FLUIDS PART 2

Pressure:

The normal force (F) exerted by a fluid at rest per unit surface area (A) of contact is called pressure (P) of the fluid

$$P = \frac{F}{A}$$

SI Unit: N/m^2 or Pa Dimensions $[M^1L^{-1}T^{-2}]$

Pressure is a scalar quantity.

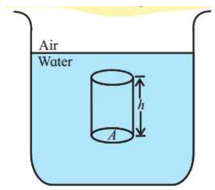
NOTE : 1 bar = 10^5 Nm^{-2}

1 hectapascal (hPa) = 100 Pa

NOTE : Atmospheric pressure is 1 bar at sea level = 10^5 Nm^{-2} = 76cm of Hg

Pressure due to Liquid Column

Consider a imaginary cylinder of cross section area A inside a container containing fluid of density ρ. Let h be the height of the imaginary cylinder. The liquid column exerts a force (its weight) F=mg on the bottom of this cykinder.



$$P = \frac{F}{A} = \frac{mg}{A} = \frac{V\rho g}{A} = \frac{Ah\rho g}{A} = h\rho g$$

Note the pressure does not depend on the area of the imaginary cylinder

Absolute Pressure and Gauge Pressure

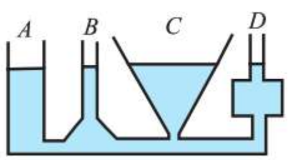
Absolute pressure P at a depth h = Po + hρg

whrere Po is the atmospheric pressure and h is the depth below the surface of the liquid, ρ is the density of the liquid and g is the accelerationn due to gravity at that place.

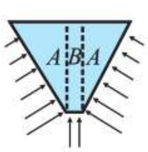
Gauge pressure = P – Po = hρg (fluid pressure alone OR difference between absolute pressure and atmospheric pressure)

HYDROSTATIC PARADOX

When the liquid is poured into an one vessel, it is noticed that the level in all vessels is the same. This observation was somewhat puzzling since the area and weight of liquid in each container was different so the pressure should be different. But this was not the case to be. This is called hydrostatic paradox.



One would think pressure at the base of C would be more than that at the base of vessel B, hence liquid from C should pass on to B and cause a rise in B. But as discussed earlier, pressure depends on the height of the liquid column above it and not on the shape (volume or mass) of the fluid in it. Therefore the pressue in each column is the same (since height is same). Hence the equilibrium and hence the liquid in C does not flow into B.



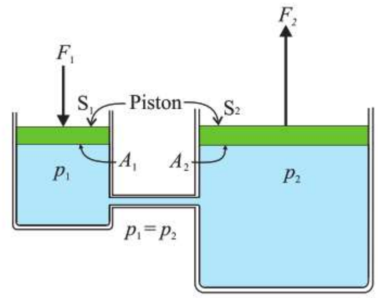
Alternately, we can see from the above figure the forces acting on the liquid by the container, marked perpendicular to the walls of the container. If we resolve these forces into horizontal and vertical direction then the vertical components, acting upwards, balaance the weight of the liquid in section A. Section B is not balanced and contributes to the pressure at the base. Thus there is no paradox any more!

PASCAL's LAW:

Plascal's law states that the pressure applied at any point on an ***enclosed fluid*** is transmitted equally and undiminished to every point of the fluid and also on the walls of the container, provided the effect of gravity is neglected.

APPLICATIONS OF PASCAL's LAW

Hydrolic Lift:



Let A_1 be the area of the smaller piston S_1 and A_2 be the area of the larger piston S_2. If we apply a force F_1 in the downward direction, on the smaller piston, the pressure generated P_1, will be tranmitted undiminished to the bigger piston S_2, which inturn will experience an upward force F_2.

By Pascal's law,

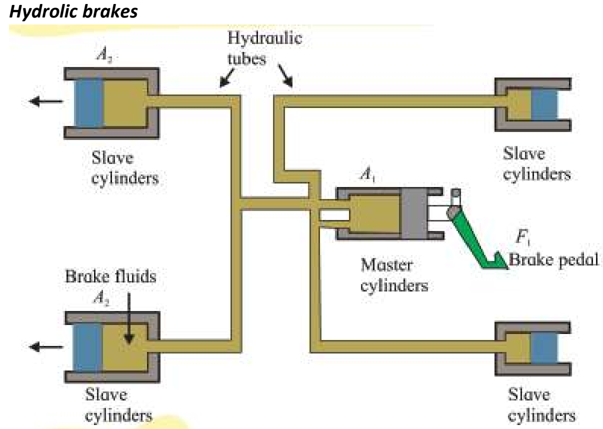
$p1 = p2$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \quad .Thus, F_2 = \left(\frac{A_2}{A_1}\right)F_1$$

Since A2 >> A1 thus F2 >> F1

Hydrolic lift are used to lift very heavy objects using a small force.

Hydrolic brakes



Hydrolic brakes are used to slow down or stop vehicles in motion.

By pressing the break pedal, the piston of the master cylinder is pushed in forward direction. As a result, the piston in the slave cylinder (which has a much larger area of cross section as compared to master cylinder) also moves in the forward direction so as to maintain the volume of oil constant. The slave pushes the friction pads against the rotating dics, which is connected to the wheel. Thus, causing the vehicle to slow down or stop.

$p1 = p2$

$$\frac{F_1}{A_1} = \frac{F_2}{A_2} \quad .Thus, F_2 = \left(\frac{A_2}{A_1}\right)F_1$$

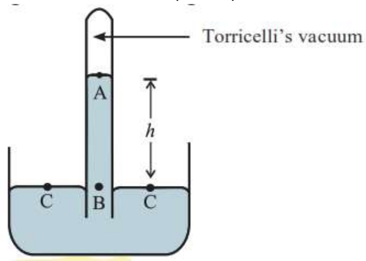
Since A2 ≫ A1 thus F2 ≫ F1

Thus small force on the break pedal translated to a large force and slows down or stops a moving vehicle.

Instruments used to measure Pressure:

- ***Mercury Barometer***

  Used to measure atmospheric presure



A glass tube is filled with mercury up to the brim. It is then quickly inverted in to a small dish containing mercury. The level of mercury in the glass tube lowers as some mercury spils in the dish. A gap is created bwteen the surface of mercury in the glass tube and the end of the glass tube (called Torricelli's vacuum).

Pressure at A is zero (P_A=0)

Pressure at C is atmospheric pressure Po

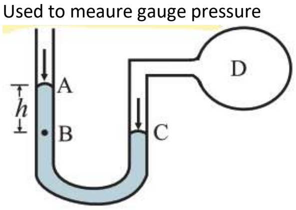
Since B and C are at the same horizontal level, thus Pressure at B = Pressure at C

$P_B = P_C = Po$

Thus $P_B = Po = P_A + h\rho g = h\rho g$ where h=height of the mercury column.

- ***Open Tube Manometer***

  Used to meaure gauge pressure



A manometer consists of a U tube, partly filled with a low density fluid like water or kerosine. One arm is open to the atmosphere and the other is connected to the cotainer D of which the pressure P is to be determined.

P_A = Po (atmospheric pressure)

$P_B = P_A + h\rho g = Po + h\rho g$

Since B and C are at the same level, thus

$P_C = P_B = Po + h\rho g$

ρ : density of the liquid in manometer

h : height of the liquid column above B

g : acceleration due to gravity

By Pascal's law

$P_D = P_C = Po + h\rho g$

Thus the gauge pressure of the gas in D will be

$P_D – Po = h\rho g$