

Course : Applied Thermal Engineering (UMT303)

Batch: B.E. Mechatronics (2nd yr.)

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Tutorial No. 06

Topic: Entropy

Q1. A cryogenic manufacturing facility handles liquid methane at 115 K and 5 MPa at a rate of 0.280 m³/s . A process requires dropping the pressure of liquid methane to 1 MPa, which is done by throttling the liquid methane by passing it through a flow resistance such as a valve. A recently hired engineer proposes to replace the throttling valve by a turbine in order to produce power while dropping the pressure to 1 MPa. Determine the maximum amount of power that can be produced by such a turbine. Also, determine how much this turbine will save the facility from electricity usage costs per year if the turbine operates continuously (8760 h/yr) and the facility pays \$0.075/kWh for electricity.[Ans. 1123kW, 737800 USD/yr]

Q2. Air is compressed steadily by a reversible compressor from an inlet state of 100 kPa and 300 K to an exit pressure of 900 kPa. Determine the compressor work per unit mass for (a) isentropic compression with $k = 1.4$, (b) polytropic compression with $n = 1.3$, (c) isothermal compression, and (d) ideal twostage compression with intercooling with a polytropic exponent of 1.3 [Ans. 263.2kJ/kg, 246.4kJ/kg, 189.2kJ/kg, 215.3kJ/kg]

Q3. Steam enters an adiabatic turbine steadily at 3 MPa and 400°C and leaves at 50 kPa and 100°C. If the power output of the turbine is 2 MW, determine (a) the isentropic efficiency of the turbine and (b) the mass flow rate of the steam flowing through the turbine.

[Ans. 66.7%, 3.64 kg/s]

Q4. Air at 200 kPa and 950 K enters an adiabatic nozzle at low velocity and is discharged at a pressure of 80 kPa. If the isentropic efficiency of the nozzle is 92%, determine (a) the maximum possible exit velocity, (b) the exit temperature, and (c) the actual exit velocity of the air. Assume constant specific heats for air. [Ans. 666m/s, 764K, 639m/s]

Q5. Steam at 7 MPa and 450C is throttled in a valve to a pressure of 3 MPa during a steady-flow process. Determine the entropy generated during this process and check if the increase of entropy principle is satisfied. [Ans. 0.3693 kJ/kgK]

Q6. A 50-kg block of iron casting at 500 K is thrown into a large lake that is at a temperature of 285K. The iron block eventually reaches thermal equilibrium with the lake water. Assuming an average specific heat of 0.45 kJ/kgK for the iron, determine (a) the entropy change of the iron block, (b) the entropy change of the lake water, and (c) the entropy generated during this process. [Ans. -12.65kJ/kgK, 16.97kJ/K, 4.32kJ/K]

Q7. Components of a heat pump for supplying heated air to a dwelling are shown in the schematic below. At steady state, Refrigerant 22 enters the compressor at 5C, 3.5 bar and is compressed adiabatically to 75C, 14 bar. From the compressor, the refrigerant passes through the condenser, where it condenses to liquid at 28C, 14 bar. The refrigerant then expands through a throttling valve to 3.5 bar. Return air from the dwelling enters the condenser at 20C, 1 bar with a volumetric flow rate of 0.42 m³/s and exits at 50C with a negligible change in pressure. Using the ideal gas model for the air and neglecting kinetic and potential energy effects,

(a) determine the rates of entropy production, in W/K, for control volumes enclosing the condenser, compressor, and expansion valve, respectively.

(b) Discuss the sources of irreversibility in the components considered in part (a)

[Ans. 1.75W/K, 0.994W/K, 0.795W/K]

Q8. A rigid, well-insulated tank is filled initially with 5 kg of air at a pressure of 5 bar and a temperature of 500 K. A leak develops, and air slowly escapes until the pressure of the air remaining in the tank is 1 bar. Employing the ideal gas model, determine the amount of mass remaining in the tank and its temperature.

[Ans. 317K, 1.58kg]