Numericals :

1. A hammer exerts a force of 1·5 N on each of the two nails *A* and *B*. The area of cross section of tip of nail *A* is 2 mm^2 while that of nail *B* is 6 mm^2. Calculate pressure on each nail in pascal.
   Ans. On ***A*** : $7·5 \times 10^5$ pascal, On ***B*** : $2·5 \times 10^5$ pascal.

2. A block of iron of mass 7·5 kg and of dimensions 12 cm × 8 cm × 10 cm is kept on a table top on its base of side 12 cm × 8 cm. Calculate : (a) thrust and (b) pressure exerted on the table top. Take 1 kgf = 10 N. **Ans.** (a) 75 N (b) 7812·5 Pa

3. A vessel contains water up to a height of 1·5 m. Taking the density of water 10^3 kg m^{-3}, acceleration due to gravity 9·8 m s^{-2} and area of base of vessel 100 cm^2, calculate : (a) the pressure and (b) the thrust, at the base of vessel. **Ans.** (a) $1·47 \times 10^4$ N m^{-2} (b) 147 N

4. The area of base of a cylindrical vessel is 300 cm^2. Water (density = 1000 kg m^{-3}) is poured into it up to a depth of 6 cm. Calculate : (a) the pressure and (b) the thrust of water on the base. (g = 10 m s^{-2}).
   Ans. (a) 600 Pa, (b) 18 N

5. (a) Calculate the height of a water column which will exert on its base the same pressure as the 70 cm 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 ? **Ans.** (a) 9·52 m (b) No

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

7. A simple U tube contains mercury to the same level in both of its arms. If water is poured to a height of 13·6 cm in one arm, how much will be the rise in mercury level in the other arm ?

Given : density of mercury = $13{\cdot}6 \times 10^3$ kg m^{-3} and density of water = 10^3 kg m^{-3}. **Ans.** 1 cm

8. In a hydraulic machine, a force of 2 N is applied on the piston of area of cross section 10 cm^2. What force is obtained on its piston of area of cross section 100 cm^2 ? **Ans.** 20 N

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 15 N can be obtained at each of its brake shoe by exerting a force of 0·5 N on the pedal ? **Ans.** 1 : 30

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

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

11. (a) The diameter of neck and bottom of a bottle are 2 cm and 10 cm respectively. The bottle is completely filled with oil. If the cork in the neck is pressed in with a force of 1·2 kgf, 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)

Ans. (a) 30 kgf (b) Pascal's law

12. A force of 50 kgf 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 5 cm and 25 cm respectively.

Ans. 1250 kgf

Solution 1N.

1. Force exerted, F = 1.5 N

Area of cross-section of tip of nail A, $a_1 = 2mm^2 = 2\times10^{-6}m^2$

Area of cross-section of tip of nail B, $a_1 = 6mm^2 = 6\times10^{-6}m^2$

$$\text{Pressure on nail A} = \frac{F}{a_1} = \frac{1.5}{2\times10^{-6}} = 7.5\times10^5\,\text{pascal}$$

$$\text{Pressure on nail B} = \frac{F}{a_2} = \frac{1.5}{6\times10^{-6}} = 2.5\times10^5\,\text{pascal}$$

Solution 2N.

1 kgf = 10 N

$\therefore$ g = 10 m s^{-2}

a) Thrust is

F = mg = 7.5 kg x 10 = 75 N

b) Pressure is force per area.

$$\therefore P = \frac{F}{A_{base}} = \frac{75}{12\times10^{-2}\times8\times10^{-2}}$$

$\therefore$ P = 7812.5 Pa

Solution 3N

$\because$ Given height, h = 1.5m

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

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

Area of base of the vessel, $a = 100\ cm^2 = 100\times10^{-4}m^2$

(a) Pressure, $P = h\rho g$

or, $P = 1.5\times10^3\times9.8$

or, $P = 1.47\times10^4\ Nm^{-2}$

(b) Thrust = Pressure $\times$ area

or, thrust = $1.47\times10^4\times100\times10^{-4}$ N

or, thrust = 147 N

Solution 4N.

Given Area of base of vessel, $a = 300 \text{ cm}^2 = 300 \times 10^{-4} \text{ m}^2$

Density of water, $\rho = 1000 \text{ kg m}^{-3}$

Depth, $h = 6 \text{ cm} = 0.06 \text{ m}$

Acceleration due to gravity, $g = 10 \text{ ms}^{-2}$

(a) Pressure $= h\rho g = 0.06 \times 1000 \times 10 = 600$ pascal

(b) Thrust, T = pressure x area $= 600 \times 300 \times 10^{-4} = 18\text{N}$

Solution 5N.

