NCERT Solutions Class 11 Physics chapter 10 Mechanical Properties of Fluids
Mechanical Properties of Fluids
ExerciseP.272
Q.10.1: 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.
Ans : (a) The pressure Of a liquid is given by the relation:
p = hpg
where,
p = Pressure
h = Height of the liquid column
p = 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 transmitted in all
directions. Hence, hydrostatic pressure does not have a fixed direction and it is a scalar
physical quantity.
Q.10.2: Explain why
(a) The angle of contact of mercury with glass is obtuse, while that of water with glass is acute.
(b) 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.)
(c) Surface tension of a liquid is independent of the area of the surface
(d) Water with detergent dissolved in it should have small angles of contact.
(e) A drop of liquid under no external forces is always spherical in shape
Ans : (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 (B), as shown in the given figure.
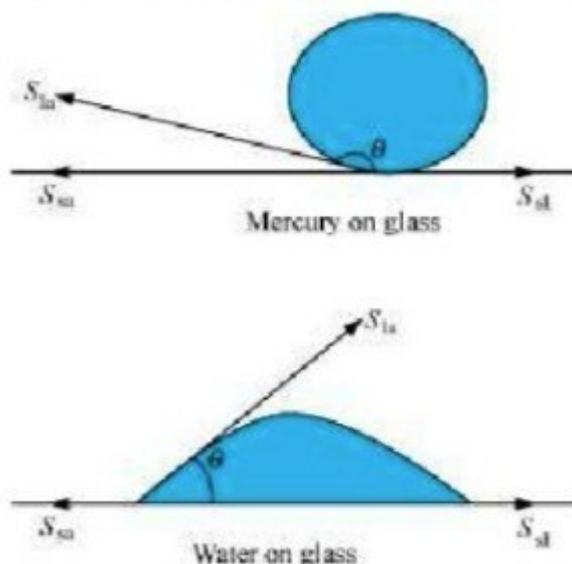
Mercury on glass

Water on glass

S lat S sat 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., S lat S sat 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.,

cosθ=Sa−SslSlacosθ=Sa−SslSla

\(\begin{array}{l}{\text { The angle of contact } \theta, \text { is obtuse if } S_{\mathrm{sa}}}

Q.10.3: Fill in the blanks using the word(s) from the list appended with each statement:

(a) Surface tension of liquids generally ... with temperatures (increases / decreases)

(b) Viscosity of gases ... with temperature, whereas viscosity of liquids ... with temperature (increases / decreases)

(c) For solids with elastic modulus of rigidity, the shearing force is proportional to ... , while for fluids it is proportional to ... (shear strain / rate of shear strain)

(d) For a fluid in a steady flow, the increase in flow speed at a constriction follows (conservation of mass / Bernoulli's principle)

(e) For the model of a plane in a wind tunnel, turbulence occurs at a ... speed for turbulence for an actual plane (greater / smaller)

Ans : (a) decreases

The surface tension of a liquid is inversely proportional to temperature.

(b) increases; decreases

Most fluids Offer resistance to their motion. This is like internal mechanical friction,

known as viscosity. Viscosity Of gases increases with temperature, while viscosity Of

liquids decreases with temperature.

(c) Shear strain; Rate of shear strain

With reference to the elastic modulus of rigidity for solids, the shearing force is

proportional to the shear strain. With reference to the elastic modulus of rigidity for

fluids, the shearing force is proportional to the rate of shear strain.

Q.10.4: 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

Ans : (a) When air is blown under a paper, the veloc ty 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.

(b) According to the equation of continuity: Area x Velocity = Constant 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 : Area x Velocity Constant According to the law of conservation of momentum, the vessel attains a backward velocity

because there are no external forces acting on the system.

(e) A spinning cricket ball has two simultaneous motions — rotary 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.

Q.10.5: 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 ?

Ans : Mass of the girl, m=50kg Diameter of the heel, d=1cm=0.01m Radius of the heel, r=d2=0.005m Mass of the girl, m=50kg Diameter of the heel, d=1cm=0.01m Radius of the heel, r=d2=0.005m

Area of the heel =πr2=π(0.005)2=7.85×10−5m2 Force exerted by the heel on the floor: F=mg Area of the heel =πr2=π(0.005)2=7.85×10−5m2 Force exerted by the heel on the floor: F=mg

=50×9.8=490N Pressure exerted by the heel on the floor: P= Force Area =50×9.8=490N Pressure exerted by the heel on the floor: P= Force Area

=4907.85×10−5=6.24×106Nm−2 Therefore, the pressure exerted by the heel on the horizontal floor

is 6.24×106Nm−2=4907.85×10−5=6.24×106Nm−2 Therefore, the pressure exerted by the heel on the horizontal floor is 6.24×106Nm−2

Q.10.19: 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 × 10–110–1 N m–1m–1. The atmospheric pressure is 1.01 × 105105 Pa. Also give the excess pressure inside the drop.

Ans : 1.01×105Pa;310Pa Radius of the mercury drop, r=3.00mm=3×10−3m Surface tension of mercury, S=4.65×10−1Nm−1 Atmospheric pressure, P0=1.01×105Pa Total pressure inside the mercury drop = Excess pressure inside mercury + Atmospheric pressure 1.01×105Pa;310Pa Radius of the mercury drop, r=3.00mm=3×10−3m Surface tension of mercury, S=4.65×10−1Nm−1 Atmospheric pressure, P0=1.01×105Pa Total pressure inside the mercury drop = Excess pressure inside mercury + Atmospheric pressure =2Sr+P0=2×4.65×10−13×10−3+1.01×105=1.0131×105=1.01×105Pa Excess pressure =2Sr=2Sr+P0=2×4.65×10−13×10−3+1.01×105=1.0131×105 =1.01×105Pa Excess pressure =2Sr

Q.10.6: Torricelli's barometer used mercury. Pascal duplicated it using French wine of density 984 kg m–3m–3. Determine the height of the wine column for normal atmospheric pressure.

