Please note: All the links in this lesson were working when this site launched. If you find a link that does not work, please use a search engine such as Google to find an article on the same topic.

Dredging up the Future

The Dredging up the Future lesson is intended to increase the students' knowledge and skills related to types of dredging and how the industry affects the environment. Students will:

- Examine dredging requirements and the future of the Port of Baltimore;
- Define dredging and types of dredges;
- Address what to do with dredge material; and
- Experiment with buoyancy

In most of the world, including the United States, the term "dredge" refers to the equipment that dredges and a "dredger" is a person who dredges. In Europe, a "dredger" is a machine that dredges. In some of the sources cited in this lesson plan, you may find this difference in meaning.

What dredging requirements might be in the future for the Port of Baltimore?

Teacher's Note

This lesson addresses why it is necessary to dredge and likely future dredging requirements. It introduces cargo ship sizes and types. Its reading and questioning format is probably most effective after students engage in the game activity. It can be assigned to individuals or pairs, or the questions can be used for full class discussion after the sections are read.

Concepts:

1. Dredging is necessary because ships travel through the water, not on top of the water. The portion of the ship that is submerged depends on the weight of the vessel and the area of the water displaced as described by the **Archimedes Principle**. Today's giant ships and tomorrow's future ships will require deeper channels leading to and from ports. **A lesson plan on "What is Dredging?" is provided.**

2. **Draft** is the term used to define the distance from the water surface to the keel - the bottom of the ship at its lowest point under the water. We tend to think of ships

sailing on top of the sea when, in fact, they actually pass through the sea, with a large portion under the water. A ship's draft is the linear distance of a ship designed to sink beneath the surface when the ship is fully loaded. The greater the load, the deeper the ship will ride through the water as governed by Archimedes Principle. Harbor dredging must be done to a depth that exceeds the draft of the largest ship coming to port. **A lesson plan and activity on "Buoyancy" is provided.**

3. The Panama Canal illustrates the problems associated with dredging as ship size increases in order to hold bigger cargoes. Panamax specifically refers to a ship's maximum dimensions that will fit through the locks of the Panama Canal. Hundreds of post-Panamax sized cargo container ships are sailing the seas today.

4. Post-Suez sized ships now are in the design phase and will probably be launched within a decade, increasing demands for deeper and wider channels into ports.

5. The approximate number of containers ships are capable of holding is used to measure container cargo ships. Containers are used to ship dry goods on the land and seas. You've probably noticed them on trucks and trains.

Technology Education Standards:

1. Students will develop an understanding of the nature, characteristics and scope of technology. (STL 1)
   a. Most development of technologies these days is driven by the profit motive and the market. (STL1-M)

2. Students will develop an understanding of the core concepts of technology. (STL 2)
   a. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. (STL 2-Z)
   b. Requirements involve the identification of the criteria and constraints of a product or system and the determination of how they affect the final design and development. (STL 2-AA)
   c. New technologies create new processes. (STL 2-DD)

3. Students will develop an understanding of the influence of technology on history. (STL 7)
   a. Throughout history, technology has been a powerful force in reshaping the social, cultural, political and economic landscape. (STL 7-I)

References:

"Archimedes - Wikipedia, the free encyclopedia." Wikipedia, the free encyclopedia. 16 Nov. 2008 http://en.wikipedia.org/wiki/Archimedes .

"Container Ship Types." GlobalSecurity.org - Reliable Security Information. 24 Nov. 2008 http://www.globalsecurity.org/military/systems/ship/container-types.htm

"Panamax - Wikipedia, the free encyclopedia." Wikipedia, the free encyclopedia. 24 Nov. 2008 http://en.wikipedia.org/wiki/Panamax
.
"The Cargo Ship." Personal Web Sites.... 24 Nov. 2008 http://mysite.du.edu/~jcalvert/tech/fluids/cargo.htm

Titov, Sergei, Vladislav Feldman, Vladislav Farafontov, and Oksana Didenko. "Archimedes Principle." Physics by Demonstrations. 17 Nov. 2008 http://library.thinkquest.org/27948/archimede.html

Key Terms:

- Archimedes Principle
- Bulk Cargo
- Canal
- Channel Depth
- Container Cargo
- Draft
- Dredging
- Locks
- Panamax
- Post-Panamax
- TEU

Key Questions:

Use the handout entitled "Container Ship Types" to have students answer the following questions, using this resource: http://www.globalsecurity.org/military/systems/ship/container-types.htm. The handout is included at the end of this lesson.

1 What is a **TEU**? Why is this measurement used to size container cargo ships? ***(first two paragraphs)***

Answer: TEU stands for twenty-foot equivalent units, which is a measurement of the area that a 20 foot long, by 8 foot wide, by 8.5 foot high cargo container occupies. This creates a convenient method for determining the amount of cargo a ship is capable of hauling.

