NCERT SOLUTIONS
CLASS-XI PHYSICS
CHAPTER-10
MECHANICAL PROPERTIES OF LIQUIDS

NCERT Solutions Class 11 Physics Mechanical Properties of Fluids

Q.1: Explain the following:
(i). Humans have a greater blood pressure in their feet than in the head
(ii). Even though the atmosphere extends over 100 km from the sea level. Atmospheric pressure at an altitude of about 6 km is almost half of its value at sea level.
(iii). Pressure is force divided by area but still, hydrostatic pressure falls into a scalar quantity.

Ans:

(i). The blood column to the feet is at a greater height than the head, thus the blood pressure in the feet is greater than that in the brain.

(ii). The density of the atmosphere does not decrease linearly with the increase in altitude, in fact, most of the air molecules are close to the surface Thus there is this nonlinear variation of atmospheric pressure.

(iii). In hydrostatic pressure the force is transmitted equally in all direction in the liquid, thus there is no fixed direction of pressure making it a scalar quantity

Q.2: Explain the following:
(a) Water droplets on clean glass surfaces will spread out while mercury will form small droplets.

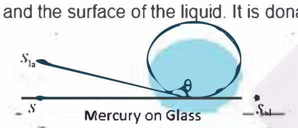
(b) Angle of contact of water with glass is acute while that of mercury is obtuse.

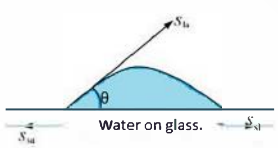
(c) A liquid drop under zero external forces is always spherical.

(d) Surface tension of a liquid does not depend upon the area of the surface.

(e) Water with soap dissolved in it should have small angles of contact.
Ans:
(a) Water molecules have weak intermolecular forces and a strong force of attraction towards solids. Thus, they spill out. Whereas mercury molecules have a stronger intermolecular force of attraction and a weak attraction force towards solids, thus they form droplets.

(b) The angle of contact is the angle between the line tangent to the liquid surface at the point of contact and the surface of the liquid. It is donated by θ in the following diagram:





In the diagram S_{SL}, S_{LA} and S_{SA}, are the respective interfacial tensions between the liquid-solid, liquid-air, and solid-air interfaces. At the line of contact, the surface forces between the three media are in equilibrium, i.e.,

$$\cos\Theta = \left(\frac{S_{SA} - S_{LA}}{S_{LA}}\right)$$

Thus, for mercury, the angle of contact θ, is obtuse because $S_{SA} < S_{LA}$. And for water, the angle is acute because $S_{SL} < S_{LA}$

(c) A liquid always tends to acquire minimum surface area because of the presence of surface tension. And as a sphere always has the smallest surface area for a given volume, a liquid drop will always take the shape of a sphere under zero external forces.

(d) Surface tension is independent of the area of the liquid surface because it is a force depending upon the unit length of the interface between the liquid and the other surface, not the area of the liquid

(e) Clothes have narrow pores that behave like capillaries, now we know that the rise of liquid in a capillary tube is directly proportional to **cos θ**. So a soap decreases the value of **θ** in order to increase the value of **cos θ**, allowing the faster rise of water through the pores of the clothes.

Q.3: Complete the sentences choosing the correct words:

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(a) With lowering of temperature surface tension of liquids generally __________ (decrease/increase)

(b) Shearing force is proportional to ______ for solids having elastic modulus of rigidity, while it is proportional to __________ for fluids. (Rate of shear strain/shear strain)

(c) Viscosity of _______ increases with the temperature while for _____ it decreases. (Liquids/gases)

(d) For model of an aircraft inside a wind tunnel, turbulence occurs at a speed ______ than the speed for turbulence for an actual plane. (Lesser / greater)

(e) A fluid in steady flow experiences increases in its flow speed at constrictions as according to ____ and the decrease of pressure there comes from ___________. (Bernoulli's principle /conservation of mass)

Ans:

(i) Decreases

(ii) Shear strain, rate of shear strain

(iii) Gases, liquid

(iv) Greater

(v) Conservation of mass, Bernoulli's principle

Q.4: Explain the following:

(a) When we place our hands over the opening of a water tap, jets of water gushes out

(b) A spinning football in the air does not follow a parabolic path.

(c) A fluid flowing through a small opening in a vessel causes a backward trust of the vessel.

(d) The size of the needle of a syringe can control the flow rate better than the thumb pressure a doctor exerts while administering an injection.

