CHAPTER-10

MECHANICAL PROPERTIES OF FLUIDS

QUESTIONS

1 marks questions

1. What are fluids?
2. How are fluids different from solids?
3. Define thrust of a liquid.
4. Define liquid pressure.
5. Is pressure a scalar quantity?
6. Write the dimensions of pressure?
7 What is the SI unit of pressure?
8. What is the atmosphere pressure at sea level in Pascal?
9. The blood pressure in human is greater at the feet then at brain
   Why?
10. Write the dimensions of density?
11. What is the SI unit of density?
12. Is density scalar or vector quantity?
13. What is the density of water at 4^0c ?
14. Define relative density.
15. State Pascal's law.
16. What is gauge pressure?
17. Write the expression for pressure exerted by a fluid .
18. Define torr.
19. Write the relation between torr & Pascal.
20. Write the relation between bar & Pascal.
21. Name the devices they work on the basis of Pascal's law.
22. What is fluid dynamics?
23. Define streamline flow.
24. Define turbulent flow.

25. Write the equation of continuity.
26. State Bernoulli’s principle.
27. Write the Bernoulli’s equation.
28. What is venturimeter?
29. On what principle venturimeter works?
30. Define dynamic lift.
31. What is Magnus effect?
32. Why two streamlines cannot cross each other?
33. Define viscosity.
34. When viscosity comes to exist?
35. Define coefficient of viscosity.
36. What is the Si unit of viscosity?
37. Write the dimensions of viscosity.
38. How viscosity of liquid varies with temperature?
39. How viscosity of gases varies with temperature?
40. State Stokes law.
41. What is Reynolds’s number?
42. Define surface tension.
43. Define surface energy.
44. How surface tension depends on temperature?
45. Write the expression to Measure surface tension.
46. Define angle of contact.
47. When does liquid wets the surface of solid?
48. When does liquid not wets the surface of solid?
49. Why drops & bubbles are spherical in shape?
50. Mention the expression for capillary rise.
51. What happens to the surface tension of water when soup is added to it?

Two marks Questions

1. Give two differences between liquids & gases.
2. Distinguish between liquid thrust & pressure.
3. Name the SI unit of fluid pressure & write the dimensional formula.
4. How the pressure at a point in a liquid vary with

   a) Depth of the point b) density of the liquid
5. What is the difference between atmospheric pressure & gauge pressure?
6. Mention any two application of Pascal's law.
7. State & explain Archimedes principle.
8. What is a force of buoyancy? What is its effect?
9. Explain hydrostatic paradox.
10. Mention the types of flow of fluid.
11. Distinguish between stream line flow & turbulent flow.
12. State & explain equation of continuity.
13. What are the different types of energy possessed by a liquid in motion? Write their Expressions. (any two)
14. State & explain Bernoulli's theorem.
15. Write a note on uplift of an aircraft .
16. Explain the working of an atomizer.
17. Define co-efficient of viscosity & name its SI unit.
18. State & explain Stokes law.
19. Write Stokes formula & explain the terms.
20. Define surface tension & write its SI unit.
21. When does liquid wets the surface of solid? Give an example.
22. When does liquid do not wets the surface of solid? Give an example.
23. Write the expression for capillary rise of liquid & explain terms.
24. Explain formations of drops & bubbles.
25. Explain action of detergents.

4 MARKS QUESTIONS

1. Derive an expression for pressure inside a liquid.
2. Explain how Pascal's law is applied in a hydraulic lift?
3. a) State Stokes law.

   b) Show that terminal velocity of a sphere falling through a viscous medium is proportional to Square of its radius.
4. Explain Bernoulli's principle.
5. Explain Torricelli's law (speed of efflux).
6. Derive an expression to measure surface energy of a liquid.

5 marks questions

1. State Bernoulli's principle. explain the Bernoulli's equation for the flow of an ideal fluid in stream line motion. Mention any two applications.
2. Describe different types of flow of fluids. State and explain equation of continuity.