(a) Given, density of mercury $\rho' = 13.6 \text{ gcm}^{-3}$

Height of mercury column, $h' = 70$ cm

Acceleration due to gravity, $g = 9.8 \text{ ms}^{-2}$

Let h be the height of the water column.

Density of water $\rho = 1 \text{ gcm}^{-3}$

Given, pressure exerted by mercury column = pressure exerted by water column

or, $h'\rho'g = h\rho g$

or, $h = \dfrac{h'\rho'}{\rho} = \dfrac{70 \times 13.6}{1} = 952\ cm$ or 95.2 m

(b) No, the height of the water column shall not change.

Solution 6N.

Pressure of water on ground floor = 40,000 pascal

Pressure of water on first floor = 10,000 pascal

Density of water, $\rho = 1000 \text{ kg m}^{-3}$

Acceleration due to gravity, $g = 10 \text{ ms}^{-2}$

Let h be the height of the first floor.

Difference in water pressure between ground and first floor = $h \rho g$

or, (40,000 - 10,000) = h (1000) (10)

or, h = 3 m

Solution 7N.

Length of mercury columns in two arms is equal. 1 cm

Height to which water is poured in one arm, h = 13.6 cm

Let h' be the rise in the mercury level in the other arm.

Given, density of mercury = $13.6 \times 10^3 \text{ kgm}^{-3}$

Density of water = 10^3 kgm^{-3}

Pressure due to water on one arm = Pressure on mercury column in the other arm

or, $13.6 \times 10^3 \times g = h' \times 13.6 \times 10^3 \times g$

or, h' = 1 cm

Solution 8N.

Force on narrow piston, $F_1 = 2N$

Area of cross-section of narrow piston, $A_1 = 10 \text{ cm}^2$

Let Force on wider piston be F_2

Area of cross-section of wider piston, $A_2 = 100 \text{ cm}^2$

By the principle of hydraulic machine,

Pressure on narrow piston = pressure on wider piston

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

or, $\frac{2}{10} = \frac{F_2}{100}$

or, $F_2 = 20N$

Solution 9N

$\therefore$ Let the ratio of area of cross-section of the master cylinder and wheel cylinder be $A_1 : A_2$

Force on pedal, $F_1 = 0.5N$

Force on break shoe, $F_2 = 15N$

By the principle of hydraulic machine,

Pressure on narrow piston = pressure on wider piston

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

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

or, $\frac{A_1}{A_2} = \frac{0.5}{15}$

or, $\frac{A_1}{A_2} = \frac{1}{30}$

Thus, the required ratio is 1:30

Solution 10N.

Area of small piston $A_1 = 5 \text{ cm}^2$

Area of wider piston, $A_2 = 625 \text{ cm}^2$

Force on small piston be F_1

Force on wider piston or load, $F_2 = 1250N$

By the principle of hydraulic machine,

Pressure on narrow piston = pressure on wider piston

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

or, $\frac{F_1}{5} = \frac{1250}{625}$

or, $F_1 = \frac{1250}{625} \times 5$

or, $F_1 = 10 \text{ N}$

Assumption: No friction or leakage of liquid happens.

Solution 11N

(i) Diameter of the neck of the bottle, $d_1 = 2$ cm

Diameter of the bottom of the bottle, $d_2 = 10$ cm

Force on the cork in the neck, $F_1 = 1.2$ kgf

Force on the bottom be F_2

By the principle of hydraulic machine,

Pressure on neck = pressure on bottom

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

or, $\frac{1.2}{\pi(d_1/2)^2} = \frac{F_2}{\pi(d_2/2)^2}$

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

(ii) Pascal's law has been used to find the force.

Solution 12N.

.. Ratio of diameter of smaller piston to bigger piston = 5 : 25

∴ Ratio of area of smaller piston to bigger piston = 25 : 625

Force applied on smaller piston, $F_1 = 50$ kgf

Let F_2 be the force on the bigger piston.

By the principle of hydraulic machine,

Pressure on narrow piston = pressure on wider piston

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

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

or, $\frac{50}{F_2} = \frac{25}{625}$

or, $F_2 = 50 \times \frac{625}{25} = 1250$ kgf