OR					
9	a)	Explain the principle of Venturimeter with a neat sketch. Derive the expression for rate of flow of fluid through it.	L3	CO4	5 M
	b)	Explain the principle of an orifice meter with a neat sketch. Derive the expression for rate of flow of fluid through it.	L3	CO4	5 M
UNIT-V					
10	a)	Define the head loss in pipes. Derive the Darcy Weishbach equation for major head loss in a pipeline.	L4	CO5	5 M
	b)	Define notches and weirs. Differentiate between them with neat sketches.	L3	CO5	5 M
OR					
11	a)	Explain the concept of equivalent pipe in fluid mechanics.	L3	CO5	5 M
	b)	Derive the expression for discharge over a trapezoidal notch.	L4	CO5	5 M

Code: 23CE3303

II B.Tech - I Semester – Regular / Supplementary Examinations
NOVEMBER 2025

FLUID MECHANICS
(CIVIL ENGINEERING)

Duration: 3 hours Max. Marks: 70

Note: 1. This question paper contains two Parts A and B.
2. Part-A contains 10 short answer questions. Each Question carries 2 Marks.
3. Part-B contains 5 essay questions with an internal choice from each unit. Each Question carries 10 marks.
4. All parts of Question paper must be answered in one place.

BL – Blooms Level CO – Course Outcome

PART – A

		BL	CO
1.a)	Write a short note on types of fluids based on viscosity.	L1	CO1
1.b)	Define the term surface tension.	L1	CO1
1.c)	Differentiate between Manometers and pressure gauges.	L1	CO2
1.d)	Write a note on hydrostatic forces.	L1	CO2
1.e)	Differentiate between uniform and non-uniform flow.	L1	CO3
1.f)	Define the term Streamline and path line.	L1	CO3
1.g)	Define the term Reynolds number.	L1	CO4
1.h)	Write a short note on Froude number.	L1	CO4
1.i)	Define the term Hydraulic gradient line and total energy line.	L1	CO5
1.j)	Write in short about minor losses in pipelines.	L1	CO5

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2	a)	Differentiate between a fluid and solid. Explain their deformation characteristics under shear stress.	L3	CO1	5 M
	b)	State and explain Newton's laws of viscosity. Differentiate between dynamic viscosity and kinematic viscosity.	L3	CO1	5 M
		OR			
3	a)	Explain the concept of capillarity. What are the factors affecting capillarity.	L3	CO1	5 M
	b)	Define vapour pressure. Explain how cavitation occurs in hydraulic machines.	L3	CO1	5 M
		UNIT-II			
4	a)	Differentiate between atmospheric, gauge and vacuum pressure with neat sketches.	L2	CO2	5 M
	b)	State and explain Pascal's law. Derive the expression.	L4	CO2	5 M
		OR			
5	a)	Discuss in detail about the working principle of U-tube manometer.	L3	CO2	5 M
	b)	The right limb of a simple U-tube manometer containing mercury is open to the atmosphere while the left limb is connected to a pipe in which a liquid of sp.gr. 0.9 is flowing. The center of the	L3	CO2	5 M

		pipe is 12cm below the level of mercury in the right limb. Find the pressure of fluid in the pipe if the difference of mercury level in two limbs is 20cm.			
		UNIT-III			
6	a)	Define and differentiate between (i) Steady and unsteady flow (ii) Compressible and incompressible flow.	L2	CO3	5 M
	b)	Write a brief note on (i) Stream function (ii) Velocity potential function.	L2	CO3	5 M
		OR			
7	a)	Define the equation of continuity. Obtain an expression for continuity equation for a three-dimensional flow.	L4	CO3	5 M
	b)	Explain the significance of streamlines in fluid motion analysis.	L3	CO3	5 M
		UNIT-IV			
8	a)	State and explain momentum principle for fluid flow. Derive it.	L4	CO4	5 M
	b)	An oil of specific gravity of 0.9 is flowing through a Venturimeter having inlet diameter 0.2m and throat diameter 0.1m. The oil - mercury differential manometer shows a reading of 0.2m. Calculate the discharge of oil through the horizontal Venturimeter. Take Coefficient of discharge, $C_d = 0.98$.	L4	CO4	5 M

Scheme of Evaluation Fluid Mechanics

PART A

1) a) Definitions of viscous, Non-viscous (or) Ideal & real fluid — 2 M

b) Definition of surface tension — 2 M.

c) working principles of Manometer and pressure gauges — 2 M.

d) Definition of hydrostatic forces — 2 M.

e) Definitions of uniform and Non uniform flow — 2 M.

f) Definition of stream line and path line — 2 M.

g) Definition of Reynold Number — 2 M.

h) " Froude Number — 2 M.

i) Definitions of HEL and TEL — 2 M

j) what are minor losses (definition) — 2 M.

