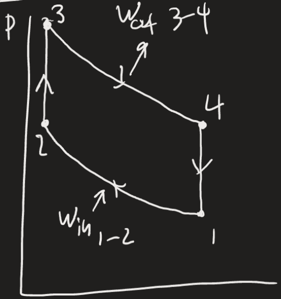
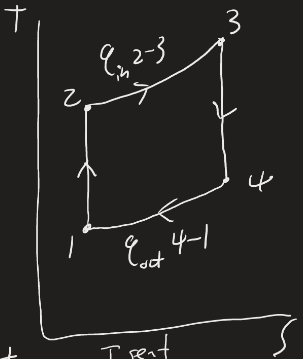
Homework 1.3

Monday, January 29, 2024 4:34 PM

9-33





1 —Isent— 2 —v = const— 3 —Isent— 4 —v = const

1

$T_1 = 300K$

$P_1 = 95\ kPa$

$\frac{v_1}{v_2} = 8$

$P_1 v_1 = RT_1$

$95 v_1 = 8.314(300K)$

$v = 26.25$

2

$q_{in} = 750\ kJ/kg$

$V_2 = 3.28$

$8 = \left(\frac{621.2}{v_{r_2}}\right)$

$v_{r_2} = 77.65$

$T_2 \approx 673K$

$u_2 = 491.2\ kJ/kg$

3

$V_3 = 3.28$

$u_3 = u_2 + q_{2-3}$

$u_3 = 491.2 + 750$

$u_3 = 1241.2\ kJ/kg$

$T_3 = 1539\ K$

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

$P_3 = 3898.8\ kPa$

4

$V_4 = 26.25$

$q_{4-1} = u_4 - u_1$

$= 357.62\ kJ/kg$

$$\frac{26.25}{V_2} = 8$$

$$V_2 = 3.28$$

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

$$\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1}$$

$$P_2 = \frac{P_1 T_2}{T_1}\left(\frac{V_1}{V_2}\right)$$

$$P_2 = 1705.18\,kPa$$

a) $\underline{P_3 = 3898.8\,kPa}$

$\underline{T_3 = 1539\,K}$

b) $W_{net} = q_{2-3} - q_{4-1}$

$= (750\,kJ/kg) - (357.62\,kJ/kg)$

$\underline{= 392.38\,kJ/kg}$

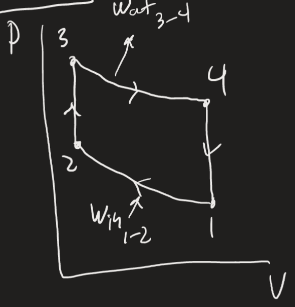
c) $\eta_{th} = \frac{W_{net}}{q_{2-3}}(100) = \frac{392.38}{750}(100)$

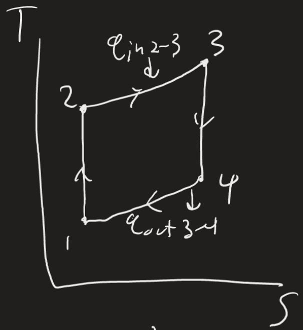
$\underline{= 52.3\%}$

d) $V_2 = 0.11325\,m^3$

$P_m = \frac{W_{net}}{V_1 - V_2}$ $\underline{P_m = 494.96\,kPa}$

9-36





$$\begin{tikzcd} 1 \arrow[r, bend left, dash, "\text{Isent}"] & 2 \arrow[r, bend left, dash, "V=\text{const}"] & 3 \arrow[r, bend left, dash, "\text{Isent}"] & 4 \arrow[r, bend left, dash, "v=\text{const}"] & {} \end{tikzcd}$$

1

$P_1 = 14\text{psia}$

$T_1 = 565\,R$

$V_1 = \frac{RT_1}{P_1}$

$V_1 = 14.95\,\frac{ft^3}{lbm}$

2

$V_2 = 13.65$

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

$= 1430.7R$

3

$T_3 = 2860\,R$

4

$T_4 = T_3\left(\frac{V_1}{V_2}\right)^{k-1}$

$T_4 = 1129.4R$

$$w_{net} = c_v(T_3 - T_4) - c_v(T_2 - T_1)$$

$$= (0.171\ BTU/lbm\cdot R)(2860 - 1129.4)R - (1.171\ Btu/lbm\cdot R)$$

$$(1430.7 - 565)R$$

$$W_{net} = 147\ Btu/lbm$$

$$m = N_{cyl}\frac{\pi B^2 \frac{S}{2}}{V_1}$$

$$= 6\ \pi\left(\frac{3.5}{12}ft\right)^2\left(\frac{3.9}{12}ft\right)^4$$

$$= 0.08716\ lbm$$

$$= mW_{net}$$

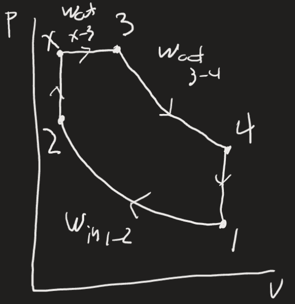
$$= 0.08716\ lbm \times 147.9\ btu/lbm$$