Ans : 10.5m Density of mercury, ρ1=13.6×103kg/m3 Height of the mercury column, h1=0.76m3 Density of French wine, ρ2=984kg/m3 Height of the French wine column =h2 Acceleration due to gravity, g=9.8m/s210.5m Density of mercury, ρ1=13.6×103kg/m3 Height of the mercury column, h1=0.76m3 Density of French wine, ρ2=984kg/m3 Height of the French wine column =h2 Acceleration due to gravity, g=9.8m/s2

The pressure in both the columns is equal, i.e., Pressure in the mercury column = Pressure in the French wine

column $\rho_1 h_1 g = \rho_2 h_2 gh_2 = \rho_1 h_1 \rho_2$ The pressure in both the columns is equal, i.e., Pressure in the mercury column = Pressure in the French wine column $\rho_1 h_1 g = \rho_2 h_2 gh_2 = \rho_1 h_1 \rho_2$
$= 13.6 \times 10^3 \times 0.76984 = 10.5m$ Hence, the height of the French wine column for normal atmospheric pressure
is $10.5m. = 13.6 \times 10^3 \times 0.76984 = 10.5m$ Hence, the height of the French wine column for normal atmospheric pressure is 10.5m.

Q.10.7: A vertical offshore structure is built to withstand a maximum stress of 109 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.

Ans : Yes The maximum allowable stress for the structure, $P = 109$ Pa Depth of the ocean, $d = 3km = 3 \times 10^3 m$ 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, $d = \rho dg$ Yes The maximum allowable stress for the structure, $P = 109$ Pa Depth of the ocean, $d = 3km = 3 \times 10^3 m$ 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, $d = \rho dg$
$= 3 \times 10^3 \times 10^3 \times 9.8 = 2.94 \times 10^7 Pa$ The maximum allowable stress for the structure (109Pa) 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. $= 3 \times 10^3 \times 10^3 \times 9.8 = 2.94 \times 10^7 Pa$ The maximum allowable stress for the structure (109Pa) 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.

Q.10.8: 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 $cm^2 cm^2$. What maximum pressure would the smaller piston have to bear ?

Ans : The maximum mass of a car that can be lifted, $m = 3000kg$ Area of cross-section of the load-carrying piston, $A = 425cm^2 = 425 \times 10^{-4} m^2$ The maximum force exerted by the load, $F = mg = 3000 \times 9.8 = 29400N$ The maximum mass of a car that can be lifted, $m = 3000kg$ Area of cross-section of the load-carrying piston, $A = 425cm^2 = 425 \times 10^{-4} m^2$ The maximum force exerted by the load, $F = mg = 3000 \times 9.8 = 29400N$
The maximum pressure exerted on the load-carrying piston, $P = \frac{F}{A} = \frac{29400}{425 \times 10^{-4}} = 6.917 \times 10^5 Pa$ 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. The maximum pressure exerted on the load-carrying piston, $P = \frac{F}{A} = \frac{29400}{425 \times 10^{-4}} = 6.917 \times 10^5 Pa$ 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.

Q.10.9: 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 ?

Ans : The given system of water, mercury, and methylated spirit is +10wn as follows:
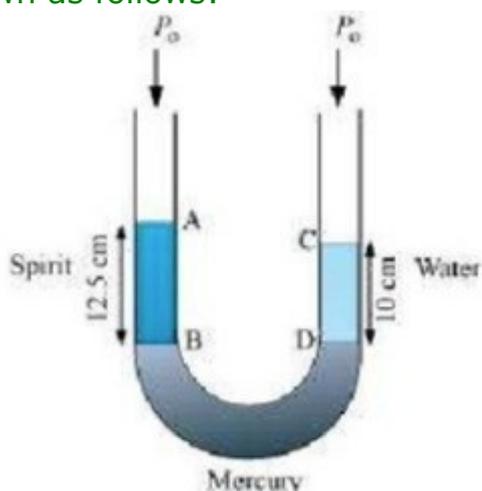
Height of the spirit column, h1=12.5cm=0.125m Height of the water column, h2=10cm=0.1mP0= Atmospheric pressure ρ1= Density of spirit ρ2= Density of water Height of the spirit column, h1=12.5cm=0.125m Height of the water column, h2=10cm=0.1mP0= Atmospheric pressure ρ1= Density of spirit ρ2= Density of water

Pressure at point B=P0+h1ρ1g Pressure at point D=P0+h2ρ2g Pressure at points B and D is the same. P0+h1ρ1g=h2ρ2gρ1ρ2=h2h1ρ1ρ2=h2h1=1012.5=0.8 Pressure at point B=P0+h1ρ1g Pressure at point D=P0+h2ρ2g Pressure at points B and D is the same. P0+h1ρ1g=h2ρ2gρ1ρ2=h2h1ρ1ρ2=h2h1=1012.5=0.8 Therefore, the specific gravity of spirit is 0.8.

