UNIT-V					
10	a)	Briefly explain the main parts of centrifugal pump with neat sketches.	L3	CO5	5 M
	b)	The internal and external diameters of the impeller of a centrifugal pump are 200 mm and 400 mm respectively. The pump is running at 1200 r.p.m. The vane angles of the impeller at inlet and outlet are 20^{o} and 30^{o} respectively. The water enters the impeller radially and velocity of flow is constant. Determine the work done by the impeller per unit weight of water.	L3	CO5	5 M
OR					
11	a)	Explain the Cavitation in centrifugal pump, its effects and precautions.	L4	CO5	5 M
	b)	How will you obtain an expression for the minimum speed for starting a centrifugal pump?	L3	CO5	5 M

Code: 23CE3403

II B.Tech - II Semester – Regular Examinations - MAY 2025

HYDRAULICS & HYDRAULIC MACHINERY
(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)	What is the effect of change in Reynold's number on the friction factor in turbulent flow?	L2	CO1
1.b)	What is role of boundary layer theory to enhance the velocity of golf ball?	L2	CO1
1.c)	What is the significance of Moody's chart?	L2	CO2
1.d)	Write the limits of Reynolds number for open channel flow and pipe flow.	L1	CO2
1.e)	What conditions are to be satisfied for a channel section is said to be efficient channel section?	L2	CO3
1.f)	If water is flowing through a pipe of 5 cm diameter under a pressure of 20 N/cm^2 and a mean velocity of 2 m/s, find the kinetic head?	L2	CO3
1.g)	Provide the details of turbines efficiency based on the depth of flow.	L2	CO4
1.h)	Distinguish between steady and unsteady flow.	L2	CO4
1.i)	For a fully-developed pipe flow, how does the pressure vary with the length of the pipe?	L2	CO5
1.j)	What is priming of a pump?	L1	CO5

PART – B

			BL	CO	Max. Marks
		UNIT-I			
2		Find an expression for the loss of head of a viscous fluid flowing between two fixed parallel plates.	L3	CO1	10 M
		OR			
3		Explain the boundary layer theory with various applications, using the concept of displacement, momentum and energy thickness for a flat plate.	L3	CO1	10 M
		UNIT-II			
4		Derive the following conditions for most economical trapezoidal channel section. i) Side length = half of the top width ii) hydraulic mean depth (m) = d/2	L4	CO2	10 M
		OR			
5		A canal of trapezoidal section has a bed width of 7 m and bed slope of 1 in 3500. If the depth of flow is 2.7 m and side slopes of the channel are 1 horizontal to 3 vertical, determine the average flow velocity and the discharge carried by the channel. Also compute the average shear stress at the channel boundary. Take value of Chezy's constant= 50.	L4	CO2	10 M
		UNIT-III			
6	a)	The discharge of water through a rectangular channel of width 8m, is 18 m^3/s when the depth of water is 1.2 m. Calculate: (i) specific energy of the flowing water, (ii) Critical depth and	L4	CO3	5 M

		Critical velocity, and (iii) value of minimum specific energy.			
	b)	The depth of flow of water, at a certain section of a rectangular channel of 4m wide is 0.5 m. The discharge through the channel is 18 m^3/sec. If a hydraulic jump takes place on the downstream side, find the depth of flow after the jump.	L4	CO3	5 M
		OR			
7		Find the slope of the free water surface in a rectangular channel of width (i) 20m and (ii) 30m, having depth of flow 5m. The discharge through the channel is 60 m^3/s. The bed of the channel is having a slope of 1 in 4000. Take the value of Chezy's constant C = 60.	L4	CO3	10 M
		UNIT-IV			
8	a)	Derive an expression for force exerted by a jet on inclined plate moving in the direction of jet.	L3	CO4	5 M
	b)	Draw the velocity triangles, work done and maximum hydraulic efficiency of a Pelton wheel turbine.	L3	CO4	5 M
		OR			
9		The penstock supplies water from a reservoir to the Pelton wheel with a gross head of 500 m. One third of the gross head is lost in friction in the penstock. The rate of flow of water through the nozzle fitted at the end of the penstock is 2.0 m^3/s. The angle of deflection of the jet is 165^o. Determine the power given by the water to the runner and also hydraulic efficiency of the Pelton wheel. Take speed ratio = 0.45 and Cv = 1.0.	L4	CO4	10 M

PART-A Scheme of Evaluation HHM.