2 What is meant by the concept: **Panamax** sized cargo ship? Approximately how big is a Panamax sized cargo ship measured in TEU? ***(first two paragraphs under the subhead "Panamax")***

Answer: A Panamax ship is the largest ship that fits easily through the Panama Canal. This was the most economically feasible cargo ship size through the 1980's and most of the 1990's. A Panamax container ship is 4500 to 5000 TEU.

Go to the site through this *Panamax* link and read from the beginning through the subsection titled *Dimensions* to find the answer to this question.

3. What part of the canal structure most limits the size of ships through it? What structure limits the height of the ships? How deep is the canal at its shallowest point?

   Answer: The size of the locks mostly limits the size of the ships that can pass through the channel. The Bridge of the Americas at Balboa limits ships' height. The depth of the south sill of the Pedro Miguel locks is 12.55 meters.

Read on through the *Panamax* link to find out about *Post-Panamax* ships and the answer to these questions.

4. Are the largest ships built today for container cargo (also for bulk cargo and the US Navy) able to pass through the current size of the Panama Canal?

5. Why do you think such large ships are built? Consider this fact: Suppose you want to travel from the Atlantic to the Pacific Ocean. The alternative to using the Panama Canal is to sail all the way around Cape Horn in South America or Cape of Good Hope in southern Africa.

6. What is the draft of the largest class of ship Panamax II cited in the article?

7. Other than the obvious problems with channel depth and dredging, what other issues do you suppose such large ships create for the ports of the world?

   Answer: The largest ships built and launched today cannot fit through the Panama Canal until the canal is enlarged and renovated. The post-Panamax cargo ships are designed to serve ports accessible to a single ocean and also remain more economically viable due to their ratio of cargo moved versus fuel used. The largest ships draft to depth of 60 meters. Beyond channel depth, these behemoths create huge logistical challenges for ports, which need to load and unload, and then move and distribute the goods into and out of the port cities. More about the economics of these ships and the port challenges can be found under the section subtitled Post-Panamax in the Container Ship Types document.

Container Ship Types Class Discussion

Teachers Note: This lesson offers a quick explanation of container ship types. It is an extending reading assignment to be used in conjunction with classroom discussion. It is offered here as background information and may be effectively introduced before students engage in the game activity to provide an understanding and knowledge base.

Technology Education Standards:

1. Students will develop an understanding of the core concepts of technology. (STL 2)
   a. Systems, which are the building blocks of technology, are imbedded with larger technological, social, and environmental systems. (STL 2-X)
   b. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. (STL 2-Z)

2. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (STL 3)
   a. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function. (STL 3-G)

References:

"Container Ship Types." GlobalSecurity.org Military Container Ship Types 3 April. 2009 http://www.globalsecurity.org/military/systems/ship/container-types.htm .

Key Terms:

- Panamax
- Post-Panamax
- Suez-Max
- Post-Suez-Max
- Post-Malacca-Max

Key Questions:

Use the following website to help guide you in your understanding of container ship types. Use the questions below as a guide for classroom discussion.

www.globalsecurity.org/military/systems/ship/container-types.htm

Questions:

1. What are the different types of container ships?

2. How have accidents changed the shipping industry?
3. How are container ships being designed today?
4. How do loading and unloading schedules affect the profitability of a container ship?
5. How have issues with propulsion of larger container ships been resolved? What factors affect the efficiency of a container ship in transit?
6. What will the future design of container ships resemble?

What is Dredging?

Teachers Note:
This lesson offers a quick explanation of dredging and the principal methods by which it is accomplished. It is basically a reading assignment and can be used as a reference handout. You will find it located at the end of this lesson plan in a reproducible format. It is offered here as background information that may be introduced most effectively before students engage in the game activity.

Technology Education Standards:

1. Students will develop an understanding of the core concepts of technology. (STL 2)
   b. Systems, which are the building blocks of technology, are imbedded with larger technological, social, and environmental systems. (STL 2-X)
   c. Selecting resources involves trade-offs between competing values, such as availability, cost, desirability, and waste. (STL 2-Z)

2. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (STL 3)
   d. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function. (STL 3-G)

References:
"Beach replenishment." Dredging and Coastal Consultants - Anthony Bates Partnership. 6 Dec. 2008 http://www.anthonybates.co.uk/capital%20dredging/beach.htm

"Dredger types." Envirotech Engineering Ltd. 6 Dec. 2008 http://www.casa2000.net/dredger%20types.htm

Key Terms:

- Mechanical Dredges
  - Backhoe or Dipper Dredge
  - Bucket Dredge
  - Grab Dredge
- Hydraulic Dredges
  - Cotton Suction Dredge
  - Plain Suction Dredge
  - Trailing Suction Hopper Dredge

Key Questions:

1. **What is dredging?** Dredging is the process of removing material from the bottom of a waterway – a harbor, river, lake, or ocean. This is usually done to increase the

depth of the waterway and improve navigation by large ships with deep drafts. (Draft is depth of the submerged part of the ship.) Increasing the depth of the harbor at the Port of Baltimore will allow bigger cargo ships to dock and increase the flow of goods and materials to and from the port. The material removed from the harbor floor must be moved to another location to be disposed of.

