PVP 23

Code: 23ME3402

II B.Tech - II Semester – Regular / Supplementary Examinations APRIL 2026

FLUID MECHANICS AND HYDRAULIC MACHINES
(MECHANICAL 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)	Define mass density, specific volume and write units.	L1	CO1
b)	Define vacuum pressure.	L1	CO1
c)	Differentiate between streak line and stream tube.	L2	CO1
d)	Explain the significance of Reynolds experiment.	L2	CO1
e)	What is a boundary layer?	L1	CO1
f)	Define Buckingham Pi theorem .	L1	CO1
g)	Differentiate between impulse and pressure turbine.	L2	CO1
h)	What is the function of braking jet in turbine?	L1	CO1
i)	How the centrifugal pumps are connected for high pressure ?	L2	CO1
j)	Define slip and percentage of slip.	L1	CO1

PART – B

			BL	CO	Max. Marks
UNIT-I					
2	a)	Derive equations for surface tension for spherical droplet and cylindrical jet.	L3	CO1	5 M
	b)	Calculate the specific weight, density and specific gravity of one liter of liquid which weighs 7N.	L3	CO1	5 M
OR					
3	a)	Classify manometers. Derive equation for differential U tube manometer.	L2	CO1	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 fluid of sp. Gr. 0.9 is flowing. The center of the pipe is 12 cm below the level of mercury in the right limb. Find the pressure of fluid in the pipe if the difference of mercury level in the two limbs is 20cm.	L3	CO1	5 M
UNIT-II					
4	a)	State and derive the Euler's equation from fundamentals. State assumptions made in the derivation.	L3	CO2	5 M
	b)	A pipe of diameter 400 mm carries water at a velocity of 25m/sec .The pressures at the points A and B are given as 29.43N/cm^2 and 22.563N/cm^2 respectively while the datum head at A and B are 28m and 30m, find the loss of head between A and B.	L3	CO2	5 M

OR					
5	a)	Derive Darcy Weisbach equation for head loss due to friction in pipe.	L3	CO2	5 M
	b)	The difference in water surface levels in two tanks, which are connected by three pipes in series of lengths 300mm,170mm and 210mm and of diameters 300mm, 200mm and 400mm respectively is 12m. Determine the flow of water if co-efficient of friction are 0.005, 0.0052 and 0.0048 respectively, considering minor losses.	L3	CO2	5 M
UNIT-III					
6	a)	Define displacement thickness, momentum thickness and energy thickness in the context of boundary layer theory.	L2	CO3	5 M
	b)	Derive the energy thickness equation from fundamentals.	L3	CO3	5 M
OR					
7	a)	Explain the Buckingham Pi theorem with one suitable example.	L2	CO3	5 M
	b)	How can you check the dimensional homogeneity of an equation?	L2	CO3	5 M
UNIT-IV					
8	a)	Find the expression for the force exerted by the jet on a stationary curved plate in the direction of the jet.	L3	CO4	5 M
	b)	A nozzle of 50 mm diameter delivers a stream of water at 20m/s perpendicular to a plate that moves away from the jet at 5 m/s. Find the force on the plate, work done and efficiency of the jet.	L3	CO4	5 M

OR					
9	a)	Describe design steps for Pelton wheel .	L2	CO4	5 M
	b)	Explain the working of Kaplan turbine with sketch and velocity triangles.	L3	CO4	5 M
UNIT-V					
10	a)	Explain the working of centrifugal pump with neat sketch.	L3	CO4	5 M
	b)	A centrifugal pump is to discharge 0.118 m^3 per sec at a speed of 1450 rpm against a head of 25m. The impeller diameter is 250mm, its width at outlet is 50mm and manometric efficiency is 75%. Determine the vane angle at the outer periphery of the impeller.	L3	CO4	5 M
OR					
11	a)	Explain the working of double acting reciprocating pump with neat sketch.	L3	CO4	5 M
	b)	Explain the concept of pressure vessels in reciprocating pumps with neat sketch.	L3	CO4	5 M

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PART-A

1.a) Mass density definition & unit – 1M
Specific volume definition & unit – 1M } (2M)

1.b) Vaccum pressure definition – 2M

1.c) Any one difference between Streakline and stream tube – 2M

1.d) Reynold's experiment significance – 2M

1.e) boundary layer definition – 2M

1.f) Buckingham Pi theorem definition – 2M

1.g) Any one difference between impulse and pressure turbine – 2M

1.h) braking jet in turbine function – 2M

.i) centrifugal pumps are connected for high pressure explanation – 2M

.j) slip definition – 1M
percentage of slip definition – 1M } 2M

10×2 = (20M)

PART-B

UNIT-I

2.a) Surface tension for spherical droplet – 2.5M
Surface tension for cylindrical jet – 2.5M } (5M)

b) specific weight, Density, Specific gravity formulas – 3M
& final answers – 2M } (5M)

(10M)

(OR)

a) Manometers classification - 2M
Differential U tube manometer equation - 3M } (5M)
b) Simple U-tube manometer figure - 1M } (5M)
formula - 2M & Answer - 2M
(10M)

UNIT-II

a) Euler's equation statement - 1M, final equation - 3M
& assumptions - 1M (5M)
b) Formula (3M) & Answer (2M) - 5M
(10M)

OR

a) Darcy weisbach equation derivation - 5M
b) Formula (3M) & Answer (2M) - 5M
(10M)

UNIT-III

.a) Displacement thickness, mometum thickness &
energy thickness definitions - 5M
6.b) Energy thickness equation derivation - 5M
(10M)

OR

7.a) Bucking ham pi theorem with example - 5M
7.b) Dimensional Homogeneity of an equation - 5M
(10M)

UNIT-IV

8.a) Stationary curved plate figure - 2M & final expression - 3M (5M)
8.b) Force, W.D. & efficiency formulas - 3M & final answers - 2M (5M)
(10M)

OR

9.a) pelton wheel figure (2M) & Design Steps (3M) - (5M)
9.b) Kaplan Turbine Sketch (3M) & explanation & velocity triangles - (2M) - 5M
(10M)

UNIT-V

10.a) Centrifugal pump neat sketch - 3M & explanation - 2M (5M)
10.b) Formulas (3M) & final answer (2M) - 5M
(10M)

OR

11.a) Double acting reciprocating pump neat sketch - 3M + explanation - 2M - (5M)
11.b) pressure vessels figure - (3M) + explanation (2M) - (5M)
(10M)

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PART–A

1.a) Define mass density, Specific Volume and write units. (L1) (CO1) (2M)

Ans: mass density $(\rho) = \frac{\text{Mass of fluid}}{\text{Volume of fluid}}$

mass density unit $\frac{Kg}{m^3}$ (or) $\frac{gm}{cm^3}$

Specific Volume $(v) = \frac{\text{Volume of fluid}}{\text{Mass of fluid}} = \frac{1}{\rho}$

Specific Volume unit $\frac{m^3}{Kg}$ (2M)

1.b) Define Vacuum pressure. (L1) (CO1) (2M)

Ans: Vacuum pressure refers to a pressure that is lower than the surrounding atmospheric pressure. Instead of measuring how much pressure is present, it describes how much pressure is missing compared to normal air pressure.

