CBCS SCHEME

17ME44

USN | | | | | | | | | | |

Fourth Semester B.E. Degree Examination, Jan./Feb. 2021
Fluid Mechanics

Time: 3 hrs. Max. Marks: 100

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. Define following terms with SI units:
i) Capillarity
ii) Surface tension
iii) Kinematic viscosity
iv) Specific volume. (06 Marks)

b. Derive relation for pressure intensity and surface tension:
i) Liquid droplet ii) Soap bubble. (06 Marks)

c. A cube of 250mm sides, 300N weight slides down an inclined plane at 30° to horizontal. An oil film of thickness 0.5mm is between inclined plane and cube surface. Uniform velocity of slide is 3 m/sec. Determine the dynamic viscosity and kinematic viscosity if specific density of oil is 900 kg/m^3. (08 Marks)

OR

2 a. State and prove Hydrostatic law. (06 Marks)

b. Explain working of U-tube differential manometer, with neat sketch. (06 Marks)

c. A circular plate of 3m in diameter is submerged in oil of specific gravity 0.9, such that its greatest and least depths below the free surface are 3.5m and 2m respectively. Determine total pressure on one face and the depth of centre of pressure. (08 Marks)

Module-2

3 a. Derive continuity equation in 3-dimensional co-ordinates. (06 Marks)

b. Explain different types of fluid flows. (06 Marks)

c. A 2-dimensional flow is given by velocity potential $\phi = x(2y - 1)$. Determine the velocity at point P(2, 3). Find also the stream function. (08 Marks)

OR

4 a. Derive Bernoulli's equation for a fluid flow. List the assumptions made. (08 Marks)

b. Differentiate between venturimeter and orificemeter. (04 Marks)

c. A venturimeter with a throat diameter 10cm and area ratio 4 is provided in a vertical pipeline carrying oil of specific gravity 0.90. The difference in elevation of throat section and entry of venturimeter is 40cm. The differential u-tube mercury manometer shows a deflection of 30cm. Find: i) Discharge of oil ii) Pressure difference. Assume $C_d = 0.98$. (08 Marks)

Module-3

5 a. Derive relation for viscous flow through circular flow and obtain relation for head loss. (10 Marks)

b. A lubricating oil of viscosity 1.0 poise and specific gravity 0.9 is pumped through 30mm diameter pipe. The pressure drop per metre length is 20kN/m^2. Determine: i) Mass flow rate ii) Reynold's iii) Shear stress at pipe wall iv) Power required per 50m length of pipe to maintain the viscous flow. (10 Marks)

OR

6 a. Derive Darcy's equation for fluid flow through circular pipe. (06 Marks)
b. Define HGL and TEL, with sketch. (04 Marks)
c. Determine flow rate of water through a pipe of diameter 20cm and length 50m, when one end of pipe is connected to tank and the other end of pipe is open to the atmosphere. The pipe is horizontal and height of water in tank is 10mts above pipe axis. Consider all losses and assume f = 0.01. (10 Marks)

Module-4

7 a. Define lift and drag force. Derive relations with neat sketch. (10 Marks)
b. Experiments were conducted in a wind tunnel with a speed of 50km/hour on a flat plate of size 2m long and 1m wide. Density of air is 1.15kg/m^3. Coefficients of lift and drag are 0.75 and 0.15 respective. Determine Drag and lift force. (10 Marks)

OR

8 a. Define model similitude and explain. List the applications. (08 Marks)
b. The force 'F' acting on a screw propeller is given by, $F = \rho D^2 V^2 \phi\left(\frac{\rho D^3 V^2}{T}, \frac{ND}{V}, \frac{\rho VD}{\mu}\right)$ where T is Torque, 'D' diameter, V is velocity, N is RPM, ρ is density and viscosity of fluid 'μ'. Use Buckingham π method. (12 Marks)

Module-5

9 a. Derive relation for velocity of sound in terms of Bulk Modulus. (08 Marks)
b. Explain the terms: i) Mach Cone ii) Mach Number. (04 Marks)
c. An aero plane is flying at a height of 12km where the temperature is -53°C. Find the speed of the plane, if Mach Number is M = 2. Assume K = 1.4 and R = 287J/kg K. (08 Marks)

OR

10 a. Explain the importance of CFD. Mentions the applications of CFD. (10 Marks)
b. Explain types of sonicflows with neat sketch. (06 Marks)
c. Explain normal shock and oblique shock. (04 Marks)

* * * * *

MODULE-1

Q1)

a)

(i) Capillarity:-

Capillarity or capillary effect is a consequonce of surface tension & is defined as the raise or fall of a liquid in a small diameter tube inserted into liquid

SI unit :→ mm or cm

(ii) Surface Tension:-

Surface Tension is defined as tensile force acting on a 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.

SI unit :→ N/m

(iii) kinematic Viscosity:-

It is defined as ratio between the dynamic viscosity and density of fluid.

SI unit :- m^2/s

(iv) Specific Volume:- It is defined as a volume of liquid or fluid occupied by a unit mass or volume per unit mass.

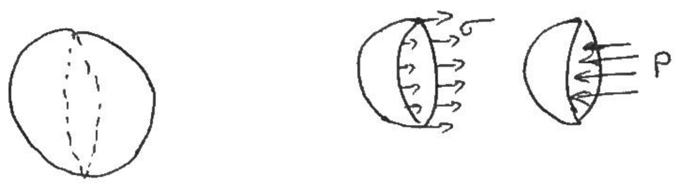
SI unit:- m^3/kg

Q 1)

b).

Relation between pressure intensity & surface tension:-

(i) Liquid Droplet :-



Consider a small spherical droplet of a liquid of radious 'r' on the entire surface of droplet the tensile force due to surface tension will be acting.

Let σ = Surface tension of liquid

p = pressure intensity inside droplet

d = Diameter of droplet.

Tensile force due to surface Tension $= \sigma \times \pi d$

Pressure force on area of $\frac{\pi}{4} d^2 = p \times \frac{\pi}{4} d^2$

For equilibrium

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

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

(ii) For Soap bubble

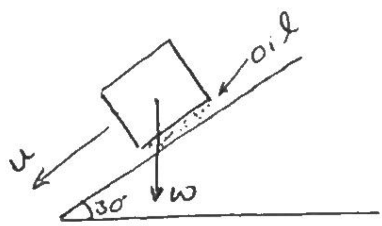
Soap bubble in air has two surfaces in contact with air, one inside & other outside.

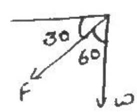
∴ For equilibrium

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

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

Q 1)
c)





$A = 250 \times 250\,mm^2 \Rightarrow 0.25 \times 0.25\ m^2$

$W = 300N, \quad \theta = 30°$

$t = 0.5\,mm = 0.5 \times 10^{-3}\,m$

$u = 3\,m/s, \quad \mu = ?, \quad \nu = ?$

$\rho = 900\,kg/m^3$

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

$\tau = F/A$

$F = W\cos 60 = 300 \cos 60 = 150\,N$

$$\therefore \tau = \frac{150}{0.25 \times 0.25} \Rightarrow \tau = 2400\,N/m^2$$

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

$$2400 = \mu \times \frac{3}{(0.5 \times 10^{-3})}$$

$\boxed{\mu = 0.4\ Ns/m^2}$ or $\boxed{\mu = 4 \text{ poise}}$

Kinematic viscosity (ν) -

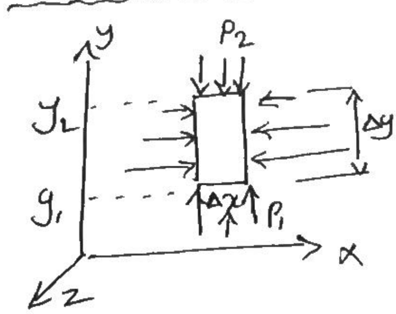
$$\nu = \frac{\mu}{\rho} \Rightarrow \frac{0.4}{900}$$

$\boxed{\nu = 0.00044\ m^2/s}$

Q2)

a) Hydrostatic Law:-

It states that the rate of increase of pressure in a vertical direction is equal to weight density of fluid at that point.



