Nilachal Polytechnic
Bhubaneswar

[redacted]

NOTE

Sem. : 4TH

Subject : HYDRAULICS (PART-A)

Branch: CIVIL ENGG.

Name of the Faculty : R.R.GIRI

Text Book to be followed by Student / Faculty

Book-1 : R.K.BANSAL (ALL CHAPTERS)

Ch. No. : 1 Name : HYDROSTATICS

1. Learning outcome

1.To familiarize with the properties of fluids and the applications of fluid mechanics
2 .Identify and obtain the values of fluid properties and relationship between them.
3. Explain Newton's law of viscosity. Classify fluids based on Newton's law of viscosity and solve problems on Viscosity .
4. Employ capillary principle to calculate capillary rise/fall in a given tube.
5. Interpret different forms of pressure measurement.

2.Essential Questions (Fundamental Question)

i) What do you mean by hydraulics?
ii) Why do you have to study it?
iii) What is hydrostatics ?
iv) What is fluid?
v) What are the properties of fluid ?
vi) What do you mean by viscosity ?

3. Hours Required

Theory	**02**
Problems	**02**
Question & Answer Theory	**02**
Total	**06**

4. Question for Teaching / Assignment / Self Practice

	02 Marks	05 Marks	10Marks
Teaching	**11**	**05**	**07**
Assignment	**05**	**03**	**02**
Self Practice	**04**	**02**	**01**
Total	**20**	**10**	**10**

Lesson Description (Abstract of the Chapter)

- It deals with the behavior of fluids at rest and in motion.
- Engineers are interested in fluid mechanics because of the forces that are produced by fluids and which can be used for practical purposes.

- Some of the well-known examples are jet propulsion, aerofoil design, wind turbines and hydraulic brakes, but there are also applications which receive less attention such as the design of mechanical heart valves.

- The transmission of pressure from various gauge machines related to liquid and its application to hydraulics.

- Hydraulics has a wide range of applications in mechanical and chemical engineering,.

- Calculation of different hydrostatic forces on horizontal and vertical plane.

Lecture Note :

ARTICLE 1.1
(PROPERTIES OF FLUIDS)

INTRODUCTION :

- Fluid is a substance that continually deforms (flows) under an applied shear stress.
- Fluids are a subset of the phases of matter and include liquids, gases, plasmas and, to some extent, plastic solids.
- A fluid is a substance which cannot resist any shear force applied to it.
- Fluid mechanics is the branch of science which deals with the behavior of fluids(liquids or gases)at rest as well as in motion.
- It deals with the static, kinematics and dynamic aspects of fluids.
- The study of fluids at rest is called fluid statics.
- The study of fluid in motion is called fluid kinematics if pressure forces are not considered if pressure force is considered in fluid in motion is called fluid dynamics.

Hydrostatics:

- Fluid statics or hydrostatics is the branch of fluid mechanics that studies "fluids at hydrostatic equilibrium and the pressure in a fluid or exerted by a fluid on an immersed body".

Application of hydraulics :

- Hydraulic engineering consists of the application of fluid mechanics to water flowing in an isolated environment (pipe, pump) or in an open channel (river, lake, ocean).

- Civil engineers are primarily concerned with open channel flow, which is governed by the interdependent interaction between the water and the channel.

- Applications include the design of hydraulic structures, such as sewage conduits, dams and breakwaters, the management of waterways, such as erosion protection and flood protection, and environmental management, such as prediction of the mixing and transport of pollutants in surface water.

PROPERTIES OF FLUIDS:

1.DENSITY or MASS DENSITY

- The density, or more precisely, the volumetric mass density, of a substance is its mass per unit volume.
- The symbol most often used for density is ρ (Greek letter rho).
- Mathematically, density is defined as mass divided by volume .

$$\rho = \frac{m}{V}$$

Where, ρ = density
m =mass and
V = volume

- Its unitr is g/cm^3 or kg/m^3

Note:-

- density of water (ρ_w)= $1 g/cm^3$ or $1000 kg/m^3$
- The density of mercury at 20 degree C to be 13545.848 kg/m3 OR 13.6 g/cm^3

2.SPECIFIC WEIGHT or WEIGHT DENSITY OR UNIT WEIGHT :

- The specific weight is the weight per unit volume of a material.
- It is denoted as the symbol w.

Mathematically,

$$w = \frac{\text{weight of fluid}}{\text{Volume of fluid}}$$

OR, w= W/V

- Its unit is N/M^3 or KN/M^3

NOTE : Unit weight of water γw = 9.81 KN/ M3

- Relation between density and unit weight :-

$$w = \rho \times g$$

3.SPECIFIC GRAVITY:

- It is defined as the ratio of the weight density of a fluid to weight density of a standard fluid.
- For liquids the standard fluid is taken as water and for gases the standard fluid is given as air.
- It is denoted as G.

G(for liquids) = weight density of LIQUID / weight density of water

Mathematically, $G = w_L / w_w$ or $G = \rho_L / \rho_w$

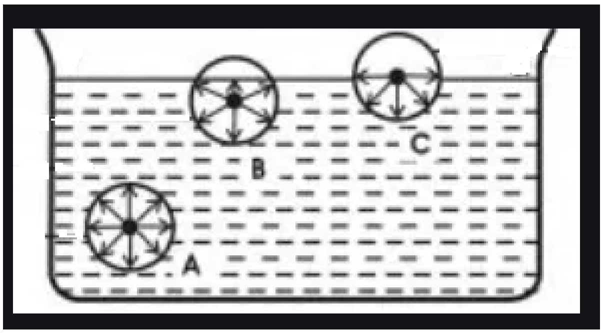
G(for gases) =weight density of gases/ weight density of air

Mathematically, $G = w_g / w_a$ or $G = \rho_g / \rho_a$

- Specific gravity of Mercury is 13.6 and water is 1.

4.SURFACE TENSION :

- It is defined as the tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquids such that the contact surface behaves like a membrane under tension.
- The magnitude of this force per unit length of the free surface will have the same value as the surface energy per unit area.
- A property of liquids such that their surfaces behave like a thin, elastic film. Surface tension is an effect of intermolecular attraction, in which molecules at or near the surface undergo a net attraction to the rest of the fluid, while molecules not near the surface are attracted to other molecules equally in all directions and undergo no net attraction.
- Surface tension is due to cohesive forces.
- It decreases with increase in temperature.
- It is denoted as σ (called sigma).
- Mathematically , σ =force / length
- Unit is N/m



Case 1: Liquid Droplet

Let d = diameter of droplet.

σ = surface tension

p = pressure in excess of atmosphere (gauge pressure)

Under equilibrium,

Pressure force = surface tension

$$p \times \frac{\pi}{4} d^2 = \sigma \times \pi \times d.$$

$$\boxed{p = \frac{4\sigma}{d}}$$

Case 2: Soap Bubble.

$$p \times \frac{\pi}{4} d^2 = \sigma (2 \times \pi \times d)$$

$$\boxed{p = \frac{8\sigma}{d}}$$

Case 3: Liquid Jet.

$$p \times l \times d = \sigma \times 2l.$$

$$\boxed{p = \frac{2\sigma}{d}}$$

Q1. The surface tension of water in contact with air at 20 $° C$ is 0.0725N/M. The pressure inside a droplet of water is to be 0.02N/CM^2 greater than the outside pressure. Calculate the diameter of droplet of water.

ANS:
Given data :
Surface tension , σ =0.0725N/M
Temperature ,t= 20 $° C$
Inside pressure ,p= 0.02N/CM^2
=0.02*10^4 N/M^2
Diameter of droplet,d=?
We know,
For droplet,P = 4 σ / d
=(4*0.0725)/ 0.02*10^4
=1.45*10^{-3} mt
=1.45 MM ANS.

Q2. Find the surface tension in a soap bubble of 40mm diameter.when the inside pressure is 2.5N/M^2 above the atmospheric pressure.
ANS:
GIVEN DATA:
Diameter of soap bubble (d)=40mm=40* 10^{-3} N/M^2
Surface tension, σ =?
WE KNOW, p=8 σ /d
=> σ =(p*d) /8
=(2.5 *40*10^{-3}) / 8
=0.0125 N/m ANS.

