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 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:

\[ p = p_a + \rho gd. \]

• PASCAL’S PRINCIPLE:

\[ \frac{F_1}{A_1} = \frac{F_2}{A_2}. \]

• 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:

\[ p + \frac{1}{2} \rho v^2 + \rho gy = \text{constant}. \]
An object less dense than water is held underwater by a thread. If the object has half the density of water, which is $\rho_w$, 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, $\rho$, and the density of water, $\rho_w$? 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 \( p_2 = p_1 - (35/2)\rho v^2 \).