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

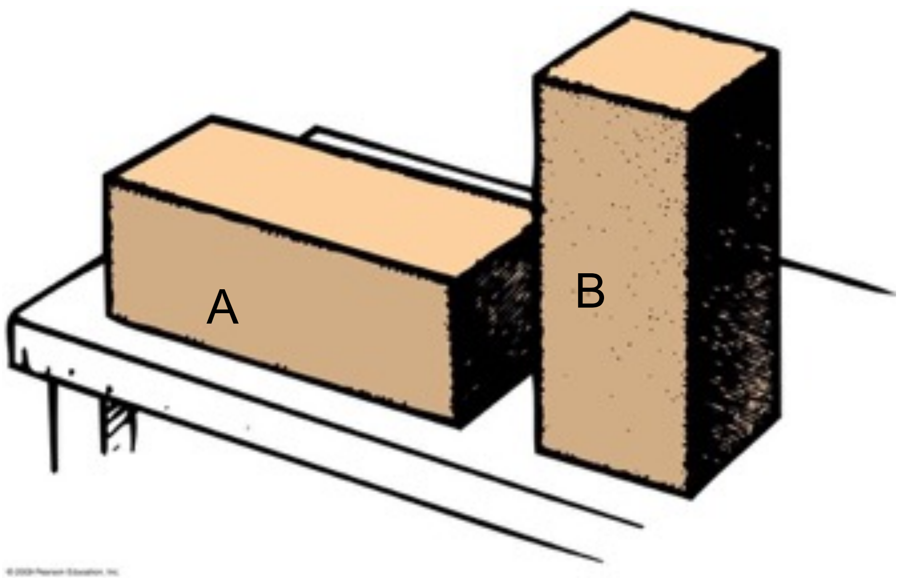
Pressure

- Pressure is a force divided by the area over which the force is exerted.

  Pressure = Force / Area

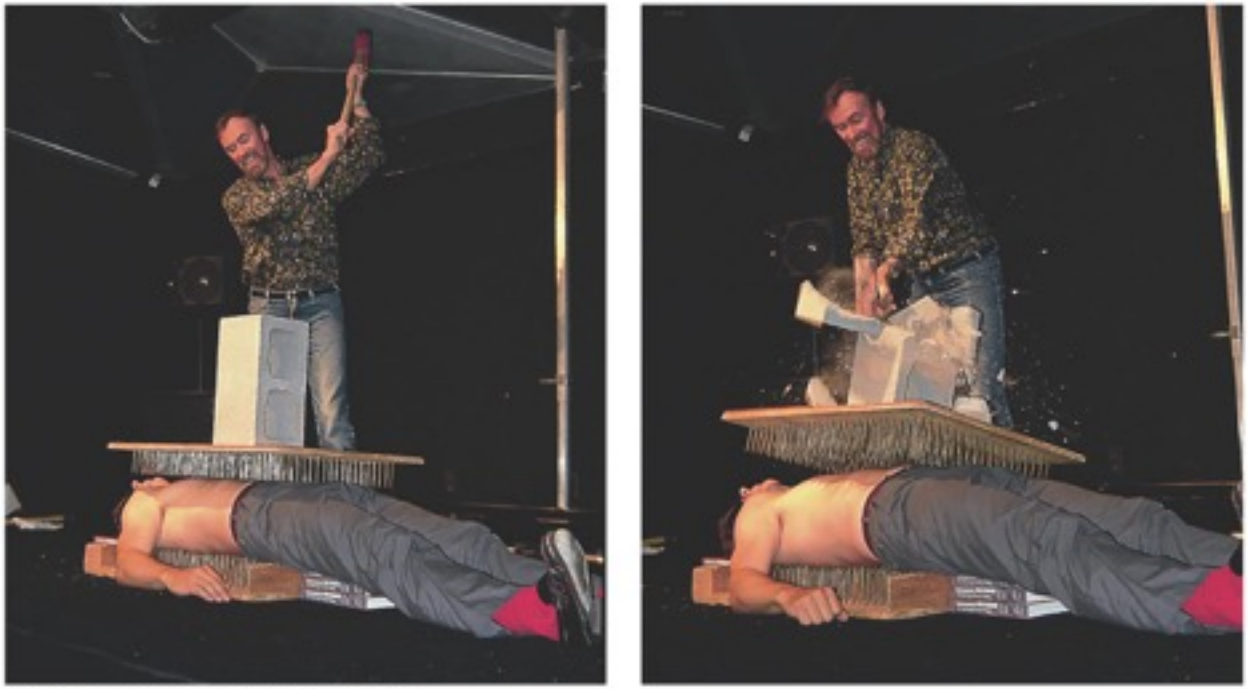
  Which block exerts more pressure on the table?

