Second Law of Thermodynamics and Entropy

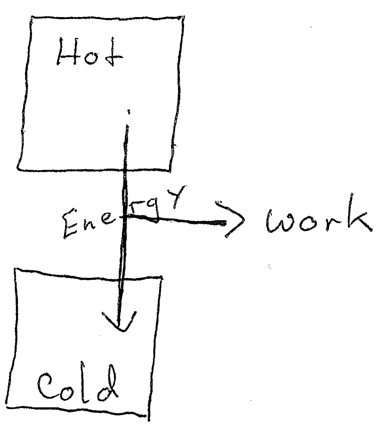
Second Law

* Heat will not spontaneously flow from a colder body to a warmer body

* Heat energy can not be completely converted into mechanical work in a thermal cycle

The second law is used to define direction of natural events.

Heat Engine Restrictions



- Thermal energy will only naturally flow from hot to cold.
- Some of the flow can be used for work.

Think of heat engines as dams.

- A dam can only generate mechanical energy if water flows from a high position to low position.

high position is like hot reservoir

low position is like cold reservoir

Just as water never naturally flows up hill, heat never naturally flows from cold to hot.

Entropy

* measure of disorder/order in a system
* Measure of a system's ability to do useful work.
  - measure of the quality of heat energy.

Quality

- High quality heat energy is contained in high temperature reservoirs
- Low quality heat energy is contained in low temperature reservoirs

Entropy for a reversible isothermal process.

$$\Delta S = \frac{Q}{T}$$

ΔS - entropy change $\left(\frac{J}{K}\right)$

T - temp. in kelvin (K)

Q - heat in Joules (J)

Q in is $+$

Q out is $-$

$$\Delta S_{total} = -\frac{Q_H}{T_H} + \frac{Q_C}{T_C}$$

Q_H = heat transfer from high temp. reservoir

T_H = temp. of high temp. reservoir

Q_C = heat transfer to cold temp. reservoir

T_C = temp. of cold temp. reservoir

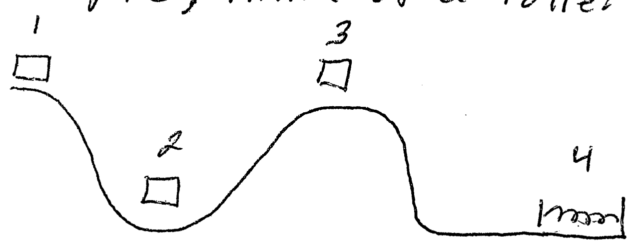
Note: For a reversible process $\Delta S_{Total} = 0$

Work done by irreversible process heat engines

$$W = T_C \, \Delta S_{universe}$$

Ordered energy can be transferred to different storage mechanisms easily.

For example, think of a roller coaster.



At 1 the rollercoaster has E_k and E_g.

At 2 E_k

At 3 E_k and E_g again.

At 4 E_{el}

As long as friction is ignored
E_k, E_g, and E_{el} can be transferred completely.

However, E_{diss}, or thermal energy is much more difficult to make a two-way transfer.

E_K, E_g, or E_{el} can easily transfer to E_{diss}, but E_{diss} to E_K, E_g, or E_{el} is difficult.

* A reversible process is entropy neutral.

  - Since an isolated system returns to an original state in a reversible process it should make sense that order is maintained.

Natural Systems

- Entropy can at best remain neutral.
- Entropy increases in nearly every process.

Order may occur locally (S decreases)
{ ice freezing, cells developing }
But somewhere else this increase in order is "paid for" with even greater disorder.
{ Electrical energy converted to heat }

Entropy and Probability

The idea of disorder can be related to the number of microstates composing the state of an object.

Example: Microstates of Four Coins

# Heads	Equivalent Microstates	# microstates
0	TTTT	1
1	HTTT, THTT, TTHT, TTTH	4
2	HHTT, THHT, TTHH, HTTH, THTH, HTHT	6
3	HHHT, THHH, HTHH, HHTH	4
4	HHHH	1
		16

The probability of finding the system in a given state is proportional to the # of microstates

W = # microstates

The more microstates that are available, the more disorder the system has.

Therefore, $S \propto W$.

However, sequential entropy changes are additive because what happens previously affects later events. Entropy must be both additive and multiplicative.

Since $\ln ab = \ln a + \ln b$
logarithms can be used to model a situation that is additive and multiplicative.

$$S = k_B \ln W$$

k_B = Boltzmann's Constant = 1.38E-23 $\frac{J}{K}$

W = # of microstates available