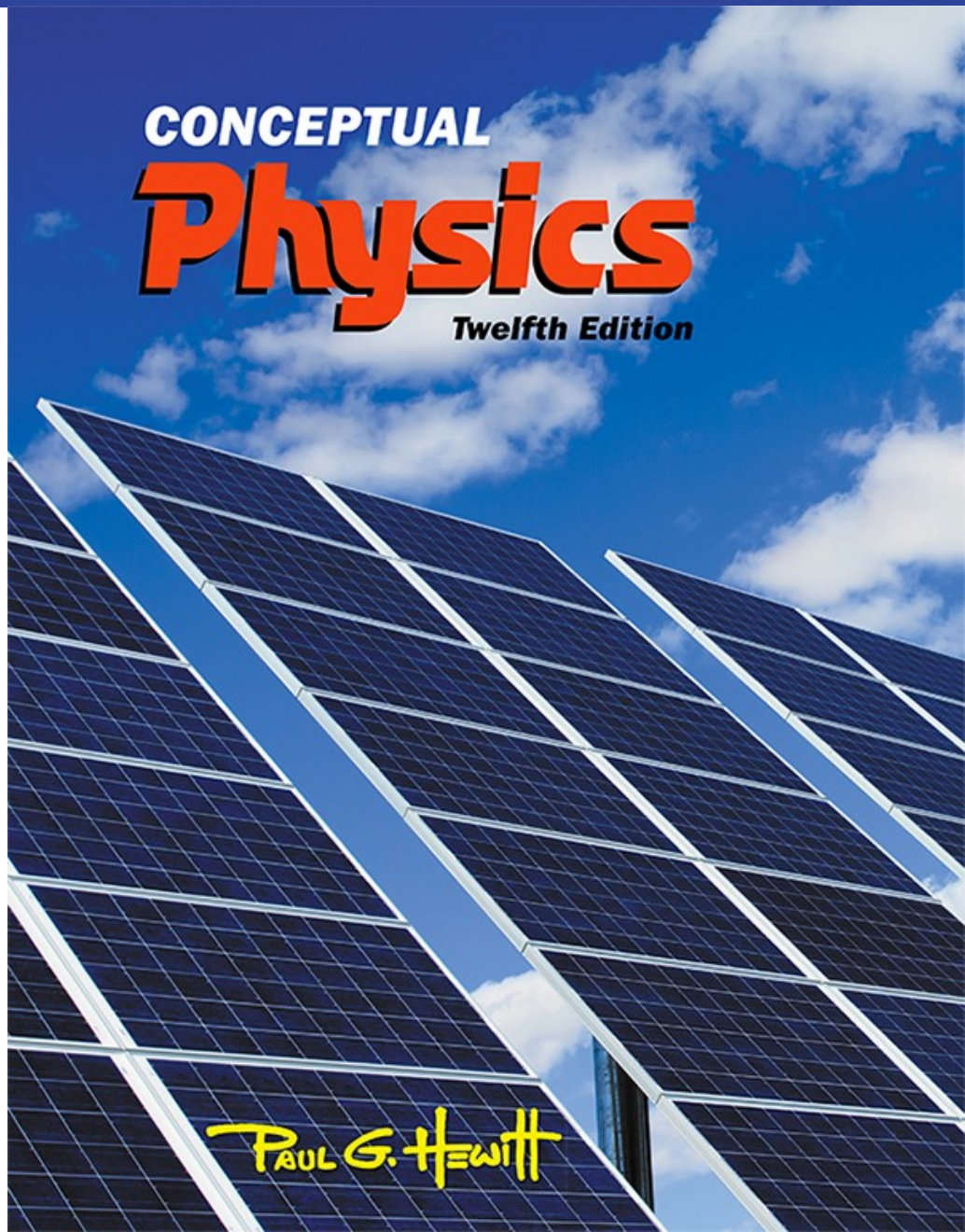
Lecture Outline

Chapter 13: Liquids



This lecture will help you understand:

- Pressure
- Pressure in a Liquid
- Buoyancy in a Liquid
- Archimedes' Principle
- What Makes an Object Sink or Float
- Flotation
- Pascal's Principle
- Surface Tension
- Capillarity

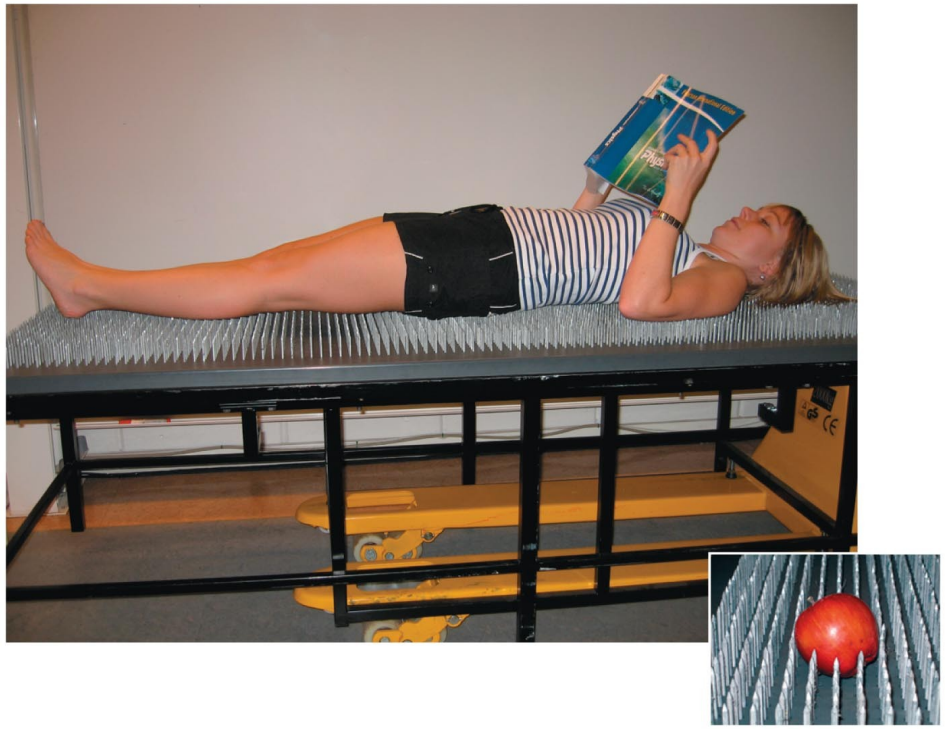
- The force per unit area that one object exerts on another
- In equation form:

$$Pressure = \frac{force}{area}$$

- Depends on area over which force is distributed
- Units: N/m^2, lb/ft^2, or Pa (Pascals)