CHAPTER -10

MECHANICAL PROPERTIES OF FLUIDS

ANSWERS

1 Mark answers

1. The materials that can flow are called fluids.
2. Fluid has no definite shape of its own.
3. The total normal force exerted by a fluid on any surface in contact with it is called thrust of a liquid.
4. Liquid pressure is defined as the normal force acting per unit area.
5. Yes
6. $ML^{-1} T^{-2}$
7. Nm^{-2}
8. 1.013×10^5Pa
9. The height of blood column is large at the feet than at the brain as a result blood pressure is human is grater at the feet.
10. ML^{-3}
11. Kg m^{-3}
12. Scalar quantity.
13. 1.0×10^3 Kg m^{-3}
14. The relative density of a substance is the ratio of its density to the density of water at 4^0 C.
15. Whenever external pressure is applied on any part of a fluid contained in a vessel it is transmitted undiminished and equally in all directions.
16. The gauge pressure is the difference of the actual pressure & the atmospheric pressure.
17. $P = \rho gh$
18. A pressure equivalent of 1mm is called a torr.
19. 1 torr = 133Pa
20. 1 bar = 10^5Pa
21. Hydraulic lift, hydraulic brakes
22. The study of the fluids in motion is known as fluid dynamics.
23. The regular and orderly flow of a liquid is known as streamline flow.
24. The irregular & disorderly flow of a liquid is known as turbulent flow.
25. av = constant
26. The sum of the pressure, KE per unit volume & the potential energy per unit volume remains a constant.

27. P + $\frac{\rho v^2}{2}$ + ρgh = constant.
28. It is a device used to measure the flow speed of incompressible fluid.
29. Bernoulli's theorem.
30. Dynamic lift is the force that acts on a body by virtue of its motion through a fluid.
31. Dynamic lift due to spinning is called magnus effect.
32. It two streamlines cross each other than at the point of intersection the liquid should move simultaneously in two different direction this is not possible.
33. The property of a liquid by which it opposes the relative motion between its different layers is called viscosity. It is also called fluid friction.
34. When there is a relative motion between layers of the liquid.
35. It is defined as the ratio of shearing stress to the strain rate.
36. Nsm^{-2} or Pa S
37. $ML^{-1}T^{-1}$
38. Viscosity of liquid decreases with temperature.
39. Viscosity of gases increases with temperature.
40. The viscous force acting on an object moving in a fluid is directly proportional to the velocity of the object.
41. Reynold's number is a pure number which determine the type of flow of a liquid through a pipe.
42. Surface tension is defined as the tangential force per unit length acting normally on either side of an imaginary line drawn on the surface of a liquid.
43. The extra potential energy of the molecules in the surface of a liquid is called surface energy.
44. The surface tension of a liquid decreases with increases in temperature.
45. S=F/2l
46. The angle between the tangent to the liquid surface at the point of contact & the solid surface inside the liquid is called the angle of contact.
47. If angle of contact is acute ($\theta < 90^0$).
48. If angle of contact is obtuse ($\theta > 90^0$).
49. Because of surface tension.
50. h = $\frac{2T\cos\theta}{r\rho g}$
51. Surface tension decreases.

Two mark answers

1. a) A liquid has a definite size but not a definite shape A gas has neither a definite size nor a definite shape.

   b) A liquid is nearly incompressible. A gas is highly compressible.
2. Liquid thrust is the total normal force exerted by a fluid on walls of container where as pressure is fluid thrust per unit area.
3. SI unit is Nm^{-2} & Dimensions are $ML^{-1}T^{-2}$
4. A) directly proportional B) directly proportional
5. The pressure of the atmosphere at any point is known as atmosphere pressure & gauge pressure is the difference of the actual pressure & the atmospheric pressure.
6. Hydraulic brake, Hydraulic lift, Hydraulic press.
7. When a body is immersed completely or partially in a liquid the apparent loss of weight of the body is equal to the weight of the liquid displaced.
8. The resultant up thrust experienced by a body immersed completely or partially in a liquid is called buoyancy because of buoyancy weight of the body decreases.
9. The liquid pressure is the same at all points at the same horizontal level (same depth) the result is appreciated through the example of hydrostatic paradox when different shaped vessels are connected at the bottom by a horizontal pipe & on filling with water the level in the three vessels is the same through they hold different amounts of water.
10. Streamline flow & Turbulent flow.
11.

Streamline flow	Turbulent flow
1. It is a regular & orderly flow of liquid. 2. In Stream line flow velocity of all the liquid particles is the same at a given point. 3. The motion of liquid particles is parallel to each other. 4. Every liquid particles moves with a velocity less then the critical velocity.	1. It is irregular & disorderly flow of liquid. 2. In Turbulent flow the velocity of all the liquid particles is different at a given point. 3. The motion of liquid particle is not parallel to each other. 4. Every liquid particles moves with a velocity grater than the critical velocity.

12. It states that the product of area of cross section & the speed of a liquid remains the same at all points of a tube of flow.

