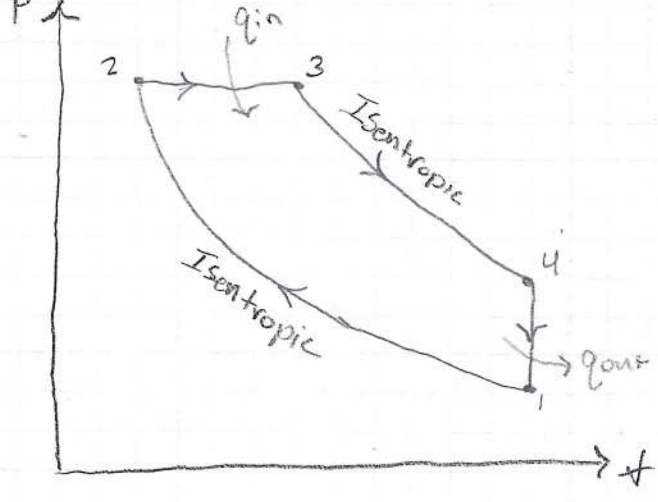
Rhiley Silvis | Hw 1.3 | MET 350

Problem 9-46

An Air Standard Diesel Cycle has a compression ratio of 16 and a cuttoff ratio of 2. At the begining of the compression process, air is at 95 kpa and 27°c. Accounting for the variation of specific heats with Temperature, determine the temperature after heat addition process, the thermal efficency, and the mean effective pressure.



given:

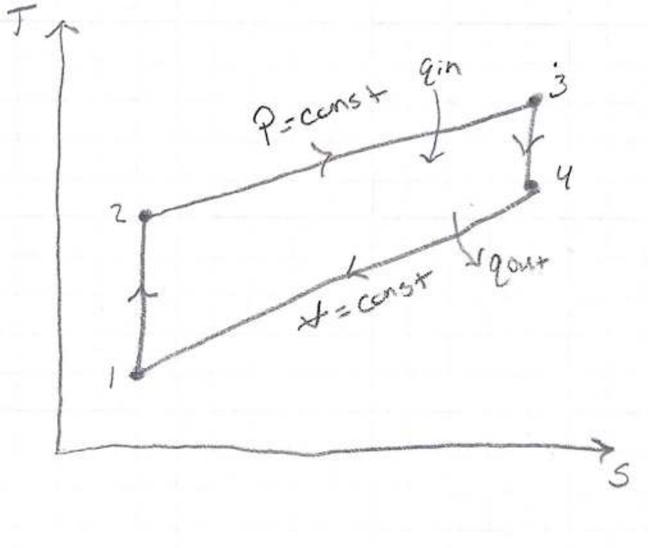
$r = 16$

$r_c = 2$

$P_1 = 95$ kpa

$T_1 = 27°c = 300$ K

(Variable specific heats)



Process $1 \to 2$) Isentropic, Ideal gas

$T_1 = 300\text{K}$ $\quad P_1 = 95 \text{ kpa}$

from A-17 @ 300k : $\quad u_1 = 214.07 \text{ kJ/kg}$

$V_{r1} = 621.2$

$$\frac{v_2}{v_1} = \frac{V_{r2}}{V_{r1}} \qquad \frac{v_1}{v_2} = r$$

$$V_{r2} = V_{r1}(r) = 621.2\left(\tfrac{1}{16}\right) = 38.825$$

V_r	T
39.12	860
38.825	T_2
36.61	880

$$\frac{38.825 - 39.12}{36.61 - 39.12} = \frac{T_2 - 860}{880 - 860}$$

$$T_2 = 862.35 \text{ K}$$

V_r	h_2
39.12	888.27
38.825	h_2
36.61	910.56

$$\frac{38.825 - 39.12}{36.61 - 39.12} = \frac{h_2 - 888.27}{910.56 - 888.27}$$

$$h_2 = 890.89 \text{ kJ/kg}$$

$$\frac{P_1 v_1}{\cancel{R} T_1} = \frac{P_2 v_2}{\cancel{R} T_2} \qquad P_2 = \frac{V_{r1}}{V_{r2}} \cdot \frac{T_2}{T_1} \cdot P_1$$

$$P_2 = \frac{621.2}{38.825} \cdot \frac{862.35}{300} \cdot 95 = 4369.24 \text{ KPa}$$