Pressure

- Example: The teacher lying on nails is unharmed because force is applied over many nails. Combined surface area of the nails results in a tolerable pressure that does not puncture the skin.



Pressure
CHECK YOUR NEIGHBOR

When you stand on one foot instead of two, the force you exert on the floor is

A. less.
B. the same.
C. more.
D. None of the above.

Pressure
CHECK YOUR ANSWER

When you stand on one foot instead of two, the force you exert on the floor is

A. less.
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Comment:
Distinguish between force and pressure!

Pressure
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Pressure
CHECK YOUR ANSWER

When you stand on one foot instead of two, the pressure you exert on the floor is

A. less.
B. the same.
C. more.
D. None of the above.

Explanation:
Twice as much, in fact!

Pressure in a Liquid

- Force per unit area that a liquid exerts on an object
- Depth dependent and not volume dependent
- Example: Swim twice as deep, then twice as much weight of water above you produces twice as much pressure on you.

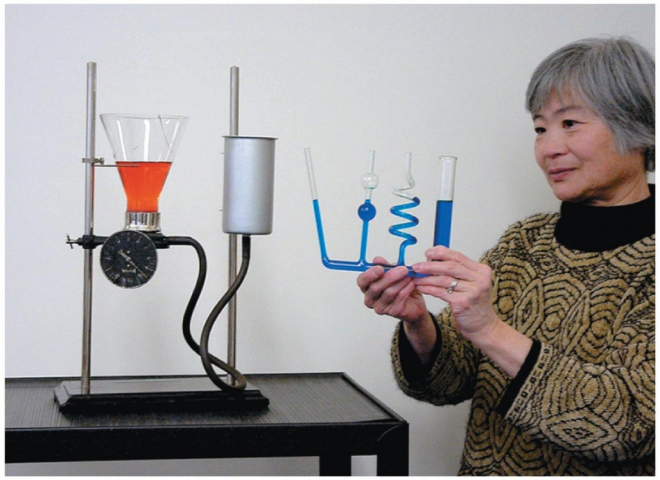
Pressure in a Liquid

- Acts equally in all directions
- Example:
  - Your ears feel the same amount of pressure under water no matter how you tip your head.
  - Bottom of a boat is pushed upward by water pressure.
  - Pressure acts upward when pushing a beach ball under water.

Pressure in a Liquid

- Independent of shape of container:
  - Whatever the shape of a container, pressure at any particular depth is the same.
- In equation form:

  Liquid pressure = *weight density* x *depth*



Pressure in a Liquid
CHECK YOUR NEIGHBOR

Water pressure provided by a water tower is greater if the tower

A. is taller.
B. holds more water.
C. Both A and B.
D. None of the above.

Pressure in a Liquid
CHECK YOUR ANSWER

Water pressure provided by a water tower is greater if the tower

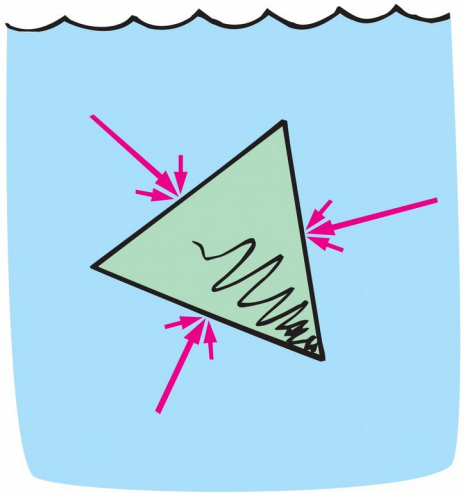
A. **is taller.**
B. holds more water.
C. Both A and B.
D. None of the above.

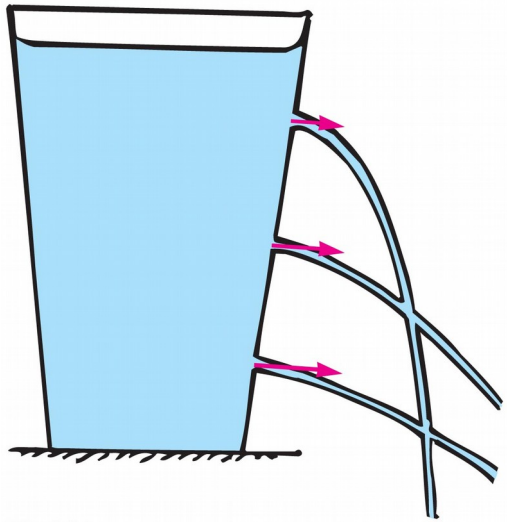
Explanation:

Only depth, not amount of water, contributes to pressure.