1) For the relationship between Reynold number and friction factor
It may be in writing (or) Expression } 2M

b) Any explanation which gives same meaning — 2M

c) Significance of Moody's chart — 2M

d) For open channel flow Reynold number limits — 1M } 2M
for pipe flow — 1M

e) Any two conditions for Most Economical Channel section — 2M

f) For writing the formula of kinetic head — 1M } 2M.
for calculation — 1M

g) For giving classification based on head — 2M

h) Steady flow and unsteady flow definitions — 2M

i) How the pressure varies in pipes in 'x' direction — 2M

j) Priming definition — 2M

— o —

PART-B

2) for diagram — 2M
For declaration of Parameters — 2M.
El expression — 2M.
For loss of head — 4M } 10M.

3) Boundary layer theory — 5M.
Applications — 1M
displacement thickness — 2M.
Momentum and Energy thickness — 2M } 10M.

4) For 1st derivation — 6M } 10M.
2nd derivation — 4M

5) For writing given data and Conversions — 2M
determination of velocity — 2M
discharge — 2M.
Area of flow — 2M
Shear stress — 2M } 10M

6)a) Specific Energy — 2M
Critical depth and critical velocity — 2M
Minimum specific Energy — 1M } 5M

b) For finding discharge / unit width — 2M
d_2 calculation — 3M } 5M

} 10M

(7) For Finding slope of 1st bit — 5M } 10M.
2nd bit — 5M

8) a) For diagram and declaration of Parameters — 2M. } 5M. } 10M.
derivation — 3M

b) For velocity triangle diagram — 2M } 5M
work done — 1M.
hydraulic Efficiency — 2M

9) For finding V_1 and u — 6M } 10M.
work done/sec — 2M
Hydraulic Efficiency — 6M

10) a) For diagram and labelling — 3M } 5M } 10M
Explanation — 2M

b) For u_1 and u_2 — 2M } 5M
V_{w_1} and V_{w_2} — 2M
work done/sec — 1M

11) a) Cavitation explanation — 2M } 5M
Effects — 2M
Precautions — 1M

b) For writing the relation between pressure rise and Manometric head } 2M } 5M
For writing Expression for u_1 and u_2 — 1M.
Rest of the derivation — 2M

— o —

Hydraulics and Hydraulic machines II B.Tech II sem

Key and Scheme of Evaluation Regular CE.

a) Effect of change in Reynold's number on the friction factor:-

A) In fluid dynamics the Reynolds number and friction factor are inter-connected. Generally friction factor decreases as Reynolds number increases, but this relationship is not always straight forward. The friction factor also depends on the type of flow and geometry of flow channel.

b) Role of Boundary layer theory to enhance the velocity of golf ball:

A) Boundary layer theory plays a crucial role in optimizing golf ball velocity by managing the airflow around the ball and minimizing drag.

c) Significance of Moody's chart: It is a graphical representation of

A) that helps to calculate the friction factor for fluid flow for pipe. It gives the relation between Reynold number and friction factor.

d) Limits of Reynold number for

A)

open channel flow	Pipe flow
If $Re < 500$ — It is laminar	If $Re < 2000$ — It is laminar
$Re > 2000$ — It is turbulent	$Re > 4000$ — It is turbulent
$Re = 500 - 2000$ — Transition flow	If $Re = 2000 - 400$ — It is transition flow

2) Conditions which are to be satisfied for a channel section to be

1:- efficient channel section:

1) When cost of construction of the channel is minimum and discharge maximum.

→ To keep the discharge maximum velocity should be maximum

$Q = AV$ $\quad Q \propto V$ $\quad A$: Constant

→ To keep velocity maximum hydraulic radius should be maximum.

$V = C\sqrt{mi}$ $\quad \therefore V \propto m$.

→ To keep hydraulic radius maximum Perimeter should be minimum

$$m = \frac{A}{P} \quad \therefore m \propto \frac{1}{P}$$

—o—

1.f) A:
diameter of pipe = 5cm = 0.05 m

Pressure = 20 N/cm^2 mean velocity = 2 m/s.

Kinetic head = $\frac{V^2}{2g} = \frac{2^2}{2\times 9.81} = \frac{4}{19.62} = \underline{0.204m}$.

g) A: classification of turbines based on depth of flow or head available at the entrance of turbine

1. High head turbines — Pelton wheel. > 150m.
2. medium head turbines — Francis turbine > 30m – 150m.
3. low head turbines — Keplan turbine < 30m.