PART - B

2) a) what is a fluid and solid — 2 } 5 M.
graph and defitions — 3

b) statement of Newton's law of viscosity — 2 } 5 M.
differences between dynamic and kinematic viscosity — 3

3) a) Concept of capillarity — 3 } 5 M.
factors affecting capillarity — 2

b) Vapour pressure definition — 2 } 5 M.
How cavitation occurs — 3

4) a) Definitions of atmosphere, gauge and Vacuum pressure — 3 } 5 M
diagram showing relationship — 2

b) Pascal's law statement — 2 } 5 M.
Derivation — 3

5) a) working principle of U-tube manometer — 2 } 5 M.
diagram and explanation — 3

b) Calculation of ~~differential head~~ density and given data conversion — 2 } 5 M
Pressure calculation — 3

6) a) Definition of steady and unsteady flow —— (3) } 5M.
" compressible and incompressible —— (2)

b) Stream function Definition and expression —— (2) } 5M
Velocity potential function " —— (3)

7) a) Continuity equation Definition —— (2) } 5M.
Derivation —— (3)

b) Significance of stream lines —— (5)M
(Definition and use.)

8) a) Momentum principle —— (3) } 5M.
Derivation —— (2)

b) Calculation of differential head —— (2) M. } 5M.
" discharge —— (3) M.

) a) Declaration of Parameters —— (2) } 5M.
Rest of the Derivation —— (3)

b) Declaration of Parameter —— (2) } 5M.
Rest of Derivation —— (3)

) a) Head losses Definition —— (2) } 5M.
Derivation —— (3)

b) Notches and weirs —— (3) } 5M.
Differences.
diagram —— (2)

) a) Definition of equivalent pipe —— (2) } 5M.
Concept —— (3)

b) For declaration of Parameters —— (2) } 5M.
Rest of the derivation —— (3)

II B.Tech I sem Regular Fluid Mechanics November-2025
Civil Engineering
(Key)

PART-A

1.

a) Based on viscosity fluids are of two types.

1. Ideal fluids :- A fluid which is not having viscosity is known as Ideal fluid.

2. Real fluid :- A fluid which possesses viscosity is known as Real fluid.

b) Surface tension :- The tensile force acting on the surface of a liquid in contact with a gas or on the surface between two immiscible liquids (or) Tensile force acting per unit length of the surface

c)

Manometers	Pressure gauges
These are used for measuring the pressure at a point in a fluid by balancing the column of fluid by same or another column of fluid	These are used for measuring pressure by balancing the fluid column by spring or dead weight.

d) Hydrostatic forces :- It is the force exerted by a fluid at rest on a submerged surface, and it acts perpendicular to the surface.

e) Uniform and Non-uniform flow :-

Uniform flow is that type of flow in which flow parameters like velocity, acceleration, discharge etc do not change or remain constant with respect to space (along the length of the flow).

Non-uniform flow is that type of flow in which flow parameters change (or) do not remain constant with respect to space.

f) Stream line :- A stream line is an imaginary line tangent to the velocity of fluid at a specific instant, showing the instantaneous direction of flow.

A path line is the actual path followed by a single fluid particle over time.

g) Reynold number: It is the ratio of Inertia force to viscous force.

$$Re = \frac{\text{Inertia force}}{\text{Viscous force}} = \frac{\rho v d}{\mu}$$

h) Froud Number: It is ratio of square root of Inertia force to gravitational force

$$\therefore F_N = \sqrt{\frac{\text{gravity force}}{\text{viscous force}}} = \frac{V}{\sqrt{gd}}.$$

i) Hydraulic gradient line: It is the line obtained by sum of the datum head and pressure head

Total energy line: It is the line obtained by sum of the datum head, pressure head, and Kinetic head.

j) Minor losses in pipe lines: The loss of energy due to change of velocity of the flowing fluid in magnitude or direction is considered as minor loss.

PART- B

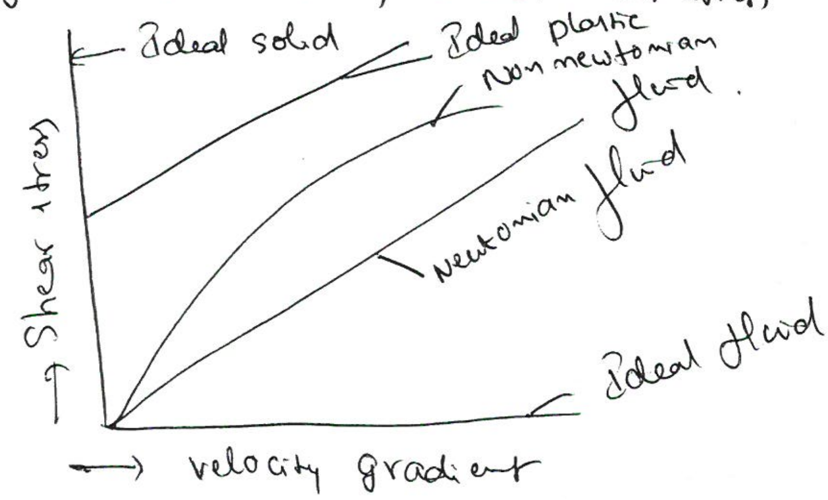
1)

a) Matter exists in 3 forms solids, liquids and gases

liquids and gases together called as fluids as they have the capacity to flow.

