SUMMER – 19 EXAMINATION

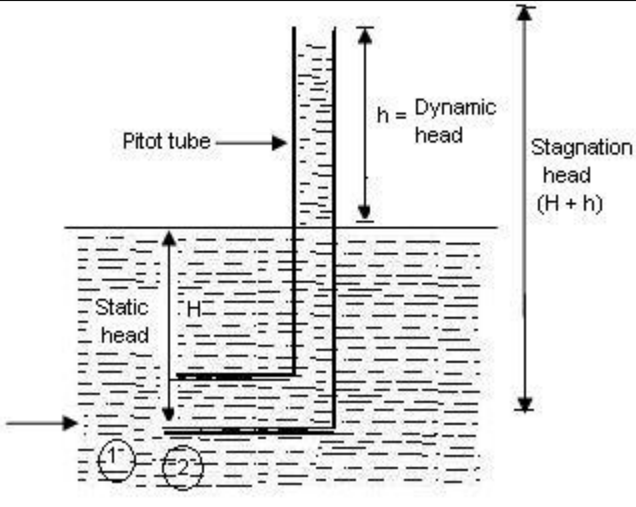
Subject Name: FLUID MECHANICS AND MACHINERY **Model Answer** **Subject C** 22445

Important Instructions to examiners:

1) The answers should be examined by key words and not as word-to-word as given in the model answer scheme.
2) The model answer and the answer written by candidate may vary but the examiner may try to assess the understanding level of the candidate.
3) The language errors such as grammatical, spelling errors should not be given more Importance (Not applicable for subject English and Communication Skills.
4) While assessing figures, examiner may give credit for principal components indicated in the figure. The figures drawn by candidate and model answer may vary. The examiner may give credit for any equivalent figure drawn.
5) Credits may be given step wise for numerical problems. In some cases, the assumed constant values may vary and there may be some difference in the candidate's answers and model answer.
6) In case of some questions credit may be given by judgement on part of examiner of relevant answer based on candidate's understanding.
7) For programming language papers, credit may be given to any other program based on equivalent concept.

Q.1.		**Attempt any FIVE of the following:**	**10 Marks**
a)	**a**	**List out the various measuring devices used for measuring fluid pressure** The Barometer, Piezometer or Pressure Tube, Manometers, The Bourdon Gauge The Diaphragm Pressure Gauge, Micro Manometer (U-Tube with Enlarged Ends)	**02**
	b	**Height of water column, h_1 = 100 m** Specific gravity of water $s_1 = 1.0$ Specific gravity of kerosene $s_2 = 0.81$ Specific gravity of carbon-tetra-chloride, $s_3 = 1.6$ For the equivalent water head Weight of the water column = Weight of the kerosene column. So, $\rho g\, h_1\, s_1 = r\, g\, h_2\, s_2 = \rho g\, h_3\, s_3$ $1000 \times 9.81 \times 100 \times 1.0 = 1000 \times 9.81 \times h_2 \times 0.81 = 1000 \times 9.81 \times h_3 \times 1.6$ $h_2 = 10/0.81$ $h_2 = 12.3456$m and $h_3 = 6.25$m	**02**

	c	**Hydraulic gradient line :** Hydraulic gradient line is basically defined as the line which will give the sum of pressure head and datum head or potential head of a fluid flowing through a pipe with respect to some reference line. **Total Energy Line** Total energy line is basically defined as the line which will give the sum of pressure head, potential head and kinetic head of a fluid flowing through a pipe with respect to some reference line.	**01** **01**
	d.	**For laminar flow-** i) The frictional resistance is proportional to velocity of flow. ii) The frictional resistance is independent of iii) The frictional resistance is proportional to the surface area in contact iv) The frictional resistance is varies with changes in temperature	**1/2 mark each**
	e	**Draft tube:** The draft tube is a conduit which connects the runner exit to the tail race where the water is being finally discharged from the turbine. The primary function of the draft tube is to reduce the velocity of the discharged water to minimize the loss of kinetic energy at the outlet. **Different types of Draft Tubes** i. Simple Elbow Draft Tube. ii. Elbow with varying cross section. iii. Moody Spreading Draft Tube. **iv.** Conical Diffuser or Divergent Draft Tube.	**01** **01**
	f	(**i)Net Positive Suction Head or NPSH for pumps:** It can be defined as the difference between liquid pressure at pump suction and liquid vapor pressure, expressed in terms of height of liquid column. Suction head is the term used to describe liquid pressure at pump suction in terms of height of liquid column. **(ii) Cavitation:** It is a phenomenon in which rapid changes of pressure in a liquid lead to the formation of small vapor-filled cavities, in places where the pressure is relatively low. When subjected to higher pressure, these cavities, called "bubbles" or "voids", collapse and can generate an intense shock wave.	**01 mark** **01 mark**
	g	**Methods of priming.** **The pumps can be primed by any of the following methods.** **1.Manually 2.With vacuum pump 3.With jet pump 4.With separator**	**½ each**