(2M)

c) Differentiate between Streak line and Stream tube. (L2) (CO1) (2M)

Ans: A Streak line is an instantaneous picture of the position of all particles in flow that have passed through a given point

A stream tube is an imaginary tube whose boundary consists of Streamlines. (2M)

d) Explain the Significance of Reynold's experiment. (L2) (CO1) (2M)

Ans: The Reynold's experiment is a classic experiment in fluid mechanics that demonstrates how fluid flow changes from laminar to turbulent (2M)

$$Re = \frac{\rho V D}{\mu} \text{ (or) } \frac{VD}{\nu} \text{ (or) } \frac{\rho V L}{\mu}$$

1.e) What is a boundary layer? (L1) (CO1) (2M)

Ans: A boundary layer is a thin region of fluid (like air or water) that forms next to a Solid Surface where the effects of Viscosity (fluid friction) are important (2M)

1.f) Define Buckingham Pi theorem. (L1) (CO1) (2M)

Ans: Buckingham's π theorem states that a physically meaningful equation involving n Variables and m fundamental dimensions (eg. M, L, T) can be reduced to relation between n–m independent dimensionless parameters (called π terms). It simplifies complex experimental data analysis by reducing the number of variables aiding in scale modeling. (2M)

1.g) Differentiate between impulse and pressure turbine. (L2) (CO1) (2M)

Ans: Impulse turbines use high velocity fluid jets (kinetic energy) from nozzles to strike blades, keeping pressure constant across the rotor.
ex: pelton wheel.
Reaction turbines use both pressure and kinetic energy, with pressure dropping as fluid flows through moving blades, creating a reactionary force.
ex: Francis/kaplan turbine. (2M)

1.h) What is the function of braking jet in turbine?
(L1) (CO1) (2M)

Ans: A braking jet is an impulse turbine (such as a pelton wheel) is a water jet directed at the back of the buckets to quickly bring the runner to a complete stop when it is not in use or during shutdown. (2M)

1.i) How the centrifugal pumps are connected for high pressure? (L2) (CO1) (2M) ns: Centrifugal pumps are connected in Series (one after another) to achieve high pressure. The discharge (outlet) of the first pump connects directly to the suction (inlet) of the second, allowing the pressure to build cumulatively across stages. (2M)

1.j) Define slip and percentage of slip.
(L1) (CO1) (2M)

Ans:

slip = $Q_{th} - Q_{act}$

Q_{th} – theoretical discharge

Q_{act} – Actual discharge

$$\text{percentage Slip} = \frac{Q_{th} - Q_{act}}{Q_{th}} \times 100$$

(or) (2M)

$$= (1 - C_d) \times 100 \quad \left[\because \frac{Q_{act}}{Q_{th}} = C_d \right]$$

PART-B UNIT-I

2.a) Derive equations for Surface tension for Spherical droplet and cylindrical jet
(L3) (CO1) (5M)

Ans: Surface Tension for Spherical droplet:

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

Let σ = Surface Tension of the liquid

p = Pressure intensity inside the droplet

d = Diameter of droplet.

Let the droplet is cut in to two halves. The forces acting on one half will be

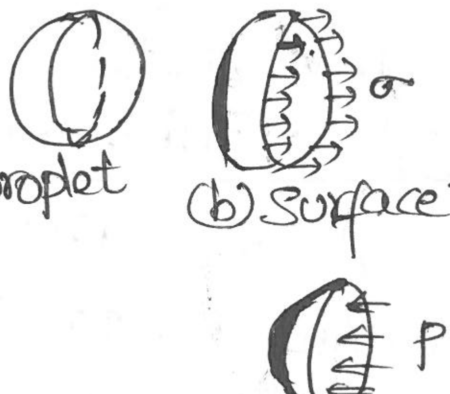
(i) tensile force due to surface tension acting around the circumference of the cut portion as shown in fig. and this is equal to

$= \sigma \times$ circumference

$= \sigma \times \pi d$

(ii) Pressure force on the area $\frac{\pi}{4}d^2 = p \times \frac{\pi}{4}d^2$

these two forces will be equal & opposite under equilibrium conditions.



(a) Droplet (b) Surface tension

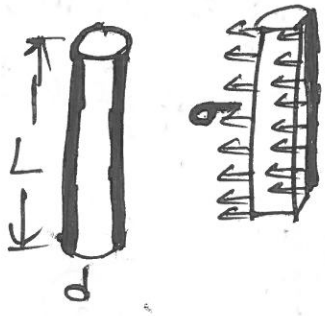
(c) Pressure Forces

Fig: Forces on droplet

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

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

Surface Tension on a <u>cylindrical jet:</u>



Equating the forces

$$p \times L \times d = \sigma \times 2L$$

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

p = Pressure intensity inside the liquid jet, above the outside pressure

σ = Surface tension of the liquid.

(5M)

2.b) Calculate the Specific weight, density and specific gravity of one liter of liquid which weighs 7N. (L3) (CO1) (5M)

Ans: (i) specific weight (w) = $\frac{\text{Weight}}{\text{Volume}} = \frac{7N}{10^{-3} m^3} = 7000 N/m^3$

(ii) Density (ρ) = $\frac{w}{g} = \frac{7000}{9.81} kg/m^3 = 713.5 kg/m^3$

(iii) Specific gravity = $\frac{\text{Density of liquid}}{\text{Density of water}}$

$= \frac{713.5}{1000} = 0.7135$ (5M)

OR

3.a) classify manometers. Derive equation for differential U tube manometer. (L2) (CO1) (5M)

Ans: Manometers are defined as the devices 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. They are classified as:

(a) Simple Manometers (b) Differential Manometers

U-tube differential Manometer:

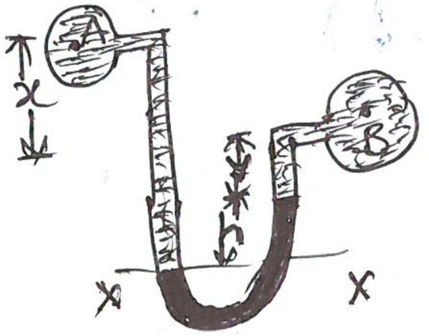


Fig. shows, the two points A and B are at different level and also contains liquids of different Sp.gr. These points are connected to the U-tube differential manometer

Let the pressure at A and B are p_A and p_B.

