2nd SAMPLE TEST

CIVIL ENG. ORIENTATION

DATE OF THE 2nd TEST

01.12.2020 2:00 PM

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Deadline: 01.12.2020 3:30 PM

- 1st TEST : 45 points
- 2 nd TEST: 50 points
- Homework + Continuity equation problems (elearning): 5 points

DATE OF THE RETAKE TEST

08.12.2020 2:00 PM

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TOPICS

I. Hydrostatic forces on surfaces

II. Fluid dynamics problems

III. Continuity equation problems

True or false?

1. When a surface is submerged in a fluid, forces develop on the surface due to the fluid (T)
2. The force must be perpendicular to the surface (T)
3. Fluid is compressible (F)
4. The hydrostatic pressure is constant at the bottom of the tank
5. The hydrostatic force refers to the amount of force that is exerted by a fluid (T)
6. $F= p/A$ (F)

Equal volume of two liquids of densities $\rho1$ and $\rho2$ are poured into two identical cuboidal beakers. The hydrostatic forces on the respective vertical face of the beakers are F1 and F2 respectively. If $\rho1 > \rho2$, which one will be the correct relation between F1 and F2?

a) F1 > F2

b) F1 ≥ F2

c) F1 < F2

d) F1 ≤ F2

True or false?

- For a horizontal surface, such as the bottom of a liquid-filled tank, the magnitude of the resultant force is simply F_R = pxA where p is the uniform pressure on the bottom and A is the area of the bottom

T

True or false?

The thrust force acting on a surface submerged in a liquid can be calculated as

$F = p_a \times A = \rho \times g \times h_a \times A$

pa = average pressure on the surface (Pa)

A = area of submerged surface (m2)

h_a = average depth (m)

T

- **How much is the hydrostatic pressure exerted by water at the bottom of a beaker? Take the depth of water as 45 cm. (density of water $10^3 kgm^{-3}$).**

A) 2450 Pa
B) 3780 Pa
C) 4410 Pa
D) 5580 Pa

Height=45cm=0.45m

gravity=$9.8ms^{-2}$

Density=$1000kgm^{-3}$

Pressure=hg

- =0.45×9.8×1000Pa=4410Pa.

- Answer: A
- Hydrostatic force per unit width on a vertical side of a beaker = 1 ⁄ 2 * $\rho g h^2$, where ρ = density of the liquid and h= height of liquid column. Thus if $\rho 1 > \rho 2$, $F1 > F2$ and $F1 \neq F2$, when the h is constant

Which of the following is the correct relation between centroid (G) and the centre of pressure (P) of a plane submerged in a liquid?

a) G is always below P

b) P is always below G

c) G is either at P or below it.

d) P is either at G or below it.

- Answer: d

A cubic tank is completely filled with water. What will be the ratio of the hydrostatic force exerted on the base and on any one of the vertical sides?

a) 1:1

b) 2:1

c) 1:2

d) 3:2

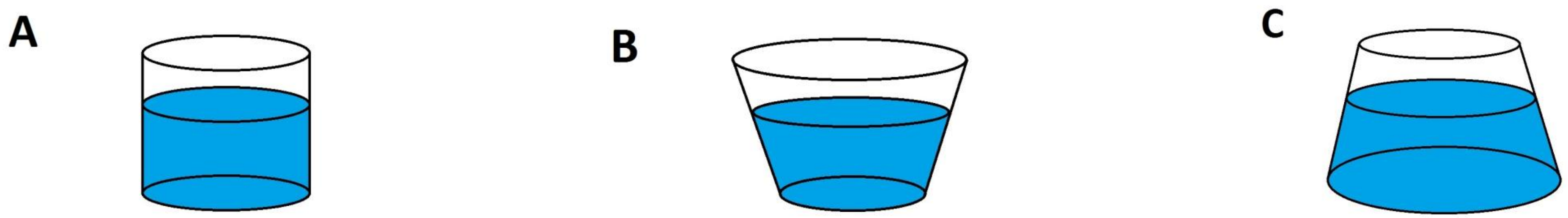
- Answer: b
- Hydrostatic force per unit width on a vertical side of a beaker $F_v = {}^1\!/_2 * \rho g h^2$

Hydrostatic force per unit width on the base of the beaker

$F_b = \rho g h * h = \rho g h^2$

Thus, Fb : Fv = 2 : 1

Consider the three differently shaped containers, as shown. Each container is filled with water to a depth of 10 m.
In which container is the pressure the greatest at the bottom?



A) Container C

B) Container A

C) It cannot be determined without knowing the volume of water in each container.

D) Each container has the same pressure at the bottom

E) Container B

D) Each container has the same pressure at the bottom

- In this question, we're told that three containers of different shapes are filled with water. We're also told that each container has the same depth of water.
- To find the pressure at the bottom of any of the containers, we'll need to remember the equation for pressure.
- Also, since each container is filled with water, the density of the fluid in each container is identical. Moreover, the depth we are considering for each container is also the same. Therefore, the pressure at the bottom of each container is exactly the same.

A ball with radius r=0.22m is submerged in syrup at a depth of 4m. What is the total force from pressure acting on the ball?

A) 32 kN

B) 66 kN

C) 78 kN

D) 46 kN

$\rho_{s} = 1370\ kg/m^3$

Patm =100 kPa

C)

The total pressure on the ball includes both hydrostatic and atmospheric pressure: $P_T = P_{atm} + P_h$

$P_h = \rho_h \times g \times h$

determine the force on the ball, we need it's surface area. For a sphere: $A=4r^2\pi$

$F = p_T \times A$

A U-shaped tube is filled with water, however the openings on either ends have different cross-sectional areas of $5m^2$ and $10m^2$. If a force of 100N is applied to the opening that is $5m^2$ in area, how much force will be exerted on the other end of the tube?