Problem 1.27 *The pressure outside the droplet of water of diameter 0.04 mm is 10.32 N/cm² (atmospheric pressure). Calculate the pressure within the droplet if surface tension is given as 0.0725 N/m of water.*

Solution. Given :

Dia. of droplet, $d = 0.04 \text{ mm} = .04 \times 10^{-3}$ m

Pressure outside the droplet $= 10.32 \text{ N/cm}^2 = 10.32 \times 10^4 \text{ N/m}^2$

Surface tension, $\sigma = 0.0725$ N/m

The pressure inside the droplet, in excess of outside pressure is given by equation (1.14)

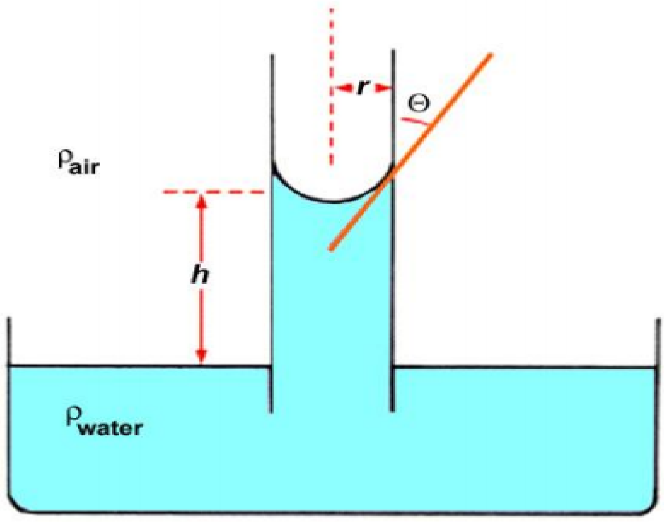
or
$$p = \frac{4\sigma}{d} = \frac{4 \times 0.0725}{.04 \times 10^{-3}} = 7250 \text{ N/m}^2 = \frac{7250 \text{ N}}{10^4 \text{ cm}^2} = 0.725 \text{ N/cm}^2$$

$\therefore$ Pressure inside the droplet $= p +$ Pressure outside the droplet

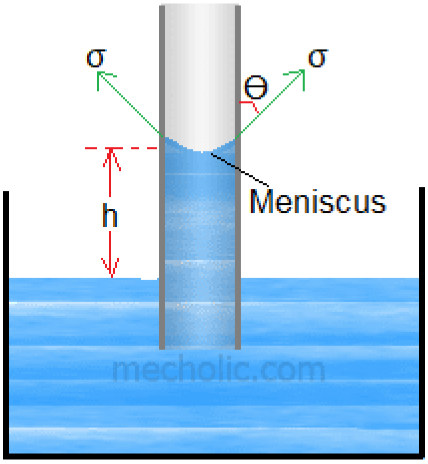
$= 0.725 + 10.32 =$ **11.045 N/cm². Ans.**

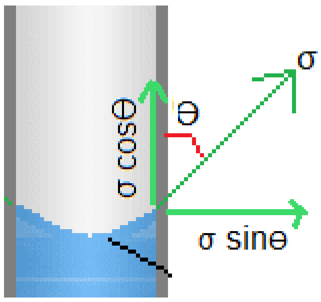
5.CAPILLARITY :

- Capillarity is defined as a phenomenon of rise or fall of a liquid surface in small tube relative to the adjacent general level of liquid when the tube is held vertically in the liquid.
- The rise of liquid surface within the narrow tube is known as capillary rise .
- While the fall of liquid surface within the narrow tube is known as capillary depression or capillary fall.
- It is expressed in terms of cm or mm of liquid.
- Its value depends upon the specific weight of the liquid, diameter of the tube and surface tension of the liquid.



A. **Expression for height in Capillary rise**





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Consider a narrow glass tube of diameter 'd' dipped in a liquid (say water).
- Water in the tube will rise above the adjacent liquid level. It is called capillary rise.

Let σ = Surface tension of liquid.
Θ = Angle of contact between the glass tube and the liquid surface.
h = Height of liquid column in glass tube.

Under equilibrium, two forces are acting on the water inside.
- The first one is weight of water column and second is the upward force acting on water due to surface tension.
- The weight of liquid of height 'h' should be balanced by the force at liquid surface.
- This force at surface of liquid is due to surface tension.

The weight of liquid of height 'h' in the tube = Volume x ρ x g
= $(\pi/4)d^2$ x h x ρ x g ----------(i)

Here, ρ = density of liquid
g = acceleration due to gravity.

The vertical component of surface tensile force = surface tension x circumference x cosΘ
= σ x πd x cosΘ -----------------(ii)

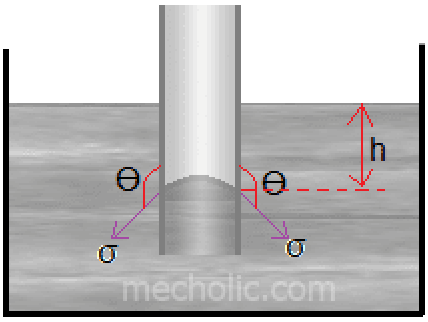
At equilibrium, the weight of liquid balanced by the vertical component of tensile force.so,

$$\frac{\pi}{4}d^2\, h\, \rho\, g = \sigma\, \pi d \cos\Theta$$

$$h = \frac{4\,\sigma \cos\Theta}{\rho g d}$$

- For water and glass tube, the angle Θ is almost zero ,so, cosΘ ≈ 1
- Then the equation for capillary rise of water in the glass tube is, h = 4 σ /(ρ g d)

B.**Expression for Capillary fall** :



- Consider a narrow glass tube dipped in mercury, the level of mercury in tube will be lower than the surface level of mercury outside the tube. It is called capillary depression or capillary fall.
- Consider the mercury glass tube arrangement as shown in figure.
- Two forces are acting on the mercury inside the tube.
- First one is hydrostatic force that acting upward, and second one is downward force due to surface tension.
- In equilibrium condition these forces must be equal.

Let h = height of capillary depression.

The hydrostatic force on liquid = Intensity of pressure at depth h x Area

= $\rho \times g \times h \times (\pi/4)d^2$ --(i)

SO, Surface tension acting downward = Surface tension x circumference x cosΘ

= $\sigma \times \pi d \times \cos\Theta$ --(ii)

Equating two forces, we get

$$\frac{\pi}{4} d^2\, h\, \rho\, g = \sigma\, \pi d \cos\Theta$$

$$h = \frac{4\, \sigma \cos\Theta}{\rho g d}$$

- The value of contact angle for mercury in glass tube = 128°

Problem 1.28 *Calculate the capillary rise in a glass tube of 2.5 mm diameter when immersed vertically in (a) water and (b) mercury. Take surface tensions $\sigma = 0.0725$ N/m for water and $\sigma = 0.52$ N/m for mercury in contact with air. The specific gravity for mercury is given as 13.6 and angle of contact = 130°.*

Solution. Given :

Dia. of tube,	$d = 2.5$ mm $= 2.5 \times 10^{-3}$ m
Surface tension, σ for water	$= 0.0725$ N/m
σ for mercury	$= 0.52$ N/m
Sp. gr. of mercury	$= 13.6$

$\therefore$ Density $= 13.6 \times 1000$ kg/m^3.

(*a*) **Capillary rise for water ($\theta = 0°$)**

Using equation (1.20), we get $h = \dfrac{4\sigma}{\rho \times g \times d} = \dfrac{4 \times 0.0725}{1000 \times 9.81 \times 2.5 \times 10^{-3}}$

$= .0118$ m $=$ **1.18 cm. Ans.**

(*b*) **For mercury**

Angle of contact between mercury and glass tube, $\theta = 130°$

Using equation (1.21), we get $h = \dfrac{4\sigma \cos\theta}{\rho \times g \times d} = \dfrac{4 \times 0.52 \times \cos 130°}{13.6 \times 1000 \times 9.81 \times 2.5 \times 10^{-3}}$

$= -.004$ m $= -$ **0.4 cm. Ans.**

The negative sign indicates the capillary depression.

