Thermal applications HW 1.5 Ben Smithson

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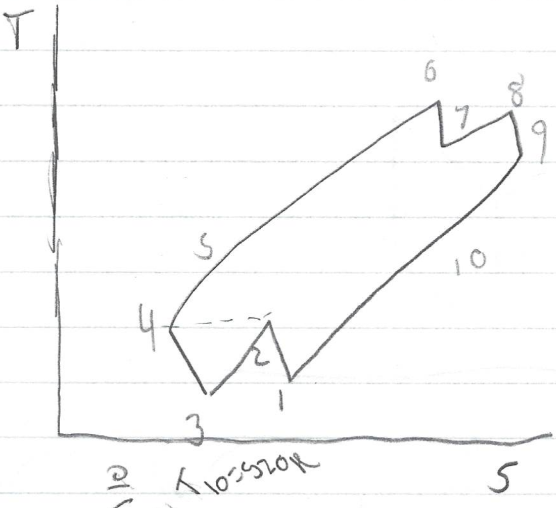

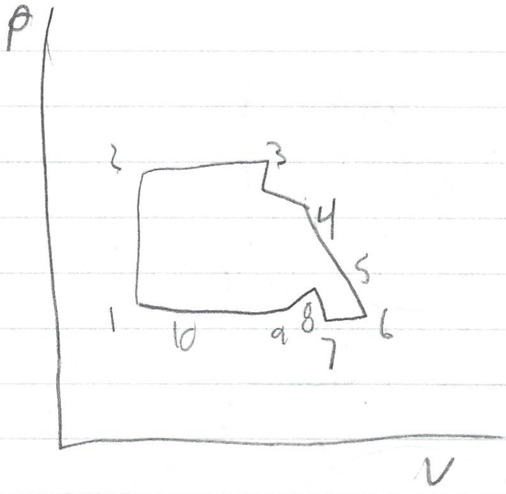

1 → 2 → 3 → 4 → 5 → 6 → 7 → 8 → 9 → 10

$T_1=290K$, $T_2=430K$, $T_4=430K$, $T_5=450K$, $T_6=750K$, $T_7=504K$, $T_8=803K$, $T_9=540K$

$P_1=100kPa$

$T_2=T_1 r^{\frac{k-1}{k}} = 290(4)^{\frac{0.4}{1.4}} = 430.9K = T_2 = T_4$

$T_5 = T_4 + 20° = 450K$

$T_6 = q_{in}/c_p + T_5 = 450 + 300/1.005 = 750K$

$T_7 = T_6\left[\frac{1}{r}\right]^{\frac{k-1}{k}} = 750\left(\frac{1}{4}\right)^{\frac{0.4}{1.4}} = 504K$

$T_8 = T_7 + q_{in}/c_p = 504 + 300/1.005 = 803K$

$T_9 = T_8\left(\frac{1}{r}\right)^{\frac{k-1}{k}} = 803\ \frac{1}{4}^{\frac{0.4}{1.4}} = 540.K$

$T_{10} = T_9 - 20 = 520K$

$\eta_{th} =$?

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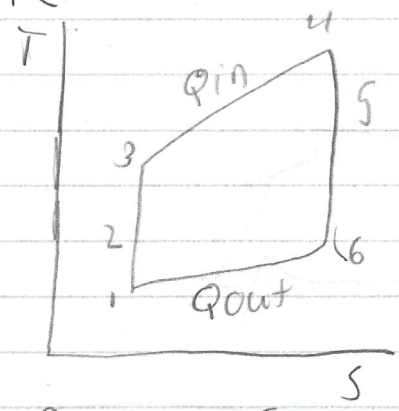