Pressure in a Liquid

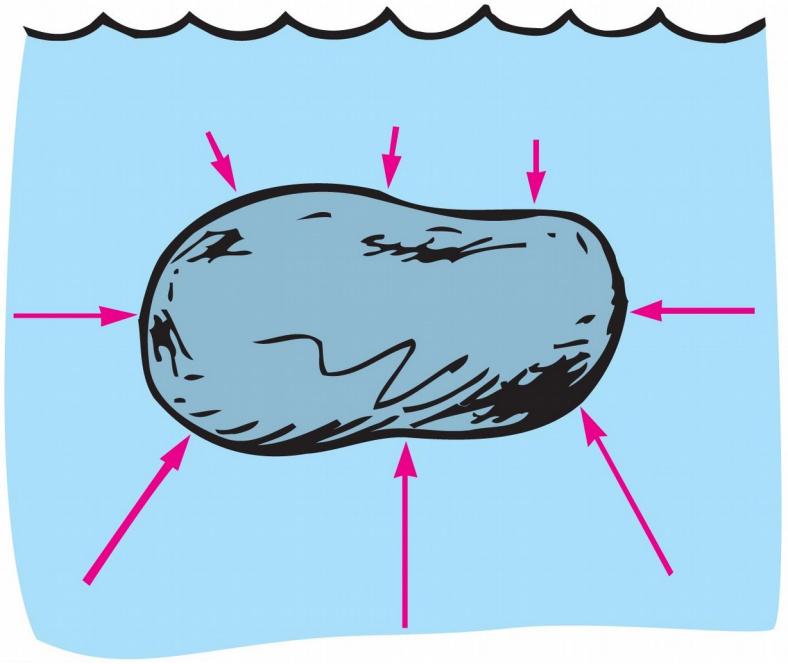
- Effects of water pressure
  - Acts perpendicular to surfaces of a container
  - Liquid spurts at right angles from a hole in the surface.
    - The greater the depth, the greater the exiting speed.





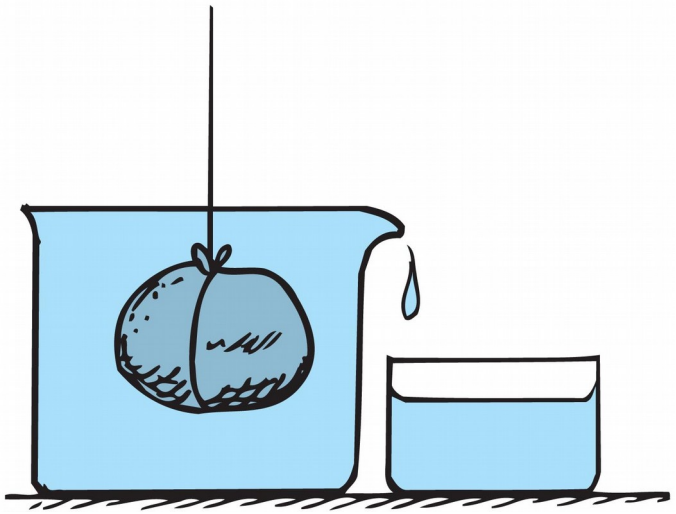
Buoyancy in a Liquid

- Buoyancy
  - Apparent loss of weight of a submerged object
  - Amount equals the weight of water displaced



Buoyancy in a Liquid

- Displacement rule:
  - A completely submerged object always displaces a volume of liquid equal to its own volume.
  - Example: Place a stone in a container that is brimful of water, and the amount of water overflow equals the volume of the stone.



Buoyancy in a Liquid
CHECK YOUR NEIGHBOR

A cook who measures a specific amount of butter by placing it in a measuring cup with water in it is using the

A. principle of buoyancy.
B. displacement rule.
C. concept of density.
D. All of the above.

Buoyancy in a Liquid
CHECK YOUR ANSWER

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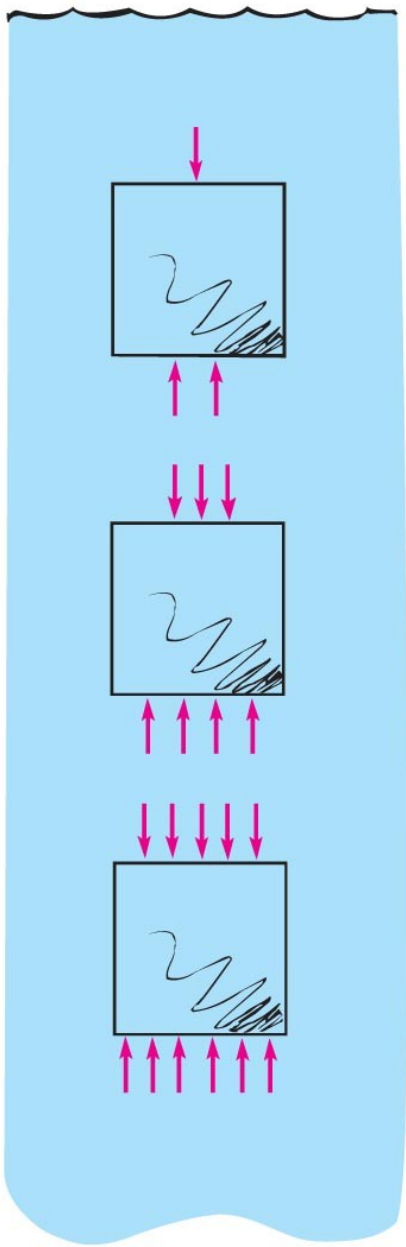
Buoyancy in a Liquid

- Buoyant force
  - Net upward force that a fluid exerts on an immersed object = weight of water displaced
  - Example: The difference in the upward and downward forces acting on the submerged block is the same at any depth



Buoyancy in a Liquid
CHECK YOUR NEIGHBOR

How many forces act on a submerged body at rest in a fluid?

A. One—buoyancy
B. Two—buoyancy and the force due to gravity
C. None—in accord with the equilibrium rule, $\Sigma F = 0$
D. None of the above.

Buoyancy in a Liquid
CHECK YOUR ANSWER

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D. None of the above.

