

Cameron Sitten

HW 1.4

9-88.) Given: $r_p = 10$

$$q_{in} = 500 \text{ kW}$$

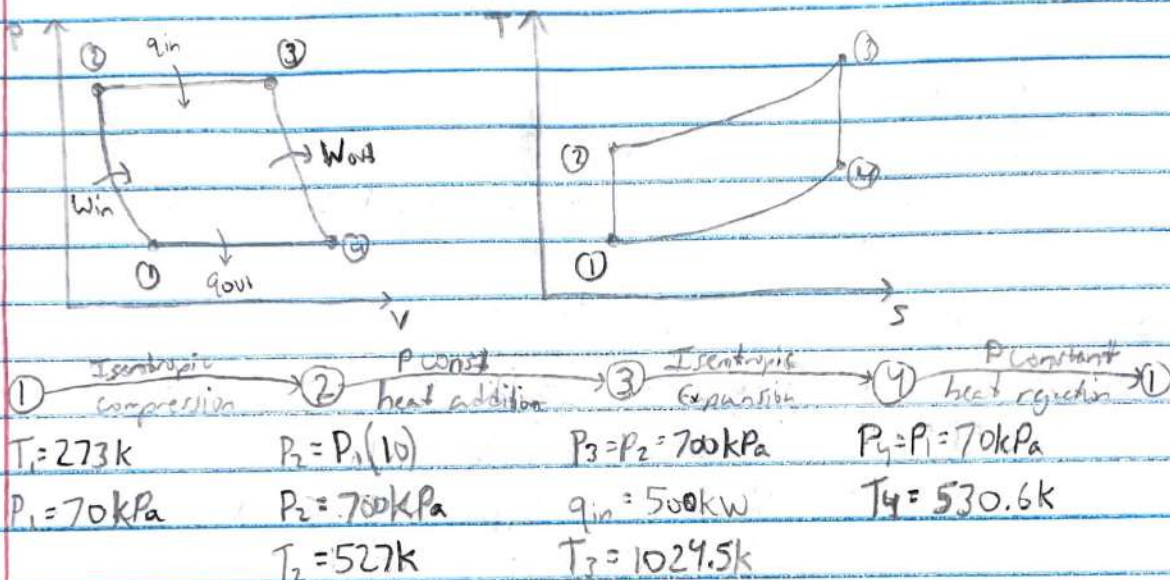
$$V = 1 \text{ kg/s}$$

air

$$P_1 = 70 \text{ kPa}$$

$$T_1 = 0^\circ\text{C} = 273^\circ\text{K}$$

C_p, C_v constant at 300°K



Find T_2

$$\frac{T_2}{T_1} = \left(\frac{P_2}{P_1} \right)^{\frac{k-1}{k}}$$

$$T_2 = 273 \left(\frac{700}{70} \right)^{\frac{1.4-1}{1.4}}$$

$$T_2 = 527 \text{ K}$$

Find T_3

First law

$$q_{in} = C_p(T_3 - T_2)$$

$$500 = 1.005(T_3 - 527)$$

$$T_3 = 1024.5 \text{ K}$$

Find T_4

$$\frac{T_4}{T_3} = \left(\frac{P_4}{P_3} \right)^{\frac{k-1}{k}}$$

$$T_4 = 1024.5 \left(\frac{70}{700} \right)^{\frac{1.4-1}{1.4}}$$

$$T_4 = 530.6 \text{ K}$$

$$W_{out} = \frac{kR(T_4 - T_3)}{k-1} = \frac{1.4 \cdot (.287) (530.6 - 1024.5)}{1.4-1} = 351 \text{ kW}$$

$$\eta_{th} = 1 - \frac{1}{r_p^{(k-1)/k}} = .48 = 48\%$$

9-99) Given: $P_1 = 100 \text{ kPa}$

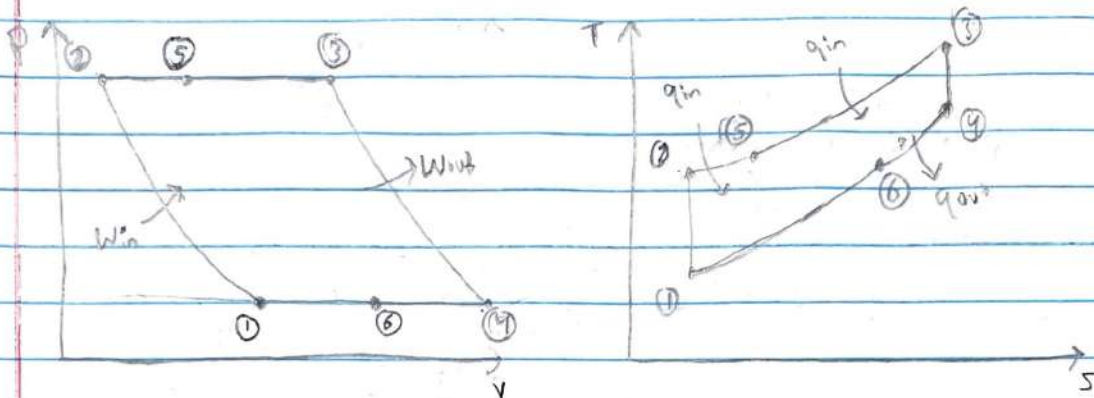
$$T_1 = 30^\circ\text{C} = 303 \text{ K}$$

$$P_r = 10$$

$$T_{\text{max}} = 800^\circ\text{C} = 1073 \text{ K}$$

$$q_{\text{out}} = 115 \text{ kW}$$

$$C_p, C_v \text{ constant at } 300 \text{ K}$$



1 Isentropic 2 P const 5 P const 3 Isentropic 4 P const 6 P const 1

$$P_1 = 100 \text{ kPa} \quad P_2 = P_{r10} = 1000 \text{ kPa} \quad P_5 = 1000 \text{ kPa} \quad T_3 = 1073 \text{ K} \quad P_4 = 100 \text{ kPa} \quad P_6 = 100 \text{ kPa}$$

$$T_1 = 303 \text{ K} \quad T_2 = 585 \text{ K} \quad T_5 = T_4 = 10 \quad P_3 = 100 \text{ kPa} \quad T_4 = 555.8 \text{ K}$$

$$T_5 = 595.8$$

Find T_2

$$T_2 = \left(\frac{P_2}{P_1} \right)^{\frac{k-1}{k}}$$

$$T_2 = 585 \text{ K}$$

Find T_4

$$T_4 = \left(\frac{P_4}{P_3} \right)^{\frac{k-1}{k}}$$

$$T_4 = 555.8 \text{ K}$$

Find T_6 (1st Law)

