



# Chapter 9

## Forces and Fluids

# Key Terms

- hydraulic systems
- incompressible
- mass
- neutral buoyancy
- pascal
- pneumatic systems
- pressure
- unbalanced forces
- weight
- Archimedes' principle
- average density
- balanced forces
- buoyancy
- buoyant force
- compressibility
- force

# Force

- Anything that causes a change in the motion of an object.
- A push or pull.



**Figure 9.1** The force applied to the tennis ball by the player and racket will make the ball change direction.

# Balanced forces:

1. Equal in strength

2. Opposite in direction

3. No movement

The forces on the person are balanced.



# Unbalanced Forces:

- Unequal in strength
- Cause a change in speed or direction



**Figure 9.2** The forces being applied to each side of the box are equal so the box does not move.



**Figure 9.3** Forces that are unbalanced will start an object moving, speed up or slow down the object, or change the direction of its movement.



Force Simulations:

<http://phet.colorado.edu/en/simulation/forces-1d>

# Mass vs. Weight

## Mass

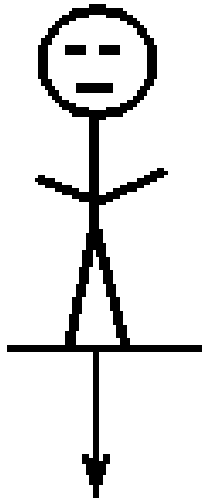
- Stays the same everywhere
- Amount of matter in a substance
- Kilograms (kg)

## Weight

- A measure of the push or pull acting on an object.
- Measure of the force of gravity on an object
- Newton (N)

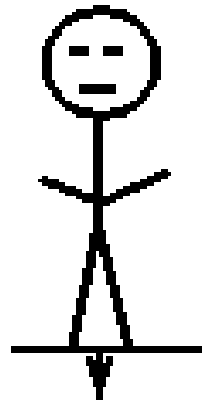


Earth



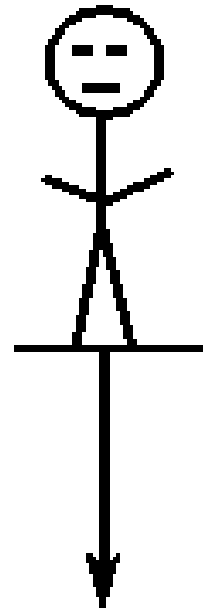
Mass = 63.5 kg  
Weight = 623 N  
(140 lbs)

Moon



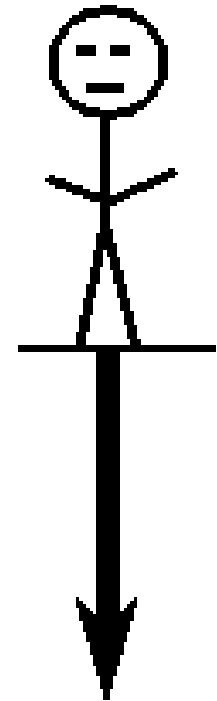
Mass = 63.5 kg  
Weight = 103 N  
(23 lbs)

Jupiter



Mass = 63.5 kg  
Weight = 1582 N  
(355 lbs)

Sun



Mass = 63.5 kg  
Weight = 17418 N  
(3914 lbs)

# Buoyancy

The **upward** force on an object submerged in or floating on a fluid.