Consider a Rectangular fluid element of hieght Δy length Δx & unit depth (Δz) as shown in fig.

Assuming ρ = constant force balance in vertical y-direction

$$\Sigma F_y = m a_y = 0$$

$$P_1 \Delta x \Delta z - P_2 \Delta x \Delta z - \rho g \Delta x \Delta y \Delta z = 0$$

$$\div \Delta x \Delta z$$

$$P_1 - P_2 - \rho g \Delta y = 0$$

$$P_1 - P_2 = \rho g \Delta y$$

$$\boxed{\Delta P = \rho g \Delta y}$$

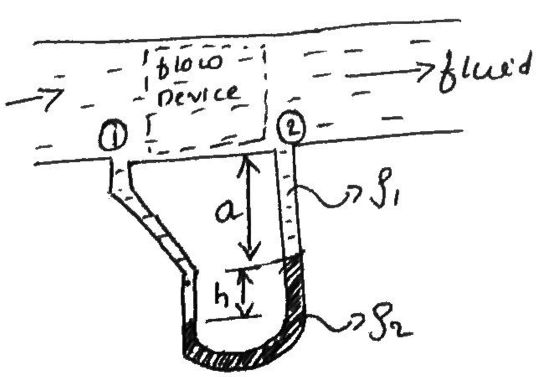
if we take the above point to be at free surface of liquid open to atmosphere, then pressure at a depth h below the free surface becomes

$$\boxed{P = P_{atm} + \rho g h}$$

or $\boxed{P_{gage} = \rho g h}$

Q 2)

(b) U-Tube Differential Manometer:-



Manometers are particularly well suited to measure pressure drops across a horizontal flow section between two specified points due to the presence of a device such as a valve or heat exchangers or any resistance to flow. This is done by connecting two limbs of manometers at these two points as show in fig.

Let ρ_1 = working fluid density

ρ_2 = manomatric fluid density

h = Differential hieght

Two fluids are immiscible & $\rho_1 < \rho_2$

Pressure at 2 is given by

$$P_1 + \rho_1 g(a+h) - \rho_2 g h - \rho_1 g a = P_2$$

$$P_1 + \cancel{\rho_1 g a} + \rho_1 g h - \rho_2 g h - \cancel{\rho_1 g a} = P_2$$

$$P_1 + \rho_1 g h - \rho_2 g h = P_2$$

$$P_1 - P_2 = gh(\rho_2 - \rho_1)$$

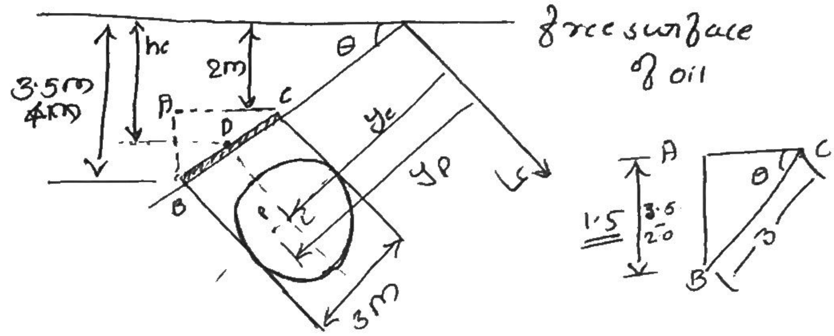
for ρ = constant

$$\boxed{P_1 - P_2 = \Delta P = \rho g h}$$

hence by measuring the differential head h in the limbs we can measure the pressure difference or pressure drop across two points

Q(2)

(C)



$d = 3m$ $\qquad$ $s = 0.9 \Rightarrow \rho_{oil} = 900\, kg/m^3$

Total pressure $(F_R) \Rightarrow$

$$F_R = \rho g h_c A$$

$$h_c = 2 + CD\sin\theta \quad | \text{ but } \sin\theta = \frac{AB}{BC}$$

$$\sin\theta = \frac{1.5}{3.0}$$

$$\theta = 30°$$

$$h_c = 2 + CD\sin\theta \Rightarrow 2 + 1.5\sin\theta$$

$$\Rightarrow 2 + 1.5\sin 30$$

$$h_c = 2 + 1.5(0.5)$$

$$h_c = 2.75\, m$$

$$A = \frac{\pi}{4}d^2 \Rightarrow \frac{\pi}{4} \times 3^2 \Rightarrow A = 7.068\, m^2$$

(i) $F_R = \rho g h_c A \Rightarrow 900 \times 9.81 \times 2.75 \times 7.068$

$$F_R = 171{,}609.27\, N \Rightarrow \boxed{F_R = 171.609\, kN}$$

(ii) Centre of pressure $\Rightarrow (y_P)$

$$y_P = y_c + \frac{I_{xx,c}}{y_c A}$$

$$y_c = \frac{h_c}{\sin\theta} \Rightarrow \frac{2.75}{\sin 30}$$

$$y_c = 5.5\,m.$$

$$I_{xx,c} = \frac{\pi d^4}{64} = \frac{\pi \times 3^4}{64} = 3.976\,m^4.$$

(ii) $y_p \Rightarrow$ Centre of Pressure $\Rightarrow$

$$y_p = 5.5 + \frac{3.976}{5.5 \times 7.068}$$

$$y_p = 5.5 + 0.1022$$

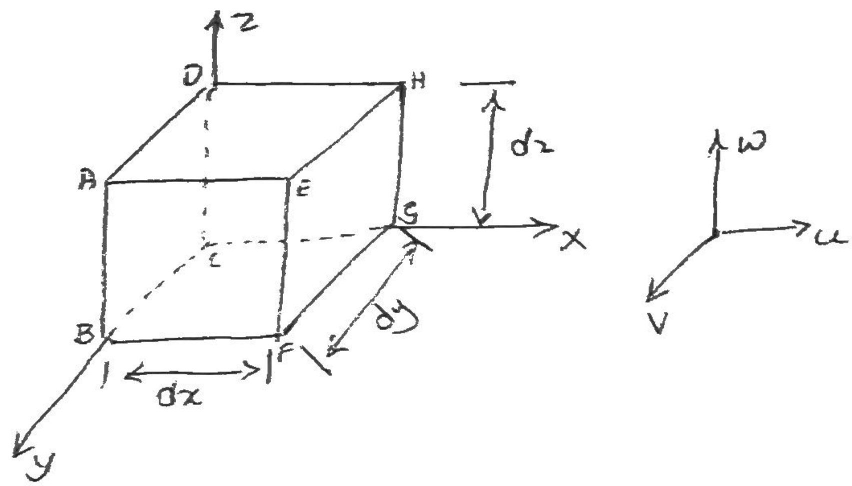
$$\boxed{y_p = 5.602\,m}$$

or $h_p = y_p \sin\theta = 5.602 \times \sin 30$

$$\boxed{h_p = 2.80\,m}$$

Q(3)

(a) <u>Continuity Equation in 3-dimensional coordinates</u> -



Consider a fluid element of length dx, dy & dz in directions of x, y & z respectively. Let u, v, w are velocity at inlet in x, y & z directions.

mass of fluid entering face ABCD = $\rho \times V \times \text{Area}$
$= \rho \times u \times (dy\,dz)$

mass of fluid leaving EFGH => $\rho u\,dy\,dz + \frac{\partial}{\partial x}(\rho u\,dy\,dz)dx$

∴ net gain in x direction =>

= mass through ABCD − mass through EFGH

$= \rho u\,dy\,dz - \rho u\,dy\,dz - \frac{\partial}{\partial x}(\rho u\,dy\,dz)dx$

$= -\frac{\partial}{\partial x}\rho u\,dx\,dy\,dz$

lly net gain y direction => $-\frac{\partial}{\partial y}\rho v\,dx\,dy\,dz$

lly net gain z direction => $-\frac{\partial}{\partial z}\rho w\,\partial x\,dy\,dz$

net gain of masses $= -\left[\frac{\partial}{\partial x}\rho u + \frac{\partial}{\partial y}\rho v + \frac{\partial}{\partial z}\rho w\right]$ —①

Rate of increase of mass in fluid element with time $= \frac{\partial}{\partial t}(\rho\, dx\,dy\,dz)$ — ②

equating ① & ②

$$-\left[\frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w)\right] = \frac{\partial}{\partial t}(\rho\, dx\,dy\,dz)$$

$$\frac{\partial \rho}{\partial t} + \frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} + \frac{\partial \rho w}{\partial z} = 0$$

For steady flow $\frac{\partial \rho}{\partial t} = 0$

$$\frac{\partial \rho u}{\partial x} + \frac{\partial \rho v}{\partial y} + \frac{\partial \rho w}{\partial z} = 0$$

for ρ = constant

$$\boxed{\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0}$$

Q 3)

(b) Different types of fluid flow:-

(i) Viscous & Inviscid Flow:-

Flows in which the frictional effect are significant are called "viscous flow."

