An SI engine operates on an air-standard four-stroke Miller cycle with turbocharging. The intake valve closes late, resulting in cycle 6-7-8-7-2-3-4-5-6. Air-fuel enters the cylinders at 70°c and 140 kPa and heat in combustion equals $q_{in} = 1800$ kJ/kg. Compression ratio $r_c = 8$, expansion ratio $r_e = 10$, and exhaust pressure $P_{ex} = 100$ kPa.

Calculate:

(a) Temperature at each state of the cycle. [K]

(b) Pressure . . . . [kPa]

(c) Work produced during expansion stroke. [kJ/kg]

(d) Work of compression stroke. [kJ/kg]

(e) Net pumping work. [kJ/kg]

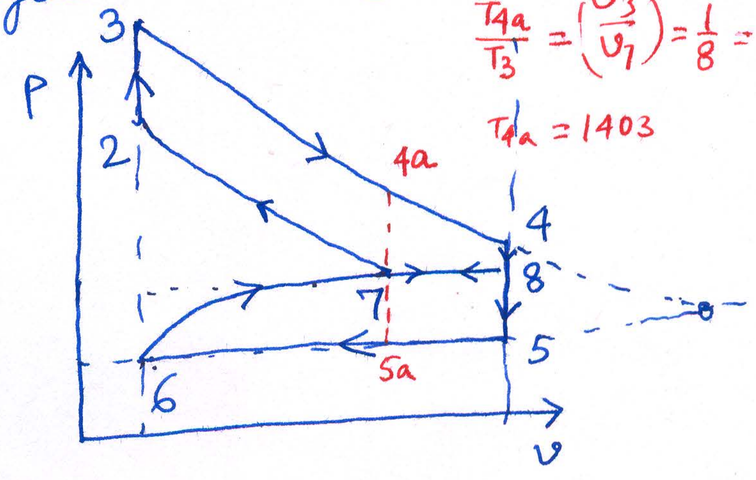
(f) Indicated thermal efficiency. [%]

(g) Compare with SI cycle with $r_c = 8$.

$$\frac{T_{4a}}{T_3} = \left(\frac{v_3}{v_7}\right)^{\gamma-1} = \frac{1}{8}^{1.35-1} = 0.483$$

$T_{4a} = 1403$

$\gamma = 1.35$, $R = 0.287$ kJ/kg-K



$$\frac{T_2}{T_7} = \left(\frac{v_7}{v_2}\right)^{\gamma-1}, \quad \frac{P_2}{P_7} = \left(\frac{v_7}{v_2}\right)^{\gamma}$$

$$\frac{T_2}{T_7} = \left(\frac{P_2}{P_7}\right)^{\frac{\gamma-1}{\gamma}}$$

K Kelvin

k kilo

$T_7 = 70 + 273 = 343$ K

$$\frac{T_2}{T_7} = \left(\frac{v_7}{v_2}\right)^{\gamma-1} = 8^{1.35-1} = 2.07 \Rightarrow T_2 = 710\text{K}$$

$$\frac{P_2}{P_7} = \left(\frac{v_7}{v_2}\right)^{\gamma} = 8^{1.35} = 16.56 \Rightarrow P_2 = 140 \times 16.56 = 2318.4 \text{ kPa}$$

$$q_{in} = c_v(T_3 - T_2) \Rightarrow 1800 = 0.82(T_3 - 710) \Rightarrow T_3 = 2905\text{K}$$

$$\frac{P_3}{P_2} = \frac{T_3}{T_2} \Rightarrow P_3 = 2318.4 \times \frac{2905}{710} = 9486 \text{ kPa}$$

$$\frac{T_4}{T_3} = \left(\frac{v_3}{v_4}\right)^{\gamma-1} = \left(\frac{1}{10}\right)^{1.35-1} = 0.447$$

$$T_4 = 2905 \times 0.447 = 1298 \text{ K}$$

$$\frac{P_4}{P_3} = \left(\frac{v_3}{v_4}\right)^{\gamma} = \left(\frac{1}{10}\right)^{1.35} = 0.0447$$