Solids have a definite shape and volume while fluids donot have definite shape and flow to attain the shape of container.

Solids resist shear stress and maintain their forms where as fluids deform continuously under shear stress and cannot sustain it



A fluid in which the shear stress is proportional to rate of ~~Shear~~ shear strain is known as a Newtonian fluid.

A fluid in which the shear stress is not proportional to the rate of shear strain is known as Non-Newtonian fluid.

Ideal plastic fluid :- A fluid in which shear stress is more than the yield value and shear stress is proportional to rate of shear strain.

---o---

b) 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 co-efficient of viscosity. It is expressed as

$$\tau = \mu \left[\frac{du}{dy}\right]$$

Fluids which obey the above relation are Newtonian fluids and which don't obey the above relation are Non-Newtonian fluids

dynamic viscosity :- It is the shear stress required to produce unit rate of shear strain. It is denoted by 'μ' (mu)

Units :- $\frac{Ns}{m^2}$

Kinematic viscosity :- It is defined as the ratio of dynamic viscosity of a fluid to its density.

It is denoted by (ν) (nu)

Units :- $\frac{m^2}{s}$.

---o---

3) a) Capillarity is defined as a phenomenon of rise or fall of a liquid surface in a small tube relative to the adjacent general level of liquid when tube is held vertically in a liquid. The rise of liquid surface is known as capillary rise while the fall of the liquid

surface is known as <u>capillary depression</u>. It is expressed in terms of cm or mm of liquid.

<u>The factors affecting capillarity are</u>:-

1. specific weight of the liquid.
2. diameter of the tube
3. surface tension of the liquid.

---

c) <u>Vapour pressure</u>:- A change from the liquid state to the gaseous state is known as <u>vaporization</u>. It occurs because of continuous escaping of the molecules through the free liquid surface. It is the pressure at which a liquid is converted into vapours.

If the pressure above the liquid surface is reduced to such an extent that it becomes equal to or less than vapour pressure, the boiling of the liquid will start. Thus a liquid may boil even at ordinary temperature if the pressure above the liquid surface is reduced

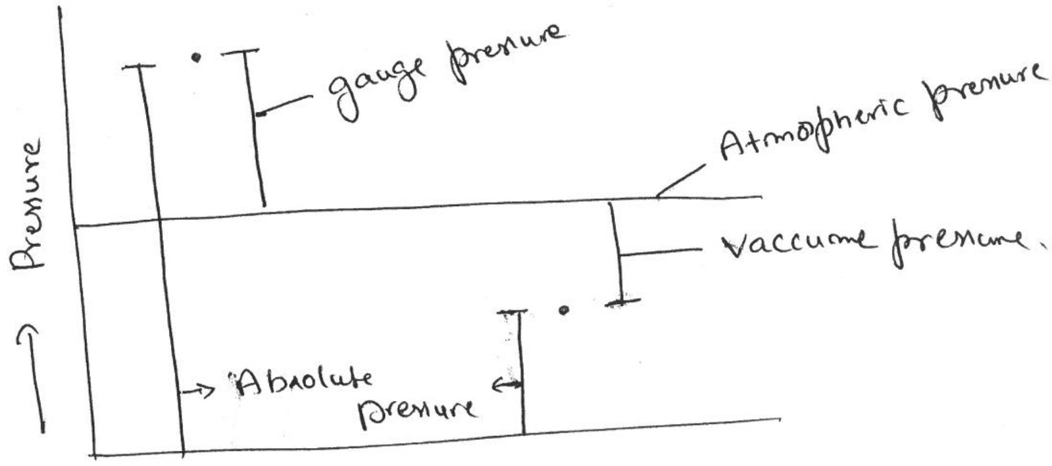
<u>Cavitation</u>:- If the pressure at any point in this flowing liquid becomes equal to or less than the vapour pressure, then vaporization starts and bubbles are formed. These bubbles are carried by the flowing liquid into the region of high pressure where they collapse giving rise to high impact pressure. This pressure is high and damages the surfaces and cavities are formed. This phenomenon is known as <u>cavitation</u>. The metallic surfaces above which the liquid is flowing is subjected to these high pressures, which cause pitting action on the surface. Thus cavities are formed on the metallic surface and hence it is called <u>cavitation</u>

---

④

a) The pressure on a fluid is measured in two systems. In one system it is measured above absolute zero or complete vaccume and it is called absolute pressure and in other system it is measured above the atmospheric pressure and it is called gauge pressure

Vaccume pressure :- is defined as the pressure below the atmospheric pressure.