If in flow viscous forces are negligible compared to inertial or pressure forces such flow are called "Inviscid flow"

(2) Internal & External flow:-

The flow of unbounded fluid over a surface such as plate or wire or plane surface is "external flow"

The fluid flow in a confined space or bounded from surfaces like flow in a pipe or duct is called "Internal flow"

(3) Compressible & Incompressible flow:-

If in a fluid flow density remains nearly constant throughout then flow is said to be "incompressible flow"

If in a flow of fluid density varies (above 5%) then the flow is said to be "compressible flow".

(4) Laminar & Turbulent flow:-

In a fluid flow if the flow streamlines are parellel to each other we call the flow as "laminar flow".

In a fluid flow if flow stream lines are not parellel to each other we call the flow as "Turbulent flow."

5) Natural & Forced flow:-

If a fluid flow is due to the natural means such as buoyancy effects then flow is called "natural flow."

If a fluid is forced to flow over a surface or in a pipe by external means such as a pump or a fan then the flow is "Forced flow"

6) Steady And Unsteady flow:-

If a flow is such that the properties are at every point in the flow donot depend upon time, it is called "steady flow"

"Unsteady flow" is one where the properties do depend on time

Q(3)

(c) velocity potential function $\phi = x(2y-1)$

$P(2,3)$, $V = ?$, $\varphi = ?$

$$\phi = x(2y-1)$$

$$\phi = 2xy - x$$

WKT, $u = -\frac{\partial \phi}{\partial x}$, $v = -\frac{\partial \phi}{\partial y}$

$$\frac{\partial \phi}{\partial x} = (2y-1) \qquad \frac{\partial \phi}{\partial y} = 2x$$

$\therefore\ u = -(2y-1) \qquad v = -2x \quad -①$

at $P = (2,3)$

$u = -[(2 \times 3) - 1] = -5$ m/s (units/sec)

$v = -2(2) = -4$ m/s (units/sec)

(i) velocity at $P \Rightarrow V = \sqrt{u^2+v^2}$

$= \sqrt{-5^2 + (-4^2)}$

$\boxed{V = 6.4 \text{ m/s}}$

or

$\boxed{V = 6.4 \text{ units/sec}}$

(ii) stream function (ψ)

$u = -\dfrac{\partial \psi}{\partial y} \qquad v = \dfrac{\partial \psi}{\partial x}$

$\dfrac{\partial \psi}{\partial y} = -u = (-2y+1) \qquad \dfrac{\partial \psi}{\partial x} = v$

$\dfrac{\partial \psi}{\partial y} = 2y - 1 \qquad \dfrac{\partial \psi}{\partial x} = -2x$

$\int \dfrac{\partial \psi}{\partial y} = \int 2y - 1$

$\int \partial \psi = \int (2y-1)\partial y$

$\psi = \dfrac{2y^2}{2} - y + \text{const}$

$\psi = y^2 - y + \text{const}$

$\dfrac{\partial \psi}{\partial x} = -2x \Rightarrow \int \partial \psi = \int (-2x)(\partial x)$

$\psi = y^2 - y + k$

diff w.r.to $x \Rightarrow \dfrac{\partial \psi}{\partial x} = \dfrac{\partial k}{\partial x}$

but $\dfrac{\partial \psi}{\partial x} = -2x$

$\therefore \dfrac{\partial k}{\partial x} = -2x$

$$\int \partial k = \int (-2x)\,\partial x$$

$$k = -\frac{2x^2}{2}$$

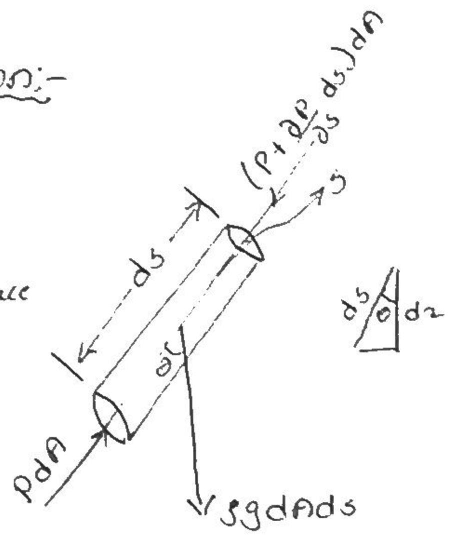
$$k = -x^2$$

$$\therefore \quad \psi = y^2 - y + (-x^2)$$

stream function $\boxed{\psi = y^2 - y - x^2}$

Q(4)

(a) Bernoulli's Equation:-



Consider a stream line in which flow is takin place in s-direction. Consider a cylindrical element of c/s area dA & length ds as shown in fig

The forces acting on cylindrical element are

1) Pressure force $= PdA$

2) Pressure force $= -\left[P + \frac{\partial P}{\partial s} ds\right] dA$

3) Weight of element $= \rho g\, dA\, ds$

For equilibrium & Resultant force $\Rightarrow F_s = m \times a_s$

$$PdA - \left[\left(P + \frac{\partial P}{\partial s} ds\right) dA\right] - \rho g\, dA\, ds \cos\theta = (\rho g\, dA\, ds) \times a_s \quad \text{— (1)}$$

$$a_s = \frac{dv}{dt} = \frac{\partial v}{\partial s} \cdot \frac{ds}{dt} + \frac{\partial v}{\partial t}$$

$$\frac{\partial v}{\partial t} \, \frac{ds}{dt} = v$$

$$\therefore a_s = \frac{\partial v}{\partial s}(v) + \frac{\partial v}{\partial t}$$

For steady flow $\frac{\partial v}{\partial t} = 0$

$$a_s = \frac{\partial v}{\partial s}(v)$$

sub a_s in (1)

$$\cancel{PdA} - \cancel{PdA} - \frac{\partial P}{\partial s} ds dA - \rho g dA ds \cos\theta = \rho dA ds \times v \frac{\partial v}{\partial s}$$

$$-\frac{\partial P}{\partial s} ds dA - \rho g dA ds \cos\theta = \rho dA ds \, v \frac{\partial v}{\partial s}$$

$\div$ by $\rho ds dA$

$$-\frac{1}{\rho} \frac{\partial P}{\partial s} - g\cos\theta = v \frac{\partial v}{\partial s}$$

$$\frac{\partial P}{\rho \partial s} + g\cos\theta + v\frac{\partial v}{\partial s} = 0$$

but $\cos\theta = \frac{\partial z}{\partial s}$

$$\frac{1}{\rho} \frac{\partial P}{\partial s} + g\frac{dz}{\partial s} + \frac{v \partial v}{\partial s} = 0$$

$$\Rightarrow \boxed{\frac{\partial P}{\rho} + g dz + v dv = 0} \quad \text{— (2)}$$

Intigrating above equation

$$\int \frac{\partial P}{\rho} + \int g dz + \int v dv = \text{const}$$

$$\frac{P}{\rho} + gz + \frac{v^2}{2} = \text{const}$$

$$\boxed{\frac{P}{\rho g} + z + \frac{v^2}{2g} = \text{const}}$$

Q4)
b)

venturimeter	orificemeter
* It consists of three parts converging, throat & Diverging part	* It consists of sharp edged small hole at centre of plate.
* Cd value varies between 0.88 to 0.98 generally	* Cd value varies between 0.4 to 0.65 generally
* Pressure losses are minimum	* pressure losses are large
* Disturbance to the flow is minimum	* Disturbance to the flow is large
* Difficult to Design & fabricate	* Easier to design & fabricate
* Greater accuracy in measurement	* Lesser accuracy compared to orificemeter.