$$P_4 = 9486 \times 0.0447 = 424 \text{ kPa}$$

$$\frac{T_5}{T_4} = \frac{P_5}{P_4} = \frac{100}{424} = 0.236$$

$$T_5 = 1298 \times 0.236 = 306 \text{ K}$$

$$\frac{T_{ex}}{T_4} = \left(\frac{P_{ex}}{P_4}\right)^{\frac{\gamma-1}{\gamma}} = \left(\frac{100}{424}\right)^{\frac{1.35-1}{1.35}} = 0.688$$

$$T_{ex} = 1298 \times 0.688 = 893 \text{ K}$$

$\cancel{P_7 v_7}$ $P_7 v_7 = RT_7$

$$v_7 = \cancel{\frac{P_7}{RT_7} = \frac{140}{0.287 \times 343}}$$

$$= \frac{RT_7}{P_7} = \frac{0.287 \times 343}{140}$$

$$= 0.703 \text{ m}^3/\text{kg}.$$

$$r_c = \frac{v_7}{v_2}$$

$$_3w_4 = c_v (T_3 - T_4) = 0.82 (2905 - 1403) = 1232$$

$$\cancel{_1q_2} - {_1w_2} = {_1u_2}$$

$$= 0.82 (2905 - 1298) \text{ kJ/kg}$$

$$-{_1w_2} = u_2 - u_1$$

$$_1w_2 = u_1 - u_2$$

$$= 1318 \text{ kJ/kg}$$

$$_7w_2 = c_v (T_7 - T_2)$$

$$= 0.82 (343 - 710) \text{ kJ/kg}$$

$$= -301 \text{ kJ/kg}$$

$$\frac{v_7}{v_2} = 8$$

$$v_2 = \frac{v_7}{8} = \frac{0.703}{8} \text{ m}^3/\text{kg} = 0.088 \text{ m}^3/\text{kg}$$

$$_6w_7 = P_7 (v_7 - v_6) \text{ kJ/kg}$$

$$= 140 (0.703 - 0.088) = 86.1 \text{ kJ/kg}$$

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$${}_5w_6 = P_{ex}(v_6 - v_5)$$

$$= 100\,(0.088 - 0.703)\ \cancel{kJ} kJ/kg$$

0.88

$100\,(0.088 - 0.703) = -61.5$

$$= -79.2\ kJ/kg$$

$$\frac{v_5}{v_6} = 10$$

$$v_5 = 10\,v_6$$

$$= 0.88$$

$$\text{Net work} = {}_3w_4 + {}_7w_2 + {}_6w_7 + \cancel{{}_5w_6} + {}_5w_6$$

$$= 1318 - 301 + 86.1 - 79.2$$

$1232 - 301 + 86.1 - 61.5$

$$= 1024\ kJ/kg$$ $= 955.6$

$$\eta_{ith} = \frac{1024}{1800} \times 100\,\%$$

$$= 56.9\,\%$$ 53.1%

An SI engine operates on an air-standard four-stroke Otto cycle with turbocharging. Air-fuel enters the cylinders at 70°C and 140 kPa and heat in ~~by~~ by combustion equals $q_{in} = 1800$ kJ/kg. Take $r_c = 8$ and $P_{ex} = 100$ kPa.

Find out η_{ith}?=

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isooctane C_8H_{18} C_8H_{18}

AF ratio.