Buoyancy in a Liquid

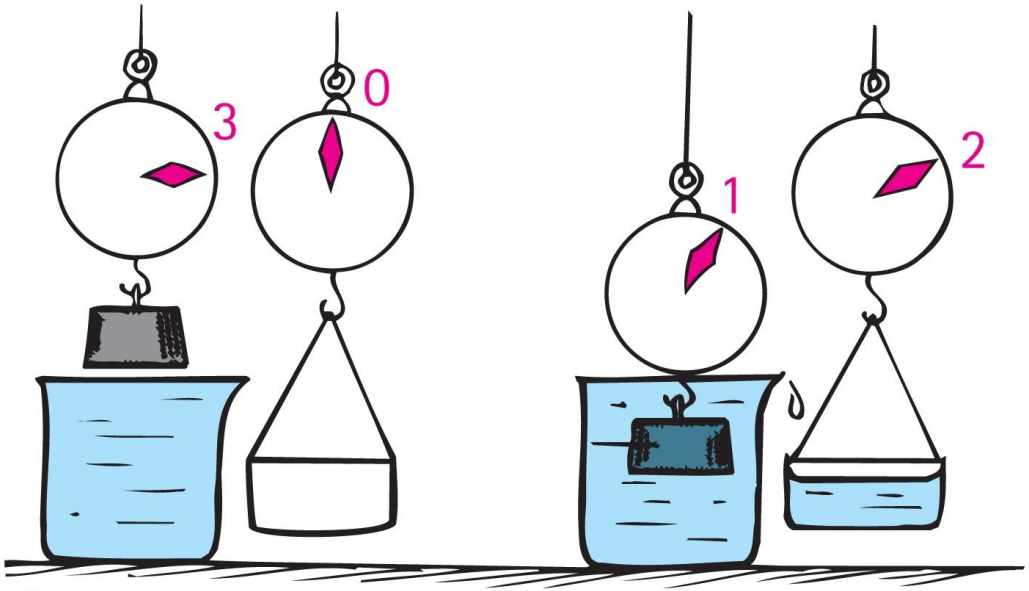
- Sink or float?
  - Sink when weight of submerged object is greater than the buoyant force.
  - Neither sink nor float when weight of a submerged object is equal to buoyant force—object will remain at any level.
  - Float when weight of submerged object is less than the buoyant force it would have when submerged—when floating, buoyant force = weight of floating object.

Archimedes' Principle

- Archimedes' principle:
  - Discovered by Greek scientist Archimedes.
  - Relates buoyancy to displaced liquid.
  - States that an immersed body (completely or partially) is buoyed up by a force equal to the weight of the fluid it displaces.
  - Applies to gases and liquids.

Archimedes' Principle

- Apparent weight of a submerged object
  - Weight out of water — buoyant force
    - Example: If a 3-kg block submerged in water apparently "weighs" 2 kg, then the buoyant force or weight of water displaced is 1 kg.



Archimedes' Principle
CHECK YOUR NEIGHBOR

On which of these blocks submerged in water is the buoyant force greatest?

A. 1 kg of lead
B. 1 kg of aluminum
C. 1 kg of uranium
D. All the same.

Archimedes' Principle
CHECK YOUR ANSWER

On which of these blocks submerged in water is the buoyant force greatest?

A. 1 kg of lead
B. 1 kg of aluminum
C. 1 kg of uranium
D. All the same.

Explanation:

The largest block is the aluminum one. It displaces more water and therefore experiences the greatest buoyant force.

Archimedes' Principle
CHECK YOUR NEIGHBOR

When a fish expands its air bladder, the density of the fish

A. decreases.
B. increases.
C. remains the same.
D. None of the above.

Archimedes' Principle
CHECK YOUR ANSWER

When a fish expands its air bladder, the density of the fish

A. **decreases.**
B. increases.
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Explanation:

The largest block is the aluminum one. It displaces more water and therefore experiences the greatest buoyant force.

Archimedes' Principle
CHECK YOUR NEIGHBOR

When a fish makes itself less dense, the buoyant force on it

A. decreases.
B. increases.
C. remains the same.
D. None of the above.

Archimedes' Principle
CHECK YOUR ANSWER

When a fish makes itself less dense, the buoyant force on it

A. decreases.
B. increases.
C. remains the same.
D. None of the above.

Archimedes' Principle
CHECK YOUR NEIGHBOR

When a fish decreases the size of its air bladder, the density of the fish

A. decreases.
B. increases.
C. remains the same.
D. None of the above.

Archimedes' Principle
CHECK YOUR ANSWER

When a fish decreases the size of its air bladder, the density of the fish

A. decreases.
B. increases.
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Archimedes' Principle
CHECK YOUR NEIGHBOR

When a submarine takes water into its ballast tanks, its density

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B. increases.
C. remains the same.
D. None of the above.

Archimedes' Principle
CHECK YOUR ANSWER

When a submarine takes water into its ballast tanks, its density

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B. increases.
C. remains the same.
D. None of the above.

Archimedes' Principle
CHECK YOUR NEIGHBOR

When a submerged submarine expels water from its ballast tanks, its density

A. decreases.
B. increases.
C. remains the same.
D. None of the above.

Archimedes' Principle
CHECK YOUR ANSWER

When a submerged submarine expels water from its ballast tanks, its density

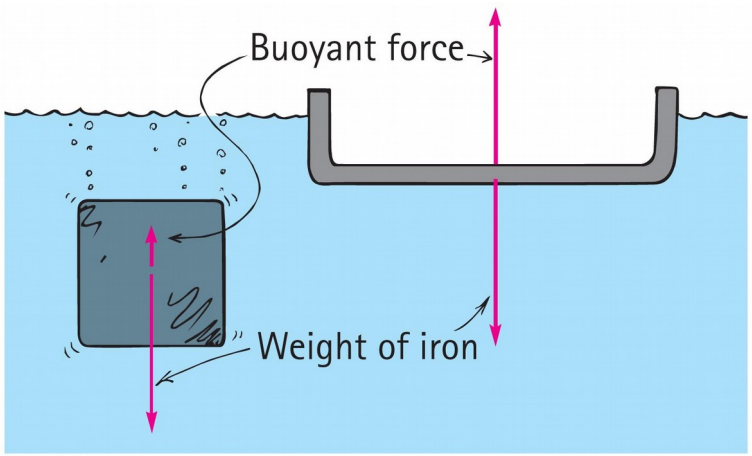
A. **decreases.**
B. increases.
C. remains the same.
D. None of the above.

