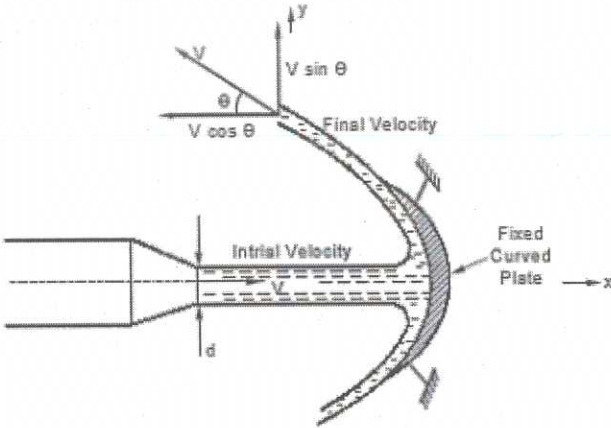


## SCHEME OF VALUATION

(scoring Indicators)

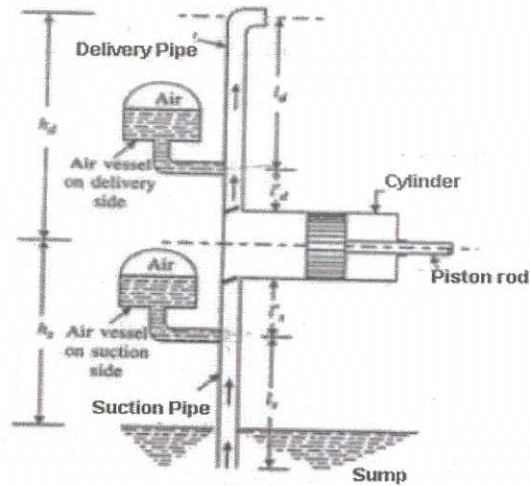
Revision: 2015		Course Code : 6022		
Course Title : <b>Hydraulic Machines</b>				
Qst No.	Scoring indicator	Split up score	S u b t o t a l	T o t a l
I(1)	<u>PART A</u> Fx=Rate of change of momentum in the direction of force	1	2	2
	Fx= $\rho a V^2$ , where $\rho$ density of fluid, a-area of cross section ,V-velocity of the jet	1		
I(2)	Jet ratio= $D/d$ , where 'D' is the diameter of the wheel and 'd' is the diameter of the jet	2	2	2
I(3)	Kaplan turbine	2	2	2
I(4)	Forced vortex flow	2	2	2
I(5)	The entire operation of completely filling suction pipe casing and a portion of delivery pipe upto delivery valve with liquid to be pumped is called priming	2	2	2
II (1)	<u>PART B</u>	2	6	6
	<div style="text-align: center;">  </div> <p>Initial velocity of jet striking on plate = V</p> <p>Final velocity of jet leaving the curved plate  in x direction = - V cos <math>\theta</math>  in y direction = -V sin <math>\theta</math></p> <p>Force exerted by jet on curved plate in x direction = <math>\rho A V (V - - V \cos \theta)</math>  = <math>\rho A V^2 (1 + \cos \theta)</math></p>			



II(3)	<p><b>1. According to the type of energy</b> (a) Impulse turbine, and (b) Reaction turbine If the energy available at the inlet of the turbine is only kinetic energy, the turbine is known as impulse turbine eg. Pelton wheel. An impulse turbine operates under atmospheric pressure throughout its passage. If water possesses both kinetic energy and pressure energy at the inlet of the turbine, then it is known as reaction turbine. eg. Francis turbine and Kaplan turbine. As the water flows through the runner, the pressure energy goes on changing into kinetic energy.</p> <p><b>2. According to the direction of flow of water in the runner</b>  (a) Tangential flow turbine  Water strikes the runner tangentially to its path of rotation (eg. Pelton wheel)  (b) Radial flow turbine  Water flows in radial direction of the runner. The flow may be inward radial (Francis(radial turbine) or outward radial flow (Fourneyron turbine)  (c) Axial flow turbine  Water flows over the vanes in a direction parallel to the axis of rotation of the runner (e.g. Kaplan turbine)  (d) Mixed flow turbine  Water enters radially but leaves in the direction parallel to the axis of rotation of the runner -Francis turbine(mixed flow)</p> <p><b>3. According to the head and quantity of water available</b>  (a) High head turbine  works under high head (above 250 m) and requires small quantity of flow (Pelton wheel)  (b) Medium head turbine  requires medium head (60 to 250 m) and requires relatively large quantity of water (Francis)  (c) Low head turbine  requires low head (less than 60) and requires very large quantity of water (Kaplan)</p> <p><b>4. According to the position of shaft</b> (a) Horizontal turbines - have horizontal shaft (Pelton wheel) (B) Vertical turbines - have vertical shafts (Kaplan)</p> <p><b>5. According to the specific speed of the turbine</b> (a) Low specific speed turbines (b) Medium specific speed turbines (c) High specific speed turbines</p>	6	6	6
II(4)	<p><b>Specific speed</b></p> <p>Less than 30</p> <p>30-50</p> <p>50-260</p> <p>260-860</p> <p><b>type of turbine</b></p> <p>Single jet Pelton wheel</p> <p>Multijet Pelton wheel</p> <p>Francis turbine</p> <p>Kaplan turbine</p>	1.5x4	6	6

