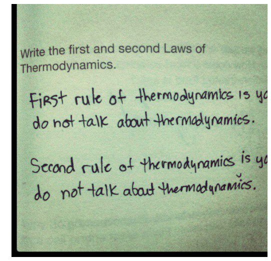


Thermodynamics

3 – Laws of Thermodyamics

Thermo….. …..Dynamics

Temperature

Changing

In short… Thermodynamics deals with systems that are not chemically changing, that are not moving, but whose temperatures are changing.

$$\Delta \cancel{E_k} + \Delta \cancel{E_p} + \Delta \cancel{E_{chem}} + \Delta U = Q + W$$

Where:

ΔU = Internal E (J)
W = Work (J)
Q = Heat (J)

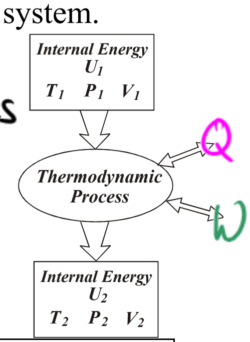
W > 0 Work done on the system.

W < 0 Work done by the system.

Q > 0 Thermal Energy transferred to the system.

Q < 0 Thermal Energy transferred away the system.

Since all the E terms cancel we are left with what is known as the 1st Law of Thermodynamics



$$\Delta U = Q + W$$

Example:

Suppose we get our hands on an insulated container (Swell or Klean Kanteen), so that no gas can escape. If a piston is used to compress the gas what happens to the *temperature* of the gas?

$Q = 0$

$\Delta U = \cancel{Q} + W \rightarrow W\uparrow$ as piston compresses work is done ON the system.

$\therefore \Delta U \uparrow$

if $\Delta U \uparrow$ the $\boxed{\text{temp}\uparrow}$

Example:

If you mix food in a magic bullet the motor does work on the system (food inside the bullet!). This work can warm up food. Suppose the Magic Bullet operates at 250 W for 100 s. During this time 4500 J of heat flow from the now warm food to the surroundings. How much does the internal energy of the food change?

$W = 250\,J/s \cdot 100\,s = 25{,}000\,J$

$\Delta U = Q + W = -4500\,J + 25{,}000\,J$

$\boxed{\Delta U = +20{,}500\,J}$

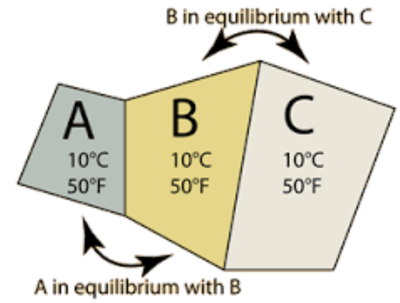
Whoops… We forgot something. Actually Everyone did… ***The Zeroth Law of Thermodynamics***

Zeroth Law of Thermodynamics: Thermal energy will be transferred from a hotter object to a colder object until thermal equilibrium is reached.

$$Q_1 = -Q_2$$

Due to the Law of Conservation of Energy, Heat lost by one object must equal Heat gained by the second object

This was actually stated ***AFTER*** the First and Second Laws but scientists deemed it important that it preceded both Laws



Energy Transfer Diagrams

Though Experiment:

If you drop a ***small*** hot rock in the Atlantic Ocean… What happens to the temperature of the ocean?

Heat would transfer from the rock to the ocean… but overall the ΔU would be so small, temperature would essentially NOT change. The ocean is know as a HEAT Reservoir/Sink

Energy Reservoir: an object or part of the environment (Surroundings) that is so large its temperature does not change when thermal energy is transferred between the system and the reservoir.

Cold Reservoir

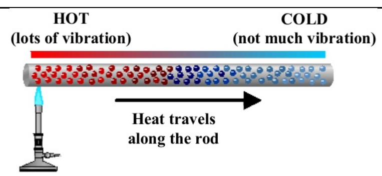
Temperature of cold Reservoir T_c

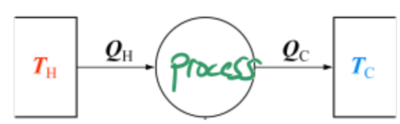
Q_C = The amount of heat transferred to or from a ***cold*** reservoir

Hot Reservoir

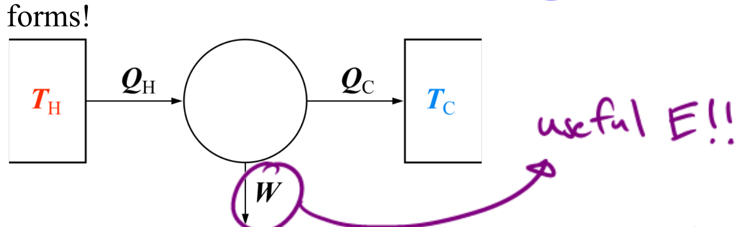
Temperature of hot Reservoir T_H

Q_H = The amount of heat transferred to or from a ***hot*** reservoir





Heat Engine: as heat is transferred from a hot reservoir to a cold reservoir, energy can be extracted and used in other ***useful*** forms!



Heat engines are often judged on their efficiency. (note: Temperature ***must*** be in Kelvin!!!.)

$$e = \frac{what\ you\ get\ out}{what\ you\ put\ in} = \frac{W_{out}}{Q_H} = \frac{Q_H - Q_C}{Q_H} = 1 - \frac{T_C}{T_H}$$

Therefore the bigger the differenc between T_H and T_c the more efficient the Heat Engine will be.