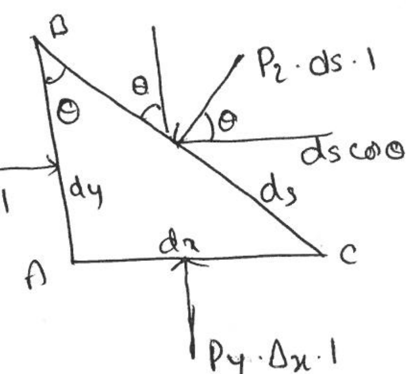
Relationship between pressure

b) Pascal's law :- It states that the pressure at a point in a static fluid is equal in all directions.

Derivation :- consider an arbitrary fluid element of wedge shape in a fluid mass at rest

Let the width of the element ⊥ to the plane of paper is unity. and P_x, P_y and P_z are the pressure intensities acting on the face AB, AC and BC respectively

Let ∠ABC = θ Then the forces acting on the element are.



1. Pressure forces normal to the surface
2. Wt of the fluid element in vertical direction.

Force on face AB = $P_x \times dy \times 1$

" AC = $P_y \times dx \times 1$

" BC = $P_z \times ds \times 1$

Wt of the element = $Mg = \rho V \times g = \left(\frac{AB \times AC}{2} \times 1\right) \times \rho \times g$

Resolving the forces in the direction-x we get

$$P_x \times dy \times 1 - P_z(ds \times 1)\sin(90^\circ - \theta) = 0$$

$$P_x \times dy \times 1 - P_z \times ds \times \cos\theta = 0.$$

But $ds\cos\theta = AB = dy$.

$$\therefore P_x \times \cancel{dy \times 1} = P_z \times ds\cos\theta = P_z \times \cancel{dy}$$

$$\therefore P_x = P_z. \quad \text{--- (1)}$$

Similarly resolving the forces in y-direction we get

$$P_y \times dx \times 1 - P_z \times ds \times 1\cos(90^\circ - \theta) - \frac{dx \times dy}{2} \times 1 \times \rho \times g = 0$$

But the element is very small hence wt can be neglected

$$\therefore P_y \times dx \times 1 - P_z \times ds \times \sin\theta = 0.$$

$\therefore$ but $ds\sin\theta = dx$

$$\therefore P_y \times \cancel{dx \times 1} = P_z \times \cancel{dx \times 1}$$

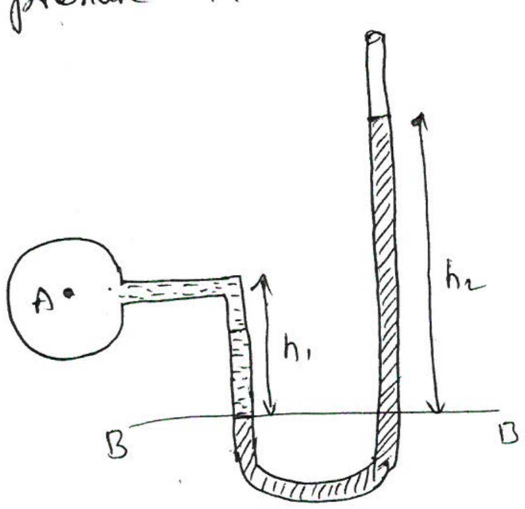
$$\therefore P_y = P_z \quad \text{--- (2)}$$

From equations (1) and (2) we have

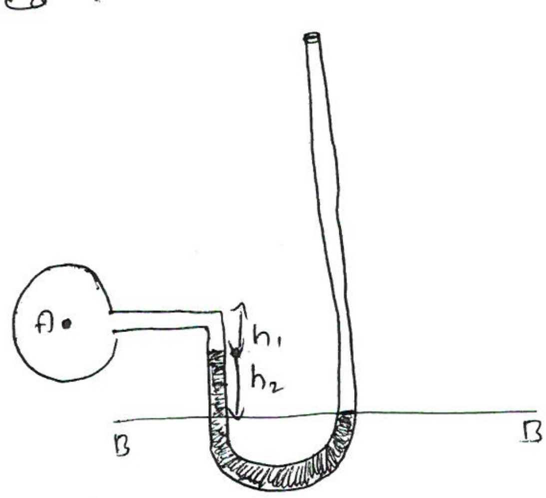
$$\boxed{P_x = P_y = P_z}$$

o

) a) U-tube manometer: It consists of glass tube bent in U-shape one end of which is connected to a point at which pressure is to be measured and other end remains open to the atmosphere. The tube generally contains mercury or any other liquid whose specific gravity is greater than specific gravity of the liquid whose pressure is to be measured.