2		**Attempt any THREE of the following:**	12
	a	There are three physical properties of fluids that are particularly important: density, viscosity, and surface tension. **Density.** Density depends on the mass of an individual molecule and the number of such molecules that occupy a unit of volume For liquids, viscosity also depends strongly on the temperature; Water at 20°C has a surface tension of 72.8 dynes/cm compared 465 for mercury. **Water** / **Mercury** I. Density of water=998 kg/m^3 at 20^0c — Density of mercuryr=13550 kg/m^3 at 20^0c II. kinematic viscosity= 0.657x 10^6 — kinematic viscosity= 0.109x ^{106} III. surface tension =71.78 N/m — surface tension = 4.6 x 10^{-1} N/m	**1 each**
	b	Area = bxd = 0.6x1.2 =0.72 m^2 X = 0.7+ 0.6 $\sin45^0$ =0.7+0.6x0.707=1.1243m Force = wAx = 9810x 0.72x1.1243=7940.90N Centre of pressure h = Ig $\sin^2 45$/A x + x Ig = bd^3/12 = 0.6 x 1.2^3/12 = $0.0864m^4$ h= 0.0864x0.5/0.72x1.1243+1.1243=1.243m	**01 mark** **01 mark** **01 mark** **01 mark**
	c	**An orifice plate:** It is a thin plate with a hole in it, which is usually placed in a pipe. When a fluid (whether liquid or gaseous) passes through the orifice, its pressure builds up slightly upstream of the orifice but as the fluid is forced to converge to pass through the hole, the velocity increases and the fluid pressure decreases. A little downstream of the orifice the flow reaches its point of maximum convergence, the vena contracta where the velocity reaches its maximum and the pressure reaches its minimum. Beyond that, the flow expands, the velocity falls and the pressure increases.	**04 marks**
	d		**01 mark Sketch**
		Explain Pitot Tube • A pitot tube is the simple device used for measuring the velocity of the flow at the required point in a pipe or a stream. It is also called as impact tube or stagnation tube. It is based on the principle that if the velocity of flow at a point becomes zero, the pressure is increased due to conversion of kinetic energy into pressure energy.	

		• In its simple form, a pitot tube consists of a transparent glass tube bent through 90^0 and with ends unsealed. Diameter of tube is larger enough to neglect capillary effects. One leg called as the body is inserted into the flow at upstream and aligned with the direction of flow whereas the other leg, called as stem, is vertical and open to atmosphere. The liquid is raise in the tube due to changes in energy. The velocity is determined by measuring the rise in the tube. Consider a section 1 and 2 at a same level just in front of inlet of the tube Apply Bernoulli's equation $P_1/\gamma + V_1^2/2g + Z_1 = P_2/\gamma + V_2^2/2g + Z_2$ $Z_1 = Z_2$ as they are at same level $V_2 = 0$ because flow of particle is comes to rest at point 2. h = rise in tube H = head of pressure at h + H = stagnation head Substitute above value in Bernoulli's $H + V_1^2/2g = h + H$ $h = V_1^2/2g$ $V_1 = \sqrt{2gh}$ Actual velocity V = Cv V theoretical $V = Cv\sqrt{2gh}$ Where Cv = Coefficient of velocity	**03 marks Explain**

