Class XI: Physics
Chapter 10: Mechanical Properties of Fluids

Key Learning:

1. Fluid has a property that is flow. The fluid does not have any resistance to change of its shape. The shape of a fluid governed by the shape of its container.
2. A liquid is incompressible and has a free surface of its own. A gas is compressible and it expands to occupy all the space available to it.
3. Liquids and gases together are known as fluids.
4. Pressure at a point is force upon area, and it is a scalar quantity. Unit of pressure is pascal. Its SI unit is N m^{-2}.
5. Average pressure P_{av} is defined as the ratio of the force to area

   $P_{av} = \frac{F}{A}$.

6. Pascal is the unit of the pressure. It is the same as N m^{-2}. Other common units of pressure are

   1 atm = 1.01 x 10^5 Pa

   1 bar = 10^5 Pa

   1 torr = 133 Pa = 0.133 kPa

   1 mm of Hg = 1 torr = 133 Pa

5. Pressure is defined as normal force per unit area.

$$P = \frac{dF_{\perp}}{dA}$$

6. The pressure difference between two points in a static fluid of uniform density r is proportional to the depth h.

7. Pascal's law states that a change in pressure at any point in an enclosed fluid at rest is transmitted undiminished to all points in the fluid.

8. Gauge pressure measures the excess pressure above the atmospheric pressure.

9. Flow of a fluid whose density is independent of both position and time is said to be incompressible.

10. If the frictional forces in a moving fluid are negligible, the flow is called non viscous.

11. If a fluid element has a nonzero angular velocity at every point, the flow is said to non-rotational.

12. Orderly flow of a fluid is called streamlined or steady flow.

13. In streamlined flow, every liquid element crossing a point has the same velocity.

14. Disorderly flow of fluid is called turbulent Flow.

15. A streamline is defined as a curve such that the tangent to any point on the curve gives the direction of fluid flow at that point.

16. Like in a steady or streamline flow, no two streamlines ever cross each other.

17. The greater is the spacing between streamlines in a region, the smaller is the fluid velocity there.

18. A bundle of streamlines forming a tubular region is called a tube of flow.

19. When the flow is incompressible, non-viscous, steady and non-rotational, it is called ideal fluid flow.

20. Equation of continuity says that the product of area of cross section and velocity remains constant through out the flow.

21. In case of varying density or compressible liquids, the equation of continuity modifies to product of the density, area of cross section and velocity of the flow remaining constant as opposed to Av =constant.

22. If the fluid velocity is less than a certain limiting value called critical velocity, the flow is steady or streamlined; as its speed exceeds the critical velocity it becomes turbulent.

23. Equation of continuity tells us that fluid speed is greater in narrow regions as compared to wider regions.

24. If the speed of a fluid element increases as it flows, the pressure of the fluid must decrease and vice versa – This is one implication of Bernoulli's Principle.

25. Bernoulli was the first one to relate this pressure difference to velocity changes.

26. Bernoulli also explained the relation between the height of a fluid and changes in pressure and speed of fluid.

27. Along a streamline, the sum of the pressure, the kinetic energy per unit volume and the potential energy per unit volume remains constant. This is the statement of Bernoulli's Principle.

28. Bernoulli's principle holds true in case of ideal fluid flow which is incompressible; irrotational and streamlined.

29. Bernoulli's principle, which results from conservation of energy, relates the height, pressure, and speed of an ideal fluid whether it is a liquid or a gas.

30. The speed of outflow of a liquid from a hole in an open tank is called the speed of efflux.

31. Velocity of fluid flowing out through end B as $v_B = \sqrt{2gh}$. This is called Torricelli's Law.

32. Venturimeter is the device used to measure the flow speed of an incompressible liquid.

33. As per Bernoulli's principle, the pressure above the wing is lower than the pressure below it because the air is moving faster above the wing. This higher pressure at the bottom compared to the top, applies an upward force to the wing to lift it upwards. This is called dynamic lift.

34. Magnus effect is the curving in the path of the ball introduced due to the difference in pressure above and below the ball.

