5E3180-R

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B. Tech. (Sem. V) (Main) Examination, December - 2011
Mechanical Engg.
5ME6 Principles of Turbomachines

Time : **3** Hours] [Maximum Marks : **80**
[Min. Passing Marks : **24**

Instructions to Candidates :

Attempt any ***five questions*** *selecting* ***one question*** *from* ***each unit.*** *All questions carry* ***equal*** *marks. Schematic diagrams must be shown wherever necessary. Any data you feel missing suitably be assumed and stated clearly. Units of quantities used/calculated must be stated clearly.*

Use of following supporting material is permitted during examination.
(Mentioned in form No. 205)

1. NIL 2. NIL

UNIT - I

1 (a) Derive an equation of moment of momentum applicable to turbomachines for the calculation of theoretical energy transfer. Transform the equation into the form which consists of centrifugal and other effects. Explain the physical significance of each term and discuss the term degree of reaction. 8

(b) Using Buckingham's π theorem show that the discharge of a centrifugal pump can be expressed as

$$Q = ND^3\phi\left[\frac{ND}{\sqrt{gH}}, \frac{ND^2}{\nu}\right]$$

Where N = speed of the pump
D = Diameter of the impeller
ν = kinematic viscosity
g = Acceleration due to gravity
H = Head. 8

OR

1 (a) Define specific speed (Ns) and non-dimensional specific speed (Kn) and prove that

Ns = 1042 Kn

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(B) Define the terms 'unit speed' and 'unit power'. Show that

$$N_S = N_u \sqrt{Pu}$$

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(c) An experiment of single stage centrifugal pump was found to operate free from cavitation under a minimum net positive suction head of 4.2 m when pumping water at the rate of 140 liters/s against a head of 39m. The impeller diameter was 450 mm and speed 1200 rpm.

A geometrically similar impeller is required to discharge 5660 liters/s against a head of 120 m. Assuming a water temperture of 20°C and allowing 0.35 m for hydraulic losses, at what speed and suction head should the prototype operate? Assuming Barometric pressure as 760 mm of mercury.

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UNIT - II

2 (a) Prove that the manometric efficiency of a centrifugal pump, when all the kinetic energy at exit from the runner is lost, is given by

$$\eta_{manometric} = \frac{U_2^2 - V_{f2}^2 \operatorname{cosec}^2\phi}{2U_2\left(U_2 - V_{f_2}\cot\phi\right)}$$

State the assumptions made in the analysis and explain why the angle ϕ is rarely less than 20°.

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(b) A centrifugal pump delivers 0.1 m^3/S of water at a rotational speed of 1200 rpm. The impeller vanes which lean backwards to the direction of rotation such that the vane tip angle is 50°. The impeller has an external diameter of 0.4 m an internal diameter of 0.2 m and an axial width of 31.7 mm. Assuming that the diffuser efficiency is 55% that the impeller head losses are 10% of the ideal head rise and that the diffuser exit is 0.15 m in diameter, estimate the manometric head and the hydraulic efficiency.

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OR

2 (a) Water is to be pumped from a river through a 150 mm diameter pipeline 950 m long to an open storage tank with a water level 4.5 m above the river. A pump is available and has the discharge head performance characteristics is given below.

Total head (m)	30	50	65	80
Discharge (liters/min)	2000	1750	1410	800

Calculate the duty point for the pump when the friction factor $\lambda = 4f = 0.04$.

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(b) A centrifugal pump of specific speed 0.683 (based on units rps, m^3/s, m) has a critical Thoma number equal to 0.2, the proposed installation of the pump requires the centre line to be 5.2 m above the sump water level. The pump when running at 1450 rpm delivers 0.0637 m^3/s. The losses in the suction pipe are estimated as 0.457 m of water. If the Barometer pressure is 749 mm of mercury and the temperature of the water is 27°C for which the vapour pressure is 0.03567 bar, establish whether cavitation likely to occur.