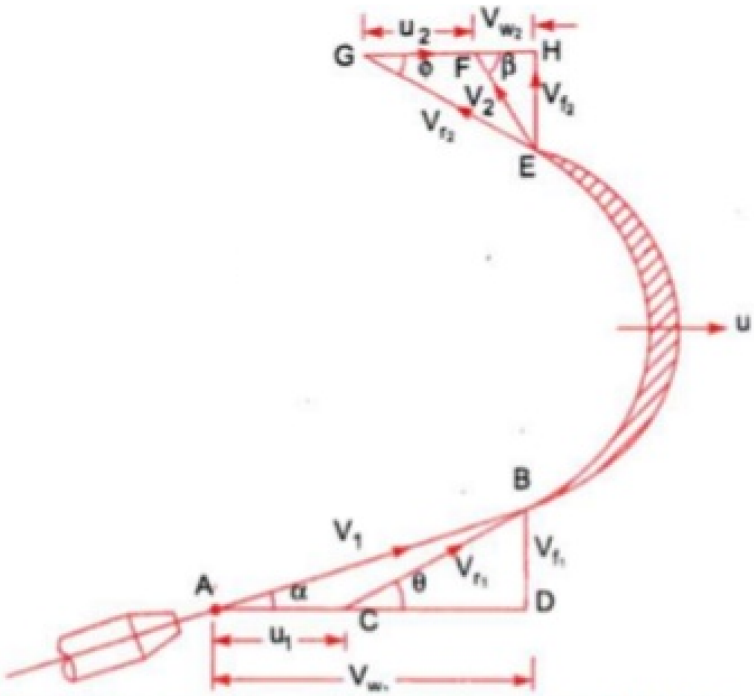
Q. No.	Sub Q. N.	Answer	Marking Scheme
3	a	**Interpret the type of flow (Laminar / Turbulent)** i. Laminar Flow ii. Turbulent Flow iii. Laminar Flow iv. Turbulent Flow	01 Mark each
3	b	**Water hammer phenomenon**: commonly occurs when a valve closes suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. **To reduce / avoid water hammer effect following things are used.** 1. Provide surge tank before the valve on main pipe line. 2. Provide bypass pipe near the valve. 3. Provide Air traps or stand pipes (open at the top) to absorb the potentially damaging forces caused by the moving water. 4. Use high strength pipes. 5. Close the valve slowly.	02 Marks for Cause 02 Marks for any 2 effects

3	c	Problem on Darcy's equation	

Q. No.	Sub Q. N.	Answer	Marking Scheme
		Q3 c) Given : N = Population = 800000 L = length of pipe = 6.4 km = 6400 m water required per day per head = 140 lit. h_f = loss of head = 60 m f = 0.04 Total water required in 1 day = 140 × 800000 = 112×10^6 lit Half of water is supplied in 8 hrs. ∴ Discharge required $Q = \frac{112 \times 10^6}{2 \times 8 \times 3600}$ = 1944.4 lit/s = 1.944 m^3/s Using Darcy's equation $h_f = \frac{4fLQ^2}{12.1 \times d^5}$ ∴ $60 = \frac{4 \times 0.04 \times 6400 \times (1.944)^2}{12.1 \times d^5}$ $d^5 = 5.330$ **d = 1.397 m** Diameter of pipe required is 1.397 m —— ans.	01 Mark for Q Calculation 01 Mark for hf formula 02 Marks for correct answer

<table>
<tr><th>Q. No.</th><th>Sub Q. N.</th><th>Answer</th><th>Marking Scheme</th></tr>
<tr><td>3</td><td>d</td><td>

Velocity diagram for the jet striking on a moving curved plate (unsymmetrical) tangentially at one end is as shown in figure.



• V1 = Velocity of the jet (AB), while entering the vane,
• V2 = Velocity of the jet (EF), while leaving the vane,
• u1, u2 = Velocity of the curved vane at inlet & outlet (AC, FG)
• α = Angle with the direction of motion of the vane, at which the jet enters the vane,
• β = Angle with the direction of motion of the vane, at which the jet leaves the vane,
• Vr1 = Relative velocity of the jet and the vane (BC) at entrance (it is the vertical difference between V1 and u1)
• Vr2 = Relative velocity of the jet and the vane (EG) at exit (it is the vertical difference between V2 and u2)
• Ɵ = Angle, which Vr1 makes with the direction of motion of the vane at inlet (known as vane angle at inlet),
• β = Angle, which Vr2 makes with the direction of motion of the vane at outlet (known as vane angle at outlet),
• Vw1 = Horizontal component of V1 (AD, equal to). It is a component parallel to the direction of motion of the vane (known as velocity of whirl at inlet),
• Vw2 = Horizontal component of V2 (FH, equal to). It is a component parallel to the direction of motion of the vane (known as velocity of whirl at outlet),
• Vf1 = Vertical component of V1 (BD, equal to). It is a component at right angles to the direction of motion of the vane (known as velocity of flow at inlet),
• Vf2 = Vertical component of V2 (EH, equal to). It is a component at right angles to the direction of motion of the vane (known as velocity of flow at outlet)

