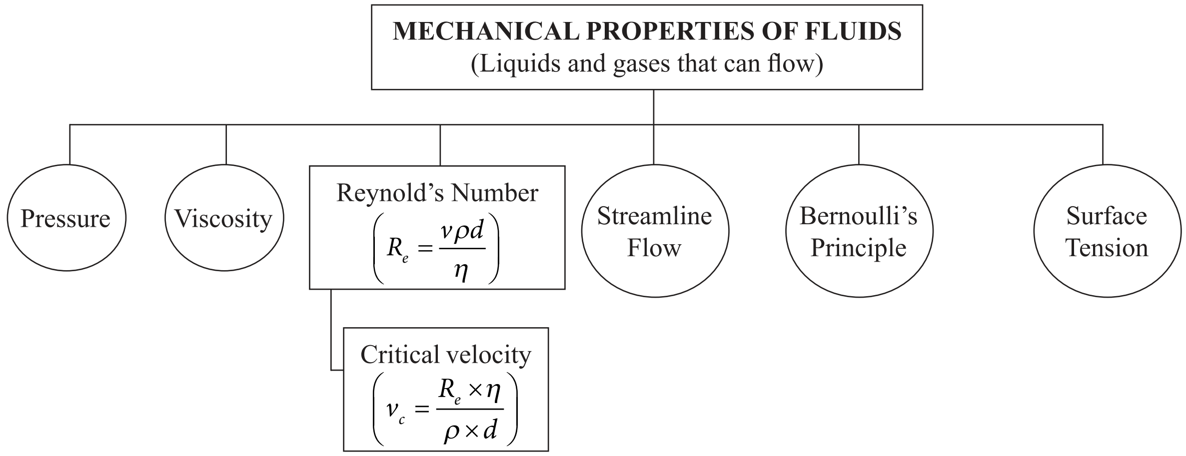
CHAPTER | 10 |

Mechanical Properties of Fluids

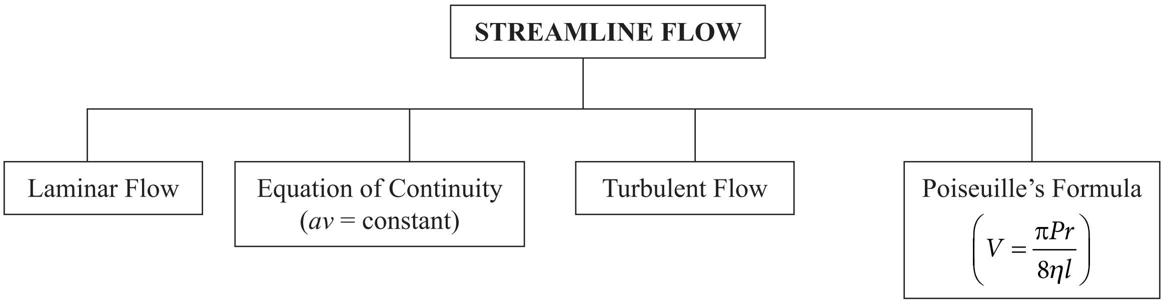
Syllabus

- **Pressure:** Pressure due to fluid column; Pascal's law and its applications; Buoyant force; Archimedes' principle.
- **Viscosity:** Details; Stokes' law; Terminal velocity.
- **Reynold's number:** Details; Critical velocity.
- **Stream line flow:** Details; Laminar flow; Equation of continuity; Turbulent flow; Poiseuille's formula.
- **Bernoulli's principle:** Details; Applications of Bernoulli's principle.
- **Surface tension:** Surface tension and surface energy; angle of contact; Applications of surface tension-drops and bubbles; Capillary rise.

MIND MAP



Mind Map 1: Mechanical Properties of Fluids



Mind Map 2: Streamline Flow at a Glance

PRESSURE

$\left(\text{Pressure } P = \dfrac{\text{thrust } (F)}{\text{area } (A)}\right)$

Pressure exerted by a liquid column of height h, density ρ, P

- Atmospheric Pressure
  [Pressure (atm) exerted by the atmosphere]
- Pressure Due to Fluid Column
  $(P = P_a + h\rho g)$
  (Where, P_a is atmospheric pressure)
- Pascal's Law and its Applications
  (Pressure exerted at any point on an enclosed liquid is transmitted equally in all directions)
- Buoyant Force
  (When a body is partially or fully dipped into a liquid, the liquid exerts force on the body)
- Archimedes' Principle
  (Loss in weight of a body in a liquid = Weight of liquid displaced = Volume × Density of liquid × g)
  (Apparent weight of solid in a liquid = True weight – Weight of liquid displaced)

Mind Map 3: Pressure at a Glance

VISCOSITY

$\left(F = \eta A \dfrac{dv}{dx}\right)$

- Coefficient of Viscosity
  $\left(\eta = \dfrac{F/A}{v/l} = \dfrac{Fl}{vA}\right)$
- Stoke's Law
  $(F = 6\pi\eta r v)$
- Terminal Velocity
  $\left(v_t = \dfrac{2}{9}\dfrac{r^2(\rho - \sigma)g}{\eta}\right)$

Mind Map 4: Viscosity at a Glance

BERNOULLI'S PRINCIPLE

$$P + \rho g h + \frac{1}{2}\rho v^2 = \text{constant}$$

- Torricelli's Law (Speed of efflux from the side of container)
  $$v_1 = \sqrt{2gh + \frac{2(P - P_a)}{\rho}}$$
- Applications of Bernoulli's Principle
  - Venturimeter: Device used to measure rate of flow of liquid, Volume of liquid flowing per second
    $$Q = Aa\sqrt{\frac{2gh}{A^2 - a^2}}$$
  - Blood flow and heart attack
  - Dynamic lift

Mind Map 5: Bernoulli's Principle at a Glance

SURFACE TENSION

$$\text{Surface tension} = \frac{\text{Force}}{\text{Length}} \text{ or } \sigma = \frac{F}{l}$$

- Surface Energy (Potential energy or work done per unit area of a surface)
- Angle of Contact (Angle between the surface of the solid and the tangent drawn to the surface of the liquid at the point of contact on the side of liquid)
- Applications of Surface Tension
  - Capillary rise
    $$h = \frac{2\sigma\cos\theta}{r\rho g}$$
  - Drops and bubbles
    - (Excess pressure inside a liquid drop)
      $$P = \frac{2\sigma}{R} = P_i - P_o \text{ (with one free surface)}$$
    - (Excess pressure inside a soap bubble)
      $$P = \frac{4\sigma}{R} = P_i - P_o \text{ (with two free surface)}$$
    - (Excess pressure in air bubble)
      $$P = \frac{2\sigma}{R} = P_i - P_o \text{ (with one free surface)}$$

Mind Map 6: Surface Tension at a Glance

RECAP

Pressure

- The normal force exerted by a liquid at rest on a given surface in contact with it is called **thrust** of liquid on that surface.
- The normal force (or thrust) exerted by liquid at rest per unit area of the surface in contact with it is called **pressure** of liquid or **hydrostatic pressure.**
- At a point, pressure acts in all directions and a definite direction is not associated with it, so pressure is a scalar quantity.

Atmospheric Pressure

- The gaseous envelope surrounding the Earth is called the Earth's atmosphere and the pressure exerted by the atmosphere is called atmospheric pressure.
- Its value on the surface of the Earth at sea level is nearly 1.013×10^5 Nm^{-2} or Pascal.
- Other practical units of pressure are atmosphere, bar and torr (mm of Hg).
- 1 atm = 1.01×10^5 Pa = 1.01 bar = 760 torr.
- The atmospheric pressure is maximum at the surface of the Earth and goes on decreasing as we move up into the Earth's atmosphere.
- **Absolute pressure** is zero-referenced against a perfect vacuum, using an absolute scale, so it is equal to gauge pressure plus atmospheric pressure.
- **Absolute pressure (P) = Gauge pressure (P_g) + Atmospheric pressure (P_a)**
- **Gauge pressure** is zero-referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure. Negative signs are usually omitted. To distinguish a negative pressure, the value may be appended with the word "vacuum" or the gauge may be labelled a "vacuum gauge".

Pressure Due to Fluid Column

- If P_1 and P_2 are pressures of liquid of density ρ at points C and D respectively then, F_1 and F_2 are forces acting vertically downwards and upwards respectively.
- At equilibrium, net force on liquid is zero.

$$\therefore \quad F_1 + Mg - F_2 = 0$$

$$\Rightarrow P_1A + Ah\rho g - P_2A = 0 \quad ...(M = Ah\rho)$$

$$P_2 - P_1 = h\rho g$$

$$\text{For } h = 0,\ P_1 = P_2$$

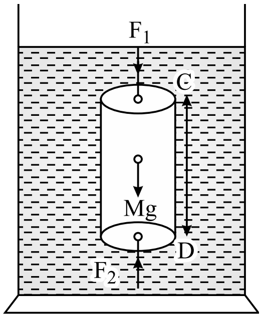


Figure: Pressure due to fluid column

- The pressure for all points in the liquid lying at same depth in horizontal plane is same.
- If point C is at liquid surface, then total pressure at point D is,

$$P = P_a + h\rho g$$

Where, P_a is atmospheric pressure.

- Thus, 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.
- The pressure exerted by liquid column depends on height and density of liquid column.
- The liquid pressure at a point is independent of quantity of liquid and depends upon the depth of point below the liquid surface. This is known as **Hydrostatic paradox.**

Pascal's Law and its Applications

- If gravity effect is neglected, the pressure at every point of liquid in equilibrium of rest is same.
- This law accounts for the principle of transmission of pressure in liquids or gases.
- Pascal's law 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 the liquid and also to the walls of the container, provided the effect of gravity is neglected.
  - Hydraulic lift:
  - Hydraulic lift is used to lift or support heavy objects such as cars, trucks, etc.
  - In hydraulic lift, a small force pushes down a smaller piston; this small force produces greater thrust on larger piston and raises the load placed on it.
  - For example as shown in above figure two pistons are separated by the space filled with a liquid. A piston of small cross-section A_1 is used to exert a force F_1 directly on the liquid. The pressure $P = \frac{F_1}{A_1}$ is transmitted throughout the liquid to the larger cylinder attached with a larger piston of area A_2, which results in an upward force of $P \times A_2$.

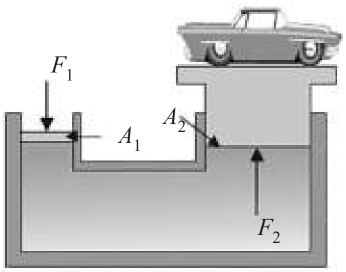


Figure: Schematic diagram illustrating the principle behind the hydraulic lift, a device used to lift heavy loads

- Since pressure is transmitted undiminished throughout the fluid,

$$\therefore \quad P_a + \frac{F_1}{A_1} = P_a + \frac{F_2}{A_2}$$

$$\Rightarrow \quad \frac{F_1}{A_1} = \frac{F_2}{A_2}$$

- **Hydraulic brakes:**
  - Small force applied to brake pedal is immediately transmitted equally by the brake; fluid in the cylinders produces a large thrust on the wheels and vehicle stops.

Buoyant Force

- When a body is partially or fully dipped into a liquid, the liquid exerts force on the body. The upward force exerted by a liquid on a solid immersed in it is called buoyant force or up thrust.
- Buoyant force is a result of pressure of the liquid in which the solid is immersed. Hence, it is not uniform but increases with depth of liquid.
- Buoyant force depends upon:
  - Volume of object:
    - The buoyant force is greater if the volume of object submerged in liquid is larger.
  - Density of liquid:
    - The buoyant force is greater if density of liquid is greater-

Archimedes' Principle

- When a body is immersed fully or partly in a liquid at rest, it looses some of its weight. The loss in weight of the body in the liquid is equal to the weight of the liquid displaced by the immersed part of the body.
- Loss in weight of a body in a liquid = Weight of liquid displaced = Volume × Density of liquid × g
- Apparent weight of solid in a liquid = True weight − Weight of liquid displaced

$$= m_S g - V_S \rho_L g = m_S g - \frac{m_S}{\rho_S} \rho_L g = m_S g \left(1 - \frac{\rho_L}{\rho_S}\right)$$

Where S and L have usual meaning for solid and liquid respectively, ρ is density.
- **Relative density** of a substance is defined as the ratio of its density to the density of water at 4° C.

