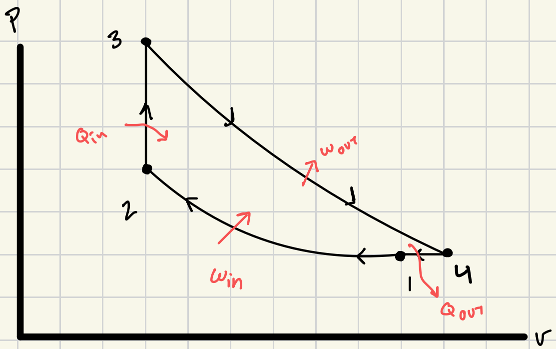
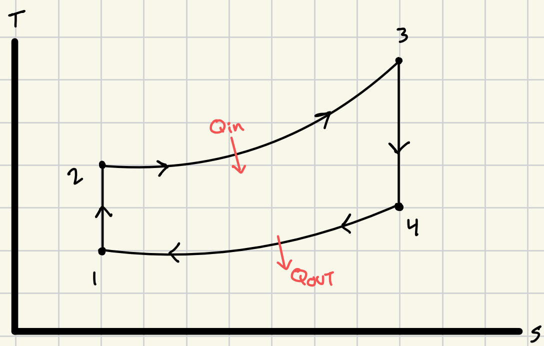
HW 1.2 – CH 9: 13, 18, 22, 31 *

9–13 An air-standard cycle with variable specific heats is executed in a closed system and is composed of the following four processes:

1-2 Isentropic compression from 100 kPa and 22°C to 600 kPa
2-3 v = *constant* heat addition to 1500 K
3-4 Isentropic expansion to 100 kPa
4-1 P = *constant* heat rejection to initial state

(*a*) Show the cycle on *P*-v and *T*-*s* diagrams. ✓
(*b*) Calculate the net work output per unit mass. ✓
(*c*) Determine the thermal efficiency. ✓





→ ① ✓ $\xrightarrow{\text{ISENTR}}$ ② $\xrightarrow{v\text{ CONST}}$ ③ $\xrightarrow{\text{ISENTR}}$ ④ $\xrightarrow{P=\text{CONST}}$

①
$P_1 = 100\,kPa$
$T_1 = 22°C = 295\,K$
$v_1 = \frac{RT_1}{P_1} = .847\ m^3/kg$

②
$P_2 = 600\,kPa$
$T_2 = 489\,K$
$v_2 = .234\ m^3/kg$

③
$T_3 = 1500\,K$
$v_3 = .234\ m^3/kg$
$P_3 = 1839\,kPa$

④
$P_4 = 100\,kPa$
$T_4 = 724.17\,K$
$v_4 = 2.078\ m^3/kg$

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

$\rightarrow P_{r2} = 7.8408$

	Y	X
1	490	7.824
	x	7.8408
2	500	8.411

$$\frac{100\,kPa}{1839\,kPa} = \frac{P_{r4}}{601.9} \Rightarrow P_{r4} = 32.7297$$

	Y	X
1	720	32.02
	x	32.7297
2	730	33.72

a) diagram displayed on previous page

b) calculate the net work output per unit mass (w_{OUT})

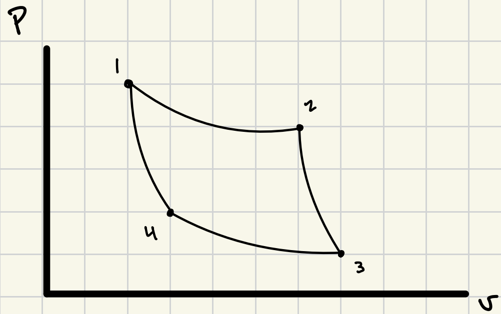
$$w_{net} = Q_{in} - Q_{OUT} = c_v(T_3 - T_2) - c_p(T_4 - T_1)$$