The following formula on pressure and area is used:

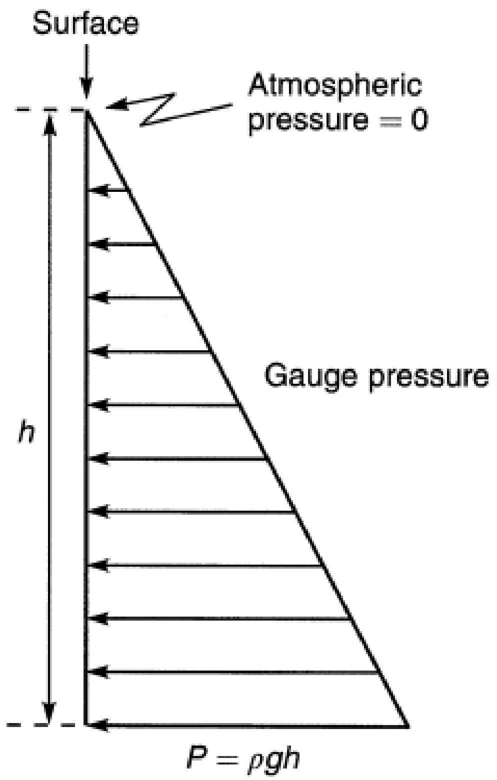
F1 x A1 = F2 x A2

We substitute our known values and solve for F2 to obtain the output force:

Therefore the correct answer is 50N of force.

True or false?

- This diagram shows the pressure intensity on a vertical surface that is immersed in a static liquid and which has the same height, h, as the depth of water.



Answer: True

- If we want to obtain the absolute pressure measured relative to an absolute vacuum, that is the total pressure exerted by both the water and the atmosphere, we have to add atmospheric pressure, P_{ATM}, to the gauge pressure. Thus the absolute pressure, P_{ABS}, is:

……………………………………………….

$$P_{ABS} = \rho g h + P_{ATM} \ \mathrm{N/m^2}$$

Oil with a weight density, w_O, of 7850 N/m^3 is contained in a vertically sided, rectangular tank which is 2.0 m long and 1.0 m wide. The depth of oil in the tank is 0.6 m.

(a) What is the gauge pressure on the bottom of the tank in N/m^2?

(b) What is the weight of the oil in the tank?

What is the average pressure intensity on the dam?

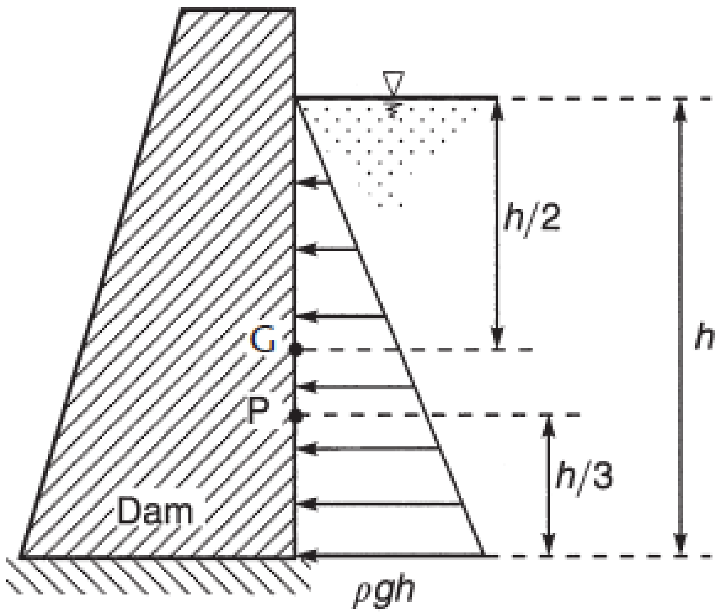
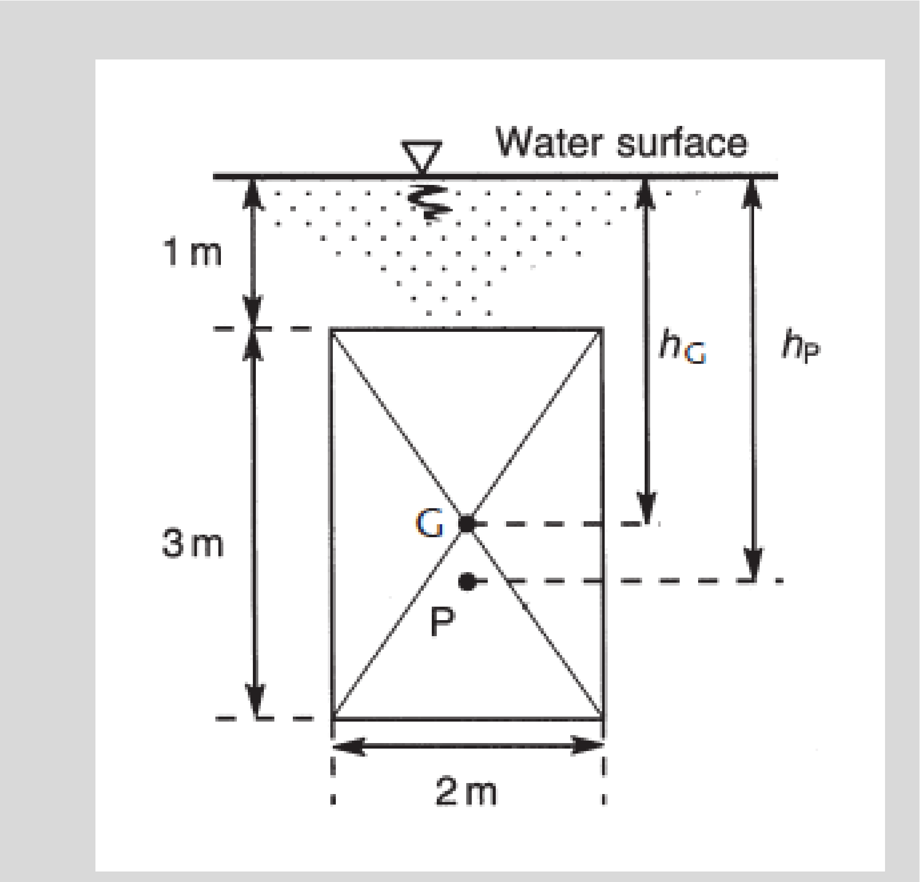


Figure 1.11 Pressure intensity on a dam. G is the centroid of the wetted area, P is the centre of pressure where the resultant force acts

Consider the dam in Fig. 1.11. In this case the pressure intensity diagram is triangular, since the gauge pressure varies from zero (atmospheric pressure) at the surface to ρgh at the bottom. The average pressure intensity on the dam is therefore $(0 + \rho gh)/2$ or $\rho gh/2$. This pressure occurs at G, half way between the water surface and the bottom of the dam.

A rectangular gate is 2 m wide and 3 m high. It hangs vertically with its top edge 1 m below the water surface. (a) Calculate the pressure at the bottom of the gate. (b) Calculate the resultant hydrostatic force on the gate. (c) Determine the depth at which the resultant force acts.