<p>II(5)</p>	<p>1. Hydraulic Efficiency  <math display="block">\eta_{hyd} = \frac{\text{Power developed by the runner}}{\text{Power supplied at the inlet of the turbine}}</math> </p> <p>2. Mechanical Efficiency  <math display="block">\eta_{mech} = \frac{\text{Actual power available at the shaft of the turbine}}{\text{Power developed by the runner}}</math> </p> <p>Overall Efficiency, <math>\eta_o = \frac{\text{Actual power available at the shaft of the turbine}}{\text{Power supplied at the inlet of the turbine}}</math></p> <p>Overall Efficiency, <math>\eta_o = \eta_{hyd} \times \eta_{mech}</math></p>	<p>2</p> <p>2</p> <p>2</p>	<p>6</p>	<p>6</p>
<p>II(6)</p>	<pre> graph TD     PUMPS --&gt; PD[Positive Displacement]     PUMPS --&gt; NPD[Non positive displacement]     PD --&gt; Rotary     PD --&gt; Reciprocating     Rotary --&gt; Gear     Rotary --&gt; Vane     Rotary --&gt; Screw     Reciprocating --&gt; AP[Axial piston]     Reciprocating --&gt; RP[Radial piston]     NPD --&gt; Centrifugal     NPD --&gt; AF[Axial flow]     NPD --&gt; RF[Radial flow]   </pre>	<p>6</p>	<p>6</p>	<p>6</p>

II(7)



Air vessels are a closed container, in which the half part is filled with water & upper half part is filled with compressed air. These airvessels installed very near to the suction valve & delivery valve to avoid the separation.

- (i) The flow fluctuation is reduced and a uniform flow is obtained.
- (ii) The friction work is reduced.
- (iii) The acceleration head is reduced considerably.
- (iv) Enables the use of higher speeds.

1

1

1

1

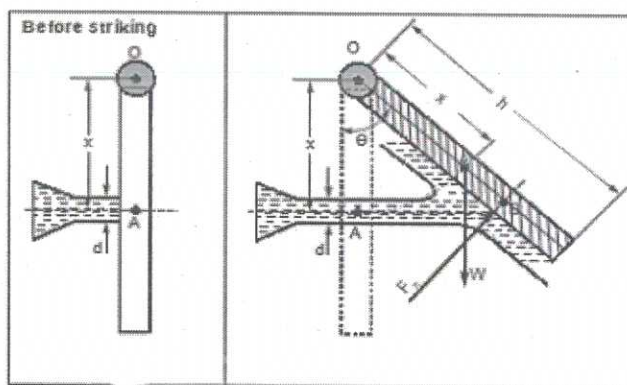
1×4

4

6

III(a)