Explanation:

This is how a submerged submarine is able to surface.

Archimedes' Principle

- Flotation
  - Principle of flotation:
    - A floating object displaces a weight of fluid equal to its own weight.
    - Example: A solid iron 1-ton block may displace 1/8 ton of water and sink. The same 1 ton of iron in a bowl shape displaces a greater volume of water—the greater buoyant force allows it to float.



Archimedes' Principle
CHECK YOUR NEIGHBOR

The reason a person finds it easier to float in saltwater compared with freshwater is that in saltwater

A. the buoyant force is greater.
B. a person feels less heavy.
C. Neither of these.
D. None of the above.

Archimedes' Principle
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C. **Neither of these.**
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Explanation:

A floating person has the same buoyant force whatever the density of water. A person floats higher because a smaller volume of the denser saltwater is displaced.

Archimedes' Principle
CHECK YOUR NEIGHBOR

On a boat ride, the skipper gives you a life preserver filled with lead pellets. When he sees the skeptical look on your face, he says that you'll experience a greater buoyant force if you fall overboard than your friends who wear Styrofoam-filled preservers.

A. He apparently doesn't know his physics.
B. He is correct.

Archimedes' Principle
CHECK YOUR ANSWER

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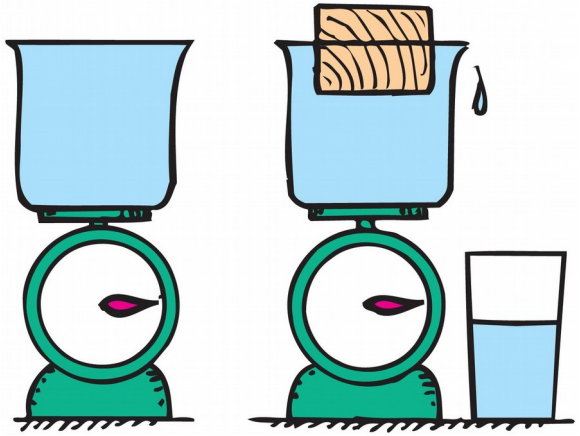
B. **He is correct.**

Explanation:

He's correct, but what he doesn't tell you is you'll drown! Your life preserver will submerge and displace more water than those of your friends who float at the surface. Although the buoyant force on you will be greater, the net force downward is greater still!

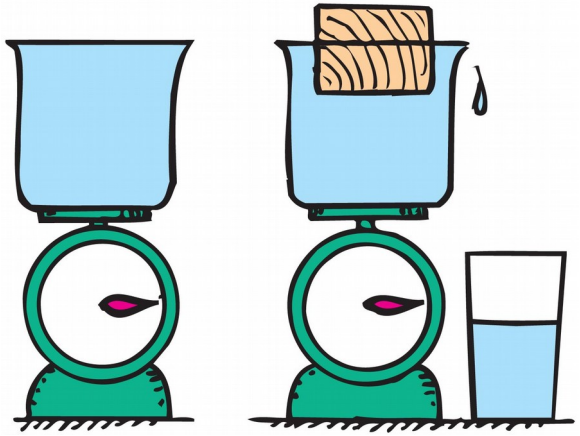
Flotation
CHECK YOUR NEIGHBOR



You place an object in a container that is full to the brim with water on a scale. The object floats, but some water spills out. How does the weight of the object compare with the weight of the water displaced?

A. Weight of object is greater than weight of water displaced.
B. Weight of object is less than weight of water displaced.
C. Weight of object is equal to weight of water displaced.
D. There is not enough information to decide.

Flotation
CHECK YOUR ANSWER



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C. **Weight of object is equal to weight of water displaced.**
D. There is not enough information to decide.

Explanation:
This principle is wonderfully illustrated with Scotland's Falkirk Wheel.

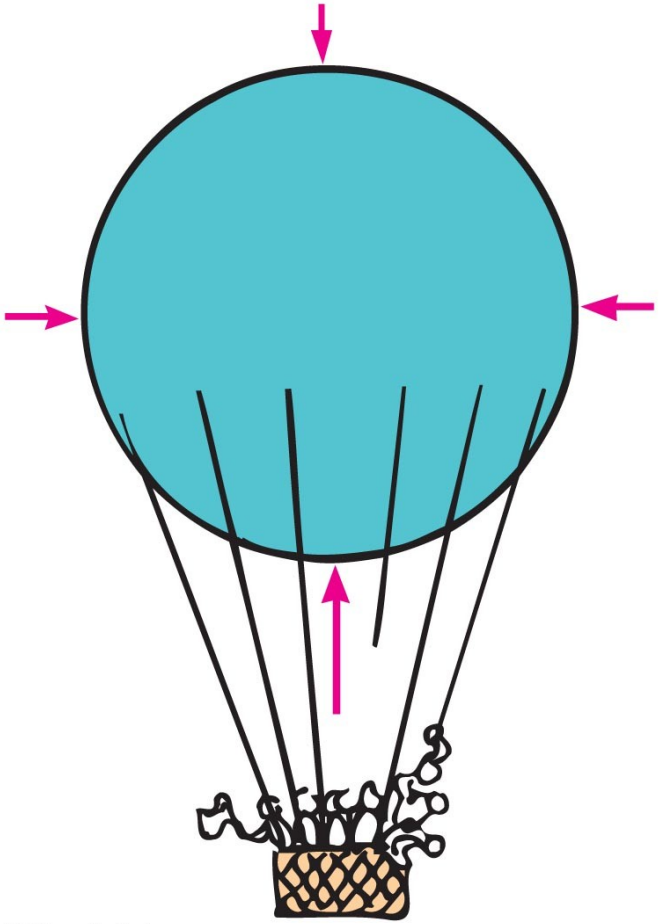
- The Falkirk Wheel's two caisson are brimful of water and the same weight, regardless of whether there are boats in them. This makes rotation and lifting almost effortless.