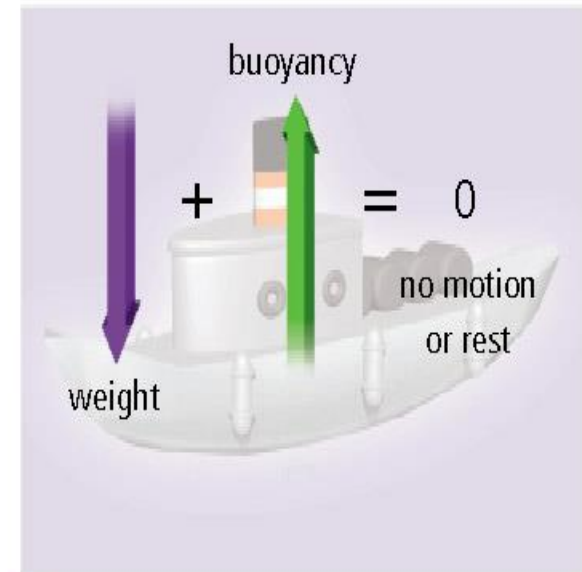
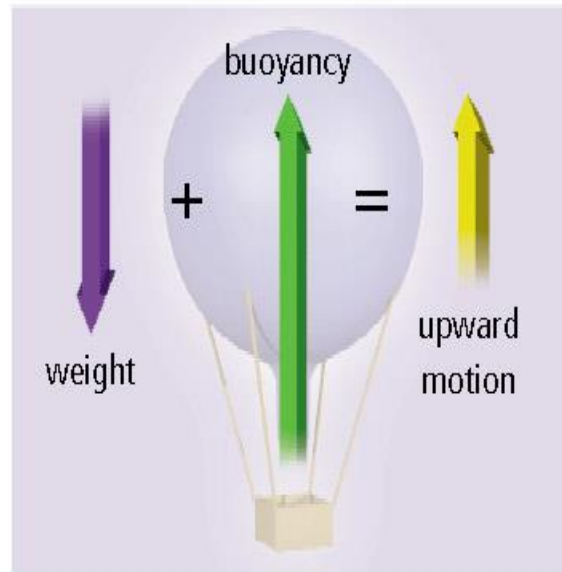
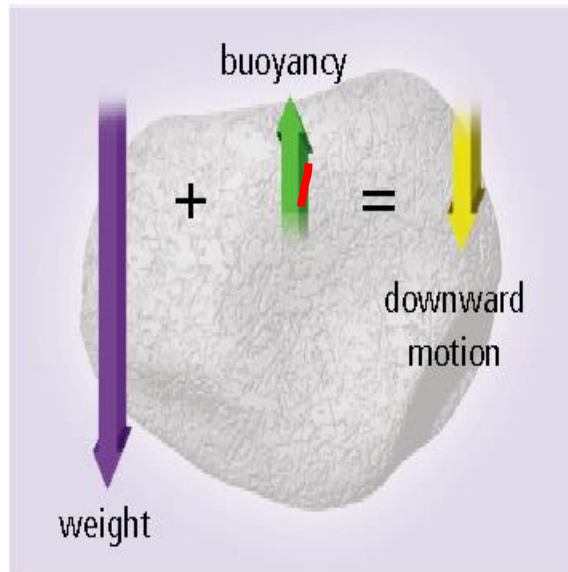
[http://phet.colorado.edu/sims/density-and-buoyancy/buoyancy\\_en.html](http://phet.colorado.edu/sims/density-and-buoyancy/buoyancy_en.html)

- A floating object has **neutral buoyancy**



- A sinking object does not.





**A** Sinking, e.g., a rock



**B** Rising, e.g., a helium balloon



**C** Floating, e.g., a boat




**Figure 9.6** The difference between an object's weight and the buoyant force acting on the object will determine whether the object sinks, rises, or floats.

# Archimedes Principle

- Buoyant force **equals** the *weight* (force of gravity) of the fluid displaced by an object.

## Examples:

- A rock sinking in a lake
  - Weight of rock  $>$  buoyant force (weight of water rock displaces)  
*(greater than)*
- A chunk of wood floating on the surface of a lake
  - NEUTRAL BUOYANCY
  - weight of the wood = Buoyant force (weight of water wood displaces)
- A helium balloon rising
  - Weight of helium balloon  $<$  buoyant force (weight of air balloon displaces)  
*(less than)*



When swimming why you do sink when you roll yourself into a ball, but you float when you lie flat on your back?

- When in a ball you weigh **more** than the water you displaced.
- As you lie back a **larger** of volume of water is displaced
- The weight of the displaced water is now **greater** than your weight and you float.

# Density and Buoyancy

- If the density of the immersed object is **greater** than the density of the fluid, it will **SINK**.
- If an object weighs the **same or less** than the water it is displacing, it will **FLOAT**.



