RE Modified 12/3/21

CBCS SCHEME

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18ME54

Fifth Semester B.E. Degree Examination, Jan./Feb. 2021
Turbo Machines

Time: 3 hrs. Max. Marks: 100

Note: ***Answer any FIVE full questions, choosing ONE full question from each module.***

Important Note : 1. On completing your answers, compulsorily draw diagonal cross lines on the remaining blank pages.
2. Any revealing of identification, appeal to evaluator and /or equations written eg, 42+8 = 50, will be treated as malpractice.

Module-1

1 a. Draw and explain the part of a general Turbo machine. **(06 Marks)**

b. Distinguish between Turbo machines with positive displacement machines. **(06 Marks)**

c. A turbine model of 1:10 develops 2kW under a head of 6m at 500rpm. Find the power developed by the prototype under a head of 40m. Also find the speed of the prototype and its specific speed. Assume the turbine efficiencies to remain same. **(08 Marks)**

OR

2 a. Define the static and stagnation state of fluid. **(04 Marks)**

b. Define the following with the help of h-s diagram for power absorbing and power generating machine :

i) Total to total efficiency
ii) Total to static efficiency
iii) Static to total efficiency
iv) Static to static efficiency **(08 Marks)**

c. Show that the polytropic efficiency during expansion process is given by

$$\eta_p = \frac{\ell n(T_2/T_1)}{\frac{\gamma-1}{\gamma}\ell n(P_1/P_2)}$$ **(08 Marks)**

Module-2

3 a. Define Utilization factor and degree of reaction. Also derive the relation between utilization factor and degree of reaction. **(10 Marks)**

b. Show that for maximum utilization of axial flow turbine with reaction = $\frac{1}{4}$. The speed ration given by $U/V_1 = 2/3 \cos\alpha_1$. Where U = Blade speed, V_1 = Inlet absolute velocity α_1 = Inlet Nozzle angle. **(10 Marks)**

OR

4 a. With necessary velocity triangles and assumption derive the expression for effect of blade discharge angle on energy transfer and degree of reaction for radial flow machines. **(10 Marks)**

b. At a stage in a 50% Reaction axial flow machine running at 3000rpm, the blade mean diameter is 685mm. If the maximum utilization for the stage is 0.915. Calculate the absolute velocity at inlet and outlet and draw velocity triangles. Also find power output for flow rate of 15 Kg/s. **(10 Marks)**

Module-3

5 a. What is compounding of steam turbine? Explain method of compounding Impulse turbine. **(10 Marks)**

b. The velocity of steam outflow from a Nozzle in a De-Laval turbine is 1200m/s, nozzle angle is 22°. The rotor blades are equiangular and rotational blade speed is 400m/s. Calculate:
i) Blade angles ii) Tangential force iii) Power product if $vr_1 = vr_2$ iv) blading efficiency. **(10 Marks)**

OR

6 a. Derive the maximum blade efficiency equation for velocity compounded impulse steam Turbine (Curtis turbine) **(10 Marks)**

b. In a Curtis steam turbine stage there are 2 row of moving blades with equiangular rotors. The steam enters 1st rotor with 29° each while second rotor with 32° each. The absolute velocity of steam enter the first rotor at 530 m/s. The friction factor is 0.9 in 1st rotor, 0.91 in stator and 0.93 in 2nd rotor. If final discharge is axial.
Find i) Mean blade speed ii) Power if $m_s = 3.2$ kg/s. **(10 Marks)**

Module-4

7 a. Derive an expression for work done by pelton wheel with necessary velocity triangles. **(08 Marks)**

b. A Pelton wheel is to be designed for the following specifications :
Shaft power = 11772kW, Head = 380m, Speed = 750rmp, Overall efficiency = 86%, jet diameter not to exceed 1/6 of wheel diameter, Determine :
i) Wheel diameter ii) jet diameter iii) Number of jets required, Take $C_v = 0.98$, $\phi = 0.46$. **(06 Marks)**

c. A Kaplan turbine develops 24647.6kW power at an average head of 39m. Assuming a speed ratio of 2, flow ratio 0.6, diameter of boss equal to 0.35 times diameter of runner and an overall efficiency of 90%, calculate the diameter, speed and specific speed of turbine. **(06 Marks)**

