TURBO MACHINERY
(MECH 3237)

Time Allotted : 2½ hrs **Full Marks : 60**

Figures out of the right margin indicate full marks.

Candidates are required to answer Group A and any 4 (four) from Group B to E, taking one from each group.

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

Group – A

1. Answer any twelve: **12 × 1 = 12**

Choose the correct alternative for the following

(i) $\frac{gH}{N^2D^2}$ is known as
(a) Pressure coefficient (b) Head coefficient
(c) Flow coefficient (d) Power coefficient

(ii) 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

(iii) Kinematic similarity between model and prototype means the
(a) similarity of force (b) similarity of shape
(c) similarity of motion (d) similarity of discharge

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

(v) For the operating point of a centrifugal pump, a system characteristic between the head required 'H' and the discharge to be maintained 'Q' is generally expressed as
(a) linear equation (b) parabolic equation
(c) exponential equation (d) cubic equation

(vi) A Pelton wheel is ideally suited for
(a) high-head and low discharge (b) high-head and high discharge
(c) low head and low discharge (d) medium head and medium discharge

(vii) 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

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

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

(x) For a centrifugal fan with the diameter *D*, having discharge *Q* and rotational speed N, according to Fan Laws
(a) $Q \propto N$ (b) $Q \propto N^2$
(c) $Q \propto N^3$ (d) $Q \propto N^5$

Fill in the blanks with the correct word

(xi) A multistage pump is used for obtaining high _____.

(xii) Cavitation in a centrifugal pump generally occurs at _____.

(xiii) The discharge is _____ from a centrifugal air compressor when 'choking' occurs.

(xiv) Torque is generated in turbo machines from _____ velocity component.

(xv) For a centrifugal air compressor, the curvature of blades at the impeller exit is _____

Group - B

2. (a) Why do we need volute casing in a centrifugal pump? Define specific speed of a pump. *[(CO2)(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)]*

6 + 6 = 12

3. (a) A centrifugal pump delivers 2.5 m^3/s under a head of 14 m and runs at a speed of 2010 rpm. The impeller diameter of the pump is 125 mm. If a 104 mm diameter impeller is fitted and the pump runs at a speed of 2210 rpm, what is the volume rate? Determine also the new pump head. *[(CO5)(Apply/IOCQ)]*

(b) Two geometrically similar pumps are running at the same speed of 1000 rpm. One pump has an impeller diameter of 0.30 m and lifts water at a rate of 20 litre/second against a head of 15 m. Determine the head and impeller diameter of the other pump to deliver half the discharge. *[(CO2)(Apply/IOCQ)]*

6 + 6 = 12

Group - C

4. (a) A centrifugal pump discharges 0.2 m^3/s of water at a head of 25 m when running at a speed of 1400 rpm. The manometric efficiency is 80%. If the impeller has an outer diameter of 30 cm and a width of 5 cm, determine the vane angle at the outlet. *[(CO4)(Evaluate/HOCQ)]*

   (b) (i) What do you mean by cavitation? (ii) Write the demerits of cavitation and how you will minimize the cavitation effects in centrifugal pumps. *[(CO1)(Remember/LOCQ)]*

6 + 6 = 12

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

   (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 rpm. 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 40^0 at the outlet. Determine: (i) Inlet vane angle, (ii) Work done by the impeller on water per second, and (iii) Manometric efficiency. *[(CO2)(Evaluate/HOCQ)]*

6 + 6 = 12

Group - D

6. (a) A Kaplan turbine develops 15 MW of power at a head of 30 m. The diameter of the hub is 0.35 times the diameter of the runner. Assuming a speed ratio of 2.0, flow ratio of 0.65 and an overall efficiency of 90%, calculate the (i) diameter of the runner, (ii) rotational speed, and (iii) specific speed of the turbine. *[(CO3)(Apply/IOCQ)]*

   (b) Write the comparison between impulse and reaction turbines. *[(CO1)(Remember/LOCQ)]*

6 + 6 = 12

7. (a) A Pelton wheel having a mean bucket diameter of 1.2 m is running at 1000 rpm. The net head on the Pelton wheel is 840 m. If the side clearance angle is 15° and discharge through the nozzle is 0.12 m^3/s, determine: (i) power available at the nozzle, and (ii) hydraulic efficiency of the turbine. *[(CO4)(Apply/IOCQ)]*

   (b) A reaction turbine works at 450 rpm. under a head of 120 m. Its diameter at inlet is 1.2 m and the flow area is 0.4 m^2. The angles made by absolute and relative velocities at inlet are 20° and 60° respectively with the tangential velocity. Determine: (i) the volume flow rate, (ii) the power developed, and (iii) the hydraulic efficiency. *[(CO4)(Apply/IOCQ)]*

6 + 6 = 12

Group - E

8. (a) A centrifugal compressor has an impeller tip speed of 360 m/s. Determine the absolute Mach number of flow leaving the radial vanes of the impeller.
   The following data are given:

Impeller Tip speed 360 m/s
Radial component of flow velocity at impeller exit 30 m/s
Slip factor 0.9
Flow area at impeller exit 0.1 m^2
Power input factor 1.0
Isentropic efficiency 0.9
Inlet stagnation temperature 300 K
Inlet stagnation pressure 100 kN/m^2
R (for air) 287 J/kg-K
γ (for air) 1.4 *[(CO3)(Analyse/HOCQ)]*

(b) Draw the velocity triangles for a stage (both rotor and stator) of an axial flow compressor following standard notations at the inlet and outlet locations. Also find the expression of specific work input following the geometry of the velocity triangles. *[(CO3)(Understand/LOCQ)]*

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 meaning). *[(CO2)(Understand/LOCQ)]*

(b) Air at a stagnation temperature of 27^0C enters the impeller of a centrifugal compressor in the axial direction. The rotor which has 15 radial vanes rotates at 20000 rpm. The stagnation pressure ratio between the diffuser outlet and the impeller inlet is 4 and the isentropic efficiency is 85%. Determine (i) the impeller tip radius and (ii) power input to the compressor when the mass flow rate is 2 kg/s. Assume a power input factor of 1.05 and a slip factor $\sigma = 1 - \frac{2}{n}$ where n is the number of vanes. For air, take γ = 1.4, R = 287 J/kg K. *[(CO3)(Evaluate/HOCQ)]*

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	37.50	31.25	31.25