Exercise-4(A)

1. **Define the term thrust. State its S.I. unit.**
   Solution:
   Thrust is the force acting normally on a surface.
   The S.I. unit of thrust is newton(N).

2. **What is meant by pressure? State its S.I. unit.**
   Solution:
   Pressure is the thrust per unit area of surface.
   The S.I. unit of pressure is newton per metre^2

3. **(a) What physical quantity is measured in bar?**
   (b) How is the unit bar related to the S.I. unit pascal?
   Solution:
   (a) The physical quantity that is measured in bar is pressure
   (b) The relation between bar and pascal is as follows:
   1 bar = 10^5 pascal

4. **Define one pascal (Pa), the S.I. unit of pressure.**
   Solution:
   One pascal can be defined as the pressure exerted on a surface of area 1m^2 by a force of 1N that acts normally on it. The S.I. unit of pressure is newton per metre^2

5. **State whether thrust is a scalar or vector?**
   Solution:
   Thrust is a vector quantity.

6. **State whether pressure is a scalar or vector?**
   Solution:
   Pressure is a scalar quantity.

7. **Differentiate between thrust and pressure.**
   Solution:
   The differences are as follows:

Thrust	Pressure
It is a force that acts normally on a surface	It is the thrust per unit area of surface
It is a vector quantity	It is a scalar quantity
S.I. unit is newton	Newton per metre^2

8. **How does the pressure exerted by a thrust depend on the area of surface on which it acts? Explain with a suitable example.**
   Solution:
   Surface of area and pressure are inversely proportional. The greater the surface area the lesser the pressure. For example: A bag with broad straps is easier to carry than a bag with thin straps. This is

because, broad straps have a larger surface area hence lesser pressure is acting on the shoulders.

9. Why is the tip of an allpin made sharp?

Solution:

It is sharpened so as to exert large pressure at the sharp end so that it can be driven effortlessly.

10. Explain the following:

(a) It is easier to cut with a sharp knife than with a blunt one.

(b) Sleepers are laid below the rails

Solution:

(a) It is because even a small thrust induces high pressure at the edges of a knife thus enabling a smoother experience comparatively

(b) In order for the pressure applied by the rails on the ground to become lesser, sleepers are laid below the rails.

11. What is a fluid?

Solution:

Any substance that can flow is known as a fluid.

12. What do you mean by the term fluid pressure?

Solution:

Fluid pressure is the pressure exerted by a fluid due to its weight in all the directions.

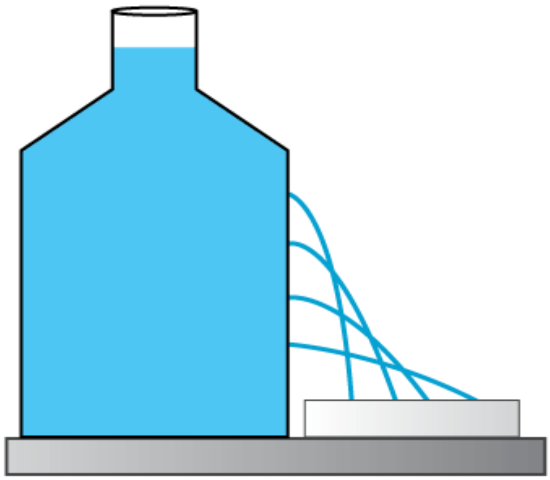
13. How does the pressure exerted by a solid and a fluid differ?

Solution:

They both differ in a way that when a solid exerts a pressure, it exerts only at the bottom, i.e., on the surface it is placed. When a fluid exerts pressure, it exerts in all the directions.