Less common reasons to dredge include situations where the removed dredge material is desirable, such as at Ocean City, Maryland where sand is dredged from offshore and placed back on the beach. This process is called beach replenishment. Storms and erosion move the sand out to sea and dredging returns it to the beach. Another example might be dredging a fairway pond to reclaim errant golf balls. Valuable minerals or other deposits are mined by dredging when they lie underwater.

2. **How is Dredging Accomplished?** Specially designed and equipped boats called dredges are commonly used to accomplish the task. The process can be done mechanically or hydraulically.

Mechanical Dredging:

A ***bucket dredge*** is an old mechanical design that utilizes a conveyer of shovels called buckets. With the boat either in a stationary position or slowly moved forward, an endless chain of buckets is scraped along the bottom to scoop dredged material and move it to the surface, where it is dumped into a waiting barge. Bucket dredges are noisy, accurate, and capable of working in water to a depth of 20 meters.

Another mechanical design is the ***grab dredge***. A pair of clamshell-shaped jaws is lowered on cables from a crane structure. As the jaws open and close, they grab chunks of materials off the bottom. The material is raised from the water and deposited into a waiting barge.

A ***backhoe or dipper dredge*** scoops individual shovels of bottom material in a way similar to the way a tractor backhoe digs a ditch on dry land. An articulating hydraulic arm reaches down to scoop material from the bottom and dumps it into a barge. Although the arm might be hydraulically manipulated, the dredging is still a mechanical digging process.

Hydraulic Dredging:

Hydraulic dredges move dredged material by means of a pump. The ***plain suction dredge*** sucks material from the bottom, much like a swimming pool is vacuumed to be cleaned. Sand is sucked up along with the surrounding water and is moved directly to the beach via a pipeline floating on or near the surface of the water. This process will work at great depths, up to 100 meters, but the material must be relatively loose to be moved easily.

Cutter suction dredges utilize a mechanical cutting device to help suction bottom material that is tightly packed. Rotating grinders or buckets are use to dislodge the material and then move it towards the suction head. Certain heavy-duty suction cutter dredges can even loosen hard rock.

Trailing suction hopper dredges pump the material from the bottom and place it into a hopper on the boat which allows them to operate independently of barges. These dredges can transport dredged material to its final destination and then deposit it. Some can actually pump the material and then spray it in an arc, called rainbowing.

What Happens to the Material Dredged from the Bottom of the Harbor?

Teacher's note:

This lesson addresses handling of dredged materials in our environmentally conscious 21st Century. It is in a reading and questioning format, probably most effective after students finish their game activity. It can be assigned to individuals or pairs, or the questions can be used for full class discussion after the sections are read.

Dredging, like every other successful technology, creates new challenges requiring unique solutions. Mishandled, dredge has the potential to become an ecological disaster. Creatively utilized, it can enrich our natural world. This lesson attempts to make students aware of the challenges and potential benefits of technological endeavor.

Concepts:

1. The relocation of the dredge materials is a giant engineering task in and of itself. The Maryland Department of Transportation has excellent web pages about environmentally sound disposal of dredge material. They can be found on the Safe Passage website at http://www.mpasafepassage.org.

2. Dredging is an ongoing process that creates close to 5 million cubic yards of material each year that must be disposed of or relocated. The stuff removed from the bottom of the shipping channels is called ***dredged material***, or, more often, ***dredge***.

The Technology Education Standards:

1. Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study. (STL 3)
   a. Technology transfer occurs when a new user applies an existing innovation developed for one purpose in a different function. (STL 3-G)
   b. Technological innovation often results when ideas, knowledge, or skills are shared within a technology, among technologies, or across fields. (STL 3-H)

2. Students will develop an understanding of the effects of technology on the environment (STL 5)
   a. With the aid of technology, various aspects of the environment can be monitored to provide information for decision-making. (STL 5-I)
   b. The alignment of technological processes with natural processes maximizes performance and reduces negative impacts on the environment. (STL 5-J)
   c. Humans devise technologies to reduce the negative consequences of other technologies. (STL 5-K)

References:

"Cox Creek Backgrounder." Safe Passage Project Sites. 24 Nov. 2008
http://www.mpasafepassage.org/projectFiles/coxcreek.pdf