Viscosity

- Viscosity is the property of a fluid (liquid or gas) by virtue of which it opposes the relative motion between its different layers. With increase in pressure, the viscosity of liquid (except water) increases while that of gases is practically independent of pressure.
- The viscosity of liquids decreases with temperature, while it increases in the case of gases.
- For a viscous liquid, viscous force acting on any layer is directly proportional to the product of area of layer and velocity gradient.
- According to Newton, viscous force (F) of a liquid between two layers is given by

$$F = \eta A \frac{dv}{dx}$$

Where, η = coefficient of viscosity of liquid, A = area of each layer, dv/dx = velocity gradient.

Coefficient of Viscosity

- The coefficient of viscosity for a fluid is defined as the ratio of shearing stress to the strain rate.

$$\eta = \frac{F/A}{v/l} = \frac{Fl}{vA}$$

- The dimensional formula of η is $[ML^{-1}T^{-1}]$.
- The SI unit of η is Poiseuille (PI) or Pa s or Nm^{-2} s.
- The CGS unit of η is dyne cm^{-2} s called poise.
- 1 PI = 10 poise
- Blood is thicker (more viscous) than water. Further, the relative viscosity (η/η_{water}) of blood remains constant between 0° C and 37° C.

Stoke's Law

- The viscous force acting on a small sphere falling through a medium is directly proportional to the radius (r) of the sphere, its velocity (v) through fluid and coefficient of viscosity (η) of the fluid.

$$F = 6\pi\eta rv$$

Terminal Velocity

- The constant maximum velocity acquired by a body while falling through viscous fluid is called terminal velocity.

$$v_t = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$$

where, r is radius of the body and ρ its density, σ is density of fluid and η is its coefficient of viscosity.

Reynold's Number

- Reynold's number is a pure number which diameter the type of flow or nature of flow of liquid through a pipe.

$$R_e = \frac{v\rho d}{\eta}$$

Where ρ is the density of the fluid flowing with a speed v, d stands for the diameter of the pipe, and η is the viscosity of the fluid. R_e is a dimensionless number, and therefore, it remains the same in any system of units.
- If the value of Reynolds number lies between zero and 2000, the flow of liquid is streamlined or laminar. For values of above 3000, the flow of liquid is turbulent and for values of between 2000 and 3000, the flow of liquid is unstable changing from streamline to turbulent.

Critical Velocity

- The maximum velocity of a fluid in a tube for which the flow remains streamlined is called its critical velocity.

$$v_c = \frac{R_e \times \eta}{\rho \times d}$$

Streamline Flow

- Streamline flow of liquid is the flow in which each element of the liquid passing through a point travels along the same path and with the same velocity as the preceding element passing through that point.

Laminar Flow

- It is that steady flow in which the liquid moves in the form of layers. In this flow, one layer slides over the other layer of liquid. The velocity of liquid flow is always less than the critical velocity of the liquid. In general, laminar flow is a streamline flow.

Equation of Continuity

- For a non-viscous liquid in streamline flow passing through a tube of varying cross-section,

av = constant or

$$a \propto \frac{1}{v}$$

where a = area of cross-section of tube, v = velocity of flow

Turbulent Flow

- When a liquid moves with a velocity greater than its critical velocity, then the motion of the particles of liquid becomes disordered or irregular. Such a flow is called as a turbulent flow.

Poiseuille's Formula

- Rate of flow of liquid through a horizontal capillary tube, i.e., volume of the liquid flowing per second is V and it is given by

$$V = \frac{\pi Pr}{8\eta l}$$

where $\frac{\pi}{8}$ is proportionality constant, P is pressure difference, r is radius of tube, l is length of tube, η is coefficient of viscosity.

Bernoulli's Principle

R The total energy (pressure energy, potential energy and kinetic energy) per unit volume or mass of an incompressible and non-viscous fluid in steady flow through a pipe remains constant throughout the flow, provided there is no source or sink of the fluid along the length of the pipe.

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

or, $$\frac{P}{\rho g} + h + \frac{v^2}{2g} = \text{constant}$$

$\frac{P}{\rho g}$ is called pressure head, h is called gravitational head and $\frac{v^2}{2g}$ is called velocity head.

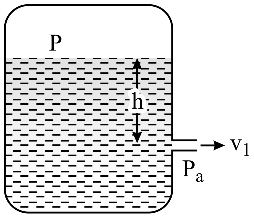


Figure : The speed of efflux, v1, from the side of the container is given by the application of Bernoulli's equation

- Torricelli's Law
  - Torricelli gave the formula for speed of efflux using Bernoulli's equation.
  - The speed of efflux from the side of the container is,

$$v_1 = \sqrt{2gh + \frac{2(P - P_a)}{\rho}}$$

  - Where, h is height of hole from surface of the liquid, P is the air pressure above the surface of the liquid. P_a is atmospheric pressure, and ρ is the density of liquid.
  - For an open tank, $P = P_a$

$v_1 = \sqrt{2gh}$ ...is the torricelli's Law

Applications of Bernoulli's Principle

- **Venturimeter:**
  - The Venturimeter is a device to measure the flow speed of incompressible fluid. It consists of a tube with a broad diameter and a small constriction at the middle. A manometer in the form of a U-tube is also attached to it, with one arm at the broad neck point of the tube and the other at constriction.

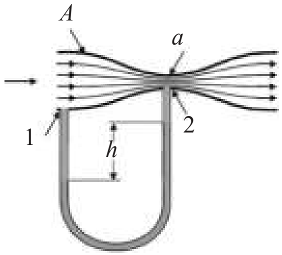


Figure: A schematic diagram of Venturimeter.

  - The manometer contains a liquid of density ρ_m. The speed v_1 of the liquid flowing through the tube at the broad neck area A is to be measured from equation of continuity.

$$v_1 = \sqrt{\left(\frac{2\rho_m gh}{\rho}\right)}\left(\left(\frac{A}{a}\right)^2 - 1\right)^{-\frac{1}{2}}$$

ρ = Density of liquid flowing through the pipe
a = Area of cross-section of smaller tube
A = Area of cross-section of bigger tube
h = Difference in the height of the liquid in two arms of U tube

  - Volume of a liquid flowing out per second through a Venturimeter

$$Q = Aa\sqrt{\frac{2gh}{A^2 - a^2}}$$

Where, A and a are the area of cross-section of bigger and smaller tubes respectively.

- **Blood flow and heart attack:**
  - Bernoulli's principle helps in explaining blood flow in artery. The artery may get constricted due to the accumulation of plaque on its inner walls.
- **Dynamic lift:**
  - Dynamic lift is the force that acts on a body, such as aeroplane wing, a hydrofoil or a spinning ball, by virtue of its motion through a fluid.
  - **Lift on air craft wing:**
  - When the aeroplane runs, air passes at higher speed above the wings than below the wings. Thus, pressure difference is created and upward force called dynamic lift acts on the plane. If this is greater than the weight of the plane, the plane will rise up.

- **Ball moving with spin:**
- A ball which is spinning drags air along with it. If the surface is rough more air will be dragged.
- The difference in the velocities of air results in the pressure difference between the lower and upper faces and there is a net upward force on the ball. This dynamic lift due to spinning is called Magnus effect.

Surface Tension

- **Surface tension** is a force per unit length (or surface energy per unit area) acting in the plane of the interface between the plane of the liquid and any other substance. It is also the extra energy that the molecules at the interface have as compared to molecules in the interior.

$$\text{Surface tension} = \frac{\text{Force}}{\text{Length}} \text{ or } \sigma = \frac{F}{l}$$

Surface Energy

- The potential energy or work done per unit area of a surface is called as surface energy.
- Increase in surface energy or work done,
  W = Surface tension × increase in area of the liquid surface
  - **Free surface energy density:**
    - It is defined as the amount of work done against the force of surface tension in increasing the unit area of the liquid surface without any change in temperature.
    - Surface energy density = Work done/area = Surface tension

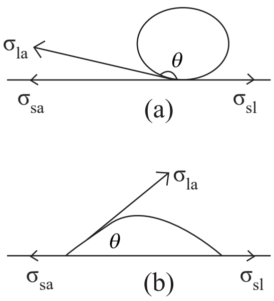


Figure: Different shapes of water drops with interfacial tensions on a (a) lotus leaf (b) clean plastic plate

Angle of Contact

- The angle between the surface of the solid and the tangent drawn to the surface of the liquid at the point of contact on the side of liquid is called the angle of contact of that liquid with that solid. It lies between 0 to 180°. It is denoted by θ.
- The value of θ determines whether a liquid will spread on the surface of a solid or it will form droplets on it. For example, water forms droplets on lotus leaf they while spreads over a clean plastic plate.
- We consider the three interfacial tensions at all the three interfaces, liquid-air, solid-air and solid-liquid denoted by σ_{la}, σ_{sa}, and σ_{sl}, respectively. At the line of contact, the surface forces between the three media must be in equilibrium.
  $$\sigma_{la} \cos\theta + \sigma_{sl} = \sigma_{sa}$$
- The angle of contact is an obtuse angle if $\sigma_{sl} > \sigma_{la}$ as in the case of water-leaf interface while it is an acute angle if $\sigma_{sl} < \sigma_{la}$ as in the case of water-plastic interface.

Applications of Surface Tension

- The spiders and insects move and run on the surface of water without sinking due to surface tension.
- Mosquitoes are killed when kerosene is sprayed on water surface in tanks or ponds.
- Dirty clothes become clean in hot detergent solution.
- It is difficult to separate two glass plates between which water film is enclosed.
- Surface tension of all lubricating oils and paints is kept low so that they spread over a large area.
- Oil spreads over the surface of water because the surface tension of oil is less than the surface tension of cold water.
  - Drops and bubbles:
    - Excess pressure inside a liquid drop
      $$P = \frac{2\sigma}{R} = P_i - P_o \text{ (with one free surface)}$$
    - Excess pressure inside a soap bubble
      $$P = \frac{4\sigma}{R} = P_i - P_o \text{ (with two free surface)}$$
    - Excess pressure in air bubble
      $$P = \frac{2\sigma}{R} = P_i - P_o \text{(with one free surface)}$$

    Where symbols have their usual meanings, i-inner, o-outer.

- When an air bubble of radius r is at depth h below the free surface of liquid of density ρ and surface tension σ, then the excess pressure inside the bubble,

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

- If r_1 and r_2 are the radii of curved liquid surface, then excess pressure inside the liquid surface is given by

$$P = \sigma\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

- When two soap bubbles of radii r_1 and r_2 coalesce to form a new soap bubble of radius r, under isothermal conditions then

$$r = \sqrt{r_1^2 + r_2^2}$$

- When two soap bubbles of radii r_1 and r_2 $(r_1 < r_2)$ are in contact with each other and r is the radius of the interface, then

$$r = \frac{r_1 r_2}{r_2 - r_1}$$

Capillary Rise

- One consequence of the pressure difference across a curved liquid-air interface is the well-known effect that liquid rises up in a narrow tube inspite of gravity.

$$h = \frac{2\sigma\cos\theta}{r\rho g}$$

- where θ is the angle of contact, σ is the surface tension of the liquid, ρ is the density of liquid, r is the radius of capillary tube, g is the acceleration due to gravity, and h is called the capillary rise.

PRACTICE TIME

Pressure

1. One of the units earlier used for expressing pressure was called bar. 1 bar is equivalent to:
(a) 10^4 Pa (b) 10^5 Pa
(c) 10^6 Pa (d) 10^3 Pa

2. Air is blown through a hole on a closed pipe containing liquid. Then the pressure will:
(a) increase on sides
(b) increase downwards
(c) increase in all directions
(d) never increase

3. Sudden fall of pressure at a place indicates:
(a) storm (b) rain
(c) hot wave (d) snowfall

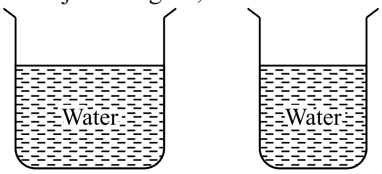
4. Why is the dam of water reservoir thick at the bottom?
(a) Quantity of water increases with depth.
(b) Density of water increases with depth.
(c) Pressure of water increases with depth.
(d) Pressure of water decreases with depth.

5. The pressure at the bottom of tank containing a liquid does not depend on:
(a) acceleration due to gravity
(b) height of the liquid column
(c) area of the bottom surface
(d) density of the liquid

6. Pressure applied to an enclosed fluid is transmitted undiminished to every point of the fluid and the walls of containing vessel. This law was first formulated by:
(a) Reynolds (b) Bernoulli
(c) Pascal (d) Torricelli

7. Pressure is a scalar quantity because
(a) it is the ratio of the component of the force normal to the area.
(b) it is the ratio of force to area and both force and area are vectors.
(c) it depends on the size of the area chosen.
(d) it is the ratio of the magnitude of the force to area.

