Model Question Paper -1 with effect from 2020-21(CBCS Scheme)

1	8	M	E	5	4				

Fifth Semester B.E. Degree Examination
TURBOMACHINES

03 Hours Max. Mar

01. Answer any **FIVE** full questions, choosing at least **ONE** question from each MO
:

		Module – 1	
Q.1	(a)	A manufacturer desires to double both the discharge and head on a geometrically similar pump. Determine the percentage change in the rotational speed and diameter under the new conditions.	6
	(b)	The quantity of water available for a hydel station is 310 m^3/s under a head of 1.8 m. Assuming speed of each turbine is 60 RPM and efficiency of 85%, find the number of turbines required and power produced by each turbine. Each turbine has a specific speed of 685.6 (SI)	6
	(c)	A model of a turbine built to a scale of 1:4 is tested under a head of 10 m. The prototype has to work under a head of 50 m at 450 RPM. (a) What speed should the model be run if it develops 60 kW using 0.9 m^3/s at this speed. (b) What power will be obtained from the prototype assuming that its efficiency is 3% better than that of model.	8
		OR	
Q.2	(a)	Obtain an expression for the polytropic efficiency for a compressor in terms of temperature, pressure and adiabatic index.	6
	(b)	Explain 1) Static state 2) Stagnation state. With a sketch explain i) Total to Total efficiency ii) Static to total efficiency iii) Static to Static efficiency.	6
	(c)	The flow rate through the compressor is 50 kg/s. The inlet static conditions are 1 bar and 30°C. Exit temperature from the last stage is 650 K (static). The compressor has five stages of equal pressure ration of 1.5. Calculate (a) the exit pressure from the last stage (b) the ideal exit temperature from the last stage, (c) the overall efficiency (d) the polytropic efficiency and (e) the stage efficiency	8
		Module – 2	
Q.3	(a)	Define Degree of reaction. Obtain an expression for Utilizatioo factor in terms of degree of reaction and absolute velocities.	6
	(b)	For 50% degree of reaction axial flow turbomachine, inlet fluid velocity is 230 m/s, out angle of inlet guide blade is 30°, inlet rotor angle is 60° and outlet rotor angle is 25°. Find the utilization factor, axial thrust and power output per unit mass flow.	6
	(c)	A turbomachine is operated such that the change in total enthalpy is 6000 N-m/kg of fluid when the total inlet temperature is 30°C and the total inlet pressure is 1 atm. (a) What general type of turbomachine would this be?. (b) What is the exit total temperature if the fluid is air (c) What is the total pressure ratio across the machine if the adiabatic total to total efficiency is 75% and the fluid is air. (d) What is the total pressure ratio across the machine if the adiabatic total to total efficiency is 75% and the fluid is liquid is water?	8
		OR	