For gauge pressure



For vaccume pressure

U-tube manometer is a device used for measuring the pressure at a point in a fluid by balancing the column of fluid by the same or another column of the fluid.

b) given data:

$S_1 = 0.9$

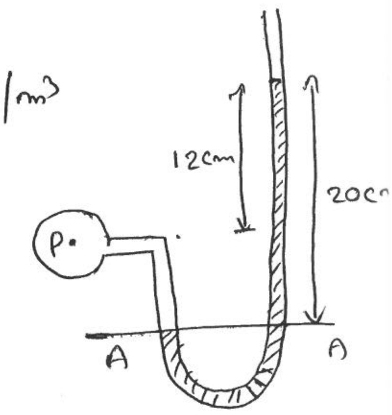
$\rho_1 = S_1 \times 1000 = 0.9 \times 1000 = 900\ kg/m^3$

$S_2 = 13.6$

$\rho_2 = 13.6 \times 1000 = 13600\ kg/m^3$

differential mercury level: $h_2 = 20\,cm = 0.2\,m$

$h_1 = 20 - 12 = 8\,cm = 0.08\,m$



equating the pressures above the datum line.

Let P = Pressures of fluid in the pipe.

$\therefore\ P + \rho_1 g h_1 = \rho_2 g h_2$

$P + 900 \times 9.81 \times 0.08 = 13600 \times 9.81 \times 0.2$

$\therefore\ P = 25977\ N/m^2 = 2.597\ N/cm^2$

6) a) i) Steady flow:- It is the ~~flow~~ flow in which flow parameters like, velocity, acceleration, discharge etc do not change or remain constant with respect to time. Mathematically it is expressed as

$$\frac{\partial v}{\partial t} = 0 \qquad \frac{\partial Q}{\partial t} = 0$$

Unsteady - flow:- It is the flow in which flow parameters change with respect to time, Mathematically it is expressed as

$$\frac{\partial v}{\partial t} \neq 0 \qquad \frac{\partial Q}{\partial t} \neq 0$$

ii) Compressible flow is that type of flow in which density remains constant. Ex: liquid flow.

$\therefore\ \rho =$ constant.

Incompressible flow: is that type of flow in which density does not remain constant. Ex: gases

$\therefore\ \rho \neq$ constant

b) Stream Potential function : It is defined as scalar function of space and time, such that its partial derivative with respect to any direction gives velocity component at right angles to that direction.

It is denoted by ψ (Psi) and is defined only for two dimensional flow. Mathematically for steady flow it is defined as $\psi = f(x, y)$ such that

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

Velocity potential function: It is defined as a scalar function of space and time such that its -ve derivative with respect to any direction gives the fluid velocity in that direction. It is denoted by ϕ (Phi). Mathematically the velocity potential function is defined as $\phi = f(x, y, z)$ for steady flow such that

$$u = -\frac{\partial \phi}{\partial x} \qquad v = -\frac{\partial \phi}{\partial y} \qquad w = -\frac{\partial \phi}{\partial z}.$$

) a) continuity equation: The equation based on Principle of Conservation of mass is called continuity equation

Continuity equation in 3-dimensions:

Consider a fluid element of length d_x, d_y and d_z in the direction of x, y and z. Let u, v, and w are the inlet velocity components in x, y and z directions respectively.

Mass of the fluid entering the face ABCD per second

$= \rho \times$ velocity in x direction $\times$ Area of ABCD

$= \rho \times u \times dy \times dz.$

Then the mass of fluid leaving the face EFGH per second

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

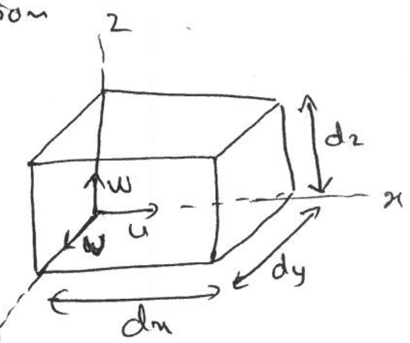
∴ Gain of mass in x-direction = Mass through ABCD − Mass through EFGH / sec

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

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

Similarly the net gain of mass in 'y' direction

$$= -\frac{\partial}{\partial y}(\rho v)\, dx\, dy\, dz$$



and in 'z' direction $= -\frac{\partial}{\partial z}(\rho w)\, dx\, dy\, dz$

∴ The net gain of mass $= -\left[\frac{\partial}{\partial x}(\rho u) + \frac{\partial}{\partial y}(\rho v) + \frac{\partial}{\partial z}(\rho w)\right] dx\, dy\, dz.$

Since the mass is neither created nor destroyed in the fluid element the net increase of mass per unit time in the fluid element must be equal to the rate of increase of mass of fluid in the element. But the mass of fluid in the element is $\rho \cdot dx\, dy\, dz$ and its rate of increase with time is $\frac{\partial}{\partial t}(\rho \cdot dx\, dy\, dz) = \frac{\partial \rho}{\partial t}(\rho \cdot dx\, dy\, dz)$

equating the two expressions we get

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

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

b) Explain the significance of streamlines in fluid motion Analysis?

