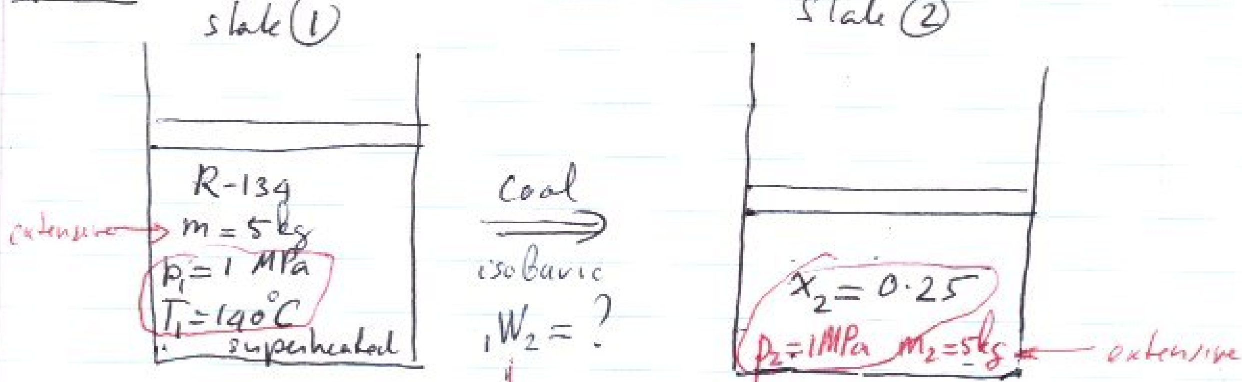
Skip 2014 (Internal friction ignored) V4

P 4.36




Asked: ${}_1W_2$

Formula for isobaric: ${}_1W_2 = p(V_2 - V_1)$

Figure out $v_1$ and $v_2$, then $V_1$ and $V_2$ from that

Answer: p712 Table B.5.2 A-13 $p = 1000$ kPa, $T = 140 \Rightarrow v_1 = 0.03150$ m³/kg

$V_1 = v_1 m = 0.1575$ m³

p 708 Table B.5.1 A-

"$x_1$" = 887.6 kPa "$x_2$" = 1017 kPa

$f = \dfrac{1000 - 887.6}{1017 - 887.6} = .8686$

~~$T_2 = 35 + .8686(40-35) = 39.34$ C~~

$v_f = 0.000857 + 0.8686(0.000873 - 0.000857)$

$= 0.0008709$

$v_g = 0.02310 + .8686(0.02002 - 0.02310)$

$= 0.02042$

$v_2 = v_f + x(v_g - v_f) = 0.00576$ m³/kg

use A-12 @ 1MPa = 1000 kPa
$v_f = 0.00087$
$v_g = 0.020313$

$V_2 = m v_2 = 0.02879$ m³

oops

${}_1W_2 = p(V_2 - V_1) = 1000$ kPa $(0.1575 - 0.02879)$ m³

$= -128.7$ kJ

Negative work is done by the substance on the surroundings, since volume decreased.

Note: can use instead ${}_1W_2 = P(v_2 - v_1)m$

Review

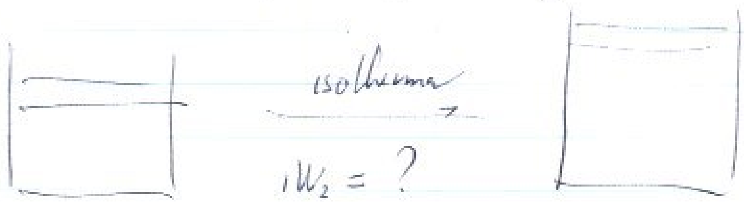
$$ {}_1W_2 = \int_1^2 p\,dV = \begin{cases} 0 & \text{if } V \text{ is constant} \\ p_1(V_2 - V_1) & \text{if } \cancel{p=p} \text{ pressure constant } = p_1 \\ \frac{p_1+p_2}{2}(V_2 - V_1) & \text{if } p \text{ varies linear with } V \\ \frac{p_2V_2 - p_1V_1}{1-n} & \text{if } pV^n = \text{constant}, n \neq 1 \\ p_1V_1 \ln\frac{V_2}{V_1} & \text{if } pV = \text{constant} \end{cases} $$

($PV = mRT$ for IG)

Typically need to complete state 1 and 2 info using Chapter 3 techniques. (Tables or ideal gas)

Read table headers!
Use units!