(e) It is easier to keep a piece of paper horizontally by blowing over it instead of under it.

Ans:

(a) By covering the opening the area of the water outlet is reduced, this causes the velocity to increase in order to satisfy the equation; **Area × Velocity = constant**

(b) A spinning football would have followed a parabolic path had there been no air, but in the presence of air **Magnus effect** takes places causing the spinning ball to take a curved path.

(c) This backward thrust on the vessel is because of the principle of conservation of momentum. The outgoing fluid has forward momentum while the vessel attains backward momentum.

(d) According to the Bernoulli's theorem $P + \frac{1}{2}pv^2$ = Constant , for a constant height.

In this equation, pressure has unit power while velocity has a square power. Hence the needle (as it controls the flow velocity of the liquid) controls the flow rate better than the pressure applied by the doctor.

(e) When we blow over a piece of paper the velocity of air over it increases, causing the pressure on it to decrease as according to Bernoulli's theorem. While blowing under it causes the pressure below it to decrease thereby making it hard for the paper to remain horizontal.

Q.5: A 60 kg lady balances on her right stiletto heel. If the diameter of the circular heel is 0.8 cm, calculate the pressure on the floor due to the heel.

Ans:

Given:

Radius of the heel, **r =** $\frac{d}{2}$ **= 0.004m**

Mass of the lady, **m = 60 kg**

Diameter of the heel, **d =** 0.8 cm **= 0.008 m**

Area of the heel, **A =** $\pi r^2 = \pi\,(0.004)^2$ **= 5.024×10^{-5} m^2**

Force on the floor due to the heel: **F =** mg = 60 × 9.8 **= 588 N**

Pressure exerted by the heel on the floor:

P = $\frac{F}{A}$ = $\frac{588}{5.024 \times 10^{-5}}$

P = 1.17×10^{7} **Nm $^{-2}$**

Q-6: Pascal replaced the mercury in Torricelli's barometer with French wine of density 984 kg m^{-3}. Calculate the height of the wine column for normal atmospheric pressure.

Ans:

We know:
Density of mercury, **ρ_1 = 13.6×10^3 kg/m^3**
Height of the mercury column, h_1 = 0.76 m
Density of French wine, **ρ_2 = 984 kg/m^3**

Let the height of the French wine column **= h_2**
Acceleration due to gravity, **g = 9.8 m/s^2.**

We know that:
Pressure in the mercury column = Pressure in the wine column
$\rho_1 h_1 g = \rho_2 h_2 g$

$\Rightarrow$ h_2 = $\frac{\rho_1 h_1}{\rho_2}$

$\Rightarrow$ h_2 = $\frac{13.6 \times 10^3 \times 0.76}{984}$ **= 10.5 m**

Q-7: A vertical offshore structure can take a maximum stress of 10^{10} Pa. Can this structure survive on top of an oil rig in a sea of depth 3 km. Neglect ocean currents.

Ans:

Given:

The maximum stress the structure can handle, **P = 10^{10} Pa**
Depth of the sea, **d =** 3 km **= 3×10^3 m**
Density of water, **ρ = 10^3 kg/m3**
Acceleration due to gravity, **g = 9.8 m/s^2**

We know:
The pressure exerted by the seawater at depth, **d = ρdg** = 10^3 x 3 × 10^3 × 9.8 **= 2.94×10^7 Pa**

As the sea exerts a pressure lesser than the maximum stress the structure can handle, the structure can survive on the oil well in the sea.

Q-8: A hydraulic lift can lift vehicles of masses up to 2500 kg. If the cross-sectional area of the load carrying piston is 500 cm^2, find the maximum pressure the smaller piston has to bear.

Ans:

Given:
Maximum mass that can be lifted, **m = 2500 kg**
Area of cross-section of the load-carrying piston, **A =** 500 cm^2 **= 500×10^{-4} m^2**

The maximum force exerted by the load,
F = **mg =** 2500 x 9.8 **= 24.5×10^{3} Pa**
The maximum pressure on the load carrying piston , **P = F / A**

P = $\frac{24500}{500 \times 10^{-4}}$ **= 4.9×10^5 Pa**

In a liquid, pressure is transmitted equally in all directions. Therefore, the maximum pressure on the smaller is 4.9×10^5 Pa

Q-9: A U-tube holds mentholated spirit and water separated by mercury. The mercury columns in the two limbs are in level with 8 cm water in one arm and 12 cm in another. Calculate the specific gravity of spirit.