Process $2 \to 3$) $P = \text{const}$

$P_2 = P_3$

$$\frac{\cancel{P_2} v_2}{\cancel{R} T_2} = \frac{\cancel{P_3} v_3}{\cancel{R} T_3} \qquad T_3 = T_2\left(\frac{v_3}{v_2}\right) \qquad \frac{v_3}{v_2} = r_c$$

$$T_3 = 862.35(2) = 1724.7 \text{ K}$$

From A-17 @ 1724.7 K

T	h_3
1700	1880.1
1724.7	h_3
1750	1941.6

$$\frac{1724.7-1700}{1750-1700} = \frac{h_3 - 1880.1}{1941.6-1880.1}$$

$$h_3 = 1910.481 \text{ KJ/kg}$$

Process $3 \rightarrow 4$) Isentropic

From Leutki Lecture 9 part 2

$$\frac{\forall_3}{\forall_4} = \frac{\forall_2}{\forall_2}\cdot\frac{\forall_3}{\forall_4} = \frac{\forall_2}{\forall_4}\cdot\frac{\forall_3}{\forall_2} = \left(\frac{1}{r}\right)\cdot r_c = \frac{r_c}{r}$$

$$T_4 = T_3\left(\frac{r_c}{r}\right) = 1724.7\left(\frac{2}{16}\right) = 215.59 \text{ K}$$

$$\frac{V_{r4}}{V_{r3}} = \frac{\forall_4}{\forall_3} \qquad V_{r4} = V_{r3}\left(\frac{r}{r_c}\right) = 4.546\left(\frac{16}{2}\right) = 36.37$$

V_r	u
36.61	657.95
36.37	u_4
34.31	674.58

$$\frac{36.37-36.61}{34.31-36.61} = \frac{u_4 - 657.95}{674.58-657.95}$$

$$u_4 = 659.69 \text{ KJ/kg}$$

Calculating Answers)

a) Temp. after heat addition

$$T_3 = \boxed{1724.7 \text{ K}}$$

b) The Thermal efficiency

$q_{in} = h_3 - h_2 = 1910.481 - 890.89$

$q_{in} = 1019.59 \ \mathrm{kJ/kg}$

$q_{out} = u_4 - u_1 = 659.69 - 214.07$

$q_{out} = 445.62 \ \mathrm{kJ/kg}$

$$\eta_{Th} = 1 - \frac{q_{out}}{q_{in}} = 1 - \frac{1445.62}{1019.59} = \boxed{56.29\%}$$

c) The mean effective pressure

$w_{out} = q_{in} - q_{out} = 1019.59 - 445.62$

$w_{out} = 573.97 \ \mathrm{kJ/kg}$

$$v_1 = \frac{R T_1}{P_1} = \frac{\left(0.287 \ \frac{\cancel{\mathrm{kPa}} \cdot \mathrm{m}^3}{\mathrm{kg} \cdot \cancel{\mathrm{K}}}\right) \cdot 300 \cancel{\mathrm{K}}}{95 \ \cancel{\mathrm{kPa}}} = 0.906 \ \frac{\mathrm{m}^3}{\mathrm{kg}}$$

$$MEP = \frac{w_{out}}{v_1 \left(1 - \frac{1}{r}\right)} = \frac{573.97 \ \cancel{\mathrm{kJ}}/\cancel{\mathrm{kg}}}{0.906 \frac{\cancel{\mathrm{m}^3}}{\cancel{\mathrm{kg}}} \left(1 - \frac{1}{16}\right)} \left(\frac{\mathrm{kPa} \cdot \cancel{\mathrm{m}^3}}{\cancel{\mathrm{kJ}}}\right)$$

