Alexander Pope

Nature and Nature's Laws
lay hid in Night.
GOD said, *Let Newton be!*
and all was Light.

It did not last :
the Devil, howling *Ho.*
Let Einstein be!
restored the status quo.

Sir John Collings Squire

Blackbody Radiation

h : *Planck's constant*

$= 6.63 \times 10^{-34}$ J-s

$h\upsilon \cong kT$

k = : *Boltzmann's const.*

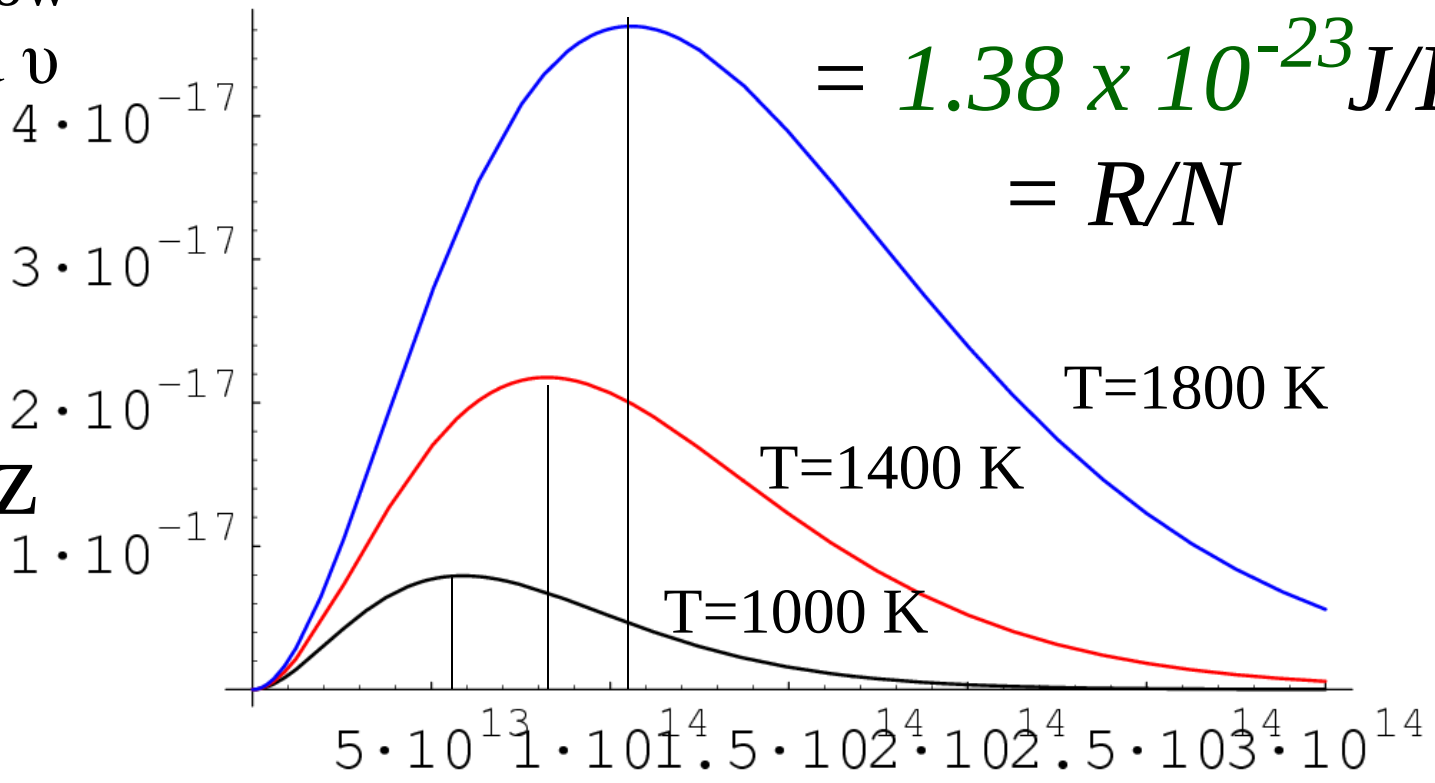
$= 1.38 \times 10^{-23}$ J/K

$= R/N$

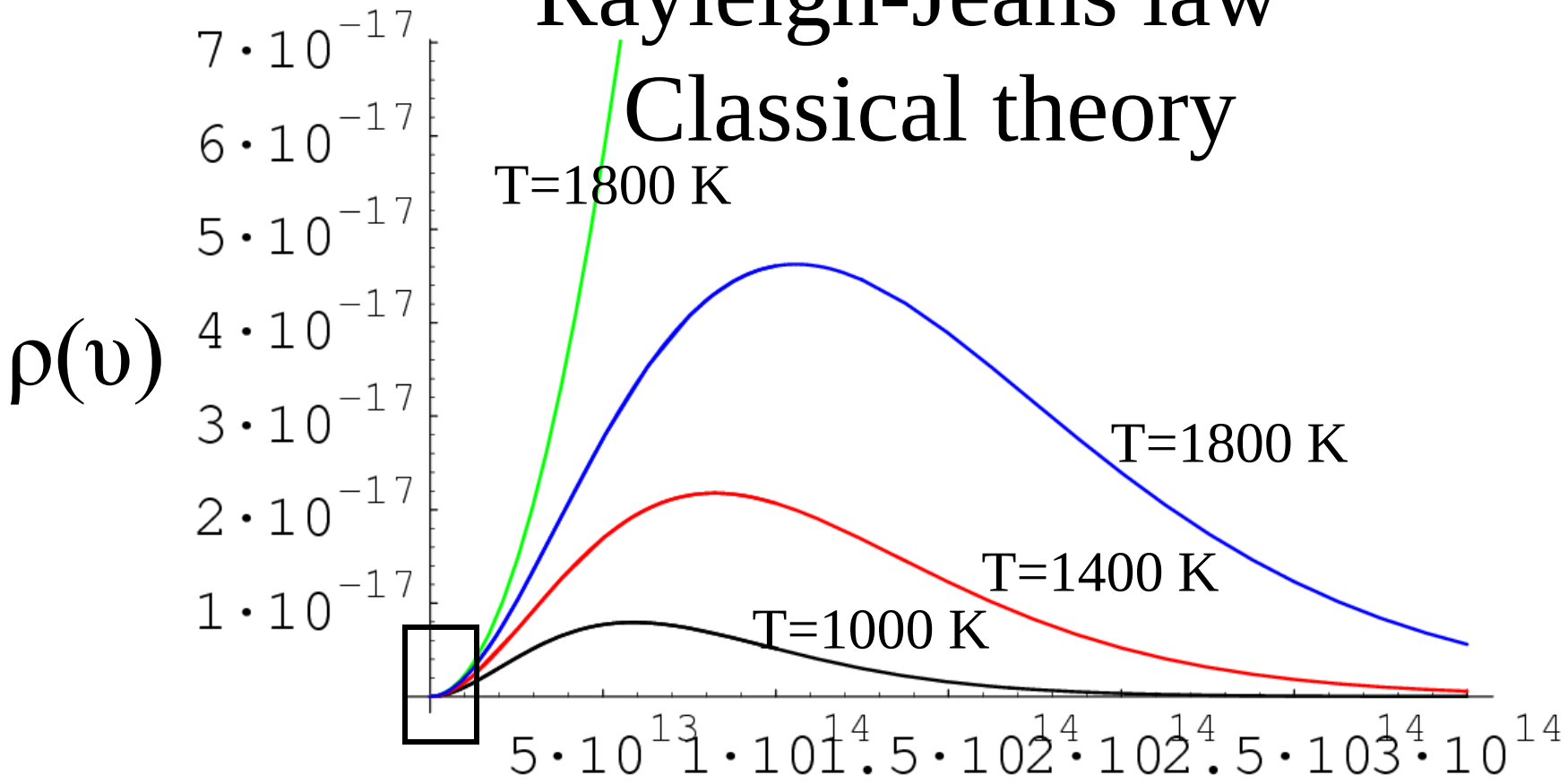
Energy density in the window υ and $\upsilon + d\upsilon$