Archimedes' Principle

- Denser fluids will exert a greater buoyant force on a body than less dense fluids of the same volume.
- Example: Ship will float higher in saltwater (density = 1.03 g/cm^3) than in freshwater (density = 1.00 g/cm^3).

Archimedes' Principle

- Applies in air
  - The more air an object displaces, the greater the buoyant force on it.
  - If an object displaces its weight, it hovers at a constant altitude.
  - If an object displaces less air, it descends.



Archimedes' Principle
CHECK YOUR NEIGHBOR

As you sit in class, is there a buoyant force acting on you?

A. No, as evidenced by an absence of lift
B. Yes, due to displacement of air

Archimedes' Principle
CHECK YOUR ANSWER

As you sit in class, is there a buoyant force acting on you?

A. No, as evidenced by an absence of lift
B. **Yes, due to displacement of air**

Explanation:

There *is* a buoyant force on you due to air displacement, but much less than your weight.

What Makes an Object Float or Sink?

- Whether an object floats or sinks depends upon the
  - volume of the object.
  - volume of the fluid displaced.
- For an object to float:
  - Weight of object is less than buoyant force of the liquid, i.e., less than the weight of the liquid it displaces.

What Makes an Object Float or Sink?

- Three rules:
  1. An object more dense than the fluid in which it is immersed will sink.
  2. An object less dense than the fluid in which it is immersed will float.
  3. An object having a density equal to the density of the fluid in which it is immersed will neither sink nor float.

What Makes an Object Float or Sink?
CHECK YOUR NEIGHBOR

Two solid blocks of identical size are submerged in water. One block is lead and the other is aluminum. Upon which is the buoyant force greater?

A. On the lead block
B. On the aluminum block
C. Same on both blocks
D. There is not enough information to decide.

What Makes an Object Float or Sink? CHECK YOUR ANSWER

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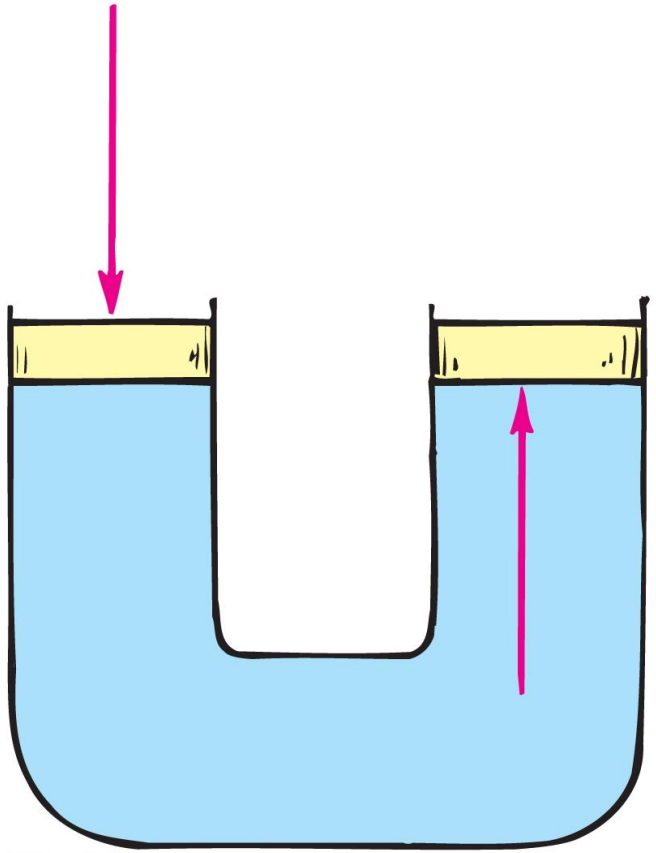
D. There is not enough information to decide.

Explanation:

The buoyant force depends upon the volume of the block that is submerged. Since both submerged blocks are the same size, they displace the same volume of water. So they have the same buoyant force.

