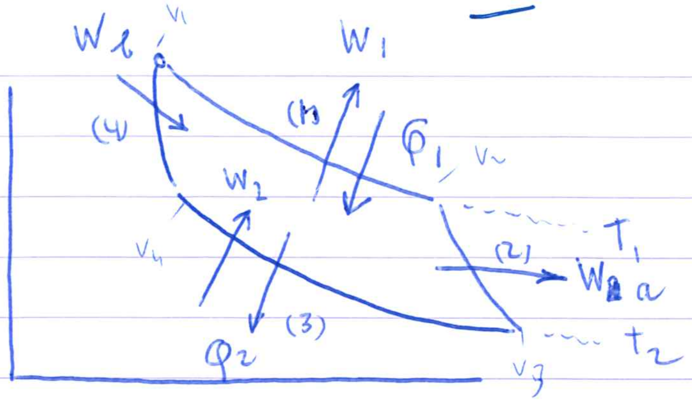
iEE1, 25-1-2017 $\underline{Q1}$

Q1




general 1

(a) 3

- isotherms: W's and Q's opposite direction 1
- adiabats: no Q's but W's 1

(b) Branch 1 $\quad Q_1 = -W_1 \qquad W_1 = (-1)\int_1^2 P\,dV$

1 $\quad = \int_1^2 \frac{RT_1}{V}\,dV = RT_1 \ln\frac{V_2}{V_1}$

1 Branch 3 analogous to branch 1 $\quad Q_2 = -W_2 = RT_2 \ln\frac{V_4}{V_3} = -RT_2 \ln\frac{V_3}{V_4}$

1 Branch 2: $\quad Q = 0 \qquad W_a = c_V (T_2 - T_1)$

Branch 4: $\quad Q = 0 \qquad W_b = c_V (T_1 - T_2) = -W_a$

(c) 3 efficiency: $\quad$ 1 $\dfrac{\sum W}{Q_1} = \dfrac{-\sum Q}{Q_1} = \dfrac{Q_2 + Q_1}{Q_1} = 1 + \dfrac{Q_2}{Q_1}$

$= 1 - \dfrac{T_2 \ln\frac{V_3}{V_4}}{T_1 \ln\frac{V_2}{V_1}}$ ;

$PV^\gamma = \text{const} \rightarrow TV^{\gamma-1}$ is constant

so $\left.\begin{array}{l} T_1 V_2^{\gamma-1} = T_2 V_3^{\gamma-1} \\ T_1 V_1^{\gamma-1} = T_2 V_4^{\gamma-1} \end{array}\right\} \quad \dfrac{V_2}{V_1} = \dfrac{V_3}{V_4}$

1

$\eta = 1 - \dfrac{T_2}{T_1}$

1

Q2

(a) total energy per day: $3\times10^6 \times 35.10^6 = 105.10^{14}$ J

order of magnitude wrong, unit wrong each time $-1/2$

# seconds in a day: $24\times3600$.

1

$$Power = \frac{1.05.10^{14}}{24\times3600} = 1.215..10^{8}\ W \qquad \underline{\underline{1215\ MW}}$$

(b) gas expansion factor: $E = \frac{T_s}{T} \cdot \frac{P}{P_s} \cdot \frac{1}{Z}$

$Z = 0.87$ (graph) $T_s = 15°C$ (288 K)

$T = T_s + 20\times3 = 75°C$ (348 K)

$P_s = 1$ bar

$P = P_s + 200\times1$ Bar $= 201$ Bar

$E = 191.2$ 1

five years of production:

$$\frac{5.478.10^9}{191.2} \qquad \frac{5\times365.25\times3.10^6}{E} = 28.65.10^6\ m^3 \quad 1$$

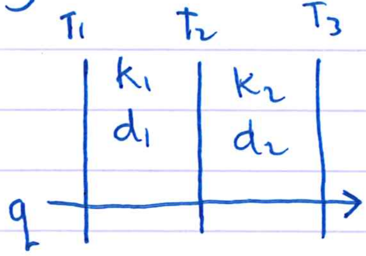
c) Total field content: $0.9\times0.2\times10.10^6\times80 = 1.44.10^8\ m^3$ 1

So production maintained for $\frac{144}{28.65}\times5$ years $= 25(.13)$ years 1

(9180 days)

# Q3

(a)




$$q = k_1 A \frac{T_1 - T_2}{d_1} = k_2 A \frac{T_3 - T_2}{d_2}$$

use second part to express $T_2$: $T_2 = T_3 - q \frac{d_2}{k_2 A}$

fill in in first part, eliminate $T_2$:

2 $$q = \frac{k_1 A}{d_1} T_1 - \frac{k_1 A}{d_1}\left(T_3 - q \frac{d_2}{k_2 A}\right)$$

$$\frac{k_1 A}{d_1}(T_1 - T_3) = q\left(1 + \frac{k_1 A}{d_1}\frac{d_2}{k_2 A}\right)$$

$$\rightarrow T_1 - T_3 = q\left(\frac{d_1}{k_1 A} + \frac{d_2}{k_2 A}\right) \equiv q(R_1 + R_2)$$

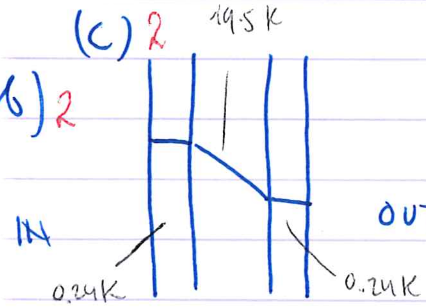
Alt, much simpler:

$\cancel{T_3 - T_1 = T_3 - T_2 + T_2 - T_1}$

$$T_1 - T_3 = T_1 - T_2 + T_2 - T_3$$
$$= \frac{q d_1}{k_1 A} + \frac{q d_2}{k_2 A}$$
$$= q\left(\frac{d_1}{k_1 A} + \frac{d_2}{k_2 A}\right)$$

(c) 2

(b) 2




$$R_{glass} = \frac{4\times10^{-3}}{1.4} = 2.8 \cdot 10^{-3} \frac{K}{W}$$

$$R_{air} = \frac{6\times10^{-3}}{0.026} = 0.23 \frac{K}{W}$$

$$R_{total} = 2\times R_{glass} + R_{air} = 0.236 \text{ K/W}$$

(d) 1 heat loss $q = \frac{\Delta T}{\Sigma R} = \frac{20}{0.236/3} = 253.8$ W

(e) 1 single glass would need to have $\frac{d}{1.4} = 0.236 \frac{K}{W} \rightarrow d = 0.33\text{ m}$ (33 cm)

Q4

(a) fission $^{235}U + {}^{1}n \longrightarrow {}^{118} + {}^{117} + n$

binding energy 7.59 MeV/nucl. — 8.51 MeV/nn

1½

So per split $^{235}U$ release of $235 \times \cancel{\quad}\,0.92$ MeV $\simeq \cancel{\quad}\,216$ MeV

b) 1½ 1 kg of $^{235}U$ $= N_{av} \times \frac{1000}{235} \times \cancel{\quad}\,216$ MeV $\rightarrow \times 1.6\cdot10^{-19} \times 10^{6} = \cancel{\quad}\,8.82 \cdot 10^{13}$ J

at a rate of 100 MJ/s this lasts $8.8 \cdot 10^{5}$ s = ~~…~~ 245 hours (~~…~~ 10.2 days)

(with 185 MeV : 8.7 days)

c) Hydrogen is just 1 proton, no binding energy : Zero

1

Q5

a) Entropy change $\Delta S = \frac{Q}{T}$

2 for low temp side: $\Delta S = -\frac{Q}{T_L}$

for high temp side $\Delta S = +\frac{Q+W}{T_H}$

b) heat pump: what matters is the supply of heat to $T_H$ $\quad \eta = \frac{Q+W}{W} = 1 + \frac{Q}{W}$

3 refrigerator: what matters is the removal of heat from $T_L$ $\quad \eta = \frac{Q}{W}$

1 c) fully reversible: $\Delta S = 0$

d) $\Delta S = 0$: $\frac{Q}{T_L} = \frac{Q+W}{T_H}$ ; refrigerator $\eta = \frac{Q}{W}$

$$Q \cdot T_H = Q T_L + W T_L$$

2 $$\frac{Q}{W} = \frac{Q T_L}{W T_H} + \frac{T_L}{T_H}$$

$$\frac{Q}{W}\left(1 - \frac{T_L}{T_H}\right) = \frac{T_L}{T_H}$$

$$\frac{Q}{W} = \frac{T_L/T_H}{1 - \frac{T_L}{T_H}} = \frac{1}{\frac{T_H}{T_L} - 1}$$

e) $T_B = 20°C$, $Q = 320$ W (J/s)

$$\eta = \frac{1}{\frac{(273+30)}{(273+4)} - 1} = 10.65$$

2 so work needed is $\frac{320}{10.65} = 30$ W (J/s)

over a full year this is $30 \frac{Wh}{h} \times 24 \times 365$

$= 263$ kWh / year