Warning: isothermal process for ideal gas:



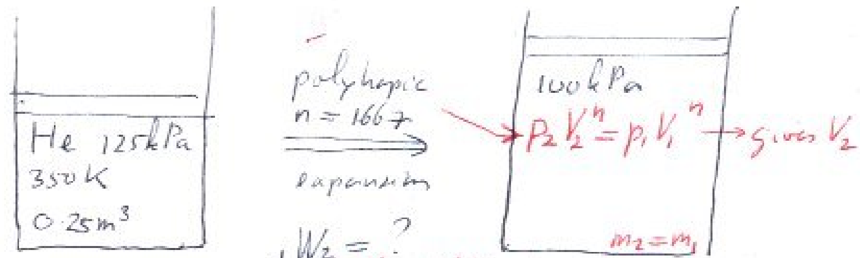

${}_1W_2 = ?$

↓

formula is?

p.4.50

V




$_1W_2 = ?$

$_1W_2 = (p_2V_2 - p_1V_1)/(1-n)$

Answer: compute $V_2$: $p_2 V_2^{1.667} = p_1 V_1^{1.667}$

put in the numbers

$$100\,kPa\, V_2^{1.666} = 125\,kPa\,(0.25\,m^3)^{1.667}$$

$$V_2^{1.667} = \frac{125}{100}(0.25\,m^3)^{1.667} =$$

$$V_2 = \left(\frac{125}{100}\right)^{\frac{1}{1.667}} (0.25\,m^3)^{\frac{1.667}{1.667}}$$

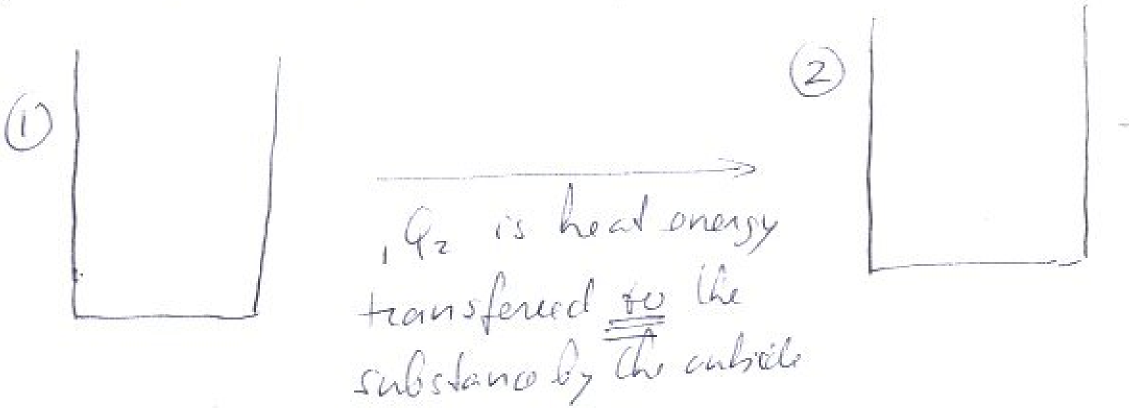
$$= 1.25^{\frac{1}{1.667}}\, 0.25\,m^3 = 0.2850\,m^3$$

$$_1W_2 = \frac{p_2V_2 - p_1V_1}{1-n} = \frac{100\,kPa\, 0.2852\,m^3 - 125\,kPa\, 0.25\,m^3}{1-1.667}$$