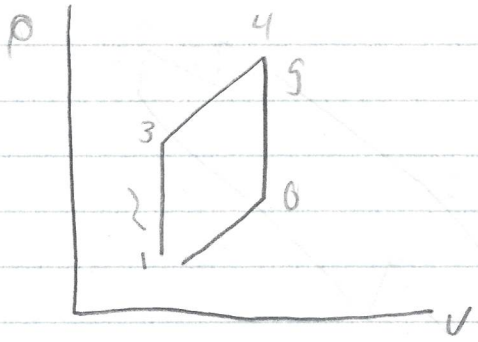

① ② ③ ④ ⑤ ⑥

$V_1 = 900$ ft/s $T_2 = 537°R$ $T_3 = 1118°R$ $T_4 = 2400°R$

$P_1 = 7$ psia $P_2 = 11.2$ psia $P_3 = 145.5$ psia $P_4 = 145.5$ psia

$T_1 = 470°R$

$$\frac{P_3}{P_2} = 13 \quad \checkmark$$

$$(h_2 - h_1) - \frac{1}{2}V_1^2$$

$$= c_p(T_2 - T_1 - \frac{1}{2}V_1^2$$

$$T_2 = T_1 \quad V^2/2c_p = 470°R + \left(\frac{900\ ft/s^2}{2(0.24\ \frac{BTU}{lbm\,R})}\right) \cdot \left(\frac{BTU/lbm}{25,037\ ft^2/s^2}\right) = 537°R$$

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

$$P_2 = P_1\left(\frac{T_2}{T_1}\right)^{k/(k-1)} = (7)\left(\frac{537}{470}\right)^{1.4/0.4} = 11.2\ psia$$

$$\left(\frac{T_3}{T_2}\right) = \left(\frac{P_3}{P_2}\right) = (537)(13)^{0.4/1.4} = 1118°R$$

$$P_3 = P_4 = P_3 \cdot P_2 = 145.5\ psia$$

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$q_{in} = c_p(T_4 - T_3) = (0.24)(2400 - 1118^\circ R) = 307.6$

$T_5 = T_2 - T_3 + T_4 = 637 - 1118 + 2400 = 1819^\circ R$

$P_5 = P_4\left(\frac{T_5}{T_4}\right)^{k/k-1} = (145.5)\left(\frac{1819}{2400}\right)^{1.4/0.4} = \boxed{55.19\ psia}$

$T_6 = T_5\left(\frac{P_6}{P_5}\right)^{k-1/k} = 1819\left(\frac{7}{55.19}\right)^{0.4/1.4} = 1008^\circ R$

$V_6 = \sqrt{2(h_5 - h_6)} = \sqrt{2c_p(T_5 - T_6)}$

$V_6 = \sqrt{2\left(0.24\ \frac{Btu}{lbm}\right)(1819 - 1008^\circ R)\left(\frac{25{,}037\ ft^2/s^2}{Btu/lbm}\right)} = \boxed{3121\ ft/s}$

$W = (V_6 - V_1)(V_1 = (3121 - 900\ ft/s)(900\ ft/s)\left(\frac{Btu/lbm}{25{,}037\ ft/s^2}\right)$

$= 79.85\ Btu/lbm$

$\eta = \frac{79.85}{307} = \boxed{0.25 = 25\%}$

Thermal

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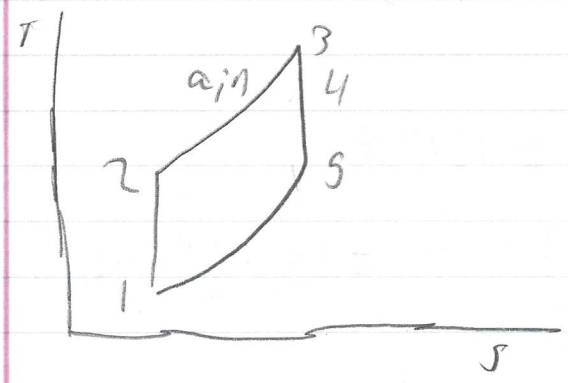

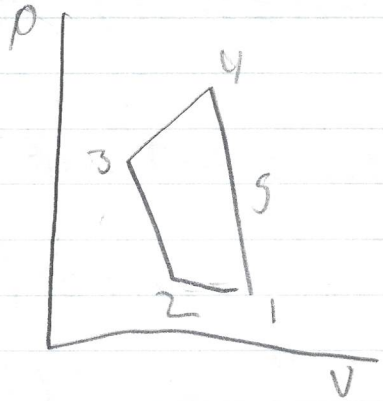

① ② ③ ④ ⑤

$h_1 = 280.13$

$T_1 = 280\ K$

$P_{r1} = 1.0889$

$P_2 = 9.8$

$h_3 = 1592.8$

$T_3 = 1464.34$

$P_{r3} = 543.99$

$h_4 = 1347.63$

$$\frac{P_2}{P_1} = \frac{P_{r2}}{P_{r1}} \Rightarrow P_{r1}\left[\frac{P_2}{P_1}\right] = 1.0889 \cdot 9 = 9.8$$

