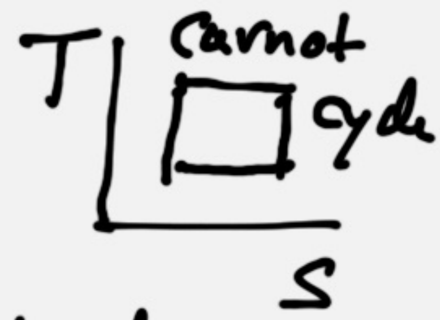
hi 3002 Entropy

$\oint_{rev} \frac{\delta q}{T}$



~~Ideal gases~~

Approximate entropy for simple liquids and solids

$$dS = \frac{\delta Q}{T} = \frac{m C_p \, dT}{T}$$

$$ds = c_p \frac{dT}{T}$$

$$\boxed{s_2 - s_1 = c_p \ln\left(\frac{T_2}{T_1}\right)}$$

simple solids + liquids

Example

①

$_1Q_2 = m_{milk} \, C_{p\,milk} \left(T_2 - T_{1\,milk}\right)$

milk is water

$\longrightarrow$

$-{}_1Q_2$ from milk to fridge

②

$_1S_{2\,gen}$ by this irreversible process

$m_{milk} = \rho_{milk} \underbrace{V_{milk}}_{4L}$

$_1S_{2\,milk} = m \, C_p \ln \frac{T_2}{T_{1\,milk}}$

$_1S_{2\,fridge} = {}_1Q_{2\,fridge} / T_{fridge} \rightarrow 5°C = 278.15\,K$

$_1S_{2\,gen} = {}_1S_{2\,milk} + {}_1S_{2\,fridge} = \overbrace{m_{milk}}^{\rho V} C_{p\,milk} \ln \frac{T_2}{T_{1\,milk}} - \frac{m_{milk} \, C_{p\,milk} \left(T_2 - T_{1\,milk}\right)}{273.15 + 5}$

Solution 1:

$$997 \frac{kg}{m^3}\, 4L\, \frac{1\,m^3}{1000\,L}\, 4.18 \frac{kJ}{kg\,K} \ln \frac{5+273}{25+273} - \frac{997\; 4L\, \frac{m^3}{1000\,L}\, 4.18 \frac{kJ}{kg\,K} (5-25)\,K}{5+273\,K}$$

$$= 0.041 \frac{kJ}{K}$$ must be positive

Thermodynamic property relations

1st law $\delta q = du + P dv$

2nd law (reversible) $\delta q_{rev} = T ds$

$u = h - Pv$

$$\boxed{\begin{aligned} T ds &= du + P dv \\ T ds &= dh - v dP \end{aligned}}$$

"Gibbs relations"

Ideal gasses

$$ds = \frac{dh}{T} - \frac{v}{T} dp$$

$\overset{I.G.}{\Longrightarrow}$ $dh = c_p dT$, $\frac{v}{T} = \frac{R}{p}$

$$ds = c_p \frac{dT}{T} - R \frac{dp}{p}$$

$$s_2 - s_1 = \underbrace{\int_1^2 c_p \frac{dT}{T}}_{f(T)} - R \ln \frac{P_2}{P_1}$$

anti-derivative of $\frac{c_p}{T}$: s_T^0

$$\boxed{s_2 - s_1 = s_{T_2}^0 - s_{T_1}^0 - R \ln \frac{P_2}{P_1}}$$

s_T^0 in A.7.1 or A.8

Else: assume c_p is constant, then

$$\boxed{\begin{aligned} s_2 - s_1 &= c_p \ln \frac{T_2}{T_1} - R \ln \frac{P_2}{P_1} = c_v \ln \frac{P_2}{P_1} + c_p \ln \frac{v_2}{v_1} \\ &= c_v \ln \frac{T_2}{T_1} + R \ln \frac{v_2}{v_1} \end{aligned}}$$

