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B.E./B.Tech. DEGREE EXAMINATIONS, NOVEMBER/DECEMBER 2023.

Third Semester

Aeronautical Engineering

AE3351 – AERO ENGINEERING THERMODYNAMICS

(Common to Aerospace Engineering)

(Regulations 2021)

Time : Three hours | Maximum : 100 marks

Answer ALL questions.

PART A — ($10 \times 2 = 20$ marks)

1. List the limitations of first law of thermodynamics.

2. What is throttling process?

3. Differentiate heat pump and refrigerator.

4. What is the principle of increase of entropy?

5. Draw p-V and T-S diagram for Stirling cycle.

6. A Diesel engine has a compression ratio of 14 and cut-off takes place at 6% of the stroke. Find the cut off ratio.

7. What is mean effective pressure?

8. How Reheat Rankine cycle is better than Rankine cycle?

9. What is thrust augmentation?

10. Differentiate forced and free convection.

PART B — (5 × 13 = 65 marks)

11. (a) (i) A fluid is confined in a cylinder by a spring - loaded, frictionless piston so that the pressure in the fluid is linear function of volume ($p = a + bV$). The internal energy if the fluid is given by $U = (34 + 3.15\ pV)$ where U is kJ, p in kPa and V in m^3. If the fluid changes from an initial state of 170 kPa, 0.03 m^3 to a final state of 400 kPa, 0.06 m^3, with no work other than that done on the piston, find the direction and magnitude of work and heat transfer. (6)

(ii) A gas occupies 0.3 m^3 at 2 bar. It executes a cycle consisting of processes : (1) 1-2; constant pressure with work interaction of 15 kJ. (2). 2-3 ; compression process which follows the law pV = constant. and $U_3 = U_2$. (3). 3-1 ; constant volume process, and change in internal energy is 40 kJ. Neglect change in KE and PE. Draw pV diagram for the process and determine network transfer for the cycle. Also show that first law is obeyed by the cycle. (7)

Or

(b) Air at a temperature of 15°C passes through a heat exchanger at a velocity of 30 m/s where its temperature is raised to 800°C. It then enters a turbine with the same velocity of 30 m/s and expands until the temperature falls to 650°C. On leaving the turbine, the air is taken at a velocity of 60 m/s to a nozzle where it expands until the temperature has fallen to 500°C. If the air flow rate is 2kg/s. calculate the

(i) rate of heat transfer to the air in the heat exchanger

(ii) power output from the turbine assuming no heat loss, and

(iii) Velocity at exit from the nozzle, assuming no heat loss.

Take the enthalpy of air as $h = C_pT$, where C_p – is the specific heat capacity equal to 1.005 kJ/Kg K and T – Temperature. (13)

12. (a) Two reversible heat engines A and B are arranged in series. Engine A rejecting head directly to engine B, receives 200 kJ at a temperature of 421°C from a hot source, while engine B is in communication with a cold sink at a temperature of 4.4°C. If the work output of A is twice that of B, Find the

(i) The intermediate temperature between A and B.

(ii) The efficiency of each engine.

(iii) The heat rejected to the cold sink. (13)

Or

(b) (i) With a neat sketch draw the Carnot cycle and derive the Carnot efficiency. (6)

(ii) One kg of ice at –5°C is exposed to the atmosphere which is at 20°C. The ice melts and comes into thermal equilibrium with the atmosphere. Determine the entropy increase of the universe. (7)

13. (a) An engine working on Otto cycle has a volume of 0.45 m^3, pressure 1 bar and temperature 30°C at the beginning of compression stroke. At the end of compression stroke, the pressure is 11 bar. 210 kJ of heat is added at constant volume. Determine :

(i) Pressures, temperatures and volumes at salient points in the cycle.

(ii) Percentage clearance.

(iii) Efficiency.

(iv) Mean effective pressure.

(v) Ideal power developed by the engine if the number of working cycles per minute is 210.

Assume the cycle is reversible. (13)

Or

(b) Derive the air standard efficiency for Atkinson cycle. (13)

14. (a) Two streams of steam, one at 2 MPa, 300°C and the other at 2 MPa, 400°C, mix in a steady, flow adiabatic process. The rates of flow of the two streams are 3 Kg/min. and 2 Kg/min. respectively. Evaluate the final temperature of the emerging steam if there is no pressure drop due to the mixing process. What would be the rate of increase in the entropy of the universe? This steam with negligible velocity now expands adiabatically in a nozzle to a pressure of 1 kPa. Determine the exit velocity of the steam and exit area of nozzle. (13)

Or

(b) A steam power station uses the following cycle :

Steam at boiler outlet 150 bar, 550 °C

Reheat at 40 bar to 550 °C

Condenser at 0.1 bar.

Assuming ideal processes, find the

(i) quality at turbine exhaust,

(ii) cycle efficiency and

(iii) steam rate. (13)

15. (a) A furnace wall is made up of three layers of thicknesses 250 mm, 100 mm and 150 mm with thermal conductivities of 1.65 k and 9.2 W/m°C respectively. The inside is exposed to gases at 1250 °C with a convection coefficient of 25 W/m^2 °C and the inside surface is at 1100 °C, the outside surface is exposed air at 25 °C with convection coefficient of 12 W/m^2 °C. Determine :

(i) The unknown thermal conductivity 'k'

(ii) The overall heat transfer coefficient

(iii) All surface temperatures. (13)

Or

(b) Calculate the thrust, specific impulse, propulsive efficiency, thermal and overall efficiencies of a rocket engine from the following data :

Effective jet velocity 1250 m/s

Flight to jet speed ratio 0.8

Oxidizer flow rate 3.5 kg/s

Fuel flow rate = 1 kg/s

Heat of reaction of exhaust gases = 2500 kJ/kg. (13)

PART C — (1 × 15 = 15 marks)

16. (a) 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.

(i) Assuming ideal processes, find per kg of steam the network and cycle efficiency.

(ii) If the turbine and pump have each 80% efficiency, find the percentage reduction in the network and cycle efficiency. (15)

Or

(b) Calculate the thrust and specific thrust of a jet propulsion unit whose data are as follows :

Total head isentropic efficiency of compressor = 80%

Total head isentropic efficiency of turbine = 85%

Total pressure ratio including combustor pressure loss = 4 : 1

Combustion efficiency = 98%

Mechanical transmission efficiency = 99%

Nozzle efficiency = 90%

Maximum cycle temperature = 1000 K

Air rate of flow = 220 N/S

For air C_p = 1005 J/kg-K ; γ = 1.4

For gases C_p = 1153 J/kg-K ; γ = 1.3

Ambient temperature and pressure are 15 °C and 1 bar.

Neglect the weight of fuel. (15)