</td><td>02 Marks for Velocity diagram

02 Marks for explain</td></tr>
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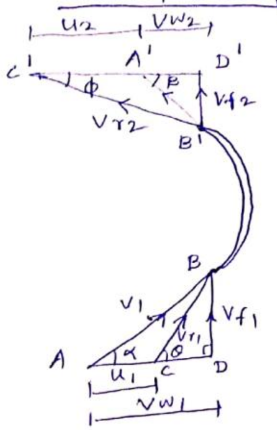
Q. No.	Sub Q. N.	Answer	Marking Scheme
3	e	Q3 e. Given: velocity of jet $V_1 = 20$ m/s velocity of vane $u_1 = u_2 = 5$ m/s Angle of deflection of jet = 120° For symmetrical curved vane $\theta = \phi$ $120^\circ = 180 - (\phi + \theta)$ $\therefore \phi = \theta = 30^\circ$ Velocity triangle for curved blade.  (i) vane angle at Inlet - α - Applying sine rule to ΔABC $\frac{AB}{\sin(180-\theta)} = \frac{AC}{\sin(\theta-\alpha)}$ $\frac{V_1}{\sin\theta} = \frac{u_1}{\sin(\theta-\alpha)}$ $\therefore \frac{20}{\sin 30} = \frac{5}{\sin(30-\alpha)}$ $\therefore \alpha = 22.82^\circ$ Vane angle at inlet = $\alpha = 22.82^\circ$ (ii) Absolute velocity of jet at exit (V_2) Applying sine rule to ΔABC $\frac{V_1}{\sin(180-\theta)} = \frac{V_{r1}}{\sin\alpha}$ $\therefore \frac{20}{\sin 30} = \frac{V_{r1}}{\sin(22.82)}$ $\therefore V_{r1} = 15.51$ m/s In ΔABC, $V_{w1} = V_1 \cos\alpha$ $= 20 \times \cos(22.82)$ $= 18.43$ m/s	01 Mark for correct value of angle 02 Mark for correct value of v2 01 Marks for correct value of Workdone

$V_{r1} = V_{r2} = 15.51$ m/s (smooth vane)

At outlet $\Delta B'C'D'$,

$V_{r2} \cos\phi = u_2 + V_{w2}$

$\therefore V_{w2} = V_{r2} \cos\phi - u_2$
$= 15.51 \times \cos 30 - 5$
$= 8.43$ m/s

$V_{f2} = V_{r2} \cdot \sin\phi$
$= 15.51 \times \sin 30$
$= 7.75$ m/s

$\tan\beta = \frac{V_{f2}}{V_{w2}} = \frac{7.75}{8.43}$

$\therefore \beta = \tan^{-1}(0.919)$
$= 42.59^\circ$

Angle made by V_2 at outlet with direction of motion of vane is
$= 180^\circ - \beta = 180 - 42.59^\circ$
$= 137.41^\circ$

Absolute velocity of jet at exit (V_2)

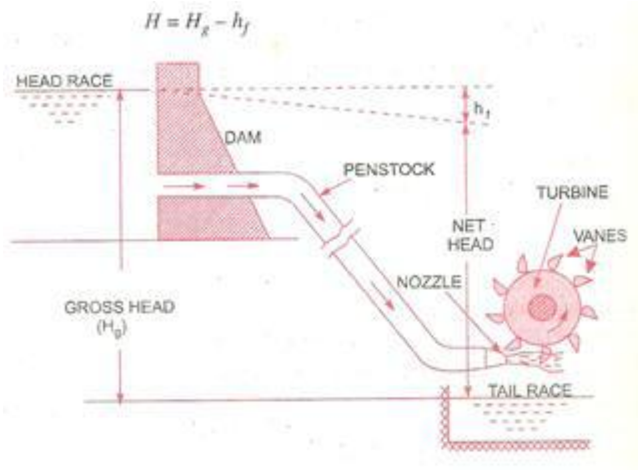
$V_2 = \sqrt{V_{w2}^2 + V_{f2}^2}$
$= \sqrt{(8.43)^2 + (7.75)^2}$
$= 11.45$ m/s. (Direction is as shown in velocity diagram)

