Name: ____________________

Skill Sheet 17-C Buoyancy

Why do some objects float in water, while other objects sink? Why do some objects (like helium balloons) rise into the air when released from your hand, while other objects drop to the ground? To answer these questions, you need to understand buoyancy. In this skill sheet, you will examine the concept of buoyant forces. Next, you will practice calculating the buoyant force acting on an object placed in a fluid. You will use your calculations to figure out whether the object floats or sinks in that particular fluid.

1. Buoyant force

Physical scientists use the word *fluid* to describe any matter that can flow. The matter could be a liquid, like water, or a gas, like air. When an object is placed in a fluid (liquid or gas), the fluid exerts an upward force upon the object. This force is called a *buoyant force*.

At the same time, there is an attractive force between the object and Earth, which we call the force of gravity. It acts as a downward force.

To determine whether an object will rise, sink, or float, compare the size of the buoyant force to the size of the gravitational force (the weight of an object). If the buoyant force and the gravitational force are equal, the object will float. If the buoyant force is greater than the gravitational force, the object will rise in the fluid. If the gravitational force is greater it will sink.

Questions to try: For each of the following, compare the buoyant force to the gravitational force acting on the object. Explain your answers.

1. A rock is dropped into a pond. (The object is the rock. The fluid is the pond water.)

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2. A child releases the string attached to a helium-filled balloon. (The object is the balloon. The fluid is air.)

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3. An inflated beach ball is tossed into a swimming pool. The object is the beach ball. The fluid is the pool water.)

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2. Calculations with buoyant force

Here is an example that illustrates how to determine whether an object will sink or float in a fluid when you have been given values for the buoyant and gravitational forces.

Example:

A 13-newton object is placed in a container of fluid. If the fluid exerts a 60-newton buoyant (upward) force on the object, will the object float or sink?

Answer:

In this case, the upward buoyant force (60 N) is greater than the weight of the object (13 N). Therefore, the object will float.

Now try these problems on your own:

1. A 4.5-newton object is placed in a tank of water. If the water exerts a force of 4.3 newtons on the object, will the object sink or float?

2. The same object is placed in a tank of glycerin. If the glycerin exerts a force of 5.2 newtons on the object, will the object sink or float?

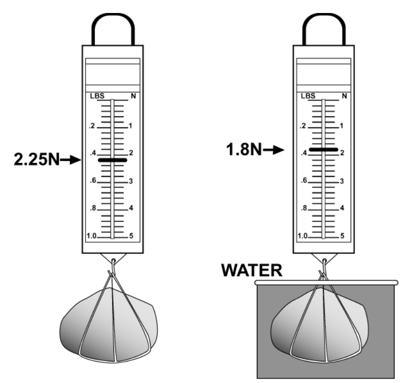
3. Would this same object be more likely to float in molasses or in vegetable oil? Explain why you think this is true.

3. Calculating buoyant force acting on an object that sinks

In the problems above, you were given the size of each force. How were those forces measured?

It's easy to find the gravitational force. You simply use a spring scale to measure the object's weight.

Finding the buoyant force is a little more complicated. Take a look at this example:



The rock weighs 2.25 newtons when suspended in air. In water, it appears to weigh only 1.8 newtons. Why? The rock didn't shrink! The water is exerting a force on the rock. You can calculate the buoyant force by finding the difference between the rock's weight in air and its apparent weight in water.

$$2.25 \text{ N} - 1.8 \text{ N} = 0.45 \text{ N}$$

The water exerts a buoyant force of 0.45 newtons on the rock.

Try these problems on your own:

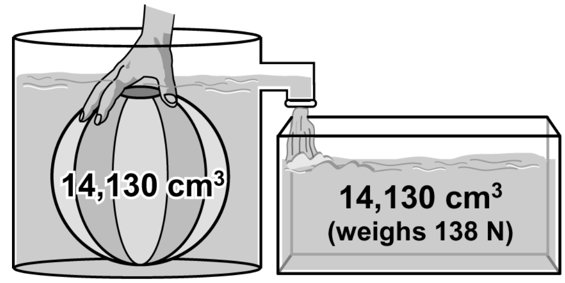
1. You suspend a brass ring from a spring scale. Its weight is 0.83 N. Next, you immerse the rock in a container of light corn syrup. The ring appears to weigh 0.71 N. What is the buoyant force acting on the ring?

2. You wash the brass ring and then suspend it in a container of vegetable oil. The ring appears to weigh 0.73 N. What is the buoyant force acting on the ring?

3. Which has greater buoyant force, the light corn syrup or the vegetable oil? Why do you think this is so?

4. Calculating buoyant force acting on an object that floats

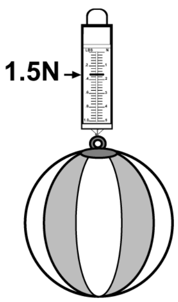
Have you ever tried to hold a beach ball underwater? It takes a lot of effort because the buoyant force is much larger than the gravitational force acting on the ball.