Problem 1.29 *Calculate the capillary effect in millimetres in a glass tube of 4 mm diameter, when immersed in (i) water, and (ii) mercury. The temperature of the liquid is 20°C and the values of the surface tension of water and mercury at 20°C in contact with air are 0.073575 N/m and 0.51 N/m respectively. The angle of contact for water is zero and that for mercury is 130°. Take density of water at 20°C as equal to 998 kg/m^3.*

Solution. Given :

Dia. of tube, $d = 4$ mm $= 4 \times 10^{-3}$ m

The capillary effect (*i.e.*, capillary rise or depression) is given by equation (1.20) as

$$h = \frac{4\sigma \cos\theta}{\rho \times g \times d}$$

where σ = surface tension in N/m

θ = angle of contact, and ρ = density

(*i*) **Capillary effect for water**

$\sigma = 0.073575$ N/m, $\theta = 0°$

$\rho = 998$ kg/m^3 at 20°C

$$\therefore \quad h = \frac{4 \times 0.073575 \times \cos 0°}{998 \times 9.81 \times 4 \times 10^{-3}} = 7.51 \times 10^{-3} \text{ m} = \textbf{7.51 mm. Ans.}$$

(*ii*) **Capillary effect for mercury**

$\sigma = 0.51$ N/m, $\theta = 130°$ and

ρ = sp. gr. $\times 1000 = 13.6 \times 1000 = 13600$ kg/m^2

$$\therefore \quad h = \frac{4 \times 0.51 \times \cos 130°}{13600 \times 9.81 \times 4 \times 10^{-3}} = -2.46 \times 10^{-3} \text{ m} = \textbf{– 2.46 mm. Ans.}$$

The negative sign indicates the capillary depression.

Problem 1.30 *The capillary rise in the glass tube is not to exceed 0.2 mm of water. Determine its minimum size, given that surface tension for water in contact with air = 0.0725 N/m.*

Solution. Given :

Capillary rise, $h = 0.2$ mm $= 0.2 \times 10^3$ m

Surface tension, $\sigma = 0.0725$ N/m

Let dia. of tube $= d$

The angle θ for water $= 0°$

Density (ρ) for water $= 1000$ kg/m^3

Using equation (1.20), we get

$$h = \frac{4\sigma}{\rho \times g \times d} \text{ or } 0.2 \times 10^{-3} = \frac{4 \times 0.0725}{1000 \times 9.81 \times d}$$

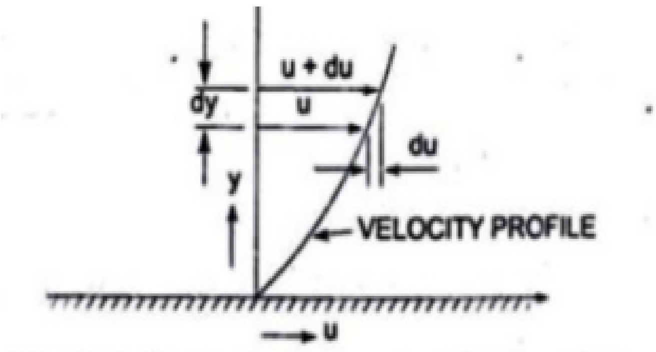
$$\therefore \quad d = \frac{4 \times 0.0725}{1000 \times 9.81 \times .2 \times 10^{-3}} = 0.148 \text{ m} = \textbf{14.8 cm. Ans.}$$

Thus minimum diameter of the tube should be 14.8 cm.

6.VISCOSITY :

It is defined as the property of a fluid which offers resistance to the movement of one layer of fluid over another adjacent layer of the fluid.
Example: Syrup or honey has a higher viscosity than water.

- When two layers of a fluid placed at a distance 'dy' apart , move one over the other at different velocities, lets say, 'u' and 'u+du' . the viscosity together with relative viscosity causes a shear stress acting between the fluid layer.



Uses of Viscosity:

- Gathering the data of the viscosity of a given material helps manufacturers predict how the material behaves in the real world.
- For example, if the toothpaste does not have the correct viscosity, it will either be too difficult to pump out the paste from the tube or too much of it will be pumped out.
- Also, knowing the viscosity of a material affects how the production and transportation processes are designed.

Types of Viscosity :

- As we know, the viscosity is the measure of the friction of fluids.
- There are two ways to measure a fluid's viscosity as follows:

  1.Dynamic Viscosity or (Absolute Viscosity)

  2. Kinematic Viscosity

1. **Dynamic Viscosity or Absolute Viscosity(**c) :

- Dynamic viscosity is also known as *absolute viscosity* and most often relates to non-Newtonian fluids.
- It refers to the fluid's internal resistance to flow when force is applied.
- Dynamic viscosity measures the ratio of the shear stress to the shear rate for a fluid."
- Mathematically ; $\mu = \tau / (du/dy)$

  unit:

- S.I unit = $N.S/m^2$

- M.K.S. unit = kgf-s/m²
- C.G.S. unit= Dyne.sec/cm^2 .

  NOTE:

  1N= 10^5 Dyne

  1kgf = 9.81 N

  1 poise= 1/10 N.S/m^2

  1 N.S/m^2 = 10 poise

2.Kinematic viscosity (v):

- Kinematic viscosity is a measure of the viscosity of a (usually Newtonian fluid) fluid in motion.
- It can be defined as the ratio of dynamic viscosity to density.
- Any viscometer that uses gravity in its measurement design is measuring kinematic viscosity
- Mathematically, v = μ / ρ

  unit :

- S.I unit = m^2/sec
- C.G.S. unit= cm^2/sec = stoke
- 1stoke = 10^{-4} m^2/sec
- 1m^2/sec =10^4 stoke

Problem 1.3 *If the velocity distribution over a plate is given by* $u = \frac{2}{3} y - y^2$ *in which u is the velocity in metre per second at a distance y metre above the plate, determine the shear stress at y = 0 and y = 0.15 m. Take dynamic viscosity of fluid as 8.63 poises.*

Solution. Given : $u = \frac{2}{3}y - y^2 \quad \therefore \quad \frac{du}{dy} = \frac{2}{3} - 2y$

$$\left(\frac{du}{dy}\right)_{\text{at } y=0} \text{ or } \left(\frac{du}{dy}\right)_{y=0} = \frac{2}{3} - 2(0) = \frac{2}{3} = 0.667$$

Also $$\left(\frac{du}{dy}\right)_{\text{at } y=0.15} \text{ or } \left(\frac{du}{dy}\right)_{y=0.15} = \frac{2}{3} - 2 \times .15 = .667 - .30 = 0.367$$

Value of $\mu = 8.63$ poise $= \frac{8.63}{10}$ SI units $= 0.863$ N s/m^2

Now shear stress is given by equation (1.2) as $\tau = \mu \frac{du}{dy}$.

(*i*) Shear stress at $y = 0$ is given by

$$\tau_0 = \mu\left(\frac{du}{dy}\right)_{y=0} = 0.863 \times 0.667 = \mathbf{0.5756\ N/m^2.\ Ans.}$$

(*ii*) Shear stress at $y = 0.15$ m is given by

$$(\tau)_{y=0.15} = \mu\left(\frac{du}{dy}\right)_{y=0.15} = 0.863 \times 0.367 = \mathbf{0.3167\ N/m^2.\ Ans.}$$

Problem 1.4 *A plate 0.025 mm distant from a fixed plate, moves at 60 cm/s and requires a force of 2 N per unit area i.e., 2 N/m^2 to maintain this speed. Determine the fluid viscosity between the plates.*

Solution. Given :

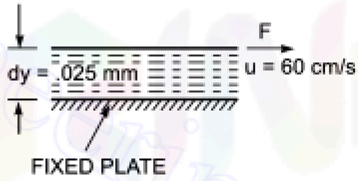


Fig. 1.3

Distance between plates, $dy = .025$ mm $= .025 \times 10^{-3}$ m

Velocity of upper plate, $u = 60$ cm/s $= 0.6$ m/s

Force on upper plate, $F = 2.0 \frac{\text{N}}{\text{m}^2}$.