Q4)
c)

$D_2 = 10cm = 0.1m$

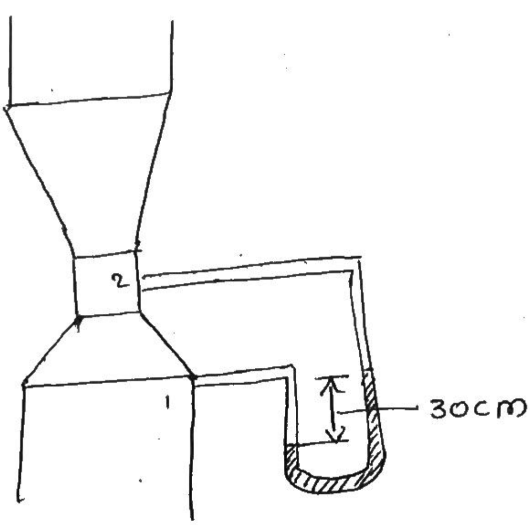
$\frac{a_1}{a_2} = 4$

$S_{oil} = 0.9$

$\rho_{oil} = 900 kg/m^3$

$x = 30cm$

$C_d = 0.98$



$$a_2 = \frac{\pi}{4} D_2^2 \Rightarrow \frac{\pi}{4}(0.1^2)$$

$$a_2 = 0.007853 m^2$$

$$\frac{a_1}{a_2} = 4 \Rightarrow a_1 = 4 \times (0.007853)$$

$$a_1 = 0.031415 \ m^2$$

$$h = \left[\frac{P_1}{\rho g} + z_1\right] - \left[\frac{P_2}{\rho g} + z_2\right]$$

$$h = x\left[\frac{\rho_m}{\rho_o} - 1\right]$$

$$= 0.3\left[\frac{13600}{900} - 1\right]$$

$$h = 4.23 \ m \text{ of oil.}$$

(i) Discharge (Q) =>

$$Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \sqrt{2gh}$$

$$= 0.98 \times \frac{0.031415 \times 0.007853}{\sqrt{0.031415^2 - 0.007853^2}} \times \sqrt{2 \times 9.81 \times 4.23}$$

$$= 0.261 \times \sqrt{2 \times 9.81 \times 4.23}$$

$$= 0.261305 \times 9.110027$$

$$\boxed{Q = 2.3804 \ m^3/s} \text{ or } \boxed{Q = 2380.4 \text{ litre/s}}$$

(ii) Pressure Difference

$$h = \left[\frac{P_1}{\rho g} + z_1\right] - \left[\frac{P_2}{\rho g} + z_2\right]$$

$$\frac{P_1}{\rho g} - \frac{P_2}{\rho g} + (z_1 - z_2) = 4.23$$

but $z_2 - z_1 = 40 cm \Rightarrow 0.4 m$

$$\left[\frac{P_1}{\rho g} - \frac{P_2}{\rho g}\right] - 0.4 = 4.23$$

$$\frac{P_1 - P_2}{\rho g} = 4.23 + 0.4$$

$$(P_1 - P_2) = 4.63 \times (\rho g)$$

$$= 4.63 \times 900 \times 9.81$$

$$(P_1 - P_2) = 40,878.27 \ N/m^2$$

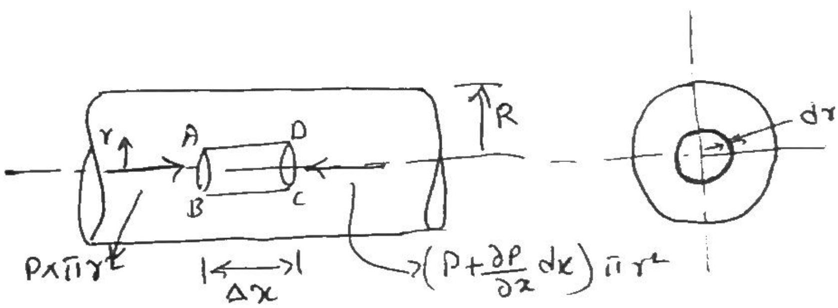
$$\boxed{(P_1 - P_2) = 40.878 \ kN/m^2}$$

MODULE-3

Q 5)

(a)

Viscous flow through circular pipe :-



Shear stress Distribution:-

Consider a horizontal pipe of radius R. The viscous fluid flowing from left to right as shown in fig. Consider a fluid element of radius r, sliding in a cylindrical fluid element of radius r+dr. Let length of fluid element be Δx

Forces acting on fluid element

1) Pressure force on $AB = P \times \pi r^2$

2) Pressure force on $CD = \left[P + \frac{\partial P}{\partial x}\Delta x\right]\pi r^2$

3) Viscous force $\Rightarrow (\tau \times 2\pi r \times \Delta x)$

$$\Sigma F_x = 0$$

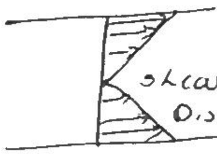
$$P \times \pi r^2 - \left[\left[P + \frac{\partial P}{\partial x}\Delta x\right]\pi r^2\right] - (\tau \times 2\pi r \Delta x) = 0$$

$$\cancel{P\pi r^2} - \cancel{P\pi r^2} - \frac{\partial P}{\partial x}\Delta x \pi r^2 - \tau\, 2\pi r \Delta x = 0$$

$\div \Delta x \pi r$

$$-\frac{\partial P}{\partial x} \cdot r - 2\tau = 0$$

$$\tau = -\frac{\partial P}{\partial x} \times \frac{r}{2} \quad -(1)$$



ii) Velocity Distribution :-

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

$$y = R - r \qquad dy = -dr$$

$$\therefore \tau = -\mu \frac{\partial u}{dr} \quad -(2)$$

from (1) & (2)

$$-\frac{\partial P}{\partial x}\frac{r}{2} = -\mu \frac{du}{dr}$$

$$\frac{du}{dr} = \frac{r}{2\mu}\frac{\partial P}{\partial x}$$

$\int$ on both side

$$\int du = \int \frac{r}{2\mu}\frac{\partial P}{\partial x}\, dr$$

$$u = \frac{1}{2\mu}\frac{\partial P}{\partial x} \cdot \frac{r^2}{2} + C$$

$$u = \frac{1}{4\mu}\frac{\partial P}{\partial x} r^2 + C \quad -(3)$$

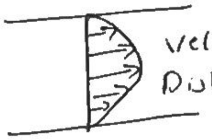
at $r = R \quad u = 0$

$$\therefore 0 = \frac{1}{4\mu}\frac{\partial P}{\partial x}R^2 + C \Rightarrow C = -\frac{1}{4\mu}\frac{\partial P}{\partial x}R^2 \quad - (4)$$

sub 4 in (3)

$$u = +\frac{1}{4\mu}\frac{\partial P}{\partial x}r^2 - \frac{1}{4\mu}\frac{\partial P}{\partial x}R^2$$

$$\boxed{u = -\frac{1}{4\mu}\frac{\partial P}{\partial x}\left[R^2 - r^2\right]} \quad - 5$$



Velocity Distribution

iii) Ratio of max velocity to mean velocity

for maximum velocity U_{max}, $r = 0$

$$\therefore U_{max} = -\frac{1}{4\mu}\frac{\partial P}{\partial x}\left[R^2\right] \quad - (6)$$

$$dQ = (u)\left[2\pi r\, dr\right)$$

$$dQ = -\frac{1}{4\mu}\frac{\partial P}{\partial x}\left[R^2 - r^2\right] \times 2\pi r\, dr$$