Ans:

Given:

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**

Let, A and B be the points of contact between spirit and mercury and water and mercury, respectively.
P_0 = Atmospheric pressure
ρ_1 = Density of spirit
ρ_2 = Density of water

Pressure a **point A** = $P_0 + \rho_1 h_1 g$

Pressure at **point B** = $P_0 + \rho_2 h_2 g$

We know pressure at B and D is the same so;

$P_0 + \rho_1 h_1 g = P_0 + \rho_2 h_2 g$

$\frac{\rho_1}{\rho_2} = \frac{h_2}{h_1} = \frac{10}{12.5} = 0.8$

Therefore the specific gravity of water is 0.8.

Q-10: In the above situation further 10 cm of water and spirit are poured into the respective arms. What will the new difference between the mercury levels in the two arms be? (Specific gravity of mercury = 13.6)

Ans:

Given:

Height of the water column, h_1 = 10 + 10 **= 20 cm**

Height of the spirit column, h_2 = 12.5 + 10 **= 22.5 cm**

Here density of water, $\rho_1 = 1\ g\ cm^{-3}$

The density of spirit, $\rho_2 = 0.8\ g\ cm^{-3}$

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

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

Pressure exerted by the mercury column of height **h =** $h\rho g$ = **h × 13.6 g** . . . . **(1)**

Difference between the pressures due to spirit and water **=** $h_1 \rho_1 g - h_2 \rho_2 g$

= g (20 × 1 – 22.5 × 0.8) = 2 g . . . . **(2)**

Equating (1) and (2) we have:

13.6 g × h = 2g

Therefore, h = 0.147 cm

Q-11: Could Bernoulli's equation be applied on the water flowing in a stream?

Ans:

Bernoulli's equation cannot be applied to the water flowing in a river because it is applicable only for **ideal liquids in a streamlined flow** and the water in a stream is turbulent.

Q-12: Can one use gauge instead of absolute pressure while applying Bernoulli's equation? Explain.

Ans:

Yes, one can definitely use a gauge instead of absolute pressure while applying **Bernoulli's equation** as long as the atmospheric pressure on the two points where the equation is being applied is significantly different.

Q-13: Glycerin flows steadily through a horizontal pipe of radius 1 cm and length 2 m. If the amount of glycerin collected at one end is 2 x 10^{-3} kg/s. Calculate the pressure difference between the two ends of the pipe. Also, check if the flow in the pipe is laminar. [Viscosity of glycerin = 0.83 Pa s and Density of glycerin = 1.3 × 103 kg m^{-3}]

Ans:

Given:
Length of the horizontal tube, **l = 2 m**

Radius of the tube, r = 1 cm **= 0.01 m**

Diameter of the tube, d = 2r **= 0.02 m**

Glycerin is flowing at the rate of **2.0 × 10^{-3} kg/s**

M = 2.0 × 10^{-3} kg/s

Density of glycerin, ρ = 1.3 × 10^3 kg m^{-3}

Viscosity of glycerin, η = 0.83 Pa s

We know, volume of glycerin flowing per sec:

V = $\frac{M}{density} = \frac{2 \times 10^{-3}}{1.3 \times 10^3}$ = 1.54 x 10^{-6} m^3 /s

Using Poiseville's formula, we get:

V = $\frac{\pi p' r^4}{8 \ \eta \ l}$

$p' = \frac{V \ 8 \ \eta \ l}{\pi r^4}$

Where **p'** is the pressure difference between the two ends of the pipe.

p' = $\frac{1.54 \times 10^{-6} \times 8 \times 0.83 \times 2}{\pi \times 0.01^4}$ = 6.51 x 10^2 Pa

And, we know:
$R = \frac{4 \ \rho \ V}{\pi \ d \ \eta}$, **[Where R = Reynolds's number]**

R = $\frac{4 \times 1.3 \times 10^3 \times 1.54 \times 10^{-6}}{\pi \times 0.83 \times 0.02}$ = 0.153

Since the Reynolds's number is 0.153 which is way smaller than 2000 , the flow of glycerin in the pipe is laminar.

