Archimedes' Principle

The buoyant force on an immersed object is equal to the weight of the fluid it displaces.

$$F_B = m_f g = \rho_f V_f g$$

- Note: Buoyant force does NOT depend on depth!

Helpful to know:

- Properties of water:
  – 1 kg of liquid water takes up 1 L of volume
  – 1 kg of water weighs 10 N.
  – Water has a mass density of 1 g/cm^3, or 1000 kg/m^3
- What would it take for the buoyant force to be greater than the weight of the object displacing some volume of water?

Using a spring scale, you measure the weight of a box to be 30 N. When you dip the box into four unknown liquids, you get the following readings on the spring scale:

Liquid A: 22 N
Liquid B: 10 N
Liquid C: 28 N
Liquid D: 0 N

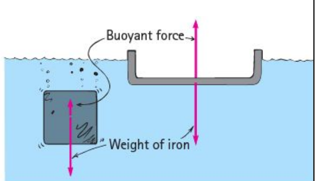
Which liquid is the most dense? Which is least dense? How do you know?

More Floating

- Remember Archimedes' Principle: An immersed object feels a buoyant force equal to the weight of the fluid it displaces.
- Objects with density less than the fluid will float.
- How do modern ships float???

Floating Depends on *Average* Density

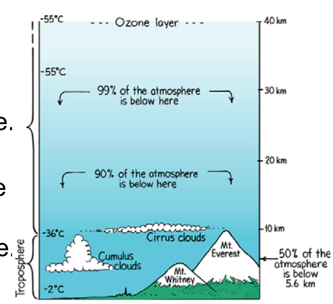
- Imagine a solid block of iron, and a sheet of iron bent into a boat-like shape.
- We have *increased* the *effective volume* of the sheet of iron
- This *lowers* its average density, allowing it to float



A floating object displaces a weight of fluid equal to its own weight

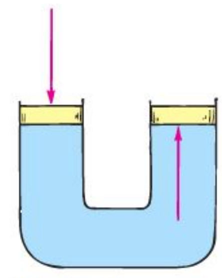
Atmospheric Pressure

- Density of air in the atmosphere decreases with increasing altitude.
- Most of atmosphere in the first 10 km (about 6 miles) of altitude.



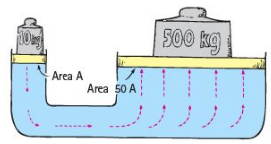
Pascal's Principle

"A change in pressure at any point in an enclosed fluid is transmitted undiminished to all points in the fluid."



Pascal's Principle: Example

- Remember, Pressure = force / area
- Pressure on both piston is the same (due to Pascal's Principle)
- Imagine the area of the small piston is 1 m^2, and the are of the large piston is 5 m^2
- What force acts on the large piston?



Continuity and Fluid Flow

Imagine water flowing through a pipe that goes from wide to narrow: speed of water increases through narrow portion of the pipe. (what goes in must come out)

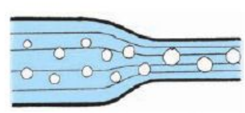
$$A_1v_1 = A_2v_2$$

A = cross-sectional area of pipe
v = velocity

Bernoulli's Principle

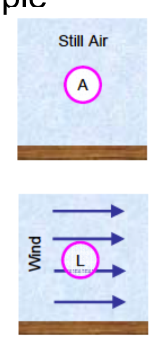
" Where the speed of a fluid increases, internal pressure in the fluid decreases."

- Additional way to change the pressure in a liquid (other was depth)



Bernoulli's Principle

- If speed of a fluid increases, the pressure in the fluid decreases.
- This phenomenon is due to energy conservation; when fluid's KE increases (velocity increases) its internal P (pressure) decreases.



Bernoulli's Equation

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

Bernoulli's equation comes from conservation of energy: P term comes from work done on a fluid, ½ρv term comes from kinetic energy, and ρgh term comes from gravitational potential energy.

Archimedes' Principle Example

A piece of wood is tied to a string inside a tub filled with water. The string is attached to the bottom of the tub, and the wood is completely submerged. If the wood has a volume of 8 cm^3 and a density of 600 kg/m^3, what is the tension in the string?

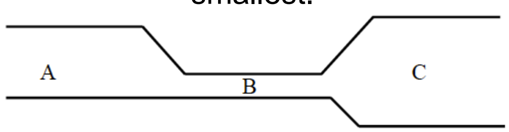
Bernoulli's Equation Example

The buildup of plaque on the walls of an artery may decrease its diameter from 1.1 cm to 0.75 cm. If the speed of the blood flow was 15 cm/s before reaching the region of plaque buildup, find:

a) The speed of blood flow

b) The pressure drop within the plaque region.