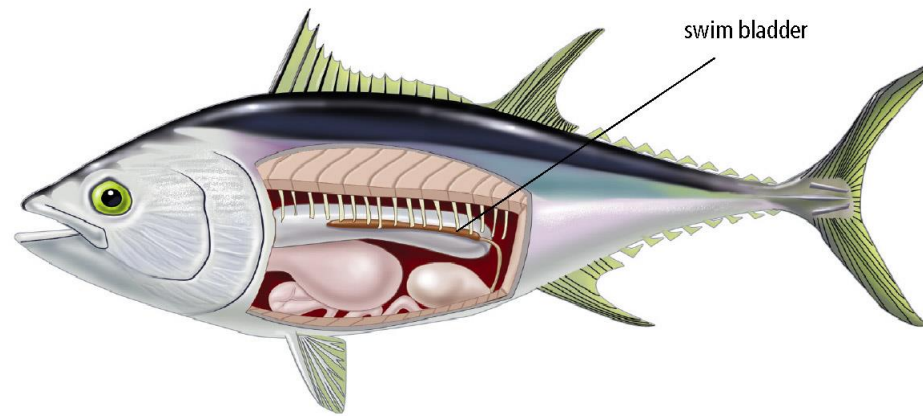


## **Which will sink and which will float?**

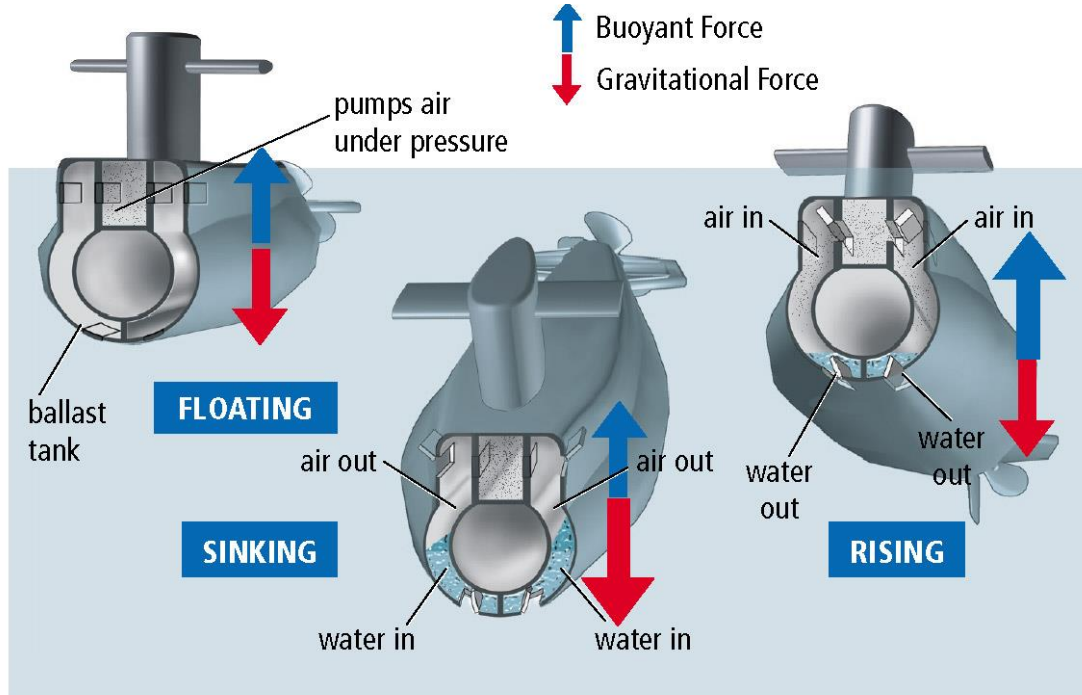
- wooden boat vs. water logged stick?
- metal block vs. metal boat?
- a sealed empty plastic bottle vs. a plastic bottle full of water?

# Average Density

- The total mass of all substances that make up an object divided by the total volume.
- If the volume of an object is **increased**, the average density will **decrease**.



**Figure 9.9** Cutaway drawing showing the swim bladder inside a fish. The fish can control its depth in the water by changing the amount of air in the bladder.



**Figure 9.10** Engineers have used the example of a fish's swim bladder to allow crews to control the depth of a submarine. By allowing water to flow in or out, the submarine can rise or sink in the water. The submarine floats when its weight is equal to the buoyant force. The submarine sinks when its weight is greater than the buoyant force.

# Technologies Developed

- Personal floatation devices

The **average density** of the person and the jacket is **less** than the density of water (floats).

The density of the person alone is more than water (sinks).

- Submarines

The sub lets water flow in to sink (density **increases**) and flow out to float (density **decreases**).

