What is matter?

- Matter is the “stuff” of the universe — the atoms, molecules and ions that make up all physical substances.
- Matter is anything that has mass and takes up space. = Everything that has mass and volume is called matter.
- Properties describe matter

STATES OF MATTER
Depend on:

- Particle arrangement
- Energy of particles
- Distance between particles

Traditionally, there are 5 states of matter:

Gas – the least organized, most energetic state
Liquid – less energetic and somewhat more organized
Solid – highly organized

A fourth state of matter - PLASMA

Hot, ionized gas particles.

Electrically charged.

Most common state in universe.

The fifth state of matter
Bose-Einstein condensates

- When atoms reach that temperature they are hardly moving relative to each other
- They have almost no free energy to do so.
- At that point, the atoms begin to clump together, and enter the same energy states.
- They become identical, from a physical point of view, and the whole group starts behaving as though it were a single atom.

Important notes regarding the states of matter:

- Most substances can exist in each of the three states under the right conditions
- State varies with temperature and pressure
- Changing states does not change chemical properties - they are physical changes.
- There are energy changes that accompany state changes.

Solids

- Definite shape
- Definite volume
- Particles close together
- Particles move very slowly

Liquids

- Indefinite shape
- Definite volume
- Take the shape of container
- Particles are close together, but mobile
- Particles move slowly

Gases

- Indefinite shape
- Indefinite volume
- Take the shape and volume of container
- Particles are far apart
- Particles move fast

Changes of State

- *Melting*, the change from solid to liquid, is endothermic (requires the *addition* of heat)
- *Freezing*, the change from liquid to solid, is exothermic (requires the *release* of heat).
- The *amount* of heat lost or gained is identical for a given substance.

- *Vaporization,* the change from liquid to gas (whether it occurs rapidly (boiling) or slowly (evaporation)), is endothermic
- *Condensation*, the change from gas to liquid, is exothermic.
- The *amount* of heat lost or gained is identical for a given substance.

Changes of State

- *Sublimation,* the change from solid to gas without entering the liquid state, is endothermic.

- The change from gas to solid, like the change from gas to liquid, is called *condensation*.

- The *amount* of heat lost or gained is identical for a given substance.

Density

- A given mass off an incompressible fluid will occupy a fixed volume, regardless of its shape.
- The density ρ of a fluid is its mass to volume ratio

$$\rho = \frac{mass}{volume} = \frac{m}{V}$$

In S.I. units, densities are measured in kilograms per cubic meter (kg m^{-3} = kg/m^3)

Pressure

The sum of the magnitude of the normal forces divided by the surface area is the average pressure P on the surface of the sphere.

$$\vec{P} = \frac{\textbf{magnitude of normal force on surface}}{\textbf{surface area}}$$

$$\vec{P} = \frac{F_N}{A}$$

- Pressure has units of force per unit area
- The S.I. unit of pressure is the pascal

$$1 \text{ Pa} = 1 \text{ N m}^{-2} = 1 \text{ N/m}^2$$

Pressure

$$F_g = mg \qquad \rho = \frac{m}{V} \qquad m = \rho V$$

$$F_g = \rho g V \qquad V = Ah$$

$$F_g = \rho g A h$$

$$\vec{P} = \frac{F_N}{A} \qquad \vec{P} = \frac{\rho g A h}{A} \qquad \vec{P} = \rho g h$$

