Chapter 2

The electromagnetic theory was developped by Maxwell.

- Hertz produced electromagnetic waves confirming Maxwell theory.
- He also showed that electromagnetic waves and light were one and the same.

  $\Rightarrow$ Light is a wave!

- Stefan found experimentally for a hot solid

Stefan's Law $\rightarrow e = \sigma T^4$ (Watt/m^2)

T: Kelvin

σ: Stefan - Boltzma const. $= 5.67 \times 10^{-8} \frac{W.m^{-2}}{K^4}$

- Five years later, Boltzman derived stefan's law from Maxwell + thermodynamics.

- A body which absorbs radiation of all wavelengths is called a <u>blackbody</u>.
- The radiation emitted from a blackbody has a continuous spectrum.
- Wien proposed a relationship between λ_{max} and T for the blackbody distributi[on]

$$\lambda_{max} = \frac{2.898\times10^{-3}}{T}$$ Wien's diplacement law.

- Wien proposed the spectral energy density for a blackbody:

$$u(f,T) = A f^3 e^{-\frac{\beta f}{T}}$$

Wien's exponential law

A & β: fitting parameters

The law <u>failed</u> to fit the experimental data at long wavelengts!

(see Fig. 2.5 in the textbook)

According to Planck, the spectral energy density $u(f,T)$ is:

$$u(f,T)\,df = \overline{E}\ \underbrace{N(f)\,df} \qquad \text{— (1)}$$

$\overline{E}$: average energy emitted per oscillator

$N(f)\,df$: # of oscillators having freq. betwen f and $f+df$

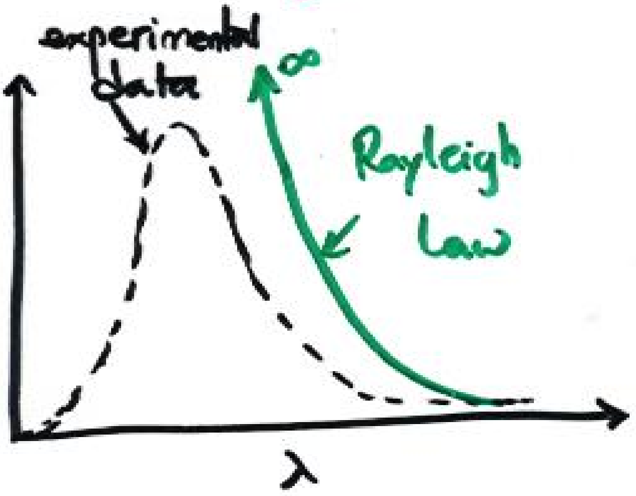
He also showed that

$$N(f)\,df = \frac{8\pi f^2}{c^3}\,df \qquad \text{— (2)}$$

Rayleigh-Jeans (classical) theory	Planck (quantum) theory
$\overline{E} = k_B T$ — (3)	$\overline{E} = \dfrac{hf}{e^{\frac{hf}{kT}} - 1}$ — (4)
energy of the oscillator is <u>continuous</u>.	using the energy of the oscillator is <u>quantized</u>

Rayleigh – Jeans law

$$u(f,T) = \frac{8\pi f^2}{c^3} k_B T$$

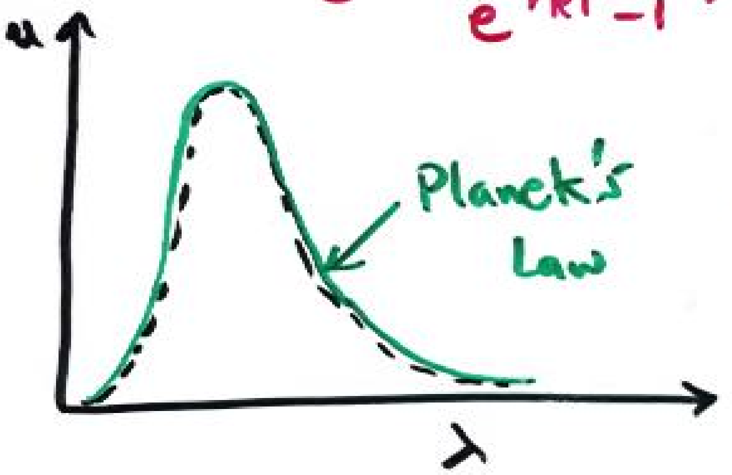


$\lambda \to 0 \quad u \to \infty$

ultraviolet catastrophe

Planck's function

$$u(f,T) = \frac{8\pi f^2}{c^3}\left(\frac{hf}{e^{hf/kT}-1}\right)$$



Planck's law fit the experimental data for the blackbody

At high f $\left(\begin{matrix} f \to \infty \\ \lambda \to 0 \end{matrix}\right)$ where $\frac{hf}{kT} \gg 1$

$$e^{\frac{hf}{kT}} - 1 \simeq e^{-\frac{hf}{kT}}$$

$$\Rightarrow \quad u(f,T) \simeq \frac{8\pi f^3 h}{c^3} e^{-\frac{hf}{kT}} \quad \text{[Wien's Law]}$$

- At low f $\left(\begin{matrix} f \rightarrow 0 \\ \lambda \rightarrow \infty \end{matrix} \right)$ $\frac{hf}{kT} << 1$

$$\frac{1}{e^{\frac{hf}{kT}} - 1} = \frac{1}{1 + \frac{hf}{kT} - 1} = \frac{kT}{hf}$$

and $u(f,T) \simeq \frac{8\pi}{c^3} f^2 kT$ [Rayleigh-Jeans Law]

Chapter 2

- Planck fitted the blackbody radiation spectrum by considering that the radiation energy is quantized and not continuous.