  Units: N/m^2, lb/ft^2, or Pa (Pascals)



Pressure

Example: The teacher between 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.



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.

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C. more.
D. None of the above.

Comment:
Distinguish between force and pressure!

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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

- Depends on the density of the liquid.
- The depth or the weight of the water above you.

Liquid pressure = Weight density x Depth (N/m^2)

- Total pressure of a liquid at a given depth is the pressure of the atmosphere plus the pressure of the liquid at that depth.
- Liquids are almost incompressible.

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.

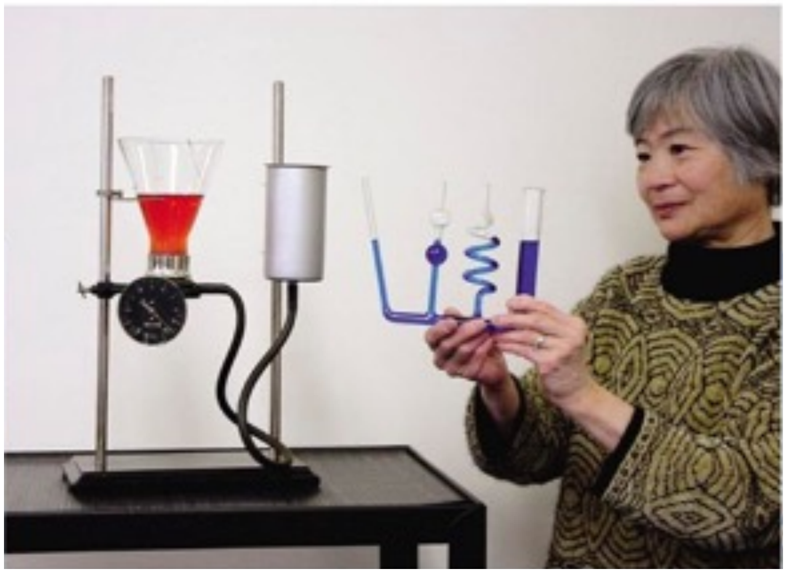
Pressure in a Liquid

- 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 × depth



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.

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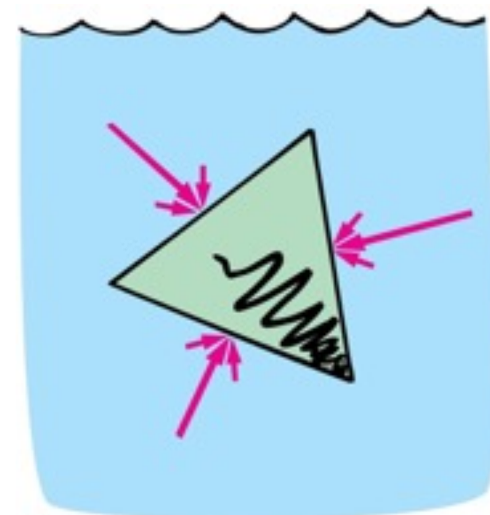
Explanation:

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

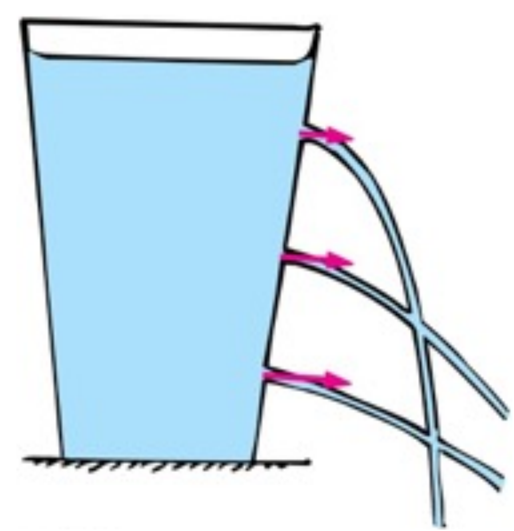
Pressure in a Liquid



Effects of water pressure

- Acts perpendicular to surfaces of a container

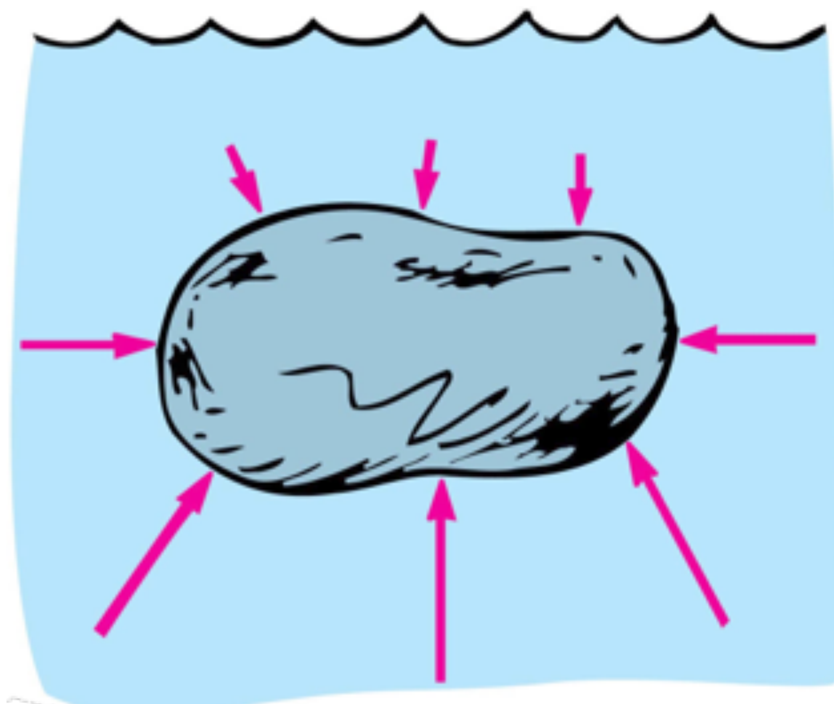
- Liquid spurts at right angles from a hole in the surface.
  - The greater the depth, the greater the exiting speed.



Buoyancy in a Liquid

Buoyancy

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

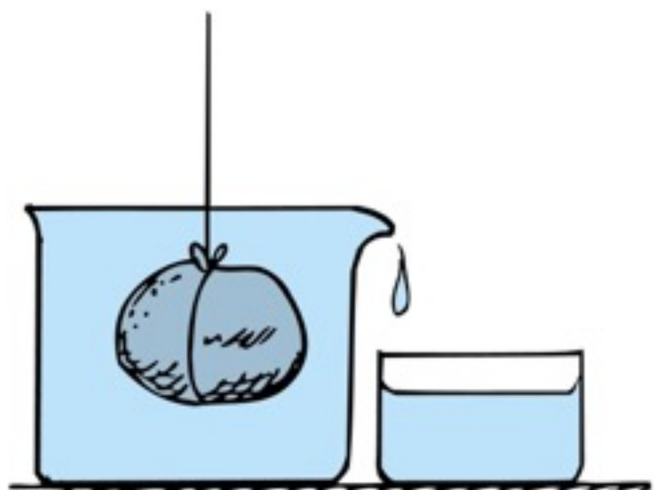


Buoyancy in a Liquid

- 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.



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.