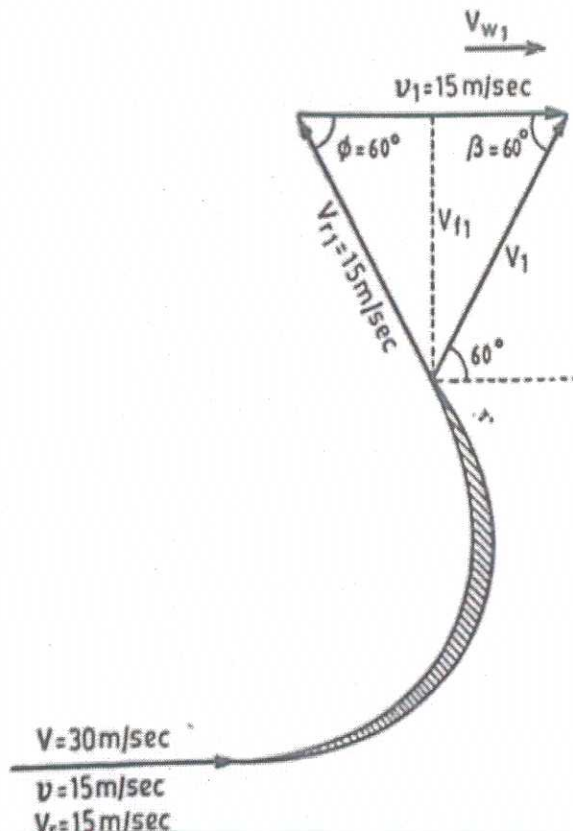
PART C  
UNIT I

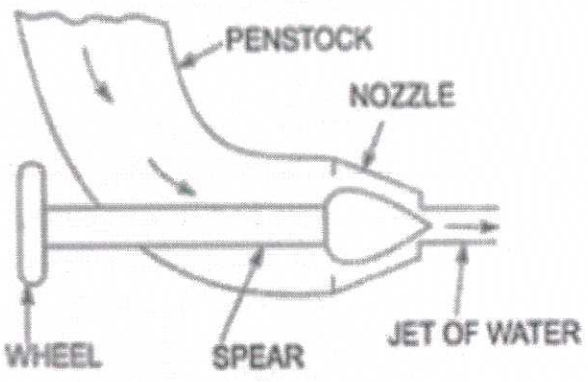
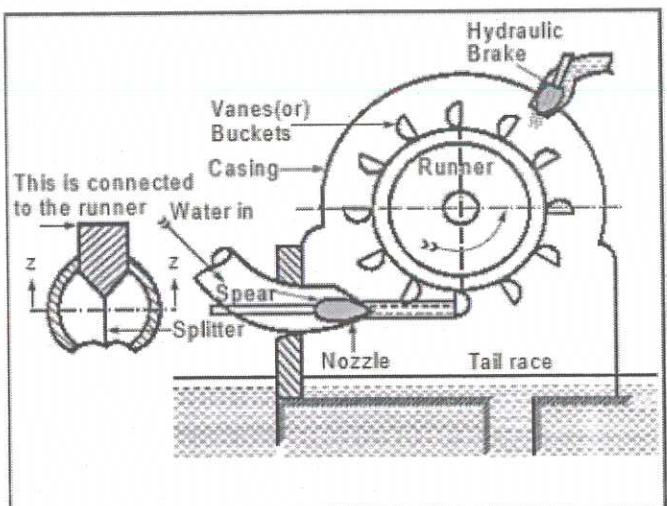


A vertical plate is hinged at one end O.  $h$  = height of plate, A = The centre point at which jet strikes the plate Consider the jet of water striking the hinged vertical plate at point A. Due to the thrust, the plate will swing through some angle  $\theta$ , B = The point at which jet strikes after it is inclined to an equilibrium position.

2 (for fig.)



	<p>Mass of the issuing jet <math>m = \rho A V r</math>  Propulsive force <math>F = \rho A V r \times (V_r - u)</math> and W.D per second <math>= \rho A V r \times (V_r - u) \times u</math>  Efficiency <math>\eta = \text{W.D per second} / \text{Kinetic energy per second}</math></p>	4	7	7
IV(b)	<div style="text-align: center;">  </div> <p> <math>\alpha = 0, \beta = 60^\circ, \theta = 0, V_w = V = 30 \text{ m/s}, u = 15 \text{ m/s}</math>  <math>V_r = V_{r1} = V - u = 30 - 15 = 15 \text{ m/s}, u_1 = 15 \text{ m/s}, \phi = 60^\circ</math>  <math>V_{w1} = u_1 - V_{r1} \cos \phi = 15 - 15 \cos 60 = 7.5 \text{ m/s}</math>  Weight of water discharged per second <math>= 9810 \times (\pi d^2 / 4) \times V = 9810 \times (\pi (0.15)^2 / 4) \times 30 = 5200.7 \text{ N/s}</math>  Force exerted by the jet <math>= W/g (V_w - V_{w1}) = (5200.7 / 9.81) \times (30 - 7.5) = 11928.2 \text{ N}</math>  Work done per second <math>= 11928.2 \times 15 = 178923 \text{ Nm/s}</math> </p>	2	8	8
		6		