Q.4	(a)	Obtain an expression for the degree of reaction of axial flow compressor in terms of rotor blade angles, axial velocity and blade speed. Assume axial velocity remains constant.	6
	(b)	At the stage of an impulse turbine, the mean blade diameter is 0.75m and its rotational speed is 3500 rpm. The absolute velocity of the fluid discharging from a nozzle inclined at 20° to the plane of the wheel is 275 m/s. If the utilization factor is 0.9 and the relative velocity of the fluid at the rotor exit is 0.9 times that at the inlet, find the inlet rotor angles. Also find the power output from the stage for a mass flow rate of 2 kg/s and the axial thrust on the shaft.	6
	(c)	A turbomachine is operated such that the change in total enthalpy is 6000 N-m/kg of fluid when the total inlet temperature is 30°C and the total inlet pressure is 1 atm. (a) What general type of turbomachine would this be?. (b) What is the exit total temperature if the fluid is air (c) What is the total pressure ratio across the machine if the adiabatic total to total efficiency is 75% and the fluid is air. (d) What is the total pressure ratio across the machine if the adiabatic total to total efficiency is 75% and the fluid is liquid is water?	8
		Module – 3	
Q.5	(a)	Show that the maximum blade efficiency of single stage impulse turbine is given by $\eta_b = ((1 + KC) \cos^2 \alpha_1)/2$ where, $K = V_{r2}/V_r$ 1 = blade velocity coefficient and $C = \cos\beta_2/\cos\beta_1$	6
	(b)	In a Parson turbine the axial velocity of steam flow is 0.5 times the mean blade speed. The outlet angle of the blade is 20°, the diameter of the blade ring is 1.3 m and the rotational speed is 3000 rpm. Determine the inlet blade angle, power developed for the steam flow is 65 kg/s and the isentropic enthalpy drop if the stage efficiency is 80 %.	6
	(c)	In a two row velocity compounded impulse steam, the steam from the nozzle issues at a velocity of 600 m/s. The nozzle angle is 20° to the plane of rotation of the wheel, The mean rotor diameter is 1m and the speed is 3000 rpm. Both rows of moving blades having equiangular blades. The intermediate row of fixed blades make the steam flow again at 20° to the second moving blade ring. The frictional losses in each row is 3%. Find (i) Inlet and outlet angles of moving blades of each row. (ii) Inlet blade angle of the guide blade (iii) Power output from the first and second moving blade rings for unit mass flow rate.	8
		OR	
Q.6	(a)	Discuss the need for compounding. Name the different methods of compounding. Draw pressure and velocity variation for any two methods.	6
	(b)	The following data refers to a single stage impulse turbine. Isentropic nozzle heat drop = 251 kJ/kg. Nozzle efficiency = 90 %. Nozzle angle = 20°. Ratio of blade speed to whirl component of steam speed = 0.5. Blade velocity coefficient = 0.9. The velocity of steam entering the nozzle = 20 m/s. Determine (i) Blade angles at inlet and outlet if steam leaves the blade in axial direction. (ii) Blade efficiency (iii) Power developed and axial thrust if the steam flow is 8 kg/s.	8
	(c)	In Parson turbine running at 1500 rpm, the available enthalpy drop for the expansion is 63 kJ/kg. If the mean diameter of the rotor is 100 cm, find the number of moving rows required. Assume the efficiency of the stage is 0.8, blade outlet angle is 20° and	6

		speed ratio 0.7.	
		Module – 4	
Q.7	(a)	Show that the maximum hydraulic efficiency of a Pelton wheel turbine is given by $(\eta_h)_{max} = \frac{1 + C_b \cos \beta_2}{2}$. Also, draw the inlet and exit velocity triangles. C_b is bucket friction coefficient & β_2 is exit blade angle.	6
	(b)	In a radial inward flow turbine, the runner outer diameter is 1.05 m and the inner diameter is 0.5 m. The runner speed is 400 rpm. Liquid water enters the wheel at a speed of 25 m/s at an angle of 15° to the wheel tangent at the entry. The discharge at the outlet is radial and absolute velocity is 5 m/s. Find the runner blade angles at the inlet. Draw the velocity triangles. What is the power output per unit mass flow of water through the blade ? Find also the degree of reaction , utilization factor and the static pressure at the turbine inlet, if the static pressure at the exit is 1 bar.	8
	(c)	A conical type draft tube attached to Francis turbine has an inlet diameter of 3 m and its area at outlet is 20 m^2. The velocity of water at inlet which is 5 m above tail race level, is 5 m/s. Assuming the loss in draft tube equals 50% of velocity head at outlet, find (a) the pressure head at the top of draft tube (b) the total head at the top of the draft tube taking tail race level as datum (c) power lost in the draft tube	6
		OR	
Q.8	(a)	In a slow speed inward flow reaction turbine degree of reaction is R and utilization factor is ϵ. Velocity of flow is constant and discharge is radial at exit. Show that the inlet nozzle angle is given by $\square_1 = \cot^{-1} \sqrt{\frac{1 - R}{1 - \epsilon}}\epsilon$	6
	(b)	A single jet Pelton turbine is supplied from a dam 300 m above the centre of nozzle. The diameter of the pipeline supplying the water is 70 cm and 5.6 km long. The friction coefficient of the pipe is 0.0075. Jet diameter is 10 cm, speed ratio is 0.47, Cv is 0.97. Outlet vane angle is 15°. The outlet relative velocity of water is reduced by 15% compared to inlet relative velocity. Assuming mechanical efficiency as 0.88, find hydraulic power, brake power, hydraulic and overall efficiency of the system.	6
	(c)	In a vertical shaft inward flow reaction turbine, the sum of the pressure and kinetic head at the entrance to the spiral casing is 120 m and the vertical distance between this section and the tail race level is 3 m. The peripheral velocity of the runner at entry is 30 m/s, and the radial velocity of flow of water is constant at 9 m/s and the discharge from the runner is without swirl. The estimated hydraulic losses are (a) between turbine entrance and exit from the guide vanes 4.8 m (b) in the runner 8.8 m (c) in the draft tube 0.79 m (d) kinetic head rejected to the tail race 0.46 m. Calculate the guide vane angle and the runner blade angle at the inlet and the pressure heads at entry to and exit from the runner.	8
		Module – 5	
Q.9	(a)	Applying Bernoulli's equation between the inlet and exit of the impeller of a centrifugal pump, show that the static pressure rise is given by $p_2 - p_1 = \frac{\rho}{2}\left[V_{f1}^2 + U_2^2 - V_{f2}^2 \mathrm{Cosec}^2 \beta_2\right]$ where, V_{f1}=velocity of flow at inlet=V_1, V_{f2}=velocity of flow at exit, U_2=blade speed at exit, β_2=blade angle at exit, ρ=density of fluid, p_2&p_1 = static pressure at inlet & exit.	6