8. From the adjacent figure, the correct observation is



(a) (b)

(a) the pressure on the bottom of tank (a) is greater than at the bottom of (b).
(b) the pressure on the bottom of the tank (a) is smaller than at the bottom of (b).
(c) the pressure depends on the shape of the container
(d) the pressure on the bottom of (a) and(b) is the same

9. Three liquids of equal masses are taken in three identical cubical vessels A, B, and C. Their densities are ρ_A, ρ_B, and ρ_C respectively. But $\rho_A < \rho_B < \rho_C$. The force of the cubical vessel is
(a) maximum in vessel A.
(b) the same in all the vessels.
(c) minimum in vessel C.
(d) maximum in vessel C.

10. Hydraulic press is based on:
(a) Archimedes' principle

(b) Bernoulli's equation
(c) Pascal's law
(d) Reynold's law

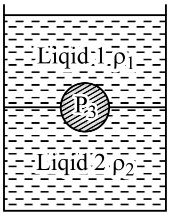
11. Which of the following works on Pascal's law?
(a) Aneroid barometer (b) Hydraulic lift
(c) Venturimeter (d) Sprayer

12. The two femurs each of cross-sectional area 10 cm^2 support the upper part of a human body of mass 50 kg. The average pressure sustained by the femurs is: (Take $g = 10\ ms^{-2}$)
(a) $2.5\times10^3\ Nm^{-2}$ (b) $5\times10^3\ Nm^{-2}$
(c) $1\times10^3\ Nm^{-2}$ (d) $2\times10^3\ Nm^{-2}$

13. A 45 kg woman wearing heel shoes balances on a single heel. The heel is circular with a diameter 1 cm. The pressure exerted by the heel on the horizontal floor is: (Take $g = 10\ ms^{-2}$)
(a) 6.4×10^4 Pa (b) 5.7×10^6 Pa
(c) 5.6×10^6 Pa (d) 6.8×10^4 Pa

14. Pressure applied to enclosed fluid is:
(a) Increased and applied to every part of the fluid
(b) Diminished and transmitted to wall of container
(c) Increased in proportion to the mass of the fluid and then transmitted
(d) Transmitted unchanged to every portion of the fluid and wall of containing vessel

15. A jar is filled with two non-mixing liquids 1 and 2 having densities ρ_1 and ρ_2 respectively. A solid ball, made of a material of density ρ_3 is dropped in the jar. It comes to:



(a) $\rho_3 < \rho_1 < \rho_2$ (b) $\rho_1 > \rho_3 > \rho_2$
(c) $\rho_3 > \rho_1 > \rho_2$ (d) $\rho_2 > \rho_3 > \rho_1$

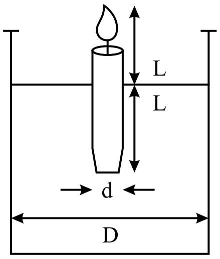
16. The height of water at two identical dams is the same, but dam A holds back a lake containing 2 cubic kilometres of water while dam B holds back a lake containing 4 cubic kilometres of water. The ratio of the total force exerted on dam A to that exerted on dam B is:
(a) 2 (b) 4
(c) 1 (d) $\frac{1}{2}$

17. A small cylinder of 2 cm diameter is connected to a large cylinder of 20 cm diameter and incompressible fluid is filled in the cylinders. If a force of 60 N is applied to the piston of the small cylinder, then the force exerted on the piston of the large cylinder will:
(a) 600 N (b) 1200 N
(c) 6000 N (d) 12000 N

18. Two vessels have different base area. They are filled with water to the same height. If the amount of water in one be 6 times that in the other, then the ratio of pressures on their bottoms will be:
(a) 1:1 (b) 4:1
(c) 8:1 (d) 16:1

19. To what height should a cylindrical vessel be filled with a homogeneous liquid to make the force with which the liquid pressure on the sides of the vessel equal to the force exerted by the liquid on the bottom of the vessel?
(a) Four times of radius
(b) Less than radius
(c) Equal to the radius
(d) More than radius

20. A candle of diameter d is floating on a liquid in a cylindrical container of diameter *D* (*D* >> *d*) as shown in figure. If it is burning at the rate of 2 cm/hr then the top of the candle will:



(a) remain at the same height
(b) fall at the rate of 1 cm/hr
(c) fall at the rate of 2 cm/hr
(d) go up at the rate of 1 cm/hr

21. Specific gravity of a body is numerically equal to:
(a) weight of the body in air
(b) weight of the body in water
(c) relative density of the body
(d) density of body in water

22. Consider an iceberg floating in sea water. The density of seawater is 1.03 g/cc and that of ice is 0.92 g/cc. The fraction of total volume of iceberg above the level of sea water is nearby:
(a) 11.8% (b) 13%
(c) 11% (d) 12%

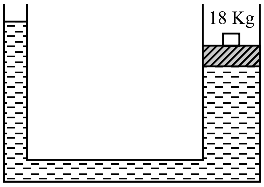
23. A block of ice floats on a liquid of density 1.2 in a beaker then level of liquid when ice completely melt:
(a) remains same (b) rises
(c) lowers (d) Either (b) or (c)

24. The force acting on a window of area 40 cm × 40 cm of a submarine at a depth of 2000 m in an ocean, the interior of which is maintained at sea level atmospheric pressure is: (Density of sea water = $10^3\ kgm^{-3}$, $g = 10\ ms^{-2}$)

(a) 5×10^3 N (b) 4×10^6 N

(c) 4.2×10^6 N (d) 3.2×10^6 N

25. The area of cross-section of the wider tube is shown in figure below is 1200 cm^2. If a mass of 18 kg is placed on the mass less piston, what is the difference in the level of water in two tubes?



(a) 15 cm (b) 18 cm

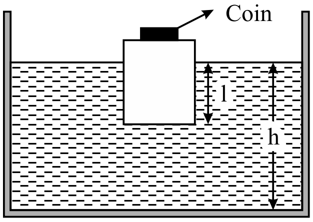
(c) 14.2 cm (d) 12 cm

26. A boy can reduce the pressure in his lungs to 750 mm of mercury. Using a straw he can drink water from a glass up to the maximum depth of (atmospheric pressure = 760 mm of mercury; density of mercury = 13.6 gcm^{-3})

(a) 13.6 cm (b) 9.8 cm

(c) 10 cm (d) 76 cm

27. A wooden block, with a coin placed on its top, floats in water as shown in fig. the distance l and h are shown there. After some time the coin falls into the water. Then:



(a) l decreases and h increases

(b) l increases and h decreases

(c) both l and h increases

(d) both l and h decreases

28. A sphere of solid material of specific gravity 8 has a concentric spherical cavity and just sinks in water. The ratio of radius of cavity to that of outer radius of the sphere must be:

(a) $\frac{7^{1/3}}{2}$ (b) $\frac{5^{1/3}}{2}$

(c) $\frac{9^{1/3}}{2}$ (d) $\frac{3^{1/3}}{2}$

Viscosity

29. With increase in temperature the viscosity of:

(a) liquids increases and of gases decreases

(b) liquids decreases and of gases increases

(c) both liquids and gases increases

(d) both liquids and gases decreases

30. Spherical balls of radius R are falling in a viscous fluid of velocity v. The retarding viscous force acting on the spherical ball is:

(a) directly proportional to R^2 but inversely proportional to v

(b) directly proportional to both radius R and velocity v

(c) inversely proportional to both radius R and velocity v^3

(d) inversely proportional to R but directly proportional to velocity v

31. After terminal velocity is reached, the acceleration of a body falling through a fluid is:

(a) equal to g (b) zero

(c) less than g (d) greater than g

32. A boat with base area 8 m^2 floating on the surface of a still river is intended to move with a constant speed of 2 ms^{-1} by the application of a horizontal force. If the river bed is 2 m deep find the force needed, (assuming a constant velocity gradient) coefficient of viscosity of water is 0.90×10^{-2} poise.

(a) 720 dyne (b) 620 dyne

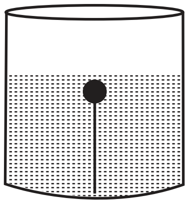
(c) 520 dyne (d) 360 dyne

33. A spherical solid ball of volume V is made of a material of density ρ_1. It is falling through a liquid of density ρ_2 ($\rho_2 < \rho_1$). Assume that the liquid applies a viscous force on the ball that is proportional to the square of its speed v, i.e., $F_{viscous} = -kv^2$ ($k > 0$). The terminal speed of the ball is:

(a) $\sqrt{\frac{Vg(\rho_1-\rho_2)}{k}}$ (b) $\frac{Vg\rho_1}{k}$

(c) $\sqrt{\frac{Vg\rho_1}{k}}$ (d) $\frac{Vg(\rho_1+\rho_2)}{k}$

34. A solid sphere of density ρ ($\rho > 1$) times lighter than water is suspended in a water tank by a string tied to its base as shown in figure. If the mass of the sphere is m, then the tension in the string is given by:



(a) $\left(\frac{\rho_w}{\rho}-1\right)mg$ (b) ρmg

(c) $\frac{mg}{\rho_w-1}$ (d) $(\rho-1)mg$

35. When cooking oil is heated in a frying pan, the oil moves around in the pan more easily when it is hot. The main reason for this is that with rise in temperature, there is a decrease in:

(a) relative density (b) surface tension

(c) angle of contact (d) viscosity

36. The velocity of water in river is 36 kmh^{-1} near the surface. If the river is 10 m deep, then the Shearing stress between the surface layer and the bottom layer is:(Coefficient of viscosity of water, $\eta = 10^{-3}$ Pas)

(a) 10^{-2} Nm^{-2} (b) 10^{-4} Nm^{-2}

(c) 10^{-6} Nm^{-2} (d) 10^{-3} Nm^{-2}

37. A square plate 0.15 m side moves parallel to second plate with a velocity of 0.1 ms^{-1} both plates being immersed in water. If the viscous force is 0.0025 N and the coefficient of viscosity 0.001 poise, distance between the plates is:

(a) 0.0015 m (b) 0.0005 m
(c) 0.0009 m (d) 0.05 m

38. A rain drop of radius 0.4 mm falls through air with a terminal velocity of 1 ms^{-1}. The viscosity of air is 18×10^{-5} poise. The viscous force on the rain drop is:

(a) 1.018×10^{-2} dyne (b) 1.357×10^{-2} dyne

(c) 1.357×10^{-3} dyne (d) 2.357×10^{-2} dyne

39. A solid sphere falls with a terminal velocity v in air. If it is allowed to fall in vacuum:

(a) terminal velocity of sphere = v
(b) terminal velocity of sphere < v
(c) terminal velocity of sphere > v
(d) sphere never attains terminal velocity

40. A good lubricant should have:

(a) moderate viscosity
(b) low viscosity
(c) high viscosity
(d) Data is insufficient

41. The viscous force acting on a small spherical rain drop falling through stormy air cannot be calculated using Stoke's law because:

(a) the medium through which the rain drop is falling is not liquid.
(b) the dimensions of rain drop is negligible.
(c) the motion of air layers relative to raindrop is not streamlined.
(d) All the above

42. Two small spheres of radii r and $3r$ fall through a viscous liquid with the same constant speed. The viscous forces experienced by them are in the ratio:

(a) 1:4 (b) 1:2
(c) 1:3 (d) 3:1

43. Match Column I with Column II with appropriate matching.

	Column I		Column II
A	Terminal velocity	(i)	$\frac{\rho}{\rho_w}$
B	Relative density	(ii)	Upthrust is zero
C	A beaker having a solid iron under free fall	(iii)	Varies with velocity
D	Viscous drag	(iv)	$\frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$

(a) A→(iv), B→(i), C→(ii), D→(iii)
(b) A→(ii), B→(iv), C→(i), D→(iii)
(c) A→(iii), B→(i), C→(iv), D→(ii)
(d) A→(iv), B→(iii), C→(i), D→(ii)

44. A metallic sphere of mass M falls through glycerine with a terminal velocity v_t. If we drop a ball of mass $27M$ of same metal into a column of glycerine, the terminal velocity of the ball will be:

(a) $2v_t$ (b) $4v_t$
(c) $6v_t$ (d) $9v_t$

45. 64 drops of water, each of radius 2 mm are falling through air at a terminal velocity of 8 cms^{-1}. If they coalesce to form a single drop, then the terminal velocity of combined drop will be:

(a) 16 cms^{-1} (b) 128 cms^{-1}
(c) 32 cms^{-1} (d) 4 cms^{-1}

46. A drop of water of radius 0.0018 mm is falling in air. If the coefficient of viscosity of air is 2.0×10^{-5} $kgm^{-1}s^{-1}$ the terminal velocity of the drop will be: (The density of water = 10^3 kgm^{-3} and g = 10 ms^{-2}

