AREN 2110, First Law Practice Problems

1. A turbine uses air as the working fluid. Air enters the turbine at 800 kPa and 600 K with a flow rate of 2 kg/s. After expansion, the air pressure at the outlet is 200 kPa and the temperature is 300 K. The rate of heat loss from the turbine is 50 kw during steady flow operation.

a) Find the volumetric flow rates, $\dot{V}_1$ and $\dot{V}_2$, at the inlet and outlet of the turbine, respectively.

b) Find the mechanical power output of the turbine.

2. A family uses500 liters/day hot water from a rooftop solar collector. Water entering the collector pipes is 15 ^{o}C and 150 kPa. Water at the collector exit is saturated liquid at 150 kPa. The collector absorbs 500 w/m^2 from the sun.

a) What is the required collector area to supply the family's hot water requirement?

b) What is the temperature of the heated water entering a well-insulated storage tank receiving water from the collector?

c) Hot water from the storage tank is mixed with 15 ^{o}C water in a shower with well-insulated pipes. What are the mass flow rates of hot and cold water that will produce a shower flow of 5 liters/min at a temperature of 40 ^{o}C.

3. Air flows through a nozzle in the following conditions.

Inlet: 27 ^{o}C, 120 kPa, 200 m/s, area = 0.04 m^2
Outlet: 60 kPa, 500 m/s

a) At what rate must heat be added/removed to maintain isothermal conditions for the air?
b) What is the outlet area?

4. 7.2 MJ of work is put into a gas at 1 MPa and 150 C while heat is removed at the rate of 1.5 kw. What is the change in internal energy of the gas after one hour?

a) –5.7 MJ

b) 1.8 MJ

c) 8.7 MJ

d) 13 MJ

5. One kg air is compressed from a volume of 1.0 m^3 and a pressure of 100 kPa to a volume of 0.147 m^3 and a pressure of 1000 kPa. Assuming the compression follows the relation Pv^n = constant, find the work done on the gas during the compression process.

a) -70 kJ
b) -100 kJ
c) -118 kJ
d) -235 kJ

6. Steam enters an adiabatic nozzle at 1 MPa, 30 m/s, and 250 C. At a point down stream in the nozzle, the enthalpy of the steam has decrease by 40 kJ/kg from the inlet value. What is the velocity at that point?

a) 31 m/s
b) 110 m/s
c) 250 m/s
d) 280 m/s

7. A boiler feedwater pump receives saturated liquid water at 50 C and compresses it isentropically to 1 MPa. For a water flow rate of 100 Mg/hr, estimate the pump power.

a) -20 kw
b) -28 kw
c) -35 kw
d) -39 kw

8. Calculate the power required to compress 10 kg/s air flow from 1 atm and 37 C to 2 atm and 707 C. For T = 310K, H = 290.4 KJ/KG AND FOR T = 980 K, h = 1023 kJ/kg.

a) –5260 kw
b) –7020 kw
c) –7260 kw
d) –7330 kw

9. Which of the following is true for an polytropic steady-flow process?

a) $\frac{P_2}{P_1} = \left(\frac{v_1}{v_2}\right)^n \ldots$

b) $w = - v(P_2 - P_1)$

c) $P_1V_1 = P_2V_2$

d) $P_1T_2 = P_2T_1$

10. Air is compressed from 100 kPa and 40 C to 1500 kPa and 130 C in a steady flow process. During the compression, each kilogram of air loses 90 kJ as heat to the surroundings. Air leaves the compressor at a rate of 10 m^3/min. What is the power requirement for the compressor?

a) –126 kw

b) –180 kw

c) –195 kw

d) –391 kw

11. Which of the following statements is the best expression of the first law of thermodynamics?

a) The mass within a closed system does not change.
b) The net energy crossing the system boundary equals the change in energy inside the system.
c) The change of total energy is equal to the rate of work performed.
d) All real process tent toward increased entropy.