Mechanical Properties of Fluids

OBJECTIVE TYPE QUESTIONS

Multiple Choice Questions (MCQs)

1. The excess pressure inside a spherical drop of water is four times that of another drop. Then their respective mass ratio is

(a) 1 : 16 (b) 8 : 1 (c) 1 : 4 (d) 1 : 64

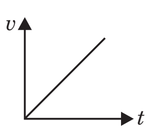
2. The two femurs each of cross-sectional area 10 cm^2 support the upper part of a human body of mass 40 kg. The average pressure sustained by the femurs is (Take g = 10 m s^{-2})

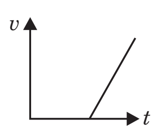
(a) 2×10^3 N m^{-2} (b) 2×10^4 N m^{-2}
(c) 2×10^5 N m^{-2} (d) 2×10^6 N m^{-2}

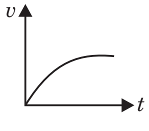
3. Two syringes of different cross section (without needle) filled with water are connected with a tightly fitted rubber tube filled with water. Diameters of the smaller piston and larger piston are 1 cm and 3 cm respectively. If a force of 10 N is applied to the smaller piston then the force exerted on the larger piston is

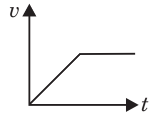
(a) 30 N (b) 60 N (c) 90 N (d) 100 N

4. 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) 

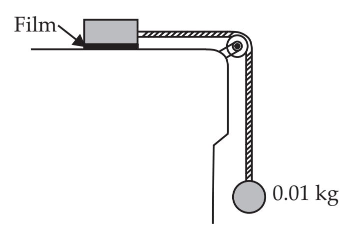
5. The angle of contact at the interface of water-glass is 0°, Ethylalcohol-glass is 0°, mercury-glass is 140° and Methyliodide-glass is 30°. A glass capillary is put in a trough containing one of these four liquids. It is observed that the meniscus is convex. The liquid in the trough is

(a) water (b) ethylalcohol
(c) mercury (d) methyliodide.

6. Water is flowing in a river. If the velocity of a layer at a distance 10 cm from the bottom is 20 cm/s, the velocity of layer at a height of 40 cm from the bottom is

(a) 10 cm/s (b) 20 cm/s (c) 30 cm/s (d) 80cm/s

7. A metal block of area 0.10 m^2 is connected to a 0.010 kg mass via a string that passes over an ideal pulley (considered massless and frictionless) as shown in figure. A liquid with a film thickness of 0.30 mm is placed between the block and the table. When released the block moves to the right with a constant speed of 0.085 m s^{-1}. The coefficient of viscosity of the liquid is (Take g = 9.8 m s^{-2})

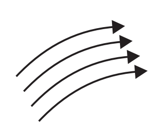


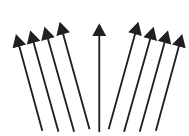
(a) 2.45×10^{-3} Pa s (b) 3.45×10^{-3} Pa s
(c) 6.45×10^{-3} Pa s (d) 7.45×10^{-3} Pa s

8. An aircraft of mass 4×10^5 kg with total wing area 500 m^2 in level flight at a speed of 720 km h^{-1}. The density of air at its height is 1.2 kg m^{-3}. The fractional increase in the speed of the air on the upper surface of its wings relative to the lower surface is (Take g = 10 m s^{-2})

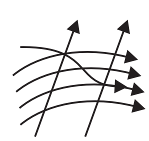
(a) 0.04 (b) 0.08 (c) 0.17 (d) 0.34

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

(a) 

(b) 

(c) 

(d) 

10. Which of the following statements is incorrect?

(a) Blood is more viscous than water.

(b) The blood pressure in humans is greater at the feet than at the brain.

(c) The angle of contact of mercury with glass is obtuse while that of water with glass is acute.

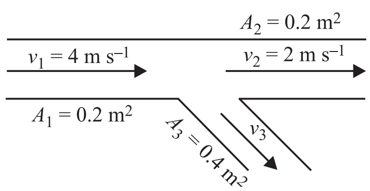
(d) A spinning cricket ball in air follows a parabolic trajectory.

11. The surface tension of soap solution at a temperature 20°C is 2.5×10^{-2} N m^{-1}. The excess pressure inside a bubble of soap solution of radius 6 mm is

(a) 12.5 Pa (b) 14.2 Pa

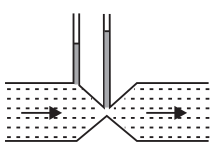
(c) 15.5 Pa (d) 16.7 Pa

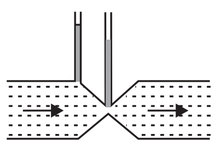
12. In the figure, the velocity v_3 will be

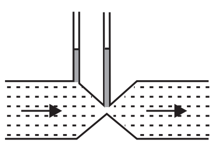


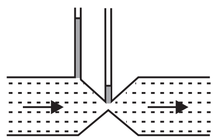
(a) zero (b) 4 m s^{-1} (c) 1 m s^{-1} (d) 3 m s^{-1}

13. Which of the following figure shown below is correct regarding the steady flow of a non viscous liquid?

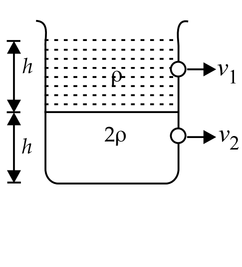
(a) 

(b) 

(c) 

(d) 

14. Equal volume of two immiscible liquids of densities ρ and 2ρ are filled in a vessel as shown in figure. Two small holes are punched at depths $\frac{h}{2}$ and $\frac{3h}{2}$ from the surface of lighter liquid. If v_1 and v_2 are the velocities of efflux at these two holes, then $\frac{v_1}{v_2}$ is



(a) $\frac{1}{2\sqrt{2}}$ (b) $\frac{1}{2}$ (c) $\frac{1}{4}$ (d) $\frac{1}{\sqrt{2}}$

15. 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) $\sqrt{2}:\sqrt{3}$

16. Along a streamline

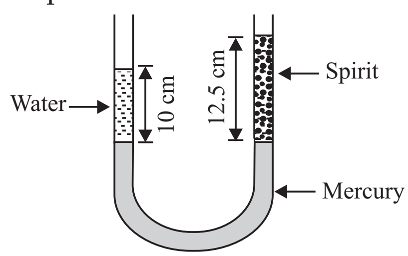
(a) the velocity of a fluid particle remains constant

(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.

17. A U tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are at the same level with 10 cm of water in one arm and 12.5 cm of spirit in the other as shown in figure.



The relative density of the spirit is

(a) 0.6 (b) 0.8 (c) 1.0 (d) 1.25

18. The terminal speed of a sphere of gold (density = 19.5 kg m^{-3}) is 0.2 m s^{-1} in a viscous liquid (density = 1.5 kg m^{-3}). Then the terminal speed of a sphere of silver (density = 10.5 kg m^{-3}) of the same size in the same liquid is

(a) 0.1 m s^{-1} (b) 0.4 m s^{-1}

(c) 0.2 m s^{-1} (d) 0.3 m s^{-1}

19. 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) Stokes' law

(c) Bernoulli's principle

(d) Archimede's principle

20. The flow rate of water from a tap of diameter 1.25 cm is 3 L per min. The coefficient of viscosity of water is 10^{-3} Pa s. The nature of the flow is

(a) Unsteady (b) Turbulent
(c) Laminar (d) None of these

21. The rate of flow of a liquid through a capillary tube of radius *r* is *V* when the pressure difference across the two ends of the capillary is *P*. If pressure is increased by 3*P* and radius is reduced to $\frac{r}{2}$, then the rate of flow becomes

(a) $\frac{V}{8}$ (b) $\frac{V}{4}$ (c) $\frac{V}{2}$ (d) $\frac{V}{9}$

22. A plane is in level fight at constant speed and each of its two wings has an area of 25 m^2. If the speed of the air on the upper and lower surfaces of the wing are 270 km h^{-1} and 234 km h^{-1} respectively, then the mass of the plane is (Take the density of the air = 1 kg m^{-3})
(a) 1550 kg (b) 1750 kg
(c) 3500 kg (d) 3200 kg

23. Iceberg floats in sea water with a part of it submerged. The percentage fraction of the ice berg above sea is (Density of ice = 0.9 g cm^{-3}, density of sea water = 1.1 g cm^{-3})
(a) 18% (b) 12% (c) 10% (d) 8%

24. The water flows from a tap of diameter 1.25 cm with a rate of 5×10^{-5} m^3 s^{-1}. The density and coefficient of viscosity of water are 10^3 kg m^{-3} and 10^{-3} Pa s respectively. The flow of water is
(a) steady with Reynolds number 5100
(b) turbulent with Reynolds number 5100
(c) steady with Reynolds number 3900
(d) turbulent with Reynolds number 3900

25. A cylindrical vessel is filled with water up to height *H*. A hole is bored in the wall at a depth *h* from the free surface of water. For maximum range, *h* is equal to

(a) $\frac{H}{4}$ (b) $\frac{H}{2}$ (c) $\frac{3H}{4}$ (d) H

26. Water rises in a capillary tube to a height of 2.0 cm. In another capillary tube whose radius is one-third of it, how much the water will rise?
(a) 5 cm (b) 3 cm (c) 6 cm (d) 9 cm

27. The cylindrical tube of a spray pump has a cross-section of 6 cm^2 one of which has 50 holes each of diameter 1 mm. If the liquid flow inside the tube is 1.2 m per minute, then the speed of ejection of the liquid through the holes is
(a) 2.1 m s^{-1} (b) 0.31 m s^{-1}
(c) 0.96 m s^{-1} (d) 3.4 m s^{-1}

28. The force acting on a window of area 50 cm × 50 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 kg m^{-3}, g = 10 m s^{-2})
(a) 5×10^5 N (b) 25×10^5 N
(c) 5×10^6 N (d) 25×10^6 N

29. 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) $\frac{R^2}{2h}$ (c) $\frac{R^2}{4h}$ (d) $\frac{4R^2}{h}$

30. A horizontal pipe line carries water in a streamline flow. At a point along the pipe where the cross sectional area is 10 cm^2, the water velocity is 1 m/s and the pressure is 2000 Pa. What is the pressure of water at another point when the cross-sectional area is 5 cm^2?
(a) 200 Pa (b) 300 Pa (c) 400 Pa (d) 500 Pa

31. A capillary tube is taken from the earth to the surface of the moon. The rise of the liquid column on the moon, if acceleration due to gravity on the earth is 6 times that of the moon, is
(a) six times that on the earth's surface
(b) 1/6 that on the earth's surface
(c) equal to that on the earth's surface
(d) zero.