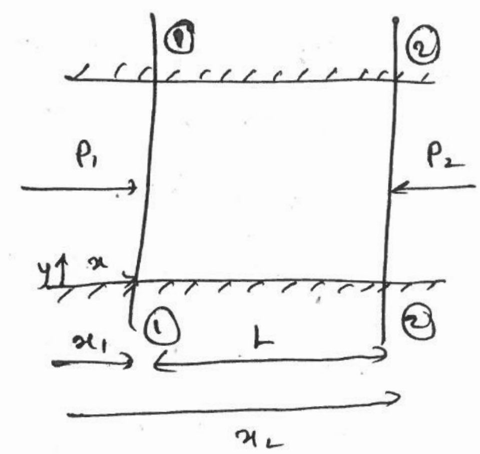
h) A:

Steady flow	Unsteady flow.
If the flow parameters like velocity of flow, depth of flow, or rate of flow donot change with respect to time then that flow is called steady flow $\frac{\partial v}{\partial t} = 0,\ \frac{\partial y}{\partial t} = 0,\ \frac{\partial Q}{\partial t} = 0$	If the flow parameters do change with respect to time then the flow is unsteady flow. $\frac{\partial v}{\partial t} \neq 0,\ \frac{\partial y}{\partial t} \neq 0,\ \frac{\partial Q}{\partial t} \neq 0$

i) A: In a fully developed pipe flow the pressure decreases linearly with the length of the pipe. This means that the pressure drop is proportional to the distance between those points.

j) Priming of a pump:- The operation in which the suction pipe, casing of the pump and a portion of the delivery pipe upto the delivery valve is completely filled up from outside source with the liquid to be raised by the pump before starting the pump. Thus the air from these parts of the pump is removed and these parts are filled with the liquid to be pumped

2) Ans. Expression for the loss of head of a viscous fluid flowing between two fixed parallel plates.



we have $\bar{u} = -\frac{1}{12\mu}\frac{\partial p}{\partial x} t^2$

$\therefore \frac{\partial p}{\partial x} = \frac{-12\mu\bar{u}}{t^2}$

integrating the above equation w.r.to x we have.

$\int_2^1 \partial p = \int_2^1 -\frac{12\mu\bar{u}}{t^2}\,dx$.

$\therefore P_1 - P_2 = -\frac{12\mu\bar{u}}{t^2}[x_1 - x_2]$

$\therefore P_1 - P_2 = \frac{12\mu\bar{u}}{t^2}(x_2 - x_1)$ but $x_2 - x_1 = L$.

$\therefore$ If h_f is the drop of pressure head then

$$h_f = \frac{P_1 - P_2}{\rho g} = \frac{12\mu\bar{u}L}{\rho g t^2}$$

---

3) Ans. Boundary layer theory:

When a viscous fluid flows past an immersed body, a thin boundary layer is formed in the immediate neighbourhood of solid surface. In the boundary layer, the velocity gradient occurs.

→ The resistance due to viscosity is confined only in the boundary layer, the fluid outside the boundary layer may be considered as ideal.

→ Near the leading edge of a flat plate, the boundary layer is wholly laminar. For a boundary layer the velocity distribution is parabolic

→ The thickness of the boundary layer increases with distance from the leading edge, as more and more fluid is slowed down by the viscous boundary, becomes unstable and breaks into a turbulent boundary layer.

→ For a flow when $Re = \frac{Ux}{\nu} < 5\times10^5$ boundary layer is Laminar

when $Re = \frac{Ux}{\nu} > 5\times10^5$ the bl is turbulent.

→ The boundary layer theory has various applications in aerodynamics, heat transfer and computational fluid dynamics.

→ It helps in understanding and designing objects that interact with fluid flow such as air craft, automobiles and heat exchangers.

displacement thickness: It is the distance measured perpendicular to the boundary, by which the free stream is displaced on account of formation of boundary layer.

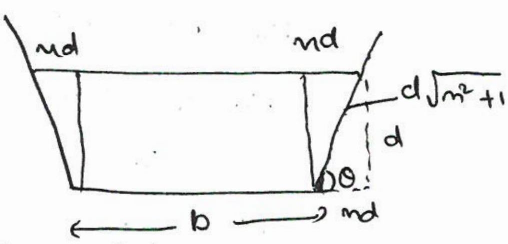
Momentum thickness: It is the distance measured perpendicular to the boundary of the solid body, by which boundary should be displaced to compensate for reduction in momentum of the flowing fluid on account of boundary layer formation.

Energy 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 K.E of the flowing fluid.

(4) **Most Economical trapezoidal channel section condition:-**

1) side length = half of top width.

Consider a trapezoidal section



Let b : width of the channel.

d : depth of flow

θ : angle made by the sides with horizontal

The side slope is given as 1 vertical to m horizontal.

so for d vertical nd horizontal.