(a) From equation (1.8), $P = \rho g h$

$$\text{Therefore } P = 1000 \times 9.81 \times (3+1)$$
$$= 39.24 \times 10^3 \text{ N/m}^2$$

(b) From equation (1.11), $F = \rho g h_G A$

$$\text{Now } h_G = 1 + (3/2) = 2.50\text{m}$$
$$A = 2 \times 3 = 6\text{m}^2$$
$$\text{Thus } F = 1000 \times 9.81 \times 2.50 \times 6$$
$$= 147.15 \times 10^3 \text{N}$$

(c) From equation (1.12)

$$h_P = (I_G / A h_G) + h_G$$
$$\text{where } I_G = LD^3/12 = 2 \times 3^3/12 = 4.50\text{m}^4$$
A and h_G are as above
$$\text{so } h_P = (4.50/6 \times 2.50) + 2.50$$
$$= 2.80\text{m}$$

True or false?

The hydrostatic pressure on the inclined surface is still caused only by the weight of water above it, so $P = \rho g h$.

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True or false?

Basically, the hydrostatic equation states that the change in pressure intensity between two levels of a homogeneous (uniform) liquid is proportional to the vertical distance between them.

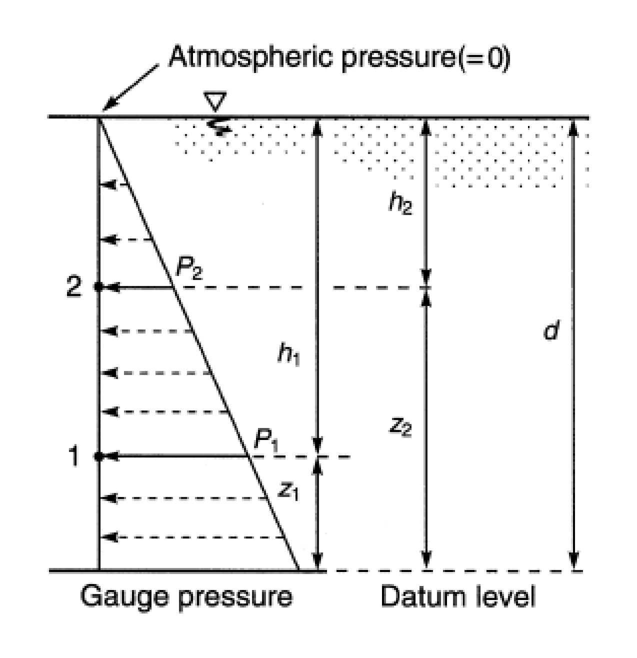


Figure 1.34 Pressure intensity at two points

Pressure at point 1, $P_1 = \rho g h_1 = \rho g(d - z_1)$

Pressure at point 2, $P_2 = \rho g h_2 = \rho g(d - z_2)$

The difference in pressure between the two points is $(P_2 - P_1)$ where:

$$(P_2 - P_1) = \rho g(d - z_2) - pg(d - z_1)$$

$$= \rho g(d - z_2 - d + z_1)$$

$$= \rho g(-z_2 + z_1)$$

$$(P_2 - P_1) = -\rho g(z_2 - z_1)$$

Consider points 1 and 2 at some distance below the surface as in Fig. 1.34. This time let us measure the depth of the points from the *bottom* (not from the surface) and let these distances be denoted by z_1 and z_2.

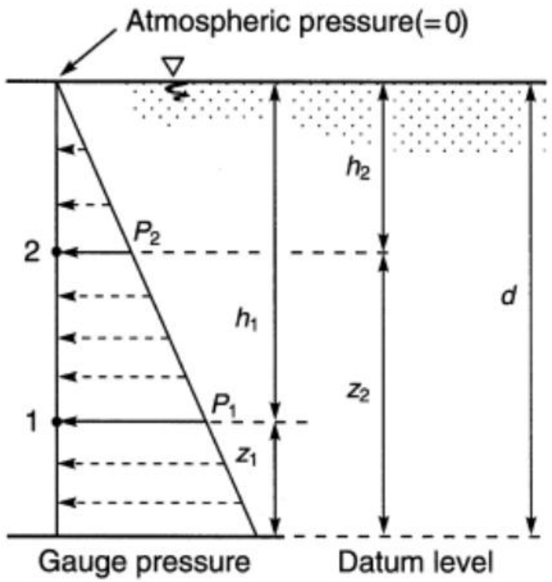


Figure 1.34 Pressure intensity at two points

A tank with vertical sides contains both oil and water. The oil has a depth of 1.5 m and a relative density of 0.8. It floats on top of the water, with which it does not mix. The water has a depth of 2.0 m and a relative density of 1.0. The tank is 3.0 m by 1.8 m in plan and open to the atmosphere. Calculate (a) the total weight of the contents of the tank; (b) the pressure on the base of the tank; (c) the variation of pressure intensity with depth; (d) the force on the side of the tank.

(a) $W_T = (\rho_1 g h_1 + \rho_2 g h_2)A$

Plan area $A = 3.0 \times 1.8 = 5.4\,\text{m}^2$

$W_T = (0.8 \times 1000 \times 9.81 \times 1.5 + 1.0 \times 1000 \times 9.81 \times 2.0)5.4$
$= (11\,772 + 19\,620)5.4 = 169\,517\,\text{N}$