Let h = Difference of mercury level in the U-tube

y = Distance of the centre of B, from the mercury level in the right limb

x = Distance of the centre of A, from the mercury level in the right limb

ρ_1 = Density of liquid at A

ρ_2 = Density of liquid at B

ρ_g = Density of heavy liquid or mercury

Taking datum line at X-X

pressure above X-X in the left limb = $\rho_1 g(h+x) + p_A$

where p_A = pressure at A.

pressure above X-X in the right limb =

$$\rho_g \times g \times h + \rho_2 \times g \times y + p_B$$

where p_B = Pressure at B.

Equating the two pressure, we have

$$\rho_1 g(h+x) + p_A = \rho_g \times g \times h + \rho_2 \times g \times y + p_B$$

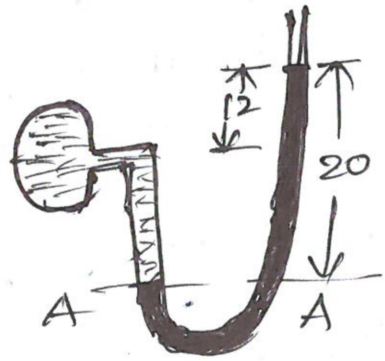
$$p_A - p_B = \rho_g \times g \times h + \rho_2 g y - \rho_1 g(h+x)$$

$$p_A - p_B = h \times g(\rho_g - \rho_1) + \rho_2 g y - \rho_1 g x \qquad (5M)$$

3.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 fluid of Sp. Gr. 0.9 is flowing. The center of the 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 the two limbs is 20cm. (L3) (CO1) (5M)

Ans:

Sp.gr. of fluid, $S_1 = 0.9$



$\therefore$ Density of fluid,

$\rho_1 = S_1 \times 1000 = 0.9 \times 1000$

$\rho_1 = 900\ Kg/m^3$

Sp.gr. of mercury, $S_2 = 13.6$

$\therefore$ Density of mercury $\rho_2 = 13.6 \times 1000\ kg/m^3$

Difference of mercury level, $h_2 = 20cm = 0.2m$

Height of fluid from A-A, $h_1 = 20 - 12 = 8\ cm$

Let p = pressure of fluid in pipe

Equating the pressure above A-A, we get

$$p + \rho_1 g h_1 = \rho_2 g h_2$$

$$p + 900 \times 9.81 \times 0.08 = 13.6 \times 1000 \times 9.81 \times 0.2$$

$$p = 2.5977\ N/cm^2\ (or)\ 25977\ N/m^2$$ (5M)

UNIT-II

4.a) State and derive the Eulers equation from fundamentals. State assumptions made in the derivation. (L3) (CO2) (5M)

Ans: Euler's equation of motion: This is the equation of motion in which the forces due to gravity

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

$$\frac{1}{\rho}\frac{dp}{ds} + g\frac{dz}{ds} + v\frac{\partial v}{\partial s} = 0 \qquad \left[\because \cos\theta = \frac{dz}{ds}\right]$$

$$\frac{dp}{\rho} + g\,dz + V\,dv = 0$$

The above equation is known as Euler's equation of motion

Assumptions: (i) The fluid is ideal
(ii) The flow is Steady (iii) The flow is incompressible
(iv) The flow is irrotational (5M)

4.b) A pipe of diameter 400mm carries water at a velocity of 25m/sec. the pressures at the points A and B are given as 29.43N/cm² and 22.563N/cm² respectively while the datum head at A and B are 28m and 30m, find the loss of head between A and B. (CL3) (CO2) (5M)

Ans: $D = 0.4m$, $V = 25 m/s$, $P_A = 29.43 \times 10^4 N/m^2$,
$Z_A = 28m$, $V_A = V = 25 m/s$

$\therefore$ Total energy at A, $E_A = \frac{P_A}{\rho g} + \frac{V_A^2}{2g} + Z_A$

$$E_A = \frac{29.43 \times 10^4}{1000 \times 9.81} + \frac{25^2}{2 \times 9.81} + 28 = 89.85m$$

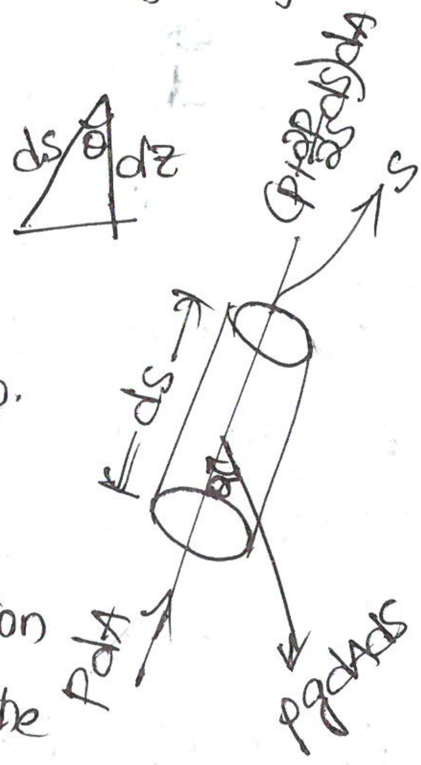
At point B,

$P_B = 22.563 \times 10^4 N/m^2$

$Z_B = 30m$

$V_B = V = V_A = 25 m/s$

and pressure are taken into consideration. This is derived by considering the motion of a fluid element along a stream-line as:



1. pressure force pdA in the direction of flow.
2. pressure force $\left[P+\frac{\partial P}{\partial s}ds\right]dA$ opposite to the direction of flow.
3. Weight of element $\rho g dA ds$

Let θ is the angle between the direction of flow and the line of action of the weight of element.