(a) 1.0×10^{-4} ms^{-1} (b) 36×10^{-4} ms^{-1}

(c) 3.6×10^{-4} ms^{-1} (d) 3.6×10^{-5} ms^{-1}

47. Water is conveyed through a uniform tube of 8 cm in diameter and 3140 m in length at the rate 2×10^{-3} m^3 per second. The pressure required to maintain the flow is: (Viscosity of water $=10^{-3}$)

(a) 6.25×10^3 Nm^{-2} (b) 9.37×10^2 Nm^{-2}

(c) 9.37×10^3 Nm^{-2} (d) 8.37×10^3 Nm^{-2}

Reynold's Number

48. Unit in SI system and dimensions respectively of Reynold's number are:

(a) No unit, $[M^0L^0T^0]$ (b) No unit, $[M^1L^1T^2]$

(c) Ns/m^2, $[M^1L^1T^0]$ (d) Poise, $[M^0L^0T^0]$

49. A flow of liquid is streamline if the Reynold's number is:

(a) between 1000 and 2000
(b) greater than 10000
(c) between 2000 and 3000
(d) between 4000 and 5000

50. If Reynold's number is greater than 3000, the flow of liquid is:
(a) laminar (b) turbulent
(c) regular (d) stab

51. A liquid of density d and viscosity coefficient η is flowing through pipe of radius r. Velocity at the area of cross-section is v. Reynold's number R_e will be:
(a) $R_e = \frac{2rdv}{\eta}$ (b) $R_e = \frac{rdv}{\eta}$
(c) $R_e = \frac{rdv}{\eta^2}$ (d) $R_e = \frac{2\eta rv}{d}$

52. The onset of turbulence in a liquid is determined by:
(a) Pascal's law
(b) Reynolds number
(c) Torricelli's law
(d) Bernoulli's principle

53. Reynolds number is the ratio of:
(a) inertial force to viscous force
(b) viscous force to inertial force
(c) volume of liquid to coefficient of viscosity of liquid
(d) coefficient of viscosity of liquid to volume of liquid

54. The flow rate of water from a tap of diameter 1.5 cm is 6 $Lmin^{-1}$. The coefficient of viscosity of water is 10^{-3} Pas. The nature of the flow is:
(a) Laminar (b) Unsteady
(c) Turbulent (d) None of these

55. The maximum average velocity of water in a tube of diameter 2 cm so that the flow becomes laminar is: (The viscosity of water is $10^{-3}\ Nm^{-2}s^{-1}$)
(a) 100 ms^{-1} (b) 10 ms^{-1}
(c) 1 ms^{-1} (d) 0.1 ms^{-1}

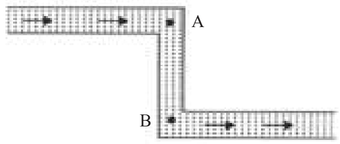
56. The speed at which the flow of water in a long cylindrical pipe of diameter 2 cm becomes turbulent is: (The viscosity of water = 1×10^{-3} Pas and the onset of turbulent flow in along cylindrical pipe Reynold's number = 3000)
(a) 10 ms^{-1} (b) 0.15 ms^{-1}
(c) 0.45 ms^{-1} (d) 0.3 ms^{-1}

57. The maximum average velocity of water required for streamline flow of liquid passing through a tube of radius 1.25 cm should be: (Coefficient of viscosity of water is 1×10^{-3} deca poise)
(a) 0.8 ms^{-1} (b) 0.08 ms^{-1}
(c) 0.008 ms^{-1} (d) 8 ms^{-1}

Stream Line Flow

58. Water is flowing continuously from a tap having an internal diameter 8×10^{-3} m. The water velocity as it leaves the tap is 0.4 ms^{-1}. The diameter of the water stream at a distance 2×10^{-1} m below the tap is close to:
(a) 9.6×10^{-3} m (b) 3.33×10^{-3} m
(c) 3.23×10^{-3} m (d) 3.23×10^{-3} m

59. In the figure shown an ideal liquid is flowing through the tube which is of uniform area of cross-section. The liquid has velocities v_A and v_B and pressures and P_A and P_B at points A and B respectively. Then:



(a) $v_B > v_A$ (b) $v_B = v_A = 0$
(c) $v_B = v_A$ (d) Data is insufficient

60. The cylindrical tube of a spray pump has a cross-section of 6 cm^2 one of which has 50 holes each of diameter 1mm. If the liquid flow inside the tube is 1.2 m min^{-1}, then the speed of ejection of the liquid through the holes is:
(a) 0.8 ms^{-1} (b) 3.1 ms^{-1}
(c) 0.031 ms^{-1} (d) 0.31 ms^{-1}

61. In a streamline (laminar) flow, the velocity of flow at a point in the liquid
(a) does not vary with time.
(b) may vary in direction but not in magnitude.
(c) may vary in magnitude but not in direction.
(d) may vary both in magnitude and direction.

62. In streamline flow, velocity of liquid at the bottom layer is:
(a) zero
(b) maximum
(c) mean of velocities of all layers
(d) infinity

63. Select the correct statement.
(a) Two streamlines are always is perpendicular.
(b) Two streamlines will intersect at an angle of 30° between them.
(c) Two streamlines will never intersect.
(d) Two streamlines will not exist.

64. Streamline flow is more likely for liquids with:
(a) high viscosity and high density
(b) low viscosity and low density
(c) high viscosity and low density
(d) low viscosity and high density

Bernoulli's Principle

65. In Bernoulli's theorem which of the following is conserved?

(a) Mass
(b) Linear momentum
(c) Energy
(d) Angular momentum

66. In old age, arteries carrying blood in the human body become narrow resulting in an increase in the blood pressure. This follows from:
(a) Pascal's law
(b) Stoke's law
(c) Bernoulli's principle
(d) Archimedes principle

67. Applications of Bernoulli's theorem is used in:
(a) dynamic lift of aeroplane
(b) hydraulic press
(c) helicopter
(d) None of these

68. Bernoulli's principle applies to streamline flow for which Reynold's number:
(a) does not exceed 2000.
(b) is between 0 and 2000.
(c) lies between 2000 and 3500.
(d) is always zero.

69. Bunsen's burner works on the principle of:
(a) Terminal velocity (b) Stoke's law
(c) Newton's law (d) Bernoulli's principle

70. To calculate the rate of flow of a liquid, which of the following is used?
(a) Stoke's law
(b) Bernoulli's theorem
(c) Poiseuille's law
(d) Conservation of pressure

71. Which of the following is NOT an example of application of Bernoulli's principle?
(a) Venturimeter (b) Dynamic lift
(c) Air purifier (d) Barometer

72. An air foil has:
(a) convex shape
(b) concave shape
(c) concavo-convex shape
(d) plane shape

73. A tank filled with non-viscous, incompressible, temperature-independent liquid has a hole in its bottom and water is flowing out of it. If the size of the hole is increased, then:
(a) the volume of water flowing out per second will decrease
(b) the velocity of outflow of water remains unchanged
(c) the volume of water flowing out per second remains zero
(d) Both (b) and (c)

74. Bernoulli's equation is valid for
(a) constant, viscous, incompressible, temperature-dependent flow.
(b) variable, non-viscous, incompressible, temperature-dependent flow.
(c) constant, non-viscous, incompressible, temperature-independent flow.
(d) variable, non-viscous, incompressible, temperature-independent flow.

75. A water barrel stands on a table of height h. If a small hole is punched in the side of the barrel at its base, it is found that the resultant stream of water strikes the ground at a horizontal distance R from the table. What is the depth of water in the barrel?
(a) $\frac{R^2}{h}$ (b) $\frac{2R^2}{h}$
(c) $\frac{R^2}{9h}$ (d) $\frac{R^2}{4h}$

76. Torricelli's barometer used mercury but Pascal duplicated it using French wine of density 955 kg m^{-3}. In that case, the height of the wine column for normal atmospheric pressure is_____. (Take the density of mercury $= 13.6 \times 10^3$ kgm^{-3})
(a) 15 m (b) 10.8 m
(c) 8.2 m (d) 5.5 m

77. What is the minimum pressure required to force the blood from the heart to the top of the head (vertical distance 0.5 m)? (Density of blood is 1040 kgm^{-3}. Friction is to be neglected and g = 9.8 ms^{-2})
(a) 1050 Nm^{-2} (b) 2080 Nm^{-2}
(c) 5096 Nm^{-2} (d) 6096 Nm^{-2}

78. At what speed is the velocity head of water equal to pressure head of 40 cm of Hg?
(a) 10.4 ms^{-1} (b) 1.43 ms^{-1}
(c) 12.3 ms^{-1} (d) 8.4 ms^{-1}

79. A pipe, 2 cm in diameter, has a constriction of diameter 1 cm. What is the velocity of flow at the constriction, if velocity of flow in the broader region of the pipe is 5 cms^{-1}?
(a) 0.10 ms^{-1} (b) 0.20 ms^{-1}
(c) 0.30 ms^{-1} (d) 2.5 ms^{-1}

80. The reading of pressure meter attached to a closed pipe is 3.5×10^5 Pa. On opening the valve of the pipe, the reading reduced to 3×10^5 Pa. The speed of the water flowing in the pipe is_____.
(a) 5 (b) 8.5
(c) 15 (d) 10

81. At what velocity does water emerge from an orifice in a tank in which gauge pressure is 3×10^5 Nm^{-2} before the flow starts? (Take the density of water = 1000 kgm^{-3})
(a) 2.45 (b) 25
(c) 24.5 (d) 25.49

82. A wind with speed 40 m/s blows parallel to the roof of a house. The area of the roof is 250 m^2. Assuming that the pressure inside the house is atmospheric pressure, the force exerted by the wind on the roof and the direction of the force will be: (ρ_{air} = 1.2 kgm^{-3})

(a) 4.8×10^5 N, upwards

(b) 4.8×10^5 N, downwards

(c) 2.4×10^5 N, upwards

(d) 2.4×10^5 N, downwards

83. A wide vessel with a small hole at the bottom is filled with water (density ρ_1, height h_1) and kerosene (density ρ_2, height h_2) neglecting viscosity effects, the speed with which water flows out is:

(a) $\left[2g\left(h_1+h_2\right)\right]^{12}$

(b) $\left[2g\left(h_1\rho_1+h_2\rho_2\right)\right]^{12}$

(c) $\left[4g\left(h_1+h_2\frac{\rho_1}{\rho_2}\right)\right]^{12}$

(d) $\left[2g\left(h_1+h_2\frac{\rho_2}{\rho_1}\right)\right]^{\frac{1}{2}}$

Surface Tension

84. If a glass rod is dipped in pure mercury and removed, then mercury does not stick to the rod. This is because

(a) the angle of contact is small.

(b) cohesive force is greater than the adhesive force.

(c) cohesive force is less than the adhesive force.

(d) density of mercury is low.

85. Surface tension depends on

(a) the area of surface.

(b) length of line considered.

(c) the area of the surface and length of line considered.

(d) the nature of the liquid.

86. Rounding of ends of glass tube on heating is due to_____.

(a) surface tension

(b) excess pressure

(c) stronger cohesive forces than adhesive forces

(d) stronger adhesive forces than cohesive forces

87. Which of the following statements is not true about surface tension?

(a) A small liquid drop takes spherical shape due to surface tension.

(b) Surface tension of liquid is a molecular phenomenon.

(c) Surface tension of liquid depends on length but not on the area.

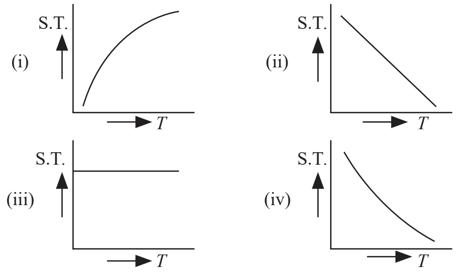
(d) Surface tension is a vector quantity.

88. The length of a needle floating on water is 2 cm. The additional force due to surface tension required to pull the needle out of water will be_____. (Surface tension of water $=7.0\times10^{-2}$ Nm^{-1})

(a) 32×10^{-4} N (b) 3.2×10^{-4} N

(c) 28×10^{-4} N (d) 2.8×10^{-4} N

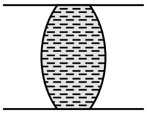
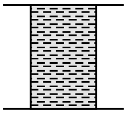
89. Which of the following graph represents the variation of surface tension with temperature over small temperature ranges for water?

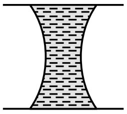


(a) (i) (b) (ii)

(c) (iii) (d) (iv)

90. If a water drop is kept between two glass plates, then its shape is:

(a)  (b) 

(c)  (d) None of these

91. If two soap bubbles of different radii are in communication with each other, then

(a) air flows from the larger bubble into the smaller one until the two bubbles are of equal size.

