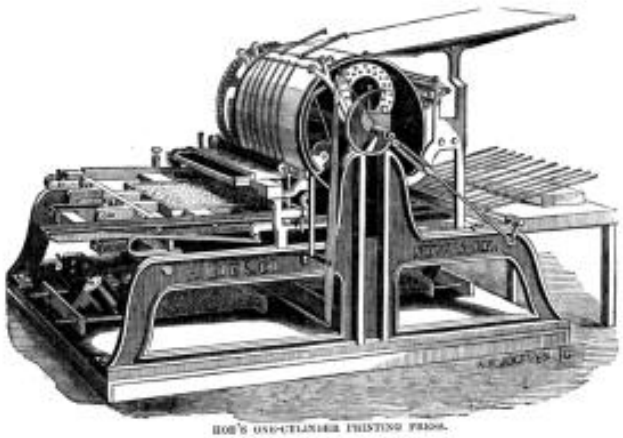
First law of Thermodynamics

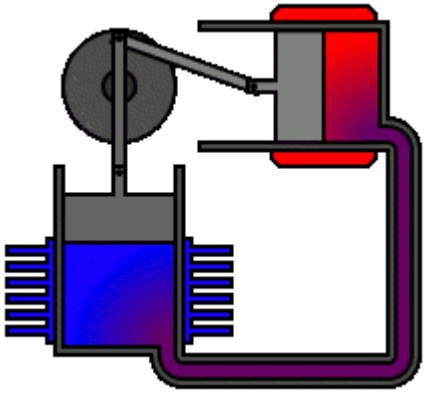
Alexei Tkachenko

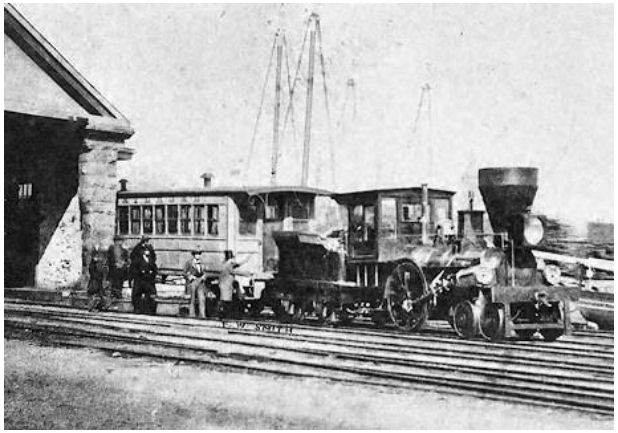
2010s-2020s: new world emerging?

1840s-1850s: the world of steam



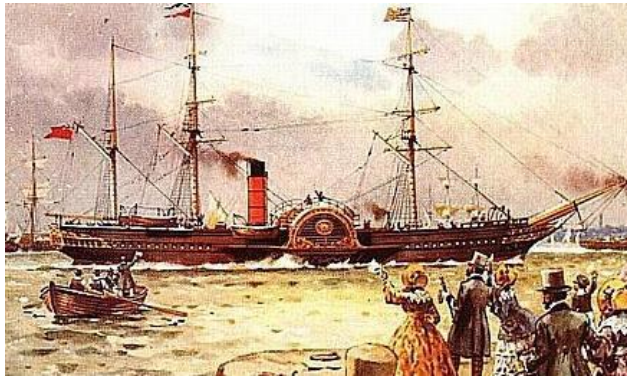
HOE'S ONE-CYLINDER PRINTING PRESS.