$\int_0^R$ on both sides

$$\int dQ = \int_0^R -\frac{2\pi}{4\mu}\frac{\partial P}{\partial x}\left[R^2 - r^2\right] \cdot r \cdot dr$$

$$Q = -\frac{2\pi}{4\mu}\frac{\partial P}{\partial x}\int_0^R \left[R^2 r - r^3\right] dr$$

$$Q = -\frac{1}{4\mu}\frac{\partial P}{\partial x}(2\pi)\left[R^2\frac{r^2}{2} - \frac{r^4}{4}\right]_0^R$$

$$Q = -\frac{1}{4\mu}\frac{\partial P}{\partial x}2\pi\left[\frac{R^4}{2} - \frac{R^4}{4}\right]$$

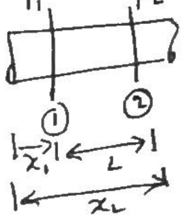
$$= -\frac{1}{4\mu}\frac{\partial P}{\partial x}\cancel{2}\pi\left[\frac{R^4}{\cancel{4}_2}\right]$$

$$Q = -\frac{\pi}{8\mu}\frac{\partial P}{\partial x}R^4 \quad \text{———} \quad (7)$$

$$\bar{U} = Q/A = \frac{\frac{-\pi}{8\mu}\frac{\partial P}{\partial x}R^4}{\pi R^2} \Rightarrow \boxed{\bar{U} = \frac{-1}{8\mu}\left(\frac{\partial P}{\partial x}\right)R^2} \quad -⑧$$

$$\therefore \frac{U_{max}}{\bar{U}} = 2.0 \Rightarrow U_{max} = 2.0 \times \bar{U} \quad -⑨$$

iv) head loss (Pressure head loss) for given length



$$\bar{U} = \frac{-1}{8\mu}\left(\frac{\partial P}{\partial x}\right)R^2 \Rightarrow \frac{\partial P}{\partial x} = \frac{-8\mu\bar{U}}{R^2}$$

$$-\int \partial P = \int_2^1 \frac{8\mu\bar{U}}{R^2}\,\partial x$$

$$-(P_1 - P_2) = \frac{8\mu\bar{U}}{R^2}(x_1 - x_2)$$

$$P_1 - P_2 = \frac{8\mu\bar{U}}{R^2}(x_2 - x_1)$$

$$P_1 - P_2 = \frac{8\mu\bar{U}}{R^2}[L]$$

$$= \frac{8\mu\bar{U}L}{[D/2]^2}$$

$$= \frac{32\mu\bar{U}L}{D^2}$$

$$P_1 - P_2 = \frac{32\mu\bar{U}L}{D^2}$$

$\therefore$ Loss of pressure head (h_f)

$$\boxed{\frac{P_1 - P_2}{\rho g} = h_f = \frac{32\mu\bar{U}L}{\rho g D^2}}$$

Q5)
(b)

$\mu = 1.0$ poise $\Rightarrow 0.1\ Ns/m^2$

$s = 0.9 \Rightarrow \rho = 900\ kg/m^3$ $\quad L = 50m$

$D = 30mm \Rightarrow 0.03m$; $R = D/2 = 0.015m$

pressure Drop $= 20kN/m^2 \Rightarrow \frac{\partial P}{\partial x} = 20kN/m^2/m = (P_1 - P_2)$

(i) mass flow Rate :- $(\dot{m})$

$$Q = \bar{U}A$$

$$\bar{U} = \frac{-1}{8\mu}\left(\frac{\partial P}{\partial x}\right)R^2 \quad \text{or} \quad \bar{U} = \frac{(P_1 - P_2)D^2}{32\mu L}$$

$$(P_1 - P_2) = \frac{32\mu \bar{U} L}{D^2} = \frac{32 \times 0.1 \times \bar{U} \times 50}{0.03m^2}$$

$$20{,}000 = 5333.33\ \bar{U}$$

$$\boxed{\bar{U} = 3.75\ m/s}$$

$$A = \frac{\pi}{4}D^2 \Rightarrow \frac{\pi}{4} \times 0.03^2 \Rightarrow A = 0.00070685\ m^2$$

$$Q = 3.75 \times 0.00070685$$

$$Q = 0.002650\ m^3/s$$

$$\dot{m} = Q \times \rho \Rightarrow 0.002650 \times 900$$

$$\boxed{\dot{m} = 2.385\ kg/s}$$

(ii) Reynolds :- (Re)

$$Re = \frac{\rho V D}{\mu} = \frac{900 \times 3.75 \times 0.03}{0.1}$$

$$\boxed{Re = 1012.5}$$

(iii) Shear stress at pipe wall (τ_0)

$$\tau_0 = -\frac{\partial P}{\partial x} \times \frac{r}{2} \cdot \text{ if } r = R$$

$$\tau_0 = -\frac{\partial P}{\partial x}\frac{R}{2}$$

$$-\frac{\partial P}{\partial x} = \frac{-(P_2 - P_1)}{x_2 - x_1} = \frac{P_1 - P_2}{L} = \frac{20,000}{50}$$

$$-\frac{\partial P}{\partial x} = 400 \ N/m^3$$

$$\tau_0 = 400 \times \frac{0.015}{2}$$

$$\boxed{\tau_0 = 3 \ N/m^2}$$

iv) Power Required per 50m length (P)

$$P = W \times h_f$$

$$W = Q \times \rho g \Rightarrow 0.002650 \times 900 \times 9.81$$

$$= 23.3968 \ kg\text{-}m/s^2$$

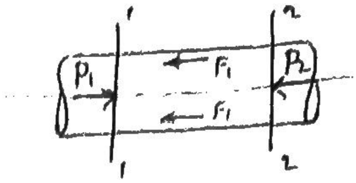
$$h_f = \frac{32 \mu \bar{U} L}{\rho g D^2} \Rightarrow \frac{32 \times 0.1 \times 3.75 \times 50}{900 \times 9.81 \times (0.03)^2}$$

$$h_f = 75.50 \ m$$

$$P = 23.3968 \times 75.50$$

$$\boxed{P = 1766.66 \ W}$$

Q(6)
(a)



Consider a uniform horizontal pipe as shown in fig

Let P_1 = Pressure intensity at section 1-1

V_1 = velocity of flow at section 1-1

L = Length of pipe betwen 1-1 & 2-2

d = diameter of pipe

f' = frictional resistance per unit wetted area per unit velocity

h_f = head loss due to friction.

P_2, V_2 : are pressure intensity & velocity at section 2-2

Applying to Bernoull's equation

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2 + h_f$$

but $Z_1 = Z_2$

& $V_1 = V_2$ (uniform velocity as $D_1 = D_2$)

$$\frac{P_1}{\rho g} = \frac{P_2}{\rho g} + h_f$$

$$h_f = \frac{P_1}{\rho g} - \frac{P_2}{\rho g} \quad -①$$

but h_f is head lost due to friction

Frictional Resistance = frictional resistance per unit wetted area per unit velocity x wetted area x velocity^2

Wetted Area $= \pi d \times L$
& $V_1 = V_2 = V$

i.e. $F_1 = f' \times \pi d L \times V^2$

$F_1 = f' \times P \times L \times V^2 \quad -②$ / $P = \pi d$ (Perimeter)

