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HPAS (Main)—2017

MECHANICAL ENGINEERING

Paper II

Time : 3 *Hours* *Maximum Marks* : 100

Note :— (1) Attempt total *five* full questions.

(2) Question No. **8** is compulsory

(3) Use of steam tables, Mollier diagram, Psychometric charts, Refrigerant Property Table, Non-Programmable calculator, Graph sheet is allowed.

(4) Assume missing data suitably, if any.

1. (*a*) A fluid contained in a horizontal cylinder fitted with a frictionless leakproof piston is continuously agitated by means of a stirrer passing through

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the cylinder cover. The cylinder diameter is 0.40 m. During the stirring process lasting 10 minutes, the piston slowly moves out a distance of 0.485 m against the atmosphere. The net work done by the fluid during the process is 2 kJ. The speed of the electric motor driving the stirrer is 840 rpm. Determine the torque in the shaft and the power output of the motor.

(*b*) A gas with a velocity of 300 m/s is flowing through a horizontal pipe at a section where pressure is 6×10^4 N/m^2 (absolute) and temperature is 40°C. The pipe changes in diameter and at this section the pressure is 9×10^4 N/m^2. Find the velocity of the gas at this section if the flow of the gas is adiabatic.

2. (*a*) One mol of an ideal gas ($\gamma = 1.4$) at 0.5 MPa and 300 K is heated at constant pressure till the volume is doubled and then it is allowed to expand reversibly and adiabatically till the temperature is reduced to 300 K. Calculate the heat and work interactions. If it is desired to restore the system from final state to its original state by a reversible isothermal path, determine the amount of work to be done on the system.

(*b*) Explain the phenomenon of diesel knock and discuss various parameters which encourage knocking.

3. (*a*) Find the surface area required for surface condenser dealing with 25,000 kg of saturated

steam per hour at a pressure of 0.5 bar. Temperature of condensing water is 25 °C. Cooling water is heated from 15 °C to 25 °C while passing through the condenser. Assume a heat transfer coefficient of 10 kW/m^2K. The condenser has 2 water passes with tubes of 19 mm outer diameter and 1.2 mm thickness. Find the length and number of tubes per pass. Assume velocity of water to be 1 m/s. Assume correction factor for two tube pass exchanger 0.86. At 0.5 bar pressure, saturation temperature is 32.55 °C and latent heat is 2560 kJ/kg. Specific heat of water is 4.18 kJ/kg.K and density is 1000 kg/m^3.

(*b*) Calculate the entropy change of the universe because of the following processes :

(*i*) A copper block of 800 g mass having C_p = 150 J/K at 120 °C is placed in a lake at 6 °C

(*ii*) The same block is dropped from a height of 100 m into the lake

(*iii*) Two such blocks at 120 °C and 0 °C, are joined together.

4. (*a*) Three thin-walled, long, circular cylinders 1, 2 and 3 of diameter 150 mm, 250 mm and 350 mm respectively are arranged concentrically. Temperature of cylinder 1 is 80 K and that of cylinder 3 is 300 K. Emissivity of cylinder 1, 2 and 3 are 0.05, 0.1 and 0.2 respectively. Assuming that there is vacuum inside the annular spaces,

determine the steady state temperature attained by cylinder 2.

(*b*) An air standard limited pressure cycle has a compression ratio of 15 and compression begins at 0.1 MPa, 40 °C. The maximum pressure is limited to 6 MPa and the heat added is 1.675 MJ/kg. Compute :

(*i*) the heat supplied at constant volume per kg of air

(*ii*) the heat supplied at constant pressure per kg of air

(*iii*) the work done per kg of air

(*iv*) the cycle efficiency

(*v*) the mean effective pressure of the cycle.

5. (*a*) What are the differences between mountings and accessories in boilers ? Discuss the following :

(*i*) Water level indicator

(*ii*) Blow of cock

(*iii*) Superheater

(*iv*) Economiser

(*b*) A layer of 5 cm refractory brick (k = 2 W/mK) is to be placed between two 4 mm thick steel (k = 40 W/mK) plates. Both faces of the brick adjacent to the plates have rough solid to solid contact over 20% of the area, where the average height of asperities is 1 mm. The outer surface temperature of steel plates are 400 °C and 100 °C respectively. Find :

(*i*) The rate of heat flow per unit area assuming that the cavity area is filled with air (k = 0.02 W/mK).

(*ii*) The rate of heat flow, if the faces of brick are smooth and have solid to solid perfect contact over entire area.

6. (*a*) Show that in a turbine, with radial vanes at inlet and outlet, the hydraulic efficiency is given by :

$$\eta_h = \frac{1}{2 + \tan^2 \alpha_1}$$

where, α_1 is the guide blade angle. Assume the flow velocity to be constant.

(*b*) A horizontal pipeline 40 m long is connected to a water tank at one end and discharges freely into the atmosphere at the other end.

For the first 25 m of its length from the tank, the pipe is 150 mm diameter and its diameter is suddenly enlarged to 300 mm. The height of the water level in the tank is 8 m above the center of the pipe. Considering all head losses which occur, determine the rate of flow. Take coefficient of friction, f = 0.01 for both the sections of pipe.

7. (*a*) Discuss various regimes of pool boiling along with a neat sketch.

(*b*) A mixture of dry air and water vapour is at a temperature of 22 °C under a total pressure of 730 mm Hg. The dew point temperature is 15 °C. Find :

(*i*) Partial pressure of water vapour

(*ii*) Relative humidity

(*iii*) Specific humidity

(*iv*) Enthalpy of air per kg of dry air

(*v*) Specific volume of air per kg of dry air.

8. Explain the following :

(*i*) Pollutants from SI engines

(*ii*) Major and minor losses in flow through pipes

(*iii*) Critical thickness of insulation

(*iv*) Cavitation.