We can use Archimedes principle to calculate the buoyant force acting on the beach ball. **Archimedes principle** states**:**

The buoyant force acting on an object in a fluid is equal to the weight of the fluid displaced by the object.

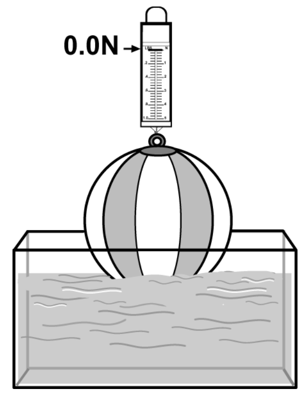
The beach ball's volume is 14,130 cm^3. If you pushed it underwater, the ball displaces 14,130 cm^3 of water. Archimedes principle tells us that the buoyant force equals the weight of that water. The weight of 14,130 cm^3 of water is 138 N. The buoyant force acting on the ball is 138 N.



If you tied a string to the beach ball and suspended it from a spring scale, the ball would weigh 1.5 newtons. That's not a lot of force to counteract 138 newtons of buoyant force! No wonder it takes a lot of effort to hold a beach ball underwater.

What would happen if you placed the ball in water to measure its apparent weight? (This is what we did with the rock in section 2).

The spring scale reading would be 0.0 newtons because the ball floats.

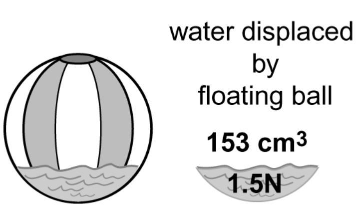


Now calculate the buoyant force acting on the floating beach ball:

gravitational force acting on ball - apparent weight of ball in water = buoyant force acting on ball:

$$1.5\text{ N} - 0.0\text{ N} = 1.5\text{ N}$$

The buoyant force acting upward on the floating beach ball is equal to the gravitational force pulling the ball downward.



The *floating* ball doesn't displace 14,130 cm^3 of water. It displaces only 153 cm^3 of water. 153 cm^3 of water weighs 1.5 newtons. The ball displaces an amount of water equal to its own weight.

5. Solving buoyancy problems

Use what you have learned to solve the following problems. The first one is done for you.

1. A 5-cm^3 block of lead weighs 0.55 N. The lead is carefully submerged (held under the surface) in a tank of mercury. One cm^3 of mercury weighs 0.13 N.
   a. What is the weight of the mercury displaced by the block of lead?
   b. If the block is released, will the block of lead rise, sink, or float in the mercury?
   c. What weight of mercury is displaced by the lead block after it is released?
   d. What volume of mercury is displaced by the lead block after it is released?

Answers to question #1:

(a) The lead will displace 5 cm^3 of mercury. 5×0.13 N = 0.65 N.

(b) The buoyant force, 0.65 N, is greater than the weight of the lead, 0.55 N, so the lead floats.

(c) The weight of the mercury displaced by the floating block of lead equals the weight of the block, 0.55 N.

(d) Since the block floats when the weight of the mercury displaced equals the weight of the lead, then the volume displaced is:

$$\frac{1.0 cm^3}{0.13 N} = \frac{\text{volume displaced in } cm^3}{0.55 N}$$

$$\text{volume displaced} = 4.2 cm^3$$

2. A 10 cm^3 block of paraffin (a type of wax) weighs 0. 085 N. It is carefully submerged in a container of gasoline. One cm^3 of gasoline weighs 0.0069 N.
a. What is the weight of the gasoline displaced by the paraffin?

b. Will the block of paraffin sink or float in the gasoline?

3. A 30 cm^3 chunk of platinum weighs 6.3 N. It is carefully submerged in a tub of molasses. One cm^3 of molasses weighs 0.013 N.
a. What is the weight of the molasses displaced by the platinum?

b. Will the platinum sink or float in the molasses?

4. A 15 cm^3 block of gold weighs 2.8 N. It is carefully submerged in a tank of mercury. One cm^3 of mercury weighs 0.13 N.
a. What is the weight of the mercury displaced by the gold?

b. Will the gold sink or float in the mercury?

5. Compare the densities of each pair of materials in the questions (1 - 4) above.

material	density (g/ cm^3)
gasoline	0.7
gold	19.3
lead	11.3
mercury	13.6
molasses	1.37
paraffin	0.87
platinum	21.4

Does an object's density have anything to do with whether or not it will float in a particular liquid? Give at least three examples to support your answer. Write your answer as a paragraph on a separate piece of paper.