

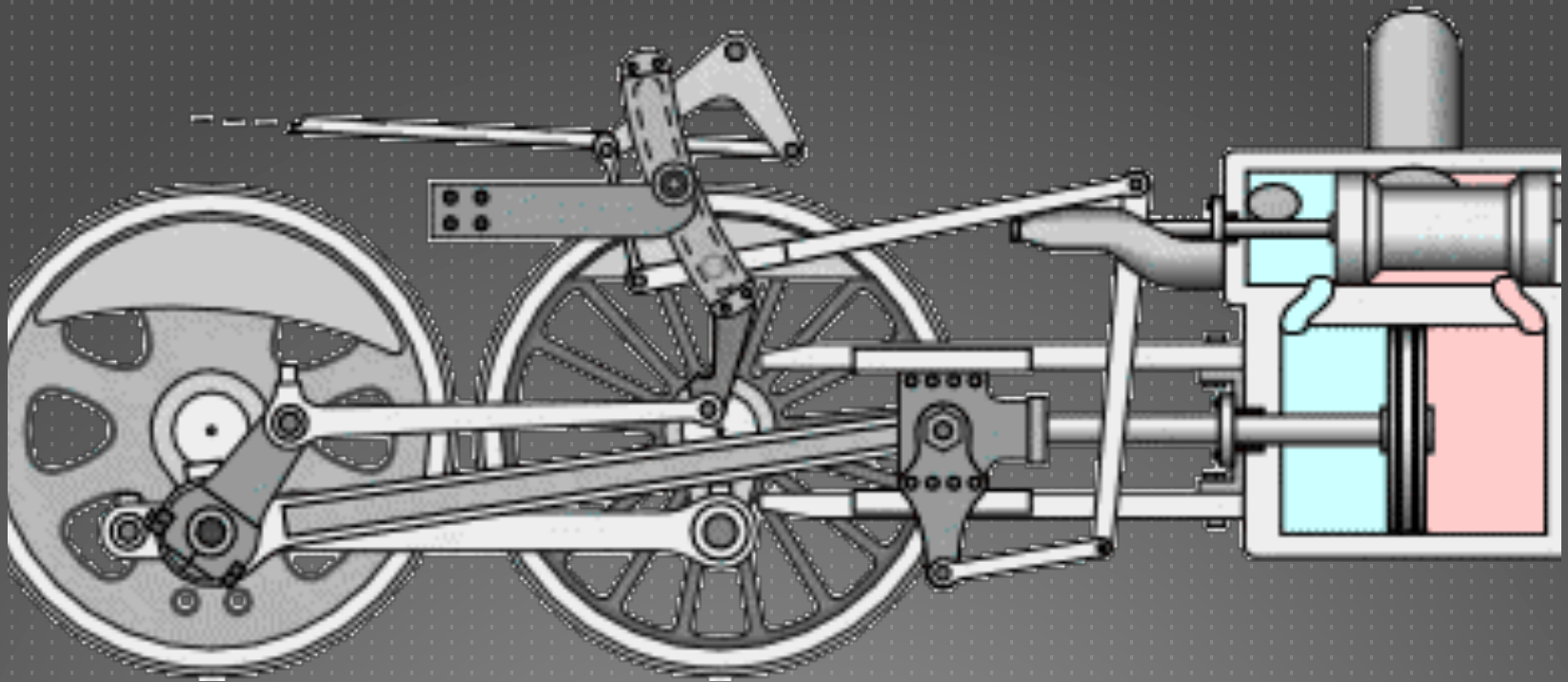
LAWS OF THERMODYNAMICS

They must be obeyed

HEAT AND WORK

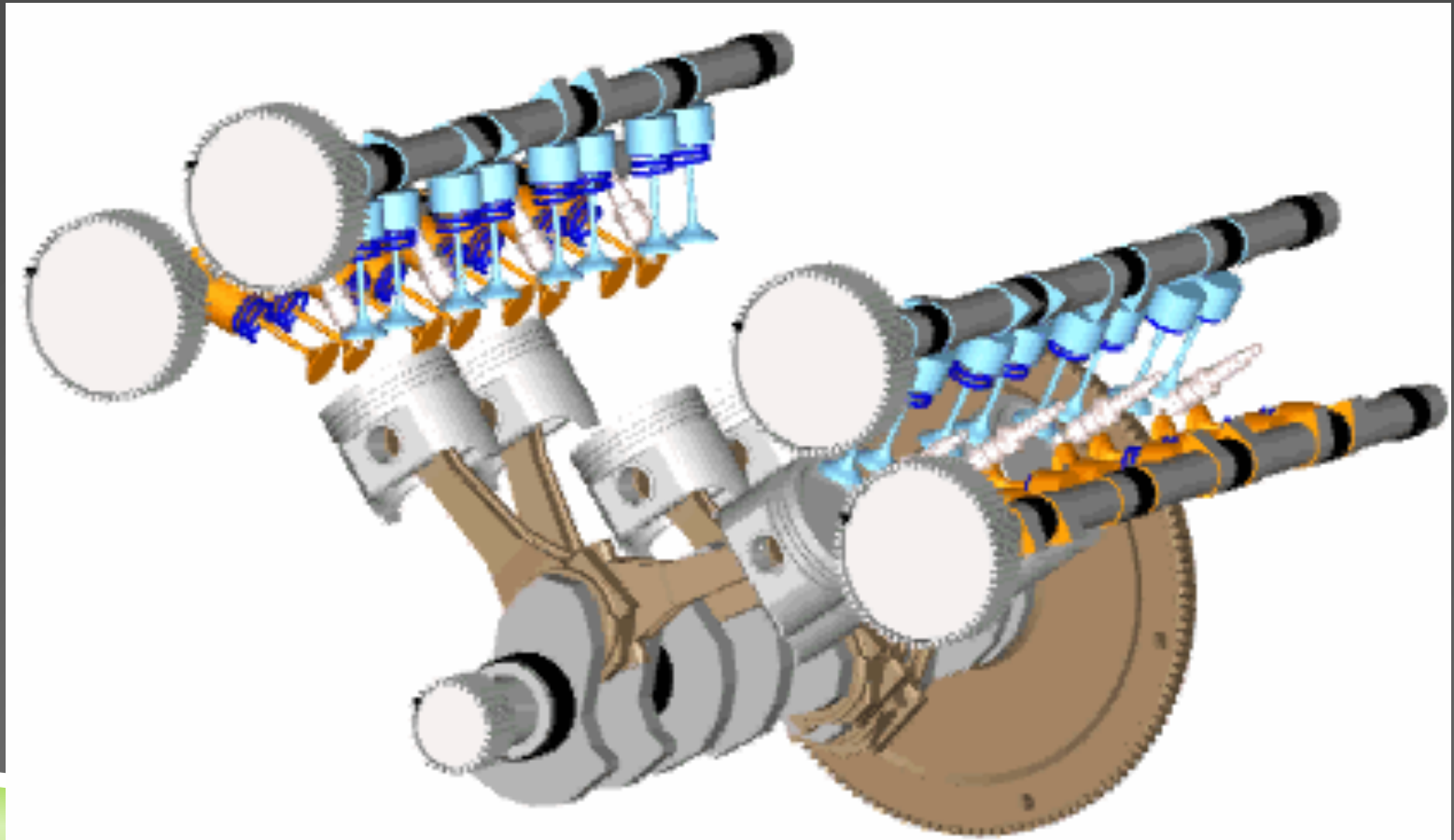
- ▶ Remember heat and work are related
- ▶ Things that do work often produce heat.
 - ▶ i.e. your car
- ▶ Heat can also do work
- ▶ Think of a system where the heat is doing work.

WHAT IS THIS?




- Is there a temperature change?
- Is it doing work?

WHAT IS THIS?

