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**Introduction**

The objective of this lab was to observe the spectral power distribution of three different light sources and analyze the various changes in the behavior of light. How does the distribution affect the way the light is perceived and its tendency to correspond with a Blackbody?

**Background/Theory**

Spectral power distribution is essentially the measurement of the radiant power emitted from a light source, and can also be known as the spectral radiance [1]. Radiance is a measurement of the radiant power exiting a source and is in units of Watts per meter squared steradians (W/m2-sr). The radiant power is a constant and as the distance from the point source increases, the area of the measurement increases as well, so the measurement of the irradiance is inversely proportional to the square of the distance. This is known as the Inverse Square Law, and is mathematically written in the Appendix.

A spectroradiometer is a device used to measure the spectral power distribution from a given light source. In this lab, the spectroradiometer we used was the PhotoResearch 465. It measures wavelengths ranging from 380-780nm with approximately a 1-pixel resolution. The object we used as the focus for the lights was a perfect reflecting diffuser (PRD) which was placed directly in the path of the lights.

Spectral radiance is measured at various wavelengths within the constraint of visible light, between 400 and 700nm. One of the reasons spectral power distribution is measured is to make quantitative analysis of the color differences within the range of wavelengths. The data that gets collected differs as sources of light vary. In this lab, the three sources measured were daylight, fluorescent light and tungsten light.

The general power distributions of daylight, fluorescent light and tungsten (incandescent) light can be seen in Figure 1 in the Appendix. By looking at these graphs, daylight and incandescent light follow a smooth pattern of distribution over various wavelengths while fluorescent light has sudden peaks in the blue and green colors. That is why the light has a blue-green tint when emitted. Tungsten lights have a higher power distribution for the higher wavelengths, corresponding with red and orange colors, which is why the light has a warmer tint. Since all of these light sources emit light to certain temperatures, they can be related to a Blackbody, which gives off radiation at all wavelengths, including those associated with visible light [3]. This means that there would be a certain temperature at which the light sources would correspond with a Blackbody. A tungsten lamp heats up around 2800 K, which means a Blackbody would be expected to correspond around that temperature. The average temperature of a photosphere of the Sun is around 5500 K [2], so a Blackbody would be expected to correspond around that temperature. On the other hand, since the fluorescent light is distributed so unevenly over the visible light wavelengths, it wouldn’t have a corresponding Blackbody. A Blackbody has a continuous spectrum, so it wouldn’t be able to match a similar pattern, at any temperature. The equation used to find the full spectrum of a blackbody is known as Planck’s Blackbody equation and can be found in the Appendix.

By looking at these graphs, it can be expected that the spectroradiometer will collect similar data of each of these three sources and that daylight and tungsten light will also have a corresponding Blackbody at a certain temperature.

**Methods/Procedures**

In order to start the experiment, we needed to learn how to use the spectroradiometer and understand what we were imaging, and therefore, needed to learn more about the PRD. The PRD is designed to absorb, diffuse and integrate the energy from the source and is able to reflect nearly 100% of the energy at every wavelength. For the daylight and fluorescent light measurements, the PRD was placed on the ground with the light source directly above (the accuracy of the light distribution if a potential source of error which is described further in the analysis). When the PRD was placed in an acceptable location, the spectroradiometer was used to measure the power distribution. As stated earlier, the spectroradiometer used for this lab was the PhotoResearch 655 spectroradiometer. Spectroradiometers generally have a longer exposure time to gather as much light as possible in from the PRD one measurement for accurate results [4]. In this case, we held the spectroradiometer right in front of the PRD and then took an image.

The tungsten lamp used was from the company Mole-Richardson and was a 600W tungsten-halogen lamp. Four measurements were made: two related to the distance of the light and two related to the distance of the spectroradiometer. By taking these measurements, we can see how distance affects the spectral radiance of the tungsten light and which change as a greater affect than the other. Since the tungsten lamp was vertical, we held the PRD right in front and held the spectroradiometer next to the lamp, facing the PRD. For the first two measurements, we changed the position of the spectroradiometer and for the last two, we changed the position of the lamp.

The fluorescent lights used for the lab were within the Motion Picture Science Post Lab in Gannett, room A096. There were a few lights spread out on the ceiling throughout the room so the PRD was placed in the center on the ground. Since the fluorescent lights were above, we needed to make sure we weren’t casting any shadow on the PRD which could limit the amount of light it reflects.

