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HPAS (Main)—2012

MECHANICAL ENGINEERING

Paper II

Time : 3 Hours *Maximum Marks :* 150

Note :— Attempt total *five* questions. Question No. 8 is compulsory. Use of calculator, steam tables, Mollier diagram, psychometric chart and Refrigerant property table is permitted. Assume missing data, if any, suitably.

1. (*a*) Discuss Kelvin-Planck statement of second law of thermodynamics, and show the equivalence of Kelvin-Planck and Clausius statements of 2nd law. 15

(*b*) A heat pump working on the Carnot cycle takes heat from a reservoir at 6°C and delivers heat to a reservoir at 62°C. The heat pump is driven by

P.T.O.

a reversible heat engine working between two thermal reservoirs at 850°C and 62°C. The reversible heat engine also drives a machine that absorbs 50 kW. If heat pump extracts 20 kJ/s from 6°C reservoir, calculate rate of heat supply to and rejection from heat engine. 15

2. (a) Discuss the limitations of Otto and Diesel cycles. Show that for the same compression ratio, efficiency of Otto cycle is more than Diesel cycle. 15

(b) Air, at 1 bar and 20°C, is supplied to Otto cycle. The compression ratio is 9 and during heat addition process 2500 kJ/kg of heat is supplied. Determine maximum pressure and temperature of the cycle. Also calculate cycle efficiency and mean effective pressure. Assume C_P = 1.005 kJ/kg.K, C_V = 0.718 kJ/kg-K and R = 0.287 kJ/kg.K, γ = 1.4. 15

3. (a) Derive continuity equation of fluid flow in 3D Cartesian coordinates. Discuss the same for steady state incompressible are dimension case. 15

(b) Derive and discuss velocity distribution for turbulent flow through a pipe. 15

4. (a) Force acting on a aircraft propeller depends on density, diameter of propeller, velocity of aircraft, viscosity of air, and revolution of propeller. Develop a formula in terms of non-dimensional numbers using Buckingham π theorem. 15

(b) Water is flowing over a plate with a velocity of 15 m/min. The plate is 2 m long and 2.5 m wide and flow is parallel to 2 m side. Assume density $\rho = 1000 \text{ kg/m}^3$ and viscosity $\mu = 0.01$ poise and velocity profile in a laminar boundary layer as :

$$\frac{u}{U} = 2\left(\frac{y}{\delta}\right) - \left(\frac{y}{\delta}\right)^2$$

Find :

(*a*) Thickness of boundary layer at end of plate.

(*b*) Drag force on the plate and average drag force.

15

5. (*a*) Derive equation of heat transfer by natural convection. Discuss the effect of different parameters on natural convection. 15

(*b*) A current of 250 ampere is passed through a stainless steel wire of 4 mm diameter and 120 cm long. The wire is submerged in a liquid at 150°C. Determine centreline temperature of the wire. Assuming the following data as :

Thermal conductivity of steel = 25 W/m-K

Resistivity of wire = 75 $\mu\Omega$-cm

Convective heat transfer coefficient on the wire surface

= 4500 W/m^2-K.

15

6. (*a*) With the help of a diagram discuss MHD used for power generation. 15

(*b*) Steam expands in a turbine from 150 bar 550°C to 0.1 bar isentropically. Assuming nozzle angle 20° and r.p.m. of turbine as 3000, determine mean diameter of turbine wheel if turbine is of :

(*i*) single impulse stage

(*ii*) single 50% reaction stage

(*iii*) one 2-raw curtis stage

(*iv*) four 50% reaction stages

Also discuss the answers. 15

7. (*a*) With the help of psychometric diagram discuss different processes used in air-conditioning :

(*i*) sensible cooling

(*ii*) sensible heating

(*iii*) Heating and humidification

(*iv*) Cooling and dehumidification. 15

(*b*) An aircraft flying at an altitude of 9000 m, where the ambient air is at 0.35 bar pressure and 263 K temperature, has a speed of 1000 km/h. The pressure ratio of the air compressure is 6. The cabin pressure is 1.01325 bar and 27°C. Determine the power required for pressurization of aircraft (excluding ram work), additional power required for refrigeration and refrigeration capacity for air flow of 1 kg/s. Assume C_p = 1.005 kJ/kg-K and ν = 1.4. 15

8. Explain any *four* of the following : 7.5×4=30

(*a*) Clausius's theorem

(*b*) Kaplan turbine

(*c*) Configuration factor

(*d*) Direct conversion of solar energy into electrical power

(*e*) Compounding of steam turbines

(*f*) Energy and displacement thickness of hydraulic boundary layer.