Pressure

- At sea level the normal atmospheric pressure in various units is

$$1 \text{ atm} = 1.013 \bullet 10^5 \text{ Pa}$$

$$1 \text{ atm} = 1.013 \text{ bars}$$

$$1 \text{ atm} = 760 \text{ torr}$$

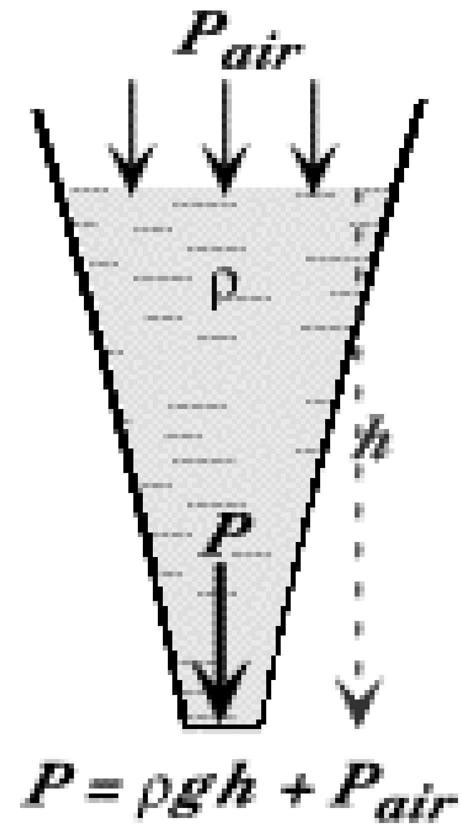
$$1 \text{ atm} = 760 \text{ mm Hg}$$

- The bar and milibar are used extensively in meteorology.
- The torr or millimeter of mercury (mm Hg) is used in medicine and physiology

Hydrostatic Pressure in Fluids

- The pressure at a given depth in a static liquid is a result the weight of the liquid acting on a unit area at that depth plus any pressure acting on the surface of the liquid.

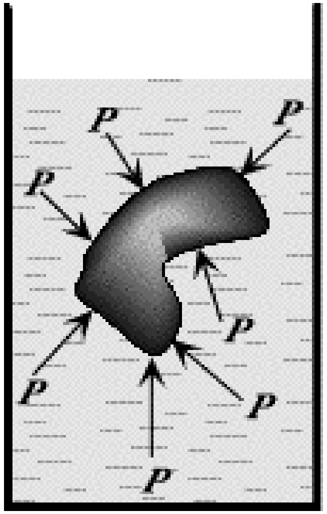
$$P = P_{atm} + \rho g h$$



- The pressure due to the liquid alone at a given depth depends only upon the density of the liquid ρ and the distance below
  the surface of the liquid h.
- $P = \rho g h$

Hydrostatic Pressure in Fluids

- Pressure can not exert any force parallel to the surface in which it is contact.



- The pressure at a given depth is independent of direction -- it is the same in all directions. This is another statement of the fact that pressure is not a vector and thus has no direction associated with it when it is not in contact with some surface.