(b) the size of the bubbles remains the same.

(c) air flows from the smaller bubble into the larger one and the larger one grows at the expense of the smaller one.

(d) the air flows from the larger into the smaller bubble until the radius of the smaller one becomes equal to that of the larger one and of the larger one equal to that of the smaller one.

92. The excess pressure inside a soap bubble is three times than excess pressure inside a second soap bubble, then the ratio of their surface area is:

(a) 1:3 (b) 3:1

(c) 9:1 (d) 1:9

93. The surface tension of soap solution is 0.03 Nm^{-1}. The work done in blowing to form a soap bubble of surface area 30 cm^2 is:

(a) 2.4×10^{-4} J (b) 1.8×10^{-4} J

(c) 1.2×10^{-4} J (d) 1.8×10^{-3} J

94. A disc of paper of radius R is floating on the surface of water of surface tension σ. If R = 20 cm and σ = 0.070 Nm^{-1}, then the force of surface tension on the disc is:

(a) 2.2×10^{-2} N (b) 4.4×10^{-2} N
(c) 8.8×10^{-2} N (d) 44×10^{-2} N

95. A clean glass plate of length 9.8 cm, breadth 4 cm and thickness 0.2 cm is suspended vertically with its long side horizontal and with half the side immersed. Pull due to surface tension will be: (Surface tension = 0.07 Nm^{-1})

(a) 16×10^{-3} N (b) 15×10^{-3} N
(c) 15.5×10^{-3} N (d) 15×10^{-3} N

96. The maximum force, in addition to the weight required, to pull a wire frame 5.0 cm long from a water surface at a temperature of 20°C is 720 dyne. The surface tension of water is:

(a) 14.5 $dynecm^{-1}$ (b) 72 $dynecm^{-1}$
(c) 145 $dynecm^{-1}$ (d) 720 $dynecm^{-1}$

97. Match the work done in different cases listed in Column I with their corresponding expressions listed in Column II: (σ = surface tension, R = radius of bigger drop/bubble, r = radius of droplet/bubble)

	Column I		Column II
A	Work done in breaking a drop into an identical droplets of smaller radius	(i)	$4\pi R^2\sigma$
B	Work done in blowing a liquid drop	(ii)	$8\pi R^2\sigma$
C	Work done in coalescing n equal droplets into a big drop of bigger size	(iii)	$4\pi\sigma R^2\left(n^{\frac{1}{3}}-1\right)$
D	Work done in blowing a soap bubble	(iv)	$4\pi r^2\sigma\left(n-n^{\frac{2}{3}}\right)$

(a) A→(iii), B→(iv), C→(i), D→(ii)
(b) A→(ii), B→(i), C→(iv), D→(iii)
(c) A→(iii), B→(i), C→(iv), D→(ii)
(d) A→(iv), B→(iii), C→(i), D→(ii)

98. A film of water is formed between two straight parallel wires of length 20 cm with separation of 0.5 cm. The work done to increase the separation by 0.1 cm is:

(a) 36×10^{-6} J (b) 28×10^{-6} J
(c) 30×10^{-6} J (d) 24×10^{-6} J

99. The amount of work done in increasing size of soap film 6 cm × 4 cm to 12 cm × 8 cm is: (surface tension 30 dyne/cm)

(a) 5160 erg (b) 4320 erg
(c) 1440 erg (d) 720 erg

100. If σ is surface tension of soap solution, then the amount of work done in blowing a soap bubble from diameter D to a diameter $2D$ is ______.

(a) $2\pi D^2\sigma$ (b) $4\pi D^2\sigma$
(c) $6\pi D^2\sigma$ (d) $8\pi D^2\sigma$

HIGH-ORDER THINKING SKILL

Pressure

1. An open glass tube is immersed in mercury in such a way that a length of 8 cm extends above the mercury level. The open end of the tube is then closed and sealed and the tube is raised vertically up by additional 46 cm. What will be length of the air column above mercury in the tube now? (Atmospheric pressure = 76 cm of Hg)

(a) 16 cm (b) 22 cm
(c) 38 cm (d) 6 cm

Viscosity

2. A small sphere of radius 'r' falls from rest in a viscous liquid. As a result, heat is produced due to viscous force. The rate of production of heat when the sphere attains its terminal velocity, is proportional to:

(a) r^3 (b) r^2
(c) r^4 (d) r^5

Reynold's Number

3. In dimension of critical velocity v_C, of liquid flowing through a tube are expressed as $\left(\eta^x\rho^y r^z\right)$ where η, ρ, and r are the coefficient of viscosity of liquid, density of liquid and radius of the tube respectively, then the values of x, y, and z are given by:

(a) 1, 1, 1 (b) 1, −1, −1
(c) −1, −1, 1 (d) −1, −1, −1

Stream Line Flow

4. The cylindrical tube of a spray pump has radius, R, one end of which has n fine holes, each of radius r. If the speed of the liquid in the tube is V, the speed of the ejection of the liquid through the holes is:

(a) $\dfrac{VR^2}{nr^2}$ (b) $\dfrac{VR^2}{n^3r^2}$

(c) $\dfrac{V^2R}{nr}$ (d) $\dfrac{VR^2}{n^2r^2}$

Bernoulli's Principle

5. A cylindrical container is filled with water and kerosene oil. The vessel has a small hole in the bottom. Neglecting viscosity, if the thickness of water layer is h_1 and kerosene layer is h_2, then the velocity v of flow of water will be: (density of water is ρ_1 g/cc and that of kerosene is ρ_2 g/cc)

(a) $v = \sqrt{2g(h_1 + h_2)}$ (b) $v = \sqrt{2g\left(h_1 + h_2\dfrac{\rho_2}{\rho_1}\right)}$

(c) $v = \sqrt{2g(h_1\rho_1 + h_2\rho_2)}$ (d) $v = \sqrt{2g\left(h_1\dfrac{\rho_2}{\rho_1} + h_2\right)}$

Surface Tension

6. Two soap bubbles A and B are kept in a closed chamber where the air is maintained at pressure 8 N/m^2. The radii of bubbles A and B are 2 cm and 4 cm, respectively. Surface tension of the soap-water used to make bubbles is 0.04 N/m. The ratio of n_B / n_A is: (where n_A and n_B are the number of moles of air in bubbles A and B, respectively.) [Neglect the effect of gravity]

(a) 2 (b) 4 (c) 6 (d) 8

7. A capillary tube of radius r is immersed vertically in a liquid such that liquid rises in it to height h (less than the length of the tube). Mass of liquid in the capillary tube is m. If radius of the capillary tube is increased by 50%, then mass of liquid that will rise in the tube, is:

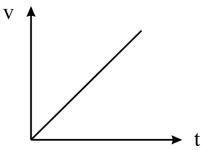
(a) $\dfrac{2}{3}m$ (b) $\dfrac{3}{2}m$

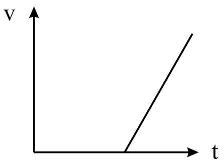
(c) $\dfrac{9}{4}m$ (d) m

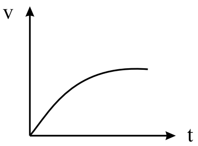
NCERT EXEMPLAR PROBLEMS

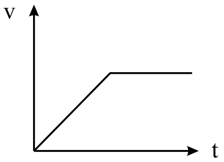
Pressure

1. A tall cylinder is filled with viscous oil. A round pebble is dropped from the top with zero initial velocity. From the plots shown, indicate the one that represents the velocity (v) of the pebble as a function of time (t).

(a)


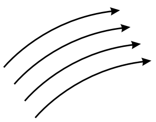
(b)


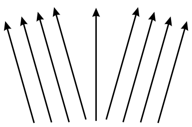
(c)


(d)


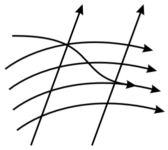
Stream Line Flow

2. Which of the following diagrams does not represent a streamline flow?

(a)


(b)


(c)


(d)


3. Along a streamline
(a) the velocity of a fluid particle remains constant.
(b) the velocity of all fluid particles crossing a given position is constant.
(c) the velocity of all fluid particles at a given instant is constant.
(d) the speed of a fluid particle remains constant.

Surface Tension

4. An ideal fluid flows through a pipe of circular cross-section made of two sections with diameters 2.5 cm and 3.75 cm. The ratio of the velocities in the two pipes is:
(a) 9:4 (b) 3:2
(c) $\sqrt{3}:\sqrt{2}$ (d) $\sqrt{2}:\sqrt{3}$

5. The angle of contact at the interface of water-glass is 0°, ethyl alcohol-glass is 0°, mercury-glass is 140° and methyl iodide-glass is 30°. A glass capillary is put in a trough containing one of these four liquids. It is observed that the meniscus is convex. The liquid in the trough is:
(a) water (b) ethyl alcohol
(c) mercury (d) methyl iodide

ASSERTION AND REASONS

Directions: In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as:
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

Pressure

1. **Assertion:** A small iron needle sinks in water while a large iron ship floats.

   Reason: The shape of iron needle is like a flat surface while the shape of a ship is that which makes it easier to float.

2. **Assertion:** If an object is submerged in fluid at rest, the fluid exerts a force on its surface.

   Reason: Force exerted by the fluid at rest has to be parallel to the surface in contact with it.

3. **Assertion:** Liquids and gases are largely incompressible and densities are therefore, nearly constant at all pressures for liquid only.

   Reason: Liquids exhibit a large variation in densities with pressure but gases do not.

4. **Assertion:** Newton's law of viscosity is the working principle of hydraulic lift.

   Reason: $\text{Pressure} = \dfrac{\text{Area}}{\text{Thrust}}$

5. **Assertion:** The apparent weight of a floating body is zero.

   Reason: The weight of the block acting vertically downwards is balanced by the buoyant force acting on the block upwards.

Viscosity

6. **Assertion:** Falling raindrops acquire a terminal velocity.

   Reason: A constant force in the direction of motion and a velocity dependent force opposite to the direction of motion, always result in the acquisition of terminal velocity.

7. **Assertion:** When fluids flow, there is some loss of energy due to friction.

   Reason: Different layers of the fluid exert forces on each other.

8. **Assertion:** The viscosity of water is less than blood.

   Reason: The viscosity of liquids increases with increase in temperature.

9. **Assertion:** The viscous force experienced by a steel ball moving in a liquid is less than that experienced by an aluminium ball of the same radius moving in the liquid with the same speed.

   Reason: The density of steel is less than that of aluminium.

Reynold's Number

10. **Assertion:** The flow is streamline for Reynolds number less than 2000.

    Reason: The flow of liquid is unstable for Reynolds number greater than 3000.

Stream Line Flow

11. **Assertion:** The flow of fluid is said to be steady if at any given point, the velocity of each passing fluid particle do not remain constant.

    Reason: The path taken by a fluid particle under a steady flow is a turbulent.

Bernoulli's Principle

12. **Assertion:** Bernoulli's equation holds for non-steady or turbulent flows.

    Reason: In these situations, velocity and pressure are constant with time.

Surface Tension

13. **Assertion:** Oil spreads on cold water.

    Reason: The surface tension of oil is greater than that of cold water.

ANSWER KEYS

Practice Time

1	(b)	2	(c)	3	(a)	4	(c)	5	(c)	6	(c)	7	(a)	8	(d)	9	(b)	10	(c)
11	(b)	12	(a)	13	(b)	14	(d)	15	(d)	16	(c)	17	(c)	18	(a)	19	(c)	20	(b)
21	(c)	22	(c)	23	(b)	24	(d)	25	(a)	26	(a)	27	(d)	28	(a)	29	(b)	30	(b)
31	(b)	32	(a)	33	(a)	34	(a)	35	(d)	36	(d)	37	(c)	38	(b)	39	(d)	40	(c)
41	(c)	42	(c)	43	(a)	44	(d)	45	(b)	46	(c)	47	(c)	48	(a)	49	(a)	50	(b)
51	(a)	52	(b)	53	(a)	54	(c)	55	(d)	56	(b)	57	(b)	58	(c)	59	(c)	60	(d)
61	(a)	62	(a)	63	(c)	64	(c)	65	(c)	66	(c)	67	(a)	68	(a)	69	(d)	70	(b)
71	(d)	72	(a)	73	(b)	74	(c)	75	(d)	76	(b)	77	(c)	78	(a)	79	(b)	80	(d)
81	(c)	82	(c)	83	(d)	84	(b)	85	(d)	86	(a)	87	(d)	88	(c)	89	(b)	90	(c)
91	(c)	92	(d)	93	(d)	94	(c)	95	(d)	96	(b)	97	(c)	98	(b)	99	(b)	100	(c)

High-Order Thinking Skill

1	(a)	2	(d)	3	(b)	4	(a)	5	(b)	6	(c)	7	(b)

NCERT Exemplar Problems3

1	(c)	2	(d)	3	(b)	4	(a)	5	(c)

Assetion and Reasons

1	(c)	2	(c)	3	(c)	4	(d)	5	(a)	6	(a)	7	(a)	8	(c)	9	(d)	10	(c)
11	(d)	12	(d)	13	(c)														

HINTS AND EXPLANATIONS

Practice Time

1 (b) 1 bar = 100,000 Pa = 100,000 Nm^{-2}

2 (c) When air is blown through a hole on a closed pipe containing liquid, then the pressure will increase in all directions.