Q-14: A drone cruising at 8000 m has winds blowing at 80 m/s and 70 m/s on the upper and lower sides of its wings respectively. Find the lift on the wing if its area is 2.5 m^2 .(Density of air = 1.3 x 10 kg m^{-3})

Ans:

Given:
Speed of wind on the upper side of the wing, **V_1 = 80 m/s**
Speed of wind on the lower side of the wing, **V_2 = 70 m/s**
Area of the wing, **A = 2.5 m^2**
Density of air, **ρ = 1.3 kg m^{-3}**

Using Bernoulli's theorem, we get :
$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$

$P_2 - P_1 = \frac{1}{2}\left(\rho V_2^2 - \rho V_1^2\right)$

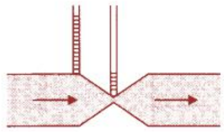
Where, P_1 = Pressure on the upper side of the wing
P_2 = Pressure on the lower side of the wing

Now the lift on the wing = (P_2 – P_1) x Area
= $\frac{1}{2}\rho\left(V_1^2 - V_2^2\right) \times A$
= $\frac{1}{2} \times 1.3\left((80)^2 - (70)^2\right) \times 2.5$ = 2.437 x 10^3 N

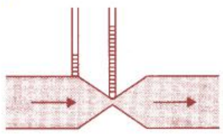
Therefore the lift experienced by the wings of the air craft is 2.437 x 10^3 N.

Q-15: The two figures below depict the steady flow of a non-viscous liquid. Identify the incorrect one and justify your answer.

(a)



(b).



Ans:

Figure (b) is the incorrect one. This is because at the kink , the velocity of the liquid increases decreasing the pressure (**Bernoulli's principle**), subsequently the liquid in the tube at the kink shouldn't have risen higher.

Q-16: The cylindrical tube of a water gun has a cross section of 10 cm^2, its one end is porous with 50 fine holes each of 0.5 mm radius. If inside the the tube the water flows at 1.5 m / min, at what speed will water eject through the holes ?

Ans:

Given:
Number of holes, n = 50
Cross-sectional area of the spray pump, A_1 = 10 cm^{-2} **= 10 × 10^{-4} m^{-2}**
Radius of each hole, **r = 0.5 × 10^{-3} m**
Cross-sectional area of each hole, a = πr^2 = **π (0.5 × 10^{-3} $)^2$ m^2**
Total area of 50 holes, A_2= n × a = $50 \times \pi(0.5 \times 10^{-3})^2$ m^2 = 3.92 × 10^{-5} m^2
Speed of flow of water inside the tube, V_1 = 1.5 m/min **= 0.025 m/s**
Let, the water ejected through the holes at a speed **= V_2**

Using the law of continuity:
$A_1V_1 = A_2V_2$

$V_2 = \frac{A_1V_1}{A_2} = \frac{10\times10^{-4}\times0.025}{3.92\times10^{-5}}$

Therefore, V_2 = 0.638 m/s

Q-17: A U bent wire is dipped in a soap solution and removed, to form a soap film between the wires. This film and a light slider can support a weight up to 2 x 10^{-2} N (including the slider's weight). If the slider is 30 cm long, find the surface tension of the film.

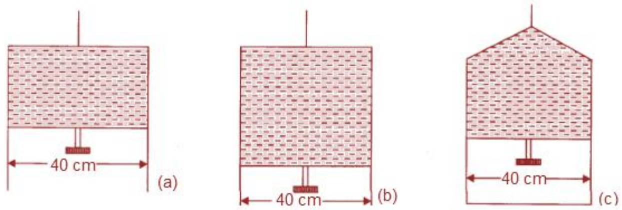
Ans:

Given:
The maximum weight the film can support, **W = 2 × 10^{-2} N**
Length of the slider, l = 30 cm **= 0.3 m**

A soap film has two free surfaces.
Thus, total length = 2l = 2 × 0.3 = 0.6m

We know, surface tension = $\frac{Weight}{2l} = \frac{2\times10^{-2}}{0.6}$
Thus the surface tension of the film = 3.3 x 10^{-2} N /m

Q-18: Figure (a) shows a small weight of 2×10^{-2} N being supported by a thin film. Calculate the weight supported by the films of the same liquid and at the same temperature in figure (b) and (c)



Ans:

Case (a):

Length of the liquid film, **l = 40 cm = 0.4 m**
Weight supported by the film, **W = 2×10^{-2} N**

We know, **Surface tension =** $\frac{W}{2l}$ **[As a film has two surface]**
= $\frac{2\times10^{-2}}{0.8}$ **= 2.5×10^{-2} N/m**
It is given that all the three figures have the same liquid at the same temperature thus they will also have the same surface tension, i.e., **2.5×10^{-2} N/m**
As all the cases have the same film lengths , the weight supported by each film will also be the same i.e. **2×10^{-2} N.**

Q-19: If the surface tension of mercury at 20°C (temperature of the room) is 4.65×10^{-1} N/m and the atmospheric pressure is 1.01×10^{5} Pa. Find the pressure inside a mercury drop of radius 2 mm. Also, find the excess pressure inside the drop.