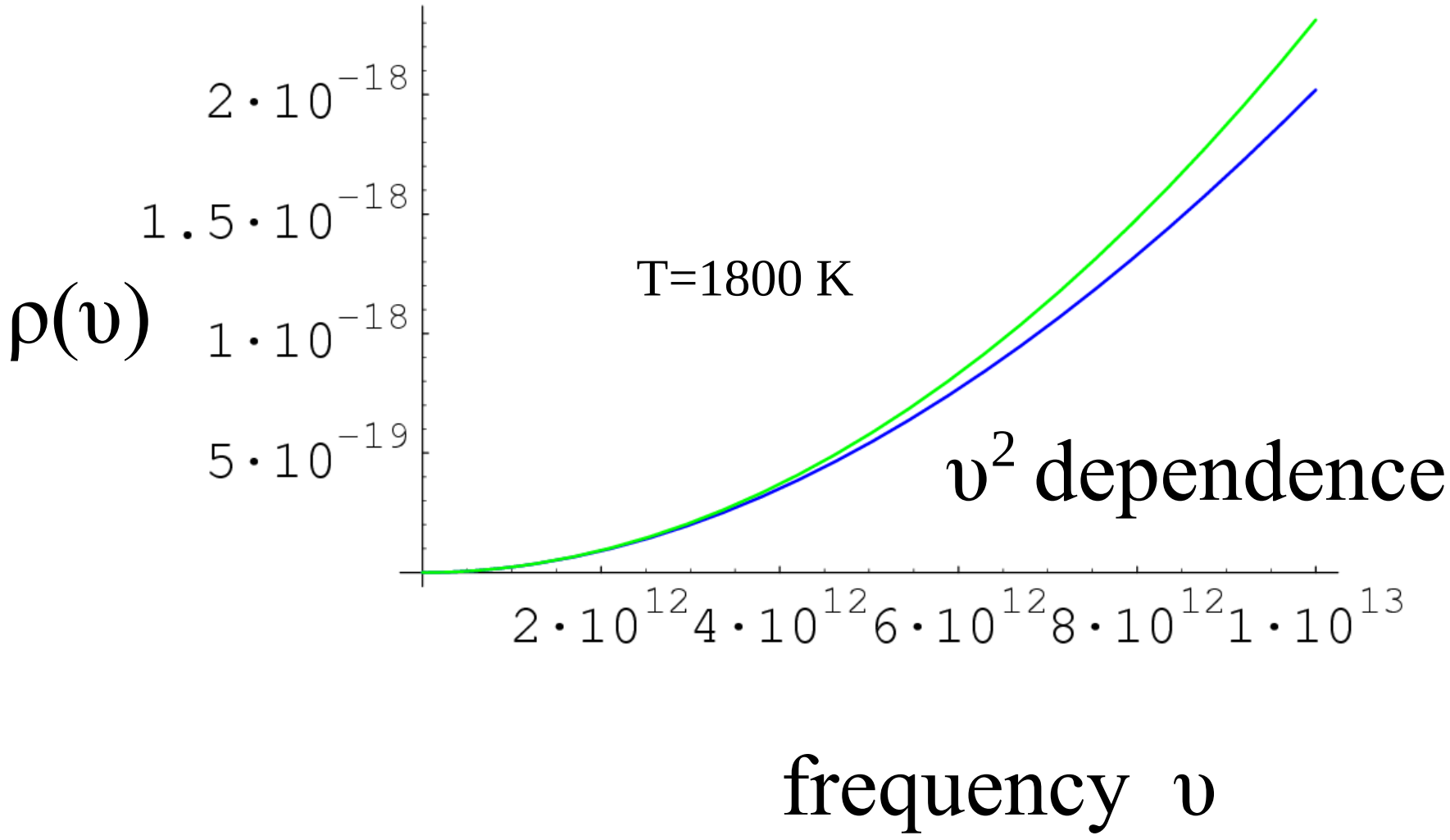
$\rho(\upsilon)$

J/m^3-Hz



Rayleigh-Jeans law
Classical theory




ρ(υ)
2·10^-18
1.5·10^-18
1·10^-18
5·10^-19
T=1800 K
υ² dependence
2·10^12 4·10^12 6·10^12 8·10^12 1·10^13
frequency υ

Planck's Formula

$$\rho(\nu)d\nu = \frac{8\pi\nu^2}{c^3}\frac{h\nu}{\exp(h\nu/kT)-1}d\nu$$

$$\nu \longrightarrow small$$

$$\rho(\nu)d\nu = \frac{8\pi\nu^2 kT}{c^3}d\nu$$

Rayleigh-Jeans law

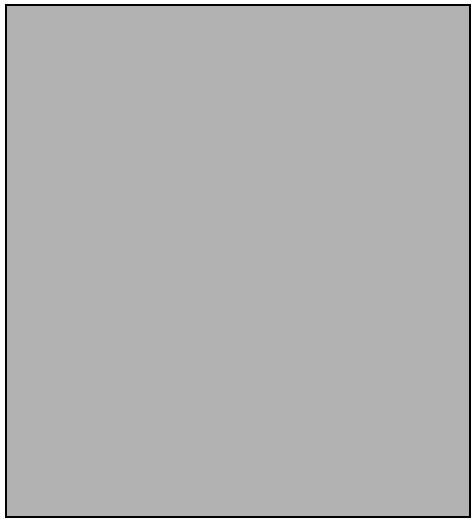
Planck's postulate

Any physical entity with one degree of freedom and whose ``co-ordinate'' is oscillating sinusoidally with frequency ν can possess only total energies *E* as integral multiple of $h\nu$

