Mechanical Properties of fluids

- The **average pressure** P_{av} is defined as the normal force acting per unit area.

  $P_{av} = F/A$
- For a fluid of
- Mass *m* occupying volume *V*, ρ = *m/V*. The dimensions of density are [ML–3].
- Pascal's Law- The pressure in a fluid at rest is the same at all points if they are at the same height.
- The pressure P, at depth below the surface of a liquid open to the atmosphere is greater than atmospheric pressure by an amount ρgh. The excess of pressure, $P - P_a$, at depth h is called a gauge pressure at that point.
- Whenever external pressure is applied on any part of a fluid contained in a vessel, it is transmitted undiminished and equally in all directions. This is the Pascal's law for transmission of fluid pressure.

- The path taken by a fluid particle under asteady flow is a streamline. It is defined as acurve whose tangent at any point is in thedirection of the fluid velocity at that point.
- Equation of continuity: Av = constant

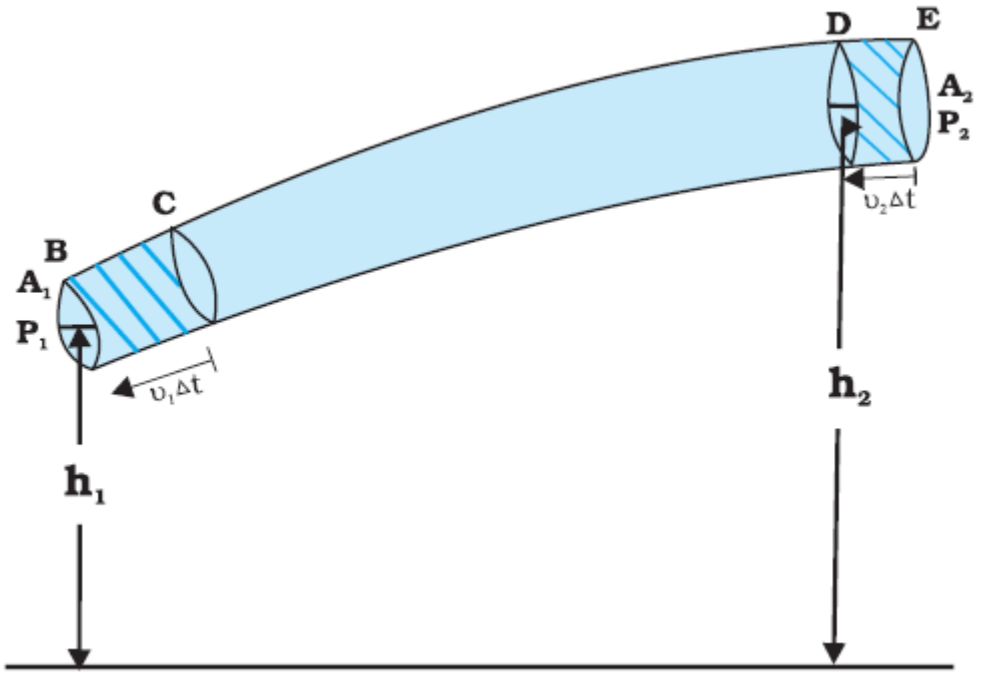
  Av gives the volume flux or flow rate andremains constant throughout the pipe of flow.Thus, at narrower portions where thestreamlines are closely spaced, velocityincreases and its vice versa.
- Steady flow is achieved at low flow speeds.Beyond a limiting value, called critical speed,this flow loses steadiness and becomesturbulent.
- Bernoulli's Equation:

  $P_1 + (1/2)\,\rho v_1^2 + \rho g h_1 = P_2 + (1/2)\,\rho v_2^2 + \rho g h_2$

  When a fluid is at rest i.e. its velocity is zero everywhere, Bernoulli's equation becomes

  $P_1 + \rho g h_1 = P_2 + \rho g h_2$

  $(P_1 - P_2) = \rho g\,(h_2 - h_1)$



- Aerofoil or lift on aircraft wing and the Magnus effect(dynamic lift of the ball due to spinning) can be explained using Bernoulli's theorem.
- The coefficient of viscosity (pronounced 'eta') for a fluid is defined as the ratio of shearing stress to the strain rate. (F/A)/(v/l)

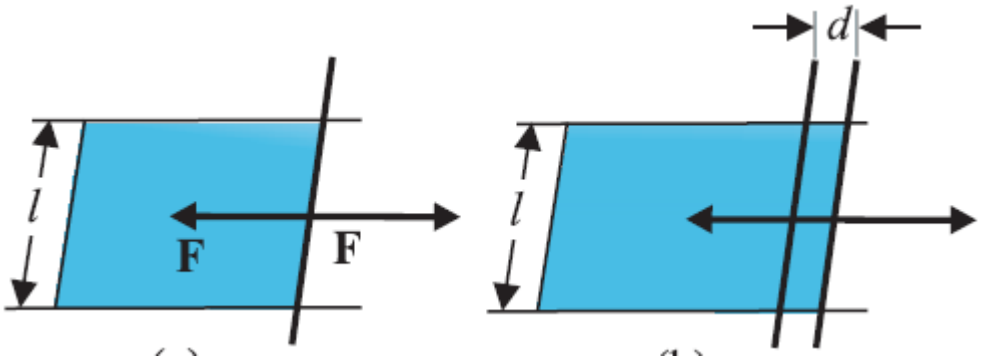
  The SI unit of viscosity is poiseiulle (Pl).