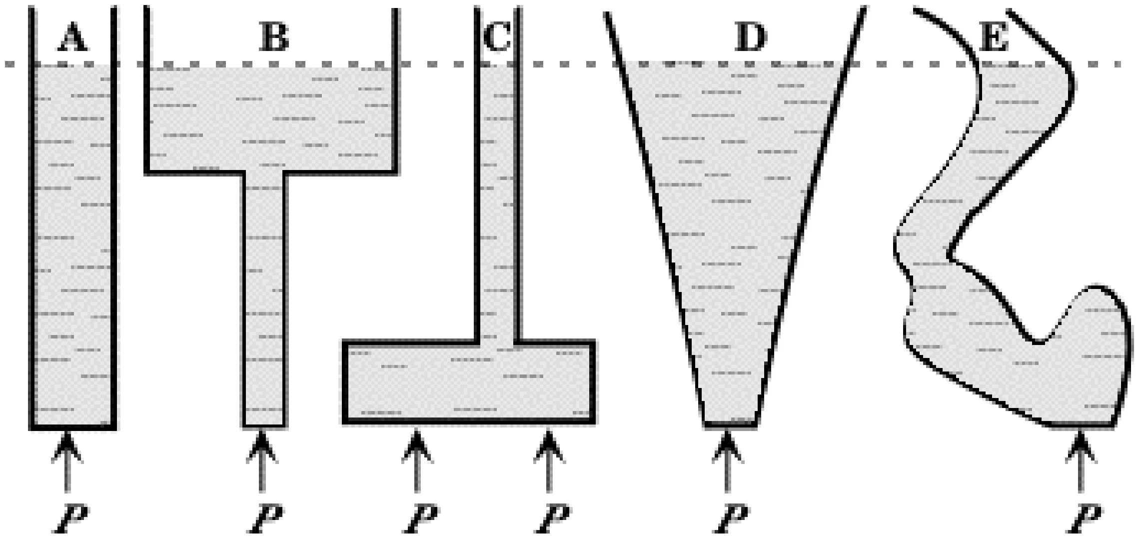
Pascal’s Principle

- Pascal's law states that when there is an increase in pressure at any point in a confined fluid, there is an equal increase at every other point in the container.

- Pressure equals force per unit area, then it follows that

$$P = \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

The pressure at a given depth <u>does not depend</u> upon the shape of the vessel containing the liquid or the amount of liquid in the vessel



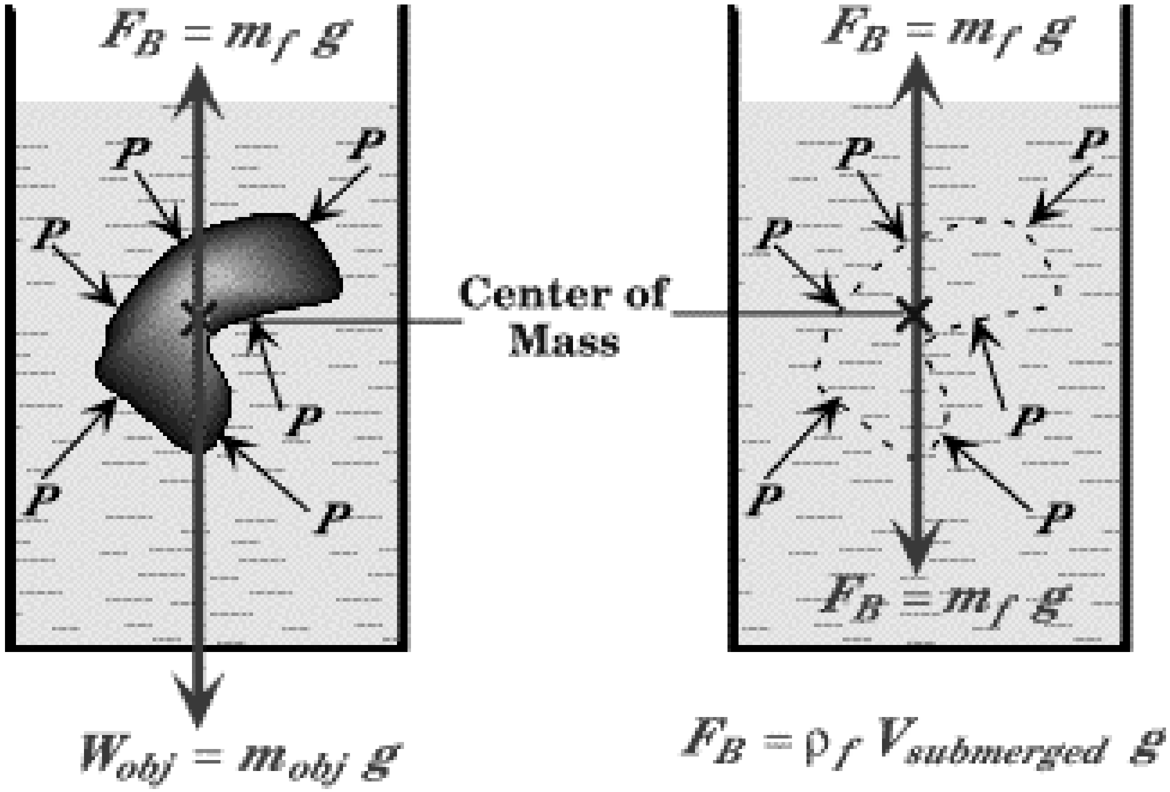
The pressure **P** is the same on the bottom of each vessel

Why the pressure does not depend upon the shape of the vessel or the amount of fluid in the vessel rests upon three things:

- Pressure is force per unit area and this is not same as the total weight of the liquid in a vessel.
- A fluid can not support itself without a container. Thus the walls of the container exert a pressure on the fluid equal to the pressure of the fluid at that depth.
- The pressure at given level is transmitted equally throughout the fluid to be the same value at that level.