	(b)	A centrifugal pump delivers water against a head of 25 m. The radial velocity of flow constant at 3.5 m/s. Flow rate of water is 0.05 m^3/s. The blades are radial at tip and pump runs at 1500 rpm. Determine (i) Diameter at tip (ii) width of blade (iii) inlet diffuser angle at impeller exit.	6
	(c)	An impeller with an eye radius of 51 mm and an outside diameter of 406 mm rotates at 900 rpm. The inlet and outlet blade angles measured from the radial flow direction are 75° and 83° while the depth of the blade is 64 mm. Assuming inlet zero whirl, zero slip and an hydraulic efficiency of 89%, calculate (i) the volume flow rate through the impeller (ii) the stagnation and static pressure rise across the impeller (iii) Power transferred to the fluid (iv) the input power to the impeller.	8
		OR	
Q.10	(a)	Explain the phenomena of slip and surging in compressors with a sketch.	4
	(b)	A Centrifugal compressor rotor has inlet radius of 30 cm and exit radius of 60 cm. Entry is radial with a component of 60m/s which is constsnt throughout. The compressor requires 700 kW of power to handle 20 kg of air per second. Find the blade angles at the inlet and outlet if the compressor runs at 5100 rpm. Calculate the width at inlet and outlet if specific volumes at inlet and outlat are 0.85 m^3/kg and 0.71 m^3/kg respectively. What is the degree of reaction.	8
	(c)	A centrifugal compressor running at 5950 rpm having an impeller tip diameter of 100 cm. Mass flow rate of air is 30 kg/s. Total pressure ratio is 2.125. Pressure at inlet is 1 bar and temperature is 25°. Slip coefficient is 0.9. Mechanical Efficiency is 0.97. Find i) Total Efficiency ii) Temperature of air at exit iii) Power input needed iv) Pressure coefficient.	8

Table showing the Bloom's Taxonomy Level, Course Outcome and Programme Outcome

Question		Bloom's Taxonomy Level attached	Course Outcome	Programme Outcome
Q.1	(a)	L3	1	2,12
	(b)	L3	1	2
	(c)	L3	1	2
Q.2	(a)	L2	1	2
	(b)	L1	1	2,12
	(c)	L3	1	2
Q.3	(a)	L2	2	2,12
	(b)	L1	2	2
	(c)	L3	2	2
Q.4	(a	L2	2	2,12