A stream line is an imaginary curve drawn through a flowing fluid in such a way that the tangent to it at any point gives the direction of velocity of flow at that point.

→ Since a fluid is composed of fluid particles the pattern of flow of fluid is represented by a series of stream lines.

→ For steady flow the stream line pattern remains the same at different times but for an unsteady flow the stream line pattern may change from time to time.

8) b) given data :

$S_o = 0.9$

$S_h = 13.6$

Reading of differential manometer $x = 0.2$ m.

$\therefore$ Differential pressure head $h = x\left[\frac{S_h}{S_o} - 1\right]$

$= 0.2\left(\frac{13.6}{0.9} - 1\right)$

$= 0.2 \times (15.1 - 1)$

$= 0.2 \times 14.1 = 2.82$ m

Dia at inlet $d_1 = 0.2$ m.

$\therefore a_1 = \frac{\pi d_1^2}{4} = \frac{3.14 \times (0.2)^2}{4} = \frac{3.14 \times 0.04}{4}$

$= \frac{0.04 \times 3.14}{4} = \frac{0.1256}{4} = 0.0314\ m^2$

Dia at throat $d_2 = 0.1$

$\therefore a_2 = \frac{\pi d_2^2}{4} = \frac{3.14 \times (0.1)^2}{4} = \frac{3.14 \times 0.01}{4}$

$= \frac{0.0314}{4} = 0.00785\ m^2$

$C_d = 0.98$.

$\therefore$ The discharge $Q = C_d \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$

$= 0.98 \times \frac{0.0314 \times 0.00785}{\sqrt{(0.0314)^2 - (0.00785)^2}} \times \sqrt{2 \times 9.81 \times 2.82}$

$= 0.00591\ m^3/sec.$

---

c) momentum priciple :- It is based on law of conservation of momentum which states that the net force acting on a fluid mass is equal to the change in momentum of flow per unit time in that direction.

The force action on a fluid mass 'm' is given by the newton's 2nd law of motion.

$F = m \times a$

where 'a' is the acceleration acting in the same direction of force F.

$$\text{But } a = \frac{dv}{dt}$$

$$\therefore F = m \cdot \frac{dv}{dt}$$

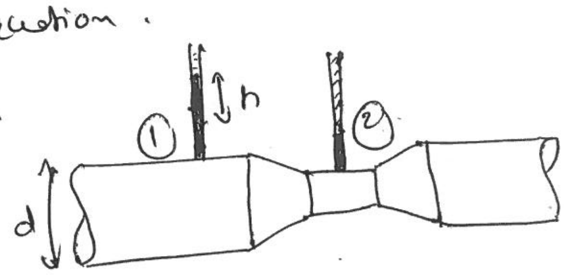
$$= \frac{d(mv)}{dt}$$ (m is constant and can be taken into differential)

$$\therefore \boxed{F = \frac{d(mv)}{dt}}$$

---

9) a) Expression for rate of flow through venturimeter: It is based on the principle of Bernoulli's equation.

Consider a venturimeter fitted in a horizontal pipe through which a fluid is flowing.



Let d_1 = diameter at inlet section (1)

P_1 = Pressure at section (1)

V_1 = velocity at section (1)

a_1 = area at section (1) $= \frac{\pi d_1^2}{4}$

and d_2, P_2, V_2 and a_2 are corresponding values at section (2)

applying Bernoulli's equation at section (1) and (2) we get

$$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + \cancel{z_1} = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + \cancel{z_2}.$$ But $z_1 = z_2$ as pipe horizontal

$$\therefore \frac{P_1 - P_2}{\rho g} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} \quad (1)$$ But $\frac{P_1 - P_2}{\rho g}$ = differential head $= h$.

$$\therefore h = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} \quad (2)$$

applying continuity equation $a_1 V_1 = a_2 V_2$ $\therefore V_1 = \frac{a_2 V_2}{a_1}$

Substituting 'V_1' value in equation (2) we get.

$$\therefore h = \frac{V_2^2}{2g}\left(\frac{a_1^2 - a_2^2}{a_1^2}\right) \therefore V_2^2 = 2gh\left(\frac{a_1^2}{a_1^2 - a_2^2}\right)$$

$$\therefore V_2 = \sqrt{2gh\frac{a_1^2}{a_1^2 - a_2^2}} = \frac{a_1}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

$\therefore$ discharge $Q = a_2 V_2$

$$\therefore Q = \frac{a_2 \, a_1}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh} = \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}$$

