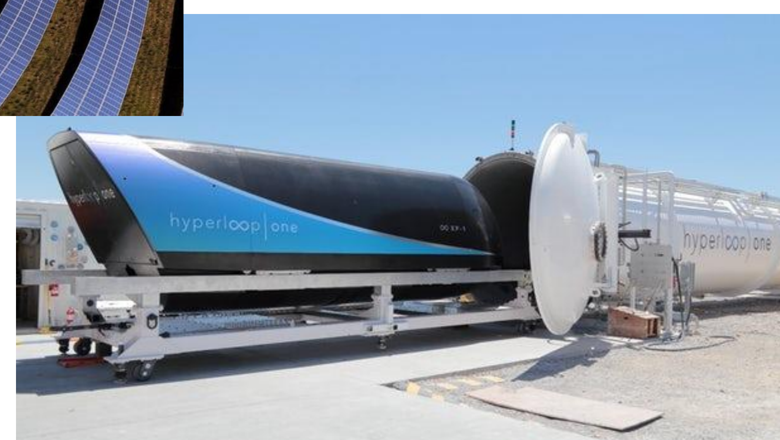
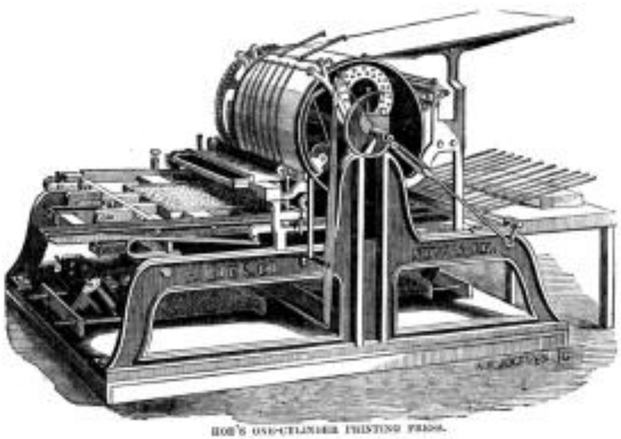
First law of Thermodynamics

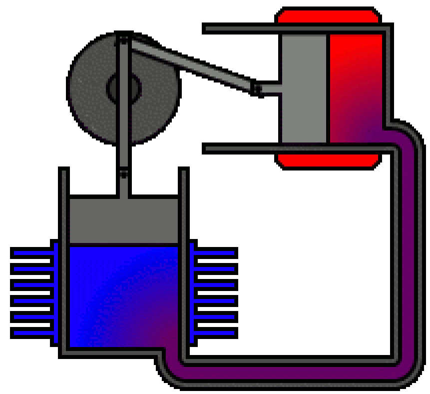
Alexei Tkachenko

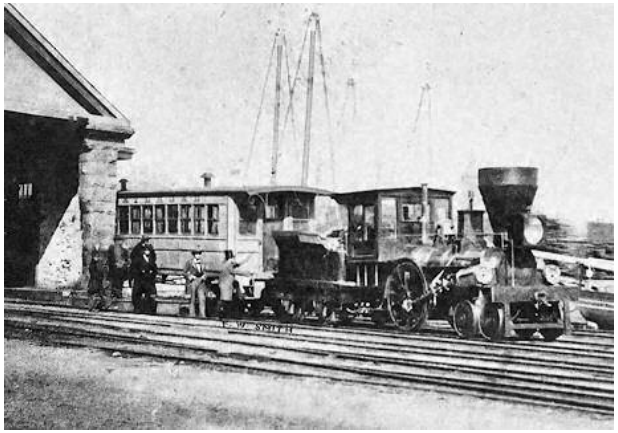
2010s-2020s: new world emerging?