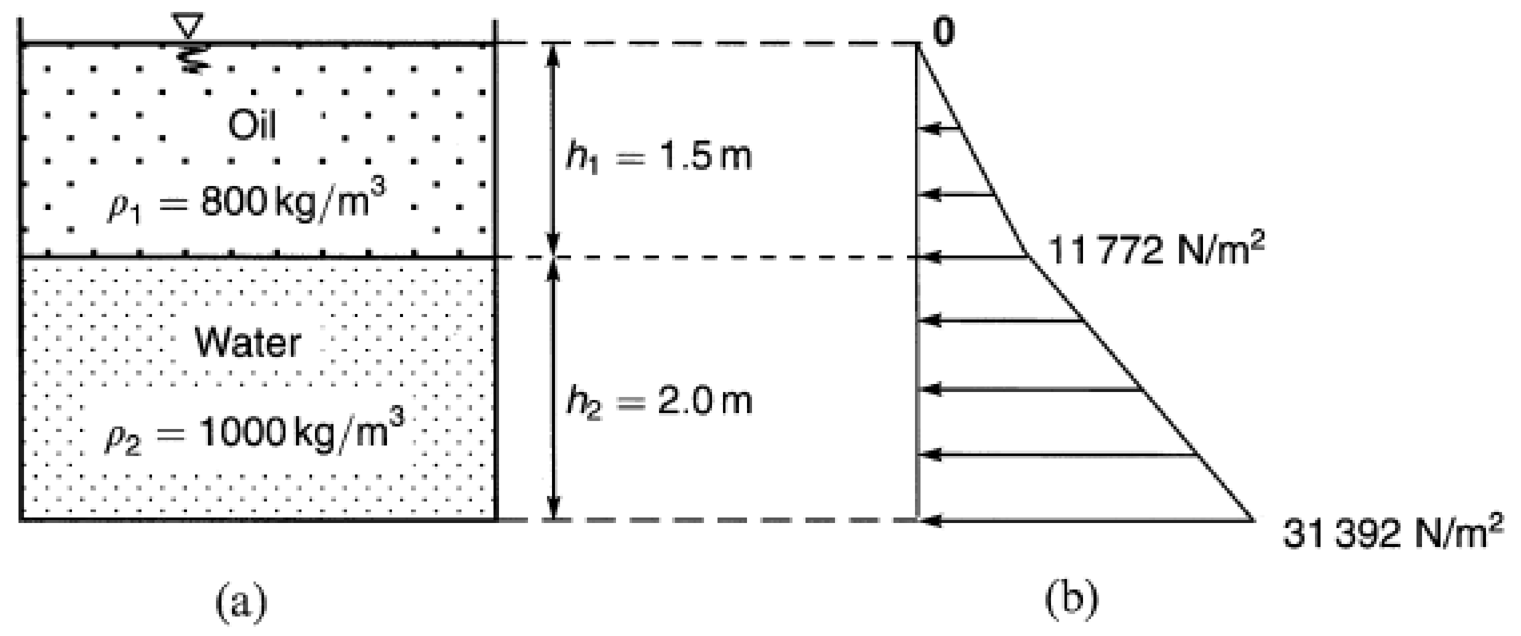
(b) Total pressure at base of tank $= W_T/A = 169\,517/5.4 = 31\,392\,\text{N/m}^2$

(c) Pressure at the surface = atmospheric = 0

Pressure at the bottom of the oil $= \rho_1 g h_1 = 11\,772\,\text{N/m}^2$

Total pressure at the bottom of the tank $= 31\,392\,\text{N/m}^2$

The pressure intensity diagram



(a) Tank containing a stratified liquid, and (b) the corresponding pressure intensity diagram

(d) The side of the tank is 3.0 m long. The force on the side of the tank can be obtained from equation (1.2) by multiplying the area of the tank in contact with each of the liquids by the average pressure intensity of the particular liquid.

Average pressure of the oil = (0 + 11 772)/2 = 5886 N/m^2

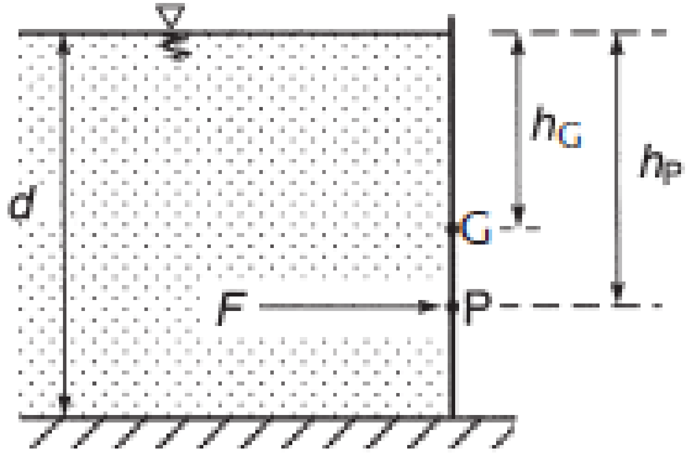
Force due to the oil = 3.0 × 1.5 × 5886 = 26 487 N

Average pressure of the water = (11 772 + 31 392)/2 = 21 582 N/m^2

Force due to the water = 3.0 × 2.0 × 21 582 = 129 492 N

Total force on the side = 26 487 + 129 492 = 155 979 N

PLANE VERTICAL SURFACE EXTENDING TO WATER SURFACE



$F = \rho g h_G A$

h_G = depth to centroid of vertical surface

A = area of vertical surface

Depth to centre of pressure, $h_P = (2/3)d$

True or false?

The relationship between the area inside the pipe (the pipe's internal diameter) and the velocity of the fluid is expressed in the equation of continuity, written as $v_1 \times A_1 = v_2 \times A_2$

If a liquid enters a pipe of diameter d with a velocity v, what will it's velocity at the exit if the diameter reduces to 0.5d?

a) v

b) 0.5v

c) 2v

d) 4v

Answer: d

The continuity equation is based on the principle of

a) conservation of mass

b) conservation of momentum

c) conservation of energy

d) conservation of force

Answer: a

Two pipes, each of diameter d, converge to form a pipe of diameter D. What should be the relation between d and D such that the flow velocity in the third pipe becomes double of that in each of the two pipes?