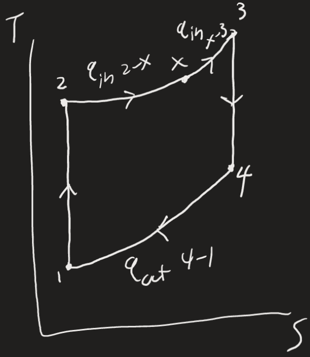
$$= 1.289\ Btu/cycle$$

$$\frac{\left((1.289)\left(\frac{2500}{60}\right)\right))}{2\ rev/cyl\left[4hp(0.7068\ Btu/s)\right]}$$

$$\underline{= 38\ hp}$$

9-46





$$r = 16 = \frac{v_1}{v_2} = \frac{v_4}{v_x}$$

$$r_c = 2 = \frac{v_3}{v_x}$$

$$1 \xrightarrow{\text{Isent}} 2 \xrightarrow{v\ \text{const}} X \xrightarrow{P\ \text{const}} 3 \xrightarrow{\text{Isent}} 4 \xrightarrow{V\ \text{const}}$$

1

$P_1 = 95\ kPa$

$T_1 = 300\ K$

$v_1 = \frac{RT_1}{P_1}$

$= 26.25$

2

$v_2 = \frac{26.25}{16}$

$= 1.64$

$\left(\frac{1.64}{26.25}\right) = \frac{v_{r_2}}{621.2}$

$v_{r_2} = 38.8$

$T_2 \approx 863\ K$

$h_2 = 890.9\ \frac{kJ}{kg}$

X

$v_x = 1.64$

3

$v_3 = 3.28$

$h_3 = 1910.6\ \frac{kJ}{kg}$

$T_3 = 2(862.44)$

$= 1724.8\ K$

4

$v_4 = 26.25$

$u_4 = 659.7\ \frac{kJ}{kg}$

$v_{r_4} = 36.37$

$$q_{in} = h_3 - h_2 = 1910.6 - 890.9$$
$$= 1019.7\ kJ/kg$$

$$q_{out} = u_4 - u_1 = 659.7 - 214.07$$
$$= 445.63\ kJ/kg$$

$$\eta = 1 - \frac{q_{out}}{q_{in}}$$

$$= 56.3\% \quad b)$$

$$T_{max} = 1724.8K \quad a)$$

c) $MEP = \frac{w_{net}}{v_1 - v_2}$

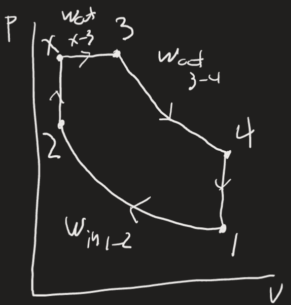
$$w_{net} = q_{in} - q_{out}$$

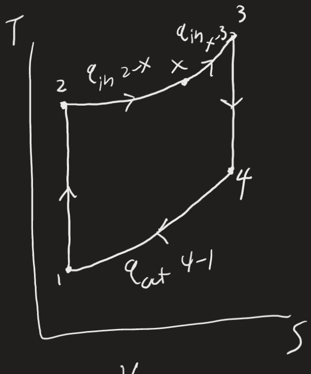
$$= 574.07 kJ/kg$$

$$MEP = \frac{574.07}{0.906(1-\frac{1}{16})}$$

$$= 675.9 kPa$$

$\boxed{9-57}$





$$r = \frac{V_1}{V_2} = 16 = \frac{V_4}{V_x} \qquad r_c = 1.8 = \frac{V_3}{V_x}$$

$$\overbrace{1 \qquad\qquad 2}^{\text{Isnt}}\overbrace{\qquad\qquad X}^{\text{Vconst}}\overbrace{\qquad\qquad 3}^{\text{Pconst}}\overbrace{\qquad\qquad 4}^{\text{Isnt}}\overbrace{\qquad\qquad}^{\text{Vconst}}$$

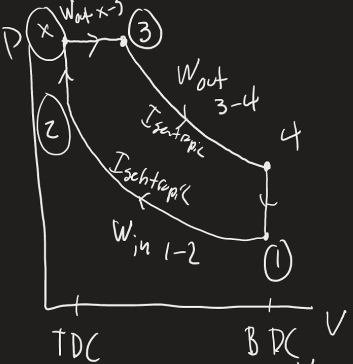
1	2	X	3	4
$P_1 = 97\,kPa$	$T_2 = T_1 \times r^{k-1}$		$T_3 = r_c \times T_2$	$T_4 = T_3 \times \left(\frac{r_c}{r}\right)^{k-1}$
$T_1 = 343\,K$	$T_2 = 1039.78$		$T_3 = 1871.61$	$T_4 = 781.04$
$U_1 = 244$	$h_2 = 1207.57$		$h_3 = 2092.14$	$U_4 = 576.12$

