Calculating Ballast
By Troy Averill

Lesson Overview: Students use the dimensions of the cargo hold of a ship's hull to calculate the volume of material that can be contained. Students will then use the density of material to determine the mass of the potential cargo being transported. Last, students will determine the amount of ballast water that must be pumped out of the ship to maintain the same waterline when the cargo is loaded.

Sources Consulted:
1. (1) www.brighthub.com – ship buoyancy picture
2. (2) tellmewhygoc.blogspot.com/2011_03_01_archive.html – bottle buoyancy picture
3. State of Michigan Grade Level Content Expectations
4. (3) U.S. Army Corps of Engineering-Detroit District Soo Locks Brochure

Learning objectives:
After this lesson, students will be able to do the following:
1. Calculate the volume of a cargo hold of a ship in cm^3
2. Using a calculator to deal with large numbers
3. Use the density equation to calculate the total mass of a potential cargo
4. Use the load capacity of a 1000-foot ship to determine if the cargo could be safely transported
5. Understand the concept of buoyancy and how ballast water is adjusted to compensate for changes in load
6. Calculate the volume of ballast water that must be pumped out to maintain the same waterline using the density of freshwater

Michigan Grade Level Content Expectations
Science
C.1.1j: Apply scientific principles or scientific data to anticipate effects of technological design decisions.
C4.7b: Compare the density of pure water to other substances
C1.1c: Conduct scientific investigations using appropriate tools and techniques
Math
M.UN.06.01: Convert between basic units of measurement within the same measurement system.
M.TE. 06.03: Compute the volume given the lengths of sides using formula
M.UN.05.01: Recognize equivalence of liters, 1000 mL, 1000 cm^3
M.UN.05.02: Know the units for measuring volume

Background:
A 3,700 kilometer (2,400 mile) marine highway stretches from the Atlantic Ocean through the St. Lawrence seaway, and Lakes Ontario, Erie, Huron, Michigan, and Superior into the U.S. and Canadian commercial, industrial, and agricultural heartland. Great ships have been constructed to haul cargos such as coal for power plants, iron ore for producing steel, limestone to make cement, and grain to feed the world.

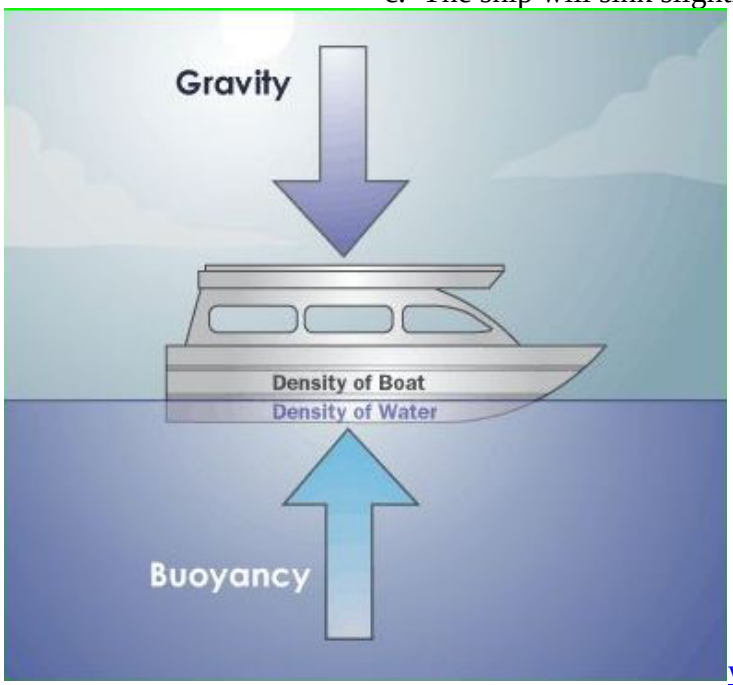
List of Materials Needed per Student:
Scientific Calculator

New Vocabulary:
Ballast water – Water pumped into and out of a ship to maintain buoyancy when changes in cargo load.
Bouyancy – Maintaining an overall density of less that 1.0 g/cm^3 to stay afloat but at the same time, keeping enough of the ship below the water to keep it upright. The law of buoyancy states that if the amount of water displaced is greater than the mass of the ship itself, the ship will float.

