The irreversibility & value of heat

→ Thus far we have established mass & energy balances. Mass & energy are conserved quantities meaning that for all systems: IN = OUT + STORED

However, we still don't have all of the tools we need to address real problems: Play movie

→ What are we missing?? ⇒ the concept of directionality

Mass & Energy Balances don't care about direction.

Example: If I have a 1Ω resistor & connect it to a 10V power supply. What happens?! Ohm's law $V=IR$ so $I=\frac{V}{R}=\frac{10}{1}=10\text{Amps}$

→ The resistor will draw 10 amps of current from the supply.

→ What else? It will get hot.

Energy Balance: (+ 10V −) Load System $\dot{Q}_{out}$

$\dot{E}_{in}=\dot{E}_{out}+\frac{dE_{stored}}{dt}$ (0 (Steady State))

$\dot{W}_{in}+\dot{Q}_{in}=\dot{W}_{out}+\dot{Q}_{out} \Rightarrow \dot{W}_{in}=\dot{Q}_{out}$

$\dot{W}_{in}=V\,I=10V(10\text{Amps}) \Rightarrow \dot{W}_{in}=100W$ so $\dot{Q}_{out}=100W$

(Voltage, Current)

Resistor will quickly become hot until (@ constant temperature $\dot{E}_{out}=\text{Constant}$)

Can I reverse this process?

14.2 ME 301 Spring 2018

→ Lets say I disconnect the resistor from the power supply & take a blow torch to put 100W of heat into the resistor. Do you think I will get 100W of electrical power out (10V & 10Amps)?

No!! I would just get a very hot resistor & nothing else.

→ Does this violate the 1st Law? No

→ Power is not generated because the original process is irreversible (cannot be reversed)

→ So what happened to the energy from the blow torch?

→ Was it destroyed? No → energy is conserved. It likely heated the surroundings, but can we ever get it back? → Probably not → Irreversible

→ Towards the end of the 19th century, scientists & engineers noticed the directionality of processes & began to develop theories to describe it.

☆ Rudolf Clausius: "Heat cannot pass spontaneously from a body of lower temperature to a body of higher temperature." (Heat has directionality)

☆ Sadi Carnot: "Heat cannot be converted completely & continuously into work."

→ Heat is ~~entirely~~ never perfectly efficient due to irreversibilities

→ In fact, any time you transfer energy by any means through any kind of gradient (unrestrained potential difference), you will have irreversibilities & not be able to get back what you put in

	Phenomena	Gradient
1)	Friction	Force
2)	Unrestrained Expansion	Pressure
3)	Heat transfer	Temperature
4)	Current flow	Voltage
5)	Mixing of 2 different substance	Chemical Potential

These are all irreversibilities that you will have to identify & account for in thermodynamics.

→ The directionality of these processes also gives value to them relative to one another.

Example: Does the temperature at which heat is supplied matter??

→ Clausius statement: heat cannot pass from cold to hot

→ The higher the temperature @ which heat supplied is, the more things you can do with it! → Nuclear reactors VS. rubbing my hands together

→ Heat is irrevocably linked to the temperature @ which it is supplied

$$\frac{Q_{Nuclear}}{T_{Hot}} = \frac{100\,W}{1000k} = \frac{1}{10}\frac{W}{K} \qquad \frac{Q_{Hands}}{T_{Hands}} = \frac{100\,W}{300k} = \frac{1}{3}\frac{W}{K}$$

the higher the ratio of $\frac{Q}{T}$ the amount of work is

14.4 ME 301 Spring 2013

Heat loses all of its value when the source reaches the same temperature as the surroundings. No more gradient, no more heat, its all around us, but none of it is useful.

Essentially all of this means that all real processes have direction, are irreversible, have relative value, & inefficient.

This is the basis for 2nd Law of thermodynamics

2nd law in general

More order/value => Less order/value

=> Apple => condensed energy provided by a tree, turns to compost over time

=> Buildings => take a lot of work to build, but always crumble over time

=> Information => becomes more disordered the more you copy it,

=> Apartment => without lots of work, becomes more disordered over time

=> People => The more ways you can do anything the more likely you will get confused or do it incorrectly.