This is the value of shear stress *i.e.*, τ

Let the fluid viscosity between the plates is μ.

Using the equation (1.2), we have $\tau = \mu \frac{du}{dy}$.

where du = Change of velocity $= u - 0 = u = 0.60$ m/s

dy = Change of distance $= .025 \times 10^{-3}$ m

τ = Force per unit area $= 2.0 \frac{\text{N}}{\text{m}^2}$

$$\therefore \quad 2.0 = \mu \frac{0.60}{.025 \times 10^{-3}} \quad \therefore \quad \mu = \frac{2.0 \times .025 \times 10^{-3}}{0.60} = 8.33 \times 10^{-5} \frac{\text{Ns}}{\text{m}^2}$$

$$= 8.33 \times 10^{-5} \times 10 \text{ poise} = \mathbf{8.33 \times 10^{-4}\ poise.\ Ans.}$$

Problem 1.6 *Determine the intensity of shear of an oil having viscosity = 1 poise. The oil is used for lubricating the clearance between a shaft of diameter 10 cm and its journal bearing. The clearance is 1.5 mm and the shaft rotates at 150 r.p.m.*

Solution. Given : $\mu = 1 \text{ poise} = \frac{1}{10} \frac{\text{N s}}{\text{m}^2}$

Dia. of shaft, $D = 10 \text{ cm} = 0.1 \text{ m}$

Distance between shaft and journal bearing,

$$dy = 1.5 \text{ mm} = 1.5 \times 10^{-3} \text{ m}$$

Speed of shaft, $N = 150$ r.p.m.

Tangential speed of shaft is given by

$$u = \frac{\pi DN}{60} = \frac{\pi \times 0.1 \times 150}{60} = 0.785 \text{ m/s}$$

Using equation (1.2), $\tau = \mu \frac{du}{dy}$,

where du = change of velocity between shaft and bearing = $u - 0 = u$

$$= \frac{1}{10} \times \frac{0.785}{1.5 \times 10^{-3}} = \mathbf{52.33 \ N/m^2.\ Ans.}$$

Problem 1.8 *Two horizontal plates are placed 1.25 cm apart, the space between them being filled with oil of viscosity 14 poises. Calculate the shear stress in oil if upper plate is moved with a velocity of 2.5 m/s.*

Solution. Given :

Distance between plates, $dy = 1.25 \text{ cm} = 0.0125 \text{ m}$

Viscosity, $\mu = 14 \text{ poise} = \frac{14}{10} \text{ N s/m}^2$

Velocity of upper plate, $u = 2.5$ m/sec.

Shear stress is given by equation (1.2) as, $\tau = \mu \frac{du}{dy}$

where du = Change of velocity between plates = $u - 0 = u = 2.5$ m/sec.

$$dy = 0.0125 \text{ m.}$$

$$\therefore \quad \tau = \frac{14}{10} \times \frac{2.5}{.0125} = \mathbf{280 \ N/m^2.\ Ans.}$$

Problem 1.9 *The space between two square flat parallel plates is filled with oil. Each side of the plate is 60 cm. The thickness of the oil film is 12.5 mm. The upper plate, which moves at 2.5 metre per sec requires a force of 98.1 N to maintain the speed. Determine :*

(i) the dynamic viscosity of the oil in poise, and

(ii) the kinematic viscosity of the oil in stokes if the specific gravity of the oil is 0.95.

Solution. Given :

Each side of a square plate = 60 cm = 0.60 m

$\therefore$ Area, $A = 0.6 \times 0.6 = 0.36 \text{ m}^2$

Thickness of oil film, $dy = 12.5 \text{ mm} = 12.5 \times 10^{-3} \text{ m}$

Velocity of upper plate, $u = 2.5$ m/sec

$\therefore$ Change of velocity between plates, $du = 2.5$ m/sec

Force required on upper plate, $F = 98.1$ N

$\therefore$ Shear stress, $\tau = \dfrac{\text{Force}}{\text{Area}} = \dfrac{F}{A} = \dfrac{98.1\text{ N}}{0.36\text{ m}^2}$

(*i*) Let μ = Dynamic viscosity of oil

Using equation (1.2), $\tau = \mu \dfrac{du}{dy}$ or $\dfrac{98.1}{0.36} = \mu \times \dfrac{2.5}{12.5 \times 10^{-3}}$

$\therefore$ $\mu = \dfrac{98.1}{0.36} \times \dfrac{12.5 \times 10^{-3}}{2.5} = 1.3635 \dfrac{\text{Ns}}{\text{m}^2}$ $\left(\because \dfrac{1\text{ Ns}}{\text{m}^2} = 10\text{ poise}\right)$

$= 1.3635 \times 10 =$ **13.635 poise. Ans.**

(*ii*) Sp. gr. of oil, S = 0.95

Let ν = kinematic viscosity of oil

Using equation (1.1*A*),

Mass density of oil, $\rho = S \times 1000 = 0.95 \times 1000 = 950$ kg/m^3

Using the relation, $\nu = \dfrac{\mu}{\rho}$, we get $\nu = \dfrac{1.3635\left(\dfrac{\text{Ns}}{\text{m}^2}\right)}{950} = .001435$ m^2/sec $= .001435 \times 10^4$ cm^2/s

$=$ **14.35 stokes. Ans.** ($\because$ cm^2/s = stoke)

Problem 1.10 *Find the kinematic viscosity of an oil having density 981 kg/m^3. The shear stress at a point in oil is 0.2452 N/m^2 and velocity gradient at that point is 0.2 per second.*

Solution. Given :

Mass density, $\rho = 981$ kg/m^3

Shear stress, $\tau = 0.2452$ N/m^2

Velocity gradient, $\dfrac{du}{dy} = 0.2$ s

Using the equation (1.2), $\tau = \mu \dfrac{du}{dy}$ or $0.2452 = \mu \times 0.2$

$\therefore$ $\mu = \dfrac{0.2452}{0.200} = 1.226$ Ns/m^2

Kinematic viscosity ν is given by

$\therefore$ $\nu = \dfrac{\mu}{\rho} = \dfrac{1.226}{981} = .125 \times 10^{-2}$ m^2/sec

$= 0.125 \times 10^{-2} \times 10^4$ cm^2/s $= 0.125 \times 10^2$ cm^2/s

$= 12.5$ cm^2/s $=$ **12.5 stoke. Ans.** ($\because$ cm^2/s = stoke)

Problem 1.11 *Determine the specific gravity of a fluid having viscosity 0.05 poise and kinematic viscosity 0.035 stokes.*

Solution. Given :

Viscosity, $\mu = 0.05$ poise $= \dfrac{0.05}{10}$ N s/m^2

Kinematic viscosity, $\nu = 0.035$ stokes

$= 0.035\ cm^2/s$ $\{\because$ Stoke $= cm^2/s\}$

$= 0.035 \times 10^{-4}\ m^2/s$

Using the relation $\nu = \frac{\mu}{\rho}$, we get $0.035 \times 10^{-4} = \frac{0.05}{10} \times \frac{1}{\rho}$

$$\therefore \quad \rho = \frac{0.05}{10} \times \frac{1}{0.035 \times 10^{-4}} = 1428.5\ kg/m^3$$

$$\therefore \quad \text{Sp. gr. of liquid} = \frac{\text{Density of liquid}}{\text{Density of water}} = \frac{1428.5}{1000} = 1.4285 \simeq \mathbf{1.43.\ Ans.}$$

NEWTON'S LAW OF VISCOSITY :

- It states that the shear stress on a fluid element layer is directly proportional to the rate of shear strain.
- The constant of proportionality is called the coefficient of viscosity.
- Mathematically,

$$\tau = \mu \frac{du}{dy}$$

Where , τ = shear stress

μ= coefficient of viscosity or viscosity

ARTICLE 1.2
(Pressure and its measurements)

Fluid pressure :

"It is defined as a normal force exerted by a fluid per unit area."
Mathematically,

Pressure = force/area
P=F/A

Unit:

S.I. unit : Pascal or N/m2
M.K.S. unit =kgf/m^2
C.G.S . unit =dyne/cm^2

1 Pa = 1 N/m2

1 bar = 10^5 N/m2 or Pascal
1 Pascal =10^{-5} bar

Pressure head(h):

"Pressure exerted by a liquid column can also be expressed as the height of equivalent liquid column called pressure head."