a) D = d

b) D = 2d

c) D = 3d

d) D = 4d

Answer: a

$A_1v_1 + A_2v_2 = Av$

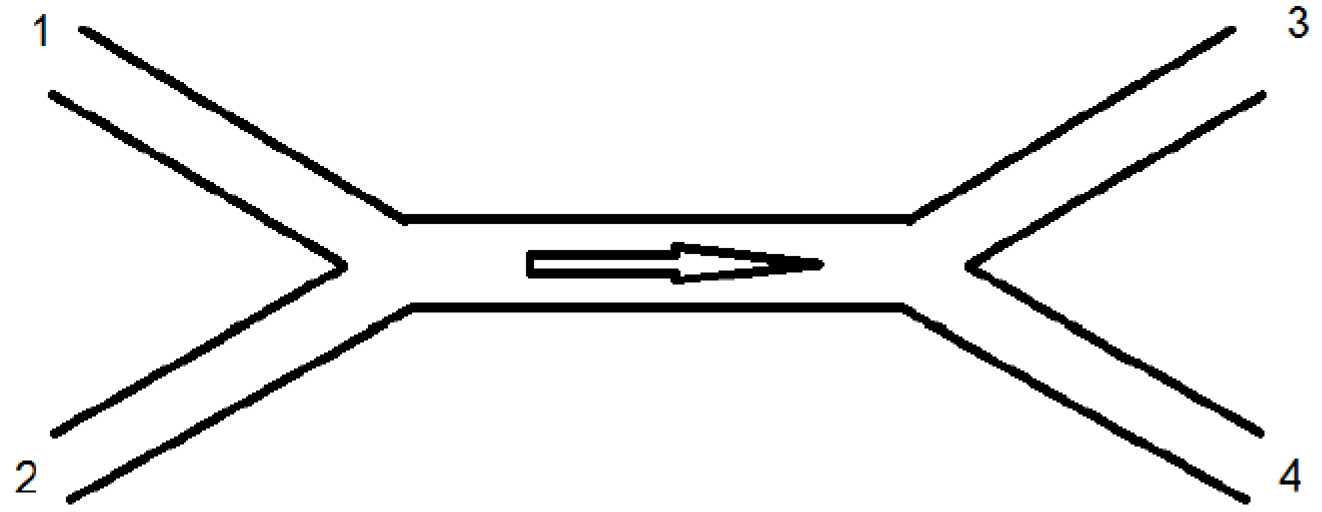
$d^2v + d^2v = D^2v$

$D = d.$

Two pipes, each of diameter d, converge to form a pipe of diameter D. What should be the relation between d and D such that the ow velocity in the third pipe becomes half of that in each of the two pipes?

a) D = d/2
b) D = d/3
c) D = d/4
d) D = d/5

- In a water supply system, water flows in from pipes 1 and 2 and goes out from pipes 3 and 4 as shown. If all the pipes have the same diameter, which of the following must be correct?



a) the sum of the flow velocities in 1 and 2 is equal to that in 3 and 4

b) the sum of the flow velocities in 1 and 3 is equal to that in 2 and 4

c) the sum of the flow velocities in 1 and 4 is equal to that in 2 and 3

d) the flow velocities in 1 and 2 is equal to that in 3 and 4

The continuity equation is only applicable to incompressible fluid.

a) True

b) False

The continuity equation is only applicable to incompressible as well as compressible fluid.

Answer: a

- $A_1v_1 + A_2v_2 = A_3v_3 + A_4v_4$
  Since $d_1 = d_2 = d_3 = d_4$, $v_1 + v_2 = v_3 + v_4$.

For an incompressible flow, the mass continuity equation changes to _________

a) energy equation

b) momentum equation

c) volume continuity equation

d) remains same

Answer: c

Continuity equation is related to _______

a) Mass conservation

b) Energy conservation

c) Momentum conservation

d) Velocity change

Answer: a

- A liquid flows through a pipe with a diameter of 10cm at a velocity of 9cm/s. If the diameter of the pipe then decreases to 6cm, what is the new velocity of the liquid?

A) 21cm/s

B) 25cm/s

C) 50 cm/s

D) 15cm/s

- Rate of flow, A * v, must remain constant. Use the continuity equation, $A_1v_1=A_2v_2$.
- Solving the initial cross-sectional area yields: $A_1=\pi r2=25\pi cm2$. The initial radius is 5cm.
- Then find the final area of the pipe: $A_2=\pi r^2=9\pi cm^2$. The final radius is 3cm.
- Using these values in the continuity equation allows us to solve the final velocity.
- $(25\pi cm^2)(9cm/s)=(9\pi cm^2)v_2$
- $v_2=25cm/s$

Which will produce the greatest increase in flow velocity through a tube?

- Halving the tube radius
- Doubling the viscosity of the liquid
- Doubling the tube area
- Dividing the tube area by three
- Doubling the tube radius

Correct answer:

Halving the tube radius

- If a pipe with flowing water has a cross-sectional area nine times greater at point 2 than at point 1, what would be the relation of flow speed at the two points?

- The flow speed relation will depend on the viscosity of the water

- The flow speed at point 1 is three times that at point 2

- The flow speed at point 1 is nine times that at point 2

- The flow speed at point 2 is nine times that at point 1

- The flow speed at point 2 is three times that at point 1

Correct answer:

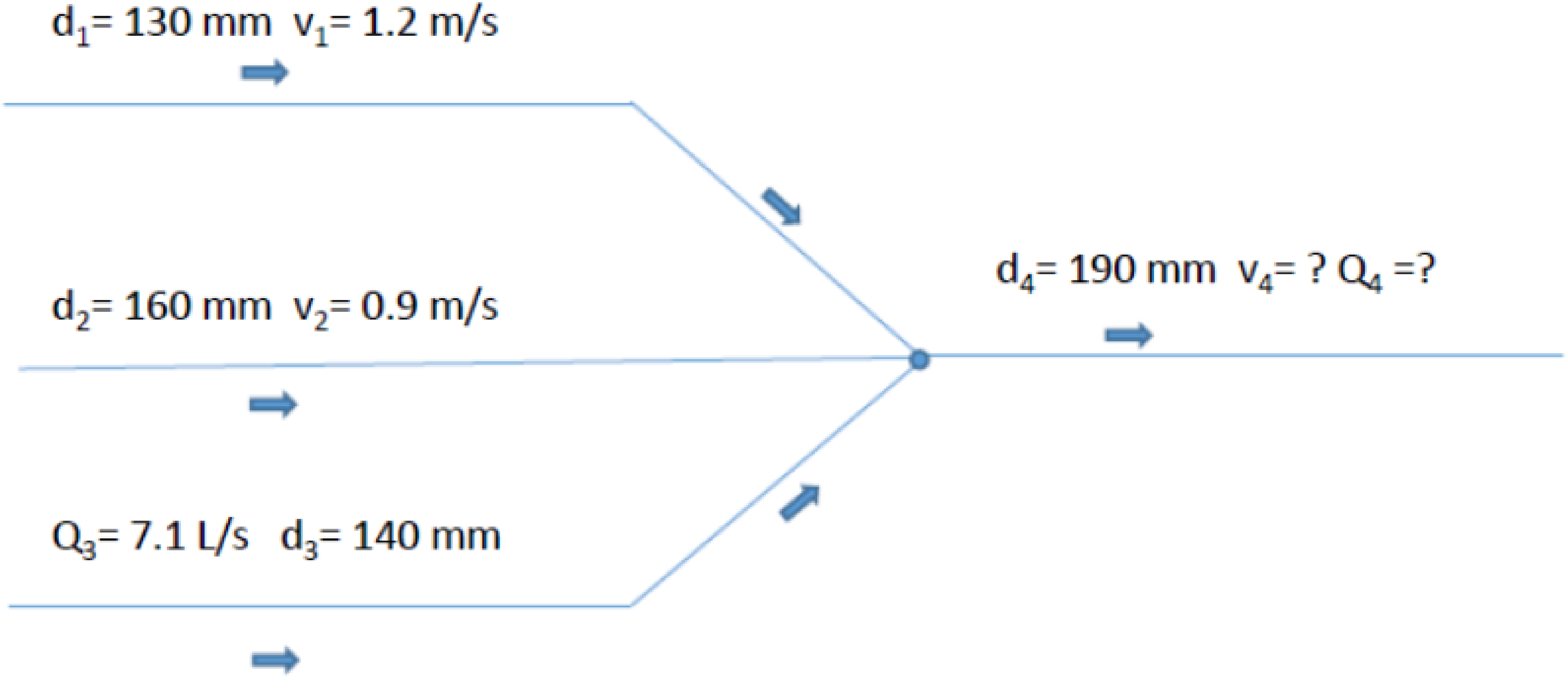
The flow speed at point 1 is nine times that at point 2

