Thermal Apps HW # 33, 36, 46, 57, 59, 80

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33

Isentropic | v = const. | Isentropic | v const.

1	2	3	4
P = 95 kPa	$V_2 = V_3$	$V_3 = V_2$	$V_4 = V_1$
T_1 = 300°K	T_2 = 671.3		
$V_1 = V_4$			
R = ?			

① 300°K => use Table A-17

u_1 = 214.07 kJ/kg

v_{r_1} = 621.2

$\frac{1}{8}(621.2)$

v_{r_2} = 77.65

② T_2 = ?

Table A-17

670°K v_r = 78.61

680°K v_r = 75.50

$670 + (680-670)\left(\frac{v_{r_2} - v_r(670)}{v_r(680) - v_r(670)}\right) = 670 + (10)\frac{77.65 - 78.61}{75.50 - 78.61}$

T_2 = 673.1°K

③ $u_2 = 488.81 + (496.62 - 488.81)\left(\frac{77.65 - 78.61}{75.5 - 78.61}\right)$

= 491.22 kJ/kg

④ $\frac{P_2 V_2}{T_2} = \frac{P_1 V_1}{T_1}$

$P_2 = \frac{V_1 (T_2)}{V_2 (T_1)} P_1 = 8\left(\frac{673.1\,K}{300\,K}\right) 95\,kPa$

= 1,705 kPa

⑤ $U_3 = U_2 + U_1$

491.2 + 750 kJ/kg

= 1,241.2 kJ/kg

(6) A-17 $1,241.2 = v_3$

$$v_{r_3} = 6.854 + (6.569 - 6.854)\left(\frac{1241.2 - 1223.87}{1242.43 - 1223.87}\right)$$

$$= 6.588$$

$T_3 = ?$

$$1,520 + (1540 - 1520)\left(\frac{1241.2 - 1223.87}{1242.43 - 1233.87}\right)$$

$$= 1539\ K$$

(7) $\frac{P_3 V_3}{T_3} = \frac{P_2 V_2}{T_2}$ $\quad \frac{1539\ K}{673.1 K}(1705\ kPa)$

$P_3 = \frac{T_3}{T_2} P_2$ $\quad = 3898 K\ P_3$

8 $v_{r_4} = v_4 / v_3 (v_{r_3})$ $\quad v_{r_4} = 8(6.588)$

$= 52.70$

(9) $T_4 = 760 + (780 - 760)\left(\frac{52.57 - 55.54}{51.64 - 55.54}\right)$

$T_4 = 774.5 K$

10 A-17 $v_4 = 560.01 + (576.12 - 560.01)\left(\frac{52.57 - 55.54}{51.64 - 55.54}\right)$

$591.74\ kJ/kg$

(11) $q_{out} = u_4 - u_1$ $(571.74 - 214.07)$ $357.67\ kJ/kg$

(12) $w_{net} = q_{in} - q_{out}$ $(750. - 357.67)\ kJ/kg$ $= 392.33$

(13) $\eta_{th} = 392.33 / 750\ kJ/kg = 52.3\%$

(14) $v_1 = \frac{RT}{P} = \frac{.287\ (kPa \cdot m^3/kg \cdot k)\ 300k}{95\ kPa}$

$= .906\ m^3/kg$

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

$\frac{392.3\ kJ/kg}{.906(1 - 1/8)}$

$= 494.89\ kPa$

36

$r = V_1/V_2$

$r = \frac{V_1}{.098V_1} = 10.20$

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

$T_2 = 565(10.20)^{.4}$

$= 1430.7R$

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

$T_4 = 2860R\left(\frac{1}{10.20}\right)^{.4}$

$= 1,129R$

$W_{net} = C_v(T_3 - T_4) - C_v(T_2 - T_1)$

$= .171 \frac{Btu}{lbm \cdot R}(2860 - 1129.4) - .171 \frac{Btu}{lbm \cdot R}(1430 - 565)$

