HW 1, 2 ch 9

13 closed system with four processes

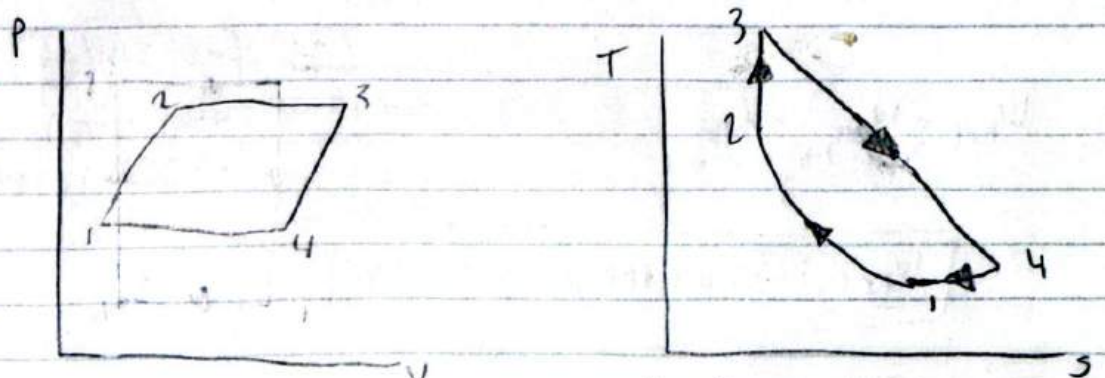
1-2 Isentropic compression from 100kPa and 22°C to 600kPa

2-3 V = constant heat addition to 1500K

3-4 Isentropic expansion to 100kPa

4-1 P = constant heat rejection to initial

a) show cycle on P-v and T-s diagram
b) calculate net work output per unit mass
c) determine thermal efficiency



$\frac{V_4}{V_3} = \frac{T_4}{T_3}$

$R = .287$

$v = \frac{(.287)(295)}{100}$ $v = \frac{(.287)(1770)}{600}$ P_{const} $P = \frac{(.287)(1500)}{.84665}$ $PV = RT$ $T_4 = \frac{P_4}{P_3} T_3 =$

$T_4 = \frac{100}{508.47}$

$P_1 = 100kPa$ $P_2 = 600kPa$ $P_3 = 508.47$ $P_4 = 100kPa$

$T_1 = 22°C = 295K$ $T_2 = \frac{P_2}{P_1} T_1$ $T_3 = 1500K$ $T_4 = 295.00$

$v_1 = .84665$ $T_2 = 1770$ $v_3 = .84665$ $v_4 = .1665$

$v = .84665$

$V_4 = \frac{295}{1500}(.84$

$$W_{in_{4-1}} = P_4(V_4 - V_1) = 100(.1665 - .84665) = -68.015 \frac{kJ}{kg}$$

$W_{out_{2-3}}$

$$(q_{in_{2-3}} - \cancel{q_{out}}^{0}) + (\cancel{w_{in}}^{0} - W_{out_{2-3}}) = U_3 - U_2$$

$$q_{in_{2-3}} - W_{out_{2-3}} = C_v(\cancel{T_3 - T_2}^{0}) \; I \circ 0$$

$$W_{out_{2-3}} = q_{in_{2-3}}$$

$$W_{out_{2-3}} = T_3(s_3 - s_2)$$

$$W_{out_{2-3}} = RT_3 \ln\left(\frac{v_3}{v_2}\right)$$

$$(.287)(1500)\ln\left(\frac{v_3}{v_2}\right)$$

$$430(\ln)\left(\frac{v_3}{v_2}\right)$$

$$(430)\ln(11.2247)$$

$$W_{out_{2-3}} = 87.159$$

$$\frac{W_{comp}}{W_{exp}} = \frac{-68.015}{87.159}$$

$$\frac{W_{comp}}{W_{exp}} = .78$$

$$W_{net} = W_{out_{2-3}} - W_{in_{4-1}}$$

$$W_{net} = 87.159 + 68.015 = 155.174 \frac{kJ}{kg}$$

$$\eta_{th} = \frac{W_{net}}{q_{in}} \qquad q_{in} = q_{in_{1-2}} + q_{in_{2-3}}$$

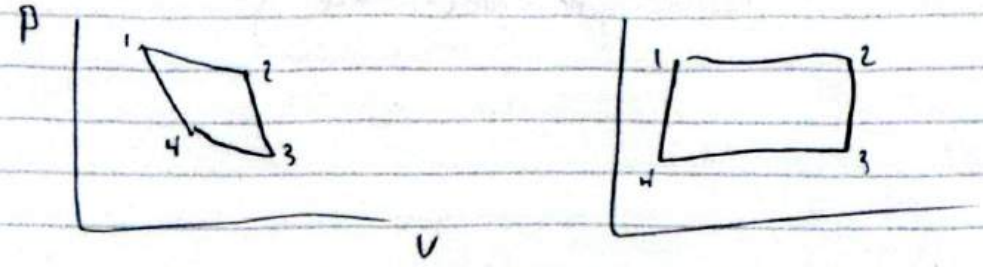
$$q_{in} = 1146.209 \qquad q_{in_{1-2}} = .718(1776 - 795)$$

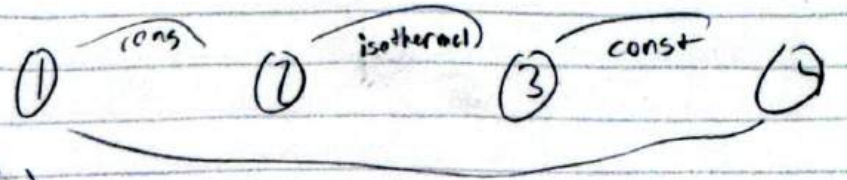
$$\frac{155.174}{1146.209} = .1354 \qquad q_{in_{1-2}} = 1059.06$$

$$\eta_{th} = 13.54\%$$

9-19

Carnot cycle
temp limits 350k and 1200 K. pressure before and after isothermal compression are 150 and 300 kPa. net work per cycle is .5 kJ determine (a) max pressure (b) heat transfer to air and (c) mass of air





$P_1 - P_4 \left(\frac{P}{P_{x1}}\right)$

$300\left(\frac{230}{2.379}\right)$

$P_1 = 30.01 \text{ mPa} = P_{max}$

$\eta_c = 1 - \frac{T_L}{T_H}$

$1 - \left(\frac{350}{1200}\right)$

$\eta_c = .7083$

$\eta_c = \frac{W_{out}}{Q_s} = .7083 = \frac{.5}{Q_s}$

$Q_{out} = .706 \text{ kJ}$

$ds = \frac{dQ}{T} = dQ = T\,ds$

$dw = (T_H - T_L)(s_4 - s_2)$

$(s_4 - s_3) = -(s_3 - s_4)$

$R \ln\left(\frac{P_4}{P_3}\right)$

$.2870 \ln\left(\frac{300}{150}\right)$

$.1989 \text{ kJ/kg·K}$

$dw = (T_H - T_L)(s_4 - s_3)$

$(1200 - 350)(.1989)$

$dw = 169.065 \text{ kJ/kg}$

$$m = \frac{w}{dw} = \frac{.5}{169.065}$$

$$\downarrow$$

$$m = .002957 \text{ kg}$$

1-2 isentropic compression initial temp $T_1 = 70\,^{\circ}C$ with compression ratio: $r = 5$