    If 'a' is the area of cross section of the tube at a point & v is the velocity of liquid in that region then

    $v \propto \frac{1}{a}$ ∴ v a = constant

13.Potential energy = ρ gh. Kinetic energy = $\frac{1}{2}\rho v^2$ & pressure energy = $\frac{p}{\rho}$

14.Statement : Along the streamline of an ideal fluid the sum of the potential energy kinetic energy & pressure energy per unit mass remains constant.

i.e gh + $\frac{v^2}{2}$ + $\frac{p}{\rho}$ = constant

For a liquid having horizontal flow h is constant then

$\frac{p}{\rho}$ + $\frac{V^2}{2}$ = constant.

Thus the velocity of flow at any point increases the pressure at that point decreases & vice versa.

15. Bernoulli's principle that the pressure of any fluid decreases with increase in its velocity is used in designing air craft wings.

The shape of the wings of an air craft is such that the speed of the air above the aircraft is greater than the speed below the wings by Bernoulli's theorem it follows that the pressure below the wing is greater than that above. As a result an upward force is produced which lifts the air craft.

16. An atomizer works on Bernoulli's principle that the pressure of a fluid decreases with increases in its peed. It consists of a cylinder fitted with piston at one end & the other end terminates in a small constriction. The constriction is connected to a vessel through a narrow tube. The air in the cylinder is pushed using the piston. As the air passes though the constriction its speed is considerably increases & consequently pressure drops the liquid rises from the vessel & is sprayed with the expelled air.

17. Coefficient of viscosity is defined the ratio of shearing stress to the strain rate i.e

$\eta = \frac{F/A}{V/l} = \frac{Fl}{VA}$ SI unit is poiseiulle or NSm^{-2} or Pa.s

18. Statement : the viscous force acting on an object moving in a fluid is directly proportional to the velocity of the object.

Stoke's showed that the viscous force F acting on a body moving in a fluid is directly proportional to its terminal velocity v i.e $F \alpha v$ or F = Kv

Where K is the constant of proportionality.

19 . For a spherical solid object F = $6\pi\eta rv$

Where $6\pi \rightarrow$ constant

$\eta \rightarrow$ coefficient of viscosity of liquid column

r $\rightarrow$ radius of the spherical object

v $\rightarrow$ terminal velocity

20. Surface tension is defined as the tangential force per unit length acting normally on

either side of an imaginary line drawn on the surface of a liquid.

If F is the force acting on a length of an imaginary line drawn on the surface of a liquid then $F \alpha L$ or $F = TL$ $\therefore T = \frac{F}{L}$ SI unit is Nm^{-1}

21. If the angle of contact is acute ie $\theta < 90^0$ liquid wets surface Ex: water & glass.
22. If the angle of contact is obtuse ie $\theta > 90^0$ liquid do not wets the surface Ex: Mercury &glass
23. $h = \frac{2T\cos\theta}{r\rho g}$ $T \rightarrow$ surface tension of the liquid $r \rightarrow$ radius of capillary tube

    $\rho \rightarrow$ density of liquid $g \rightarrow$ acceleration due to gravity

    $\theta \rightarrow$ Angle of contact
24. a liquid surface has a tendancy to have minimum surface area due to the property of surface tension.for a given volume,the surface area is minimum for a sphere. This is why small drops of liquid and bubbles attain spherical shape
25. When detergent is added to water it decreases the surface tension of water.Therefore when a dirty cloth is dipped in soapwater,it penetrates in to the interior parts of cloth and removes the dirt,

4 mark answers

1. Consider a fluid at rest in a container as shown in the fig. the point 1 is at a height h above a point 2 & the pressures at point 1& 2 are P_1 & P_2 respectively consider a cylindrical element of fluid having area of base A & height h. As the fluid is at rest the resultant vertical forces should balances the weight of the element. The forces acing in the vertical direction are due to the fluid pressure at the top (P_1 A) ($\therefore P=\frac{F}{A}$) acting downward at the bottom (P_2 A) acting upward. If mg is weight of the fluid in the cylinder we have

$(P_2-P_1) A = F$ but $F = mg$

$\therefore (P_2 - P_1) A = mg$ ……….. (1)

If ρ is the density of the fluid then mass of fluid is $m = \rho V = \rho h A$ ($\therefore V= hA$)

$\therefore$ Equation (1) becomes

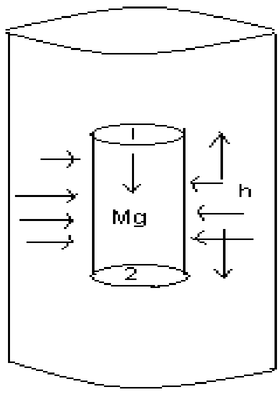
$(P_2-P_1) A = \rho h A g$

$\therefore P_2-P_1 = \rho g h$ ……… (2)

If point 1 is shifted to the top of the fluid which is open to the atmosphere then P1=Pa atmospheric pressure & replace P_2 by P then equation (2) becomes

$P - P_a = \rho gh$

Or $P = P_a + \rho gh$



2. For a confined static liquid pressure applied at any point in the liquid is transmitted equally & undiminished in all direction throughout the liquid.