3 (a) Fall in pressure at a point into rushing of air to that point from the places with greater pressure.

4 (c) Pressure at the bottom is maximum. To with stand at, the bottom is made thick.

5 (c) As we know that,

$P = h\rho g$

6 (c) The given law was first formulated by Pascal.

7 (a) Pressure is a scalar quantity because it is the ratio of the component of the force normal to the area and it is independent on the size of the area chosen.

8 (d) Pressure = $h\rho g$

i.e., pressure at the bottom depends upon the height of water up to which the tank is filled with water. As the level of water in both the tanks is same, pressure at the bottom is also same.

9 (b) As we know that, $F = mg$ and $m_A = m_B = m_C$

Therefore, $F_A = F_B = F_C$

10 (c) Hydraulic press is based on Pascal's law.

11 (b) Venturimeter and sprayer based on Bernoulli's principle. Hydraulic lift is based on Pascal's law.

12 (a) Total cross-sectional area of the femurs is,

$A = 2 \times 10\ cm^2 = 20 \times 10^{-4}\ m^2$

Force acting on them is

$$F = mg = 50 \times 10 = 500\ N$$

Average pressure sustained by them is

$$P = \frac{F}{A} = \frac{500}{20 \times 10^{-4}} = 2.5 \times 10^5\ Nm^{-2}$$

13 (b) Here, $m = 45$ kg, $D = 1$ cm $= 10^{-2}$ m, $g = 10\ ms^{-2}$

Pressure exerted by the heel on the horizontal floor is

$$P=\frac{F}{A}=\frac{mg}{\pi(D/2)^2}=\frac{45\times10}{\pi D^2}\times4$$

$$=\frac{4\times45\times10}{3.14\times(10^{-2}\text{ m})^2}=5.7\times10^6\text{ Pa}$$

14 (d) Pressure applied to enclosed fluid is transmitted equally in all direction according to Pascal law.

15 (d) From the figure it is clear that liquid 1 floats on liquid 2. The lighter liquid floats over heavier liquid. Therefore we can conclude that $\rho_1<\rho_2$

Also $\rho_3<\rho_2$ otherwise the ball would have sink to the bottom of the jar.

Also $\rho_3>\rho_1$ otherwise the ball would have floated in liquid 1. From the above discussion we conclude that $\rho_2>\rho_3>\rho_1$.

16 (c) As we know that,

$F=PA$ and $P_1=P_2$ (as height of liquid is same) and $A_1=A_2$ (as dams are identical.),

$\therefore\quad F_1=F_2\ \&\ F_1:F_2=1$

17 (c) According to Pascal's law, pressure of a fluid is transmitted in equal directions. Therefore,

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

or $$F_2=\left(\frac{F_1}{A_1}\right)\times A_2=\frac{60}{\pi\left(\frac{2}{2}\right)^2}\times\pi\left(\frac{20}{2}\right)^2$$

$$=6000\text{ N}$$

18 (a) Pressure depends on the depth alone.

19 (c) Let h be the desired height of liquid in cylinder for which the force on the bottom and sides of the vessel is equal.

Force on bottom $=\rho gh\times\pi R^2$

Force on walls of vessel $=\rho g(h/2)\times2\pi Rh$

According to question,

$\rho gh\pi R^2=\rho g\pi Rh^2$

$\Rightarrow\quad R=h$

20 (b) The candle floats on the water with half of its length above and below water level. Let its length be 10 cm with 5 cm below the surface and 5 cm above it. If its length is reduced to 8 cm, it will have 4 cm. above water surface. So we see tip going down by 1 cm. So rate of fall of tip = 1 cm/hr.

21 (c) Specific gravity of a body is defined as ratio of weight of body in air to the loss of weight of body in water at 4°C.

$$=\frac{V\rho g}{V\rho_w g}=\frac{\rho}{\rho_w}=\text{Relative density of body}$$

22 (c) Let V_i be the volume of the iceberg inside sea water and V is the total volume of iceberg.

Total weight of iceberg = weight of water displaced by iceberg.

$V\rho_{ice}g=V_iP_{water}g$

$$\Rightarrow\frac{V_i}{V}=\frac{\rho_{ice}}{\rho_{water}}$$

$$=\frac{0.92}{1.03}$$

Thus the fraction of total volume of iceberg above the sea level

$$=\left(\frac{V-V_i}{V}\right)\times100\%=\frac{\left[V-\left(\frac{0.92}{1.03}\right)V\right]}{V}\times100\%$$

$$=\left(1-\frac{0.92}{1.03}\right)\times100\%=\frac{0.11}{1.03}\times100\%\approx11\%$$

23 (b) The volume of liquid displaced by floating ice

$$V_D=\frac{M}{\rho_L}$$

Volume of water formed by melting ice

$$V_F=\frac{M}{\rho_W}$$

i.e., volume of liquid displaced by floating ice will be lesser than water formed and so the level of liquid will rise.

24 (d) Here, h= 2000 m, $\rho=10^3$ kgm^{-3}, g = 10 ms^{-2}

The pressure outside the submarine is

$P=P_a+\rho gh$

where, P_a is the atmospheric pressure. Pressure inside the submarine is P_a. Hence, net pressure acting on the window is gauge pressure.

Gauge pressure,

$P_g=P-P_a=\rho gh$

$=10^3\times10\times2000=2\times10^7$ Pa

Area of a window,

$A=40\times10^{-2}\times40\times10^{-2}$

$=1600\times10^{-4}\text{ m}^2$

Force acting on window,

$F=P_a=2\times10^7\times1600\times10^{-4}=3.2\times10^6$ N

25 (a) Given that,

$A=1200\text{ cm}^2$

$F=mg=(18\times1000\times980)$ dynes

Thus, pressure on liquid,

$$P=\frac{F}{A}=\frac{18\times1000\times980}{1200}\text{ dyne cm}^{-2}$$

If h is the difference in level of liquid in the two tubes then,

$$P = h\rho g$$
$$= h \times 1 \times 980$$
$$h \times 1 \times 980 = \frac{18 \times 1000 \times 980}{1200}$$
$$h = 15 \text{ cm}$$

26 (a) Pressure difference between lungs and atmosphere,

$$= (760 - 750) = 10 \text{ mm of Hg} = 1 \text{ cm of Hg}$$

Let the boy can suck water from depth h. Then pressure difference,

$$h\rho_{\text{water}}\, g = 1 \text{ cm of Hg}$$
$$\therefore \quad h \times 1 \text{ g cm}^{-3} \times 980 \text{ cm s}^{-2}$$
$$= 1 \text{ cm} \times 13.6 \text{ g cm}^{-3} \times 980 \text{ cm s}^{-2}$$
$$\Rightarrow \quad h = 13.6 \text{ cm}$$

27 (d) The block moves up with the fall of coin, l decreases, similarly h will also decrease because when the coin is in water, it displaces water equal to its own volume only.

28 (a) Let ρ be the density of the material, ρ_0 be the density of water when the sphere has just started sinking,

The weight of the sphere = weight of water displaced (approx)

$$\therefore \quad \frac{4}{3}\pi\left(R^3 - r^3\right)\rho g = \frac{4}{3}\pi R^3 \rho_0 g$$
$$\Rightarrow \quad (R^3 - r^3)\rho = R^3 \rho_0$$
$$\Rightarrow \quad \frac{\left(R^3 - r^3\right)}{R^3} = \frac{\rho^0}{\rho}$$
$$\Rightarrow \quad \frac{r}{R} = \frac{(7)^{1/3}}{2}$$

29 (b) With the increase in temperature, the viscosity of liquids decreases and that of gases increases.

30 (b) According to Stokes' law,

Viscous drag force,

$$F = 6\pi\eta Rv$$

31 (b) When terminal velocity is reached then body moves with constant velocity, hence, acceleration is zero.

32 (a) For low velocity, the water layer in contact with the river bed can be assumed to be stationary. Since the velocity of water layers, increase from 0 to 2 m/s over a vertical height of 2 m so, the velocity gradient

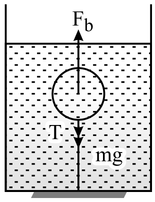
$$= \frac{\Delta v}{\Delta y} = \frac{2 - 0}{2} = 1 \text{ s}^{-1}$$
$$\because \quad F = \eta A\left(\frac{\Delta v}{\Delta y}\right)$$
$$\therefore \quad F = 0.90 \times 10^{-2} \times 8 \times 10^4 \times 1$$
$$= 720 \text{ dyne}$$

33 (a) The condition for terminal speed(v_t) is

Weight = Buoyant force + Viscous force

$$\therefore \quad V\rho_1 g = V\rho_2 g + kv_t^2$$
$$\therefore \quad v_t = \sqrt{\frac{Vg\left(\rho_1 - \rho_2\right)}{k}}$$

34 (a) By balancing the forces on the sphere for equilibrium,



$$T + mg = F_b T$$
$$T = F_b - mg$$
$$\text{Then, } T = V\rho_w g - mg \quad \ldots\left(\rho_w = \text{density of water}\right)$$
$$= \frac{m}{\rho}\rho_w g - mg = \left(\frac{\rho_w}{\rho} - 1\right)mg$$

35 (d) As we know that, by increasing the temperature viscosity decreases, so the oil moves around in the pan more easily.

36 (d) As the velocity of water at the bottom of the river is zero, therefore

$$dv = 36 \text{ kmh}^{-1} = 36 \times \frac{5}{18} = 10 \text{ ms}^{-1}$$

Also given that,

$$dx = 10 \text{ m}, \ \eta = 10^{-3} \text{ Pas}$$
$$\because \quad F = \eta A \frac{dv}{dx}$$

Therefore,

$$\text{Shearing stress} = \frac{F}{A} = \eta\frac{dv}{dx}$$
$$= \frac{10^{-3} \times 10}{10} = 10^{-3} \text{Nm}^{-2}$$

37 (c) As we know that,

$$F = \eta A \frac{dv}{dx}$$
$$\therefore \quad dx = \eta \frac{Adv}{F}$$
$$= \frac{0.001 \times (0.15)^2 \times 0.1}{0.0025} = 0.0009 \text{ m}$$

38 (b) Given that, r = 0.4 mm = 0.04 cm, v = 1 ms^{-1} = 100 cms^{-1}, $\eta = 18 \times 10^{-5}$ poise

According to stokes law, force of viscosity on rain drop is,

$$F = 6\pi\eta rv$$
$$= 6 \times 3.142 \times 18 \times 10^{-5} \times 0.04 \times 100$$
$$= 1.357 \times 10^{-2} \text{ dyne}$$

39 (d) When a solid sphere falls in vacuum, no viscous force is acting on the sphere and the sphere falls under gravity. Due to which sphere never attains terminal velocity.

40 (c) A good lubricant have high viscosity.

41 (c) Stoke's law is applicable only if there is no slip between the body and layers of fluid in contact and the motion of the fluid layers relative to the body remains streamlined.

42 (c) By using Stoke's law,

$$\because \quad F = 6\pi\eta rv$$
$$\therefore \quad \frac{F_1}{F_2} = \frac{r_1 v}{r_2 v} \qquad ...(\because v_1 = v_2)$$
$$\Rightarrow \frac{F_1}{F_2} = \frac{r_1}{r_2} = \frac{r}{3r} = \frac{1}{3}$$

43 (a) As we know that,

Viscous drag = $6\pi\eta rv$

Terminal velocity = $\dfrac{2r2(\rho - \sigma)g}{\eta}$

Since system is in free fall, the body's apparent weight becomes zero. Since the body is not exerting any force on the liquid, therefore the liquid will not be displaced, and no up thrust will act on the body.

