TURBO MACHINERY
(MECH 3237)

Time Allotted : 3 hrs **Full Marks : 70**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 5 (five) from Group B to E, taking at least one from each group.

Candidates are required to give answer in their own words as far as practicable.

Group – A
(Multiple Choice Type Questions)

1. Choose the correct alternative for the following: **10 × 1 = 10**

(i) Specific speed is minimum for
(a) Francis turbine (b) Pelton turbine
(c) Axial flow turbine (d) Radial flow turbine.

(ii) The ratio of actual whirl velocity to the ideal whirl velocity in the centrifugal compressor is called as _____.
(a) velocity factor (b) slip factor
(c) work factor (d) none of the above

(iii) Which one of the following is an axial flow type turbine?
(a) Francis turbine (b) Propeller turbine
(c) Pelton turbine (d) None of these.

(iv) The purpose of diffuser vanes is to convert _____.
(a) potential head to pressure head (b) velocity head to potential head
(c) velocity head to pressure head (d) pressure head to velocity head

(v) The main function of the governor is to maintain the turbine _____ constant irrespective of load on the turbine.
(a) head (b) power
(c) speed (d) discharge

(vi) The compression ratio for a fan is
(a) more than 2 (b) in between 1.5 and 2
(c) in between 1.1 and 1.2 (d) less than 1.1.

(vii) The degree of reaction for a pure reaction turbine is
(a) 0.5 (b) 0
(c) 2 (d) 1.

(viii) Stagnation condition is defined for
(a) isentropic process
(b) isobaric process
(c) reversible process with heat transfer
(d) irreversible process without heat transfer.

(ix) For an axial flow pump
(a) head is more and discharge is less
(b) discharge is more and head is more
(c) discharge is more and head is less
(d) both head and discharge are very less.

(x) Cordier Diagram shows the empirical relationship between
(a) Specific speed and specific diameter
(b) Specific speed and specific gravity
(c) Specific speed and specific volume
(d) Specific speed and specific weight.

Group- B

2. (a) Explain the Radial, Axial and Mixed flow type rotodynamic machines with their applications. [(CO5)(Remember/LOCQ)]

(b) The discharge Q of a centrifugal pump depends upon the mass density of the fluid (ρ), the speed of the pump (N), the diameter of the impeller (D), the manometric head (H_m) and the viscosity of fluid (μ). Show that $Q = ND^3 \emptyset \left(\frac{gH}{N^2D^2}, \frac{\mu}{\rho N D^2}\right)$. [(CO1)(Analyse/IOCQ)]

6 + 6 = 12

3. (a) What are the differences between a turbo machine and a positive displacement machine? [(CO3)(Remember/LOCQ)]

(b) In order to predict the performance of a large centrifugal pump, a scale model of one-sixth size was made with the following specifications: Power (P) = 25 kW; Head (H_{mano}) = 7 m; Speed (N) = 1000 rpm. If the prototype pump has to work against a head of 22 m, calculate (i) its working speed, (ii) the power required to drive it, and (iii) the ratio of the flow rates handled by the two pumps. [(CO5)(Evaluate/HOCQ)]

(4 + 2) + 6 = 12

Group - C

4. (a) Explain the series and parallel operation of a pump with an H-Q diagram. [(CO2)(Remember/LOCQ)]

(b) A centrifugal pump impeller runs at 1400 rpm and vanes angle at exit is 25°. The impeller has an external diameter of 0.4 m and an internal diameter of 0.2 m. Assuming a constant radial flow through the impeller at 2.6 m/s, calculate
(i) The angle made by the absolute velocity of water at exit with the tangent.

