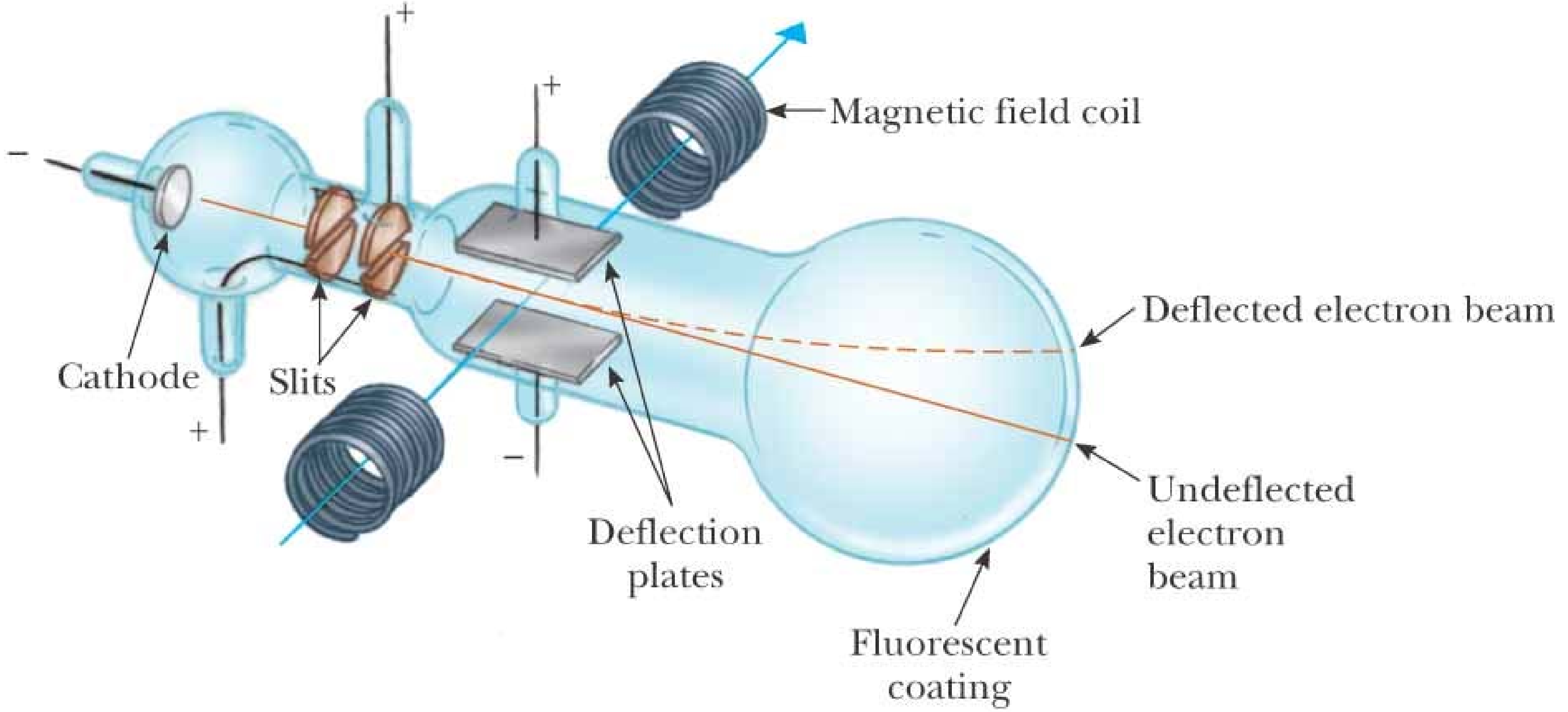
Introduction

- By the end of the 19th century with Newtonian mechanics and Maxwell's equations, physics almost seemed complete

- But some puzzling observations:

  - Michelson-Morley experiment:
    - **Special and General relativity**

  - Atomic line spectra
  - Properties of atoms
  - Blackbody Radiation
  - Photoelectric effect
    - **"Old Quantum theory" and Quantum mechanics.**


