Exploring Gravity's Effect on Ship Stability

Subject (Focus/Topic):	Locate Center of Gravity Given Multiple Loads
Grade Level:	Grades 11-12
Average Learning Time:	30 minutes
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LESSON PLAN DESCRIPTION

Lesson Summary (Overview/Purpose)

Student will be introduced to the three centers related to ship stability with a focus on gravity. Students will locate gravity when given multiple load masses and sites on a "ship."

Overall Concept (Big Idea/Essential Question)

How does gravity and load placement impact ship stability?

Specific Concepts (Key Concepts)

- Naval architecture
- Stability
- Center of Gravity
- Flotation
- Buoyancy
- Weighted average

Focus Questions (Specific Questions)

- What is naval architecture?
- What three elements impact a ship's stability?
- Why is stability so important to a ship?
- How does load placement impact a ship's stability?
- How can I use weighted averages to determine the point of gravity?

Objectives/Learning Goals

1. The student will be able to describe the role of a naval architect and provide 2 real world job opportunities.
2. The student will be able to describe how center of gravity applies to engineering and everyday life.
3. The student will determine the location of gravity given multiple loads of varying masses with 80% accuracy.
4. The student will determine the gravity value with a precision of 3 significant figures.

Background Information

Ship Stability and Why It Is Important:

NOAA research vessels, like many other ships, carry enough cargo, supplies, and equipment for trips that frequently last several weeks. All of the additional weight from the equipment, supplies, people, and on-board fluids is generally referred to as the ship's load. This load must be managed to ensure the ship's stability and safety at all times.

The three elements that impact a ship's stability are gravity (G), buoyancy (B), and flotation (F). Ships possess a center of gravity, which helps to counteract natural movements of the sea and keep the ship upright. This gravity exists in three planes and has three centers: longitudinal, transverse, and vertical. In planar terms, the longitudinal center of gravity (LCG) exists on the X-axis. Transverse center of gravity (TCG) exists on the Y-axis. Vertical center of gravity (VCG) exists on the Z-axis. As you can imagine, when cargo, supplies, fuel, and other fluids are loaded on-board, it will alter the vessel's natural center of gravity. Therefore, a weighted average of the cargo is taken into account to determine where the ship's new center of gravity it located.

To do this, the ship's captain and engineer use on-board computer programs to monitor the distribution of weight on the ship. These two individuals also communicate with each other to make sure that as supplies and fluids are drawn down during the trip that it does not negatively impact the ship's stability.

Naval Architecture:

Naval architects are basically ship designers who are responsible for designing, building, and repairing vessels ranging from sailboats to commercial tankers to submarines. Some of their job tasks might include analyzing the stability, buoyancy, gravity, and trim of a ship. Their designs inherently make the vessel safer or less stable and dangerous. Their work can also influence the overall ride of the ship. Naval architecture is currently an in-demand profession. Many of its experienced professionals are reaching the age of retirement. Therefore, there exists a supply gap in which many more jobs are available than people with the knowledge to fill them.

Math Skills:

Students will practice weighted averages and graphing in this activity. They must be able to successfully apply order of operations to determine the weighted average. The basic equation that will be used is:

$X= (x1m1 + x2m2 + x3m3)/(m1+m2+m3)$

Common Misconceptions/Preconceptions:

This lesson will primarily focus on longitudinal and transverse centers of gravity, which is 2-dimensional. Students might forget about the 3rd, vertical dimension. A simple teacher demo using a clear plastic container with an object placed within could easily act as a reminder of the vertical dimension.

Teaching Materials

Appended Resources (AR's)

Non-interactive, printed materials inserted into this document after the Lesson Plan Description.

- none

Digital Resources (DR's)

Interactive, electronic files created by the Teacher-At-Sea to support this lesson.

- none

Physical Items

Items used in the classroom to facilitate learning, especially during activities:

- Large sheet of paper
- Markers
- Rulers or meter sticks
- Clear rectangular containers (plastic food storage containers work great)
    - Note: Instead of containers filled with water you can also use small rectangular weights or blocks with different masses.
- Balance or electronic scale
- Calculators
- Water
- Paper towels

Technical Requirements

Any connectivity, software, hardware, or A/V equipment needed to teach this lesson:

- Internet access to research naval careers

Teacher Preparation

Gather materials before class. Review naval architecture university and career options. Be sure to have paper towels or other materials on hand to clean up and water spills.

