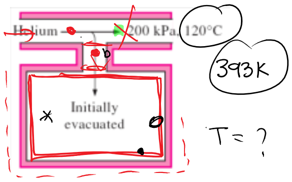
5–124 A rigid, insulated tank that is initially evacuated is connected through a valve to a supply line that carries helium at 200 kPa and 120°C. Now the valve is opened, and helium is allowed to flow into the tank until the pressure reaches 200 kPa, at which point the valve is closed. Determine the flow work of the helium in the supply line and the final temperature of the helium in the tank. *Answers:* 816 kJ/kg, 655 K



Unsteady flow energy eqn.

$$E_2 - E_1 = \cancel{Q}^{0} - \cancel{W}^{0} + \sum m_i \left(h_i + \frac{C_i^2}{2} + gz\right) - \sum m_e \left(h_i + \frac{C_e^2}{2} + gz\right)$$

$m_e \to 0$

within the cylinder $\quad P_f = 200\,\text{kPa}$

	1	2
M	0	m_i
T (K)	x	T_f
P (kPa)	0	200

$M_f e_f - 0 = m_i \times h_i$ (neglecting the KE & PE)

initial stored energy

Final stored energy $\quad M_f = m_i$ = the mass that has entered, since initial mass within the open system was zero (cylinder was evacuated)

$\cancel{m_i}\, u_f = \cancel{m_i}\, h_i$

↳ enthalpy of incoming fluid

$u_f = h_i$

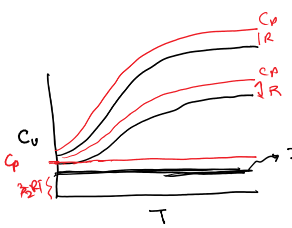
Enthalpy $\Rightarrow dh = C_p\,dT$

Internal energy $\Rightarrow du = C_v\,dT$

For ideal gases we consider $u_{ref} = 0$ at $T = 0$

$$\Rightarrow u = \int_{T_0 = 0\,K}^{T} C_v\,dT = C_{v_{av}}(T - 0) = C_{v_{av}} T$$

$$h = \int_{T_0 = 0}^{T} C_p\,dT = C_{p_{av}}(T - 0) = C_{p_{av}} T$$

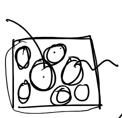


For monoatomic gas

$$\left.\begin{aligned} u_f &= C_v \times T_f \\ h_i &= C_p\, T_i \end{aligned}\right\} \quad C_v T_f = C_p T_i \Rightarrow T_f = \gamma T_i = 1.67 \times 393$$

$$\boxed{T_f = 656.31}$$

$h_i = u_i + p_i v_i$ (393 K; 200 ×)



$\boxed{u_i @ 393\,K}$

$u_i @ 393$

He

$p_i v_i = R_{He} T_i = \frac{\bar{R}}{M_{He}} \cdot T_i$

$$= \frac{8.315}{4} \times 393$$

$$= 816.94 \text{ kJ}$$

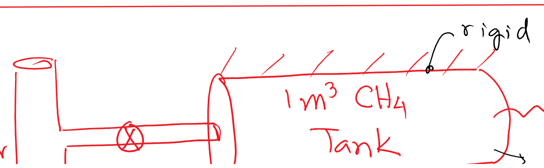
$$C_v = \frac{R}{\gamma - 1} = \frac{R_u}{M_{He}} \times \frac{1}{\gamma - 1} = \frac{8.315}{4 \times 0.67} \frac{kJ}{kgK} = 3.102 \frac{kJ}{kgK}$$

$$\boxed{\text{Flow work} \Rightarrow \text{increase in } T}$$

$$C_v \times \Delta T = 3.102 \times (655 - 393)$$

$\gamma_{CH_4} = 1.306$

Find i) T_f = final temp in the cyl

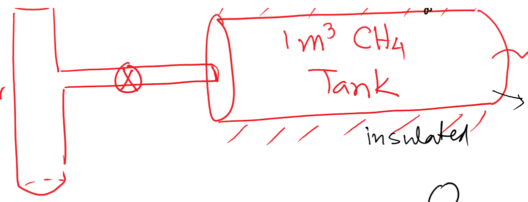


initially at 1 bar & 300K

Find

1) T_f = final temp in the cyl.

2) m_i = mass of CH_4 that has entered



initially at $\underline{1\text{ bar}}$ & 300K

Energy Eqn.

$$E_f - E_{in} = \cancel{Q}^{0} - \cancel{W}^{0} + m_i h_i - \cancel{m_e h_e}^{0}$$

i = inlet

Assume const. C_p & C_v and a ref. temp. T_0

$$E_f - E_{in} = m_i h_i$$

$$m_f u_f - m_{in} u_{in} = m_i h_i$$

$$m_f = (m_{in} + m_i)$$

$$\Rightarrow m_f \cancel{C_v} T_f - m_{in} \cancel{C_v} T_{in} = m_i \cancel{C_p}^{\gamma} T_i$$

$$m_{in} = \frac{P_{in} V_{in}}{R_{CH_4} T_{in}}$$

1 bar, $1 m^3$, 300K

$$(m_{in} + \boxed{m_i}) \boxed{T_f} - m_{in} T_{in} = m_i \gamma T_i \quad —— (1)$$

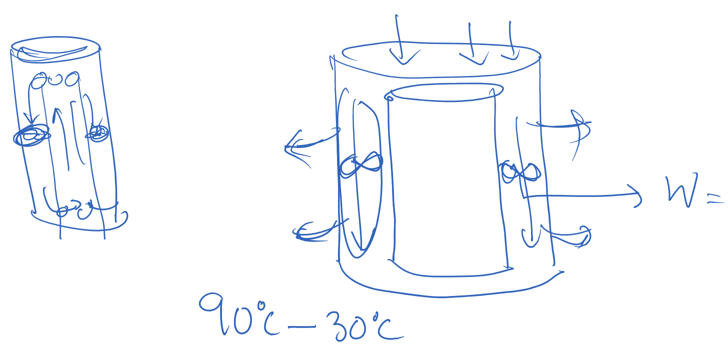
? ?