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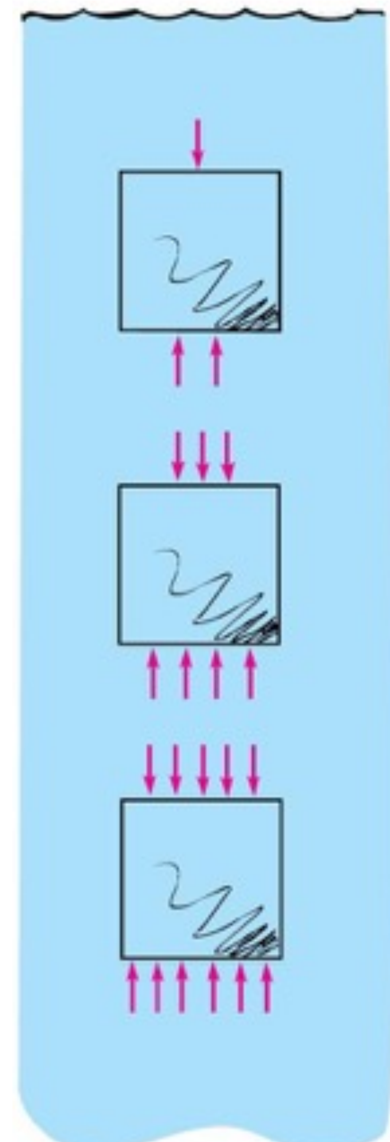
D. All of the above.

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



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.

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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.

Density

Density = Mass per unit volume

Density $D = \frac{M}{V}$

Units : kg/m^3 , g/cm^3

Archimedes’ Principle

Archimedes’ principle:

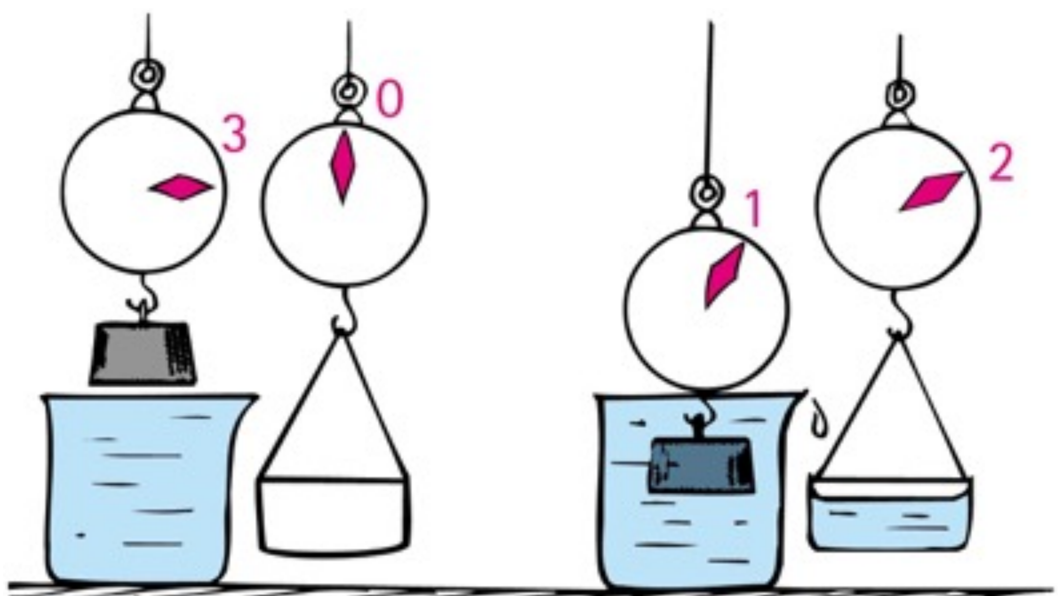
- Discovered by Greek scientist Archimedes.
- Relates buoyancy to displaced liquid.
- States that an immersed body (completely or partially) is buoyed up by a force equal to the weight of the fluid it displaces.
- Applies to gases and liquids.

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.



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.

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.

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.

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.

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.

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.

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

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

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

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

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.

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:

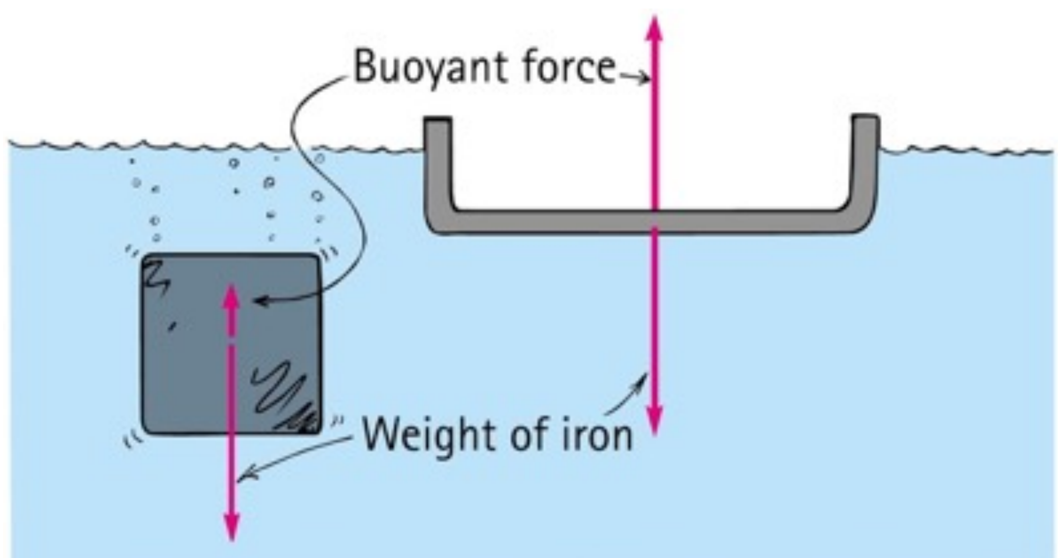
This is how a submerged submarine is able to surface.

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.



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.

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.

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.

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.

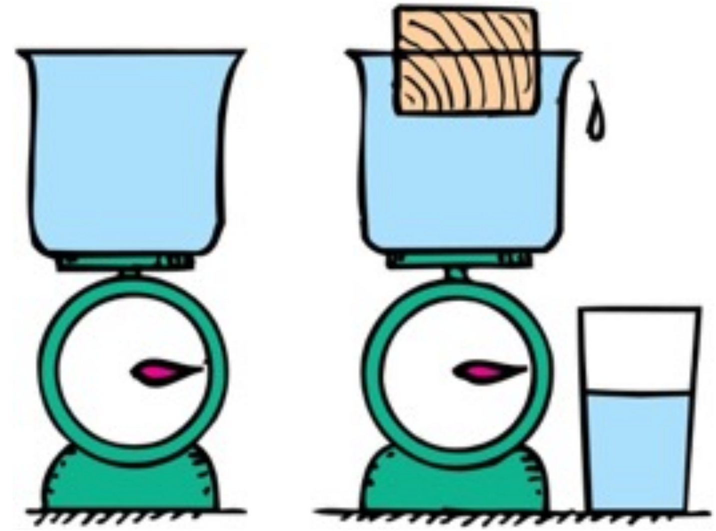
On a boat ride, the skipper gives you a life preserver filled with lead pellets. When he sees the skeptical look on your face, he says that you'll experience a greater buoyant force if you fall overboard than your friends who wear Styrofoam-filled preservers.

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

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!

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.

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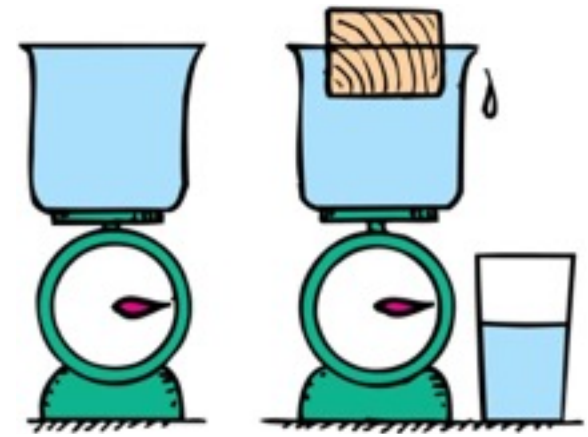


A. Weight of object is greater than weight of water displaced.

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.