35. The speed of efflux from a hole in an open tank is given by $\sqrt{2gh}$.

36. Ideal fluid is incompressible and nonviscous.

37. Viscosity describes a fluid's internal resistance to flow and may be thought of as a measure of fluid friction.

38. Viscous fluid flows fastest at the center of the cylindrical pipe and is at rest at the surface of the cylinder.

39. Viscosity is internal friction in a fluid.

40. Surface tension is due to molecular forces.

41. The difference in energy of the bulk molecules and the surface molecules gives rise to surface tension.

42. Drops have a spherical shape because spherical shape has the minimum surface area for a given volume of a free liquid.

43. Surface tension is also responsible for the wiggling of soap bubbles. Greater is the attractive force between molecules of a liquid, greater is its surface tension and greater is its resistance to the increase in surface area.

44. Surface tension can be quantitatively defined as the energy required per unit increase in surface area.

45. Angle of contact is the angle formed between the solid/liquid interface and the liquid/vapor interface and it has a vertex where the three interfaces meet.

46. When the contact angle is acute, the liquid wets the solid, like water on a glass surface.

47. When the contact angle is obtuse, the liquid does not wet the solid like water on these flower petals.

48. Angle of contact is a good measure of Cleanliness of a surface. Organic Contamination increases the angle of contact.

49. Surface tension of a liquid decreases with the rise in temperature because molecules get extra energy to overcome their mutual attraction.

50. Due to surface tension, the liquid surface squeezes itself to minimum surface area.

51. The greater is the surface tension of the liquid, greater is the excess pressure required for bubble formation inside it.

52. Capillary action is the tendency of a liquid to rise in narrow tubes due to surface tension,

53. Height of liquid column rising in a capillary tube depends upon:
- On its contact angle θ
- directly on its surface tension S
- Inversely on its density ρ
- Inversely on radius r of the tube

54. Addition of detergent in water lowers the surface tension which helps with the cleansing action.

Top Formulae:

1. Pressure of a fluid having density ρ at height h, $P = h\rho g$
2. Gauge pressure = total pressure – atmospheric pressure
3. For hydraulic lift

$$\frac{F_1}{a_1} = \frac{F_2}{a_2}$$

4. Surface tension, $S = F / \ell$
5. Work done = surface tension x increase in area
6. Excess of pressure inside the liquid drop $p = P_i - P_o = \frac{2S}{r}$
7. Excess of pressure inside the soap bubble $p = P_i - P_o = \frac{4S}{r}$
8. Total pressure in the air bubble at a depth h below the surface of liquid of density ρ is

$$P = P_o + h\rho g + \frac{2S}{r}$$

9. In case of capillary, ascent / descent formula, $h = \frac{2S\cos\theta}{r\rho g}$, where θ is the angle of contact.

10. Newton's viscous dragging force, $F = \eta A\frac{dv}{dx}$, where η is coefficient of viscosity, A is the area of layer of liquid and $\frac{dv}{dx}$ is the velocity gradient.

11. According to Poisseuille, the volume of the liquid flowing per second through the tube $V = \frac{\pi Pr^4}{8\eta\ell}$

12. Stoke's law, $F = 6\pi\eta rv$

13. Terminal velocity, $v = \frac{2r^2(\rho-\sigma)g}{9\eta}$, where ρ and σ are the densities of spherical body and medium respectively; r is the radius of spherical body.

14. Reynold's number, $R_N = \frac{\rho Dv}{\eta}$, where D is the diameter of the tube and v is the velocity of liquid flow through tube.

15. Volume of liquid flowing per second through a tube, V = a v, where a is the area of cross section and v is the velocity of liquid through tube.

16. Bernoulli's theorem:

Pressure energy per unit mass + potential energy per unit mass + kinetic energy per unit mass = constant

$$\frac{P}{\rho} + gh + \frac{1}{2}v^2 = constant$$

17. Venturimeter, volume of liquid flowing per second

$$V = a_1a_2\sqrt{\frac{2\rho_m gh}{\rho(a_1^2 - a_2^2)}}$$

Where a_1 and a_2 are the areas of cross-section of bigger and smaller tube; h is the difference of pressure head at two tubes of venturimeter.

18. Velocity of efflux, $v = \sqrt{2gh}$