"Dredged Materials Monitoring Plan." Safe Passage Project Sites. 24 Nov. 2008
http://www.mpasafepassage.org/projectFiles/monitoring.pdf

"Dredged Materials Monitoring Programs." Safe Passage Project Sites. 24 Nov. 2008
http://www.mpasafepassage.org/projectFiles/dredging.pdf

"Hart-Miller Island Backgrounder." Safe Passage Project Sites. 24 Nov. 2008
http://www.mpasafepassage.org/projectFiles/hmi.pdf

"Hart-Miller Island Backgrounder." Safe Passage Project Sites. 24 Nov. 2008
http://www.mpasafepassage.org/projectFiles/PoplarIsland.pdf

Key Questions:

To find out exactly what dredge is composed of, how it keeps returning to the same cleared channels, and what is done with it, visit the Safe Passage web site: http://www.mpasafepassage.org

1. **Click on the tab labeled "Safe Channels" on the Safe Passage web site.**

   How do most ships travel to and from the Port of Baltimore?

   Answer: "Ocean-going ships travel to and from the Port of Baltimore by two routes. Most travel to Baltimore through the southern approach commonly referred to as the 50-Foot Channel, a deep, north-south route extending 150 nautical miles from the Port of Baltimore to the Atlantic Ocean at Cape Henry, Virginia. The second route is the Chesapeake and Delaware (C&D) Canal, which is maintained by the US Army Corps of Engineers. The C&D Canal is a 14-mile commercial waterway that crosses the Delmarva Peninsula at the northernmost ends of the Chesapeake and Delaware Bays."

2. **Click on the tab labeled "Dredging Program" on the Safe Passage web site:**

   Shipping channels are continually dredged to 'maintain' their depth. Why do they keep filling up? (Hint: you might have to 'read on' and click "Dredged Material Management Program")

   Answer: (quoted from the text)>"…several hundred streams and rivers deliver a constant stream of fine silt into the channels every day." For discussion: Presumably storms, current and tides also naturally reshape the bottom, as well as the movement of ships through the channels, but that is not discussed in this reading.

3. **From *Sediment Quality link*, find the answer to the following questions:**

   'Clean' dredge material consists of clay, silt and mud from natural sources. What are the 'human activities' that generate contaminants that may be present in the dredge?

   Answer: Intense industrial activity, and run off from populated areas and farmland carrying fertilizers, oil, pesticides and other pollutants.

   How do scientists and engineers prefer to use the 'clean' dredge material?

   Answer: Rebuild islands, restore wetlands and create wildlife habitats.

   What is a confined disposal facility?

   Answer: A storage area for contaminated dredge that prevents contaminates from reentering the bay.

4. **From *Placement and Use of Dredged Material link*, find the answer to the following questions:**

   How much dredge material must be relocated from the harbor and its approach channels each year?

   Answer: Approximately 4.7 million cubic yards.

   In the less environmentally conscious past, what was traditionally done with the dredge?

   Answer: The dredge was dumped into the open waters of the bay away from the channels.

   Maryland's Dredged Material Management Program is designed to ensure that no harm is done to the environment by the relocation of dredge. The two main options discussed in this article are "Beneficial use" and "Innovative reuse". In a paragraph describe and compare and contrast these two options.

   Answer: Beneficial use applies the dredge to the bay environment to rebuild island and wetland habitats. Innovative reuse employs the dredge outside of the immediate bay waters for beaches, land, farming and mining purposes.

   Monitoring programs ensure the environmental neutrality of dredge relocation. How do the scientists evaluate the relocation sites?

Answer: Baseline studies, water quality tests and research on fish tissue and bottom-dwelling organisms.

5. **From *Project Sites link*, find the answer to the following question:**

   This article describes beneficial use sites around the bay. Why do you think it is important to establish new beneficial use sites and explore innovative reuse alternatives for the future?

   Answer: After the existing beneficial use sites are created, established and finally developed with native plantings for wildlife use, they must be abandoned to allow the wildlife to return, nest and repopulate the area. Continuing to pump in new dredge will disturb the natural processes that must take place. New sites and/or innovative reuses must be established to allow nature to benefit from the past and present beneficial use sites.

Teacher's note:

Five excellent Port Administration PDF publications (written or last updated in 2008) provide additional information on these topics and could supply a supplemental source for research, report or study:

- Cox Creek Backgrounder
- Dredged Material Monitoring Programs
- Hart-Miller Island Backgrounder
- Dredged Material Monitoring Plan
- Poplar Island Backgrounder

Find out what site your class will be visiting. Read the corresponding Backgrounder and answer the following questions:

1. What was the history of the site? What was it before it became a Dredged Material Containment Facility?
2. Where is the site located?
3. When did construction begin?
4. How many acres compose the site? How many millions of cubic yards will the site contain when it is finished?
5. What kind of wildlife can you find here?
6. What are future plans for the site?