$$E = nh\nu$$

h = *Planck's constant*

Classical



$E = 0$

$4h\nu$

$2h\nu$

$h\nu$

Quantum Physics

Experiments

Waves behaving as particles

1. Photoelectric effect (1902)
2. Compton effect (1922)
3. Pair Production

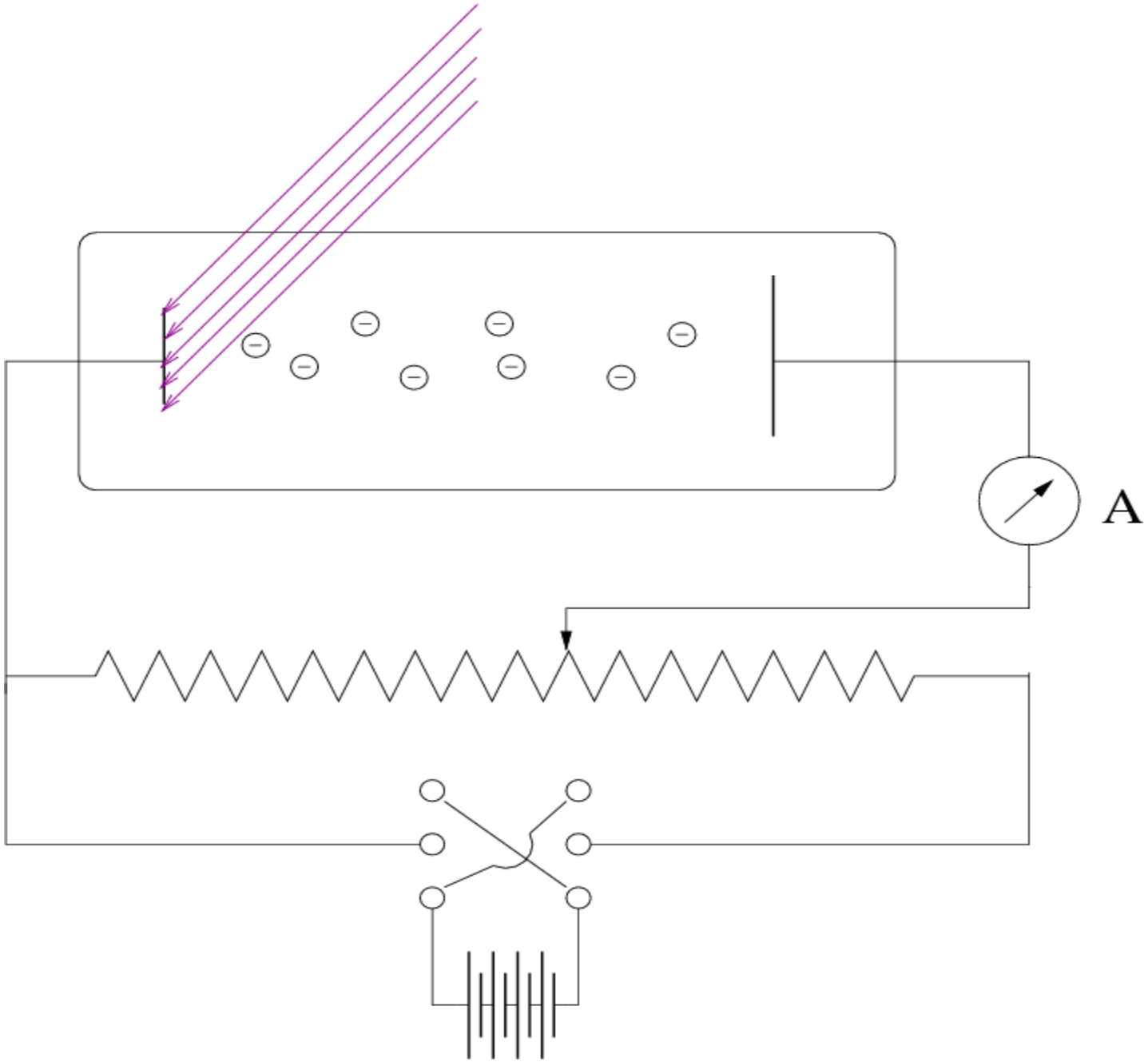
de Broglie wave particle duality

$$\lambda = \frac{h}{p}$$

$$p\lambda = h$$

$$E = h\nu = \frac{h}{T}$$