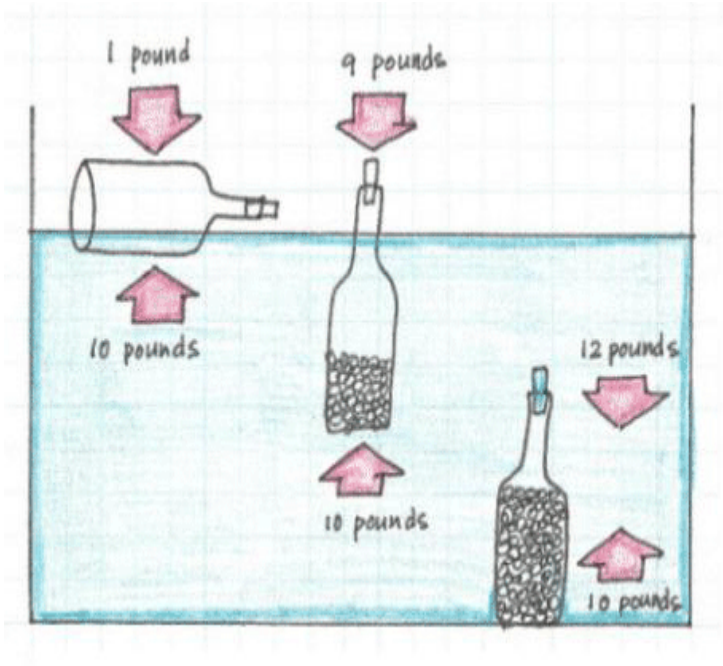
Student Worksheet: Ballast Water, Density, Bouyancy, and Maritime Transport

Focus Question #1: Imagine that the ship below is sitting in a harbor with an empty cargo hold. What will happen to the waterline of the ship if it takes on a load of Styrofoam?

a. The ship will rise slightly causing the waterline to be lower on the ship
b. The waterline will stay the same
c. The ship will sink slightly causing the waterline to be higher on the ship

