

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) Dynamic similarity between model and prototype is the similarity of
 - (a) motion
 - (b) lengths
 - (c) forces
 - (d) all of these
- (ii) Adjustable runner blades are found in
 - (a) Francis turbine
 - (b) Pelton turbine
 - (c) Kaplan turbine
 - (d) Propeller turbine
- (iii) 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
- (iv) A centrifugal pump is started with its delivery valve kept
 - (a) fully open
 - (b) fully closed
 - (c) partially open
 - (d) none of these
- (v) The degree of reaction of an impulse turbine is
 - (a) greater than unity
 - (b) equal to zero
 - (c) equal to unity
 - (d) all of these

- (vi) Generally axial flow compressor consists of
 - (a) single stage
 - (b) multiple stages
 - (c) rotor blades only
 - (d) stator blades only
- (vii) 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
- (viii) Pressure rise of gases achieved up to 0.07 bar by a device, which is called a
 - (a) fan
 - (b) blower
 - (c) compressor
 - (d) both blower and compressor
- (ix) Slip factor of a centrifugal compressor is
 - (a) $\sigma = \frac{V_{w2}}{U_2}$
 - (b) $\sigma = \frac{V_{w1}}{U_1}$
 - (c) $\sigma = \frac{U_2}{V_{w2}}$
 - (d) none of the above
- (x) Compression ratio for 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

Fill in the blanks with the correct word

- (xi) A multistage pump is used for obtaining high _____.
- (xii) The discharge is _____ from a centrifugal air compressor when 'choking' occurs.
- (xiii) Inducer is placed in the centrifugal compressor before _____.
- (xiv) Torque is generated in turbo machines from _____ velocity component.
- (xv) Surge tank is used for _____.

Group - B

2. (a) Write the differences between positive displacement machines and turbo machines. [[C01](Remember/LOCQ)]
- (b) Describe the classification of turbomachines based on 'direction of flow' and 'specific speed'. [[C01](Remember/LOCQ)]

6 + 6 = 12

3. (a) The flow rate (Q) of a rotodynamic pump depends on impeller diameter (D), speed (N), fluid density (ρ), and head (H). Find the expression of **Flow Coefficient** using Buckingham- π theorem. [[CO1](Analyze/IOCQ)]
- (b) A Pelton turbine operates under a head of 250 m, has a rotational speed of 120 rpm and develops 5 MW of power. The overall efficiency of the turbine is 90%. Calculate the specific speed, unit speed, and unit discharge and unit power. [[CO4](Apply/IOCQ)]
- 6 + 6 = 12**

Group - C

4. (a) A centrifugal pump running at 800 rpm is working against a total head of 20 m. The external diameter of the impeller is 480 mm and outlet width 60 mm. If the vanes angle at outlet is 40° and manometric efficiency is 70%, determine: (i) Flow velocity at outlet, (ii) Absolute velocity of water leaving the vane. [[CO3, CO4](Apply/IOCQ)]
- (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 rpm. 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. [[CO3, CO4](Apply/IOCQ)]
- (3 + 3) + 6 = 12**
5. (a) Explain series and parallel operation of pump with H-Q diagram. [[CO2](Remember/LOCQ)]
- (b) A centrifugal pump impeller runs at 80 rpm and has outlet vane angle of 60° . The velocity of flow is 2.5 m/s throughout and diameter of the impeller at exit is twice that at inlet. If the manometric head is 20 m and the manometric efficiency is 75%, determine: (i) The diameter of the impeller at the exit, and (ii) Inlet vane angle. [[CO3, CO4](Apply/IOCQ)]
- 6 + 6 = 12**

Group - D

6. (a) (i) Discuss the functions of different components of a Francis turbine with a neat sketch. (ii) Which turbine is suitable to run under the head of 650m, justify your answer. [[CO1, CO5](Remember/LOCQ)]
- (b) 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 $0.12 \text{ m}^3/\text{s}$, determine : (i) Power available at the nozzle, and (ii) Hydraulic efficiency of the turbine. [[CO3, CO4](Apply/IOCQ)]
- (4+2) + 6 = 12**
7. (a) With the help of a figure, explain the deflector regulation governing system of a Pelton turbine. [[CO2](Remember/LOCQ)]
- (b) 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 (a) diameter of the runner, (b) rotational speed, and (c) specific speed of the turbine.

[[CO3,CO4](Apply/IOCQ)]

6 + 6 = 12

Group - E

8. (a) 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, $\gamma = 1.4$, $C_p = 1000$ J/kgK.

[[CO3](Evaluate/HOCQ)]

- (b) Air at 30°C enters into a centrifugal compressor running at 20000 rpm. Assume slip factor 0.8, power input factor 1, isentropic efficiency 80% and outer blade tip diameter 0.5 m. Assuming same inlet and exit absolute velocities, calculate the static temperature rise and static pressure ratio for the compressor. Given C_p of air = 1005 J/kg-K.

[[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 the usual standard meanings).

[[CO4](Analyze/IOCQ)]

- (b) The conditions of air at the entry of an axial flow compressor stage are $p_1 = 100$ kN/m² and $T_1 = 300$ K. The air angles are $\beta_1 = 51^\circ$, $\beta_2 = 10^\circ$, $\alpha_1 = \alpha_3 = 8^\circ$. The mean diameter and peripheral speed are 0.5 m and 150 m/s respectively. Mass flow rate through the stage is 30 kg/s; the work done factor is 0.95 and mechanical efficiency is 90%. Assuming an isentropic stage efficiency of 85%, determine (i) blade height at entry, (ii) stage pressure ratio, and (iii) the power required to drive the stage. For air, $\gamma = 1.4$ and $R = 287$ J/kgK.

[[CO3] (Evaluate/HOCQ)]

6 + 6 = 12

Cognition Level	LOCQ	IOCQ	HOCQ
Percentage distribution	31.25	56.25	12.5

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.