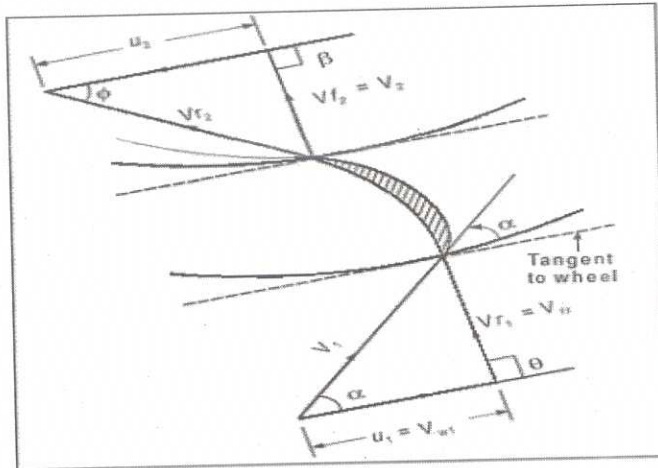
V(a)	UNIT II			
	 <p data-bbox="295 761 1220 1008">It consists of a nozzle in which a spear moves to and fro by the action of the servomotor piston and controls the quantity of water at changing demand of load. This to and fro movement of the spear causes variation in cross sectional area of the jet coming out from the nozzle without changing its velocity. When the spear is move backward the rate of flow of water increases and when it is pushed forward the rate of flow of water decreases.</p>	2	7	7
V(b)	$V = C_v \sqrt{2gH} = 0.97 \times \sqrt{2 \times 9.81 \times 310} = 75.65 \text{ m/sec}$ $u = 0.47 \times V = 0.47 \times 75.65 = 35.56 \text{ m/sec}$ $\eta_o = \frac{\text{shaft power} \times 1000}{9810 \times QH}, \quad 0.8 = \frac{(5890 \times 1000)}{9810Q \times 310}$ $\therefore Q = 2.420 \text{ cumec}$ $u = \frac{\pi DN}{60} \therefore D = \frac{60u}{\pi N} = \frac{60 \times 35.56}{\pi \times 560} = 1.212 \text{ m}$	1 1 3 3	8	8
VI(a)	 <p data-bbox="311 1780 1236 1881">This is a commonly used tangential flow impulse type of turbine. It is suitable for very high heads and requires lesser quantity of water. A Pelton Wheel shown in Fig. consists of runner, buckets, nozzle, guide mechanism,</p>	3 (for fig.)		

	<p>hydraulic brake and casing.</p> <p>Working of a Pelton Wheel The water is conveyed to the power house from the head race through penstocks. The nozzle fitted to the end of the penstock (power house end) delivers a high velocity water jet into the buckets. One or more jets of water are arranged to impinge on the buckets tangentially. The impact of water jet on the bucket causes the wheel to rotate, thus producing mechanical work. An electric generator coupled to the runner shaft and mechanical energy is converted into electric power.</p> <p>After leaving the turbine wheel, water falls into the tail race. The Pelton wheel is located above the tail race so that, the buckets do not splash the tail race water.</p>	4	7	7
VI(b)	$\eta_o = \text{shaft power} / (9810 QH / 1000)$ $0.85 = 6990 / (9810 Q \times 500 / 1000)$ $V = C_v \sqrt{2gH} = 0.97 \sqrt{2 \times 9.81 \times 500} = 96.07 \text{ m/sec.}$ $u = u_1 = 0.47 V$ $= 0.47 \times 96.07 = 45.15 \text{ m/sec}$ $u = \pi DN / 60 \therefore \text{wheel dia. } D = 60u / \pi N = 60 \times 45.15 / (\pi \times 430) = 2 \text{ m}$ $Q = \pi D^2 \times V / 4 \therefore d^2 = 4Q / \pi V = 4 \times 1.676 / (3.1415 \times 96.07) = 0.0222 \text{ m}^2$ $\therefore \text{jet dia. } d = 0.149 \text{ m}$	8	8	8
	<b>UNIT III</b>			
VII(a)	<b>Francis turbine</b>		<b>Kaplan turbine</b>	
	<b>According to type of flow</b>	Francis turbine is radial flow turbine but in case of modern Francis turbine water enters radially and leaves the turbine axially which is called as mixed flow turbine.	<b>According to type of flow</b>	Kaplan turbine is axial flow turbine i.e. water enters and leaves the turbine runner both in axial direction.
	<b>Efficiency</b>	Efficiency of Francis turbine is less as compare to Kaplan turbine	<b>Efficiency</b>	Efficiency of Kaplan turbine is higher than Francis turbine
	<b>Losses</b>	Friction losses are higher	<b>Losses</b>	Less friction losses as compare to Francis turbine
	<b>Size</b>	The size of Francis turbine is quite large as compare to Kaplan turbine	<b>Size</b>	Kaplan turbine compact in cross sectional area