Q.10.10: In the previous problem, 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)

Ans : Height of the water column, h1=10+15=25cm Height of the spirit column, h2=12.5+15=27.5cm Density of water, ρ1=1gcm−3 Density of spirit, ρ2=0.8gcm−3 Density of mercury =13.6gcm−3 Let h be the difference between the levels of mercury in the two arms Height of the water column, h1=10+15=25cm Height of the spirit column, h2=12.5+15=27.5cm Density of water, ρ1=1gcm−3 Density of spirit, ρ2=0.8gcm−3 Density of mercury =13.6gcm−3 Let h be the difference between the levels of mercury in the two arms

Pressure exerted by height h, of the mercury column: =hρg=h×13.6g…
(i) Difference between the pressures exerted by water and spirit: Pressure exerted by height h, of the mercury column: =hρg=h×13.6g…
(i) Difference between the pressures exerted by water and spirit: =h1ρ1g−h1ρ1g=g(25×1−27.5×0.8)=3g…
(ii)=h1ρ1g−h1ρ1g=g(25×1−27.5×0.8)=3g…(ii)
Equating equations (i) and (ii), we get: 13.6hg=3gh=0.220588≈0.221cm Hence, the difference between the levels of mercury in the two arms is 0.221cm Equating

equations (i) and (ii), we get: 13.6hg=3gh=0.220588≈0.221cm Hence, the difference between the levels of mercury in the two arms is 0.221cm

Q.10.11: Can Bernoulli's equation be used to describe the flow of water through a rapid in a river ? Explain.

Ans : NO

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.

Q.10.12: Does it matter if one uses gauge instead of absolute pressures in applying Bernoulli's equation ? Explain

Ans : 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.

Q.10.13: Glycerine flows steadily through a horizontal tube of length 1.5 m and radius 1.0 cm. If the amount of glycerine collected per second at one end is 4.0 × 10–310–3 kg s–1s–1 , what is the pressure difference between the two ends of the tube ? (Density of glycerine = 1.3 × 103 kg m–3m–3 and viscosity of glycerine = 0.83 Pa s). [You may also like to check if the assumption of laminar flow in the tube is correct].

Ans : 9.8×102Pa Length of the horizontal tube, l=1.5m Radius of the tube, r=1cm=0.01m Diameter of the tube, d=2r=0.02m Glycerine is flowing at a rate of 4.0×10−3kgs−1M=4.0×10−3kgs−19.8×102Pa Length of the horizontal tube, l=1.5m Radius of the tube, r=1cm=0.01m Diameter of the tube, d=2r=0.02m Glycerine is flowing at a rate of 4.0×10−3kgs−1M=4.0×10−3kgs−1

 Density of glycerine, ρ=1.3×103kgm−3 viscosity of glycerine, η=0.83Pa s Volume of glycerine flowing per sec: V=Mρ Density of glycerine, ρ=1.3×103kgm−3 viscosity of glycerine, η=0.83Pa s Volume of glycerine flowing per sec: V=Mρ =4.0×10−31.3×103=3.08×10−6m3s−1 According to Poiseville's formula, we have the relation for the rate of

flow: =4.0×10−31.3×103=3.08×10−6m3s−1 According to Poiseville's formula, we have the relation for the rate of flow:

V=πpr48nl Where, p is the pressure difference between the two ends of the tube ∴p=V8nlπr4V=πpr48nl Where, p is the pressure difference between the two ends of the tube ∴p=V8nlπr4

=3.08×10−6×8×0.83×1.5π×(0.01)4=9.8×102Pa Reynolds' number is given by the

relation: =3.08×10−6×8×0.83×1.5π×(0.01)4=9.8×102Pa Reynolds' number is given by the relation:

R=4ρVπdη=4×1.3×103×3.08×10−6π×(0.02)×0.83=0.3 Reynolds' number is about 0.3. Hence, the flow is

laminar. R=4ρVπdη=4×1.3×103×3.08×10−6π×(0.02)×0.83=0.3 Reynolds' number is about 0.3. Hence, the flow is laminar.

Q.10.14: 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 m s–1s–1and 63 m s–1s–1 respectively. What is the lift on the wing if its area is 2.5 m2m2 ? Take the density of air to be 1.3 kg m–3m–3 .

Ans : Speed of wind on the upper surface of the wing, V1=70m/s Speed of wind on the lower surface of the wing, V2=63m/s Area of the wing, A=2.5m2 Density of air, ρ=1.3kgm−3 According to Bernoulli's theorem, we have the relation: Speed of wind on the upper surface of the wing, V1=70m/s Speed of wind on the lower surface of the wing, V2=63m/s Area of the wing, A=2.5m2 Density of air, ρ=1.3kgm−3 According to Bernoulli's theorem, we have the relation: P1+12ρV21=P2+12ρV22P2−P1=12ρ(V21−V22) Where, P1= Pressure on the upper surface of the wing P1+12ρV12=P2+12ρV22P2−P1=12ρ(V12−V22) Where, P1= Pressure on the upper surface of the wing P2= 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. Lift on the wing =(P2−P1)A=12ρ(V21−V22)AP2= 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. Lift on the wing =(P2−P1)A=12ρ(V12−V22)A =121.3((70)2−(63)2)×2.5=1512.87=1.51×103N Therefore, the lift on the wing of the aeroplane is 1.51×103N=121.3((70)2−(63)2)×2.5=1512.87=1.51×103N Therefore, the lift on the wing of the aeroplane is 1.51×103N

Q.10.15: Figures 10.23(a) and (b) refer to the steady flow of a (non-viscous) liquid. Which of the two figures is incorrect ? Why ?

