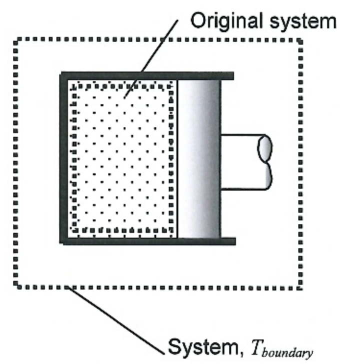
Example

Reconsider the piston-cylinder from the last example. The device contains 1.5 kg of air. Initially, the air is at 150 kPa and 20°C. The air is compressed in an *isobaric process* until the volume is 1 m³. Assuming the compression to be quasistatic, you already found



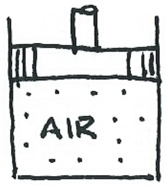
a) the work into the system, in kJ, and
b) the heat transfer into the system, in kJ.

Now for something new!

c) Find the entropy generation for the following systems:
   1) the system shown for $T_{boundary}$ = 400 K
   2) the system shown for $T_{boundary}$ = 300 K, and
   3) your original system.

NEW!

– example –



$m = 1.5\ kg$

① $P_1 = 150\ kPa$, $T_1 = 20\ °C$

② $P_2 = P_1$, $V_2 = 1\ m^3$

① TO ② IS A CONST. P PROCESS

FIND
(a) W_{12}
(b) Q_{12}
(c) S_{gen} FOR $T_{BOUND.} = 400K$ AND $T_{BOUND} = 300K$

NEW!

SOL'N:

(a) $$W_{12} = -\int_{V_1}^{V_2} p\, dV = -p\int dV = -p(V_2 - V_1)$$

• $$V_1 = \frac{mRT_1}{P_1} = \frac{(1.5\ kg)\left(0.287\ \frac{kPa\text{-}m^3}{kg\cdot K}\right)(20+273)\ K}{150\ kPa} = 0.84\ m^3$$

$$W_{12} = -(150\ kPa)(1-0.84) = \boxed{-23.9\ kJ}$$

(b) *Cons. of Energy* →

$$\frac{dE}{dt} = \dot{Q} + \dot{W} + \cancel{\dot{m}(\ldots)} \quad \text{INTEGRATE} \rightarrow E_2 - E_1 = Q_{12} + W_{12}$$

IGNORE KE & PE → $U_2 - U_1 = Q_{12} + W_{12}$

$$Q_{12} = m(u_2 - u_1) - W_{12}$$

TABLE A-5

$u_1 = u(T_1) = u(293K) = 209.1\ kJ/kg$

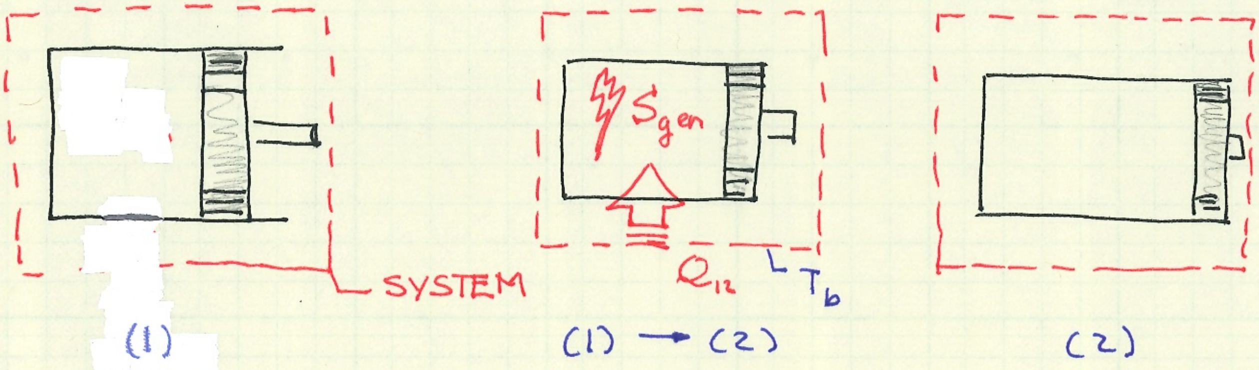
$u_2 = u(T_2) = ?$

T_2: $$T_2 = \frac{P_2 V_2}{mR} = \frac{(150)(1)}{(1.5)(0.287)} = 348.4\ K$$

$\therefore u_2 = u(348.4) = 248.9\ kJ/kg$

• $$Q_{12} = m(u_2 - u_1) - W_{12} = (1.5)(248.9 - 209.1) - (-23.9)$$

$$= \boxed{83.6\ kJ}$$



Accting of S:

$$\frac{d}{dt}(S_{sys}) = \sum \frac{\dot{Q}_{IN,i}}{T_{b,i}} + \sum_{IN} \dot{m}(s) - \sum_{OUT} \dot{m}(s) + \dot{S}_{gen}$$

FINITE TIME, CLOSED SYSTEM

$$dS_{sys} = \frac{\dot{Q}_{IN}}{T_b}\,dt + \dot{S}_{gen}\,dt$$

$$\int_{S_1}^{S_2} dS_{sys} = \int_{t_1}^{t_2} \frac{\dot{Q}_{IN}}{T_b}\,dt + \int_{t_1}^{t_2} \dot{S}_{gen}\,dt$$

$$\parallel$$

$$\frac{1}{T_b}\int_{t_1}^{t_2} \dot{Q}_{IN}\,dt$$

$$\left(S_2 - S_1\right)_{SYS} = \frac{Q_{12,IN}}{T_b} + S_{gen}$$

$$S_{gen} = S_2 - S_1 - \frac{Q_{12,IN}}{T_b}$$

$$= m(s_2 - s_1) - \frac{Q_{IN,12}}{T_b}$$

$$= m\left(s^\circ(T_2) - s^\circ(T_1) - R \ln\frac{P_2}{P_1}\right) - \frac{Q_{IN,12}}{T_b}$$

FROM IDEAL GAS TABLES FOR AIR:

@ $T_2 = 348.4K$ $s^\circ = 1.85241$

@ $T_1 = 293 K$ $s^\circ = 1.67830$

$$\therefore S_{GEN} = (15 \text{ kg})\left[(1.85241 - 1.67830)\frac{kJ}{kg \cdot K} - 0.287 \frac{kJ}{kg \cdot K} \ln\left(\frac{150 \text{ kPa}}{150 \text{ kPa}}\right)\right] - \frac{83.6 \text{ kJ}}{400 \text{ K}}$$

$$= \boxed{0.0522 \frac{kJ}{K}}$$

WITH $T_b = 300 K$

$$S_{gen} = -0.0175 \text{ kJ/K}$$

IMPOSSIBLE!