<b>Vanes</b>	Large number of vanes in runner, generally the number of vanes are 16 to 24	Kaplan turbine is compact in size so the numbers of vanes are also less; generally the number of vanes is 4 to 8.			
<b>Type of shaft</b>	The direction of shaft is may be vertical or horizontal as per requirement.	The direction of shaft is always in vertical direction because it is axial flow turbine.			
<b>Head available</b>	Francis turbine requires medium range of water head i.e. it generally varies from 100-600 meters	Kaplan turbine works on very low head, the requirement of head is generally 100 meters.			
<b>Flow rate</b>	As it is works in medium head therefore it requires medium flow rate.	Kaplan turbine requires high flow rate of water.			
<b>Specific speed</b>	Francis turbine works on medium range of specific speed i.e. the specific speed varies from 60 to 300.	Kaplan turbine requires high value of specific speed because it is works on low head. Generally the range of specific speed varies from 600-1000.	1x7(c onsid er any seven )	7	7
<b>Governing mechanism</b>	Fancies turbine has simple governing mechanism.	The governing mechanism of Kaplan turbine is quite complicated in construction and working.			
<b>Runner vanes</b>	Francis turbine has fixed runner vanes on the shaft	Kaplan turbines vanes are adjustable i.e. we can easily adjust the runner vanes as per our requirements.			

VII(b)

Francis turbine is an inward flow reaction turbine  $\therefore$  The vane angle at exit =  $90^\circ$ . The velocity triangle is



$$\tan \alpha =$$

$$V_{f1} / u_1$$

$$\therefore u_1 = V_{w1}$$

$$u_1 =$$

$$V_{f1} / \tan \alpha$$

$$= 2.5 / \tan 12$$

$$= 11.761575 \text{ m/sec}$$

: Since 5% area of flow is blocked by the runner blades, therefore the actual area of flow will be 95%

$$Q = 0.95 \pi D_1 B_1 V_{f1} = 0.95 \pi D_2 B_2 V_{f2} \therefore D_1 B_1 = D_2 B_2$$

$$B_2 = B_1 \times D_1 / D_2 = 0.1 \times 1 / 0.6$$

$$= 0.166666 \text{ m}$$

$$u_1 = \pi D_1 N / 60$$

$$\therefore D_1 =$$

$$60 \times u_1 / \pi N$$

$$= 60 \times 11.761575 / (\pi \times 280)$$

$$= 0.802 \text{ m}$$

$$\therefore D_2 = 0.6 \times 0.802 = 0.481 \text{ m}$$

$$Q = 0.95 \times \pi D_1 \times B_1 \times V_{f1} = 0.95 \times \pi \times 0.802 \times 0.1 \times 2.5 = 0.599 \text{ m}^3 / \text{sec}$$