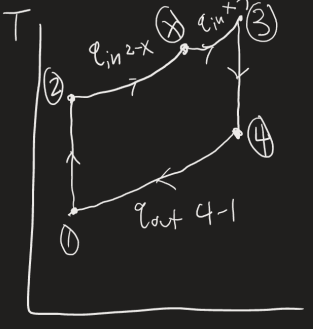
$$Q_{in} = m(h_3 - h_2)$$
$$= \frac{P_1 V}{R T_1}(h_3 - h_2)$$
$$= \frac{(97)(2.4\times10^{-3})}{(0.287)(343)}(2092.14 - 1207.57)$$
$$= 2.0919$$

$$Q_{out} = m(U_4 - U_1)$$
$$= 0.002(576.12 - 244)$$
$$= 0.7854$$

$$W = n(Q_{in} - Q_{out})$$
$$= 5000(2.092 - 0.7854)$$
$$= 6532.36\,kW$$

9-59E





$r = 15 = \frac{V_1}{V_2}$ $\quad r_c = 1.4 = \frac{V_3}{V_x}$

$C_p = 0.240$ Btu/lbm·R

$C_v = 0.171$ Btu/lbm·R

$R = 0.3704$ psia·ft^3/lbm·R

1

$T_1 = 535\,R$

$P_1 = 14.2$ psia

2

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

$= 1580\,R$

$P_2 = P_1\left(\frac{V_1}{V_2}\right)^{k}$

$= 629.2$ psia

x

$T_x = T_2\left(\frac{P_x}{P_2}\right)$

$= 1738\,R$

3

$T_3 = T_x r_c$

$= 2433\,R$

4

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

$= 942.2\,R$

$W_{1-2} = C_v(T_2 - T_1) = 178.7$ Btu/lbm

$w_{3-4} = C_v(T_3 - T_4) = 254.9$ Btu/lbm

$q_{2-x} = C_v(T_x - T_2) = 27.02$ Btu/lbm

$q_{x-3} = C_p(T_3 - T_x) = 166.8$ Btu/lbm

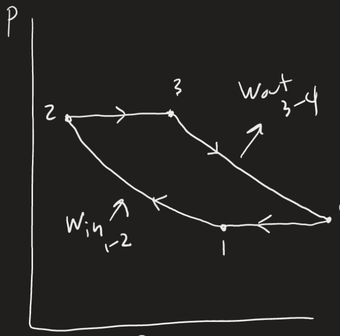
$w_{x-3} = q_{x-3} - C_v(T_3 - T_x) = 47.96$ Btu/lbm

$W_{net} = W_{3-4} + W_{x-3} - W_{1-2} = \underline{124.2\text{ Btu/lbm}}$

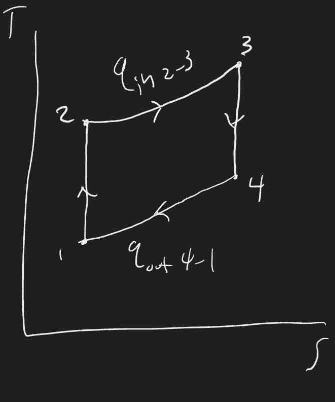
$q_{in} = q_{2-x} + q_{x-3} = \underline{193.8\text{ Btu/lbm}}$

$\eta_{th} = \frac{W_{net}}{q_{in}} = \underline{0.641}$ or $\underline{64.1\%}$

$\boxed{\text{9-80E}}$ $T_2 = ?$ BWR = ? $\eta_{th\,Bray} = ?$



$\underline{P_2} = 10$



P_1

Isent | P = const | Isent | P = const

1 | 2 | 3 | 4

$T_1 = 520\,R$

$P_1 = \frac{P_3}{10}$

$h_1 = 124.27 \frac{Btu}{lbm}$

$10 = \frac{Pr_2}{1.2311}$

$Pr_2 = 12.31$

$T_2 = 1008\,R$

$h_2 = 240.11 \frac{Btu}{lbm}$

$T_3 = 2000\,R$

$h_3 = 504.71\ Btu/lbm$

$Pr_3 = 174.0$

$Pr_4 = \frac{P_4}{P_3} Pr_3$

$= \frac{1}{10}(174) = 17.4$ ↑

$h_4 = 265.83 \frac{Btu}{lbm}$

$w_{C,in} = h_2 - h_1 = 115.84\ Btu/lbm$

$w_{T,out} = h_3 - h_4 = 238.88\ Btu/lbm$

a) $T_2 = 1008\,R$

b) $r_{bw} = \frac{w_C}{w_T} = \frac{115.84}{238.88} = 48.5\%$

c) $\eta_{th} = \frac{w_{net,out}}{q_{in}} = \frac{123.04}{264.60} = 46.5\%$