Using the continuity equation we know that $A_1V_1=A_2V_2$.

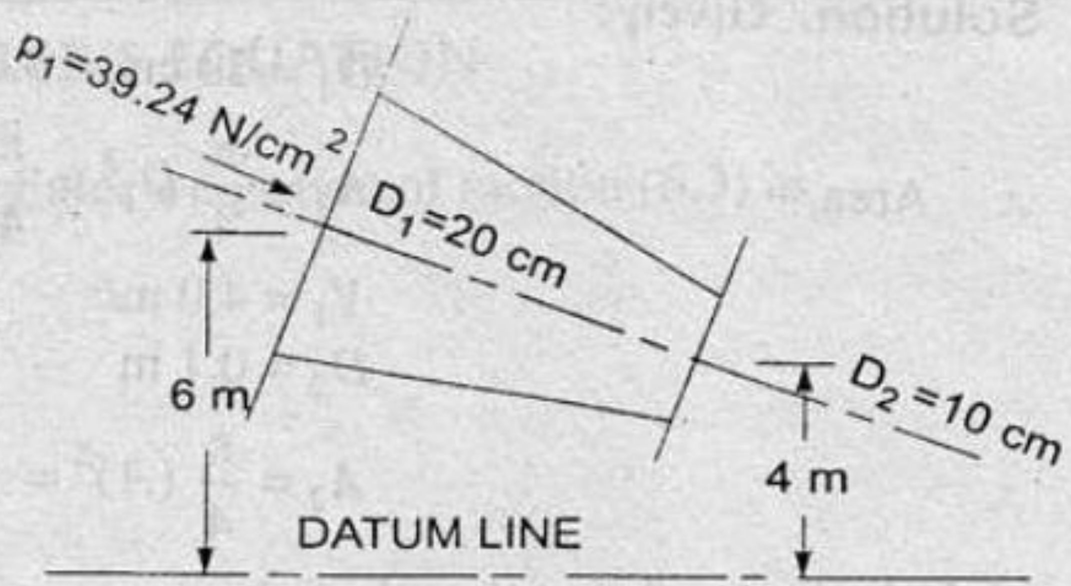
The question tells us that the cross-sectional area at point 2 is nine times greater that at point 1 ($9A_1=A_2$).

Using the continuity equation we can make $A_1= 1$ and $A_2 = 9$.
$1V_1=9V_2$
$V_1 / V_2=9 / 1$

Flow speed at point 1 is nine times that at point 2.


d_1= 130 mm v_1= 1.2 m/s
d_2= 160 mm v_2= 0.9 m/s
Q_3= 7.1 L/s d_3= 140 mm
d_4= 190 mm v_4= ? Q_4 =?

Problem 6.4 *The water is flowing through a pipe having diameters 20 cm and 10 cm at sections 1 and 2 respectively. The rate of flow through pipe is 35 litres/s. The section 1 is 6 m above datum and section 2 is 4 m above datum. If the pressure at section 1 is 39.24 N/cm², find the intensity of pressure at section 2.*



Solution. Given :

At section 1, $D_1 = 20 \text{ cm} = 0.2 \text{ m}$

$$A_1 = \frac{\pi}{4}(.2)^2 = .0314 \text{ m}^2$$

$$p_1 = 39.24 \text{ N/cm}^2 = 39.24 \times 10^4 \text{ N/m}^2$$

$$z_1 = 6.0 \text{ m}$$

At section 2, $D_2 = 0.10 \text{ m}$

$$A_2 = \frac{\pi}{4}(0.1)^2 = .00785 \text{ m}^2$$

$$z_2 = 4 \text{ m}$$

$$p_2 = ?$$

Rate of flow, $Q = 35 \text{ lit/s} = \frac{35}{1000} = .035 \text{ m}^3\text{/s}$

$$Q = A_1 V_1 = A_2 V_2$$

$$V_1 = \frac{Q}{A_1} = \frac{.035}{.0314} = 1.114 \text{ m/s}$$

$$V_2 = \frac{Q}{A_2} = \frac{.035}{.00785} = 4.456 \text{ m/s}$$

$$\frac{p_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{p_2}{\rho g} + \frac{V_2^2}{2g} + z_2$$

$$\frac{39.24 \times 10^4}{1000 \times 9.81} + \frac{(1.114)^2}{2 \times 9.81} + 6.0 = \frac{p_2}{1000 \times 9.81} + \frac{(4.456)^2}{2 \times 9.81} + 4.0$$