Water is flowing continuously in the pipe from point A to point C. Rank the three points in terms of the internal pressure from biggest to smallest.



Transforming Energy

- Recall: energy is always conserved, just changes from one form to another
- Thermal energy is not very useful (incredibly difficult to transform into another form of energy!), we mostly consider thermal energy to be "lost" to surrounding objects, air, etc.
- Other forms (U_{sp}, KE, U_{grav}, work done by conservative forces) are not considered lost in this way.

Efficiency

- Real-life processes always include some friction, which means we'll always lose some energy to heat (more on this later). How much we lose determines the efficiency of the process:

$$e = \text{Energy out/ Energy in}$$

(Efficiency is a percentage, so no units)

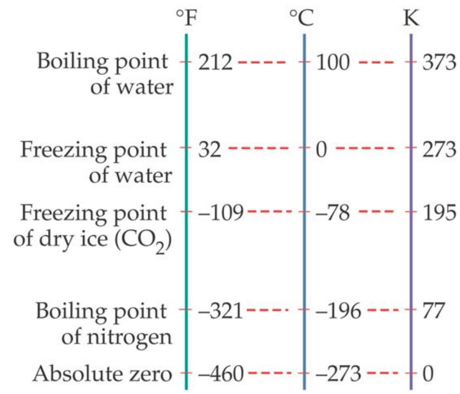
Temperature

- Temperature (T) is a measure of how "hot" or "cold" something is
- Temperature measures the random KE of each particle in an object.
  - The greater the motion/vibration the greater the T
  - The smaller the motion/vibration the lower the T
- SI Unit: kelvin (K)
  - Room temperature is about 295K-300K

Kelvin Temp. Scale

- The Kelvin scale has the same step size (size of one degree) as the Celsius scale, but the Kelvin scale has its zero at absolute zero.
- Conversion between a Celsius temperature and a Kelvin temperature:

$$T = T_C + 273.15$$



Thermometers

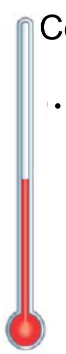
- Thermometers are instruments designed to measure temperature. In order to do this, they take advantage of some property of matter that changes with temperature.
  - Length of a solid or liquid column
  - Volume of a solid, liquid, or gas
  - Electromagnetic waves (infrared light) given off by hot objects

Thermal Expansion

- When you heat something up, it expands! (usually…)
- The effect is less dramatic in solids than in liquids or gases

Common Thermometers

- Liquid-in-tube



(a)

- Bimetallic Strip

(b)

If you have a glass jar with a metal lid that's stuck, which of these might help you loosen the lid?

A. Running the lid under hot water
B. Running the lid under cold water
C. Running the lid under lukewarm water

Thermal Expansion

- (most) Objects expand when heated up
- $\Delta V = \beta V_i \Delta T$
- β = coefficient of volume expansion (K^{-1})
- $\Delta L = \alpha L_i \Delta T$ (for solids only)
- α = coefficient of linear expansion (K^{-1})

Example: Railroad tracks

- A 10-cm wide steel railroad tie is heated from 275 K to 310 K (about 35F to 100F). How much wider is the railroad tie after this?
- α for steel is 1.2×10^{-5} K^{-1}

Heat (Q)

Definition of heat:

- Heat is the energy transferred between objects because of a temperature difference, or through work.
- Objects are in thermal contact if heat can flow between them.
- Connection from momentum: we treat collisions between atoms as perfectly elastic collisions

Thermal Equilibrium

- When the transfer of heat between objects in thermal contact stops, they are in thermal equilibrium.
- The objects will then be at the same temperature (they won't necessarily have the same thermal energy!)

Units of Heat

- Since heat is just a flow of energy, the SI unit is the energy unit, the joule (J).
- Other heat units
  - calorie (cal): Heat needed to raise temperature of 1 gram of water by 1°C (or 1 K)
  - Calorie (Cal or kcal or food cal): Heat needed to raise temperature of 1 kg of water by 1°C (or 1 K)

Conversions:

1 cal = 4.186 J

1 kcal = 1 Cal (food Cal.) = 4.186 kJ

Specific Heat Capacity

- Specific heat capacity is the amount of heat energy required to raise the temperature of one unit mass of a material by one degree.
- SI Unit: J/(kg•K)

Heat Capacity vs. Specific Heat

- Heat capacity, C [J/K]
  - Q needed for a given ΔT
- Specific Heat, c [J/kg K] (this is more frequently used)
  - Q needed for a given ΔT for a particular amount of material
- Both c and C are particular to a given substance (water, glass, etc.) See Table 16-2.