10/20

MAE91 Summer 2004 – Quiz 2
Dr. H. Susan Zhou

Closed book and notes – 25 minutes

Name: Nasser Abbasi
ID:____________________

5/10

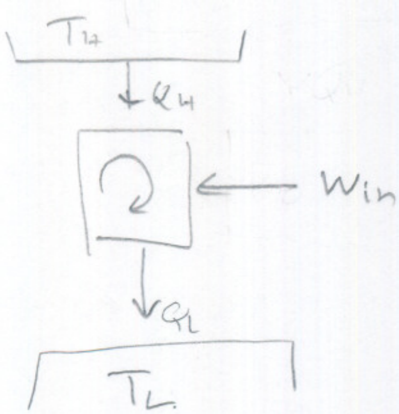
1. Write down the Kelvin Planck and the Clausius statement of the second law and prove that the two statements are equivalent.

KP: impossible to have 100% efficient heat engine.

C-statement: must have 2 heat resivours of different temperatures for a cycle heat engine that produces work.

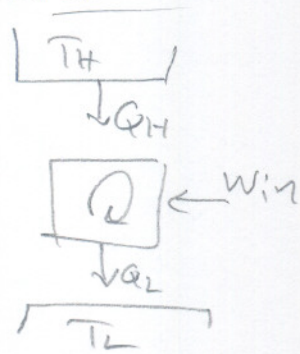
-2

-3 prove equivalent



5/10

2. In Carnot engine with ammonia as the working fluid, the high temp is 60°C, and as Q_H is received, the ammonia changes from saturated liquid to saturated vapor. The ammonia pressure at low temperature is 190kPa. Find T_L, the cycle thermal efficiency, the heat added per kilogram, and entropy s at the beginning of the heat rejection process. (No numerical numbers substitution is required). (Hint: use T-s diagram to solve the problem).



Statment

$T_H = 60°C$

$\downarrow Q_H$

state ①	Process → v constant	state ②
$x = 0$ $P_1 = 190kPa$ v_1		$x_2 = 1$ $v_2 = v_1$

Find T_L, η, ΔQ per kg, s.

Assumptions

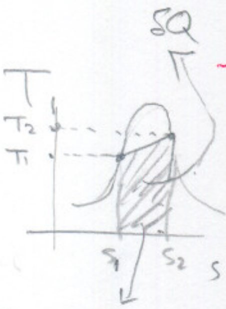
Constant mass, ~~constant volume of ammonia.~~ This is ΔQ under T-S curve.
Carnot heat engine

Laws

$$\eta_{actual} = \frac{W_{in}}{Q_H} = \frac{Q_H - Q_L}{Q_H} = 1 - \frac{Q_L}{Q_H}, \quad \eta_{Carnot} = \frac{T_H - T_L}{T_H} = 1 - \frac{T_L}{T_H}$$

$${}_1Q_2 - {}_1W_2 = m(u_2 - u_1) \quad \text{or} \quad {}_1q_2 - {}_1w_2 = (u_2 - u_1)$$

steps



-1

${}_1q_2 - \cancel{{}_1w_2} = u_2 - u_1$ (=0)

so ${}_1q_2 = u_2 - u_1$ ——— ① -1

at state 1 find u_1 from ammonia table given (P_1, x_1)

at state 2 find u_2 from ammonia table given $(v_2 = v_1, x_2)$

area = $\frac{1}{2}(T_2 + T_1)(s_2 - s_1)$

so use eq ① to find ${}_1q_2$, $\boxed{\text{this is } \Delta q}$ ← heat added per kg. $= q_H$

δQ ← $\boxed{\frac{q_H - q_L}{q_H} = 1 - \frac{T_L}{T_H}}$ ⟹ $\boxed{\text{solve for } T_L.}$ -1

this is area under curve of T-S

Calculated above. given

to find s_1, from table at state ① find. $s = s_f + x_1 s_{fg}$ (given; table @ P_1; Table ammonia @ P_1)

to find s_2, from Table at state ② using $(P_2 = P_1, x_2 = 0)$

-2

find T_1, T_2 from Table as well (from Table $(x_1, v_2 = v_1)$; using (P_1, x_1))

MAE91 Summer 2004 – Quiz 2
Dr. H. Susan Zhou

Closed book and notes – 25 minutes

Name:_______________

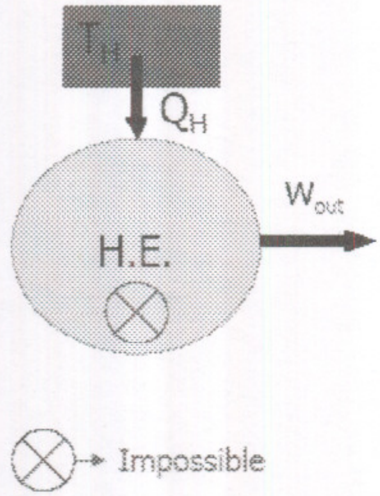
ID:_________________

1. Write down the Kelvin Planck and the Clausius statement of the second law and prove that the two statements are equivalent.

- The Kelvin-Planck statement: It is impossible to build a H.E. that exchange heat with only one thermal reservoir.

$$\boxed{\eta_{th} = 100\% \text{ is impossible.}}$$

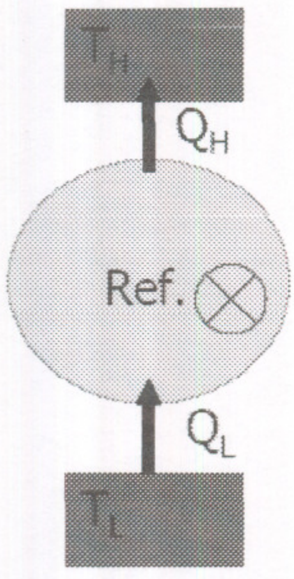
- In a border sense: It is impossible to construct a device that will operate in a cycle and produce no effect other that the raising of a weight and the exchange of heat with a single reservoir.



- The Clausius statement: It is impossible to build a refrigerator without W_{in}.

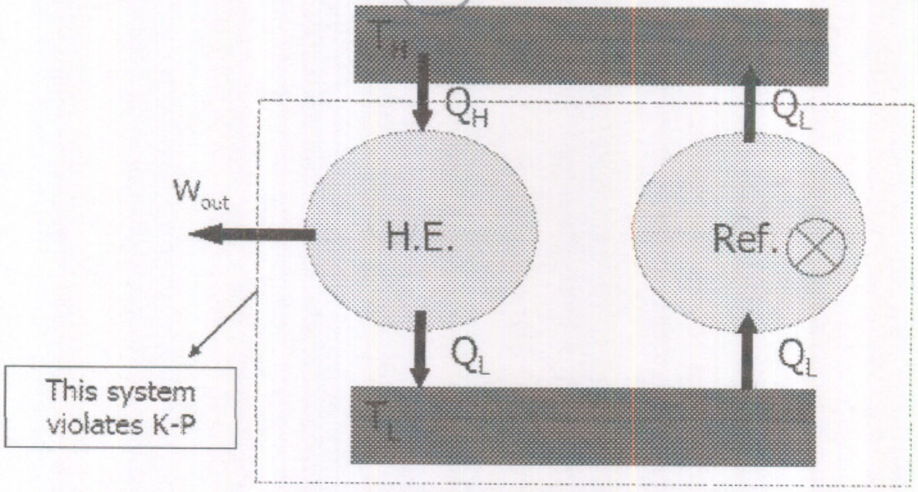
$$\boxed{\beta = \frac{Q_L}{0} = \infty \text{ is impossible.}}$$

- In a broader sense: It is impossible to construct a device that operates in a cycle and produced no effect other than the transfer from a cooler body to a hotter body.



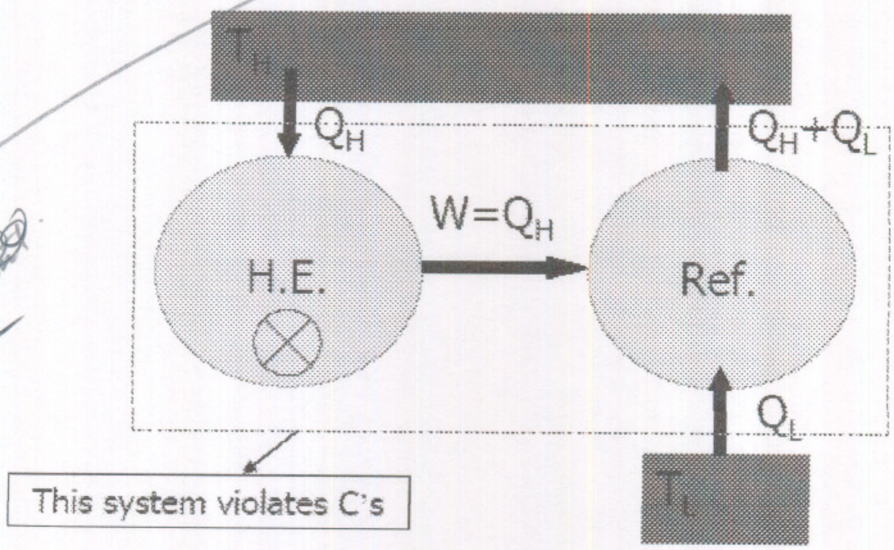
i.e. make a refrigerator without Win

- Violation of C's 2nd law is a violation of K-P:

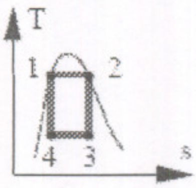


- Violation of K-P is a violation of C's 2nd law:

i.e. make a heat engine without Q_L



2. In Carnot engine with ammonia as the working fluid, the high temp is 60°C, and as Q_H is received, the ammonia changes from saturated liquid to saturated vapor. The ammonia pressure at low temperature is 190kPa. Find T_L, the cycle thermal efficiency, the heat added per kilogram, and entropy s at the beginning of the heat rejection process. (No numerical numbers substitution is required). (Hint: use T-s diagram to solve the problem).



Assumptions and Givens:

C.V. is ammonia.

State 1: $T_1 = T_H, x_1$

Process: Heat added to ammonia at constant T (and P because it is under the dome) and there is a phase change.

State 2: $T_2 = T_1 = T_H, x_2$

Find: T_L, η, q_H, s_3

Fundamental Laws:

Continuity:

$$m_i + m_1 = m_e + m_2 \Rightarrow$$
$$\dot{m}_1 = \dot{m}_2$$

First Law for Control Volume:

$$\dot{Q}_{in} + \dot{W}_{in} + \dot{m}_i(KE + PE + h)_i = \dot{Q}_{out} + \dot{W}_{out} + \dot{m}_e(KE + PE + h)_e + \left(\frac{dE}{dt}\right)_{C.V.}$$

Entropy Equation:

$$m(s_2 - s_1) = \int \frac{dQ}{T}$$

Steps:

To find the heat added into the system, we use the entropy equation with a constant. Since T is constant in the process:

ask about

$$m(s_2 - s_1) = \int \frac{dQ}{T} \Rightarrow (s_2 - s_1) = \frac{q_H}{T}$$
$$\therefore q_H = T(s_2 - s_1)$$

Using Table B.2.1 we can find the entropy and the enthalpy which can be related to the entropy with Gibbs equations, reme:

$$T_1, x_1 = 0 \Rightarrow s_1 = s_f, h_1 = h_f$$
$$T_2 = T_1, x_2 = 1 \Rightarrow s_2 = s_g, h_2 = h_g$$

Gibbs equation tells us that with a constant pressure process.

$$Tds = dh - vdP = dh$$
$$\therefore q_H = T(s_2 - s_1) = (h_2 - h_1)$$

To find the low temperature we just use the pressure and table B.2.1:

$$T_L = T_3 = T_4 = T_{sat}(P)$$

The efficiency is then just the Carnot efficiency given by:

$$\eta = 1 - \frac{T_L}{T_H}$$

To find the entropy at the beginning of the heat rejection process we see that the entropy is the same as the end of the high temperature process (we can't find it directly because we do not know two independent intensive properties). So using the value from table B.2.1:

$$s_3 = s_2 = s_g(T_H)$$