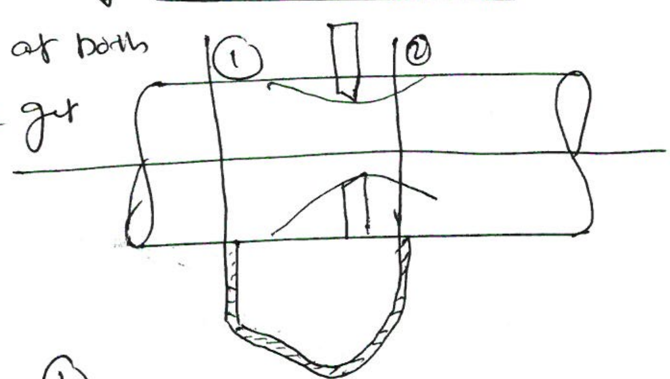
$\therefore$ Q is theoretical discharge.

$$\boxed{Q_{act} = C_d \times \frac{a_1 a_2}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2gh}}$$

---

ii) Orifice meter :- It is based on the Bernoulli's Principle.

After applying Bernoulli's equation at both section we get



$$\therefore h = \frac{V_2^2}{2g} - \frac{V_1^2}{2g}$$

$$V_2^2 - V_1^2 = 2gh$$

$$\therefore V_2 = \sqrt{2gh + V_1^2} \quad \text{--- (1)}$$

Now section (2) is at vena contracta and a_2 represents the area at vena contracta

$\therefore$ If a_0 is the area of the orifice. then we have,

$$C_c = \frac{a_2}{a_0}$$

$$\therefore a_2 = a_0 \times C_c \quad \text{--- (2)}$$

By continuity equation we have, $a_1 V_1 = a_2 V_2$

$$\therefore V_1 = \frac{a_0 \, C_c}{a_1} V_2 \quad \text{--- (3)}$$

Substituting the value of (V_1) in equation (1)

$$\therefore V_2 = \sqrt{2gh + \frac{a_0 C_c^2 V_2^2}{a_1^2}}$$

$$\therefore V_2 = \frac{\sqrt{2gh}}{\sqrt{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$\therefore$ The discharge $Q = a_2 V_2 = V_2 \times a_0 C_c$

$$= \frac{a_0 \, C_c \sqrt{2gh}}{1 - \left(\frac{a_0}{a_1}\right)^2 C_c^2} \quad \text{--- (4)}$$

The above expression is simplified by way.

$$C_d = C_c \frac{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}$$

$$\therefore C_c = C_d \frac{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2}}$$

Substituting this value in equation (4) we get

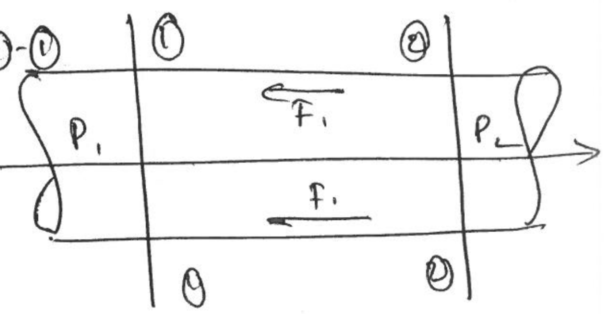
$$Q = a_0 \times C_d \frac{\cancel{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}}{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2}} \times \frac{\sqrt{2gh}}{\cancel{\sqrt{1-\left(\frac{a_0}{a_1}\right)^2 C_c^2}}}$$

$$\boxed{Q = C_d \frac{a_0 a_1}{\sqrt{a_1^2 - a_0^2}} \times \sqrt{2gh}}$$

---

10) a) Head loss in pipes: The loss of head a energy due to friction in a pipe is known as major loss while the loss of energy due to change of velocity of flowing fluid in magnitude or direction is called minor head loss.

Darcy-weisbach equation:- Consider a uniform horizontal pipe having steady flow. Let us consider 2 sections (1) and (2).



Let P_1 = Pressure intensity at section (1)-(1)

V_1 = velocity of flow at section (1)-(1)

L = length of pipe between two section

d = diameter of pipe.

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

h_f = loss of head due to friction.

and P_2, V_2 and are corresponding value at section (2)

Applying Bernoulli's equation between ② sections.

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

But $z_1 = z_2$ as pipe is horizontal

$$\therefore h_f = \frac{P_1}{\rho g} - \frac{P_2}{\rho g} \quad \text{—} (1)$$

$V_1 = V_2$ as dia is same.

<u>Frictional force</u>: Frictional resistance per unit wetted area per unit velocity

$$\therefore F_1 = f' \times \pi d L \times V^2$$

But $P = \pi d$.

$\downarrow$ wetted perimeter

$$F_1 = f' \times P \times L \times V^2 \quad \text{—} (2)$$

Force acting on the fluid between two sections.