	)			
	(b)	L3	2	2
	(c)	L3	2	2
Q.5	(a)	L2	3	2,12
	(b)	L3	3	2
	(c)	L3	3	2
Q.6	(a)	L1	3	2,12
	(b)	L3	3	2
	(c)	L3	3	2
Q.7	(a)	L2	4	2,12
	(b)	L3	4	2
	(c)	L3	4	2
Q.8	(a)	L2	4	2,12
	(b)	L3	4	2
	(c)	L3	4	2
Q.9	(a)	L2	5	2,12
	(b)	L3	5	2
	(c)	L3	5	2
Q.10	(a)	L1	5	2,12
	(b)	L3	5	2
	(c)	L3	5	2

Bloom's Taxonomy Levels	**Lower order thinking skills**		
	Remembering(knowledge):□$_1$	Understanding Comprehension): □$_2$	Applying (Application): □$_3$
	Higher order thinking skills		
	Analyzing (Analysis): □$_4$	Valuating (Evaluation): □$_5$	Creating (Synthesis): □$_6$

<u>Program Outcomes:</u>

1. Engineering Knowledge
2. Problem Analysis
3. Design / Development Solutions
4. Conduct Investigations of Complex problems
5. Modern tool usage
6. Engineer and Society
7. Environment and Sustainability
8. Ethics
9. Individual and Team-Work
10. Communication
11. Project Management and Finance
12. Life-long Learning

Model Question Paper -2 with effect from 2020-21(CBCS Scheme)

USN

Fifth Semester B.E. Degree Examination

TURBO MACHINES

TIME: 03 Hours Max. Marks: 100

Note:
02. Answer any **FIVE** full questions, choosing at least **ONE** question from each **MODULE.**
03. Thermodynamics Data Hand Book/Steam Table are permitted
04. Missing data may be assumed suitably by giving proper reason.

		Module – 1	Marks
Q.1	(a)	Define Turbo machine. With neat sketch explain the principal parts of general turbomachine.	06
	(b)	Explain the following with appropriate equation: (i). Flow coefficient (ii) Head coefficient (iii) Power coefficient (iv) Specific speed of a turbine.	06
	(c)	From the performance curves of turbines, it is seen that a turbine of one-meter diameter acting under a head of one meter, develops a speed of 25 RPM. What diameter should be the prototype have if it is develop 10,000 kW working under a head of 200m, with a specific speed of 150.	08
		OR	
Q.2	(a)	With the application of 1st law of thermodynamics, show the work transfer is numerically equal to the change in stagnation enthalpy between the inlet and outlet of a turbomachine.	06
	(b)	Prove that the overall efficiency is greater than the stage efficiency in a multistage turbine.	06
	(c)	Air enters a compressor at a static pressure of 1.5 bar, a static temperature of 15^0C and a flow velocity of 50 m/s. At the exit the static pressure is 3 bar, the static temperature is 100^0C and the flow velocity is 100 m/s. The outlet is 1 m above the inlet. Evaluate (a) the isentropic change in enthalpy, (b) the actual change in enthalpy and (c) efficiency of the compressor.	08
		Module – 2	
Q.3	(a)	With the help of velocity triangles at inlet and outlet, derive an alternate form of Euler's turbine equation.	06
	(b)	Show that maximum utilization factor of an axial flow turbine with degree of reaction R=1/3, the relationship of blade speed U to absolute velocity at rotor inlet V_1, should be $U/V_1 = 3/4\cos\alpha_1$. Where α_1 is the nozzle angle with respect to tangential direction.	06
	(c)	The mean rotor blade speed of an axial flow turbine stage with a degree of reaction of 50% is 210 m/s. The steam emerges from the nozzle inclined at 28^0 to the wheel plane, with an axial velocity component which is equal to the blade speed. Assuming symmetric inlet and outlet velocity triangles, find the rotor blade angles and the utilization factor.	08

