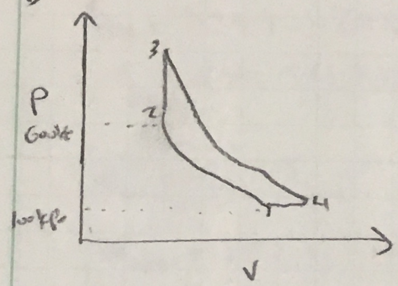
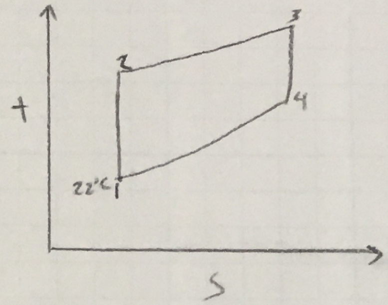
HW 1.2 Ch.9: 13, 18, 22, 31

9.13) An air standard cycle with variable specific heats is executed in a closed system and is composed of the following 4 processes;

1-2 isentropic compression from 100kPa and 22°C to 600kPa.
2-3 V = constant heat addition to 1500k
3-4 isentropic expansion to 100kPa
4-1 P = constant heat rejection to initial state.

a)





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

$T_1 = 22°C = 295\,K$

$h_1 = 295.17\ kJ/kg$

$u_1 = 210.49\ kJ/kg$

$P_{r1} = 1.3068$

$\frac{P_{r2}}{1.3068} = \frac{600}{100}$

$\frac{P_{r2}}{1.3068} = 6$

$P_{r2} = 7.8408$

$T_2 = 490 + (500-490)\left(\frac{7.8408-7.824}{8.411-7.824}\right)$

$T_2 = 490.286K$

$u_2 = 352.08 + (359.49-352.08)\left(\frac{7.8408-7.824}{8.411-7.824}\right)$

$u_2 = 352.29\ kJ/kg$

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

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

$P_3 = 600\left(\frac{1500}{490.4}\right)$

$P_3 = 1835.23\ kPa$

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

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

$P_{r4} = \frac{100}{1835.23}(601.9)$

$P_{r4} = 32.79$

$h_4 = 734.82 + (745.62-734.82)\left(\frac{32.79-32.02}{33.72-32.02}\right)$

$h_4 = 739.71\ kJ/kg$

$q_{in} = u_3 - u_2$

$q_{in} = 1205.41 - 352.29$

$q_{in} = 853.12 \text{ KJ/kg}$

$q_{out} = h_4 - h_1$

$q_{out} = 739.71 - 295.17$

$q_{out} = 444.54 \text{ KJ/kg}$

$w_{net} = q_{in} - q_{out}$

$w_{net} = 853.12 - 444.54$

$w_{net} = 408.58 \text{ KJ/kg}$

c)

$$n_{th} = \frac{w_{net}}{q_{in}}$$

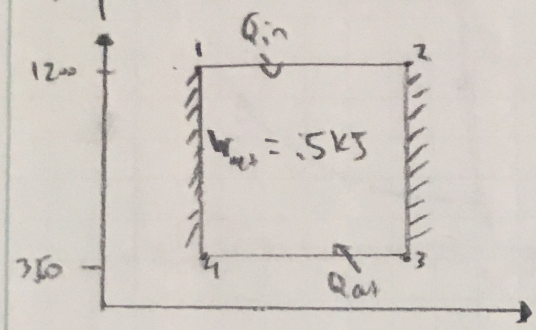
$$n_{th} = \frac{408.58}{853.12}$$

$n_{th} = .478$

47.8%

18)

a)



