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HW#2

9-13.) Assumptions: Air-standard cycle

Ideal gas

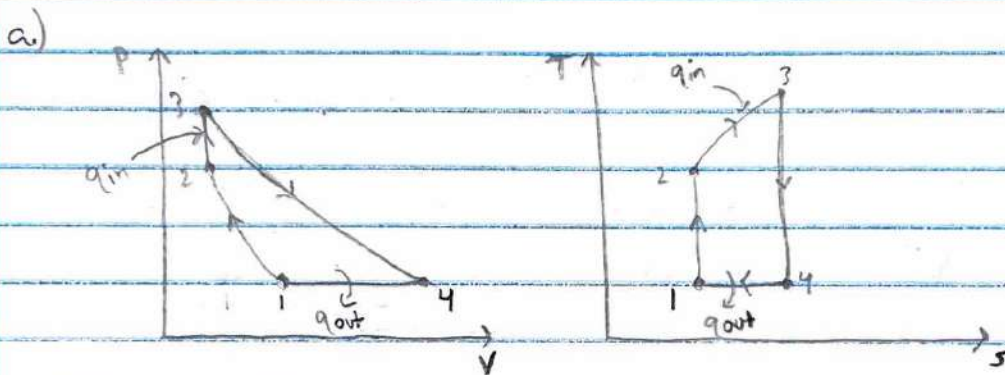
Properties: C_v, C_p - variable

Processes: 1→2 Isentropic 100 kPa at 22°C to 600 kPa

2→3 $v = \text{constant}$ heat addition to 1500K

3→4 Isentropic to 100 kPa

4→1 $P = \text{constant}$ heat rejection



States

① $\xrightarrow{\text{Isentropic}}$ ② $\xrightarrow{\text{Isobaric}}$ ③ $\xrightarrow{\text{Isentropic}}$ ④ $\xrightarrow{\text{Isobaric}}$ ①

$$P_1 = 100 \text{ kPa}$$

$$P_2 = 600 \text{ kPa}$$

$$T_3 = 1500 \text{ K}$$

$$P_4 = 100 \text{ kPa}$$

$$T_1 = 22^\circ\text{C} = 295.15 \text{ K}$$

$$P_{r2} = 7.8408$$

$$P_{r3} = 601.9$$

$$P_{r4} = 32.79$$

$$P_{r1} = 1.3068 \text{ (Table A-17)}$$

$$U_2 = 352.29 \text{ kJ/kg}$$

$$U_3 = 1205.41 \text{ kJ/kg}$$

$$h_4 = 739.71 \text{ kJ/kg}$$

$$h_1 = 295.17 \text{ kJ/kg}$$

Find T_2 (Interpolate)

$$P_2 = \frac{P_{r2}}{P_{r1}}$$

$$P_1 = \frac{P_{r1}}{P_{r1}}$$

$$600 = \frac{P_{r2}}{1.3068}$$

$$100 = 1.3068$$

$$P_{r2} = 7.8408$$

$$\frac{T}{P_r}$$

$$\frac{490}{7.824}$$

$$\frac{T_2}{7.8408}$$

$$\frac{500}{8.411}$$

$$T_2 = 490.29 \text{ K}$$

$$U$$

$$352.08$$

$$U_2$$

$$359.99$$

$$P_r$$

$$7.824$$

$$7.8408$$

$$8.411$$

$$\frac{T_2 - 490}{500 - 490} = \frac{7.8408 - 7.824}{8.411 - 7.824}$$

$$T_2 = 490.29 \text{ K}$$

$$\frac{U_2 - 352.08}{359.99 - 352.08} = \frac{7.8408 - 7.824}{8.411 - 7.824}$$

$$U_2 = 352.29 \text{ kJ/kg}$$

$$\frac{P_4}{P_3} = \frac{P_{r4}}{P_{r3}}$$

$$\frac{100}{1835.65} = \frac{P_{r4}}{601.9}$$

$$P_{r4} = 32.79$$

$$\frac{P_2}{P_3} = \frac{T_2}{T_3}$$

$$\frac{600}{1500k} = \frac{490.29k}{T_3}$$

$$P_3 = 1835.65 \text{ kPa}$$

Find T_4

T	P_r	h	P_r
720	32.02	737.82	32.02
T_4	32.79	h_4	32.79
730	33.72	745.62	33.72

$$\frac{T_4 - 720}{730 - 720} = \frac{32.79 - 32.02}{33.72 - 32.02}$$

$$T_4 = 727.53 \text{ K}$$

$$\frac{h_4 - 737.82}{745.62 - 737.82} = \frac{32.79 - 32.02}{33.72 - 32.02}$$

$$h_4 = 739.71 \text{ kJ/kg}$$

$$q_{in} = U_3 - U_2$$

$$= 1205.91 \text{ kJ/kg} - 352.29 \text{ kJ/kg}$$

$$= 853.12 \text{ kJ/kg}$$

$$q_{out} = h_4 - h_1$$

$$= 739.71 \text{ kJ/kg} - 295.17 \text{ kJ/kg}$$

$$= 444.54 \text{ kJ/kg}$$

b.) $W_{net} = q_{in} - q_{out}$

$$= 853.12 - 444.54$$

$$= 408.58 \text{ kJ/kg}$$

c.) $\eta_{th} = 1 - \frac{q_{out}}{q_{in}}$

$$= 1 - \frac{444.54}{853.12} = 0.479 = 47.9\%$$

9-18.) Assumptions: Air-standard Carnot cycle

Ideal gas

Closed system

Properties: C_p, C_v - variable

$$T_H = 1200 \text{ K}$$

$$P_1 = 150 \text{ kPa}$$

$$W_{\text{net}} = 0.5 \text{ kJ}$$

$$T_L = 350 \text{ K}$$

$$P_2 = 300 \text{ kPa}$$

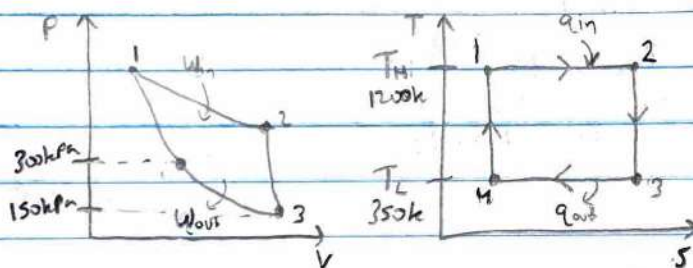
$$R = 8.3145 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$$

Processes: 1→2 Isothermal heat addition

2→3 Isentropic expansion

3→4 Isothermal heat rejection

4→1 Isentropic compression



States

① $\xrightarrow{\text{Isothermal expansion}}$ ② $\xrightarrow{\text{Isentropic expansion}}$ ③ $\xrightarrow{\text{Isothermal compression}}$ ④ $\xrightarrow{\text{Isentropic compression}}$ ①

