13.2: Archimedes' Law

Figure 10.2.1

This cargo ship displaces an amount of water such that the weight of the displaced water is exactly equal to the weight of the ship and its cargo. The displacement of water is what produces the buoyancy to float this ship. When this photo was taken, the ship was empty so it did not sink very deep in the water to displace the necessary weight. When this ship is fully loaded with cargo, the water line will be where the black paint meets the red paint.

Archimedes' Principle and Buoyancy

If an object is submerged in a liquid, the object displaces a volume of the liquid equal to the volume of the submerged object. Legend has it that this observation was made by Archimedes when he sat in a bath tub that was filled to the top of the tub. The volume of water that overflowed was equal to his own volume. The forces exerted by the fluid on the sides of the submerged object are balanced. However, the forces exerted by the fluid on the top and bottom of the object are not equal. The force exerted by the liquid below the object is greater than the force exerted by the liquid above it; the liquid exerts a net upward force on the submerged or floating object. This force is called **buoyancy**, and its magnitude is equal to the weight of the displaced water. **Archimedes' Principle** states that the buoyant force is equal to the weight of the displaced liquid.

Examples

Example 10.2.1

The density of steel is 9000. kg/m^3 and the density of water is 1000. kg/m^3. If a cube of steel that is 0.100 m on each side is placed in a tank of water and weighed while under water, what is the apparent weight of the cube?

Solution

The volume of the cube is 0.00100 m^3.

The mass of the cube is 9.00 kg.

The weight of the cube when not submerged in water = (9.00 kg)(9.80 m/s^2) = 88.2 N

The mass of water displaced by the cube = 1.00 kg

The weight of the water displaced by the cube = 9.80 N

The buoyant force on the steel cube = 9.80 N

Apparent weight of cube under water = 88.2 N - 9.80 N = 78.4 N

Example 10.2.2

A hollow metal cube 1.00 m on each side has a mass of 600. kg. How deep will this cube sink when placed in a vat of water?

Solution

Since the weight of the cube is 5880 N, it will need to displace 5880 N of water in order to float.

Volume of submerged portion of cube =(1.00 m)(1.00 m)(x m)=x m3

Mass of water displaced =1000x kg

Weight of water displaced =9800x N

9800x=5880

x=0.600 m

The cube will sink such that 0.60 m are underwater and 0.40 m are above water.

Have you ever gone fishing? A sinker is often attached to a fishing line in order to sink the hook deep enough in the water to bait a fish. Use the simulation below to adjust the material of the sinker so that it submerges in the water. Then, play around with the different materials to see if they will sink or float. Challenge: Can you get the rubber ducky to sink?

Summary

- If an object is submerged in a liquid, the object will displace a volume of the liquid equal to the volume of the submerged object.
- The forces exerted by the fluid on the sides of the submerged object are balanced, but the forces exerted by the fluid on the top and bottom of the object are not equal.
- The liquid exerts a net upward force on the submerged or floating object, called buoancy.
- The magnitude of buoancy is equal to the weight of the displaced water.
- Archimedes' Principle states that the buoyant force is equal to the weight of the displaced liquid.

Review

1. A cylinder with a radius of 11 cm and a height of 3.4 cm has a mass of 10.0 kg.
    1. What is the weight of this cylinder?
    2. What is the weight of this cylinder when it is submerged in water?
2. A wooden raft is 2.00 m wide, 3.00 m long, and 0.200 m deep. The raft and its occupants have a mass of 700. kg. How deep will the raft sink below the water when floating?
3. For the raft in problem #2, how many 50. kg people can be added to the raft before it sinks completely under water?
4. The density of gold is 19,320 kg/m^3 and the density of mercury is 13,500 kg/m^3. If a cube of gold that is 0.100 m on each side is placed in a tank of mercury and weighed while under the surface, what is the apparent weight of the cube?

Additional Resources

PLIX: Play, Learn, Interact, eXplore: Archimedes' Principle: The Gold Crown Mystery

Real World Application: USS Iowa, The Weight of Gold

Videos:

Study Guide: Fluids Study Guide