44 (d) As we know that, Mass = Volume × density

$$\therefore \quad M = \frac{4}{3}\pi r^3 \rho$$
$$\text{and } 27M = \frac{4}{3}\pi R^3 \rho$$
$$\therefore \quad R^3 = 27r^3$$
$$\text{or} \quad R = 3r$$
$$v_t = \frac{2}{9}\frac{r^2(\rho - \sigma)g}{\eta}$$
$$\therefore \quad \frac{v_t'}{v_t} = \left(\frac{R}{r}\right)^2 = \left(\frac{3r}{r}\right)^2 = 9$$
$$\text{or} \quad v_t' = 9v_t$$

45 (b) Let the radius of bigger drop is R and smaller drop is r then

$$\frac{4}{3}\pi R^3 = 64 \times \frac{4}{3} \times \pi r^3$$
$$\text{or} \quad R = 4r \qquad ...(i)$$

Since terminal velocity,

$$v \propto r^2$$
$$\therefore \quad \frac{v'}{v} = \frac{R^2}{r^2} = \left(\frac{4r}{r}\right)^2 \qquad ...(\text{Using eq. (i)})$$
$$= 16$$
$$\text{or} \quad v' = 16v = 16 \times 8 = 128 \text{ cms}^{-1}$$

46 (c) Given that,

$$r = 0.0018 \text{ mm} = 0.0018 \times 10^{-3} \text{ m}$$
$$\eta = 2.0 \times 10^{-5} \text{ kg m}^{-1}\text{s}^{-1}$$
$$\rho = 1.0 \times 10^{3} \text{ kg m}^{-3}$$
$$g = 10 \text{ ms}^{-2}$$

Neglecting the density of air, the terminal velocity of the water drop is

$$v_t = \frac{2}{9}\frac{r^2 \rho g}{\eta}$$
$$= \frac{2 \times (0.0018 \times 10^{-3})^2 \times 1.0 \times 10^3 \times 10}{9 \times 2.0 \times 10^{-5}}$$
$$= 3.6 \times 10^{-4} \text{ ms}^{-1}$$

47 (c) According to Poiseuille formula,
Rate of flow,

$$V = \frac{\pi P r^4}{8\eta l}$$
$$\therefore \quad P = \frac{V 8\eta l}{\pi r^4}$$

Given that,

$$V = 3 \times 10^{-3} \text{ m}^3\text{s}^{-1}$$
$$r = \frac{8}{2} \text{ cm} = 4 \text{ cm} = 4 \times 10^{-2} \text{ m}$$
$$l = 3140 \text{ m}$$
$$\eta = 10^{-3} \text{ Nsm}^{-2}$$

Substituting the given values, we get

$$P = \frac{3 \times 10^{-3} \times 8 \times 10^{-3} \times 3140}{3.14 \times (4 \times 10^{-2})^4}$$
$$= 9.37 \times 10^3 \text{ Nm}^{-2}$$

48 (a) For a liquid at viscosity η, density ρ and flowing through pipe of diameter D, Reynold's number is given by

$$R_e = \frac{\rho v D}{\eta} \text{ and } \eta = \frac{F}{6\pi rv}$$

49 (a) If the value of Reynolds number lies between 0 and 2000, the flow of liquid is streamlined or laminar. For values of R_e above 3000, the flow of liquid is turbulent and for values of R_e between 2000 and 3000, the flow of liquid is unstable changing from streamline to turbulent.

50 (b) Same as above question 50.

51 (a) As we know that,

$$R_e = \frac{\rho v D}{\eta} = \frac{dv2r}{\eta} = \frac{2rdv}{\eta}$$

($\because$ density $= d$, velocity $= v$, $D = 2r$)

52 (b) The onset of turbulence in a liquid is determined by a dimensionless parameter called Reynold's number.

53 (a) Reynolds number represents the ratio of inertial force to viscous force.

54 (c) Given that,

Diameter of the tap, $D = 1.5$ cm

$= 1.5 \times 10^{-2}$ m

Density of water, $\rho = 10^3$ kgm^{-3}

Efficient of viscosity, $\eta = 10^{-3}$ Pas

Volume of water flowing out per second is

$$Q = 6 \text{ Lmin}^{-1} = \frac{6 \times 10^{-3} \text{ m}^3}{60 \text{ s}} = 10^{-4} \text{ m}^3\text{s}^{-1}$$

Reynolds number is given by

$$R_e = \frac{4\rho Q}{\pi D \eta} = \frac{4 \times 10^3 \times 10^{-4}}{3.14 \times 1.5 \times 10^{-2} \times 10^{-3}} = 8492$$

i.e. > 2000

Thus, the flow will be turbulent.

55 (d) As we know that,

$$v_c = \frac{R_e \times \eta}{\rho \times d}$$

For laminar flow, Reynold's number,

$R_e = 2000$, $\eta = 10^{-3}$ Nm^{-2}s^{-1}

Substituting the given values, we get

$$\therefore \ v_c = \frac{2000 \times 10^{-3}}{10^3 \times 2 \times 10^{-2}} = 0.1 \text{ ms}^{-1}$$

56 (b) By using,

$$v_c = \frac{R_e \times \eta}{\rho \times d} = \frac{3000 \times 10^{-3}}{10^3 \times 0.02} = 0.15 \text{ ms}^{-1}$$

57 (b) As we know that,

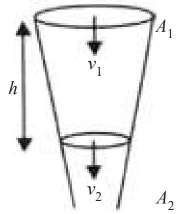
$$v_c = \frac{R_e \times \eta}{\rho \times d}$$

Maximum value of R_e is 2000.

$$\therefore \ v_c = \frac{2000 \times 10^{-3}}{10^3 \times 2 \times 1.25 \times 10^{-2}} = 0.08 \text{ ms}^{-1}$$

58 (c) Given that,

$d_1 = 8 \times 10^{-3}$ m, $v_1 = 0.4$ ms^{-1}, $h = 0.2$ m



According to equation of motion,

$$v_2 = \sqrt{v_1^2 + 2gh} = \sqrt{(0.4)^2 + 2 \times 10 \times 0.2} = 2.039 \text{ ms}^{-1}$$

According to equation of continuity,

$$\because \quad A_1 v_1 = A_2 v_2$$

$$\therefore \quad \pi \times \left(\frac{8 \times 10^{-3}}{2}\right)^2 \times 0.4 = \pi \times \left(\frac{d_2}{2}\right)^2 \times 2.45$$

or $d_2 = 3.543 \times 10^{-3}$ m

59 (c) For a streamline flow of an ideal liquid, $v_B = v_A$. The pressure at B = pressure at A + pressure due to column of liquid of height AB.

60 (d) Given that,

Area of cross-section of tube,

$a_1 = 6 \text{ cm}^2 = 6 \times 10^{-4} \text{ m}^2$

Number of holes = 50

Diameter of each hole,

$D = 1 \text{ mm} = 10^{-3}$ m

Radius of hole,

$$r = \frac{D}{2} = \frac{1}{2} \times 10^{-3} = 5 \times 10^{-4} \text{ m}$$

Area of cross-section of each hole,

$$= \pi r^2 = \pi \left(5 \times 10^{-4}\right)^2 \text{ m}^2$$

Total area of cross-section of 50 holes,

$$a_2 = 50 \times \pi \left(5 \times 10^{-4}\right)^2 \text{ m}^2$$

Speed of liquid inside the tube,

$$v_1 = 1.2 \text{ m min}^{-1} = \frac{1.2}{60} \text{ ms}^{-1} = 0.02 \text{ ms}^{-1}$$

Let the velocity of ejection of the liquid through the hole v_2,

As, $a_1 v_1 = a_2 v_2$

$$\text{or,} \quad v_2 = \frac{a_1 v_1}{a_2} = \frac{6 \times 10^{-4} \times 0.02}{50 \times \pi \left(5 \times 10^{-4}\right)^2} = 0.31 \text{ ms}^{-1}$$

61 (a) For a streamline flow, velocity of each particle at a point is a particular cross-section is constant.

62 (a) In the case of a moving plate in a liquid, it is found that there is a layer (lamina) that moves with the plate, and a layer next to any stationary plate that is stationary.

63 (c) Streamline flow occurs when a fluid flows in parallel layers.

64 (c) Streamline flow is more likely for liquids with low density and high viscosity.

65 (c) In Bernoulli's theorem only law of conservation of energy is obeyed.

66 (c) According to equation of continuity, av = a constant. It means, as area increases, velocity decreases. Thus, as blood flows from narrow arteries to wider one, velocity decreases. According to Bernoulli's theorem, $P+\frac{1}{2}\rho v^2 = \text{a constant}$. It means, as velocity decreases, pressure increases. Thus, when arteries become narrow, blood pressure increases.

67 (a) The shape of the aeroplane wings is such that when it moves forward, the air molecules at the top of the wings have a greater velocity (relative to the wings) compared to the air molecules at the bottom. Therefore, it is in accordance with Bernoulli's principle, the pressure at the top of the wings is less than that at the bottom. This results in a dynamic lift of the wings which balances the weight of the plane.

68 (a) Value of Reynolds number lies between 0 and 2000, the flow of liquid is streamlined or laminar.

69 (d) Bunsen's burner works on the principle of Bernoulli's principle.

70 (b) Bernoulli's theorem is used to calculate the rate of flow of a liquid.

71 (d) The principle of the mercury barometer was discovered by the Italian physicist Evangelista Torricelli in about 1643.

72 (a) An air foil has convex shape.

73 (b) The velocity of outflow of liquid remains unchanged because it depends upon the height of liquid level and is independent of the size of the hole. The volume depends directly on the size of the hole.

74 (c) Bernoulli's equation is valid for constant, non-viscous, incompressible, temperature-independent flow.

75 (d) By using Torricelli's law for open tank,

$$v=\sqrt{2gd} \qquad \text{...(i)}$$

where v is horizontal velocity and d is the depth of water in barrel.

Time t to hit the ground is given by,

$$h=\frac{1}{2}gt^2$$

or $t=\sqrt{\frac{2h}{g}}$

$\therefore\ R = vt = \sqrt{(2gd)}\sqrt{\frac{2h}{g}}$ [Using eq. (i)]

$= 2\sqrt{dh}$

$\therefore\ R^2 = 4dh$

or $d=\frac{R^2}{4h}$

76 (b) As we know that, $P = h\rho g$

Height of mercury column in Torricelli's barometer = 0.76 mm of Hg

$\rho_{\text{mercury}} = 13.6\times10^3 \text{ kg m}^{-3}$

$\rho_{\text{french wine}} = 955 \text{ kg m}^{-3}$

or $\quad 0.76\times(13.6\times10^3)\times9.8$

$= h\times955\times9.8$

or $\quad h=\frac{0.76\times13.6\times10^3\times9.8}{955\times9.8}$

$= 10.82$ m

77 (c) As we know that,

$P = h\rho g$

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

$= 1040\times9.8\times0.5$

$\Rightarrow\ P_1 - P_2 = 5096 \text{ Nm}^{-2}$

78 (a) Given that,

Pressure head = 40 cm of Hg, $g = 1000 \text{ cms}^{-2}$

$\because$ Velocity head $=\frac{v^2}{2g}$

$\therefore\quad 40\times13.6=\frac{v^2}{2\times1000}$

$\therefore\quad v = 1043 \text{ cms}^{-1} = 10.43 \text{ ms}^{-1}$

79 (b) By using,

$a_1v_1 = a_2v_2$

$\pi(1)^2\times5 = \pi(0.5)^2\times v_2$

$\therefore\quad v_2=\frac{1\times5}{0.5\times0.5} = 20 \text{ cms}^{-1} = 0.2 \text{ ms}^{-1}$

80 (d) By using Bernoulli's equation,

$\because\ P_1+\frac{1}{2}\rho v_1^2 = P_2+\frac{1}{2}\rho v_2^2$

$\therefore\ \frac{(P_1-P_2)}{\rho}=\frac{1}{2}v^2$

or $\frac{2(P_1-P_2)}{\rho}=v^2$

$\therefore\ v=\sqrt{\frac{2(P_1-P_2)}{\rho}}$

$$= \sqrt{\frac{2(3.5-3)\times10^5}{10^3}}$$
$$= 10 \text{ m/s}$$

81 (c) Given that,

$P = 3\times10^5 \text{ Nm}^{-2}, \rho = 1000 \text{ kg m}^{-3}, g = 9.8 \text{ ms}^{-2}$

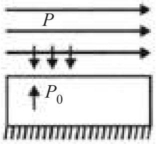
$\because \quad P = h\rho g$

$\therefore \quad h = \frac{P}{\rho g} = \frac{3\times10^5}{1000\times9.8} \text{ m} \quad ...(i)$

Velocity of efflux,

$$v = \sqrt{2gh}$$
$$= \sqrt{\frac{2\times9.8\times3\times10^5}{1000\times9.8}} \quad ...(\text{By using eq. (i)})$$
$$= \sqrt{600} = 24.495 \text{ ms}^{-1}$$

82 (c) According to Bernoulli's theorem,



$$P + \frac{1}{2}\rho v^2 = P_0 + 0$$
$$\therefore \quad \Delta P = \frac{1}{2}\rho v^2$$
$$F = \Delta P A = \frac{1}{2}\rho v^2 A$$
$$= \frac{1}{2}\times1.2\times40\times40\times250$$
$$= 2.4\times10^5 \text{ N (upwards)}$$

83 (d) As we know that,

$$P_0 + \frac{1}{2}\rho_1 v_1^2 + 0 = P_a + \frac{1}{2}\rho_2 v_2^2 + (\rho_1 g h_1 + \rho_2 g h_2)$$

As, $v_2 << v_1$

$$\therefore \quad v_1 = \sqrt{2g\left(h_1 + h_2\frac{\rho_2}{\rho_1}\right)}$$

84 (b) When liquid water is confined in a tube, its surface (meniscus) has a concave shape because water wets the surface and creeps up the side. Mercury does not wet glass - the cohesive forces within the drops are stronger than the adhesive forces between the drops and glass.