- Hot air balloons

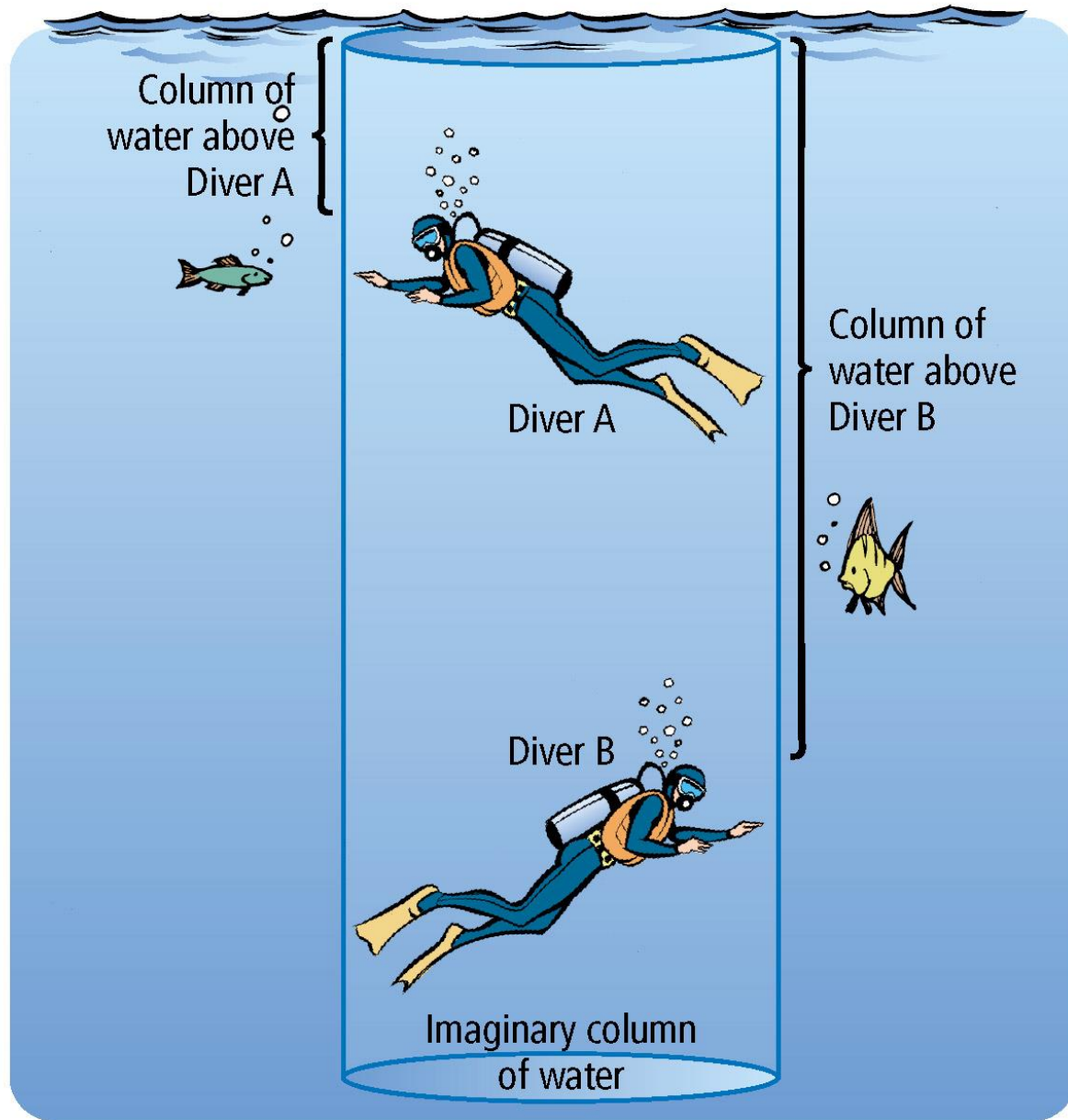
Air inside is forced out when heated (density **decreases**). The air inside is then less dense than the air outside and the balloon **floats**.

# Pressure

- The force acting on a certain area of surface.
- *The larger the force, the greater the pressure.*
- *The smaller the area, the greater the pressure.*



**Figure 9.14A and 9.14B** High heels exert more pressure on the ground because the pressure is concentrated into a smaller area than a flat shoe.