32. A metal ball B_1 (density 3.2 g cm^{-3}) is dropped in water while another metal ball B_2 (density 6.0 g cm^{-3}) is dropped in a liquid of density 1.6 g cm^{-3}. If both the balls have the same diameter and attain the same terminal velocity, the ratio of viscosity of water to that of the liquid is
(a) 2.0
(b) 0.5
(c) 4.0
(d) indeterminate due to insufficient data

33. Eight drops of water, each of radius 2 mm are falling through air at a terminal velocity of 8 cm s^{-1}. If they coalesce to form a single drop, then the terminal velocity of combined drop will be
(a) 32 cm s^{-1} (b) 30 cm s^{-1}
(c) 28 cm s^{-1} (d) 24 cm s^{-1}

34. The radii of two columns in a U tube are r_1 and r_2. When a liquid of density ρ (angle of contact is 0°) is filled in it, the difference in levels of liquid in two arms is h. The surface tension of liquid is (g = acceleration due to gravity)

(a) $\frac{\rho g h r_1 r_2}{2(r_2 - r_1)}$ (b) $\frac{\rho g h(r_2 - r_1)}{2 r_1 r_2}$

(c) $\frac{2(r_2 - r_1)}{\rho g h r_1 r_2}$ (d) $\frac{\rho g h}{2(r_2 - r_1)}$

35. A metallic sphere of mass M falls through glycerine with a terminal velocity v. If we drop a ball of mass $8M$ of same metal into a column of glycerine, the terminal velocity of the ball will be

(a) $2v$ (b) $4v$ (c) $8v$ (d) $16v$

36. Two capillaries of same length and radii in the ratio 1 : 2 are connected in series. A liquid flows through them in streamlined condition. If the pressure across the two extreme ends of the combination is 1 m of water, the pressure difference across first capillary is

(a) 9.4 m (b) 4.9 m (c) 0.49 m (d) 0.94 m

37. If W_1 be the work to be done to form a bubble of volume V from a given solution. The work required to be done to form a bubble of volume $2\,V$ is

(a) $4^{2/3}\,W_1$ (b) $4^{1/3}\,W_1$ (c) $2^{1/2}\,W_1$ (d) $2^{3/2}\,W_1$

38. A piece of solid weighs 120 g in air, 50 g in water and 60 g in a liquid. The relative density of the solid and that of the liquid are respectively

(a) $2, \frac{1}{2}$ (b) $2, \frac{3}{2}$ (c) $3, \frac{1}{2}$ (d) $3, \frac{3}{2}$

Case Based MCQs

Case I : Read the passage given below and answer the following questions from 39 to 43.

Surface Tension

The property due to which the free surface of liquid tends to have minimum surface area and behaves like a stretched membrane is called surface tension. It is a force per unit length acting in the plane of interface between the liquid and the bounding surface *i.e.*, $S = \frac{F}{L}$, where F = force acting on either side of imaginary line on surface and L = length of imaginary line.

Surface tension decreases with rise in temperature. Highly soluble impurities increases surface tension and sparingly soluble impurities decreases surface tension.

39. 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) 9 : 1 (b) 1 : 3 (c) 1 : 9 (d) 3 : 1

40. 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 is a vector quantity.
(c) Surface tension of liquid is a molecular phenomenon.
(d) Surface tension of liquid depends on length but not on the area.

41. Which of the following statement is not true about angle of contact?

(a) The value of angle of contact for pure water and glass is zero.
(b) Angle of contact increases with increase in temperature of liquid.
(c) If the angle of contact of a liquid and a solid surface is less than 90°, then the liquid spreads on the surface of solid.
(d) Angle of contact depend upon the inclination of the solid surface to the liquid surface.

42. Which of the following statements is correct?

(a) Viscosity is a vector quantity.
(b) Surface tension is a vector quantity.
(c) Reynolds number is a dimensionless quantity.
(d) Angle of contact is a vector quantity.

43. A liquid does not wet the solid surface if the angle of contact is

(a) 0° (b) equal to 45°
(c) equal to 90° (d) greater than 90°

Case II : Read the passage given below and answer the following questions from 44 to 46.

Bernoulli's Theorem

It states that for the streamline flow of an ideal liquid through a tube, the total energy (the sum of pressure energy, the potential energy and kinetic energy) per unit volume remains constant at every cross-section throughout the tube.

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

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

Here, $\dfrac{P}{\rho g}$ = pressure head;

h = potential head and $\dfrac{1}{2}\dfrac{v^2}{g}$ = velocity head.

If the liquid is flowing through a horizontal tube, then h is constant, then according to Bernoulli's theorem,

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

Bernoulli's theorem is based on law of conservation of energy.

44. Bernoulli's equation for steady, non-viscous, incompressible flow expresses the
(a) conservation of linear momentum
(b) conservation of angular momentum
(c) conservation of energy
(d) conservation of mass

45. Applications of Bernoulli's theorem can be seen in
(a) dynamic lift of aeroplane
(b) hydraulic press
(c) helicopter
(d) none of these

46. A tank filled with fresh water 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)

Assertion & Reasoning Based MCQs

For question numbers 47-55, two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is NOT the correct explanation of A
(c) A is true but R is false
(d) A is false and R is also false

47. Assertion (A) : The blood pressure in humans is greater at the feet than at the brain.
Reason (R) : Pressure of liquid at any point is proportional to height, density of liquid and acceleration due to gravity.

48. Assertion (A) : To float, a body must displace liquid whose weight is equal to the actual weight of the body.
Reason (R) : The body will experiences no net downward force, in the case of floating.

49. Assertion (A) : A man sitting in a boat which is floating on a pond. If the man drinks some water from the pond, the level of the water in the pond remain unchanged.
Reason (R) : According to Archimedes' principle the weight of water displaced by body is equal to the weight of the body, if the body is floating.

50. Assertion (A) : When height of a tube is less than liquid rise in the capillary tube, the liquid does not overflow.
Reason (R) : Product of radius of meniscus and height of liquid in the capillary tube is always one.

51. Assertion (A) : The size of the needle of a syringe controls flow rate better than the thumb pressure exerted by a doctor while administering an injection.
Reason (R) : Flow rate is independent of pressure exerted by the thumb of the doctor.

52. Assertion (A) : A fluid flowing out of a small hole in a vessel apply a backward thrust on the vessel.
Reason (R) : According to equation of continuity, the product of area and velocity remain constant.

53. Assertion (A) : For a floating body to be in stable equilibrium, its centre of buoyancy must be located above the centre of gravity.
Reason (R) : The torque required by the weight of the body and the upthrust will restore body back to its normal position, after the body is disturbed.

54. Assertion (A) : The impurities always decrease the surface tension of a liquid.
Reason (R) : The change in surface tension of the liquid depends upon the degree of contamination of the impurity.

55. Assertion (A) : The viscosity of liquid decreases rapidly with rise of temperature.
Reason (R) : Viscosity of a liquid is the property of the liquid by virtue of which it opposes the relative motion amongst its different layers.

SUBJECTIVE TYPE QUESTIONS

Very Short Answer Type Questions (VSA)

1. Why does velocity increase when water flowing in a broad pipe enters a narrow pipe?

2. What is reciprocal of viscosity known as?

3. It is painful to walk barefooted on the ground covered with edged pebbles. Why?

4. Why two ships moving in parallel directions close to each other get attracted?

5. When air is blown between two balls suspended close to each other they are attracted towards each other. Why?

6. Does it matter if one uses gauge instead of absolute pressures in applying Bernoulli's equation? Explain.

7. What is the net weight of a body when it falls with terminal velocity through a viscous medium?

8. Two soap bubbles have radii in the ratio 2 : 3. Find the ratio of the work done in blowing these bubbles.

9. The diameter of ball A is half of that of ball B. What will be the ratio of their terminal velocities in water if all the factors remain same?

10. What is the effect of temperature on surface tension?

Short Answer Type Questions (SA-I)

11. A 50 kg girl wearing high heel shoes balances on a single heel. The heel is circular with a diameter 1.0 cm. What is the pressure exerted by the heel on the horizontal floor?

12. Explain why, when we try to close a water tap with our fingers, fast jets of water gush through the openings between our fingers?