So, Pressure, P = ρ g h

Where,

P = Fluid Pressure,
ρ = Density of fluid,

h = Pressure head

or, Pressure head,

h = P/ ρ g

Unit : meter or cm

Problem 2.3 *Calculate the pressure due to a column of 0.3 of (a) water, (b) an oil of sp. gr. 0.8, and (c) mercury of sp. gr. 13.6. Take density of water, ρ = 1000 kg/m³.*

Solution. Given :

Height of liquid column, $Z = 0.3$ m.

The pressure at any point in a liquid is given by equation (2.5) as

$$p = \rho g Z$$

(*a*) For water, $\rho = 1000 \text{ kg/m}^3$

$$\therefore \quad p = \rho g Z = 1000 \times 9.81 \times 0.3 = 2943 \text{ N/m}^2$$
$$= \frac{2943}{10^4} \text{ N/cm}^2 = \mathbf{0.2943 \text{ N/cm}^2}. \textbf{ Ans.}$$

(*b*) For oil of sp. gr. 0.8,

From equation (1.1*A*), we know that the density of a fluid is equal to specific gravity of fluid multiplied by density of water.

$\therefore$ Density of oil, ρ_0 = Sp. gr. of oil × Density of water (ρ_0 = Density of oil)

$$= 0.8 \times \rho = 0.8 \times 1000 = 800 \text{ kg/m}^3$$

Now pressure, $p = \rho_0 \times g \times Z$

$$= 800 \times 9.81 \times 0.3 = 2354.4 \frac{\text{N}}{\text{m}^2} = \frac{2354.4}{10^4} \frac{\text{N}}{\text{cm}^2}.$$
$$= \mathbf{0.2354 \frac{N}{cm^2}}. \textbf{ Ans.}$$

(*c*) For mercury, sp. gr. = 13.6

From equation (1.1*A*) we know that the density of a fluid is equal to specific gravity of fluid multiplied by density of water

$\therefore$ Density of mercury, ρ_s = Specific gravity of mercury × Density of water

$$= 13.6 \times 1000 = 13600 \text{ kg/m}^3$$

$$\therefore \quad p = \rho_s \times g \times Z$$
$$= 13600 \times 9.81 \times 0.3 = 40025 \frac{\text{N}}{\text{m}^2}$$
$$= \frac{40025}{10^4} = \mathbf{4.002 \frac{N}{cm^2}}. \textbf{ Ans.}$$

Problem 2.4 *The pressure intensity at a point in a fluid is given 3.924 N/cm². Find the corresponding height of fluid when the fluid is : (a) water, and (b) oil of sp. gr. 0.9.*

Solution. Given :

Pressure intensity, $p = 3.924 \dfrac{\text{N}}{\text{cm}^2} = 3.924 \times 10^4 \dfrac{\text{N}}{\text{m}^2}$.

The corresponding height, Z, of the fluid is given by equation (2.6) as

$$Z = \frac{p}{\rho \times g}$$

(*a*) For water, $\rho = 1000 \text{ kg/m}^3$

$$\therefore \quad Z = \frac{p}{\rho \times g} = \frac{3.924 \times 10^4}{1000 \times 9.81} = \textbf{4 m of water. Ans.}$$

(*b*) For oil, sp. gr. $= 0.9$

∴ Density of oil $\rho_0 = 0.9 \times 1000 = 900 \text{ kg/m}^3$

$$\therefore \quad Z = \frac{p}{\rho_0 \times g} = \frac{3.924 \times 10^4}{900 \times 9.81} = \textbf{4.44 m of oil. Ans.}$$

Problem 2.5 *An oil of sp. gr. 0.9 is contained in a vessel. At a point the height of oil is 40 m. Find the corresponding height of water at the point.*

Solution. Given :

Sp. gr. of oil, $S_0 = 0.9$

Height of oil, $Z_0 = 40$ m

Density of oil, $\rho_0 = $ Sp. gr. of oil × Density of water $= 0.9 \times 1000 = 900 \text{ kg/m}^3$

Intensity of pressure, $p = \rho_0 \times g \times Z_0 = 900 \times 9.81 \times 40 \dfrac{\text{N}}{\text{m}^2}$

$$\therefore \text{ Corresponding height of water} = \frac{p}{\text{Density of water} \times g}$$

$$= \frac{900 \times 9.81 \times 40}{1000 \times 9.81} = 0.9 \times 40 = \textbf{36 m of water. Ans.}$$

Problem 2.6 *An open tank contains water upto a depth of 2 m and above it an oil of sp. gr. 0.9 for a depth of 1 m. Find the pressure intensity (i) at the interface of the two liquids, and (ii) at the bottom of the tank.*

Solution. Given :

Height of water, $Z_1 = 2$ m

Height of oil, $Z_2 = 1$ m

Sp. gr. of oil, $S_0 = 0.9$

Density of water, $\rho_1 = 1000 \text{ kg/m}^3$

Density of oil, $\rho_2 = $ Sp. gr. of oil × Density of water $= 0.9 \times 1000 = 900 \text{ kg/m}^3$

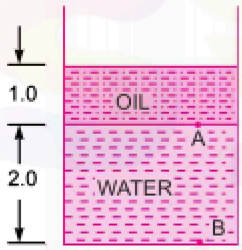


Fig. 2.4

Pressure intensity at any point is given by

$$p = \rho \times g \times Z.$$

(*i*) At interface, *i.e.*, at *A*

$$p = \rho_2 \times g \times 1.0$$
$$= 900 \times 9.81 \times 1.0$$
$$= 8829 \frac{\text{N}}{\text{m}^2} = \frac{8829}{10^4} = \textbf{0.8829 N/cm}^2\textbf{. Ans.}$$

(*ii*) At the bottom, *i.e.*, at *B*

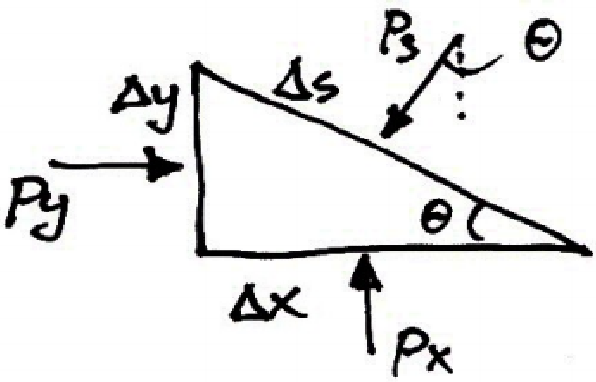
$$p = \rho_2 \times gZ_2 + \rho_1 \times g \times Z_1 = 900 \times 9.81 \times 1.0 + 1000 \times 9.81 \times 2.0$$
$$= 8829 + 19620 = 28449 \text{ N/m}^2 = \frac{28449}{10^4} \text{ N/cm}^2 = \textbf{2.8449 N/cm}^2\textbf{. Ans.}$$

Pascal's Law :

- "Pressure or Intensity of pressure at a point in a static fluid is equal in all directions."

