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) Compression ratio for a compressor is
(a) More than 3 (b) In between 1.5 and 2
(c) In between 1.1 and 1.2 (d) Less than 1.1.

(ii) The discharge is _____ from a centrifugal air compressor when 'choking' occurs.
(a) Minimum (b) Variable (c) Maximum (d) Constant.

(iii) Slip factor of a centrifugal pump is
(a) $\sigma = \frac{V_{w2}}{U_2}$ (b) $\sigma = \frac{V_{w1}}{U_1}$ (c) $\sigma = \frac{U_2}{V_{w2}}$ (d) $\sigma = \frac{U_1}{V_{w1}}$.

(iv) Inducer is placed in the centrifugal compressor before
(a) Volute casing (b) Impeller eye (c) Diffuser vane (d) Both (a) and (c).

(v) In MLT system, what is the dimension of the specific speed of a rotodynamic pump?
(a) $LT^{3/2}$ (b) $L^{-3/4}T^{3/2}$ (c) $M^{1/2}L^{1/4}T^{-5/2}$ (d) $L^{3/4}T^{-3/2}$.

(vi) Using of large diameter pipes in a pumping system results in the reduction in
(a) static head (b) frictional head
(c) both static head and frictional heads (d) manometric head.

(vii) Pressure rise of gases achieved above 3 bar by a device, which is called a
(a) Fan (b) Blower (c) Compressor (d) None of (a), (b) & (c).

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

(ix) Torque is generated in turbo machines from
(a) Flow velocity component (b) Whirl velocity component
(c) Both flow and whirl velocity components (d) Relative velocity component.

(x) Adjustable runner blades are found in
(a) Francis turbine (b) Propeller turbine
(c) Pelton turbine (d) Kaplan turbine.

Group- B

2. (a) Compare turbo machines with positive displacement machines.
[(CO5)(Remember/LOCQ)]

(b) A water turbine delivering 10 MW power is to be tested with the help of a geometrically similar 1:8 model, which runs at the same speed as the prototype. (i) Find the power developed by the model assuming the efficiencies of the model and the prototype are equal. (ii) Find the ratio of the heads and the ratio of mass flow rates between the prototype and the model.
[(CO5)(Evaluate/HOCQ)]
5 + 7 = 12

3. (a) What is the significance of similarity and model study for turbo machines?
[(CO3)(Remember/LOCQ)]

(b) A turbine is to operate under a head of 25 m at 200 r.p.m. The discharge is 9 m^3/s. If the efficiency is 90 per cent determine the (i) speed, (ii) flow rate and (iii) power developed of the turbine under a head of 20 m.
[(CO1)(Analyse/IOCQ)]
5 + 7 = 12

Group - C

4. (a) Explain the working principle of deep well pump with application.
[(CO2)(Remember/LOCQ)]

(b) The impeller of a centrifugal pump has an external diameter of 450 mm and internal diameter of 200 mm and it runs at 1440 r.p.m. Assuming a constant radial flow through the impeller at 2.5 m/s and that the vanes at exit are set back at an angle 25°, determine: (i) Inlet vane angle, (ii) The angle, absolute velocity of water at exit makes with the tangent, and (iii) The work done per kg of water. *[(CO4)(Evaluate/HOCQ)]*
5 + 7 = 12

5. (a) A centrifugal pump running at 800 r.p.m. is working against a total head of 20.2 m. The external diameter of the impeller is 480 mm and outlet width 60 mm. If the vane angle at outlet is 40° and manometric efficiency is 70 %, determine: (i) Flow velocity at outlet, (ii) Absolute velocity of water leaving the vane, (iii) Angle made by the absolute velocity at outlet with the direction of motion at outlet. *[(CO2)(Analyze/IOCQ)]*

(b) The impeller of a centrifugal pump having external and internal diameters 500 mm and 250 mm respectively, width at outlet 50 mm and running at 1200 r.p.m. works against a head of 48 m. The velocity of flow through the impeller is constant and equal to 3.0 m/s. The vanes are set back at an angle of 40° at outlet.

Determine: (i) Inlet vane angle, (ii) Work done by the impeller on water per second, and (iii) Manometric efficiency. *[(CO2)(Evaluate/HOCQ)]*

5 + 7 = 12

Group - D

6. (a) Discuss the functions of different components of a Pelton with a neat sketch. *[(CO3)(Remember/LOCQ)]*

(b) An inward flow reaction turbine has external and internal diameters as 1.08 m and 0.54 m. The turbine is running at 200 r.p.m. The width of the turbine at inlet is 240 mm and velocity of flow through the runner is constant and is equal to 2.16 m/s. The guide blades make an angle of 10° to the tangent of the wheel and discharge at the outlet of the turbine is radial. Draw the inlet and outlet velocity triangles and determine the: (i) absolute velocity of water at inlet of the runner, (ii) velocity of whirl at inlet, (iii) relative velocity at inlet, (iv) runner blade angles. *[(CO2)(Evaluate/HOCQ)]*

5 + 7 = 12

7. (a) A Pelton wheel running at 480 r.p.m. and operating under an available head of 420 m is required to develop 4800 kW. There are two equal jets and the bucket deflection angle is 165°. The overall efficiency is 85 percent when the water is discharged from the wheel in a direction parallel to the axis of rotation. The coefficient of velocity of nozzle = 0.97 and blade speed ratio = 0.46. The relative velocity of water at exit from the bucket is 0.86 times the relative velocity at inlet. Calculate the following: (i) Cross-sectional area of each jet, (ii) Bucket pitch circle diameter, and (iii) Hydraulic efficiency of the turbine. *[(CO2)(Analyze/IOCQ)]*

(b) A Kaplan turbine develops 22000 kW at an average head of 35 m. Assuming a speed ratio of 2, flow ratio of 0.6, diameter of the boss equal to 0·35 times the diameter of the runner and an overall efficiency of 88%, calculate the diameter, speed and specific speed of the turbine. *[(CO5)(Analyze/IOCQ)]*

6 + 6 = 12

Group - E

8. (a) Explain surging, choking and stall related to the centrifugal compressor. *[(CO1)(Understand/LOCQ)]*

(b) Air at a temperature of 27°C flows into a centrifugal compressor at 20000 rpm. The following data are given:
Slip factor = 0.80
Power input factor = 1
Isentropic efficiency = 80%
Outer diameter of blade tip = 0.5 m
Assuming the absolute velocities of air entering and leaving the compressor are same, find (i) static temperature rise of air passing through the compressor, and (ii) the static pressure ratio. c_p of air is 1005 J/kgK. *[(CO3)(Analyze/IOCQ)]*

6 + 6 = 12

9. (a) With a neat sketch, describe the working principle of an axial compressor.
[(CO2)(Understand/LOCQ)]

(b) For an axial flow compressor, at the mean diameter, U = 20 m/s, V_f = 180 m/s, β_1 = 43.9° and β_2 =13.5°. The factor λ = 0.86 and η_s = 0.85 and inlet temperature T_{01} is 288 K. Calculate the pressure ratio. *[(CO3)(Evaluate/HOCQ)]*

6 + 6 = 12

Cognition Level	*LOCQ*	*IOCQ*	*HOCQ*
Percentage distribution	*33*	*31*	*36*

Course Outcome (CO):

After the completion of the course students will be able to
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 turbo machinery 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.*