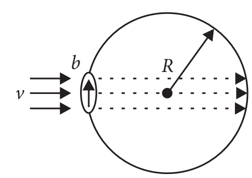
13. On what principle working of hydraulic brakes are based? State that principle.

14. Explain, why a fluid flowing out of a small hole in a vessel results in a backward thrust on the vessel?

15. The excess pressure inside a soap bubble is thrice the excess pressure inside a second soap bubble. What is the ratio between the volume of the first and the second bubble?

16. Why the passengers are advised to remove the ink from their pens while going up in an aeroplane?

17. A bubble having surface tension S and radius R is formed on a ring of radius b ($b << R$). Air is blown inside the tube with velocity v as shown. The air molecule collides perpendicularly with the wall of the bubble and stops. Calculate the radius at which the bubble separates from the ring.



18. Why two streamlines cannot intersect each other?

19. In streamline flow, water entering a pipe having diameter of 2 cm and the speed of water is 1.0 m s^{-1}. Eventually, the pipe tapers to a diameter of 1 cm. Calculate the speed of water where diameter of pipe is 1 cm.

20. What is the importance of Reynold's number?

Short Answer Type Questions (SA-II)

21. An air bubble of diameter 2 mm rises steadily through a solution of density 1750 kg m^{-3} at the rate of 0.35 cm s^{-1}. Calculate the coefficient of viscosity of the solution. The density of air is negligible.

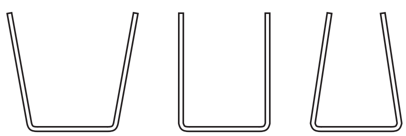
22. A vessel filled with water is kept on a weighing pan and the scale adjusted to zero. A block of mass M and density ρ is suspended by a massless spring of spring constant k. This block is submerged inside the water in the vessel. What is the reading of the scale?

23. The sap in trees, which consists mainly of water in summer, rises in a system of capillaries of radius $r = 2.5 \times 10^{-5}$ m. The surface tension of sap is $T = 7.28 \times 10^{-2}$ N m^{-1} and the angle of contact is 0°. Does surface tension alone account for the supply of water to the top of all trees?

24. The drop of liquid of density ρ is floating with $\frac{1}{4}$th inside the liquid A of density ρ_1 and remaining in the liquid B of density ρ_2. Then, find the relation between the densities of liquid A and B.

25. A vertical off-shore structure is built to withstand a maximum stress of 10^9 Pa. Is the structure suitable for putting up on top of an oil well in the ocean? Take the depth of the ocean to be roughly 3 km, and ignore ocean currents.

26. (a) The three vessels shown in the given figure are filled with water. The three vessels have same base area.



In which vessel, will the force on the base be minimum if,

(i) the vessels are filled to the same height.

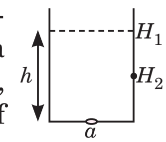
(ii) the vessels are filled with equal volumes of water.

Give reason for your answer.

(b) An air bubble at the bottom of a lake rises to the sea level. What happens to its radius? Give reasons :

27. Water from a tap emerges vertically downwards with an initial velocity v_0. Assume pressure is constant throughout the stream of water and the flow is steady, find the distance from the tap at which cross-sectional area of stream is half of the cross-sectional area of stream at the tap.

28. A vessel having area of cross-section A contains a liquid upto a height h. At the bottom of the vessel, there is a small hole having area of cross-section a. Then what is the time taken for the liquid level to fall from height H_1 to H_2?



29. A frame made of metallic wire enclosing a surface area A is covered with a soap film. If the area of the frame of metallic wire is reduced by 50%. What will be the change in the energy of the soap film?

30. A Venturimeter introduces a constriction of cross-sectional area A_2 in a pipe of cross-sectional area A_1. The meter records the difference in pressure, $P_1–P_2$, between the ordinary fluid pressure, P_1 and the pressure at the constriction, P_2. From this, find the fluid speed in the unconstricted pipe.

31. Show that the Reynold's number represents the ratio of the inertial force per unit area to the viscous force per unit area.

33. Derive an expression for the pressure difference across the soap bubble.

33. (a) What is the largest average velocity of blood flow in an artery of radius 2×10^{-3} m if the flow must remain laminar?

(b) What is the corresponding flow rate? (Take viscosity of blood to be 2.084×10^{-3} Pa s and density of blood is 1.06×10^3 kg/m^3).

Long Answer Type Questions (LA)

34. What is a tube of flow? Obtain a relation between the area of cross-section and the velocity of liquid at any point in a tube of flow. What conclusion do you draw from it?

35. Derive the ascent formula for rise of liquid in capillary tube. What will happen, if the length of the capillary tube is smaller than the height to which the liquid rises. Explain.

36. Explain how a small spherical rigid body attains terminal velocity while falling through a viscous liquid. Hence derive an expression for the terminal speed.

37. (a) Show that the pressure exerted by a liquid column is proportional to its height.

(b) State Pascal's law.

ANSWERS

OBJECTIVE TYPE QUESTIONS

1. (d) : Excess pressure inside the liquid drop,

$P = \frac{2S}{R}$, where S is the surface tension and R its radius.

$\therefore \quad P_1 = \frac{2S}{R_1}$ and $P_2 = \frac{2S}{R_2}$

But $P_1 = 4P_2$ (Given)

$\therefore \quad \frac{2S}{R_1} = 4\left(\frac{2S}{R_2}\right)$ or $\frac{R_1}{R_2} = \frac{1}{4}$

If ρ is the density of water, then

$m_1 = \frac{4}{3}\pi R_1^3 \rho$ and $m_2 = \frac{4}{3}\pi R_2^3 \rho$

$\therefore \quad \frac{m_1}{m_2} = \left(\frac{R_1}{R_2}\right)^3 = \left(\frac{1}{4}\right)^3 = \frac{1}{64}$

2. (c) : Total cross-sectional area of the femurs is,

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

Force acting on them is

$F = mg = 40\ \text{kg} \times 10\ \text{m s}^{-2} = 400\ \text{N}$

$\therefore$ Average pressure sustained by them is

$$P = \frac{F}{A} = \frac{400\ \text{N}}{20 \times 10^{-4}\ \text{m}^2} = 2 \times 10^5\ \text{N m}^{-2}$$

3. (c) : Since pressure is transmitted undiminished throughout the water

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

where F_1 and F_2 are the forces on the smaller and on the larger pistons respectively and A_1 and A_2 are the respective areas.

$$\therefore \quad F_2 = \frac{A_2}{A_1}F_1 = \frac{\pi(D_2/2)^2}{\pi(D_1/2)^2}F_1 = \left(\frac{D_2}{D_1}\right)^2 F_1$$

$$= \frac{\left(3 \times 10^{-2}\ \text{m}\right)^2}{\left(1 \times 10^{-2}\ \text{m}\right)^2} \times 10\ \text{N} = 90\ \text{N}$$

4. (c) : 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. Hence option (c) represents the correct graph.

5. (c) : The meniscus of liquid in a capillary tube will be convex upwards if angle of contact is obtuse. It is so when one end of glass capillary tube is immersed in a trough of mercury.

6. (d) : As $F = -\eta A \frac{dv}{dx}$

$\therefore \quad F \propto \frac{dv}{dx}$ or $F \propto \frac{\Delta v}{\Delta x}$

or $\quad F \propto \frac{v}{x}$ (since, velocity of the layer at the bottom is zero)

or $x \propto \frac{v}{F}$

But F is constant, so $x \propto v$

$\therefore \quad \frac{v_2}{v_1} = \frac{x_2}{x_1}$ or $\frac{v_2}{20} = \frac{40}{10}$ or $v_2 = 80$ cm/s

7. (b) : The metal block moves to the right due to the tension T in the string, which is equal to the weight of the suspended mass m at the end of the string. Thus the shear force F is

$F = T = mg = 0.010\ \text{kg} \times 9.8\ \text{m s}^{-2} = 9.8 \times 10^{-2}\ \text{N}$

Shear stress on the fluid $= \frac{F}{A} = \frac{9.8 \times 10^{-2}\ \text{N}}{0.10\ \text{m}^2}$

Strain rate $= \frac{v}{l} = \frac{0.085\ \text{ms}^{-1}}{0.30 \times 10^{-3}\ \text{m}}$

$$\eta = \frac{\text{Shear stress}}{\text{Strain rate}} = \frac{(9.8 \times 10^{-2}\ \text{N})(0.30 \times 10^{-3}\ \text{m})}{(0.085\ \text{m s}^{-1})(0.10\ \text{m}^2)}$$

$$= 3.45 \times 10^{-3}\ \text{Pa s}$$

8. (c) : The weight of the aircraft is balanced by the upward force due to the pressure difference.

i.e., $\Delta PA = mg$

$$\Delta P = \frac{mg}{A} = \frac{(4 \times 10^5\ \text{kg})(10\ \text{m s}^{-2})}{500\ \text{m}^2} = \frac{4}{5} \times 10^4\ \text{N m}^{-2}$$

$$= 8 \times 10^3\ \text{N m}^{-2}$$

Let v_1, v_2 are the speed of air on the lower and upper surface of the wings of the aircraft and P_1, P_2 are the pressures there.