Ans:

Given:
Surface tension of mercury, S = 4.65×10^{-1} N m^{-1}
Radius of the mercury drop, r = 2.00 mm = 2×10^{-3} m
Atmospheric pressure, P_0 = 1.01×10^{5} Pa

We know:

Total pressure inside the mercury drop = Excess pressure inside mercury + Atmospheric pressure
= 2S/r + P_0 = $\left(\frac{2\times4.65\times10^{-1}}{2\times10^{-3}}\right)+1.01\times10^{5}$ = 1.014×10^{5} Pa

Excess pressure = $\frac{2S}{r}$

= $\left(\frac{2\times4.65\times10^{-1}}{2\times10^{-3}}\right)$ **= 4.65×10^{2} Pa**

Q-20: If the surface tension of a soap solution at 20°C is 2.5×10^{-2} N/m, find the excess pressure inside a soap bubble of radius 4mm in that solution. If an air bubble of the same dimensions were to be formed at a depth of 30 cm inside a vessel containing the soap solution what would the pressure inside this bubble be? [1 atm = 1.01×10^{5}, Relative density of the soap solution = 1.20]

Ans:

Given:
Surface tension of the soap solution, **S = 2.50×10^{-2} N/m**
r = 4.00 mm = 4×10^{-3} m
Density of the soap solution, **ρ = 1.2×10^{3} kg/m^3**
Relative density of the soap solution **= 1.20**
Air bubble is at a depth, h = 30 cm **= 0.3 m**
Radius of the air bubble, r = 4 mm **= 4×10^{-3} m**
Acceleration due to gravity, **g = 9.8 m/s^2**
1 atmospheric pressure = **1.01×10^{5} Pa**
We know;
P = $\frac{4S}{r}$

= $\left(\frac{4\times2.5\times10^{-2}}{4\times10^{-3}}\right)$ **= 25 Pa**

Thus the excess pressure inside the soap bubble is 25 Pa.

Now for the excess pressure inside the air bubble, P' = $\frac{2S}{r}$

P' = $\left(\frac{2\times2.5\times10^{-2}}{4\times10^{-3}}\right)$ = 12.5 Pa

Thus, the excess pressure inside the air bubble is 12.5 Pa

At the depth of 0.3 m, the total pressure inside the air bubble = Atmospheric pressure + hρg + P'

= $1.01 \times 10^5 + 0.3 \times 1.2 \times 10^3 \times 9.8 + 12.5$

= 1.05×10^5 Pa.

Q-21: A cistern with a square base of area 2 m^2 is vertically partitioned into two halves. The lower portion of the partition has a hinged door of area 20 cm^2. One-half of the partition is filled with water and the other with acid (relative density 1.7), both up to a height of 3m. Calculate the force required to keep the door from opening.

Ans:

Given:

Area of the hinged door, a = 20 cm^2 **= 20×10^{-4} m**

Base area of the given tank, **A = 2 m^2**

Density of water, **$\rho_1 = 10^3$ kg/m^3**

Density of acid, **$\rho_2 = 1.7 \times 10^3$ kg/m^3**

Height of the water column, **h_1 = 3 m**

Height of the acid column, **h_2 = 3 m**

Acceleration due to gravity, **g = 9.8 ms^{-2}**

Pressure exerted by water , **$P_1 = h_1\rho_1 g$** = $3 \times 10^3 \times 9.8$ **= 2.94×10^4 Pa**

the pressure exerted by acid , **$P_2 = h_2\rho_2 g$** = $3 \times 1.7 \times 10^3 \times 9.8$ **= 5×10^4 Pa**

Pressure difference between the above two :

$\Delta P = P_2 - P_1$

= $(5 - 2.94) \times 10^4$ **= 2.06×10^4Pa**

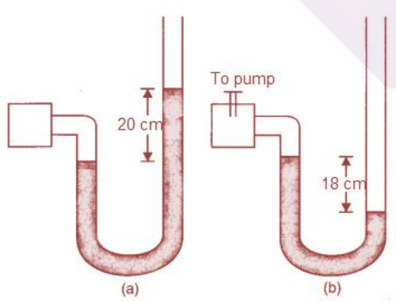
Thus, the force on the door = ΔP x a

=$2.06 \times 10^4 \times 20 \times 10^{-4}$ **= 41.2 N**

Hence the force required to keep the door closed is 41.2 N

Q-22: A manometer indicates that the pressure of a gas in a tube as shown in diagram (a).
(i) When some of the gas is pumped out, the manometer indicates as shown in diagram (b). The liquid inside the manometer is mercury and the atmospheric pressure is 76cm of Hg
1. What is the absolute and gauge pressure of the enclosed gas in case (a) and case (b), in units of cm of mercury?