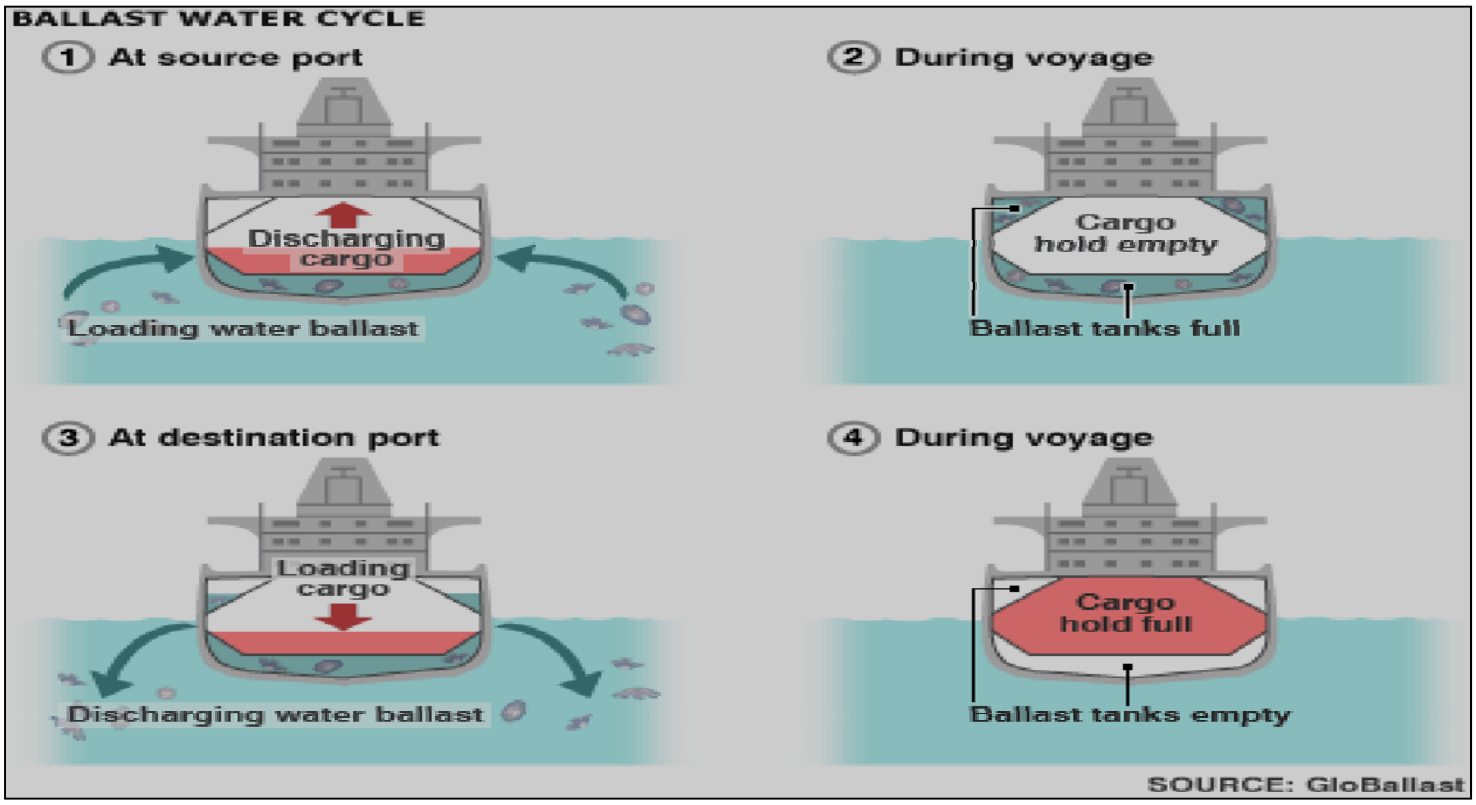


www.brighthub.com(1)



tellmewhygoc.blogspot.com/2011_03_01_archive.html(2)

Introduction: A 3,700 kilometer (2,400 mile) marine highway stretches from the Atlantic Ocean through the St. Lawrence seaway, and Lakes Ontario, Erie, Huron, Michigan, and Superior into the U.S. and Canadian commercial, industrial, and agricultural heartland. Great Ships have been constructed to haul cargos such as low sulfur coal for power plants, iron ore for producing steel, limestone for producing cement, and grain to feed the world. How do ships carry such cargo without sinking?



Research the term "Ballast" and study the picture above. Write a short paragraph describing what you see in each drawing #1-4 above.

1. _____
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3. _____
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4. _____
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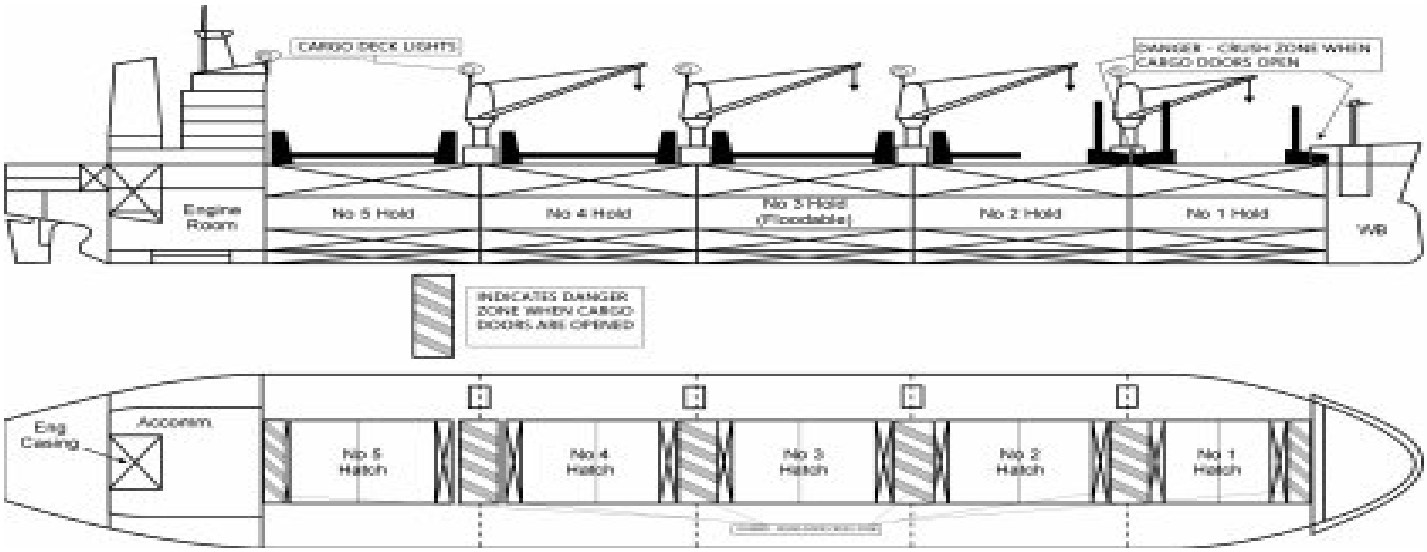
The largest ships on the Great Lakes are called Lakers. These ships can be up to 1000 feet (304.8 m) long and transport up to 60,000 tons of cargo (120,000,000 pounds)[3].

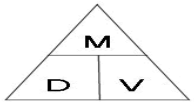
Question 1: How many grams of cargo can a 1000 foot Laker transport if 1.0 pound = 454 grams? (Show work)



The ship diagram above shows 5 cargo holds. Each of the cargo holds is 100 ft * 20 ft * 10 ft.

