Float a Boat

Description:
Students draw upon their understanding of buoyancy and density, as well as potential and kinetic energy, to design and build a floating vessel with its own propulsion system that will carry cargo across a wading pool.

Grade Levels: 3-8

Educational Outcomes:
1) Students will understand that a Buoyant Force is an upward force exerted by a fluid on a submerged object.
2) Students will understand that there are other factors beside the type of material that will make an object sink or float. (Shape, mass, volume and density of object; density of surrounding liquid)
3) Students will understand and apply the key concepts of: buoyancy, density, and the balancing of forces to solve a design challenge.
4) Students will demonstrate their knowledge of Potential and Kinetic Energy.
5) Students will get a first-hand experience of the design process that scientists and engineers undergo.

Estimated Time: 30 minutes per session (range between 1-3 sessions).

California Science Standards Connections:
Grade 3 - Physical Science: 1. Energy and matter have multiple forms and can be changed from one form to another.
Grade 6 - Physical Science: 3 a. Students know energy can be carried from one place to another by heat flow or by waves, including water, light and sound waves, or by moving objects.
Grade 8 - Physical Science: **Density & Buoyancy:** 8. All objects experience a buoyant force when immersed in a fluid; Forces**:** Unbalanced forces cause changes in velocity.
Grade 8 - Physical Science: **Forces:** 2. Unbalanced Forces cause changes in velocity.
All Grades: Investigation and Experimentation: Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations.

The Tech Museum Connections:
Explorations Gallery- Destination Space: jet pack chair, The Deep Frontier: ROV tank
LifeTech – Beyond Our Limits: human powered vessels

Suggested Materials And Set-Up (Per Team Of 2-3):

Plastic bottles	Thumbtacks
Foam plates & bowls	Pins
Milk cartons (various sizes)	Plastic straws
Petri dishes	Aluminum foil
Pieces of stiff foam	Saran wrap
Styrofoam peanuts	Tape (masking, packing)
Bubble wrap	Pipe cleaners
Craft sticks	Scissors
Balloons	X-acto knife (for facilitator)
Rubber bands	Tarp
Plastic propellers	Pennies (10-20 per team)
Paper clips	Construction paper
Aquarium tubing	**Testing:** Small inflatable wading pool

Please note: This activity was initially developed to be a floor activity for guests of The Tech Museum. It has been modified for classroom use and is a good example of an introductory level design challenge.

Notes to teachers

You may need to tailor this lesson to fit the age and experience levels of your students.

Depending on the needs of your students and your time constraints, you may choose to use this as a stand-alone challenge (where you would only do the initial design challenge) or go into greater depth by including the Science Demonstration and Discussion followed by the 2nd Design Challenge. Please note that the teaching points from the Science Demonstration and Discussion can also be addressed by the instructor when facilitating the DC Demonstration and Reflection (of student designs).

Key Words:
Archimedes Principle: A body immersed in a fluid is buoyed up by a force equal to the weight of the displaced fluid.

Buoyancy: The apparent loss of weight of an object submerged in a fluid.

Buoyant Force: The net upward force exerted by a fluid on a submerged object.

Density: The property of a substance, equal to the mass divided by the volume.

Mass: The amount of matter that is contained by an object.

Volume: The amount of space occupied in three dimensions.

A. DESIGN CHALLENGE

Challenge

It's 2020 and fossil fuels have reached an all-time low! The Tech is trying to do its part by creating vessels that can move visitors across the Bay. Your job is to design an efficient vessel that that can hold as many passengers* as possible and then glide across water using its own power.
* Note: Pennies will represent passengers

Constraints

- Your vessel must be able to hold at least 10 pennies (more for older students) without sinking.
- Your vessel must float on the water and be stable.
- Your vessel must be able to float from one end of the pool to the other.
- Your vessel must be self-propelled so that it can glide, using stored energy

Testing

The vessel should be placed at one end of the wading pool. After making sure that the vessel can hold the designated number of pennies, it should be sent off to the other side. The vessel needs to reach the other side at least two times without any physical help.

DC Demonstration and Reflection:

Demonstration: Have students demonstrate their vessel designs.

Reflection: Have each group of students explain their design strategy and how their vessel propels itself across the water. Instructor should ask leading questions to get at the science behind the designs.

Teaching Points to guide Reflection Questions:

- ❑ Potential Energy is stored energy and Kinetic Energy is energy in motion.
- ❑ Buoyant Force is the net upward force exerted by a fluid on a submerged object.
- ❑ Density is an object's mass divided by its volume.

Questions to encourage Teaching Points:

How does your design work?
Can you tell me how your design stores enough energy to propel itself across the wading pool? (How is Potential Energy stored?)
Did you have to redesign your vessel for stability or better buoyancy? What did you find you needed to do to ensure that your vessel floated, especially with the pennies?
How can you improve upon your design?