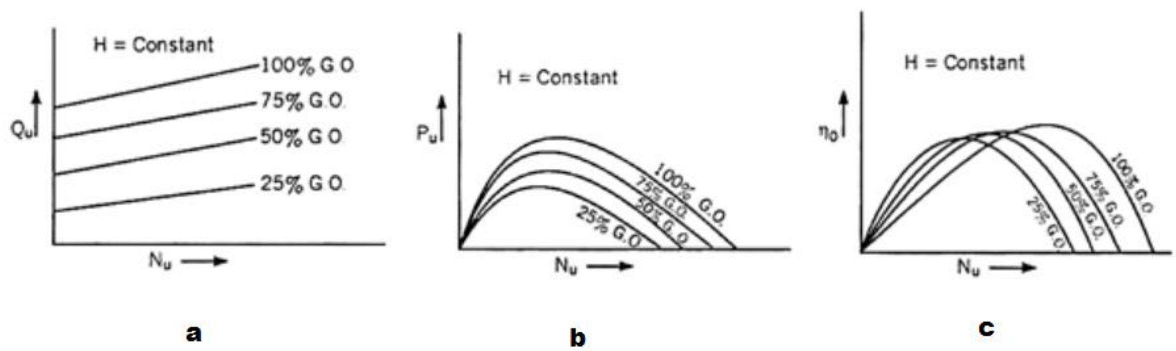
(3) Workdone per second per N of water

$W.D = \frac{1}{g}(V_{w1} \cdot u_1 + V_{w2} \cdot u_2)$

$= \frac{1}{9.81}(18.43 \times 5 + 8.43 \times 5)$

W.D. = 13.69 Nm

Q. No.	Sub Q. N.	Answer	Marking Scheme
4	a	**Layout of Hydroelectric Power Plant:**  Layout of Hydraulic Power plant **Function of all elements of Hydroelectric Power Plant** i) Dam (Reservoir):- It is water reservoir generally constructed over the river it contains lot of potential energy. ii) Penstock: - Pipes of large diameters called penstock, which carries water under high pressure from storage reservoir to the turbines. iii) Turbines:- These are the wheels on which number of vanes are fitted and converts hydraulic energy of water into rotary mechanical energy. iv) Tail race:- It is the channel which carries water away from turbines after the water has worked on turbines. v) Surge tank:-It is the tank provided in the path of penstock to avoid pulsating discharge at inlet of turbines and to avoid water hammer effect.	02 marks for sketch 02 marks for function of any 4 elements
4	b	**Name of turbine for given conditions:** i. Impulse Turbine (Pelton Wheel Turbine) ii. Reaction Turbine (Kaplan Turbine) iii. Francis Turbine iv. Modern Francis Turbine	01 Mark each

Q. No.	Sub Q. N.	Answer	Marking Scheme
4	c	**Characteristics curve of Kaplan turbine** The characteristic curves drawn are: (a) Unit quantity v/s unit speed (b) Unit power v/s unit speed (c) Overall efficiency v/s unit speed  	02 marks for each curve (any 2)
4	d	**Submersible Pump:** **Definition**: A submersible pump is a device which has a hermetically sealed motor close-coupled to the pump body. The whole assembly is submerged in the fluid to be pumped. **Application**: Irrigation, drinking water supply **Jet Pump:** **Definition**: Jet pumps are a class of liquid-handling device whereby a motive fluid is passed through an orifice or nozzle to increase its velocity. **Application**: Feed water to boiler, chemical processing industries, fuel storage industries, pumping of hazardous liquids and processes at reactors.	01 Mark definition and 01 Mark for any one application

Q. No.	Sub Q. N.	Answer	Marking Scheme
4	e	**Remedial action for troubles during operation of centrifugal pump are as follows**	01 mark for any one remedy for each case

A) Pump fails to start pumping

	Reason	Remedy
1	Pump may not be properly primed	Re prime the pump
2	Total head against which the pump is working may be more than the designed head.	Reduce the head or change the pump
3	Impeller, strainer or suction line may be clogged.	Clean the pump parts.
4	Suction lift may be excessive. Check the vacuum gauge fitted on the suction side.	Reduce the suction lift.
5	Speed may be low. Check the speed with a tachometer and compare it with the design speed.	Increase the speed.
6	The impeller might be rotating in the wrong direction. Check the direction of the impeller with that marked on the casing.	Change the direction of rotation.

B) Pump is not working at the required capacity.

	Reason	Remedy
1	There may be leakage of air into the pump through the suction line or the stuffing box.	Plug the leakage.
2	There may be excessive wear and tear. Some of the parts may be damaged.	Replace the damaged parts.

C) Pump stop working.

	Reason	Remedy
1	Air in suction line. This may be due to leakage or improper priming . Sometimes, air enters the suction pipe from the inlet.	Remove the air by priming and plug the air entry.
2	Suction lift is high.	Reduce the suction lift.