Answer key:

	Poplar Island	Hart-Miller Island	Cox Creek	Masonville
What was the history of the site? What was it before it became a Dredged Material Containment Facility?	"In the 1800s, Poplar Island boasted at least 1,100 acres, including fields, forests, and marsh. Through the years, it played host to early colonial settlers, a small farming village, a hunting club, and a presidential retreat for both Franklin D. Roosevelt and Harry S. Truman."	Hart-Miller Island was an historic island chain that suffered from severe erosion.	"The US Army Corps of Engineers constructed the Cox Creek site in the 1960s. It operated through 1984, mostly as a private industrial site, and fell into disuse until the Maryland Port Administration acquired it through purchases in 1993 and 1997."	Masonville is part of an old industrial area that was historically used as a dumping ground for concrete, timber, cables, unexploded ordinance, tires, and abandoned ships, along with equipment containing PCBs, mercury, and asbestos.
Where is the site located?	Poplar Island is in the mid-Chesapeake Bay, approximately 34 nautical miles southeast of Baltimore and one mile northwest of Tilghman Island in Talbot County.	Hart-Miller Island is in the upper Chesapeake Bay, at the mouth of the Back River in Baltimore County.	"The Cox Creek facility is located on the western shore of the Patapsco River, one mile South of the Francis Scott Key Bridge.	Masonville lies along the Middle Branch of the Patapsco River, one mile downstream of the Hanover Street Bridge.
When did construction begin?	Construction began in 1998.	Construction of the outer dike began in 1981 and the island began receiving dredged material in 1984.	The Cox Creek facility began receiving dredged material in 2005.	Masonville is one of the Maryland Port Administration's newest dredged material placement sites and will be ready to receive dredged material by the end of 2010.
What is the total area of the site? How many millions of cubic yards of dredged material will the site contain when it is finished?	Originally the goal was to restore Poplar to 1,100 acres. Studies are underway for expanding the project by as much as 575 additional acres. The 1,100-acre footprint will contain 40 million cubic yards of dredged material.	"When filled, the facility will contain approximately 100 mcy of dredged material and create 1,100 acres of land."	"Within the dike, approximately 102 acres are available for dredged material placement… Managers estimate its total capacity at 6 million cubic yards…"	The dike encloses 127 acres of open water that will be filled with dredged material. The total site covers 141 acres, including land and water. Masonville has the capacity to receive about 15 million cubic yards of dredged material.
What kind of wildlife can you find here?	"Eighty-nine species of birds have been	Songbirds, owls, heron, deer, foxes, muskrat,	"The Swan Creek wetlands already attract egrets,	Clean-up efforts are still underway, but

	observed at Poplar Island, including eagles, herons, pelicans, egrets, and double-breasted cormorants. Diamondback terrapin nest on the shore, while otters, raccoons, beaver, and deer roam the marsh and woody areas." Editor's note: raccoons are found on neighboring Coach's Island, but to this date, they do not inhabit Poplar Island.	and 285 species of birds.	herons, and ibis. Sampling has shown a large increase in the types and numbers of fish and benthic species that populate the reef ball area."	in the future Masonville Cove will be an area of protected shoreline habitat, where "wetlands and reef areas will be enhanced for shoreline habitat, and stream restoration work will improve habitat in upstream areas."
What are future plans for the site?	"Eventually, 555 acres will be shaped into upland habitat and 555 acres will become intertidal wetlands…" Habitat options will be increased. A long-term monitoring framework will monitor environmental changes for at least 20 years. The island may be expanded by 575 additional acres.	Several acres have been designated as a State Park. The South cell has been developed and is managed for wildlife. The North Cell has been closed; it receives no more dredged material and plans are underway for closing and creating a cover for the North Cell.	Swan Creek will continue to be a valuable wildlife habitat. As of 2009, Cox Creek has become an active containment site after the closing of Hart-Miller Island. Cox Creek contains 30 upland acres and could be an efficient location for a port terminal. Cox Creek may also play a role in exploring the options for innovative reuse.	Once Masonville and the Cove are cleaned up, "additional projects will transform Masonville Cove into a local environmental centerpiece and educational resource… Walking trails and an observation tower will be anchored by a new $750,000 nature center…"

Experiments with Buoyancy

Teachers Note:
"Experiments with Buoyancy" is a hands-on lesson designed to familiarize students with Archimedes Principle of buoyancy and provide a basis for the rationale for the necessity to dredge. A fully loaded cargo ship rides deeply in the water, so deep channels are required for ships to move in and out of port. By varying both hull design and load students are exposed to their impact on draft. This lesson could be effectively done either before or after students engage in the game activity.