Mathematically, $Px = Py = Pz$

- To show this, we will consider a very small wedge of fluid surrounding the point. This wedge is unit thickness into the page :



Concept of atmospheric pressure ,absolute pressure, gauge pressure, vacuum pressure:

1. Atmospheric Pressure -

- This pressure exerted by the atmosphere on any surface is called atmospheric pressure.
- Atmospheric pressure at a place depends on the elevation of the place and the temperature.
- Atmospheric pressure is measured using an instrument called „Barometer" and hence atmospheric pressure is also called Barometric pressure.

2.Absolute Pressure –

- It is defined as the pressure which is measured with reference to absolute zero pressure.

- Absolute pressure at a point can never be negative since there can be no pressure less than absolute zero pressure.

3. Gauge Pressure -

- It is defined as the pressure which is measured above the atmospheric pressure.

- It can be measured by pressure measuring instrument in which atmospheric pressure is taken as datum and it marked as zero.

4. Vacuum Pressure (Negative Gauge Pressure) –

- It is defined as the pressure below the atmospheric pressure.

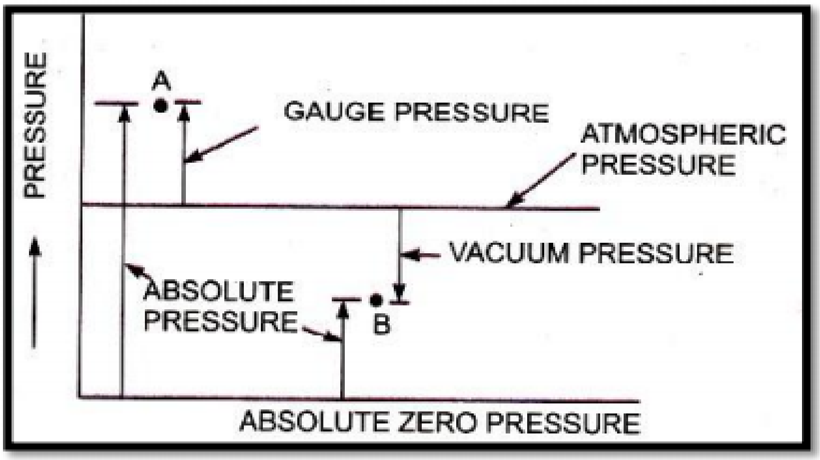


Fig. Relationship between pressures

NOTE:

- Absolute Gauge Pressure = Atmospheric Pressure + Gauge Pressure
- Absolute Vacuum Pressure = Atmospheric Pressure - Vacuum Pressure

$$P_{gage} = P_{abs} - P_{atm}$$
$$P_{vac} = P_{atm} - P_{abs}$$

Problem 2.8 *What are the gauge pressure and absolute pressure at a point 3 m below the free surface of a liquid having a density of 1.53×10^3 kg/m^3 if the atmospheric pressure is equivalent to 750 mm of mercury ? The specific gravity of mercury is 13.6 and density of water = 1000 kg/m^3.*

Solution. Given :

Depth of liquid, $Z_1 = 3$ m

Density of liquid, $\rho_1 = 1.53 \times 10^3$ kg/m^3

Atmospheric pressure head, $Z_0 = 750$ mm of Hg

$$= \frac{750}{1000} = 0.75 \text{ m of Hg}$$

$\therefore$ Atmospheric pressure, $p_{atm} = \rho_0 \times g \times Z_0$

where ρ_0 = Density of Hg = Sp. gr. of mercury × Density of water = 13.6 × 1000 kg/m^3

and Z_0 = Pressure head in terms of mercury.

$$\therefore \quad p_{atm} = (13.6 \times 1000) \times 9.81 \times 0.75 \text{ N/m}^2 \quad (\because \; Z_0 = 0.75)$$
$$= 100062 \text{ N/m}^2$$

Pressure at a point, which is at a depth of 3 m from the free surface of the liquid is given by,

$$p = \rho_1 \times g \times Z_1$$
$$= (1.53 \times 1000) \times 9.81 \times 3 = 45028 \text{ N/m}^2$$

$\therefore$ Gauge pressure, p = **45028 N/m^2. Ans.**

Now absolute pressure = Gauge pressure + Atmospheric pressure

= 45028 + 100062 = **145090 N/m^2. Ans.**

Measurement of Pressure:

Various devices used to measure fluid pressure can be classified into,

1. Manometers

2. Mechanical gauges

1. Manometers-

- Manometers are the pressure measuring devices which are based on the principal of balancing the column of the liquids whose pressure is to be measured by the same liquid or another liquid.

- Manometers are broadly classified into:
  A. Simple Manometers
  B. Differential Manometers

2. **Mechanical Gauges** –

- Mechanical gauges consist of an elastic element which deflects under the action of applied pressure and this movement will operate a pointer on a graduated scale.
- The mechanical pressure gauges are:
- A. Diaphragm pressure gauge
- B. Bourdon tube pressure gauge
- C. Dead weight pressure gauge
- D. Below pressure gauge

ARTICLE-1.3
[Pressure exerted on an immersed surface]

<u>Total Pressure and Centre of Pressure</u>

Total Pressure (P):

- Total pressure is defined as the force exerted by a static fluid on a surface either plane or curved when the fluid comes in contact with the surface and this force always normal to the surface.

Centre of Pressure (G):

- Centre of pressure is defined as the point of application of the total pressure on the surface.
- The submerged surfaces may be:

  1. Plane surface submerged in static fluid
     a. Vertical plane surface
     b. Horizontal plane surface
     c. Inclined plane surface

  2. Curved surface submerged in static fluid

a.VERTICAL PLANE SURFACE SUBMERGED IN LIQUID

(*a*) **Total Pressure (F)**. The total pressure on the surface may be determined by dividing the entire surface into a number of small parallel strips. The force on small strip is then calculated and the total pressure force on the whole area is calculated by integrating the force on small strip.

Consider a strip of thickness dh and width b at a depth of h from free surface of liquid as shown in Fig. 3.1

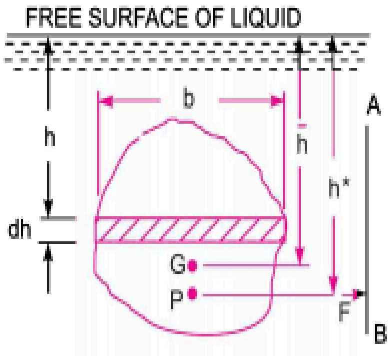


Fig. 3.1

Pressure intensity on the strip, $p = \rho g h$

(See equation 2.5)

Area of the strip, $dA = b \times dh$

Total pressure force on strip, $dF = p \times \text{Area}$

$= \rho g h \times b \times dh$

$\therefore$ Total pressure force on the whole surface,

$$F = \int dF = \int \rho g h \times b \times dh = \rho g \int b \times h \times dh$$

But $\int b \times h \times dh = \int h \times dA$

= Moment of surface area about the free surface of liquid

= Area of surface × Distance of C.G. from free surface

$= A \times \bar{h}$

$$\therefore \quad F = \rho g A \bar{h} \qquad \ldots(3.1)$$

For water the value of $\rho = 1000\ \text{kg/m}^3$ and $g = 9.81\ \text{m/s}^2$. The force will be in Newton.

(*b*) **Centre of Pressure (h*)**. Centre of pressure is calculated by using the "Principle of Moments", which states that the moment of the resultant force about an axis is equal to the sum of moments of the components about the same axis.

