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Question Paper Code: E3129

B.E./B.Tech. DEGREE EXAMINATION, APRIL/MAY 2010

Third Semester

Mechanical Engineering

ME2202 — ENGINEERING THERMODYNAMICS

(Regulation 2008)

Time: Three hours Maximum: 100 Marks

(Use of Standard Thermodynamic Tables, Mollier Diagram, Psychometric Chart and Refrigerant Property Tables is permitted)

Answer ALL Questions

PART A — (10 × 2 = 20 Marks)

1. What do you understand by flow work? Is it different from displacement work?

2. Which property of a system increases when heat is transferred:

   (a) At constant volume

   (b) At constant pressure?

3. What do you understand by dissipative effects? When work is said to be dissipated?

4. Isentropic process need not be necessarily an adiabatic process – Justify.

5. What is critical state? Define the term critical pressure, critical temperature and critical volume of water.

6. Why is Carnot Cycle not practicable for a steam power plant?

7. Write down the Vander Waals equation of state. How does it differ from the ideal gas equation of state?

8. Define Joule – Kelvin effect. What is inversion temperature?

9. Define specific humidity. How does it differ from relative humidity?

10. What is evaporative cooling? Will it work in humid climates?

PART B — (5 × 16 = 80 Marks)

11. (a) (i) The resistance of the windings in a certain motor is found to be 75 ohms at room temperature (25°C). When operating at full load under steady state conditions, the motor is switched off and the resistance of the windings is immediately measured again, and found to be 90 ohms. The windings are made of copper whose resistance at temperature at t°C is given by $R_t = R_0[1 + 0.00393t]$ where R_0 is the resistance at 0°C. Find the temperature by the coil during full load. (8)

(ii) At the beginning of the compression stroke of a two-cylinder internal combustion engine the air is at a pressure of 101.325 kPa. Compression reduces the volume by 1/5 of its original volume, and the law of compression is given by $pv^{1.2}$ = constant. If the bore and stroke of each cylinder is 0.15 m and 0.25 m respectively, determine the power absorbed in kW by compression strokes when the engine speed is such that each cylinder undergoes 500 compression strokes per minute. (8)

Or

(b) (i) The properties of a system, during a reversible constant pressure non-flow process at $P = 1.6$ bar, changed from $v_1 = 0.3\text{m}^3/\text{kg}$, $T_1 = 20°\text{C}$ to $v_2 = 0.55\text{m}^3/\text{kg}$, $T_2 = 260°\text{C}$. The specific heat of the fluid is given by

$$C_p = \left(1.5 + \frac{75}{T + 45}\right) \text{kJ/kg°C}$$

where T is in °C. Determine the heat added, work done, change in internal energy and change in enthalpy per kg of fluid. (8)

(ii) A nozzle is a device for increasing the velocity of a steadily flowing stream. At the inlet to a certain nozzle, the enthalpy of the fluid passing is 3000 kJ/kg and the velocity is 60 m/s. At the discharge end, the enthalpy is 2762 kJ/kg. The nozzle is horizontal and there is negligible heat loss from it.

(1) Find the velocity at exit from the nozzle.

(2) If the inlet area is 0.1 m^2 and the specific volume at the inlet is 0.187 m^3/kg, find the mass flow rate.

(3) If the specific volume at the nozzle exit is 0.498 m^3/kg, find the exit area of the nozzle. (8)

12. (a) (i) Show that the efficiency of a reversible engine operating between two given constant temperatures is the maximum. (8)

(ii) A heat pump working on the Carnot cycle takes in heat from a reservoir at 5°C and delivers heat to a reservoir at 60°C. The heat pump is driven by a reversible heat engine which takes heat from reservoir at 840°C and rejects heat to a reservoir at 60°C. The reversible heat engine also drives a machine that absorbs 30 kW. If the heat pump extracts 17 kJ/s from the reservoir at 5°C, determine

(1) The rate of heat supply from 840°C source, and

(2) The rate of heat rejection to 60°C sink. (8)

Or

(b) (i) Determine the maximum work obtainable by using one finite body at temperature T and a thermal energy reservoir at temperature T_0, $T > T_0$. (8)

(ii) An aluminium block $(c_p = 400\,J/kg\,K)$ with a mass of 5 kg is initially at 40°C in room air at 20°C. It is cooled reversibly by transferring heat to a completely reversible cyclic heat engine until the block reaches 20°C. The 20°C room air serves as a constant temperature sink for the engine. Compute

(1) The change in entropy for the block,

(2) The change in entropy for the room air,

(3) The work done by the engine. (8)

13. (a) (i) Steam flows through a small turbine at the rate of 5000 kg/h entering at 15 bar, 300°C and leaving at 0.1 bar with 4% moisture. The steam enters at 80 m/s at a point 2 m above the discharge and leaves at 40 m/s. Compute the shaft power assuming that the device is adiabatic but considering kinetic and potential energy changes. Calculate the diameters of the inlet and discharge tubes. (8)

(ii) Steam expands isentropically in a nozzle from 1 MPa, 250°C to 10 kPa. The steam flow rate is 1 kg/s. Find the velocity of steam at the exit from the nozzle, and the exit area of the nozzle. Neglect the velocity of steam at inlet to the nozzle. The exhaust steam from the nozzle flows into a condenser and flows out as saturated water. The cooling water enters the condenser at 25°C and leaves at 35°C. Determine the mass flow rate. (8)

Or

(b) (i) With a neat diagram, explain the regenerative Rankine cycle with an open feedwater heater. (8)

(ii) In a thermal plant operating on a Rankine cycle, superheated steam at 50 bar and 500°C enters a turbine, the isentropic efficiency of which is 0.8. The condenser pressure is 0.05 bar and it delivers saturated liquid to a feed pump, the isentropic efficiency of which is 0.7. Determine the thermal efficiency of the power plant and the mass flow rate of steam required for 50 MW net power generation. (8)

14. (a) (i) Explain how real gases deviate from an ideal gas behaviour. (4)

(ii) Why does isothermal compression need minimum work and adiabatic compression need maximum work? (4)

(iii) A certain quantity of air initially at a pressure of 8 bar and 280°C has a volume of 0.035 m^3. It undergoes a cycle consisting of the following processes:

(1) Expands at constant pressure to 0.1 m^3.

(2) Follows polytropic process with $n = 1.4$ and

(3) A constant temperature process which completes the cycle.

Evaluate the heat received and rejected in the cycle and cycle efficiency. (8)

Or

(b) (i) Derive the Clapeyron equation. (8)

(ii) Over a certain range of pressures and temperatures the equation of a certain substance is given by the relation

$$v = \frac{RT}{p} - \frac{C}{T^3}$$

where C is constant. Derive an expression for:

(1) The change of enthalpy and

(2) The change of entropy, of this substance in an isothermal process. (8)

15. (a) (i) Explain the process of cooling and dehumidification. (8)

(ii) Explain with an example evaporative cooling. (8)

Or

(b) (i) Two streams of air 25°C, 50% RH and 25°C, 60% RH are mixed adiabatically to obtain 0.3 kg/s of dry air at 30°C. Calculate the amounts of air drawn from both the streams and humidity ratio of the mixed air. (6)

(ii) An air-conditioned room requires 30 m^3/min of air at 1.013 bar, 20°C, 52.5% RH. The steady flow conditioner takes in air at 1.013 bar, 77%RH, which it cools to adjust the moisture content and reheats to room temperature. Find the temperature to which the air is cooled and thermal loading on both the cooler and heater. Assume that a fan before the cooler absorbs 0.5 kW, and that the condensate is discharged at the temperature to which the air is cooled. (10)

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