

Archimedes' Principle

Experimental Equipment: 1 oddly shaped metal objects (either iron, copper, brass, aluminum or some alloy); Vernier force probe, Lab Pro Interface, cables, string, table clamp and rods for hanging force probe; large and small beaker, 100 g mass.

Theory

To understand how we are going to determine the density of an object using Archimedes Principle there are a few preliminary ideas to consider:

1. The pressure in a fluid of density ρ at a depth h is given by:

$$P = F/A = mg/A = \rho gV/A = \rho g(Ah)/A = \rho gh$$

$$\mathbf{P = \rho gh}$$

2. Objects seem to have less weight when submerged in fluids due to the upward thrust of the buoyant force. The buoyant force acting on a submerged object is due to the difference in pressure above and below the object at different depths. The buoyant force is also equal to the weight of the object in the air minus the weight of the object in the fluid:

$$\mathbf{BF = W_{in\ air} - W_{in\ fluid} \quad (1)}$$

3. An object submerged in a fluid displaces a volume of fluid that is equal to its own volume. The weight of the displaced fluid can be expressed in terms of its density and volume:

$$W_{fluid} = mg = m(V/V) = (m/V)g V = \rho gV$$

$$\mathbf{W_{fluid} = \rho_{fluid} gV \quad (2)}$$

Archimedes' Principle: The buoyant force on a submerged body equals the weight of the fluid it displaces:

$$\mathbf{BF = \rho_{fluid} gV \quad (3)}$$

Equating the two expressions (1) and (3) for the buoyant force we can solve for the volume of the object (which is the same as the volume of the displaced fluid):

$$W_{in\ air} - W_{in\ fluid} = \rho_{fluid} gV$$

$$\mathbf{V = (W_{in\ air} - W_{in\ fluid}) / \rho_{fluid} g}$$

This relationship is very useful if you want to determine the volume of an object with an odd shape. All you have to do is weigh the object in a fluid of known density (water) and then weigh it in air to determine the buoyant force and thus its volume. That is exactly what Archimedes did in order to determine that the density and composition of the king's crown was gold! Putting it all together:

$$\mathbf{\rho_{object} = m/V = m / [(W_{in\ air} - W_{in\ fluid}) / \rho_{fluid} g]}$$

Experimental Procedure

Density of a Metallic Object: Determine the density and therefore the composition of an irregularly shaped metal object using Archimedes Principle as outlined above using water as your fluid ($\rho_{\text{water}} = 1000\text{kg/m}^3$). Your metal will be either iron, copper, brass, aluminum or some alloy – sorry no gold!

1. First examine your metal object. What do you think it is and why?

2. Examine your measuring devices. How many significant figures are you keeping?

significant figures: _____

3. Measure the mass of the object:

m _____ (kg)

4. Weigh the object suspended from a string.

Weight in Air = _____ (N)

5. Weigh the object in water.

Weight in Water = _____ (N)

6. Calculate the density of your object.

$\rho_{\text{object}} = \text{_____} (\text{kg/m}^3)$

7. Compare your object's density to other known densities of metals. What do you think your object is made of? How far off are your results from the closest matching metal (as a percent)?

Archimedes Principle To test Archimedes Principle, we will weigh the water displaced by the object. Fill your beaker up to the brim and then submerge your object so that the displaced water spills out into another beaker. Measure the mass of the beaker empty and then with the water to find the mass of the water displaced. Calculate the buoyant force from the above procedure and then compare.

1. Calculate the Buoyant Force: $\mathbf{BF = W_{in\ air} - W_{in\ fluid}}$ BF = _____(N)

2. Measure the mass of the beaker with no water. $m_{beaker} =$ _____(kg)

3. Measure the mass of the beaker with displaced water. $m_{beaker+ water} =$ _____(kg)

4. Calculate the mass of the displaced water: $m_{water} =$ _____(kg)

5. Calculate the weight of the displaced water: $W_{water} =$ _____(N)

Is the Buoyant Force equal to the weight of the displaced fluid? What is your percent error?

Unloading a Boat There is a famous problem about throwing a stone from a boat into the swimming pool where the boat is floating. When the stone is thrown from the boat into the water, does the water level rise, fall or remain the same?

Procedure: Place a 100 g weight in a small beaker and float it inside a larger beaker. Tie a string to the weight so you can easily lift it out. Note the level of the water in the large beaker. Lift the weight out of the smaller beaker and put it into the larger beaker. What happens to the water level? Explain your results below.

Level of beaker before: _____

Level after: _____

Explain your results in terms of Archimedes Principle: