Problem 3

Given: 1 kg of air behaving as an ideal gas executes a Carnot Power Cycle with Thermal Efficiency = 50%. The heat transfer to the air during the isothermal expansion is 50 kJ. at the end of the isotermal expansion, the pressure is 574 kPa and the volume is $0.3 m^3$

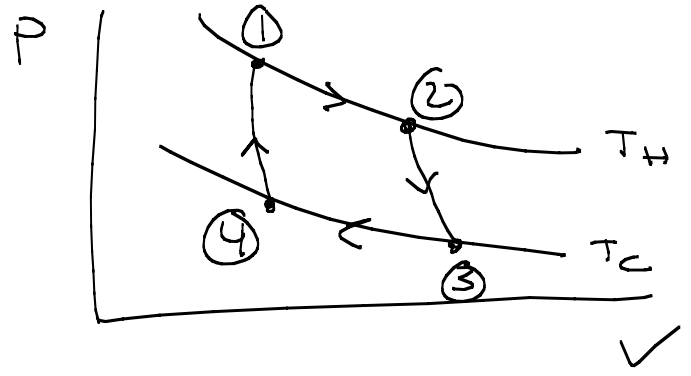
Determine: - The minimum and maximum temperatures for the cycle
- The work and heat transfer for each process

$\eta = 50\%$

$Q_{12} = 50 kJ$

$P_2 = 574 kPa$

$V_2 = 0.3 m^3$



$$\eta_{max} = 0.5 = 1 - \frac{T_C}{T_H}$$

$$pV = mRT \qquad P_2 V_2 = mRT_2$$

$$(574 \times 10^3\ N/m^2)(0.3\ m^3) = (1\ kg)\left(\frac{8314\ J/kmol \cdot K}{28.97\ kg/kmol}\right)(T_2)$$

Table A-1

$$\boxed{T_2 = 600\ K} = T_H = T_1$$

$$0.5 = 1 - \frac{T_C}{600\ K} \Rightarrow \boxed{T_C = 300\ K} = T_3 = T_4$$

1-2 $\boxed{Q_{12} = 50\ kJ}$ $\qquad U_2 - U_1 = Q_{12} - W_{12}$

Table A-22 (Ideal Gas Properties of Air)

u depends only on T

Process 1-2 => Isothermal => $u_1 = u_2 = 434.78\ kJ/kg$

$Q_{12} = W_{12}$ $\qquad \boxed{W_{12} = 50\ kJ}$

Process 2-3 Adiabatic $\Rightarrow$ $\boxed{Q_{23} = 0}$

$$U_3 - U_2 = \cancel{Q_{23}}^{\,0} - W_{23}$$

$$u_2 = 434.78 \text{ kJ/kg}$$

Table A-22: @ $T_3 = 300\text{K}$, $u_3 = 214.07 \text{ kJ/kg}$

$$(1\text{kg})(214.07 - 434.78 \text{ kJ/kg}) = -W_{23}$$

$$\boxed{W_{23} = 220.7 \text{ kJ}}$$

Process 3-4 $\cancel{0}$ (Isothermal)

$$\cancel{U_4 - U_3} = Q_{34} - W_{34} \qquad W_{34} = Q_{34}$$

$$\left(\frac{Q_C}{Q_H}\right)_{\substack{rev \\ cycle}} = \frac{T_C}{T_H} \Rightarrow \qquad \frac{Q_{34}}{Q_{12}} = \frac{T_C}{T_H}$$

$$\frac{Q_{34}}{50\text{kJ}} = \left(\frac{300\text{K}}{600\text{K}}\right) \Rightarrow \boxed{Q_{34} = -25\text{kJ}} \qquad \boxed{W_{34} = -25\text{kJ}}$$

Proces 4-1 Adiabatic $\boxed{Q_{41} = 0}$

$$U_1 - U_4 = \cancel{Q_{41}}^{\,0} - W_{41}$$

$$u_1 = u_2 = 434.78 \text{ kJ/kg}$$

$$u_4 = u_3 = 214.07 \text{ kJ/kg}$$

$$(1 \text{ kg})(434.78 - 214.07) = -W_{41}$$

$$\boxed{W_{41} = -220.7 \text{ kJ}}$$