2. Find the change in the reading of case (b) if 13.6 cm of water was poured into the right arm of the manometer.



Ans:

For diagram (a):

Given, Atmospheric pressure, P_0 = 76 cm of Hg

The difference between the levels of mercury in the two arms is gauge pressure.

Thus, gauge pressure is 20 cm of Hg.

We know, Absolute pressure = Atmospheric pressure + Gauge pressure

= 76 + 20 = 96 cm of Hg

For diagram (b):

Difference between the levels of mercury in the two arms = –18 cm

Hence, gauge pressure is –18 cm of Hg.

And, Absolute pressure = Atmospheric pressure + Gauge pressure

= 76 cm – 18 cm = 58 cm

(2) It is given that 13.6 cm of water is poured into the right arm of figure (b).
We know that relative density of mercury = 13.6
=> A 13.6 cm column of water is equivalent to 1 cm of mercury.
Let, h be the difference in the mercury levels of the two arms.
Now, pressure in the right arm P_R = Atmospheric pressure + 1 cm of Hg

= 76 + 1 = 77 cm of Hg . . . . . . (a)

The mercury column rises in the left arm, thus the pressure in the left limb, **P_L = 58 + h . . . . . . (b)**
Equating equations (a) and (b) we get :

77 = 58 + h

Therefore the difference in the mercury levels of the two arms, h = 19 cm

Q-23: There are two vessels of different shapes but equal base areas. The second vessel takes half the volume of water the first takes in getting filled up to a common height. Will the force on the base of the two vessels exerted by water be the same? If it is so, why do these vessels filled with water up to the same height have different weights?

Ans:

As the base area is the same the pressure and thus the force acting on the two vessels will also be the same. However, force is also exerted on the walls of the vessel, which have a nonvertical component when the walls are not perpendicular to the base. The net non-vertical component on the sides of the vessel is lesser for the second vessel than the first. Therefore, **the vessels have different weights despite having the same force on the base.**

Q-24: During a surgery, the needle is inserted into a vein with a gauge pressure of 1800 Pa. Find the height the blood bag must be placed at so as to allow blood to flow through the needle into the vein. (Density of whole blood = 1.06 x 10^3 kg m^{-3})

Ans:

Given:
Density of whole blood, **$\rho = 1.06 \times 10^3$ kg m^{-3}**
Gauge pressure, **P = 1800 Pa**
Acceleration due to gravity, **g = 9.8 m/s^2**
let, the blood vessel be at a height = h
We know,
Pressure of the blood container, **$P = h\rho g$**
$h = \frac{P}{\rho g} = \frac{1800}{9.8 \times 1.06 \times 10^3} = 0.173$ m.
Thus, the blood will enter the vein if the blood bag is kept at height equal to or greater than 0.173m.

Q-25: While deriving Bernoulli's equation the work done on the fluid in the tube was equated to the change units potential and kinetic energy.

(a) Find the greatest average velocity of blood flow in an arteriole of diameter 1 x 10^{-3} m if the flow should remain laminar?

(b)When do the velocity of the fluid increases the dissipative forces become more significant? (Viscosity of blood = 2.08 x 10^{-3} Pa)

Ans:

(a) Given:
Viscosity of blood , **η= 2.08 x 10^{-3} m**
Diameter of the arteriole, **d = 1 × 10^{-3} m**
Density of blood, **$\rho = 1.06 \times 10^3$ kg/m^3**
We know, Reynolds' number for laminar flow, N_R = 2000
Therefore, greatest average velocity of blood is:
$V_{AVG} = \frac{N_R \eta}{\rho d}$
$= \frac{2000 \times 2.08 \times 10^{-3}}{1.06 \times 10^3 \times 1 \times 10^{-3}}$ **= 3.924 m/s**

(b). With the increase in fluid velocity, the dissipative forces become more significant because of the increase in turbulence.
Q-26: Find the greatest average velocity of blood flow in a vein of radius 1 x 10^{-3} m if the flow should remain laminar? Also find the flow rate at this velocity. (Viscosity of blood = 2.08 x 10^{-3} Pa)

Pa).