1840s-1850s: the world of steam

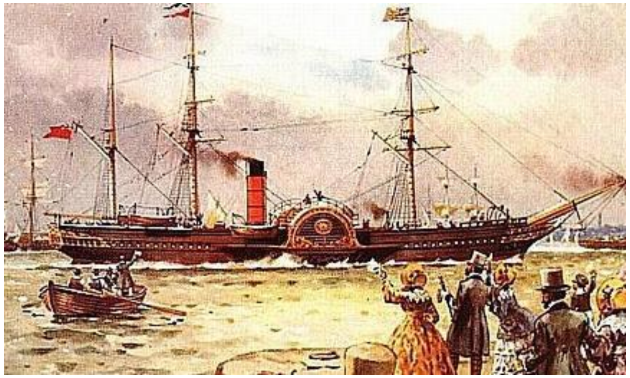




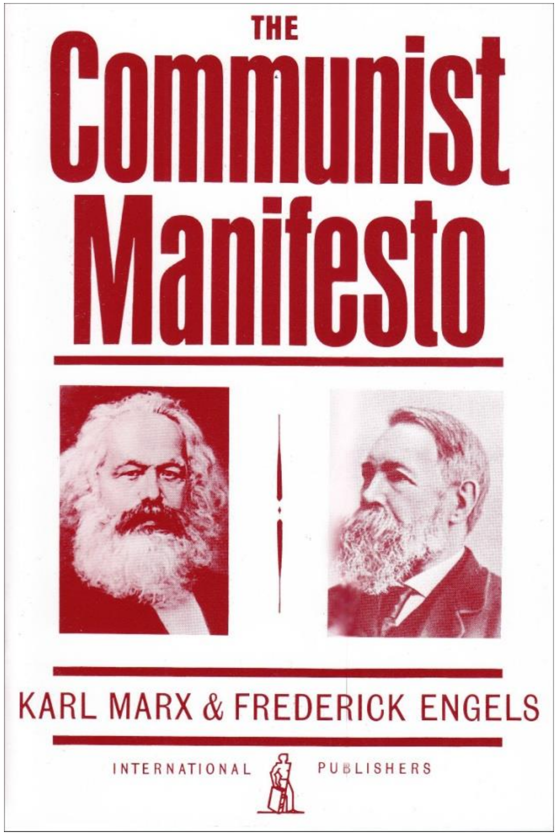



New-York Daily Times.

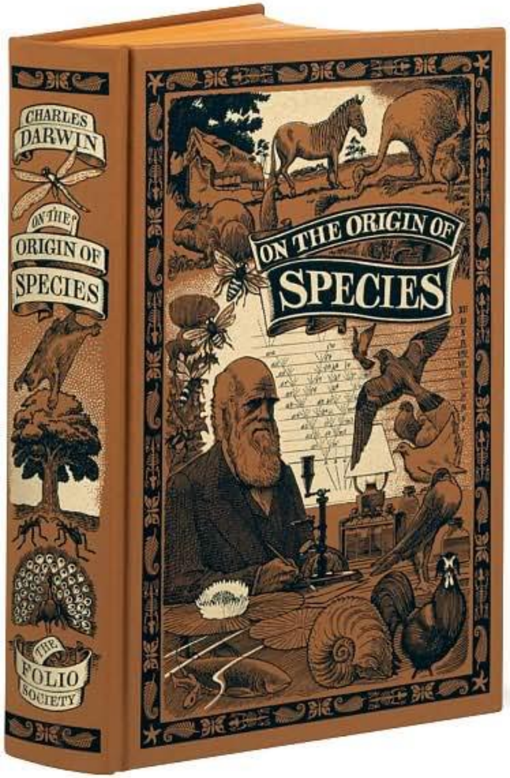
VOL. I....NO. 1. NEW-YORK, THURSDAY, SEPTEMBER 18, 1851. PRICE ONE CENT.



Revolution & Evolution

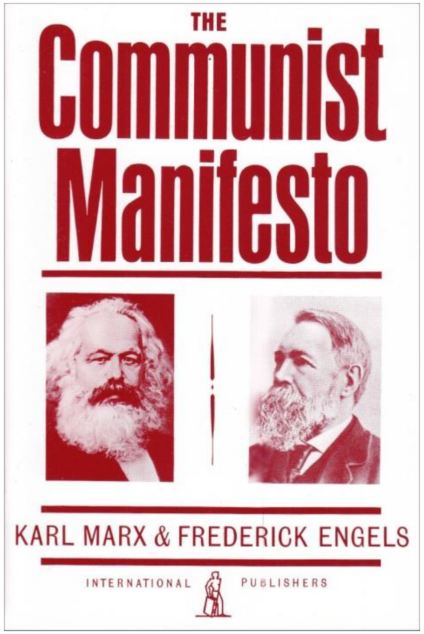


1848



1859

+ Thermodynamics!



