) *(Sink or Float?)*, p. 36	corks, washers, foam pieces, sponges, nails, pennies, Ping Pong balls, marbles, pumice, pebbles, balls of different materials and sizes, soap, containers of water	This activity could be extended to include an exploration of degree of buoyancy, i.e., where is the waterline on the floating objects?

Key Activity	SLE	Print Resources	Essential Materials	Comments
Investigating the buoyancy of different materials	1	*Explorations in Science, Level 2, On the Water (Below the Waterline)*, p. 12	collection of floating and sinking materials such as corks, empty film canisters, different types of wood, sponges, washers, erasers, pop cans, detergent bottles, balls	Buoyancy should be investigated informally by observing sinking and floating objects. Speed of sinking or the amount of an object that sits above water are both indicators of an objects' buoyancy.
		Explorations in Science, Level 2, On the Water (Ice—From Cubes to Bergs), p. 10	ice cubes of different sizes, food colouring, large blocks of ice, plastic cups, chart paper	
Investigating the effect of shape on whether objects sink or float	2, 3, 7	*Explorations in Science, Level 2, Wet and Wonderful (Make it Float or Sink!)*, p. 19	clay, foil, water containers	Children should learn that some shapes will float even when the materials are very heavy (dense). In the process they will discover some basic shapes of boats and discover other shapes that are not sufficiently stable.
		Windows on Beginning Science: Water and Ice (Westley) *(Floating Foil)*, p. 40	plastic spoons, foil, measuring cup	
Exploring ways of altering "sinkers" so they will float or altering "floaters" so they will sink	2	*Innovations in Science, Level 2, Waterways (Floating Sinkers)*, p. 18 *Innovations in Science, Level 2, Waterways (Sinking Floaters)*, p. 21	water tubs, small plastic figures, washers, paper clips, pennies, Popsicle sticks, cardboard, building blocks, marbles, coins, Ping Pong balls, toothpicks, balloons, string, tart tins, straws	
		Windows on Beginning Science: Water and Ice (Westley) *(Message in a Bottle)*, p. 38	plastic bottles with tight-fitting lids or corks, wash tubs, sand, tablespoons, funnel	
		Explorations in Science, Level 2, On the Water (That Sinking Feeling), p. 13 *Explorations in Science, Level 2, On the Water (Floating—Under Water)*, p. 21	very buoyant items (such as dry sponges, film canisters and corks), materials that will sink (such as clay, washers and weights), elastics, non-paper straws (one straw should be flexible)	

Key Activity	SLE	Print Resources	Essential Materials	Comments
Experimenting with shapes and materials to create watercraft that float and can carry a load	3, 4, 6	*Explorations in Science, Level 2, Wet and Wonderful (Boat Making)*, p. 24	boat-making materials such as Styrofoam food trays, milk cartons, scrap wood, modelling clay, foil, Popsicle sticks, rubber bands, art materials, *Who Sank the Boat* (Allen), plastic animals, water containers	Students can be made responsible for bringing in special boat-making materials they wish to investigate. Waterproof—use of duct tape and non-waterproof glue (white glue). Both materials will help the students set up investigations designed to evaluate materials.
		Innovations in Science, Level 2, Waterways (The Boat Show), p. 25 *Windows on Beginning Science: Water and Ice* (Westley) *(Boats Afloat)*, p. 42	boat-making materials, water containers, Popsicle sticks, film canisters, erasers, modelling clay, sand, boxes of paper clips, different types of art paper, pennies, washers, foil and student suggested materials for boat building	Boat-making tasks can be completed in centres with the assistance of parent volunteers as students work with different fasteners (duct tape, glue) and test their boats in water.
		Explorations in Science, Level 2, On the Water (Loaded Up), p. 17	pennies or washers, Plasticine, tin or aluminum foil, other boat-making materials such as recyclable materials.	
		Explorations in Science, Level 2, On the Water (Cargo Carry), p. 16	Popsicle sticks, glue, Plasticine, different types of art paper, cardboard, corks, containers, erasers, film canisters, sand, paper clips	
Exploring the effect of shape on the stability of floating objects	2, 3, 4, 5, 7	*Explorations in Science, Level 2, Wet and Wonderful (Floating Containers)*, p. 18	containers (such as tin cans, plastic trays, styrene foam trays, foil trays, plastic and waxed cups), water containers	

Key Activity	SLE	Print Resources	Essential Materials	Comments
Exploring how the addition and position of mass affects flotation and stability	2, 3, 4, 5	*Explorations in Science, Level 2, Wet and Wonderful (Sinking Containers)*, p. 17 *Explorations in Science, Level 2, On the Water (All Aboard)*, p. 14 *Explorations in Science, Level 2, Floating and Sinking (Rock and Roll)*, p. 24	containers (such as tin cans, plastic trays, foam trays, foil trays, waxed cups), tubs of water floatable items with large surfaces (such as deli foam trays, small cookie sheets, foil pieces, plastic container lids, pieces of wood, washers (small building blocks), gym mat, water tub	
Investigating ways to propel a watercraft	6, 7, 8, 9	*Explorations in Science, Level 2, On the Water (Full Sail Ahead)*, p. 18 *Explorations in Science, Level 2, On the Water (Elastic Energy)*, p. 19 *Explorations in Science, Level 2, On the Water (Air Power)*, p. 20	straws, construction paper, light cardboard, Bristol board, floating surfaces, glue, string, toothpicks, art materials, Popsicle sticks, wind source, small pieces of plywood, elastics, milk cartons, balloons, narrow-end cedar shingles	

Extension Activities

Extension Activity	SLE	Print Resources	Essential Materials	Comments
Designing and creating the boat of their dreams	3, 6, 7, 8, 9	*Explorations in Science, Level 2, On the Water (Superlative Boat Building)*, p. 23 *Innovations in Science, Level 2, Waterways (The Boat Show)*, p. 25	foil trays, cans, string, elastics, straws, milk cartons, corks, clay, Popsicle sticks, balsa wood, foam trays, plastic bottles, fabric swatch, thick cardboard, art materials, old magazines, books about boats, egg cartons, shoe boxes, paper towel tubes, Plasticine, toothpicks, waterproof glue and/or duct tape	These boats could be displayed in a boat show at school, in conjunction with a local hobby show, or as a display in a civic location during Education Week.
Creating other watercraft and exploring modifications	6, 7, 8, 9	*Explorations in Science, Level 2, On the Water (Don't Rock the Boat!)*, p. 15	Popsicle sticks, corks, washers, toothpicks, glue, paper clips, floatable items with large surfaces, building blocks	
Building on top of a floating surface	6, 7, 8, 9	*Explorations in Science, Level 2, On the Water (How High Can You Go?)*, p. 22	pictures of structures that stand up in water, floating surfaces, classroom building materials, Popsicle sticks, art materials	

Assessment

For a broader discussion of science classroom assessment techniques see *Assessing Student Learning* in the introduction of this publication on p. 15. Good places to begin looking for the unit-related ideas are *Explorations in Science* assessment handbooks, *Innovations in Science* teaching notes, Unit tests and Portfolio ideas, Alberta Education sample tests at **www.education.gov.ab.ca** and Alberta Assessment Consortium at **www.aac.ab.ca**

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