D) Pump takes too much power

	Reason	Remedy
1	Speed may be high	Reduce the speed
2	Pump may be rotating in wrong direction	Change the direction of rotation of pump
3	Shaft of pump and motor may not be aligned properly	Align the shaft of motor and pump properly

Q. No.	Sub Q. N.	Answer	Marking Scheme
Q. 5		**Attempt any TWO of the following**	**12 Marks**
	a)	**A pipe carrying water has a 30 cm X 15 cm venturimeter, which is positioned inclined at 30^0 to the horizontal. The flow is upward. The converging cone is 45 cm in length and C_d of the meter is 0.98. A differential U-tube Manometer with mercury as indicating fluid is connected to the inlet and to the throat and shows a differential column height of 30 cm.** **(i) Calculate discharge of the pipe** **(ii) If the pressure in the inlet section is 50 kPa determine the pressure at the throat** (iii)**Find the head loss in the converging section of the venturimeter.**	
	Sol.	see below	

$d_1 = 30\,cm = 0.30\,m \qquad a_1 = \frac{\pi}{4} d_1^2 = 0.0706\,m^2$

$P_1 = 50\,KPa = 50 \times 10^3\,N/m^2$

$d_2 = 15\,cm = 0.15\,m \qquad a_2 = \frac{\pi}{4} d_2^2 = 0.0176\,m^2$

$C_d = 0.98$

$x = 30\,cm = 0.30\,m$

$$h = x\left[\frac{S_m}{S_L} - 1\right] = 0.30 \times \left[\frac{13.6}{1} - 1\right]$$

$\therefore h = 3.78\,m$ head of water — 01 Mark

i) Discharge $= Q = \dfrac{C_d \cdot a_1 a_2 \sqrt{2gh}}{\sqrt{a_1^2 - a_2^2}}$

$\therefore Q = 0.1533\,m^3/sec$ — 01 mark

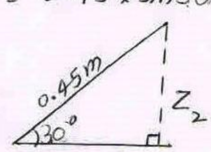
$\therefore Q = 153.3$ Lit/sec .... Discharge of the pipe

ii) Now, By Bernoulli's theorem,

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

Now, Take $Z_1 = 0$; $Z_2 = 0.45 \times \sin 30^\circ$

$\therefore Z_2 = 0.225\,m$



$Q = a_1 V_1$ $\qquad$ $Q = a_2 V_2$

$0.1533 = 0.0706 \times V_1$ $\qquad$ $0.1533 = 0.0176 \times V_2$

$\therefore V_1 = 2.1713 \ m/s$ $\qquad$ $\therefore V_2 = 8.71 \ m/s$

Now,

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

$$\frac{50\times10^3}{9810} + \frac{2.1713^2}{2\times9.81} + 0 = \frac{P_2}{9810} + \frac{8.71^2}{2\times9.81} + 0.225$$

$$P_2 = 12{,}217.66 \ N/m^2$$

$\therefore P_2 = 12.21$ kPa ...... Pressure at the throat

02 Mark

iii)
$$\frac{P_1}{w} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{w} + \frac{V_2^2}{2g} + Z_2 + h_L$$

$$\left(\frac{P_1}{w} - \frac{P_2}{w}\right) + \left(\frac{V_1^2}{2g} - \frac{V_2^2}{2g}\right) + (Z_1 - Z_2) = h_L$$

$$h + \left(\frac{V_1^2 - V_2^2}{2g}\right) + (Z_1 - Z_2) = h_L$$

$$3.78 + \left(\frac{2.1713^2 - 8.71^2}{2\times9.81}\right) + (0 - 0.225) = h_L$$

$$3.78 - 3.62 - 0.225 = h_L$$

$$\therefore h_L = -0.065 \ m$$

02 Mark

b) **Explain the terms involved in Darcy's equation, Chezy's equation for frictional loss, also show that for given total head H, the power transmitted through a pipeline connected to a reservoir is maximum when the loss of head due to friction h_f = H/3 (Minor losses can be neglected)**

Sol. **Darcy's equation**

$$h_f = \frac{4fLV^2}{2gd} = \frac{fLQ^2}{3d^5}$$

01 Mark

Where,
h_f = Head loss due to friction (m)
f = Darcy's coefficient of friction
L = Length of pipe (m)

01 Mark

V = Velocity of flowing fluid (m/s)
Q = Discharge through pipe (m^3/s)
d = Diameter of pipe (m)
g = Acceleration due to gravity (9.81 m/s^2)

Chezy's equation

01 Mark

$$V = C\sqrt{mi}$$

Where,
V = velocity of water in pipe — 01 Mark
m = hydraulic mean depth =A/P = d/4
i = loss of head per unit length = h_f/L
C =Chezy's constant