2

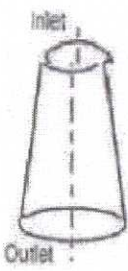
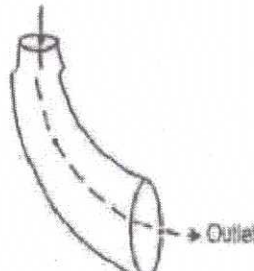
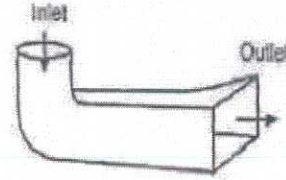
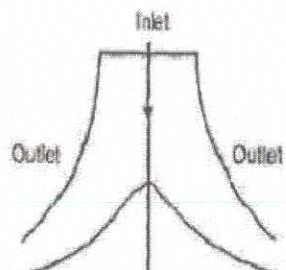
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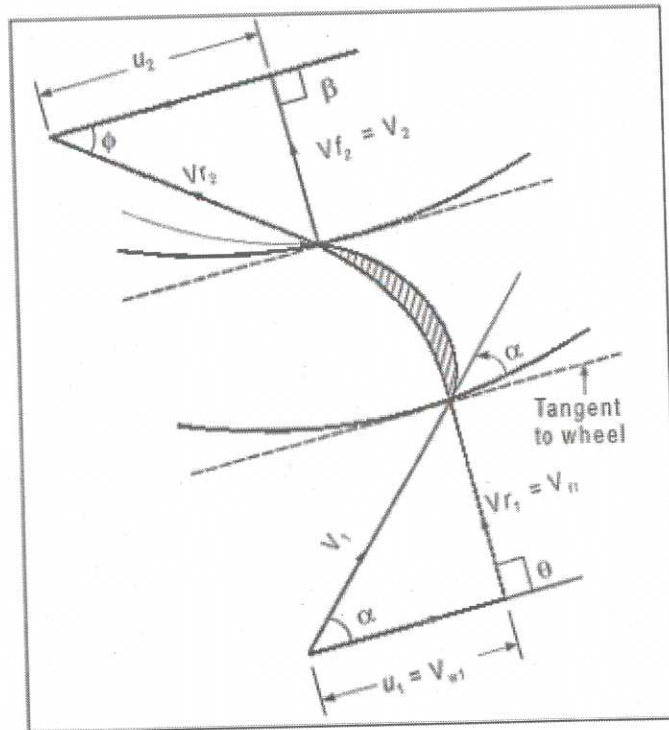
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VIII(a)	<p>A draft tube is a pipe of gradually increasing area which connects the outlet of the runner to the tail race and is used to discharge water from the turbine exit to the tail race. One end of the draft tube is connected to the outlet of the runner while the other end is submerged below the level of water in tail race.</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;">  <p><u>Conical or Divergent Draft Tube</u></p> </div> <div style="text-align: center;">  <p>Simple Elbow Draft Tube</p> </div> </div> <div style="display: flex; justify-content: space-around; align-items: flex-start; margin-top: 20px;"> <div style="text-align: center;">  <p>Elbow Tube Having Circular Cross-section at Inlet and rectangular at Outlet</p> </div> <div style="text-align: center;">  <p>Hydracone or Moody Spreading Draft Tube</p> </div> </div>	3		
VIII(b)	<p>Given Data: <math>D_2 = 0.6 D_1</math> ; <math>\alpha = 12^\circ</math> ; <math>\theta = 90^\circ</math> ; <math>N = 280 \text{ rpm}</math>    <math>B_1 = 0.1 \text{ m}</math> ;  <math>V_{f1} = V_{f2} = 2.5 \text{ m/sec}</math></p> <p><math>\tan \alpha = V_{f1} / u_1</math></p> <p>... (<math>u_1 = V_{w1}</math>)</p>	4	7	7

$$u_1 = V_{f1} / \tan \alpha$$

$$= 2.5 / \tan 12 = 11.761575 \text{ m / sec}$$

Since 5% area of flow is blocked by the runner blades, therefore the actual area of flow will be 95%  $Q = 0.95 \pi D_1 B_1 V_{f1} = 0.95 \pi D_2 B_2 V_{f2}$   
 $\therefore D_1 B_1 = D_2 B_2 \therefore B_2 = B_1 \times D_1 / D_2 = 0.1 \times 1 / 0.6 = 0.166666 \text{ m}$



$$\sin \alpha = V_{f1} / V_1$$

$$\therefore V_1 = V_{f1} / \sin \alpha$$

$$= 2.5 / \sin 12 = 12.02 \text{ m / sec}$$

$$u_1 = \pi D_1 N / 60$$

$$\therefore D_1 = 60 \times u_1 / (\pi N)$$

$$= 60 \times 11.761575 / (\pi \times 280)$$

$$= 0.802 \text{ m}$$

$$\therefore D_2 = 0.6 \times 0.802 = 0.481 \text{ m}$$

$$u_2 = \pi \times 0.481 \times 280 / 60$$

$$= 7.06 \text{ m / sec}$$

$$Q = 0.95 \times \pi D_1 B_1 V_{f1}$$

$$= 0.95 \pi \times 0.802 \times 0.1 \times 2.5 = 0.599 \text{ m}^3 / \text{sec}$$

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2(for fig.)