OR

8 a. Explain the working of Francis turbine with help of sectional arrangement diagram. Also draw the velocity triangles of Francis turbine. **(12 Marks)**

b. Explain the function of draft tubes. **(02 Marks)**

c. With neat sketches, explain the applications of draft tubes. **(06 Marks)**

Module-5

9 a. Derive an expression for the minimum speed of staring a centrifugal pump. **(06 Marks)**

b. Derive the expression for pressure rise in the centrifugal pump. **(08 Marks)**

c. The impeller of a centrifugal pump has outer diameter 1.2m is used to lift water at a rate of 1800kg/s. The blade is making an angle of 150° with the direction of motion at outlet and speed is being 2000rpm. If the radial velocity flow is 2.5m/s. Find impeller power. **(06 Marks)**

OR

10 a. Explain the working principle of centrifugal compressor with neat sketch. **(10 Marks)**

b. A centrifugal compressor compresses 30kg of air per second at a rotational speed of 15000rpm. The air enter the compressor axially and the conditions at exit sections are :
radius = 0.3m, relative velocity of air at the tip is 100m/s at an exit angle of 80°. Find the torque and power required to drive the compressor and also the ideal head developed. Take P_{01} = 1 bar and T_{01} = 300K. **(10 Marks)**

* * * * *

9(c) $d_2 = 1.2m$ $\dot{m} = 1800 kg/s$. $\beta_2 = 30^0$

$N = 2000$ rpm. $V_{f2} = 2.5 m/s$.

$$\tan\beta_2 = \frac{V_{f2}}{U_2 - V_{u2}}$$

$$U_2 = \frac{\pi d_2 N}{60} m/s$$

$$= \frac{\pi \times 1.2 \times 2000}{60}$$

$$= 125.6 m/s.$$

$$\tan 30^0 = \frac{2.5}{(125.6 - V_{u2})}$$

$$0.577 = \frac{2.5}{(125.6 - V_{u2})}$$

$$(125.6 - V_{u2}) = 4.333$$

$$V_{u2} = 121.27 m/s$$

$$P = \frac{\dot{m} V_{u2} U_2}{1000} KW.$$

$$= \frac{1800 \times 121.27 \times 125.6}{1000}$$

$$P = 27.4 MW$$

1/6

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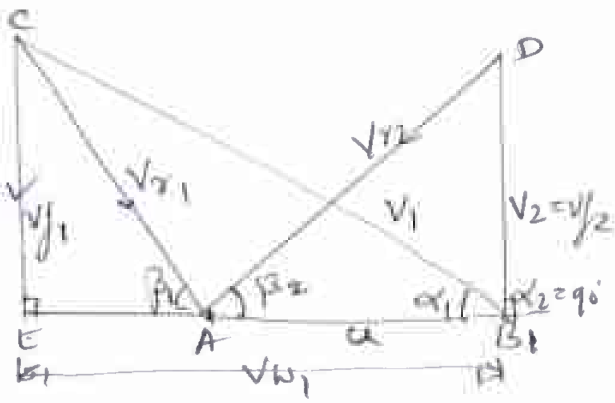
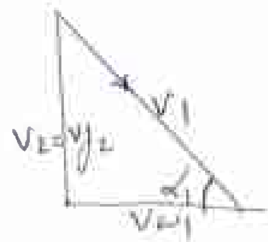
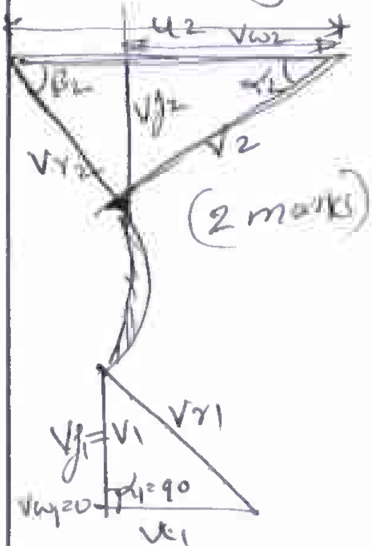
Scheme & Solutions