$$40 + 0.063 + 6.0 = \frac{p_2}{9810} + 1.012 + 4.0$$

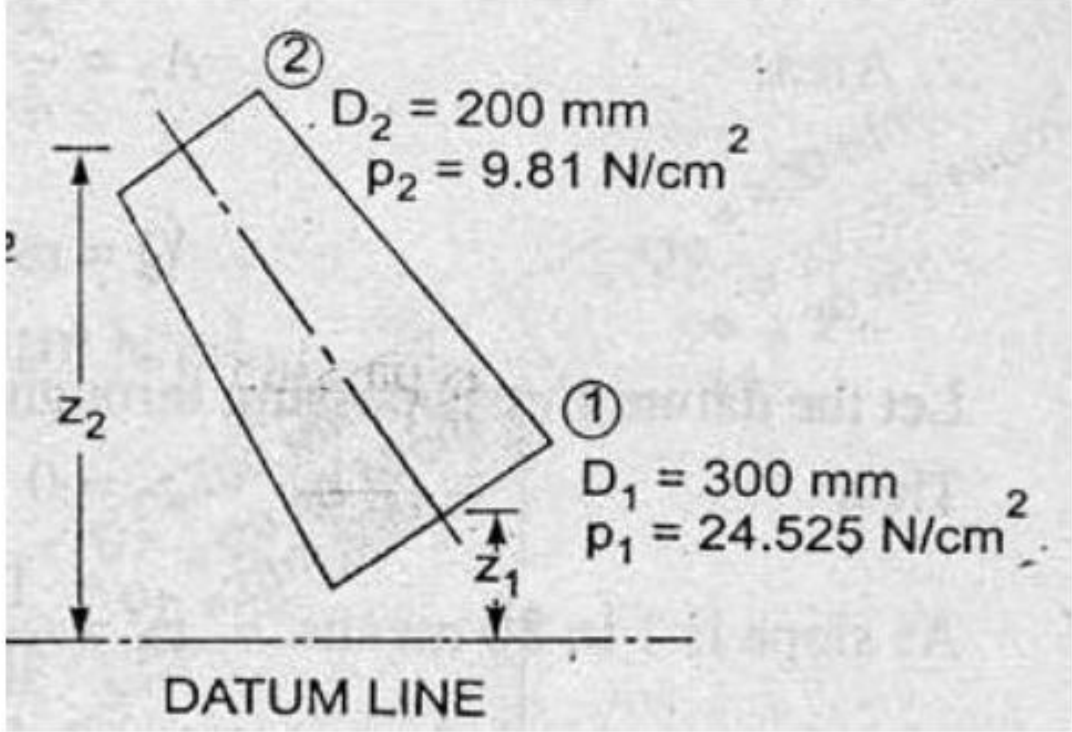
$$46.063 = \frac{p_2}{9810} + 5.012$$

$$\therefore \quad \frac{p_2}{9810} = 46.063 - 5.012 = 41.051$$

$$\therefore \quad p_2 = 41.051 \times 9810 \text{ N/m}^2$$

$$= \frac{41.051 \times 9810}{10^4} \text{ N/cm}^2 = \mathbf{40.27 \ N/cm^2}$$

Problem 6.5 *Water is flowing through a pipe having diameter 300 mm and 200 mm at the bottom and upper end respectively. The intensity of pressure at the bottom end is 24.525 N/cm² and the pressure at the upper end is 9.81 N/cm². Determine the difference in datum head if the rate of flow through pipe is 40 lit/s.*



Section 1, $D_1 = 300 \text{ mm} = 0.3 \text{ m}$

$p_1 = 24.525 \text{ N/cm}^2 = 24.525 \times 10^4 \text{ N/m}^2$

Section 2, $D_2 = 200 \text{ mm} = 0.2 \text{ m}$

$p_2 = 9.81 \text{ N/cm}^2 = 9.81 \times 10^4 \text{ N/m}^2$

Rate of flow $= 40 \text{ lit/s}$

or $$Q = \frac{40}{1000} = 0.04 \text{ m}^3/\text{s}$$

$$A_1V_1 = A_2V_2 = \text{rate of flow} = 0.04$$

$$V_1 = \frac{.04}{A_1} = \frac{.04}{\frac{\pi}{4} D_1^2} = \frac{0.04}{\frac{\pi}{4}(0.3)^2} = 0.5658 \text{ m/s}$$

$$\simeq 0.566 \text{ m/s}$$

$$V_2 = \frac{.04}{A_2} = \frac{.04}{\frac{\pi}{4}(D_2)^2} = \frac{0.04}{\frac{\pi}{4}(0.2)^2} = 1.274 \text{ m/s}$$

Problem 3.2 *Determine the total pressure on a circular plate of diameter 1.5 m which is placed vertically in water in such a way that the centre of the plate is 3 m below the free surface of water. Find the position of centre of pressure also.*

Given : Dia. of plate, $d = 1.5$ m

$$A = \frac{\pi}{4}(1.5)^2 = 1.767 \text{ m}^2$$

$$\bar{h} = 3.0 \text{ m}$$

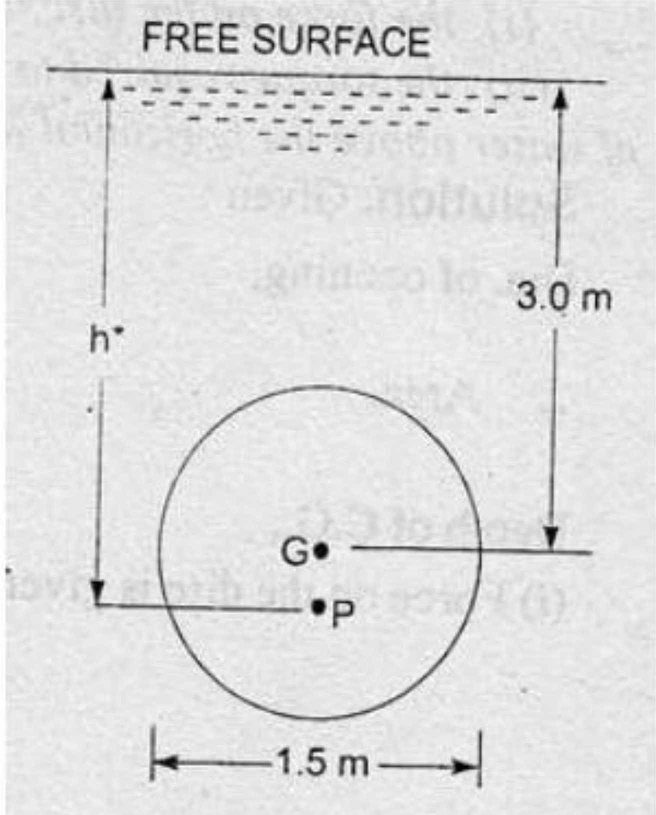


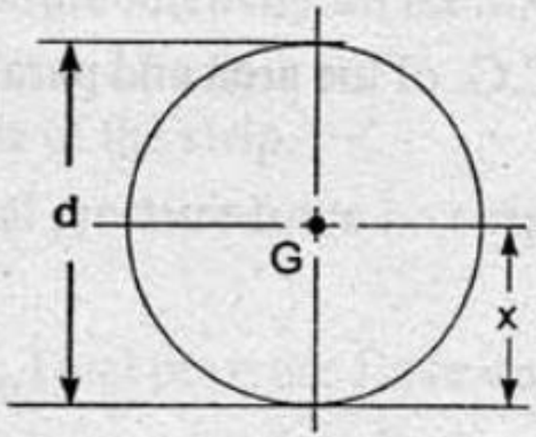
Fig. 3.4

Total pressure is given by equation $F = \rho g A \bar{h}$

$$F = \rho g A \bar{h}$$

$$= 1000 \times 9.81 \times 1.767 \times 3.0 \text{ N}$$

$$= \mathbf{52002.81\ N}$$

Plane surface	*C.G. from the base*	*Area*	*Moment of inertia about an axis passing through C.G. and parallel to base* (I_G)	*Moment of inertia about base* (I_0)
3. Circle 	$x = \frac{d}{2}$	$\frac{\pi d^2}{4}$	$\frac{\pi d^4}{64}$	—