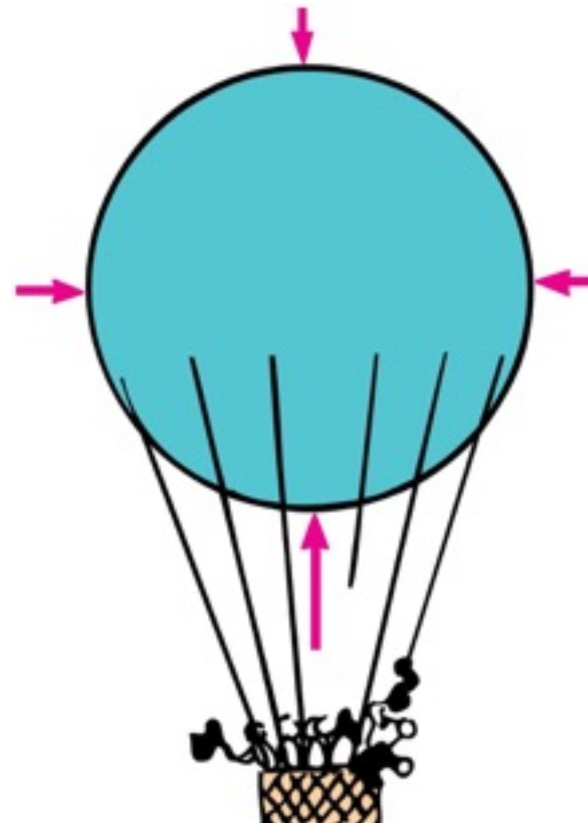
Archimedes' Principle

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.



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

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.

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.

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A. On the lead block
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C. **Same on both blocks**
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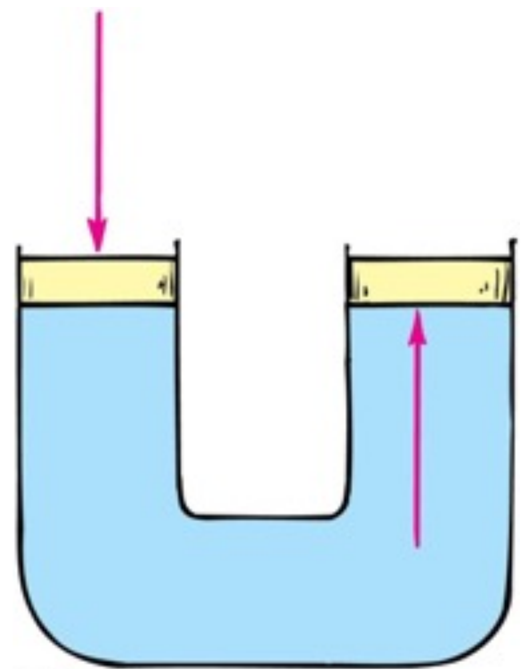
Explanation:
The buoyant force depends upon the volume of the block that is submerged. Since both submerged blocks are the same size, they displace the same volume of water. So they have the same buoyant force.

Pascal's Principle

Pascal's principle:

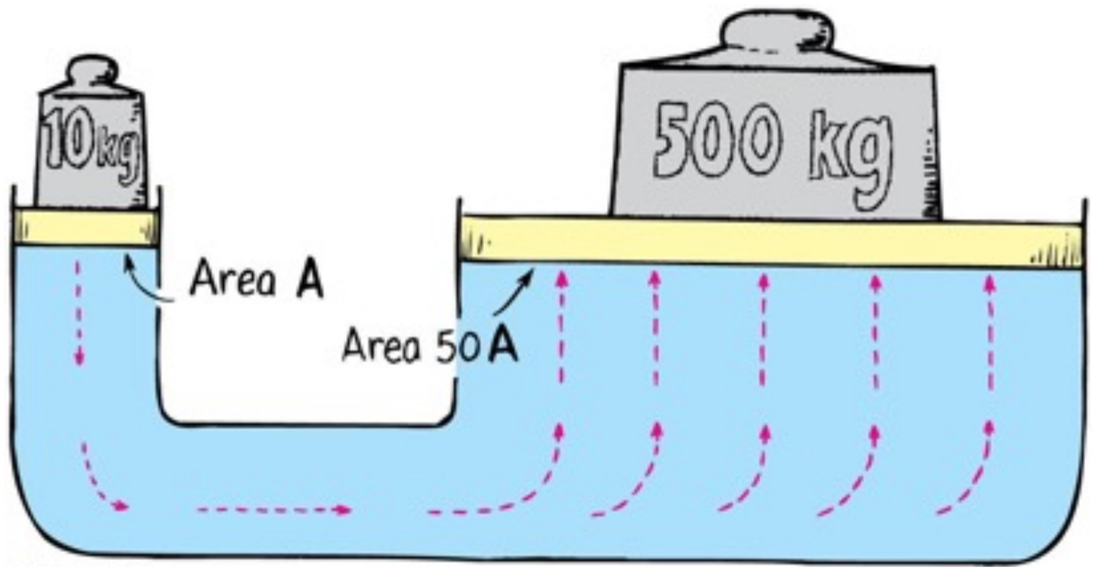
- Discovered by Blaise Pascal, a scientist and theologian in the 17th century
- States that a change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid
- Applies to all fluids—gases and liquids