Ans:

Given:
Radius of the vein, **$r = 1 \times 10^{-3}$ m**
Diameter of the vein, $d = 2 \times 1 \times 10^{-3}$ m = **2×10^{-3} m**
Viscosity of blood ,**$\eta = 2.08 \times 10^{-3}$ m**
Density of blood, **$\rho = 1.06 \times 10^{3}$ kg/m^3**

We know, Reynolds' number for laminar flow, N_R = 2000
Therefore, greatest average velocity of blood is:
$V_{AVG} = \frac{N_R \eta}{\rho d}$
$= \frac{2000 \times 2.08 \times 10^{-3}}{1.06 \times 10^{3} \times 2 \times 10^{-3}}$ **= 1.962 m/s**

And, flow rate **$R = V_{AVG}\, \pi r^2$** $= 1.962 \times 3.14 \times (10^{-3})^2$ **$= 6.160 \times 10^{-6}$ m^3/s**

Q-27: A plane is cruising at a constant speed with winds blowing at 50 m/s and 30 m/s on the upper and lower sides of its wings respectively. Find the plane's mass if the area of each wing is 25 m^2. (Density of air = 1.0 kg m^{-3}).

Ans:

Given:
Total area of the wings of the plane, **$A = 2 \times 25 = 50$ m^2**
Velocity of wind over the lower wing, **V_1 = 30 m/s**
Velocity of wind over the upper wing, **V_2 = 50 m/s**
Density of air, **ρ = 1 kg m^{-3}**
Let, the pressure of air over the lower wing = P_1 and the pressure of air over the upper wing= P_2
According to Bernoulli's equation :
$P_1 + \frac{1}{2}\rho V_1^2 = P_2 + \frac{1}{2}\rho V_2^2$

$P_2 - P_1 = \frac{1}{2}\rho\left(V_2^2 - V_1^2\right)$
Now the upward force = ($P_2 - P_1$) x Area
$= \frac{1}{2}\rho\left(V_2^2 - V_1^2\right) A$
$= \frac{1}{2} \times 1\left((50)^2 - (30)^2\right) 50 = 40000$ N
We know, F = mg

i.e. 40000 = m x 9.8
Therefore, the mass of the plane is , m = 4081.63 kg

Q-28: In Millikan's oil drop experiment, find the terminal speed of an uncharged drop of radius 1.0 × 10^{-5} m and density 1.2 × 10^{3} kg m^{-3} ? What is the viscous force on the oil drop at that velocity? (Take viscosity of air = 1.8 × 10^{-5} Pa s and do not consider the buoyancy on the drop because of air).

Ans:

Given:
Acceleration due to gravity, **g = 9.8 m/s^2**
Radius of the uncharged drop, **$r = 1.0 \times 10^{-5}$ 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**
We consider the density of air to be zero in order to neglect the buoyancy of air.
Therefore terminal velocity (v) is :

$v = \frac{2r^2 g\rho}{9\eta}$

$= \frac{2\left(1.0 \times 10^{-5}\right)^2 \times 9.8 \times 1.2 \times 10^{3}}{9 \times 1.8 \times 10^{-5}}$ **$= 1.45 \times 10^{-2}$ m/s**
And the viscous force on the drop is :
$F = 6\pi\eta r v$
$= 6 \times 3.14 \times 1.8 \times 10^{-5} \times 1.45 \times 10^{-2} \times 10^{-5}$
$= 4.91 \times 10^{-11}$ N

Q-29: Mercury makes an angle of 140^0 with soda lime glass. A straw of diameter 2 mm made of soda lime glass is dipped in a container containing mercury. By what height does mercury that

dip down in the straw relative to the surface of the liquid outside? (Surface tension of mercury at the temperature of the experiment = 0.465 N/m, density of mercury = 13.6×10^3 kg m^{-3}).

Ans:

Given:

Density of mercury, **ρ =13.6 × 10^3 kg/m^3**
Angle of contact between mercury and soda lime glass, **θ = 140°**
Surface tension of mercury at that temperature , **s = 0.465 N m^{-3}**
Radius of the narrow tube, r = 2/2 = 1 mm **= 1 × 10^{-3} m**
Let, the dip in the depth of mercury = h
Acceleration due to gravity, **g = 9.8 m/s^2**
We know, surface tension S = $\frac{hg\rho r}{2cos\Theta}$
$\Rightarrow h = \frac{2Scos\Theta}{g\rho r}$

$\Rightarrow h = \frac{2\times 0.465\times cos140^\circ}{13.6\times 9.8}$ = -5.34 mm

The negative sign indicates the falling level of mercury. Thus, the mercury dips by 5.34 mm.