The forces acting on fluid

1) Pressure force at 1-1 $\Rightarrow P_1 \times A$

2) Pressure force at 2-2 $\Rightarrow P_2 \times A$

3) Frictional force $F_1 \Rightarrow f' \times P L V^2$

Resolving all horizontal forces

$$P_1 A - P_2 A - F_1 = 0$$

$$(P_1 - P_2) A = F_1$$

$$(P_1 - P_2) A = \cancel{\rho} f' \times P L V^2$$

$$P_1 - P_2 = \frac{f' P L V^2}{A} \quad - \text{②}$$

from ① $P_1 - P_2 = h_f (\rho g)$

$$\therefore h_f (\rho g) = \cancel{\rho} \frac{f' P L V^2}{A}$$

$$h_f = \frac{f'}{\rho g} \times \frac{P}{A} \times L \times V^2$$

$$h_f = \frac{f'}{\rho g} \times \frac{[\pi \times d]}{\left[\frac{\pi}{4} \times d^2\right]} \times L \times V^2$$

$$h_f = \frac{f'}{\rho g} \times \frac{4}{d} \times L \times V^2$$

$$h_f = \frac{f'}{\rho g} \frac{4 L V^2}{d}$$

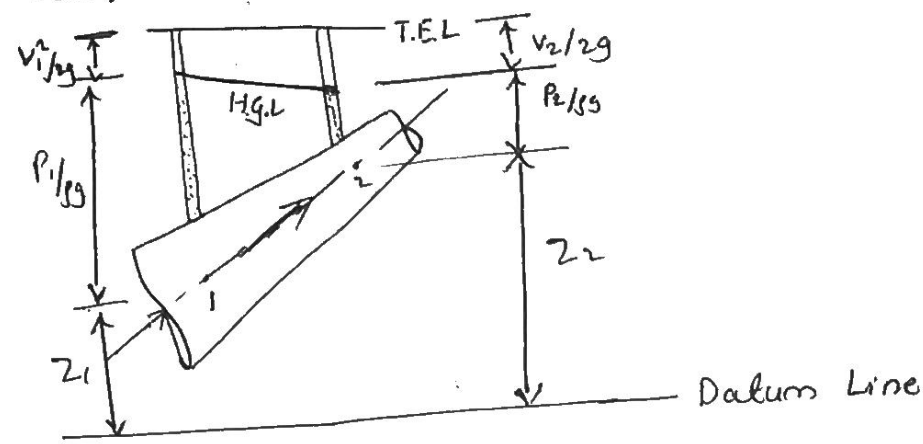
putting $\frac{f'}{\rho} = \frac{f}{2}$ where f is co-efficient of friction

$$\therefore h_f = \frac{4f}{2g} \frac{L V^2}{d} \Rightarrow \boxed{h_f = \frac{4 f L V^2}{d \times 2g}} \Rightarrow \text{Darcy-weisbach equation}$$

sometimes $\boxed{h_f = \frac{f L V^2}{d\,2g}}$ when f = friction factor

Q 6)
(b)

HGL & TEL :-



Hydraulic Gradient Line (HGL) :→ It is define as a line which gives sum of pressure head, and datum head of flowing fluid in a pipe with ~~reference~~ respect to some reference Line.

Total Energy Line (TEL) :- It is defined as a line which gives sum of pressure head, datum head and kinetic head of a flowing fluid in a pipe with respect to some reference line.

Q 6)

c)

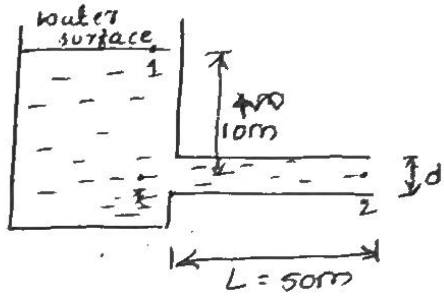
$d = 20cm = 0.2m$

$L = 50m$

$H = 10m$

$f = 0.01$

$Q = ?$



$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + z_2 + \text{losses}$$

We have losses here are $= h_i + h_f$

$P_1 = P_2 = P_{atm}$, $V_1 = 0$, $z_1 = 10m$, $V_2 = V$, $z_2 = 0$

$$\cancel{\frac{P_1}{\rho g}} + \frac{V_1^2}{2g} + z_1 = \cancel{\frac{P_2}{\rho g}} + \frac{V_2^2}{2g} + z_2 + h_i + h_f$$

$$0 + 10 = \frac{V^2}{2g} + h_i + h_f \quad \text{— } (1)$$

h_i = loss of head at pipe entrance $= 0.5\frac{V^2}{2g}$ — (2)

& $h_f = \frac{4fLV^2}{d \times 2g}$ — (3)

$\therefore$ sub 2 & 3 in (1)

$$10 = \frac{V^2}{2g} + \frac{0.5V^2}{2g} + \frac{4fLV^2}{d \times 2g}$$

$$10 = \frac{V^2}{2g}\left[1 + 0.5 + \frac{4 \times 0.01 \times 50}{0.2}\right]$$

$$10 = \frac{V^2}{2g}(11.5) \Rightarrow V^2 = \frac{10 \times 2 \times 9.81}{11.5} = 17.06$$

$$V = 4.13 m/s$$

$$Q = A \cdot V$$

$$= \frac{\pi}{4} \times d^2 \times V$$

$$= \frac{\pi}{4} \times 0.2^2 \times 4.13$$

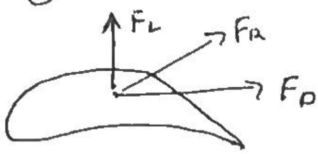
$\boxed{Q = 0.1297\ m^3/s}$ or $\boxed{Q = 129.7\ lit/sec}$

MODULE - 4

Q 7)

a)

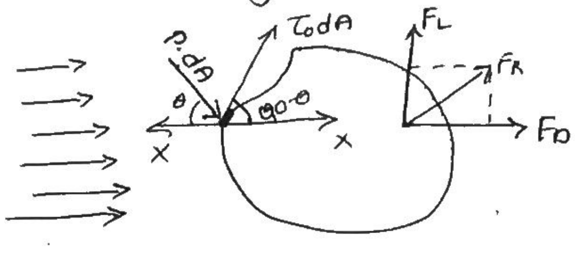
Lift and Drag Force :-



Drag Force (F_D):- The component of total force (F_R) in the direction of motion is called drag force.

Lift Force (F_L):- The component of total forcce (F_R) in the direction perpendicular to direction of motion is known as Lift force.

Expressions for Drag & Lift force :→



Consider an arbitrary shaped body placed in real fluid, which is flowing with a uniform velocity U in horizontal direction as show in fig

Consider small elemental area dA on surface of body, Forces acting on dA are

1) Pressure force = $P \times dA$ (perpendicular surface)
2) Shear force = $\tau_0 \times dA$ (tangential to surface)

a) Drag force (F_D):-

F_{D_E} = Force due to pressure + force due to shear

$= P\,dA\cos\theta + \tau_0\,dA\cos(90-\theta)$

$= P\,dA\cos\theta + \tau_0\,dA\sin\theta$

∴ Total drag force => $\boxed{F_D = \int P\,dA\cos\theta + \int \tau_0 \sin\theta\,dA}$

(b) Lift force (F_L)

$F_{L_E} = -P\,dA\,\cancel{\cos\theta}\,\sin\theta + \tau_0\,dA\sin(90-\theta)$

$= -P\,dA\,\cancel{\cos\theta}\,\sin\theta + \tau_0\,dA\cos\theta$

∴ Total lift force => $\boxed{F_L = \int \tau_0\,dA\cos\theta - \int P\,dA\sin\theta}$

The drag and lift for a body moving in a fluid of density ρ, at a uniform velocity U are calculated mathematically as from the method of Dimensional analysis →

$$\boxed{F_D = \frac{C_D \rho U^2 A}{2}}$$

$$\boxed{F_L = \frac{C_L \rho A U^2}{2}}$$

Q 7)
(b)

$U = 50 km/hr = \frac{50 \times 1000}{3600} = 13.89 m/s$

$A = 2 \times 1 = 2 m^2$

$\rho = 1.15 kg/m^3$

$C_L = 0.75$, $C_D = 0.15$

$F_D = ?$, $F_L = ?$

(i) $F_D \rightarrow$ Drag force

$$F_D = C_D \times \frac{\rho A U^2}{2}$$

$$= 0.15 \times 1.15 \times \frac{2 \times 13.89^2}{2}$$

$$\boxed{F_D = 33.28 N}$$ – Drag force

(ii) Lift force (F_L)

$$F_L = C_L \times \frac{\rho U^2 A}{2}$$

$$= 0.75 \times 1.15 \times \frac{2 \times 13.89^2}{2} = 166.40 N$$

$$\boxed{F_L = 166.40 N}$$ → Lift force

Resultant force => $F_R = \sqrt{F_D^2 + F_L^2}$

$$= \sqrt{33.28^2 + 166.40^2}$$

$$\boxed{F_R = 169.6 N}$$ – Resultant force

Q 8)

a) Model similitude :-

Similitude is defined as the similarity between the model and its prototype in every respect, which means that the model and prototype have similar properties or model and prototype are completely similar

Three types of similarity must exist between model and prototype →

1) Geometric Similarity
2) Kinematic Similarity
3) Dynamic Similarity

1) Geometric Similarity :- Geometric Similarity is said to exist between model and prototype i.e ratio of all corrosponding linear dimensions in model & prototype are equal.

