Topic 4 – Force, Pressure, and Area

Calculating Pressure

Pressure is a measure of the amount of force applied to a given area.

$$p = F / A$$

p is pressure **F** is Force and **A** is Area

The unit of measurement for pressure is a pascal (Pa), named after Blaise Pascal who did important research on fluids.

1 **Pa**scal is equal to the force of 1 **N**ewton over an area of 1 $\mathbf{m}^2$

1 **K**ilo**pa**scal is equal to 1000 **pa**scals

Equipped Against Pressure

Safety equipment is need in many situations in order to protect our body from injury or accident. Most of the safety equipment is designed *to spread the force over a larger area*.

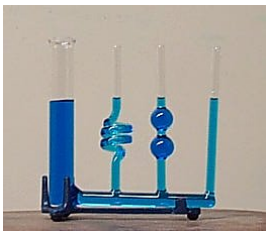
Pascal's Law

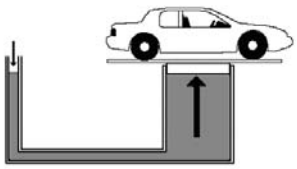
Blaise Pascal (1623-1662) discovered that …

Pressure applied to an enclosed fluid is transmitted undiminished in all directions throughout the fluid and perpendicular to the walls of the container.

This is known as **Pascal's Law** and it makes **hydraulic** (liquid) and **pneumatic** (air) systems possible.

He was the first to notice that the shape of the container had no effect on the pressure at any given depth as illustrated here.





A common application of Pascal's law is the *hydraulic lift.*

It is a mechanical system that raises heavy objects, using a fluid under pressure in a *closed system* (self-contained collection of parts).

Pascal's Law and Mechanical Advantage

$$\textit{Mechanical Advantage} = \frac{\textit{Load Force}}{\textit{Effort Force}}$$

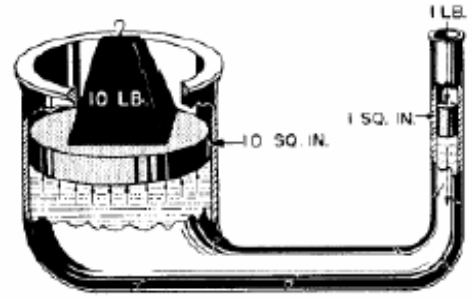
In hydraulic systems, the pressure is created using a piston. Pistons can be different sizes and hydraulic devices use pistons that are different sizes attached to each other with a flexible pipe. The **Input piston** is used to apply force to the fluid, which creates pressure in the fluid. The fluid transfers this pressure to the **output piston**. This pressure exerts a force on the output piston and the result is a mechanical advantage that makes the hydraulic system very useful.

The mechanical advantage in a hydraulic system comes from the fluid pressure in the system.

Calculating the input force and the output force will give you the Mechanical advantage of the system.

MA = Output force / Input force

MA = $F_o x d_o$ / $F_i x d_i$ MA = 10 / 1 = 10



This hydraulic system has a mechanical advantage of 10

Mechanical advantages in hydraulic systems are usually quite high, showing how useful they are.

Pressure and Mechanical Advantage

The reason for the large mechanical advantage in a hydraulic system is the ability of the fluid to transmit pressure equally. It allows you to use a small force on the small piston to produce a larger force on the large piston.

$$p = F / A$$

From Pascal's law, we know that the pressure the small piston creates is the same everywhere in the fluid. So the large piston has a larger area and is able to multiply the pressure because of its larger area. The force and area at each piston act as ratios that have to be equal.

$$\frac{\text{Force of the small piston}}{\text{Area of the small piston}} = \frac{\text{Force of the large piston}}{\text{Area of the large piston}}$$

$$\frac{F_{small}}{A_{small}} = \frac{F_{large}}{A_{large}}$$

By solving this ratio you will find that the forces created within a hydraulic system provides very large mechanical advantages - making them useful in many applications.

Larger Force – Greater Distance To Move

Mechanical advantage in hydraulic systems has a cost. That cost is the increased distance the smaller force must go through to make the large force move a small distance.

To increase the force on the output piston ,
the input piston must move through a greater distance.



Amusement park rides make extensive use of hydraulic systems