$$= 4.69\,kJ$$

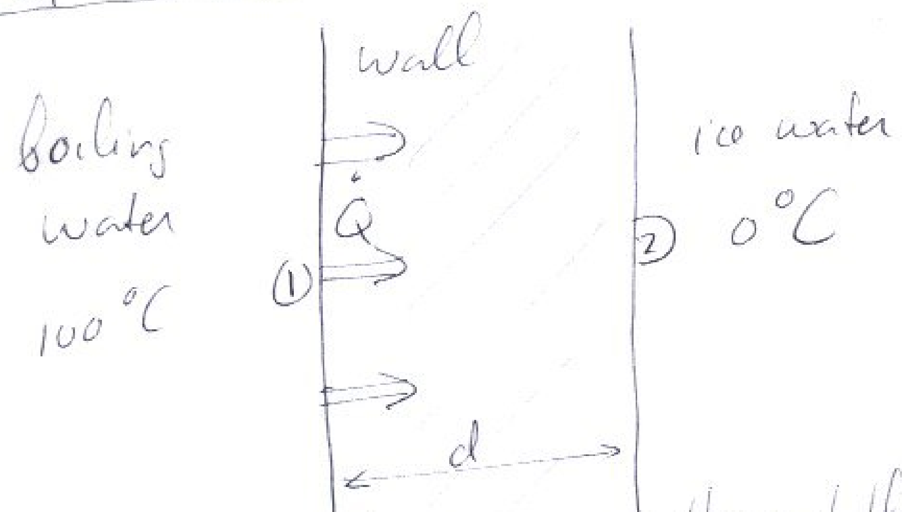
## 4.6 Heat

"energy transferred by virtue of temperature differences"




$$\boxed{\text{Specific heat transfer } {}_1q_2 = \frac{{}_1Q_2}{m}}$$

### Details of simple heat transfer



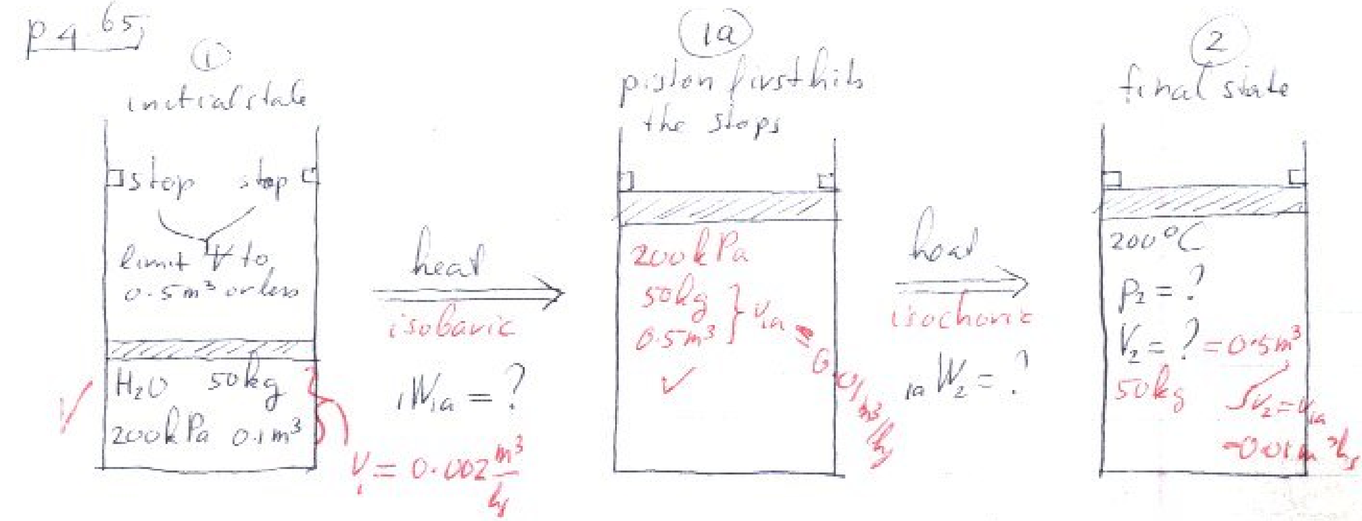

$\dot{Q}$ is heat energy (flux) passing through the wall per unit time.

