ME301 F2010 16.1

Up until now, our discussions about the 2nd law have considered the concept of irreversibility & the maximum efficiencies of idealized systems.

→ How would we apply the second law for a substance? ← We can't yet

→ We need a thermodynamic property that describes how <u>ordered</u> something is; one that is ultimately related to the irreversibility of a system: Entropy: $S\left(\frac{J}{k}\right)$ $s\left(\frac{J}{kg\,k}\right)$

To derivation of entropy starts from a reversible process; a heat engine for example

$$\eta_{max} \overset{?}{=} \eta_{Carnot} = 1 - \frac{T_C}{T_H} = \frac{\dot{W}_{net}}{\dot{Q}_H} \Rightarrow \dot{Q}_H - \dot{Q}_H \frac{T_C}{T_H} - \dot{W}_{net} \Rightarrow \frac{\dot{Q}_H - \dot{W}_{net}}{\dot{Q}_H} = \frac{T_C}{T_H} \Rightarrow$$

$$\Rightarrow \frac{\dot{Q}_C}{\dot{Q}_H} = \frac{T_C}{T_H} \Rightarrow \frac{\dot{Q}_C}{T_C} = \frac{\dot{Q}_H}{T_H}$$

for a reversible process, for any real process with irreversibilities we define entropy as $dS = \left.\frac{\delta Q}{T}\right|_{rev}$

The differential change in entropy is the ratio to the differential heat transfer reversibly to the temperature it was transferred.

The 2nd Law states that processes go from more ordered → less ordered

if entropy is a property that describes this order, the 2nd law necessitates that entropy is <u>not</u> conserved → it's always increasing!

Entropy can only be generated (produced), it can never be destroyed. $\Delta S \geq 0$

What would an entropy balance look like? IN + PRODUCED = OUT + ~~DESTROYED~~ + STORED
$\underbrace{}_{0}$

$$S_{in} + S_{Gen} = S_{out} + \Delta S_{STORED}$$

16.2 ME301 F2010

Like energy, we need to understand how entropy is transferred across our system boundary (INS & OUTs) & stored in our system before we can balance entropy & apply the 2nd law.

Entropy is transferred by 2 mechanisms:

1) heat transfer, 2) mass entering/leaving system

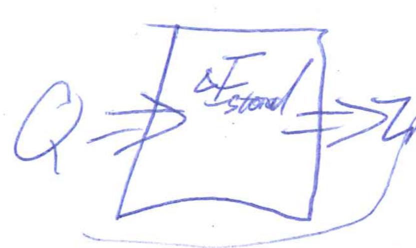
Note!!: entropy is not transferred by work.

→ in a way this is a useful way to define work: energy transfer with no entropy

→ From an energy/1st law standpoint, work & heat are equivalent

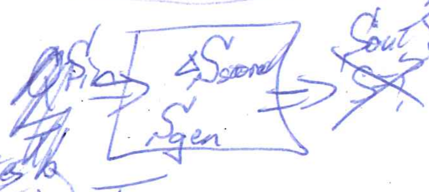
→ From an entropy/2nd law standpoint, they are very different

→ General Closed System



Energy Balance: $E_{in} = E_{out} + \Delta E_{stored} \Rightarrow Q_{in} = W_{out} + \overbrace{E_2 - E_1}^{\Delta U}$

Entropy Balance: $S_{in} + S_{gen} = S_{out} + \Delta S_{stored}$



→ Entropy transferred in with heat is directly related to the temperature of the surface: $S_{in} = \dfrac{Q}{T_b}$ where Q is occurring — Boundary temp

Notes:

1) It is important to carefully draw your system so that you know the temperature of the boundary, hopefully this choice will maximize S_{gen}.

2) Have to use absolute temperature!

3) Entropy transfers in same direction as heat.

What about the storage term? $\Delta S_{stored} = m(s_2 - s_1)$

Entropy is a property, just like internal energy or mass, therefore if we fix the state with 2 independent properties we can find entropy.

