Note-A-Rific: Blackbody Radiation

What is Blackbody Radiation	How to Calculate Peak Wavelength	Failure of Classical Physics

What is Blackbody Radiation?

As thermal energy is added to an object to heat it up, the object will emit radiation at various wavelengths.

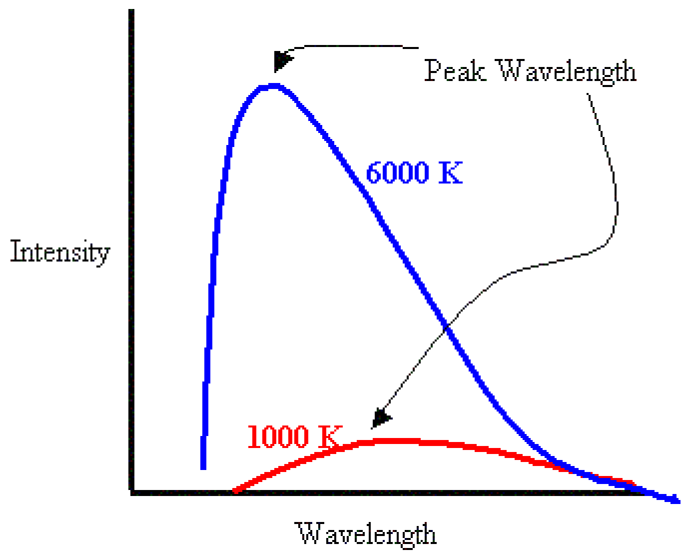
- All objects emit radiation at an intensity equal to its temperature (in degrees Kelvin, see Glossary) to the fourth power.

$$\text{Intensity} = T^4$$

  - At room temperatures, we are not aware of objects emitting radiation because it's at such a low intensity.
  - At higher temperatures there is enough infrared radiation that we can feel it.
  - At still higher temperatures (about 1000K) we can actually see the object glowing red
  - At temperatures above 2000K, objects glow yellowish or white hot.

No real object will absorb all radiation falling on it, nor will it re-emit <u>all</u> of the energy it absorbs.

- Instead physicists came up with a theoretical model called a Blackbody.
- A blackbody absorbs all radiation falling on it, and then releases all that energy as radiation in the form of EM waves.
- As the temperature of a blackbody increases, it will emit more and more intense radiation.
- At the same time, as the temperature increases, most of the radiation is released at higher and higher frequencies (lower and lower wavelengths).
- The frequency at which the emitted radiation is at the highest intensity is called the peak frequency or (more typically) the **peak wavelength**.



- This explains why an object at room temperature does not emit much radiation, and what radiation it does emit is at higher wavelengths, like infrared.
  - That's why you can't see an object in the dark with your eyes, but you can with infrared goggles.
- Hotter objects will glow red first (700 nm) and shift to the violet end of the spectrum (400 nm).
- Because the intensity is pretty well spread out across the visible spectrum by then, you see it glowing white hot.

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How to Calculate the Peak Wavelength for a Given Temperature

It was found that the wavelength at the peak of the spectrum (λ_p) is related to the temperature of the object in degrees Kelvin…

<u>Wien's Displacement Law!</u>

$$(\lambda_p)(T) = 2.90 \times 10^{-3}$$

λ_p = peak wavelength (m)

T = temperature (K)

Example: What is the peak frequency on the EM spectrum for our sun (surface temperature ≈ 5725°C)?

First, Calculate Temperature in Degrees Kelvin	*Second, Calculate Peak Wavelength*

$T(K) = T(°C) + 273.15$
$T(K) = 5725°C + 273.15$
$T(K) \approx 6000$ K

$(\lambda_p)(T) = 2.90 \times 10^{-3}$
$\lambda_p = 2.90\text{x}10^{-3}/6000\text{K}$
$\lambda_p \approx 500\text{nm}$

Notice that this peak is almost in the middle of the visible spectrum of light… so we see "white" light, a mixture of all the colors at about the same intensity.

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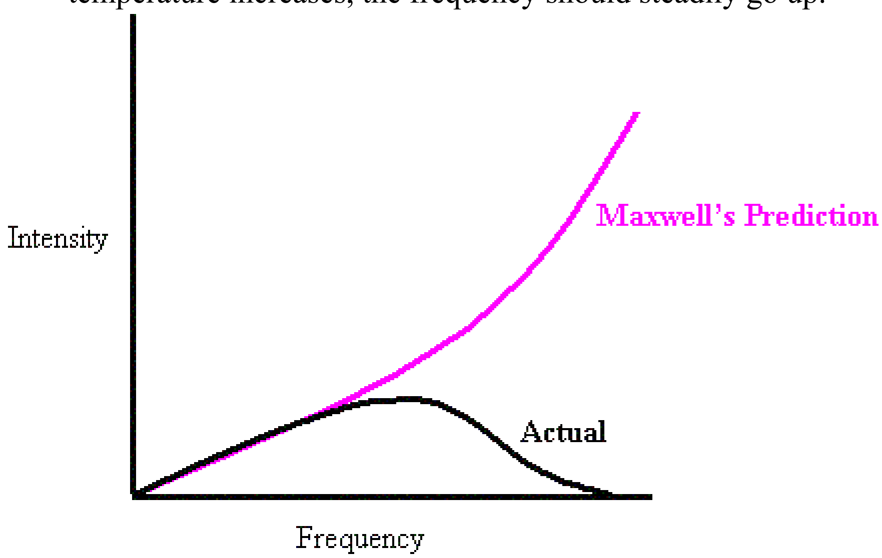
The Failure of Classical Physics

A major problem scientist in the 1890s had was explaining blackbody radiation.

- Maxwell's EM theory predicted that moving charges make EM waves.
    - The more a charge vibrates as the temperature increases, the greater the frequency of the waves.
    - This should continue on and on for blackbody radiation. As the temperature increases, the frequency should steadily go up.



    - Because Maxwell's theory was wrong at higher frequencies, in the ultraviolet range and beyond, this problem became known as the "**ultraviolet catastrophe**".

- Two more theories were proposed… still based on classical physics.
    - Wien's was good only at short wavelengths.
    - Rayleigh-Jeans was only good at long wavelengths.

Classical physics had failed. Something new needed to be proposed to explain the observed blackbody radiation. It would find its roots in the work of people like Millikan and Thomson, while also explaining some unbelievable results that were about to be seen.

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