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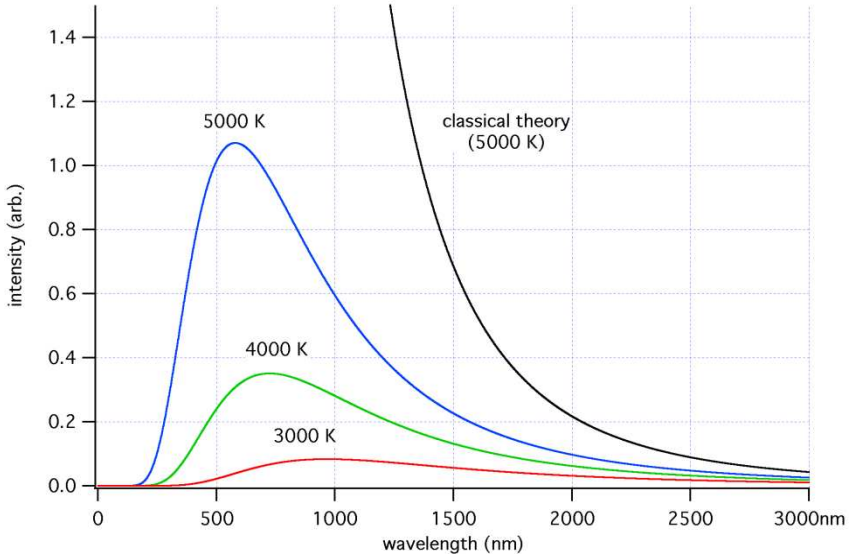
Assignment 1- The Efficiency of Different Lighting Methods

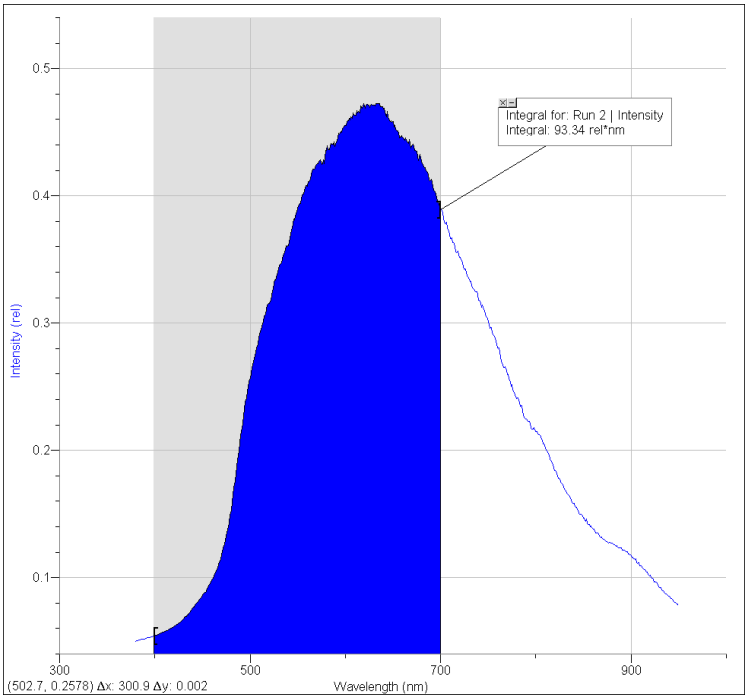
There are several types of ways in which people light their homes. Two popular ways that are utilized are incandescent and fluorescent lighting. It has been known for a while that conventional incandescent lighting is very inefficient. In fact, incandescent light bulbs are black body radiators. Black body radiation, also known as thermal radiation, is electromagnetic radiation that is emitted from the surface of an object . Black body objects are objects that absorb all the electromagnetic radiation that falls on them; no electromagnetic radiation passes through it and none is reflected from it; because of this, a black body object will appear black when it is cold. However, if a black body is heated up it will emit a spectrum that is dependent on the temperature of the black body itself. A typical diagram of the temperature dependence of a black body is represented as thus




As can be seen from the diagram, a black body does have a maximum wavelength at which it emits light. An incandescent bulb has a peak wavelength in the infrared region. This means that most of the electromagnetic radiation that is being emitted is being emitted in a region that humans cannot see. This is why an incandescent bulb is so inefficient. The efficiency of an incandescent bulb is around 10%.