$$T_1 = 1200 \text{ K}$$

$$T_2 = 1200 \text{ K}$$

$$T_3 = 350 \text{ K}$$

$$T_4 = 350 \text{ K}$$

$$P_1 = 238$$

$$P_2 = 238$$

$$P_3 = 150 \text{ kPa}$$

$$P_4 = 300 \text{ kPa}$$

$$S_1^\circ = 3.1788 \text{ kJ/kg} \cdot \text{K}$$

$$S_2^\circ = 3.1788 \text{ kJ/kg} \cdot \text{K}$$

$$P_3 = 2.379$$

$$P_4 = 2.379$$

$$S_2^\circ = 1.85708 \text{ kJ/kg} \cdot \text{K}$$

$$S_2^\circ = 1.85708 \text{ kJ/kg} \cdot \text{K}$$

$$a) \frac{P_1}{P_4} = \frac{P_1}{P_4}$$

$$\frac{P_1}{P_4} = \frac{238}{2.379}$$

$$\frac{P_1}{300} = \frac{238}{2.379}$$

$$P_1 = 300 \times 2.61 \text{ kPa} = 30 \text{ MPa}$$

$$b) \eta_{\text{th}} = \frac{W_{\text{net}}}{q_{\text{in}}}$$

$$\eta_{\text{th}} = 1 - \frac{T_L}{T_H}$$

$$\eta_{th} = 1 - \frac{350k}{1200k}$$

$$\eta_{th} = 0.708 = 71\%$$

$$\eta_{th} = \frac{W_{net}}{q_{in}}$$

$$0.708 = \frac{0.5 kJ}{q_{in}}$$

$$q_{in} = 0.706 kJ$$

c.) $PV = mRT$

$$m = \frac{PV}{RT}$$

$$RT$$

9-22.) Properties: Ideal gas

$$c_v = 0.7 kJ/kg \cdot K$$

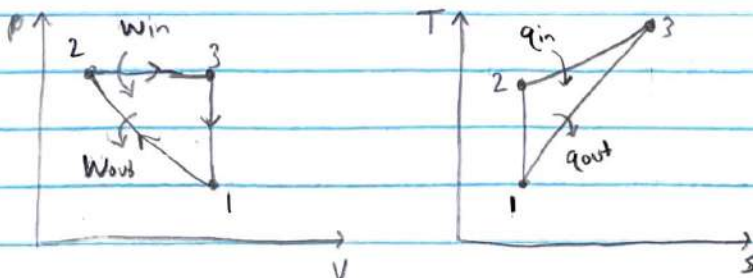
$$R = 0.3 kJ/kg \cdot K$$

Processes: $1 \rightarrow 2$ Isentropic $T_1 = 20^\circ C$ $r = 5$

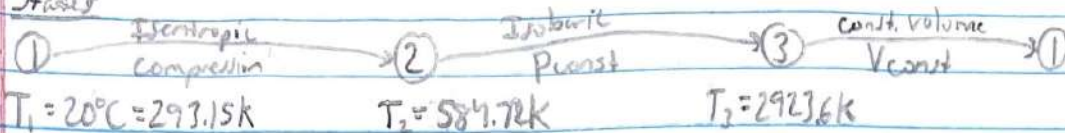
$2 \rightarrow 3$ Isobaric heat addition

$3 \rightarrow 1$ Constant Volume heat rejection

a)



Stator



$$T_1 = 20^\circ\text{C} = 293.15\text{K}$$

$$T_2 = 584.72\text{K}$$

$$T_3 = 2923.6\text{K}$$

$$r = 5$$

1-2 Isentropic

$$C_p = C_v + R$$

$$C_p = 0.7 + 0.3$$

$$C_p = 1$$

$$k = \frac{C_p}{C_v}$$

$$k = \frac{1}{0.7} = 1.429$$

$$\frac{V_1}{V_2} = r$$

$$\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{k-1}$$

$$\frac{T_2}{T_1} = r^{k-1}$$

$$T_2 = (5)^{1.429-1}$$

$$293.15$$

$$T_2 = 584.72\text{K}$$

$$q_{1-2} = 0$$

$$W_{1-2} = C_v \Delta T$$

$$= 0.7(293.15 - 584.72)$$

$$= -204.1 \text{ KJ/kg}$$

2-3 Isobaric

$$\frac{V_2}{V_3} = \frac{T_2}{T_3}$$

$$T_3 = (5)(584.72\text{K})$$

$$T_3 = 2923.6\text{K}$$

$$\begin{aligned}
 q_{2 \rightarrow 3} &= C_p \Delta T \\
 &= 1(2923.6 - 584.72) \\
 &= \boxed{2338.88 \text{ kJ/kg}}
 \end{aligned}$$

$$\begin{aligned}
 W_{1 \rightarrow 2} &= q - C_v \Delta T \\
 &= 2338.88 - 0.7(2338.88) \\
 &= \boxed{701.6 \text{ kJ/kg}}
 \end{aligned}$$

