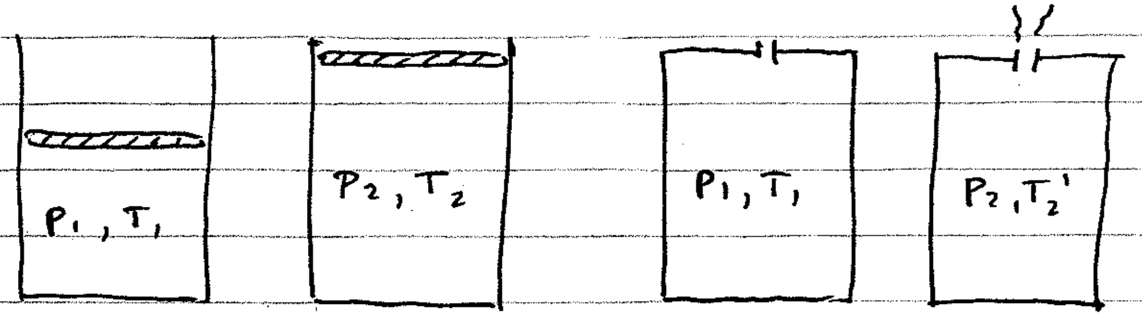
Quiz 1 — Spring 2007, ZSP

1.

a)



no friction, slowly moving piston, insulated cylinder → adiabatic reversible expansion of gas

tiny hole, air leaking out slowly, insulated → adiabatic reversible expansion of gas inside cylinder

so same process inside cylinder → yes, $\Delta S_A = \Delta S_B = 0$

b) $T_2' = T_2$ entropy is a state variable, gas inside cylinder undergoes the same process in each of the two cases

c) yes; left: can lift a weight → useful work done
right: unrestrained expansion outside of cylinder lost work!

d) yes; quasi-static process, lifting weight $P_{system} = P_x$ always. Can return to initial state without leaving mark on the environment.

e) No; although gas inside cylinder undergoes quasi-static (rev.) adiabatic expansion, flow outside mixes out → dissipation.

Entropy is generated in unrestrained expansion outside of cylinder.

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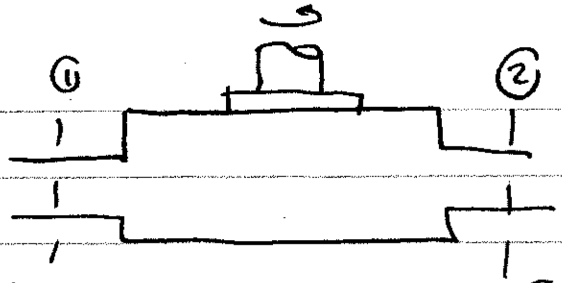
2.



insulated device, steady operation

perfect gas $c_p = 1004\ J/kg\,K$
$\gamma = 1.4$

$p = 1\ bar$	$p = 5\ bar$
$T = 600K$	$T = 900K$
$c = 1000\ m/s$	$c = 5\ m/s$

a) entropy change of air $T\,ds = dh - v\,dp = \cancel{dq}^{\,0} + d\ell \geq 0$!

assume direction, say $1 \rightarrow 2$

$$\Delta s^{air}_{1\rightarrow 2} = s_2 - s_1 = c_p \int_1^2 \frac{dT}{T} - R \int_1^2 \frac{dp}{p} = c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{p_2}{p_1}\right)$$

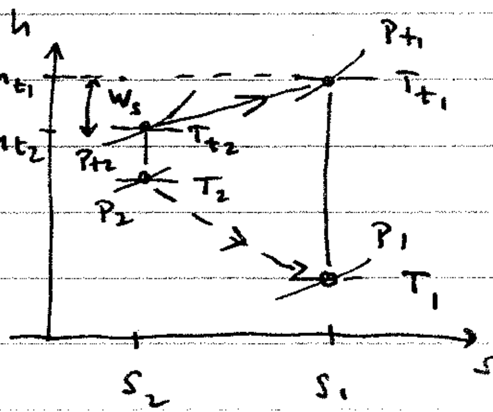
adiabatic device so entropy (of air) cannot decrease : $d\ell \geq 0 \rightarrow ds \geq 0$

check $\Delta s^{air}_{1\rightarrow 2} \geq 0$? $\Delta s^{air}_{1\rightarrow 2} = 407.1 - 461.9\ J/kg\,K < 0$!
(this is Δs_{total}!)