Signature of Scrutinizer

Subject Title : TurboMachines **Subject Code :** 18ME54

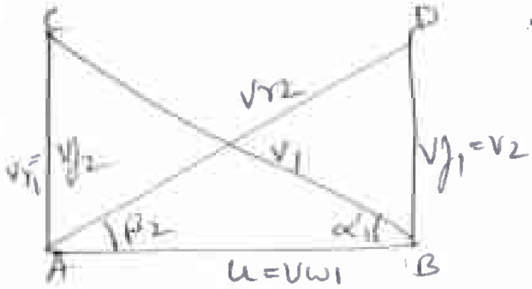
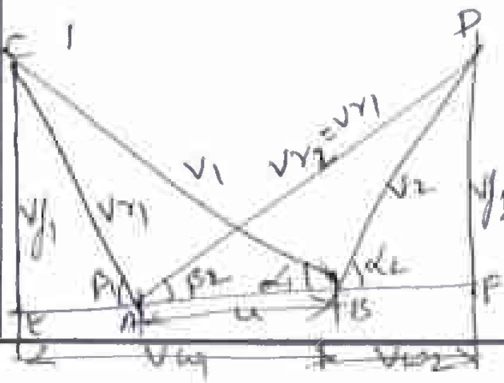
Question Number	Solution	Marks Allocated
1 (a)	Sketch – 03 (sketch any type of Turbomachine) Explanation – 03 Explain the parts – Ex – Rotating element, stationary element, Housing, Shaft etc	06
(b)	List differences at least 6 × 1 marks each	06
(c)	$\frac{d_m}{d_p} = \frac{1}{10}$, Model: $P_m = 2$ kW, $H_m = 6$ m, $N_m = 500$ rpm; Prototype: $P_p = ?$, $H_p = 40$ m, $N_p = ?$, $N_s = ?$ # Using Head Co-efficient $\frac{H_m}{N_m^2 d_m^2} = \frac{H_p}{N_p^2 d_p^2}$ $N_p = 129$ rpm — 3 marks # Using power Co-efficient $\frac{P_m}{N_m^3 d_m^5} = \frac{P_p}{N_p^3 d_p^5}$ $P_p = 3434$ kW — 3 m. # $N_s = \frac{N_p \sqrt{P_p}}{H_p^{5/4}} = 75.15$ — 2 m	08
2 (a)	Definition 2 mark each 2×2	04
(b)	Defining with h-s diagram 2 mark each 2×4	08
(c)	Polytropic efficiency during expansion. T-S diagram — 2 m Differentiating - $T = T_s = P^{\epsilon} \cdot C$ — 2 m, where $\epsilon = \frac{\gamma - 1}{\gamma}$ Integrating — $\frac{dT}{T} = \eta_p \epsilon \frac{dp}{p}$ & obtain final expression — 04 m	8

Subject Title: TurboMachines   Subject Code: 18ME54

Question Number	Solution	Marks Allocated
Q. 3(a)	Definition of utilization — 2 m Definition of degree of reaction — 2 m writing expression for utilization & degree of reaction in terms of energy components & $S = (R/1-R)D$ — 2 m obtaining $\epsilon = \frac{V_1^2 - V_2^2}{V_1^2 - R V_2^2}$ — 4 m	10
(b)	 Vel. Δle — 3 m  $V_2 = V_1 \sin\alpha_1$ $V_2 = V_{f_1} = V_{f_2} = V_f$ $R = \frac{(V_{r_2}^2 - V_{r_1}^2)}{(V_1^2 - V_2^2) + (V_{r_2}^2 - V_{r_1}^2)} = \frac{1}{4}$ Given — 2 m For axial flow, $u_1^2 - u_2^2 = 0$. $V_{r_1}^2 = V_1^2 \sin^2\alpha_1 + V_1^2 \cos^2\alpha_1 + u^2 - 2uV_1\cos\alpha_1$ $V_{r_2}^2 = V_1^2 \sin^2\alpha_1 + u^2$ — 2 m obtaining $\frac{u}{V_1} = \frac{2}{3}\cos\alpha_1$ — 3 m	10
4(a)	 (2 marks) Assumptions — (2 marks) * No Inlet whirl $V_{w_1} = 0$, $\alpha_1 = 90°$, $V_{f_1} = V_1$ * $\beta_1 = 45°$ * $u_2 = 2u_1$ * $V_{f_1} = V_{f_2} = V_f = V_1$	

(PTO)

