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Rock and Boat Worksheet Answer Key

Objectives

- To demonstrate understanding of Archimedes' principle.
- To answer an objective question based on understanding of volume, mass, density and weight.

Challenge Question

You have a large rock on a boat that is floating in a pond. You throw the rock overboard and it sinks to the bottom of the pond. Does the water level in the pond rise, drop or remain the same?

Definitions

volume A measurement of the amount of space an object occupies.

mass A measurement of the amount of matter in an object.

density A measurement of the compactness of an object.

buoyancy The ability of an object to float in a liquid.

pressure A measurement of force per unit area.

weight A measurement of force on an object due to gravity.

Relationship Questions

1. What is the relationship between volume, mass and density?

The density of an object is equal to its mass divided by its volume; ($\rho = m / v$).

2. What is the relationship between mass and weight?

The weight of an object is equal to its mass times the gravitational acceleration constant; ($w = m * g$).

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Materials

- clear bucket filled with water
- model boat
- large rock
- sticky notes and pen, to mark the water level
- large poster-sized paper

Procedure

1. Fill the clear bucket with water.
2. Place the boat in the water so it floats.
3. Place the rock on the boat ensuring that the boat is still floating.
4. Mark the water level with a sticky note labeled “rock in boat.”
5. Take the rock off of the boat and place it in the water.
6. Mark the water level with a sticky note labeled “rock in water.”

Questions

1. How does Archimedes’ principle apply to the rock and boat?
   Archimedes’ Principle states that the buoyant force is equal to the weight of the water displaced by the boat. If the weight of the water displaced by the boat is less than the weight of the boat, the boat sinks. In this activity, the weight of the water is greater than the weight of the boat with the rock, so the boat and rock float.

2. What variables need to be defined to solve this problem?
   v_{wdisp_b} = volume of the water displaced by the rock in the boat
   v_{wdisp_s} = volume of the water displaced by the rock when it is fully submerged
   w_{rock} = weight of the rock
   w_{wdisp} = weight of the water displaced by the rock in the boat
   ρ_{rock} = density of the rock
   ρ_w = density of water

3. Derive an equation for v_{wdisp_b} the volume of the water displaced by the rock in the boat.
   Hint: use Archimedes’ principle to begin.
   $w_{rock} = w_{wdisp\_b}$ use $w = m * g$ for substitution
   $m_{rock} * g = m_{wdisp\_b} * g$ g cancels out
   $m_{rock} = m_{wdisp\_b}$ use $\rho = m / v$ for substitution
   $\rho_{rock} * v_{rock} = \rho_w * v_{wdisp\_b}$
   $v_{wdisp\_b} = (\rho_{rock} * v_{rock}) / \rho_w$

4. Derive an equation for v_{wdisp_s} the volume of the water displaced when the rock is fully submerged.
   $v_{wdisp\_s} = v_{rock}$

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5. Compare v_{wdisp_b} to v_{wdisp_s} to mathematically and physically explain whether the water level rises, drops or remains the same when the rock is thrown overboard.

   $(v_{wdisp\_b} / v_{wdisp\_s}) = [(\rho_{rock} * v_{rock}) / \rho_w] / v_{rock}$ v_{rock} cancels out

   $(v_{wdisp\_b} / v_{wdisp\_s}) = (\rho_{rock} / \rho_w)$

   The rock sinks, so $\rho_{rock} > \rho_w$, therefore, $v_{wdisp\_b} > v_{wdisp\_s}$

6. What role does the boat play in this activity? Do we need to account for the volume of water displaced by the boat? Why or why not?

   The role of the boat is to provide a vessel to float the rock in the water. We do not need to account for the volume of water displaced by the boat because that volume is the same whether the rock is in the boat or fully submerged, and thus does not affect the water level change due to the placement of the rock.

7. What would change if we used:
   a. A boat with a rounded hull (bottom)?

      A larger volume of water would be displaced, however as stated in number 6, the volume of water displaced by the boat does not affect the change in water level due to the placement of the rock.

   b. A larger rock?

      The larger rock does not necessarily weigh more, but it could weigh more or less depending on the density. If it weighed more, there would be an increase the volume of water displaced when the rock is on the boat, but if it weighed less, there would be a decrease in the volume of water displaced when the rock is on the boat. The larger rock also has a greater volume, so it would increase the volume of water displaced when the rock is fully submerged.

   c. Molasses instead of water?

      The rock takes longer to sink due to the viscosity of the molasses compared to that of water; however, the rock is still denser than the molasses so the outcome will remain the same.

8. BONUS: Provide a few examples of how these principles are used in real-world science, engineering and/or technology.

   Archimedes' principle and a density-buoyancy relationship are important in science, engineering and technology applications, such as the rise of a balloon in the air and apparent loss of weight of submerged objects and various floating vessels. A balloon filled with helium is less dense than the surrounding air so it rises up into the atmosphere, and when an object or a human body is submerged under water, there is an apparent loss of weight equal to the weight of the water displaced by the submerged object. Naval architects and engineers design the hull shapes of ships to be buoyant by distributing their weight over a larger surface area so the weight of the water displaced is greater than the weight of the ship. In order to prevent flooding, especially after storm events, engineers must also know how much water will be displaced when ships navigate through small channels and lock-systems. Engineers also apply their understanding of buoyancy and Archimedes' principle in the design of offshore oil rigs and production platforms, which are essential for the production of natural gas and petroleum from open ocean wells. It is important that oil production platforms float without sinking or overturning to ensure maximum efficiency and production of oil for consumer use.