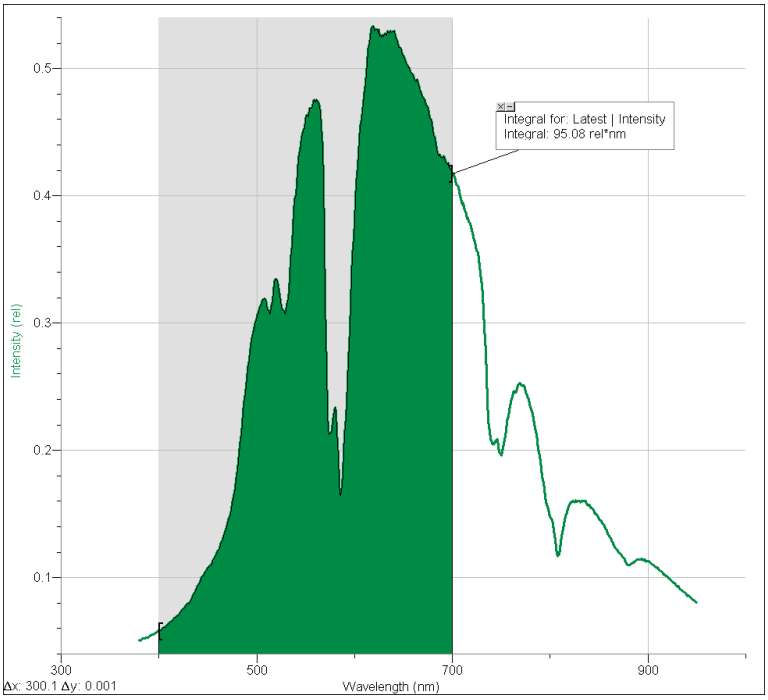
Fluorescent bulbs rely of a different mechanism in order to produce light. Fluorescent tubes generate light through the process of fluorescence. The general explanation of fluorescence is that a molecule/material will absorb a photon of light and emit a photon of light that has a longer wavelength (less energy). In the common fluorescent light tubes, mercury vapor is excited. The excited mercury atoms emit photon in the ultraviolet region of the electromagnetic spectrum. The tube containing the mercury vapor is coated with a phosphor which absorbs the UV radiation produced by the mercury and emits photons, via fluorescence, in the visible range. As one can see, fluorescent light tubes emit more in the visible region than fluorescent bulbs do; this is why the fluorescent tubes are more efficient than incandescent bulbs.

An interesting thing to note about incandescent bulbs is that the light they produce is often described as being yellow or orangish. A product that I recently saw advertized is a incandescent bulb that has a more natural look. So, I bought a neodymium (Nd) coated incandescent bulb, and I recorded several different incandescent spectra. The spectrum of a regular, non-coated incandescent bulb is as follows:



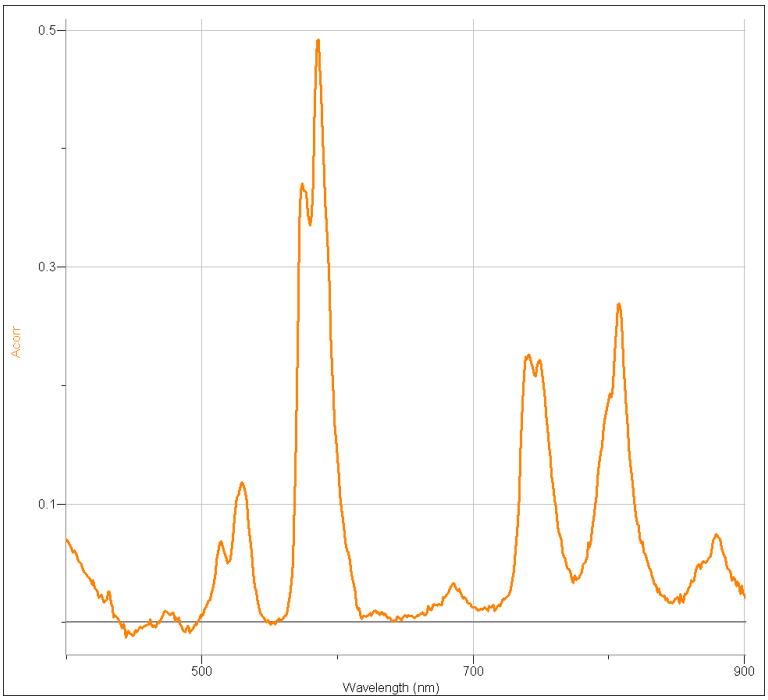

So, it can be observed that the maximum peak for the regular incandescent bulb is around 630nm, or in the orange region of the spectrum. Now, you might be asking yourself what happens to all of the other electromagnetic radiation that the incandescent bulb emits. Well, the rest of the emitted radiation that the bulb emits is emitted as infrared radiation. IR radiation is also known as heat radiation. So, all of the money that you are paying in electricity to power your incandescent bulb is thrown away in the form of heat, and you are only using about 10% of the power to produce light aht you can use.

The fact that we are throwing away a lot of electrical energy in order to produce more heat than useful light is more than a little disturbing to me. This made me even more eager to observe the emittance spectrum of the neodymium bulb. What makes the light it produces more like natural light? Does the Nd coating emit at a higher wavelength so the peak wavelength is shifted more into the visible range? Well, let's take a look at the spectrum of the Nd coated incandescent bulb.




The two incandescent spectra look very similar in general shape; however, the Nd-coated incandescent bulb emits even less light in the visible region. This is true because neodymium absorbs some of the emitted light from the tungsten wire. This makes the Nd-coated bulb even less efficient because it cuts out even more of the emitted light. So, when one uses the Nd-incandescent bulbs to produce light that is more natural looking, one is using a bulb that is less than 10% efficient!

I was also able to experimentally determine the absorption spectrum of neodymium from the two incandescent spectra that I obtained.



One can see a few pretty big absorption peaks in the neodymium spectra at 590nm, 750nm, and 810nm. One can refer to the Nd-coated bulb spectrum and observe these absorption peaks. They are the ‘missing’ pieces of the regular incandescent bulbs spectrum.