Pascal's Principle

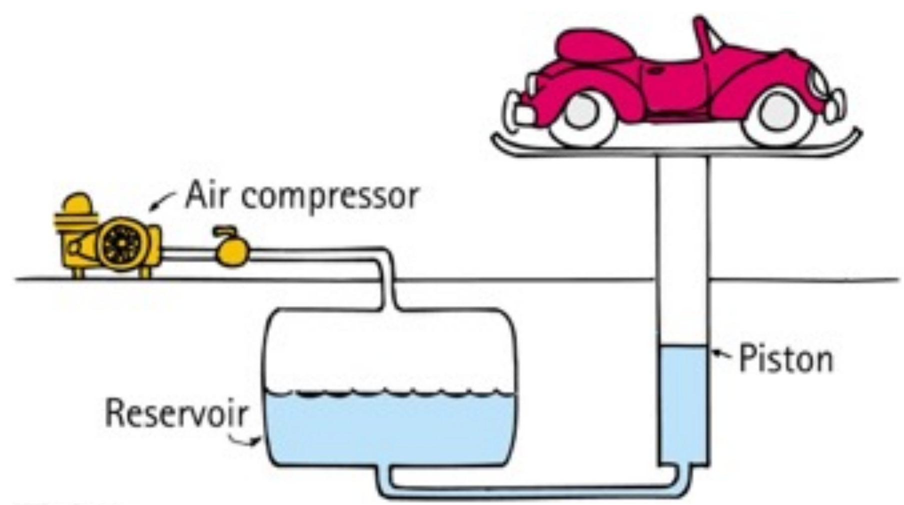
- Application in hydraulic press

  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).



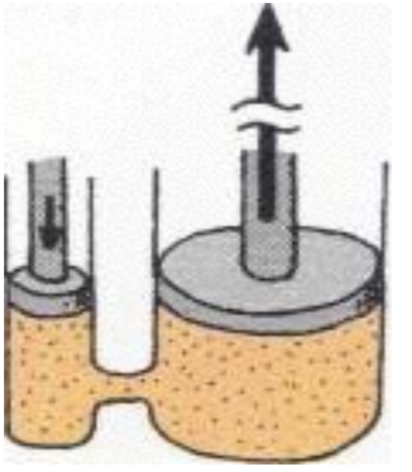
Pascal’s Principle

- 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.



Chapter 13 Problem # 7

In the hydraulic pistons shown in the sketch, the small piston has a diameter of 2 cm. The larger piston has a diameter of 6 cm. How much more force can the larger piston exert compared with the force applied to the smaller piston?



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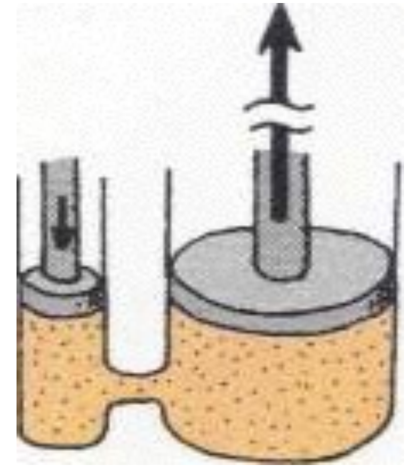

Pascal's Principle sates that the force is proportional to the relative areas. The areas are as the proportional to the squares of the diameters;

$$F_{\mathbf{larger}}/\ F_{\mathbf{smaller}} = 6^2/2^2 = 36/4 = 9.$$

The larger piston can exert 9 times the force applied to the smaller piston.

Homework

- Read Chapter 13 in Detail.
- Do Ranking # 3
- Do Exercises # 3, 7, 11,15, 35, 45, 47, 55
- Do Problems # 5

Due: June 27