

[This question paper contains 4 printed pages.]

Your Roll No.

3188

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MEM

Paper — ME.553

TURBOMACHINERY-I

Time : 3 Hours

Maximum Marks : 100

(Write your Roll No. on the top immediately
on receipt of this question paper.)

Attempt any five questions.

Assume a suitable value of any missing data, if required.

1. (a) For a high-speed flow what is a shockwave ? In a normal shockwave, derive relation for Mach number, static pressure, static temperature after a shock, in terms of the values before the shock. 12
- (b) Explain and plot the effect of varying the back pressure for a converging-diverging nozzle. Explain the occurrence of a shockwave. 8
2. (a) What is infinitesimal stage efficiency in the expansion through a turbine ? How is it determined ? 4
- (b) Show that the index 'n' of polytropic expansion in a turbine of infinitesimal stage efficiency η_p is :

$$n = \frac{r}{r - (r-1)\eta_p} \quad 6$$

[P. T. O.]

- (c) A diffuser at the exit of a gas turbine has an area ratio of 2.0. If the static pressure at the diffuser exit is 1.013 bar and the velocity of gas 30 m/s, calculate the static pressure of the gas at the turbine exit. Take diffuser efficiency equal to 77% and density of gas as 1.25 kg/m^3 (constant). State the assumptions used.

Draw the actual and ideal diffusion processes on the $h-s$ diagram. 10

3. (a) What are the different variables involved in determining the performance of axial and centrifugal compressors ? 5

- (b) Show graphically the variation of the following dimensionless parameters :

(i) Air compressor : pressure ratio with mass-flow rate.

(ii) Axial flow compressor : efficiency with specific speed.

(iii) Backward swept centrifugal blower : pressure coefficient with flow coefficient. 15

4. (a) Draw the following for axial compressor cascade and explain them :

(i) Typical static pressure and velocity distribution curves around the blades.

(ii) Variation of compressor cascade losses with incidence. 10

(b) Prove the following relation for an axial compressor cascade with usual notations :

$$C_L = 2 \left(\frac{s}{l} \right) (\tan \alpha_1 - \tan \alpha_2) \cos \alpha_m - C_D \tan \alpha_m. \quad 10$$

5. (a) Sketch the velocity triangles at the inlet and exit of rotor and stator blades for a compressor stage. Show these processes on $h-s$ diagram. 10
- (b) Derive relation for degree of reaction for axial flow compressor and explain advantages of 50% value of degree of reaction. 10
6. The conditions of air at the entry of an axial compressor stage are $p_1 = 768$ mm Hg and $T_1 = 314$ K. The blade and air angles are $\beta_1 = 51^\circ$, $\beta_2 = 9^\circ$, $\alpha_1 = \alpha_3 = 7^\circ$. The mean diameter and peripheral speed are 50 cm and 100 m/s respectively. Mass-flow rate through the stage is 25 kg/s, the work-done factor is 0.95 and mechanical efficiency 92%. Assuming a stage efficiency of 88% determine :
- air angle at the stator entry,
 - blade height at entry and hub-tip diameter ratio,
 - stage loading coefficient,
 - stage pressure ratio and
 - the power required to drive the stage. 20

7. (a) Why is the radial-tipped impeller most widely used in centrifugal compressor stages ? 5
- (b) Explain briefly what is the purpose of inlet guide vanes and inducer blades in centrifugal compressor ? 5
- (c) What are the various losses occurring in a centrifugal compressor stage ? 5
- (d) Explain with the aid of velocity triangles the mechanism of shock losses (due to incidence) at the impeller and diffuser entry ? 5
8. Air enters the inducer blades of a centrifugal compressor at $p_{01} = 1.02$ bar, $T_{01} = 335$ K. The hub and tip diameters of the impeller eye are 10 and 25 cm respectively. If the compressor runs at 7200 rpm and delivers 5.0 kg/s of air, determine the air angle at the inducer blade entry and the relative Mach number.
- If 1GV's are used to obtain a straight inducer section, determine the air angles at the 1GV's exit and the new value of the relative Mach number. 20