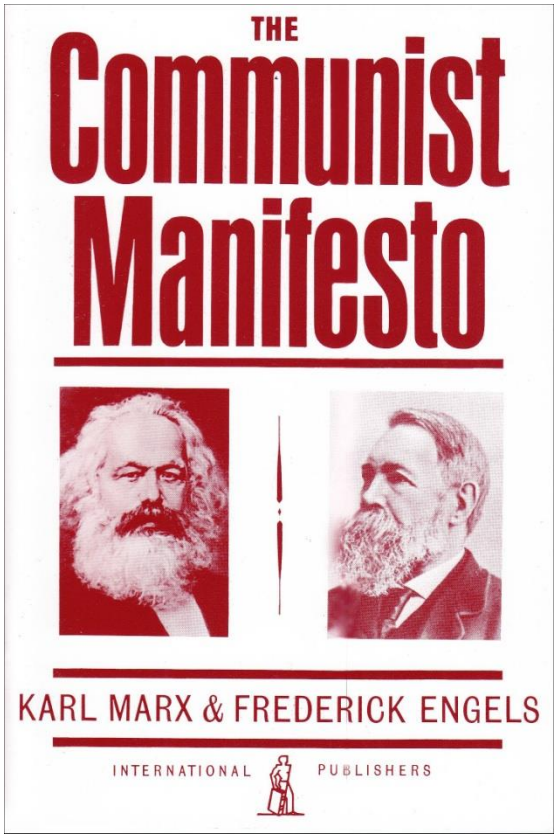


New-York Daily Times.

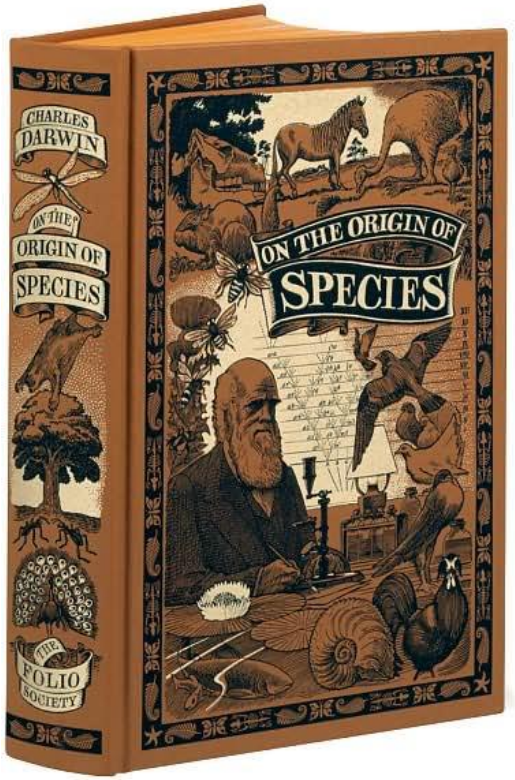
VOL. I.—NO. 1. NEW-YORK, THURSDAY, SEPTEMBER 18, 1851. PRICE ONE CENT.



Revolution & Evolution

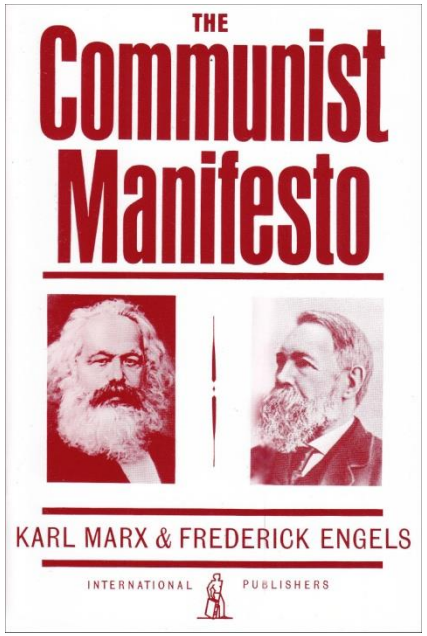


1848

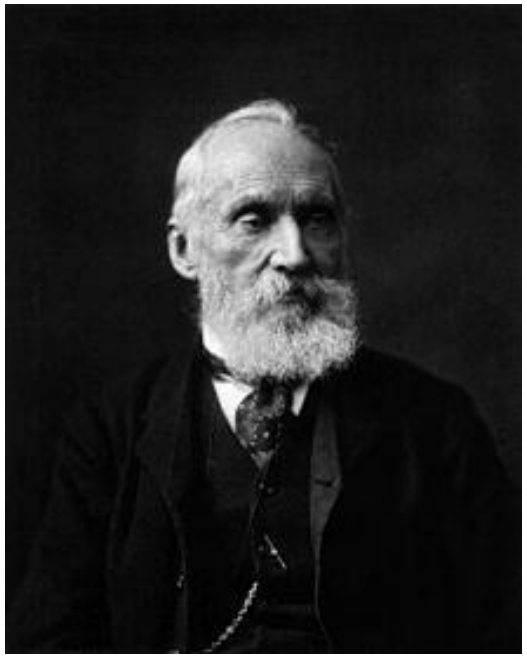


1859

+ Thermodynamics!