$$\boxed{MEP = 675.76 \ \mathrm{kPa}}$$

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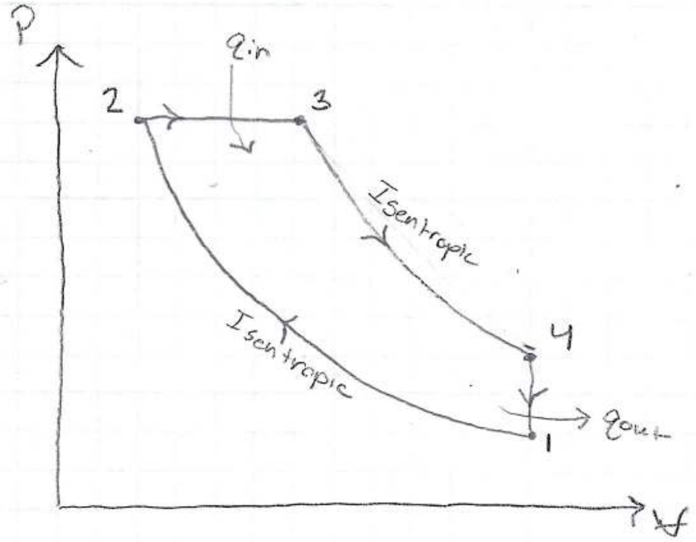
Problem 9-57

A four cylinder two-stroke 2.4 L Diesel engine that operates on an ideal Diesel cycle has a compression ratio of 22 and a cutt-off ratio of 1.8. Air is at 70°c and 97 kPa at the begining of the compression Process. Using the cold air standard assumptions, determin how much power the engine will delever at 3500 rpm.



given:

4 cylinder

$V_d = 2.4 L$

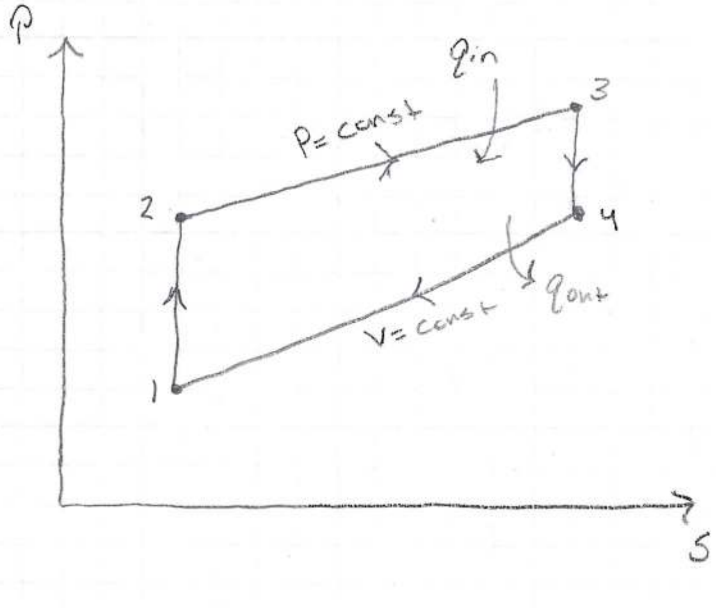
$r = 22$

$r_c = 1.8$

$T_1 = 70°c = 343 K$

$P_1 = 97$ kpa

(const specific Heats)



Process $1 \to 2$) Isentropic

$T_1 = 343\,K \quad P_1 = 97$ kpa

$$\frac{T_2}{T_1} = \left(\frac{\forall_1}{\forall_2}\right)^{k-1} \qquad \left(\frac{\forall_1}{\forall_2}\right) = r$$

$$T_2 = T_1 \left(r\right)^{k-1} = 343\left(22\right)^{1.4-1} = 1181.1\,K$$

Process $2 \to 3$) P = const

$$\frac{\cancel{P_2}\forall_2}{\cancel{R}T_2} = \frac{\cancel{P_3}\forall_3}{\cancel{R}T_3} \qquad \frac{\forall_3}{\forall_2} = r_c$$

$$T_3 = T_2\left(r_c\right) = 1181.1\,K\left(1.8\right) = 2125.98\,K$$

Process $3 \to 4$) Isentropic

From Luetke Lectue 9 Part 2

$$\frac{\forall_3}{\forall_4} = \frac{\forall_2}{\forall_2} \cdot \frac{\forall_3}{\forall_4} = \frac{\forall_2}{\forall_4} \cdot \frac{\forall_3}{\forall_2} = \frac{1}{r} \cdot r_c = \frac{r_c}{r}$$

$$T_4 = T_3\left(\frac{r_c}{r}\right)^{k-1} = 2125.98\left(\frac{1.8}{22}\right)^{1.4-1} = 781.1\,K$$