Using Bernoulli's theorem, we get

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

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

$$\Delta P = \frac{\rho}{2}(v_2 + v_1)(v_2 - v_1) = \rho v_{av}(v_2 - v_1)$$

or $\quad v_2 - v_1 = \frac{\Delta P}{\rho v_{av}}$

Here, $v_{av} = \dfrac{v_1+v_2}{2} = 720\,\text{km h}^{-1}$

$= 720\times\dfrac{5}{18}\,\text{m s}^{-1} = 200\text{ m s}^{-1}$

$$\therefore\quad \frac{v_2-v_1}{v_{av}} = \frac{\Delta P}{\rho v_{av}^2} = \frac{\frac{4}{5}\times 10^4}{1.2\times(200)^2}$$

$$= \frac{4\times10^4}{5\times1.2\times4\times10^4} = 0.1$$

9. **(d) :** Lines of flow do not intersect each other.

10. **(d) :** As $\eta_{blood} > \eta_{water}$, therefore blood is more viscous than water.

Hence, option (a) is a correct statement.

The height of the blood column in the human body is more at feet than at the brain. Consequently, the blood pressure in humans is greater at the feet than in the brain.

Hence, option (b) is correct statement.

The angle of contact with mercury with glass is obtuse while that of water with glass is acute.

Hence option (c) is a correct statement.

A spinning cricket ball in air does not follow a parabolic trajectory.

Hence, option (d) is an incorrect statement.

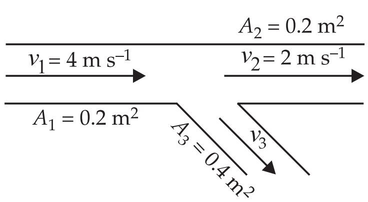
11. **(d) :** Here, surface tension, $S = 2.5\times10^{-2}\text{ N m}^{-1}$

$r = 6\text{ mm} = 6\times10^{-3}\text{ m}$

Excess pressure inside the soap bubble,

$$P = \frac{4S}{r} = \frac{4\times2.5\times10^{-2}}{6\times10^{-3}} = 16.7\,\text{Pa}$$

12. **(c) :**



According to steady flow,

$A_1v_1 = A_2v_2 + A_3v_3$

or $A_3v_3 = A_1v_1 - A_2v_2$

or $v_3 = \dfrac{1}{A_3}[A_1v_1 - A_2v_2]$

$= \dfrac{1}{0.4}[0.2\times4 - 0.2\times2] = 1\,\text{m s}^{-1}$

13. **(a) :** By equation of continuity

$Av = \text{constant}$ ...(i)

where A is the area of cross-section of tube and v is the velocity of flow.

From (i) it is clear that, when area of cross section of tube is less, the velocity of the liquid flow is more.

So the velocity of liquid flow of a constriction of tube is more than the other portion of tube.

By Bernoulli's theorem $P + \dfrac{1}{2}\rho v^2$ = constant.

Therefore if v is more, P is less and vice versa

14. **(d) :** $v_1 = \sqrt{2g\left(\dfrac{h}{2}\right)} = \sqrt{gh}$

Using Bernoulli's theorem, we get

$P_a + \rho gh + 2\rho g\left(\dfrac{h}{2}\right) = P_a + \dfrac{1}{2}(2\rho)v_2^2$ or $v_2 = \sqrt{2gh}$

$\therefore\quad \dfrac{v_1}{v_2} = \dfrac{1}{\sqrt{2}}$

15. **(a) :** According to equation of continuity $A_1v_1 = A_2v_2$

$$\frac{v_1}{v_2} = \frac{A_2}{A_1} = \frac{\pi D_2^2/4}{\pi D_1^2/4} = \left(\frac{D_2}{D_1}\right)^2$$

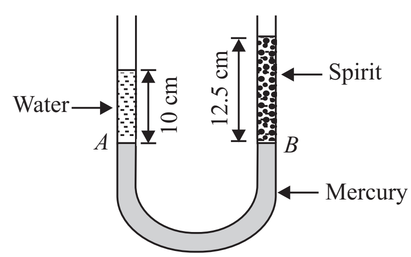
Here, D_1 = 2.5 cm, D_2 = 3.75 cm

$$\therefore\quad \frac{v_1}{v_2} = \left(\frac{3.75}{2.5}\right)^2 = \left(\frac{3}{2}\right)^2 = \frac{9}{4}$$

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

17. **(b) :** Refer figure.

As the mercury columns in the two arms of U tube are at the same level, therefore



Pressure due to water = Pressure due to spirit column

$\rho_w h_w g = \rho_s h_s g$

$\rho_s = \dfrac{h_w}{h_s}\rho_w$

$\therefore$ Relative density of spirit $= \dfrac{\rho_s}{\rho_w} = \dfrac{h_w}{h_s} = \dfrac{10\text{ cm}}{12.5\text{ cm}} = 0.8$

18. **(a) :** The terminal speed of a spherical body of radius r, density ρ falling through a medium of density σ is given by

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

where η is the coefficient of viscosity of the medium.

$\therefore \quad v_g = \frac{2}{9}\frac{r_g^2(\rho_g - \sigma_{\text{liquid}})g}{\eta_{\text{liquid}}}$ and $v_s = \frac{2}{9}\frac{r_s^2(\rho_s - \sigma_{\text{liquid}})g}{\eta_{\text{liquid}}}$

where the subscripts g and s represent gold and silver spheres respectively.

Since both the spheres are of same size and falling in the same liquid,

$$\therefore \quad \frac{v_g}{v_s} = \frac{\rho_g - \sigma_{\text{liquid}}}{\rho_s - \sigma_{\text{liquid}}} = \frac{(19.5-1.5)\,\text{kg m}^{-3}}{(10.5-1.5)\,\text{kg m}^{-3}} = \frac{18}{9} = 2$$

or $\quad v_s = \frac{v_g}{2} = \frac{0.2}{2}\text{ m s}^{-1} = 0.1\text{ m s}^{-1}$

19. (c) : According to equation of continuity, av = 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, $P + \frac{1}{2}\rho v^2$ = a constant

It means, as velocity decreases, pressure increases.

Thus, when arteries become narrow, blood pressure increases.

20. (b) : Here, diameter of the tap,

$D = 1.25$ cm $= 1.25 \times 10^{-2}$ m

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

Coefficient of viscosity, $\eta = 10^{-3}$ Pa s

Volume of water flowing out per second is

$$Q = 3\text{ L per min} = \frac{3\times10^{-3}\text{ m}^3}{60\text{ s}} = 5\times10^{-5}\text{ m}^3\text{ s}^{-1}$$

Reynolds number is given by

$$R_e = \frac{4\rho Q}{\pi D\eta} = \frac{4\times10^3\text{ kg m}^{-3}\times5\times10^{-5}\text{ m}^3\text{ s}^{-1}}{3.14\times1.25\times10^{-2}\text{ m}\times10^{-3}\text{ Pa s}}$$

$= 5095 > 2000$

Thus, the flow will be turbulent.

21. (b) : According to Poiseuille's equation

$$V = \frac{\pi P r^4}{8\eta l} \quad \text{...(i)}$$

$$V' = \frac{\pi(4P)\left(\frac{r}{2}\right)^4}{8\eta l} \quad \text{...(ii)}$$

Divide (ii) by (i), we get $\frac{V'}{V} = \frac{4}{16} = \frac{1}{4}$ or $V' = \frac{V}{4}$

22. (c) : Let v_1, v_2 are the speed of air on the lower and upper surface S of the wings of the plane P_1 and P_2 are the pressure there.

According to Bernoulli's theorem

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

$$P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$$

Here, $v_1 = 234\text{ km h}^{-1} = 234\times\frac{5}{18}\text{ m s}^{-1} = 65\text{ m s}^{-1}$

$$v_2 = 270\text{ km h}^{-1} = 270\times\frac{5}{18} = 75\text{ m s}^{-1}$$

Area of wings $= 2 \times 25$ m^2 $= 50$ m^2

$$\therefore \quad P_1 - P_2 = \frac{1}{2}\times1(75^2 - 65^2)$$

Upward force on the plane $= (P_1 - P_2)\,A$

$$= \frac{1}{2}\times1\times(75^2 - 65^2)\times50\text{ m}^2$$

As the plane is in level flight, therefore upward force balances the weight of the plane.

$\therefore \quad mg = (P_1 - P_2)\,A$

Mass of the plane, $m = \frac{(P_1 - P_2)}{g}A$

$$= \frac{1}{2}\times\frac{1\times(75^2-65^2)}{10}\times50$$

$$= \frac{(75+65)(75-65)\times50}{2\times10}$$

$= 3500$ kg

23. (a) : V be the volume of the iceberg, x be the volume out of sea water.

The iceberg is floating in sea water then

$V\rho_{\text{ice}}\,g = (V - x)\,\rho_{\text{sea water}}\,g$

or $\quad V \times 0.9 \times g = (V - x)\ 1.1\ g$

or $\quad 0.9\text{ V} = 1.1\ V - 1.1x$

$0.2\text{ V} = 1.1x$

$$\therefore \quad \frac{x}{V} = \frac{0.2}{1.1}$$

Percentage of fraction of the volume of iceberg above the level of sea water

$$\frac{x}{V}\times100 = \frac{0.2}{1.1}\times100 = 18\%$$

24. (b) : Here, diameter, $D = 1.25$ cm $= 1.25 \times 10^{-2}$ m

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

Coefficient of viscosity, $\eta = 10^{-3}$ Pa s

Rate of flow of water, $Q = 5 \times 10^{-5}$ m^3 s^{-1}

Reynolds number, $N_R = \frac{v\rho D}{\eta} \quad$ ...(i) where v is the speed of flow.