**Figure 9.15** As you swim deeper in water, more pressure is exerted on you from the water above.

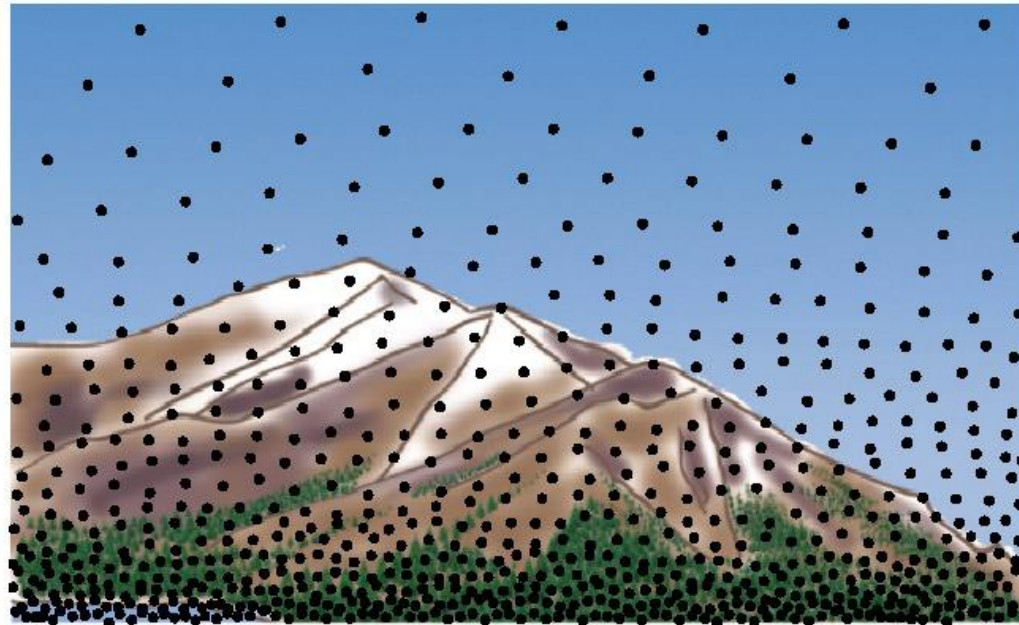
**Figure 9.16** Have you felt pain in your ears when you swam underwater?





# Atmospheric Pressure

- The pressure exerted by the layers of air surrounding the Earth that are held by the Earth's gravity. (~ 160 km above the Earth)

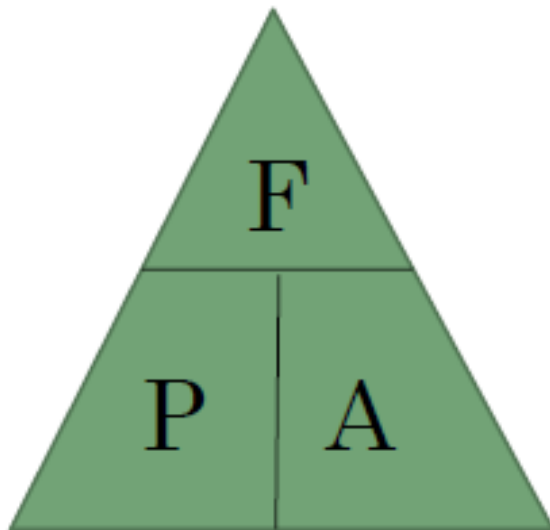


# Calculating Pressure

- The unit for pressure is the Pascal (Pa)
- $1 \text{ Pa} = 1 \text{ N/m}^2$
- You can determine pressure if you know the force and the area.

# Formula:

$$\text{Pressure (P)} = \frac{\text{Force (F)}}{\text{Area (A)}}$$



# SAMPLE PROBLEMS

1. An aquarium is filled with water that weighs 10 000N. If the base of the aquarium has an area of 1.6 m<sup>2</sup>, what pressure does the water exert on its base?

$$P = \frac{F}{A} \quad P = \frac{10\,000\text{N}}{1.6\text{m}^2}$$


$$P = 6250 \text{ Pa}$$

2. If the atmospheric pressure is 101 200 Pa and you are holding your hand, the atmosphere is exerting a force on your hand. If the area of your palm is 0.006m<sup>2</sup>, calculate the force on your hand.

$$F = P \times A$$

$$F = 101\,200 \text{ Pa} \times 0.006 \text{ m}^2$$

$$F = 607 \text{ N}$$



3. The weight of water in a glass is 4.9 N. If the water is exerting a pressure of 1700 Pa on the bottom of the glass, what is the area of the bottom of the glass?

# Why can....

A person wearing snowshoes walk across a section of deep, soft snow without sinking?

Page 351 #'s 1-3

Page 352 #'s 1-3

Page 353 #'s 1-3

Pressure Assignment



The nozzle on a garden hose be used to create a faster or slower flow of water.





# PASCAL'S LAW



- Pressure applied to a enclosed fluid is transmitted with **equal** force throughout the entire container
- Basis for hydraulic and pneumatic devices.

