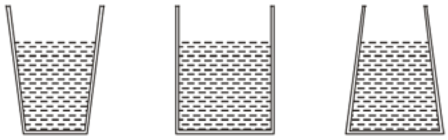
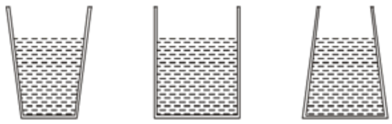
Date: 14/10/2021

Q1. In the vessels shown in figure, equal volumes water are poured. In which vessel, will the force on the base be maximum?



Q2. The three vessels shown in the figure, are filled to the same height with water. The three vessels have the same base area. In which vessel, will the force on the base be minimum?



Q3. A storage tank are made thick near its bottom. Why?

Q4. The blood pressure in humans is usually taken using the arm. However, suppose the pressure reading were taken on the calf of the leg of a standing person. Would there be a difference?

Q5. In a dropper, water does not come out, unless rubber bulb is pressed. Why?

Q6. While skiing on snow, a skier wear skis in addition to the shoes. Why?

Q7. The sports boot for soccer and hockey have studs on their soles. Why?

Q8. A drawing pin having a broad head can be easily fixed on a board. Explain, how?

Q9. Blood velocity: The flow of blood in a large artery of an anesthetised dog is diverted through a Venturi meter. The wider part of the meter has a cross-sectional area equal to that of the artery. $A = 8\ mm^2$. The narrower part has an area $a = 4\ mm^2$. The pressure drop in the artery is 24 Pa. What is the speed of the blood in the artery?

Q10. What is the pressure on a swimmer 10 m below the surface of a lake?

Q11. The two thigh bones (femurs), each of cross-sectional area $10\ cm^2$ support the upper part of a human body of mass 40 kg. Estimate the average pressure sustained by the femurs.

Q12. A hole of area $5\ cm^2$ is formed in the side of a ship 3 m below the water level. What minimum force is required to hold on a patch covering the hole from the side of the ship?

Q13. A vessel containing water is equalized on a balance and then the end of a wooden rod is immersed in the water, its other end being held by hand. What additional weight should be placed on the pan to restore the equilibrium, if the volume of the submerged part of the wood is $50\ cm^3$?

Q14. Why it may be difficult to stop bleeding from a cut the body at high altitudes?

Q15. Why is it that the smaller bubbles have a greater excess pressure?

Q16. If the torricellian tube is tilted by 30° with the vertical how much length of mercury will stand at atmospheric pressure at sea-level?

Q17. What is effect of gravity on pressure?

Q18. A cork is floating in a water tube. What is the apparent weight of the cork?

Q19. What is the principal of floatation?

Q20. How is barometric height altered, if a drop of water is introduced in a mercury barometer tube?

Q21. Which is the practical unit of pressure in meteorological science?

Q22. What are the factors, which affect the atmospheric pressure at a place?

Q23. Cork is only one fourth as dense water. Could you lift a sphere of cork one meter in diameter?

Q24. Water cannot be used in place of mercury is barometer. Why?

Q25. What is the buoyant force on a helium balloon with a radius of 30 cm in air, If the density of air is 1.9 kg m^{-3}.

Q26. A *U*-tube contain water and olive oil separated by mercury. The mercury columns in the two arms are in level with 12.0 cm of water in one arm and 7.5 cm of olive oil in the other. What is the relative density of the olive oil? (Relative density of mercury = 13.6).

Q27. The gauge pressure in both the tyres of a cycle is 6.9×10^5 Pa. If the cycle and the person riding it have a combined mass of 90 kg, what is the area of contact of each tyre with the ground?

Q28. A cubic body floats on mercury with a part of its volume below the surface. Will the fractional volume of the body immersed in the mercury increase or decrease, if a layer of water poured on the top of the mercury covers the body completely?

Q29. A balloon filled with helium does not rise in air indefinitely but halts after a certain height (neglect winds). Explain, why?

Q30. State and explain Pascal's law.

Q31. Wooden sleepers are provided below the rails, while laying a railway track. Why?

Q32. What happens to the candle, as its portion above the water burns down *i.e.*, it is extinguished or it rises above and stays lit sinks relative to the base of the container?

Q33. How much pressure will a man of weight 80 kg exert on the ground, when (a) he is lying, (b) standing on both the feet? Given that area of the body of the man is 0.6 m^2 and that of a foot is 80 cm^2.

Q34. A boat carrying a number of large stones is floating in a water tank. What happen to the level of water in the tank, if the stones are unloaded into water?

Q35. The mass of the earth has been calculated to be 5.98×10^{24} kg and its mean radius as 6.38×10^6 m. (a) What is the average density of the earth. (b) Would you expect the average density of the material near the surface to be same as the average density near the centre of the earth? Give reasons.

Q36. The neck and bottom of a bottle are 2 cm and 10 cm in diameter respectively. If the cork is pressed with a force of 1.2 k gf in the neck of the bottle, calculate the force exerted on the bottom of the bottle.

Q37. What will be the length of mercury column in a barometer tube, when the atmospheric pressure is 75 cm of mercury and the tube is inclined at an angle of 30° to the vertical?

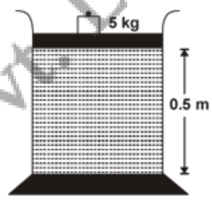
Q38. A piece of iron floats in mercury. Given that the density of iron is 7.8×10^3 kgm^{-3} and that of mercury is 13.6×10^3 kg m^{-3}, calculate the fraction of the volume of iron piece that remains outside the mercury.

Q39. The density of ice is 917 kg m^{-3}. What friction of ice lies below water? The density of sea water is 1,024 kg m^{-3}. What fraction of iceberg do we see, assuming that it has the same density as ordinary ice (917 kg m^{-3}).

Q40. A body weight 25 *gf* in air and 20 *gf* in water. What would be its weight in a liquid of density 0.8 cm^{-3}?

Q41. A cork of density 0.15 g cm^{-3} floats in water with 10 cm^3 of its volume above the surface of water. Calculate the mass of the cork.

Q42. A cylindrical jar of cross-sectional area 0.01 m^2 is filled with water to a height of 50 cm (given figure). It carries a tight fitting piston of negligible mass. Calculate the pressure at the bottom of the jar when a mass of 5 kg is placed on the piston.



Q43. In a car lift compressed air exerts a force F_1 on a small piston having a radius of 5.0 cm. This pressure is transmitted to a second piston of radius 15 cm (see figure). If the mass of the car to be lifted is 1350 kg, calculate F_1. What is the pressure necessary to accomplish this task? (g = 9.8 ms^{-2}).

Q44. The density of the atmosphere at sea level is 1.29 kg/m^3. Assume that it does not change with altitude. Then how high would the atmosphere extend?

Q45. A piece of iron weight 400 *gf* in water. Determine its volume. Given that density of iron = 7.8 g cm^{-3}.

Q46. A piece of cork of density 250 kg m^{-3} is tied with a lump of metal of density 8×10^3 m^{-3} and of mass 0.024 kg. The combination just floats in water. Calculate the volume and the mass of the cork.

Q47. A piece of metal of mass 17 g is tied to a cork of mass 5 g and the two remain suspended under water without sinking, when lowered into water. If the density of cork is 0.25 g cm^{-3}, find the density of metal.

Q48. Prove that the pressure at a depth h from the free surface of a liquid (P) in a container is $P = P_0 + h\rho g$ where P_0 is the atmospheric pressure.

Q49. 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?

Q50. At a depth of 1000 m in an ocean (a) what is the absolute pressure? (b) What is the gauge pressure? (c) Find the force acting on the window of area 20 cm $\times$ 20 cm of a submarine at this depth, the interior of which is maintained at sea-level atmospheric pressure. (The density of sea water is 1.03×10^3 kg m^{-3}, g = 10m s^{-2}.)

Q51. When a body of mass 240 kg is placed on an iceberg floating in sea water, it is found that the iceberg just sinks. What is the mass of the iceberg? Take the relative density of ice as 0.9 and that of sea water as 1.02.

Q52. What must the ratio of volume of water and alcohol be for their mixture to have a density of 900 kg m^{-3}? When the alcohol is mixed with the water, the volume of the mixture diminishes to 0.97 of the initial volume of the water and the alcohol. Given that the density of alcohol = 795 kg m^{-3}.

Q53. A vessel contains two immiscible liquids of densities ρ_1 and ρ_2 ($\rho_1 > \rho_2$). A body of volume V and density ρ floats such that its volume V_1 is inside liquid of density ρ_1 and volume V_2 inside the other liquid. Find the fractional volume of the body inside the two liquids in terms of densities.

Q54. The manual of a car instructs the owner to inflate the tyres to pressure of 200 kPa. (a) What is the recommended gauge pressure? (b) What is the recommended absolute pressure? (c) If after the required inflation of the tyre, the car is driven to a mountain peak, where the atmospheric pressure is 10% below that at sea level, what the tyre gauge read?

Q55. (a) What is the total pressure on the back of a scuba diver in a lake at a depth of 8 m, if the atmospheric pressure is equal to 1.01×10^5 Nm^{-2}?

(b) What is the force on the diver's back due to water alone, taking the surface of the back to be a rectangle of dimensions 60 cm $\times$ 50 cm.

Q56. Explain why:

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

(b) Atmospheric pressure at a height of about 6 km decreases to nearly half of its value at the sea level, though the height of the atmosphere is more than 100 km

(c) Hydrostatic pressure is a scalar quantity even though pressure is force divided by area.

Q57. When do we say that a floating body is in stable equilibrium? A sample of milk diluted with water has a density of 1,032 kg m^{-3}. If pure milk has a density of 1,080 kg m^{-3}, find the percentage of water by volume in milk.

Q58. (a) State and prove Archimedes' Principle.

(b) What would be pressure inside a small air bubble of 0.1 mm radius situated just below the surface of water? Surface tension of water 72×10^{-3} N/m and atmospheric pressure is 1.1×10^5 N/m^2.

Date: 14/10/2021

S1. When equal volumes of water are poured in the three vessel having the same base area [as shown in figure], the height of water in the third vessel will be the greatest. As the pressure at the base of the third vessel will be the greatest, the force on the base of the third vessel, will be maximum.

S2. Since the height of water column is same in the three vessel, the pressure at the will be same. As the three vessels have the same base area, the force will also be the same in the three cases.

S3. Pressure due to a liquid column of height $p = h\rho g$

$$\Rightarrow \qquad h = \frac{p}{\rho g}$$

Since the value of 'h' is more near the bottom, pressure due to liquid is also greater near the bottom. Therefore, the storage tanks are made thick near the bottom.

S4. Yes, blood pressure taken on the calf of the leg will be higher than taken from the arm. It is because, the height of the blood column is quite large at leg than that at the arm.

S5. Water is held inside the dropper against the atmospheric pressure on water become greater than the atmospheric pressure and it come out.

S6. On wearing skis, force due to the weight of the skier acts over a much larger area than the area of the soles of the shoes. This reduces the pressure on the soft surface of the snow and allows the skier to slide over it without sinking.

S7. The studs reduce the area in contact between the feet of the player and the ground. As the weight of the player acts over a smaller area, he presses on the ground with increased pressure. As a result, the feet of the player sink into the turf on the play ground and grip the surface more firmly. This enables him to run about on the ground without slipping.

S8. When the drawing pin is pushed into the board with the thumb, the applied force is spread out over the broad head of the pin. As the pressure experienced is small, the thumb does not get hurt. The same force, however acts at the tiny area of the pin point. The resulting high pressure forces the pin into the board.

S9. We take the density of blood from Table 10.1 to be $1.06 \times 10^3\,\text{kg m}^{-3}$. The ratio of the areas is $\left(\frac{A}{a}\right) = 2$. Using Eq. (10.17) we obtain

$$v_1 = \sqrt{\frac{2 \times 24\,\text{Pa}}{1060\,\text{kg m}^{-3}\ \ (2^2 - 1)}} = 0.125\,\text{m s}^{-1}.$$

S10. Here, $h = 10$ m and $\rho = 1000$ kg m^{-3}. Take $g = 10$ m s^{-2}

From Eq. (10.7) $P = P_a + \rho gh$ [Pa = atmospheric pressure ρgh = pressure due to water]

$$= 1.01 \times 10^5 \text{ Pa} + 1000 \text{ kg m}^{-3} \times 10 \text{ m s}^{-2} \times 10 \text{ m}$$

$$= 2.01 \times 10^5 \text{ Pa}$$

$$\approx 2 \text{ atm.}$$

This is a 100% increase in pressure from surface level. At a depth of 1 km the increase in pressure is 100 atm! Submarines are designed to withstand such enormous pressures.

S11. Total cross-sectional area of the femurs is $A = 2 \times 10$ cm^2 = 20×10^{-4} m^2. The force acting on them is F = 40 kg wt = 400 N (taking g = 10 m s^{-2}). This force is acting vertically down and hence, normally on the femurs. Thus, the average pressure is

$$P_{av} = \frac{F}{A} = 2 \times 10^5 \text{ N m}^{-2}.$$

S12. Given: h = 3 m

$\therefore$ $P = h\rho g = 3 \times 10^3 \times 9.8$ ($\because$ density of water, $\rho = 10^3$ kg m^{-3})

Area of hole, $A = 5$ cm^2 = 5×10^{-4} m^2

Therefore, force required to hold a patch covering the hole,

$$F = P \times A = 3 \times 10^3 \times 9.8 \times 5 \times 10^{-4} = 1.5 \times 9.8 \text{ N}$$

= **14.7 N**

S13. Now, loss in weight of the vessel

= weight of the water displaced by the submerged part of the wood. Since density of water is 1 g cm^{-3}, loss in weight of the vessel

= $50 \times 1 \times 980$ dyne = 50 *gf*

Therefore, in order to restore the equilibrium, an additional weight of 50 *gf* has to be placed in the other pan.

S14. At high altitudes, the atmospheric pressure is lesser. Due to greater difference in blood pressure and the atmospheric pressure, to stop the bleeding from a cut in the body at high altitude is found to be difficult.

S15. Excess pressure is inversely proportional to the radius.

S16. Mercury rises in the tube is for atmospheric pressure up to 76 cm of vertical length. If it is tilted also, the vertical length should be same.

S17. Pressure increases as it is proportional to the depth we move into a liquid due to the weight of the liquid between the two layers.

S18. The weight of the cork acting vertically downwards is balanced by the up thrust due to the water. Therefore, the apparent weight of the floating cork is zero.

S19. Whenever a body floats (partly submerged) in a liquid, the weight of the body is equal to the weight of the liquid displaced by the submerged part of the body.

S20. It decreases due to the water vapour pressure.

S21. Atmospheric pressure (atm). In SI,

$$1 \text{ atm} = 1.013 \times 10^5 \text{ Nm}^{-2}$$

S22. Height of the atmospheric, density of the atmosphere and the acceleration due to gravity.

S23. Here, diameter of the sphere of cork, $d = 1$ m

Therefore, volume of the sphere of cork,

$$V = \frac{4}{3}\pi\left(\frac{d}{2}\right)^3$$

$$= \frac{4}{3}\pi\left(\frac{1}{2}\right)^3 = 0.524 \text{ m}^3$$

Now, density of cork,

$$\rho = \frac{1}{4} \times \text{density of water}$$

$$= \frac{1}{4} \times 10^3 \text{ kg m}^{-3}$$

Therefore, mass of the sphere of cork,

$$M = V\rho = 0.524 \times \frac{1}{4} \times 10^3 = \mathbf{131\ kg}.$$

For an ordinary person, a weight of 131 kgf is too large to be lifted. Thus, a sphere of cork 1 m in diameter cannot be lifted.

S24. The atmospheric pressure at sea level,

$$P = 1.013 \times 10^5 \text{ Nm}^{-2}$$

In a barometer, a liquid column of height h balances the atmospheric pressure.

When mercury is used as barometric substance: If h_1 is the height of mercury column and ρ_1 (= 13.6×10^3 kg m^{-3}) the density of mercury, then

$$h_1 \rho_1 g = 1.013 \times 10^5$$

or $$h_1 = \frac{1.013 \times 10^5}{\rho_1 g} = \frac{1.013 \times 10^5}{13.6 \times 10^3 \times 9.8} = 0.76 \text{ m}$$

When water is used as barometric substance: If h_2 is the height of water column, then

$$h_2 \rho_2 g = 1.013 \times 10^5$$

or $$h_2 = \frac{1.013 \times 10^5}{\rho_2 g} = \frac{1.013 \times 10^5}{10^3 \times 9.8} = 10.3 \text{ m}$$

If water is used as barometric substance, it will be very difficult to hold such a long barometer tube in vertical position.

S25. Given, $r = 30$ cm = 0.3 m; $\rho = 1.9$ kg m^{-3}

Now, volume of the air displaced by the balloon,

$$V = \text{volume of the balloon}$$

$$= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi \times 0.3^3 = 0.11 \text{ m}^3$$

Hence, buoyant force on the balloon

$$= \text{weight of the air displaced}$$

$$= V\rho g = 0.11 \times 1.9 \times 9.8 = \mathbf{2.05\ N}$$

S26. Let ρ_1 and ρ_2 be the densities and h_1 and h_2 be the height of the water and spirit columns respectively.

As the mercury columns in the two arms are in level, therefore

$$h_1 \rho_1 g = h_2 \rho_2 g$$

Here, $h_1 = 12$ cm; $h_2 = 7.5$ cm and $\rho_1 = 1$ g cm^{-3}

$$\rho_2 = \frac{h_1 \rho_1}{h_2} = \frac{12 \times 1}{7.5} = \mathbf{1.6\ cm^{-3}}$$

Hence, the relative density of spirit is **1.6**.

S27. Let A be the area of contact of each tyre with the ground, when the person rides the bicycle.

Then, pressure exerted by the person on the each tyre,

$$P = \frac{\text{Weight of the person and bicycle}}{\text{Area of contact of the two tyres}} = \frac{\text{Mg}}{2 \times A}$$

$$= \frac{90 \times 9.8}{2 \times A} = \frac{441}{A}$$

Since the gauge pressure in both the tyres of the bicycle is 6.9×10^5 Pa, we have

$$\frac{441}{A} = 6.9 \times 10^5$$

or $$A = \frac{441}{6.9 \times 10^5} = 6.39 \times 10^{-4}\ \text{m}^2$$

S28. Initially, the weight of the mercury displaced by the part of the body inside the mercury is equal to the weight of the body.

When the water is poured on mercury, so as to cover the body completely, then the weight of the mercury together with the weight of the water displaced by the body is equal to the weight of the body. Obviously, the weight of the mercury displaced now will be less than that displaced initially. Hence, the fractional volume of the body inside the mercury will decrease, when water is poured on top of the mercury to cover the body completely.

S29. Initially, the balloon filled with helium rises in air as the weight of the air displaced by the balloon is greater than the weight of the helium gas and the balloon. Therefore, the balloon halts after attaining a height at which the density of air decreases to a value, such that the weight of the air displaced just equals the weight of helium gas and the balloon halts after a certain height.

S30. Pascal's law. It state that in an enclosed fluid, if an increased pressure is produced in any part of the fluid, then this change of pressure is transmitted undiminished to all the other parts of the fluid.

Explanation: Take a hollow rubber ball and make a number of fine pin holes at different places over the surface of the ball. Pour water into the ball through a wider hole. After closing the wider hole with a finger; if we squeeze the ball, water will be seen to rush out of the pin holes in the shape of fine streams. Further, the streams of water will reach up to the same distance in air indicating that the increased pressure on the water has been transmitted equally in all directions.

S31. Railway tracks are laid on large sized wooden sleepers. In the absence of wooden sleepers, the weight of the train acts on the ground through rails and as such pressure would be so large that the rails may get depressed. When wooden sleepers are provided below the rails, the weight acts on greater area and hence pressure is reduced quite appreciably. Due to this, the rails don't get depressed.

S32. Initially the buoyant force balances the weight of the original candle, so that it floats at a level. When the candle burns gradually, its weight at any instant will be lesser as compared to the weight of the original candle. To remain floating, the buoyant force on the candle at any instant must be equal to its weight at that instant. Therefore, in order that the buoyant force balances the decreased weight of the candle, it becomes less submerged *i.e.*, it rises up accordingly. Hence, the candle rises above relative to the base of the container and stay lit.

S33. Here, weight of the man,

$$F = 80\ \text{k}gf = 80 \times 9.8\ \text{N}$$

(a) Area of the body of the man,

$$A = 0.6\ \text{m}^2$$

$$P = \frac{80 \times 9.8}{0.6}$$

$$= \mathbf{1.0307 \times 10^3\ N\ m^{-2}}.$$

(b) Area of both the feet of the man,

$$A = 80 \times 2 = 160 \text{ cm}^2$$
$$= 1.6 \times 10^{-2} \text{ m}^2$$

$$\therefore \qquad P = \frac{80 \times 9.8}{1.6 \times 10^{-2}}$$
$$= \mathbf{4.9 \times 10^4 \ N\,m^{-2}}.$$

S34. Let M_1 be the mass of the boat and M_2 the mass of the stones.

When the stones are lying in the boat: If ρ_2 is density of water, then volume of water displaced by the boat and stones,

$$V = \frac{(M_1 + M_2)}{\rho_0} \qquad \dots \text{(i)}$$

When the stones are unloaded into water: Volume of water displaced by the boat,

$$V_1 = \frac{M_1}{\rho_0}$$

And volume of water displaced by the stones,

$$V_2 = \frac{M_2}{\rho}$$

Where ρ is density of the stones. Therefore, total volume of water displaced by the boat and stones,

$$V' = V_1 + V_2 = \frac{M_1}{\rho_0} + \frac{M_2}{\rho} \qquad \dots \text{(ii)}$$

Since density of stones is greater than that of water ($\rho > \rho_0$), from the equation (i) and (ii), it follows that $V' < V$. Thus, the volume of water displaced on unloading the stones will be less then that before unloading.

Hence, the level of water in the tank will ***decrease***.

S35. Given, $M = 5.98 \times 10^{24}$ kg; $R = 6.38 \times 10^6$ m.

(a) The average density of the earth,

$$\rho = \frac{M}{V} = \frac{M}{\frac{4}{3}\pi R^3}$$

$$= \frac{5.98 \times 10^{24}}{\frac{4}{3}\pi \times (6.38 \times 10^6)^3}$$
$$= 5.5 \times 10^3 \text{ kg m}^{-3}.$$

(b) In the history of earth, when the earth was born from the sun, it was in molten state. Its lighter constituents literally 'floated' to the top of the molten sphere and the heavier constituents 'sank' to the centre. Thus, near the centre, earth's material is denser than that near the surface of earth. It is found that the average density of the material near the earth's surface is about half the value for that of the material near its centre.

S36. Here, diameter of the neck of the bottle,

$$d_1 = 2 \text{ cm}$$

Therefore, area of cross-section of the neck of the bottle.

$$A_1 = \frac{\pi d_1^2}{4} = \frac{\pi \times 2^2}{4}$$

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

Diameter of the bottom of the bottle,

$$d_2 = 10 \text{ cm}$$

Therefore, area of cross-section of the bottom of the bottle.

$$A_2 = \frac{\pi d_2^2}{4} = \frac{\pi \times 10^2}{4}$$

$$= 25\pi \text{ cm}^2 = 25\pi \times 10^{-4} \text{ m}^1$$

Force applied on the cork in the neck of the bottle,

$$F_1 = 1.2 \text{ kgf} = 1.2 \times 9.8 \text{ N} = 11.76 \text{ N}$$

Therefore, pressure applied on the cork,

$$P = \frac{F_1}{A_1} = \frac{1.2 \times 9.8}{\pi \times 10^{-4}} \text{ Nm}^{-2}$$

Hence, force on the bottom of the bottle,

$$F_2 = P \times A_2 = \frac{1.2 \times 9.8}{\pi \times 10^{-4}} \times 25\pi \times 10^{-4}$$

$$= 30 \times 9.8 \text{ N} = \mathbf{294\ N}$$

S37. Let l be length of the mercury in the barometer tube. As the barometer tube is inclined at an angle of 30° to the vertical, effective height (vertical) of the mercury column = $l \cos 30°$ since atmospheric pressure is 75 cm of column $l \cos 30° = 75$

or $$l = \frac{75}{\cos 30°} = \frac{75}{0.8660} = \mathbf{86.6\ cm}.$$

S38. Let V be the total volume of the piece of iron and V', its volume inside the mercury. If ρ and ρ' are densities of iron and mercury respectively, then

$$V \rho g = V' \rho' g$$

or $$\frac{V'}{V} = \frac{\rho}{\rho'} = \frac{7.8 \times 10^3}{13.6 \times 10^3} = 0.574$$

Therefore, fraction of volume of the piece of iron outside the mercury,

$$\frac{V - V'}{V} = 1 - \frac{V'}{V} = 1 - 0.574 = \mathbf{0.426}.$$

S39. Here, density of ice, ρ = 917 kg m^{-3} and density of sea water, ρ' = 1,024 kg m^{-3}

Let V be the total volume of the iceberg and V', the volume below the water.

According to the law of floatation,

Weight of the iceberg = weight of seawater displaced by it

or $$V \rho g = V' \rho' g$$

or $$V' = \frac{V\rho}{\rho'} = \frac{V \times 917}{1024} = 0.896\ \text{V}$$

Therefore, volume of the iceberg above the water

$$\text{V} - V' = V - 0.896\ \text{V} = 0.104\ \text{V}$$

Hence, fraction of the iceberg seen by us,

$$\frac{V - V'}{V} = \frac{0.104\,V}{V} = \mathbf{0.104}.$$

S40. Here, weight of the body in air, $W_1 = 25\,gf = 25 \times 980$ dyne weight of the body in water, $W_2 = 20\,gf = 20 \times 980$ dyne

If V is volume of the body and ρ, the density of water, then

$$W_1 - W_2 = V \rho g$$

or $$V = \frac{W_1 - W_2}{\rho g}$$

or $$V = \frac{25 \times 980 - 20 \times 980}{1 \times 980} = 5\ \text{cm}^3 \qquad (\because\ \rho = 1\ \text{g cm}^{-3})$$

If ρ' is density of the liquid, then weight of the body in liquid,

$$W_2' = W_1 - V\rho' g = 25 \times 980 - 5 \times 0.8 \times 980$$
$$= 21 \times 980 \text{ dyne} = \mathbf{21\ \textit{gf}}.$$

S41. Let V be the volume of the cork.

Volume of the cork inside water = $(V - 10)$ cm^3

Let ρ and ρ' be the densities of the cork and the water respectively.

For the cork to float,

Weight of the cork = weight of the water displaced

$$V\rho g = (V - 10)\rho' g$$

or $$V\rho = (V - 10)\rho' \text{ or } V \times 0.15 = (V - 10) \times 1$$

or $$V = 11.765 \text{ cm}^3$$

Therefore, mass of the cork,

$$M = V\rho = 11.765 \times 0.15 = \mathbf{1.765\ g}.$$

S42. Given, $h = 0.5$ M, $\rho = 1000 \text{ kg m}^{-3}$, $A = 0.01 \text{ m}^{-2}$, $m = 5$ kg

Total force acting on the base = $hg\rho A + mg$

$$F = 0.5 \times 9.8 \times 1000 \times 0.01 + 5 \times 9.8$$

$$= 5 \times 9.8 + 5 \times 9.8 = 98.0 \text{ N}$$

$\therefore$ $$\text{Pressure} = \frac{\text{Force}}{\text{Area}} = \frac{98.0}{0.01} = 9800 \text{ Nm}^{-2}$$

S43. Since pressure is transmitted undiminished throughout the fluid,

$$F_1 = \frac{A_1}{A_2} F_2 = \frac{\pi(5 \times 10^{-2}\text{ m})^2}{\pi(15 \times 10^{-2}\text{ m})^2}(1350\text{ N} \times 9.8\text{ m s}^{-2})$$

$$= 1470 \text{ N} \approx 1.5 \times 10^3 \text{ N}$$

The air pressure that will produce this force is

$$P = \frac{F_1}{A_1} F_2 = \frac{F_1}{A_1} = \frac{1.5 \times 10^3 \text{ N}}{\pi(5 \times 10^{-2})^2 \text{ m}} \approx 1.9 \times 10^{-5} \text{ Pa}$$

This is almost double the atmospheric pressure.

S44. We use Eq. (10.7)

$$\rho gh = 1.29 \text{ kg m}^{-3} \times 9.8 \text{ m s}^{-2} \times h \text{ m}$$

$$= 1.01 \times 10^5 \text{ Pa}$$

$\therefore$ $$h = 7989 \text{ m} \approx 8 \text{ km}$$

In reality the density of air decreases with height. So does the value of g. The atmospheric cover extends with decreasing pressure over 100 km. We should also note that the sea level atmospheric pressure is not always 760 mm of Hg. A drop in the Hg level by 10 mm or more is a sign of an approaching storm.

S45. Here, weight of the piece of iron in water,

$$W_2 = 400\,gf = 400 \times 980 \text{ dyne}$$

Density of iron, $\rho = 7.8 \text{ g cm}^{-2}$

Let m be the mass of piece of iron. Then,

Volume of the piece of iron,

$$V = \frac{m}{\rho} = \frac{m}{7.8}$$

If ρ' density of water, then loss of weight of the piece of iron in water

$$= V\rho' g = \frac{m}{7.8} \times 1 \times 980$$

If W_1 is weight of the piece of iron in air, then

$$W_1 - W_2 = \text{loss of weight in water}$$

or $$m \times 980 - 400 \times 980 = \frac{m}{7.8} \times .1 \times 980$$

or $$7.8\text{ m} - 400 \times 7.8 = \text{m}$$

or $$6.8\text{ m} = 400 \times 7.8$$

or $$m = 458.82\text{ g}$$

Therefore, volume of the piece of iron

$$V = \frac{m}{\rho} = \frac{458.82}{7.8} = \mathbf{58.82\ cm^3}.$$

S46. Let V and V' be the volumes of the piece of cork and the lump of metal respectively,

Here, density of the cork, $\rho = 250\text{ kg m}^{-3}$

Density of the metal, $\rho' = 8 \times 10^3\text{ kg m}^{-3}$

Mass of the lump of metal, $M = V\rho = V \times 250$

As the combination of the piece of cork and the metal just float in water

$$Mg + M'g = \text{weight of the water displaced}$$

or $$V \times 250 \times g + 0.024 \times g = (V + V') \times 10^3 \times g$$ (Density of water = 10^3 kg m^{-3})

or $$250\text{V} + 0.024 = \left(V + \frac{0.024}{8 \times 10^3}\right) \times 10^3 \qquad \left[\because\ V' = \frac{M'}{\rho'}\right]$$

or $$750\text{ V} = 0.024 - 0.003$$

or $$V = 2.8 \times 10^{-5}\text{ m}^3$$

Therefore, mass of the piece of cork,

$$M = V\rho$$

$$= 2.8 \times 10^{-5} \times 250 = \mathbf{7 \times 10^{-3}\ kg}.$$

S47. Let m_1 and m_2 be the masses; V_1 and V_2 the volumes; and ρ_1 and ρ_2, the densities of the piece of metal and the cork respectively. Let ρ be the density of the water.

Here, $m_1 = 17$ g; $m_2 = 5$ g; $\rho_2 = 0.25$ g cm^{-3} and $\rho = 1$ g cm^{-3}

According to the principle of floatation, weight of the piece of metal and cork

= weight of the water displaced by both of them

or $$m_1 g + m_2 g = (V_1 + V_2)\rho g$$

or $$m_1 + m_2 = \left(\frac{m_1}{\rho_1} + \frac{m_2}{\rho_2}\right)\rho$$

or $$17 + 5 = \left(\frac{17}{\rho_1} + \frac{5}{0.25}\right) \times 1$$

or $$22 = \frac{17}{\rho_1} + 20$$

or $$\rho_1 = \mathbf{8.5\ g\ cm^{-3}}.$$

S48. Consider two points *A* and *B* at two levels separated by *h* column of a liquid of density ρ surrounding the points *A* and *B*. Consider an area '*a*' forming a cylinder of liquid of length *h*.

The pressure at *A*, P_A = Atmospheric pressure (P_0).

Weight of the liquid at centre of gravity

$$W = Mg = h a \rho g$$

For equilibrium, pressure / force at *B* should nullify the forces acting down.

$\therefore$ $$P_A \,.\, a + h a \rho g = P_B \,.\, a$$

$\therefore$ $$P_B = P_A + h\rho g = P_0 + h \rho g.$$

S49. Given, Mass of the girl, $m = 50$ kg

Diameter of the heel, $d = 1$ cm $= 0.01$ m

Radius of the heel, $r = \frac{d}{2} = 0.005$ m

Area of the heel $= \pi r^2$

$= \pi(0.005)^2 = 7.85 \times 10^{-5}$ m^2

Force exerted by the heel on the floor:

$$F = mg$$
$$= 50 \times 9.8 = 490 \text{ N}$$

Pressure exerted by the heel on the floor:

$$P = \frac{\text{Force}}{\text{Area}}$$

$$= \frac{490}{7.85 \times 10^{-5}} = 6.24 \times 10^6 \text{ N m}^{-2}$$

Therefore, the pressure exerted by the heel on the horizontal floor is 6.24×10^6 Nm^{-2}.

S50. Here, $h = 1000$ m and $\rho = 1.03 \times 10^3$ kg m^{-3}.

(a) From Eq. (10.6), absolute pressure

$$P = P_a + \rho gh$$

$$= 1.01 \times 10^5 \text{ Pa} + 1.03 \times 10^3 \text{ kg m}^{-3} \times 10 \text{ m s}^{-2} \times 1000 \text{ m}$$

$$= 104.01 \times 10^5 \text{ Pa} \qquad [\because \ 1 \text{ atm} = 1.01 \times 10^5 \text{ Pa}]$$

$$\approx 104 \text{ atm}$$

(b) Gauge pressure is $P - P_a = \rho gh = P_g$

$$P_g = 1.03 \times 10^3 \text{ kg m}^{-3} \times 10 \text{ m s}^{-2} \times 1000 \text{ m}$$

$$= 103 \times 10^5 \text{ Pa}$$

$$\approx 103 \text{ atm}$$

(c) The pressure outside the submarine is $P = P_a + \rho gh$ and the pressure inside it is P_a. Hence, the net pressure acting on the window is gauge pressure, $P_g = \rho gh$. Since the area of the window is $A = 0.04$ m^2, the force acting on it is

$$F = P_g A = 103 \times 10^5 \text{ Pa} \times 0.04 \text{ m}^2 = 4.12 \times 10^5 \text{ N}.$$

S51. Let V be the volume of the iceberg

Here, density of the ice,

$$\rho = 0.9 \text{ g cm}^{-3} = 900 \text{ kg m}^{-3}$$

and density of the sea water,

$$\rho' = 1.02 \text{ g cm}^{-3} = 1{,}020 \text{ kg m}^{-3}$$

Now, on placing the body of mass M (= 240 kg) on the iceberg, the iceberg just sinks.

Therefore, according to the principle of floating,

weight of the iceberg + weight placed on the iceberg

= weight of the sea water displaced by the iceberg

or $V\rho g + Mg = V\rho' g$

or $V(\rho' - \rho) = M$

or $V(1{,}020 - 900) = 240$

or $V = 2 \text{ m}^3$

Therefore, mass of the iceberg

$$= V\rho = 2 \times 900 = \mathbf{1{,}800 \text{ kg}}.$$

S52. Let V_1 and V_2 be the volume of alcohol and water, which will produce the desired mixture.

Here, Density of alcohol, $\rho_1 = 795\ \text{kg m}^{-3}$

Density of water, $\rho_2 = 1{,}000\ \text{kg m}^{-3}$

and Density of the mixture, $\rho = 900\ \text{kg m}^{-3}$

Mass of alcohol, $m_1 = V_1 \times 795;$

Mass of water, $m_2 = V_2 \times 1{,}000$

Volume of the mixture, $V = V_1 + V_2$

Since volume of the mixture diminished to 0.97 of the initial volume, effective volume of the mixture. Therefore,

$$V_1 \rho_1 + V_2 \rho_2 = V'.\ \rho$$

or $$V_1 \times 795 \times V_2 + 1{,}000 = 0.97\ (V_1 + V_2) \times 900$$

or $$78\ V_1 = 127\ V_2$$

or $$\frac{V_2}{V_1} = \mathbf{0.614}.$$

S53. Weight of the body = $V \rho g$

Weight of the two liquids displaced by the sphere

$$= V_1 \rho_1 g + V_2 \rho_2 g$$

According to the principle of floatation,

$$V \rho g = V_1 \rho_1 g + V_2 \rho_2 g$$

or $$V\rho = V_1 \rho_1 + V_2 \rho_2 \qquad \text{... (i)}$$

Also, $V = V_1 + V_2$ or $V_2 = V - V_1$

Substituting for V_2 in the Eq. (i), we have

$$V\rho = V_1 \rho_1 + (V - V_1) \rho_2$$

or $$V(\rho - \rho_2) = V_1(\rho_1 - \rho_2)$$

or $$\frac{V_1}{V} = \frac{\rho - \rho_2}{\rho_1 - \rho_2}$$

Again, $V_1 = V - V_2$

Substituting for V_1 in the Eq. (i), we have

$$V\rho = (V - V_2) \rho_1 + V_2 \rho_2$$

or $$V(\rho - \rho_1) = V_2(\rho_2 - \rho_1)$$

or $$\frac{V_2}{V} = \frac{\rho - \rho_1}{\rho_2 - \rho_1}.$$

S54. (a) The car manual always refers to the gauge pressure.

Therefore, gauge pressure = **200 kPa**

(b) Now, gauge pressure = absolute pressure – atmospheric pressure

$\therefore$ absolute pressure = gauge pressure + atmospheric pressure

$= 200 \text{ kPa} + 1.013 \times 10^5 \text{ Pa}$

$= 200 \text{ kPa} + 101.3 \text{ kPa}$

$= \mathbf{301.3 \text{ kPa}}$

(c) Atmospheric pressure at the mountain

$$= 101.3 \times \frac{90}{100} = \mathbf{91.2 \text{ kPa}}$$

The tyre gauges the gauge pressure.

Therefore gauge pressure at the mountain

$= 301.3 - 91.2 = \mathbf{210.1 \text{ kPa}}$.

S55. (a) Given, $h = 8$ m; $P_{atmos} = 1.01 \times 10^5 \text{ Nm}^{-2}$

Also, density of water, $\rho = 10^5 \text{ kg m}^{-3}$

Total pressure on the back of a scuba diver,

$$P = P_{atmos} + h\rho g$$
$$= 1.01 \times 10^5 + 8 \times 10^3 \times 9.8$$
$$= 1.01 \times 10^5 + 0.784 \times 10^5$$
$$= 1.794 \times 10^5 \text{ Nm}^{-2}.$$

(b) Given, $A = 60 \times 50 = 3 \times 10^3 \text{ cm}^2 = 0.3 \text{ m}^2$

Pressure due to water,

$$P_{water} = 0.784 \times 10^5 \text{ Nm}^{-2}$$

Hence, force on the back of the diver,

$$F = P_{water} \times A = 0.784 \times 10^5 \times 0.3 = \mathbf{2.352 \times 10^4 \text{ N}}.$$

S56. (a) The pressure of a liquid is given by the relation:

$$P = h\rho g$$

Where, P = Pressure

h = Height of the liquid column

ρ = Density of the liquid

g = Acceleration due to the gravity

It can be inferred that pressure is directly proportional to height. Hence, the blood pressure in human vessels depends on the height of the blood column in the body. The height of the blood column is more at the feet than it is at the brain. Hence, the blood pressure at the feet is more than it is at the brain.

(b) Density of air is the maximum near the sea level. Density of air decreases with increase in height from the surface. At a height of about 6 km, density decreases to nearly half of its value at the sea level. Atmospheric pressure is proportional to density. Hence, at a height of 6 km from the surface, it decreases to nearly half of its value at the sea level.

(c) When force is applied on a liquid, the pressure in the liquid is transmit in all directions. Hence, hydrostatic pressure does not have a fixed direction and it is a scalar physical quantity.

S57. When the up thrust balances the weight of the body, the floating body is equilibrium.

Let V be the volume of the sample (diluted) of milk. If V' is volume of water in the sample, then volume of pure milk is $V - V'$.

Here, density of the sample of milk, $\rho_1 = 1{,}032\ \text{kg m}^{-3}$; density of pure milk, $\rho_2 = 1{,}080\ \text{kg m}^{-3}$;

We know that the density of water = $1{,}000\ \text{kg m}^{-3}$

Now, density of the sample of milk,

$$\rho_1 = \frac{\text{Mass of pure milk and water in the sample}}{\text{Volume of the sample of the milk}}$$

or $$1{,}032 = \frac{(V - V') \times 1{,}080 + V' \times 1{,}000}{V}$$

or $$1{,}032\,V = 1{,}080\,V - 1{,}080\,V' + 1{,}000\,V'$$

or $$\frac{V'}{V} = \frac{48}{80} = 0.6$$

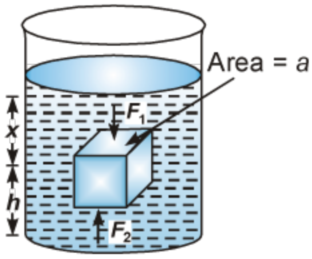
Therefore, percentage of water by volume in the milk

$$= 0.6 \times 100 = \mathbf{60\%}.$$

S58. (a) ***Archimedes' Principle:*** When a body is partially or completely immersed in a liquid, it loses weight due to the presence of upthrust, which is equal to the weight of liquid displaced by the submerged part of the body.

To prove the principle, consider a body of height h lying at a depth x below the free surface of a liquid of density ρ (as shown in the figure). Let a be the area of the face of the body parallel to the horizontal.

Now, pressure at the upper face of the body,



$$P_1 = x\rho g$$

and pressure at the lower face of the body,

$$P_2 = (x + h)\rho g$$

Thrust on he upper face of the body,

$$F_1 = P_1 a = a x \rho g \qquad \text{(vertically downwards)}$$

Also, thrust on the lower face of the body,

$$F_2 = P_2 a = a(x + h)\rho g \qquad \text{(vertically upwards)}$$

Since, F_2 is greater than F_1, the net thrust acts on the body in the upward direction. It is called the upthrust and is denoted by U. Therefore,

$$U = F_2 - F_1 = a(x + h)\rho g - a x \rho g$$

or $U = a h \rho g$

Now $a h = V$ (the volume of the body)

ρ $U = V\rho g$

Weight in air, $W_1 = V\rho g$

Apparent weight $W_a = W_1 - U$

Loss in weight $= W_1 -$ Apparent weight

$= W_1 - W_a = W_1 - (W_1 - U)$

$= W_1 - W_1 + U = U$

$= V\sigma g$

So, there is a loss equal to upthrust.

(b) Excess pressure $= \dfrac{2\sigma}{r} = \dfrac{2 \times 72 \times 10^{-3}}{0.1 \times 10^{-3}}$

$= 1440\ \text{N/m}^2$

$= 0.01440 \times 10^5\ \text{N/m}^2$

So, Net pressure $= (1.1 - 0.0144) \times 10^5$

$= 1.0856 \times 10^5\ \text{N/m}^2$.

Date: 14/10/2021

Q1. What will be the ratio of the velocity of efflux from two holes made with a separation ($H - 2h$) in a container holding liquid of height 'H' and one hole at a depth 'h' from its bottom? Give reason.

Q2. If a capillary tube of insufficient length is dipped into a liquid, what will happen to the liquid rising?

Q3. Why does the cotton wick in an oil filled lamp keep on burning?

Q4. Explain why? The angle of contact of mercury with glass is obtuse, while that of water with glass is acute.

Q5. Distinguish between streamline and turbulent flow of a liquid.

Q6. Two streamlines cannot cross each other. Explain, why.

Q7. When air is blown in between two balls suspended close to each other, they are attracted towards each other. Given reason.

Q8. It is advised not to stand near a running train. Why?

Q9. Calculate the excess of pressure inside (a) a drop of liquid of radius 0.2 cm and (b) a bubble of liquid of radius 0.3 cm. Given that surface tension of liquid is 24 dyne cm^{-1}.

Q10. Two syringes of different cross sections (without needles) filled with water are connected with a tightly fitted rubber tube filled with water. Diameters of the smaller piston and larger piston are 1.0 cm and 3.0 cm respectively. (a) Find the force exerted on the larger piston when a force of 10 N is applied to the smaller piston. (b) If the smaller piston is pushed in through 6.0 cm, how much does the larger piston move out?

Q11. A spray pump used for killing insects is made of a cylindrical tube of cross-section of 10 cm^2. It has 50 fine holes, each of radius 0.05 cm. If the insect killing agent (a liquid) enters the tube of the pump at 2.4. m min^{-1}, what is speed of ejection of the liquid through the holes?

Q12. (a) Define streamline.
(b) Write any two properties of streamlines.
(c) Draw streamline for a clockwise spinning sphere.
(d) Drive equation of continuity.

Q13. A plane is in level flight at constant speed and each of its two wings has an area of 25 m^2. If the speed of the air is 180 km/h over the lower wing and 234 km/h over the upper wing surface, determine the plane's mass. (Take air density to be 1 kg m^{-3}).

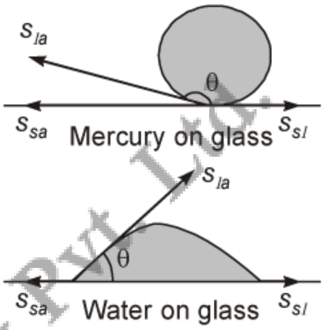
Date: 14/10/2021

S1. 1 : 1 as the velocity of efflux will be the same at two places – both at a depth '*h*' from the free surface and at a height '*H*' from the bottom.

S2. The liquid will rise to the level available and form a meniscus of large value.

S3. In the cotton wick, there are very large number of capillaries in which oil continues to rise.

S4. The angle between the tangent to the liquid surface at the point of contact and the surface inside the liquid is called the angle of contact (θ), as shown in the given figure.



S_{la}, S_{sa}, and S_{sl} are the respective interfacial tensions between the liquid-air, solid-air, and solid-liquid interfaces. At the line of contact, the surface forces between the three media must be in equilibrium, *i.e.*,

$$\cos\theta = \frac{S_{Sa} - S_{sl}}{S_{la}}$$

S5. (a) In streamline flow, the velocity of liquid is low and steady, while in turbulent flow, the velocity is high and unsteady.

(b) In streamline flow, the velocity of liquid is below its critical velocity; while in case of turbulent motion, the velocity is greater than the critical velocity.

(c) The velocity of every element of the liquid crossing a particular point is same in case of streamline flow, while it keeps on changing in case of turbulent motion.

S6. The tangent at any point on a streamline gives the direction of flow of liquid molecule at that point. In case, the two streamlines cross each other; it would mean that the liquid molecule can have two velocities along the two different directions, which is against the definition of streamline motion. Hence, two streamlines cannot cross each other.

S7. When air is blown in between two balls suspended close to each other high speed, a low pressure is created between the balls which is much less than the atmospheric pressure beyond the balls. Due to this, balls attracted towards each other according to Bernoulli's theorem.

S8. When fast moving train passes on a rail, then the velocity of air streams in between the rail and the person standing near rail will be very large as compared to the velocity of air streams on the other side of person away from the rail. According to Bernoulli's theorem, the pressure of air will become low in between person and rail and is high on the other side of person. As a result of the pressure difference, a thrust acts on the person which may push the person towards rail side and the person may meet with an accident.

S9. (a) Given, $T = 24$ dyne cm^{-1} ; $r = 0.2$ cm

Now, excess of pressure inside the liquid the drop,

$$P_i - P_0 = \frac{2T}{r} = \frac{2 \times 24}{0.2} = \mathbf{240\ dyne\ cm^{-2}}.$$

(b) Here, $T = 24$ dyne cm^{-1}

Now, excess of pressure inside the liquid bubble,

$$P_i - P_0 = \frac{4T}{r} = \frac{4 \times 24}{0.3} = \mathbf{320\ dyne\ cm^{-2}}.$$

S10. (a) Since pressure is transmitted undiminished throughout the fluid,

$\therefore$ $$P_1 = P_2$$

$$F_2 = \frac{A_2}{A_1} F_1 = \frac{\pi(3/2 \times 10^{-2}\ \text{m})^2}{\pi(1/2 \times 10^{-2}\ \text{m})^2} \times 10\ \text{N} = 90\ \text{N}$$

(b) Water is considered to be perfectly incompressible. Volume covered by the movement of smaller piston inwards is equal to volume moved outwards due to the larger piston.

$$L_1 A_1 = L_2 A_2$$

$$= \frac{A_1}{A_2} L_1 = \frac{\pi(1/2 \times 10^{-2}\ \text{m})^2}{\pi(3/2 \times 10^{-2}\ \text{m})^2} \times 6 \times 10^{-2}\ \text{m}$$

$$\simeq 0.67 \times 10^{-2}\ \text{m} = 0.67\ \text{cm}$$

Note, atmospheric pressure is common to both pistons and has been ignored.

S11. Given, cross-section of the tube,

$$a_1 = 10\ \text{cm}^2 = 10 \times 10^{-4} = 10^{-3}\ \text{m}^2;$$

The speed of liquid in the tube, (v_1)

$$v_1 = 2.4\ \text{m min}^{-1} = \frac{2.4}{60}\ \text{ms}^{-1}$$

$$= 0.04\ \text{ms}^{-1}$$

Radius of a hole, $r = 0.05\ \text{cm} = 5 \times 10^{-4}\ \text{m}$

Therefore, cross-section of a hole,

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

$$= 7.854 \times 10^{-7}\ \text{m}^2$$

Therefore, total cross-section of 50 holes,

$$a_2 = \pi r^2 \times 50$$

$$= 7.854 \times 10^{-7} \times 50\ \text{m}^2$$
$$= 3.927 \times 10^{-5}\ \text{m}^2$$

If v_2 is the speed of ejection of the liquid through the holes, then

$$a_1 v_1 = a_2 v_2$$

or $$v_2 = \frac{a_1 v_1}{a_2} = \frac{10^{-3} \times 0.04}{3.927 \times 10^{-5}} = \mathbf{1.018\ ms^{-1}}.$$

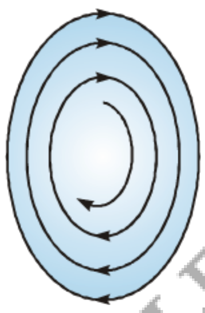
S12. (a) Streamline is the actual path followed by the procession of particles in a steady flow, which may be straight or curved such that tangent to it at any point indicate the direction of flow of a liquid at that point.

(b) Two properties of streamline are:

(i) Two streamlines can never cross each other.

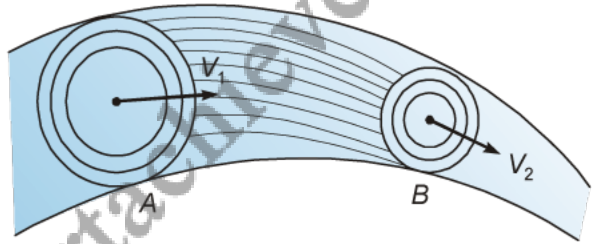
(ii) The greater is the crowding of streamlines at a place, the greater will be the velocity of liquid particles at that place and vice-versa.

(c) Due to spinning sphere, concentric streamlines are formed.



(d) Volume of liquid entering per second at

$$A = a_1 v_1$$



Mass of liquid entering per second at

$$A = a_1 v_1 \rho_1$$

Similarly, mass of liquid leaving per second at

$$B = a_2 v_2 \rho_2$$

If there is no loss of liquid in tube and the flow is steady then,

Mass of liquid entering per second at A = Mass of liquid leaving per second at B

$$a_1 v_1 \rho_1 = a_2 v_2 \rho_2$$

If liquid is incompressible then, $\rho_1 = \rho_2$

$$a_1 v_1 = a_2 v_2$$

$$av = \text{constant}$$

This is the equation of continuity.

S13. The area of the wings of the plane, $A = 2 \times 25 = 50\ \text{m}^2$

Speed of air over the lower wing, $v_1 = 180\ \text{km/h} = 50\ \text{m/s}$

Speed of air over the upper wing, $v_2 = 234\ \text{km/h} = 65\ \text{m/s}$

Density of air, $\rho = 1\ \text{kg m}^{-3}$

Pressure of air over the lower wing = P_1

Pressure of air over the upper wing = P_2

The upward force on the plane can be obtained using Bernoulli's equation as:

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

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

The upward force (F) on the plane can be calculated as:

$$(P_1 - P_2)A = \frac{1}{2}\rho(v_2^2 - v_1^2)A \quad \text{Using equation (i)}$$

$$= \frac{1}{2} \times \left((65)^2 - (50)^2\right) \times 50 = 43125\ \text{N}$$

Using Newton's force equation, we can obtain the mass (m) of the plane as:

$$F = mg$$

$$\therefore \quad m = \frac{43125}{9.8} = 4400.51\ \text{kg}$$

$$= \sim 4400\ \text{kg}$$

Hence, the mass of the plane is about 4400 kg.

Date: 14/10/2021

Q1. What is pilot tube? State the principle on which it is based.

Q2. When a shaving brush is taken out of water its hairs cling together. Why?

Q3. Bernoulli's theorem hold for in incompressible, non-viscous fluids. What will happen, if the viscosity of the fluid is not negligible?

Q4. What is pressure head?

Q5. What should be the properties of a liquid to satisfy Bernoulli's theorem?

Q6. Why does the speed of a liquid increase, when the liquid passes through a constriction in a pipe?

Q7. What is the cause far velocity gradient as a liquid flows in a tube of radius. '*r*' with its velocity along the axis being '*v*'?

Q8. The diameter of ball *A* is twice of that of *B*. What will be the ratio of their terminal velocities in water?

Q9. If two row-boats happen to sail parallel, and close of each other, they experience a force which pulls them towards each other. Give reasons for it.

Q10. Why the speed of a whirl wind in a tornado is alarmingly high?

Q11. Does Archimedes' principle hold in a vessel in free fall or in a satellite moving in a circular orbit?

Q12. Can Bernoulli's equation be used to describe the flow of water through a rapid in a river? Explain.

Q13. Why a light ball can remain suspended on a vertical jet of water?

Q14. Does it matter if one uses gauge instead of absolute pressures in applying Bernoulli's equation? Explain.

Q15. What is the relation for maximum range of water coming out from an orifice on the side wall of a tank?

Q16. When 200 g mass placed in a cylindrical beaker of base area '*a*' is removed, the vertical length comes out of water by 2 cm. What is the radius of the cylinder?

Q17. Two liquids of equal mass and different densities ρ_1 and ρ_2 are mixed, what is the density of the mixture?

Q18. When two soap bubbles stay in contact, what is the radius of the interface?

Q19. A small hole is made at a height $1/\sqrt{2}$ m from the bottom of a cylindrical water tank and at a depth of $\sqrt{2}$ m from the free surface of water in the tank. Find the distance, where the water emerging from the hole strikes the ground.

Q20. At what speed will the velocity head of stream of water be equal to 40 cm?

Q21. A cylinder of height 20 m is completely filled with water. Find the velocity of efflux of water (in ms^{-1}) through a small hole on the side wall of the cylinder near its bottom. Given, $g = 10\ ms^{-2}$.

Q22. Why is it impossible to remove a filter paper from a funnel by bellowing it into the narrow end of the funnel?

Q23. Explain using Bernoulli's equation, why there is a lifting force produced by the flow of air past the wings of an aeroplane.

Q24. When air is blown in between the two balls suspended from a string such that they do not touch each other, the balls come nearer to each other, instead of moving away. Why?

Q25. Why does a flag flutter, when strong winds are blowing on a certain day? Explain.

Q26. Why the speed of innermost layer of a whirlwind is alarming high? Explain.

Q27. If a small ping pong ball is placed in a vertical jet of air or water, it will rise to a certain height above the nozzle and stay at that level. Explain.

Q28. What is the minimum pressure required to force blood from the heart to the top of the head (vertical distance 50 cm)? Assume that density of blood to be $1.06\ g\ cm^{-3}$.

Q29. A venturimeter is 3.75 cm is diameter in the mains and 15 cm diameter in the throat. The difference between the pressure of water in the mains and the throat is 23 cm of mercury. Find the rate of discharge of water from the venturimeter.

Q30. Air of density $1.3\ kg\ m^{-3}$ blows horizontally with a speed of $108\ km\ h^{-1}$. A house has a plane roof of area $40\ m^2$. Find the magnitude of aerodynamic lift on the roof.

Q31. The accumulation of snow on an aeroplane wings may reduce the lift. Explain.

Q32. A hydraulic automobile lift is designed to lift cars with maximum mass of 300 kg. The area of cross-section of the piston carrying the load is $425\ cm^2$. What maximum pressure would the smaller piston have to bear?

Q33. Water flows through a horizontal pipe of which the cross-section is not constant. The pressure is 1 cm of mercury where the velocity is 0.35 m/s. Find the pressure at a point where the velocity is 0.65 m/s.

Q34. Calculate the velocity of efflux of kerosene oil from an orifice of a tank in which pressure is 4 atmosphere. The density of kerosene oil = $720\ kg\ m^{-3}$ and 1 atmospheric pressure = $1.013 \times 10^5\ Nm^{-2.}$

Q35. A fully loaded Boeing aircraft has a mass of 3.3×10^5 kg. Its total wing area is $500\ m^2$. It is in level flight with a speed of 960 km/h. (a) Estimate the pressure difference between the lower and upper surfaces of the wings (b) Estimate the fractional increase in the speed of the air on the upper surface of the wing relative to the lower surface. [The density of air is $\rho = 1.2\ kg\ m^{-3}$]

Q36. In problem 10.9, if 15.0 cm of water and spirit each are further poured into the respective arms of the tube, what is the difference in the levels of mercury in the two arms? (Specific gravity of mercury = 13.6)

Q37. In deriving Bernoulli's equation, we equated the work done on the fluid in the tube to its change in the potential and kinetic energy. (a) What is the largest average velocity of blood flow in an artery of diameter 2×10^{-3} m if the flow must remain laminar? (b) Do the dissipative forces become more important as the fluid velocity increases? Discuss qualitatively.

Q38. The reading of a pressure meter attached with a closed water pipe is 3.5×10^5 N m^{-2}.On opening the valve of the pipe, the reading of pressure meter is reduce to 3×10^5 N m^{-2}. Calculate the speed of water flowing in pipe. Given that the density of water = 1,000 kg m^{-3}.

Q39. A pilot tube is mounted on an aeroplane wing to measure the speed of the aeroplane. The tube contains alcohol and shows a level difference of 40 cm as shown in the figure. What is the speed of the plane relative to air? Given the relative density of alcohol = 0.8 and density of air = 1 kg m^{-3}.

Q40. (a) The flow of blood in a large artery of an anaesthetized dog is diverted through a venturimeter. The wider part of the meter has a cross-sectional are equal to that of the artery *i.e.*, 8 mm^2.The narrower part an area 4 mm^2. The pressure drop in the artery is 24 Pa. What is the speed of the blood in the artery? Given that density of the blood = 1.06×10^3 kg m^{-3}.

(b) 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.

Q41. Water is flowing through a horizontal pipe of varying cross-section. If the pressure of water equals 2 cm of mercury, where the velocity of the flow is 32 cm s^{-1}, what is the pressure at another point, where the velocity of flow is 65 cm s^{-1}.

Q42. Water flowing in a horizontal main of uniform bore has a velocity of 100 cm s^{-1} at a point, where the pressure is 1/10th of the atmospheric pressure. What will be the velocity at a point, where the pressure is one half of that at the first point?

Q43. Air is streamlining past a horizontal airplane wing, such that its speed is 120 m s^{-1} over the upper surface and 90 m s^{-1} at the lower surface. If the density of air is 1.3 kg m^{-3}, find the difference in pressure between the top and bottom of the wing. If the wing is 10 m long and has an average width of 2 m, calculate the gross lift of the wing.

Q44. Water is maintained at a height of 10 m in a tank. Calculate the diameter of a circular aperture needed at the base of the tank to discharge water at the rate of 26.4 m^3 min^{-1}. Given that g = 9.8 m s^{-2}.

Q45. Explain why:

(a) To keep a piece of paper horizontal, you should blow over, not under, it

(b) When we try to close a water tap with our fingers, fast jets of water gush through the openings between our fingers.

(c) The size of the needle of a syringe controls flow rate better than the thumb pressure exerted by a doctor while administering an injection.

(d) A fluid flowing out of a small hole in a vessel results in a backward thrust on the vessel.

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

Q46. State and prove Bernoulli's theorem.

Date: 14/10/2021

S1. It is a simple device which is used for measuring velocity of the flow at any depth in a flowing liquid. It is based on Bernoulli's theorem.

S2. Due to surface tension, the water film formed in between the hairs that tends to make the surface area minimum. As a result of which the hairs of shaving brush come close to each other.

S3. The total energy of the fluid will decrease, if the viscosity of the fluid is not negligible.

S4. The factor $\frac{P}{\rho g}$ is called pressure head.

S5. The liquid should be non-viscous, incompressible and the flow of liquid should be streamline.

S6. It is in accordance with equation of continuity *i.e.*,

$$a_1 v_1 = a_2 v_2$$

S7. A velocity gradient of "*v*/*r*" is seen in the tube due to the phenomenon of viscosity.

S8.

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

As terminal velocity $\propto$ (radius of ball)^2, therefore, ratio of terminal velocities of A and B will be 4 : 1.

S9. When the boats come closer to each other, the air velocity between the narrow gap increases and pressure decreases. Thus the boats air are further pushed towards each other.

S10. Due to reduction in moment of inertia, angular velocity increases to keep the angular momentum constant.

S11. No.

S12. Bernoulli's equation cannot be used to describe the flow of water through a rapid in a river because of the turbulent flow of water. This principle can only be applied to a streamline flow.

S13. When a light ball is held over a vertical jet of water the pressure below the ball decreases due to the large velocity of the water jet. The greater pressure on the other side of the ball keeps it in contact with the jet by pressing against it and thus the ball remains suspended.

S14. No, it does not matter if one uses gauge pressure instead of absolute pressure while applying Bernoulli's equation. The two points where Bernoulli's equation is applied should have significantly different atmospheric pressures.

S15. Maximum range = $2\sqrt{h(H - h)}$, where h is the depth from top surface at which the hole is.

S16. Upthrust due to 2 cm = $2 \times a^2$

This should be balanced by 200 g mass.

$$\therefore \qquad 2a^2 = 200,\ a = 10\ \text{m}^2$$

$$\pi r^2 = 10$$

$$r = \sqrt{\frac{10}{\pi}}\ \text{cm}$$

S17. Volumes of the two liquids are $\frac{1}{\rho_1}$ and $\frac{1}{\rho_2}$.

$$\text{Density of mixture} = \frac{2m}{\frac{m}{\rho_1} + \frac{m}{\rho_2}} = \frac{2\rho_1\rho_2}{(\rho_1 + \rho_2)}$$

S18. If r_1 and r_2 are the radii of the soap bubbles, the net excess pressure at the interface is

$$\frac{4\sigma}{r_{eq}} = \frac{4\sigma}{r_1} - \frac{4\sigma}{r_2} \quad \therefore \quad \frac{1}{r_{eq}} = \frac{1}{r_1} - \frac{1}{r_2}$$

S19. Given: $h = \sqrt{2}\,\text{m}$; $h' = \frac{1}{\sqrt{2}}\,\text{m}$

Now, $R = 2\sqrt{hh'} = 2\sqrt{\sqrt{2} \times (1/\sqrt{2})}$ = **2m**.

S20. Here, velocity head, $v^2/2g = 40$ cm

$$= \sqrt{2g \times 40} = \sqrt{2 \times 980 \times 40} = 280\ \text{cm s}^{-1}.$$

S21. Given, $h = 20$ m and $g = 10\ \text{ms}^{-2}$

Now, velocity of efflux,

$$v = \sqrt{2gh} = \sqrt{2 \times 10 \times 20} = \mathbf{20\ ms^{-1}}.$$

S22. If the air is blow into the narrow end of the funnel, then velocity of the air enclosed between the filter paper and curved wall of the funnel increases. Due to increases in kinetic energy of the air, the pressure energy and hence pressure of the air decreases. Due to this, the filter paper will get more firmly stuck to the wall of the funnel. Thus, it is not possible to remove the filter paper from a funnel by blowing air into the narrow end of the funnel.

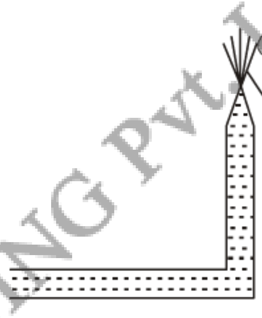
S23. Due to the typical shape of wings, the layers of the air (or the streamlines) above the wing come closer to each other. Due to this, velocity of the air above the wings increases (in accordance with the equation of continuity). Now, as air above the wings possesses more kinetic energy; according to Bernoulli's equation, pressure energy and hence pressure above the wing will become smaller. Due to the difference of pressure above and below the wings, the wings get uplift and help the aeroplane to rise up against gravity.

S24. When air is blown between the two suspended balls, the kinetic energy of the air between the balls increases. Consequently, pressure energy decreases. Due to pressure difference on the two sides of the two balls, the balls come nearer to each other.

S25. When strong winds blow over the top of the flag, the kinetic energy of the wind at the top is more than that of the air below it. In accordance with Bernoulli's equation, the pressure energy and hence pressure of the air above the flag decreases. Due to difference in pressure (above and below the flag), the flag flutters.

S26. When a whirl is formed, the air is drawn into circular layers and the pressure at the inner layer becomes less than that at the outer layers. As such, pressure energy of the inner layers of air becomes less than that of the outer layers. In accordance with Bernoulli's theorem, the kinetic energy of the inner layers increases i.e. the speed of the whirlwind becomes extremely high.

S27. Due to high velocity of the jet of water, pressure on the side of the ping pong ball, that faces the water jet, decreases. On the other side of the ball, the pressure is still equal to the atmospheric pressure. Due to the difference in pressure on the two sides, the ball gets pushed towards the jet of water. The high velocity of the water jet carries the ball upwards along with it and makes it to spin [as shown in figure].



The ball does not fall down as it is constantly pressed against the water jet due to difference of pressure on the two sides of the ball.

S28. According to Bernoulli's theorem,

$$\frac{P_1}{\rho} + gh_1 + \frac{1}{2}v_1^2 = \frac{P_2}{\rho} + gh_2 + \frac{1}{2}v_2^2$$

If speed of the blood remains unchanged *i.e.*, $v_1 = v_2$, then

$$\frac{P_1}{\rho} + gh_1 = \frac{P_2}{\rho} + gh_2$$

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

Here, $$\rho = 1.06 \text{ g cm}^{-3}; \quad h_2 - h_1 = 50 \text{ cm}$$

$\therefore$ $$P_1 - P_2 = 1.06 \times 980 \times 50$$

$$= \mathbf{5.194 \times 10^4 \text{ dyne cm}^{-2}}.$$

S29. Here,

$$a_1 = \frac{\pi d_1^2}{4} = \frac{\pi \times (37.5)^2}{4} = 1{,}104.47 \text{ cm}^2;$$

$$a_2 = \frac{\pi d_2^2}{4} = \frac{\pi \times 15^2}{4} = 176.71 \text{ cm}^2;$$

$$P_1 - P_2 = 23 \text{ cm of mercury column}$$
$$= 23 \times 13.6 \times 980 \text{ dyne cm}^{-2}$$

Now, rate flow of water,

$$v = a_1 a_2 \sqrt{\frac{2(P_1 - P_2)}{\rho(a_1^2 - a_2^2)}}$$

Here, density of water, $\rho = 1 \text{ g cm}^{-3}$

$\therefore$ $$v = 1{,}104.47 \times 176.71 \sqrt{\frac{2 \times 23 \times 13.6 \times 980}{1 \times (104.47)^2 - (176.71)^2}}$$
$$= \mathbf{1.402 \times 10^5 \text{ cm}^3 \text{ s}^{-1}}.$$

S30. Let P_1 and P_2 be the pressure; and v_1 and v_2 be respectively the speeds of the air below and above the roof.

Here, $v_1 = 0$ (inside the room, air cannot blow)

$v_2 = 108 \text{ km h}^{-1} = 30 \text{ ms}^{-1}$; $\rho = 1.3 \text{ kg m}^{-3}$

According to Bernoulli's theorem,

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

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

or $$P_1 - P_2 = \frac{1}{2} \times 1.3 \times (30^2 - 0^2) = 585 \text{ N m}^{-2}.$$

Therefore aerodynamic lift on the roof,

$$F = (P_1 - P_2) \times \text{area of roof}$$
$$= 585 \times 40 = \mathbf{2.34 \times 10^4 \text{ N}}.$$

S31. Due to accumulation of snow on the wings of the aeroplane, the structure of wings no longer remains as that of air foil and hence it results in a decrease in the lift.

S32. Given, $M = 300$ kg, $A = 425 \text{ cm}^2 = 4.25 \times 10^{-2} \text{ m}^2$.

In hydraulic systems, $P_1 = P_2$ or $\dfrac{F_1}{A_1} = \dfrac{F_2}{A_2}$

$\therefore$ Maximum pressure on smaller piston

= Maximum pressure on the larger piston

$\Rightarrow$ $$\frac{300 \times 9.8}{425 \times 10^{-4}} = 6.92 \times 10^4 \text{ N/m}^2$$

S33. For streamlined flow, the sum of the pressure head, velocity head and gravitational head is a constant, *.i.e.*,

Given, P_1 = 1 cm of Hg, v_1 = 0.35 m/s, v_2 = 0.65 m/s, P_2 = ?.

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

Taking h the same, we have,

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

$$1 + \frac{(0.35)^2}{2g} = \frac{P_2}{\rho g} + \frac{(0.65)^2}{2g}$$

$$1 - P_2 = \frac{(0.65)^2 - (0.35)^2}{2g} = 1 - \frac{0.3}{2g}$$

$$= 1 - 0.015 = \mathbf{0.985}$$

$\therefore$ Pressure = 0.985 cm of Hg.

S34. Given, $P = 4$ atm $= 4 \times 1.013 \times 10^5 = 4.052 \times 10^5$ Nm^{-2} density of kerosene oil, $\rho = 720$ kg m^{-3}

Let h be the depth of the orifice below the free surface of oil in the tank. Then,

$$P = h \rho g$$

or

$$h = \frac{P}{\rho g} = \frac{4.052 \times 10^5}{720 \times 9.8} = \mathbf{57.43\ m}$$

Now, velocity of efflux,

$$v = \sqrt{2gh} = \sqrt{2g\left(\frac{P}{\rho g}\right)}$$

$$= \sqrt{\frac{2P}{\rho}} = \sqrt{\frac{2 \times 4.052 \times 10^5}{720}} = \mathbf{33.55\ ms^{-1}}.$$

S35. (a) The weight of the Boeing aircraft is balanced by the upward force due to the pressure difference

$$F = \Delta P \times A$$

$$\Delta P \times A = 3.3 \times 10^5 \text{ kg} \times 9.8$$

$$\Delta P = (3.3 \times 10^5 \text{ kg} \times 9.8 \text{ m s}^{-2})/500 \text{ m}^2$$

$$= 6.5 \times 10^3 \text{ N m}^{-2}$$

(b) We ignore the small height difference between the top and bottom sides in Eq. (10.12). The pressure difference between them is then

$$\Delta P = \frac{\rho}{2}(v_2^2 - v_1^2)$$

where v_2 is the speed of air over the upper surface and v_1 is the speed under the bottom surface.

$$(v_2 \, v_1) = \frac{2\Delta P}{\rho(v_2 + v_1)}$$

Taking the average speed

$$v_{av} = (v_2 + v_1)/2 = 960 \text{ km/h} = 267 \text{ m s}^{-1},$$

we have

$$(v_2 \, v_1)/v_{av} = \frac{\Delta P}{\rho v_{av}^2} \approx 0.08 \, .$$

The speed above the wing needs to be only 8% higher than that below.

S36. Height of the water column, $h_1 = 10 + 15 = 25$ cm

Height of the spirit column, $h_2 = 12.5 + 15 = 27.5$ cm

Density of water, $\rho_1 = 1 \text{ g cm}^{-3}$

Density of spirit, $\rho_2 = 0.8 \text{ g cm}^{-3}$

Density of mercury $= 13.6 \text{ g cm}^{-3}$

Let h be the difference between the levels of mercury in the two arms.

Pressure exerted by height h, of the mercury column:

$$= h\rho g = h \times 13.6\text{g} \quad \text{… (i)}$$

Difference between the pressures exerted by water and spirit:

$$= h_1\rho_1 g - h_1\rho_1 g$$

$$= g(25 \times 1 - 27.5 \times 0.8)$$

$$= 3\text{g} \quad \text{… (ii)}$$

Equating equations (i) and (ii), we get

$$13.6\, hg = 3\text{g}$$

$$h = 0.220588 \approx 0.221 \text{ cm}$$

Hence, the difference between the levels of mercury in the two arms is 0.221 cm.

S37. **(a)** 1.966 m/s **(b)** Yes

Diameter of the artery, $d = 2 \times 10^{-3}$ m

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

Density of blood, $\rho = 1.06 \times 10^3 \text{ kg/m}^3$

Reynolds' number for laminar flow, $N_R = 2000$

The largest average velocity of blood is given as:

$$V_{avg} = \frac{N_R \eta}{\rho d}$$

$$= \frac{2000 \times 2.084 \times 10^{-3}}{1.06 \times 10^{3} \times 2 \times 10^{-3}} = 1.966 \text{ m/s}$$

Therefore, the largest average velocity of blood is 1.966 m/s.

As the fluid velocity increases, the dissipative forces become more important. This is because of the rise of turbulence. Turbulent flow causes dissipative loss in a fluid.

S38. Given, pressure before opening the valve of the pipe,

$$P_1 = 3.5 \times 10^5 \text{ Nm}^{-2};$$

Velocity of flow before opening the valve of the pipe,

$$v_1 = 0$$

and pressure on opening the valve,

$$P_2 = 3 \times 10^5 \text{ Nm}^{-2}$$

Let v_2 be the velocity of flow on opening the valve of the pipe.

For flow of water along a horizontal pipe,

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

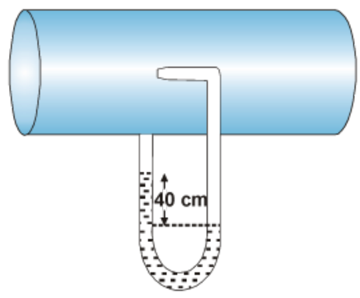
or $$\frac{3.5 \times 10^5}{1{,}000} + \frac{1}{2}(0)^2 = \frac{3 \times 10^5}{1{,}000} + \frac{1}{2} v_2^2$$

or $$\frac{1}{2} v_2^2 = \left(\frac{3.5 \times 10^5}{1{,}000} - \frac{3 \times 10^5}{1{,}000}\right)$$

or $$v_2 = \sqrt{\frac{2(3.5 \times 10^5 - 3 \times 10^5)}{1{,}000}}$$

$$= \sqrt{\frac{2 \times 0.5 \times 10^5}{1{,}000}} = \mathbf{10 \text{ ms}^{-1}}.$$

S39. Given, Density of air, $\rho = 1\ \text{kg m}^{-3}$



Since relative density of alcohol = 0.8,

Density of alcohol = $0.8\ \text{g cm}^{-3} = 800\ \text{kg m}^{-3}$

Let P_1 be pressure of air at the nozzle of the *U*-tube and P_2, the value of pressure of air at the other end connected to the main tube [as shown in the figure].

Now, $P_1 - P_2$ = 40 cm of alcohol = 0.4 m of alcohol

$= 0.4 \times \text{density of alcohol} \times g$

$= 0.4 \times 800 \times 9.8\ \text{Nm}^{-2}$

If v_1 is velocity of air at the nozzle and v_2, at the other end of the tube, then

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

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

As the nozzle of the tube is parallel to direction of motion of air, $v_1 = 0$.

$\therefore$ $$P_1 - P_2 = \frac{1}{2}\rho v_2^2$$

or $$v_2 = \sqrt{\frac{2(P_1 - P_2)}{\rho}} = \sqrt{\frac{2 \times 0.4 \times 800 \times 9.8}{1}} = \mathbf{79.2\ ms^{-1}}.$$

S40. (a) Here, $P_1 - P_2 = 24$ Pa; $a_1 = 8\ \text{mm}^2 = 8 \times 10^{-6}\ \text{m}^2$;

$a_2 = 4\ \text{mm}^2 = 4 \times 10^{-6}\ \text{m}^2$; $\rho = 1.06 \times 10^3\ \text{kg m}^{-3}$

If v_1 is the speed of the blood in the artery (speed of blood in winder part of the venturimeter), then

$$P_1 - P_2 = \frac{1}{2}\rho v_1^2 \left(\frac{a_1^2 - a_2^2}{a_2^2}\right)$$

or $$v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho(a_1^2 - a_2^2)}}\, a_2$$

$$= \sqrt{\frac{2 \times 24}{1.06 \times 10^3[(8 \times 10^{-6})^2 - (4 \times 10^{-6})^2]}} \times 4 \times 10^{-6}$$

$= \mathbf{0.123\ m\ s^{-1}}$.

(b) Yes, the maximum allowable stress for the structure,

$P = 10^9$ Pa

Depth of the ocean, $d = 3\ \text{km} = 3 \times 10^3$ m

Density of water, $\rho = 10^3$ kg/m^3

Acceleration due to gravity, $g = 9.8$ m/s^2

The pressure exerted because of the sea water at depth,

$$d' = \rho d g$$
$$= 3 \times 10^3 \times 10^3 \times 9.8$$
$$= \mathbf{2.94 \times 10^7\ Pa}.$$

The maximum allowable stress for the structure (10^9 Pa) is greater than the pressure of the sea water (2.94×10^7 Pa). The pressure exerted by the ocean is less than the pressure that the structure can withstand. Hence, the structure is suitable for putting up on top of an oil well in the ocean.

S41. Given, $P_1 = 2$ cm of mercury

$$= 2 \times 13.6 \times 980 = 2.666 \times 10^4 \text{ dyne cm}^{-2}$$

$$v_1 = 32 \text{ cm s}^{-1}; \quad v_2 = 65 \text{ cm s}^{-1}$$

For a horizontal pipe, according to Bernoulli's theorem,

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

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

or $$P_2 = 2.666 \times 10^4 + \frac{1}{2} \times 1 \times (32^2 - 65^2)$$

$$= 2.666 \times 10^4 - 0.16 \times 10^4$$

$$\rho g h = 2.506 \times 10^4 \text{ dyne cm}^{-2}$$

$$h = \frac{2.506 \times 10^4}{13.6 \times 980} = \mathbf{1.88\ cm\ of\ mercury}.$$

S42. Given, $v_1 = 100 \text{ cm s}^{-1}$,

$$P_1 = \frac{1}{10} \text{ atm} = \frac{1}{10} \times 76 \times 13.6 \times 980$$

$$= 1.013 \times 10^5 \text{ dyne cm}^{-2}$$

$$P_2 = \frac{1}{2} P_1 = \frac{1}{2} \times 1.013 \times 10^5$$

$$= 5.065 \times 10^4 \text{ dyne cm}^{-2}$$

For a horizontal pipe, according to Bernoulli's theorem,

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

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

or $$v_2^2 = \frac{2(1.013 \times 10^5 - 0.5065 \times 10^5)}{1} + (100)^2$$

$$= 1.013 \times 10^5 + 10^4 = 1.13 \times 10^5$$

or $v_2 =$ **333.6 cm s^{-1}**.

S43. Given, $v_1 = 120\ \text{ms}^{-1}$; $v_2 = 90\ \text{ms}^{-1}$;

Area of the wing, $A = 10 \times 2 = 20\ \text{m}^2$

and Density of air, $\rho = 1.3\ \text{kg m}^{-3}$

According to Bernoulli's theorem,

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

or $$P_1 - P_2 = \frac{1}{2}(v_1^2 - v_2^2)\rho = \frac{1}{2}(120^2 - 90^2) \times 1.3$$

$$= \mathbf{4.095 \times 10^3\ N\,m^{-2}}$$

Then, gross lift of the wing = $(P_2 - P_1) \times$ area of the wing

$$= 4.095 \times 10^3 \times 20 = \mathbf{8.19 \times 10^4\ N}.$$

S44. Given, $h = 10$ m; $g = 9.8\ \text{m s}^{-2}$

Now, velocity of efflux, $v = \sqrt{2gh} = \sqrt{2 \times 9.8 \times 10}$

$$= 14\ \text{m s}^{-1}$$

If a is area of cross-section of the circular aperture, then rate of discharge of the liquid,

$$V = av = \frac{\pi D^2}{4} \times v$$

Here, $V = 26.4\ \text{m}^3\text{min}^{-1} = \frac{26.4}{60} = 0.44\ \text{m}^3\text{s}^{-1}$

$\therefore$ $$0.44 = \frac{\pi D^2}{4} \times 14$$

or $$D^2 = \frac{0.44 \times 4}{\pi \times 14}$$

or $D =$ **0.2 m**.

S45. (a) When air is blown under a paper, the velocity of air is greater under the paper than it is above it. As per Bernoulli's principle, atmospheric pressure reduces under the paper. This makes the paper fall. To keep a piece of paper horizontal, one should blow over it. This increases the velocity of air above the paper. As per Bernoulli's principle, atmospheric pressure reduces above the paper and the paper remains horizontal.

According to the equation of continuity:

$$\text{Area} \times \text{Velocity} = \text{Constant}$$

(b) For a smaller opening, the velocity of flow of a fluid is greater than it is when the opening is bigger. When we try to close a tap of water with our fingers, fast jets of water gush through the openings between our fingers. This is because very small openings are left for the water to flow out of the pipe. Hence, area and velocity are inversely proportional to each other.

(c) The small opening of a syringe needle controls the velocity of the blood flowing out. This is because of the equation of continuity. At the constriction point of the syringe system, the flow rate suddenly increases to a high value for a constant thumb pressure applied.

(d) When a fluid flows out from a small hole in a vessel, the vessel receives a backward thrust. A fluid flowing out from a small hole has a large velocity according to the equation of continuity:

$$\text{Area} \times \text{Velocity} = \text{Constant}$$

(e) According to the law of conservation of momentum, the vessel attains a backward velocity because there are no external forces acting on the system.

A spinning cricket ball has two simultaneous motions – rotatory and linear. These two types of motion oppose the effect of each other. This decreases the velocity of air flowing below the ball. Hence, the pressure on the upper side of the ball becomes lesser than that on the lower side. An upward force acts upon the ball. Therefore, the ball takes a curved path. It does not follow a parabolic path.

S46. According to ***Bernoulli's theorem***, for an incompressible, non-viscous liquid having streamlined flow, the sum of pressure head, velocity head and gravitational head is a constant,

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

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

The P.E. increase since h_2 and v_2 are more than h_1 and v_1 respectively. This is done by the pressure doing work on the liquid. If P_1 and P_2 are the pressure at A and B, for a small displacement at A and B,

The work done on the liquid at $A = (P_1 A_1)$

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

The work done by the liquid at B

$$\Delta x_2 = -(P_2 A_2)$$

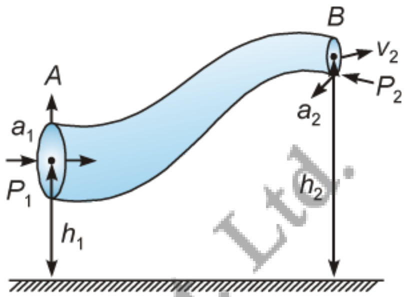
$$\Delta x_2 = -P_2 A_2 v_2 \Delta t$$

The work done by the liquid at (Considering a small time Δt so that area may be same)

Net work done by pressure = $(P_1 - P_2)\, Av\Delta t$

Since, $A_1 v_1 = A_2 v_2$

From conservation of energy,



$$(P_1 - P_2)\, Av\Delta t = \text{change in (K.E. + P.E.)}$$

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

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

(*i.e.*) $$P_1 + \rho g h_1 + \frac{\rho}{2} v_1^2 = P_2 + \rho g h_2 + \frac{\rho}{2} v_2^2$$

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

Date: 14/10/2021

Q1. If honey and water are dropped out of a tube separately, the honey comes out later than water. Why?

Q2. The velocity of water in a river is less on the bank and large in the middle. Explain, Why?

Q3. Why is it that we need a constant driving force for maintenance of the flow of oil through pipe-lines in oil refineries?

Q4. The dimensions of viscosity is same as those of the product of pressure and time. It this correct?

Q5. Hotter liquid flow speeder than cold ones. Explain, why?

Q6. Why machine parts are jammed in water?

Q7. Why high viscosity liquids are used as buffers in trains?

O8. How does viscous force differ from normal friction?

Q9. A square framed with a wire of side '*L*' is dipped in a liquid. On taking out, a membrane is formed. What will be the force acting on the frame if the surface tension of liquid is *S*?

Q10. Why does a soft plastic bag weight the same when empty as when filled with air at atmospheric pressure?

Q11. Why do we prefer mercury in a barometer?

Q12. What will be the effect on the angle of contact of a liquid if the temperature increase?

Q13. What is the acceleration of a body falling through a viscous medium after terminal velocity is reached?

Q14. How does the viscosity of gases depend upon temperature?

Q15. The terminal velocity of a copper ball of radius 2.0 mm falling through a tank of oil at 20°C is 6.5 cm s^{-1}. Compute the viscosity of the oil at 20°C. Density of oil is 1.5×10^3 kg m^{-3}, density of copper is 8.9×10^3 kg m^{-3}.

Q16. Why does an object entering the earth's atmosphere at high velocity catch fire?

Q17. What is the weight of a body, when it balls with terminal velocity through a viscous medium?

Q18. The radius of ball *A* is twice that of *B*. What will be the ration of their terminal velocities in a liquid?

Q19. A bigger rain drop falls faster than a smaller one. Why?

Q20. Explain, why a parachute is invariably used, while jumping from an aeroplane?

Q21. As soon as parachute of a falling soldier opens, his acceleration decreases and soon becomes zero. Why?

Q22. Why oils of different viscosities are used in automobiles in different seasons?

Q23. Why should the lubricant oils be of high viscosity?

Q24. What is the terminal velocity in a horizontal direction for any object thrown through air?

Q25. Explain, why rain drops falling under gravity do not acquire very high velocity.

Q26. Dust generally settles down in a closed roof. Explain.

Q27. Why do the clouds seem floating in the sky?

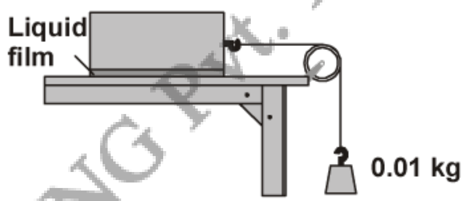
Q28. What are practical applications of stokes' law?

Q29. What are the conditions for equilibrium of floating bodies?

Q30. As soon as parachute of a falling soldier opens, his acceleration decreases and soon becomes zero. Explain.

Q31. A metal plate of area 0.1 m^2 is connected to a 0.01 kg of mass via a string that passes over an ideal pulley.

A liquid with a film thickness of 0.3 mm is placed between the plate and the table as shown in figure. When released, the plate moves to the right with a constant speed of 0.085 ms^{-1}. Find the coefficient of viscosity of the liquid. The pulley may be considered massless and frictionless.



Q32. In an experiment with Poiseuille's apparatus, the following figures were observed:

Volume of liquid collected per minute =15 cm^3; head of liquid = 30 cm; length of tube = 25 cm; diameter of tube = 0.2 cm; density of liquid = 2.3 g cm^{-3}. Find the coefficient of viscosity.

Q33. A drop of water of diameter 0.02 mm is falling through a medium, whose density is 1.21×10^{-3} g cm^{-3} and coefficient of viscosity is 1.8×10^{-4} poise. Find the terminal velocity of the drop.

Q34. A ball bearing of radius 1.5 mm made of iron of density 7.85 g cm^{-3} is allowed to fall through a long column of glycerin of density 1.25 g cm^{-3}. It is found to attain a terminal velocity of 2.25 cm s^{-1}. Determine the viscosity of glycerin in centipoises.

Q35. 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 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}. Find the coefficient of viscosity of the liquid.

Q36. A square plate of 10 cm side moves parallel to another plate with a velocity of 10 cm s^{-1}, both plates immersed in water. If the viscous force is 200 dyne and viscosity of water is 0.01 poise, what is their distance apart?

Q37. During blood transfusion the needle is inserted in a vein where the gauge pressure is 2000 Pa. At what height must the blood container be placed so that blood may just enter the vein? [Given density of blood 1.06×10^5].

Q38. According to stoke, the viscous force experienced by a sphere of radius *r* depends on the terminal velocity and viscosity of the liquid besides radius. Derive the formula.

Q39. Eight rain drop of radius 1 mm each falling downwards with a terminal velocity of $5\ \text{cm s}^{-1}$ coalesce to from a bigger drop. Find the terminal velocity of the bigger drop.

Q40. In Millikan's oil drop experiment, what is the terminal speed of a drop of radius 2.0×10^{-5} m and density $1.2\times10^{3}\ \text{kg m}^{-3}$? Take the viscosity of air at the temperature of the experiment to be $1.8\times10^{-5}\ \text{N s m}^{-2}$. How much is the viscous force on the drop at that speed? Neglect buoyancy of the drop due to air.

Q41. An engineer wants to have the same flow rate of water and light machine oil from the pipes of the same length and with the same pressure heads. What should be ration of the radii of the two pipes? Given that viscosity of water = 0.01 poise and that of light machine oil = 11 poise.

Q42. The radius of a pipe carrying a liquid gets decreased by 5% because of deposits on the inner surface. By how much would the pressure difference. Between the ends of the constricted pipe have to be increased to maintain a constant flow rate?

Q43. In a test experiment on a model aeroplane in a wind tunnel, the flow speeds on the upper and lower surfaces of the wing are $70\ \text{m s}^{-1}$ and $63\ \text{m s}^{-1}$ respectively. What is the lift on the wing if its area is $2.5\ \text{m}^2$? Take the density of air to be $1.3\ \text{kg m}^{-3}$.

Q44. Emery powder particles are stirred up in a beaker of water 0.1 m deep. Assuming the particles to be spherical and of all sizes, calculate the radius of the largest particles remaining in suspension after 24 hours. Given that density of emery is $4000\ \text{kg m}^{-3}$ and coefficient of viscosity of water is 0.001 decapoise.

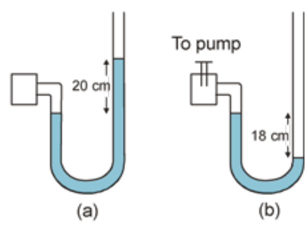
Q45. Three capillary tubes of length l, $2l$ and $l/2$ are connected in series. Their radii are r, $r/2$ and $r/3$ respectively, If streamline flow is maintained and the pressure difference across the first capillary tube is p, find the pressure difference across the other tubes.

Q46. 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).

Q47. A manometer reads the pressure of a gas in a enclosure as shown in Fig. (a). When a pump removes some of the gas, the manometer reads as in Fig. (b). The liquid used in the manometers is mercury and the atmospheric pressure is 76 cm mercury.

(a) Give the absolute and gauge pressure of the gas in the enclosure for cases (a) and (b), in units of cm of mercury.

(b) How would the levels change in case (b) if 13.6 cm of water (immiscible with mercury) are poured into the right limb of the manometer? (Ignore the small change in the volume of the gas).



Q48. In Millikan's oil drop experiment, what is the terminal speed of an uncharged drop of radius 2.0×10^{-5} m and density $1.2\times10^{3}\ \text{kg m}^{-3}$? Take the viscosity of air at the temperature of the experiment to be 1.8×10^{-5} Pa s. How much is the viscous force on the drop at that speed? Neglect buoyancy of the drop due to air.

Q49. **Define coefficient of viscosity and give its SI unit, On what factors does the terminal velocity of a spherical ball falling through a viscous liquid depend? Drive the formula:**

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

Where the symbols have their usual meaning.

Q50. **Two narrow bores of diameters 3.0 mm and 6.0 mm are joined together to form a U-tube open at both ends. If the U-tube contains water, what is the difference in its levels in the two limbs of the tube? Surface tension of water at the temperature of the experiment is 7.3×10^{-2} N m^{-1}. Take the angle of contact to be zero and density of water to be 1.0×10^3 kg m^{-3} ($g = 9.8$ m s^{-2}).**

Date: 14/10/2021

S1. It is because, coefficient of viscosity of honey is very large as compared to the coefficient of viscosity of water.

S2. Due to large force of adhesion between the water streams and the bank of the river, the velocity of water is quite small near the bank than in the middle of the river.

S3. Due to layers of the oil, its motion continuously retards down with the distance. Hence, a constant driving force is needed for the maintenance of the flow of oil through the pipe lines in oil refineries.

S4. We know, $[\eta] = [ML^{-1}T^{-1}]$

and $[Pt] = [ML^{-1}T^{-2}][T] = [ML^{-1}T^{-1}]$

Hence, the given statement is ***correct***.

S5. The coefficient of viscosity of a liquid decreases with rise in temperature. As a result, the hotter liquid will flow speeder than the cold one.

S6. Due to low temperature in winter, the coefficient of viscosity of the engine oil and the lubricants increases. Due to this, the machine parts get jammed.

S7. High viscosity liquids are used as buffers, so as to absorb the shock.

S8. It depends on the area of the layer and velocity gradient in contrast to normal friction.

S9. The membrane has two surface. Force on frame due to surface tension = S.T. × total length = $S \times (4L \times 2) = 8SL$.

S10. Actually the weight of plastic bag when filled with air pressure is more than when it is empty. The increase in weight equal the buoyant force due to air, so the bag weighs the same.

S11. There are two main reasons of using mercury:

(a) Very high density of mercury.

(b) Negligible vapour pressure of mercury.

S12. The angle of contact of a liquid increases with the increase in temperature.

S13. Zero, because the body after attaining terminal velocity

S14. For gases, $\eta \propto T^{1/2}$

S15. We have, $v_t = 6.5 \times 10^{-2}$ m s^{-1}, $a = 2 \times 1^{0-3}$ m, $g = 9.8$ ms^{-2}, $\rho = 8.9 \times 10^3$ kg m^{-3}, $\sigma = 1.5 \times 10^3$ kg m^{-3}. From Eq. (10.20)

$$\eta = \frac{2}{9} \times \frac{(2 \times 10^{-3})\,m^2 \times 9.8\,m\,s^{-2}}{6.5 \times 10^{-2}\,m\,s^{-1}} \times 7.4 \times 10^3\,kg\,m^{-3}$$

$$= 9.9 \times 10^{-1}\,kg\,m^{-1}\,s^{-1}.$$

S16. When an object enters the earth's atmosphere at high velocity, its motion is opposed due to velocity of the air. The kinetic energy of the object is dissipated in the form of heat energy due to viscous force and the object catches fire.

S17. When a body falling through a viscous medium attains terminal velocity, the apparent weight of the body (weight of the body-upthrust) is balanced by the viscous form due to the medium. Therefore, the weight of the body falling with terminal velocity is zero.

S18. A ball of radius *r* and of material of density ρ falling through a liquid of density σ and coefficient viscosity η of will attain terminal velocity,

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

As $v \propto r^2$, the ration of the terminal velocities of the balls *A* and *B* will be in the ration **4 : 1**.

S19. When a rain drop attains terminal velocity, the viscous force on the drop due to air becomes equal to its weight *i.e.*,

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

or $$v \propto r^2,$$

For the reason, a bigger rain drops falls faster than a smaller one.

S20. We know, viscous force, $F = 6\pi\eta rv$.

Due to its large structure (*r* large), a parachute experiences a large viscous force and hence while descending through air, it acquires a very small terminal velocity. Due to the low velocity of descent, the person using the parachute will not get hurt.

S21. As soon as parachute of the solider opens, a large viscous force starts acting on the parachute due to its large structure. As a result, its acceleration decreases. However, it soon attains terminal velocity. On attaining the terminal velocity, the soldier falls with a constant velocity *i.e.*, the acceleration of the soldier becomes zero.

S22. The viscosity of lubricating oils (liquids in general) decreases with increases of temperature. Therefore, an oil suitable as lubricant in one seasons, say winter may not be suitable in summer. Therefore, oils of different viscosities are used as lubricant in different seasons.

S23. An oil, when used as lubricant in a machine, forms a thin layer of the oil over the metallic parts of the machinery. During working of the machinery, the metallic parts do not come in direct contact with each other. The friction between solid-liquid surfaces. So that the oil layer is effective as lubricant for a long time, the oil should be of high viscosity.

S24. When an object is thrown along horizontal, only decelerating force due to air resistance acts on the body. As a result, the velocity of the object along the horizontal becomes zero ultimately. Hence, the terminal velocity for an object thrown in a horizontal direction is zero.

S25. After falling through certain distance in air, rain drops acquire terminal velocity. After that, they fall with the constant velocity. The terminal velocity is attained, what viscous force due to air becomes equal to the apparent weight of the rain drop. It can be shown that terminal velocity of the rain drop is proportional to square of its radius. As radius the rain drop is small, it does not acquire very high velocity.

S26. Dust particles are spheres of very small radii. After acquiring the terminal velocity, they start falling through air with a constant velocity. As the terminal velocity for the due particles will be very small ($v \propto r^2$), they will settle down in a closed room after some time.

S27. The terminal velocity attained by a small drop of water is also small. This is because, the terminal velocity of a drop is directly proportional to square of its radius. The small rain drop acquires terminal velocity much before reaching the earth and as a result they are seen to float in the sky in the shape of clouds.

S28. Applications:

1. Rain drops do not acquire alarmingly high velocity during their free fall. Otherwise, a person moving in rain would get hurt.

2. While jumping from an aeroplane, a parachute helps us to land safely on the earth.

3. Stokes' law is used to determine the value of charge on an electron (Millikan's oil drop method).

S29. There are two conditions for equilibrium of floating bodies :

(a) ***Condition of floatation:*** For a body to float, the weight of the liquid displaced must be equal to its own weight.

(b) ***Condition for equilibrium:*** The centre of gravity of the body, and that of the displaced liquid must be on the same vertical line.

S30. Because of the viscosity of the air. Due to the viscosity effect a resistive force is offered on the soldier by the air, hence some upward acceleration acts on the soldier.

$\therefore$ Net acceleration = $g - a$, as the soldier proceeds downward.

S31. Here, $A = 0.1\ m^2$; $dx = 0.3\ mm = 3 \times 10^{-4}\ m$; $dv = 0.085\ ms^{-1}$

The metal plate will move under the action of force,

$$F = mg = 0.01 \times 9.8\ N$$

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

or
$$\eta = \frac{F\,dx}{A\,dv} = \frac{0.01 \times 9.8 \times 3 \times 10^{-4}}{0.1 \times 0.085} = \mathbf{3.46 \times 10^{-3}\ Pa\,s}.$$

S32. Here, volume of liquid collected per second,

$$V = \frac{15}{60} = 0.25\ \text{cm}^3\ s^{-1}$$

head of liquid, $h = 30$ cm; density of liquid, $\rho = 2.3\ \text{g cm}^{-3}$

Therefore, pressure difference between the two ends of the tube,

$$p = h\rho g = 30 \times 2.3 \times 980 = 6.76 \times 10^4\ \text{dyne cm}^{-2}$$

length of the tube, $l = 25$ cm,

Radius of the tube, $r = \frac{0.2}{2} = 0.1$ cm

Now, $V = \frac{\pi p r^4}{8\eta l}$ or $\eta = \frac{\pi p r^4}{8Vl}$

or $\eta = \frac{\pi \times 6.76 \times 10^4 \times (0.1)^4}{8 \times 0.25 \times 25}$ = **0.425 poise**.

S33. Given, $r = \frac{0.02}{2} = 0.01$ mm = 0.001 cm; $\rho = 1\ \text{g cm}^{-3}$; $\sigma = 1.21 \times 10^{-3}\ \text{g cm}^{-3}$; $\eta = 1.8 \times 10^{-4}$ poise

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

or $v = \frac{2}{9} \times \frac{(0.001)^2 \times (1 - 1.21 \times 10^{-3}) \times 980}{1.8 \times 10^{-4}}$

$= \frac{2 \times 10^{-6} \times 0.999 \times 980}{9 \times 1.8 \times 10^{-4}}$ = **1.21 cm s^{-1}**.

S34. Given, $r = 1.5$ mm = 0.15 cm; $\rho = 7.85\ \text{g cm}^{-3}$; $\sigma = 1.25\ \text{g cm}^{-3}$; $v = 2.25\ \text{cm s}^{-1}$

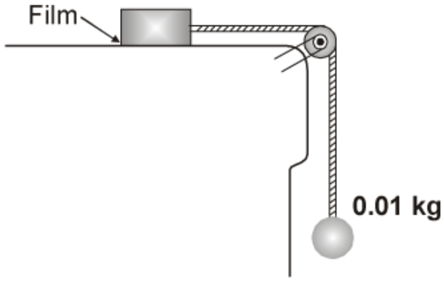
Now, $v = \frac{2}{9} \times \frac{r^2(\rho - \sigma)g}{\eta}$ or $\eta = \frac{2}{9} \times \frac{r^2(\rho - \sigma)g}{v}$

or $\eta = \frac{2 \times (0.15)^2 \times (7.85 - 1.25) \times 980}{9 \times 2.25}$

= 14.37 poise = **1437 centipoises**.

S35. The metal block moves to the right because of the tension in the string. The tension T is equal in magnitude to the weight of the suspended mass m. Thus the shear force F is $F = T = mg = 0.010\ \text{kg} \times 9.8\ \text{m s}^{-2} = 9.8 \times 10^{-2}$ N

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



Strain rate = $\frac{v}{l} = \frac{0.085}{0.030}$

·Cofficient of viscosity = $\frac{\text{Stress}}{\text{Strain rate}}$

$$= \frac{(9.8 \times 10^{-2}\,\text{N})(0.30 \times 10^{-3}\,\text{m})}{(0.085\,\text{m s}^{-1})(0.10 \times \text{m}^2)}$$

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

S36. Here, coefficient of viscosity, η = 0.01 poise; viscous force, F = 200 dyne; velocity of one plate w.r.t. the other plate, dv = 10 cm s^{-1}; side of the square plate = 10 cm.

Therefore, area of the plate = 10 × 10 = 100 cm^2

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

$\therefore$ $$dx = \frac{\eta A dv}{F} = \frac{0.01 \times 100 \times 10}{200} = \mathbf{0.05\ cm}.$$

S37. Given, Gauge pressure, P = 2000 Pa

Density of whole blood, $\rho = 1.06 \times 10^3$ kg m^{-3}

Acceleration due to gravity, $g = 9.8$ m/s^2

Height of the blood container = h

Pressure of the blood container, $P = h\rho g$

$\therefore$ $$h = \frac{P}{\rho g}$$

$$= \frac{2000}{1.06 \times 10^3 \times 9.8} = \mathbf{0.1925\ m}$$

The blood may enter the vein if the blood container is kept at a height greater than 0.1925 m, *i.e.*, about 0.2 m.

S38. $F \propto v^a \gamma^b \eta^c \Rightarrow F = K v^a \gamma^b \eta^c$,

Equating the powers of :

$M : 1 = c, \quad L : 1 = a + b - c,$

$T : 2 = -a - c$

$c = 1, \quad a = -c + 2 = 1, \quad b = 1 - a + c = 1$

$\therefore$ $$F = kv\eta = 6\,\pi\eta rv,$$

$K = 6\pi$ was found experimentally by stoke.

S39. Here, number of drops, $n = 8$; radius of each drop, $r = 1$ mm = 0.1 cm; terminal velocity of each rain drop, $v = 5\ \text{cm s}^{-1}$

Let m be the mass of each rain drop. When the rain drop attains terminal velocity,

$$6\pi\eta rv = mg. \quad \text{... (i)}$$

Where η is the coefficient of viscosity of the medium (air) through which the rain drop fall.

Let R be the radius of the big drop formed, when 8 small drops coalesce. Then,

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

or $$R = (8)^{1/3} r = 2r = 2 \times 0.1 = 0.2 \text{ cm}$$

Let v' be terminal velocity acquired by the big drop.

Then, $$6\pi R v' = 8\, mg \quad \text{... (ii)}$$

Dividing the Eq. (ii) by (i), we get

$$\frac{6\pi\eta R v'}{6\pi\eta r v} = \frac{8mg}{mg}$$

or $$v' = \frac{8vr}{R} = \frac{8 \times 5 \times 0.1}{0.2} = \mathbf{20\ cm\ s^{-1}}.$$

S40. Here, $r = 2.0 \times 10^{-5}$ m; $\rho = 1.2 \times 10^3\ \text{kg m}^{-3}$; $\eta = 1.8 \times 10^{-5}\ \text{N s m}^{-2}$

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

where σ is density of the medium in which the drop is falling. If the buoyancy of the drop due to air is neglected, then

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

$$= \frac{2 \times (2.0 \times 10^{-5})^2 \times 1.2 \times 10^3 \times 9.8}{9 \times 1.8 \times 10^{-5}}$$

$$= 5.81 \times 10^{-2}\ \text{m s}^{-1} = 5.81\ \text{cm s}^{-1}$$

Viscous force on the drop,

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

$$= 6\pi \times 1.8 \times 10^{-5} \times 2.0 \times 10^{-5} \times 5.81 \times 10^{-2}$$

$$= \mathbf{3.94 \times 10^{-10}\ N}.$$

S41. Let l and r be the length and radius of the pipe. Let p be the pressure difference between the two ends of the pipe. If η is viscosity of the water, then the rate flow of the water through the pipe,

$$v = \frac{\pi p r^4}{8\eta l} = \frac{\pi p r^4}{8 \times 0.01 \times l} \quad \text{... (i)}$$

Suppose that the radius of the pipe through which light machine oil flow has to be taken as r', so as to keep the rate of flow same in the two cases, If η' is viscosity of the light machine oil, then the rate of flow of the oil through the pipe,

$$v = \frac{\pi p r'^4}{8\eta' l} = \frac{\pi p r'^4}{8 \times 0.01 \times l} \quad \text{... (ii)}$$

From the Eqns (i) and (ii), we have

$$\frac{\pi p r'^4}{8 \times 11 \times l} = \frac{\pi p r^4}{8 \times 0.01 \times l}$$

or $$\frac{r'}{r} = \left(\frac{11}{0.01}\right)^{1/4} = (1{,}100)^{1/4} = \mathbf{5.76}.$$

S42. Let l and r be the length and radius of the pipe. If p is the pressure difference between the two ends of the pipe, then the rate of flow of the liquid through the pipe,

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

Suppose that the pressure difference has to be changed to p', when the radius of pipe decreases by 5%. *i.e.*, becomes $r' = 0.95\, r$, so as to keep the rate of flow of the liquid same.

Then, $$V = \frac{\pi p' r'^4}{8\eta l} = \frac{\pi p' \times (0.95\, r)^4}{8\eta l} \quad \text{... (ii)}$$

From the Eqns (i) and (ii), we have

$$\frac{\pi p' \times (0.95\, r)^4}{8\eta l} = \frac{\pi p r^4}{8\eta l}$$

or $$\frac{p'}{p} = \frac{r^4}{(0.95\, r)^4} = \frac{1}{(0.95)^4} = 1.23$$

or $$p' = \mathbf{1.23\, p}.$$

S43. Speed of wind on the upper surface of the wing, $v_1 = 70$ m/s

Speed of wind on the lower surface of the wing, $v_2 = 63$ m/s

Area of the wing, $A = 2.5 \text{ m}^2$

Density of air, $\rho = 1.3 \text{ kg m}^{-3}$

According to Bernoulli's theorem, we have the relation:

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

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

Where,

P_1 = Pressure on the upper surface of the wing

P_2 = Pressure on the lower surface of the wing

The pressure difference between the upper and lower surfaces of the wing provides lift to the aeroplane.

$$\text{Lift on the wing} = (P_2 - P_1)A$$

$$= \left\{\frac{1}{2}\rho(v_1^2 - v_2^2)\right\}A$$

$$= \frac{1}{2} \times 1.3 \times \left((70)^2 - (63)^2\right) \times 2.5 = 1512.87$$

$$= 1.51 \times 10^3 \text{ N}$$

Therefore, the lift on the wing of the aeroplane is 1.51×10^3 N.

S44. Here, length of water column, $l = 0.1$ m

Time for which energy power particles remain suspended.

$$t = 24\,h = 24 \times 60 \times 60 \text{ s}$$

Therefore, terminal velocity

$$v = \frac{l}{t} = \frac{0.1}{24 \times 60 \times 60} = 1.1574 \times 10^{-6} \text{ m s}^{-1}$$

The terminal velocity attained by the emery powder particles is given by

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

$$\therefore \qquad r = \left[\frac{9\eta v}{2(\rho - \sigma)g}\right]^{1/2}$$

Here, $\rho = 4000 \text{ kg m}^{-3}$; $\sigma = 1000 \text{ kg m}^{-3}$; $\eta = 0.0001$ decapoise

$$r = \left[\frac{9 \times 0.001 \times 1.1574 \times 10^{-6}}{2 \times (4000 - 1000) \times 9.8}\right]^{1/2}$$

$$= \mathbf{4.21 \times 10^{-7}\ m}.$$

S45. Let p_1, p_2 and p_3 be pressure difference across the first, second and third tube respectively.

Since the three tubes are connected in series, the rate of flow of liquid through the three tubes is same it be V. Then,

$$V = \frac{\pi p_1 r_1^4}{8\eta l_1} = \frac{\pi p_2 r_2^4}{8\eta l_2} = \frac{\pi p_3 r_3^4}{8\eta l_3}$$

Here, $l_1 = l$; $l_2 = 2l$; $l_3 = l/2$

$r_1 = r$; $r_2 = r/2$; $r_3 = r/3$ and $p_1 = p$

$$\therefore \quad \frac{\pi p r^4}{8\eta l} = \frac{\pi p_2 (r/2)^4}{8\eta(2l)} = \frac{\pi p_3 (r/3)^4}{8\eta(l/2)}$$

or $$p = \frac{p_2}{32} = \frac{2p_3}{81}$$

It follows that

$$p_2 = \mathbf{32\,p} \quad \text{and} \quad p_3 = \mathbf{40.5\,p}.$$

S46. (a) Radius of the artery, $r = 2 \times 10^{-3}$ m

Diameter of the artery, $d = 2 \times 2 \times 10^{-3}\ \text{m} = 4 \times 10^{-3}$ m

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

Density of blood, $\rho = 1.06 \times 10^3\ \text{kg/m}^3$

Reynolds' number for laminar flow,

$$N_R = 2000$$

The largest average velocity of blood is given by the relation:

$$v_{avg} = \frac{N_R \eta}{\rho d}$$

$$= \frac{2000 \times 2.084 \times 10^{-3}}{1.06 \times 10^3 \times 4 \times 10^{-3}} = 0.983\ \text{m/s}$$

Therefore, the largest average velocity of blood is 0.983 m/s.

(b) Flow rate is given by the relation:

$$R = \pi r^2 v_{avg}$$

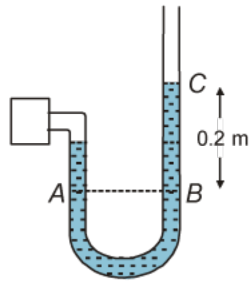
$$= 3.14 \times (2 \times 10^{-3})^2 \times 0.983$$

$$= 1.235 \times 10^{-5}\ m^3\ s^{-1}$$

Therefore, the corresponding flow rate is $\mathbf{1.235 \times 10^{-5}\ m^3\ s^{-1}}$.

S47. (a) Suppose P_A be the pressure of gas in enclosure shown in figure. Pressure at the point C is atmospheric pressure P_0, *i.e.*, $P_C = P_0$.

Pressure at the point B, *i.e.*, P_B is the sum of atmospheric pressure P_0 plus the pressure due to mercury column of height 0.2 m, *i.e.*,

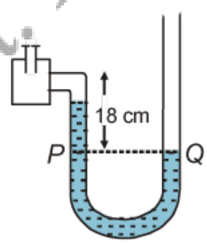


$$P_B = P_0 + 0.2 \times \rho_{Hg} \times g$$

In equilibrium, pressure is same at all points in a given liquid layer. Points A and B are at liquid layer, therefore

$$P_A = P_B = P_0 + 0.2 \times \rho_{Hg} \times g$$
$$= 0.76 \times \rho_{Hg} g + 0.2\ \rho_{Hg}\ g$$
$$= 0.96 \times 13.6 \times 10^3 \times 9.8$$

$$P_A = 1.279 \times 10^5\ Pa$$



or Absolute pressure $= P_0 + h$

$= 76 + 20 = 96$ cm (Hg)

Gauge pressure $= h = 20$ cm (Hg)

Suppose P' be the pressure of the gas in enclosure shown in figure.

$$P_P = \text{pressure at point } P = P'$$
$$P_Q = \text{pressure at point } Q = P_0$$

Also $P_B = P_P$ + pressure due to mercury column of height 0.18 m

$$= P' + 0.18\ \rho_{Hg} g$$

Since point P and Q are in the same liquid layer in equilibrium.

$$P_P = P_Q$$

or $P' = 0.18\ \rho_{Hg} g = 0.76\ \rho_{Hg} g$

or $P' = 058\ \rho_{Hg} g = 58$ cm (Hg)

or $P' = 0.58 \times 13.6 \times 10^3 \times 9.8$ Pa

$$= 0.773 \times 10^5\ Pa$$

Gauge pressure $= h = -18$ cm (Hg)

S48. Radius of the given uncharged drop, $r = 2.0 \times 10^{-5}$ m

Density of the uncharged drop, $\rho = 1.2 \times 10^3\ kg\ m^{-3}$

Viscosity of air, $\eta = 1.8 \times 10^{-5}$ Pa s

Density of air (ρ_a) can be taken as zero in order to neglect buoyancy of air.

Acceleration due to gravity, $g = 9.8 \text{ m/s}^2$

Terminal velocity (v) is given by the relation:

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

$$= \frac{2 \times (2.0 \times 10^{-5})^2 (1.2 \times 10^3 - 0) \times 9.8}{9 \times 1.8 \times 10^{-5}}$$

$$= 5.807 \times 10^{-2} \text{ m s}^{-1}$$

$$= 5.8 \text{ cm s}^{-1}$$

Hence, the terminal speed of the drop is 5.8 cm s^{-1}.

The viscous force on the drop is given by:

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

$$\therefore \quad F = 6 \times 3.14 \times 1.8 \times 10^{-5} \times 2.0 \times 10^{-5} \times 5.8 \times 10^{-2}$$

$$= 3.9 \times 10^{-10} \text{ N}$$

Hence, the viscous force on the drop is 3.9×10^{-10} N.

S49. ***Coefficient of Viscosity:*** Coefficient of viscosity is defined as the viscous force acting in unit area of a layer having unit velocity gradient. It is measured in Nsm^{-2} and has dimension of $[ML^{-1}T^{-1}]$.

Terminal Velocity: The constant velocity with which a body drops down after initial acceleration in a dense liquid or fluid is called terminal velocity. This is attained when the apparent weight is compensated by the viscous force. It is given by

$$v = \frac{2}{9}\frac{a^2 g}{\eta}(\rho - \rho'),$$

where ρ and η are densities of the body and liquid respectively, η is the coefficient of viscosity of the liquid and r is the radius of the spherical body.

Consider a length column of a dense liquid like glycerin. As the ball or spherical ball is dropped in it, the forces experienced are,

(a) Weight = $mg = \frac{4}{3}\pi a^3 \rho' g$ where ρ-density of ball

(b) Upthrust, $U = \frac{4}{3}\pi a^3 \rho' g$ where ρ'-density of liquid

(c) Viscous force $F_v = 6\pi\eta a v_t$ where v_t-terminal velocity

Where terminal velocity is attained, acceleration should be zero and the net force should be zero.

$\therefore \qquad mg - U - F_v = 0$

$\Rightarrow \qquad \frac{4}{3}\pi a^3 \rho g - \frac{4}{3}\pi a^3 \rho' g - 6\pi\eta a v_t = 0$

$$\therefore \qquad v_t = \frac{\frac{4}{3}\pi a^3 g(\rho - \rho')}{6\pi\eta a}$$

$$= \frac{2}{9}\frac{a^2 g(\rho - \rho')}{\eta}$$

Thus, terminal velocity depends upon

(a) Square of radius of the body.

(b) Coefficient of viscosity of the medium.

(c) Density of the body and the medium.

S50. Diameter of the first bore, $d_1 = 3.0 \text{ mm} = 3 \times 10^{-3}$ m

Hence, the radius of the first bore, $r_1 = \frac{d_1}{2} = 1.5 \times 10^{-3}$ m

Diameter of the second bore, $d_2 = 6.0$ mm

Hence, the radius of the first bore, $r_2 = \frac{d_2}{2} = 3 \times 10^{-3}$ m

Surface tension of water, $s = 7.3 \times 10^{-2} \text{ N m}^{-1}$

Angle of contact between the bore surface and water, $\theta = 0$

Density of water, $\rho = 1.0 \times 10^3 \text{ kg/m}^{-3}$

Acceleration due to gravity, $g = 9.8 \text{ m/s}^2$

Let h_1 and h_2 be the heights to which water rises in the first and second tubes respectively. These heights are given by the relations:

$$h_1 = \frac{2s\cos\theta}{r_1 \rho g} \qquad \dots \text{(i)}$$

$$h_2 = \frac{2s\cos\theta}{r_2 \rho g} \qquad \dots \text{(ii)}$$

The difference between the levels of water in the two limbs of the tube can be calculated as:

$$h_1 - h_2 = \frac{2s\cos\theta}{r_1 \rho g} - \frac{2s\cos\theta}{r_2 \rho g}$$

$$= \frac{2s\cos\theta}{\rho g}\left[\frac{1}{r_1} - \frac{1}{r_2}\right]$$

$$= \frac{2 \times 7.3 \times 10^{-2} \times 1}{1 \times 10^3 \times 9.8}\left[\frac{1}{1.5 \times 10^{-3}} - \frac{1}{3 \times 10^{-3}}\right]$$

$$= 4.966 \times 10^{-3} \text{ m} = 4.97 \text{ mm}$$

Hence, the difference between levels of water in the two bores is 4.97 mm.

Date: 14/10/2021

Q1. Cars and aeroplanes are streamlined. Explain, Why?

Q2. What is (a) velocity head (b) pressure head?

Q3. Verify that the quantity $\frac{\rho v D}{\eta}$ (Reynolds number) is dimensionless.

Q4. What is Reynolds number of a liquid?

Q5. When a body is fully or partly immersed in a liquid, name the forces acting on the body.

Q6. What is the significance of: (a) wetting agent used by dyers, and (b) water proofing agents?

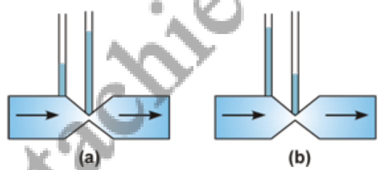
Q7. A liquid of density 1.15 g cm^{-3} flow through a pipe of diameter 1.5 cm. What would be the minimum average flow speed, if the flow were turbulent? Given that coefficient of viscosity of the liquid is 0.022 poise.

Q8. The flow rate of water from a tap of diameter 1.25 cm is 0.48 L/min. The coefficient of viscosity of water is 10^{-3} Pa s. After sometime the flow rate is increased to 3 L/min. Characterise the flow for both the flow rates.

Q9. The flow rate from of diameter 1.25 cm is 3 litres per minute. The coefficient of viscosity of water is 10^{-3} Pa s. Characterize the flow.

Q10. What is the largest average velocity of blood flow in an artery of radius 2×10^{-3} m, if the flow must remain laminar. What is the corresponding flow rate? Take viscosity of blood = 2.084×10^{-3} Pa and density of blood = 1.06×10^{3} kg m^{-3}.

Q11. Figures, (a) and (b) refer to the steady flow of a (non-viscous) liquid. Which of the two figures is incorrect? Why?



Q12. A U-tube contains water and methylated spirit separated by mercury. The mercury columns in the two arms are in level with 10.0 cm of water in one arm and 12.5 cm of spirit in the other. What is the specific gravity of spirit?

Q13. A hydraulic automobile lift is designed to lift cars with a maximum mass of 3000 kg. The area of cross-section of the piston carrying the load is 425 cm^2. What maximum pressure would the smaller piston have to bear?

Q14. Toricelli's barometer used mercury. Pascal duplicated it using French wine of density 984 kg m^{-3}. Determine the height of the wine column for normal atmospheric pressure.

Q15. The cylindrical tube of a spray pump has a cross-section of 8.0 cm^2 one end of which has 40 fine holes each of diameter 1.0 mm. If the liquid flow inside the tube is 1.5 m min^{-1}, what is the speed of ejection of the liquid through the holes?

Q16. Explain why: The angle of contact of mercury with glass is obtuse, while that of water with glass is acute.

(a) Water on a clean glass surface tends to spread out while mercury on the same surface tends to form drops. (Put differently, water wets glass while mercury does not.)

(b) Surface tension of a liquid is independent of the area of the surface.

(C) Water with detergent dissolved in it should have small angles of contact.

(d) A drop of liquid under no external forces is always spherical in shape.

Q17. Glycerin flows steadily through a horizontal tube of length 1.5 m and radius 1.0 cm. If the amount of glycerin collected per second at one end is 4.0×10^{-3} kg s^{-1}, what is the pressure difference between the two ends of the tube? (Density of glycerin = 1.3×10^{3} kg m^{-3} and viscosity of glycerin = 0.83 Pa s). [You may also like to check if the assumption of laminar flow in the tube is correct].

Date: 14/10/2021

S1. Cars and aeroplanes are streamlined to decrease the viscous drag due to the atmosphere.

S2. (a) $\frac{v^2}{2g}$ (b) $\frac{P}{\rho g}$

S3. The dimensional formulae of density (ρ), velocity (v), diameter (D) and coefficient of viscosity (η) are $[ML^{-3}]$, $[LT^{-1}]$, $[L]$ and $[ML^{-1}T^{-1}]$ respectively.

Therefore, the dimensional formula of the given quantity. *i.e.*,

$$\left[\frac{\rho v D}{\eta}\right] = \frac{[ML^{-3}][LT^{-1}][L]}{[ML^{-1}T^{-1}]} = [M^0L^0T^0]$$

Hence, the quantity $\frac{\rho v D}{\eta}$ *i.e.*, Reynolds number is dimensionless.

S4. Reynolds number of a liquid determines, whether the flow of a liquid will be streamlined or turbulent. It is given by

$$N = \frac{\rho D v_c}{\eta}$$

Where v_c is critical velocity of the liquid; η, coefficient of viscosity; ρ, density and D, the diameter of the tube through which, the liquid is flowing. The flow is streamlined, when N above 3,000.

S5. There are two vertical forces acting on the body:

(a) The true weight of the body acting vertically downwards.

(b) The force of buoyancy equal to the weight of the liquid displaced.

S6. (a) They are added to decrease the angle of contact between the fabric and the dye so that the dye may penetrate well.

(b) They are used to increase the angle of contact between the fabric and water to prevent the water from penetrating the cloth.

S7. Given, $D = 1.5$ cm; $\eta = 0.022$ poise; $\rho = 1.15$ g cm^{-3}. The critical velocity of the flow of liquid is given by

$$v_c = \frac{N\eta}{\rho D}$$

For a viscous liquid, flow is observed to be laminar, when N lies between 0 to 2,000. The flow of liquid becomes turbulent, when the value of N is above 2,000.

Therefore, the minimum average flow speed of the liquid corresponds to $N = 2{,}000$ and is given by

$$v_{min}\ (\text{turbulent}) = \frac{2{,}000 \times 0.022}{1.15 \times 1.5} = \mathbf{25.2\ cm\,s^{-1}}.$$

S8. Let the speed of the flow be v and the diameter of the tap be d = 1.25 cm. The volume of the water flowing out per second is

$$Q = v \times \pi d^2/4$$
$$v = 4Q/d^2\pi$$

We then estimate the Reynolds number to be

$$R_e = 4\ \rho\ Q/\pi\ d\eta$$
$$= 4 \times 10^3\ \text{kg m}^{-3} \times Q/(3.14 \times 1.25 \times 10^{-2}\ \text{m} \times 10^{-3}\ \text{Pa s})$$
$$= 1.019 \times 10^8\ \text{m}^{-3}\ \text{s}\ Q.$$

Since initially $Q = 0.48\ \text{L/min} = 8\ \text{cm}^3/\text{s} = 8 \times 10^{-6}\ \text{m}^3\ \text{s}^{-1}$,

we obtain, $R_e = 815$

Since this is below 1000, the flow is steady.

After some time when $Q = 3\ \text{L / min} = 50\ \text{cm}^3/\text{s} = 5 \times 10^{-5}\ \text{m}^3\ \text{s}^{-1}$,

we obtain, $R_e = 5095$

The flow will be turbulent. You may carry out an experiment in your washbasin to determine the transition from laminar to turbulent flow.

S9. Given, $D = 1.25\ \text{cm} = 1.25 \times 10^{-2}$ m; $\eta = 10^{-3}$ Pa s

$$v = 3\ \text{litres per minute} = \frac{3 \times 1000}{60}\ \text{cm}^3\ \text{s}^{-1}$$

$$= 50 \times 10^{-6}\ \text{m}^3\ \text{s}^{-1}$$

If v is velocity of flow of water from the tap and a, the area of cross-section of the tap, then

$$V = a \times v = \frac{\pi D^2}{4} \times v$$

or $$v = \frac{4V}{\pi D^2} = \frac{4 \times 50 \times 10^{-6}}{\pi \times (1.25 \times 10^{-2})^2} = 0.4074\ \text{m s}^{-1}$$

Now, Reynolds number,

$$N = \frac{\rho D v}{\eta} = \frac{10^3 \times 1.25 \times 10^{-2} \times 0.4074}{10^{-3}} = \mathbf{5.092.5}$$

Since N is greater than 2,000, the flow of water from the tap will be ***turbulent***.

S10. Here, $D = 2r = 2 \times 2 \times 10^{-3} = 4 \times 10^{-3}$ m; $\eta = 2.084 \times 10^{-3}$ Pa s; $\rho = 1.06 \times 10^{3}$ kg m^{-3}

For flow to remain laminar, Reynolds number should be at maximum equal to 2,000.

Now, $$N = \frac{\rho D v}{\eta}$$

Therefore, largest velocity of blood, at which flow can remain laminar,

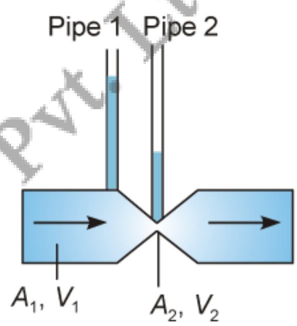
$$v = \frac{N\eta}{\rho D} = \frac{2,000 \times 2.084 \times 10^{-3}}{1.06 \times 10^{3} \times 4 \times 10^{-3}} = \mathbf{0.983\ m\,s^{-1}}$$

Also, flow rate of the blood,

$$= \pi r^2 \times v = \pi \times (2 \times 10^{-3})^2 \times 0.983$$

$$= \mathbf{1.235 \times 10^{-5}\ m^3\,s^{-1}}.$$

S11. Take the case given in figure (b).



Where, A_1 = Area of pipe1

A_2 = Area of pipe 2

v_1 = Speed of the fluid in pipe1

v_2 = Speed of the fluid in pipe 2

From the law of continuity, we have:

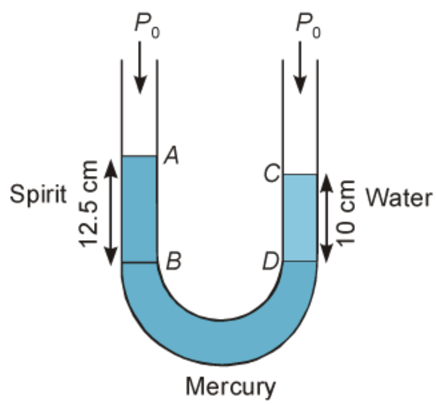
$$A_1 v_1 = A_2 v_2$$

When the area of cross-section in the middle of the venturimeter is small, the speed of the flow of liquid through this part is more. According to Bernoulli's principle, if speed is more, then pressure is less.

Pressure is directly proportional to height. Hence, the level of water in pipe 2 is less.

Therefore, figure (a) is not possible.

S12. The given system of water, mercury, and methylated spirit is shown as follows:



Height of the spirit column, h_1 = 12.5 cm = 0.125 m

Height of the water column, h_2 = 10 cm = 0.1 m

P_0 = Atmospheric pressure

ρ_1 = Density of spirit

ρ_2 = Density of water

Pressure at point $B = P_0 + h_1\rho_1 g$

Pressure at point $D = P_0 + h_2\rho_2 g$

Pressure at points B and D is the same.

$$P_0 + h_1\rho_1 g = P_0 + h_2\rho_2 g$$

$$\frac{\rho_1}{\rho_2} = \frac{h_2}{h_1} = \frac{10}{12.5}$$

Therefore, the specific gravity of spirit is 0.8.

S13. The maximum mass of a car that can be lifted,

$$m = 3000 \text{ kg}$$

Area of cross-section of the load-carrying piston,

$$A = 425 \text{ cm}^2 = 425 \times 10^{-4} \text{ m}$$

The maximum force exerted by the load,

$$F = mg$$

$$= 3000 \times 9.8$$

$$= 29400 \text{ N}$$

The maximum pressure exerted on the load-carrying piston,

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

$$= \frac{29400}{425 \times 10^{-4}} = 6.917 \times 10^5 \text{ Pa}$$

Pressure is transmitted equally in all directions in a liquid. Therefore, the maximum pressure that the smaller piston would have to bear is 6.917×10^5 Pa.

S14. Density of mercury, $\rho_1 = 13.6 \times 10^3 \text{ kg/m}^3$

Height of the mercury column, $h_1 = 0.76$ m

Density of French wine, $\rho_2 = 984 \text{ kg/m}^3$

Height of the French wine column = h_2

Acceleration due to gravity, $g = 9.8$ m/s

The pressure in both the columns is equal, *i.e.*,

Pressure in the mercury column = Pressure in the French wine column

$$\rho_1 h_1 g = \rho_2 h_2 g$$

$$h_2 = \frac{\rho_1 h_1}{\rho_2}$$

$$= \frac{13.6 \times 10^3 \times 0.76}{984} = 10.5 \text{ m}$$

Hence, the height of the French wine column for normal atmospheric pressure is 10.5 m.

S15. Area of cross-section of the spray pump,

$$A_1 = 8 \text{ cm}^2 = 8 \times 10^{-4} \text{ m}^2$$

Number of holes, $n = 40$

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

Radius of each hole, $r = d/2 = 0.5 \times 10^{-3} \text{ m}$

Area of cross-section of each hole, $a = \pi r^2 = \pi (0.5 \times 10^{-3})^2 \text{ m}^2$

Total area of 40 holes, $A_2 = n \times a$

$$= 40 \times \pi (0.5 \times 10^{-3})^2 \text{ m}^2$$

$$= 31.41 \times 10^{-6} \text{ m}^2$$

Speed of flow of liquid inside the tube,

$$v_1 = 1.5 \text{ m/min} = 0.025 \text{ m/s}$$

Speed of ejection of liquid through the holes = v_2

According to the law of continuity, we have:

$$A_1 v_1 = A_2 v_2$$

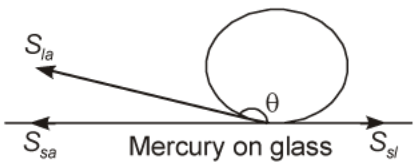
$$v_2 = \frac{A_1 v_1}{A_2}$$

$$= \frac{8 \times 10^{-4} \times 0.025}{31.61 \times 10^{-6}} = 0.633 \text{ m/s}$$

Therefore, the speed of ejection of the liquid through the holes is 0.633 m/s.

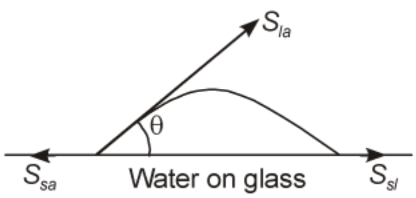
S16. (a) The angle between the tangent to the liquid surface at the point of contact and the surface inside the liquid is called the angle of contact (θ), as shown in the given figure.

S_{la}, S_{sa}, and S_{sl} are the respective interfacial tensions between the liquid-air, solid-air, and solid-liquid interfaces. At the line of contact, the surface forces between the three media must be in equilibrium, *i.e.*,



$$\cos\theta = \frac{S_{sa} - S_{sl}}{S_{la}}$$

The angle of contact θ, is obtuse if $S_{sa} < S_{la}$ (as in the case of mercury on glass). This angle is acute if $S_{sl} < S_{la}$ (as in the case of water on glass).



Mercury molecules (which make an obtuse angle with glass) have a strong force of attraction 0between themselves and a weak force of attraction toward solids. Hence, they tend to form drops.

On the other hand, water molecules make acute angles with glass. They have a weak force of attraction between themselves and a strong force of attraction toward solids. Hence, they tend to spread out.

(b) Surface tension is the force acting per unit length at the interface between the plane of a liquid and any other surface. This force is independent of the area of the liquid surface. Hence, surface tension is also independent of the area of the liquid surface.

(c) Water with detergent dissolved in it has small angles of contact (θ). This is because for a small θ, there is a fast capillary rise of the detergent in the cloth. The capillary rise of a liquid is directly proportional to the cosine of the angle of contact (θ). If θ is small then cos θ will be large and the rise of the detergent water in the cloth will be fast.

(d) A liquid tends to acquire the minimum surface area because of the presence of surface tension. The surface area of a sphere is the minimum for a given volume. Hence, under no external forces, liquid drops always take spherical shape.

S17. Length of the horizontal tube, $l = 1.5$ m

Radius of the tube, $r = 1$ cm $= 0.01$ m

Diameter of the tube, $d = 2r = 0.02$ m

Glycerin is flowing at a rate of 4.0×10^{-3} kg s^{-1}.

$$M = 4.0 \times 10^{-3} \text{ kg s}^{-1}$$

Density of glycerin, $\rho = 1.3 \times 10^{3}$ kg m^{-3}

Viscosity of glycerin, $\eta = 0.83$ Pa s

Volume of glycerin flowing per sec:

$$V = \frac{M}{\rho} = \frac{4.0 \times 10^{-3}}{1.3 \times 10^{3}}$$

$$= 3.08 \times 10^{-6} \text{ m}^3 \text{ s}^{-1}$$

According to Postville's formula, we have the relation for the rate of flow:

$$V = \frac{\pi p r^4}{8\eta l}$$

Where, p is the pressure difference between the two ends of the tube

$$= \frac{3.08 \times 10^{-6} \times 8 \times 0.83 \times 1.5}{\pi \times (0.01)^4}$$

$$= 9.8 \times 10^{2} \text{ Pa}$$

Reynolds' number is given by the relation:

$$R = \frac{4\rho V}{\pi d \eta}$$

$$= \frac{4 \times 1.3 \times 10^3 \times 3.08 \times 10^{-6}}{\pi \times (0.02) \times 0.83} = 0.3$$

Reynolds' number is about 0.3. Hence, the flow is laminar.

Date: 14/10/2021

Q1. Why does free surface of a liquid behave like a stretched membrane?

Q2. What is meant by sphere of influence of a liquid molecule?

Q3. How is surface energy related to surface tension of a liquid?

Q4. Why are rain drops spherical?

Q5. Why a small drop of mercury is spherical but bigger drop are oval in shape?

Q6. What is the angle of contact?

Q7. What are the factors on which angle of contact depends?

Q8. Why are brick walls plastered with cement?

Q9. What will be the effect on the angle of contact of a liquid, if the temperature increases?

Q10. Why does wet ink get absorbed by a blotting paper?

Q11. In summer, cotton dress is preferable. Give reason.

Q12. The addition of flux (soldering paste) to the tin makes soldering easy. Why?

Q13. How does the plugging of fields help in preservation of moisture in the soil?

Q14. A mercury barometer always reads less than actual pressure. Why?

Q15. Why is the tip of the nib of your writing pen split? Explain.

Q16. Why smearing of glycerin over the glass windows prevents rain drop from sticking to it?

Q17. Teflon is coated on the surface of non-sticking pans. Explain, why?

Q18. Surface tension of all lubricating oils and paints is kept low. Why?

Q19. If a mercury barometer is fitted such that the angle with the vertical is 30°, what will be the height of mercury column under on atmosphere?

Q20. Why do the asbestos roof of houses get lifted in hurricane?

Q21. What is the impact on surface tension when (i) impurity in increased, and (ii) temperature is decreased?

Q22. Why does mercury drop its level in a capillary tube?

Q23. Air is blow into a soap bubble to increase its size. What will be the effect on the air pressure inside it?

Q24. How will the raise of a liquid be affected, if the top of capillary tube is closed?

Q25. If you double the radius capillary tube, what will be the drop in height rise in the tube?

Q26. What happens to surface tension, when impurity is added to a liquid?

Q27. Water flows faster than honey. Why?

Q28. What is effect on the equilibrium of a physical balance when air is blown below one pan?

Q29. The lower end of a capillary tube of diameter 2.00 mm is dipped 8.00 cm below the surface of water in a beaker. What is the pressure required in the tube in order to blow a hemispherical bubble at its end in water? The surface tension of water at temperature of the experiments is 7.30 10^{-2} Nm^{-1}. 1 atmospheric pressure = 1.01 $\times 10^5$ Pa, density of water = 1000 kg/m^3, g = 9.80 $m s^{-2}$. Also calculate the excess pressure.

Q30. Two soap bubbles have radii in the ratio 2 : 3. Calculate the ratio of work done in blowing these bubbles.

Q31. What is the excess pressure in a soap bubble of radius 10 mm, if surface tension is 2.5×10^{-2} N/m?

Q32. Explain why "A drop of liquid under no external force is always spherical in shape".

Q33. What is the cause of excess pressure inside a soap bubble?

Q34. Why does oil form a thin film over the surface of water?

Q35. Why is it not possible to separate two pieces of paper joined by glue or gum? Explain.

Q36. It is possible to produce fairly vertical film of soap solution but not of pure water? Why.

Q37. In order to increase the surface area of a liquid work has to be done. Is it against the law of conservation of energy?

Q38. Why is it that molecules of a liquid lying near the free surface possess extra energy?

Q39. A small boat with wax sticking to its one end, when placed on water, starts moving. Explain, why?

Q40. A piece of chalk immersed into water emits bubbles in all direction. Why?

Q41. The new earthen pots keep water cooler than the old ones. Why?

Q42. Water wets the glass, while mercury does not. Explain, why.

Q43. Why is it that a needle may float on clear water but will sink, when some detergent is added to water?

Q44. It is difficult to make mercury enter a fine thermometer tube. Explain, why?

Q45. Kerosene oil spreads over the surface of water, whereas water does not spread over the surface of oil.

Q46. Sand is a drier soil than clay. Why?

Q47. Why does a small piece of camphor dance about on the water surface?

Q48. It is easier to spray water in which some soap is dissolved. Explain, why?

Q49. It is easier to wash clothes in hot water soap solution. Why?

Q50. Water is depressed in a glass tube, whose bore is coated with paraffin wax. Explain, why?

Q51. The antiseptics used for cuts and wounds in the human flesh have low surface tensions. Why?

Q52. A large bubble is formed at one end of a capillary tube and a small one at the other end. Which one will grow at the expense of the other?

Q53. Explain the variation of surface tension with temperature.

Q54. Water can be poured into a bottle having narrow neck with the aid of a glass rod. Explain, why?

Q55. Two vessels have the same base area but different shapes. The first vessel takes twice the volume of water that the second vessel requires to fill upto a particular common height. Is the force exerted by the water on the base of the vessel the same in the two cases? If so, why do the vessels filled with water to that same height give different readings on a weighing scale?

Q56. Derive an expression for the excess of pressure inside an air bubble.

Q57. Calculate the work done in blowing a soap bubble from a radius of 2 cm to 3 cm, the surface tension of the soap solution is 30 dyne cm^{-1}.

Q58. Calculate the pressure inside an air bubble of radius 0.1 mm situated at a depth of 30 cm below the free surface of a liquid of density 0.9 g cm^{-3} and surface tension 72 dyne cm^{-1}. Take atmospheric pressure to be 76 cm of mercury column.

Q59. In an experiment to determine the surface tension of water by capillary rise, in a capillary tube of diameter 10^{-3} m, water rises to a height of 0.03 m. Calculate the surface tension of water. Given, g = 9.8 m s^{-2}, density of water = 1,000 kg m^{-3}.

Q60. Two soap bubbles have radii in the ratio 1 : 2. Compare the excess of pressure inside these bubbles. Also compare the work done in blowing these bubbles.

Q61. Water flows through a horizontal pipe of radius 1 cm at a speed of 2 ms^{-1}, What should be the diameter of its nozzle if the water is to come out at a speed of 10 ms^{-1}?

Q62. Two liquids of specific gravity 1.2 and 0.84 are poured into the limbs of a *U*-tube until the difference in level of their upper surfaces is 9 cm. What will be the heights of their respective surfaces above the common surface in *U*-tube? What is the pressure at the common surface? [g = 10 ms^{-2}]

Q63. The excess pressure inside a soap bubble is thrice the excess pressure inside a moving soap bubble. What is the ratio between the volume of the first and second bubble?

Q64. What would be the gauge pressure inside an air bubble of 0.2 mm radius situated just below the surface of water? Surface tension of water is 0.07 Nm^{-1}.

Q65. A *U*-shaped wire loop having a slider (of negligible mass) is dipped in a soap solution and then removed. A thin soap film is formed between the wire and the light slider. It is found that the film can support a weight of 0.006 N, before it will break. If the length of the slider is 0.1 m, what is the surface tension of the film?

Q66. What is the pressure inside the drop of mercury of radius 3.00 mm at room temperature? Surface tension of mercury at that temperature (20°C) is 4.65×10^{-1} N m^{-1}. The atmospheric pressure is 1.01×10^{5} Pa. Also give the excess pressure inside the drop.

Q67. A *U*-shaped wire is dipped in a soap solution, and removed. The thin soap film formed between the wire and the light slider supports a weight of 1.5×10^{-2} N (which includes the small weight of the slider). The length of the slider 30 cm. What is the surface tension of the film?

Q68. Calculate the force required to separate two glass plates of area $10^{-2}\ m^2$ with a film of water 0.05 mm thick between them. Surface tension of water is $72 \times 10^{-3}\ N m^{-1}$.

Q69. Why does free surface of a liquid behave like a stretched membrane? A wire ring of 3 cm. radius is rested on the surface of a liquid and then raised. The pull required is 3.03 g more before the film breaks than it is after. Find the surface tension of the liquid.

Q70. A film of water if formed between two straight-parallel wires each 10 cm long and at separation 0.5 cm. Calculate the work required to increase 1 mm distance between the wires. Surface tension of water $72 \times 10^{-3}\ N m^{-1}$.

Q71. Calculate the energy spent in spraying a drop of mercury of 1 cm radius into 10^6 droplets all of same size. Surface tension of mercury is $35 \times 10^{-3}\ N m^{-1}$.

Q72. Why are rain drops spherical? A soap film is formed in a rectangular frame of length 7 cm dipping into soap solution. The frame work hangs from the arm of a balance. An extra weight 0.38 g must be placed in the opposite arm to balance the pull of the film. Calculate the surface tension of soap solution.

Q73. How is surface energy related to surface tension of a liquid? What is the excess pressure inside a bubble of soap solution of radius 3 mm, given that the surface tension of soap solution is 25 dyne cm^{-1}? Also find the pressure inside the bubble, if the atmospheric pressure is 1.013×10^6 dyne cm^{-2}.

Q74. What is meant by sphere of influence of a liquid molecule? A liquid drop of diameter *D* breaks up into 27 tiny drop. Find the resulting change in energy. Take surface tension of the liquid as *T*.

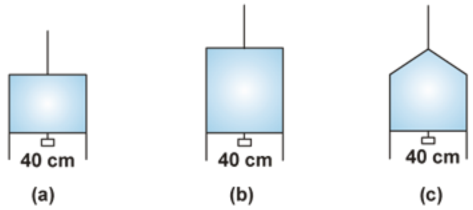
Q75. Why a small drop of mercury is spherical but bigger drop are oval in shape? Establish a relation for the excess pressure on a drop of liquid of surface tension σ giving reason for its presence.

Q76. Water rises in a capillary tube to a height 2 cm. In an other capillary tube, whose radius is one third of it, how much water will rise? If the first capillary tube is inclined at an angle of 60° with the vertical, then what will be the position of water in the tube?

Q77. The limbs of a capillary U-tube have the internal diameters of 1 mm and 2 mm. The tube is held vertically and is partially filled with a liquid of surface tension 50 dyne cm^{-1}. Find the density of liquid, if the difference of levels in the two limbs is 1.25 cm. Assume angle of contact to be 0°.

Q78. What will be the effect on the angle of contact of a liquid, if the temperature increases? A liquid drop of diameter 4 mm breaks into 1000 droplets of equal size. Calculate the resultant change in surface energy, the surface tension of the liquid is 0.07 Nm^{-1}.

Q79. Figure (a) shows a thin liquid film supporting a small weight = 4.5×10^{-2} N. What is the weight supported by a film of the same liquid at the same temperature in Fig. (b) and (c)? Explain your answer physically.



Q80. (a) What is the phenomenon of capillarity? Derive an expression for the rise of liquid in a capillary tube.

(b) What will happen if length of the capillary tube is smaller than the height to which the liquid rises? Explain briefly.

Q81. Define surface tension and surface energy. Write units and dimension of surface tension. Also prove that surface energy numerically equal to the surface tension.

Q82. What is the excess pressure inside a bubble of soap solution of radius 5.00 mm, given that the surface tension of soap solution at the temperature (20 °C) is $S = 2.50 \times 10^{-2}$ Nm^{-1}? If an air bubble of the same dimension were formed at depth of 40.0 cm inside a container containing the soap solution (of relative density 1.20), what would be the pressure inside the bubble? (1 atmospheric pressure is 1.01×10^5 Pa).

Q83. Mercury has an angle of contact equal to 140° with soda lime glass. A narrow tube of radius 1.00 mm made of this glass is dipped in a trough containing mercury. By what amount does the mercury dip down in the tube relative to the liquid surface outside? Surface tension of mercury at the temperature of the experiment is 0.465 N m^{-1}. Density of mercury = 13.6×10^3 kg m^{-3}.

Q84. (a) It is known that density ρ of air decreases with height y as

$$\rho = \rho_0 e^{y/y_0}.$$

Where ρ_0= 1.25 kg m^{-3} is the density at sea level, and y_0 is a constant. This density variation is called the law of atmospheres. Obtain this law assuming that the temperature of atmosphere remains a constant (isothermal conditions). Also assume that the value of gremains constant.

(b) A large He balloon of volume 1425 m^3 is used to lift a payload of 400 kg. Assume that the balloon maintains constant radius as it rises. How high does it rise?

[Take y_0= 8000 m and ρ_{He}= 0.18 kg m^{-3}]

Q85. A tank with a square base of area 1.0 m^2 is divided by a vertical partition in the middle. The bottom of the partition has a small small-hinged door of area 20 cm^2. The tank is filled with water in one compartment, and an acid (of relative density 1.7) in the other, both to a height of 4.0 m. compute the force necessary to keep the door close.

Date: 14/10/2021

S1. The liquid molecules in the free surface of the liquid experiences inward force and as a result, the free surface of the liquid tends to acquire minimum surface area.

S2. A sphere of radius equal to the ranges of the molecular force about a given molecule as centre is called its sphere of influence.

S3. Surface tension = surface energy per unit area

i.e., surface tension is equal to work done in increasing unit area of the surface film.

S4. The free surface of a rain drop tries to acquire minimum surface area. Since for a given volume, the surface area of a sphere is minimum, the rain drops acquire spherical shape.

S5. In a small drop, the force due to surface tension is very large as compared to its weight and hence it is spherical in shape. A big drop becomes oval in shape due to its large weight.

S6. It is the angle between the tangent to the free surface of the liquid at the point of contact and the wall of the container, when measured inside the liquid.

S7. The angle of contact depends upon the nature of the liquid and the nature of the material of the container. It also depends upon the temperature of the liquid.

S8. Brick have pores. During rainy season, the water will be sucked in due to capillary action. To prevent it, brick walls are plastered with cement.

S9. The angle of contact of a liquid increases with increase of temperature.

S10. The fine pores in the blotting paper act as capillaries, when it is placed on the wet ink, the rises due to capillary action.

S11. The cotton dresses have fine pores. In summer, when our body sweats, the sweat is sucked by the cloth due to capillary action.

S12. When the flux is added to the molten tin, it decreases the surface tension of the molten tin. As a result, the molten tin spreads easily over the junction, where soldering is to be done.

S13. The plugging of the field destroys the capillaries in the soil. Due to this, water does not rise up and is retained by the soil.

S14. Due to capillary action, mercury is depressed in the barometer tube and hence it will always read less than the actual pressure.

S15. The split in the tip of the nib of the writing pen acts as a fine capillary. It makes ink to rise up due to the capillary action.

S16. The angle of contact between glass and water is acute. But on smearing with glycerin, the angle of contact between glass and water becomes obtuse. Due to this, the rain drops do not stick to glass windows.

S17. When Teflon is coated on the surface of a pen, the angle of contact between the pan and the oil used for the purpose of frying becomes obtuse. It makes the fry-pan a non-sticking one.

S18. Low value of surface tension has been kept for paints and oils so that it can spread over large area.

S19. Under normal conditions, it will be 76 cm of vertical column. So, the height of mercury vertical column. So, the height of mercury in the slant length has to be 76 cm.

S20. Due to high velocity of air outside the house, the pressure inside becomes more than outside. So, it rises up.

S21. Surface tension (a) reduces with increasing impurity and (b) increases with decrease in temperature.

S22. Excess pressure always acts on the concave side and for mercury there is upper convex surface. So, it drops its level capillary tube.

S23. Excess of pressure inside a soap bubble = $\frac{4T}{R}$

When air is blow into the soap bubble, its radius will increase and hence excess of pressure will decrease.

S24. The air trapped between the closed end of the tube and the meniscus of liquid will get compressed due to the capillary rise. It will, in turn, oppose the rise of the liquid.

S25. For the same liquid, hr = constant

$\therefore$ Doubling the radius makes the height half.

S26. When impurity is added to a liquid, its surface tension increases.

S27. Coefficient of viscosity η is less as compared to the value of honey. So, water flows faster than honey.

S28. When air is blown below one pan, there will be increase in air velocity and due to which the pressure drops there. Hence, the pan goes down.

S29. The excess pressure in a bubble of gas in a liquid is given by $2S/r$, where S is the surface tension of the liquid-gas interface. You should note there is only one liquid surface in this case. (For a bubble of liquid in a gas, there are two liquid surfaces, so the formula for excess pressure in that case is $4S/r$.) The radius of the bubble is r. Now the pressure outside the bubble P_o equals atmospheric pressure plus the pressure due to 8.00 cm of water column. That is

$$P_o = (1.01 \times 10^5 \text{ Pa} + 0.08 \text{ m} \times 1000 \text{ kg m}^{-3}\ 9.80 \text{ m s}^{-2})$$
$$= 1.01784 \times 10^5 \text{ Pa}$$

Therefore, the pressure inside the bubble is

$$P_i = P_o + 2S/r$$
$$= 1.01784 \times 10^5 \text{ Pa} + (2 \times 7.3 \times 10^{-2} \text{ Pa m}/10^{-3} \text{ m})$$
$$= (1.01784 + 0.00146) \times 10^5 \text{ Pa}$$
$$= 1.02 \times 10^5 \text{ Pa}$$

where the radius of the bubble is taken to be equal to the radius of the capillary tube, since the bubble is hemispherical ! (The answer has been rounded off to three significant figures.) The excess pressure in the bubble is 146 Pa.

S30.
$$W_1 = 2 \times \sigma \times 4\pi r_1^2$$
$$W_2 = 2 \times \sigma \times 4\pi r_2^2$$
$$\frac{W_1}{W_2} = \left(\frac{r_1}{r_2}\right)^2 = \frac{4}{9}.$$

S31. In a soap bubble, excess pressure, $P = \dfrac{4\sigma}{r}$

$$\therefore \quad P = \frac{4 \times 2.5 \times 10^{-2}}{10 \times 10^{-3}} = 10 \text{ Nm}^{-2}.$$

S32. To reduce the *P.E.*, the surface area for a given volume is reduced by forming a spherical shape.

S33. Surface tension.

S34. Oil has low surface tension than water. So, if forms a thin layer over water.

S35. The forced of adhesion between the molecules of glue and the paper is very large as compared to the force of cohesion between the glue molecules. For this reason, two pieces of paper joined by glue cannot be separated.

S36. It is because, surface tension of soap solution is quite small as compared to that of pure water. When attempt is made to produce a vertical film of pure water, it due to the high value of its surface tension.

S37. The molecules in the free surface of the liquid experience inward pull. To increase the surface area of the liquid, molecules have to be moved from the interior of the liquid to the free surface against this inward pull. The work done stored in the surface as the potential energy of the molecules. Therefore, work done to increase the surface area of a liquid is not against the law of conservation of energy.

S38. A molecules in the free surface experience a net inward force. As the molecule is present in the free surface against an inward force, it possesses extra potential energy.

S39. The wax attached to the boat decreases the value of the surface tension of the water in that region. Due to this, the boat experiences a net unbalanced force due to surface tension of water and as a result, it moves on the water surface.

S40. A piece of chalk has extremely narrow capillaries. As it is immersed in water, water rises due to capillary action. The air present in the capillaries in the chalk is forced out by the rising water. As a result, bubbles are emitted from the chalk in all directions.

S41. An earthen pot has fine capillaries in its surface. In old earthen pots, the capillaries get blocked. However, in new earthen pots, the water rises in the capillaries and comes out. The water, then, takes heat from the earthen pot to evaporate and as a result, the water in the pots gets cooled.

S42. It is because, angle of contact between water and glass is acute; while that between mercury and glass is obtuse. As a rule, if the angle of contact between a liquid and a solid is acute, it wet the solid and in case the angle of contact is obtuse, it will not wet.

S43. When a needle is gently placed on the surface of water, the water surface just below the needle gets depressed and its weight is supported by the surface tension. When some detergent is added to the water, its surface tension decreases. As such, the surface is no longer able to support the weight of the needle. So it sinks.

S44. The meniscus of mercury in a glass tube is convex. On the curved side of a curved liquid surface, there is always an excess of pressure $(p = \frac{2T}{r})$. Therefore, below the mercury meniscus, pressure will be more than the atmospheric pressure. This excess pressure assumes a very high value in case of a capillary tube (radius very small). Owing to this, the mercury does not enter into the thermometer tube.

S45. Surface tension of kerosene oil is very small as compared to that of water.

As kerosene oil is poured on water, the kerosene oil drops cannot maintain their spherical due to small value of its surface tension. Moreover, water due to its high value of surface tension makes it to spread all over the surface.

When water is poured on the oil, the situation will be exactly reverse.

S46. In clay, capillaries are formed due to pores, while in sand, no such capillaries are formed. Due to capillary action, water rises in clay and it appears damp. In the absence of capillaries, water cannot rise in sand and dance it is a drier soil.

S47. When camphor dissolved in water, the surface tension of water decrease. Due to irregular shape of the camphor piece, it may dissolve more at one end than at the other end. Thus, surface tension of water will decreases by unequal amounts at the different end of the camphor piece. It produces a resultant force on the camphor piece and it starts moving. Further, wherever it goes, the process repeats itself and the camphor piece dances about on the water surface.

S48. When water is sprayed in the form of fine drops, then surface area of the water increases. Therefore, work has to be done in spraying the water, which is directly proportional to the value of its surface tension. On adding soap, surface tension of water decreases. The spraying of water, in which some soap has been dissolved, becomes easy due to the lower value of surface tension.

S49. A hot water soap solution has considerably lower value of surface tension than that of normal water. Due to lower value of surface tension, the hot soap solution wets the dirty cloth in a better way and thus achieves greater cleansing action.

S50. When the bore of the glass tube is coated with paraffin wax, the force of adhesion between glass surface (coated with paraffin wax) and water becomes smaller than the force of cohesion between water molecules. Due to this, water does not wet the glass tube *i.e.*, the angle of contact becomes obtuse.

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

For obtuse value of θ, h will be negative. Therefore, water is depressed in the tube coated with paraffin wax.

S51. For wound to heal quickly, the antiseptic used should be able to spread itself into a thin layer on the wound. A liquid spreads more on a surface if its own surface tension is less. Therefore, the antiseptic should possess a low surface tension.

S52. Since the excess of pressure inside a bubble is inversely proportional to radius of the bubble $(p = \frac{4T}{R})$, the pressure inside the bigger bubble will be less than that inside the smaller bubble. As air will flow from a region of greater pressure to the region of lower pressure, the bigger bubble will grow at the expense of the smaller bubble.

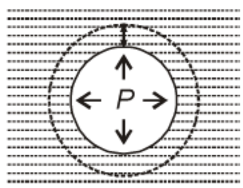
S53. In most of the liquids, the surface tension of a liquid decreases with increase in temperature. However, in case of molten copper and cadmium, it increases with increase in temperature. At the critical temperature, it becomes zero. It is because, the interface between the liquid and its vapour phase disappears at the critical temperature.

S54. If water is poured directly into a bottle having narrow neck, the water does not enter the bottle due to pressure of the inside air and the strong force of adhesion between the glass and water.

If a small part of a glass rod is placed inside the bottle and water is poured along the length of the rod outside the bottle, the water molecules cling to the rod and move into the bottle along the rod under the effect of gravity.

S55. Yes, two vessels having the same base area have identical force and equal pressure acting on their common base area. Since the shapes of the two vessels are different, the force exerted on the sides of the vessels has non-zero vertical components. When these vertical components are added, the total force on one vessel comes out to be greater than that on the other vessel. Hence, when these vessels are filled with water to the same height, they give different readings on a weighing scale.

S56. Consider a bubble of radius R with σ the surface tension of liquid.



Excess pressure inside the bubble,

$$P = P_i - P_0 \qquad (\therefore \text{ air bubble has only one free surface})$$

ΔR = Small increase in radius of bubble due to excess pressure

Work done, W = Force $\times$ Displacement

= (Excess pressure $\times$ Area $\times$ increase in radius)

Increase in surface area of bubble

= Final surface area – initial surface area

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

$= 8\pi R (\Delta R)$

$\therefore \quad P \times 4\pi R^2 \times \Delta R = 8\pi R (\Delta R) \times \sigma$

Increase in P.E. = Increase in surface area $\times$ Surface tension

Since the drop is in equilibrium.

$\therefore \quad P \times 4\pi R^2 \times \Delta R = 8\pi R (\Delta R) \times \sigma$

$$P = \frac{2\sigma}{R}.$$

S57. Here, $T = 30$ dyne cm^{-1}

Initial radius of the soap bubble, $r_1 = 2$ cm and final radius of the soap bubble, $r_2 = 3$ cm.

Since the soap bubble has two free surfaces, increase in surface area $= 2\,(4\pi r_2^2 - 4\pi r_1^2)$

$= 8\pi (r_2^2 - r_1^2)$

$= 8\pi \times (3^2 - 2^2) = 40\pi$ cm^2

Therefore, work done to blow up the soap bubble,

$W = T \times$ increase in surface area

$= 30 \times 40\pi =$ **3,769.9 erg**.

S58. Given, $T = 72$ dyne cm^{-1}; $r = 0.1$ mm $= 0.01$ cm

Excess of pressure inside the air bubble,

$$p_i - p_0 = \frac{2T}{r} = \frac{2 \times 72}{0.01} = 14{,}400 \text{ dyne cm}^{-2}$$

Now, pressure inside the bubble at a depth of 30 cm,

$p = (p_i - p_0)$ + atmospheric pressure

+ pressure due to 30 cm column of liquid

$= 14{,}400 + 76 \times 13.6 \times 980 + 30 \times 0.9 \times 980$

$= 14{,}400 + 10{,}12{,}928 + 26{,}460 = 10{,}53{,}788$

$=$ $\mathbf{1.054 \times 10^6}$ **dyne cm^{-2}**.

S59. Given, $r = \frac{10^{-3}}{2} = 5 \times 10^{-4}$ m; $h = 0.03$ m; $g = 9.8$ m s^{-2};

$$\rho = 1{,}000 \text{ kg m}^{-3}$$

Now, $$T = \frac{rh\rho g}{2\cos\theta} = \frac{5 \times 10^{-4} \times 0.03 \times 1{,}000 \times 9.8}{2 \times \cos 0^\circ} \quad \text{[For water } \theta = 0°]$$

$$= \mathbf{0.0735\ Nm^{-1}}.$$

S60. Given, $$\frac{r}{r'} = \frac{1}{2}$$

Now, excess of pressure onside a bubble,

$$p_i - p_0 = \frac{4T}{r}$$

$$p_i' - p_0 = \frac{4T}{r'}$$

$\therefore$ $$\frac{p_i - p_0}{p_i' - p_0} = \frac{4T}{r} \times \frac{r'}{4T}$$

$$= \frac{r'}{r} = \frac{1}{1/2} = \frac{2}{1} \quad \textit{i.e.,} \quad \mathbf{2:1}.$$

Also, work done in blowing a bubble of radius r,

$$W = T \times 4\pi r^2$$

$\therefore$ $$\frac{W}{W'} = \frac{T \times 4\pi r^2}{T \times 4\pi r'^2} = \left(\frac{r}{r'}\right)^2 = \left(\frac{1}{2}\right)^2 = \frac{1}{4} \quad \textit{i.e.,} \quad \mathbf{1:4}.$$

S61. $$\pi r_1^2 v_1 = \pi r_2^2 v_2$$

$$10^{-4} \times 2 = r_2^2 \times 10$$

$\Rightarrow$ $$r_2^2 = 2 \times 10^{-5}$$

$$r_2 = \sqrt{2 \times 10^{-5}} = 4.47 \times 10^{-3} \text{m}$$

Diameter = $\mathbf{8.94 \times 10^{-3}\ m}$.

S62. Let h_1, h_2 be the heights of denser and lighter liquids above the common level.

Then $$h_2 - h_1 = 9.0 \text{ cm} \quad \text{... (i)}$$

Also $$1.2\, h_1 g = 0.84\, h_2 g$$

or $$h_1 = \frac{0.84}{1.2} h_2 = 0.7\, h_2$$

$$h_1 = 0.7\, h_2$$

$$h_2 - 0.7\, h_2 = 9 \qquad \text{From Eq. (i)}$$

or $$h_2 = 30 \text{ cm and}$$

$$h_1 = 0.7 \times 30 = 21 \text{ cm}$$

Pressure at the common surface $= h\rho g$

$$= 0.3 \times (0.84 \times 10^3) \times 10$$

$$= \mathbf{2520\ Nm^{-2}}.$$

S63. Let r_1 and r_2 be the radii of soap bubbles, excess pressure in them are $\frac{4\sigma}{r_1}$ and $\frac{4\sigma}{r_2}$, where σ is the surface tension.

Given : $$P_1 = 3P_2$$

$$\frac{4\sigma}{r_1} = 3\,\frac{4\sigma}{r_2} \qquad \therefore \quad r_2 = 3\,r_1$$

Volume of first to second bubble

$$= \frac{r_1^3}{r_2^3} = \frac{1}{3^3} = \frac{1}{27}.$$

S64. Given, $T = 0.07\ \text{Nm}^{-1}$; $R = 0.2\ \text{mm} = 2 \times 10^{-4}\ \text{m}$

The excess of pressure inside the air bubble,

$$p_i - p_o = \frac{2T}{R} = \frac{2 \times 0.07}{2 \times 10^{-4}} = 700\ \text{Nm}^{-2}$$

Let the gauge pressure inside the air bubbled be equal to h cm of mercury column. If ρ is density of the mercury, then

$$h\,\rho\,g = 700$$

or $$h = \frac{700}{\rho g} = \frac{700}{13.6 \times 10^3 \times 9.8}$$

$$= 5.25 \times 10^{-3} \text{ cm of Hg} = \mathbf{5.25 \times 10^{-2}\ mm\ of\ Hg}.$$

S65. Due to surface tension, the soap film tries to make its surface area minimum. As it has two free surface, the total force due to tension on the slider will be

$$F = 2\,(T \times l)$$

In equilibrium, total force due to surface tension on the slider will be equal to its weight *i.e.*,

$$2\,(T \times l) = Mg$$

Here, $$Mg = 0.0006\ \text{N}; \quad l = 0.1\ \text{m}$$

$$T = \frac{Mg}{2l} = \frac{0.006}{2 \times 0.1} = \mathbf{0.03\ Nm^{-1}}.$$

S66. Radius of the mercury drop, $r = 3.00 \text{ mm} = 3 \times 10^{-3}$ m

Surface tension of mercury, $S = 4.65 \times 10^{-1}$ N m^{-1}

Atmospheric pressure, $P_0 = 1.01 \times 10^5$ Pa

Total pressure inside the mercury drop = Excess pressure inside mercury + Atmospheric pressure

$= 1.0131 \times 10^5$

$= 1.01 \times 10^5$ Pa

$$\text{Excess pressure} = \frac{2S}{r}$$

$$= \frac{2 \times 4.65 \times 10^{-1}}{3 \times 10^{-3}} = \mathbf{310\ Pa}.$$

S67. The weight that the soap film supports, $W = 1.5 \times 10^{-2}$ N

Length of the slider, $l = 30 \text{ cm} = 0.3$ m

A soap film has two free surfaces.

$\therefore$ Total length $= 2l = 2 \times 0.3 = 0.6$ m

Surface tension, $$S = \frac{\text{Force or Weight}}{2l}$$

$$= \frac{1.5 \times 10^{-2}}{0.6} = 2.5 \times 10^{-2} \text{ N/m}$$

Therefore, the surface tension of the film is $\mathbf{2.5 \times 10^{-2}\ N\ m^{-1}}$.

S68. Here, $T = 72 \times 10^{-3}$ N m^{-1};

Area of the glass plates, $A = 10^{-2}$ m^2

Thickness of water film, $t = 0.05 \text{ mm} = 5 \times 10^{-5}$ m

The radius of curvature of the concave surface of the water film formed between the two glass plates may be taken as half the thickness of the film.

$$\therefore \quad r = \frac{t}{2} = \frac{5 \times 10^{-5}}{2} = 2.5 \times 10^{-5} \text{ m}$$

Now, excess of pressure inside the film (having one cylindrical concave surface),

$$p = \frac{T}{r} = \frac{72 \times 10^{-3}}{2.5 \times 10^{-5}} = 2{,}880 \text{ N m}^{-2}$$

Therefore, force required to separate the two plates,

$$F = p \times A = 2{,}880 \times 10^{-2} = \mathbf{28.8\ N}.$$

S69. The liquid molecules in the free surface of the liquid experiences inward force and as a result, the free surface of the liquid tends to acquire minimum surface area.

When the ring rests on the liquid surface, a thin film is in contact with the ring. Force due to surface tension acts along the circumference. Therefore, the force required to lift the ring is equal to the sum of the weight of the ring and the force due to surface tension. Hence, the extra pull required to break the film is equal to the force on the ring due to surface tension *i.e.*

Pull required to break the film = force on the ring due to surface tension

Here, Pull required to break the film = $3.03\, gf = 3.03 \times 980$ dyne

and radius of the ring, $r = 3$ cm

The liquid is in contact with the ring both along its inner and outer circumference.

Therefore, force on the ring due to surface tension

$$= 2\,(2\pi r T) = 2 \times 2\pi \times 3 \times T = 12\pi T$$

Hence, $12\pi T = 3.03 \times 980$

or $T = \dfrac{3.03 \;\; 980}{12\pi} = 78.77$ dyne cm^{-1}.

S70. Here, $T = 72 \times 10^{-3}$ N m^{-1}

Length of the water film, $l = 10$ cm

Breadth of the water film, $b = 0.5$ cm

The water film formed between the two wires has two free surface. Therefore,

Initial surface area of the water film

$$= 2 \times (10 \times 0.5) = 10 \text{ cm}^2$$

On increasing the distance between the two wires by 1 mm *i.e.*, 0.1 cm, breadth of the water film becomes,

$$b' = 0.5 + 0.1 = 0.6 \text{ cm}$$

Therefore, final surface area of the water film

$$= 2 \times (10 \times 0.6) = 12 \text{ cm}^2$$

Therefore, increase in surface area of the water film

$$= 12 - 10 = 2 \text{ cm}^2 = 2 \times 10^{-4} \text{ m}^2$$

Hence, amount of work done

$$= T \times \text{increase in surface area}$$

$$= 72 \times 10^{-3} \times 2 \times 10^{-4} = \mathbf{1.44 \times 10^{-5}\ J}.$$

S71. Here, $T = 35 \times 10^{-3}$ N m^{-1}; $R = 1$ cm

Let r be the radius of each small drop, when the original drop is splitted into 10^6 small drops. Then,

$$\frac{4}{3}\pi R^3 = 8 \times \frac{4}{3}\pi r^3 \quad \text{or} \quad R = 2r$$

or $$r = 10^{-2} \times 1 = 10^{-2} \text{ cm}$$

Initial surface area of the original drop

$$4\pi R^2 = 4\pi \times 1^2 = 4\pi \text{ cm}^2$$

Final surface area of the 10^6 small drops

$$= 10^6 \times 4\pi r^2 = 10^6 \times 4\pi \times (10^{-2}) = 400\pi \text{ cm}^2$$

Therefore, increase in surface area

$$= 400\pi - 4\pi = 396\pi \text{ cm}^2 = 396\pi \times 10^{-4} \text{ m}^2$$

Therefore, Energy spent = T × increase in surface area

$$= 35 \times 10^{-3} \times 396\pi \times 10^{-4} = \mathbf{4.354 \times 10^{-3}\ N}.$$

S72. The free surface of a rain drop tries to acquire minimum surface area. Since for a given volume, the surface area of a sphere is minimum, the rain drops acquire spherical shape.

When the rectangular frame hanging from the arm of a balance is raised, a soap film is formed between the side of the frame and the soap solution in the container. The soap film has two free surface. It is length of the side of the frame and T. the surface tension of the soap solution, then pull on the rectangular frame,

$$F = 2\,(T \times l)$$

Here, $$l = 7 \text{ cm}$$

$$F = 2\,(T \times 7) = 14\,T$$

Extra weight required to balance the pull on the frame,

$$m\,g = 0.38\,gf = 0.38 \times 980 \text{ dyne}$$

Since the extra weight counter balances the pull on the frame,

$$14\,T = 0.38 \times 980$$

or $$T = \mathbf{26.6\ dyne\ cm^{-1}}.$$

S73. Surface tension = surface energy

i.e., surface tension is equal to work done in increasing unit area of the surface film.

Here, surface tension of the soap solution,

$$T = 25 \text{ dyne cm}^{-1};$$

Radius of the soap bubble, $R = 3 \text{ mm} = 0.3 \text{ cm}$

Pressure outside the soap bubble,

$$p_0 = \text{atmospheric pressure} = 1.013 \times 10^6 \text{ dyne cm}^{-2}$$

If p_i is pressure inside the soap bubble, then excess of pressure inside the soap bubble,

$$p_i - p_0 = \frac{4T}{R} = \frac{4 \times 25}{0.3} = 333.3 \text{ dyne cm}^{-2}$$

Hence, pressure inside the soap bubble,

$$p_i = p_0 + \frac{4T}{R} = 1.013 \times 10^6 + 333.3$$

$$= \mathbf{1.0133 \times 10^6 \text{ dyne cm}^{-2}}.$$

S74. A sphere of radius equal to the ranges of the molecular force about a given molecule as centre is called its sphere of influence.

Here, radius of the drop, $R = D/2$; and number of small drops formed, $n = 27$.

If r is radius of each of the 27 small drops formed, then volume of 27 small drops = volume of the big drop

i.e., $$27 \times \frac{4}{3}\pi r^3 = \frac{4}{3}\pi\left(\frac{D}{2}\right)^3 \quad \text{or} \quad 27\,r^3 = \left(\frac{D}{2}\right)^3$$

or $$r = D/6$$

Initial surface area of the big drop

$$= 4\pi R^2 = 4\pi = \left(\frac{D}{2}\right)^2 = \pi D^2$$

Final surface area of the 27 small drops formed

$$= 27 \times 4\pi r^2 = 27 \times 4\pi\left(\frac{D}{6}\right)^2 = 3\pi D^2$$

Therefore, increase in surface area of the liquid drop

$$= 3\pi D^2 - \pi D^2 = 2\pi D^2$$

Hence, change in energy (energy needed to break the drop)

= increase in surface area $\times$ surface tension

$= 2\pi D^2 T$.

S75. In a small drop, the force due to surface tension is very large as compared to its weight and hence it is spherical in shape. A big drop becomes oval in shape due to its large weight.

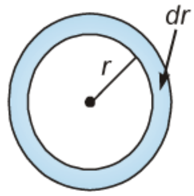
Consider a liquid drop of radius r. If one tries to enhance the radius by a small amount 'dr', work has to be done to overcome the excess pressure (p).

$$\text{Work done} = dW = p \times 4\pi r^2 \times dr$$

Due to surface 'σ', the excess pressure exists. The work done to change the area is also written as

$$dW = \sigma \times \text{change in area}$$

$$= \sigma 4\pi \{(r + dr)^2 - r^2)\} = \sigma 8 \pi r dr$$



$$\therefore \qquad p 4\pi r^2 dr = \sigma 8 \pi r dr \qquad \therefore \quad p = \frac{2\sigma}{r}.$$

S76. Let $r_1 = r$. Then, $r_2 = r/3$

Hence, $h_1 = 2$ cm

Let h_2 be the height, to which liquid rises in the second tube.

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

or $$h \propto \frac{1}{r}$$

$$\therefore \qquad \frac{h_1}{h_2} = \frac{r_2}{r_1}$$

or $$h_2 = \frac{r_1 h_1}{r_2}$$

or $$h_2 = \frac{r \times 2}{(r/3)} = \textbf{6 cm}.$$

When the capillary tube is inclined: In the ascent formula, h refers to the vertical height of the liquid in the capillary tube. If the tube is inclined at an angle θ with the vertical, then length of liquid column in the tube,

$$L = \frac{h}{\cos\theta} = \frac{6}{\cos 60^\circ} = \frac{6}{0.5} = 12 \text{ cm}.$$

S77. Here, $T = 50$ dyne cm^{-1}; $\theta = 0°$; $h_1 - h_2 = 1.25$ cm

$$r_1 = \frac{1}{2} = 0.5 \text{ mm} = 0.05 \text{ cm};$$

$$r_2 = \frac{2}{2} = 1 \text{ mm} = 0.1 \text{ cm}$$

Let ρ be the density of the liquid. Then,

$$h_1 = \frac{2T \cos\theta}{r_1 \rho g}$$

and $$h_2 = \frac{2T \cos\theta}{r_2 \rho g}$$

$$h_1 - h_2 = \frac{2T\cos\theta}{\rho g}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

or $$\rho = \frac{2T\cos\theta}{(h_1 - h_2)g}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$$

$$= \frac{2 \times 50 \times \cos 0^\circ}{1.25 \times 980}\left(\frac{1}{0.05} - \frac{1}{0.1}\right)$$

$$= \frac{2 \times 50 \times 1}{1.25 \times 980}\,(20 - 10) = \mathbf{0.816\ g\ cm^{-3}}.$$

S78. The angle of contact of a liquid increases with increase of temperature.

Given: $\sigma = 0.07\ \text{Nm}^{-1}$; $R = 2\ \text{mm} = 2 \times 10^{-3}\,\text{m}$; $N = 1000$

Change in surface energy,

$$W = \sigma\,[N4\pi r^2 - 4\pi R^2]$$

where $r = RN^{-1/3}$

$$W = \sigma[N^{1-\frac{2}{3}}\,.\,4\pi R^2 - 4\pi R^2]$$

$$= \sigma 4\pi R^2[N^{\frac{1}{3}} - 1]$$

$$\text{W} = 0.07 \times 4 \times \frac{22}{7} \times (2 \times 10^{-3})^2 \times [(1000)^{\frac{1}{3}} - 1]$$

$$= 0.07 \times 4 \times \frac{22}{7} \times 4 \times 10^{-6} \times 9$$

$$W = \mathbf{31.68 \times 10^{-6}\ J}.$$

S79. Take case (a):

The length of the liquid film supported by the weight, $l = 40\ \text{cm} = 0.4\ \text{cm}$

The weight supported by the film,

$$W = 4.5 \times 10^{-2}\ \text{N}$$

A liquid film has two free surfaces.

$\therefore$ Surface tension $= \dfrac{W}{2l}$

$$= \frac{4.5 \times 10^{-2}}{2 \times 0.4} = 5.625 \times 10^{-2}\ \text{N m}^{-1}.$$

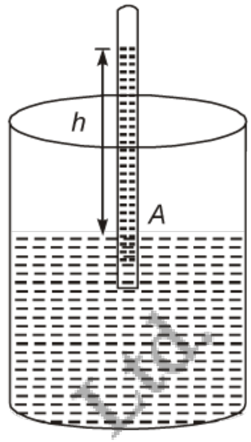
In all the three figures, the liquid is the same. Temperature is also the same for each case.

Hence, the surface tension in figure (b) and figure (c) is the same as in figure (a), *i.e.*, $5.625 \times 10^{-2}\ \text{N m}^{-1}$.

Since the length of the film in all the cases is 40 cm, the weight supported in each case is 4.5×10^{-2} N.

S80. (a) ***Phenomenon of Capillarity:*** Any liquid rises in a capillary tube to compensate for the excess of radius r by a liquid of density ρ and angle of contact θ is,

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



(a)

For mercury, θ being obtuse there is a drop in the level. In a capillary tube of insufficient length, the liquid rises to the level available and then forms a meniscus of higher radius.

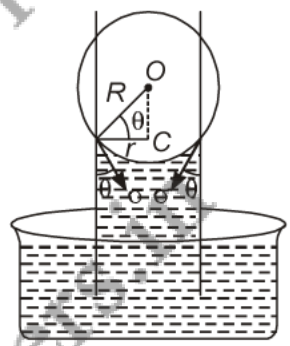
A liquid rises in a capillary tube to compensate for the excess pressure in level with the liquid in the container (A). Let R be the radius of the meniscus at A. Then excess pressure will be $\frac{2\sigma}{R}$ where σ is the surface tension. If the pressure tension. Pressure is compensate by h column of liquid rise, then

$$h\rho g = \frac{2\sigma}{R}$$

$$\therefore \quad h = \frac{2\sigma}{R\rho g}$$

From Fig. (b), $\frac{r}{R} = \cos \Rightarrow R = \frac{r}{\cos\theta}$

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



(b)

(b) The liquid will rise to the level available and from a meniscus of larger radius due to lesser uncompensated excess pressure.

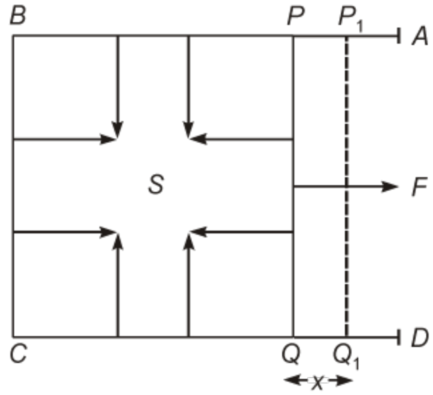
S81. ***Surface Tension:*** Force on unit length of an imaginary line drawn on the surface of the liquid is called surface tension. Its S.I. unit is Nm^{-1} and its dimension is $[ML^0 T^{-2}]$.

Surface Energy: Energy possessed by the surface of the liquid is called surface energy.

Change in surface energy is the product of surface tension and change in surface area under constant temperature.

Let S = Surface tension of soap solution

l = length of wire PQ



Surface tension acts on both the free surface of film.

Hence, total inward force or wire PQ

$$F = S \times 2l$$

Increase in area of the film PQQ_1P_1

$$= \Delta A = 2\,(l \times x)$$

$\therefore$ Work done in stretching film is

$$W = \text{Force applied} \times \text{Distance moved}$$

$$= (S \times 2l) \times x = S \times (2lx)$$

$$= S \times \Delta A \qquad (\because\ 2lx = A)$$

This done is stored in the film as its surface energy.

$$E = W = S \times \Delta A$$

$\Rightarrow$ $$S = W/\Delta A$$

If increase in area is unity then,

$$\Delta A = 1$$

$$S = W$$

$\therefore$ Surface tension of a liquid is numerically equal to surface energy of the liquid surface.

S82. Given, Excess pressure inside the soap bubble is 20 Pa; Pressure inside the air bubble is 1.06×10^5 Pa

Soap bubble is of radius, $r = 5.00 \text{ mm} = 5 \times 10^{-3}$ m

Surface tension of the soap solution, $S = 2.50 \times 10^{-2}\ \text{Nm}^{-1}$

Relative density of the soap solution = 1.20

$\therefore$ Density of the soap solution, $\rho = 1.2 \times 10^3\ \text{kg/m}^3$

Air bubble formed at a depth, $h = 40$ cm = 0.4 m

Radius of the air bubble, $r = 5 \text{ mm} = 5 \times 10^{-3}$ m

1 atmospheric pressure = 1.01×10^5 Pa

Acceleration due to gravity, $g = 9.8\ \text{m/s}^2$

Hence, the excess pressure inside the soap bubble is given by the relation:

$$P = \frac{4S}{r}$$

$$= \frac{4 \times 2.5 \times 10^{-2}}{5 \times 10^{-3}} = 20 \text{ Pa}$$

Therefore, the excess pressure inside the soap bubble is 20 Pa.

The excess pressure inside the air bubble is given by the relation:

$$P' = \frac{2S}{r}$$

$$= \frac{2 \times 2.5 \times 10^{-2}}{5 \times 10^{-3}} = 10 \text{ Pa}$$

Therefore, the excess pressure inside the air bubble is 10 Pa.

At a depth of 0.4 m, the total pressure inside the air bubble

$$= \text{Atmospheric pressure} + h\rho g + P'$$

$$= 1.01 \times 10^5 + 0.4 \times 1.2 \times 10^3 \times 9.8 + 10$$

$$= 1.057 \times 10^5 \text{ Pa}$$

$$= 1.06 \times 10^5 \text{ Pa}$$

Therefore, the pressure inside the air bubble is 1.06×10^5 Pa.

S83. Given, Angle of contact between mercury and soda lime glass, $\theta = 140°$

Radius of the narrow tube, $r = 1 \text{ mm} = 1 \times 10^{-3}$ m

Surface tension of mercury at the given temperature, $s = 0.465 \text{ N m}^{-1}$.

Density of mercury, $\rho = 13.6 \times 10^3 \text{ kg/m}^3$

Dip in the height of mercury $= h$

Acceleration due to gravity, $g = 9.8$ m/s

Surface tension is related with the angle of contact and the dip in the height as:

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

$$\therefore \quad h = \frac{2s\cos\theta}{r\rho g}$$

$$= \frac{2 \times 0.465 \times \cos 140}{1 \times 10^{-3} \times 13.6 \times 10^3 \times 9.8}$$

$$= -4.10 \times 10^{-3} \text{ m} = -4.10 \text{ mm}$$

Here, the negative sign shows the decreasing level of mercury. Hence, the mercury level dips by 4.10 mm.

S84. Given: Volume of the balloon, $V = 1425\ m^3$

Mass of the payload, $m = 400$ kg

Acceleration due to gravity, $g = 9.8\ m/s^2$

$y_0 = 8000$ m

$\rho_{He} = 0.18\ kg\ m^{-3}$

$\rho_0 = 1.25$ kg/m3

Density of the balloon = ρ

Height to which the balloon rises = y

(a) Density (ρ) of air decreases with height (y) as:

$$\rho = \rho_0 e^{-y/y_0}$$

$$\frac{\rho}{\rho_0} = e^{-y/y_0} \quad \text{... (i)}$$

This density variation is called the law of atmospherics.

It can be inferred from equation (i) that the rate of decrease of density with height is directly proportional to ρ, *i.e.*,

$$-\frac{d\rho}{dy} \propto \rho$$

$$\frac{d\rho}{dy} = -k\rho$$

$$\frac{d\rho}{\rho} = -kdy$$

Where, k is the constant of proportionality.

Height changes from 0 to y, while density changes from ρ_0 to ρ.

Integrating the sides between these limits, we get:

$$\int_{\rho_0}^{\rho} \frac{d\rho}{\rho} = -\int_0^y kdy$$

$$[\log_e \rho]_{\rho_0}^{\rho} = -ky$$

$$\log_e \frac{\rho}{\rho_0} = -ky$$

$$\frac{\rho}{\rho_0} = e^{-ky} \quad \text{... (ii)}$$

Comparing equations (i) and (ii), we get:

$$y_0 = \frac{1}{k} \quad \dots \text{(iii)}$$

$$\rho = \rho_0 e^{-y/y_0}$$

(b) Density $\rho = \dfrac{\text{Mass}}{\text{Volume}}$

$$= \frac{\text{Mass of the payload} + \text{Mass of helium}}{\text{Volume}}$$

$$= \frac{m + V\rho_{He}}{V}$$

$$= \frac{400 + 1425 \times 0.18}{1425}$$

$$= 0.46 \text{ kg/m}^3$$

From equations (ii) and (iii), we can obtain y as:

$$\rho = \rho_0 e^{-y/y_0}$$

$$\log_e \frac{\rho}{\rho_0} = -\frac{y}{y_0}$$

$\therefore$
$$y = -8000 \times \log_e \frac{0.46}{1.25}$$

$$y = -8000 \times -1$$

$$= 8000 \text{ m} = 8 \text{ km}$$

Hence, the balloon will rise to a height of 8 km.

S85. Given, Base area of the given tank, $A = 1.0 \text{ m}^2$

Area of the hinged door, $a = 20 \text{ cm}^2 = 20 \times 10^{-4} \text{ m}^2$

Density of water, $\rho_1 = 10^3 \text{ kg/m}^3$

Density of acid, $\rho_2 = 1.7 \times 10^3 \text{ kg/m}^3$

Height of the water column, $h_1 = 4$ m

Height of the acid column, $h_2 = 4$ m

Acceleration due to gravity, $g = 9.8$

Pressure due to water is given as:

$$P_1 = h_1 \rho_1 g$$

$$= 4 \times 10^3 \times 9.8$$

$$= 3.32 \times 10^4 \text{ Pa}$$

Pressure due to acid is given as:

$$P_2 = h_2\rho_2 g$$
$$= 4 \times 1.7 \times 10^3 \times 9.8$$
$$= 6.664 \times 10^4 \text{ Pa}$$

Pressure difference between the water and acid columns:

$$\Delta P = P_2 - P_1$$
$$= 6.664 \times 10^4 + 3.92 \times 10^4$$
$$= 2.744 \times 10^4 \text{ Pa}$$

Hence, the force exerted on the door = $\Delta P \times a$

$$= 2.744 \times 10^4 \times 20 \times 10^{-4}$$
$$= 54.88 \text{ N}$$

Therefore, the force necessary to keep the door closed is 54.88 N.