(ii) The inlet vane angle.
(iii) The work done per kg of water. [(CO4)(Evaluate/HOCQ)]

4 + 8 = 12

5. (a) A single-stage centrifugal pump has a discharge of 600 litre/minute of oil of relative density 0.9 against a head of 20 m. The speed of the pump is 1250 rpm. The efficiency of the pump can be taken as 0.82. Estimate the brake power at this speed and the expected power requirement if the speed is increased to 1500 rpm. [(CO2)(Analyze/IOCQ)]

(b) A centrifugal pump delivers water against a total head of 10 m at a design speed of 1000 rpm. The vanes are curved backward and make an angle of 30^0 with the tangent at the outer periphery of the impeller. The impeller diameter is 30 cm and has a width of 5 cm at the outlet. (i) If the manometric efficiency is 0.95%, estimate the discharge of the pump. (ii) Assuming an overall efficiency of 76%, estimate the power required to drive the pump. [(CO2)(Evaluate/HOCQ)]

6 + 6 = 12

Group - D

6. (a) Draw a schematic diagram and discuss the governing mechanism for reaction turbines. [(CO3)(Remember/LOCQ)]

(b) A propeller turbine develops 12000 hp, and rotates at 145 rpm under a head of 20 m. The outer and hub diameters are 4 m and 1.75 m respectively. Calculate the inlet and outlet blade angles measured at mean radius if overall and hydraulic efficiencies are 85% and 93% respectively. [(CO2)(Evaluate/HOCQ)]

4 + 8 = 12

7. (a) A generator is to be driven by a Pelton wheel with a head of 220 m and a discharge of 145 L/s. The mean peripheral velocity of the wheel is 14 m/s. If the outlet tip angle of the bucket is 160°. Find out the power developed. [(CO2)(Analyze/IOCQ)]

(b) A reaction turbine works under a head of 115 m and its speed is 450 rpm. The diameter of the inlet is 1.2 m and the flow area is 0.4 m^2. At the inlet, the absolute and the relative velocities make angles of 20° and 60° respectively with the tangential velocity. Determine (i) the power developed and (ii) the hydraulic efficiency. Assume the velocity of whirl at the outlet is zero. [(CO5)(Analyze/IOCQ)]

6 + 6 = 12

Group - E

8. (a) Discuss different losses in a centrifugal compressor with the necessary graph showing their dependence on mass flow. [(CO1)(Understand/LOCQ)]

(b) Determine the pressure ratio developed and the specific work input to drive a centrifugal air compressor with an impeller diameter of 0.5 m and running at 7000 rpm. Assume zero whirl at the entry and T_{1t} = 290 K. The slip factor and

power input factor to be unity, the process of compression is isentropic and for air, γ = 1.4, C_p= 1000 J/kgK. [(CO3)(Analyze/IOCQ)]

6 + 6 = 12

9. (a) Show that the stagnation temperature ratio at the diffuser vane outlet and the impeller inlet of a centrifugal compressor may be expressed as $\frac{T_{3t}}{T_{1t}} = 1 + \frac{\psi\sigma U_2^2}{C_P T_{1t}}$ (Symbols have usual standard meaning). [(CO4)(Analyze/IOCQ)]

(b) At the mean diameter of an axial flow air compressor, blade velocity U = 200m/s, flow velocity V_f = 180m/s, blade angle β_1 = 44°, β_2 = 14°, work done factor λ = 0.9, stage isentropic efficiency η_s = 0.85, and inlet stagnation temperature T_{01} = 290 K. Calculate the pressure ratio. Given C_p = 1005 J/kgK, and γ = 1.4 for air. [(CO3)(Analyze/IOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	27.08	43.75	29.17

Course Outcome (CO):

1. Describe the knowledge on pumps, turbines and compressors.
2. Explain the basic working principle of different types of turbo machines.
3. Solve problems using velocity triangles in turbomachinery stages.
4. Analyze the hydrodynamic forces acting on vanes and their performance evaluation.
5. Select an appropriate class of turbo machine for a particular application.
6. Compare different types of turbo machines.

*LOCQ: Lower Order Cognitive Question; IOCQ: Intermediate Order Cognitive Question; HOCQ: Higher Order Cognitive Question