Contents

1 Lecture 1: Blackbody Radiation

1.1 What is Physics?

Why do we need quantum mechanics? The older (classical) theory was wrong!

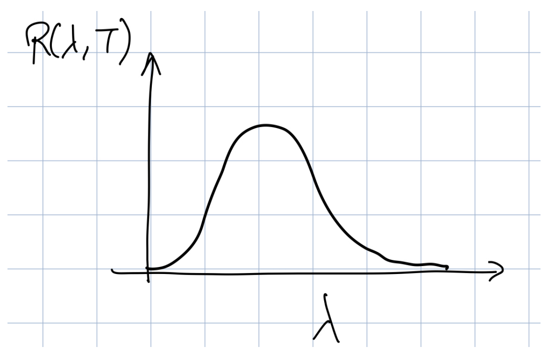
Physics doesn't tell you "why" things work–it tells you "how" things work. The reality is not observable, quantum mechanics "describes" observations rather than helping you "understand" some. By throwing away our philosophical concerns, we instead directly study the mathematics.

1.2 The Potter's Problem: Blackbody Radiation

Take a cube of some solid and heat it up to some temperature T. When you do this, it emits light (it glows). For a long time, no one knew how this phenomenon worked. Here are some observations throw the ages:

- 1792: Wedgewood notes that all objects (at a certain T) glow the same color.
- 1800s: With improvements in spectroscopy, we can now measure the frequency content of light.
- 1859: Kirchoff proposes a model. R is the "emissive power/area", λ is wavelength of the light and T is the temperature.

$$R(\lambda, T)$$



The idea is that there are multiple collisions between the walls and the radiation field. The blackbody (as a perfect absorber) is absorbing all light at all frequencies. It looked something like this. The left-side is near 0 because you have no wave at that wavelength. The right side must be bounded because we want total emissive power to be finite (or do we?).

- 1879: Stefan's Law

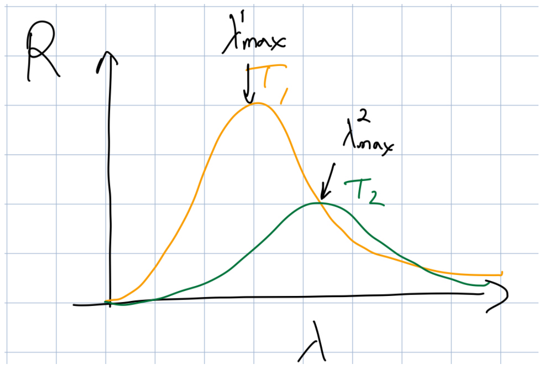
$$\int_0^\infty R(\lambda, T)\, \mathrm{d}\lambda = \sigma T^4$$

i.e. the total radiation emitted is proportional to T^4, which $\sigma \approx 5.67 \times 10^{-8} \frac{W}{m^2 K^4}$

- ????: Wien's Law

$$\lambda_{max} T \approxeq 2.898 \times 10^{-3} m \cdot K$$

i.e. these curves all have the same constant for the quantity. For example, in the following graph, $T_1 > T_2$.



- ????: Rayleigh-Jeans Law

$$R(\lambda, T) \propto \frac{8\pi k_B T}{\lambda^4}$$

which only works at longer frequencies (the area is unbounded).

Let's derive the last law using thermodynamic principles and waves. Suppose our blackbody is a cube. Let's find the waves that are stable in the cube. First, we write the wave equation.

$$\nabla^2 \psi(\vec{r}, t) = \frac{1}{c^2} \frac{\partial}{\partial t^2} \psi(\vec{r}, t)$$

where

$$\nabla^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}$$

In addition, we need boundary conditions–consider a standing wave in 1-d. At the ends it is fixed at 0. For 3-d this is:

$$\psi(x = 0, y, z, t) = \psi(x = L, y, z, t) = 0, \forall y, z, t$$

The solution is:

$$\psi(\vec{r}, t) = A(t) \sin(k_x x) \sin(k_y y) \sin(k_z z)$$

where $k_i = \frac{n_i \pi}{L}$ for $n_i \in \mathbb{N}$. This looks like:

$$\psi(\vec{r}, t) = A(t) B(x, y, z)$$