		Find also the degree of reaction to make the utilization a maximum, if the axial velocity and the blade speed as well as the nozzle remain the same as above.	
		OR	
Q.4	**(a)**	Prove that, with usual notations, the degree of reaction for an axial flow compressor (assuming constant velocity of flow) is given by $R = \frac{V_f}{2U}\left(\frac{\tan\beta_2 + \tan\beta_1}{\tan\beta_1 \tan\beta_2}\right)$	06
	(b)	Draw the inlet and exit velocity triangles for a radial flow power absorbing turbomachine with (i) Backward curved vane (ii) Radial vane (iii) Forward vane. Assume inlet whirl velocity to be zero. Also draw the head-capacity curves for the above *3* types of vanes.	06
	(c)	A mixed flow turbine handling water operates under a static head of 65m. In a steady flow, the static pressure at the rotor inlet is 3.5 atm (gauge). The absolute velocity at the rotor inlet has no axial component and is directed at an angle of 25^0 to the tangent of wheel so that V_{u1} is positive. The absolute velocity at exit purely axial. If the degree of reaction for the machine is 0.47 and utilization factor is 0.896, compute the tangential blade speed at inlet as well as the inlet blade angle Find also the work output per unit mass flow of water.	08
		Module – 3	
Q.5	**(a)**	Show that for a two-row Curtis steam turbine stage in the absence of friction and for axial discharge at exit under maximum utilization condition, $\frac{U}{V_1} = \frac{\cos\alpha_1}{4}$. Where U=blade speed, V_1= absolute velocity of inlet, α_1= nozzle angle at inlet.	08
	(b)	Dry saturated steam at 10 bar pressure is supplied to single rotor impulse wheel, the condenser pressure being 0.5 bar with the nozzle efficiency of 0.94 and the nozzle angle at the rotor inlet is 18^0 to the wheel plane. The rotor blades which move with the speed of 450 m/s are equiangular. If the coefficient of velocity for the rotor blades is 0.92, find (i) The specific power output (ii) The rotor efficiency (iii) The Stage efficiency (iv) Axial thrust (v) The direction of exit steam.	12
		OR	
Q.6	**(a)**	Prove that the maximum blade efficiency in a Parason's reaction turbine is given by $\eta_{b,max} = \frac{2\cos^2\alpha_1}{1+\cos^2\alpha_1}$	08
	(b)	The velocity of steam at the exit of a nozzle is 440 m/s which is compounded in an Impulse turbine by passing successively through moving, fixed and finally through a second ring of moving blades. The tip angles of moving blades throughout the turbine are 30^0. Assume loss of 10% in velocity due to friction when the steam passes over a blade ring. Find the velocity of moving blades in order to have a final discharge of steam as axial. Also determine the diagram efficiency.	12
		Module – 4	
Q.7	**(a)**	Define the following refers to hydraulic turbine with appropriate equations: (i). Hydraulic efficiency (ii) Volumetric efficiency (iii) Mechanical efficiency (iv) Overall efficiency	06