The resultant force on the fluid element in the direction of s must be equal to the mass of fluid element × acceleration in the directions

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

$$a_s=\frac{dv}{dt}=\frac{\partial V}{\partial S}\frac{ds}{dt}+\frac{\partial V}{\partial t}=\frac{V\partial V}{\partial S}+\frac{\partial V}{\partial t}$$

If the flow is steady, $\frac{\partial V}{\partial t}=0$

$$a_s=\frac{V\partial V}{\partial S}$$

Substituting the value of a_s in equation ① & simplifying the equation, we get

$$-\frac{\partial P}{\partial S}dsdA-\rho g dA ds\cos\theta=\rho dA ds \times \frac{\partial V}{\partial S}$$

Dividing by $\rho ds dA$,

$$-\frac{\partial P}{\rho\partial S}-g\cos\theta=\frac{V\partial V}{\partial S}$$

∴ Total energy at B,

$$E_B = \frac{P_B}{\rho g} + \frac{V_B^2}{2g} + z_B$$

$$E_B = \frac{22.563 \times 10^4}{1000 \times 9.81} + \frac{25^2}{2 \times 9.81} + 30 = 84.85m$$

∴ Loss of energy $= E_A - E_B = 89.85 - 84.85$
$= 5m$ (5M)

OR

5. a) Derive Darcy weisbach equation for head loss due to friction in pipe. (L3)(CO2)(5M)

Ans: Consider a uniform horizontal pipe, having steady flow as shown in fig. Let 1-1 and 2-2 are two sections of pipe.

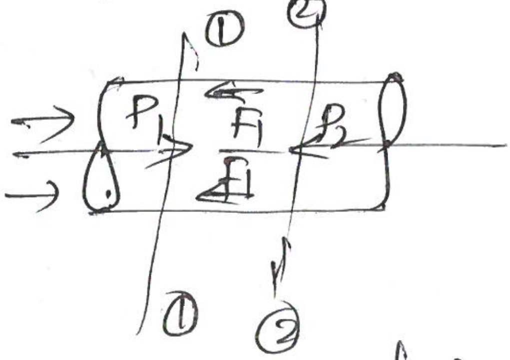
Let P_1 = pressure intensity at section 1-1,
V_1 = Velocity of flow at section 1-1,
L = Length of the pipe between sections 1-1 & 2-2.
d = diameter of pipe,
f' = frictional resistance per unit wetted area per unit velocity,
h_f = loss of head due to friction,
& P_2, V_2 = are values of pressure intensity and velocity at section 2-2.

Applying Bernoulli's equations between sections 1-1 and 2-2, Total head at 1-1 = Total head at 2-2 + loss of head due to friction b/w 1-1 & 2-2

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

$Z_1 = Z_2$ as pipe is horizontal

$V_1 = V_2$ as dia. of pipe is same at 1-1 and 2-2



$$\frac{P_1}{\rho g}=\frac{P_2}{\rho g}+h_f \text{ (or) } h_f=\frac{P_1}{\rho g}-\frac{P_2}{\rho g}$$

Fig: uniform horizontal pipe

Frictional resistance = frictional resistance per unit wetted area per unit velocity × wetted area × velocity^2

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

Resolving all forces in the horizontal direction,

$$P_1 A - P_2 A - F_1 = 0$$
$$(P_1-P_2)A = F_1 = f' \times P \times L \times V^2$$
$$P_1-P_2 = \frac{f' \times P \times L \times V^2}{A}$$
$$\rho g h_f = \frac{f' \times P \times L \times V^2}{A} \qquad \left[\because P_1-P_2=\rho g h_f\right]$$
$$h_f = \frac{f'}{\rho g}\times\frac{4}{d}\times L \times V^2 \qquad \left[\because \frac{P}{A}=\frac{\pi d}{\frac{\pi}{4}d^2}=\frac{4}{d}\right]$$
$$\boxed{h_f=\frac{4fLV^2}{2gd}} \qquad \left[\because \frac{f'}{\rho}=\frac{f}{2}\right]$$

(5M)

5.5) The difference in water surface levels in two tanks, which are connected by three pipes in series of lengths 300mm, 170mm and 210mm and of diameters 300mm 200mm and 400mm respectively is 12m. Determine the flow of water if co-efficient of friction are 0.005, 0.0052 and 0.0048 respectively, considering minor losses. (L3) (CO2) (5M)

Ans: Difference of water level, $H = 12m$

Length of pipe1, $L_1 = 300mm = 0.3m$, $d_1 = 300mm = 0.3m$

$L_2 = 170mm = 0.17m$, $d_2 = 200mm = 0.2m$

$L_3 = 210mm = 0.21m$, $d_3 = 400mm = 0.4m$

$f_1 = 0.005$, $f_2 = 0.0052$, $f_3 = 0.0048$

considering minor losses:

From continuity, $A_1V_1 = A_2V_2 = A_3V_3$

$$V_2 = \frac{A_1V_1}{A_2} = 2.25V_1 \quad ; \quad V_3 = 0.5625V_1$$

$$H = \frac{0.5V_1^2}{2g} + \frac{4f_1L_1V_1^2}{2gd_1} + \frac{0.5V_2^2}{2g} + \frac{4f_2L_2V_2^2}{2gd_2} + \frac{(V_2-V_3)^2}{2g} + \frac{4f_3L_3V_3^2}{2gd_3} + \frac{V_3^2}{2g}$$

$$12 = \frac{0.5V_1^2}{2g} + \frac{4\times0.005\times0.3\times V_1^2}{0.3\times2\times9.81} + \frac{0.5\times(2.25V_1)^2}{2\times9.81} + 4\times0.0052\times0.17\times\frac{(2.25V_1)^2}{0.2\times2\times9.81} + \frac{(2.25V_1-0.562V_1)^2}{2\times9.81} + \frac{4\times0.0048\times0.21\times(0.5625V_1)^2}{0.4\times2\times9.81} + \frac{(0.5625V_1)^2}{2\times9.81}$$

$$12 = \frac{V_1^2}{2g}\left[0.5+0.02+2.53+0.0895+2.847+ 0.003189+0.316\right]$$

$$12 = \frac{V_1^2}{2g}[6.305694]$$

$$V_1 = 6.11\ m/s$$

$\therefore$ Rate of flow, $Q = A_1 V_1$

$$Q = \frac{\pi}{4} d_1^2 \times V_1 = \frac{\pi}{4}(0.3)^2 \times 6.11$$

(5M)

$$Q = 0.4316\ m^3/s$$

UNIT-III

5.a) Define displacement thickness momentum thickness and energy thickness in the context of boundary layer theory. (L2) (CO3) (5M)

Ans: Displacement Thickness: It is the distance, measured perpendicular to the boundary, by which the main/free stream is displayed on account of formation of boundary layer

$$\delta^* = \int_0^\delta \left[1-\frac{u}{U}\right] dy$$

Momentum thickness: It is the distance, measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for reduction in momentum of the flowing fluid on account of boundary layer formation.