Two handouts are included at the end of this lesson: a response sheet for data and observations called "Experiments with Buoyancy" and a mathematical model analysis work sheet labelled "Mathematical Model for Floating Golf Balls Challenge."

The Technology Education Standards:

1. Students will develop an understanding of the attributes of design. (STL 8)
    a. The design needs to be continually checked and critiqued, and the ideas of the design must be redefined and improved. (STL 8-J)
    b. Requirements of a design, such as criteria, constraints and efficiency, sometimes compete with each other. (STL 8-K)

2. Students will develop an understanding of engineering design. (STL 9)
    a. Engineering design is influenced by personal characteristics, such as creativity, resourcefulness, and the ability to visualize and think abstractly. (STL 9-J)
    b. A prototype is a working model used to test a design concept by making actual observations and necessary adjustments. (STL 9-K)

3. Students will develop the abilities to apply the design process. (STL 11)
    a. Refine a design by using prototypes and modeling to ensure quality, efficiency, and productivity of the final product. (STL 11-O)
    b. Evaluate the design solution using conceptual, physical, and mathematical models at various intervals of the design process in order to check for proper design and to note areas where improvements are needed. (STL 11-P)

References:

"Archimedes - Wikipedia, the free encyclopedia." Wikipedia, the free encyclopedia. 16 Nov. 2008 http://en.wikipedia.org/wiki/Archimedes

Titov, Sergei, Vladislav Feldman, Vladislav Farafontov, and Oksana Didenko. "Archimede's Principle." Physics by Demonstrations. 17 Nov. 2008 http://library.thinkquest.org/27948/archimede.html

Experiments with Buoyancy

This is a simple lab experiment about buoyancy using aluminum foil to form vessels and golf balls as weights. It is designed to illustrate Archimedes Principle of buoyancy and complicate the situation with a shallow bottom.

Materials:

- Several plastic tubs – approx. 12” x 20” x 5” deep will work fine (Fill these with 2.5 inches of water.) (One tub for each group of students would be splendid, but as many as 4 groups could share a tub for experimenting.)
- 30 squares of heavy duty aluminum foil – 12” x 12”
- Approx 50 golf balls – or other suitable weight unit
- Paper towels - for maintaining a clean and dry work place
- ***Student feedback handout*** – (included below) for written instructions and recording observations

Break the class into groups of 4 or less depending on the facility and the materials available.

Place 2.5 inches of water in the plastic tubs and arrange them around the room near the groups of students. Explain that the water in the tub represents the channel in a harbor.

Experiment 1:

1. Have the groups form a hemisphere from a 1-foot square of aluminum foil. Explain that they should make the largest half-circle bowl possible. They should be able to create one with a diameter of at least 6 inches. Model this as needed.
2. Have students float the aluminum bowl on the water and, one by one, add golf balls as weight. Have them continue to add golf balls until the vessel touches the bottom of the tub or takes on water and sinks.
3. Have students record results and observations.

Experiment 2:

1. Have the groups form a rectangular box with 3-inch vertical sides from a 1 foot square of aluminum foil. They should be able to form a box that is open at the top with a 4 inch square bottom. Have them make sure the corners are tightly folded to keep out the water.
2. Have students float the aluminum box on the water and, one by one, add golf balls as weight. Have them continue to add golf balls until the vessel touches the bottom of the tub or takes on water and sinks.
3. Have students record results and observations.

Experiment 3:

1. Have the groups brainstorm and design their own vessel with the challenge of floating more golf balls before touching bottom or sinking.
2. Have students float their designed vessel on the water and, one by one, add golf balls as weight. Have them continue to add golf balls until the vessel touches the bottom of the tub or takes on water and sinks.
3. Have students record results and observations.

Analysis: Have the groups share their results with the class and discuss.

Follow-up: Explain Archimedes Principle of buoyancy and relate it to the experiment. Refer to links as needed: Archimedes, Archimedes Principle

Extension: Use the handout ***Mathematical Model for Floating Golf Balls Challenge*** (included at the end of the lesson) to teach how to mathematically model problems of buoyancy. Notice that neither the shallow amount of water nor the relative shape of container (the vessel), nor the load (the golf balls) is addressed in the mathematical model.

Mathematical Model for Floating Golf Balls Challenge

Student: ___________________________________

Archimedes Principle of Buoyancy:

Archimedes Principle of buoyancy states that the upward force on an object in a fluid is equal to the weight of the *fluid that is displaced*.

> If this buoyant force is less than the weight of the object itself, the object will be left with a net downward force and will sink. If the object floats, the buoyant force exactly balances its weight or is greater than the weight exerted by the object.

Application Problem:

> Assuming we can form a hemisphere from a 1 foot square piece of aluminum foil with a diameter of 6.5 inches, how many golf balls should we be able to float?