(a)   (b)
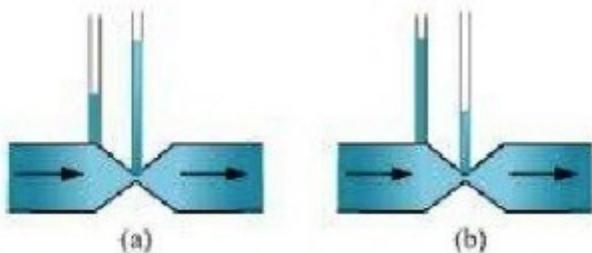
Ans : (a) Take the case given in figure (b). (a) Take the case given in figure (b).
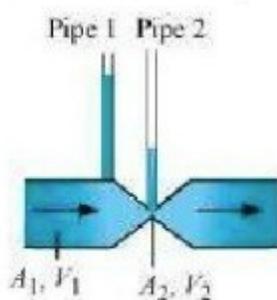
Pipe 1 Pipe 2

A_1, V_1 A_2, V_2

Where, A1= Area of pipe1 A2= Area of pipe 2V2= Speed of the fluid in pipe 2V2= Speed of the fluid in pipe 2 From the law of continuity, we have: Where, A1= Area of pipe1 A2= Area of pipe 2V2= Speed of the fluid

in pipe 2V2= Speed of the fluid in pipe 2 From the law of continuity, we have:
A1V1=A2V2 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. A1V1=A2V2 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. Pressure is directly proportional to height. Hence, the level of water in pipe 2 is less. Therefore, figure (a) is not possible.

Q.10.16: The cylindrical tube of a spray pump has a cross-section of 8.0 cm2cm2 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–1min–1, what is the speed of ejection of the liquid through the holes ?

Ans : Area of cross-section of the spray pump, A1=8cm2=8×10−4m2 Number of holes, n=40 Diameter of each hole, d=1mm=1×10−3m Radius of each hole, r=d/2=0.5×10−3m Area of cross-section of each hole, a=πr2=π(0.5×10−3)2m2 Area of cross-section of the spray pump, A1=8cm2=8×10−4m2 Number of holes, n=40 Diameter of each hole, d=1mm=1×10−3m Radius of each hole, r=d/2=0.5×10−3m Area of cross-section of each hole, a=πr2=π(0.5×10−3)2m2
Total area of 40 holes, A2=n×a=40×π(0.5×10−3)2m2=31.41×10−6m2 Speed of flow of liquid inside the tube, V1=1.5m/min=0.025m/s Speed of ejection of liquid through the holes =V2 According to the law of continuity, we have: Total area of 40 holes, A2=n×a=40×π(0.5×10−3)2m2=31.41×10−6m2 Speed of flow of liquid inside the tube, V1=1.5m/min=0.025m/s Speed of ejection of liquid through the holes =V2 According to the law of continuity, we have:
A1V1=A2V2V2=A1V1A2=8×10−×0.02531.61×10−6=0.633m/sA1V1=A2V2V2=A1V1A2=8×10−×0.02531.61×10−6=0.633m/s
Therefore, the speed Of ejection Of the liquid through the holes is O. 633 m/s.

Q.10.17: 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 × 10–210–2 N (which includes the small weight of the slider). The length of the slider is 30 cm. What is the surface tension of the film ?

Ans : The weight that the soap film supports, W=1.5×10−2N Length of the slider, I=30cm=0.3m A soap film has two free surfaces. ∴ Total length =2l=2×0.3=0.6m The weight that the soap film supports, W=1.5×10−2N Length of the slider, I=30cm=0.3m A soap film has two free surfaces. ∴ Total length =2l=2×0.3=0.6m

S= Force or Weight 2l Surface tension, =1.5×10−20.6=2.5×10−2N/m Therefore, the surface tension of the film is 2.5×10−2Nm−1S= Force or Weight 2l Surface tension, =1.5×10−20.6=2.5×10−2N/m Therefore, the surface tension of the film is 2.5×10−2Nm−1

Q.10.18: Figure 10.24 (a) shows a thin liquid film supporting a small weight = 4.5 × 10–210−2 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.

(a)   (b)   (c)
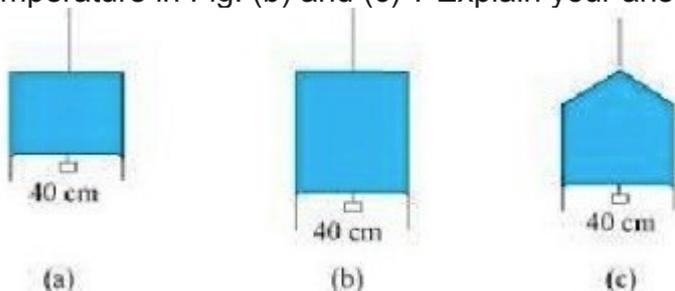
Ans : Take case (a): The length of the liquid film supported by the weight, l=40cm=0.4cm The weight supported by the film, W=4.5×10−2N A liquid film has two free surfaces. Take case (a): The length of the liquid film supported by the weight, l=40cm=0.4cm The weight supported by the film, W=4.5×10−2N A liquid film has two free surfaces. ∴ Surface tension =W2l=4.5×10−22×0.4=5.625×10−2Nm−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., 5.625×10−2Nm−1.∴ Surface tension =W2l=4.5×10−22×0.4=5.625×10−2Nm−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., 5.625×10−2Nm−1.
 since the length of the film in all the cases is 40cm, the weight supported in each case is 4.5×10−2N. since the length of the film in all the cases is 40cm, the weight supported in each case is 4.5×10−2N.