Fourier: $\dot{Q} = A\,k\,\dfrac{T_1 - T_2}{d} = -A\,k\,\dfrac{dT}{dx}$

Also: convective heat transfer, radiative heat transfer

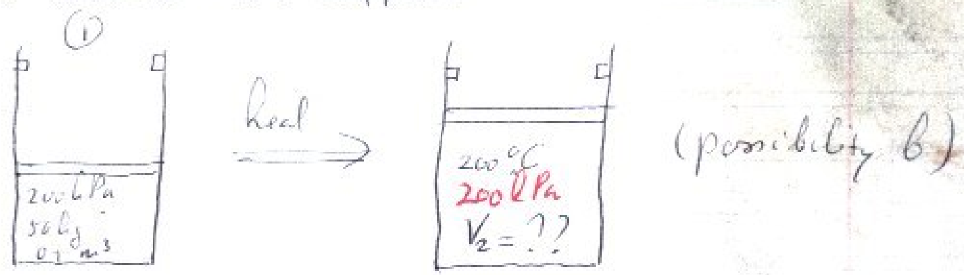
# Multistep processes

p4.65




Asked: $_1W_2$, $P_2$, $V_2$. PV diagram

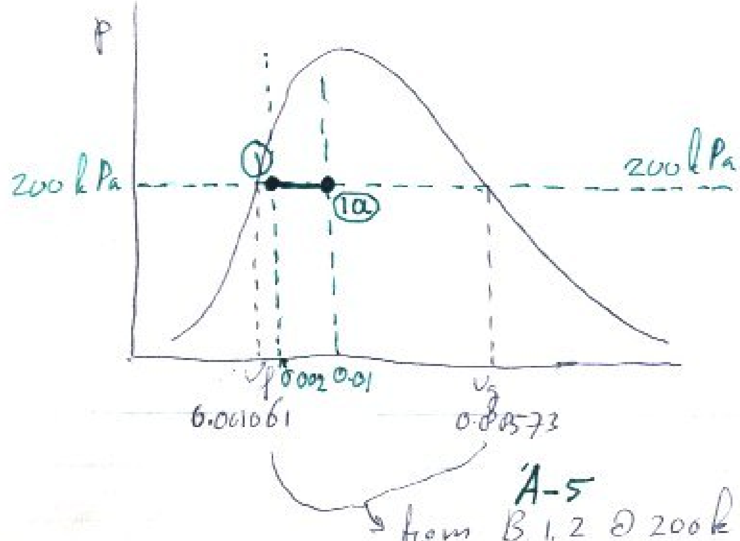
Note: $V_2$ may seem trivial, but it is not given that the piston reaches the stops. I am just guessing that. If the piston does not reach the stops, then the problem would look different




So, I need to check that $T_{1a}$ in the assumed process is still less than 200°C. If it is more, I have to go back and solve possibility b instead.

Answer:

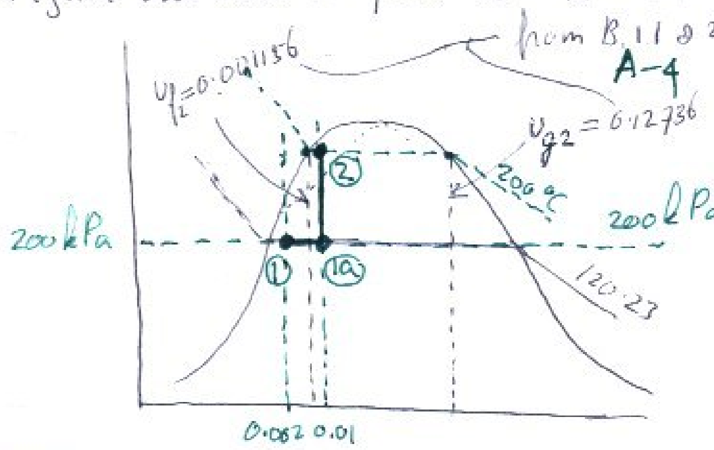
1) figure out state ① in the pv-diagram from $p_1 = 200$ kPa and
$v_1 = \frac{0.1 \, m^3}{50 \, kg} = 0.002$




2) figure out state 1a in the same diagram from $p_{1a} = 200$ kPa and
$v_{1a} = \frac{0.5 \, m^3}{50 \, kg} = 0.01 \, m^3/kg$ (above).

