Homework 4

Thursday, March 11, 2021 1:55 PM

"I pledge my honor I have abided by the Stevens Honor system."

- Alex Gaskins

1. *Boundary work*: Nitrogen at an initial state of 300 K, 150 kPa, and 0.2 m³ is compressed slowly in an isothermal process to a final pressure of 800 kPa. Determine the boundary work done during this process. [10]

$$W = P_1 V_1 \ln\left(\frac{P_1}{P_2}\right)$$

$$W = 150(.2)\ln\left(\frac{150}{800}\right)$$

$$\boxed{W = -50.22\text{ kJ}}$$

2. *Boundary work:* A piston–cylinder device initially contains 0.07 m³ of nitrogen gas at 130 kPa and 120°C. The nitrogen is now expanded polytropically (PV^n=C) to a state of 100 kPa and 100°C. Find the value of 'n' (in PV^n=C) and determine the boundary work done during this process. [10]

$$PV = mRT$$

$$m = \frac{P_1 V_1}{R T_1} = \frac{130(.07)}{(.2968)(393)} = .078\text{ kg}$$

$$V_2 = \frac{mRT_2}{P_2} = \frac{.078(.2968)(373)}{100} = .086\text{ m}^3$$

$$(PV^n)_1 = (PV^n)_2$$

$$(130(.07))^n = (100(.086))^n$$

$$n = 1.25$$

$$W = \frac{P_2 V_2 - P_1 V_1}{1-n} = \frac{(100(.086)) - (130(.07))}{(1-1.25)}$$

$$\boxed{W = 1.86\text{ kJ}}$$

3. *Energy equations:* Saturated R-134a vapor at 100°F is condensed at constant pressure to a saturated liquid in a closed piston–cylinder system. Calculate the heat transfer and work done during this process, in Btu/lbm. [20]

$$w = P(v_2 - v_1)$$

Using table A-11E:

$$w = (138.93(.01386 - .34074))$$

Using Table A-17E.

$$W = \frac{(138.93\,(.01386 - .34074))}{5.404}$$

$$\boxed{W = -8.404\ \frac{Btu}{lbm}}$$

$$Q = -(-W + (u_2 - u_1)) = 8.4037 - (44.774 - 107.46)$$

$$\boxed{Q = 71.1\ Btu/lbm}$$

4. *Specific heats:* Air is compressed in the compressor of a turbojet engine. The air enters the compressor at 270 K and 58 kPa and exits the compressor at 465 K and 350 kPa. Determine the specific enthalpy change and specific internal energy change associated with this process. [15]

$$h_f - h_i = c_p(T_2 - T_1)$$

$$\Delta h = 1.015(465 - 270)$$

$$\boxed{\Delta h = 197.9\ kJ/kg}$$

$$u_f - u_i = c_v(T_2 - T_1)$$

$$\Delta u = .728(465 - 270)$$

$$\boxed{\Delta u = 141.9\ kJ/kg}$$

5. *Specific heats:* Is the energy required to heat air from 295 to 305 K the same as the energy required to heat it from 345 to 355 K? Assume the pressure remains constant in both cases. [5]

No, the energy will change with the value of c_p, which is dependent on temperature.

6. *Energy equations:* A piston–cylinder device contains 2.2 kg of nitrogen initially at 100 kPa and 25°C. The nitrogen is now compressed slowly in a polytropic process during which $PV^{1.3} = C$ until the volume is reduced by one-half. Determine the work done and the heat transfer for this process. [20]

$$P_2 = P_1 \left(\frac{V_1}{V_2}\right)^{1.3} = 100 \left(\frac{2}{1}\right)^{1.3} = 246.2\ \text{KPa}$$

$$T_2 = T_1 \left(\frac{P_2 V_2}{P_1 V_1}\right) = 298 \left(\frac{246.2}{2(100)}\right) = 366.9\ \text{K}$$

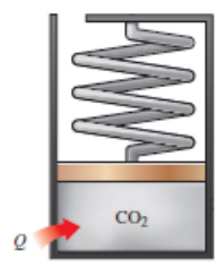
$$W = -\frac{P_2V_2 - P_1V_1}{1-n} = -\frac{mR(T_2 - T_1)}{1-n} = -\frac{2.2(.2968)(366.9-298)}{1-1.3}$$

$$\boxed{W = 149.9\ \text{kJ}}$$

$$Q = W - mc_v\Delta T = 149.9 - 2.2(.744)(366.9-298)$$

$$\boxed{Q = 37.2\ \text{kJ}}$$

7. *Energy equations:* A spring-loaded piston-cylinder device contains 1 kg of carbon dioxide. This system is heated from 100 kPa and 25°C to 1000 kPa and 300°C. Determine the total heat transfer to (or from) and work produced by this system. [20]



$$V = \frac{mRT}{P}$$

$$V_1 = \frac{1(.1889)(298)}{100} = .563\ \text{m}^3$$

$$V_2 = \frac{1(.1889)(573)}{1000} = .108\ \text{m}^3$$

$$W = \frac{P_1 + P_2}{2}(V_2 - V_1) = \frac{100 + 1000}{2}(.108 - .563)$$

$$\boxed{W = -250.25\ kJ}$$

$$\Delta U = m c_v \Delta T = 1(.657)(573 - 298)$$

$$\Delta U = 180.68\ kJ$$

$$\Delta U = Q - W$$

$$Q = W + \Delta U = -250.25 + 180.68$$

$$\boxed{Q = -69.57\ kJ}$$