$$h_2 = \frac{(9.8 - 9.684)(533 - 523)}{10.37 - 9.68} + 528.6 = 525.38\ KJ/Kg$$

$$q_{in} = m_{fuel} \cdot H.V = 0.5 \cdot 42700 = 21350\ KW$$

$$q_{in} = \frac{q_{in}}{m_{air}} = \frac{21350}{20} = 1067.5\ KJ/Kg$$

$$Q_{in} = h_3 - h_2 = 1067.5 = h_3 - 525.38 = 1592.88$$

$$T_3 = \frac{(1592.88 - 1587.63)(1480 - 1460)}{1611.79 - 1587.63} + 1460 = 1464.3$$

$$P_{r3} = \frac{(1592 - 1587)(568 - 537)}{1611 - 1587} + 537 = 543.99 =$$

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$h_3 - h_4 = h_2 - h_1$

$1592.8 - h_4 = 525.3 - 80.13 = 1347.63$

$\frac{P_{r3}}{P_{r6}} = \frac{P_3}{P_5} = \frac{543.99}{P_{r3}} = 9 \quad P_{r3} = 60.44$

$h_{r5} = \frac{(60.44 - 57.6)(888.27 - 866.0)}{639 - 57.6} + 866.08 = 877.57$

$v_{exit} = \sqrt{2(h_4 - h_5)} = \sqrt{2(1347.65) - 877.57 \cdot 1000} = 989.6 \text{ m/s}$

$F = ma = 20(969.99 - 0) = \boxed{19388.9 \text{ N}}$

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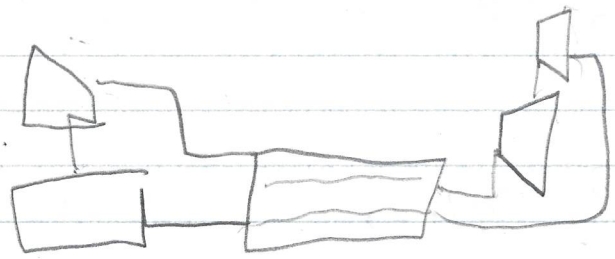

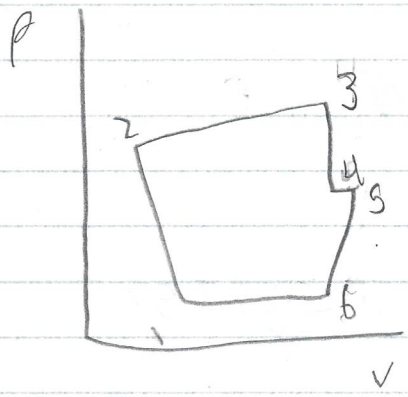

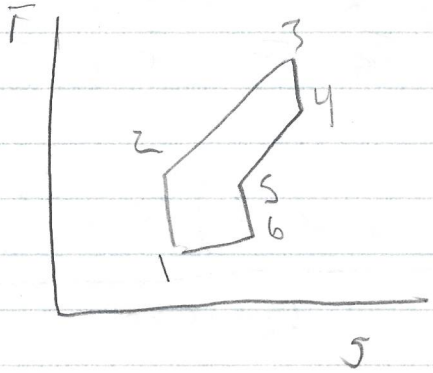

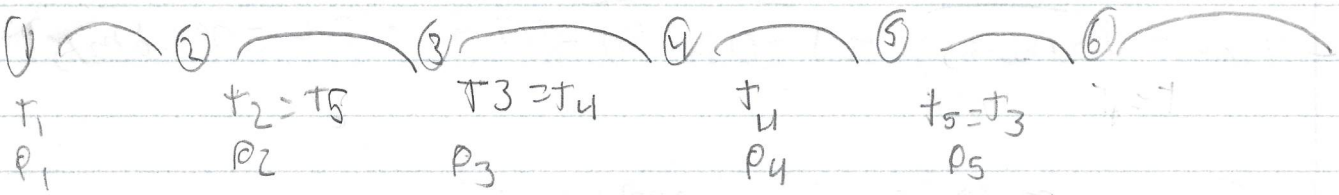

$$T_2 = T_1 \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}}$$

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

$$T_6 = T_5 \left(\frac{P_6}{P_5}\right)^{\frac{K-1}{K}}$$

$$\eta th = q_{out} - q_{in} = 1 - C_p T_1 \left(\frac{P_2}{P_1}\right)^{\frac{K-1}{K}} / C_p (T_6 - T_1)$$

$$= 1 - C_p T_1 - T_6 / 1 - T_2 / T_1$$