Q.10.20: 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 2.50 × 10–210−2 N m–1m–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 × 105105 Pa)

Ans : Excess pressure inside the soap bubble is 20Pa ; Pressure inside the air bubble is 1.06×105Pa Soap bubble is of radius, r=5.00mm=5×10−3m Surface tension of the soap solution, S=2.50×10−2Nm−1 Relative density of the soap solution = 1.20×10−2Nm−1 Excess pressure inside the soap bubble is 20Pa ; Pressure inside the air bubble is 1.06×105Pa Soap bubble is of radius, r=5.00mm=5×10−3m Surface tension of the soap solution, S=2.50×10−2Nm−1 Relative density of the soap solution = 1.20×10−2Nm−1

∴ Density of the soap solution, ρ=1.2×103kg/m3 Air bubble formed at a depth, h=40cm=0.4m Radius of the air
bubble, r=5mm=5×10−3m1 atmospheric
pressure =1.01×105Pa Acceleration due to gravity, g=9.8m/s2 Hence, the excess pressure inside the soap bubble is given by the relation: ∴ Density of the soap solution, ρ=1.2×103kg/m3 Air bubble formed at a
depth, h=40cm=0.4m Radius of the air
bubble, r=5mm=5×10−3m1 atmospheric
pressure =1.01×105Pa Acceleration due to gravity, g=9.8m/s2 Hence, the excess pressure inside the soap bubble is given by the relation:
P=4Sr=4×2.5×10−25×10−3=20PaP=4Sr=4×2.5×10−25×10−3=20Pa
 Therefore, the excess pressure inside the soap bubble is 20 Pa. The excess pressure inside the air bubble is given by the relation: Therefore, the excess pressure inside the soap bubble is 20 Pa. The excess pressure inside the air bubble is given by the relation:
P′=2Sr=2×2.5×10−25×10−3=10PaP'=2Sr=2×2.5×10−25×10−3=10Pa
 Therefore, the excess pressure inside the air bubble is 10 Pa. At a depth of 0.4m, the total pressure inside the air bubble = Atmospheric pressure +hρg+P
′=1.01×105+0.4×1.2×103×9.8+10=1.057×105Pa=1.06×105Pa Therefore, the excess pressure inside the air bubble is 10 Pa. At a depth of 0.4m, the total pressure inside the air bubble = Atmospheric pressure +hρg+P
′=1.01×105+0.4×1.2×103×9.8+10=1.057×105Pa=1.06×105Pa Therefore, the pressure inside the air bubble is 1.06×105Pa1.06×105Pa
Additional ExercisesP.274
Q.10.21: A tank with a square base of area 1.0 m2m2 is divided by a vertical partition in the middle. The bottom of the partition has a small-hinged door of area 20 cm2cm2 . 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.
Ans : Base area of the given tank, A=1.0m2 Area of the hinged door, a=20cm2=20×10−4m2 Density of water, ρ1=103kg/m3 Density of acid, ρ2=1.7×103kg/m3 Height of the water column, h1=4m Base area of the given tank, A=1.0m2 Area of the hinged
door, a=20cm2=20×10−4m2 Density of water, ρ1=103kg/m3 Density of acid, ρ2=1.7×103kg/m3 Height of the water column, h1=4m
 Height of the acid column, h2=4m Acceleration due to gravity, g=9.8 Pressure due to water is given as: P1=h1ρ1g Height of the acid column, h2=4m Acceleration due to gravity, g=9.8 Pressure due to water is given as: P1=h1ρ1g
=4×103×9.8=3.92×104Pa Pressure due to acid is given as: P2=h2ρ2g=4×1.7×103×9.8=6.664×104Pa Pressure difference between the water and acid columns: =4×103×9.8=3.92×104Pa Pressure due to acid is given as: P2=h2ρ2g=4×1.7×103×9.8=6.664×104Pa Pressure difference between the water and acid columns:

ΔP=P2−P1=6.664×104−3.92×104=2.744×104Pa Hence, the force exerted on the
door =ΔP×a=2.744×104×20×10−4=54.88N=54.88N Therefore, the force necessary to keep the door closed
is 54.88NΔP=P2−P1=6.664×104−3.92×104=2.744×104Pa Hence, the force exerted on the
door =ΔP×a=2.744×104×20×10−4=54.88N=54.88N Therefore, the force necessary to keep the door closed is 54.88N

Q.10.22: A manometer reads the pressure of a gas in an enclosure as shown in Fig. 10.25 (a) When a pump removes some of the gas, the manometer reads as in Fig. 10.25 (b) The liquid used in the manometers is mercury and the atmospheric pressure is 76 cm of 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).
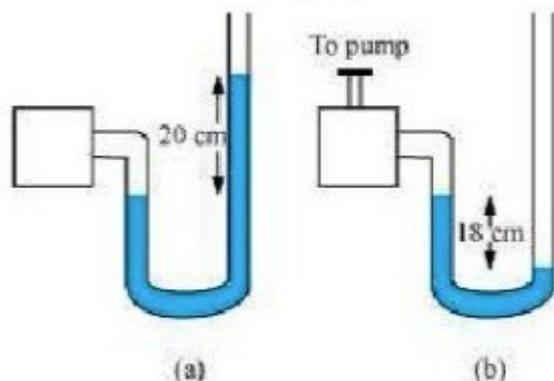
Ans : (a) 96 cm of Hg & 20 cm of Hg; 58 cm of Hg & −18 cm of Hg
(b) 19 cm
 (a) For fiaure (a) Atmospheric pressure, P0=76cm of Hg Difference between the levels of mercury in the two limbs gives gauge
pressure Hence, gauge pressure is 20cm of Hg. Absolute pressure = Atmospheric pressure + Gauge pressure =76+20=96cm of Hg (a) For fiaure (a) Atmospheric pressure, P0=76cm of Hg Difference between the levels of mercury in the two limbs gives gauge pressure Hence, gauge pressure is 20cm of Hg. Absolute pressure = Atmospheric pressure + Gauge pressure =76+20=96cm of Hg
 For figure(b) Difference between the levels of mercury in the two limbs =−18cm Hence, gauge pressure is −18cm of Hg. Absolute pressure = Atmospheric pressure + Gauge
pressure =76cm−18cm=58cm For figure(b) Difference between the levels of mercury in the two limbs =−18cm Hence, gauge pressure is −18cm of Hg. Absolute pressure = Atmospheric pressure + Gauge pressure =76cm−18cm=58cm
 (b) 13.6cm of water is poured into the right limb of figure (b) Relative density of mercury =13.6 Hence, a column of 13.6cmcm of water is equivalent to 1cm of mercury. Let h be the difference between the levels