Example:

When one gallon of gasoline is burned in a car engine, 1.30×10^8 J of internal energy is released. Suppose that 1.12×10^8 J of this energy flows directly into the surroundings (engine block and exhaust system) in the form of heat. If 1.32×10^5 J of work is required to make the car go one km, what is the efficiency of the car?

Q_H Q_C

$$e = \frac{Q_H - Q_C}{Q_H} \times 100\% = \frac{1.30\times10^8 J - 1.12\times10^8 J}{1.30\times10^8 J} \times 100\% = \boxed{13.8\%}$$

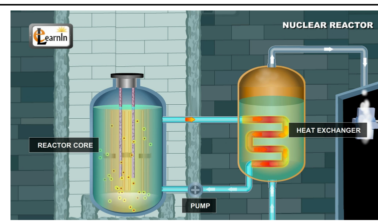
How many km's can the car travel on one gallon of gas?

$$W_{out} = Q_H - Q_C = 1.30\times10^8 J - 1.12\times10^8 J = 1.80\times10^7 J$$

$$d = 1.80\times10^7 J \times \frac{1\ km}{1.32\times10^5 J} = \boxed{136\ km}$$

Example:

In the core of a nuclear reactor nuclear reactions produce steam at extremely high pressures at a temperature of 310 °C. The steam is used to generate energy (in a steam turbine) and condensed to water at 22 °C. The excess heat is transferred to a nearby lake. What is the maximum possible efficiency of the nuclear reactor?



$$T_H = 310°C + 273.15 = 583.15 K$$

$$T_C = 22°C + 273.15 = 295.15 K$$

$$e = \left(1 - \frac{T_C}{T_H}\right) \times 100\% = \left(1 - \frac{295.15K}{583.15K}\right) \times 100\% = \boxed{49.4\%}$$

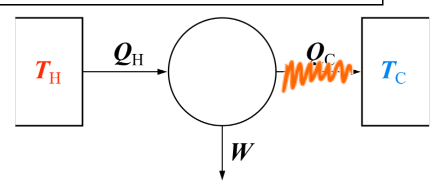
Example:

Based on the options below, which will ***increase*** the efficiency of a heat engine?

a. Increase T_C
b. Increase T_H
c. Decrease T_C
d. Decrease T_H

$$e = \left(1 - \frac{T_C}{T_H}\right) \times 100\%$$

Why not build a perfect Heat Engine you say?!

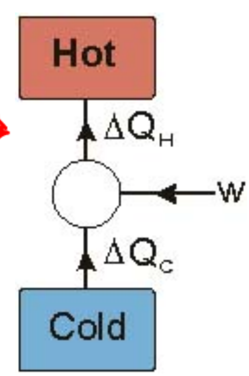


Carnot's Perfect Heat Engine: The most efficient heat engine allowed by ***Physical Laws***. (*check out the reading online for more details!*)

No heat engine can be 100% efficient. Some fraction of heat must be exhausted to the cold reservoir.

This is a fundamental law of nature! (As stated by the 2nd Law of Thermodynamics)

Heat Pumps, Refrigerators and Air Conditioners (AC)



Heat Pump: The opposite of a heat engine… transfers energy from a cold reservoir to a hot reservoir.

In order for this to "work"… work must be done on the system! ☺

Inside a refrigerator, a heat pump moves heat from it's interior (Q_C) to the outside air (Q_H).

2^{nd} Law of Thermodynamics

"I blame entropy."

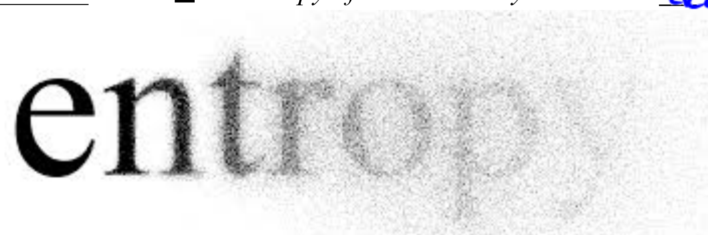
Entropy (S) (*Quantitatively*): the probability that a certain state will occur…. (confusing)

Entropy (S) (*Qualitatively*): a measure of chaos… greater S = greater chaos (less confusing)

If left to it's own devices ***order*** turns into ***disorder/randomness/chaos***…

If your bedroom is currently in an extremely clean state: ~~High Entropy~~/Low Entropy?

The 2^{nd} Law… $\mathbf{S \geq 0}$ *Entropy of an isolated system never* decreases.



Do living organisms violate the 2^{nd} Law?

The argument goes evolution is a decrease of entropy, because it involves things getting more ***organized*** over time, while the second law says that things get more ***disordered*** over time. ***So evolution violates the second law.*** Do you ***agree*** or ***disagree***? Explain below.

The statement above assumes humans exist in an isolated system… We do NOT!

While as a species we may lower entropy (organization), by living we increase overall entropy in the environment through a transfer of Thermal Energy to the environment.

Energy Conservation

We have been asked for years to turn of lights, bike to work/school, and to turn down the heat. But if energy can neither be created or destroyed why are we "*conserving energy*"? How can there be an energy crisis? Explain your thoughts below.

The energy lost is converted to Thermal Energy…

This change is irreversible because it cannot (efficently) be converted back to other forms of energy.