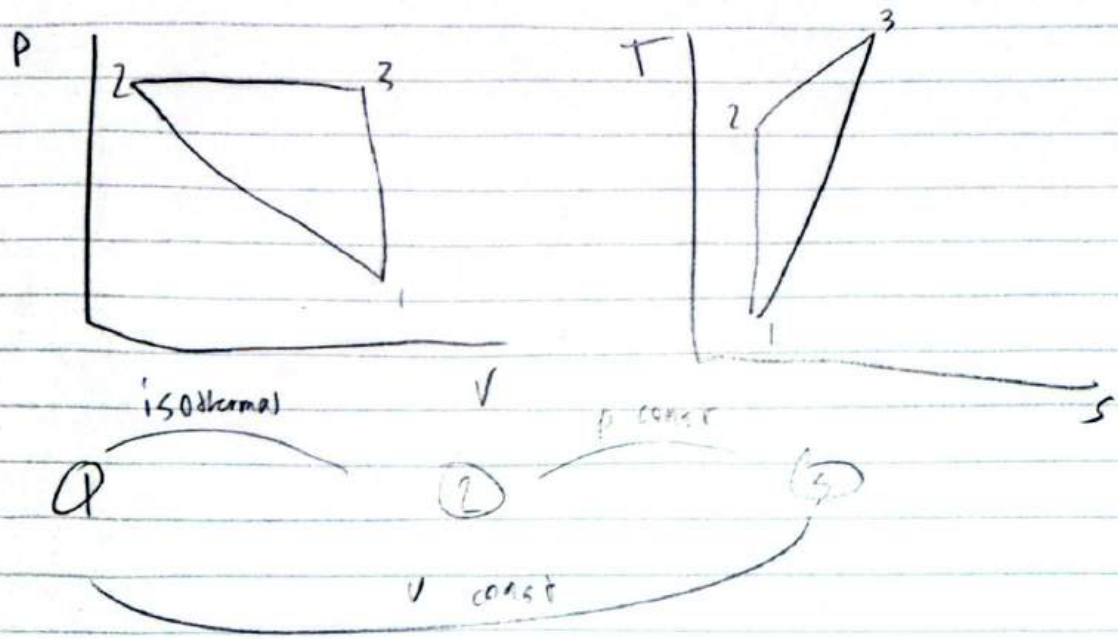
2-3 constant pressure heat addition

3-1 constant volume heat rejection

$c_v = .7\ kJ/kg \cdot K$

$R = .3\ kJ/kg \cdot K$

a) sketch diagrams
b) heat work interactions
c) thermal efficiency
d) expression for cycle thermal efficiency as function of the compression ratio r and ratio of specific heats α



1-2 $T_2 = T_1(r^{k-1})$

$293(5^{1.42857-1})$

$T_2 = 584.02\ k$

$q_{1-2} = 0\ kJ/kg$

$w_{1-2} = \frac{R(T_1 - T_2)}{k-1}$

$\frac{.3(293-583.48)}{1.42857-1}$

$w_{1-2} = -203.72\ kJ/kg$

2-3 $\frac{V_2}{T_2} = \frac{V_3}{T_3}$

$T_3 = T_2\left(\frac{V_3}{V_2}\right) = T_2\left(\frac{V_1}{V_2}\right) = T_2 \cdot r$

$584.02(5)$

$T_3 = 2920.1\ k$

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

$1(2920.1 - 584.02)$

$q_{2-3} = 2336.08$

$\Delta U_{2-3} = U_3 - U_2 = c_v(T_3 - T_2)$

$.7(2920.1 - 584.02)$

1633.26

$w_{2-3} = q_{2-3} - \Delta U_{2-3}$

$w_{2-3} = 700.82 \text{ kJ/kg}$

3-1

$$q_{3-1} = c_v (T_1 - T_3)$$

$$.7(293 - 2720.1)$$

$$q_{3-1} = -1828.17 \text{ kJ/kg}$$

$$w_{3-1} = 0 \text{ kJ/kg}$$

$$\eta_{TH} = 1 - \frac{q_{out}}{q_{in}}$$

$$1 - \frac{1838.97\ (100)}{2336.69}$$

$$\downarrow$$

$$.2178 = 21.78\%$$

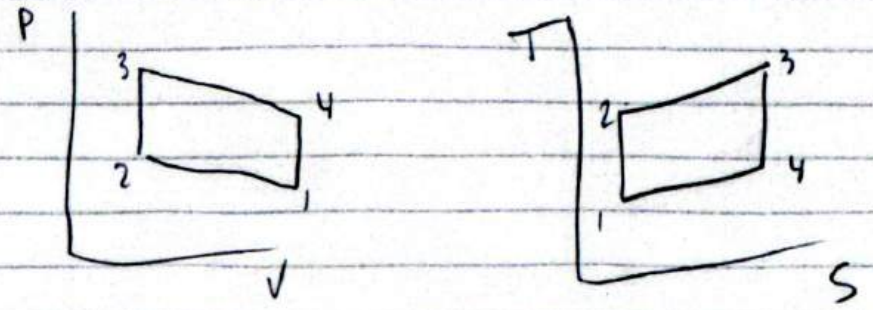
$$\eta_{TH} = 1 - \frac{1}{k} \cdot \frac{1}{r^{k-1}} \cdot \frac{r^{k}-1}{r-1}$$

$$\downarrow$$

$$\eta_{TH} = 1 - \frac{1}{r^{k-1}}$$

9-31 Otto cycle compression ratio of 10.5 takes in air at 90 kPa and 40°C and is repeated 2500 times per min

Determine thermal efficiency and rate of heat input if cycle is to produce 90 kW of power



$K = \frac{C_p}{C_v}$ $\quad k = \frac{1.005}{.718} = 1.399$

$$\eta = 1 - \frac{1}{r^{k-1}}$$

$$1 - \frac{1}{(10.5)^{1.399-1}} = 1 - \frac{1}{2.555} = 1 - .391 = .609$$

$\eta = 60.9\%$

ROH = P/cycle Frequency

$ROH = \frac{90000}{150000}$

90 kW

90000

2500

150000 sec

ROH = .6