The resultant force F is acting at P, at a distance h^* from free surface of the liquid as shown in Fig. 3.1. Hence moment of the force F about free surface of the liquid $= F \times h^*$ ...(3.2)

Moment of force dF, acting on a strip about free surface of liquid

$= dF \times h$ $\quad \{\because \ dF = \rho g h \times b \times dh\}$

$= \rho g h \times b \times dh \times h$

Sum of moments of all such forces about free surface of liquid

$$= \int \rho g h \times b \times dh \times h = \rho g \int b \times h \times h dh$$

$$= \rho g \int b h^2 \, dh = \rho g \int h^2 \, dA \qquad (\because \ b dh = dA)$$

But $\int h^2 dA = \int b h^2 dh$

= Moment of Inertia of the surface about free surface of liquid

$= I_0$

$\therefore$ Sum of moments about free surface

$$= \rho g I_0 \qquad \ldots(3.3)$$

Equating (3.2) and (3.3), we get

$$F \times h^* = \rho g I_0$$

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

$\therefore \quad \rho g A\bar{h} \times h^* = \rho g I_0$

or
$$h^* = \frac{\rho g I_0}{\rho g A\bar{h}} = \frac{I_0}{A\bar{h}} \qquad \ldots(3.4)$$

By the theorem of parallel axis, we have

$$I_0 = I_G + A \times \bar{h}^2$$

where I_G = Moment of Inertia of area about an axis passing through the C.G. of the area and parallel to the free surface of liquid.

Substituting I_0 in equation (3.4), we get

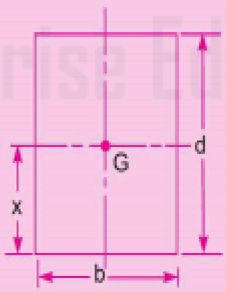
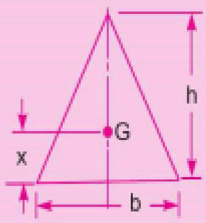
$$h^* = \frac{I_G + A\bar{h}^2}{A\bar{h}} = \frac{I_G}{A\bar{h}} + \bar{h} \qquad \ldots(3.5)$$

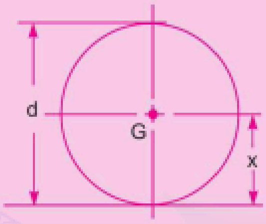
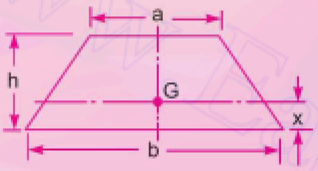
In equation (3.5), $\bar{h}$ is the distance of C.G. of the area of the vertical surface from free surface of the liquid. Hence from equation (3.5), it is clear that :

(*i*) Centre of pressure (*i.e.*, h^*) lies below the centre of gravity of the vertical surface.

(*ii*) The distance of centre of pressure from free surface of liquid is independent of the density of the liquid.

Table 3.1 The moments of inertia and other geometric properties of some important plane surfaces

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)*
1. Rectangle 	$x = \frac{d}{2}$	bd	$\frac{bd^3}{12}$	$\frac{bd^3}{3}$
2. Triangle 	$x = \frac{h}{3}$	$\frac{bh}{2}$	$\frac{bh^3}{36}$	$\frac{bh^3}{12}$

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 	$x = \frac{d}{2}$	$\frac{\pi d^2}{4}$	$\frac{\pi d^4}{64}$	—
4. Trapezium 	$x = \left(\frac{2a+b}{a+b}\right)\frac{h}{3}$	$\frac{(a+b)}{2} \times h$	$\left(\frac{a^2+4ab+b^2}{36(a+b)}\right) \times h^3$	—

Problem 3.1 *A rectangular plane surface is 2 m wide and 3 m deep. It lies in vertical plane in water. Determine the total pressure and position of centre of pressure on the plane surface when its upper edge is horizontal and (a) coincides with water surface, (b) 2.5 m below the free water surface.*

Solution. Given :

Width of plane surface, $b = 2$ m

Depth of plane surface, $d = 3$ m

(*a*) **Upper edge coincides with water surface (Fig. 3.2).** Total pressure is given by equation (3.1) as

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

where $\rho = 1000$ kg/m^3, $g = 9.81$ m/s^2

$$A = 3 \times 2 = 6 \text{ m}^2, \bar{h} = \frac{1}{2}(3) = 1.5 \text{ m}.$$

$$\therefore \quad F = 1000 \times 9.81 \times 6 \times 1.5$$

$$= \mathbf{88290 \text{ N. Ans.}}$$

Depth of centre of pressure is given by equation (3.5) as

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

where I_G = M.O.I. about C.G. of the area of surface

$$= \frac{bd^3}{12} = \frac{2 \times 3^3}{12} = 4.5 \text{ m}^4$$

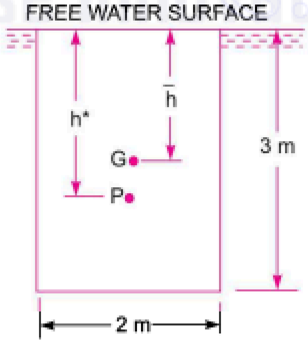


Fig. 3.2

$$\therefore \qquad h^* = \frac{4.5}{6 \times 1.5} + 1.5 = 0.5 + 1.5 = \mathbf{2.0\ m.\ Ans.}$$

(*b*) **Upper edge is 2.5 m below water surface (Fig. 3.3).** Total pressure (F) is given by (3.1)

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

where $\bar{h}$ = Distance of C.G. from free surface of water

$$= 2.5 + \frac{3}{2} = 4.0 \text{ m}$$

$$\therefore \qquad F = 1000 \times 9.81 \times 6 \times 4.0$$

$$= \mathbf{235440\ N.\ Ans.}$$

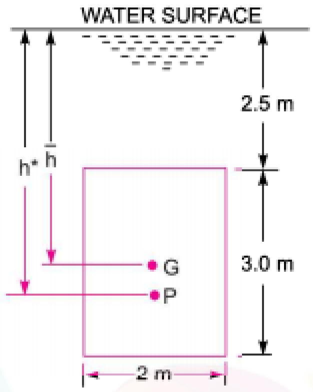


Fig. 3.3

Centre of pressure is given by $h^* = \dfrac{I_G}{A\bar{h}} + \bar{h}$

where $I_G = 4.5$, $A = 6.0$, $\bar{h} = 4.0$

$$\therefore \qquad h^* = \frac{4.5}{6.0 \times 4.0} + 4.0$$

$$= 0.1875 + 4.0 = 4.1875 = \mathbf{4.1875\ m.\ Ans.}$$

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.*

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

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

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

Total pressure is given by equation (3.1),

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

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

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

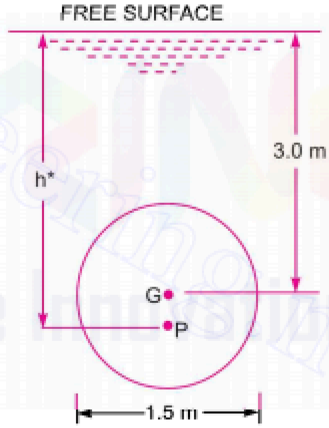


Fig. 3.4

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

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

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

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

$$= \mathbf{3.0468\ m.\ Ans.}$$

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.*

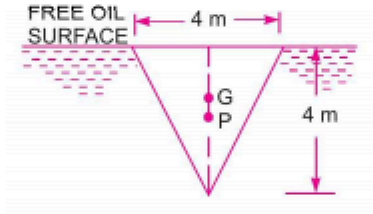


Fig. 3.8

Solution. Given :

Base of plate, $b = 4$ m

Height of plate, $h = 4$ m

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

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

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

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

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

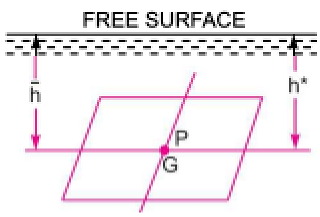
where I_G = M.O.I. of triangular section about its C.G.

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

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

b. Horizontal plane surface submerged in liquid :

Consider a plane horizontal surface immersed in a static fluid. As every point of the surface is at the same depth from the free surface of the liquid, the pressure intensity will be equal on the entire surface and equal to, $p = \rho g h$, where h is depth of surface.



Let $\qquad A$ = Total area of surface

Then total force, F, on the surface

$$= p \times \text{Area} = \rho g \times h \times A = \rho g A \bar{h}$$

where $\quad \bar{h}$ = Depth of C.G. from free surface of liquid = h

also $\quad h^*$ = Depth of centre of pressure from free surface = h.