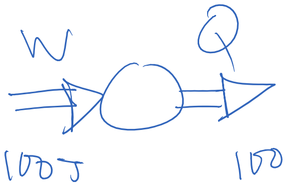
Equation of state in cylinder

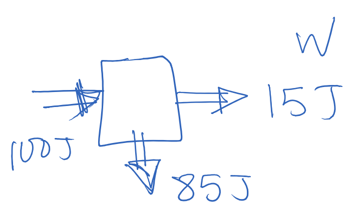
$$P_f V_f = (m_{in} + m_i) R_{CH_4} T_f \quad —— (2)$$

T_f
m_{in}

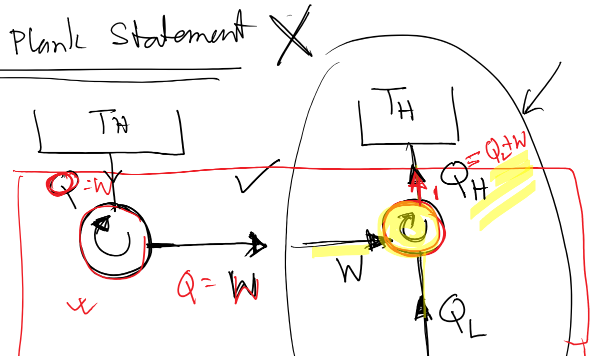
$\boxed{T_f = 385K}$ | check

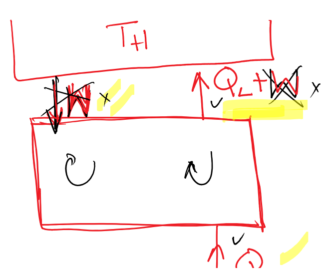


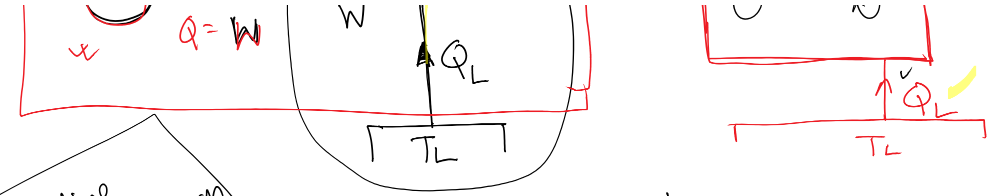




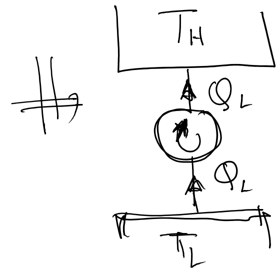
Kelvin Plank Statement



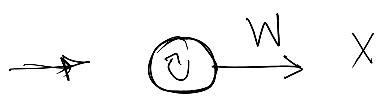


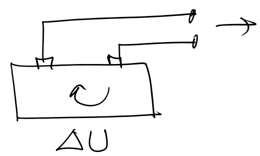


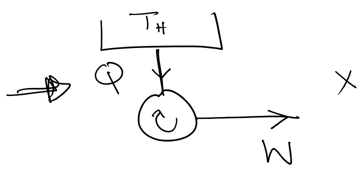
Show that violating Clausius statement leads to the violation of KP statement



$$\frac{\text{PMM II}}{\text{PMM I}} = \frac{\text{Perpetual Motion Machine of 2nd kind}}{\text{Perpetual Motion Machine of 1st kind}}$$





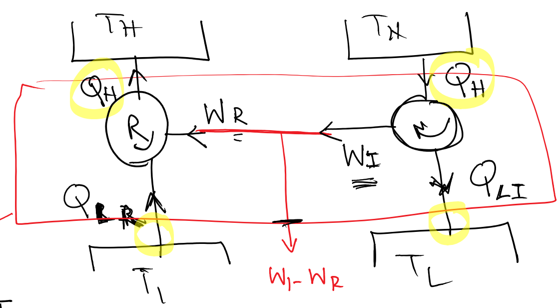


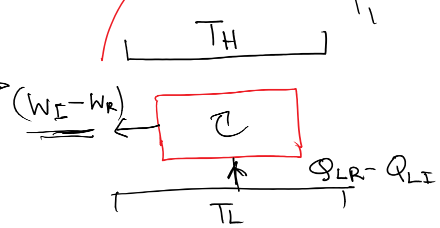
PMMI violates 1st Law

PMMII does not violate 1st Law, but it violates 2nd Law

$W_R \ngtr W_I$ (R)

$\boxed{W_I > W_R}$





$\boxed{\text{PMM 2}}$