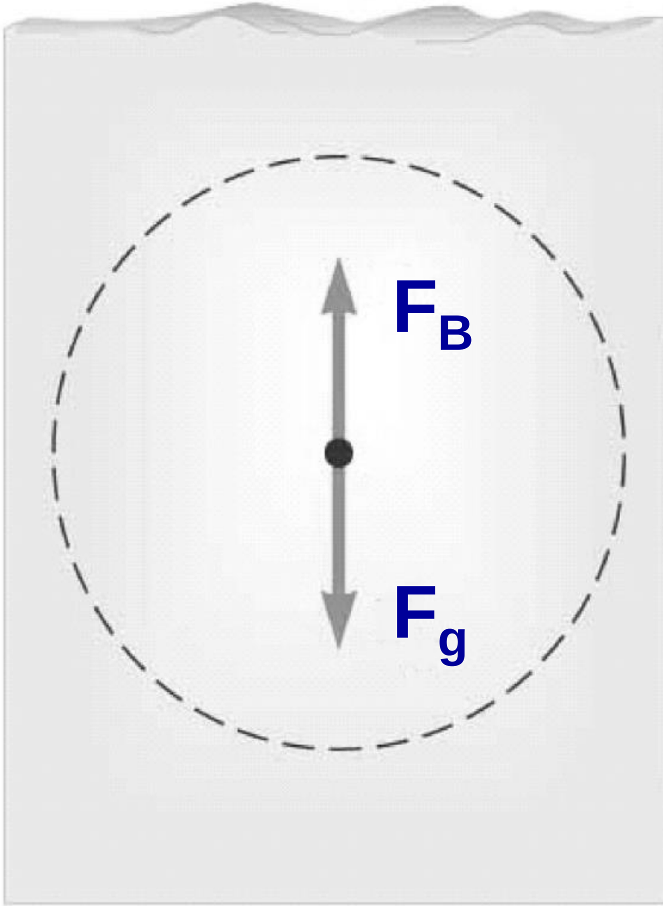
The buoyant force

When a rigid object is submerged in a fluid (completely or partially), there exits an upward force F_B on the object that is equal to the weight of the fluid that is displaced by the object.



$$F_{net,obj} = F_B - W_{obj} = (\rho_f \bullet V_s \bullet g) - (\rho_{obj} \bullet V_{obj} \bullet g)$$

The buoyant force



- The **buoyant force** is the upward force exerted by a fluid on any immersed object
- The parcel is in equilibrium
- There must be an upward force to balance the downward force
- The upward force, $\mathbf{F_B}$, must equal (in magnitude) the downward gravitational force F_g
- The upward force is called the buoyant force
- The buoyant force is the resultant force due to all forces applied by the fluid surrounding the parcel

The buoyant force

object sinks if $\rho_{object} > \rho_{fluid}$

object floats if $\rho_{object} < \rho_{fluid}$

If object floats… $F_B = F_g$

Therefore: $\rho_{fluid} \cdot g \cdot V_{displaced} = \rho_{object} \cdot g \cdot V_{object}$