Question 2: Using the conversion, 1.0 inch = 2.54 cm, calculate the <u>total</u> volume of cargo hold in cm^3. (Show work)

Iron Ore is a material commonly transported by Lakers from the port of Duluth Minnesota to its final destination for production into steel. Iron has a density of 7.9 g/cm^3.

Question 3: Using the density equation 

, calculate the mass of iron that would fill the total cargo hold of this ship. (Show work)

Question 4 Is the ship capable of filing its cargo holds to capacity with iron ore? Explain

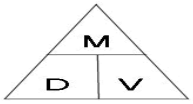
Question 5: As iron ore is loaded onto the ship, what must the Captain do to compensate for the added load?

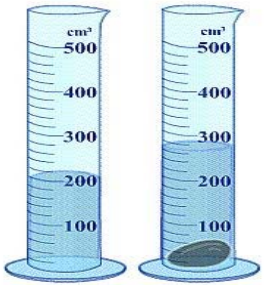
Question 6: Freshwater has a density of 1.0 g/mL. 1000 mL = 1.0 Liter. How many liters of ballast water must be pumped out to compensate for the load of iron ore taken on to the ship if the Captain wants to maintain the same waterline?

Sources of information:

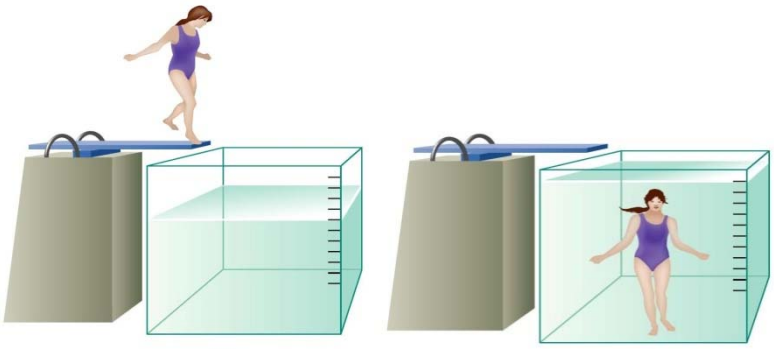
(3) U.S. Army Corps of Engineering-Detroit District Soo Locks Brochure

Assessment:





1. A graduated cylinder contains 180 mL of water. When a rock is placed in the graduated cylinder, the water level rises to 260 mL. The mass of the rock is 400 grams. What is the density of the rock?
*(Remember units g/cm^3) _____

2. 

A pool contains 100 L of water. After a girl gets into the pool, the water level rises to 146 L. The mass of the girl is 45.4 Kg. What is the density of the girl and will she sink or float?

a. Density is approximately 0.987 g/cm^3, girl will float.
b. Density is approximately 0.987 g/cm^3, girl will sink.
c. Density is approximately 1.013 g/cm^3, girl will float.
d. Density is approximately 1.013 g/cm^3, girl will sink.

3. A Greek scientist and philosopher named Archimedes was given the task of determining if the royal crown was pure gold. The crown had a mass of 553.7 grams and displaced 49.0 mL of water. Use the table below to determine the likely composition of the crown.

Substance:	Density (g/mL @ 20 C)
Magnesium	1.740
Aluminum	2.700
Silver	10.500
Lead	11.300
Gold	19.300

a. Lead
b. Aluminum
c. Gold
d. Magnesium
e. Silver

4. A cargo hold has the following dimensions: 10 meters * 5 meters * 5 meters.
How many cm^3 of volume in the ship's cargo hold?
a. 500 cm^3 b. 50,000 cm^3 c. 250,000,000 cm^3 d. 6.02 E^{23} cm^3

5. Bituminous coal has a density of 0.84 g/ cm^3. What would be the mass of the coal that could be transported in the cargo hold of the ship above in kilograms?
a. 420 kg b. 210,000 kg c. 1,200,000 kg d. 4,895,300 kg

6. What volume of water must be pumped out of the ballast tanks to compensate for the added load in the question above if the Captain wants to maintain the same waterline?
(Hint: Density of water = 1.0 g/ mL)
a. 1500 Liters b. 37,000 Liters c. 153,000 Liters d. 210,000 Liters

7. Prior to the modern loaders, maritime workers had to shovel material out of the cargo holds. Calculate the mass of each shovel full of iron ore using the following information: (Show work)
Shovel is 30 cm * 20 cm and load is average 5 cm high
Density of iron is $7.9 cm^3$

8. Essay Question: Explain what could happen if the Captain failed to pump water into the ballast tanks when the load was being removed from the ship.

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9. Extra Credit:
Explain how the Captain must adjust ballast water when moving from salt water (Density = 1.03 g/ cm^3) to freshwater (Density = 1.0 g/ cm^3) to maintain the same waterline.

_____
_____
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