Short Answer Type Questions – II

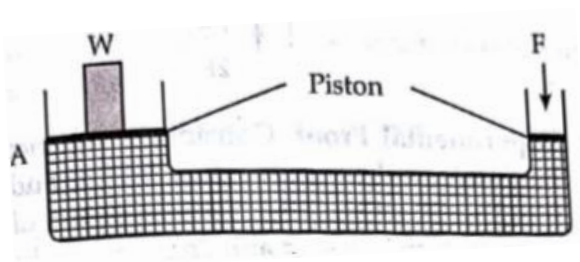
Q.1. Define Pascal law and give its practical applications.

Ans. Pascal's Law: It states that if gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same. Pascal's law also states that the increase in pressure at one point of the enclosed liquid in equilibrium of rest is transmitted equally to all other points of liquid provided the gravity effect is neglected.

Applications: This principle is used to manufacture hydraulic lift. It consists of two cylinders, one of larger area of cross-section A and the other smaller piston of cross-sectional area a. Force is applied to piston to produce a pressure,

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

As per Pascal's law same pressure is transmitted to larger piston. Then W = P × A.



Clearly large area A is producing more lifting force W.

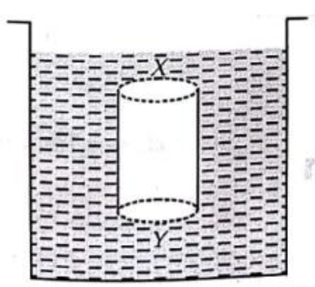
Hydraulic brakes are also based upon Pascal's law.

Q.2. What is column pressure? Derive a relation for the same.

Ans. Pressure exerted by a liquid due to its height is called column pressure.

Consider two points X and Y to be lying on the top and bottom circular faces of an imaginary cylinder of liquid. Let area of the circular faces by a each and height of the cylinder by h. If pressure exerted at point X is P_x and at Y is P_y, then

$$P_x = \frac{F_x}{a}$$



$F_x = P_x a$ acting downward Weight of this cylinder, W = mg = V$\rho g = ah\rho g$ is also acting downwards so total downward force = $F_x + W = P_x a + ah\rho g$

The lower face of the cylinder experiences upward force given by

$$F_y = P_y a.$$

In equilibrium, $F_y = F_x + W$

i.e., $P_y a = P_x a + ah\rho g$

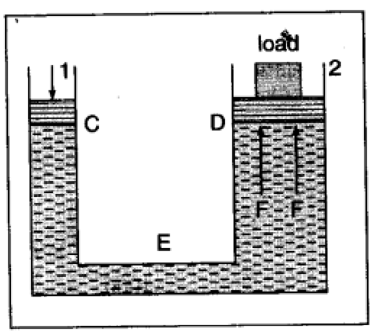
or $(P_x - P_y) = h\rho g$

or $P = h\rho g$

Q.3. State Pascal's law of transmission of fluid pressure. Explain how is Pascal's law applied in a hydraulic lift. (With suitable diagram).

Ans. Pascal law: If gravity effect is neglected the pressure at every point of liquid in equilibrium of rest is same.

Hydraulic lift It is used to lift the heavy loads. Its working is based on Pascal's law. A simple hydraulic lift is shown in Figure. Here C and D are two cylinders of different areas of cross section. They are connected to each other with a pipe E. Each cylinder is provided with airtight frictionless piston. Let a, and A be the areas of cross-sections of the pistons in C and D respectively, where a < < A. The cylinders are filled with an incompressible liquid.



Let a downward force f be applied on the piston of C. Then the pressure exerted on the liquid, of C. Then the pressure exerted on the liquid, P = F/a.

According to Pascal's law, this pressure is transmitted equally to piston of cylinder D will be

$$F' = PA = \frac{F}{a}A = F\frac{A}{a}.$$

Q.4. A razor blade can be made to float on water. What forces acts on this blade? Is Archimedes' principle applicable?

Ans. When a razor blade is made to float on water, three forces act on the blade:

(i) Weight of the blade acting vertically downwards.
(ii) Reaction on blade exerted by the liquid surface acting vertically upwards.
(iii) Force of the surface tension on circumference of the blade acting tangentially to the liquid surface. 1 In this case, as no portion of razor blade is immersed in water, hence Archimede's principle is not applicable.

Q.5. Two capillaries of same length and radii in the ratio 1 : 2 are connected in series. A liquid flows through them in a stream lined condition if the pressure across the two extreme ends of the combination is 1 m of water, find the pressure difference across first capillary.

Ans. Here, $\frac{\pi P_1 r^4}{8\eta l} = \frac{\pi P_1 (2r)^4}{8\eta l}$

i.e., $P_1 = 16P_2$

Given that $P_1 + P_2 = 1\,m$

$P_1 + \frac{P_1}{16} = 1$

or $P_1 = \frac{16}{17} = 0.94$ m

Q.6. Explain why small drops of mercury are spherical and large drops become flat?

Ans. In one case of a small drop of mercury one force of gravity is small and force of surface tension plays a vital role. Therefore, the free surface of drop tends to have minimum surface area for given volume the sphere has minimum area. Hence the small drops are of spherical shape.

In the case of large mercury drop, the gravitational pull becomes more effective than the surface tension and exerts downward pull on the drop so that its centre of gravity may lied at one lowest possible position. Hence, the large drop of mercury becomes elliptical or flat in shape.

Q.7. State and prove Bernoulli's principle for the flow of non-viscous fluids and give its limitations.

OR

A liquid is in stream lined flow through a tube of non-uniform cross-section the prove that sum of its kinetic energy, pressure energy and potential energy per unit volume is constant.