Helpful Facts:

- Golf balls weigh: 45.9 grams each
- Water weighs: 16.39 grams per cubic inch
- Formula for the volume of a Sphere: $V = 4/3\pi r^3$

Extension Problem:

> Assuming a rectangular vessel 3 X 4 inches with 3-inch sides, what is the potential buoyant effect in water?

Fact: the formula for the volume of a rectangular prism: height x width x depth

Calculation solution:

Calculate the volume of the sphere:

Volume of a sphere 6.5"

$V = 4/3\Pi r^3$

$V= (1.33) \times (3.14) \times (3.25)^3$

V = (1.33) x (3.14) x (34.33)

V = 143.37 Cubic Inches

Calculate the volume of the hemisphere:

Volume of ½ of the sphere:

143.37 / 2 = 71.68 Cubic inches

Calculate the weight of water conceivably displaced by the hemisphere:

1 cubic inch of water weighs 16.39 grams

71.68 x 16.39 = 1174.90 grams

Calculate the number of balls in the weight of water:

Weight of golf balls:

1 golf ball weighs 45.9 grams

Number of balls in weight of water displaced:

1174.9/45.9

25.6

Solution to Extension:

The extension problem would be the same step, substituting the rectangular prism volume formula for the sphere volume formula.

V = H x W x D

V = 3 X 4 X 3

V = 36 cubic inches

Weight of water displaced = 16.39 x 36

590.04 grams

Container Ship Types

Name ______________________________ Date: ____________________

Directions: Use the online sources to answer these questions,

Use this site http://www.globalsecurity.org/military/systems/ship/container-types.htm to answer the first two questions.

1. What is a **TEU**? Why is this measurement used to size container cargo ships? ***(first two paragraphs)***

2. What is meant by the concept: **Panamax** sized cargo ship? Approximately how big is a Panamax sized cargo ship measured in TEU? ***(first two paragraphs under the subhead "Panamax")***

Go to this site http://en.wikipedia.org/wiki/Panamax and read from the beginning through the subsection titled *Dimensions* to find the answer to this question.

3. What part of the canal structure most limits the size of ships through it? What structure limits the height of the ships? How deep is the canal at its shallowest point?

Read on through this site http://en.wikipedia.org/wiki/Panamax to find out about *Post-Panamax* ships and the answer to these questions.

4. Are the largest ships built today for container cargo (also for bulk cargo and the US Navy) able to pass through the current size of the Panama Canal?

5. Why do you think such large ships are built? Consider this fact: Suppose you want to travel from the Atlantic to the Pacific Ocean. The alternative to using the Panama Canal is to sail all the way around Cape Horn in South America or Cape of Good Hope in southern Africa.

6. What is the draft of the largest class of ship Panamax II cited in the article?

7. Other than the obvious problems with channel depth and dredging, what other issues do you suppose such large ships create for the ports of the world?

What is Dredging?

Name: ______________________________ Date: ____________________

1. **What is dredging?** Dredging is the process of removing material from the bottom of a waterway – a harbor, river, lake, or ocean. This is usually done to increase the depth of the waterway and improve navigation by large ships with deep drafts. (Draft is depth of the submerged part of the ship.) Increasing the depth of the harbor at the Port of Baltimore will allow bigger cargo ships to dock and increase the flow of goods and materials to and from the port. The material removed from the harbor floor must be moved to another location to be disposed of.

   Less common reasons to dredge include situations where the removed dredge material is desirable, such as at Ocean City, Maryland where sand is dredged from offshore and placed back on the beach. This process is called beach replenishment. Storms and erosion move the sand out to sea and dredging returns it to the beach. Another example might be dredging a fairway pond to reclaim errant golf balls. Valuable minerals or other deposits are mined by dredging when they lie underwater.

2. **How is Dredging Accomplished?** Specially designed and equipped boats called dredges are commonly used to accomplish the task. The process can be done mechanically or hydraulically.

   <u>Mechanical Dredging</u>:

   A ***bucket dredge*** is an old mechanical design that utilizes a conveyer of shovels called buckets. With the boat either in a stationary position or slowly moved forward, an endless chain of buckets is scraped along the bottom to scoop dredged material and move it to the surface, where it is dumped into a waiting barge. Bucket dredges are noisy, accurate, and capable of working in water to a depth of 20 meters.

   Another mechanical design is the ***grab dredge***. A pair of clamshell-shaped jaws is lowered on cables from a crane structure. As the jaws open and close, they grab chunks of materials off the bottom. The material is raised from the water and deposited into a waiting barge.

   A ***backhoe or dipper dredge*** scoops individual shovels of bottom material in a way similar to the way a tractor backhoe digs a ditch on dry land. An articulating hydraulic arm reaches down to scoop material from the bottom and dumps it into a barge. Although the arm might be hydraulically manipulated, the dredging is still a mechanical digging process.