Problem 3.13 *Fig. 3.17 shows a tank full of water. Find :*

(*i*) *Total pressure on the bottom of tank.*

(*ii*) *Weight of water in the tank.*

(*iii*) *Hydrostatic paradox between the results of (i) and (ii). Width of tank is 2 m.*

Fig. 3.16

Solution. Given :

Depth of water on bottom of tank

$$h_1 = 3 + 0.6 = 3.6 \text{ m}$$

Width of tank $= 2$ m

Length of tank at bottom $= 4$ m

$\therefore$ Area at the bottom, $A = 4 \times 2 = 8 \text{ m}^2$

(*i*) Total pressure F, on the bottom is

$$F = \rho g A \bar{h} = 1000 \times 9.81 \times 8 \times 3.6$$
$$= \mathbf{282528 \text{ N. Ans.}}$$

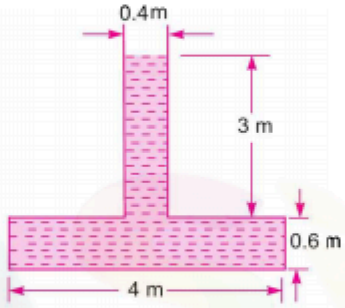


Fig. 3.17

(*ii*) Weight of water in tank $= \rho g \times$ Volume of tank

$$= 1000 \times 9.81 \times [3 \times 0.4 \times 2 + 4 \times .6 \times 2]$$
$$= 1000 \times 9.81\ [2.4 + 4.8] = \mathbf{70632 \text{ N. Ans.}}$$

(*iii*) From the results of (*i*) and (*ii*), it is observed that the total weight of water in the tank is much less than the total pressure at the bottom of the tank. This is known as Hydrostatic paradox.

QUESTION SET

<u>Teaching Questions</u>

GROUP-A(2 MARK)

1.Find the specific gravity of an oil whose specific weight is 9.81kn/m3. [2014s,2017,2018w]
2.Write the relationship between specific weight & density of a liquid. [2014w,2015s,2019w]
3.What is mean by capillarity. [2017s,2015s,2019s]
4. Write the formula for pressure inside a water droplet. [2015w,2016s]
5. State the Newton's law of viscosity.

6. Define pressure head. [2014w,2018s]
7.What is the atmospheric pressure in N/MM2. [2015w,2014s,2017w]
8.State the relation between absolute pressure and vacuum pressure.
9. Define centre of pressure and total pressure
10. State the expression for centre of pressure & total pressure for vertical plane immersed surface.
11.What is the uses of viscosity?

GROUP-B(5 MARK)

1.A plate 0.025 mm distance from a fixed plate, moves at 50 cm/c and required a force of 1.471 N/m^2 to maintain this speed. Determine the fluid viscosity between the plates in the .[2015s,2013w]

2. Determine the specific gravity of a fluid having viscosity 0.05 poise and kinematic viscosity 0.035 stokes). [2013w,2015w]
3. Name of the properties of fluid. Define any two of them. [2014s,2012w]
4. The capillary rise in the glass tube is not exceed 0.2mm of water. Determine its minimum size, given that surface tension for water in contact with air=0.0725 N/M. [2016s,2013w]

5.An isosceles triangles of base 3m and altitude 6m is immersed vertically in water, with its axis of symmetry horizontal. If the head of water on its axis is 9mt. Calculate the total pressure on the plate also locate the center of pressure both vertically and laterally?

GROUP-C(10 MARK)

1. The pressure intensity at a point in fluid is 4.925 N/cm2. Find the corresponding height of the fluid in (i) water (ii) oil of specific gravity 0.9. [2016S,2019s]
2. Convert a pressure intensity of 8 kg/cm2 to pressure head in meter of water & meter of oil of specific gravity 0.9 . [2017s,2018w]

3. The space between two square flat parallel plates is filled with oil .Each side of the plate is 720mm.The thickness of the oil film is 15mm.The upper plate, which moves at 3m/sec requires a force of 120N to maintain the speed. Determine
(i)the dynamic viscosity of the oil.(ii) the kinetic viscosity of the oil if the specific gravity of oil is 0.95.
(2017s**)**

4. Determine the total pressure on a circular plate of diamt 2.5m, which is placed vertically in water, in such way that the C.G of plate is 4m below the free surface of water. Find the position of center of pressure? [2016s,2014s]

5 .An open tank contains water up to a depth of 2m and above it an oil of specific gravity 0.9 for a depth of 1m. Find the pressure intensity (i) at the interface of the two liquids, and (ii) at the bottom of the tank.

6 .An oil of sp.gr. 0.9 is contained in a vessel .At a point the height of oil is 40m.find the corresponding height of water at the point.

7.The pressure intensity at a point in a fluid is given 3.924N/CM^2.Find the corresponding height of fluid when the fluid is (a) water and (b) oil of sp.gr.0.9.

<u>Assignment Questions</u>

GROUP-A(2 MARK)

1. Name any two properties of fluid and state its unit. [2018,2016ws,2014w]
2 .Define surface tension .Write down its unit .
3 .What do you mean by hydrostatic law . [2019w,2014s]

4. Mention the relation between absolute pressure and gauge pressure and atmospheric pressure.

[2017s,2019w]

5.. State expression for pressure at a depth of ‘h’ meter in water.

GROUP-B(5 MARK)

1.Find what force is required to drag a thin plate of area 0.5m2 between two surfaces 2.5m apart filled with liquid viscosity of 8.2x10-2 kg-sec/m2 at velocity of 0.6m/sec. The position of plate is

i) 1cm below the top surface

ii) 2cm below the top surface [2014w,2015s]

2. Find the kinematic viscosity of an oil having density 970 kg/m^3. The shear stress at a point in oil is 0.3245 N/m2 and velocity gradient at the point is 0.35 per sec.). [2014s,2015w]

3. An open tank contains water for a depth of 1.5m and above it oil specific gravity 0.8 for a depth of 0.75m.Find the pressure intensity .[2014w,2013s,2015w]

i) At the interface of two liquids

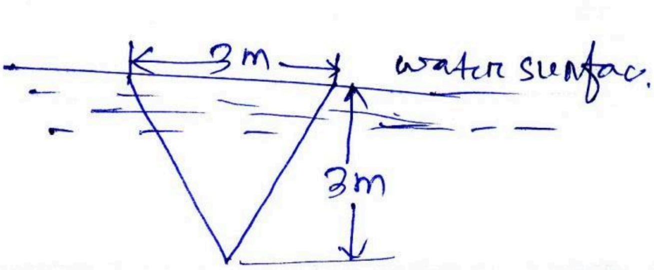
ii) At the bottom of the tank.

GROUP-C(10 MARK)

1. The Velocity distribution for flow over a flat plate is given by u = ¾y-y^2 in which u is the velocity in meter per second at a distance y m above the plate. Determine the shear stress at y=0.15m. Take dynamic viscosity of fluid as 8.6 poise. [2017w,2016w,2015s,2014s]

2. An isosceles triangles plate of 3m and altitude 3mt is immersed vertically in water as shown in fig. Determine the total pressure & center of pressure of the plate?

. What is the total pressure on a rectangular plate 2m×4m immersed vertically in water with its 2m side at a depth of 2m from the surface? [2013w,2014s]



Self PracticeQuestions

GROUP-A(2 MARK)

1. Define viscosity & write down its unit ? . [2017s,2014w,2014w(BP)]
2.Mention density of mercury. [2014w,2016s]
3.Define gauge pressure. [2019s,2017w]
4.What is fluid ?

GROUP-B(5 MARK)

1. Calculate the specific weight, specific volume, density and sp. Gravity of 2.5 lit of a liquid which weights 15N? [2017s,2013w]
2. Explain the phenomenon of capillarity .Obtain an expression for capillary rise of a liquid. [2014s,2015w]

GROUP-C(10 MARK)

1. Derive expression for total pressure for a vertically immersed surface in liquid.

Faculty **HOD** **Principal**