   At piston P, the force F_1 acts over the area A_1

   $\therefore P_1 = \frac{F_1}{A_1}$

   At piston Q the force F_2 acts over area A_2 $\therefore P_2 = \frac{F_2}{A_2}$

   But according to Pascal's law the pressure P_1 is transmitted equally to piston Q

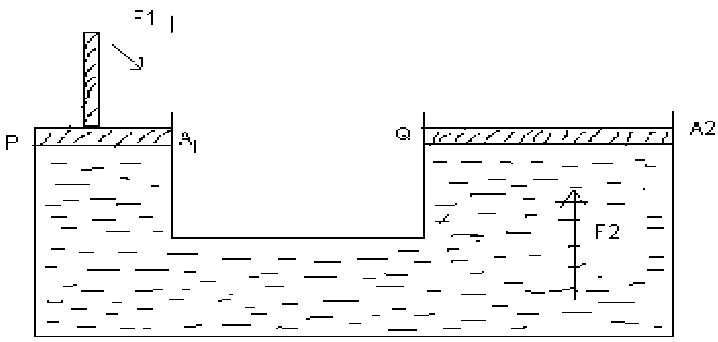
   $\therefore P_1 = P_2$

   $\therefore \frac{F_1}{A_1} = \frac{F_2}{A_2}$

   $F_2 = F_1 \left(\frac{A_2}{A_1}\right)$

   Since $A_2 > A_1$, $F_2 > F_1$

   Thus a small force applied on the smaller piston appears as a large force on the larges piston.



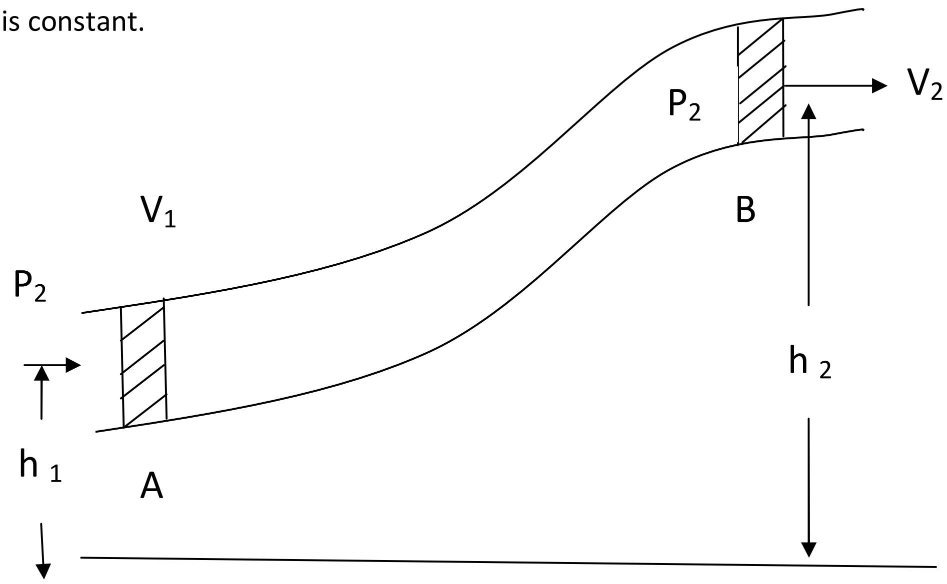
3. The viscous force acting on an object moving in a fluid is directly proportional to the velocity of the object.
   When a body falls through a fluid it drags the layer of the fluid in contact with it. A relative motion between the different layers of the fluid is set and as a result the body experiences a retarding force. Stokes an English scientist enunciated clearly the viscous drag force F as
   $F = 6\pi\eta av$
   When a body falls through a fluid, initially it accelerates due to gravity. As the velocity increases the retarding force also increases. Finally when viscous force & buoyant force becomes equal to force due to gravity the net force becomes zero & acceleration also zero. Then the body moves with constant velocity called terminal velocity Vt is given by $F = 6\pi\eta a v_t = \frac{4}{3}\pi a^3 (\rho - \sigma)\ g$.