Ans. Statement: Bernoulli's theorem state that the total energy (pressure energy, P.E. and K.E.) of an incompressible non-viscous liquid in steady flow remain constant throughout the flow of the liquid P + $\rho g h + \frac{1}{2}\rho v^2$ = constant.

Proof: Consider an incompressible non-viscous liquid entering the cross-section A_1 at A with a velocity v_1 and coming out at a height h_2 at B with velocity v_2.

The P.E. and K.E. increase since h_2 and v_2 are more than h_1 and v_1 respectively. If P_1 and P_2 are the pressure at A and B and a small displacement at A and B,

The work done on the liquid

FA = $(P_1 A_1)$

F$\Delta x_1 = P_1 A_1 v_1 \Delta t$

The work done by liquid at B, F = -$(P_2 A_2)$

$F\Delta x_2 = -P_1 A_2 v_2 \Delta t$

(Considering a small time Δt so that area may be same.)

Net work done by pressure

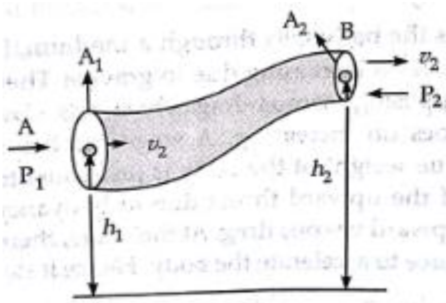
$= (P_1 - P_2) A v \Delta t$

$\therefore \quad A_1 v_1 = A_2 v_2$

From the conservation of energy,

$(P_1 - P_2) A v \Delta t =$ Change in (K.E. + P.E.)

$(P_1 - P_2) A v \Delta t = A v \rho \Delta t g (h_2 - h_1) + \frac{1}{2} A v \rho \Delta t g (v_2^2 - v_1^2)$



$(P_1 - P_2) = \rho g (h_2 - h_1) + \frac{\rho}{2}(v_2^2 - v_1^2)$

i.e., $P_1 + \rho g h_1 + \frac{\rho}{2} v_1^2 = P_2 + \rho h g_2 + \frac{\rho}{2} v_2^2$

i.e., $\frac{P}{\rho g} + h + \frac{v^2}{2g}$ = constant

Bernoulli’s Theorem Limitations:

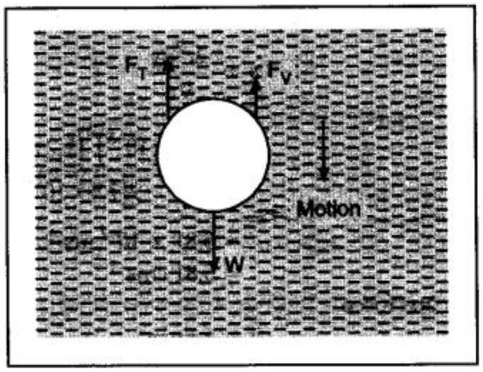
(a) While deriving Bernoulli’s theorem it is assumed that velocity of every particle of liquid across any cross section of tube is uniform. Practically it is incorrect.
(b) The viscous drag of the liquid which comes into play when liquid is in motion has not been taken into account.
(c) While deriving the equation, it is assumed that there is no loss of energy when liquid is in motion.

Q.8. By using Stokes law, derive an expression for terminal velocity. On what factors does it depend?

Ans. Terminal velocity: It is maximum constant velocity acquired by the body while falling freely in a viscous medium.

When a small spherical body falls freely through a viscous medium, three force act on it

(i) Weight of the body acting vertically downwards.
(ii) Upward thrust due to buoyancy equal to weight of liquid displaced.



Viscous drag acting in the direction opposite to the motion of body. According to Stoke's law, F $\propto v$, i.e., the opposing viscous drag goes on increasing with the increasing velocity of the body.

As the body falls through a medium, its velocity goes on increasing due to gravity. Therefore, the opposing viscous drag which acts upwards also goes on increasing. A stag reaches when the true weight of the body is just equal to the sum of the upward viscous drag. At this stage, there is no net force to accelerate the body. Hence it starts falling with a constant velocity, which is called terminal velocity.

Let ρ be the density of the material of the spherical body of radius r and ρ_0 be the density of the medium.

∴ The weight of the body,

$$W = \text{Volume} \times \text{Density} \times g$$

$$= \frac{4}{3}\pi r^3 \rho g$$

Upward thrust due to buoyancy,

$$F_T = \text{Weight of the medium displaced}$$

∴ $$F_T = \text{Volume of the medium displaced} \times \text{Density} \times g$$

$$= \frac{4}{3}\pi r^3 \rho_0 g$$

If v is the terminal velocity of the body, then according to Stoke's law, upward viscous drag,

$$F_v = 6\pi\eta r v$$

When body attains terminal velocity, then

$$F_T + F_v = W$$

$$\therefore \frac{4}{3}\pi r^3 \rho_0 g + 6\pi\eta r v = \frac{4}{3}\pi r^3 \rho g$$

or $$6\pi\eta r v = \frac{4}{3}\pi r^3 (\rho - \rho_0) g$$

or $$v = \frac{2r^2(\rho - \rho_0)g}{9\eta}$$

It depends upon the terminal velocity as it varies directly as the square of the radius of the body and inversely as the coefficient of viscosity of the medium. It also depends upon densities of the body and the medium.

Q.9. An air bubble of radius r rises steadily through a liquid of density ρ at the rate of v. Neglecting density of air, find the coefficient of viscosity of liquid.

Ans. Buoyant force = weight of liquid displaced

$$= \frac{4}{3}\pi r^3 \rho g$$

Viscous force = Stoke's drag force

$$= 6\pi\eta r v$$

$$6\pi\eta r v = \frac{4}{3}\pi r^3 \rho g$$

$$\eta = \frac{2}{9}\frac{r^2 \rho g}{v}$$