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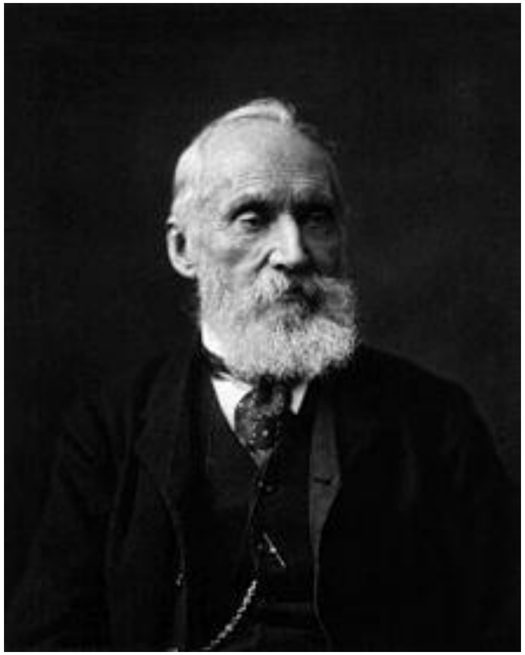
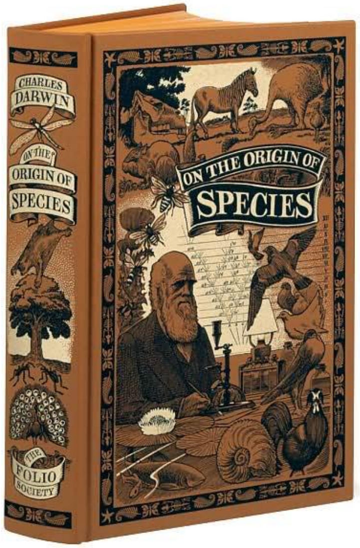


William Thomson
aka Lord Kelvin

Rudolf Clausius



1859

James Joule:
mechanical equivalent of heat

1 cal = 4.184 J

First Law of Thermodynamics

$$\Delta U = Q + W$$

U – Internal (Thermal) Energy

Q – Heat adsorbed by the System

W=Fd – Work done by external forces (Force * Displacement)

Conservation of Energy Revisited:

$$E_{kin} + E_{pot} + U = const$$

"In thermally isolated system (Q=0),
Total Energy (Mechanical+Internal) is conserved"

Calories and Joules

Traditionally, Heat was measured in calories (cal):

- **1 calorie** is an amount of heat needed to increase the temperature of 1g of water by 1°C.
- For nutritional/dietary purposes people use "big Calories" (Cal, with capital "C").
  1 Cal=1000cal (or simply kilocalorie). By definition, this is an amount of heat needed to increase the temperature of 1 kg (1 liter) of water by 1°C.
- Since Heat is a form or energy, calories can be converted to Joules:

1 cal = 4.184 J

1 Cal = 1000cal = 4184 J (used for dietary purposes)

Specific Heat

In order to know how much energy is needed to heat up an object by certain temperature, you need to know the specific heat capacity (aka specific heat) of the material, C:

$$Q = m\, C\, \Delta T$$

Here m is mass of the object, ΔT is change of its temperature, C is specific heat of its material. For instance, specific heat of liquid water is:

$$C_{water} = 1000 \frac{cal}{kg \cdot {}^{0}C} = 4184 \frac{J}{kg \cdot {}^{0}C}$$

Homework

Problem 1

A cyclist is moving at speed v=5m/s. He applies breaks and comes to a complete stop. Assuming that all the heat generated during the breaking is concentrated in rubber blocks that "squeeze" the wheel, find the change in temperature of the rubber after the breaking, ΔT. Mass of the cyclist with the bicycle is M=100kg, total mass of all rubber blocks is m=50g. Specific heat capacity of rubber is C=2 kJ/kg/K.

Problem 2

A droplet of water falls from the height h=100m, onto a thermally isolating surface. Assume that all mechanical energy is converted into the internal energy of the water. Find the change in temperature of water, ΔT. Specific heat capacity of water is 4.2 kJ/kg/K