Calculating for power)

$$W_{net} = q_{in} - q_{out} = c_p\left(T_3 - T_2\right) - c_v\left(T_4 - T_1\right)$$

$$W_{net} = 1.005\left(2125.98 - 1181.1\right) - 0.718\left(781.1 - 343\right)$$

$$W_{net} = 635.05\ \mathrm{kJ/kg}$$

$$\dot{W}_{net} = m\,W_{net}$$

$\forall_1$ = TDC volume $\qquad \forall_1 = \dfrac{2.4L}{4} = 0.6L$

$$m = \frac{P_1 \forall_1}{R T_1} = \frac{(97\,\cancel{kPa})(0.6\,\cancel{L})\left(\frac{1\,\cancel{m^3}}{1000\,\cancel{L}}\right)}{\left(0.287\,\frac{\cancel{kJ}}{kg\cdot\cancel{K}}\right)(343\,\cancel{K})}$$

$m = 5,912 \cdot 10^{-4}$ per cylinder

$m_{Total} = 0,002365$ kg

$W_{net} = m \cdot w_{net} = 0.002365\,\cancel{kg} \cdot 635.05\,\frac{kJ}{\cancel{kg}}$

$W_{net} = 1,502$ kJ

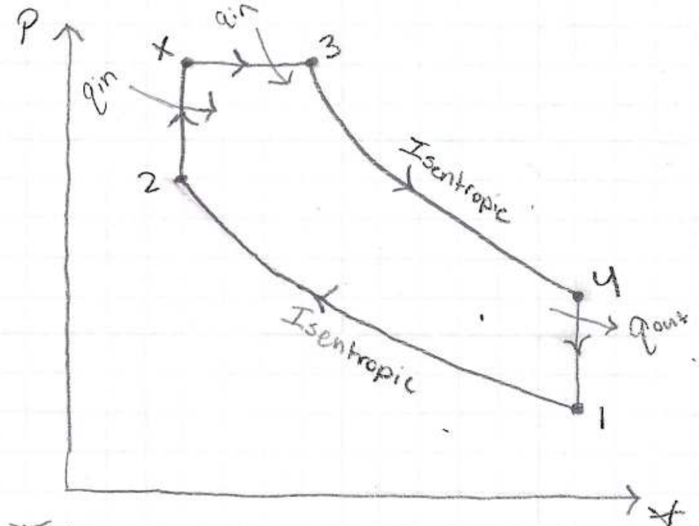
$\dot{W}_{net} = N \cdot W_{net}$

$$4260\,\frac{\cancel{rev}}{\cancel{min}}\left(\frac{1\,\cancel{min}}{60\,sec}\right) 1,502\,\frac{kJ}{\cancel{cycle}}\left(\frac{1\,\cancel{cycle}}{2\,\cancel{rev}}\right) = 53.2\text{ kW}$$

$$\boxed{53.2\text{ kW} = 71.34\text{ hp}}$$

Problem 9-59

An Ideal dual cycle has a compression ratio of 15 and a cutt-off ratio of 1.4. The pressure ratio during constant-volume heat addition process of 1.1. The state of the air at the begining of the compression is $P_1 = 14.2$ psia and $T_1 = 75\,°F$. Calculate the cycles net specific work, specific heat addition, and thermal efficienty. Use constant specific heats at room temperatum



Given:

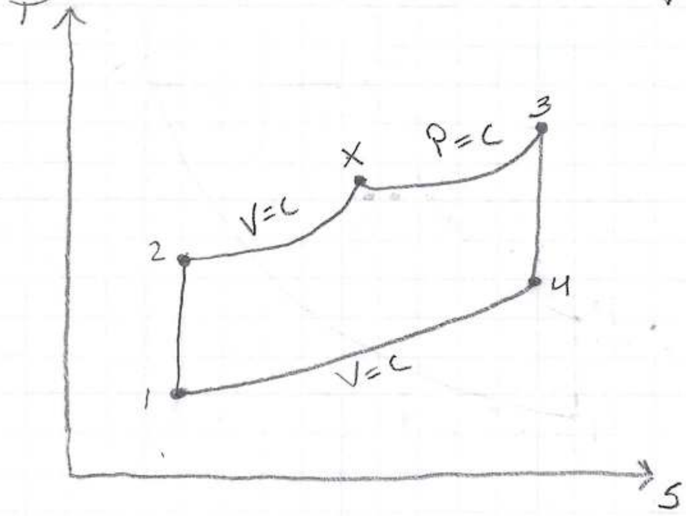
$r = 15$

$r_c = 1.4$

$PR = 1.1$

$P_1 = 14.2$ psia

$T_1 = 75\,°F = 534.67\,R$



Process 1→2) Isentropic

$$\left(\frac{P_2}{P_1}\right)^{\frac{k-1}{k}} = \left(\frac{\forall_1}{\forall_2}\right)^{k-1} \qquad r = \frac{\forall_1}{\forall_2} \qquad P_2 = P_1\left(r\right)^k$$

$$P_2 = 14.2\left(15\right)^{1.4} = 629.24 \text{ psia}$$

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

$$T_2 = 534.67 \left(\frac{629.4}{14.2}\right)^{\frac{1.4-1}{1.4}} = 1579.62 \ R$$