of mercury in the two limbs. The pressure in the right limb is given as: (b) 13.6cm of water is poured into the right limb of figure
(b) Relative density of mercury =13.6 Hence, a column of 13.6cmcm of water is equivalent to 1cm of mercury. Let h be the difference between the levels of mercury in the two limbs. The pressure in the right limb is given as:
PR= Atmospheric pressure +1cm of Hg=76+1=77cm of Hg…(i) The mercury column will rise in the left limb. Hence, pressure in the left limb, PL=58+h Equating equations (i) and (ii), we get: PR= Atmospheric pressure +1cm of Hg=76+1=77cm of Hg…(i) The mercury column will rise in the left limb. Hence, pressure in the left limb, PL=58+h Equating equations (i) and (ii), we get:
77=58+h∴h=19cm Hence, the difference between the levels of mercury in the two limbs will be 19cm.77=58+h∴h=19cm Hence, the difference between the levels of mercury in the two limbs will be 19cm.

Q.10.23: 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 ?

Ans : 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 vessel. Hence, when these vessels are filled with to the same height, they give different readings

Q.10.24: 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 ? [Use the density of whole blood from Table 10.1]

Ans : Gauge pressure, P=2000Pa Density of whole blood, ρ=1.06×103kgm−3 Acceleration due to gravity, g=9.8m/s2 Height of the blood container =h Pressure of the blood container, P= hρg Gauge pressure, P=2000Pa Density of whole blood, ρ=1.06×103kgm−3 Acceleration due to gravity, g=9.8m/s2 Height of the blood container =h Pressure of the blood container, P= hρg
∴h=Pρg=20001.06×103×9.8=0.1925m∴h=Pρg=20001.06×103×9.8=0.1925m
The blood may enter the vein if the blood container is kept at a height greater than 0.1925m, i.e., about 0.2m. The blood may enter the vein if the blood container is kept at a height greater than 0.1925m, i.e., about 0.2m.

Q.10.25: 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 × 10–310–3 m if the flow must remain laminar ? (b) Do the dissipative forces become more important as the fluid velocity increases ? Discuss qualitatively.

Ans : (a) 1.966m/s (b) Yes (a) Diameter of the artery, d=2×10−3m Viscosity of blood, η=2.084×10−3Pas Density of blood, ρ=1.06×103kg/m3 Reynolds' number for laminar flow, NR=2000 The largest average velocity of blood is given as: (a) 1.966m/s (b) Yes (a) Diameter of the artery, d=2×10−3m Viscosity of blood, η=2.084×10−3Pas Density of blood, ρ=1.06×103kg/m3 Reynolds' number for laminar flow, NR=2000 The largest average velocity of blood is given as: Varg=NRηρd=2000×2.084×10−31.06×103×2×10−3=1.966m/sVarg=NRηρd=2000×2.084×10−31.06×103×2×10−3=1.966m/s

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

(b) 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.

Q.10.26: (a) What is the largest average velocity of blood flow in an artery of radius 2× 10–310–3m if the flow must remain lanimar? (b) What is the corresponding flow rate ? (Take viscosity of blood to be 2.084 ×10–310–3Pa s)

Ans : (a)Radius of the artery, r=2×10−3m Diameter of the artery, d=2×2×10−3m=4×10−3m Viscosity of blood, η=2.084×10−3Pa s Density of blood, ρ=1.06×103kg/m3 Reynolds' number for laminar flow, NR=2000 (a)Radius of the artery, r=2×10−3m Diameter of the artery, d=2×2×10−3m=4×10−3m Viscosity of blood, η=2.084×10−3Pa s Density of blood, ρ=1.06×103kg/m3 Reynolds' number for laminar flow, NR=2000 The largest average velocity of blood is given by the relation V arg =NRηρd=2000×2.084×10−31.06×103×4×10−3=0.983m/s The largest average velocity of blood is given by the relation V arg =NRηρd=2000×2.084×10−31.06×103×4×10−3=0.983m/s

Therefore, the largest average velocity Of blood is 0.983 m/s.

(b) Flow rate is given by the relation: R=πr2V arg =3.14×(2×10−3)2×0.983=1.235×10−5m3s−1 Therefore, the corresponding flow rate is 1.235×10−5m3s−1 (b) Flow rate is given by the relation: R=πr2V arg =3.14×(2×10−3)2×0.983=1.235×10−5m3s−1 Therefore, the corresponding flow rate is 1.235×10−5m3s−1

Q.10.27: A plane is in level flight at constant speed and each of its two wings has an area of 25 m2m2 . 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–3m–3).

