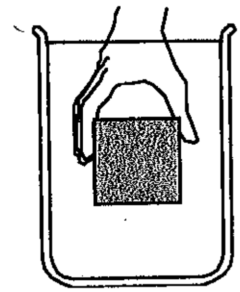
I. Buoyant force



A. A cubical block is observed to float in a beaker of water. The block is then held near the center of the beaker as shown and released.

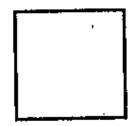
1. Describe the motion of the block after it is released.

2. In the space provided, draw a free-body diagram for the block at the instant that it is released. Show the forces that the water exerts on each of the surfaces of the block separately.

   Make sure the label for each force indicates:

   - the type of force,
   - the object on which the force is exerted, and
   - the object exerting the force.

Free-body diagram for block at instant it is released



3. Rank the magnitudes of the vertical forces in your free-body diagram. If you cannot completely rank the forces, explain why you cannot.

   Did you use the relationship between pressure and depth to compare the magnitudes of any of the vertical forces? If so, how?

   Did you use information about the motion of the block to compare the magnitudes of any of the vertical forces? If so, how?

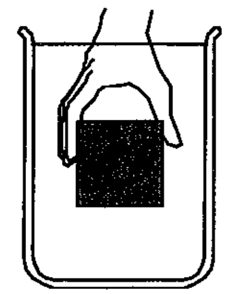
4. In the box at right, draw an arrow to represent the vector sum of the forces exerted on the block by the surrounding water. How did you determine the direction?

   Sum of forces on block by water

   Is this vector sum the *net force* on the block? (Recall that the net force is defined as the vector sum of *all* forces acting on an object.)

   Is the magnitude of the sum of the forces exerted on the block by the water *greater than*, *less than*, or *equal to* the weight of the block? Explain.

B. The experiment is repeated with a second block that has the same volume and shape as the original block. However, this block is observed to sink in water.

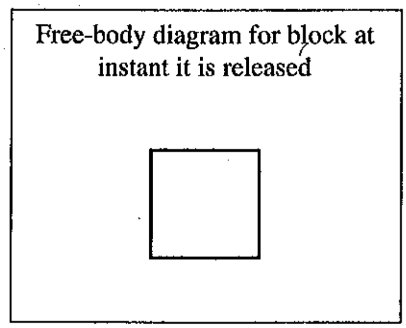


1. In the space provided, draw a free-body diagram for the block at the instant it is released. As before, draw the forces exerted on each surface of the block by the water.

2. Compare the free-body diagram for the block that sinks to the one you drew in part A for the block that floats.

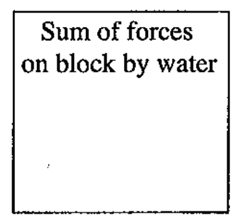
   Which forces are the same in magnitude and which are different? (*Hint:* How does the pressure at each surface of this block compare to the pressure at the corresponding surface of the block in part A?)

   Do any forces appear on one diagram but not on the other?



3. In the space provided, draw an arrow to represent the vector sum of the forces exerted on the block by the water.

   How does this vector compare to the one you drew for the block that floats? (Consider both magnitude and direction.)



C. Imagine that you were to release the block from part B at a much greater depth. State whether each of the following forces on the block would be *greater than, less than,* or *equal to* the corresponding force on the block in part B above:

1. the upward force on the bottom surface on the block.

2. the downward force on the top surface of the block.

3. the vector sum of the forces on the block by the surrounding water. (*Hint:* Does the difference between the pressures at the top and bottom surfaces of the block change?)

The vector sum of the forces exerted on an object by a surrounding liquid is called the *buoyant force*. This force is customarily represented by a single arrow on a free-body diagram.

D. In general, does the buoyant force on an object that is completely submerged in an incompressible liquid depend on:

- the *mass* or *weight* of the object?

- the *depth* below the surface at which the object is located?

- the *volume* of the object?

➪ Check your answers with a tutorial instructor before continuing.

II. Displaced volume

Consider two blocks of the same size and shape: one made of aluminum; the other, of brass. Both blocks sink in water. The aluminum block is placed in a graduated cylinder containing water. The volume reading increases by 3 mL.

A. By how much does the volume reading increase when the brass block is placed in the cylinder? (Assume that no water leaves the cylinder.) Explain.

When an object is placed in a graduated cylinder of liquid, the increase in the volume reading is called the *volume of liquid displaced* by the object.

B. Does the volume of water displaced by a *completely submerged* object depend on

- the *mass* or *weight* of the object?

- the *depth* below the surface at which the object is located?

- the *volume* of the object?

- the *shape* of the object?

III. Archimedes' principle

According to *Archimedes' principle*, the magnitude of the buoyant force exerted on an object by a liquid is equal to the weight of the volume of that liquid displaced by the object.

A. Consider the following statement made by a student:

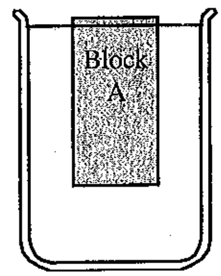
> *"Archimedes' principle simply means that the weight of the water displaced by an object is equal to the weight of the object itself."*

Do you agree with the student? Explain.

IV. Sinking and floating

A. A rectangular block, A, is released from rest at the center of a beaker of water. The block accelerates upward.

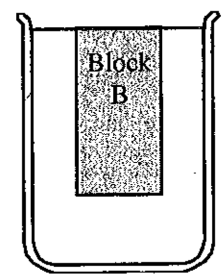
1. At the instant it is released, is the buoyant force on block A *greater than, less than,* or *equal to* its weight? Explain.



2. When block A reaches the surface, it is observed to float at rest as shown. In this final position, is the buoyant force on the block *greater than, less than,* or *equal to* the weight of the block? (*Hint:* What is the net force on the object?)

3. Are your answers to the questions above consistent with Archimedes' principle? (*Hint:* How does the volume of water displaced when the block is floating compare to that displaced when it was completely submerged?)

B. A second block, B, of the same size and shape as A but slightly greater mass is released from rest at the center of the beaker. The final position of this block is shown at right.



How does the buoyant force on block B compare to the buoyant force on block A:

- at the instant they are released? Explain.

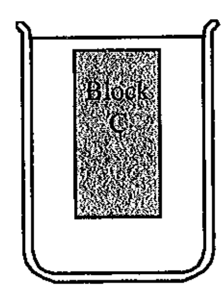
- at their final positions? Explain.

C. A third block, C, of the same size and shape as A and B but with slightly greater mass than block B is released from rest at the center of the beaker. Two students predict the final position of the block and draw the sketch at right.

Student 1: *Since this block is heavier than block B, it will not go up as high after it is released, as shown at right.*

Student 2: *Yes, I agree, the buoyant force is slightly less than the weight of this block, so it should come to rest a bit below the surface.*

Explain what is *wrong* with each statement and with the diagram.



Student drawing