Assignment 6

Note: A large number of problems is given so that students can practice. For submission, odd and even roll number students may give odd and even numbered problems respectively

1. A conductor connects reservoirs at temperatures of 1000 K and 400 K. The steady rate of heat from the hot to the cold reservoir is 100 W. Determine the rate of entropy production in the conductor. (Ans.: S_p = 0 15 W/K))
2. 1 kg of water in a cylinder piston arrangement is initially in saturated liquid state at 7 bar, it absorbs heat from a reservoir at 200°C. During the process, the piston moves in such a way that the pressure remains constant. At the end of the process, water has completely evaporated into steam (x = 1). Determine (a) Heat transfer, (b) Change in entropy of the system, (c) Change in entropy of the reservoir and (d) Change in entropy of the universe (Ans.: Q = 2066.3 kJ, ΔS_{sys} = 4.716 kJ/K, ΔS_{res} -4.367 kJ/K, ΔS_u = 0.349 kJ/K).
3. A thermally insulated cylinder, closed at both ends, is fitted with a leak proof, frictionless, diathermic piston, which divides the cylinder into two parts. Initially, the piston is clamped in the centre, with 1 litre of air at 300 K and 2 bar on one side and 1 litre of air at 300 K and 1 bar on the other side. The piston is released, and it reaches equilibrium in pressure and temperature at a new position. Compute the final pressure, temperature and the change in entropy. Which irreversible process has taken place? (Ans. P_{final} = 1.5 bar, T_{final} = 300 K, ΔS = 0.05663 J/K)
4. 3 kg of an ideal gas in a rigid insulated container changes its state from 50 N/m^2 and 300 K to 150 N/m^2, while it is stirred. Assuming c_p = 1.0 kJ/kg-K and Υ = 1.4, determine change in entropy of the system. (Ans: ΔS = 2.354 kJ/K)
5. An insulated chamber of volume $2V_o$ is divided by a thin, rigid partition into two parts of volume V_o each. One chamber contains an ideal gas at a pressure of P_0 and T_0. The other chamber is evacuated. The partition is suddenly removed. Show that when equilibrium is re-established, the temperature is T_0. Determine the change in entropy, which irreversible process has taken place. (Ans: ΔS = mR1n2)
6. 10 kg of dry saturated steam at 30 bar, contained in a cylinder-piston arrangement is brought into thermal contact with a heat sink at 200°C. The steam rejects 16,200kJ of heat during a constant pressure process. Determine (a) final state of the steam, (b) change in entropy of steam, and (c) change in entropy of the universe (Ans: x = 0.0979, ΔS = -31.943 kJ/K, ΔS_u = 2.296 kJ/K).
7. 2 kg of saturated liquid water at 1 bar is mixed adiabatically with 4 kg of steam at I bar and 300°C. During this process, the pressure remains constant. Determine the final state and the change in entropy. (Ans: x = 0.7844, ΔS = 0.855 kJ/K).
8. 1 kg of liquid at 300 K is mixed with 1 kg of the same liquid at 400 K in an adiabatic calorimeter. Assume that there is no change of phase and that the density and specific heat of the liquid remains constant at 1200 kg/m^3 and 5 kJ/kg-K. Calculate the change in entropy of the system. (Ans: ΔS = 0.1031 kJ/K).
9. 1 kg of an ideal gas at 10 bar and 600 K is mixed with 1 kg of the same gas at 5 bar and 400 K. The mixing takes place at constant volume. During the process, the system rejects 200 kJ of heat to the environment, which remains at 300 K. If the gas properties are, RMM = 32 and

$\Upsilon = 1.4$, determine (a) final state (volume, temperature, pressure) and (b) change in entropy of the universe. (Ans: (a) $T_3 = 346$ K, $V_3 = 0.3637\ m^3$, $P_3 = 4.945$ bar, (b) $\Delta S_u = 0.22$ kJ/K).

10. Determine if the processes in exercises 4.7 and 4.8 are possible or impossible. Determine the limiting exit state in either case. Assume the pressure at exit is maintained. (Ans: (4.7) possible, $x_{limit} = 0.985$, $W_{limit} = -409.2$ kW, (4.8) Not possible, $x_{limit} = 0.969$ $V_{e\text{-}limit} = 797.4$ m/s).
11. Steam enters the nozzle of a steam turbine with a velocity of 3 m/s at a pressure of 40 bar and 600^o C. The pressure and temperature at the nozzle exit were measured as 1 bar, 250^oC. Determine (a) exit velocity (b) the entropy production rate, if the flow rate of steam is 1.6 kg/s and (c) isentropic efficiency of the nozzle. (Ans: (a) $V_e = 1183.3$ m/s, (b) $\dot{S}_p = 1.0624$ kW/K, $\eta_e = 0.7034$)
12. An adiabatic steam turbine handles 10 kg/s of steam. The inlet state is at 10 bar, dry saturated steam. The exit pressure is 1 bar. The isentropic efficiency of the turbine is 0.8. Determine (a) exit state, (b) power output and (c) entropy production rate. (Ans: a) $x_e = 0.907$, b) $\dot{S}_p = 2.096$ kW/K, c) W= 3126 kW).
13. In a heat exchanger, air is heated from 20 ^oC to 80 ^oC by means of a second stream which enters the heat exchanger at 150 ^oC. Both streams have a flow rate of 1 kg/s and flow is without any loss in pressure. Determine (a) heat transferred between the two streams and (b) entropy production rate. Assume $c_p = 1.0$ kJ/Kg-K for air. (Ans: Q = 60 kW, $\dot{S}_p = 0.0333$ kW/K).
14. 150 kg/hr of saturated water at 7 bar enters a heat exchanger and leaves at 5 bar, 200^oC. Hot air enters at 500^oC, 2 bar and leaves at 250^oC, 2 bar. Determine (a) flow rate of air, (b) heat transfer rate from air to water, (c) rate of net entropy outflow for each steam and (d) entropy production rate. (Take $c_p = 1.0$ kJ/kg-K for air). (Ans: $\dot{m} = 0.3597$kg/s, $\dot{Q} = 89.93$ kW, (c) For stream $\dot{m}\Delta S = -01405$kW.K, (d) $S_p = 0.0706$ kW/K).
15. An inventor claims to have built an engine that works between 600 ^oC and 300 ^oC, and works with an efficiency of 40 percent. Do you think this claim is justified? Explain (Ans. not possible, $\eta_{engine} > \eta_{carnot}$).
16. A steel casting of mass 100 kg is quenched in oil of specific heat of which is 2.0 kJ/kg K. The mass of oil in the quenching tank is 5000 kg and it is initially at a temperature of 300 K. The initial temperature of the casting is 700 K and its specific heat is 0.4 kJ/kg-K. Determine the temperature after quenching and the entropy produced during the process. (Ans.: T = 298.4 K, $S_p = 18.9$kJ/K).
17. A 5 kg metal block falls down 10 m onto a solid ground. If the initial and final temperatures of the block are both 30^o C, determine the entropy produced. What irreversible process has taken place? Assume that the environment remains at 30^oC throughout. (Ans.: $S_p = 1.618$ J/K)
18. A compressor is used to compress 3 kg/s of carbon dioxide form 0.1 bar 300 K to 10 bar. If the isentropic efficiency of the compressor is 0.8, determine (a) compressor exit temperature (b) power required to drive the compressor and (c) what is the rate of entropy in the compressor? Data $\gamma = 4/3$ for CO_2, (Ans.: T = 1110.8 K, W = -1839 kW, $S_p = 0.3578$kW/K)