$$\frac{V_{displaced}}{V_{object}} = \frac{\rho_{displaced}}{\rho_{object}}$$

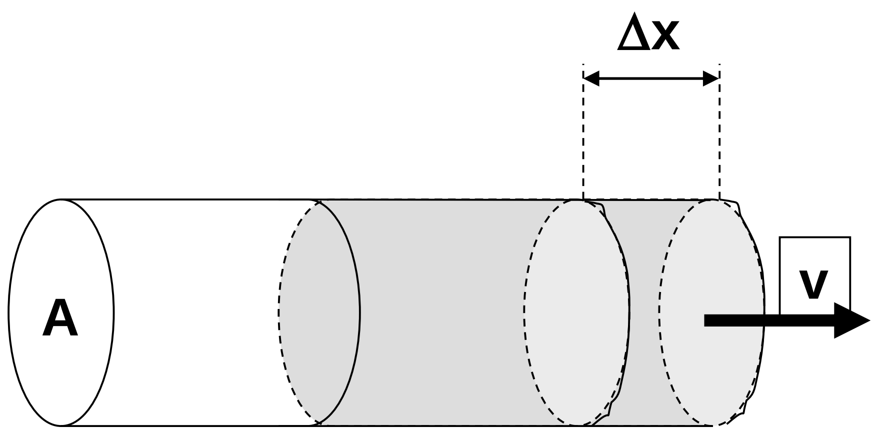
Archimedes' Principle

The buoyant force on any submerged object is equal to the weight of the water displaced.

Stream flow

- Supposed an incompressible fluid completely fills a channel such as a pipe or an artery.
- If more fluid enters one end of the channel, an equal amount must leave the other end.
- This principle is called:
  The equation of continuity.

The equation of continuity



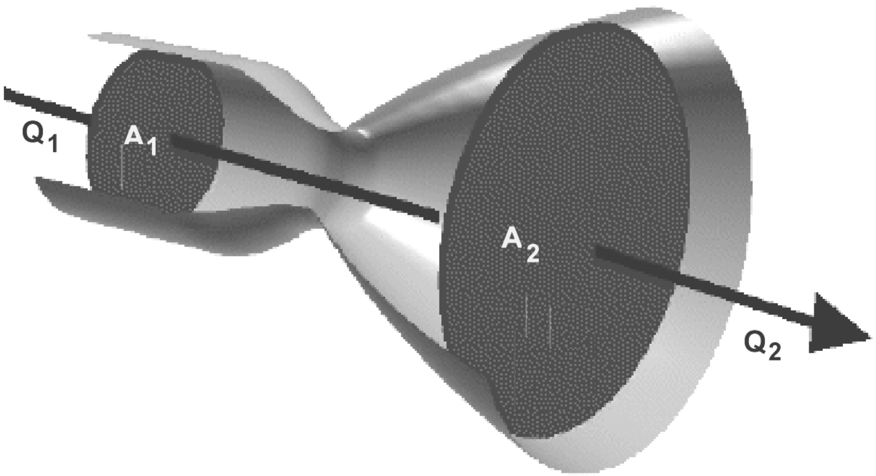
$$\Delta x = v\,\Delta t$$

$$\Delta V = A\,\Delta x = Av\,\Delta t \qquad \text{or} \qquad \Delta V = Q\,\Delta t$$

$$Q = Av$$

The flow rate equals the cross-sectional area of the channel times the velocity of the fluid.

The equation of continuity



$$Q_1 = Q_2$$

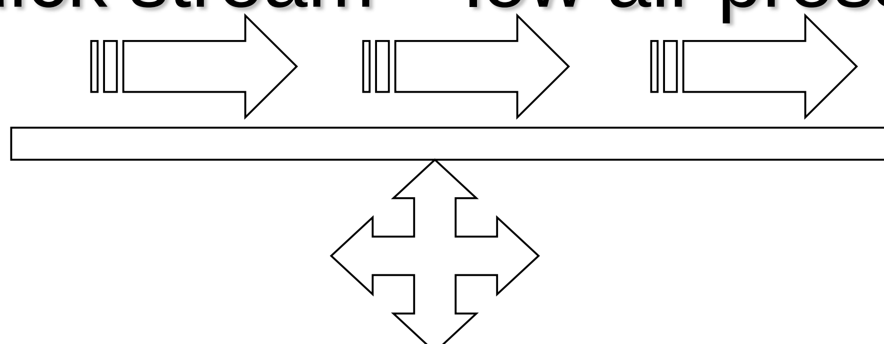
$$A_1 v_1 = A_2 v_2$$

The product of the cross-sectional area and the velocity of the fluid is constant.