$= 147.9 Btu/lbm$

$V_1 = .3704 \frac{psia \cdot ft}{lbm \cdot R}(565R) \Big/ 14psia = 14.95 ft^3/lbm$

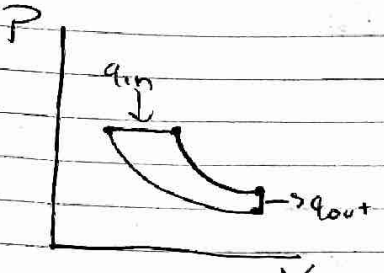
$m = N_{cyl} \cdot \frac{\pi B^2 S/4}{V_1} = 6 \cdot \frac{\pi(3.5)ft^2 \cdot \frac{3.9}{12ft.}}{14.95 ft^3/lbm} = .008716 lbm$

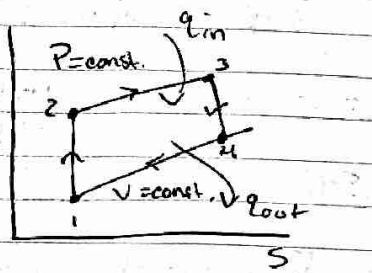
$W_{net} = mW_{net}$

$\frac{.008716(147.9 Btu/lbm)}{1.289 Btu/cyc}$

$Power = \dot{W}_{net} = \frac{1.289 Btu/cyc\left(2500\frac{rev}{min}\right)\left(\frac{1}{60 s/min}\right)}{2 rev/cycle} \cdot \frac{1}{.7608 Btu/s} = \boxed{38.0 hp}$

4.16





Const v. → Isentropic → v=const. → Isentropic →

1	2	3	4
$T_1 = 27°C$	$v_2 = v_4$	$T = 1724$	
$P_1 = 95kPa$	$T_2 = 862.4$		

Table A-17 — Relation b/t u and v_r

$u_1 = 214.07\ kJ/kg$

$v_{r_1} = 621.2$

$v_{r_2} = \frac{1}{16}(621.2)$ — Compression Ratio

$= 38.85$

Table A-17 — Temp of air @ v_{r_2}

$860 + (70)\left(\frac{38.825 - 39.12}{36.61 - 39.12}\right)$

$= 862.4\ K$

A-17 Specific enthalpy v_{r_2}

$888.27 + (22.29)\left(\frac{38.825 - 39.12}{36.61 - 39.12}\right)$

$= 890.9\ kJ/kg$

Solve for T_3

$\frac{P_3 v_3}{T_3} = \frac{P_2 v_2}{T_2}$

$T_3 = 2(862.4)K$

$= 1724.8K$

Table A-17 Find relative psi 1724.8°K

$4.761 + (4.328 - 4.761)\left(\frac{1724.8-1700}{1750-1700}\right)$

$= 4.546$

Table A-17 Find specific enthalpy 1724.8°K

$1880.1 (1941.6 - 1880.1)\left(\frac{1724.8-1700}{1750-1700}\right)$

$= 1910.6 \text{ kJ/kg}$

Find q_{in} "2-3"

$q_{in} = h_3 - h_2$

$1910.6 - 850.6$

$= 1019.7 \text{ kJ/kg}$

Find relation v ? v_r

$v_{r4} = v_4/v_3 (v_{r3})$

$16/2 (4.546)$

$= 36.37$

A-17 v_{r4}

Find internal energy 36.37

$u_4 = 657.95 + (674 - 657.95)\left(\frac{36.37-36.61}{34.31-36.61}\right)$

$= 659.7 \text{ kJ/kg}$

Find q_{out} $u_4 - u_1$

$659.7 - 214.07$

$= 445.63 \text{ kJ/kg}$

η_{th} thermal eff.