C	12
H	1
O_2	32
Air	28.97

$$C_8H_{18} + \underset{\lambda}{} 12.5\,O_2 \xrightarrow{} 8CO_2 + 9H_2O + 3.76 \times 12.5\,N_2$$

$3.76 \times 12.5\, N_2$

$\frac{79}{21} \approx 3.76$

$C_8H_{18} = 8 \times 12 + 18 \times 1 = 114$

$3.76 \times 28 + 32 = 137.28$

$3.76 \times 28.01 + 32.02 = \frac{137.33}{4.76} \rightarrow 28.85$

$$\frac{12.5 \times 28.9 \times 4.76}{114} = 15.08 \approx 15.1$$

$C_8H_{18} + 12.5 \times 4.76 \times$

$C_8H_{18} + 12.5 \times (3.76N_2 + O_2) \rightarrow 8CO_2 + 9H_2O + 47\,N_2$

20% excess air

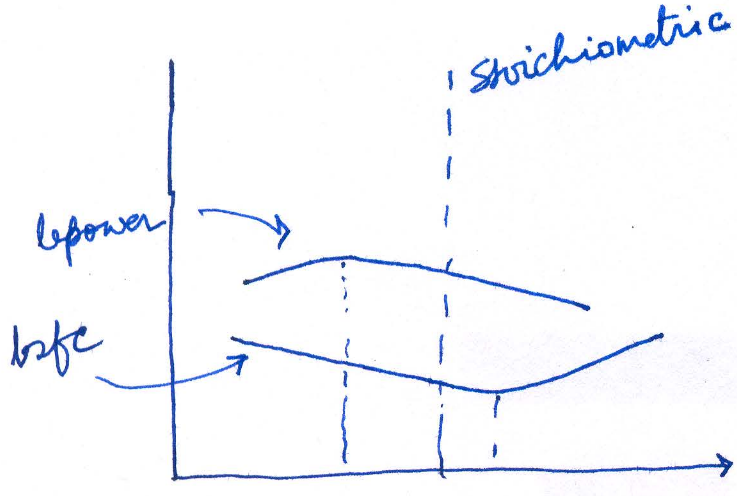
AFT EGR
Exhaust Gas Recirculation.

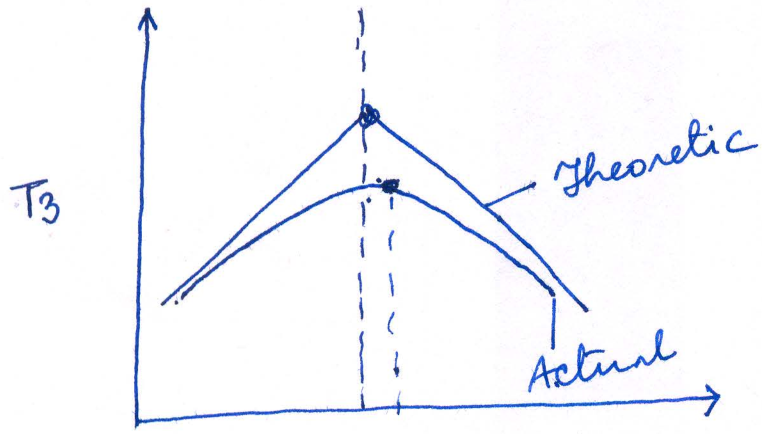
$+47N_2 \times$
$\uparrow \times 12.5$

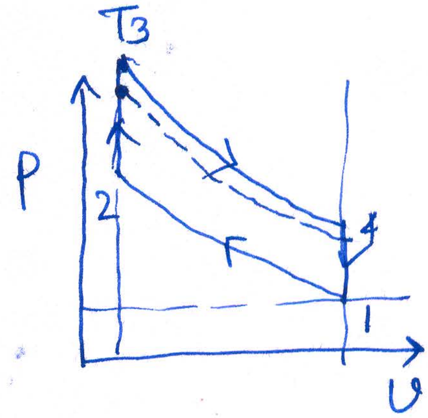
$\phi = ?$

$C_8H_{18} + \cancel{1.2} \times \underset{\phi}{12.5} \times (3.76N_2 + O_2) \rightarrow 8CO_2 + 9H_2O + \underset{\lambda}{0.2}(3.76N_2 + O_2)$

$\phi = (FA)_{act} / (FA)_{stoichiometric} = \frac{1}{1.2}$


Stoichiometric
bpower
bsfc
A/F


T3
Theoretic
Actual
F/A


T3
P
2
4
1
v