85 (d) Surface tension depends on nature of liquid.

86 (a) Upon heating glass melts into a liquid and tends to acquire a minimum area, i.e., spherical shape.

87 (d) Surface tension is a scalar quantity because it has no specific direction for a given liquid.

88 (c) As we know that,

$$\sigma = \frac{F}{l}$$

So, for this case

$$\sigma = \frac{F}{2l}$$
$$\therefore \quad F = \sigma\times2l$$
$$= 2\times7\times10^{-2}\times2\times10^{-2}$$
$$= 28\times10^{-4}$$

89 (b) Over a small temperature ranges, S.T. of water decreases linearly with rise of temperature.

90 (c) Angle of contact is acute.

91 (c) Excess of pressure in a soap bubble, $P = \frac{4\sigma}{r}$, i.e., $P \propto \frac{1}{r}$, therefore pressure in a smaller bubble is more than that of a bigger bubble. When two bubbles of different radii are in communication, then the air flows from higher pressure to lower pressure, i.e., from smaller bubble into larger one.

92 (d) As we know that,

$$P = \frac{4\sigma}{r} \text{ or } P \propto \frac{1}{r}$$
$$\therefore \quad \frac{P_1}{P_2} = \frac{r_2}{r_1} = \frac{3}{1} \quad ...(i)$$
$$\because \quad \frac{A_1}{A_2} = \frac{4\pi r_1^2}{4\pi r_2^2} = \left(\frac{r_1}{r_2}\right)^2$$
$$= \left(\frac{1}{3}\right)^2 = \frac{1}{9} \quad ...(\text{By using eq. (i)})$$

93 (d) As we know that,

$\sigma = 0.03 \text{ Nm}^{-1}$,

surface area $= 30 \text{ cm}^2 = 30\times10^{-4} \text{ m}^2$

$\because$ W = Surface tension × change in surface area

$\therefore \quad W = 0.03\times2\times30\times10^{-4} = 1.8\times10^{-4} \text{ J}$

94 (c) As we know that,

Force on disc $= \sigma \times$ circumference

$$= 7\times10^{-2}\times2\times\pi\times R$$
$$= 7\times10^{-2}\times2\times\frac{22}{7}\times(20\times10^{-2})$$
$$= 8.8\times10^{-2} \text{ N}$$

95 (d) As we know that,

Pull due to surface tension $= \sigma\times2\times(l+t)$

$$= 0.07\times2(9.8+0.2)\times10^{-2}$$
$$= 14\times10^{-3} \text{ N}$$

96 (b) As we know that,

$$\sigma = \frac{F}{2l} \quad ...(\because \text{ there are two surfaces})$$
$$= \frac{720}{2\times5} = 72 \text{ dyne/cm}$$

97 (c) As we know that,
Energy needed to break a big drop in small drops
= Increment in surface energy n small drops

$$= n4\pi r^2\sigma - 4\pi R^2\sigma = 4\pi\sigma\left(nr^2 - R^2\right)$$

98 (b) As we know that,
Initial surface area $= 2\times \text{length}\times\text{separation}$

$$= 2\times 20\times 0.5 = 20\ \text{cm}^2$$
$$= 20\times 10^{-4}\ \text{m}$$

Final surface area $= 2\times 20\times(0.5+0.1)$

$$= 24\ \text{cm}^2$$
$$= 24\times 10^{-4}\ \text{m}^2$$

$\therefore$ $\quad W = T\times \Delta A$

$$= 0.070\times\left[24\times 10^{-4} - 20\times 10^{-4}\right]$$
$$= 28\times 10^{-6}\ \text{J}$$

99 (b) As we know that,
Work done = Change in area $\times\sigma$

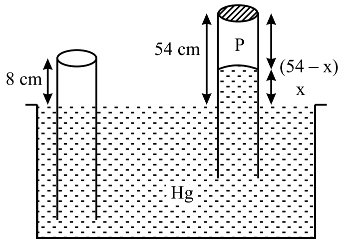
$$= (96-24)\times 30 = 4320\ \text{erg}$$

100 (c) As we know that,

$$\text{Work done} = 8\pi\sigma\left(R_2^2 - R_i^2\right)$$
$$= 2\pi\sigma\left[\left(2R_2\right)^2 - \left(2R_1\right)^2\right]$$
$$= 2\pi\sigma\left(D_2^2 - D_1^2\right)$$
$$= 2\pi\sigma\left((2D)^2 - D^2\right)$$
$$= 2\pi\sigma\left(4D^2 - D^2\right) = 6\pi D^2\sigma$$

High-Order Thinking Skill

1 (a)



Length of the air column above mercury in the tube is,

$$P + x = P_0$$

$\Rightarrow \quad P = (76 - x)$

$\Rightarrow \quad 8\times A\times 76 = (76-x)\times A\times(54-x)$

$\therefore \quad x = 38$

Thus, length of air column,
$= 54 - 38 = 16$ cm

2 (d) As we know that,
Power = rate of production of heat

$$= F\times V$$

$\because \quad F = 6\pi\eta r V_T$ ...(By using Stoke's formula)

$\therefore \quad F = 6\pi\eta r V_T\cdot V_T$

$$= 6\pi\eta r V_T^{\,2}$$

$\because \quad V_T = \dfrac{2}{9}\dfrac{r^2(\rho-\sigma)}{\eta}g$

$\Rightarrow \quad V_T \propto r^2$

$\therefore$ Power $\propto r^5$

3 (b) As we know that,

$$\left[v_c\right] = \left[\eta^x\rho^y r^z\right]$$
$$\left[M^0L^1T^{-1}\right] = \left[M^1L^{-1}T^{-1}\right]^x\left[M^1L^{-3}\right]^y\left[L^1\right]^z$$
$$\left[M^0L^1T^{-1}\right] = \left[M^{x+y}\right]\left[L^{-x-3y+z}\right]\left[T^{-x}\right]$$

Comparing both sides,

$$x + y = 0,$$
$$-x - 3y + z = 1,$$
$$-x = -1$$
$$x = 1$$

$\Rightarrow \quad y = -1$

$$z = -1$$

4 (a) As we know that,
Inflow rate of volume of the liquid = Outflow rate of volume of the liquid

$$\pi R^2 V = n\pi r^2(v)$$

$\Rightarrow \quad v = \dfrac{\pi R^2 V}{n\pi r^2}$

$$= \frac{VR^2}{nr^2}$$

5 (b) As we know that,
$h = h_1 + h_2$ = height of free surface above hole
While at hole, horizontal velocity will be zero,
By using Bernoulli's equation,

$$P + \rho_1 gh_1 + \rho_2 gh_2 = P + \frac{1}{2}\rho_1 v^2$$

$\therefore \quad v = \sqrt{2g\left(\dfrac{\rho_1 h_1 + \rho_2 h_2}{\rho_1}\right)}$

$$v = \sqrt{2g\left(h_1 + h_2\frac{\rho_2}{\rho_1}\right)}$$

6 (c) As we know that,

The excess of pressure above atmospheric pressure, due to surface tension in a bubble $= \frac{4\sigma}{r}$

The surrounding pressure, $P_0 = 8\ N/m^2$

$$\therefore\ P_A \text{ for first bubble } = P_0 + \frac{4\sigma}{r_A}$$

$$= 8 + \frac{4\times 0.04}{0.02}$$

$$P_A = 16\ N/m^2$$

$$P_B = P_0 + \frac{4\sigma}{r_B}$$

$$= 8 + \frac{4\times 0.04}{0.04}$$

$$= 12\ N/m^2$$

$$\because\ PV = nRT$$

$$(16)\left[\frac{4}{3}\pi(0.02)^3\right] = n_A RT$$

$$(12)\left(\frac{4}{3}\pi(0.04)^3\right) = n_B RT$$

$$\frac{n_B}{n_A} = 6$$

7 (b) As we know that,

$$h = \frac{2\sigma\cos\theta}{r\rho g} \quad \text{So that, } h \propto \frac{1}{r}$$

$$\frac{h_2}{h_1} = \frac{r_1}{r_2} \ldots \left(\begin{array}{l}\because r_1 = r,\ r_2 \\ = r + 50\% \text{ of } r = \frac{3}{2}r\end{array}\right) = \frac{2}{3}$$

Now new mass,

$$m_2 = \pi r_2^2 h_2 \rho = \pi\left(\frac{3}{2}r_1\right)^2\left(\frac{2}{3}h_1\right)\rho$$

$$= \frac{3}{2}\left(\pi r_1^2 h_1\right)\rho = \frac{3}{2}m$$

NCERT Exemplar Problems

1 (c) Option (c) represents the correct graph as when a round pebble is dropped from the top of a tall cylinder filled with viscous oil the pebble acquires terminal velocity after some time.

2 (d) Lines of flow do not intersect each other.

3 (b) Along a streamline, the velocity of every fluid particle while crossing a given position is the same.

4 (a) According to equation of continuity,

$$a_1v_1 = a_2v_2 \text{ or } \frac{v_1}{v_2} = \frac{a_2}{a_1}$$

$$= \frac{\frac{\pi d_2^2}{4}}{\frac{\pi d_1^2}{4}} = \left(\frac{d_2}{d_1}\right)^2$$

$$= \left(\frac{3.75}{2.50}\right)^2 = \frac{9}{4}$$

5 (c) If angle of contact is obtuse then the meniscus of liquid in a capillary tube will be convex upwards. It happens when one end of glass capillary tube is immersed in a trough of mercury.

Assertion and Reasons

1 (c) In case of iron needle, the weight of water displaced by the needle is much less than the weight of the needle, hence it sinks but in case of a large iron ship the weight of water displaced by the ship is higher than the weight of the ship, hence it floats in water.

2 (c) When an object is placed in fluid at rest, the fluid always exerts a force normal to the objects surface.

3 (c) A liquid is largely incompressible and its density is constant at all pressures. Gases exhibit a large variation in densities with pressure.

4 (d) A hydraulic lift is an arrangement used to multiply the force. When a force is applied, hydraulic pressure is transmitted in all direction. Thus it works on the principle of Pascal's laws.

$$\text{Pressure} = \frac{\text{Thrust}}{\text{Area}}$$

5 (a) By using Archimedes' Principle
Apparent weight of solid in a liquid = True weight − weight of liquid displaced

6 (a) As we know that,
The constant maximum velocity acquired by a body while falling through viscous fluid is called terminal velocity, $v_t = \frac{2}{9}\frac{r^2(\rho-\sigma)g}{\eta}$.

7 (a) In the flow of fluids, some energy does get lost due to internal friction. This arises due to the fact that in a fluid flow, the different layers of the fluid flow with different velocities. These layers exert frictional forces on each other resulting in a loss of energy.

8 (c) The blood is thicker, i.e., more viscous than water. The viscosity of liquids decreases with temperature while it increases in the case of gases.

9 (d) The viscous force is independent of the density of the body. It depends only on the radius and speed of the body and the viscosity of the fluid in which it moves $(F = 6\pi\eta rv)$.

10 (c) Value of Reynolds number lies between 0 and 2000, the flow of liquid is streamlined or laminar. For values of above 3000, the flow of liquid is turbulent and for values of between 2000 and 3000, the flow of liquid is unstable changing from streamline to turbulent.

11 (d) A streamline is the actual path followed by the procession of particles in a steady flow, which may be straight or curved such that tangent to it at any point indicates the direction of flow of liquid at that point.

12 (d) Bernoulli's equation does not hold for non-steady or turbulent flow of liquid, it is because velocity and pressure are constantly fluctuating with time.

13 (c) Surface tension of oil is less than that of water. So oil spreads on water.