Area of flow $A = (b+nd)d$ — (1)

$\therefore \frac{A}{d} = b + nd \quad \therefore b = \frac{A}{d} - nd$ — (2)

wetted perimeter $P = b + 2d\sqrt{m^2+1}$

Substituting the value of 'b' in the above eq we get

$$P = \frac{A}{d} - md + 2d\sqrt{m^2+1} \quad — (3)$$

For most economical section the perimeter should be minimum.

$$\therefore \frac{\partial P}{\partial d} = 0.$$

differentiating the eq (3) with respect to 'd' and equating it to zero we get

$$\frac{\partial}{\partial d}\left[\frac{A}{d} - md + 2d\sqrt{m^2+1}\right] = 0$$

$$\frac{A}{d^2} + m = 2\sqrt{m^2+1}$$

Substituting the value of 'A' in the above equation

$$\frac{(b+md)d}{d^2} + \frac{m}{1} = 2\sqrt{m^2+1}$$

$$\frac{b+md+md}{d} = 2\sqrt{m^2+1}$$

$$\therefore \boxed{\frac{b+2md}{2} = d\sqrt{m^2+1}}$$

$\therefore$ Side length = half of top width

(2) $m = \frac{A}{P}$ we have $A = (b+md)d$

$P = b + 2d\sqrt{m^2+1}$

but we have $b+2md = 2d\sqrt{m^2+1}$ and substituting this value in P we get.

$$\therefore P = 2b + 2md = 2(b+md)$$

$$\therefore \text{but } m = \frac{A}{P} = \frac{\cancel{(b+md)}\,d}{2\cancel{(b+md)}} = \frac{d}{2}$$

$$\therefore \boxed{m = \frac{d}{2}}$$

(3) given data:

width of the channel = $b = 7m$ Depth of flow: $d = 2.7m$

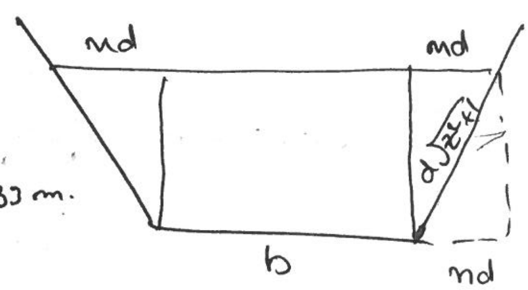
Bed slope, $S = \frac{1}{3500}$ Chezy's constant = 50

Side slope = 1H to 3V $z = \frac{1}{3}$

Area of flow = $(b+md)d$

$= 2.7\left(7 + \frac{1}{3} \times 2.7\right)$

$= 2.7(7 + 0.9) = 21.33\, m.$



Perimeter $= P = b + 2d\sqrt{z^2+1}$

$$= 7 + 2\times 2.7\sqrt{\left(\tfrac{1}{3}\right)^2+1} = 12.69\,m.$$

Hydraulic Radius $= \frac{A}{P} = \frac{21.33}{12.69} = 1.681\,m.$

Average flow velocity $V = C\sqrt{mi}$

$$= 50\sqrt{1.681 \times \frac{1}{3500}} = 1.095\,m/s$$

$\therefore$ Discharge $Q = AV = 21.33 \times 1.095 = 23.36\,m^3/s$

Shear stress at the channel boundary can be calculated by

$$\tau_0 LP = wAL\sin\theta$$

$$\therefore \tau_0 = \frac{wAL\sin\theta}{LP} = w \cdot m \cdot s = 9810 \times 1.681 \times \frac{1}{3500}$$

$$\therefore \boxed{\tau_0 = 4.71\,N/m^2}$$

———— o ————

6) a) Ans

<u>given data</u> :- width of the channel = 8 m

discharge $Q = 18\,m^3/s$

depth of flow = 1.2 m

$\therefore$ discharge per unit width $= q = \frac{Q}{b} = \frac{18}{8} = 2.25\,m^2/s$

velocity of flow $V = \frac{Q}{A} = \frac{18}{b\times h} = \frac{18}{8\times 1.2} = \frac{18}{9.6} = \underline{1.875\,m/s}$

$\therefore$ specific energy $E = h + \frac{V^2}{2g} = 1.2 + \frac{1.875^2}{2\times 9.81} = \underline{\underline{1.379\,m}}$

