

## -Fluids -

THE AVERAGE PRESSURE on a surface area A is force divided by area, where it is stipulated that the force must be perpendicular (or normal) to the area.

$$\text{average pressure } p = \frac{\text{force } F \text{ acting normal to area}}{\text{area } A \text{ over which } F \text{ is distributed}}$$

The units of pressure are N/m(2); lb/ft(2); lb/in(2). The SI name given to the N/m(2) is the pascal (Pa), where 1Pa=1N/m(2)

STANDARD ATMOSPHERIC PRESSURE is 1.01 x 10(5) Pa and is equivalent to 14.7 lb/in(2). Others are:

$$\begin{aligned} 1 \text{ atmosphere (atm)} &= 1.013 \times 10(5) \text{ Pa} \\ 1 \text{ torr} &= 1 \text{ mm of Hg} = 133.32 \text{ Pa} \end{aligned}$$

HYDROSTATIC PRESSURE due to a column of fluid of height h and mass density ( $\rho$ ) (or weight density D) is:

$$p = h \rho \quad g = hD$$

PASCAL'S PRINCIPLE: When the pressure on any part of a confined fluid (liquid or gas) is changed, the pressure on every other part of the fluid is also changed by the same amount.

ARCHIMEDE'S PRINCIPLE: A body wholly or partly immersed in a fluid is buoyed up by a force equal to the weight of the fluid it displaces. The buoyant force can be considered to act vertically upward through the center of gravity of the displaced fluid.

$$BF = \text{buoyant force} = \text{weight of displaced fluid}$$

THE FLUID FLOW OR DISCHARGE (Q): When a fluid that fills a pipe flows through the pipe with average velocity v, the flow or discharge, Q, is

$$Q = Av$$

Where A is the cross sectional area of the pipe. The units for Q are m(3)/s in the SI system and ft(3)/s in the British system. Sometimes Q is called the rate of flow or discharge.

EQUATION OF CONTINUITY: Suppose an incompressible (constant-density) fluid fills a pipe and flows through it. Suppose further that the cross section area is A1 at one point and A2 at another. Since the flow through A1 must equal the flow through A2, one has

$$Q = A_1 v_1 = A_2 v_2 = \text{constant}$$

where v1 and v2 are the average fluid velocities over A1 and A2 respectively.

VISCOSITY ( $\eta$ ) OF A FLUID is a measure of how difficult it is to cause the fluid to flow. A very viscous fluid, such as tar, has a high viscosity. Suppose that a nonelastic fluid is sheared between two plates

If the velocity v of the upper plate is not too large, the fluid shears in the way indicated by the drawing. The viscosity  $\eta$  is related to force F required to produce velocity v by:

$$F = \frac{v A}{d} \eta$$

where A is area of either plate, d is the distance between the plates. The SI unit for  $\eta$  is N.s/m(2). Other units:

$$1 \text{ poiseuille (PI)} = 1 \text{ N.s/m(2)} = 1 \text{ kg/m.s}$$

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1 poise(P) = 0.1 kg/m.s

1 centipoise(cP) =  $10^{-3}$  kg/m.s

The British unit is lb.s/ft<sup>2</sup>

POISEUILLE'S LAW: The fluid flow through a cylindrical pipe of length L and cross-sectional radius r is given by:

$$Q = \frac{\pi r^4 \{p_1 - p_2\}}{8 \eta L}$$

where  $p_1 - p_2$  is the pressure difference between the two ends of pipe.

WORK done by a piston forcing a volume V of a fluid into a cylinder against an opposing pressure p is given by pV.

BERNOULLI'S EQUATION for steady flow of a continuous stream of fluid: Consider two different points along the stream path. Let point 1 be at the height  $h_1$ , let  $v_1$ ,  $\rho$  and  $p_1$  be the fluid velocity, density, and pressure at point 1. Similarly define  $h_2$ ,  $v_2$ ,  $\rho$ ,  $p_2$  for point 2. The, provided the fluid is incompressible and has negligible viscosity:

$$p_1 + \frac{1}{2} \rho v_1^2 + \rho h_1 g = p_2 + \frac{1}{2} \rho v_2^2 + \rho h_2 g$$

where  $p_1 = p_2 = p$  and g is the acceleration due to gravity

TORRICELLI'S THEOREM: Suppose that a tank contains liquid open to the atmosphere at its top. If an orifice (opening) exists in the tank at a distance h below the top of the liquid, then the velocity of outflow from the orifice is:

$\sqrt{2gh}$ , provided the liquid obeys Bernoulli's equation and the top of the liquid may be regarded as motionless.