B. SCIENCE DEMONSTRATIONS & DISCUSSION

Buoyancy and Shape: Floating Clay Activity
This activity encourages students to see how shape and size (**volume and density)** affects an objects ability to float (**buoyancy**).

Procedure: Give students a 2-inch diameter ball of clay. Have them put it in a water tank (can be any large plastic container). What happened? Now ask students to take the clay out and dry it off. Tell the students you want them to make this same piece of clay float. Give them time to test out ideas.

NOTE: Some students will find that a flat circular shape will float. Others may begin forming the clay into more of a boat shape, making it a little deeper.

Teacher Notes:

Potential Energy: Energy that is stored. One way to think of it is that something with potential energy has the capability to do something. For example, a stretched rubber band can fly across the room, a relaxed rubber band cannot.

Kinetic Energy: Energy of motion. One way to think of this is something with kinetic energy is moving. For example, as the rubber band flies across the room it has kinetic energy.

Buoyant Force and Volume: The buoyant force that acts upon an object depends upon the volume of the object (smaller objects displace smaller amounts of water, therefore they are acted upon by a smaller buoyant force; larger objects displace larger amounts of water, therefore they are acted upon by a larger buoyant force). It is the volume of the object and not the weight that determines the buoyant force. *Buoyant force is the weight of the volume of fluid displaced.*

Principle of Floatation
A floating object displaces a weight of fluid equal to its own weight.

Buoyancy and Density: When an object has greater density than its surrounding fluid, it will sink. When an object has less density than its surrounding fluid, it will float. And when the density of an object is equal to its surrounding fluid, it will neither sink nor float (it will hover). This holds true for all fluids including air.

Ask students how they made the clay float. Reflect upon the fact the clay sinks when its volume or size is smallest, however it will float when its surface area or volume is increased significantly. Try to get the students to come up with the idea that shape matters. Explain how buoyancy works (see teacher notes on previous page).

C. DESIGN CHALLENGE #2:
Challenge:
Redesign your vessel so that you can increase the number of pennies you can carry across the wading pool (how many pennies can you carry?).

Constraints
- Same constraints as before

Demonstration and Reflection:
Demonstration: Have students demonstrate their vessel designs.

Reflection: Have each group of students explain their design strategy and how their vessel propels itself and uses stored energy to glide across the water. Instructor should ask leading questions to get at the science behind the designs.

Questions to elicit student thinking & understanding:
- How did you change your original design? What affect did this/these change(s) have upon the performance of your vessel?
- How many pennies can your vessel safely carry across the wading pool?
- Did you do anything specific to increase the buoyancy of your vessel?
- If you had more time what would you add, change, or do differently?

Discussion:
If you were to do this again, how many of you think you could design a vessel that carried even more pennies in a safe and efficient way? Discuss how scientists & engineers go through this Design Challenge process daily….learning from their mistakes, reflecting and improving upon what they have already designed.

D. CLEAN UP: REDUCE! RE-USE! RECYCLE!
Only throw away items that cannot be re-used. All items should be returned to the appropriate place.

E. POST ACTIVITIES:
- Restrict building materials to specific supplies, such as a ball of clay or piece of aluminum foil for the vessel.
- Participate in The Tech's *Suspended: Underwater Explorations* lesson, to further explore buoyancy.

Glossary & Concepts:

Archimedes principle: The relationship between buoyancy and displaced fluid: An immersed object is buoyed up by a force equal to the weight of the fluid it displaces.
Boyle's Law: At a constant temperature, the volume of a given quantity of gas is inversely proportional to the pressure upon the gas.
Buoyancy: The apparent loss of weight of an object submerged in a fluid.
Buoyant force: The net upward force exerted by a fluid on a submerged object.
Density: A property of a substance, equal to the mass divided by the volume; commonly thought of as the lightness or heaviness of a substance.
Displaced: Term applied to fluid that is moved out of the way when an object is placed in the fluid. A completely submerged object displaces a volume of fluid equal to its own volume.
Elastic Potential Energy: Potential energy due to tension -- either stretch (rubber bands, etc.) or compression (springs, etc.).
Energy: "Nature's way of keeping score." Measured in joules. Appears in many forms, most of which are ultimately derived from the sun or from radioactivity.
Equilibrium: A state of balance, e.g. the state of a body on which no net force acts.
Fluid: Anything that flows; any liquid or gas.
Force: Any influence that tends to accelerate an object; a push or a pull; force = mass x acceleration (F = ma: Newton's 2nd law), measured in Newton's (N).
Gravity: A pulling force exerted by any mass upon another; the Earth's gravitational force exerts an acceleration (g) of 9.8 m/s2.
Inertia: The tendency of matter to remain at rest if at rest, or, if moving, to keep moving in the same direction, unless affected by an outside (or unbalanced) force.
Kinetic Energy (KE): Energy of motion. KE= ½ mass x velocity^2 = ½ mv^2 Note that small changes in speed can result in large changes of KE (it's speed squared!). Net force x distance = KE. Includes heat, sound, and light (motion of molecules). KE is a scalar quantity; it cannot be canceled.
Mass: A measure of the quantity of matter in a body; a measure of the inertia of an object; the amount of stuff in an object.
Momentum: The quantity of motion of a moving object, equal to the product of its mass and its velocity.
Neutrally buoyant: A state in which the forces of gravity and buoyancy are in equilibrium or balanced.
Potential Energy (PE): Energy of position; energy that is stored and held in readiness. Includes chemical energy, such as fossil fuels, electric batteries, and the food we eat.
Pressure: The force per unit of surface area; exerted perpendicular to the surface; measured in Pascals.
Principle of flotation: A floating object displaces a weight of fluid equal to its own weight.
Velocity (speed): How fast an object is moving. The distance traveled over time.
Volume: The amount of space occupied in three dimensions.
Weight: The force on a body due to the gravitational attraction of another body (usually, the Earth).

Newton's Law of Momentum Conservation:

The amount of momentum remains constant - momentum is neither created nor destroyed, but only changed through the action of **forces.**

Newton's Law of Conservation of Energy:

Energy cannot be created or destroyed; it may be transformed from one form into another, or transferred from one place to another, but the total amount of energy never changes.

Newton's Laws of Motion:

1st Law (Law of Inertia):

An object at rest tends to stay at rest and an object in motion tends to stay in motion with the same speed and in the same direction unless acted upon by an unbalanced force.

2nd Law:

When an unbalanced force acts on a body, it is accelerated in the direction of the force; the magnitude of the acceleration is directly proportional to the force and inversely proportional to the mass of the body… **F=ma**

3rd Law:

For every action, there is an equal and opposite reaction.

Resources:

Boats, Ships, Submarines, and other Floating Machines by Ian Graham. Kingfisher Books, New York, NY, 1993.
Conceptual Physics: a High School Physics Program by Paul G. Hewitt. Addison-Wesley Publishing Co., Inc., Menlo Park, CA, 1997.
Experiments with Balloons by Robert Gardner and David Webster. Enslow Publishers, Inc., Springfield NJ, 1995.
Aquarius website: http://www.uncwil.edu/nurc/aquarius/lessons.htm
AskERIC educational website: http://askeric.org/
The Gateway to Educational Materials website: http://thegateway.org/
How Stuff Works: http://www.howstuffworks.com
How Things Work: http://howthingswork.virigina.edu
Roberts, Robert S., (1982), "Teaching an Old Diver New tricks," The Science Teacher, Vol. 49 No. 7, pp. 25-27,October.
Carusella, Brian, (1998) "Cartesian Diver", freeweb.pdq.net/headstrong/cart.htm

Literature Connections

The Magic School Bus Ups and Downs: A Book About Floating and Sinking (Magic School Bus) by Jane B. Mason, et al (February 1997)

Tell Me How Ships Float (Whiz Kids) by Shirley Willis (March 2000)

Ogs Learn to Float (Reading for Beginners Series) by Felicity Everett, Graham Round (Illustrator) (March 1996)

How Do Big Ships Float? by Isaac Asimov (December 1992)

Tom Swift and His Submarine Boat by Victor Appleton (July 2000)

Little Orange Submarine by Ken Wilson-Max (June 2001)

Life on a Submarine (High Interest Duties: On Duty) by Gregory Payan, Alexander Guelke (September 2000)

Monsters Don't Scuba Dive by Debbie Dadey, et al (May 1995)

Imagine You Are a Scuba Diver (Action Sports Library) by Carolyn J. Crooke (December 2001)

Dive to the Deep Ocean: Voyages of Exploration and Discovery (Turnstone Ocean Explorer Book) by Deborah Kovacs (March 1999

The Discovery of the Titanic by Robert D. Ballard, et al (October 1995)

The History of Underwater Exploration by Robert F. Marx (December 1990)

Water and Light: A Diver's Journey to a Coral Reef (Southwestern Writers Collection Series) by Stephen Harrigan (May 1999)

A Pictorial History of Oceanographic Submersibles, by James B. Sweeney

Ships and Other Seacraft (Rand McNally Factbooks) by Brian Williams

Water Baby: The Story of Alvin by Victoria A. Kaharl