Rate of flow of water Q = area of cross section × speed of flow

$$Q=\frac{\pi D^2}{4}\times v \quad \text{or} \quad v=\frac{4Q}{\pi D^2}$$

Substituting the value of v in eqn (i), we get

$$N_R=\frac{4Q\rho D}{\pi D^2\eta}=\frac{4Q\rho}{\pi D\eta}$$

$$=\frac{4\times5\times10^{-5}\times10^{3}}{\left(\frac{22}{7}\right)\times1.25\times10^{-2}\times10^{-3}}\approx5100$$

For $N_R > 3000$, the flow is turbulent.

Hence, the flow of water is turbulent with Reynolds number 5100.

25. (b) : Velocity of water flowing out of hole, $v=\sqrt{2gh}$

Height of hole from ground level = $(H-h)$.

The time taken by water to cover vertical distance $(H-h)$ is given by

$$(H-h)=\frac{1}{2}gt^2 \quad \text{or} \quad t=\sqrt{\frac{2(H-h)}{g}}$$

Horizontal range,

$$R=vt=\sqrt{2gh}\times\sqrt{\frac{2(H-h)}{g}}=2\sqrt{h(H-h)}$$

Horizontal range will be maximum if $\frac{dR}{dh}=0$

i.e. $2\times\frac{1}{2}(hH-h^2)^{-1/2}\times(H-2h)=0$

or $H=2h$ or $h=\frac{H}{2}$

26. (c) : According to ascent formula, $h=\frac{2S\cos\theta}{r\rho g}$

For a given liquid, $hr=\frac{2S\cos\theta}{\rho g}=\text{constant}$

$\therefore \quad h_1r_1=h_2r_2$

or $h_2=\frac{h_1r_1}{r_2}=\frac{(2.0)(r_1)}{(r_1/3)}$ = (2.0)(3) = 6.0 cm

27. (b) : Here, area of cross section of tube

$a_1 = 6\text{ cm}^2 = 6\times10^{-4}\text{ m}^2$

Number of holes = 50

Diameter of each hole, $D = 1\text{ mm} = 10^{-3}\text{ m}$

Radius of hole, $r=\frac{D}{2}=\frac{1}{2}\times10^{-3}=5\times10^{-4}\text{ m}$

Area of cross-section of each hole

$=\pi r^2=\pi(5\times10^{-4})^2\text{ m}^2$

Total area of cross-section of 50 holes,

$a_2=50\times\pi(5\times10^{-4})^2\text{ m}^2$

Speed of liquid inside the tube,

$v_1 = 1.2\text{ m min}^{-1}$

$$=\frac{1.2}{60}\text{ m s}^{-1}=0.02\text{ m s}^{-1}$$

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

As $a_1v_1 = a_2v_2$

or $v_2=\frac{a_1v_1}{a_2}=\frac{6\times10^{-4}\times0.02}{50\times\pi(5\times10^{-4})^2}=0.31\text{ m s}^{-1}$

28. (c) : Here, $h = 2000$ m, $\rho = 10^3\text{ kg m}^{-3}$, $g = 10\text{ m s}^{-2}$

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, $P_g = P - P_a = \rho gh$

$= 10^3\text{ kg m}^{-3}\times10\text{ m s}^{-2}\times2000\text{ m} = 2\times10^7\text{ Pa}$

Area of a window is

$A = 50\text{ cm}\times50\text{ cm} = 2500\times10^{-4}\text{ m}^2$

Force acting on the window is

$F = P_gA = 2\times10^7\text{ Pa}\times2500\times10^{-4}\text{ m}^2 = 5\times10^6\text{ N}$

29. (c) : From Torricelli's theorem, $v=\sqrt{(2gd)}$

Time t to hit the ground is given by $h=\frac{1}{2}gt^2$ or $t=\sqrt{\frac{2h}{g}}$

$\therefore \quad R=vt=\sqrt{(2gd)}\sqrt{\frac{2h}{g}}=2\sqrt{dh}$ or $d=\frac{R^2}{4h}$

30. (d) : According to equation of continuity

$$A_1v_1=A_2v_2, \quad \text{or} \quad v_2=\frac{A_1}{A_2}v_1=\frac{10}{5}\times1=2\text{ m/s}$$

Now according to Bernoulli's equation,

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

$$2000+\frac{1}{2}\times10^3\times1^2=P_2+\frac{1}{2}\times10^3\times2^2$$

On solving, we get $P_2 = 500$ Pa

31. (a) : Rise of liquid in a capillary tube, $h=\frac{2s\cos\theta}{r\rho g}$

$$h\propto\frac{1}{g}$$

$$\therefore \quad \frac{h_{moon}}{h_{earth}} = \frac{g_{earth}}{g_{moon}} = \frac{6g_{moon}}{g_{moon}} = 6$$

$$h_{moon} = 6h_{earth}$$

32. (b) : The terminal velocity of the body of radius r, density ρ falling through a medium of density σ is given by

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

where η is the coefficient of viscosity of the medium

$$\therefore \quad v_{B_1} = \frac{2}{9}\frac{r_{B_1}^2}{\eta_{water}}(\rho_{B_1}-\sigma_{water})g \qquad \text{...(i)}$$

$$\text{and} \quad v_{B_2} = \frac{2}{9}\frac{r_{B_2}^2}{\eta_{liquid}}(\rho_{B_2}-\sigma_{liquid})g \qquad \text{...(ii)}$$

where the subscripts B_1 and B_2 represent metal ball B_1 and metal ball B_2 respectively.

$\because \quad r_{B_1} = r_{B_2}$ and $v_{B_1} = v_{B_2}$ (Given)

Substituting these values in (i) and (ii), we get

$$\frac{\eta_{water}}{\eta_{liquid}} = \frac{(\rho_{B_1}-\sigma_{water})}{(\rho_{B_2}-\sigma_{liquid})}$$

Substituting the given values, we get

$$\frac{\eta_{water}}{\eta_{liquid}} = \frac{(3.2-1)}{(6.0-1.6)} \quad (\because \text{Density of water} = 1\text{ g cm}^{-3})$$

$$= \frac{2.2}{4.4} = 0.5$$

33. (a) : Let the radius of bigger drop is R and smaller drop is r then

$$\frac{4}{3}\pi R^3 = 8\times\frac{4}{3}\times\pi r^3$$

or $\quad R = 2r \qquad$ ...(i)

Terminal velocity, $v \propto r^2$

$$\therefore \quad \frac{v'}{v} = \frac{R^2}{r^2} = \left(\frac{2r}{r}\right)^2 = 4 \qquad \text{(Using (i))}$$

or $\quad v' = 4v = 4 \times 8 = 32$ cm s^{-1}

34. (a) : Here, $h_1 = \dfrac{2S\cos 0°}{r_1\rho g}$ and $h_2 = \dfrac{2S\cos 0°}{r_2\rho g}$

$$\therefore \quad h_1 - h_2 = \frac{2S\cos 0°}{\rho g}\left[\frac{1}{r_1}-\frac{1}{r_2}\right] = \frac{2S(r_2-r_1)}{r_1r_2\rho g}$$

But $\quad h_1 - h_2 = h$ (given)

$$\therefore \quad h = \frac{2S(r_2-r_1)}{r_1r_2\rho g} \quad \text{or} \quad S = \frac{r_1r_2h\rho g}{2(r_2-r_1)}$$

35. (b) : $M = \dfrac{4}{3}\pi r^3\rho$ and $8M = \dfrac{4}{3}\pi R^3\rho$,

$\therefore \quad R^3 = 8r^3$ or $\quad R = 2r$

As $\quad v \propto r^2$

$$\therefore \quad \frac{v'}{v} = \left(\frac{R}{r}\right)^2 = \left(\frac{2r}{r}\right)^2 = 4 \text{ or } v' = 4v$$

36. (d) : Here, $l_1 = l_2 = 1$ m,

and $\quad \dfrac{r_1}{r_2} = \dfrac{1}{2}$

As $\quad V = \dfrac{\pi P_1 r_1^4}{8\eta l} = \dfrac{\pi P_2 r_2^4}{8\eta l}$

or $\quad \dfrac{P_1}{P_2} = \left(\dfrac{r_2}{r_1}\right)^4 = 16$

$\therefore \quad P_1 = 16P_2$

Since, both tubes are connected in series, hence pressure difference across the combination is

$P = P_1 + P_2$

$\Rightarrow \quad 1 = P_1 + \dfrac{P_1}{16}$

or $\quad P_1 = \dfrac{16}{17} = 0.94$ m

37. (b) : Here, volume of bubble, $V = \dfrac{4}{3}\pi R^3$

or $\quad R = \left(\dfrac{3V}{4\pi}\right)^{1/3}$

Work done, $W = S \times 8\pi R^2 = S \times 8\pi\left(\dfrac{3V}{4\pi}\right)^{2/3}$

or $\quad W \propto V^{2/3}$

$$\therefore \quad \frac{W_2}{W_1} = \left(\frac{V_2}{V_1}\right)^{2/3} = \left(\frac{2V}{V}\right)^{2/3}$$

$$= 2^{2/3}$$

$\therefore \quad W_2 = 4^{1/3}W_1$

38. (d) : Relative density of solid

$$= \frac{\text{weight in air}}{\text{weight in air} - \text{weight in water}} = \frac{120}{120-80} = \frac{120}{40} = 3$$

$$\text{Relative density of liquid} = \frac{\text{weight in air} - \text{weight in liquid}}{\text{weight in air} - \text{weight in water}}$$

$$= \frac{120-60}{120-80} = \frac{60}{40} = \frac{3}{2}$$

39. (c) : Pressure, $P = \dfrac{4S}{r}$ or $P \propto \dfrac{1}{r}$ $\therefore$ $\dfrac{P_1}{P_2} = \dfrac{r_2}{r_1} = \dfrac{3}{1}$ $\quad$ ... (i) or $r_2 = 3r_1$

Also $\dfrac{A_1}{A_2} = \dfrac{4\pi r_1^2}{4\pi r_2^2} = \left(\dfrac{r_1}{r_2}\right)^2 = \left(\dfrac{r_1}{3r_1}\right)^2 = \dfrac{1}{9}$ (Using (i))

40. (b) : Surface tension is a scalar quantity because it has no specific direction for a given liquid.