	(b)	What are the functions of draft tubes?. With sketches explain the different types of draft tubes.	06
	(c)	Pelton wheel has to be designed for the following data: Power to be developed = 5880 kW, Net head available = 300m, Speed = 550 RPM, ratio of jet diameter to wheel diameter = 1/10 and overall efficiency = 85%. Find the number of jets, diameter of jet, diameter of the wheel and the quantity of water required. Assume C_v = 0.98, □ = 0.46.	08
OR			
Q.8	(a)	Determine the efficiency of a Kaplan turbine developing 2940 kW under a head of 5m. It is provided with a draft tube with its inlet diameter 3m set at 1.6m above the tail race level. A vacuum pressure gauge connected to the draft tube inlet indicates a reading of 5m of water. Assume that draft tube efficiency is 78%.	08
	(b)	An inward flow reaction turbine with radial discharge with an overall efficiency of 80% is required to develop 147 kW. The head is 8m. Peripheral velocity of the wheel is $0.96\sqrt{2gH}$, the radial velocity of the flow is $0.36\sqrt{2gH}$. The wheel is to make 150RPM and the hydraulic losses in the turbine are 22% of the available energy. Determine: (i) The angle of the guide blade at inlet, (ii) The wheel vane angle at inlet (iii) The diameter of the wheel and (iv) The width of the wheel at inlet	12
Module – 5			
Q.9	(a)	Define the following with respect to centrifugal pumps: i) Manometric head, ii) Priming (iii) Cavitation and (iv) Slip coefficient.	06
	(b)	Derive an expression for minimum starting speed of Centrifugal pump with usual notations.	06
	(c)	The following data refers to a CF Pump: - Pump being single stage radial bladed with: (i) Impeller diameter=200mm, (ii) Discharge gauge reading =1.5 bar, (iii) Suction gauge reading = 150mm of Hg below atmosphere, (iv) RPM = 1440, (v) Flow rate = 240 lit /min, (vi) Power required = 1 kW (vii)Impeller width at tip = 10 mm. Find: (i) Manometric efficiency (ii) Mechanical efficiency (iii) the overall efficiency and (iv) Specific speed.	08
OR			
Q.10	(a)	Derive an expression for overall pressure ratio across the stage of a centrifugal compressor.	06
	(b)	Prove that the pressure coefficient in a centrifugal blower is given by $□_p$ □ $□_c$□□. Where $□_c$ = Isentropic efficiency of compressor, □ = work done factor and □ = slip coefficient.	06
	(c)	A centrifugal compressor runs at a speed of 15000 rpm and delivers 30 kg/s of air. The exit diameter is 70cm, relative velocity at exit is 100m/s at an exit angle of 75^0. Assume axial inlet and inlet total temperature = 300K, inlet total pressure=1bar. Determine: i) Power required to drive the compressor ii) Ideal head developed iii) work done v) exit total pressure.	08

Table showing the Bloom's Taxonomy Level, Course Outcome and Programme Outcome				
Question		Bloom's Taxonomy Level (attached)	Course Outcome	Programme Outcome
Q.1	(a)	L2	CO1	PO1
	(b)	L2	CO1	PO1
	(c)	L3	CO1	PO1, PO2, PO3
Q.2	(a)	L3	CO1	PO1, PO2
	(b)	L3	CO1	PO1,
	(c)	L4	CO1	PO1, PO2, PO3
Q.3	(a)	L2	CO2	PO1, PO2
	(b)	L3	CO2	PO1, PO2
	(c)	L4	CO2	PO1, PO2, PO3
Q.4	(a)	L3	CO2	PO1
	(b)	L2	CO2	PO1
	(c)	L4	CO2	PO1, PO2, PO3
Q.5	(a)	L2	CO3	PO1,PO2
	(b)	L4	CO3	PO1, PO2, PO3
Q.6	(a)	L3	CO3	PO1,PO2
	(b)	L4	CO3	PO1, PO2, PO3
Q.7	(a)	L1	CO4	PO1
	(b)	L2	CO4	PO1
	(c)	L4	CO4	PO1, PO2, PO3
Q.8	(a)	L3	CO4	PO1, PO2, PO3
	(b)	L4	CO4	PO1, PO2, PO3
Q.9	(a)	L1	CO5	PO1
	(b)	L2	CO5	PO1, PO2
	(c)	L4	CO5	PO1, PO2, PO3
Q.10	(a)	L2	CO5	PO1, PO2
	(b	L3	CO5	PO1, PO2

	)			
	(c)	L4	CO5	PO1, PO2, PO3

Bloom's Taxonomy Levels	**Lower order thinking skills**		
	Remembering (knowledge): $\square_1$	Understanding (Comprehension): $\square_2$	Applying (Application): $\square_3$
	Higher order thinking skills		
	Analyzing (Analysis): $\square_4$	Valuating (Evaluation): $\square_5$	Creating (Synthesis): $\square_6$