Bernoulli Equation

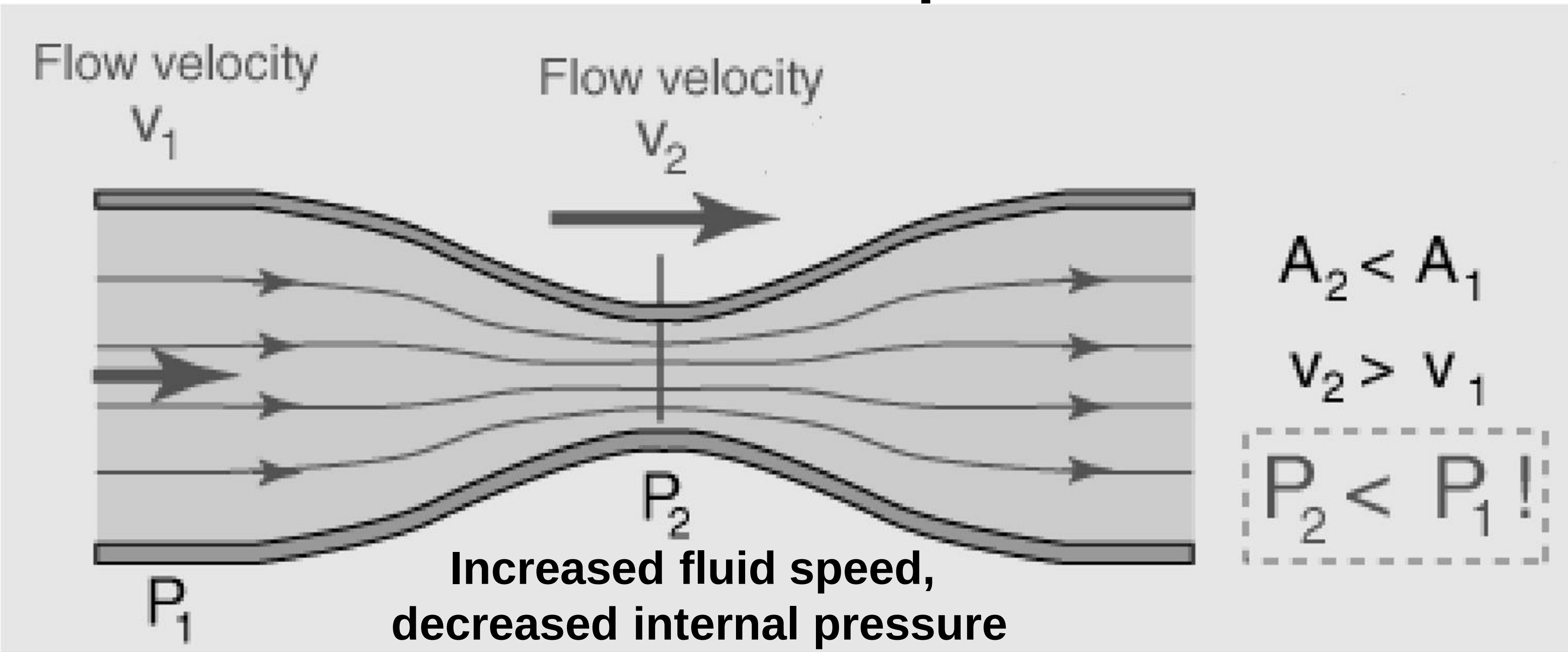
- Pressure in a moving stream exerts less pressure than the air surrounding the moving stream

Quick stream = low air pressure



Slow stream = high air pressure

Bernoulli Equation



Energy per unit volume before = Energy per unit volume after

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

Pressure energy

Kinetic energy per unit volume

Potential energy per unit volume