$1\rightarrow 2$ impossible

so air must flow $2 \rightarrow 1$ such that $\Delta s_{total} = s_1 - s_2 > 0$

b)

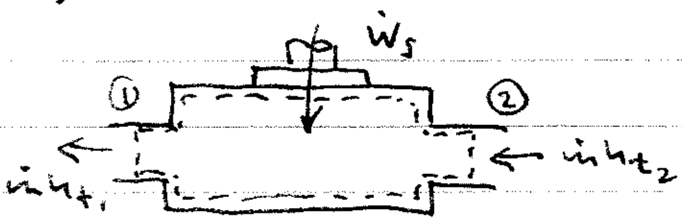


$$T_{t_2} = T_2 + \frac{c_2^2}{2c_p} = 900\ K$$

$$T_{t_1} = T_1 + \frac{c_1^2}{2c_p} = 1098\ K$$

note: $T_{t_1} > T_{t_2}$

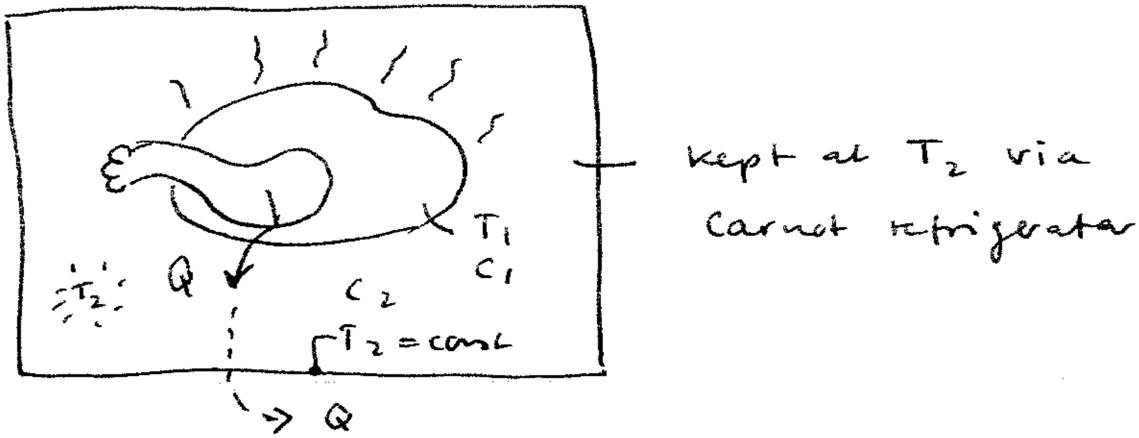
c) $0 = 0 + \dot{W}_s + \dot{m}\left(h_2 + \frac{c_2^2}{2}\right) - \dot{m}\left(h_1 + \frac{c_1^2}{2}\right)$



$\dot{W}_s = 1988\ kW$

shaft power into system

3.



a) $T_f = T_2$ since refrigerated space kept at $T_2 = \text{const}$

b) $$\Delta S_{turkey} = \int_i^f \frac{dQ}{T} = C_1 \int_{T_1}^{T_2} \frac{dT}{T} = \underline{C_1 \ln\left(\frac{T_2}{T_1}\right)} < 0$$

c) $\Delta S_{\substack{ref. \\ space}} = \underline{0}$ since $T_2 = \text{const}$ OR: $\frac{Q}{T_2} - \frac{Q}{T_2} = 0$

d) $$\Delta S_{\substack{pumped \\ out}} = \frac{Q}{T_2} = \underline{\frac{C_1(T_1 - T_2)}{T_2}}$$, $\Delta S_{\substack{pumped \\ out}} = \Delta S_{\substack{rest \\ of\ univ}}$

(Carnot refrigerator does not generate entropy!)

e) $$\Delta S_{total} = \Delta S_{turkey} + \Delta S_{\substack{ref \\ space}} + \Delta S_{\substack{rest \\ of\ univ}}$$

$$\Delta S_{total} = C_1 \ln\left(\frac{T_2}{T_1}\right) + C_1\left(\frac{T_1}{T_2} - 1\right) = \Delta S_{gen}$$

f) Heat transfer between finite temperature differences when turkey cools down! → dissipation