$T_1 = 1200\ K$ $\quad$ $T_4 = 350\ K$

$P_{r1} = 238$ $\quad$ $P_{r4} = 2.379$

$P_1 = \frac{P_{r1}}{P_{r4}} P_4$

$P_1 = \frac{238}{2.379}(300\ kPa)$

$P_1 = 30.0\ MPa$

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

$= 1 - \frac{350K}{1200K}$

$= .7083$

$\eta_{th} = 70.83\%$

$Q_{in} = W_{net,out} / \eta_{th}$

$Q_{in} = .5kJ / .7083$

$Q_{in} = .706\ kJ$

c) $s_4 - s_3 = (s_4^\circ - s_3^\circ) - R \ln \frac{P_4}{P_3}$

$= -(.287\ kJ/kg\cdot K) \ln \frac{300\ kPa}{150\ kPa}$

$s_4 - s_3 = -.199\ kJ/kg\cdot K = s_1 - s_2$

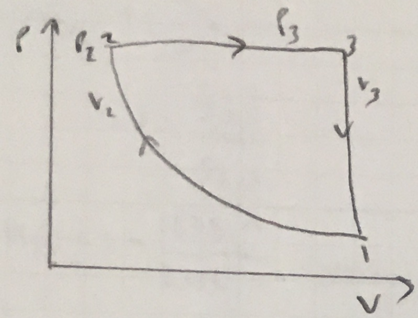
$W_{net,out} = (s_2 - s_1)(T_H - T_L)$

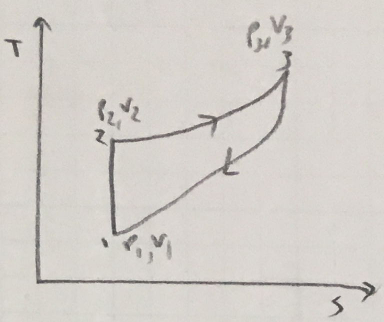
$= (.199\ kJ/kg\cdot K)(1200 - 350K)$

$W_{net,out} = 169.15\ kJ/kg$

22)

a)





b) $C_p = C_v + R$

$C_p = .7 + .3$

$C_p = 1 \text{ KJ/Kg K}$

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

$K = \frac{1}{.7}$

$K = 1.428$

• 1-2

$T_1 V_1^{K-1} = T_2 V_2^{K-1}$

$T_2 = T_1 \cdot \frac{V_1^{K-1}}{V_2^{K-1}}$

$T_2 = T_1 \left(\frac{V_1}{V_2}\right)$

$T_2 = T_1 (r)^{K-1}$

$T_2 = (293)(5)^{1.428-1}$

$T_2 = 584 K$

• 2-3

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

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

$T_3 = T_2 \frac{V_1}{V_2}$

$T_3 = T_2 (r)$

$T_3 = 584 (5)$

$T_3 = 2920 K$

• W 1-2

$W_{1-2} = C_v (T_1 - T_2)$

$W_{1-2} = .7 (293 - 584)$

$W_{1-2} = -203.7 \text{ KJ/kg}$

• q_{2-3}

$q_{2-3} = C_p (T_3 - T_2)$

$q_{23} = 1 (2920 - 584)$

$q_{2-3} = 2336 \text{ KJ/kg}$

• $W_{1-2} = 0$

• W_{2-3}

$W_{2-3} = 2336 - .7 (2920 - 584)$

$W_{2-3} = 700.8 \text{ KJ/kg}$

• W_{3-1}

$W_{3-1} = C_v (T_3 - T_1)$

$= .7 (2920 - 293)$

$W_{3-1} = 1838.9 \text{ KJ/kg}$

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

$$= 1 - \frac{q_{3-1}}{q_{2-3}}$$

$$n_{th} = 1 - \frac{1838.9}{2336}$$

$$1 - .787$$

$$n_{th} = .213$$

$$n_{th} = 21.3\%$$

d) $$n_{th} = 1 - \frac{q_{out}}{q_{in}}$$

$$n_{th} = 1 - \frac{q_{3-1}}{q_{2-3}}$$

$$n_{th} = 1 - \frac{c_v(T_3 - T_1)}{c_p(T_3 - T_2)}$$

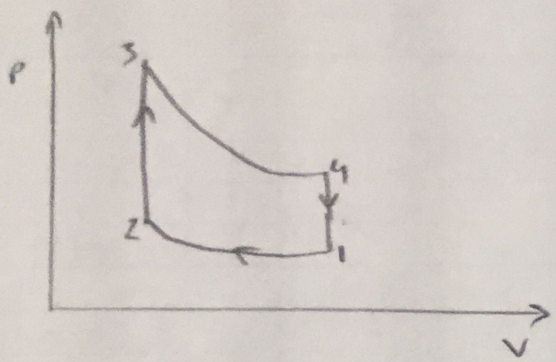
$$n_{th} = 1 - \frac{c_v(5T_2 - T_1)}{c_p(5T_1 r^{k-1} - T_1 r^{k-1})}$$

$$n_{th} = 1 - \frac{1}{\gamma} \frac{(5r^{k-1} - 1)}{5r^{k-1} - r^{k-1}}$$

$$n_{th} = \left(1 - \frac{5r^{k-1} - 1}{\gamma 4 r^{k-1}}\right)$$

$$n_{th} = 1 - \left(\frac{5r^{k-1} - 1}{\gamma 4 r^{k-1}}\right)$$

31)



$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

$$T_2 = \frac{T_1 V_1^{\gamma-1}}{V_2^{\gamma-1}}$$

$$T_2 = T_1 (r)^{\gamma-1}$$

$$T_2 = (313)(10.5)^{1.41}$$

$$T_2 = 801.715\ K$$

$$n_{th} = 1 - \frac{T_1}{T_2}$$

$$= 1 - \frac{313}{801.715\ K}$$

$$n_{th} = .61$$

$$W_{net} = n_{th} \cdot Q_{in}$$

$$Q_{in} = \frac{W_{net}}{n_{th}}$$

$$Q_{in} = \frac{90\ KW}{.61}$$

$$Q_{in} = 147.54\ KW$$