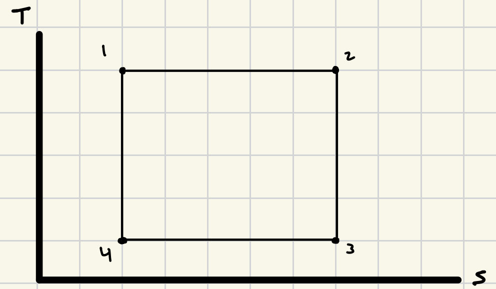
$$.718(1500K - 489K) - 1.007(724.17K - 295K) \Rightarrow \boxed{w_{net} = 293.72\ kJ/kg}$$

c) determine the thermal efficiency

$$\eta_{TH} = \frac{w_{net}}{c_v(T_3 - T_2)} \rightarrow \frac{293.72}{.718(1500 - 489)} \Rightarrow \boxed{\eta_{TH} = .405 \text{ or } 40.5\%}$$

9–18 An air-standard Carnot cycle is executed in a closed system between the temperature limits of 350 and 1200 K. The pressures before and after the isothermal compression are 150 and 300 kPa, respectively. If the net work output per cycle is 0.5 kJ, determine (*a*) the maximum pressure in the cycle, (*b*) the heat transfer to air, and (*c*) the mass of air. Assume variable specific heats for air. *Answers:* (*a*) 30.0 MPa, (*b*) 0.706 kJ, (*c*) 0.00296 kg





① $T_1 = 1200K$, $P_2 = 30 MPa$

② $T_2 = 1200K$, $P_2 = 15 MPa$

③ $T_3 = 350K$, $P_3 = 150kPa$

④ $T_4 = 350K$, $P_4 = 300kPa$

$$P_1 = \frac{238.0}{2.379} \cdot 300k$$

$$\frac{150kPa}{P_2} = \frac{2.379}{238.0}$$

$\boxed{a)\ 30MPa}$

b) $\eta_{TH} = 1 - \frac{350}{1200} \Rightarrow \eta_{TH} = .7083$

$\rightarrow Q_{in} = \frac{.5kJ}{.7083} \Rightarrow \boxed{Q_{in} = .706kJ}$

c) $\omega = -(-R \ln P_4/P_3)(T_H - T_L)$

$= (.287 \ln \frac{300}{150})(1200 - 350) \Rightarrow \omega = 169.09\ kJ/kg$

$m = \frac{W}{\omega} \rightarrow \frac{.5kJ}{169.09\ kJ/kg} \Rightarrow \boxed{m = .00296\ kg}$

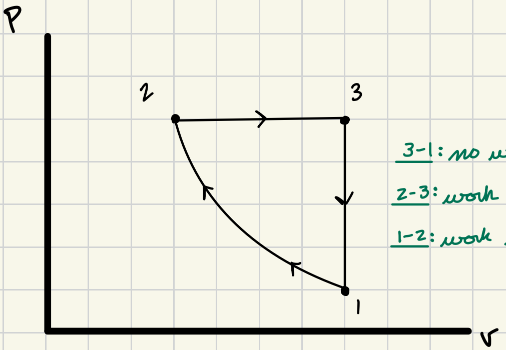
9–22 An ideal gas is contained in a piston-cylinder device and undergoes a power cycle as follows:

1-2 isentropic compression from an initial temperature $T_1 = 20°C$ with a compression ratio $r = 5$
2-3 constant pressure heat addition
3-1 constant volume heat rejection

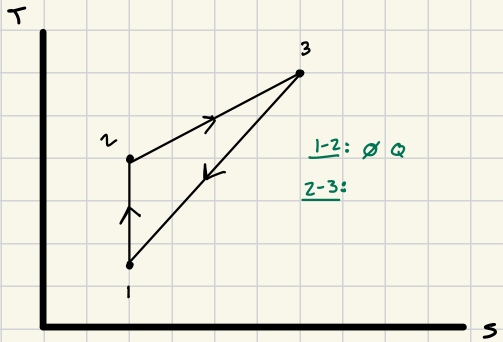
The gas has constant specific heats with $c_v = 0.7$ kJ/kg·K and $R = 0.3$ kJ/kg·K.