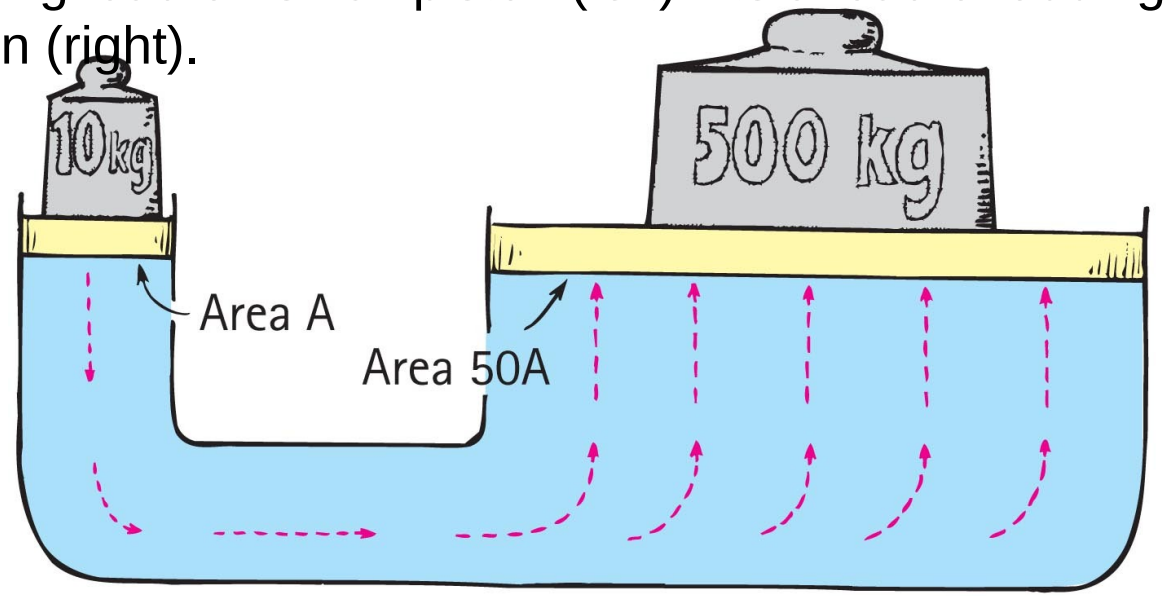
Pascal's Principle

- Pascal's principle:
  - Discovered by Blaise Pascal, a scientist and theologian in the 17th century
  - States that a change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid
  - Applies to all fluids—gases and liquids



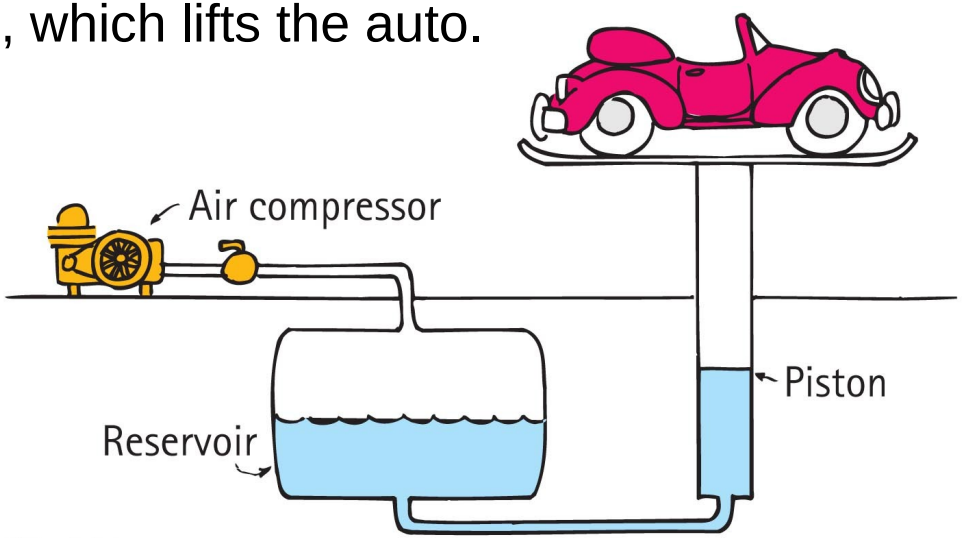
Pascal's Principle

- Application in hydraulic press
- Example:
  - Pressure applied to the left piston is transmitted to the right piston.
  - A 10-kg load on small piston (left) lifts a load of 500 kg on large piston (right).



Pascal's Principle

- Application for gases and liquids:
  - Seen in everyday hydraulic devices used in construction
  - In auto lifts in service stations
    - Increased air pressure produced by an air compressor is transmitted through the air to the surface of oil in an underground reservoir. The oil transmits the pressure to the piston, which lifts the auto.



Pascal's Principle
CHECK YOUR NEIGHBOR

In a hydraulic device, it is impossible for the

A. output piston to move farther than the input piston.
B. force output to exceed the force input.
C. output piston's speed to exceed the input piston's speed.
D. energy output to exceed energy input.

Pascal's Principle
CHECK YOUR ANSWER

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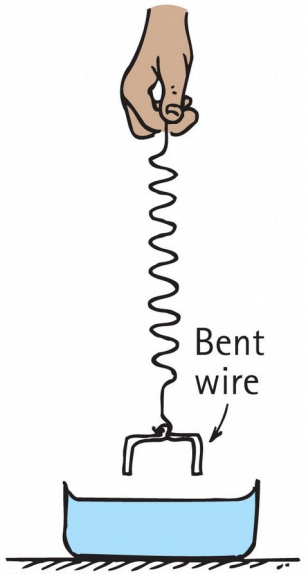
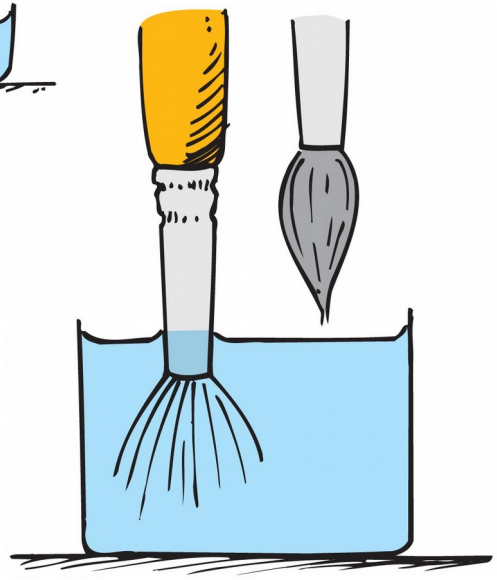
C. output piston's speed to exceed the input piston's speed.
D. **energy output to exceed energy input.**

Surface Tension

- The contractive tendency of the surface of liquids is due to **surface tension.**
- Examples:
  - When you submerge a wire in water and pull it out with a spring, the spring stretches.
  - When you place a paintbrush in water and pull it out, the water contracts and pulls the hairs together.