14. Describe a simple experiment to demonstrate that a liquid enclosed in a vessel exerts pressure in all directions.

Solution:



Liquid exerts presure at all points in all directions

The experiment explained below demonstrates how a liquid enclosed in a vessel exerts pressure in all directions:

Procedure:

- Fill a large plastic bottle or a can with water
- Set it on a horizontal surface
- Punch a few holes in the wall of the vessel at any point below the liquid surface

Observation

- Through each of the hole, water spurts out

Inference

- The spurting out of the liquid indicates that the liquid exerts pressure at every point on the walls of the can/bottle

15. State three factors on which the pressure at a point in a liquid depends.

Solution:

The factors on which the pressure at a point in a liquid depends are:

- Depth of the point below the free surface
- Density of liquid
- Acceleration due to gravity

16. Write an expression for the pressure at a point inside a liquid. Explain the meaning of the symbols used.

Solution:

The pressure at a point inside a liquid is given by:

$$P = P_0 + h \rho g$$

where P is the point where pressure is exerted in the liquid

P_0 is the atmospheric pressure

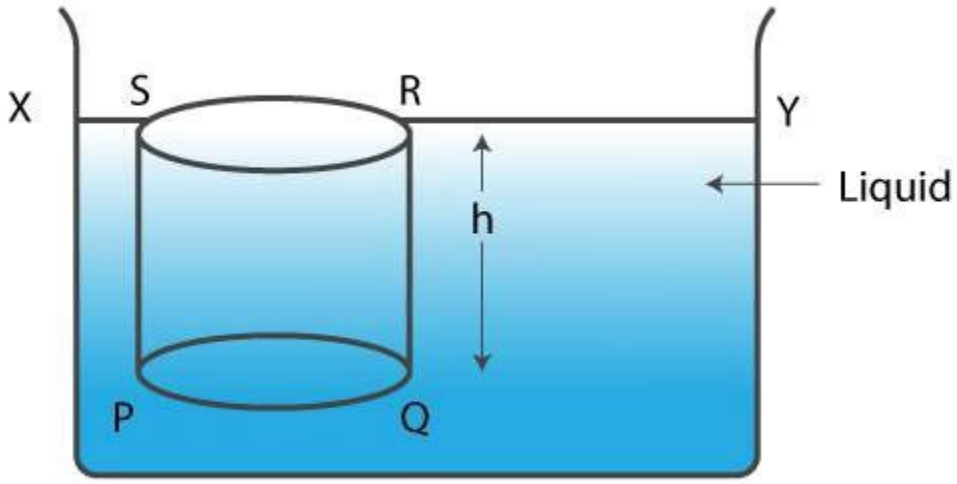
h is the depth of the point below the free surface

ρ is the density of the fluid

g is the acceleration due to gravity

17. Deduce an expression for the pressure at a depth inside a liquid.

Solution:



- Consider a vessel containing a liquid with density ρ.
- Allow the liquid to be stationary
- To calculate the pressure at a depth consider a horizontal circular surface PQ with area 'A', depth 'h' below the free surface XY of the liquid
- The pressure on surface PQ will be due to the weight of the liquid column above the surface PQ, liquid contained in cylinder PQRS of height h with PQ as its base and top face RS lying on the free surface XY of the liquid

Thrust exerted on the surface PQ

= weight of the liquid column PQRS

= volume of liquid column PQRS x density x g

= (Area of base PQ x height) x density x g

= (A x h) ρ x g = A h ρ g

The thrust obtained is exerted on the surface PQ of area A.

Pressure P = thrust on surface/ area of surface

P = A h ρ g/A = h ρ g

Hence, Pressure = depth x density of liquid x acceleration due to gravity

18. How does the pressure at a certain depth in sea water differ from that at the same depth in river water? Explain your answer.

Solution:

Density of sea water is more compared to the density of river water because of dissolved salts in sea water. Hence, pressure at a particular depth in sea water is more than that at the same depth in river water.

19. Pressure at free surface of a water lake is P_1, while at a point at depth h below its free surface is P_2. (a) How are P_1 and P_2 related? (b) Which is more P_1 or P_2?

Solution:

(a) $P_2 = P_1 + h \rho g$

(b) $P_2 > P_1$

20. Explain why a gas bubble released at the bottom of a lake grows in size as it rises to the surface of lake.

Solution:

A gas bubble released at the bottom of a lake grows in size as it rises to the surface of lake because when the bubble is at the bottom of the lake, the total pressure exerted on it is the sum of pressure due to the water column and the atmospheric pressure. As the gas bubble rises, because of the decline in the depth, the pressure because of the water column declines.