Ans : The area of the wings of the plane, A=2×25=50m2 Speed of air over the lower wing, V1=180km/h=50m/s Speed of air over the upper wing, V2=234km/h=65m/s Density of air, ρ=1kgm−3 Pressure of air over

the lower wing =P1 Pressure of air over the lower wing =P2 The area of the wings of the plane, A=2×25=50m2 Speed of air over the lower wing, V1=180km/h=50m/s Speed of air over the upper wing, V2=234km/h=65m/s Density of air, ρ=1kgm−3 Pressure of air over the lower wing =P1 Pressure of air over the lower wing =P2

The upward force on the plane can be obtained using Bernoull's equation as: P1+12ρV21=P2+12ρV22P1−P2=12ρ(V22−V21) The upward force on the plane can be obtained using Bernoull's equation as: P1+12ρV12=P2+12ρV22P1−P2=12ρ(V22−V12)

The upward force (F) on the plane can be calculated as: (P1−P2)A=12ρ(V22−V21)A Using equation (i)=12×1×((65)2−(50)2)×50=43125N The upward force (F) on the plane can be calculated as: (P1−P2)A=12ρ(V22−V12)A Using equation (i)=12×1×((65)2−(50)2)×50=43125N

Using Newton's force equation, we can obtain the mass (m) of the plane as: F=mg∴m=431259.8=4400.51kg~4400kg Hence, the mass of the plane is about 4400kg. Using Newton's force equation, we can obtain the mass (m) of the plane as: F=mg∴m=431259.8=4400.51kg~4400kg Hence, the mass of the plane is about 4400kg.

Q.10.28: In Millikan's oil drop experiment, what is the terminal speed of an uncharged drop of radius 2.0 × 10–510–5 m and density 1.2 × 103103 kg m–3m–3. Take the viscosity of air at the temperature of the experiment to be 1.8 × 105105 Pa s. How much is the viscous force on the drop at that speed ? Neglect buoyancy of the drop due to air

Ans : Terminal speed =5.8cm/s; Viscous force =3.9×10−10N Radius of the given uncharged drop, r=2.0×10−5m Density of the uncharged drop, ρ=1.2×103kgm−3 viscosity of air, η=1.8×10−5Pa s Terminal speed =5.8cm/s; Viscous force =3.9×10−10N Radius of the given uncharged drop, r=2.0×10−5m Density of the uncharged drop, ρ=1.2×103kgm−3 viscosity of air, η=1.8×10−5Pa s

Density of air (ρo) can be taken as zero in order to neglect buoyancy of air. Acceleration due to gravity, g=9.8m/s2 Terminal velocity (v) is given by the relation: Density of air (ρo) can be taken as zero in order to neglect buoyancy of air. Acceleration due to gravity, g=9.8m/s2 Terminal velocity (v) is given by the relation:

v=2r2×(ρ−ρ0)g9η=2×(2.0×10−5)2(1.2×103−0)×9.89×1.8×10−3=5.807×10−2ms−1=5.8cms−1v=2r2×(ρ−ρ0)g9η=2×(2.0×10−5)2(1.2×103−0)×9.89×1.8×10−3=5.807×10−2ms−1=5.8cms−1

Hence, the terminal speed of the drop is 5.8cms−1 . The viscous force on the drop is given by: F=6πηrv∴F=6×3.14×1.8×10−5×2.0×10−5×5.8×10−2=3.9×10−10N Hence, the viscous force on the drop is 3.9×10−10N . Hence, the terminal speed of the drop is 5.8cms−1 . The viscous force on the drop is given by: F=6πηrv∴F=6×3.14×1.8×10−5×2.0×10−5×5.8×10−2=3.9×10−10N Hence, the viscous force on the drop is 3.9×10−10N .

Q.10.29: 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–1m–1. Density of mercury = 13.6 × 103103 kg m–3m–3 .

Ans : Angle of contact between mercury and soda lime glass, $\theta=140°$ Radius of the narrow tube, $r=1mm=1\times10−3m$ Surface tension of mercury at the given temperature, $s=0.465Nm−1$ Density of mercury, $\rho=13.6\times103kg/m3$ Dip in the height of mercury $=ħ$ Angle of contact between mercury and soda lime glass, $\theta=140°$ Radius of the narrow tube, $r=1mm=1\times10−3m$ Surface tension of mercury at the given temperature, $s=0.465Nm−1$ Density of mercury, $\rho=13.6\times103kg/m3$ Dip in the height of mercury $=ħ$

Acceleration due to gravity, $g=9.8m/s2$ Surface tension is related with the angle of contact and the dip in the height as: $s=h\rho gr2cos\theta\therefore h=2scos\theta r\rho g$ Acceleration due to gravity, $g=9.8m/s2$ Surface tension is related with the angle of contact and the dip in the height as: $s=h\rho gr2cos\theta\therefore h=2scos\theta r\rho g$

$\therefore h=2scos\theta r\rho g=2\times0.465\times cos1401\times10−3\times13.6\times103\times9.8\therefore h=2scos\theta r\rho g=2\times0.465\times cos1401\times10−3\times13.6\times103\times9.8$

$=−0.00534m=−5.34mm=−0.00534m=−5.34mm$

Here, the negative sign shows the decreasing level of mercury. Hence, the mercury level dips by 5.34 mm.

Q.10.30: 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 × 10–210–2 N m–1m–1. Take the angle of contact to be zero and density of water to be 1.0 × 103103 kg m–3m–3 (g = 9.8 m s–2s–2) .