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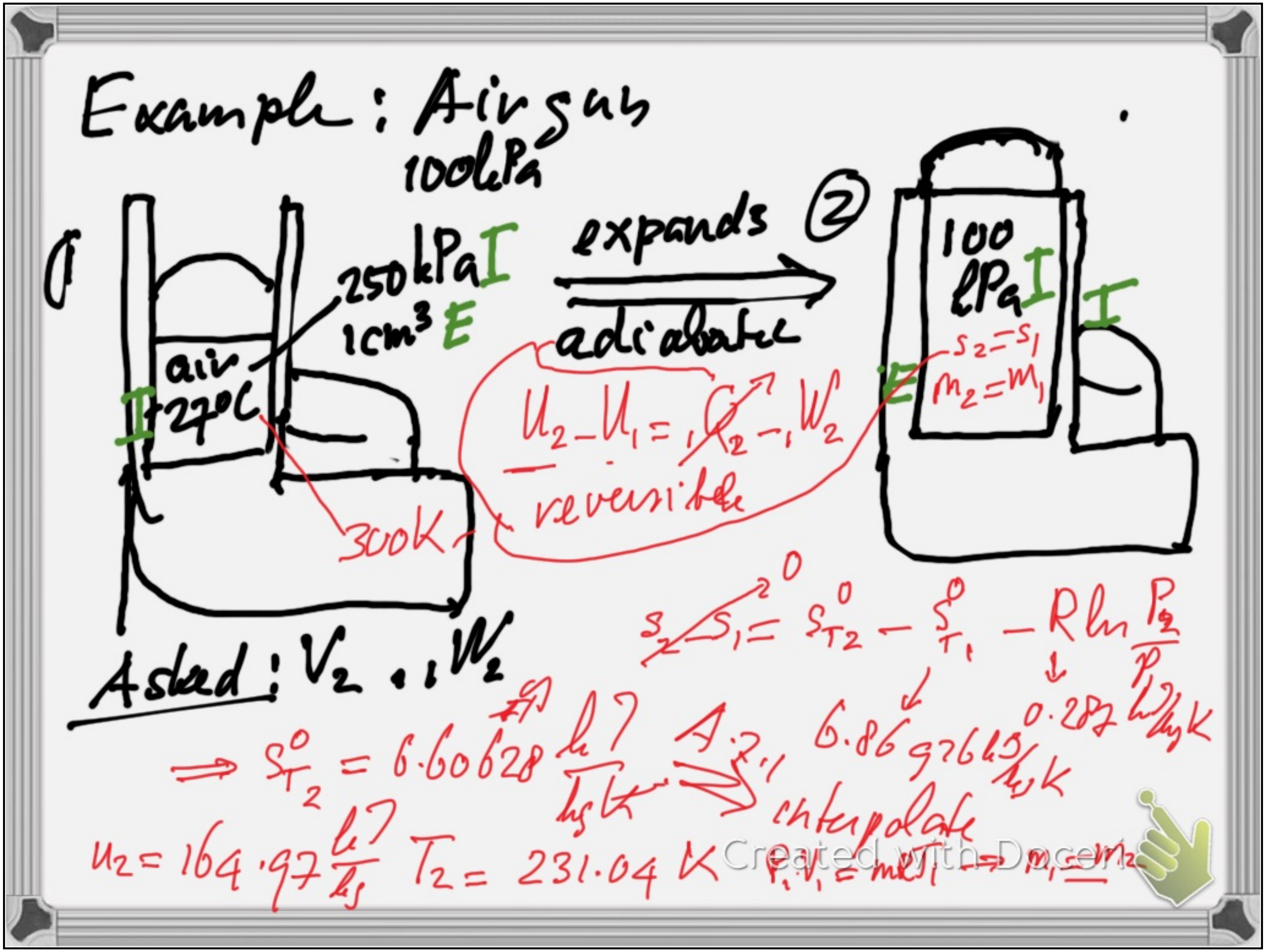
Example: Air gas
100kPa
① air 27°C
250 kPa I
1 cm^3 E
expands
adiabatic
②
100 kPa I
$s_2 = s_1$
$m_2 = m_1$
$U_2 - U_1 = {}_1\cancel{Q}_2 - {}_1W_2$
reversible
300K
Asked: V_2, ${}_1W_2$
$\cancel{s_2 - s_1} = s^0_{T2} - s^0_{T1} - R \ln \frac{P_2}{P_1}$
6.8692649 kJ/kgK
0.287 kJ/kgK
$\Rightarrow s^0_{T_2} = 6.60628$ kJ/kgK
A.7.1 interpolate
$u_2 = 164.97$ kJ/kg
$T_2 = 231.04$ K
$P_1V_1 = mRT_1 \Rightarrow m_1 =$
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$\cancel{s_2 - s_1} = 0$ adiabat

$s_2 - s_1 = c_v \ln \frac{P_2}{P_1} + c_p \ln \frac{v_2}{v_1}$

only adiabatic reversible and constant c_v, c_p / + IG

$0 = \ln \frac{P_2}{P_1} + \frac{c_p}{c_v} \ln \frac{v_2}{v_1}$ $\frac{c_p}{c_v} = k$

$0 = \ln \frac{P_2}{P_1} + \ln \left(\frac{v_2}{v_1}\right)^k$

$0 = \ln \frac{P_2 v_2^k}{P_1 v_1^k}$ $1 = \frac{P_2 v_2^k}{P_1 v_1^k}$

$P_2 v_2^k = P_1 v_1^k$

polytropic with $n = k$

Polytropic relations

Ideal gas + isothermal : $n = 1$

I.G. + adiabatic + reversible + k constant : $n = k$

$$P_2 V_2^n = P_1 V_1^n$$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n$$

If polytropic I.G.:

$$\boxed{\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n = \left(\frac{T_2}{T_1}\right)^{\frac{n}{n-1}}}$$