$$C_p(T_4 - T_6) = C_p(T_5 - T_2)$$

$$555.8 - T_6 = 595.8 - 585$$

$$T_6 = 595.8$$

$$W_{\text{net}} = W_{T,\text{out}}$$

$$W_{c,\text{in}}$$

$$= \frac{C_p(T_4 - T_3)}{C_p(T_2 - T_1)}$$

$$= \frac{1.005(555.8 - 1073)}{1.005(585 - 303)}$$

$$= 233.79$$

$$q_{\text{in}} = h_3 - h_2 = C_p(T_3 - T_2)$$

$$= 1.005(595.8 - 585)$$

$$= 39.4 \text{ kJ/kg}$$

$$q_{\text{out}} = h_4 - h_1 = C_p(h_4 - h_1)$$

9-107.) Given: Air

$$P_r = 7$$

$$T_{min} = 310k$$

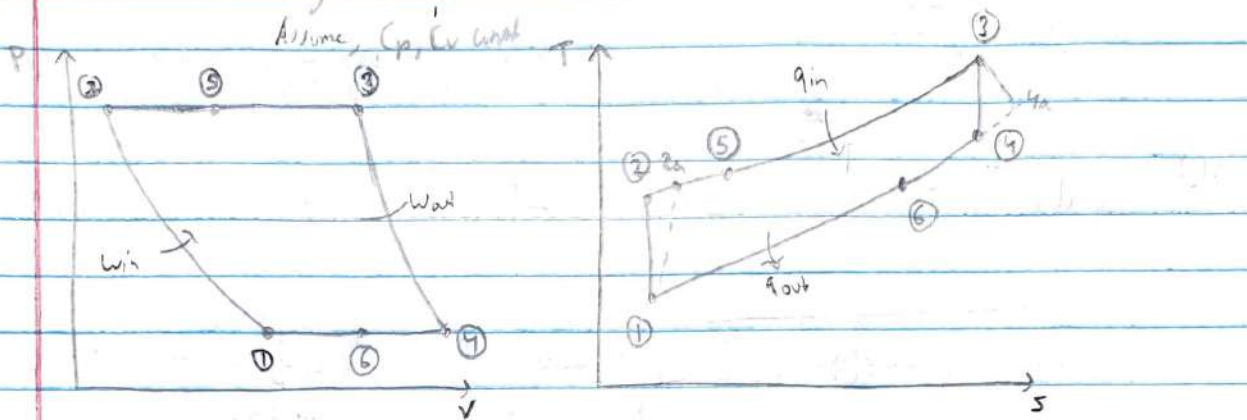
$$T_{max} = 1150k$$

$$\eta_{comp} = 75\%$$

$$\eta_{Turb} = 82\%$$

$$\epsilon_{reg} = 65\%$$

Assume, C_p, C_v const



① Isentropic η_c ② P_{const} ϵ_{reg} ⑤ P_{const} ③ Isentropic η_T ④ P_{const} ⑥ P_{const} ①
 $T_1 = 310k$ $P_2 = 7P_1$ $P_5 = P_2$ $T_3 = 1150k$ $P_4 = P_1$ $P_6 = P_1$
 $T_2 = 540.5k$ $T_5 = 597.9k$ $P_3 = P_5 = P_2 = 7P_1$ $T_4 = 659.5k$

Find T_2

$$T_2 = \left(\frac{P_2}{P_1} \right)^{\frac{k-1}{k}}$$

$$T_2 = 310 \left(\frac{7P_1}{P_1} \right)^{\frac{1.4}{1.4}}$$

$$T_2 = 540.5k$$

$\eta_c = \frac{T_2 - T_1}{T_{2a} - T_1}$

$$.75 = \frac{540.5 - 310}{T_{2a} - 310}$$

$$T_{2a} = 616.7k$$

Find T_5

$$\epsilon = \frac{T_5 - T_2}{T_{4a} - T_{2a}}$$

$$.65 = \frac{T_5 - 540.5k}{777.8 - 659.5}$$

$$T_5 = 597.9k$$

$\eta_T = \frac{T_3 - T_{4a}}{T_3 - T_4}$

$$.82 = \frac{1150 - T_{4a}}{1150 - 659.5}$$

$$T_{4a} = 777.8k$$

Find T_4

$$T_4 = \left(\frac{P_4}{P_3} \right)^{\frac{k-1}{k}}$$

$$T_4 = 659.5k$$

Find T_6 (in h_u)

$$h_5 - h_{2a} = h_{4a} - h_6$$

$$c_p(T_5 - T_{2a}) = c_p(T_{4a} - T_6)$$

$$(597.9 - 616.7) = 777.8 - T_6$$

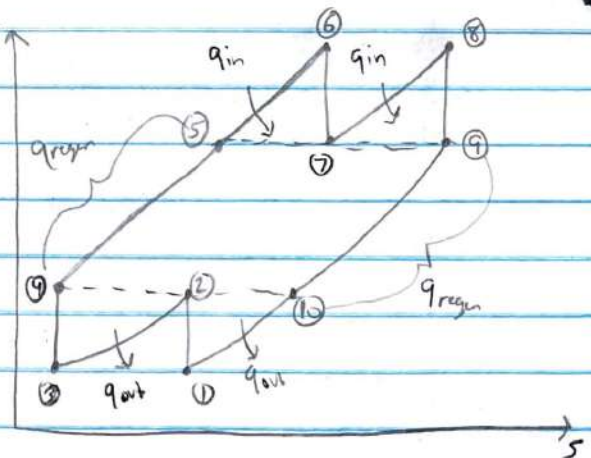
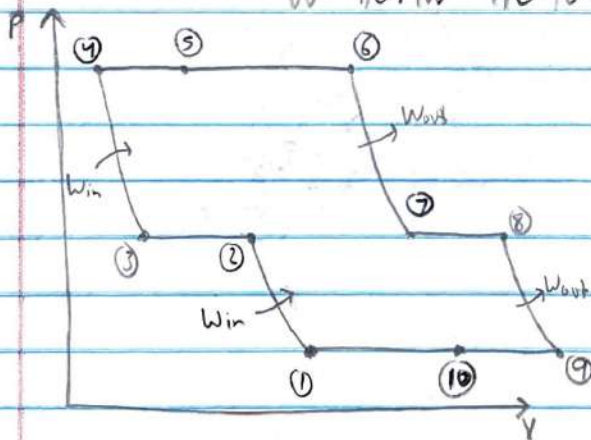
$$T_6 = 766.6k$$

