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B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2022.

Third Semester

Aeronautical Engineering

AE 8301 — AERO ENGINEERING THERMODYNAMICS

(Common to Aerospace Engineering)

(Regulations 2017)

Time : Three hours Maximum : 100 marks

(Use of steam table is permitted)

Answer ALL questions.

PART A — (10 × 2 = 20 marks)

1. What is meant by microscopic and macroscopic form of thermodynamic studies?
2. What is meant by throttling process?
3. What are the various irreversibilities that are commonly encountered?
4. State Clausius inequality for a cyclic process.
5. What is meant by detonation?
6. Define back work ratio of a gas turbine.
7. Define dryness fraction.
8. What is the difference between reheat and regeneration cycle?
9. Define specific impulse.
10. State Fourier's law of heat conduction.

PART B — (5 × 13 = 65 marks)

11. (a) (i) One kg of air is expanded in piston-cylinder system from a specific volume of v = 0.2 m³/kg and temperature of 580 K to a specific volume of v = 0.8 m³/kg and a temperature of 290 K. The expansion process is given by $pv^{1.5} = 0.75$ (p in bar and v in m³/kg). Determine the work and heat interaction. (8)

(ii) Nitrogen gas flows into a convergent nozzle at 200 kPa, 400 K and very low velocity. It flows out of the nozzle at 100 kPa, 330 K. If the nozzle is insulated, find the exit velocity. (5)

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(b) (i) In a gas turbine the gas enters at the rate of 5 kg/s with a velocity of 50 m/s and enthalpy of 900 kJ/kg leaves the turbine with a velocity of 150 m/s and enthalpy of 400 kJ/kg. The loss of heat from the gases to the surroundings is 25 kJ/kg. Assume for gas R = 0.285 kJ/kgK and c_p = 1.004 kJ/kgK and inlet conditions to be at 100 kPa and 27°C. Determine the power output of the turbine. (8)

(ii) Air is flowing in a 0.2 m diameter pipe at a uniform velocity of 0.1 m/s. The temperature is 25°C and the pressure 150 kPa. Determine the mass flow rate. (5)

12. (a) (i) An insulated cylinder of volume capacity 4 m³ contains 20 kg of nitrogen. Paddle work is done on the gas be stirring it till the pressure in the vessel gets increased from 4 bar to 8 bar. Determine change in internal energy, work done, change in entropy. Take for nitrogen $c_p = 1.04\ kJ/kg$ K and $c_v = 0.7432$ kJ/kg K. (8)

(ii) Show that the efficiency of all reversible heat engines operating between the given two thermal reservoirs is same. (5)

Or

(b) (i) Demonstrate the equivalence of Kelvin-Planck and Clausius statement with necessary sketches. (8)

(ii) Find out the maximum work that can be obtained in cyclic processes when the heat is withdrawn with and without constant source temperature. (5)

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13. (a) An air standard dual cycle has a compression ratio of 16 and compression begins at 1 bar, 50°C. The maximum pressure is 70 bar. The heat transferred to air at constant pressure is equal to that at a constant volume. Estimate (i) the pressures and temperatures at the cardinal points of the cycle, (ii) the cycle efficiency (iii) the mean effective pressure of the cycle, c_v = 0.718 kJ/kg K, cp 1.005 kJ/kg K.

Or

(b) (i) A gas-turbine power plant operating on an ideal Brayton cycle has a pressure ratio of 8.The gas temperature is 300 K at the compressor inlet and 1300 K at the turbine inlet. Utilizing the air-standard assumptions, determine

(1) The gas temperature at the exits of the compressor and the turbine,

(2) The back work ratio and

(3) The thermal efficiency. (8)

(ii) An air-standard Ericsson cycle has an ideal regenerator. Heat is supplied at 1000°C and heat is rejected at 80°C. Pressure at the beginning of the isothermal compression process is 70 kPa. The heat added is 700 kJ/kg. Find the compressor work, the turbine work, and the cycle efficiency. (5)

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14. (a) (i) Explain in detail about the formation of superheated steam from 20°C of ice with T-v diagram. Also explain various processes involved in it. (8)

(ii) Find the dryness fraction, specific volume and internal energy of steam at 7 bar and enthalpy 2550 kJ/kg. (5)

Or

(b) (i) Steam at 20 bar, 360°C is expanded in a steam turbine to 0.08 bar. It then enters a condenser, where it is condensed to saturated liquid water. The pump feeds back the water into the boiler.

(1) Assuming ideal processes, find net work per kg of steam and the cycle efficiency.

(2) If the turbine and the pump each have 80% efficiency, find the percentage reduction in the net work and cycle efficiency. (10)

(ii) What are the difficulties in applying Carnot cycle to steam power plant? (3)

15. (a) A turbojet aircraft flies at sea level at a Mach number of 1.5 at an altitude where ambient pressure and ambient temperature are 11.6 kPa and 205 K respectively, Mass flow rate is 50 kg/s, compressor pressure ratio is 12, temperature in combustion chamber is 1400 K. Assume the turbojet operates on ideal Brayton cycle. Take calorific value of fuel used as 45 MJ/kg, $\gamma = 1.4$, $C_p = 1$ kJ/kg-K. Calculate the thrust developed by the engine by assuming the nozzle exit pressure is equal to the ambient pressure.

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Or

(b) (i) A plane wall is 150 mm thick and its wall area is 4.5 m². If its conductivity is 9.35 W/m°C and surface temperatures are steady at 150°C and 45°C , determine :

(1) Heat flow across the plane wall;

(2) Temperature gradient in the flow direction. (8)

(ii) A surface at 250°C exposed to the surroundings at 110°C convects and radiates heat to the surroundings. The convective coefficient and radiation factor are 75 W/m² °C and unity respectively. If the heat is conducted to the surface through a solid of conductivity 10 W/m°C, what is the temperature gradient at the surface in the solid? (5)

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PART C — (1 × 15 = 15 marks)

16. (a) (i) Steam is the working fluid in an ideal Rankine cycle with superheat and reheat. Steam enters the first-stage turbine at 8.0 MPa, 480°C, and expands to 0.7 MPa. It is then reheated to 440°C before entering the second-stage turbine, where it expands to the condenser pressure of 0.008 MPa. The net power output is 100 MW. Determine

(1) The thermal efficiency of the cycle,

(2) The mass flow rate of steam, in kg/h,

(3) The rate of heat transfer Q_{out} from the condensing steam as it passes through the condenser, in MW. Discuss the effects of reheat on the vapor power cycle. (10)

(ii) Determine whether water at each of the following states is a compressed liquid, a superheated vapor, or a mixture of saturated liquid and vapor. (5)

(1) P = 10 MPa, V = 0.003 m³/kg

(2) 1 MPa, 190°C.

Or

(b) (i) Steam enters a nozzle at 400°C and 800 kPa with a velocity of 10 m/s, and leaves at 300°C and 200 kPa while losing heat at a rate of 25 kW. For an inlet area of 800 cm², determine the velocity and the volume flow rate of the steam at the nozzle exit. (8)

(ii) Calculate the entropy change of the universe as a result of the following processes : (7)

(1) A copper block of 600 g mass and with C = 250 J/kg.K at 100°C is placed in a lake at 8°C.

(2) The same block, at 8°C, is dropped from a height of 100 m into the lake.

(3) Two such blocks at 100°C and 0°C are joined together.

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