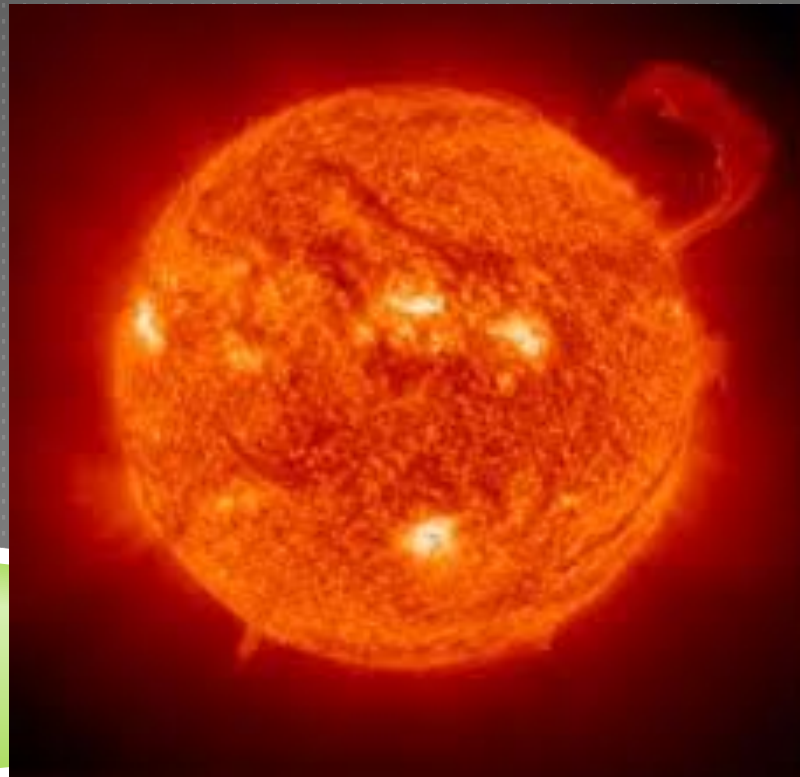


HEAT CHANGES MAKE THINGS MOVE

- ▶ Do cars work very well if the engine temperature is the same as the fire being produced from the exploding gasoline?
 - ▶ Can the air expand if it is already that temperature?
 - ▶ How well does your phone battery work when it is left in the sun for a few hours?
 - ▶ If heat cannot be changed or transferred, engines don't work.
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LAWS OF THERMODYNAMICS

- ▶ There are 4
 - ▶ 0-3
- ▶ They were not discovered in the correct order which is why law 0 exists.



0TH LAW

- ▶ Thermal equilibrium is a thing that happens.
- ▶ If two bodies are in thermal equilibrium with a 3rd, they are all in thermal equilibrium
- ▶ This really just states that two things can have the same temperature and that temperature is something that exists.
- ▶ This wasn't discovered until 1935.
- ▶ Ralph Fowler is credited



IST LAW

(shouldn't this be the second law?)

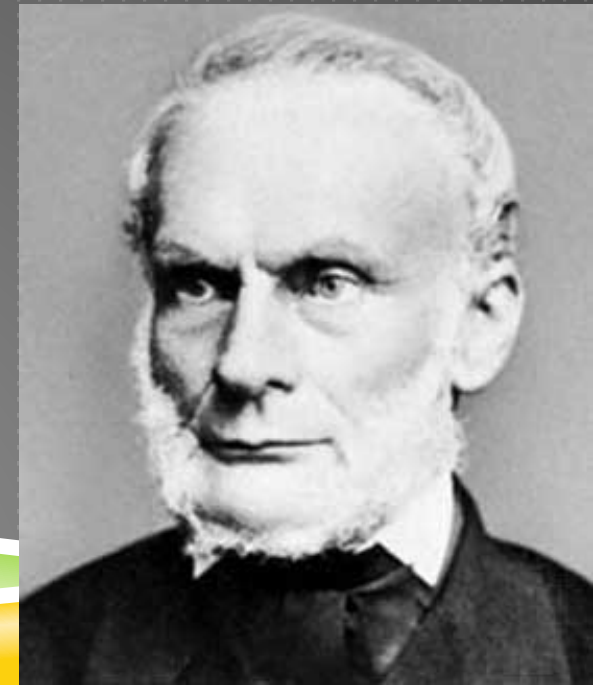
- ▶ Increasing the energy of a closed system is equal to the heat supplied minus the work done by it