41. (d) : Angle of contact does not depend upon the inclination of the solid surface to the liquid surface.

42. (c) : Viscosity is a scalar quantity.

Surface tension is a scalar quantity.

Reynolds number is a dimensionless quantity.

43. (d) : A liquid does not wet the solid surface if the angle of contact is obtuse (*i.e.* $\theta > 90°$).

44. (c) : Bernoullis equation for steady, non-viscous, in compressible flow express the conservation of energy.

45. (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 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.

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

47. (a) : The height of the blood column in the human body is more at feet than at the brain [$\therefore$ $P = h\rho g$]. That is why, the blood exerts more pressure at the feet than at the brain.

48. (b) : The body will rise above the surface of liquid to such an extent that the weight of the liquid displaced by the immersed part of the body (*i.e.*, upward thrust) becomes equal to the weight of the body. Thus the body will float when upward thrust is equal to its actual weight.

49. (a) : The level of water does not change. The reason is that on drinking the water (say m g), the weight of man increases by m g and hence water displaced by man increases by m g, tending to raise the level. However, this much amount of water has already been consumed by the man. Therefore the level of pond remain same.

50. (c) : From equation $hR = \dfrac{2S}{\rho g}$ = a finite constant.

Hence when the tube is of insufficient length, radius of curvature of the liquid meniscus increases, so as to maintain the product hR a finite constant, *i.e.*, as h decreases, R increases and the liquid meniscus becomes more and more flat, but the liquid does not overflow.

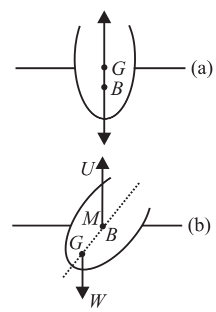
51. (c) : According to Bernoulli's equation,

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

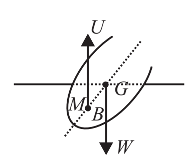
Thus, total energy of the injectable medicine depends upon second power of the velocity and first power of the pressure. It implies that total energy of the injectable medicine has greater dependence on its velocity. Therefore, a doctor adjust the flow of the medicine with the help of the size of the needle of the syringe ($a_1v_1 = a_2v_2$) rather than the thumb pressure.

52. (a) : Due to small area of cross-section of the hole, fluid flows out of the vessel with a large speed and thus the fluid possesses a large linear momentum. As no external force acts on the system, in order to conserve linear momentum, the vessel acquires a velocity in backward direction or in other words a backward thrust results on the vessel.

53. (a) : The stability of a floating body depends on the relative position of centre of gravity (G) of a body, through which its weight acts and centre of gravity of the displaced water called centre of buoyancy (B), through which the upthrust act. If centre of gravity and centre of buoyancy is on the same vertical line, the body is said to be stable.



Let us consider a case of ship. If it heels over the shape of the displaced water change, causing the point of centre of buoyancy to move and this sets a couple which tends either to return the ship to its original position or to make it heel over more. The point of interaction of the vertical line from centre of buoyancy with the central line is called meta centre (M). If metacentre is above centre of gravity, the couple has anticlockwise moment which acts to decrease the ship heel and the equilibrium is stable. Thus if M is above G the body will be in stable equilibrium. If metacentre is below centre of gravity, equilibrium is unstable since the couple has a clockwise moment which cause further rotation of the body. For maximum stability centre of gravity should be low and metacentre should be high.



54. (a) : The presence of impurities either on the liquid surface or dissolved in it, considerably affect the force of surface tension, depending upon the degree of contamination. A highly soluble substance like sodium chloride when dissolved in water, increase the surface tension of water. But the sparingly soluble like phenol when dissolved in water reduces the surface tension of water.

55. (b) : The viscosity of liquid decreases rapidly with rise of temperature. The variation of viscosity of liquid with temperature is given by

$$\eta_t = \eta_0/(1 + \alpha t + \beta t^2),$$

where η_t and η_0 are the coefficient of viscosities at t°C and 0°C respectively and α and β are constants. Where as the viscosity of all gases increases with increases in temperature $(\eta \propto \sqrt{t})$.

SUBJECTIVE TYPE QUESTIONS

1. When water enters into a narrow pipe, the area of cross-section (A) decreases and consequently velocity (v) increases as Av = constant.

2. Fluidity is the reciprocal of viscosity.

3. While walking, when entire weight of our body gets supported on the sharp edge of any pebble, it will exert a large pressure on our feet due to reaction. This causes considerable pain on our feet.

4. According to Bernoulli's theorem for horizontal flow $P+\frac{1}{2}\rho v^2 = \text{constant}$.

As speed of water between the ships is more than outside the pressure between them gets reduced and pressure outside is more so the excess pressure pushes the ships close to each other therefore they get attracted.

5. When air is blown between the two balls, the velocity is increased and hence pressure is decreased (as per the Bernoulli's principle). On the outer sides of the balls, the pressure is high and hence the two balls get attracted.

6. No, it does not matter if one uses gauge instead of absolute pressures in applying Bernoulli's equation, provided the atmospheric pressure at the two points where Bernoulli's equation is applied are significantly different.

7. Zero, because when the body attains terminal velocity then the net force acting on the body is zero.

8. Given : $r_A : r_B = 2 : 3$

As work done in blowing a soap bubble is given by $W = T \times 2 \times 4\pi r^2$

where T is surface tension of the soap solution.

$$\therefore \frac{W_A}{W_B} = \left(\frac{r_A}{r_B}\right)^2 = \left(\frac{2}{3}\right)^2 = \frac{4}{9}$$

9. As, terminal velocity, $v \propto r^2 \propto d^2$.

Therefore, ratio of terminal velocities of balls A and B is

$$\frac{v_A}{v_B} = \frac{d_A^2}{d_B^2} = \frac{1}{4} \qquad \left[\because d_A = \frac{1}{2} d_B\right]$$

10. Surface tension decreases when temperature of the liquid increases because cohesive forces decrease with an increase of molecular thermal activity.

11. Here, $m = 50$ kg; $r = \frac{D}{2} = \frac{1}{2}\text{ cm} = \frac{1}{200}\text{ m}$

$$\text{Pressure} = \frac{\text{force}}{\text{area}} = \frac{mg}{\pi r^2}$$

$$= \frac{50\times 9.8}{(22/7)\times(1/200)^2} = 6.24\times 10^6 \text{ N m}^{-2}.$$

12. This can be explained from the equation of continuity *i.e.* $a_1 v_1 = a_2 v_2$. As we try to close a water tap with our fingers, the area of cross-section of the outlet of water jet is reduced considerably as the openings between our fingers provide constriction (*i.e.*, regions of smaller area).

Thus velocity of water increases greatly and fast jets of water come through the openings between our fingers.

13. Hydraulic brakes are based on the principle of Pascal's law. It states that if gravity effect is neglected, the pressure in a fluid at rest is same at all points.

14. When a fluid is flowing out of a small hole in a vessel, it acquires a large velocity and hence possesses large momentum. Since no external force is acting on the system, a backward velocity must be attained by the vessel (according to the law of conservation of momentum). As a result of it, backward thrust is experienced by the vessel.

15. Given : $P_1 = 3P_2$

$\therefore$ Excess pressure inside a soap bubble, $P = \frac{4\sigma}{r}$

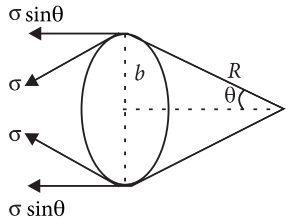
$$\therefore \frac{4\sigma}{r_1} = \frac{3\times 4\sigma}{r_2} \text{ or } r_2 = 3r_1$$

$$\frac{V_1}{V_2} = \frac{\frac{4}{3}\pi r_1^3}{\frac{4}{3}\pi r_2^3} = \left(\frac{r_1}{r_2}\right)^3 = \left(\frac{1}{3}\right)^3 = \frac{1}{27} \Rightarrow V_1 : V_2 = 1:27$$

16. We know that atmospheric pressure decreases with height. Since ink inside the pen is filled at the atmospheric pressure existing on the surface of earth, it tends to come out to equalise the pressure. This can spoil the clothes of the passengers, so they are advised to remove the ink from the pen.

17. The bubble will separate from the ring when

$$2\pi b \times 2\sigma \sin\theta = \rho A v^2$$



or $\quad 4\pi b\sigma \times \dfrac{b}{R} = \rho \times \pi b^2 \times v^2$ or $R = \dfrac{4\sigma}{\rho v^2}$

18. The tangent to a streamline at any point gives the direction of flow of a liquid at that point. If two streamlines cross each other at a point, then two tangents can be drawn on that point, one to each streamline. This means that at that point, the liquid has two velocities of flow which is not possible in a streamline flow of a liquid. Hence, two streamlines cannot cross each other.