$$ET = h$$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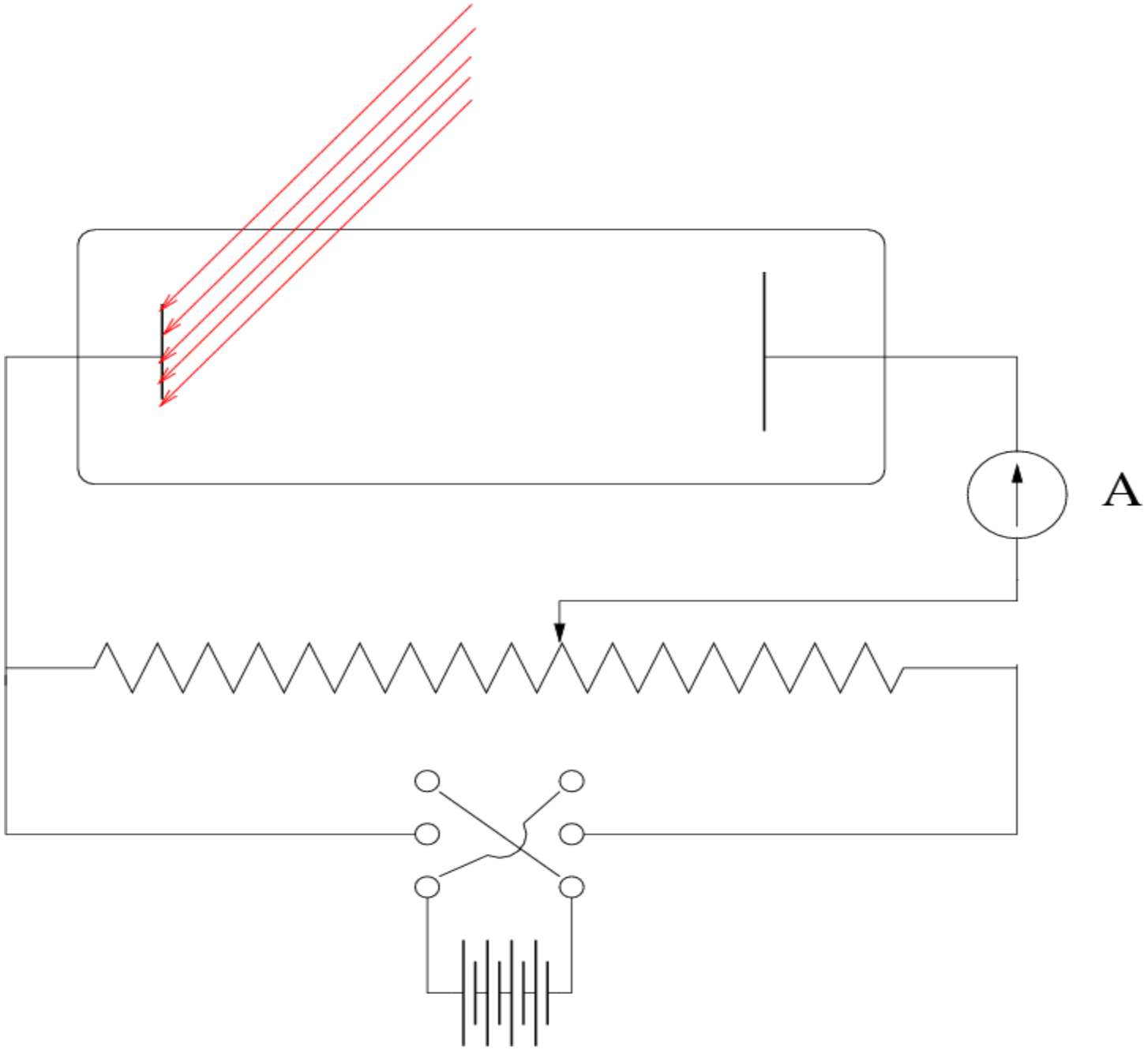
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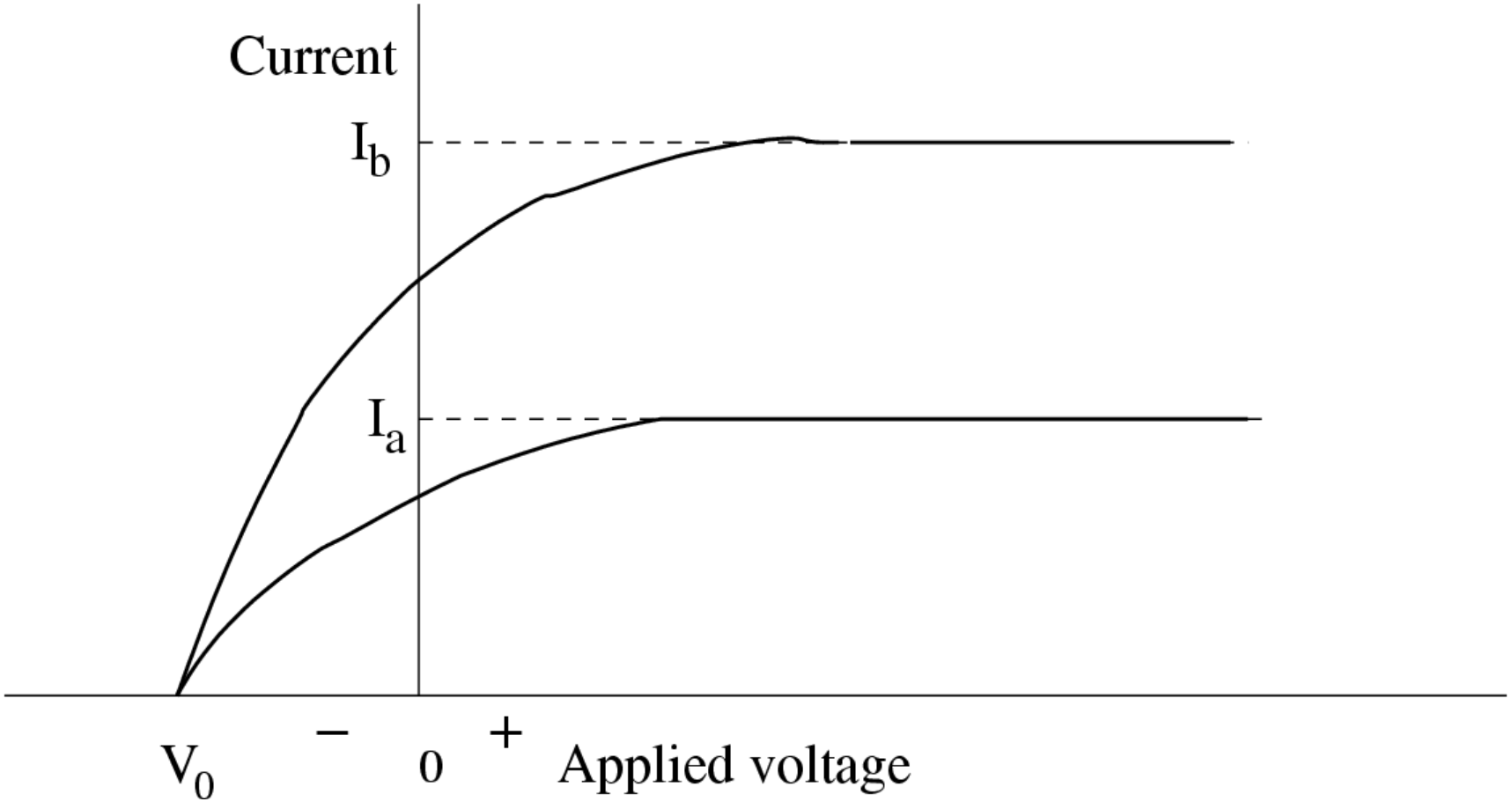
Lenard 1902: Studied energy of the photoelectrons with intensity of light. He could increase the intensity thousand fold.

1. Noticed a well defined minimum voltage V_{stop} to stop the current in the circuit. V_{stop} was independent of the intensity of light.

Current vs Voltage



2. Increasing the intensity of light would increase the current

3. He performed the experiment with various coloured lights and found the maximum energy of the electrons *did* depend on the frequency of light. Qualitatively he obtained more the frequency more the energy.

