K.S. SCHOOL OF ENGINEERING AND MANAGEMENT, BANGALORE - 560109

DEPARTMENT OF MECHANICAL ENGINEERING

I SESSIONAL TEST QUESTION PAPER 2018 – 19 ODD SEMESTER

SET-A

USN										

Degree	**:**	**B.E**	**Semester**	**:**	**V**
Branch	**:**	**Mechanical Engineering**	**Date**	**:**	**4-9-2019**
Course Title	**:**	**Turbo Machines**	**Course Code**	**:**	**17ME53**
Duration	**:**	**90 Minutes**	**Max Marks**	**:**	**30**

Note: Answer ONE full question from each part

Q. No.	Question	Marks	K Level	CO mapping
	PART-A			
1(a)	With suitable velocity triangles, **derive** an expression for maximum hydraulic efficiency of a Pelton wheel in terms of blade velocity coefficient and blade discharge angle.	**5**	**K3** Applying	**CO1**
(b)	A 137 mm diameter jet of water issuing from a nozzle impinges on the buckets of a Pelton wheel and the jet is deflected through an angle of 165° by the buckets. The head available at the nozzle is 400m. Assuming coefficient of velocity as 0.97, speed ratio as 0.46 and reduction in the relative velocity while passing through the buckets as 15%, **find:** (i) Force exerted by the jet on the buckets in the tangential direction (ii) the power developed.	**5**	**K3** Applying	**CO1**
(c)	**Define** a Turbo machine. With a neat sketch **explain** the parts of a turbo machine.	**5**	**K2** Understanding	**CO2**
	OR			
2(a)	**Define** and **explain** the following efficiencies of a hydraulic turbine: (i) Hydraulic efficiency (ii) Mechanical Efficiency (iii) Overall efficiency	**5**	**K2** Understanding	**CO1**
(b)	A double jet Pelton wheel is required to generate 7500kW when the available head at the base of the nozzle is 400m. The jet is deflected through 165^0 and the relative velocity of the jet is reduced by 15% in passing over the buckets. **Determine:** (i) diameter of each jet (ii) Total flow rate (iii) Force exerted by the jet in the tangential direction. Assume Overall efficiency = 80%, Speed ratio = 0.47, C_v = 0.97.	**5**	**K3** Applying	**CO1**
(c)	**Explain** how turbo machines are classified.	**5**	**K2** Understanding	**CO2**

PART-B				
3(a)	**Draw** a neat sketch of a Francis turbine and **explain** the functions of each part. **Draw** the velocity triangles of a Francis turbine.	**5**	**K2** Understanding	**CO1**
(b)	The following data is given for a Francis turbine: Net head = 70m, Speed = 600RPM, Shaft power = 368kW, Overall efficiency = 85%, Hydraulic efficiency = 95%, Flow ratio = 0.25, Breadth ratio = 0.1, Outer diameter of the runner = 2 x inner diameter of the runner. Velocity of flow is constant at outlet and inlet. The thickness of the vanes occupies 10% of the circumferential area of the runner and discharge is radial at outlet. **Determine:** (i) Guide blade angle (ii) Runner vane angles at inlet and outlet (iii) Diameter of runner at inlet and outlet (iv) width of the runner at inlet.	**5**	**K3** Applying	**CO1**
(c)	**Differentiate** between a turbo machine and a positive displacement machine.	**5**	**K2** Understanding	**CO2**
OR				
4(a)	**Draw** a neat sketch of a Kaplan turbine and **explain** the functions of each part. **Draw** the velocity triangles of a Kaplan turbine.	**5**	**K2** Understanding	**CO1**
(b)	A Kaplan turbine working under a head of 20m develops 11775kW. The outer diameter of the runner is 3.5m, hub diameter is 1.75m. The guide blade angle at the extreme edge of the runner is 35^0.The hydraulic and overall efficiencies of the turbine are 0.88 and 0.84 respectively. If the velocity of whirl at outlet is zero, **determine:** (i) runner vane angles at inlet and outlet at the extreme edge of the runner (ii) speed of the turbine.	**5**	**K3** Applying	**CO1**
(c)	**Classify** the following as Power generating or Power absorbing turbo machine: (i) Steam Turbine (ii) Fan (iii) Air blower (iv) Axial flow compressor (v) Wind Turbine	**5**	**K2** Understanding	**CO2**