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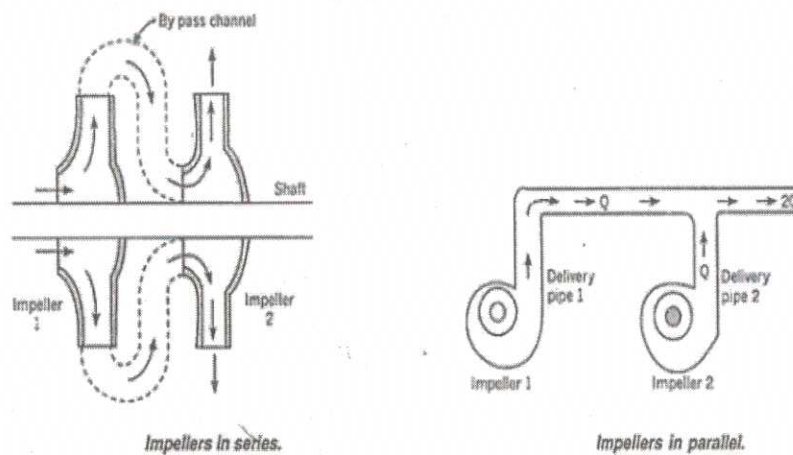
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IX(a)

## UNIT IV

2(for  
figure  
)

A centrifugal pump with a single impeller can develop a head up to nearly 40 metres. In order to develop greater heads or to discharge a high rate, a multistage pump is used. A multistage pump is a pump with more than one impeller.

## (i) Impellers in Series:

In this case, a number of impellers are mounted over a common shaft. The discharge from the first impeller is guided into the inlet of the second impeller. The discharge from the second impeller is guided into the inlet of the third impeller and so on and finally, the discharge from the last impeller is directed to the delivery pipe.

2.5

As the liquid flows through each impeller, the head  $H_m$  is impressed on it. Suppose there are  $n$  impellers. The total head developed =  $H_t = n H_m$ . The same discharge  $Q$  passes through all the impellers and is finally delivered to the delivery pipe.

## (ii) Impellers in Parallel:

This arrangement is meant for discharging a high rate of flow at a given small head  $H_m$ . The impellers in this case are mounted on separate shafts. The discharges from the various delivery pipes are collected in a collecting pipe which communicates to the final delivery pipe.

If  $Q$  = discharge from one impeller, then  $Q_t = n \times Q$  where 'n' number of impellers

2.5

7 7

IX(b)

$N=1450 \text{ rpm}, Q=110 \text{ litres/sec}=0.11 \text{ cumec}, H_m=23\text{m}, d_1=250\text{mm}, b_1=50 \text{ mm}$   
 $\eta_{mano}=75\%$

Manometric efficiency  $\eta_{man}$

$$= \frac{H_m}{\left( \frac{V_{w1}v_1}{g} \right)}$$

$$\therefore 0.75 = \frac{23}{\left[ \frac{V_{w1}v_1}{g} \right]}$$

$$\therefore \frac{V_{w1}v_1}{g} = \frac{23}{0.75}$$

$$= 30.67 \text{ Nm/sec/N of water}$$

$$\text{But } v_1 = \frac{\pi d_1 N}{60} = \frac{\pi \times 0.25 \times 1450}{60}$$

$$= 18.98 \text{ m/sec}$$

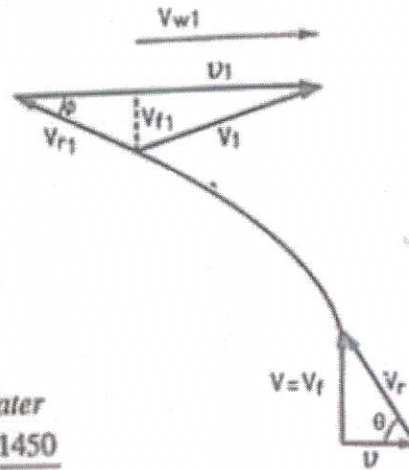
$$\therefore \frac{V_{w1} \times 18.98}{9.81} = 30.67$$

$$\therefore V_{w1} = \frac{30.67 \times 9.81}{18.98} = 15.85 \text{ m/sec}$$

$$V_{f1} = \frac{Q}{\pi d_1 b_1} = \frac{0.11}{\pi \times 0.25 \times 0.05} = 2.80 \text{ m/sec}$$

$$\tan \phi = \frac{V_{f1}}{v_1 - V_{w1}} = \frac{2.80}{18.98 - 15.85} = 0.8945$$

$$\therefore \phi = 41^\circ 49'$$



2(for  
fig.)