$$1 - \frac{q_0}{q_i} = 1 - \frac{445.63}{1017.7} = 56.3\%$$

Total work $= w_{net}$

$q_{in} - q_{out}$

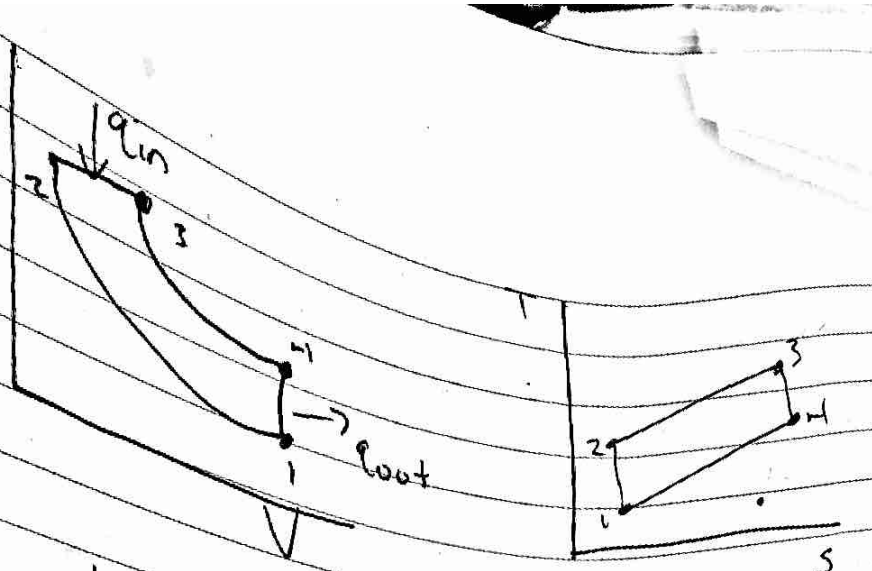
574.07 kJ/kg

Find v_1 $\frac{Pv}{T} = \frac{RT}{P}$

$$v = \frac{.287 \frac{\text{kPa} \cdot \text{m}^3}{\text{kg}} (300\text{k})}{95 \text{kPa}} = .906 \text{ m}^3/\text{kg}$$

$$MEP = \frac{w_{net}}{v_1 - v_2} = \frac{574.07 \text{ kJ/kg}}{.906 \text{ m}^3/\text{kg} (1 - 1/16)}$$

$= 675.9 \text{ kPa}$



1 2 3 4

$T_2 = 1181°K$ $T_3 = 2125.8°K$ $T_4 = 781°K$

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

$T_2 = (70°C + 273K)\cdot k(22)^{1.4-1}$

$343(22)^{.4}$

$= 1181°K$

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

$1.8 = \frac{T_3}{1181}$ $T_3 = 2125.8K$

③ $\frac{T_4}{V_4} = \frac{T_3}{V_3}$ $T_4 = 2125.8\left(\frac{1.8V_2}{V_1}\right)^{.4}$

$= 2125.8\left(1.8\cdot\frac{1}{22}\right)^{.4}$

$= 781K$

④ $m = \frac{P_1V_1}{RT_1} = \frac{97kPa(2.4L)(1m^3/1000L)}{.287\frac{kPa\cdot m^3}{kg\cdot K}(-70°C+273°K)}$

$= .002365\,kg$

$q_{out} = mC_v(T_4 - T_1)$

$= .7438kJ$

$W_{net_{out}} = q_{in} - q_{out}$

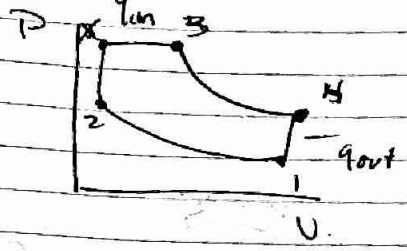
$2.245 - .7438$

$= 1.5012\,kJ$

$Power = \frac{3500(1/60)(1.5012kJ)}{1\,rev/cyc}$

$= 87.57\,kW$

59.