   When ρ & σ are densities of sphere & the fluid respectively then.
   $Vt = \frac{2a^2(\rho-\sigma)g}{9\eta}$

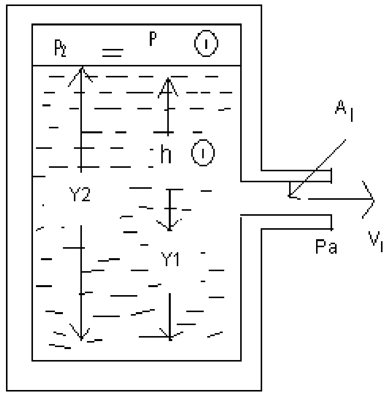
   ∴ the terminal velocity V_t is directly proportional to square of the radious of the sphere & inversely on the viscosity of the medium.

4. Bernoulli's theorem relates the speed of a fluid at a given point, the pressure at that point & the height of that point above a reference level. consider a liquid contained between cross sections A & B of the tube as shown in fig. The height of A & B are h_1 & h_2 respectively from a reference level.
   Let the pressure at A & B be P_1 & P_2. The velocities at A and B be V_1 and V_2 and the density of the liquid is ρ According to Bernoulli's theorem.
   $P_1 + \frac{1}{2}\rho V_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho V_2^2 + \rho g h_2$
   i.e $P + \frac{1}{2}\rho V^2 + \rho g h$ =constant.

   This is known as Bernoulli's equation. Thus for incompressible non viscous fluid in steady state flow, the sum of pressure energy, kinetic energy and potential energy per unit volume is constant.



5. The word efflux means fluid out flow. Torrecelli discovered that speed of efflux from an open tank is given by a formula identical to that of a freely falling body. Consider a tank containing a liquid of density ρ with a small hole in its side at a height Y_1 from the bottom. The air above the liquid is at height Y_2 is at a pressure P. From the equation of continuity we have



$V_1 A_1 = V_2 A_2$

$\therefore V_2 = \frac{A_1}{A_2} V_1$

$A_2 >> A_1, V_2 \approx 0$

i.e the fluid to be approximately at rest at the top.

Now applying Bernoulli's equation at points 1 and 2 & noting that at the whole $P_1 = P_a$, the atmospheric pressure we have

$P_a + \frac{1}{2} \rho V_1^2 + \rho g Y_1 = P + \rho g Y_2$

Take $Y_2 - Y_1 = h$ then

$V_1 = \sqrt{2gh + \frac{2(P-Pa)}{\rho}}$

If the tank is open to atmosphere than $P = P_a$

Then $V_1 = \sqrt{2gh}$

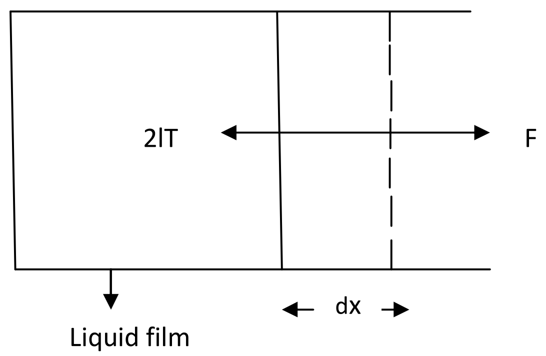
This is known as Torricelli's law

6. Consider a liquid film held by a U shaped wire and movable wire at one side. Let l be the length of the movable wire. Since the liquid film has two surfaces, the wire experiences a force 2lT. If the wire is moved to stretch the surface through a distance dx then
   Work done = force X displacement.

= 2lT X dx

This is equal to the energy gained by the surface, 2l dx is the increase in the surface area of the film.

Thus surface energy = T X surface area



5 mark answers

1. **Statement:** Along the stream line of an ideal fluid, the sum of the potential energy, kinetic energy & pressure energy per unit mass remains constant.
   Explanation: It is same as Q.No 4 (4 mark question)
   Application: Venturimeter, Atomisers and sprayers

2. There are to type of flow of fluids (1) stream line (2) Turbulent flow.
   In stream line flow velocity of all the liquid particles is the same at a given point & it is regular & orderly flow.
   In turbulent flow the velocity of all the liquid particles is different at a given point & it is irregular & disorderly flow of liquid.
   When a non viscous & in compressible liquid flow in streamline motion in a tube of non uniform cross section then the product of the area of cross section & velocity of liquid at any point remains constant.
   If 'a' is the area of cross section of the tube at a point & V be the velocity of liquid then $V \alpha \frac{1}{a}$ or Va = constant.
   This is known as the equation of continuity.
   Similarly let A_1 & A_2 be the areas of cross section at M & N respectively. Let V_1 & V_2 be the velocities in these sections then according to the equation of continuity $V_1A_1 = V_2A_2$