1) Pressure force $= P_1 \times A$. at section (1)

2) " $= P_2 \times A$ at section (2)

3) Frictional force $F_1 = f' P L V^2$

Resolving forces in the direction of flow we get

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

$$\therefore (P_1 - P_2) A = F_1 = f' P L V^2$$

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

But from the equation (1).

$$P_1 - P_2 = \rho g h_f.$$

Substituting the value of $P_1 - P_2$ in the above eq. we get

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

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

$$\frac{P}{A} = \frac{4}{d}.$$

$$\frac{f'}{\rho} = \frac{f}{2} \text{ where}$$

f is frictional co-efficient

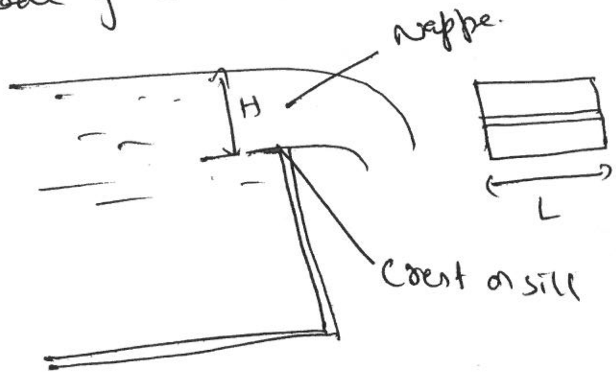
$$\therefore \boxed{h_f = \frac{4 f L V^2}{2 g d}}$$

b) <u>Notches and weirs</u>

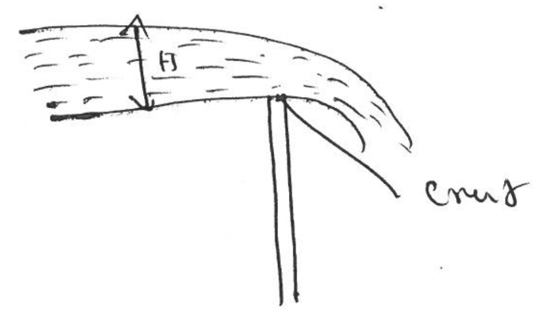
106) A Notch is a device used for measuring rate of flow of a liquid through a small channel or tank. It may be defined as an opening in the side of a tank or a small channel in such a way that the liquid surface in the tank is below the top edge of the opening.

A weir is a concrete or masonry structure placed in an open channel over which the flow occurs. It is generally in the form of vertical wall, with a sharp edge at the top running all the way across the open channel.

A notch is of small size while weir is of a large size. Notch is generally made of metallic plate while weir is made of concrete masonry.



Rectangular notch



Rectangular weir.

a

11) a) <u>Equivalent pipe</u>:- It is defined as the pipe of uniform diameter having loss of head and discharge equal to the loss of head and discharge of a compound pipe consisting of several pipes of different lengths and diameters. The uniform diameter of the pipe is called equivalent size of the pipe. The length of the pipe is equal to the sum of the lengths of pipes of compound pipe.

Let L_1, L_2, and L_3 are the lengths of pipes of a compound pipe

d_1, d_2 and d_3 are diameter of pipes of compound pipe

H = total head loss

L = length of equivalent pipe.

d = diameter of equivalent pipe. Then

$L = L_1 + L_2 + L_3$

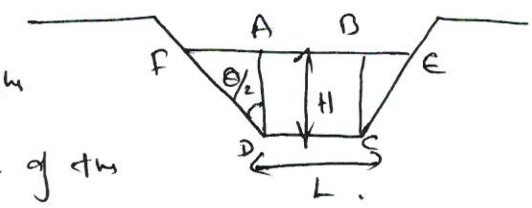
Total head loss in the compound pipe neglecting minor losses

$$H = \frac{4 f_1 L_1 V_1^2}{2 g d_1} + \frac{4 f_2 L_2 V_2^2}{2 g d_2} + \frac{4 f_3 L_3 V_3^2}{2 g d_3}$$

—— o ——

) **Expression for discharge over a trapezoidal Notch:-**

A trapezoidal notch is a combination of rectangular and triangular notch. Thus the total discharge will be equal to the sum of the discharge through a rectangular and triangular notch.



Let H = Height of water over the Notch

L = Length of the crest of Notch

Cd_1 = co-efficient of discharge for rectangular portion of Notch (ABCD)

Cd_2 = " " " triangular portion FAD and BCE.

∴ discharge through rectangular Notch ABCD

$$Q_1 = \frac{2}{3} Cd_1 \times L \times \sqrt{2g} \times H^{3/2}$$

The discharge through two triangular notches FDA and BCE is equal to the discharge through a single triangular notch of angle 'θ' and is equal to.

$$Q_2 = \frac{8}{15} \times Cd_2 \times \tan\frac{\theta}{2} \times \sqrt{2g} \times H^{5/2}$$

∴ The discharge through trapezoidal notch

$$= \frac{2}{3} Cd_1 \times L \times \sqrt{2g} \times H^{3/2} + \frac{8}{15} Cd_2 \times \tan\theta/2 \times \sqrt{2g} \times H^{5/2}$$

—— o ——