19. Given that, $r_1 = \dfrac{2}{2} = 1$ cm,

$v_1 = 1.0$ m s^{-1} = 100 cm s^{-1}

$r_2 = \dfrac{1}{2} = 0.5$ cm

$A_1v_1 = A_2v_2$ or $(\pi r_1^2)v_1 = (\pi r_2^2)v_2$

$$\therefore \quad v_2 = \left(\frac{r_1}{r_2}\right)^2 v_1 = \left(\frac{1}{0.5}\right)^2 \times 100$$

$v_2 = 400$ cm s^{-1}

20. (i) If Reynold's number R_e lies between 0 and 2000, the liquid flow is streamlined or laminar.

(ii) If $R_e > 3000$, the liquid flow is turbulent.

(iii) If $2000 < R_e < 3000$, the flow is unstable.

21. The force of buoyancy B is equal to the weight of the displaced liquid. Thus, $B = \dfrac{4}{3}\pi r^3 \sigma g$.

This force is upward. The viscous force acting downward is $F = 6\pi\eta rv$.

The weight of the air bubble may be neglected as the density of air is small. For uniform velocity, $F = B$

or, $\quad 6\pi\eta rv = \dfrac{4}{3}\pi r^3 \sigma g \quad$ or, $\quad \eta = \dfrac{2r^2\sigma g}{9v}$

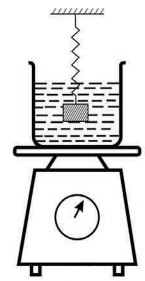
$$\text{or,} \quad \eta = \frac{2 \times (1 \times 10^{-3}\,\text{m})^2 \times (1750\ \text{kg m}^{-3})(9\cdot 8\ \text{m s}^{-2})}{9 \times (0\cdot 35 \times 10^{-2}\ \text{m s}^{-1})}$$

≈ 1.1 poise.

22. Let x be the compression on the spring.

As the block is in equilibrium

$Mg - (kx + \rho_W Vg) = 0$



where ρ_W is the density of water and V is the volume of the block. The reading in the pan is the force applied by the water on the pan *i.e.*,

$m_{vessel} + m_{water} + \rho_w Vg$.

Since the scale has been adjusted to zero without the block, the new reading is $\rho_w Vg$.

23. Given $r = 2.5 \times 10^{-5}$ m, $T = 7.28 \times 10^{-2}$ N m^{-1}

$\rho = 10^3$ kg m^{-3}, $\theta = 0°$, h = ?

$$h = \frac{2T\cos\theta}{r\rho g} = \frac{2 \times 7.28 \times 10^{-2} \times \cos 0°}{2.5 \times 10^{-5} \times 10^3 \times 9.8} = 0.59\ \text{m} \approx 0.6\ \text{m}$$

Which is the maximum height of rise of water in capillary action.

Many trees have heights much greater than 0.6 m so only this action is not sufficient for supply of water to the top of such long tree.

24. Upthrust in liquid A, $F_1 = \dfrac{1}{4}V\rho_1 g$

Upthrust in liquid B, $F_2 = \dfrac{3}{4}V\rho_2 g$

where V is the volume of drop of liquid

$$\therefore \quad \frac{F_1}{F_2} = \frac{\rho_1}{3\rho_2}$$

For floatation,

$$\frac{1}{4}V\rho_1 g + \frac{3}{4}V\rho_2 g = V\rho g$$

$\Rightarrow \quad \rho_1 + 3\rho_2 = 4\rho$

25. Here, depth of water column,

$h = 3$ km $= 3 \times 10^3$ m

density of water, $\rho = 10^3$ kg m^{-3}

If P be the pressure exerted by this water column at this depth, then

$P = h\rho g = 3 \times 10^3 \times 10^3 \times 9.8$

$= 29.4 \times 10^6$ Pa $= 30 \times 10^6$ Pa $= 3 \times 10^7$ Pa

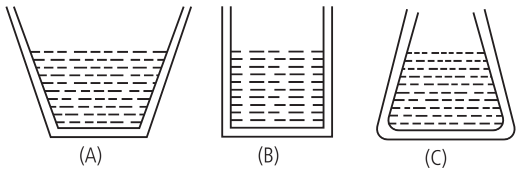
As the structure is put on the sea, sea water will exert upward thrust of 3×10^7 Pa.

Maximum stress which the vertical off-shore structure can withstand $= 10^9$ Pa. (Given)

Then 3×10^7 Pa $< 10^9$ Pa

Thus we conclude that the structure is suitable as the stress applied by it is much lesser than the maximum stress it can withstand.

26. (a)



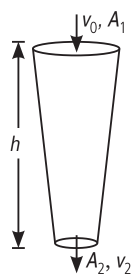
(i) Pressure depends upon the depth (h), nature of liquid (ρ) and acceleration due to gravity (g) while it is independent of the shape or cross-sectional area of the container. So, if the vessels of different shapes are filled to same height, the pressure at the base in each vessel will be the same

$\therefore \quad P_A = P_B = P_C$

(ii) If the vessels are filled with equal volumes of water, each vessel may attain different height (h) of water due to different shapes of the vessels. The vessel with least height will have minimum pressure on its base. Therefore vessel A will have minimum pressure.

(b) The fluids moves from higher pressure to lower pressure and fluid pressure increases with depth. Hence, pressure at the top is less than that at the bottom so the air bubble will rise from bottom to sea level. When bubble moves from bottom to top, pressure decreases and in accordance with Boyle's law volume V will increase *i.e.*, the radius of the bubble increases.

27. In the shown figure, $v_2^2 = v_0^2 + 2gh$ and $A_1 v_0 = A_2 v_2$



Solving, $\dfrac{A_2}{A_1} = \dfrac{v_0}{\sqrt{v_0^2 + 2gh}}$

$$\frac{A_2}{A_1} = \frac{A_2}{2A_2} = \frac{v_0}{\sqrt{v_0^2 + 2gh}}$$

$$4v_0^2 = v_0^2 + 2gh \quad \Rightarrow \quad h = \frac{3v_0^2}{2g}$$

28. The velocity of efflux from the hole, $v = \sqrt{2gh}$

Using equation of continuity, $A_1 v_1 = A_2 v_2$

$$A\left(-\frac{dh}{dt}\right) = a(\sqrt{2gh}) \quad \Rightarrow \quad \frac{-dh}{\sqrt{h}} = \frac{a}{A}\sqrt{2g}dt$$

$$-\int_{H_1}^{H_2} h^{-\frac{1}{2}} dh = \frac{a}{A}\sqrt{2g}\int_0^t dt \text{ or } -\left[2h^{\frac{1}{2}}\right]_{H_1}^{H_2} = \frac{a}{A}t\sqrt{2g}$$

or $\quad 2(\sqrt{H_1} - \sqrt{H_2}) = \dfrac{a}{A}\sqrt{2g}\, t$

$$\Rightarrow \; t = \frac{A}{a}\cdot\sqrt{\frac{2}{g}}(\sqrt{H_1} - \sqrt{H_2})$$

29. Surface energy = surface tension × surface area,

$E = S \times 2A$ $\quad$ ($\because$ Soap film has two surfaces)

As $\quad A' = \left[A - \dfrac{50A}{100}\right] = \dfrac{A}{2}$

$$\therefore \; E' = S \times 2\left(\frac{A}{2}\right) = SA$$

Percentage decrease in surface energy

$$= \frac{E - E'}{E} \times 100\% = \frac{2SA - SA}{2SA} \times 100\%$$

$$= \frac{1}{2} \times 100\% = 50\%$$

30. As $P_1 + \dfrac{1}{2}\rho v_1^2 = P_2 + \dfrac{1}{2}\rho v_2^2$,

$$\frac{1}{2}\rho(v_2^2 - v_1^2) = P_1 - P_2$$

or $\quad \dfrac{1}{2}\rho\left[\left(\dfrac{A_1 v_1}{A_2}\right)^2 - v_1^2\right] = P_1 - P_2$ (as $A_1 v_1 = A_2 v_2$)

or $\quad v_1^2 = \dfrac{2(P_1 - P_2)A_2^2}{\rho(A_1^2 - A_2^2)}$ $\quad$ or $\quad v_1 = A_2\sqrt{\dfrac{2(P_1 - P_2)}{\rho(A_1^2 - A_2^2)}}$

31. Consider a narrow tube having a cross-sectional area A. Suppose a fluid flows through it with a velocity v for a time interval Δt.

Length of the fluid = Velocity × time = $v\,\Delta t$

Volume of the fluid flowing through the tube in time $\Delta t = Av\,\Delta t$

Mass of the fluid,

Δm = Volume × density = $Av\,\Delta t \times \rho$

Inertial force acting per unit area of the fluid

$$= \frac{F}{A} = \frac{\text{Rate of change of momentum}}{A}$$

$$= \frac{\Delta m \times v}{\Delta t \times A} = \frac{Av\Delta t\rho \times v}{\Delta t \times A} = \rho v^2$$

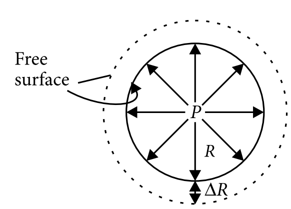
Viscous force per unit area of the fluid

$$= \eta \times \text{velocity gradient} = \eta\frac{v}{D}$$

$$\frac{\text{Inertial force per unit area}}{\text{Viscous force per unit area}} = \frac{\rho v^2}{\eta v / D} = \frac{\rho v D}{\eta} = R_e$$

Thus Reynold's number represents the ratio of the inertial force per unit area to the viscous force per unit area.

32. Excess pressure inside a soap bubble : Let us consider a liquid bubble (say a soap bubble) of radius R and let S be the surface tension of the liquid. We know that there is



an excess pressure (P) inside the bubble and it acts normally outwards. Let the excess pressure increase the radius of the bubble from R to ($R + \Delta R$) as shown.

Work done by the excess pressure, *i.e.*,

W = force × distance

= excess pressure × surface area × distance

$= P \times 4\pi R^2 \times \Delta R$

i.e., $W = 4\pi PR^2 \times \Delta R$ ...(i)

The soap bubble has two free surfaces, one inside the bubble the other outside it.

Total increase in the surface area of the bubble, *i.e.*,

$\Delta A = 2[4\pi(R + \Delta R)^2 - 4\pi R^2]$

$= 8\pi[R^2 + (\Delta R)^2 + 2R \times \Delta R - R^2]$

$= 16\pi R\Delta R$ ...(ii)

[neglecting $(\Delta R)^2$ as it is very small]

We know that $S = \dfrac{W}{\Delta A}$ ...(iii)

From eqns. (i), (ii) and (iii),

$$S = \frac{4\pi PR^2\,\Delta R}{16\pi R\Delta R} = \frac{PR}{4} \quad \text{or} \quad P = \frac{4S}{R}$$

Since the excess pressure is inversely proportional to the radius of the bubble, it means smaller the bubble, greater the excess pressure inside it.

33. Here, $\rho = 1.06 \times 10^3$ kg/m^3

$D = 2r = 2 \times 2 \times 10^{-3} = 4 \times 10^{-3}$ m;

$\eta = 2.084 \times 10^{-3}$ Pa s,

For flow to be laminar, $N_R = 2000$

(a) Now, $v_c = \dfrac{N_R \eta}{\rho D} = \dfrac{2000 \times (2.084 \times 10^{-3})}{(1.06 \times 10^3) \times (4 \times 10^{-3})}$

$= 0.98$ m s^{-1}

(b) Volume flowing per second

$$= \pi r^2 v_c = \frac{22}{7} \times (2 \times 10^{-3})^2 \times 0.98$$

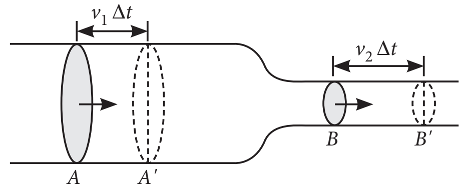
$= 1.23 \times 10^{-5}$ m^3 s^{-1}.

34. Tube of flow : A bundle of streamlines forming a tubular region is called a tube of flow.

Relation between the area of cross-section and the velocity is given by equation of continuity of flow of incompressible fluids.

Equation of continuity : av = constant

Derivation :Consider a non-viscous and incompressible liquid flowing steadily between the sections A and B of a pipe of varying cross-section. Let a_1 be the area of cross-section, v_1 fluid velocity, ρ_1 fluid density at section A; and the values of corresponding quantities at section B be a_2, v_2 and ρ_2.



As m = volume × density = Area of cross-section × length × density

∴ Mass of fluid that flows through section A in time Δt,

$m_1 = a_1 v_1\,\Delta t \rho_1$

Mass of fluid that flows through section B in time Δt,

$m_2 = a_2 v_2\,\Delta t \rho_2$

By conservation of mass, $m_1 = m_2$

or $a_1 v_1\,\Delta t \rho_1 = a_2 v_2\,\Delta t \rho_2$

As the fluid is incompressible, so $\rho_1 = \rho_2$, and hence $a_1 v_1 = a_2 v_2$ or av = constant.

This is the equation of continuity.

Conclusion:

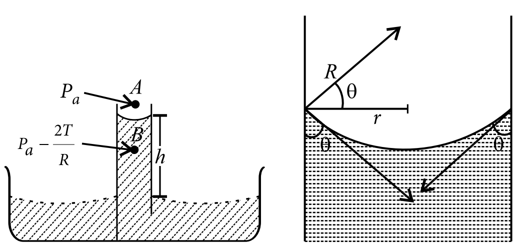
(i) When a fluid is in motion, it must move in such a way that mass is conserved

(ii) For a steady flow through a control volume with many inlets and outlets, the net mass flow must be zero.

(iii) The liquid velocity at any section of the pipe is inversely proportional to the area of cross-section of the pipe at that section.

(iv) Velocity of flow decreases when the area of cross-section increases and vice versa.

35. Ascent formula : Consider a capillary tube of radius r dipped in a liquid of surface tension T and density ρ. Suppose the liquid wets the sides of the tube. Then its meniscus will be concave. The shape of the meniscus of water will be nearly spherical if the capillary tube is of sufficiently narrow bore.



(a) (b)

As the pressure is greater on the concave side of a liquid surface, so excess of pressure at a point A just above the meniscus compared to point B just below the meniscus is

$P = \dfrac{2T}{R}$,

where R = radius of curvature of the concave meniscus. If θ is the angle of contact, then from the right angled triangle shown in figure (b), we have

$$\frac{r}{R} = \cos\theta ; R = \frac{r}{\cos\theta}$$

$$\therefore \quad P = \frac{2T\cos\theta}{r}$$

Due to this excess pressure P, the liquid rises in the capillary tube to height h when the hydrostatic pressure exerted by the liquid column becomes equal to the excess pressure P. Therefore, at equilibrium we have

$P = h \rho g$

or $\dfrac{2T\cos\theta}{r} = h\rho g$ or $h = \dfrac{2T\cos\theta}{r\rho g}$

This is the ascent formula for the rise of liquid in a capillary tube. If we take into account the volume of the liquid contained in the meniscus, then the above formula gets modified as

$$h = \frac{2T\cos\theta}{r\rho g} - \frac{r}{3}$$

However, the factor $r/3$ can be neglected for a narrow tube.

(i) inversely proportional to the radius of the tube.

(ii) inversely proportional to the density of the liquid

(iii) directly proportional to the surface tension of the liquid.

Hence a liquid rises more in a narrower tube than in wider tube.

Rise of liquid in a tube of insufficient height: The height to which a liquid rises in a capillary tube is given by

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

The radius r of the capillary tube and radius of curvature R of the liquid meniscus are related by $r = R\cos\theta$. Therefore

$$h = \frac{2T\cos\theta}{R\cos\theta\rho g} = \frac{2T}{R\rho g}$$

As T, ρ and g are constants, so

$$hR = \frac{2\sigma}{\rho g} = \text{ a constant}$$

The liquid rises to height h', $\therefore$ $hR = h'R'$

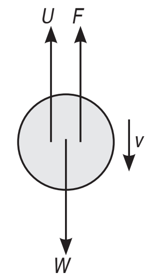
where R' is the radius of curvature of the new meniscus at a height h'. As $h' < h$, so $R' > R$

Hence in a capillary tube of insufficient height, the liquid rises to the top and spreads out to a new radius of curvature R' given by, $R' = \dfrac{hR}{h'}$

But the liquid will not overflow.

36. Terminal velocity : It is the maximum constant velocity acquired by the drop while falling in a viscous medium.

Expression for terminal velocity : Consider a spherical body of radius r falling through a viscous liquid of density σ and coefficient of viscosity η. Let ρ be the density of the body. As the body falls, the various forces acting on the body are as shown in figure. These are



(i) Weight of the body acting vertically downwards.

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

(ii) Upward thrust equal to the weight of the liquid displaced.

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

(iii) Force of viscosity F acting in the upward direction. According to Stokes' law,

$F = 6\pi\eta r v$

Clearly, the force of viscosity increases as the velocity of the body increases. A stage is reached, when the weight of the body becomes just equal to the sum of the upthrust and the viscous force. Then the body begins to fall with a constant maximum velocity, called terminal velocity.

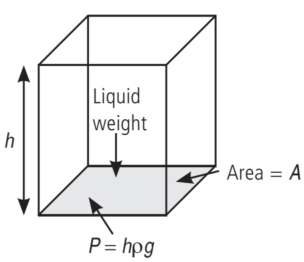
When the body attains terminal velocity v, $U + F = W$

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

or $\quad 6\pi\eta r v = \dfrac{4}{3}\pi r^3 (\rho - \sigma) g \quad$ or $v = \dfrac{2}{9} \cdot \dfrac{r^2(\rho - \sigma) g}{\eta}$

Thus, the value of terminal velocity v depends upon r, ρ, σ and η.

37. (a) Consider a vessel of height h and cross-sectional area A filled with a liquid of density ρ. The weight of the liquid column exerts a downward thrust on the bottom of the vessel and the liquid exerts pressure.



Weight of liquid column,

W = Mass of liquid $\times g$ = Volume $\times$ density $\times g$

$= Ah \times \rho \times g = Ah\rho g$

Pressure exerted by the liquid column on the bottom of the vessel is

$$P = \frac{\text{Thrust}}{\text{Area}} = \frac{W}{A} = \frac{Ah\rho g}{A}$$

or $\quad P = h\rho g$

Thus, the pressure exerted by a liquid column at rest is proportional to (i) height of the liquid column and (ii) density of the liquid.

(b) Pascal's law : If gravity effect is neglected, the pressure in a fluid at rest is same at all points.