Where for a real fluid? Tables in book

still applies

$$x = \frac{s - s_f}{s_g - s_f}$$

EES: s = entropy('real fluid', Property1 = value1, Property2 = value2)

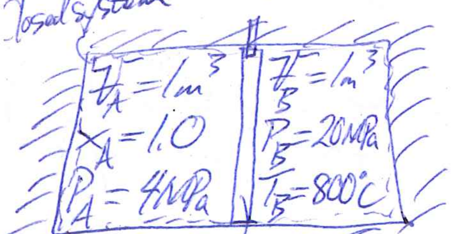
REFPROP => link posted on line for mini version

Let's do an example with REFPROP!

Insulated tank filled with water vapor is divided by a thermally conductive piston. The piston is released & the system equilibrates.

Find: a) Final Pressure, b) final Temperature, c) the entropy produced.

Closed system



How do we start? => Define system

Energy Balance: $E_{in} = E_{out} + \Delta E_{stored} \Rightarrow 0 = \Delta U_A + \Delta U_B \Rightarrow$

Thermally conductive piston $\Rightarrow 0 = m_A(u_{2A} - u_{1A}) + m_B(u_{2B} - u_{1B})$ what do we know?

$$m_A = \frac{V_A}{v_A} = \frac{1\,m^3}{0.04977\,\frac{m^3}{kg}} \Rightarrow m_A = 20.09\,kg \qquad m_B = \frac{V_B}{v_B} = \frac{1\,m^3}{0.023869\,\frac{m^3}{kg}} \Rightarrow m_B = 41.895\,kg$$

$u_A = 2601.7\,\frac{kJ}{kg}$

$s_A = 6.0696\,\frac{kJ}{kg\text{-}K}$

What do we know about state 2?

$T_{2A} = T_{2B}$, $P_{2A} = P_{2B}$ so $u_{2A} = u_{2B} = u_2$

1 eq. 1 unk.

$u_B = 3590.1\,\frac{kJ}{kg}$

$s_B = 7.0531\,\frac{kJ}{kg\text{-}K}$

16.4 ME301 F2010 (

$\underline{u_2 = 3269.75\ \frac{kJ}{kg}}$ ← do we know enough to fix system state? we know $T_{2A} = T_{2B}$ & $P_{2A} = P_{2B}$ but we don't know the values!

well we know $v_{2A} = v_{2B} = v_2$ & $V_2 = \cancel{A} V_A + V_B$ so $v_2 = \frac{V_A + V_B}{m_A + m_B}$

$\underline{v_2 = 0.032227\ \frac{m^3}{kg}}$ => how do we find T_2 & P_2 from u_2 & v_2?

-Tables this is tough! EES easy, REFPROP easy too

From REFPROP $T_2 = 621.13°C$, $P_2 = 12.122\ MPA$, $s_2 = 6.8599\ \frac{kJ}{kg\,K}$

Now lets find S_{gen}

Entropy Balance: ~~$S_{in} + S_{Gen} = S_{out}$~~ $\overset{0\ (adiabatic)}{S_{in}} + S_{Gen} = \overset{0\ (closed)}{S_{out}} + \Delta S_{stored}$

$S_{Gen} = m_A(s_{2A} - s_{1A}) + m_B(s_{2B} - s_{1B})$ $\quad \overbrace{s_{2A} = s_{2B}}^{\text{Same state}} = s_2$

$S_{Gen} = 20.09\,kg\left(6.8599\ \frac{kJ}{kg\text{-}k} - 6.0696\ \frac{kJ}{kg\text{-}k}\right) + 41.895\,kg\left(6.8599\ \frac{kJ}{kg\text{-}k} - 7.0531\ \frac{kJ}{kg\text{-}k}\right)$

$$\boxed{S_{gen} = 7.657\ \frac{kJ}{K}}$$