Mass of fluid flowing thr' elemental strip per sec. $= \rho *$ velocity $*$ Area $= \rho u\, b dy$

Kinetic Energy/sec. of this fluid inside the boundary layer $= \frac{1}{2} * \rho u b dy \times u^2$

If there has been no plate then fluid would be flowing with free stream velocity say 'U'

Kinetic energy of this mass flow per second through the elementary strip if the plate were not there

$$= \frac{1}{2} * \rho u b dy \times U^2$$

Loss of K.E through strip $= \frac{1}{2}(\rho u b dy) U^2 - \frac{1}{2}(\rho u b dy) u^2$

$$= \frac{1}{2} \rho u b [U^2 - u^2] dy$$

Total loss of K.E flow rate due to introduction of plate thr' BC $= \int_0^\delta \frac{1}{2} \rho u b [U^2 - u^2] dy$

$$= \frac{1}{2} \rho b \int_0^\delta u (U^2 - u^2) dy \quad \text{— (1)}$$

Let the plate is displaced by a distance (δ^{**}) and velocity of flow for the distance (δ^{**}) is equal to main/free stream velocity (i.e. U).

Then, loss of the K.E of the fluid/sec flowing through the distance (δ^{**}) with velocity U.

$= \frac{1}{2}$ (mass) $\times$ velocity^2 $= \frac{1}{2}$($\rho \times$ area $\times$ velocity) $\times$ vel.^{2}

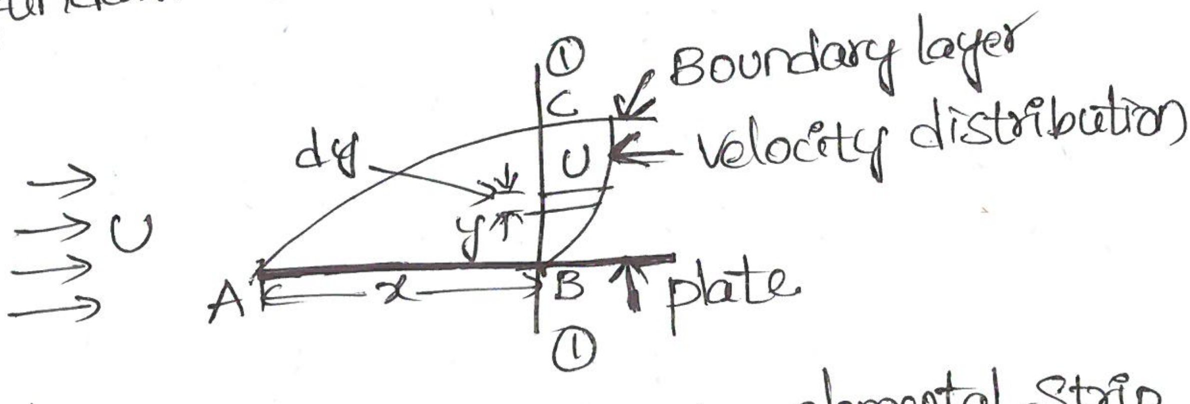
$$\theta = \int_0^{\delta} \frac{u}{U}\left[1 - \frac{u}{U}\right] dy$$

Energy Thickness: It may be defined as the distance measured perpendicular to the boundary of the solid body, by which the boundary should be displaced to compensate for reduction in kinetic energy of the flowing fluid on account of boundary layer formation.

$$\delta^{**} = \int_0^{\delta} \frac{u}{U}\left[1 - \frac{u^2}{U^2}\right] dy$$ (5M)

6. b) Derive the energy thickness equation from fundamentals. (L3) (CO3) (5M)

Ans:



Let, At section 1-1 consider elemental strip

ρ = Density of fluid

y = Distance of elemental strip from plate

dy = thickness of elemental strip

u = Velocity of fluid at elemental strip

b = width of plate

Area of strip = $b \times dy$

$$= \frac{1}{2}(\rho \times b \times \delta^{**} \times U)U^2$$

$$= \frac{1}{2}\rho b \delta^{**} U^3 \quad \text{—— ②}$$

Equating ① and ② equations

$$\frac{1}{2}\rho b \delta^{**} U^3 = \frac{1}{2}\rho b \int_0^{\delta} u(U^2 - u^2)\,dy$$

$$\delta^{**} = \frac{1}{U^3}\int_0^{\delta} u(U^2 - u^2)\,dy$$

$$\delta^{**} = \int_0^{\delta} \frac{u}{U}\left[1 - \frac{u^2}{U^2}\right] dy$$

(5M)

OR

7.a) Explain the Buckingham Pi theorem with one Suitable example. (L2) (CO3) (5M)

Ans: Buckingham π theorem States that a physically meaningful equation involving n variables and m fundamental dimensions (eg, M, L, T) can be reduced to relation between n-m independent dimensionless parameters (called π terms). It Simplifies complex experimental data analysis by reducing the number of variables aiding in Scale modeling.

Ex: The resisting force R of a Supersonic plane during flight can be considered as dependent upon the length of the aircraft l, velocity V, air viscosity μ, air density ρ and bulk modulus of air K. Express the functional relationship between these Variables and the resisting force.

Solution: The resisting force R depends upon (i) l, (ii) V, (iii) μ, (iv) ρ and (v) K. Hence R is a function of l, V, μ, ρ and K. Mathematically

$$R = f(l, V, \mu, \rho, K)$$

or it can be written as $f_1(R, l, V, \mu, \rho, K) = 0$

$\therefore$ Total number of Variables, $n = 6$.

