# 21

## *Archimedes' Principle*

# Float a Big Stick

## Purpose

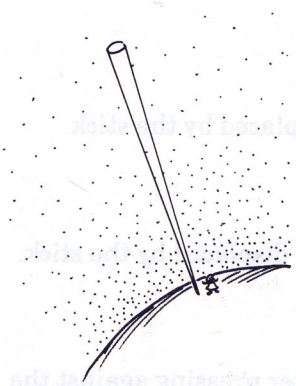
To investigate how objects float by analyzing forces acting on a floating stick.

## Required Equipment and Supplies

vernier calipers
250 ml graduated cylinder
meterstick
triple-beam balance
stick, about 30.5 cm long and 2.54 cm square, or a cylinder of similar dimensions

Note: It is helpful if the sticks have been oiled, varnished or painted in some manner to prevent them from absorbing water.

## Discussion



An object submerged in water takes up space and pushes water out of the way. The water is said to be *displaced*. Interestingly enough, the water that is pushed out of the way in effect pushes back on the submerged object. For example, if the object pushes a volume of water with a weight of 10 N out of its way, then the water reacts by pushing back on the object with a force of 10 N. We say that the object is *buoyed* upward with a force of 10 N. This is summed up in *Archimedes' Principle*, which states that the buoyant force that acts on any completely or partially submerged object is equal to the *weight of the fluid it displaces*.

If the buoyant force is less than the weight of the submerged object, the object sinks. If the buoyant force is equal to the weight of a submerged object, as in the case of a fish, the object neither sinks nor floats. If the buoyant force is greater than the weight of a submerged object, the object rises until it floats. It will float at a level that makes the weight of water displaced exactly equal to the weight of the floating object. This is summed up by the *principle of flotation*, which states that the *weight of the fluid displaced by any floating object is equal to the weight of the object.*

The fluid pressure at a depth, $h$, in a fluid of density, $\rho$, is given by

$$P = P_0 + \rho g h$$

In this experiment, you will investigate the force and the pressure that a fluid exerts on objects under different conditions.

## Procedure

Show your calculations. Be sure to express your data and subsequent calculations with the appropriate number of significant figures.

**Step 1.** Determine, in cubic centimeters, the volume of the stick.

$V =$ _____ $cm^3$

**Step 2.** Determine, in grams, the mass of the stick.

$m =$ _____ g

**Step 3.** Calculate, in $g/cm^3$, the density of the stick.

$d =$ _____ $g/cm^3$

**Step 4.** The definition of a newton is the force required to accelerate one kilogram one $m/s^2$ (e.g., SI units). Calculate the weight of the stick in newtons.

$W_{newtons} =$ _____ N

**Step 5.** Place the stick in the graduated cylinder. Fill the cylinder with enough water to float the stick. Determine the volume of the water displaced by the floating stick.

$V =$ _____

**Step 6.** Calculate the mass, in grams, of water displaced by the stick.

$m =$ _____

**Step 7.** Calculate the weight, in newtons, of water displaced by the stick.

$W_{newtons} =$ _____ N

**Step 8.** Calculate the *pressure*, in $N/m^2$, of the water pressing against the bottom of the stick at that depth. Convert your answer to pascals. Show your calculations.

$P =$ _____ $N/m^2 =$ _____ Pa

**Step 9.** Determine, in $cm^2$, the area of the bottom (or the top) of the stick. Convert your answer in $cm^2$ into $m^2$.

$A =$ _____ $cm^2 =$ _____ $m^2$

**Step 10.** Calculate, in newtons, the *force,* exerted by the stick at the bottom of the stick. Express your answer in pascals.

$F_{bottom} =$ _____ newtons

## Analysis

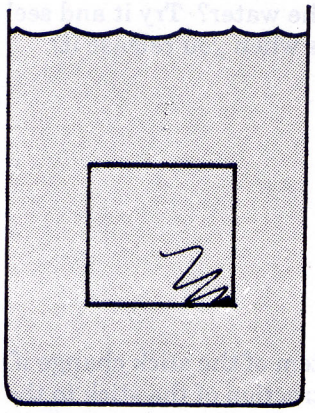


*Figure 21.1*

1. What is the *pressure* being exerted by air on the *top* of the stick? Does this pressure act to submerge the stick into the water or to buoy it up?

2. An object is completely submerged in water as shown in Figure 21.1. Draw arrows, which represent the *force* of the water at that depth, at various locations on the top, bottom, and sides of the object. How does the force on one side of the object compare to the force on the the other? How does the force on the top compare to that on the bottom?

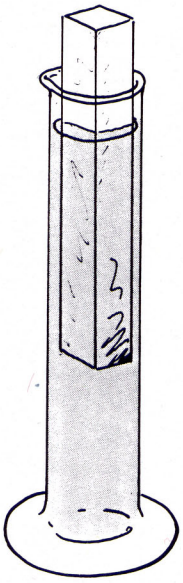


*Figure 21.2*

3. A sketch of a stick floating in a graduated cylinder, much like yours, is shown in Figure 21.2. Label all the forces acting on the stick. Make a vector diagram that represents your floating stick.

4. How does the mass of the stick compare to the mass of water it displaces when floating?

5. How does the weight of the stick compare to the weight of water it displaces when floating?

6. How does the *weight* of the stick compare to the *force* exerted by the water on the bottom of the stick when floating?

7. How does the ratio of the density of the stick to water compare to the fraction of the stick immersed in the water when floating? Can you explain?

8. Does the force the water exerts against the bottom of the stick change if you shove the stick deeper in the water? Does the attraction of the stick to the earth change if you shove the stick deeper in the water? Try it and see! Push the stick deeper in the water. What happens when you release it?

9. Does the force the water exerts against the bottom of the stick change if you lift the stick higher in the water? Does the attraction of the stick to the earth change if you lift the stick higher in the water? Try it and see! Lift the stick higher in the water. What happens when you release it?