STATES OF MATTER: [In order from highest to lowest potential energy]

• Plasma— Atoms have lost electrons, so that the system is a mixture of charged particles, positively charged atoms and negatively charged electrons. Most of the visible matter in the universe is in the form of a plasma. Everyday example: fire.

• Gas— atoms or molecules are roughly 10 diameters apart (for example in this room). Everyday example: air.

• Vapor— the constituents are microscopic clusters of molecules. Everyday example: clouds or fog.

• Liquid— the molecules or atoms are nearly in contact but can slide past one another. Everyday example: water.

• Solid— the molecules or atoms are in contact, and stay roughly in the same position relative to one another. Everyday example: a rock.

Young's Modulus: Stretching or compressing a solid:

$$\frac{F}{A} = Y\frac{\Delta L}{L_0}.$$

Shear Modulus: Twisting a solid:

$$\frac{F}{A} = S\frac{\Delta x}{h}.$$

Bulk Modulus: Compressing a solid, liquid or gas:

$$\Delta p = -B\frac{\Delta V}{V}.$$

Typically Y, S and B are all of order 10^{11} J/m^3.

- PRESSURE IN A LIQUID:

$$p = p_a + \rho g d.$$

- PASCAL'S PRINCIPLE:

$$F_1/A_1 = F_2/A_2.$$

- GAUGE PRESSURE:

$$p = p_{\text{actual}} - p_a.$$

- BUOYANT FORCE:

$$B = \rho_{\text{liquid}} g V.$$

- CONTINUITY EQUATION:

$$A_1 v_1 = A_2 v_2.$$

- BERNOULLI'S EQUATION:

$$p + (1/2)\rho v^2 + \rho g y = \text{constant}$$

An object less dense than water is held underwater by a thread. If the object has half the density of water, which is ρ_w, and a volume V, what is the tension in the thread? Answer: $T = (\rho_w g V)/2$.

An object less dense than water floats on the surface with a fraction of its volume f below the surface. What is f in terms of the density of the object, ρ, and the density of water, ρ_w? Answer: $f = \rho/\rho_w$.

Under ideal conditions the total internal energy of a gas can be expressed as

$$\mathcal{E} = \frac{3}{2}pV.$$

Thus we can say the pressure is a measure of the total internal energy per unit volume.

A very large cylindrical container is full of water. At a certain instant, there is a small hole a distance d below the water level, and a distance h above the container bottom. The water strikes the level ground on which the container sits, a distance D from the side of the container. Show that $D = 2\sqrt{dh}$.

A horizontal pipe has a fluid flowing at speed v and pressure p_1. The pipe narrows down drastically in area so that the new flow speed is $6v$. Show that the new pressure is $p_2 = p_1 - (35/2)\rho v^2$.