+
+
Magnetic field coil
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Deflected electron beam
Cathode
Slits
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Deflection
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Fluorescent
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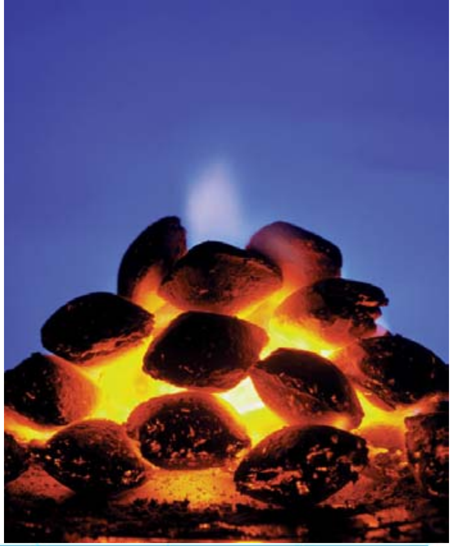
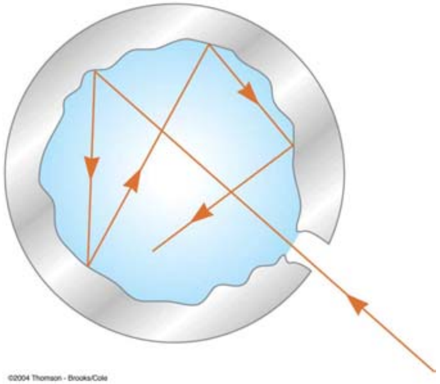
(a)

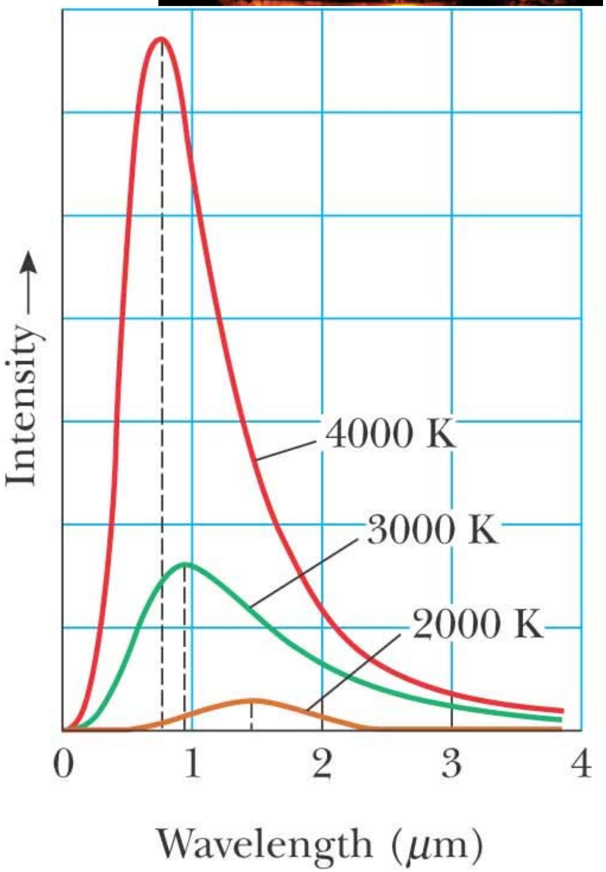
Blackbody Radiation



- A Blackbody is an ideal system that absorbs all radiation incident on it. Emission of radiation by a blackbody is independent of the properties of its wall, but depends only on its temperature

- When the temperature of the blackbody increases, the spectrum of emitted radiation shifts to lower λ.