Ans : Diameter of the first bore, $d1=3.0mm=3\times10−3m$ Hence, the radius of the first bore, $r1=d12=1.5\times10−3m$ Diameter of the second bore, $d2=6.0mm$ Hence, the radius of the second bore, $r2=d22=^3\times10−3m$ Diameter of the first bore, $d1=3.0mm=3\times10−3m$ Hence, the radius of the first bore, $r1=d12=1.5\times10−3m$ Diameter of the second bore, $d2=6.0mm$ Hence, the radius of the second bore, $r2=d22=3^\times10−3m$

Surface tension of water, $s=7.3\times10−2Nm−1$ Angle of contact between the bore surface and water, $\theta=0$ Density of water, $\rho=1.0\times103kg/m−3$ Acceleration due to gravity, $g=9.8m/s2$ Let h1 and h2 be the heights to which water rises in the first and second tubes respectively. These heights are given by the relations: Surface tension of water, $s=7.3\times10−2Nm−1$ Angle of contact between the bore surface and water, $\theta=0$ Density of water, $\rho=1.0\times103kg/m−3$ Acceleration due to gravity, $g=9.8m/s2$ Let h1 and h2 be the heights to which water rises in the first and second tubes respectively. These heights are given by the relations:

$h1=2scos\theta r1\rho gh2=2xcos\theta r2\rho gh1=2scos\theta r1\rho gh2=2xcos\theta r2\rho g$

The difference between the levels of water in the two limbs of the tube can be calculated as: $=2scos\theta r1\rho g−2scos\theta r2\rho g=2scos\theta\rho g[1r1−1r2]$ The

difference between the levels of water in the two limbs of the tube can be calculated as: $=2s\cos\theta r_1\rho g - 2s\cos\theta r_2\rho g = 2s\cos\theta\rho g[\frac{1}{r_1}-\frac{1}{r_2}]$ $=2s\cos\theta\rho g[\frac{1}{r_i}-\frac{1}{r_2}]=2\times7.3\times10^{-2}\times11\times10^3\times9.8[\frac{1}{1.5\times10^{-3}}-\frac{1}{3\times10^{-3}}]$ $=4.966\times10^{-3}m=4.97mm=2s\cos\theta\rho g[\frac{1}{r_i}-\frac{1}{r_2}]=2\times7.3\times10^{-2}\times11\times10^3\times9.8[\frac{1}{1.5\times10^{-3}}-\frac{1}{3\times10^{-3}}]=4.966\times10^{-3}m=4.97mm$

Hence, the difference between levels of water in the two bores is 4.97 mm.

Q.10.31: (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 y0 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 g remains constant. (b) A large He balloon of volume 1425 m3 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 y0 = 8000 m and ρHe = 0.18 kg m−3].

Ans : (a) Volume of the balloon, V=1425m3 Mass of the payload, m=400kg Acceleration due to gravity, g=9.8m/s2 (a) Volume of the balloon, V=1425m3 Mass of the payload, m=400kg Acceleration due to gravity, g=9.8m/s2

y0=8000m ρlk=0.18kgm−3 ρb=1.25kg/m3 Density of the balloon =ρ Helght to which the balloon rises =y Density (ρ) of air decreases with

height (y) as: y0=8000m ρlk=0.18kgm−3 ρb=1.25kg/m3 Density of the balloon =ρ Helght to which the balloon rises =y Density (ρ) of air decreases with height (y) as:

$\rho=\rho_0 e^{-y/y_0}$ $\frac{\rho}{\rho_0}=e^{-yf_0}$ This density variation is called the law of atmospherics. $\rho=\rho_0 e^{-y/y_0}$ $\frac{\rho}{\rho_0}=e^{-yf_0}$ 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., It can be inferred from equation (i) that the rate of decrease of density with height is directly proportional to ρ, i.e.,

$-\frac{d\rho}{dy}\propto\rho$ $\frac{d\rho}{\rho}=-kdy$ Where, k is the constant of proportionality $-\frac{d\rho}{dy}\propto\rho$ $\frac{d\rho}{\rho}=-kdy$ Where, k is the constant of proportionality

Height changes from 0 to y , while density changes from ρ oto ρ. Integrating the sides between these limits, we get: Height changes from 0 to y , while density changes from ρ oto ρ. Integrating the sides between these limits, we get:

$\int_{\rho_0}^{\rho}\frac{d\rho}{\rho}=-\int_0^y kdy$ $\int_{\rho_0}^{\rho}\frac{d\rho}{\rho}=-\int_0^y kdy$

$[\log_e\rho]_{\rho_0}^{\rho}=-ky$ $[\log_e\rho]_{\rho_0}^{\rho}=-ky$

$\log_e\frac{\rho}{\rho_0}=-ky$ $\frac{\rho}{\rho_0}=e^{-ky}$ $\log_e\frac{\rho}{\rho_0}=-ky$ $\frac{\rho}{\rho_0}=e^{-ky}$

Comparing equations (i) and (ii), we get: $y_0=\frac{1}{k}$ $k=\frac{1}{y_0}$ Comparing equations (i) and (ii), we get: $y_0=\frac{1}{k}$ $k=\frac{1}{y_0}$

From equations (i) and (iii), we get: $\rho=\rho_0 e^{-y/y_0}$ (b) From equations (i) and (iii), we get: $\rho=\rho_0 e^{-y/y_0}$ (b)

Density ρ= $\frac{Mass}{Volume}$ = $\frac{Mass\ of\ the\ payload + Mass\ of\ helium}{Volume}$ = $\frac{m+V\rho_{he}}{V}$ $\frac{400+1425\times0.18}{1425}=0.46kg/m2$ Density

$\rho=$ Mass Volume = Mass of the payload + Mass of helium Volume $=m+V\rho$ he V=400+1425×0.181425=0.46kg/m2
 From equations (ij) and (iii), we can obtain y as $\rho=\rho_0 e^{-y/y_n}$ From equations (ij) and (iii), we can obtain y as $\rho=\rho_0 e^{-y/y_n}$
$\log\frac{d\rho}{p_0}=-\frac{y}{y_0}\therefore y=-8000\times\log_e 0.461.25$$\log\frac{d\rho}{p_0}=-\frac{y}{y_0}\therefore y=-8000\times\log_e 0.461.25$
=−8000×−1=8000m=8km=−8000×−1=8000m=8km
Hence, the balloon will rise to a height of 8 km.