Number of fundamental dimensions $m = 3$

No. of dimensionless π-terms $= n - m = 6 - 3 = 3$

$$f_1(\pi_1, \pi_2, \pi_3) = 0$$

Each π-term is written as

$$\pi_1 = l^{a_1} \cdot V^{b_1} \cdot \rho^{c_1} \cdot R$$

$$\pi_2 = l^{a_2} \cdot V^{b_2} \cdot \rho^{c_2} \cdot \mu$$

$$\pi_3 = l^{a_3} \cdot V^{b_3} \cdot \rho^{c_3} \cdot K$$

first π-term,

$$\pi_1 = M^0 L^0 T^0 = L^{a_1} \cdot (LT^{-1})^{b_1} \cdot (ML^{-3})^{c_1} \cdot MLT^{-2}$$

Equating the powers of M, L, T on both sides

power of M, $0 = c_1 + 1$ $\quad \therefore c_1 = -1$

Power of L, $0 = a_1 + b_1 - 3c_1 + 1$ $\quad \therefore a_1 = -2$

power of T, $0 = -b_1 - 2$ $\quad \therefore b_1 = -2$

$$\pi_1 = l^{-2} \cdot V^{-2} \cdot \rho^{-1} \cdot R$$

$$\pi_1 = \frac{R}{\rho l^2 V^2}$$

Similarly
2nd π term, $\pi_2 = \frac{\mu}{l V \rho}$

Similarly
3rd π term, $\pi_3 = \frac{K}{V^2 \rho}$

Finally

$$f_1\left[\frac{R}{\rho l^2 V^2}, \frac{\mu}{l V \rho}, \frac{K}{V^2 \rho}\right] = 0$$

(5M)

$$R = \rho l^2 V^2 \phi\left[\frac{\mu}{l V \rho}, \frac{K}{V^2 \rho}\right]$$

7.b) How can you checks the dimensional homogeneity of an equation? (L2) (CO3) (5M)

Ans: Dimensional Homogeneity means the dimensions of each terms in an equation on both sides are equal. Thus if the dimensions of each term on both sides of an equation are the same the equation is known as dimensionally homogeneous equation. The powers of fundamental dimensions (i.e, L, M, T) on both sides of the equation will be identical for a dimensionally homogeneous equation. Such equations are independent of the systems of units.

Let us consider the equation, $V=\sqrt{2gH}$

Dimension of L.H.S. $= V = \frac{L}{T} = LT^{-1}$

Dimension of R.H.S. $= \sqrt{2gH} = \sqrt{\frac{L}{T^2} \times L} = LT^{-1}$

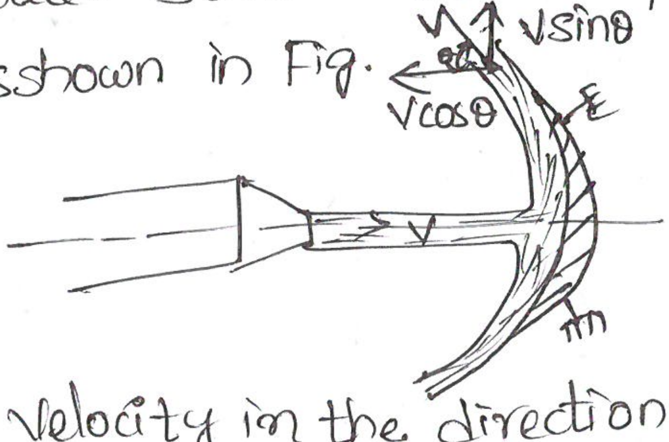
Dimension of L.H.S. = Dimension of R.H.S. $= LT^{-1}$

$\therefore$ Equation $V=\sqrt{2gH}$ is dimensionally homogeneous so it can be used in any system of units (5M)

UNIT-IV

3.a) Find the expression for the force exerted by the jet on a stationary curved plate in the direction of the jet. (L3) (CO4) (5M)

Ans: Let a jet of water strikes curved plate at the centre as shown in Fig.



component of velocity in the direction of jet $= -V\cos\theta$

component of velocity perpendicular to the jet $= V\sin\theta$

Force exerted by the jet in the direction of jet, $F_x =$ Mass per sec $\times [V_{1x} - V_{2x}]$

Where V_{1x} = Initial velocity in the direction of jet $= V$

V_{2x} = Final velocity in the direction of jet = $-V\cos\theta$

$F_x = \rho a V[V - (-V\cos\theta)] = \rho a V[V + V\cos\theta]$
$= \rho a V^2[1 + \cos\theta]$

F_y = Mass per sec × $[V_{1y} - V_{2y}]$

V_{1y} = Initial velocity in the direction of $y = 0$

V_{2y} = Final velocity in the direction of $y = V\sin\theta$

$F_y = \rho a V[0 - V\sin\theta] = -\rho a V^2\sin\theta$

-ve sign means that force is acting in the downward direction. In this case the angle of deflection of the jet. (5M)

8.b) A nozzle of 50mm diameter delivers a stream of water at 20m/s perpendicular to a plate that moves away from the jet at 5m/s. Find the force on the plate, workdone and efficiency of the jet (L3) (CO4) (5M)

Ans: Dia. of jet = 50mm = 0.05m

Area $a = \frac{\pi}{4}(0.05^2) = 0.0019635 m^2$

Velocity of jet, $V = 20 m/s$, velocity of plate, $u = 5 m/s$

(i) The force on the plate

$F_x = \rho a (V-u)^2$

$F_x = 1000 \times 0.0019635 \times (20-5)^2 = 441.78 N$

(ii) The workdone by the jet

$= F_x \times u = 441.78 \times 5 = 2208.9\ Nm/s$

(iii) The efficiency of the jet, $\eta = \frac{\text{Output of jet}}{\text{Input of jet}}$

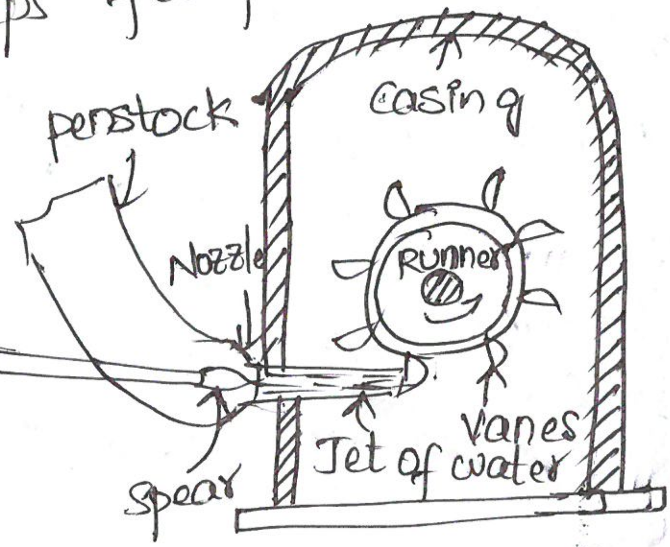
$= \frac{\text{Workdone/s}}{\text{K.E. of jet/s}} = \frac{F_x \times u}{\frac{1}{2} m v^2}$

$= \frac{F_x \times u}{\frac{1}{2}(\rho a v) \times v^2} = \frac{2208.9}{\frac{1}{2}(1000 \times 0.0019635 \times 20) \times 20^2}$

$= 33.77\%$ (5M)