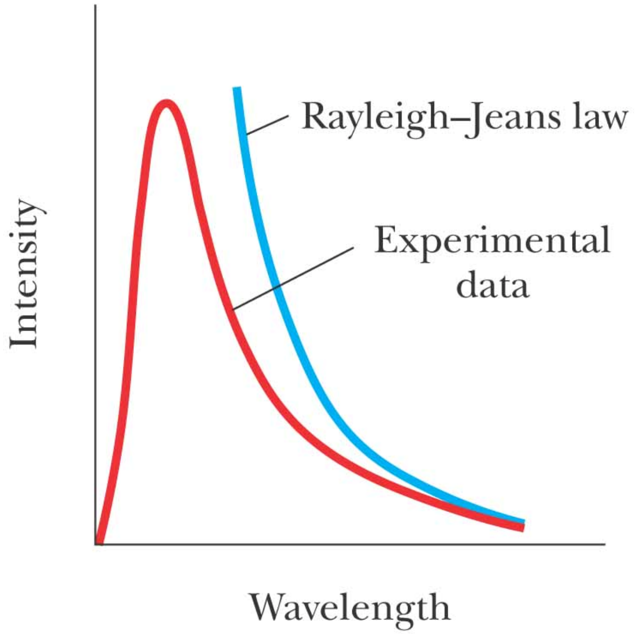




- Rayleigh-Jeans law was an attempt to explain blackbody radiation based on classical ideas:
  - Blackbody is modeled in terms of modes of oscillations of the e/m field in the cavity due to the accelerating charges on cavity walls.
  - # of Degrees of Freedom for oscillations go up as λ goes down
  - Equipartition of energy: Each DOF carries an energy $\boldsymbol{k_B T}$: where $\boldsymbol{k_B}$ is the Boltzman constant.
  - Intensity (power per unit area):

$$I(\lambda, T) = \frac{2\pi k_B T}{\lambda^4}$$

Ultraviolet Catastrophe



Max Planck's theory of Blackbody radiation

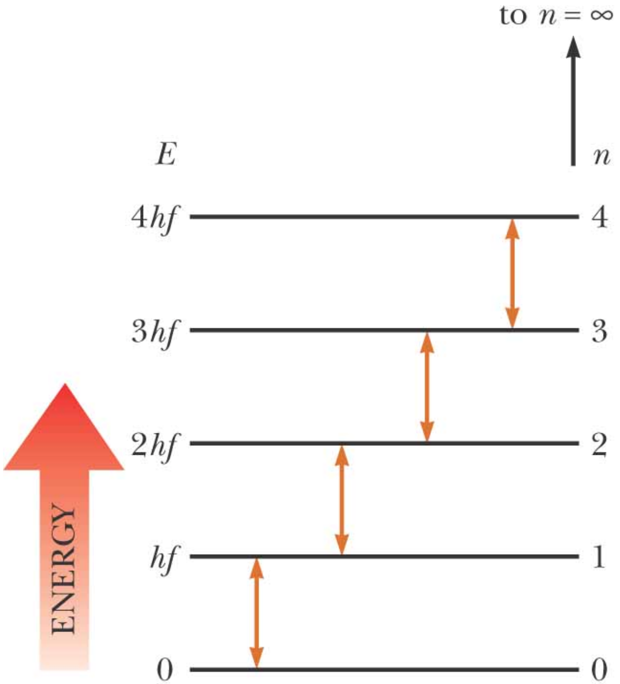
- Planck's assumptions on the nature of the oscillators in the cell walls:

  – The energy of an oscillator can only have a **discrete** set of values E_n:

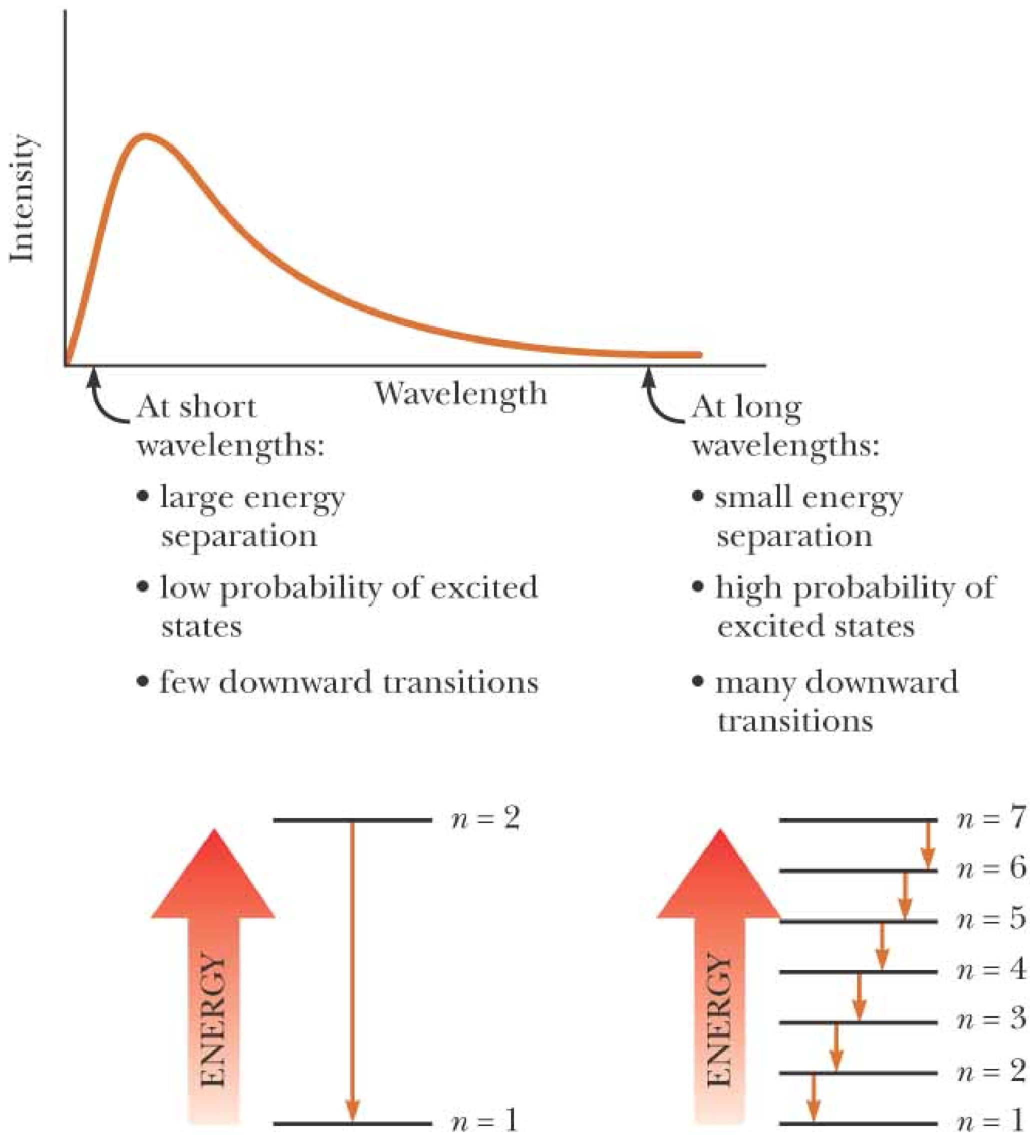
$$E_n = nh\nu$$

  n is the **quantum number**, ν ***is*** the frequency of oscillations and ***h*** is a new parameter Planck introduced: it is called **Planck's Constant** now. Energy is said to be **quantized** and each discrete value of energy corresponds to a **quantum state**.

- The oscillators emit or absorb energy when making a transition from one quantum state to another. The amount of energy emitted or absorbed is equal to the energy difference between initial and final quantum states:



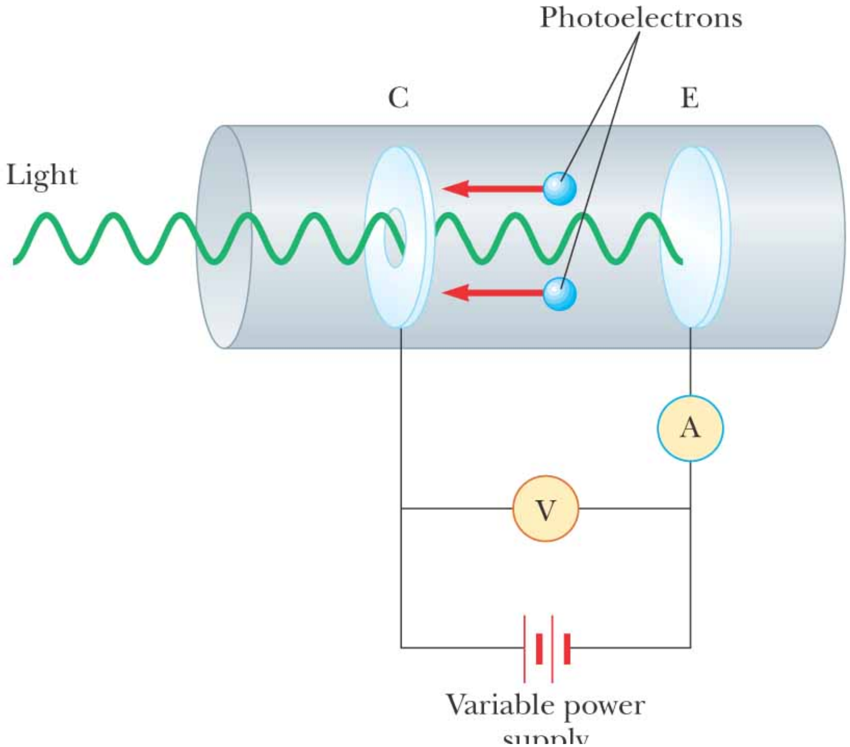
- As λ increases the gap between energy levels goes down
- Boltzman's distribution law:
  - the probability of a state of being occupied is proportional to: $e^{-E/k_B T}$

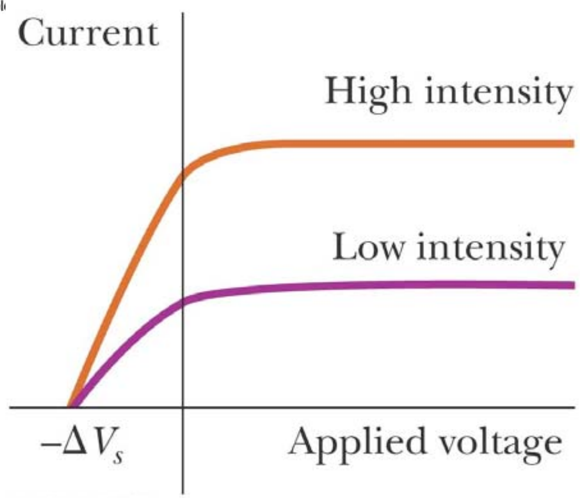


$$I(\lambda, T) = \frac{2\pi hc^2}{\lambda^5 (e^{hc/\lambda k_B T} - 1)}$$

h = 6.626 x 10^{-34} **J.s**

The Photoelectric Effect





•**A classical explanation of the photoelectric effect would predict**:

- •Kinetic energy of the photoelectrons should increase with light intensity
- •Emission of photoelectrons and their kinetic energy should be independent of the light frequency
- •When the light intensity is very low there should be a time delay before the photoelectron emission

•**Experimental observation:**

- •Kinetic energy of the photoelectrons is independent of the light intensity but increases with the frequency
- •No photoelectrons are emitted below some **cutoff frequency** f_c
- •Photoelectrons are emitted instantaneously independent of the intensity.

In 1905 Einstein extended Planck's quantization to e/m waves to explain the photoelectric effect:

- Light and other e/m waves consist of particles (quanta) called photons.
- Each photon has energy ***E = hf,*** where ***f*** is the frequency of the wave.
- An incident light photon gives all its energy to a single electron in the metal

Absorption of light is not continuous: it is delivered in discrete packets

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

W *:* **work function** of the metal; the minimum energy required to remove an electron from the metal

The Compton Effect: Scattering of X-rays from electrons

Einstein: Photons of light: Energy = $h\nu$, momentum = $E/c=h\nu/c$