Con. 3168-09.

(4 Hours) [Total Marks : 100

N.B. : (1) Question No. 1 is **compulsory.**
(2) Solve any **three** questions from **remaining** question.
(3) If **required** assume the **data** with **justification.**

1. (a) Air flows through a convergent-divergent nozzle. At some section in the nozzle, pressure is 2 bar, velocity is 170 m.s, temperature is 200°C and cross sectional area is 1000 mm^2. Assuming isentropic flow conditions determine :— 8
   (i) stagnation pressure and temperature.
   (ii) sonic velocity and Mach number at this section
   (iii) velocity, Mach number and flow area at outlet section where pressure is 1.1 bar
   (iv) pressure, temperature, velocity and flow area at throat of the nozzle.
   Take R = 287 J/kgK, Cp = 1000 J/kgK and λ = 1.4.

   (b) Explain why air flowing at low velocities can be considered incompressible. 2

   (c) "Higher the velocity of supersonic flow, smaller the angle of Mach cone." Comment on the validity of this statement. 3

   (d) Show that for steady one-dimensional isentropic compressible flow through a duct— 7
   $$dA/A = dV/V(M^2 - 1)$$
   and explain its implication in the design of nozzles.

   (e) Give the valid argument to show that a normal shock can occur only in supersonic flow and that after the shock there must be supersonic flow. 5

2. (a) Starting from Euler's energy equation of a centrifugal compressor, show that, if there is no pre-whirl, 5
   $$E = K_1 - K_2 Q \cot \beta_2$$
   Where Q- compressor discharge in m^3/s
   β_2 - Impeller blade angle at the exit
   K_1 and K_2 are constants.

   (b) An aircraft engine is fitted with a single-sided centrifugal compressor. The aircraft flies with a speed of 850 km/h at an altitude where the pressure is 0.23 bar and the temperature 217 K. The inlet duct of the impeller eye contains fixed vanes which give the air pre-whirl of 25° at all radii. The inner and outer diameters of the eye are 180 and 330 mm respectively, the diameter of the impeller tip is 540 mm and the rotational speed 16000 rpm. Estimate the stagnation pressure at the compressor outlet when the mass flow is 216 kg per minute. 6
   Neglect losses in inlet duct and fixed vanes and assume that the isentropic efficiency of the compressor is 0.8. Take the slip factor as 0.9 and the power input factor as 1.04.

   (c) Define slip factor. Derive the expression for calculating the slip factor by using Stodola's concept. 8

   (d) Explain the factors influencing the selection of number of blades used in an impeller of a centrifugal compressor. 6

3. (a) Define degree of reaction. Obtain an expression for degree of reaction and show that for 50% degree of reaction the blades are symmetrical. 8

(b) A helicopter gas turbine requires an overall pressure ratio of 10:1. This is to be obtained using a two-spool layout consisting of a four stage axial flow compressor followed by a single stage centrifugal compressor. The polytropic efficiency of the axial flow compressor is 92% and that of the centrifugal is 83%. 17

The axial compressor has stage temperature rise of 30°C, using symmetrical stages with a stator outlet angle of 20°. If the mean diameter of each stage is identical, calculate the required rotational speed. Assume a work done factor of 0.86 and a constant axial velocity of 150 m/s.

Assuming an axial inlet at the eye of the impeller, an impeller diameter of 330mm, a slip factor of 0.9 and a power input factor of 1.04, calculate the rotational speed required for centrifugal compressor. Ambient conditions are 1.01 bar and 288 K.

4. Design the blower completely for the following data : 25

Pressure (P) = 3.0 bar
Discharge (Q) = 15000 LPM
Speed (N) = 3500 RPM

The design of blower should include the design of Impeller and vanes, shaft, casing and selection of proper motor. Draw the neat sketches wherever necessary.

5. (a) Why testing of pressure increasing equipments are necessary? Explain in detail the procedure for carrying out the test of fan with standard set up. 15

(b) Explain the phenomenon of fan noise. Explain the methods to control the fan noise. 10

6. (a) A centrifugal compressor is desired to have a total pressure ratio of 4:1. The inlet eye of the compressor impeller is 30 cm in diameter. The axial velocity at inlet is 130 m/s and the mass flow is 10 kg/s. the velocity in delivery duct is 115 m/s. The tip speed of impeller is 450 m/s and runs at 16000 rpm with total head isentropic efficiency of 78% and pressure coefficient of 0.72. The ambient conditions are 1 bar and 15°C. 10

Calculate :—

(i) Static pressure ratio.
(ii) Static pressure and temperature at inlet and exit of compressor.
(iii) Work of compressor per kg of air and
(iv) Theoretical h.p. required to drive the compressor.

(b) Explain the phenomenon of stalling, surging and choking in centrifugal compressors. 8

Identify on the characteristic curve of a centrifugal compressor.

(c) Define lift and drag forces on the airfoil. Show the variation of lift and drag coefficients with respect to the angle of incidence. 7