Homework #8

MEMS 0051 - Introduction to Thermodynamics

Assigned April 2$^{\text{nd}}$, 2020
Due April 9$^{\text{th}}$, 2020

Problem #1

Steam enters a turbine through a pipe with a diameter of 0.2 [m]. The steam enters with a velocity of 100 [m/s], a pressure of 14,000 [kPa] and a temperature of 600 °C. The steam is exhausted through a pipe with a diameter of 0.8 [m], a pressure of 500 [kPa] and a temperature of 180 °C. Determine:

a) the exit velocity of the steam;
b) the mass flow rate of the steam.

Problem #2

An open feedwater heater (OFWH) accepts liquid water at 1,000 [kPa] and a temperature of 50 °C. The OFWH also accepts water with a mass flow rate per that of inlet one, i.e. $\dot{m}_2/\dot{m}_1$=0.22. Saturated liquid water exits the OFWH. Determine:

a) the temperature of the second incoming stream, if superheated;
b) the quality of the second incoming stream, if saturated.

Problem #3

Steam enters a nozzle operating at a pressure of 30 [bar] and a temperature of 320 °C with negligible velocity. The steam exits the nozzle at a pressure of 15 [bar] and a velocity of 10 [m/s]. The mass flow rate is 2.5 [kg/s]. Assume the nozzle is well insulated.

a) Determine the exit temperature of the steam.

Problem #4

Air expands through a turbine with a mass flow rate of 10 [kg/s] from a pressure of 5 [bar] to 1 [bar] The temperature of the air at the inlet is 900 [K] where it is 600 [K] at the outlet. The inlet velocity is negligible, but the exit velocity is 100 [m/s]. All heat transfer and potential energy changes can be neglected.

a) Determine the power output of the turbine in [kW].
b) Determine the exit cross-sectional flow area in [m^2].

Problem #5

An air-conditioner's cooling coil is a heat exchanger that extracts heat from air and it is picked up by the working fluid, R-134A (Table B.5, page 180). Air is passed over the heat exchanger coils. Air enters the heat exchanger with a volumetric flow rate of 40 [m^3/min], a temperature of 40 °C and a pressure of 1 [bar] and exits at a temperature of 20 °C. The R-134A enters the heat exchanger with a quality of 40% at a temperature of 10 °C and exits as a saturated vapor at the same temperature.

a) Determine the mass flow rate of the R-134A.
b) Determine the rate of energy transfer, in [kJ/min], form the air to the refrigerant.

Problem #6

A pump delivers water at a volumetric flow rate of 0.05 [m^3] through an 18 [cm] diameter pipe located 100 [m] above the pump inlet, which has a diameter of 15 [cm]. The pressure at the inlet and exit of the pump is equal to 1 [bar], and the temperature can be assumed constant at 20 °C.

a) Determine the power input into the pump in [kW].

Problem #7

A tank contains 2 [ft^3] of air with an initial pressure of 50 [psi] and an initial temperature of 70 °F. The tank is punctured and air flows out at a constant mass flow rate of 0.01 [$\mathrm{lb_m/s}$]. Using the ideal gas law, determine:

a) the rate of change of mass within the tank the moment the leak occurs;
b) the mass of air in the tank as a function of time (plot).

Problem #8

A very well insulated chamber with volume of 1 [m^3] contains air initially at 101 [kPa] and 37.8 °C. Supply and discharge lines are connected to the chamber. The supply air is at 200 [kPa] and 93.3 °C. The discharge line is connected to atmosphere. At time t=0, the valves are simultaneously opened, allowing air to flow at a constant rate of 1 [kg/min] through both lines. The air within the chamber can be assumed well mixed, i.e. a uniform temperature and pressure at each time step. Determine:

a) the temperature, in °C, as a function of time;
b) the pressure, in [kPa], as a function of time.

Problem #9

A Rankine cycle consists of a boiler, turbine, condenser and pump. Steam enters the turbine at 8.0 [MPa] and 480 °C. Saturated liquid exits the condenser at a pressure of 8.0 [kPa]. The net power output of the cycle is 100 [MW]. Treating each device as a steady-state device, however, linked in series (i.e. constant mass flow), determine:

a) the mass flow rate of the steam, $\dot{m}_{steam}$;
b) the heat input through the boiler, $\dot{Q}_h$ in [MW];
c) the heat output through the condenser, $\dot{Q}_c$ in [MW];
d) the thermal efficiency, and compare to the Carnot efficiency.