Process $2 \rightarrow x$) constant volume

$$P_r = 1.1$$

$$\frac{P_x}{P_2} = 1.1 \qquad P_x = P_2 (1.1) = 629.24 (1.1) = 692.16 \text{ psia}$$

$$\frac{T_x}{T_2} = \frac{P_x}{P_2} \qquad T_x = T_2 (1.1) = 1579.62 (1.1) = 1737.58 \ R$$

Process $x \rightarrow 3$) constant pressure

$$r_c = \frac{\forall_3}{\forall_2} = \frac{\forall_3}{\forall_x}$$

$$\frac{\forall_3}{\forall_x} = \frac{T_3}{T_x} \qquad T_3 = T_x (r_c) = 1737.58 (1.4) = 2432.61 R$$

Process $3 \rightarrow 4$) Isentropic

$$V_1 = \frac{R T_1}{P_1} = \frac{0.3704 \frac{\cancel{\text{psia}} \cdot ft^3}{lbm \cdot \cancel{R}} \cdot 534.67 \cancel{R}}{14.2 \cancel{\text{psia}}}$$

$$V_1 = 13.95 \frac{ft^3}{lbm} \qquad V_2 = \frac{V_1}{r} = \frac{13.95}{15} = 0.93 \frac{ft^3}{lbm}$$

$$V_3 = r_c \cdot V_x \qquad V_x = V_2 \qquad V_3 = r_c \cdot V_2 = 1.4 \cdot 0.93 = 1.302 \frac{ft^3}{lbm}$$

$$\frac{T_4}{T_3} = \left(\frac{V_3}{V_4}\right)^{K-1} \qquad V_4 = V_1 \qquad T_4 = T_3 \left(\frac{V_3}{V_1}\right)^{K-1}$$

$$T_4 = 2432.61 \left(\frac{1.302}{13.95}\right)^{1.4-1} = 942.08 \ R$$

Calculating Questions }

a) net specific work

$q_{in} = c_v(T_x - T_2) + c_p(T_3 - T_x)$

$= 0.171(1737.58 - 1679.62) + 0.240(2432.61 - 1737.58)$

$= 27.011 + 166.807$

$q_{in} = 193.81$ BTU/lbm

$q_{out} = c_v(T_4 - T_1) = 0.171(942.08 - 534.67)$

$q_{out} = 69.67$ BTU/lbm

$w_{net} = q_{in} - q_{out} = 193.81 - 69.67 = \boxed{124.14 \frac{BTU}{lbm}}$

b) Specific heat addition

$\boxed{q_{in} = 193.81 \text{ BTU/lbm}}$

c) Thermal efficiency

$\eta_{Th} = \frac{w_{net}}{q_{in}} = \frac{124.14}{193.81} = \boxed{64\%}$

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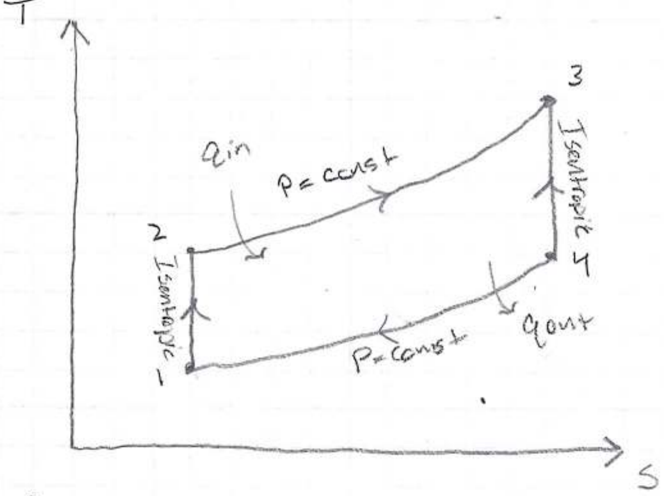
Problem 9-80

A simple Ideal Brayton cyle with air is working fluid has a pressure ratio of 10. The air enters the compressor at 520 R and the turbine at 2000 R. Accounting for the variation of specific heats with temperature, determine the air temp at compressor exit, the back work ratio, and the Thermal efficiency.