3 → 1 Const V

$$\begin{aligned}
 q_{3 \rightarrow 1} &= C_v \Delta T \\
 &= 0.7(2923.6 - 297.15) \\
 &= \boxed{1841.72 \text{ kJ/kg}}
 \end{aligned}$$

$$W_{3 \rightarrow 1} = 0$$

$$\begin{aligned}
 \text{c.) } \eta &= 1 - \frac{T_L}{T_H} = 1 - \frac{Q_{out}}{Q_{in}} \\
 &= 1 - \frac{1841.72}{2338.88} \\
 &= .213 \\
 &= \boxed{21.3\%}
 \end{aligned}$$

$$\begin{aligned}
 \text{d.) } \eta &= 1 - \frac{Q_{out}}{Q_{in}} \\
 &= 1 - \frac{C_v(T_3 - T_1)}{C_p(T_3 - T_2)} \\
 &= \boxed{1 - \frac{C_v(rT_2 - T_1)}{C_p(rT_2 - T_2)}}
 \end{aligned}$$

9-31.) Ideal Otto Cycle

$$r = 10.5$$

$$P_1 = 90 \text{ kPa}$$

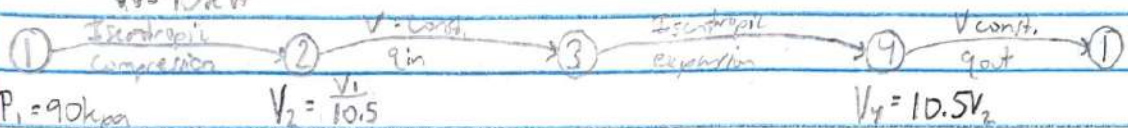
$$T_1 = 70^\circ\text{C} = 313\text{K}$$

Air

$$N = 2500/\text{min}$$

C_p, C_v - constant at room temp (300K)

$$W = 90 \text{ kW}$$



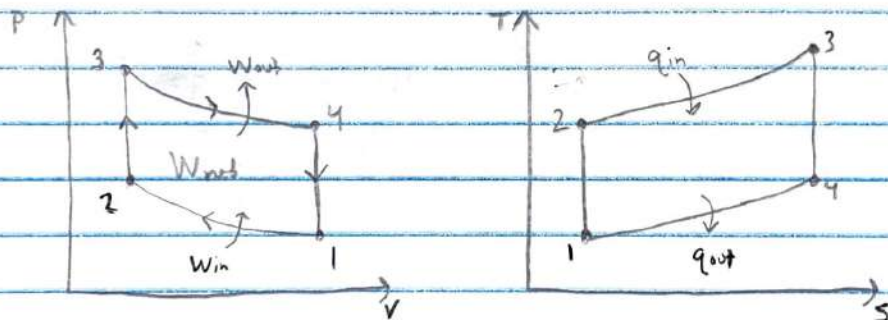
$$P_1 = 90 \text{ kPa}$$

$$V_2 = \frac{V_1}{10.5}$$

$$V_4 = 10.5V_2$$

$$T_1 = 313\text{K}$$

$$V_1 = 10.5V_2$$



$$r = \frac{V_1}{V_2} = \frac{V_4}{V_3}$$

$$10.5 = \frac{V_1}{V_2}$$

$$V_1 = V_4 = 10.5V_2$$

$$V_2 = V_3 = \frac{V_1}{10.5}$$

$$k = \frac{C_p}{C_v} = \frac{1.005}{0.718} = 1.399$$

a.) Thermal efficiency

$$\eta_{th, Otto} = 1 - \frac{1}{r^{k-1}}$$

$$\eta_{\text{net}} = 1 - \frac{1}{10.5^{(1.799-1)}}$$

$$= .609 = \boxed{60.9\%}$$

b.) q_{in} to produce 90kW

$$\eta_{\text{net}} = \frac{W}{q_{\text{in}}}$$

$$.609 = \frac{90 \text{ kW}}{q_{\text{in}}}$$

$$\boxed{q_{\text{in}} = 147.78 \text{ kW}}$$