$\therefore$ critical depth $= h_c = \left(\frac{q^2}{g}\right)^{1/3} = \left[\frac{(2.25)^2}{9.81}\right]^{1/3} = \underline{\underline{0.804\,m}}$

critical velocity $= V_c = \sqrt{g \times h_c} = \sqrt{9.81 \times 0.804}$

$$= \underline{\underline{2.808\,m/s}}$$

minimum specific Energy, is given by

$$E_{minimum} = \frac{3}{2}h_c = \frac{3}{2}\times 0.804 = \underline{\underline{1.206\,m}}$$

———— o ————

6).b) A:- given data:- width of the channel = $b = 4m$

depth of flow before jump = $d_1 = 0.5m$

discharge $Q = 18\ m^3/sec$

$\therefore$ discharge per unit width = $\frac{18}{4} = 4.5\ m^2/s$

$\therefore$ depth of flow after the jump $d_2 = -\frac{d_1}{2} + \sqrt{\frac{d_1^2}{4} + \frac{2q^2}{gd_1}}$

$$\therefore d_2 = -0.25 + \sqrt{\frac{0.5^2}{4} + \frac{2 \times 4.5^2}{9.81 \times 0.5}}$$

$$= -0.25 + \sqrt{0.0625 + 8.257}$$

$$= -0.25 + 2.88 = \underline{\underline{2.63\ m}}$$

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7) A:- given data:-

1) $b = 20m$ $h = 5m$ $Q = 60\ m^3/s$

Bed slope $i_b = \frac{1}{4000} = 0.00025$

Chezy's constant = 60

Area of flow = $b \times h = 20 \times 5 = 100\ m^2$

$$m = \frac{A}{P} = \frac{\cancel{100}}{b+2h} = \frac{100}{20 + 2\times5} = \frac{100}{30} = \frac{10}{3}\ m$$

slope of the energy line from Chezy's formula.

$$Q = AC\sqrt{mi}$$

$$60 = 100 \times 60\sqrt{\frac{10}{3} \times ie} = 10954.45\sqrt{ie}$$

$$\therefore ie = \left(\frac{60}{10954.45}\right)^2 = 0.00003$$

Slope of free surface = $\frac{dh}{dx}$

$$\therefore \frac{dh}{dx} = \frac{i_b - i_e}{1 - \frac{V^2}{gh}} = \frac{0.00025 - 0.00003}{1 - \frac{V^2}{9.81 \times 5}}$$

$$V = \frac{Q}{A} = \frac{60}{b \times h} = \frac{60}{20 \times 5} = 0.6\ m/s$$

$$\therefore \frac{dh}{dx} = \frac{0.00022}{0.99266} = \underline{\underline{0.00022}}.$$

2) $b = 30m$

Area of flow = $b \times h$

$= 30 \times 5 = 150\ m^2$

$$m = \frac{A}{P} = \frac{150}{30 + 2\times5} = 3.75\ m$$

$$Q = AC\sqrt{mi}$$

$$60 = 150 \times 60 \times \sqrt{3.75 \times ie}$$

$\therefore i_e = 0.00001185$

$$V = \frac{Q}{A} = \frac{60}{30\times5} = \frac{60}{150} = 0.4\ m/s.$$

$$\frac{dh}{dx} = \frac{0.00025 - 0.00001185}{1 - \frac{0.4^2}{9.81\times5}}$$

$$= \frac{0.000238}{0.9967}$$

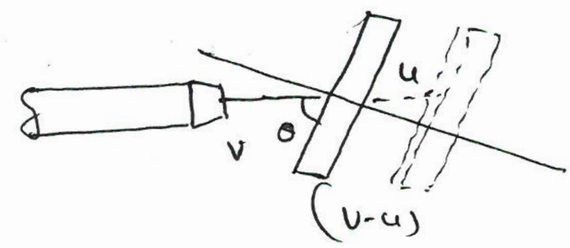
$$\therefore \frac{dh}{dx} = \underline{\underline{0.0002389}}$$

8) a) **Expression for force exerted by a jet on inclined moving plate in the direction of jet:**

Let a jet of water strikes an inclined plate, which is moving with a uniform velocity in the direction of jet

Let V = absolute velocity of jet

u = velocity of plate in the direction of jet



a = cross sectional area of jet

θ = angle between jet and plate

∴ Relative velocity of jet of water $= V-u$

∴ Mass of water striking per second $= \rho a(V-u)$

If the plate is smooth the loss of energy due to impact of jet is assumed zero. So, the jet of water will leave the inclined plate with velocity equal to $(V-u)$