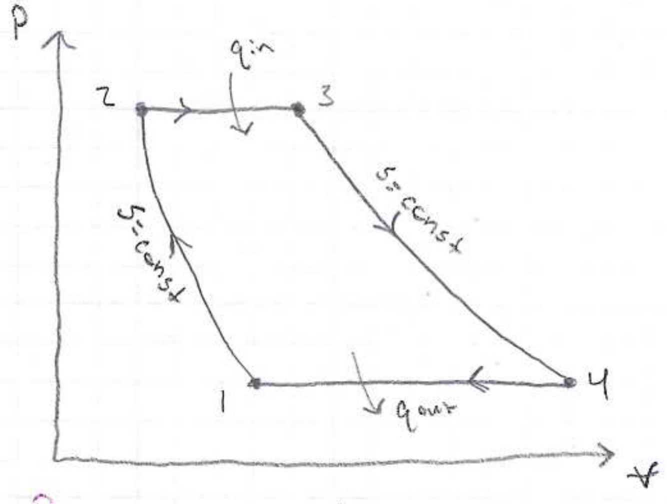
Given:

$r_p = 10 = \frac{P_2}{P_1}$

$T_1 = 520\ R$

$T_3 = 2000\ R$

(Variable specific Heats)



Process 1 → 2)

From A-17 @ 520 R $\quad h_1 = 124.27\ \text{BTu/lbm}$

$P_r = 1.2147$

$$\frac{P_2}{P_1} = \frac{P_{r_2}}{P_{r_1}} \qquad P_2 = r_p \cdot P_{r_1} = 10 \cdot 1.2147 = 12.147$$

P_r	h
11.43	236.02
12.147	h_2
12.30	240.98

$$\frac{12.147 - 11.43}{12.30 - 11.43} = \frac{h_2 - 236.02}{240.98 - 236.02}$$

$$h_2 = 240.11\ \text{Btu/lbm}$$

P_r	T
11.43	980
12,147	T_2
12,30	1000

$$\frac{12{,}147 - 11.43}{12.30 - 11.43} = \frac{T_2 - 980}{1000 - 980}$$

$T_2 = 996.48\ R$

Process $2 \to 3$) P = const

$T_3 = 2000\ R$

From A-17 @ 2000R $\quad h_3 = 504.71\ Btu/lbm$

$P_{r3} = 174.0$

Process $3 \to 4$) Isentropic

$$\frac{P_4}{P_3} = \frac{P_{r4}}{P_{r3}} \qquad P_{r4} = \left(\frac{1}{10}\right) P_{r3} = \frac{1}{10} \cdot 174.0 = 17.4$$

P_r	h
16, 28	260.97
17, 4	h_4
18,60	271.03

$$\frac{17.4 - 16.28}{18.60 - 16.28} = \frac{h_4 - 260.97}{271.03 - 260.97}$$

$h_4 = 265.83\ Btu/lbm$

P_r	T
16, 28	1080
17.4	T_4
18.60	1120

$$\frac{17.4 - 16.28}{18.60 - 16.28} = \frac{T_4 - 1080}{1120 - 1080}$$

$T_4 = 1099.31\ R$

Calculating Questions)

a) air temp at compressor exit

$\boxed{T_2 = 996.48\ R}$

b) The back work Ratio

$$\text{Back work ratio} = \frac{W_c}{W_T} = \frac{h_2 - h_1}{h_3 - h_4}$$

$$= \frac{240.11 - 124.27}{504.71 - 265.83} = \boxed{0.485}$$

c) Thermal effiency

$$\eta_{Th} = \frac{W_{net}}{q_{in}} = \frac{W_T - W_c}{q_{in}} = \frac{(h_3 - h_4) - (h_2 - h_1)}{h_3 - h_2}$$

$$\frac{(504.71 - 265.83) - (240.11 - 124.27)}{(504.71 - 240.11)} = \boxed{46.5\%}$$