Keywords

- Naval architecture
- Center of gravity
- Buoyancy
- Longitudinal
- Transverse

Pre-assessment Strategy/Anticipatory Set (Optional)

Have students explore their own center of gravity. This can be done as a demo for the whole class or in small groups if time and materials allow.

1. Having student balance on one foot (if this is too easy for the student, have him/her balance on the toes of one foot) hands by their side. Record how long the student can stand like this and how much "wobbling" occurs.
2. Repeat the same motion but now have the student hold their arms stretched out in front of them, perpendicular to their body. Repeat again with arms held out at a "T shape" at the shoulders and overhead.
3. Repeat another series of rounds but add flexible ankle weights to their wrists or have the student hold something like water bottles.

Lead a class discussion and let the student describe how shifting his/her arms and adding weight affected their balance/center of gravity.

Lesson Procedure

Graphing Prep

1. On the left-hand side of the large sheet of paper, use a marker to draw a straight vertical line from the top to the bottom of the sheet of paper. Now find the halfway point of that vertical line. From there draw a horizontal line all the way over to the right hand side of the graph paper. Label these as the Y-axis and X-axis.
2. Starting on the left-hand side of the graph paper where the Y-axis is, draw an outline of the ship. It is important to make sure you draw the bow, or front of the ship, so the nose of it is on the Y-axis.
3. Fill 3 plastic containers with varying amounts of water.
4. Place the 3 containers in random spots within your "boat." Be sure the containers are parallel, or "face the same direction," as the ship outline on the graph paper.

Find Longitudinal Center of Gravity (X)

5. Starting from the Y-axis determine the X value for each of the 3 containers. Use the approximate middle point for each of the containers. Record this value.
6. Use a scale or electronic balance to determine the mass of each container. Record this value.
7. Determine and record the position of longitudinal center of gravity via a weighted average using the formula:

$$X = (x1m1 + x2m2 + x3m3) / (m1+m2+m3)$$

Find Transverse Center of Gravity (Y)

8. Locate the Y value for each of the 3 containers. Use the approximate middle point for each of the containers. Record this value.
9. Use a scale or electronic balance to determine the mass of each container. Record this value.
10. Determine and record the position of the transverse center of gravity via a weighted average using the formula:

$$Y = (y1m1 + y2m2 + y3m3) / (m1+m2+m3)$$

Center of Gravity Location

11. Using the X, Y values just calculated mark the position of the vessel's new center of gravity with the three loads on your piece of graph paper.

Assessment and Evaluation

Both informal and formal assessment will occur during this activity. Student participation and discussion during the pre-assessment activity will identify student misconceptions and knowledge growth throughout the lesson. It will serve as informal assessment. Student measurements of mass and their weighted average calculation results will serve as formal assessment. Students should be able to record significant figures during data collection and analysis with 80% accuracy. Students should be able to complete weighted average calculations and plot resulting X, Y values with 80% accuracy.

Standards

Ocean Literacy Principles Addressed

- 6B: The ocean provides food, medicines, and mineral and energy resources. It supports jobs and national economies, serves as a highway for transportation of goods and people, and plays a role in national security.
- 6C: The ocean is a source of inspiration, recreation, rejuvenation, and discovery. It is also an important element in the heritage of many cultures.
- 7D: New technologies, sensors, and tools are expanding our ability to explore the ocean. Scientists are relying more and more on satellites, drifters, buoys, subsea observatories, and unmanned submersibles.
- 7F: Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, physicists, animators, and illustrators. And these interactions foster new ideas and new perspectives for inquiries.

State Science Standard(s) Addressed:

Virginia SOLs:

- PH.2: The student will investigate and understand how to analyze and interpret data. Key concepts include
  - a) a description of a physical problem is translated into a mathematical statement in order to find a solution
- PH.4: The student will investigate and understand how applications of physics affect the world. Key concepts include
  - a) examples from the real world; and
  - b) exploration of the roles and contributions of science and technology.
- Math 6.5: The student will
  - c) solve multistep practical problems involving addition, subtraction, multiplication, and division of decimals.
- Math 6.8: The student will
  - a) identify the components of the coordinate plane; and
  - b) identify the coordinates of a point and graph ordered pairs in a coordinate plane.
- Math 6.11: The student will
  - a) represent the mean of a data set graphically as the balance point; and
  - b) determine the effect on measures of center when a single value of a data set is added, removed, or changed.

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