Q-30: Two narrow tubes of diameters 4 mm and 6 mm are connected to make a U-tube open at the two ends. If this tube contains water, find the difference in the water levels in the two arms of the tube. The surface tension of water at this temperature is 7.3 x 10^{-2} Nm $^{-2}$ and the density of water is 10^3 kg m^{-3}. Consider the angle of contact to be zero.

Ans:

Given:

Diameter of the first bore, d_1 = 4.0 mm **= 4 × 10^{-3} m**
Radius of the first bore, r_1 = 4/2 **= 2 x 10^{-3} m.**
Diameter of the second bore, **d_2 =6mm**
Radius of the second bore, r_2 = 6/2 **= 3 x 10^{-3} mm**
Surface tension of water, **s = 7.3 × 10^{-2} N /m**
Angle of contact between the bore surface and water, **θ= 0**
Density of water, **ρ =1.0 × 10^3 kg/m^{-3}**
Acceleration due to gravity, **g = 9.8 m/s^2**
Let, h_1 and h_2 be the heights to which water rises in the first and second tubes respectively.
Thus, the difference in the height:
$h_1 - h_2$ = $\frac{2sCos\Theta}{r_1\rho g} - \frac{2sCos\Theta}{r_2\rho g}$

Since, h = $\frac{2sCos\Theta}{r\rho g}$

$h_1 - h_2$ = $\frac{2sCos\Theta}{\rho g}[\frac{1}{r_1} - \frac{1}{r_2}]$
= $\frac{2\times 7.3\times 10^{-2}\times 1}{10^3\times 9.8}\left[\frac{1}{2\times 10^{-3}} - \frac{1}{3\times 10^{-3}}\right]$ = 2.482 mm
Therefore, the difference in the water levels of the two arms =2.482 mm.
Q-31: (a) According to the law of atmospheres density of air decreases with increase in height y as $\rho_o e^{\frac{-y}{y_0}}$. Where ρ_0 =1.25 kg m^{-3} is the density of air at sea level and y_0 is a constant. Derive this equation/law considering that the atmosphere and acceleration due to gravity remain constant.

(b) A zeppelin of volume 1500 m^3 is filled with helium and it is lifting a mass of 400 kg. Assuming that the radius of the zeppelin remains constant as it ascends. How high will it rise?[y_0 = 8000 m and ρH_e =0.18 kg m^{-3}].
Ans:

(a). We know that rate of decrease of density ρ of air is directly proportional to the height y.
i.e., $\frac{d\rho}{dy} = -\frac{\rho}{y_0}$ . . . . **(1)**
Where y is the constant of proportionality and the –ve sign indicates the decrease in density with increase in height.

Integrating equation (1) , we get :
$\int_{\rho_0}^{\rho}\frac{d}{\rho} = -\int_0^y\frac{1}{y_0}dy$

$[log\rho]_{\rho_0}^{\rho} = -[\frac{y}{y_0}]_0^y$
Where ρ_0 = density of air at sea level ie y =0
Or, $\log_e(\rho_0 / \rho)$ = $-y/y_0$
Therefore, $\rho = \rho_0\, e^{\frac{y}{y_0}}$

(b). Given:
Volume of zeppelin = 1500 m^3
Mass of payload m = 400 kg

Mass of payload, m = 400 kg

y_0 = 8000 m

ρ_0 =1.25 kg m^{-3}

density of helium, $\rho\ H_e$ =0.18 kg m^{-3}

Density ρ = $\frac{Mass}{Volume}$ = $\frac{Mass\ of\ payload+Mass\ of\ helium}{Volume}$

= $\frac{400+1500\times0.18}{1500}$ [Mass = volume × density]

= 0.45 kg m^{-3}

Using equation (1), we will get:

$\rho = \rho_0 e^{\frac{y}{y_0}}$

$\Rightarrow log_e(\frac{\rho_0}{\rho}) = \frac{y_0}{y}$

Or, $y = \frac{y_0}{log_e(\frac{\rho_0}{\rho})}$

$\Rightarrow y = \frac{8000}{log_e(\frac{1.25}{0.45})}$

Therefore, y ≈ 8km

*Learn more about **Reynolds' number**, **Torricelli's barometer** and much more with Byju's Learning App.*