a.) $T = 747.8 \text{ K}$

b.) $W_{\text{net}} = W_{\text{out}} - W_{\text{in}} = C_p(T_3 - T_{4a}) - C_p(T_{2a} - T_1)$
 $= 1.005(1150 - 747.8) - 1.005(616.7 - 310)$
 $= 404.211 - 308.21$
 $= \boxed{95.98 \text{ kJ/kg}}$

c.) $\eta = 1 - \left(\frac{T_1}{T_3} \right)^{\frac{\gamma-1}{\gamma}}$
 $\eta = .53 = \boxed{53\%}$

9-119.) Given: $r_p = 9$
 $T_c = 300 \text{ K}$
 $T_T = 1200 \text{ K}$
 C_p, C_v variable
 $W = 110 \text{ MW} = 110 \times 10^3 \text{ kW}$



$$\frac{P_2}{P_1} = \frac{P_4}{P_3} = \sqrt{9} = 3$$

$$\frac{P_6}{P_7} = \frac{P_8}{P_9} = \sqrt{9} = 3$$

See next page for states



$$T_1 = 300K$$

$$P_2 = 3P_1$$

$$P_{r2} = 4.158$$

$$T_2 = 410.14K$$

$$P_{r3} = 1.386$$

$$P_3 = P_2$$

$$h_1 = 300.19 \frac{kJ}{kg}$$

$$h_2 = 411.26 \frac{kJ}{kg}$$

$$P_5 = P_4$$

$$T_5 = T_7$$

$$T_6 = 1200K$$

$$P_{r6} = 238$$

$$P_6 = P_5$$

$$h_6 = 1277.79 \frac{kJ}{kg}$$

$$P_7 = P_6/3$$

$$P_{r7} = 79.3$$

$$T_7 = 911.86K$$

$$h_7 = 946.25 \frac{kJ}{kg}$$

$$T_8 = 1200K$$

$$P_{r8} = 238$$

$$P_8 = P_7$$

$$h_8 = 1277.79 \frac{kJ}{kg}$$

$$P_9 = P_{r9}$$

$$T_9 = T_7$$

$$P_{10} = P_1$$

Find P_{r2}

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$$

$$\frac{3P_1}{P_1} = \frac{P_{r2}}{1.386}$$

$$P_{r2} = 4.158$$

Find T_2 (Interpolated using calculator)

T	P_r
410	4.153
T_2	4.158
420	4.522

Find h_2	
410	411.12
410.14	h_2
420	421.26

Find P_{r7}

$$\frac{P_7}{P_6} = \frac{P_{r7}}{P_{r6}}$$

$$\frac{P_6/3}{P_6} = \frac{P_{r7}}{238}$$

$$P_{r7} = 79.3$$

Find T_7 (Interpolated using calculator)