According to Boyle's law, PV is equivalent to a constant hence the bubble grows in size because the pressure decreases.

21. A dam has broader walls at the bottom than at the top. Explain.

Solution:

Pressure exerted by a liquid is dependent on the depth in a way that it increases with greater pressure. That is to say, as the depth increases, pressure applied by water on the walls of the dam also increases. In order to withstand the great pressure, the walls are built thicker. Hence a dam has broader walls at the bottom than at the top.

22. Why do sea divers need special protective suit?

Solution:

It is due to the great pressure exerted on the diver's body at the depth of the sea. The total pressure exerted is much more than his blood pressure. Consequently, to withstand that sea divers require special protective suit.

23. State the laws of liquid pressure.

Solution:

Listed below are the five laws of liquid pressure:

(i) Inside the liquid, pressure increases with the increase in depth from its free surface

(ii) In a stationary liquid, pressure is same at all points on a horizontal plane

(iii) Pressure is same in all directions about a point inside the liquid

(iv) Pressure at same depth is different in different liquids. It increases with the increase in density of liquid

(v) A liquid seeks its own level.

24. A tall vertical cylinder filled with water is kept on a horizontal table top. Two small holes A and B are made on the wall of the cylinder, A near the middle and B just below the free surface of water. State and explain your observation.

Solution:

The liquid from hole B stretches to higher distance than from hole A on the horizontal surface which demonstrates that liquid pressure at a given point from the free surface increases with the depth of point.

25. How does the liquid pressure on a diver change if:

(i) The diver moves to the greater depth, and

(ii) The diver moves horizontally?

Solution:

(i) The liquid pressure increases on the diver as it moves to greater depth

(ii) When the diver moves horizontally, the pressure is unaffected.

26. State Pascal's law of transmission of pressure.

Solution:

Pascal's law states that the pressure exerted anywhere in a confined liquid is transmitted equally and undiminished in all directions throughout the liquid.

27. Name two applications of Pascal's law.

Solution:

Two applications of Pascal's law are:

- Hydraulic press
- Hydraulic jack

28. Explain the principle of a hydraulic machine. Name two devices which work on this principle.

Solution:

The principle of hydraulic machine is that a small force applied on a small piston is conveyed to generate a large force on the bigger piston.

Two devices that work on this principle:

- Hydraulic brakes
- Hydraulic press

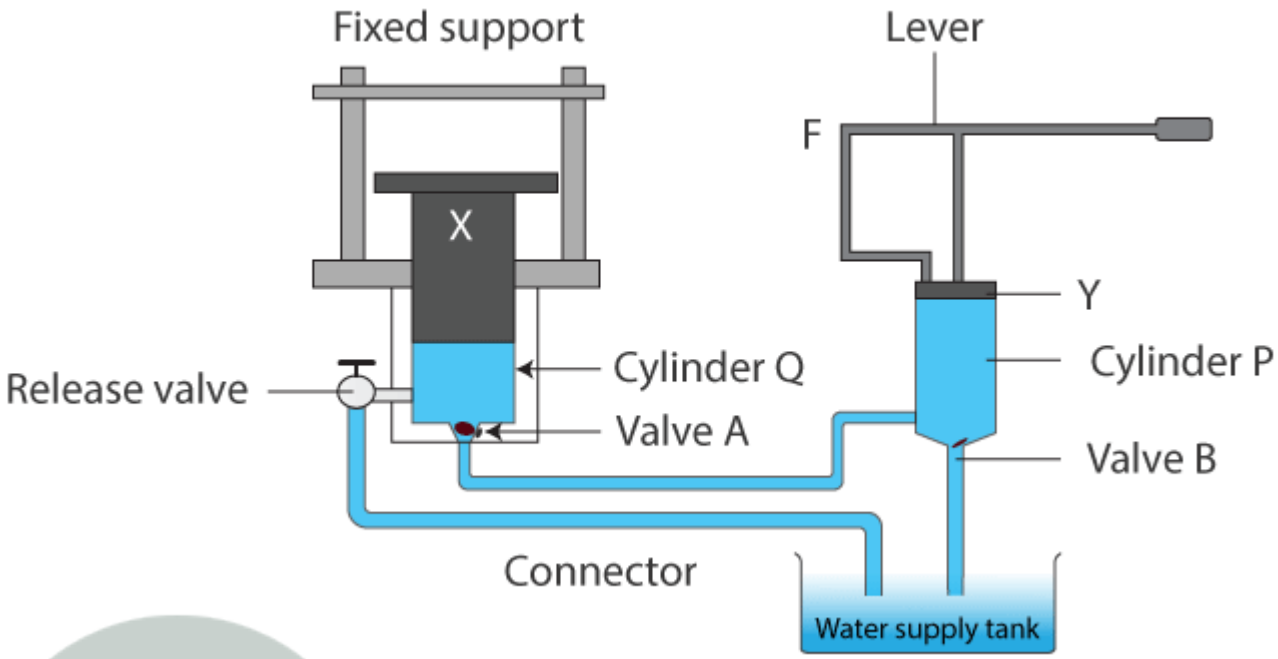
29. Name and state the principle on which a hydraulic press works. Write one use of the hydraulic press.