Course In charge **Head - Dept** **Principal**

K.S. SCHOOL OF ENGINEERING AND MANAGEMENT, BANGALORE - 560109

DEPARTMENT OF MECHANICAL ENGINEERING

I SESSIONAL TEST SCHEME & SOLUTION 2019 – 20 ODD SEMESTER

SET-A

USN										

Degree	: B.E		Semester	:	V
Branch	: Mechanical Engineering		Date	:	4-9-2019
Course Title	: Turbo Machines		Course Code	:	17ME53 | 15ME53
Duration	: 90 Minutes		Max Marks	:	30

Note: Answer ONE full question from each part

Q. No.	Questions with Scheme & Solution	Marks	K Level	CO mapping
	PART-A			
1(a)		5	K3	CO1

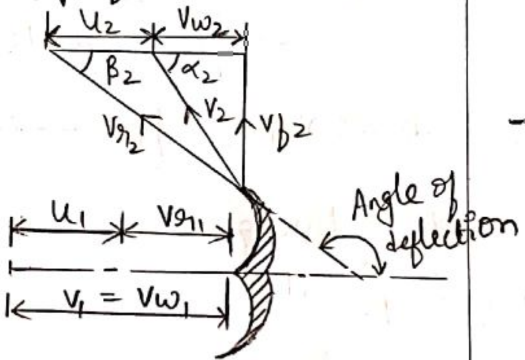
Sol

Expression for maximum efficiency of a Pelton wheel.

$V_1 = C_v \cdot \sqrt{2gH}$

$u_1 = u_2 = \frac{\pi D N}{60}$ —1—

$V_{w_1} = V_1$



Work done per second $= F_x \times u$

$$W \cdot D/_s = \rho a V_1 \times u \left[V_{w_1} + V_{w_2}\right] \quad — (1)$$ —1—

$$\eta_H = \frac{\text{Work done per second}}{\text{Kinetic Energy of jet}} = \frac{\rho a V_1 u \left[V_{w_1} + V_{w_2}\right]}{\frac{1}{2} \rho a V_1 \cdot V_1^2}$$

$$\eta_H = \frac{2u\left[V_{w_1} + V_{w_2}\right]}{V_1^2} \quad — (2)$$ —1—

Efficiency will be maximum when $\frac{d}{du}(\eta_h) = 0$

$$\Rightarrow u = \frac{V_1}{2} \quad — (3)$$ Substituting (3) in (2) —1—

$$\therefore \eta_{H_{max}} = \frac{(1 + \cos \beta_2)}{2}$$ —1—

1.(b)		5	K3	C

Sol

Given: diameter of jet, $d = 0.137\,m$ — Velocity triangle — -1-

area of jet, $a = \frac{\pi}{4} \times 0.137^2 = 0.014\,m^2$

Angle of deflection, $(180 - \beta_2) = 165^\circ \Rightarrow \boxed{\beta_2 = 15^\circ}$

Net Head, $H = 400\,m$

$C_v = 0.97$, Speed ratio $= 0.46$

Relative velocity at outlet $= (1 - 0.15) \times$ relative velocity at inlet.

$\therefore \boxed{V_{r_2} = 0.85\,V_{r_1}}$

$V_1 = C_v\sqrt{2gH} \Rightarrow \boxed{85.93\,m/s = V_1} \Rightarrow \boxed{V_{w_1} = 85.93\,m/s}$

$u_1 = \phi\sqrt{2gH} \Rightarrow \boxed{u_1 = 40.75\,m/s} = u_2 = u$ -1-

$\therefore$ From Inlet velocity triangle, $V_{r_1} = V_1 - u$

$\Rightarrow \boxed{V_{r_1} = 45.18\,m/s}$

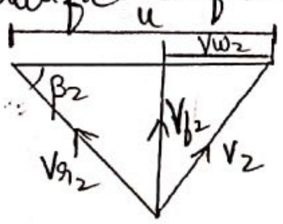
W.K.T. $V_{r_2} = 0.85\,V_{r_1} \Rightarrow \boxed{V_{r_2} = 38.4\,m/s}$ -1-

From outlet velocity triangle,

$V_{w_2} = V_{r_2}\cos\beta_2 - u$

$\boxed{V_{w_2} = -3.65\,m/s}$

Since, $V_{w_2} < u$, the outlet velocity triangle is modified as follows:



(i) $\therefore F_x = \rho . a . V_1 [V_{w_1} - V_{w_2}]$ -1-

$\boxed{F_x = 104.2\,kN}$

(ii) Power developed, $P = \frac{F_x \times u}{1000}$

$\boxed{P = 4247.15\,kW}$ -1-

1.(c)		5	K2	CO2
Sol	Turbomachine – Definition	-1-		
	– Neat sketch	-1-		
	– Explanation of basic parts ↳ Rotor ↳ Stator ↳ Casing ↳ Input or output shaft	-3-		

OR

2(a)		5	K2	CO1
Sol	Definitions of all efficiencies	-3-		
	Explanation of all the terms along with units	-2-		
2.(b)		5	K3	CO1

Sol

Given:

No. of jets = 2

Power generated = 7500 kW

Net Head, H = 400 m

$\eta_0 = 0.8$

$\phi = 0.47$

Angle of deflection $= (180 - \beta_2) = 165°$

$\Rightarrow \boxed{\beta_2 = 15°}$ -1-

$V_{r_2} = (1 - 0.15)\, V_{r_1}$

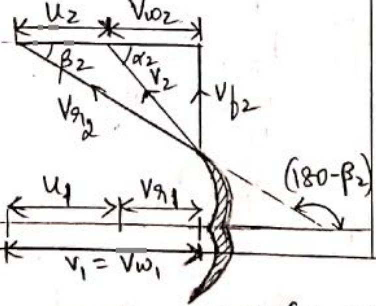
$\boxed{V_{r_2} = 0.85\, V_{r_1}}$

$C_v = 0.97$

(i) diameter of each jet, d = ? (ii) Total flow rate, Q_{Total} = ? (iii) Force exerted in tangential direction, F_x = ?

W.K.T $\eta_0 = \dfrac{P}{\dfrac{w\, Q_{Total}\, H}{1000}}$

$\Rightarrow \boxed{Q_{Total} = 2.41\, m^3/s}$ -1-



$V_{w_1} = V_1 = C_v\sqrt{2gH} = \underline{85.93\, m/s}$

$u_1 = u_2 = u = \phi\sqrt{2gH} = \underline{41.63\, m/s}$

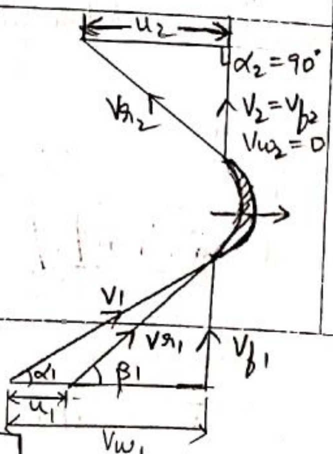
$V_{r_1} = V_1 - u = \underline{44.3\, m/s}$

$V_{r_2} = 0.85(44.3) = \underline{37.65\, m/s}$

	(i) Discharge through 1 jet $= \frac{Q_{Total}}{\text{no. of jets}} = 1.2\ m^3/s \Rightarrow$ $d = 0.133\,m$	-1-		
	(iii) $F_x = \rho a V_1 [V_{w_1} + V_{w_2}]$ $= \rho a V_1 [V_{w_1} - V_{w_2}]$ $F_x = 96.376\ kN$ From outlet velocity triangle, $V_{w_2} = V_{r_2}\cos\beta_2 - u$ $V_{w2} = -5.2\ m/s$ Since $V_{w_2} < u_2$, modified velocity triangle is drawn.	-2-		
2.(c)		5	K2	CO2
Sol	Detailed classification of turbomachines	-5-		

PART-B

3(a)		5	K2	CO1
Sol	→ Neat sketch of Francis Turbine	-1-		
	→ Explanation for basic parts of Francis Turbine	-2-		
	→ Inlet and outlet velocity triangles with proper representation of velocities.	-2-		
3.(b)		5	K3	CO1
Sol	Given: $H = 70\,m$, $N = 600\,rpm$, $P = 368\,kW$, $\eta_o = 0.85$, $D_1 = 2\times D_2$, $\eta_H = 0.95$, $K_f = 0.25$, $\frac{B_1}{D_1} = 0.1$, $V_{f1} = V_{f2}$, Area blocked $= 10\%$	-1-		



WKT $\eta_o = \frac{P}{\left(\frac{w Q H}{1000}\right)} \Rightarrow$ $Q = 0.6304\ m^3/s$