3) Find $T_{1a}$: still saturated at 200 kPa, so use table B.1.2 @ 200 kPa → $T_{1a} = T_1 = 120.23°C$. So at the stops, it has not yet reached 200°C! I guessed right! $V_2 = 0.5 \, m^3$

4) Figure out state 2 from $v_2 = v_{1a} = 0.01 \, m^3/kg$ and $T_2 = 200°C$ (below):




Since, $v_{f2} \le v_2 = 0.01 < v_{g2}$, state 2 is also 2-phase, as shown

So $p_2$ is the saturated pressure at 200°C
= 1553.8 kPa

Work: $\;_1W_{1a} = p_1 (V_{1a} - V_1)$ since isobaric

$= 200 \text{ kPa} (0.5 - 0.1) \text{ m}^3$

$= 80 \text{ kJ}$

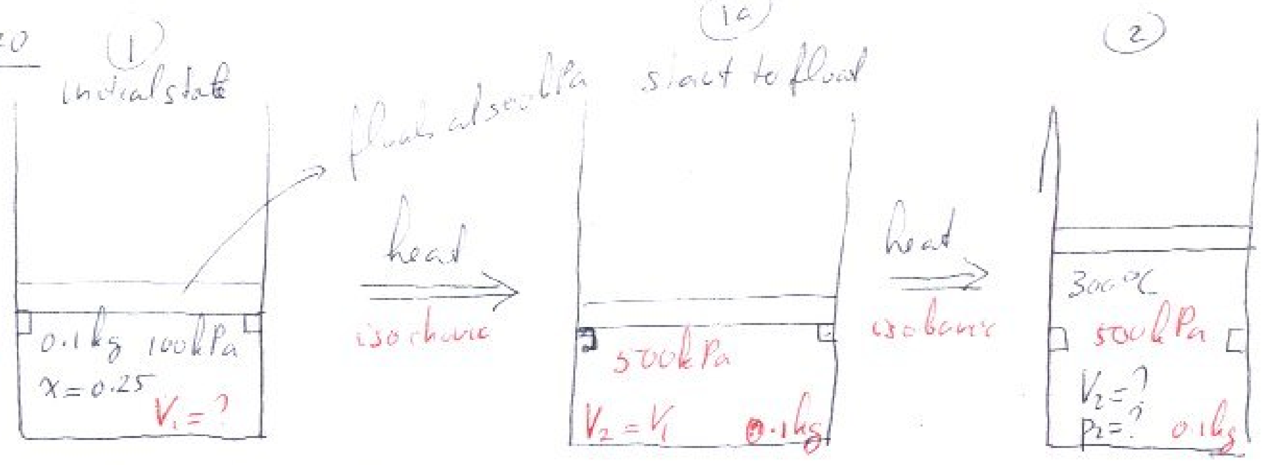
$_{1a}W_2 = 0$ since isochoric

end of 2/7/6 (Board$_7$)

$_1W_2 = {}_1W_{1a} + {}_{1a}W_2 = \underline{\underline{80 \text{ kJ}}}$

SKIPPED

p 4.70




Asked: $p_2$? $V_2$? , $W_2$?

Answer: phase 1 trivial.

1) $V_1 = ?$  $v_1 = v_f + x\, v_{fg}$  Table B.1.2 @ 100 kPa :

$v_{f1} = 0.001043 \frac{m^3}{kg}$  $v_{fg} = 1.69296 \frac{m^3}{kg}$

$v_1 = 0.001043 \frac{m^3}{kg} + 0.25 \cdot 1.69296 \frac{m^3}{kg} = 0.4243 \frac{m^3}{kg}$