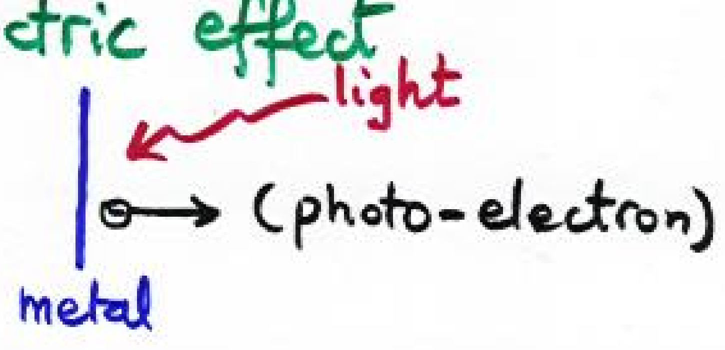
- Energy is <u>emitted</u> or <u>absorbed</u> in bundles called <u>photons</u> of energy hf.

- The spectral distribution of a blackbody is given by the Planck radiation law:

$$u(f,T) = \frac{8\pi h f^3}{c^3} \frac{1}{e^{hf/kT}-1}$$

- when $f \to \infty$ we recover Wien's law
- when $f \to 0$ we recover Rayleigh-Jeans law

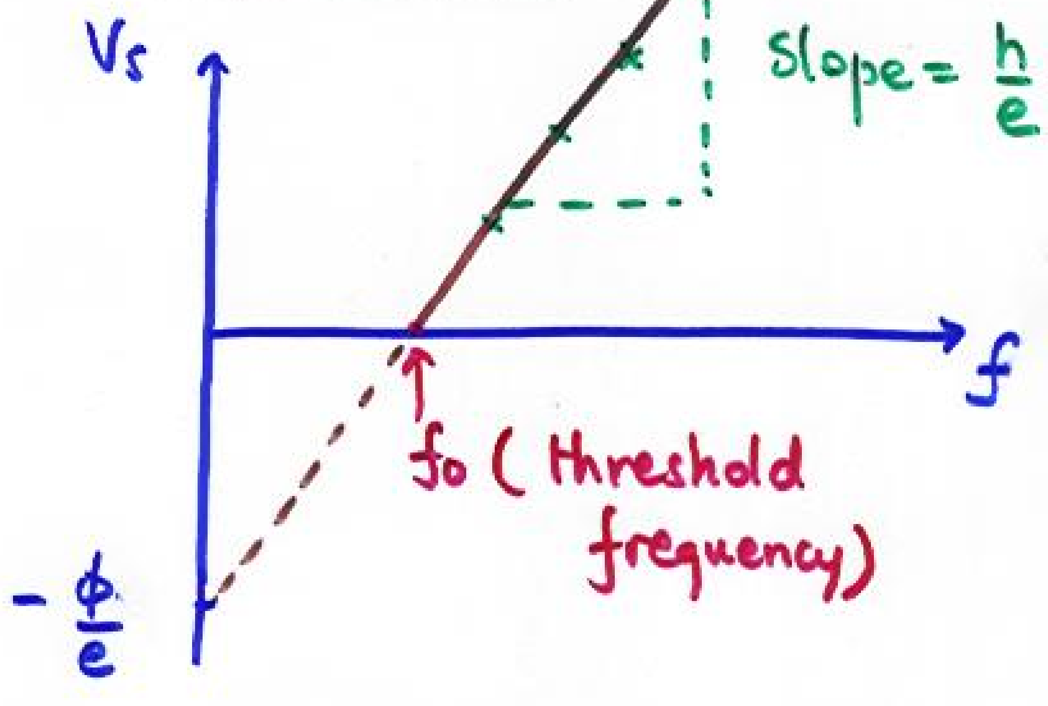
* Photoelectric effect



- The wave nature of light cannot explain some features of the photo-electric effect.

- Einstein had to consider light as quanta. Each quantum has an energy $E = hf$ so that

$$\boxed{eV_s = hf - \phi} \qquad (1)$$



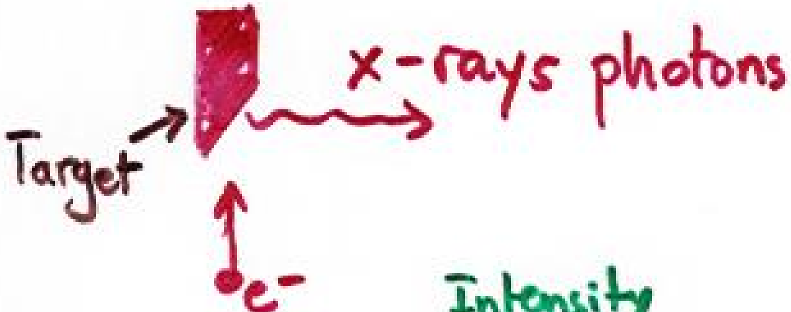
V_s: stopping potential

ϕ: Work function of the metal

- The ejected e^- has energy $K = hf - \phi$!

. There will be no ejected e^- if the frequency of light is less than f_0.

* X-rays are produced by bombarding a target with fast moving electrons.
(This is the opposite of the photoelectric effect)



$$\boxed{\lambda_{min} = \frac{hc}{eV} = \frac{12400\ eV.\mathring{A}}{V}}$$

accelerating potential