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UNIT - III

3 (a) How will you select the pump for particular application ? Draw a pump selection chart between Total head and flow and give the range of Axial flow pump. **5**

(b) Draw the pump selection chart between specific speed and specific diameter for the axial flow pump. **5**

(c) Compare the pump performance with reference to the following characteristics

(i) Discharge and Head

(ii) Discharge and power

(iii) Discharge and efficiency

Show clearly centrifugal pump, axial flow pump and mixed flow pump on the chart. **6**

OR

3 (a) Draw a graph between Head v/s Discharge showing matching of pump with a pipeline also show the duty point. **4**

(b) Draw typical curve related to cavitation for a axial flow pump. **4**

(c) On what factors does the cavitation in axial flow pump depend ? Describe some methods to avoid cavitation in axial flow pump. **4**

(d) Develop an expression for cavitation number for axial flow pump. What are the causes of cavitation in axial flow pump ? How will you prevent cavitation in pump. **4**

UNIT - IV

4 (a) Define the following :

(i) Prewhirl

(ii) Power input factor

(iii) Surging, choking and stall

(iv) Rotating stall

(v) Slip factor

(vi) Degree of reaction

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(b) The inlet of a centrifugal compressor is fitted with free vortex guide vanes to provide positive prewhirl of 30° at the shroud. The inlet hub-shroud radius ratio is 0.4 and a requirement of the design is that the relative Mach number does not exceed 0.9. The air mass flow is 1 kg/s, stagnation pressure and temperature are 101.3 kPa and 288 K. For air take R = 0.287 kJ/kgK and r = 1.4.

Assuming optimum conditions at the shroud, determine

(i) impeller rpm

(ii) the inlet static density downstream of the guide vanes at the shroud and the axial velocity

(iii) the inducer tip diameter and velocity.

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OR

4 (a) Draw a neat sketch showing guide vanes and impeller blades and draw velocity diagram at shroud and at hub.

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(b) Draw graph between radius ratio v/s incidence angle and radius ratio v/s absolute flow angles for various whirl distribution for n = –1, n = 0, n = 1 and n = 2. Where

n = 0 for simple untwisted blade shape

n = 2 free vortex design or quadratic design.

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(c) Air at a stagnation temperature of 22°C enters the impeller of a centrifugal compressor in the axial direction. The rotor, which has 17 radial vanes, rotates at 15000 rpm. The stagnation pressure ratio between diffuser outlet and impeller inlet is 4.2 and the total to total efficiency is 83%. Determine the impeller tip radius and power required to drive the compressor when the mass flow rate is 2 kg/s and the mechanical efficiency is 97%. Given that the air density at impeller outlet is 2 kg/m^3 and the axial width at entrance to the diffuser is 11 mm, determine the absolute Mach number at that point. Assume that the slip factor $\sigma_s = 1 - 2/z$ where z is the number of vanes. Take r=1.4 and R = 0.287 kJ/kgK for air. **10**

UNIT - V

5 (a) Prove that for Axial flow compressor Total to Total stage efficiency is

$$\eta_{tt} = 1 - \frac{\Delta p_{0\,stator} + \Delta p_{0\,rotor}}{\rho(h_{03} - h_{01})}$$

and reaction ratio R

$$R = \frac{(\omega_{y_1} + \omega_{y_2})(\omega_{y_1} - \omega_{y_2})}{2U(\tau_{y_2} - \tau_{y_1})}$$

OR

$$R = \frac{1}{2} + (\tan p2 - \tan\alpha_1)\,{C_x}/{2U}$$

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(b) A multistage axial compressor is required for compressing air at 293 K through a pressure ratio 5 to 1. Each stage is to be 50% reaction and the mean blade speed 275 m/s. How coefficient 0.5 and stage loading factor 0.3, are taken, for simplicity, as constant for all stages. Determine the flow angles and the number of stages required if the stage efficiency is 88.8%. Take Cp = 1.005 kJ/kgK and r = 1.4 for air.

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OR

5 (a) Derive an expression for the degree of reaction of an axial compressor stage in terms of the flow angles relative to the rotor and the flow coefficient.

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(b) A 16 stage axial flow compressor is to have a pressure ratio of 6.3. Tests have shown that a stage total to total efficiency of 0.9 can be obtained for each of the first six stages and 0.89 for each of the running ten stages. Assuming constant work done in each stage and similar stages find the compressor over total to total efficiency. For a mass flow rate of 40 kg/s determine the power required by the compressor. Assume an inlet total temperature of 288 K.

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