Force exerted by jet on the plate in normal direction $= F_N$

$$\therefore F_N = \rho a(V-u)\left[(V-u)\sin\theta - 0\right] = \rho a(V-u)^2 \sin\theta$$

This force in normal direction is resolved into two components F_x and F_y.

$$\therefore F_x = F_N \sin\theta = \rho a(V-u)^2 \sin^2\theta$$

$$F_y = F_N \cos\theta = \rho a(V-u)^2 \sin\theta \cdot \cos\theta$$

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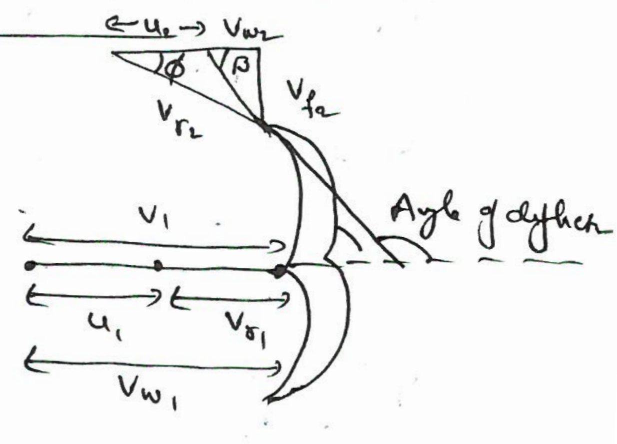
8) b) **Velocity triangles of Pelton wheel**



Let H = net head acting on the Pelton wheel $= H_g - h_f$

where H_g = gross head.

$$\therefore h_f = \frac{4fLV^2}{2gd}.$$

and V_1 = velocity of jet $= \sqrt{2gH}$

$$u = u_1 = u_2 = \frac{\pi DN}{60}$$

The velocity triangle at inlet will be a straight line where

$$V_{r_1} = V_1 - u_1 = V_1 - u \quad \therefore V_{w_1} = V_1$$

$$\alpha = 0 \text{ and } \theta = 0$$

From the velocity triangle at outlet we have

$$V_{r_2} = V_{r_1} \quad \text{and} \quad V_{w_2} = V_{r_2}\cos\phi - u_2$$

$\therefore$ Force exerted by jet in 'x' direction $F_x = \rho a V_1 \left[V_{w_1} + V_{w_2}\right]$

Work done by jet / sec $= F_x \times u = \rho a V_1 \left(V_{w_1} + V_{w_2}\right) u$ Nm/s

Hydraulic Efficiency $\eta_h = \dfrac{\text{Work done / sec}}{\text{K.E of jet / sec}} = \dfrac{\rho a V_1 \left[V_{w_1} + V_{w_2}\right] u}{\frac{1}{2}\rho a V_1 \times V_1^2}$

$$\eta_h = \frac{2\left[V_{w_1} + V_{w_2}\right] u}{V_1^2}$$

Substituting the value of V_{w_1} and V_{w_2} in the above eq,

$$\eta_h = \frac{2\left[V_1 + (V_1 - u)\cos\phi - u\right] u}{V_1^2} = \frac{2(V_1 - u)\left[1 + \cos\phi\right] u}{V_1^2}$$

For maximum efficiency we have

$$\frac{\partial(\eta_h)}{\partial u} = 0 \quad \therefore \frac{\partial}{\partial u}\left[\frac{2u(V_1 - u)\, 1 + \cos\phi}{V_1^2}\right] = 0$$

$$\therefore u = \frac{V_1}{2}$$

Substituting the value of 'u' in above eq we get

$$\text{Max. } \eta_h = \frac{2\left(V_1 - \frac{V_1}{2}\right)(1 + \cos\phi)\frac{V_1}{2}}{V_1^2} = \frac{2 \times \frac{V_1}{2}(1 + \cos\phi)\frac{V_1}{2}}{V_1^2}$$

$$\therefore \boxed{\text{Max } \eta_h = \frac{1 + \cos\phi}{2}}$$

---

1) Given data: $H_g = 500$ m

Head lost in friction $h_f = \dfrac{H_g}{3} = \dfrac{500}{3} = 166.7$ m

$\therefore$ Net head $= H_g - h_f = 500 - 166.7 = 333.3$ m

$Q = 2$ m³/s Angle of deflection $= 165^\circ$

$\therefore \phi = 180 - 165 = 15^\circ$ speed ratio $= 0.45$ $C_v = 1.0$

$\therefore V_1 = \sqrt{2gH} = 1.0 \times \sqrt{2 \times 9.81 \times 333.3} = 80.87$ m/s