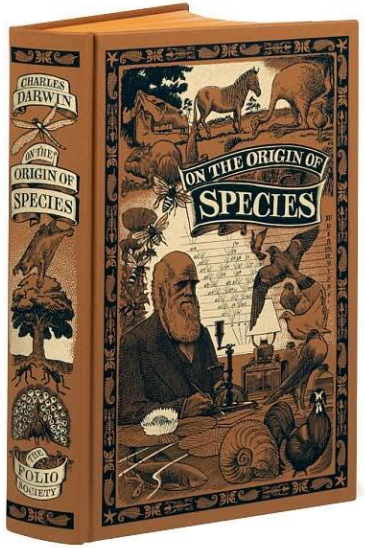


1848



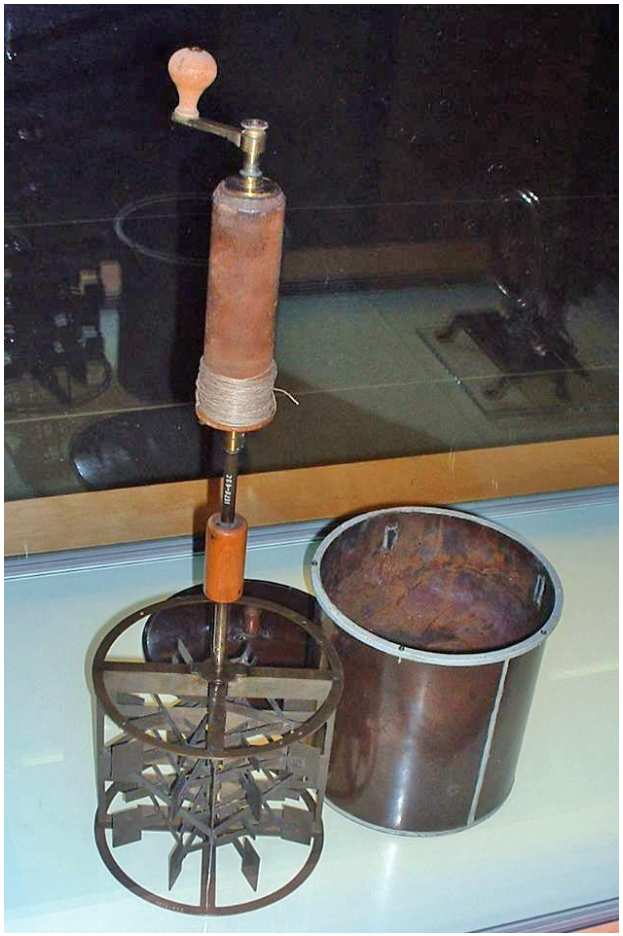
William Thomson
aka Lord Kelvin

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:

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

Homework 1

Problem 1

A bullet made of lead has initial speed v_0=350 m/s. After it hits a wooden wall, its speed is reduced to v=300 m/s. Assuming that half of the mechanical energy lost was adsorbed by the bullet itself, find how much its temperature has changed. Specific heat of lead is C=128 J/kg/^{o}C.

Problem 2

An electric motor consumes P=150 Watt of power, and lifts a payload of M=50 kg to a height of h=2 m in t=20 sec. Assume that all heat generated in this process is adsorbed by the motor. How much its temperature have changed? The motor is made of material with specific heat 400 J/kg/^{o}C , and its mass is 0.5 kg.

Reminder: *Power is energy consumed per second.*