(*a*) Sketch the *P-v* and *T-s* diagrams for the cycle. ✓
(*b*) Determine the heat and work interactions for each process, in kJ/kg.
(*c*) Determine the cycle thermal efficiency.
(*d*) Obtain the expression for the cycle thermal efficiency as a function of the compression ratio r and ratio of specific heats k.

$$r = 5 = \frac{v_{max}}{v_{min}}$$



3-1: no work
2-3: work out
1-2: work in



1-2: ∅ Q
2-3:

$\rightarrow$ ① $\xrightarrow{\text{ISENTR}}$ ② $\xrightarrow{P\ \text{const}}$ ③ $\xrightarrow{v\ \text{const}}$

$T_1 = 20°C = 293K$ $\quad T_2 = 583.9K$ $\quad T_3 = 2919.8K$

$C_p = R + C \rightarrow .3 + .7 \Rightarrow C_p = 1\ kJ/kg \cdot K$
& $k = c_p/c_v = 1/.7 \Rightarrow k = 1.428$

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

$$\frac{293K}{T_3} = 5^{-1.428}$$

Made with Goodnotes

b) $\underline{1-2}$

$Q_{1-2} = 0\ kJ/kg$ $\quad W_{1-2} = \dfrac{.3(583.9-293)}{1.428-1} = 203.7\ kJ/kg\ (OUT)$

$\underline{2-3}$

$Q_{2-3} = 1(2919.8-583.9) = 2335.9\ kJ/kg$ $\quad W_{2-3} = .3(2919.8-583.9) = 700.8\ kJ/kg$

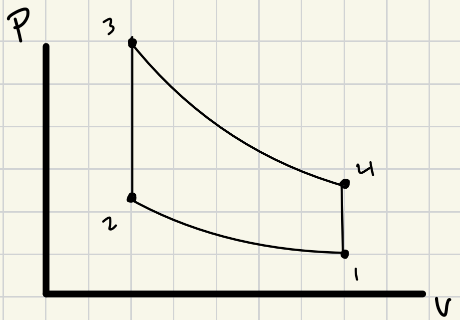
$\underline{3-1}$

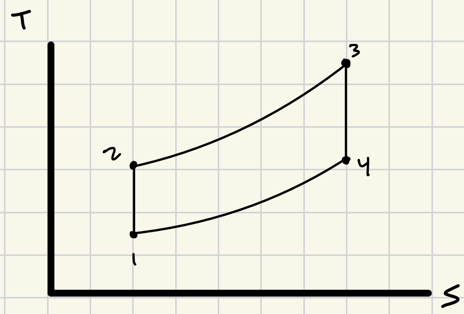
$Q_{3-1} = .7(2919.8-293) = 1838.8\ kJ/kg$ $\quad W_{3-1} = 0\ kJ/kg$

c) $\eta_{TH} = 1 - \left|\dfrac{Q_{3-1}}{Q_{2-3}}\right| = 1 - \left|\dfrac{1838.8}{2335.9}\right| \Rightarrow \eta_{TH} = .213$ or 21.3%

d) $\eta_{TH} = \dfrac{(r^{-k} - 1)}{k(r-1)}$

9-31 An ideal Otto cycle has a compression ratio of 10.5, takes in air at 90 kPa and 40°C, and is repeated 2500 times per minute. Using constant specific heats at room temperature, determine thermal efficiency of this cycle and the rate of heat input if the cycle is to produce 90 kW of power.





a) $\eta_{TH,OTTO} = 1 - \frac{1}{10.5^{(1.4-1)}} \Rightarrow \boxed{\eta = .609 \text{ or } 60.9\%}$

b) $w = P/t = 90\,kW \cdot \frac{60}{2500} \Rightarrow w = 2.16\,kJ$

$Q_s = 2.16\,kJ / .609 \Rightarrow \boxed{Q_s = 3.54\,kJ}$

Made with Goodnotes