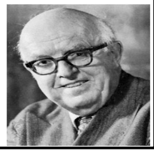
The Second Law

A good many times I have been present at gatherings of people who, by the standards of the traditional culture, are thought highly educated and who have with considerable gusto been expressing their incredulity of scientists. Once or twice I have been provoked and have asked the company how many of them could describe the Second law of thermodynamics. The response was cold: it was also negative. Yet I was asking something which is the scientific equivalent of: Have you read a work of Shakespeare's?

C.P. Snow, 1959



The Zeroth Law

If A is in thermal equilibrium with B

And B is in thermal equilibrium with C

then A is in thermal equilibrium with C

…where A, B and C could be devices like this…

Not The Zeroth Law

If A is in chemical equilibrium with B

And B is in chemical equilibrium with C

then A is in chemical equilibrium with C

The First Law

For any system going through a cycle, the net amount of work crossing the boundaries of the system is equal to the net amount of heat crossing the boundaries of the system

From this we deduce that there is a property known as energy, and that energy is conserved.

Alternative statement of First Law:

If we define efficiency as

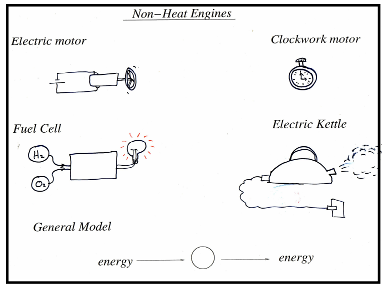
Efficiency = *Energy Out/Energy In*

then every machine is 100% efficient

Apparent Consequence of First Law:

Since energy can never be destroyed,

there can never be an energy crisis



The Second Law

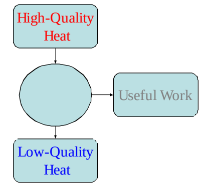
Given a heat engine operating between a hot source at T_H and a cold sink at T_C, the efficiency of the engine cannot exceed:

$$\eta = \frac{T_H - T_C}{T_H}$$

Carnot Efficiency

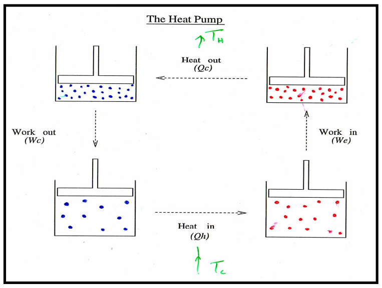
$$\eta = \frac{T_H - T_C}{T_H}$$

Alternative Statement of Second Law

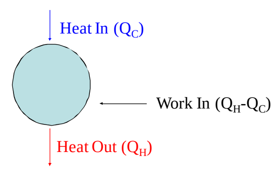


Alternative Statement of Second Law

``Perpetual motion machines of the second kind are impossible''



Heat Pump Energy Balance



Heat Out = Heat In + Work In = Work In * $T_H/(T_H-T_C)$

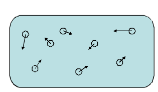
Entropy

The *entropy* of a source of energy is inversely related to its quality.

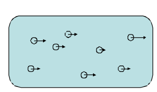
So the lower the entropy of a system containing a certain amount of energy, the more of that energy can be converted to work.

Formally, the change in entropy when a quantity of heat ΔQ is transferred at temperature T is

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



Molecules in random motion



A wind in a box

Entropy is the opposite of *order*

``Recycling is not an option, because materials scattered through a landfill are more disordered than materials in a mine, and we can't beat the Second Law, which says that entropy must always increase''

This argument is incorrect because…

The Third Law

As the temperature approaches absolute zero, the entropy of a system in equilibrium goes to zero.