$V_1 = 0.1 kg \cdot 0.4243 \frac{m^3}{kg} = 0.04243\ m^3 = V_{1a}$

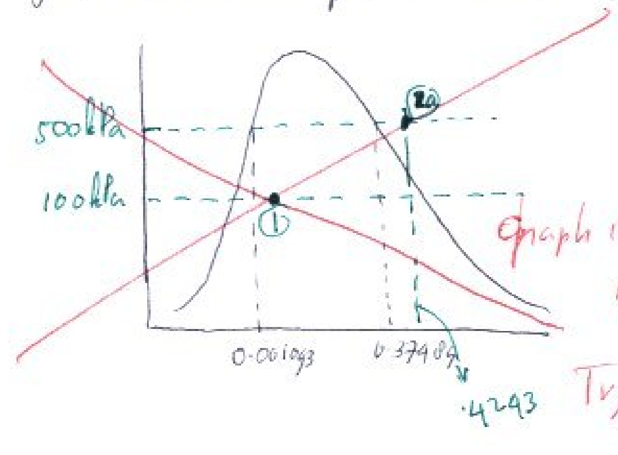
2) $p_{1a} = 500$ kPa, $v_{1a} = 0.4243 \frac{m^3}{kg} = v_1$

Figure out state in pv : Table B.1.2 @ 500 kPa :

$v_{f1a} = 0.001093\ m^3/kg$

$v_{g1a} = 0.37489\ m^3/kg$

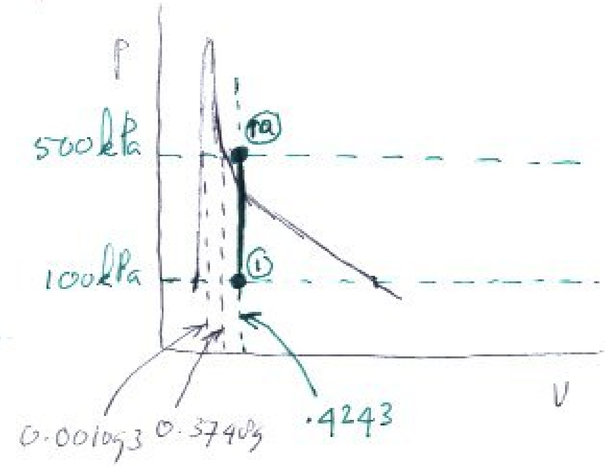
$\Longrightarrow$




Graph is scaled wrong since 1a must be ~~above~~ straight above 1 (isochoric process)

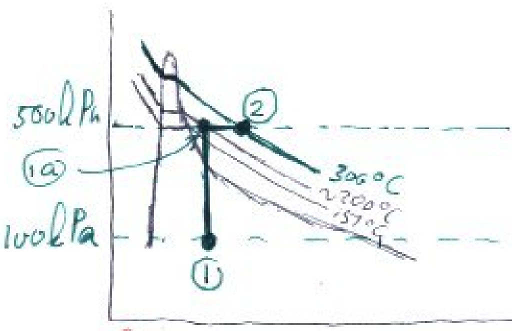
Try again

Try again




3) Check temperature $T_{1a}$: Table B.13.0 500kPa and 0.4243 $m^3/kg$
$\Rightarrow T_{1a}$ is just below 200°C, which is still less than 300°C. So we were right to guess that the piston will float before the temperature reaches 300°C.
Also: $\underline{p_2 = 500\,kPa}$ now established.

4) Figure out state 2 from $p_2 = 500\,kPa$, $T_2 = 300°C$.
Since we already have the 500kPa straight line, let's do "straight line first". Look up the pressure 500kPa in the saturated table B.1.2. $T_s$ (500kPa) = 151.86. Draw this isotherm, then draw the broken 300°C line




(2) is superheated vapor too.
Look up 500kPa and 300°C in table B.1.3: $v_2 = 0.52256\ m^3/kg$
$\Rightarrow V_2 = 0.1kg \cdot 0.52256\ m^3/kg$
$= \underline{0.052256\,m^3}$

$${}_1W_2 = {}_1W_{1a}^{\nearrow 0} + {}_{1a}W_2 = p(V_2 - V_{1a}) = 500\,kPa\,(0.052256 - 0.04243)\,\frac{m^3}{kg}$$
$$= \underline{4.913\,kJ}$$