Find P_{r4}

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

$$\frac{3P_3}{P_3} = \frac{P_{r4}}{1.386}$$

$$P_{r4} = 4.158$$

$$W_{in} = h_2 - h_1 = 111.07 \frac{kJ}{kg} \times 2 = 222.13 \frac{kJ}{kg}$$

$$W_{out} = h_6 - h_7 = 331.54 \times 2 = 663.08 \frac{kJ}{kg}$$

$$W_{net} = W_{out} - W_{in}$$

$$= 663.08 - 222.13$$

$$= 440.95 \frac{kJ}{kg}$$

$$W = \dot{m} W_{net}$$

$$110 \times 10^3 = \dot{m} (440.95)$$

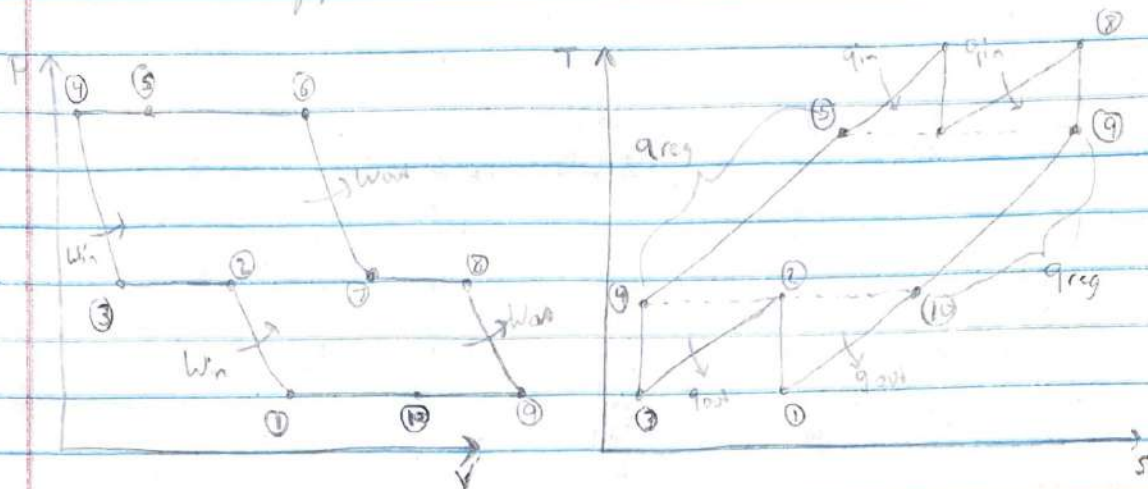
$$\dot{m} = 249 \frac{kg}{s}$$

9-121.) Given: $r_p = 3$

$T_c = 300\text{K}$

$T_T = 1200\text{K}$

C_p, C_v Variable



$$\frac{P_2}{P_1} = \frac{P_4}{P_3} = 3 \quad \frac{P_6}{P_7} = \frac{P_8}{P_9} = 3$$

See next page for states



$$T_1 = 300K$$

$$P_1 = 1.386$$

$$h_1 = 300.19 \frac{kJ}{kg}$$

$$P_2 = 3P_1$$

$$P_{r2} = 4.158$$

$$h_2 = 411.36 \frac{kJ}{kg}$$

$$T_2 = 410.14K$$

$$T_3 = 300K$$

$$P_4 = 3P_3$$

$$P_{r4} = 4.158$$

$$h_4 = h_3$$

$$P_5 = P_4$$

$$T_6 = 1200K$$

$$P_{r6} = 238$$

$$h_6 = 1277.79 \frac{kJ}{kg}$$

$$P_6 = P_5$$

$$P_7 = P_6/5$$

$$P_{r7} = 79.3$$

$$T_7 = 911.86K$$

$$h_7 = 911.25 \frac{kJ}{kg}$$

$$P_8 = P_7$$

$$T_8 = 1200K$$

$$P_9 = P_8$$

$$T_9 = T_8$$

$$P_{10} = P_1$$

$$T_{10} = T_2$$

Find P_{r2}

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}}$$

$$P_{r2} = 4.158$$

Find T_2

$$\begin{array}{l|l} h_1 & 300.19 \\ T_2 & 410.14 \\ \hline \end{array}$$

Find h_2

$$\begin{array}{l|l} h_1 & 300.19 \\ h_2 & 411.36 \\ \hline \end{array}$$

Find P_{r7}

$$\frac{P_7}{P_5} = \frac{P_{r7}}{P_{r5}}$$

$$P_{r7} = 79.3$$

Find P_{r7}

$$\frac{P_7}{P_5} = \frac{P_{r7}}{P_{r5}}$$

$$P_{r7} = 79.3$$

$$W_{comp,in} = 2(h_2 - h_1) = 2(411.36 - 300.19) = 222.13 \frac{kJ}{kg}$$

$$W_{turb,out} = 2(h_6 - h_7) = 2(1277.79 - 911.86) = 663.08 \frac{kJ}{kg}$$

$$a) \quad \eta_{bw} = \frac{W_{net}}{W_{turb,out}} = \frac{222.13}{663.08} = \boxed{.33}$$

$$q_{in} = (h_6 - h_7) + (h_8 - h_7) = 222.36 \frac{kJ}{kg}$$

$$\eta_{th} = \frac{W_{net}}{q_{in}} = .36 = \boxed{36\%}$$

$$b) \quad \epsilon = \frac{q_{regen,out}}{q_{regen,in}}$$