Problem 1

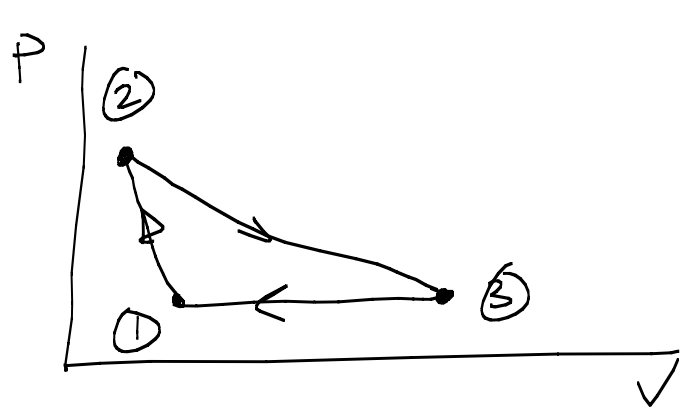
Given: Air as an ideal gas initially at 1 atm, -40°F undergoing three internally reversible processes

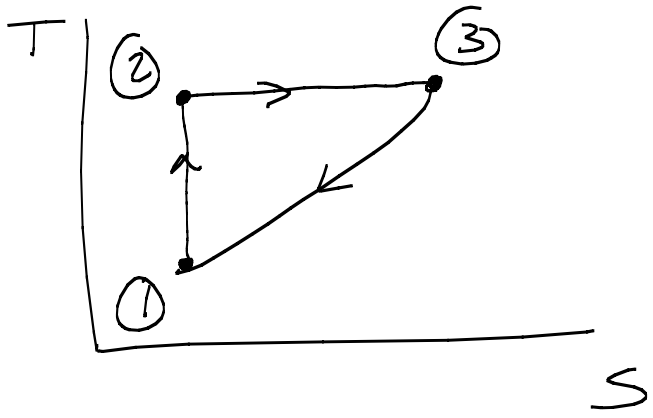
Process 1-2: Adiabatic Compression to 8 atm

Process 2-3: Isothermal Expansion to 1 atm

Process 3-1: Constant Pressure compression

Determine:
- Temperature at State 3
- Net Work per lb
- Thermal Efficiency





1-2 $\quad Q_{12} = 0 \qquad s_1 = s_2$

$$m(u_2 - u_1) = \cancel{Q_{12}}^{\,0} - W_{12} \qquad \frac{W_{12}}{m} = -(u_2 - u_1)$$

$$\cancel{s_2 - s_1}^{\,0} = s^\circ(T_2) - s^\circ(T_1) - R \ln\left(\frac{P_2}{P_1}\right)$$

Table A-22E @ $T_1 = 420^\circ R$ $\quad s^\circ(T_1) = 0.54058 \text{ Btu/lb}\cdot^\circ R$

$u_1 = 71.52 \text{ Btu/lb}$

$$0 = s^\circ(T_2) - 0.54058 \text{ Btu/lb}\cdot^\circ R - \left(\frac{1.986 \text{ Btu/lbmol}\cdot^\circ R}{28.97}\right) \ln\left(\frac{8 \text{ atm}}{1 \text{ atm}}\right)$$

$$s^\circ(T_2) = 0.6831 \text{ Btu/lb}\cdot^\circ R$$

Table A-22E @ $s^\circ(T_2) = 0.6831 \text{ Btu/lb}\cdot^\circ R$

$u_2 = 129.99 \text{ Btu/lb}, \quad T_2 = 760^\circ R$

$$\frac{W_{12}}{m} = -(129.99 \text{ Btu/lb} - 71.52 \text{ Btu/lb}) = \boxed{-58.5 \text{ Btu/lb}}$$

2-3

$$\boxed{T_3 = T_2 = 760^\circ R}$$

$$\frac{Q_{23}}{m} = T(s_3 - s_2)$$

$$s_3 - s_2 = \cancel{s^\circ(T_3)}^{\,0} - s^\circ(T_2) - R \ln\left(\frac{P_3}{P_2}\right)$$

$$s_3 - s_2 = -\left(\frac{1.986}{28.97}\right)\left(\ln\left(\frac{1\,atm}{8\,atm}\right)\right) = 0.14255\ Btu/lb\cdot{}^\circ R$$

$$\frac{Q_{23}}{m} = (760^\circ R)(0.14255\ Btu/lb\cdot{}^\circ R)$$

$$\boxed{\frac{Q_{23}}{m} = 108.34\ Btu/lb}$$

$$\cancel{u_3}^{\,0} - u_2 = \frac{Q_{23}}{m} - \frac{W_{23}}{m}$$

$$\boxed{\frac{W_{23}}{m} = 108.34\ Btu/lb}$$

3-1

$$\frac{W_{31}}{m} = p(v_1 - v_3) = R(T_1 - T_3)$$

$$= \left(\frac{1.986}{28.97}\right)(420°R - 760°R) = \boxed{-23.3 \text{ Btu/lb}}$$

$$u_1 - u_3 = \frac{Q_{31}}{m} - \frac{W_{31}}{m}$$

$$u_3 = u_2 = 129.99 \text{ Btu/lb}$$

$$(71.52 - 129.99)\text{ Btu/lb} = \frac{Q_{31}}{m} - (-23.3 \text{ Btu/lb})$$

$$\boxed{\frac{Q_{31}}{m} = -81.77 \text{ Btu/lb}}$$

$$\eta = \frac{W_{cycle}}{Q_{23}} = \frac{-58.5 + 108.34 - 23.3}{108.34}$$

$$\boxed{\eta = 0.245 = 24.5\%}$$