Solution:

The principle on which hydraulic press works is hydraulic machine.

Use of hydraulic press: It is used for pressing cotton bales and goods such as books, quilts etc.

30. The diagram in figure shows a device which makes use of the principle of transmission of pressure.



(i) Name the parts labelled by the letters X and Y.
(ii) Describe what happens to the valves A and B and to the quantity of water in the two cylinders when the lever arm is moved down.
(iii) Give reasons for what happens to the valves A and B in part (ii).
(iv) What happens when the release valve is opened?
(v) What happens to the valve B in cylinder P when the lever arm is moved up?
(vi) Give a reason for your answer in part (v)
(vii) State one use of the above device.

Solution:

(i) X – Press plunger
Y – Pump plunger

(ii) When the lever arm is moved down, valve A opens while valve B closes. Because of this water from cylinder P is propelled into the cylinder Q

(iii) Valve B closes. It is because of an increase in the pressure in cylinder P. The pressure is conveyed to the connecting pipe and when the pressure in the pipe is higher than the pressure in the cylinder Q, valve A discloses.

(iv) The ram plunger Q is lowered and water of the cylinder Q releases in the reservoir when the release valve is opened.

(v) The valve B opens upwards.

(vi) It is because the pressure in cylinder P decreases

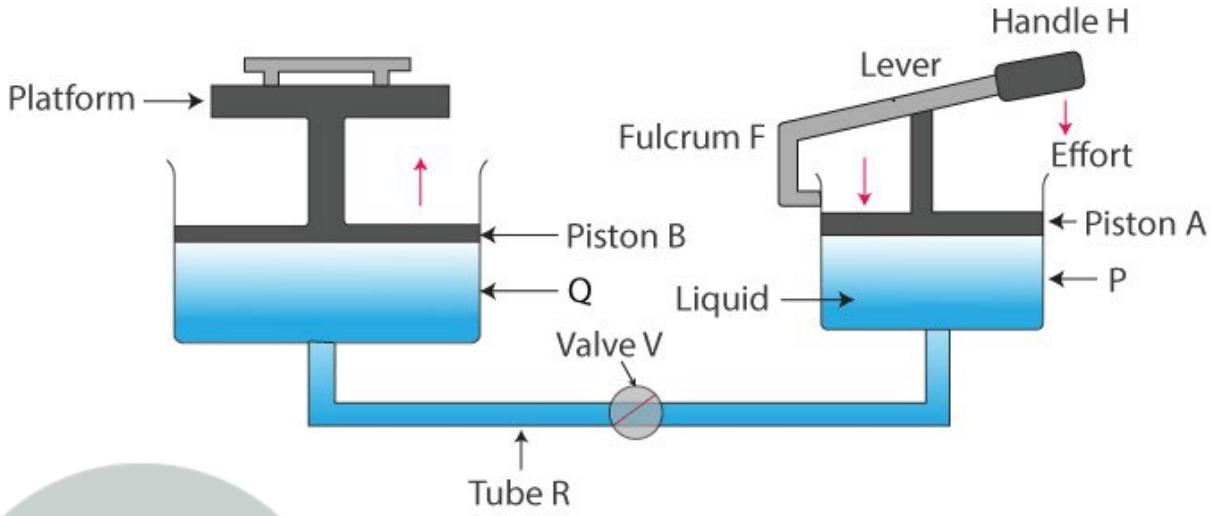
(vii) One use – used for squeezing oil out of linseed and cotton seeds

