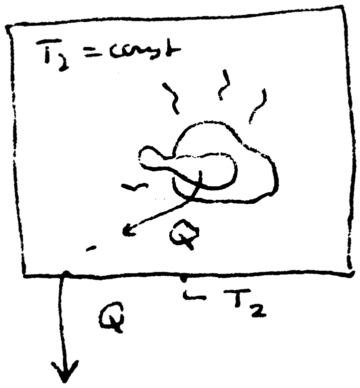
T2i

16. Unified Fall 07



turkey : C_1 ; initially T_1

refrigerator: C_2; kept at $T_2 = \text{const}$ through Carnot refrigerator

a) thermal equilibrium $T_{system} = T_2$ system: turkey and refrigerated space

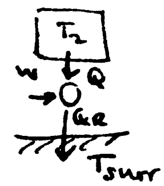
b) turkey: $dS = \frac{dQ}{T}$; 1st law $dU = dQ$ $dU = C_1 dT$

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

c) T_2 = constant ; entropy is state var. $\rightarrow$ $\underline{\Delta S_{ref\ space} = 0}$

d) $\Delta S_{pumped\ out} = \frac{-Q}{T_2}$ Carnot : $\Delta S_{pumped\ out} + \Delta S_{surr} = 0$

↳ no entropy gen. when pumping heat out

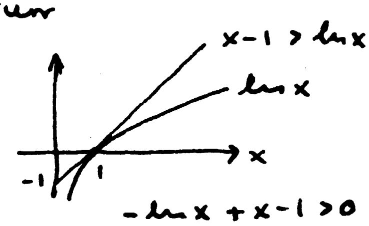


$\Delta S_{surr} = -\Delta S_{pumped\ out}$

1st law: $dU = dQ$ $\rightarrow$ $Q = C_1(T_1 - T_2)$; $\underline{\Delta S_{surr} = C_1\left(\frac{T_1}{T_2} - 1\right)}$

e) $\Delta S_{total} = \Delta S_{gen} = \Delta S_{turkey} + \Delta S_{ref\ space} + \Delta S_{surr}$

$\underline{\Delta S_{gen} = C_1\left[\ln\left(\frac{T_2}{T_1}\right) + \frac{T_1}{T_2} - 1\right]} > 0$ since

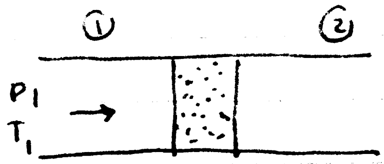


$-\ln x + x - 1 > 0$

f) mechanism for entropy generation:
→ heat transfer between finite temp differences (thermal boundary layer and conduction inside turkey)

T22/23 — 16. Unified Fall 07

Case A



know $p_2/p_1 = 0.5$, adiab. pipe
neglect kinetic energy changes

a) 1st law porous plug: $0 = h_1 - h_2 \rightarrow \underline{T_2/T_1 = 1}$

ideal gas law: $p = \rho R T \rightarrow \frac{\rho_2}{\rho_1} = \frac{p_2}{p_1}$ $\qquad \underline{\frac{\rho_2}{\rho_1} = 1/2}$

b) spec. entropy change across plug: $\Delta s_{12} = s_2 - s_1 = c_p \ln\left(\frac{T_2}{T_1}\right) - R \ln\left(\frac{p_2}{p_1}\right)$

Gibbs $\qquad$ 1

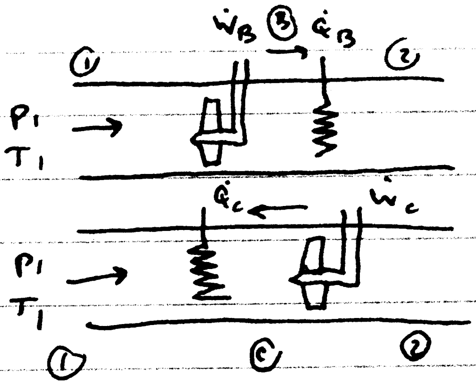
$$\underline{\Delta s_{12} = R \ln\left(\frac{p_1}{p_2}\right) = 199 \text{ J/kg-K}}$$

c) $\Delta s_{surr} = 0$ since no heat interaction (adiabatic pipe)

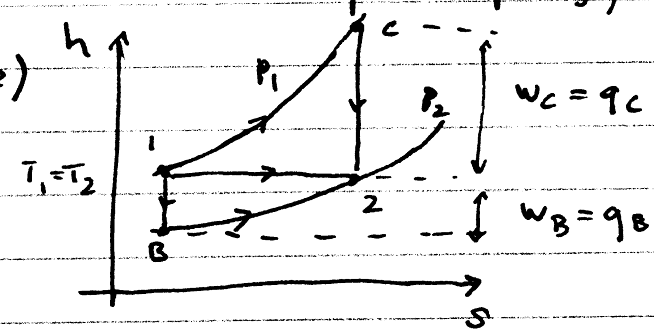
d) $\underline{\Delta s_{total}} = \Delta s_{plug} + \Delta s_{surr} = \Delta s_{plug} \underline{> 0} \rightarrow$ irreversible (viscous dissipation in porous plug)

Case B

case C



e)



f) power per kg air flow: $w_B = c_p(T_1 - T_B) = c_p T_1\left(1 - \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}}\right)$; $\underline{\frac{w_B}{c_p T_1} = 0.179}$

$w_c = c_p(T_c - T_1) = c_p T_1\left(\left(\frac{p_1}{p_2}\right)^{\frac{\gamma-1}{\gamma}} - 1\right)$; $\underline{\frac{w_c}{c_p T_1} = 0.219}$

$\underline{w_B < w_c}$ since $1 - \left(\frac{1}{x}\right)^k < x^k - 1$ and $x > 1$, $k < 1$

case C requires more power (work) since adding heat at higher p

g) entropy is state variable, all three case between ① and ②

$$\underline{\rightarrow \Delta s_A = \Delta s_B = \Delta s_C = R \ln\left(\frac{p_1}{p_2}\right) = 199 \text{ J/kg-K}}$$

entropy change the same but different amount of lost work (highest for C) since different paths between same states