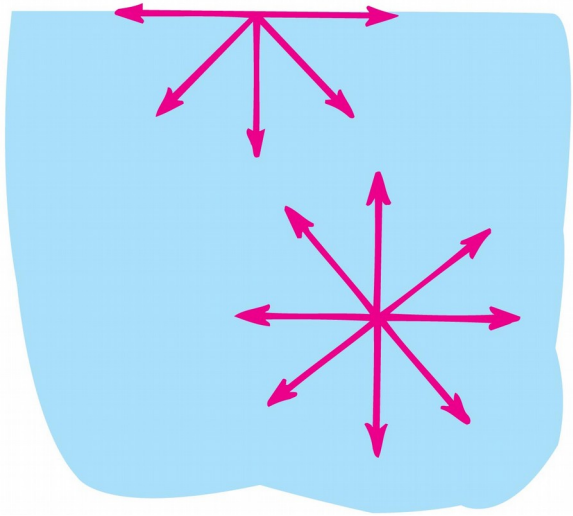




Surface Tension

- Other examples:
  - Drops of any kind are spherical because their surfaces tend to contract and force each drop into the shape having the least surface area for a given volume – a sphere.
  - Bubbles are spherical for the same reason – surface tension.

Surface Tension



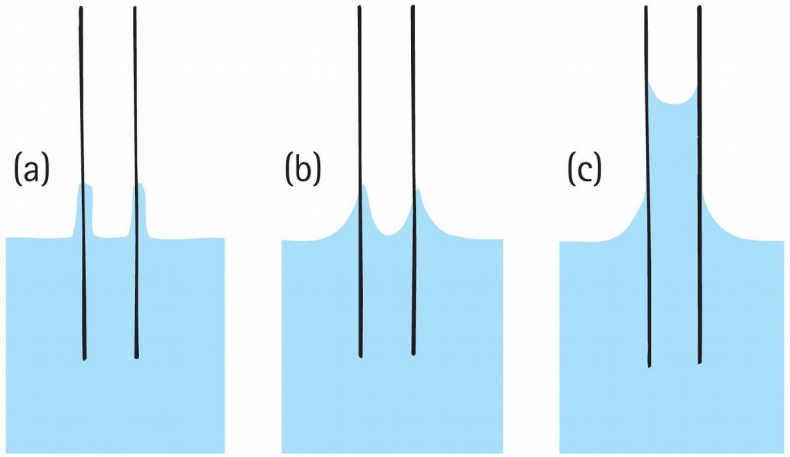
- Surface tension is caused by molecular attractions.
- Beneath the surface, each molecule is attracted in every direction by neighboring molecules.
- A molecule on the surface of a liquid is pulled only by neighbors on each side and downward from below; there is no pull upward.
- These molecular attractions tend to pull the molecule from the surface into the liquid, causing surface tension.

Surface Tension

- Factors affecting surface tension:
  - The type of liquid
    - Water has greater surface tension than oil.
  - What is mixed with the liquid
    - Soapy water has lower surface tension than water without soap.
  - Temperature of the liquid
    - The molecules in a hot liquid have higher energy and are not bound tightly as in a cooler liquid.

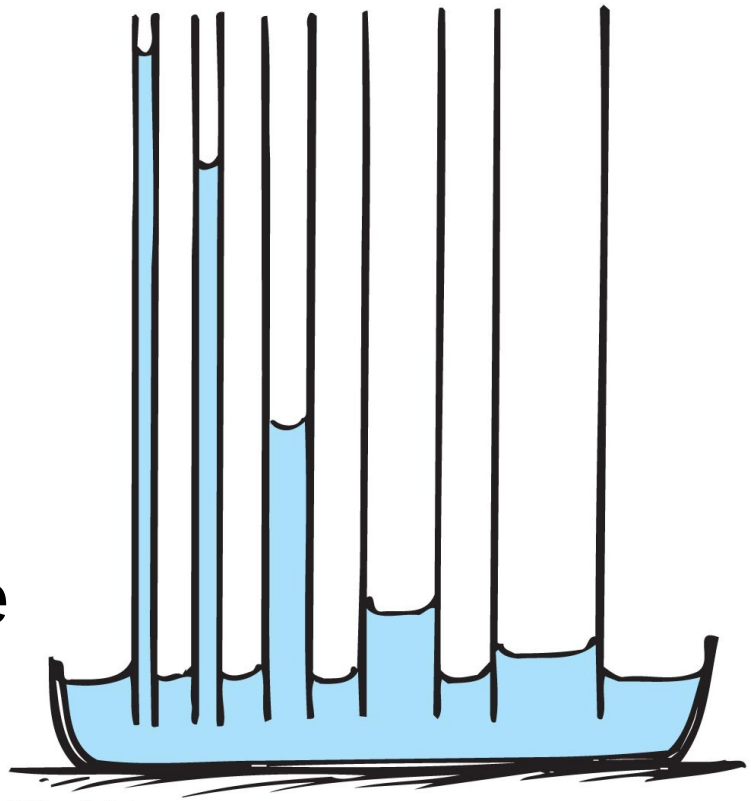
Capillarity

- The rise of a liquid in a fine, hollow tube or in a narrow space is called **capillarity**.
  - Adhesion between the molecules of the glass and water draws the film of water into the tube.
  - Surface tension causes the film on the surface to contract.
  - This raises the liquid from below to rise into the tube.
  - When the force of the surface tension balances out the weight of the liquid, the liquid stops rising.



Capillarity

- The height of rise depends upon the weight of the liquid and the narrowness of the tube.
  - The lighter the liquid, the higher the capillary rise.
  - The narrower the tube, the higher the capillary rise



Capillarity

- Examples:
  - Oil rises in a wick.
  - Hair let loose in a bathtub causes the scalp to get wet.
  - Insects have a hard time getting out of water when their legs get wet.