31. Draw a simple diagram of a hydraulic jack and explain its working.

Solution:

When handle H of lever is pressed down by applying an effort, the valve V opens because of increase in pressure in the cylinder P. The liquid runs out from the cylinder P to the cylinder Q. As a

result, the piston B rises up and it raises the car placed on the platform. When the car reaches the desired height, the handle H of lever is no longer pressed. The valve V gets closed (since the pressure on either side of the valve becomes same) so that the liquid may not run back from the cylinder Q to the cylinder P.



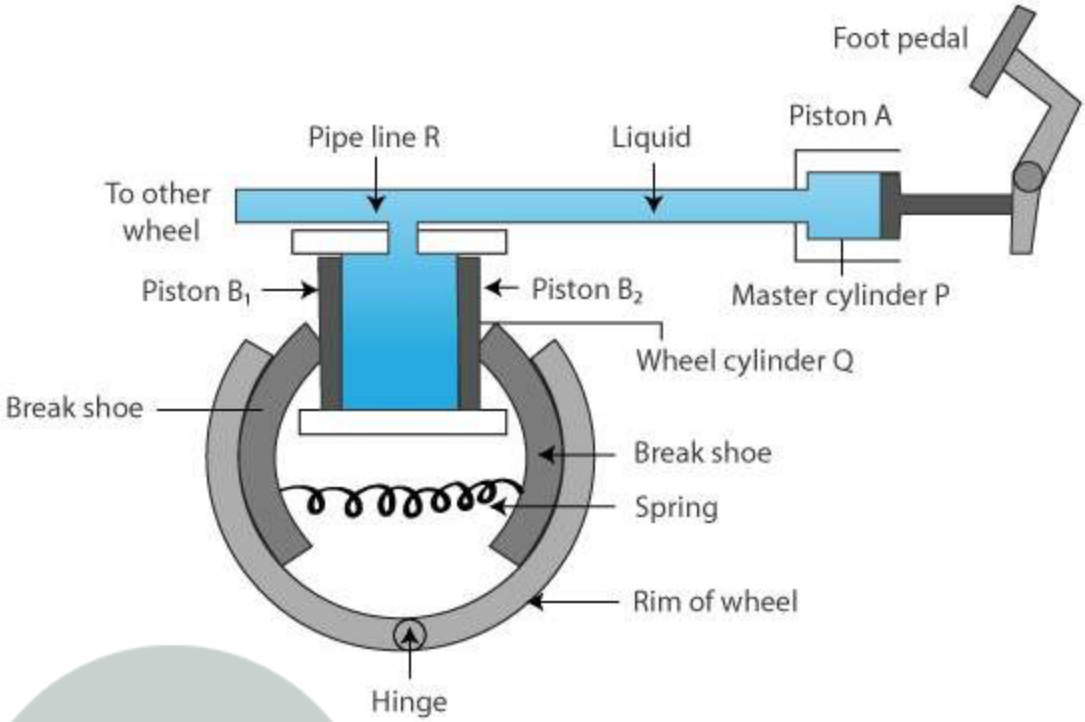
32. Explain the working of a hydraulic brake with a simple labelled diagram.

Solution:

To apply brakes, the foot pedal is pressed due to which pressure is exerted on the liquid in the master cylinder P, so liquid runs out from the master cylinder P to the wheel cylinder Q. As a result, the pressure is equally transmitted and undiminished through the liquid to the pistons B_1 and B_2 of the wheel cylinder because of which both pistons gets pushed outwards and brake shoes gets pressed against the rim of the wheel due to which the motion of the wheel retards.