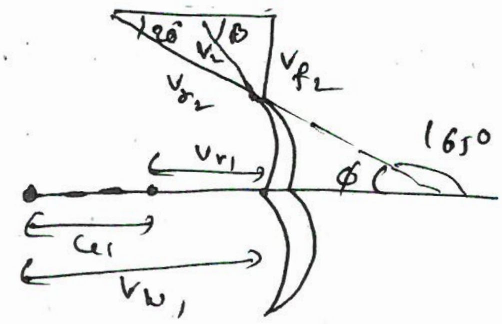
Velocity of wheel $u =$ speed ratio $\times \sqrt{2gH}$

$\therefore u = u_1 = u_2 = 0.45 \times \sqrt{2 \times 9.81 \times 333.3} = 36.387$ m/s

$V_{r_1} = V_1 - u_1 = 80.86 - 36.387$

$= 44.473$ m/s

$V_{w_1} = V_1 = 80.86$ m/s



but $V_{r_1} = V_{r_2} = 44.473$ m/s

$V_{w_1} = V_1 = 80.86$ m/s

$V_{r_2} \cos\phi = u_2 + V_{w_2}$

$44.475 \cos 15 = 36.387 + V_{w_2}$ $\therefore V_{w_2} = 6.57$ m/s

work done/sec $= \rho a V_1 [V_{w_1} + V_{w_2}] u = \rho Q [V_{w_1} + V_{w_2}] u$

$= 1000 \times 2.0 \times [80.86 + 6.57]\, 36.387 = 6362630$ Nm/s

Power given $= \frac{w/\sec}{1000} = \frac{6362630}{1000} = 6362.63$ kW.

Hydraulic efficiency $= \eta_h = \frac{2(V_{w_1} + V_{w_2})u}{V_1^2} = \frac{2[80.86 + 6.57]36.38}{80.86 \times 80.86}$

$\therefore \boxed{\eta_h = 0.9731 = 97.31\%}$

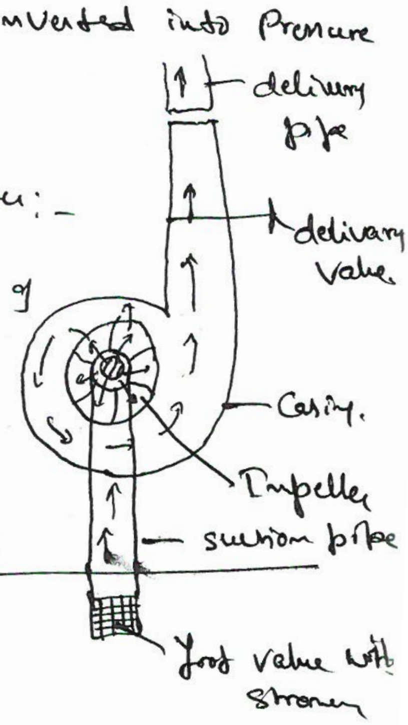
10)
a) centrifugal pump:- The main parts of centrifugal pump

1. Impeller: The rotating part of a centrifugal pump is called impeller. It consists of a series of backwardly curved vanes. The impeller is mounted on a shaft which is connected to shaft of electric motor

2. Casing: It is similar to casing of a reaction turbine. It is an airtight passage surrounding the impeller and is designed in such a way that the kinetic energy is converted into pressure energy.

3. Suction pipe with a foot valve and a strainer:-

A pipe whose end is connected to the inlet of the pump and other end dips into water in a sump. A foot valve is a one way valve fitted at the lower end of suction pipe



delivery pipe: A pipe whose end is connected to the outlet of the pump and other end delivers the water at a required height.

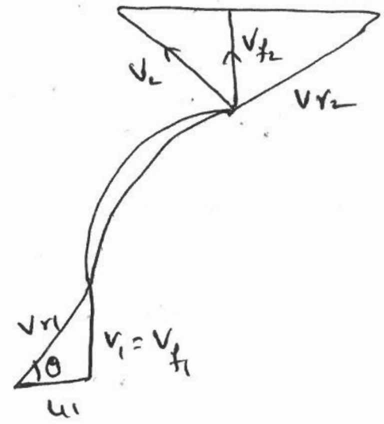
10) b)
As.

given data: Internal dia of impeller : $D_1 = 200\text{ mm} = 0.20\text{ m}$.

External dia " $= D_2 = 400\text{ mm} = 0.40\text{ m}$

Speed $= N = 1200$ r.p.m.