Subject Title : Turbomachines **Subject Code :** 18ME54

Question Number	Solution	Marks Allocated
	$E = WD = V_{w_1}u_1 - V_{w_2}u_2 = V_{w_2}u_2$ J/kg.	
	$WD = 2V_f^2(\cot\beta_2 - 2)$ —— 2m	
	$R = \frac{S}{D+S} = \frac{(u_1^2-u_2^2)+(V_{r_2}^2-V_{r_1}^2)}{(V_1^2-V_2^2)+(u_1^2-u_2^2)+(V_{r_2}^2-V_{r_1}^2)}$	10
	to obtain $R = \frac{2+\cot\beta_2}{4}$ — 08m	
4 (b)	$R = 0.5$, $N = 3000$ rpm, $d = 685$ mm, $G_{max} = 0.915$ $V_1 = ?$ $V_2 = ?$ & $P = ?$	
		
	vel. Δle — (2m) $u = \frac{\pi d N}{60} = 107.6$ m/s $V_1^2 = 6.38 V_2^2$ $V_1 = 50.2$ m/s — (2m) $V_2 = 19.88$ m/s — (2m)	10
	$P = \frac{m_s \cdot V_{w_1} \cdot u}{1000}$ kW $P = \frac{15 \times 107.6 \times 107.6}{1000} = 173.66$ kW — (4m)	
5 (a)	Define Compounding — 1m Velocity " — 3m pressure " — 3m Combined " — 3m (pressure-velocity curve – 2m + 1m (explanation) in each.	10
(b)	vel. Δle — 2m.	
		
	$\beta_1 = \beta_2 = 32°$ — 2m $F_x = m(V_{w_1} \pm V_{w_2})$ $T = 1420$ N — 2m $P = \frac{m(V_{w_1} \pm V_{w_2})u}{1000}$ — 2m $T = 568$ kW $\eta_b = \frac{2u(V_{w_1} \pm V_{w_2})}{V_1^2}$ — 2m $T = 76.66$ %.	10

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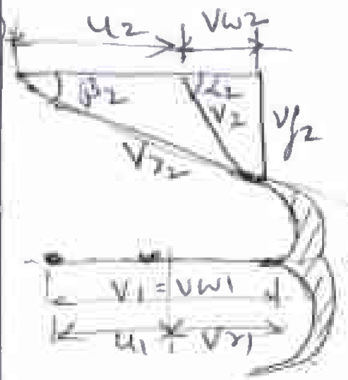
Question Number	Solution	Marks Allocated
6 (a)	maximum blading efficiency for Curtis stage Vel. Δles — 1st row & 2nd row —— 3 m $W = W_1 + W_2$ for no friction & symmetric blade profile $\beta_1 = \beta_2$ & $\beta_3 = \beta_4$ $WD = 2u(V_{r1}\cos\beta_1 + V_{r1}\cos\beta_1)$ $WD = 4u(V_1\cos\alpha_1 - 2u)$ —— 2m $\eta_b = 8\rho(\cos\alpha_1 - 2\rho)$ —— 2m $(\eta_b)_{max} = \frac{d(\eta_b)}{d\rho} = 0$, $\rho_{opt} = \frac{\cos\alpha_1}{4}$ —— 1m $\eta_{max} = \cos^2\alpha_1$ —— 2m	10
(b)	Vel. Δle — 4 m. — 2 stages. Power = $\frac{m_s[(V_{w1}+V_{w2}) + V_{w3}]}{1000}$ kW P = 357.15 kW —— 2m u = 146.9 m/s —— 2m $F_y = m[V_{f1} - V_{f2}] + [V_{f3} - V_{f4}]$ F_y = 91.2 N —— 2m	10
7 (a)	— vel. Δle —— 3m $F = \rho Q(V_{w1} \pm V_{w2})$ — 2m $WD = \rho Q(V_{w1} \pm V_{w2})u$ — 3m	08
(b)	$V_1 = C_v\sqrt{2gH} = 85.05$ m/s $u_1 = u_2 = u = \frac{\pi D N}{60} = \phi\sqrt{2gH} = 38.86$ m/s — 1 m D = 0.989 m — 1m d = 0.165 m — 2m n = 2 — 2m $n = \frac{Q}{q}$ & $\eta_0 = \frac{SP}{WP}$ obtaining q from η_0.	06

7 (c) Kaplan Turbine $d=?$, $N=?$ & $Ns=?$

$\eta_o = \frac{SP}{WP}$, $Q = 71.58\ m^3/s$, $D_o = 2.5\ m$, $D_b = 0.875\ m$ — 3 m