As the pressure is transmitted through the liquid, equal pressure is exerted on all the wheels of the vehicle that are connected to the pipe line R.

When the pressure on the pedals is released, the liquid runs back from the wheel cylinder Q to the master cylinder P and the spring pulls the brake shoes to their original position and compels the pistons B_1 and B_2 to return back into the wheel cylinder Q. Hence, brakes are released.



33. Complete the following sentences:

(a) Pressure at a depth h in a liquid of density ρ is _____

(b) Pressure is _____ in all directions about a point in a liquid

(c) Pressure at all points at the same depth is _____

(d) Pressure at a point inside a liquid is _____ to its depth.

(e) Pressure of a liquid at a given depth is _____ to the density of liquid.

Solution:

(a) h ρ g

(b) same

(c) same

(d) directly proportional

(e) directly proportional

Multiple choice type:

1. **The S.I. unit of pressure is:**
   (a) N cm^{-2}
   (b) Pa
   (c) N
   (d) N m^2
   Solution:
   (b) Pa
   Pressure is a scalar quantity.

2. **The pressure inside a liquid of density ρ at a depth h is:**
   (a) h ρ g

(b) h/ ρ g
(c) h ρ/ g
(d) h ρ
Solution:
(a) h ρ g

3. **The pressure P_1 at a certain depth in river water and P_2 at the same depth in sea water are related as:**
(a) $P_1 > P_2$
(b) $P_1 = P_2$
(c) $P_1 < P_2$
(d) $P_1 - P_2$ = atmospheric pressure
Solution:
(c) $P_1 < P_2$

4. **The pressure P_1 at the top of a dam and P_2 at a depth h from the top inside water (density ρ) are related as:**
(a) $P_1 > P_2$
(b) $P_1 = P_2$
(c) $P_1 - P_2 = h \rho g$
(d) $P_2 - P_1 = h \rho g$
Solution:
(d) $P_2 - P_1 = h \rho g$

Numericals:

1. **A hammer exerts a force of 1.5N on each of the two nails A and B. The area of cross section of tip of nail A is 2mm^2 while that of nail B is 6 mm^2. Calculate pressure on each nail in pascal.**
Solution:
Given:
Force acting on nail A is 1.5N, area = 2mm^2
Expressing 2mm^2 in metre
1mm=0.001m,
$\therefore 1mm^2 = 1mm \times 1mm = 0.001m \times 0.001m = 1 \times 10^{-6}\ m^2$
Pressure on B = Force/area
$= 1.5/(2 \times 1 \times 10^{-6})$
$= 7.5 \times 10^5$ Pa
Pressure on B
$= 1.5/(6 \times 1 \times 10^{-6})$
$= 2.5 \times 10^5$ Pa

2. **A block of iron of mass 7.5kg and of dimensions 12cm x 8cm x 10cm is kept on a table top on its base of side 12cm x 8cm. Calculate : (a) thrust and (b) pressure exerted on the table**

top. Take 1kgf = 10N.

Solution:

(a) To calculate thrust

Force = mass x acceleration due to gravity

= 7.5 x 10

= 75N

Area of the base = 12 x 8 = 96cm^2 or 0.0096m^2

(b) To calculate pressure exerted

Pressure = thrust/area

= 75/0.0096

= 7182.5 Pa

3. A vessel contains water up to a height of 1.5m. Taking the density of water 10^3 kg m^{-3}, acceleration due to gravity 9.8ms^{-2} and area of base vessel 100cm^2, calculate: (a) the pressure and (b) the thrust, at the base of vessel.