Objections with wave theory

1. Kinetic energy of the photo-electron should increase with intensity of the beam.

But K_{max} was found to be independent of the intensity of the falling light.

2. Effect should occur for any frequency of light provided only that light is intense enough to eject the electron.

But a cut-off frequency ν_0 was observed below which photoelectrons were not ejected (no matter how intense was beam).

3. Energy in the classical theory is uniformly distributed over the wave front. If light is feeble, there should be a time lag between the light striking the plate and ejection of photoelectrons.

Ejection is instant, $t < 10^{-9}$ sec

Einstein equation

$$K = h\nu - W$$

$$K_{max} = eV_0 = eV_{stop}$$

$$K_{max} = h\nu - W_0$$

$$eV_0 = h\nu - W_0$$

$$V_0 = \frac{h}{e}(\nu - \nu_0)$$

$$h\nu_0 = W_0$$

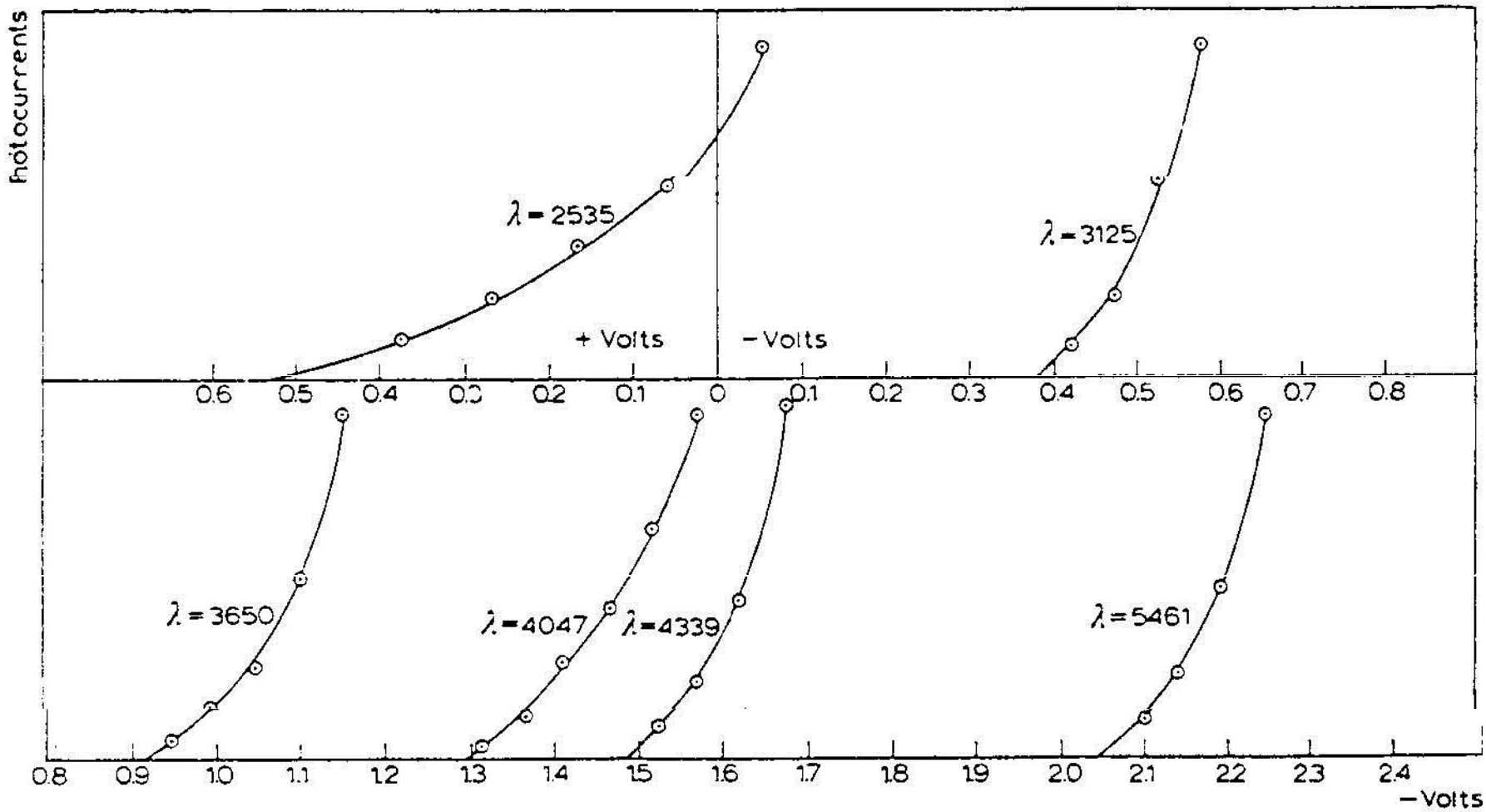
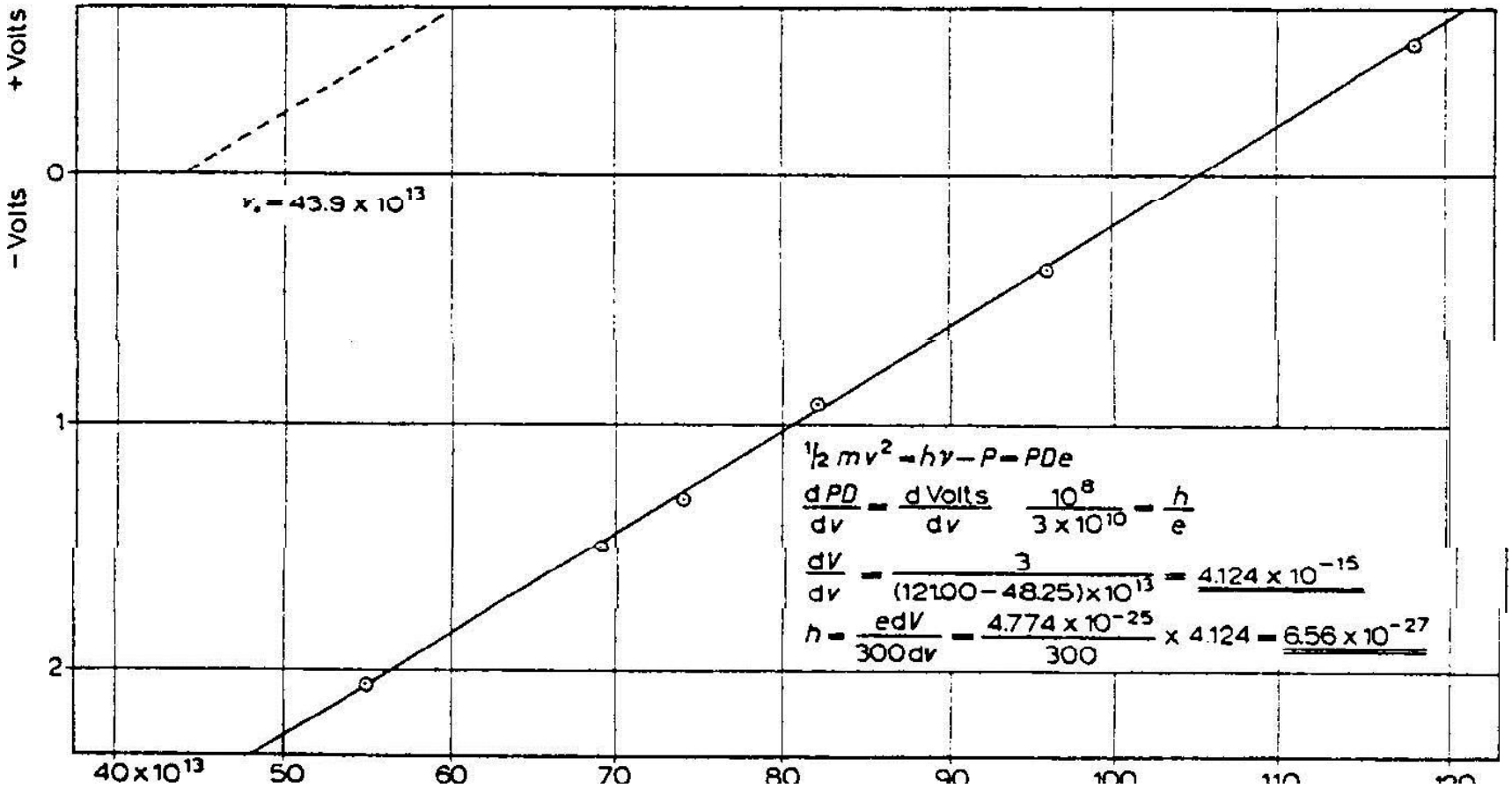


Fig. 3.

Photocurrent vs voltage

R. Millikan



Stopping voltage V_{stop} vs frequency

R. Millikan