Hydraulic Dredging:

Hydraulic dredges move dredged material by means of a pump. The ***plain suction dredge*** sucks material from the bottom, much like a swimming pool is vacuumed to be cleaned. Sand is sucked up along with the surrounding water and is moved directly to the beach via a pipeline floating on or near the surface of the water. This process will work at great depths, up to 100 meters, but the material must be relatively loose to be moved easily.

Cutter suction dredges utilize a mechanical cutting device to help suction bottom material that is tightly packed. Rotating grinders or buckets are use to dislodge the material and then move it towards the suction head. Certain heavy-duty suction cutter dredges can even loosen hard rock.

Trailing suction hopper dredges pump the material from the bottom and place it into a hopper on the boat which allows them to operate independently of barges. These dredges can transport dredged material to its final destination and then deposit it. Some can actually pump the material and then spray it in an arc, called rainbowing.

What Happens to the Material Dredged from the Bottom of the Harbor?

Name: ______________________________________ Date: ________________

To find out exactly what dredge is composed of, how it keeps returning to the same cleared channels, and what is done with it, read the following web pages:

1. **From this site: http://www.mpasafepassage.org/dmmp_files/dredging.htm, find the answer to the following question:**

   Shipping channels are continually dredged to 'maintain' their depth. Why do they keep filling up?

2. **From this link http://www.mpasafepassage.org/dmmp_files/sediment_quality.htm, find the answer to the following questions:**

   'Clean' dredge material consists of clay, silt and mud from natural sources. What are the 'human activities' that generate contaminants that may be present in the dredge?

   How do scientists and engineers prefer to use the 'clean' dredge material?

   What is a confined disposal facility?

3. **From this link http://www.mpasafepassage.org/dmmp_files/placement_n_use.htm, find the answer to the following questions:**

   How much dredge material must be relocated from the harbor and its approach channels each year?

   In the less environmentally conscious past, what was traditionally done with the dredge?

   Maryland's Dredged Material Management Program is designed to ensure that no harm is done to the environment by the relocation of dredge. The two main options discussed in this article are "Beneficial use" and "Innovative reuse". In a paragraph describe and compare and contrast these two options.

   Monitoring programs ensure the environmental neutrality of dredge relocation. How do the scientists evaluate the relocation sites?

4. **From this link http://www.mpasafepassage.org/projects/projects.htm, find the answer to the following question:**

   This article describes beneficial use sites around the bay. Why do you think it is important to establish new beneficial use sites and explore innovate reuse alternatives for the future?

Experiments with Buoyancy

Group Name: ______________________________

Students in group: ______________________________

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Experiment 1:

- Form a hemisphere from a 1-foot square of aluminum foil. Make the largest half-circle bowl possible. You should be able to create one with a diameter of at least 6 inches.
- Float the aluminum bowl on the water and, one by one, add golf balls as weight. Continue to add golf balls until the vessel touches the bottom of the tub or takes on water and sinks.

How many golf balls were successfully floated?	What did you observe?

Experiment 2:

- Form a rectangular box with 3-inch vertical sides from a 1-foot square of aluminum foil. You should be able to form a box, open at the top, with a 4 inch square bottom. Make sure the corners are tightly folded to keep out the water.
- Float the aluminum box on the water and, one by one, add golf balls as weight. Continue to add golf balls until the vessel touches the bottom of the tub or takes on water and sinks.

How many golf balls were successfully floated?	What did you observe?

Experiment 3:

- Brainstorm with your group and design your own vessel that will float more golf balls before it touches bottom or sinks.
- Float your designed vessel on the water and, one by one, add golf balls as weight. Continue to add golf balls until the vessel touches the bottom of the tub or takes on water and sinks.
- Prepare to show your vessel and report your results to the class.

Mathematical Model for Floating Golf Balls Challenge

Student: ___________________________________

Archimedes Principle of Buoyancy:

The *Archimedes Principle* of buoyancy states that the upward force on an object in a fluid is equal to the weight of the *fluid that is displaced*.

> If this buoyant force is less than the weight of the object itself, the object will be left with a net downward force and will sink. If the object floats, the buoyant force exactly balances its weight or is greater than the weight exerted by the object.

Application Problem:

> Assuming we can form a hemisphere from a 1 foot square piece of aluminum foil with a diameter of 6.5 inches, how many golf balls should we be able to float?

Helpful Facts:

- Golf balls weigh: 45.9 grams each
- Water weighs: 16.39 grams per cubic inch
- Formula for the volume of a Sphere: $V = 4/3\pi r^3$

Extension Problem:

> Assuming a rectangular vessel 3 X 4 inches with 3-inch sides, what is the potential buoyant effect in water?

ANSWER:

Fact: The formula for the volume of a rectangular prism: height x width x depth