Solution:

(a) To calculate pressure:

Given: h=1.5m, ρ = 1000, g=9.8m/s^2

P = h ρ g

= 1.5 x 1000 x 9.8

= 14700 Pa

(b) To calculate the thrust at the base of the vessel:

Pressure = Force/area

⇨ Thrust = force = P x a

⇨ 14700 x 100 x 10^{-4}

⇨ 147N

4. The area of base of a cylindrical vessel is 300cm^2. Water (Density = 1000 kg m^{-3}) is poured into it up to a depth of 6cm. Calculate: (a) the pressure and (b) the thrust of water on the base. (g = 10m/s^2).

Solution:

(i) To calculate pressure

Given: density of water, ρ = 1000kg/m^3

g=10m/s^2

h = 6cm or 0.06m

We know that:

P = h ρ g

= 1000 x 0.06 x 10

= 600 Pa

(ii) Thrust of water on the base

Pressure = thrust / area

⇨ Thrust = force = P x a

= 6 x 10^{-2} x 1000 x 10 x area

= 6 x 10^{-2} x 1000 x 10 x 300 cm^2

= 6 x 10^{-2} x 1000 x 10 x 300 x 10^{-4} m^2

= 18N

5. (a) Calculate the height of a water column which will exert on its base the same pressure as the 70cm column of mercury. Density of mercury is 13.6 g cm^{-3}.
(b) Will the height of the water column in part (a) change if the cross section of the water column is made wider?

Solution:

(a) We know that the pressure exerted by the water column, $P = h \rho g$

Density of water = 1

As the pressure of water and mercury is same,

$h_w \rho_w g = h_m \rho_m g$

$h_w \times 1 \times g = h_m \rho_m g$

$h_w = h_m \rho_m$

$= \frac{70}{100} \times 13.6$

Height of the water column= 9.52m

(b) If the water column is made wider, the height of the water column will be unaffected.

6. The pressure of water on the ground floor is 40,000 Pa and on the first floor is 10,000Pa. Find the height of the first floor. (Take: density of water = 1000kg m^{-3}, g=10m/s^2)

Solution:

To find the height of the first floor:

Given: P_w on ground floor P_{wg}= 40,000Pa

P_w on first floor P_{wf} = 10,000Pa

From the formula of pressure,

$P = h \rho g$

In order to know the height of the first floor, let us calculate the difference in pressure

$P = P_{wg} - P_{wf}$

$= 40000 - 10000$

$= 30000Pa$

Substituting this value in the formula for pressure to calculate height;

$P = h \rho g$

$30000 = 1000 \times 10 \times h$

$h = 3m$

The height of the floor is 3m.

7. A simple U tube contains mercury to the same level in both of its arms. If water is poured to a height of 13.6cm in one arm, how much will be the rise in mercury level in the other arm?
Given: density of mercury = 13.6 x 10^3 kg m^{-3} and density of water = 10^3 kg m^{-3}

Solution:

Rise of water in the other side of the u-tube when water is added from one end depends on the density of water and mercury.

Given: Water poured to the height 13.6cm or 0.136m in one arm.

To find the rise at the other end of the u-tube:

Since it is a u-tube, pressure on both the arms is the same, hence:

Difference in pressure in the water column = difference in pressure in the mercury column

$h_w \rho_w g = h_m \rho_m g$

$h_m = h_w \rho_w / \rho_m$
$= 13.6 \times 10^3 / 13.6 \times 10^3$
$= 1cm$

∴ The other end of the u-tube will see a rise of 1cm in the mercury level.

8. In a hydraulic machine, a force of 2N is applied on the piston of area of cross section $10cm^2$. What force is obtained on its piston of area of cross section $100cm^2$?

Solution:

As per Pascal's law, When pressure increases, it uniformly increases through all the points when any force is exerted.

Pressure = force/ area

$(2N \times 10^{-4})/10 = (F \times 10^{-4})/ 100$

$2N = F/10$

$F = 20N$

9. What should be the ratio of area of cross section of the master cylinder and wheel cylinder of a hydraulic brake so that a force of 15N can be obtained at each of its brake show by exerting a force of 0.5N on the pedal?