2) Kinematic Similarity :- Kinematic similarity means the similarity of motion between model & prototype. Thus kinematic similarity is said to exist between model and prototype if ratio of velocity and acceleration at corrosponding points in model & prototype are same.

3) Dynamic Similarity :-

Dynamic Similarity means the similarity of forces between the model and prototype i.e. the ratio of corresponding forces acting at corresponding points are equal. Also the direction of corresponding forces at corresponding points should be same.

Applications :- in the fields of following →

1) studying and understanding flow over the bodies such as, wings of plane.

2) Designing of blades of wind turbine

3) Design and Development of more Aerodynamic automobiles.

4) Design and Development of missiles.

5) In studying & understanding of flow of air over skyscrapers, dams & bridges.

6) Design and Development of submarines & ships.

Q 8)

(b)

F = Force

T = Torque

V = velocity

D = Diameter

N = rpm

ρ = Density

μ = Viscosity

$$\therefore F = f[T, D, V, N, \rho, \mu]$$

$$f_1(F, T, D, V, N, \rho, \mu] = 0$$

Total number of variables $\rightarrow n = 7$

Dimensions of each term $\rightarrow$

$F = MLT^{-2}$, $T = ML^2T^{-2}$, $D = L$

$V = LT^{-1}$, $N = T^{-1}$, $\rho = ML^{-3}$

$\mu = ML^{-1}T^{-1}$

$\therefore$ Fundamental Dimensions $\rightarrow m = 3$

$\therefore$ number of π terms $\Rightarrow n - m \Rightarrow 7 - 3 = 4$

Hence $f_1(\pi_1, \pi_2, \pi_3, \pi_4) = 0$ — ①

Choosing D, V, ρ as repeating variables

$\pi_1 = D^{a_1} V^{b_1} \rho^{c_1} F$

$\pi_2 = D^{a_2} V^{b_2} \rho^{c_2} T$

$\pi_3 = D^{a_3} V^{b_3} \rho^{c_3} N$

$\pi_4 = D^{a_4} V^{b_4} \rho^{c_4} \mu$

First π term :-> $\pi_1 = D^{a_1} V^{b_1} \rho^{c_1} F$

$$M^0 L^0 T^0 = L^{a_1} [L T^{-1}]^{b_1} (M L^{-3})^{c_1} (M L^{+1} T^{-2})$$

equating powers

$(M) \to \quad 0 = c_1 + 1 \Rightarrow c_1 = -1$

$(L) \to \quad 0 = a_1 + b_1 - 3c_1 + 1 \Rightarrow a_1 + b_1 - 3(-1) + 1 = 0$

$a_1 + b_1 = -4$

$(T) \to \quad 0 = -b_1 - 2 \Rightarrow b_1 = -2 \quad \& \quad a_1 = -2$

$$\therefore \pi_1 = D^{-2} V^{-2} \rho^{-1} F \Rightarrow \pi_1 = \frac{F}{\rho V^2 D^2}$$

Second π- term :-

$$\pi_2 = D^{a_2} V^{b_2} \rho^{c_2} T$$

$$M^0 L^0 T^0 = L^{a_2} (L T^{-1})^{b_2} (M L^{-3})^{c_2} (M L^2 T^{-2})$$

$(M) \to \quad 0 = c_2 + 1 \Rightarrow c_2 = -1$

$(L) \to \quad 0 = a_2 + b_2 - 3c_2 + 2 \Rightarrow a_2 + b_2 - 3(-1) + 2 = 0$

$a_2 + b_2 = -5$

$(T) \to \quad 0 = -b_2 - 2 \Rightarrow -b_2 = 2 \Rightarrow b_2 = -2 \quad \&$

$a_2 = -3$

$$\pi_2 = D^{-3} V^{-2} \rho^{-1} T$$

$$\pi_2 = \frac{T}{\rho V^2 D^3}$$

Third π-term:-

$$\Pi_3 = D^{a_3} V^{b_3} \rho^{c_3} N$$

$$M^0 L^0 T^0 = L^{a_3} (LT^{-1})^{b_3} (ML^{-3})^{c_3} (T^{-1})$$

$(M) \rightarrow 0 = c_3 \Rightarrow c_3 = 0$

$(L) \rightarrow 0 = a_3 + b_3 - 3c_3$

$0 = a_3 + b_3 \Rightarrow a_3 = -b_3$

$(T) \rightarrow 0 = -b_3 - 1 \Rightarrow b_3 = -1$ &

$a_3 = +1$

$$\Pi_3 = D^1 V^{-1} \rho^0 N$$

$$\Pi_3 = \frac{ND}{V}$$

Fourth π-term:->

$$\Pi_4 = D^{a_4} V^{b_4} \rho^{c_4} \mu$$

$$M^0 L^0 T^0 = L^{a_4} (LT^{-1})^{b_4} (ML^{-3})^{c_4} (ML^{-1}T^{-1})$$

$(M) \rightarrow 0 = c_4 + 1$

$c_4 = -1$

$(L) \rightarrow$

$0 = a_4 + b_4 - 3c_4 - 1$

$0 = a_4 + b_4 - 3(-1) - 1$

$a_4 + b_4 = -2$

$(T) \rightarrow$

$$0 = -b_4 - 1$$

$$b_4 = -1 \;\&$$

$$a_4 = -2-(-1)$$

$$a_4 = -1$$

$$\therefore \Pi_4 = D^{-1} V^{-1} \rho^{-1} \mu$$

$$\Pi_4 = \frac{\mu}{\rho V D}$$

sub all Π terms in (1)

$$f_1 \left[\frac{F}{\rho V^2 D^2}, \frac{T}{\rho V^2 D^3}, \frac{ND}{V}, \frac{\mu}{\rho V D} \right] = 0$$

$$\frac{F}{\rho V^2 D^2} = \phi \left[\frac{T}{\rho V^2 D^3}, \frac{ND}{V}, \frac{\mu}{\rho V D} \right]$$

$$\Rightarrow \boxed{F = \rho D^2 V^2 \phi \left[\frac{T}{\rho V^2 D^3}, \frac{ND}{V}, \frac{\mu}{\rho V D} \right]}$$

MODULE - 5

Q 9)

(a) Relation for velocity of sound interms of bulk modulus →

$$\text{Bulk modulus (k)} = \frac{\text{Increase in Pressure}}{\frac{\text{Decrease in volume}}{\text{Original Area}}}$$

$$\therefore k = \frac{dP}{-\left(\frac{dv}{V}\right)}$$

Where dv = Decrease in volume , V = original volume

mass of fluid $= \rho \times V = \text{const}$ — ①

Differentiating ①

$$\rho dv + V d\rho = 0$$

$$\rho dv = -V d\rho$$

$$\frac{-dv}{V} = \frac{d\rho}{\rho} \quad \text{— ②}$$

sub ② in k equ^n

$$k = \frac{dP}{\frac{d\rho}{\rho}} \Rightarrow \rho \frac{dP}{d\rho}$$

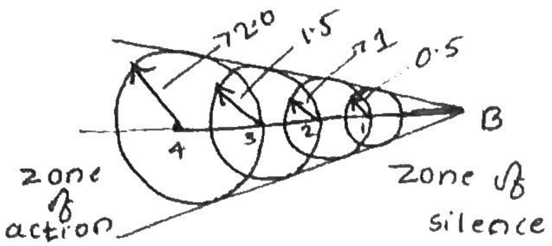
$$\Rightarrow \frac{dP}{d\rho} = \frac{k}{\rho}$$

WKT $c = \sqrt{\frac{dP}{d\rho}}$

$$\therefore \boxed{c = \sqrt{\frac{k}{\rho}}}$$

Q 9)
b)

(i) Mach Cone :-



When $M > 1$ (super sonic flow)

When the flow is supersonic the sphere of propogation of disturbance always lags behind the projectile. If we draw a tangent to the different circles which represent the propogated spherical waves on both sides, we shall get a cone with vertex at B as showing in fig. This cone is known as "Mach Cone."