$$\Delta U = q_{\text{in}} - W$$

- ▶ Which is really just stating that energy is conserved. This is the basis for that law.
- ▶ Can be credited to Rudolf Clausius, William Rankine or Germain Hess
 - ▶ Seems a lot of people had this idea in the mid 19th century

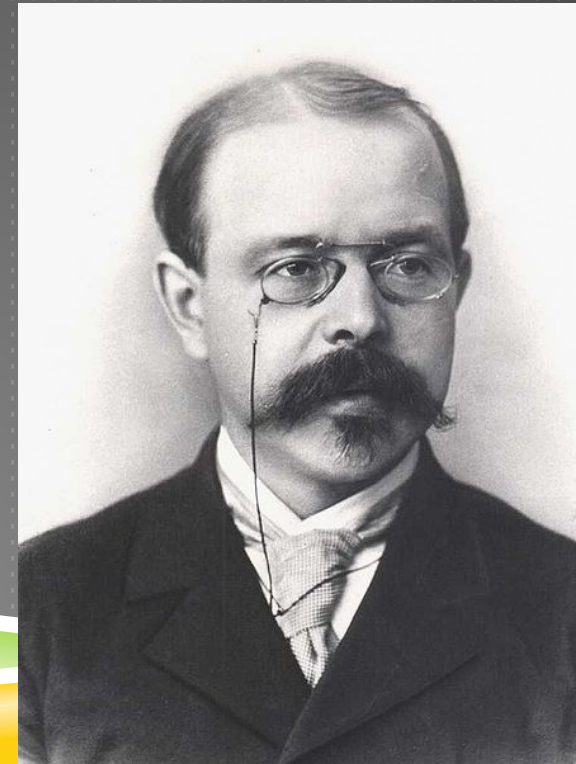
2ND LAW - THE AWESOMEST LAW

- ▶ This is the law that defines entropy.
- ▶ Entropy is always increasing.
- ▶ The entropy of a system is defined only when it has reached thermal equilibrium in itself.
- ▶ Rudolf Clausius is credited for the concept of entropy. (1850s)
- ▶ Entropy explains why time moves forward and apparatuses like “perpetual motion machines” cannot exist.



3RD LAW – THE ONE THAT SHOULD BE 0

- ▶ Developed by Walter Nernst in the early 1900's
- ▶ Absolute zero or 0Kelvins is a temperature that not only exists but cannot be achieved
- ▶ Merely trying to sense the temperature will cause the system to warm as they are not in equilibrium.
- ▶ The closest we have come to $T=0$ is
 - ▶ 0.0000000001K or 100pK



PERPETUAL MOTION

- ▶ Any machine that claims to continue to operate after initiation without further work is a violation of the 2nd law of thermodynamics and therefore impossible
- ▶ However! One could postulate that the 2nd law only complies with our current understanding of the physical universe and that in reality science changes constantly and our current physical paradigm could change.
- ▶ This was theorized by Emmy Noether in 1918.
- ▶ Much theoretical science and hopeful inventors quote her.



NO MACHINE IS 100% EFFICIENT

- ▶ There is no machine that can convert 100% of one type of energy into another type.
- ▶ This is why lightbulbs and engines get warm.
- ▶ This is why terminal velocity exists.
- ▶ This is why we are always searching for more efficient means and devices.



ONE OF THE MOST EFFICIENT ENGINES IN THE WORLD



6-cyl version (up to 14)
11,000 Liter displacement
50% efficient
47,000hp
16.5 Gal/min