1	2	3	4
$P_1 = 14.2$	$T_2 = 1580$	$T = 2433$	$T = 942.2$
$T_1 = 80°F$	$P_2 = 629.2$	$P = 1.1$	
535			

① $T_2 = T_1(r)^{k-1}$

$535R(15)^{.4}$

$1580R$

② $P_2 = P_1 r^k$

$14.2psia(15)^{1.4}$

$= 629.2psia$

③ $P_x = P_3$

$r_p P_2$

$1.1(629.2)$

$= 692.1 psia$

④ 2-x Process $T_x = T_2\left(\frac{P_x}{P_2}\right)$

$1580R\left(\frac{692.1}{629.2}\right)$

$1738R$

⑤ x-3

$T_x r_c = T_3$

$1738(1.4)$

$T_3 = 2433R$

$\eta_{th} = 124.2/193.8 = \boxed{64.1\%}$

⑥ $T_4 = T_3\left(\frac{r_c}{r}\right)^{1.4}$

$2433\left(\frac{1.4}{15}\right)^{.4}$

$= 942.2R$

⑦ $w_{1-2} = c_v(T_2 - T_1)$

$.171(1580 - 535R)$

$178.7 Btu/lbm$

$q_{2-x} = T_x - T_2(c_v)$

$.171(1738 - 1580R)$

$= 27.02 Btu/lbm$

$q_{x-3} = (T_3 - T_x) - (q_{x-3} - c_v)$

$166.8 - .171(2433 - 1738)$

$= 47.96 Btu/lbm$

$w_{3-4} = .171(2433 - 942.2)$

$254.9 Btu/lbm$

$w_{net} = 254.9 + 47.9 - 178.7$

$= 124.2 Btu/lbm$

$q_{in} = q_{2-x} + q_{x-3}$

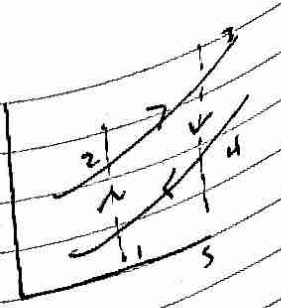
$27.02 + 166.8$

$= 193.82 Btu/lbm$

80 $r_p = 10$

$T_1 = 520$

$T_3 = 2000\,R$



Isentropic

const P

2

$P = 10$

1

$T = 520$

Isentropic

const. P

4

$T = 1075.3$

3

$T = 2000$

$T_1 = 520\,R$

$h_1 = 124.27\ Btu/lbm$

$P_{r_1} = 1.2147$

$T_3 = 2000\,R$

$h_3 = 504.71\ Btu/lbm$

$Pr_3 = 174$

$$\frac{P_2}{P_1} = \frac{P_{r_2}}{P_{r_1}}$$

$P_{r_2} = 1.2147\,(10)$

$= 12.147$

A-17

$$980 + (1000-980)\left(\frac{12.147-11.43}{12.30-11.43}\right)$$

$= 996.48R$

Same for h

$$h_2 = 236.02 + (240.98-236.02)\left(\frac{12.147-11.43}{12.30-11.43}\right)$$

$= 240.107\ Btu/lbm$

$$\frac{P_4}{P_3} = \frac{P_{r4}}{P_{r3}} \qquad P_{r4} = 174(1/10) = 17.4$$

A-17

$$1080 + (1120-1080)\left(\frac{17.4-16.28}{18.6-16.28}\right)$$

$$= 265.826 \text{ Btu/lbm}$$

$$w_c = h_2 - h_1 = 115.837$$

$$w_t = h_3 - h_4 = 504.71 - 265.826 = 238.884 \text{ Btu/lbm}$$

Back work ratio

$$r_{bw} = \frac{w_c}{w_t} = \frac{115.837}{238.884} = .484$$

$$\eta_{th} = \frac{w_{net}}{q_{in}} = \frac{123.047}{264.603} \Rightarrow 46.5\%$$

$$w_{net} = w_t - w_c$$