OR

a) Describe design steps for pelton wheel.
(L2)(CO4) (5M)



Ans: Design of pelton wheel:

1. Diameter of the jet (d)

2. Diameter of wheel (D).

3. Width of the buckets $= 5 \times d$

4. Depth of the buckets $= 1.2 \times d$

5. Number of buckets on the wheel $Z = 15 + \frac{D}{2d}$

Jet ratio $(m) = \frac{D}{d}$

Number of Jets: It is obtained by dividing the total rate of flow through the turbine by the rate of flow of water through a single jet. (5M)

Q.5) Explain the working of Kaplan turbine with Sketch and velocity triangles. (L3) (CO4) (5M)

Ans:

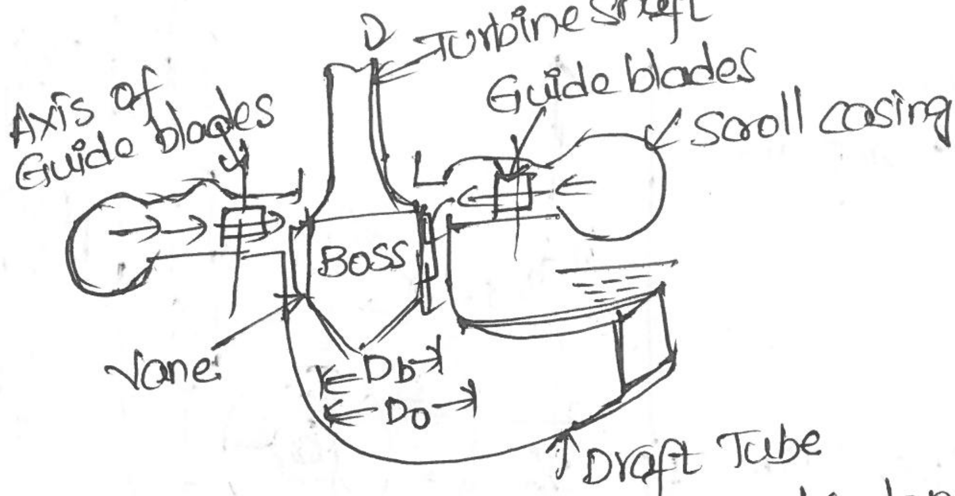
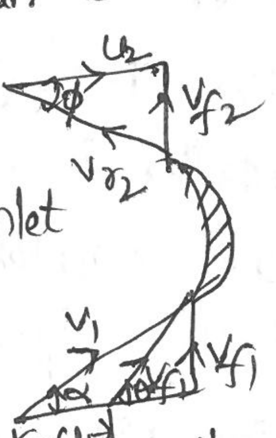


Fig. shows all main parts of a Kaplan turbine. The water from penstock enters the Scroll casing and then moves to the guide Vanes. From the guide vanes, the water turns through 90° and flows axially through the runner as shown in fig. When the Vanes are fixed to the hub and they are not adjustable, the turbine is known as propeller turbine. But if the Vanes on the hub are adjustable, the turbine is known as a Kaplan Turbine.



V_1 = Velocity of the jet at inlet

u_1 = Velocity of the plate (vane) at inlet

V_{r_1} = Relative velocity of jet & plate at inlet

α & β – jet angle at inlet & outlet

θ & ϕ – Vane angle at inlet & outlet

V_{f_1} & V_{f_2} – velocity of flow at inlet & outlet

V_{w_1} – Velocity of whirl at inlet

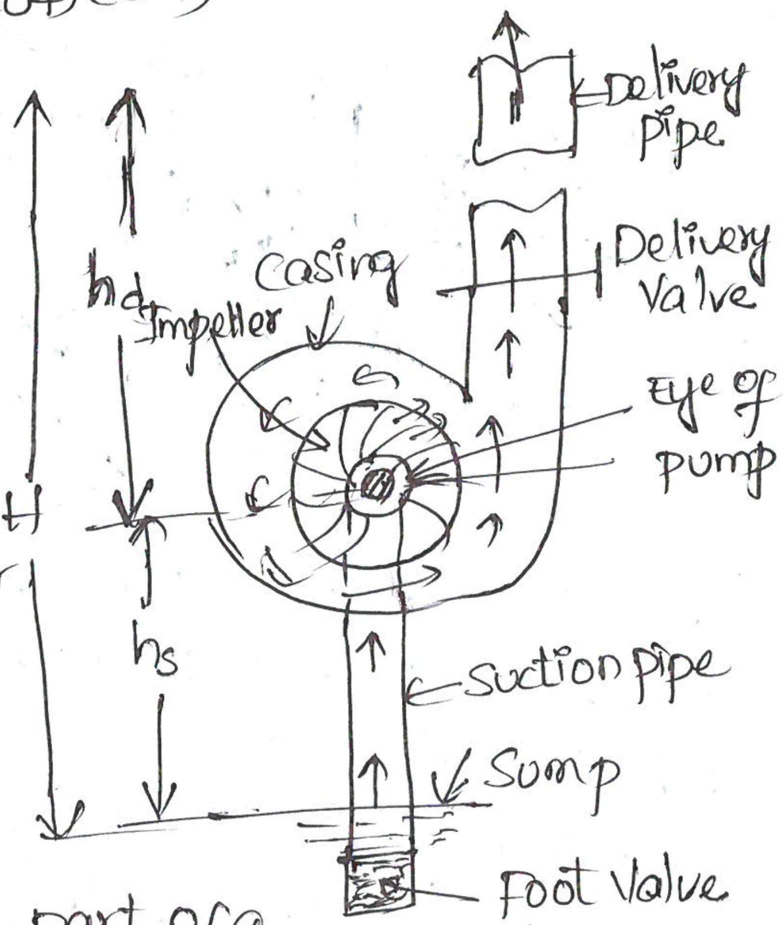
(5M)

UNIT-V

10.a) Explain the working of centrifugal pump with neat sketch. (L3) (CO4) (5M)

Ans: Main parts of a centrifugal pump are

1. Impeller
2. casing
3. Suction pipe with a foot valve & a strainer
4. Delivery pipe



1. Impeller: The rotating part of a centrifugal is called Impeller

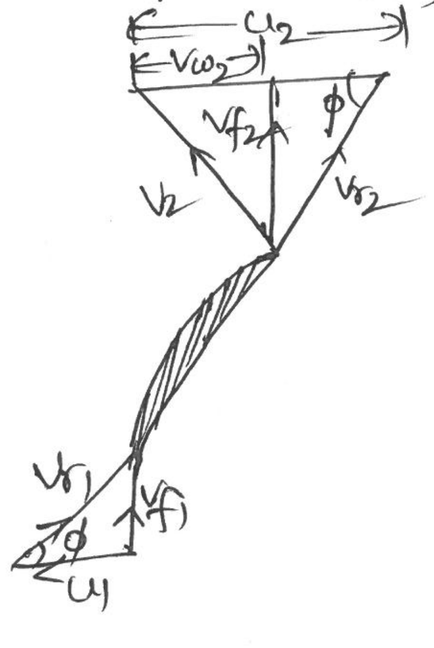
2. casing: It is an air-tight passage surrounding the impeller and is designed in such away that the kinetic energy of the water discharged at the outlet of the impeller is converted in to pressure energy before the water leaves the casing and enters the delivery pipe.

