Total Pages—6

(Set-Q_1)

M.Tech - 1st(Mech-HPE)

Advanced Engineering Thermodynamics

Full Marks : 70

Time : 3 hours

Answer any six questions including Q. No. 1 which is compulsory

The figures in the right-hand margin indicate marks

Use of standard tables and charts are permitted

1. Explain *all* questions : 2 × 10

(*a*) Air at 500K, 500kPa is expanded to 100 kPa in two steady-flow cases. Case 1 is a throttle and case 2 is a turbine. Which has highest exit temperature ? Why ?

(*b*) An initially empty cylinder is adiabatically filled with air from 20°C, 100 kPa until it is full. Is the final temperature larger, equal to, or smaller then 20°C ? Does the final T depend on the size of the cylinder ?

(*c*) A room is heated with a 1500 W electric

heater. How much power can be saved ? If a heat pump with a COP of 2·0 is used instead ?

(*d*) A computer chip dissipates 2 kJ of electric work over time and rejects that as heat transfer from its 50°C surface to 25°C ambient. How much entropy is generated in the chip ? How much, if any, is generated outside the chip ?

(*e*) An inventor claims to develop an adiabatic, steady flow turbine such that entropy at the exit is less then entropy at inlet. Is the claim true ? Justify.

(*f*) The shaft work in a pump to increase the pressure is small compared to the shaft work in an air compressor for the same pressure increase. Why ?

(*g*) Does a reversible process change the availability if there is no work involved ?

(*h*) A heat engine receives 1000 W heat at 1000 K and gives out 600 W as work with the rest as heat transfer to the ambient. Find the first and second law efficiencies.

(*i*) Define enthalpy of formation and its significance in analysis of reactive system.

(*j*) Discuss metastable equilibrium with suitable examples.

2. (*a*) A vessel having a volume of 5 m^3 contains 0·05m^3 of saturated liquid water and 4·95 m^3 saturated vapor at 0·1 MPa. Heat is transferred until the vessel is filled with saturated vapor. During the process the vessel is lifted to a height of 100 m at constant velocity from the ground. Determine the heat transfer for the process. 5

(*b*) Oxygen at 300 kPa and 100°C is in a piston/cylinder arrangement with a volume of 0·1 m^3. It is now compressed in a polytropic process with exponent $n = 1·2$ to a final temperature of 200°C. Calculate the heat transfer for the process. 5

3. (*a*) A 750-L rigid tank, initially contains water at 250°C, which is 50% liquid and 50% vapor, by volume. A valve at the top of the tank

is opened and saturated vapor is slowly withdrawn. Heat transfer takes place such that the temperature remains constant. Find the amount of heat transfer required to reach the state where half the initial mass is withdrawn. 6

(*b*) A diffuser, has air entering at 100 kPa and 300 K with a velocity of 200 m/s. The inlet cross-sectional area of the diffuser is 100 mm^2. At the exit, the area is 860 mm^2, and the exit velocity is 20 m/s. Determine the exit pressure and temperature of the air. 4

4. (*a*) Air at 300 K and 100 kPa with a volume 0·1 m^3 is compressed in a reversible adiabatic process to a final temperature of 700 K. Find the final pressure and volume. 4

(*b*) A de-superheater works by injecting liquid water into a flow of superheated steam. With 2 kg/s at 300 kPa, 200°C, steam flowing in, what mass flow rate of liquid water at 20°C should be added to generate saturated vapor at 300 kPa ? What will be the rate of entropy generation in the process ? 6

5. (*a*) A gas mixture at 120°C and 125 kPa is 50%N_2, 30%H_2O, and 20% O_2 on a mole basis. Find the mass fractions, the mixture gas constant and the volume for 5 kg of mixture. 5

(*b*) Nitrogen at 8 MPa, 150 K, is throttled to 0·5 MPa. After the gas passes through a short length of pipe, its temperature is measured and found to be 125 K. Determine the heat transfer using the generalized charts. 5

6. (*a*) 5 kg/s water at 5 MPa and 40°C flowing through a feed water heater. The feed water heater is heated from two sources, one source adds 900 kW from a 100°C reservoir, and the other source adds heat from a 200°C reservoir such that the water exit condition is 5MPa, 180°C. Find the irreversibility and second law efficiency. 6

(*b*) A heat exchanger increases the availability of 3 kg/s water by 1650 kJ/kg using 10kg/s air coming in at 1400 K and leaving with 600 kJ/kg less availability. What are the irreversibility and second law efficiency ? 4

7. (*a*) A small gas turbine uses C_8H_{18}(I) for fuel and 400% theoretical air. The air and fuel enter at 25°C and the product of combustion leave at 900 K. The output of the engine and the fuel consumption are measured, and it is found that the specific fuel consumption is 0·25 kg/s of fuel per megawatt output. Determine the heat transfer from the engine per kilomole of the fuel. 6

(*b*) Discuss : 4

(*i*) Enthalpy of combustion.

(*ii*) Adiabatic flame temperature.

8. One kilomole of carbon at 25°C and 0·1 MPa pressure reacts with 1 kmol of oxygen at 25°C and 0·1 MPa pressure to form an equilibrium mixture of CO_2, CO and O_2 at 3000 K, 0·1 MPa pressure in a steady-state process, Determine

(*a*) The equilibrium composition. 6

(*b*) Heat transfer for the above process. 4