(ii) Mach Number :- (M)

Mach Number is defined as square root of the ratio of the inertia force of a flowing fluid to elastic force. i.e. $M = \sqrt{\frac{\text{Inertia Force}}{\text{Elastic force}}}$

g $\boxed{M = \frac{V}{C}}$

Mach Number is a non dimensional parameter

on basis of mach number flow can be defined

as ->

1) Subsonic Flow ($M < 1$)

2) Sonic Flow ($M = 1$)

3) Supersonic Flow ($M > 1$)

Q 9)

(c) $Z = 12 km$

$T = -53°C + 273 = 220K$

$V = ?$

$M = 2$

$K = 1.4$ & $R = 287 J/kgK$

velocity of sound (c)

$$c = \sqrt{KRT} = \sqrt{1.4 \times 287 \times 220}$$

$$c = 297.31 m/s$$

WKT $M = \frac{V}{c}$

$$2.0 = \frac{V}{297.31}$$

$$\boxed{V = 594.62 m/s}$$ $\Rightarrow \frac{594 \times 3600}{1000} = 2140.63 km/hr$

or

$$\boxed{V = 2140.63 \frac{km}{hr}}$$

8)

Q 10)

a)

Importance of CFD: →

CFD analyses have a great potential to save time in design process and are therefore cheaper and faster compared to conventional testing for data acquisition. Furthermore, in real life tests a limited amount of quantities is measured at a time, while in CFD analysis of all desired quantities can be measured at once and with a high resolution of space and time.

Because CFD analyses approximate a real physical solution, it should be noted that these CFD analyses cannot fully exclude physical testing procedures. Modern Engineers apply both experimental and CFD analyses & the two complete each other.

With CFD analysis one can understand the flow and heat transfer throught the design process

CFD, also sometimes referred to as fluid flow simulation, which is a numerical computer simulation that permits the fluid flows around or through any object, so the impact on that object can be analysed in detail.

When using CFD, an engineer can establish early on whether their product will conform to the desired requirements Hence CFD methods significantly increases the level of design insight available to engineers throughout design process.

Application of CFD:→

* CFD simulation for preventing Cavitation
* Simulation of Rotating machinery using CFD
* CFD simulation for analysis of laminar and Turbulent flow.
* CFD simulation in HVAC applications
* Simulation of Aerodynamics with CFD
* Simulation by CFD in Heat transfer & Thermal management simulation
* CFD simulation in Pipe & valve

* simulating electronic cooling with CFD
* simulation of Turbomachinery with CFD
* Simulating Reacting Flows and combustion with CFD.

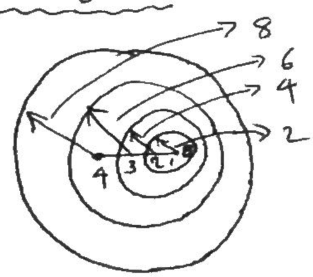
Q10)

b) Types of sonic Flows: ->

on the basis of Mach number, the flows are classified as ->

1) subsonic flow
2) Sonic flow
3) Super Sonic flow

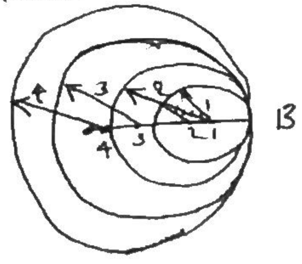
1) Sub sonic flow:- (when $M<1$)



when mach number is less than 1.0, flow is called subsonic flow. For $M<1$ means $V<C$

As in this case $V<C$ the pressure wave is always ahead of projectile & point B is inside the sphere of radius.

2) Sonic Flow:- (when $M=1$)

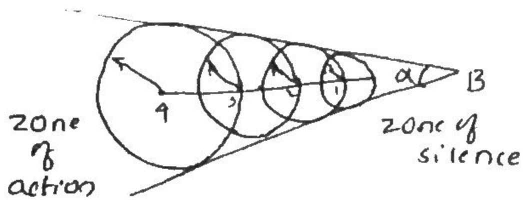


When $M=1$, the flow is known as sonic flow

As in this case $M=1$ means $V=C$

In this case, the disturbance always travels with the projectile as shown in fig.

3) Super sonic flow:- [when ($M>1$)]



When mach number M is greater than one i.e. $M>1$ the flow is known as supersonic flow.

As in this case $M>1$ means $V>C$.

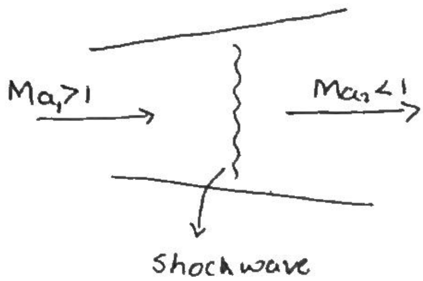
In this case the sphere of propogation of disturbance always lags behind the projectile. If we draw a tangent to different circles which represent the propogated waves on both side we shall get cone with vertex at B & is known as Mach Cone.

Q 10)

c)

Normal shock & Oblique shock:->

Normal shock:-



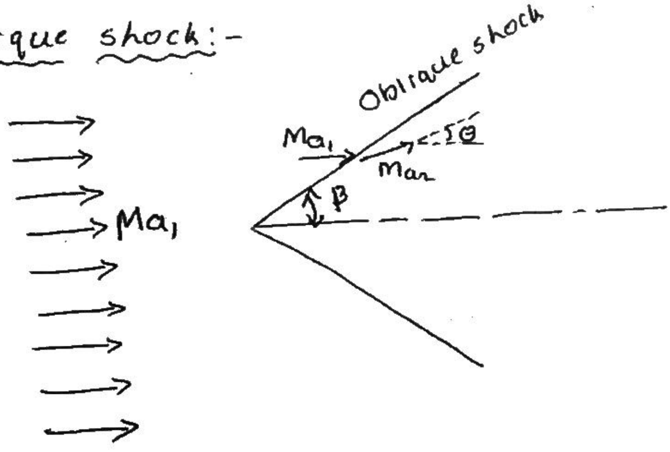
* In normal shocks mach number decreases across normal shock.

* Downstream Mach number is always subsonic.

Some backpressure values, abrupt changes in fluid properties occur in very thin section of converging - diverging nozzle, under supersonic flow conditions, creating shock wave.

If the shock waves that occur in a plane normal to direction of flow, such waves are called normal shock waves.

Oblique shock:-



β => Shock Angle

θ => Deflection Angle of flow

Not all shock waves are normal shocks

For example, when the space shuttle travels at supersonic speeds through atmosphere, it produces a complicated shock pattern consisting of inclined shock waves.

Such kind of inclined shockwaves are called oblique shock waves.

Mach number decreases ~~along~~ across a oblique shock and oblique shocks are possible only if upstream flow is supersonic. Downstream of oblique shock can be subsonic, sonic or supersonic depending on upstream Mach number Ma_1 & turning angle.