Position of centre of pressure (h^*) is given by equation (3.5)

$$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$$

where $I_G = \frac{\pi d^4}{64} = \frac{\pi \times 1.5^4}{64} = 0.2485 \text{ m}^4$

$$h^* = \frac{0.2485}{1.767 \times 3.0} + 3.0 = 0.0468 + 3.0$$

= 3.0468 m.

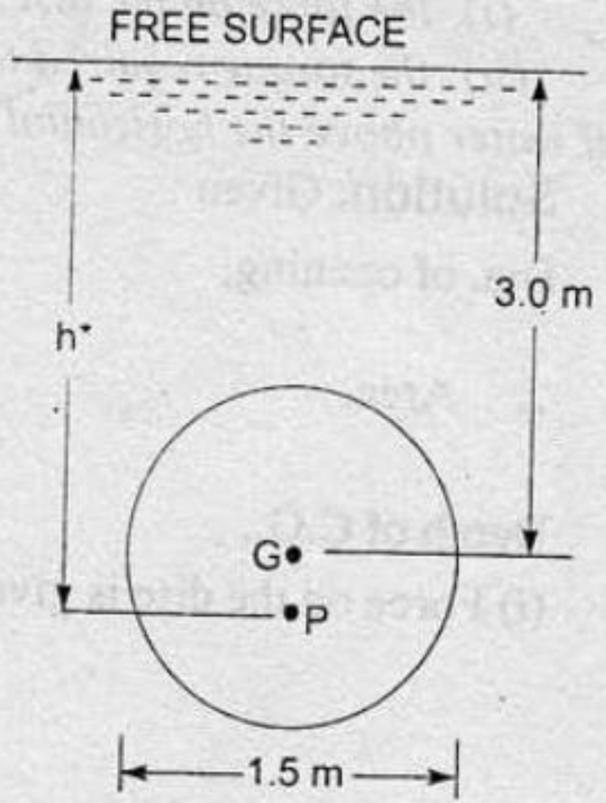


Fig. 3.4

Problem 3.4 *A circular opening, 3 m diameter, in a vertical side of a tank is closed by a disc of 3 m diameter which can rotate about a horizontal diameter. Calculate :*

the force on the disc,

Dia. of opening, $d = 3$ m

$\therefore$ Area, $A = \frac{\pi}{4} \times 3^2 = 7.0685 \text{ m}^2$.

Depth of C.G., $\bar{h} = 4$ m

(*i*) Force on the disc is given by equation (3.1) as

$$F = \rho g A \bar{h} = 1000 \times 9.81 \times 7.0685 \times 4.0$$

$$= \mathbf{277368 \text{ N} = 277.368 \text{ kN}}$$

Problem 3.6 *Determine the total pressure and centre of pressure on an isosceles triangular plate of base 4 m and altitude 4 m when it is immersed vertically in an oil of sp. gr. 0.9. The base of the plate coincides with the free surface of oil.*

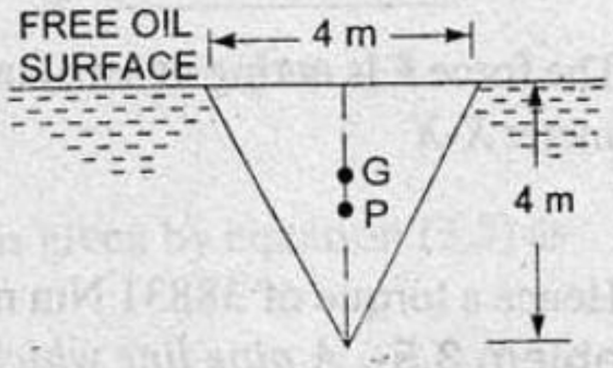


Fig. 3.8

Solution. Given :

Base of plate, $b = 4$ m

Height of plate, $h = 4$ m

$\therefore$ Area, $A = \frac{b \times h}{2} = \frac{4 \times 4}{2} = 8.0 \text{ m}^2$

Sp. gr. of oil, $S = 0.9$

$\therefore$ Density of oil, $\rho = 900 \text{ kg/m}^3$.

The distance of C.G. from free surface of oil,

$$\bar{h} = \frac{1}{3} \times h = \frac{1}{3} \times 4 = 1.33 \text{ m.}$$

Total pressure (F) is given by $F = \rho g A \bar{h}$

$$= 900 \times 9.81 \times 8.0 \times 1.33 \text{ N} = \mathbf{9597.6.\ N.}$$

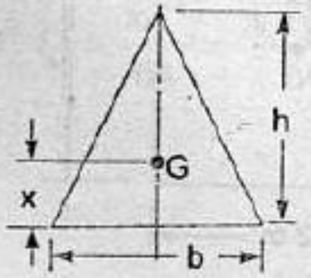
Centre of pressure (h^*) from free surface of oil is given by

$$h^* = \frac{I_G}{A\bar{h}} + \bar{h}$$

where I_G = M.O.I. of triangular section about its C.G.

$$= \frac{bh^3}{36} = \frac{4 \times 4^3}{36} = 7.11 \text{ m}^4$$

$$\therefore \quad h^* = \frac{7.11}{8.0 \times 1.33} + 1.33 = 0.6667 + 1.33 = \mathbf{1.99\ m}$$

Plane surface	*C.G. from the base*	*Area*	*Moment of inertia about an axis passing through C.G. and parallel to base (I_G)*	*Moment of inertia about base (I_0)*
2. Triangle 	$x = \frac{h}{3}$	$\frac{bh}{2}$	$\frac{bh^3}{36}$	$\frac{bh^3}{12}$