Let there be light!

An article on the technologies of artificial illumination by Jamie I, 12PHYS

Incandescence can be seen in everyday life, I will use the candle as an example as it has stood the test of time. As you light the candle, the air particles begin to heat up which causes the particles to gain more kinetic energy. When a charged particle begins to gain more kinetic energy, causing more movement, this will create an electromagnetic field which has its own electromagnetic energy. Light energy is a form of electromagnetic energy, hence why when air particles around a candle heat up, it results in a light being formed. Blackbody radiation also plays a role in how the candle can cause light to be formed. On the lower end of the blackbody spectrum, there is infrared light (heat). The radiation the candle produces, can only emit infrared light as the frequency is too low to produce anything else, so the candle loses a lot of energy in the form of heat.

Blackbody radiation is found in anything that is warmer than absolute zero (0 Kelvin = -273 C). Planck's law accurately describes this phenomenon, the law states: the higher the temperature of a body (object), the more radiation it emits at every wavelength. This means that different temperatures will create diverse intensities of radiation that will emit various colours of lights. Frequency of light increases proportionally with temperature. A way to think of the blackbody spectrum is like football leagues. Towards the lower end of the spectrum you would find non-league – infrared radiation. Red light wavelength will be efl league 2, green light being league 1, blue light being the championship. Finally, UV light being the premier league. Chelsea for example being in the UV section, the highest frequency, as opposed to Borehamwood having the lowest frequency, found in the infrared league.

The incandescent bulb, developed by Joseph Swan achieves blackbody radiation in a different way. Electrification. As opposed to using fire, Swan opted to use an electrically heated piece of tungsten filament. The science behind this is, when the filament had an electric current run through it, the resistance of the tungsten would cause it to heat up. Resistance is the opposition to current, tungsten having a high resistivity made it a perfect material for this design. It reaches a very high temperature (2700K = 2427 C), this causes it to emit intense wavelengths of light due to blackbody radiation. Referencing Planck's law we know that this means the incandescent light bulb will be a massive step up in performance from the candle. However, Joseph Swan faced a problem, the design had a flaw. Longevity. The filament would oxidise and burn out in a short period of time. To oppose this flaw, he vaulted the filament in a vacuum. This means that oxygen would be taken out of the equation completely, preventing oxidation. Another issue that the incandescent bulb faces is the same as the candle, it is limited to what light it can emit due to poor efficiency. Its efficiency is poor as a lot of energy is lost due to the heat the filament produces. However, the bulb can emit radiations further along the blackbody spectrum.

Let's discuss Mercury vapor lamps, the step up from the incandescent light bulb. To begin with I will discuss the key components in the mercury vapor lamps' structure. There is an inner tube, containing solid mercury residue, starting electrode and a main electrode. When the lamp is turned on, the two electrodes form an arc. This arc heats the tube, given enough time (usually a few minutes), it will become hot enough (about 6000K) to vaporise the solid mercury. The now vaporised mercury creates a very strong light between the electrodes, again referencing Planck's law this means that it will emit an even more intense light and a lighter colour than the incandescent bulb. The colour is usually an intense blue/white light. This is similar to the sun, because the temperature inside the inner tube of the lamp is about the same temperature as the surface of the sun. Opposed to a bulb that's lifespan relies on a filament that will burn out over time, the vapor lamp is more evolved than the incandescent bulb but faces a similar issue, that it cannot sustainably produce UV light. However, as the incandescent bulb to the candle, the same as the vapor lamp to the bulb. The vapor lamp has unlocked a larger piece of the blackbody spectrum. Being able to emit infrared, red, green and blue wavelengths sustainably. Still limited to unlocking the full blackbody radiation spectrum. The LED solves these problems.

The science behind the LED is that it restricts minimal electron jumps between bands when excited with kinetic energy, only allowing large jumps between the valence and conduction band. Imagine, you are in a river and you are the electron, taking steps between small rocks is like a minimal jump between bands, producing infrared-level frequency (heat energy), taking a big leap is the same as large jumps between the valence and conduction band, producing RGB level frequency. The LED only allows the big leaps between rocks, emitting more energy and a higher frequency, opposed to wasting energy on small jumps between stones. The frequency per jump is high enough to exclude infrared energy as that is located at the lower end of the blackbody spectrum. This means that it cannot emit infrared wavelength, so it cannot lose energy in the form of heat. This solves the problem that its predecessors faced, losing too much energy in the form of heat causing poor energy efficiency. This most recent stage in the development of artificial illumination radiates no heat at all, only pure almost perfectly efficient, light.