Solution:

Consider the ratio of cross-section of the master cylinder and wheel cylinder be $X_1 : X_2$

Let the force applied on pedal be F_1=0.5N

And the force applied on brake shoe F_2 =15N

We know from the hydraulic machine,

Pressure on narrow piston = pressure on broader piston

$\frac{F_1}{X_1} = \frac{F_2}{X_2}$

⇨ $\frac{F_1}{F_2} = \frac{X_1}{X_2}$

⇨ $\frac{X_1}{X_2} = \frac{0.5}{15}$

⇨ $\frac{X_1}{X_2} = 1/30$

⇨ Hence, the ratio is 1:30

10. The areas of pistons in a hydraulic machine are $5cm^2$ and $625\ cm^2$. What force on the smaller piston will support a load of 1250N on the larger piston? State any assumption which you make in your calculation.

Assumption: There is no friction and no leakage of liquid.

Solution:

Given:

Area of narrow piston = $5cm^2 = A_1$, let force applied be F_1

Area of wider piston = $625cm^2 = A_2$, let force applied be F_2 = 1250N

We know from the hydraulic machine,

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

⇨ $\frac{F_1}{5} = \frac{1250}{625}$

⇨ $F_1 = 10N$

11. (a) The diameter of neck and bottom of a bottle are 2cm and 10cm respectively. The bottle is completely filled with oil. If the cork in the neck is pressed in with a force of 1.2kgf, what force is exerted on the bottom of the bottle?
(b) Name the law/principle you have used to find the force in part (a)

Solution:

(a) Diameter of neck, d1=2cm
Diameter of bottom of bottle, d2=10cm
Force applied on the cork in the neck, F_1 = 1.2kgf
Force applied on the bottom of the bottle, F_2
We know from the principle of Hydraulic machine:
Pressure on neck = pressure on the bottom of bottle

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

$$\Rightarrow \frac{1.2}{\pi(\frac{d1}{2})^2} = \frac{F_2}{\pi(\frac{d2}{2})^2}$$

$$\Rightarrow F_2 = \frac{1.2}{2^2} \times (10)^2 = 30 \text{ kgf}$$

(b) To find the force in part (a), Pascal's law is applied.

12. A force of 50kgf is applied to the smaller piston of a hydraulic machine. Neglecting friction, find the force exerted on the large piston, if the diameters of the pistons are 5cm and 25cm respectively.

Solution:

Comparing the diameter of narrow piston and broader piston = 5/25 or 5:25
= 25:625
Force exerted on narrow piston, F_1 = 50kgf
Consider F_2 to be the force exerted on the broader piston
We know from the principle of Hydraulic machine,
Pressure on narrow piston = pressure on broader piston

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

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

$$\Rightarrow 50/F_2 = 25/625$$
$$\Rightarrow F_2 = 1250 \text{ kgf}$$

13. Two cylindrical vessels fitted with pistons A and B of area of cross section 8cm^2 and 320cm^2 respectively, are joined at their bottom by a tube and they are completely filled with water. When a mass of 4kg is placed on piston A, find: (i) the pressure on piston A, (ii) the pressure on piston B, and (iii) the thrust on piston B.

Solution:

Given: Force applied on the narrow piston= 4kg
Area of cross section of A = 8cm^2
Area of cross section of B = 320cm^2

(i) Pressure on piston A = Thrust/area = 4/8 = 0.5 kg cm^{-2}

(ii) Pressure on piston A = pressure on piston B (as per Pascal's law)
∴ Pressure on piston B is 0.5 kg cm^{-2}

(iii) Thrust on piston B is acting in the upward direction, which is given by

- ⇨ Pressure/area
- ⇨ 4kg x (320/8)
- ⇨ 160kg

14. What force is applied on a piston of area of cross section $2cm^2$ to obtain a force 150N on the piston of area of cross section $12cm^2$ in a hydraulic machine?

Solution:

We know that pressure on smaller piston = pressure on wider piston in a hydraulic machine

$\therefore P_1 = P_2$

- ⇨ $\frac{F_1}{A_1} = \frac{F_2}{A_2}$
- ⇨ $\frac{F_1}{2 \times 10^{-4}} = \frac{150}{12 \times 10^{-4}}$
- ⇨ $F_1 = 25N$