$U = \frac{\pi D_o N}{60}$, $N = 422.64$ rpm — 1 m

$Ns = \frac{N\sqrt{P}}{H^{5/4}}$ $Ns = 680.81$ rpm — 2 m

06

8 (a) Francis Turbine

Sectional diagram — 5 m

Explanation — 3 m

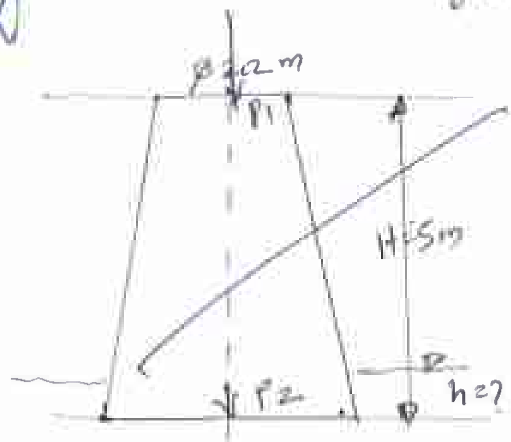
Velocity triangles — 4 m

12

12

(b) Functions of draft tubes — 1 × 2 = 02

~~(b) Conical draft tube~~ (c) Types of draft tubes — $\frac{1}{2} \times 4$ = 02



$d_1 = 2.2\ m$

$\frac{P_1}{\omega} = 6\ m$ (vaccum) $= 4.3\ m$ absolute

$V_2 = 1.5\ m/s$, $Q = 24\ m^3/s$

$P_a = 10.3\ m$, $Z_1 = 5\ m$, $h_f = 0$.

— 2 m

$V_1 = \frac{Q}{A_1} = 6.31\ m$ — 1 m

Applying bernoulli's eqn & obtain

$h = 0.458\ m$. — 5 m

08

9 (a) Minimum starting speed meaning — 2 m

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

$\eta_{mano} = \frac{H_m}{He}$, $u_1 = \frac{\pi D_1 N}{60}$ & $u_2 = \frac{\pi D_2 N}{60}$ — 2 m.

Substituting u_1 & u_2 & obtaining N_{min} — 2 m

$N_{min} = \left[\left(\frac{60}{\pi}\right)^2 \frac{2g\ \eta_{mano} \cdot He}{(D_2^2 - D_1^2)}\right]^{1/2}$ rpm

06

(b) pressure rise in centrifugal pump.

Value — 2 m

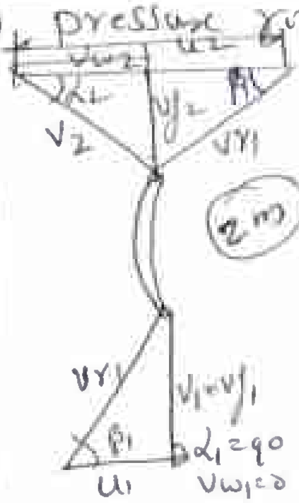
Applying B.E — 2 m

obtaining pressure rise — 4 m

08

(PTO)

Subject Title : TurboMachines Subject Code : 18ME54

Question Number	Solution	Marks Allocated
9 (b)	Pressure rise in CFP.  Vel. Δle. (2m) BE, $\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + H_c = \frac{P_2}{\rho g} + \frac{V_2^2}{2g}$ (2m) $P_2 - P_1 = \frac{\rho}{2}\left[V_{f1}^2 + u_2^2 - V_{f2}^2 \operatorname{cosec}^2\beta_2\right]$ (4m)	
(c)	Vel. Δle — (2m) $d_2 = 1.2\,m$ $m = 1800\,kg/s$ $\beta_2 = 180 - 150 = 30°$ $N = 2000\,rpm$ $V_{f2} = 2.5\,m/s$ $u_2 = \frac{\pi d_2 N}{60} = 12.56\,m/s$ $V_{w2} = 8.23\,m/s$ (2m) $P = \frac{m V_{w2} u_2}{1000}\,kW$ $P = 186\,kW$ — (2m)	06
10 (a)	Centrifugal Compressor Sketch — 6 Explanation — 4	10
(b)	Vel. Δle — (2m) $u_2 = \frac{\pi d_2 N}{60} = 471.24\,m/s$ $V_{w2} = u_2 - V_{r2}\cos\beta_2 = 453.85\,m/s$ (2m) # Torque $= Fr = m V_{w2} r = 4084.92\,N\text{-}m$ — (1m) # power $= \frac{2\pi N T}{60} = 6.417\,MW$ — (2m) # WD by Impeller $w = u_2 V_{w2} = C_p \Delta T = C_p T_{01}\left[\left(\frac{P_2}{P_1}\right)^{\frac{\gamma-1}{\gamma}} - 1\right]$ $\frac{P_2}{P_1} = 6.531$ — (2m) $\therefore P_2 = 6.531\,bar$ — (1m)	10