Power Transmitted Through a Pipe

Power = W x Q x (H - h_f) — 01 Mark

For Maximum Power Transmission

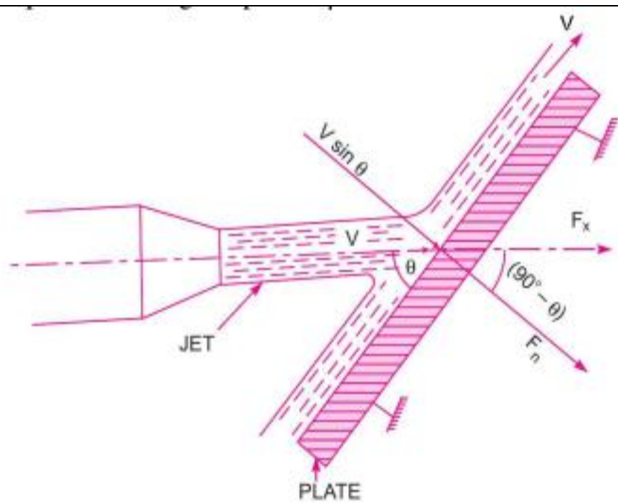
Power = W x Q x (H – H/3)

01 Mark

Where,
W = Specific Weight of fluid (N/m^3)
Q = Volume flow rate (m^3/s)
H = Head of fluid available at inlet of pipe (m)
h_f = Head loss due to friction (m)

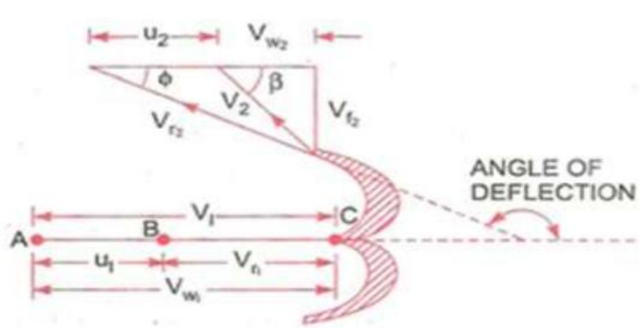
c) **Explain the expression of force exerted by the impact of jet on an inclined fixed plate and also draw in neat sketch for the same. Also find the work done.**

Sol.

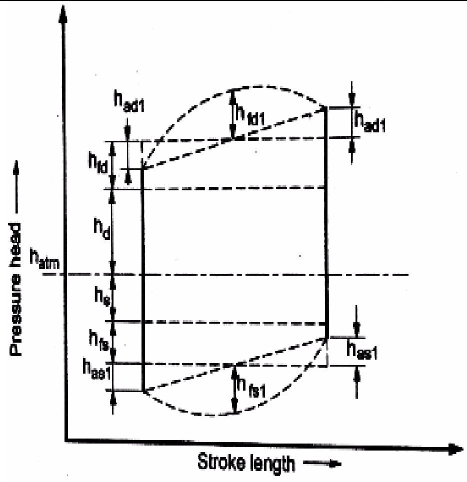
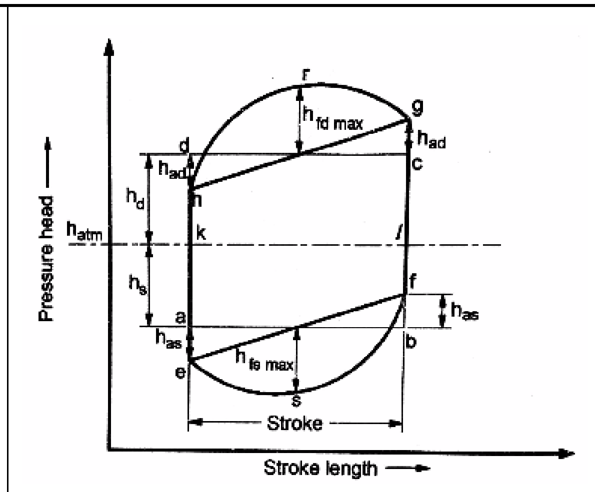


01 Mark

Fig. Impact of jet on an inclined fixed plate

		Let, d = diameter of jet a = Area of jet = $(\pi/4)\ d^2$ V = Velocity of jet before striking the plate $V\sin\theta$ = component of velocity normal to plate m = mass of water striking the plate per sec in Kg. m= ρ a V Fn = Normal force on the plate. Fn = mass of water X (velocity before impact in the direction normal to plate − Velocity after impact in the direction normal to plate) $F_n = \rho a V (V\sin\theta - 0)$ $= \rho a V^2 \sin\theta$ F_x = Force in the direction of jet $= F_n \sin\theta = \rho a V^2 \sin^2\theta$ F_y = Force in the direction normal to the jet $= F_n \cos\theta = \rho a V^2 \sin\theta \times \cos\theta$ $= \frac{\rho a V^2 \sin 2\theta}{2}$ **Work done = 0** …..since plate is stationary	01 Mark 01 Mark 01 Mark 01 Mark 01 Mark
Q.6		**Attempt any <u>TWO</u> of the following**	**12 Marks**
	a)	**A Pelton wheel has a mean bucket speed of 12 m/s and is supplied with water at a rate of 750 lite per sec under a head of 35 m. If the bucket deflects the jet through an angle of 160^0, find the power developed by turbine and its hydraulic efficiency. Take the coefficient of velocity as 0.98. Neglect friction in the bucket. Also determine the overall efficiency of the turbine, if its mechanical efficiency is 80 %.**	
	Sol.	 **Fig:** Velocity triangle for Pelton wheel turbine	