2

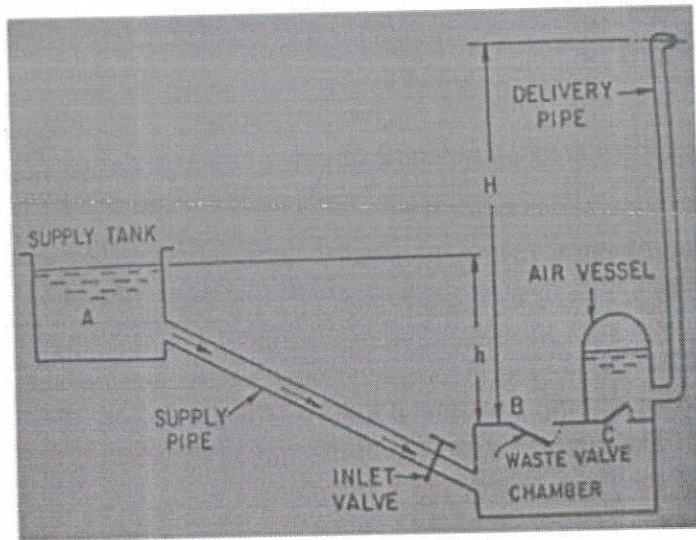
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8

X(a)



2(for  
fig.)

The hydraulic ram is a pump which raises water without any external power for its operation. One essential requirement for the satisfactory operation of a hydraulic ram is the availability of a large quantity of water with a small positive head or height. This large quantity of water at a small height is sufficient to lift small quantity of water to a greater height. It works on the principle of "Water Hammer."

The system has a chamber with two flap valves and an air vessel. This chamber is connected to the water supply from a supply tank or a water reservoir at a small height. The supply tank and the pumping chamber are separated by a valve which controls the flow of water.

When the inlet valve fitted on the supply line is opened, water starts flowing from the supply tank to the pumping chamber. The chamber has two valves, "B" and "C." Valve "B" is the waste valve and "C" is called the delivery valve. The valve "C" is fitted to an air vessel. As water is flowing from the supply tank, the chamber gets filled up and valve "B" starts to move upwards. A moment comes, when the valve "B" suddenly closes. This sudden closure of valve "B" creates high pressure inside the chamber. This sudden increase in pressure opens "C" which is the delivery valve. Thus the water from the chamber enters the air vessel and compresses the air inside the vessel. The compressed air exerts a force on water which is inside the air vessel. Thus a small quantity of water is raised to a greater height. As the water in the chamber loses momentum, the waste valve "B" gradually opens in downward direction and flow of water from the supply tank starts flowing to the chamber and the cycle will be repeated.

7

7

5

X (b)	<p>Sol. Single acting pump  <math>D = 150 \text{ mm}, L = 300 \text{ mm}</math>  <math>N = 40 \text{ rpm}</math>  <math>Q_{\text{theoretical}} = ?</math>  <math>\% \text{ slip} = ?</math>  <math>Q_{\text{actual}} = 209.5 \text{ lit/min}</math>  <math>= \frac{209.5}{1000 \times 60} \text{ cumec} = 0.003492 \text{ cumec}</math></p> <p>Theoretical average discharge  <math>= Q_{\text{theoretical}} = \frac{ALN}{60}</math>  <math>= \frac{\pi}{4} (0.15)^2 (0.3) \frac{40}{60}</math>  <math>= 0.003534 \text{ cumec} = 3.534 \text{ litres/sec}</math></p> <p>Slip  <math>= Q_{\text{theoretical}} - Q_{\text{actual}}</math>  <math>= 0.003534 - 0.003492 = 0.000042 \text{ cumec}</math></p> <p><math>\therefore</math> Slip percentage  <math>= \frac{0.000042}{0.003534} \times 100\% = 1.118\%</math></p>	2		
			8	8
		3		

al