$K_f = \frac{V_{f1}}{\sqrt{2gH}} \Rightarrow$ $V_{f1} = 9.264\ m/s = V_{f2}$

	Also, $Q = \pi D_1 B_1 \times V_{f1}$ $Q = A_f \times V_{f1}$ W.K.T $A_f = (1 - 0.1)$ because, 10% is blocked. $\therefore Q = 0.9 A_f \times V_{f1}$ $\Rightarrow A_f = 0.0756\, m^2 \Rightarrow D_1 = 0.4905\, m \Rightarrow B_1 = 0.049\, m$ $\therefore D_1 = 2 \times D_2 \Rightarrow D_2 = 0.245\, m$ From Inlet velocity triangle, $\tan\alpha_1 = \frac{V_{f1}}{V_{w1}} \Rightarrow \alpha_1 = 12.33°$ $\tan\beta_1 = \frac{V_{f1}}{(V_{w1} - u_1)} \Rightarrow \beta_1 = 18.96°$ $u_1 = \frac{\pi D_1 N}{60} = 15.4\, m/s$ $u_2 = \frac{\pi D_2 N}{60} = 7.69\, m/s$ $\eta_H = \frac{V_{w1} u_1}{gH}$ $\Rightarrow V_{w1} = 42.36\, m/s$ From outlet velocity triangle, $\tan\beta_2 = \frac{V_{f2}}{u_2}$ $\Rightarrow \beta_2 = 50.304°$ (i) $\alpha_1 = 12.33$, (ii) $\beta_1 = 18.96°$, $\beta_2 = 50.304°$, (iii) $D_1 = 0.4905\, m$, $D_2 = 0.245\, m$ (iv) $B_1 = 0.049\, m$	-2- -2-		
3.(c)		5	K2	CO2
Sol	Differences between a turbomachine and a positive displacement machine: → Differences with respect to different operating conditions along with examples.	-5-		

	OR			
4(a)		5	K2	CO1
Sol	→ Neat sketch of Kaplan Turbine → Explanation of the functions of each part → Drawing the velocity triangles for kaplan turbine	-1- -2- -2-		
4(b)		5	K3	CO1

Sol

Given: Head, $H = 20m$

Power, $P = 11775$ kW

Outer dia, $D_o = 3.5$ m

Hub dia, $D_b = 1.75$ m

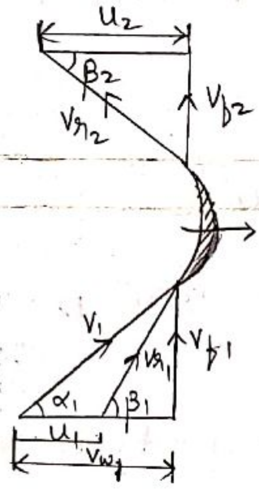
Guide blade angle, $\alpha_1 = 35^\circ$

$\eta_H = 0.88$

$\eta_o = 0.84$

$V_{w_2} = 0$

W.K.T $\eta_o = \dfrac{P}{\frac{wQH}{1000}} \Rightarrow \boxed{Q = 71.44 m^3/s}$



Also, $Q = \frac{\pi}{4}\left[D_o^2 - D_b^2\right] \times V_{f_1}$

$\Rightarrow \boxed{V_{f_1} = 9.9 m/s} = V_{f2}$

From inlet velocity triangle,

$\tan\alpha_1 = \dfrac{V_{f1}}{V_{w_1}} \Rightarrow \boxed{V_{w_1} = 14.14 m/s}$

W.K.T $\eta_H = \dfrac{V_{w_1} u_1}{gH} \Rightarrow \boxed{u_1 = 12.20 m/s} = u_2$

(i) Now, $\tan\beta_1 = \dfrac{V_{f1}}{(V_{w_1} - u_1)} \Rightarrow \boxed{\beta_1 = 78.96^\circ}$

From outlet velocity triangle,

(ii) $\tan\beta_2 = \dfrac{V_{f2}}{u_2} \Rightarrow \boxed{\beta_2 = 39.05^\circ}$

(iii) Speed of turbine $\Rightarrow u_1 = u_2 = u = \dfrac{\pi D_o N}{60}$

$\Rightarrow \boxed{N = 66.57 \text{ rpm}}$

4 (c)				
Sol	| Power Generating | Power Absorbing Turbomachine | | (i) Steam Turbine | (i) Fan | | (ii) Wind turbine | (ii) Air blower | | | (iii) Axial Flow compressor. |	5 -5-	K2	CO2

Course In charge

Head - Dept

Principal