		Data: $U_1 = 12$ m/s $Q = 750$ lit/sec = $0.750\ m^3/s$ $H = 35$ m $Ø = 180^0 – 160^0 = 20^0$ $C_v = 0.98$ $\eta_{mech} = 80\ \% = 0.80$ Power = ? η_{hyd} = ? $\eta_{overall}$ = ? $V_1 = C_v\sqrt{2gh}$ $= 0.98 \times (2 \times 9.81 \times 35)^{1/2}$ = 25.68 m/s From Inlet Velocity triangle, $V_{w1} = V_1 = 25.68$ m/s $V_{r1} = V_1 – U_1 = 25.68 – 12 = 13.68$ m/s But, $V_{r2} = V_{r1} = 13.68$ m/s From Outlet Velocity triangle, $\cos Ø = \frac{U + V_{w2}}{V_{r2}}$ $V_{w2} = \cos Ø\ V_{r2} - U = (\cos 20^0 \times 13.68) - 12$ $V_{w2} = 0.8558$ m/s Power = $\rho Q\ (V_{w1} + V_{w2})\ U$ Power = 238.82×10^3 Watt $\eta_{hyd} = \frac{2\ (V_{w1} + V_{w2})\ U}{V_1^2}$ η_{hyd} = **0.9656 = 96.56 %** $\eta_{overall} = \frac{\text{Power}}{WQH}$ = **92.74 %**	**02 Marks** **02 Marks** **02 Marks**

	b)	**Draw indicator diagrams of a reciprocating pump showing the effect of acceleration and friction head on suction and delivery pipes connected with air vessels and without air vessels.**	
	Sol.	 **Fig.** Effect of acceleration and friction in indicator diagram with air vessels  **Fig.** Effect of acceleration and friction in indicator diagram without air vessels	03 Marks for each diagram
	c)	**A centrifugal pump has following characteristics: outer diameter of impeller = 800 mm; width of impeller vanes at outlet = 100 mm; angle of impeller vanes at outlet = 40^0. The impeller runes at 550 rpm and delivers 0.98 cubic meters of water per sec under an effective head of 35 m. a 500 KW motors is used to drive the pump. Determine the manometric, mechanical and overall efficiencies of the pump. Assume water enters the impeller vanes radially at inlet.**	

Sol.

$Q = 0.98\ m^3/s$, $D_1 = 800\ mm = 0.8\ m$ $N = 550\ rpm$

$B_1 = 100\ rpm = 0.1\ m$, $\phi = 40^\circ$, $H_m = 35\ m$

$P = 500\ kW = 500 \times 10^3$ watt

$$u_1 = \frac{\pi D_1 N}{60} = \frac{\pi \times 0.8 \times 550}{60} = 23.04\ m/s$$

$$V_{f_1} = \frac{Q}{\pi D_1 B_1} = \frac{0.98}{\pi \times 0.8 \times 0.1} = 3.90\ m/s$$

$$V_{w_1} = (u_1 - V_{f_1} \cdot \cot\phi) = (23.04 - 3.90 \times \cot 40^\circ)$$

$$V_{w_1} = 18.39\ m/s$$

* Manometric efficiency, $\eta_{mano} = \frac{g \cdot H_m}{V_{w_1} \cdot u_1} = \frac{9.81 \times 35}{18.39 \times 23.04}$

$$= 0.81 = 81\ \%$$

02 Marks

*Overall efficiency,

$$\eta_{overall} = \frac{W \cdot Q \cdot H_m}{P} = \frac{9810 \times 0.98 \times 35}{500 \times 10^3}$$

$$= 0.67 = 67\ \%$$

02 Marks

* Mechanical efficiency,

$$\eta_{mech.} = \frac{\eta_o}{\eta_{mano}} = \frac{0.67}{0.81} = 0.83$$

$$\therefore \eta_{mech} = 83\ \%$$

02 Marks