# Examples:

- car lift or hoist
- hydraulic jack
- automobile braking system
- air compressors
- automobile/bicycle tires



# HYDRAULICS

- The study of pressure in **liquids**.
- Hydraulic systems: devices that transmit applied force through a liquid to move something else.





- Hydraulic systems use **liquids** because they are **incompressible** (they cannot be squeezed into a smaller volume).
- The liquid must be enclosed in a tube or pipe.
- The pressure produced will exert in all directions **equally**.
- This pressure will cause **motion** at the other end of the hydraulic system.

# PNEUMATIC SYSTEMS

- The study of pressure in **gases**.
- Compressors are necessary as gases can be **compressed**.
- They build up air pressure.



# Summary:

Property	Hydraulic System	Pneumatic System
State	Liquid	Gas
Volume	Definite	Indefinite
Pressure	Not Compressible	Compressible

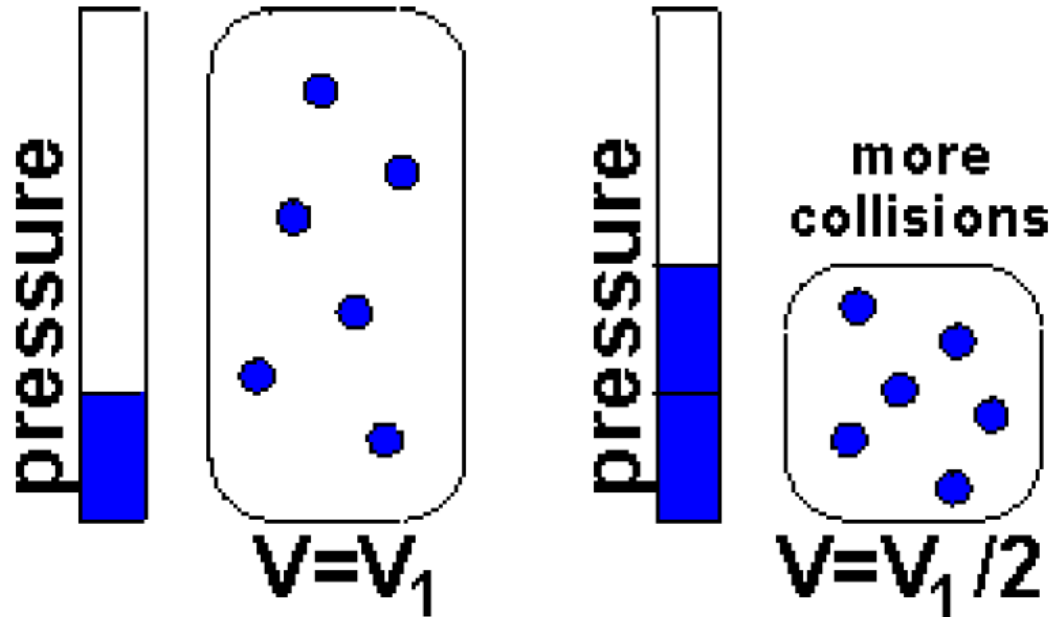
<http://www.youtube.com/watch?v=YImRa-9zDF8>

<http://www.youtube.com/watch?v=UuK3ESGgbqk&feature=related>

Page 359 reading check: #'s 1-5; page 363 #'s 1-2, 4-8

# PRESSURE & VOLUME

- **Increasing** pressure of a fluid will **decrease** volume by the same amount.
- known as **Boyle's Law**



# Example: Propane Cylinders (Page 366)

- **Increase** in pressure with a **decrease** in volume at constant temperature.





# TEMPERATURE & VOLUME

- **Increasing** temperature will **increase** the volume of a fluid.



# TEMPERATURE & PRESSURE

- **Increasing** temperature of a fluid will **increase** the pressure.



# In other words...

If the temperature of a fluid is constant (not changing)...

$$\uparrow P = \downarrow V$$

If the pressure of a fluid is constant...

$$\uparrow T = \uparrow V$$

If the volume of a fluid is constant...

$$\uparrow T = \uparrow P$$

# Why does this symbol appear on aerosol cans?

<http://www.youtube.com/watch?v=wlfKCBt5jVQ>



- 
- <http://phet.colorado.edu/en/simulation/gas-properties>

# Questions in Textbook pages 380-383

- Answer all questions

Except for:

16, 38, 39, 40, & 41

- Lab Stations  
(hydraulics/pneumatics)