- When a body falls through a fluid it drags thelayer of the fluid in contact with it. A relativemotion between the different layers of the fluidset and as a result the body experiences aretarding force.It is seen that theviscous force is proportional to the velocity ofthe object and is opposite to the direction ofmotion. The other quantities on which the force*F* depends on viscosity η of the fluid and radius*a* of the sphere.

  F = 6πηav (Stoke's Law).
- Reynolds defined a dimensionless number, whose value gives one an approximate idea whether the flow would be turbulent. This number is called the Reynolds Re.

  $R_e = \rho vd/\eta$

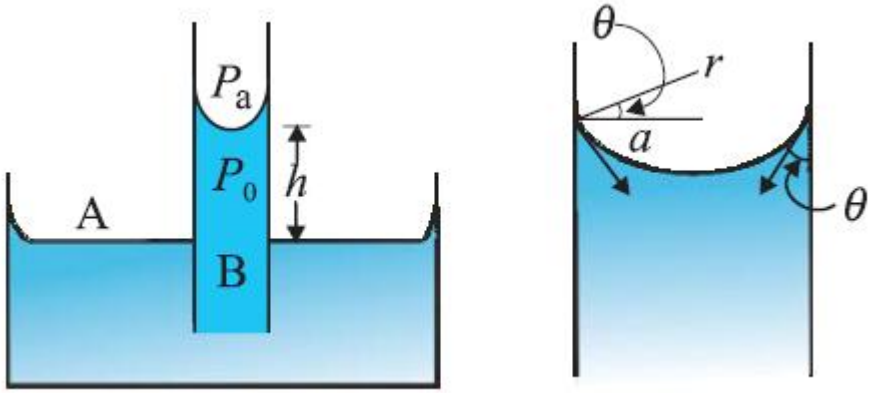
  where ρ is the density of the fluid flowing with a speed v, d stands for the dimension of the pipe, and η is the viscosity of the fluid. R_e is a dimensionless number and therefore, it remains same in any system of units. It is found that flow is streamline or laminar for R_e less than 1000. The flow is turbulent for R_e> 2000. The flow becomes unsteady for Re between 1000 and 2000.
- Liquids have no definite shape but have a definitevolume, they acquire a free surface when pouredin a container. These surfaces possess someadditional energy. This phenomenon is knownas surface tension and it is concerned with onlyliquid as gases do not have free surfaces.



S (2dl) = Fd (10.23)

Or, S=Fd/2dl = F/2l (10.24)

This quantity S is the magnitude of surface tension.



- The contact angle between waterand glass is acute. Thus the surface of water inthe capillary is concave. This means thatthere is a pressure difference between thetwo sides of the top surface. This is given by

  $(P_i - P_o) = (2S/r) = 2S/(a \sec \theta) = (2S/a) \cos \theta$

  Thus the pressure of the water inside thetube, just at the meniscus (air-water interface)is less than the atmospheric pressure.Theymust be at the same pressure, namely$P_0 + h \rho g = P_i = P_A$

  where ρ is the density of water and h is called the capillary rise.

Sample Examples

- At a depth of 1000 m in anocean (a) what is the absolute pressure?(b) What is the gauge pressure? (c) Findthe force acting on the window of area depth, the interior of which is maintainedat sea-level atmospheric pressure.

  Answer

  Here h = 1000 m and $\rho = 1.03 \times 10^3$ kg m^{-3}.

  (a) Absolute pressure$P = Pa + \rho gh$

  $= 1.01 \times 10^5$ Pa + 1.03×10^3 kg $m^{-3} \times 10$ m $s^{-2} \times 1000$ m

  $= 104.01 \times 10^5$ Pa $\approx 10^4$ atm

  (b) Gauge pressure is P − Pa = ρgh = Pg

  Pg = 1.03×10^3 kg $m^{-3} \times 10$ $ms^2 \times 1000$ m = $10^3 \times 10^5$ Pa ≈ 103 atm

  The pressure outside the submarine is P = Pa + ρgh and the pressure inside it is Pa. Hence, the net pressure acting on the window is gauge pressure, Pg = ρgh. Since the area of the window is A = 0.04 m^2, the force acting on it is

  F = Pg A = $10^3 \times 10^5$ Pa × 0.04 m^2 = 4.12×10^5 N

- What is the pressure on aswimmer 10 m below the surface of a lake?

  Answer

  Hereh = 10 m and ρ = 1000 kg m^{-3}. Take g = 10 m s^{-2}

  P = Pa + ρgh

  = 1.01 × 10^5 Pa + 1000 kg m^{-3} × 10 m s^{-2} × 10 m

  = 2.01 × 10^5 Pa

  ≈ 2 atm

- The density of theatmosphere at sea level is 1.29 kg/m3.Assume that it does not change withaltitude. Then how high would theatmosphere extend?

  Answer

  ρ*gh*= 1.29 kg m^{-3} × 9.8 m s^2 × *h* m = 1.01 × 10^5 Pa

  ∴*h* = 7989 m ≈ 8 km

  In reality the density of air decreases withheight. So does the value of *g*.