$\theta = 20 \quad \phi = 30°$



water enters radially $\alpha = 90°$ and $V_{w_1} = 0$

velocity of flow $V_{f_1} = V_{f_2}$

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.20 \times 1200}{60} = 12.56\text{ m/s}$$

$$u_2 = \frac{\pi D_2 N}{60} = \frac{\pi \times 0.4 \times 1200}{60} = 25.13\text{ m/s}$$

From inlet triangle

$$\tan\theta = \frac{V_{f_1}}{u_1} = \frac{V_{f_1}}{12.56} \quad \therefore V_{f_1} = 12.56 \tan 20 = 4.57\text{ m/s}$$

$$\therefore V_{f_1} = V_{f_2} = 4.57\text{ m/s}$$

From outlet triangle $\tan\phi = \dfrac{V_{f_2}}{u_2 - V_{w_2}} = \dfrac{4.57}{25.13 - V_{w_2}}$

$$\therefore 25.13 - V_{w_2} = \frac{4.57}{\tan\phi} = \frac{4.57}{\tan 30} = 7.915$$

$$\therefore V_{w_2} = 25.13 - 7.915 = 17.215\text{ m/s}$$

Work done by impeller / kg of water / sec $= \dfrac{1}{g} V_{w_2} u_2$

$$= \frac{17.215 \times 25.13}{9.81} = \underline{\underline{44.1\text{ Nm/N}}}.$$

)a)

cavitation: when the pressure in any part of the flow passage reaches the vapour pressure of flowing liquid, it starts vaporising and small bubbles of vapour form in large numbers. Then bubbles are carried along the flow and on reaching the high pressure zones, these bubbles suddenly collapse as the vapour condenses to liquid again. Due to sudden collapsing of bubbles the surrounding liquid rushes into fill them thus giving rise to very high local pressure. Any solid surface in the vicinity also subjected to these intense pressures.

→ The alternate formation and collapse of vapour bubbles cause severe damage to the surface

→ This phenomenon is known as cavitation which is found to occur in hydraulic structures like pumps and turbines.

Effects of Cavitation :-

1. Metallic surfaces are damaged and cavities are formed on the surface.
2. due to sudden collapse of vapour bubble, noise and vibrations are produced.
3. The efficiency of the pumps decreases

Precautions :- 1. The pressure of the flowing liquid in any part of the hydraulic system should not be allowed to fall below its vapour pressure.

2. The special materials or coating such as aluminium-bronze and stainless steel which are cavitation resistant should be used.

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11) b) **Expression for minimum speed for starting a centrifugal pump.**

A:-

If the pressure rise in the impeller is more than or equal to manometric head the centrifugal pump will start delivering water. otherwise the pump will not discharge any water though the impeller is rotating.

Then in case of forced vortex, the pressure rise in the impeller $= \frac{\omega^2 r_2^2}{2g} - \frac{\omega^2 r_1^2}{2g}$ —— (1)

where ωr_2 = Tangential velocity at outlet $= u_2$

ωr_1 = " " at inlet $= u_1$

$\therefore$ Head due to pressure rise $= \frac{u_2^2}{2g} - \frac{u_1^2}{2g}$

The flow will commence only if the head in the impeller $\geq H_m$

$$\therefore \frac{u_2^2}{2g} - \frac{u_1^2}{2g} \geq H_m$$

For the minimum speed we must have $\frac{u_2^2}{2g} - \frac{u_1^2}{2g} = H_m$ — (2)

But we have $\eta_{mano} = \frac{g H_m}{V_{w_2} u_2}$

$$\therefore H_m = \eta_{mano} \times \frac{V_{w_2} u_2}{g}$$

Substituting this value of H_m in eq (2)

$$\frac{u_2^2}{2g} - \frac{u_1^2}{2g} = \eta_{mano} \times \frac{V_{w_2} u_2}{g} \quad \text{— (3)}$$

But $u_2 = \frac{\pi D_2 N}{60}$ and $u_1 = \frac{\pi D_1 N}{60}$

Substituting the value of u_1 and u_2 in eq (3) we get

$$\frac{1}{2g}\left[\frac{\pi D_2 N}{60}\right]^2 - \frac{1}{2g}\left[\frac{\pi D_1 N}{60}\right]^2 = \eta_{mano} \times \frac{V_{w_2} \times \pi D_2 N}{g \times 60}$$

Dividing the above equation by $\frac{\pi N}{g \times 60}$ we get

$$\therefore \boxed{N = \frac{120 \times \eta_{mano} \times V_{w_2} \times D_2}{\pi \left[D_2^2 - D_1^2\right]}}$$

Scheme of Evaluation :-