3. Suction pipe with a foot valve & a strainer: A pipe whose one end is connected to the inlet of the pump and other end dips in to a water in a sump is known as suction pipe. A foot valve which is a non-return valve is fitted at the lower end

of the Suction pipe. The foot valve opens only in the upward direction. A Strainer is also fitted at the lower end of the Suction pipe.

4. Delivery pipe: A pipe whose one end is connected to the inlet of the pump and other end delivers the water at a required height is known as delivery pipe. (5M)

Q.b) A centrifugal pump is to discharge 0.118 m³ per Sec at a Speed of 1450 rpm against a head of 25m. The impeller diameter is 250mm, its width at outlet is 50mm and manometric efficiency is 75%. Determine the vane angle at the outer periphery of the impeller. (L3)(CO4) (5M)



Ans: Given data: $Q = 0.118\ m^3/s$,

$N = 1450\ rpm$, $H_m = 25m$, $D_2 = 0.25m$,

$B_2 = 0.05m$, $\eta_{man} = 0.75$

Tangential velocity of impeller at outlet

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.25 \times 1450}{60}$$

$$u_2 = 18.98\ m/s$$

Discharge is given by $Q = \pi D_2 B_2 V_{f_2}$

$$V_{f_2} = \frac{Q}{\pi D_2 B_2} = \frac{0.118}{\pi \times 0.25 \times 0.05} = 3\ m/s$$

∴ manometric efficiency $\eta_{man} = \frac{gH_m}{V_{w_2} u_2}$

$$V_{w_2} = \frac{gH_m}{\eta_{man} \times u_2} = \frac{9.8 \times 25}{0.75 \times 18.98} = 17.23$$

From outlet velocity triangle,

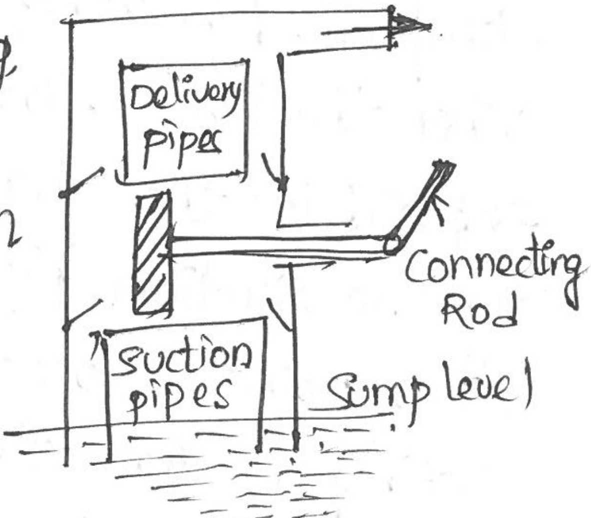
$$\tan\phi = \frac{V_{f_2}}{u_2 - V_{w_2}} = \frac{3}{(18.98 - 17.23)} = 1.7143$$

Tangential velocity of impeller at outlet $\phi = 59°44'$ (5M)

OR

11.a) Explain the working of double acting reciprocating pump with neat sketch. (L3) (CO4) (5M)

Ans: In case of double-acting pump the water is acting on both sides of the piston as shown in Fig. Thus, we require two suction pipes & two delivery pipes for double acting pump.

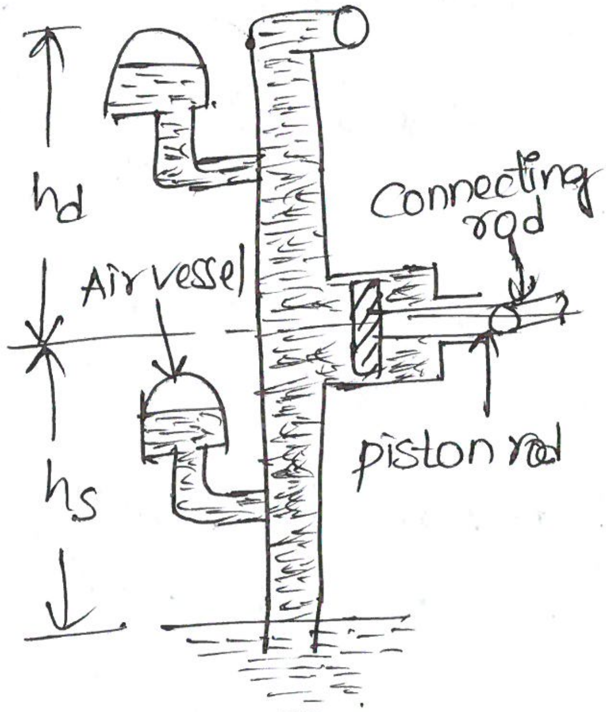


When there is a suction stroke on one side of the piston, there is at the same time a delivery stroke on the other side of the piston. Thus for one complete revolution of the crank there are two delivery strokes and water is delivered to the pipes by the pump during these two delivery strokes. (5M)

11.b) Explain the concept of pressure vessels in reciprocating pumps with neat sketch. (L3)(CO4) (5M)

Ans: pressure (Air) vessels: It is a closed chamber containing compressed air in the top portion and liquid (or water) at the bottom of the chamber.

At the base of the chamber there is an opening through which the liquid (or water) may flow in to the vessel or out from the vessel. When the liquid enters the air vessel, the air gets compressed further and



when the liquid flows out the vessel, the air will expand in the chamber. An air vessel is fitted to the suction pipe and to the delivery pipe at a point close to the cylinder of a single-acting reciprocating pump:

(i) to obtain a continous supply of liquid at a uniform rate,

(ii) to save a considerable amount of work in overcoming the frictional resistance in the suction and delivery pipes, and

(iii) to run the pump at a high speed without seperation (5M)