**Results and Discussion**

After gathering the results, the data was graphed into various categories. I first graphed the absolute spectral power distribution (Figure 2) and then normalized it to 1 at 560nm (Figure 3). However, the pattern of the fluorescent light was off when it was normalized at 560nm, so I changed it to be normalized at 490nm instead. Looking at the normalized graph, the patterns for the three sources of light do follow the general outline of what is said to be the spectral power distribution over the wavelengths of 400-700nm. The only exception comes from the daylight curve, which is due to the timing of the trial. We collected the data at approximately 5:10PM on Friday February 12, 2016. Since the timing was later in the evening, the sun was beginning to set and therefore, not all of the light radiated from its photosphere was visible. So when the data was collected, the power distribution was uneven and was higher for the blue colors (400-500nm) and red (650-780nm).

The graphs that were made next were one that related each of the light sources to a Blackbody. In the hypothesis, we expected the daylight and tungsten light to have a corresponding Blackbody at a certain temperature, while the fluorescent light wouldn’t because of its distribution of light at different wavelengths. After graphing each of the normalized light sources along with the Planck’s Blackbody equation, I found that tungsten light was the only source that had a corresponding Blackbody at a temperature of 3150 K (Figure 4). Going back to the data collected of daylight, there was no temperature at which the Blackbody would accurately correspond, even though daylight does generally have one. Typically, daylight has a corresponding Blackbody at around 5500 K. In the graph, the Blackbody was set at 6500 K but it’s obvious that it doesn’t follow a similar pattern as the daylight curve (Figure 5). The same situation occurred with the fluorescent light, but that was decided in the theory. Since the distribution of fluorescent light doesn’t follow a smooth pattern, there isn’t a Blackbody that can correspond at any temperature (Figure 6).

After graphing these behaviors, the four trials of the tungsten light were divided into two graphs, each showing the two changes that were done. For the first graph (Figure 7), which shows the two trials when the spectroradiometer was moved, shows very little difference between the two trials. This means that even when the spectroradiometer changes its distance, the amount of light it collects remains somewhat the same, and this does confirm one of the expectations before beginning the lab. The distance of the tungsten light from the PRD remains the same during these trials, so the PRD reflects the same amount of light both times.

For the last two trials – showing a change in the distance of the tungsten light – there is a major change in the spectral power distribution (Figure 8). In this case, the distance between the spectroradiometer and the tungsten light does change, so the PRD reflects different amounts during each trial. Relating back to the Inverse Square Law, the distance is cut in half, so irradiance is higher, and in turn the spectral radiance is also higher when the light is closer. The increase is also towards the higher wavelengths, corresponding to red light, which shows why tungsten light has a warmer tint as compared to other light sources.

There were some sources of error that occurred in this lab, one of which being the accuracy of the distance. The distance was measured accurately before taking the measurement but there is a possibility that the distance may have shifted as we were holding on to the spectroradiometer or the PRD during the Tungsten light trials. Another source of error comes from any shadows that potentially could have appeared in the focus of the spectroradiometer. We checked for the fluorescent and tungsten light trials for any shadows, but the results from the daylight trial skewed due to the shadows that appeared because of the time of day. Positioning the PRD in the best place could be another source of error. We needed to place it in an area directly in front of the light source to ensure full distribution of light, so there could have been a possibility during the fluorescent light trials of an uneven distribution on the PRD. This ties back into the daylight trials since it was later in the day, and therefore the light wasn’t distributed evenly to get accurate results.

**Conclusions**

After completing this lab, it’s simpler to see how different light sources have different spectral power distributions at various wavelengths. The lab also confirmed the theory that fluorescent light doesn’t have a corresponding Blackbody while tungsten light does. The data collected for daylight is an error that can be taken into consideration when conducting this experiment again. We could make sure the data is collected at a time when the sun is directly overhead and the PRD is reflecting the maximum amount of light.

**References**

[1] “Spectral Power Distribution, SPD”. *Lighting Research Center Collection*. Web. <http://www.lrc.rpi.edu/education/learning/terminology/spectralpowerdistribution.asp>

[2] “Blackbody Radiation”. Physics Stack Exchange. *Stack Exchange Inc.* Web. <http://physics.stackexchange.com/questions/48721/calculate-temperature-of-the-earth-through-blackbody-radiation>

[3] “Example of Spectral Power Distribution Application”. Web. <http://hyperphysics.phy-astr.gsu.edu/hbase/vision/spd.html>

[4] “Radiometers, Spectrometers, and Spectroradiometers”. Konica Minolta. 2006. Web. <http://sensing.konicaminolta.us/2013/11/what-is-the-difference-between-radiometers-spectrometers-and-spectroradiometers/>

**Appendix**

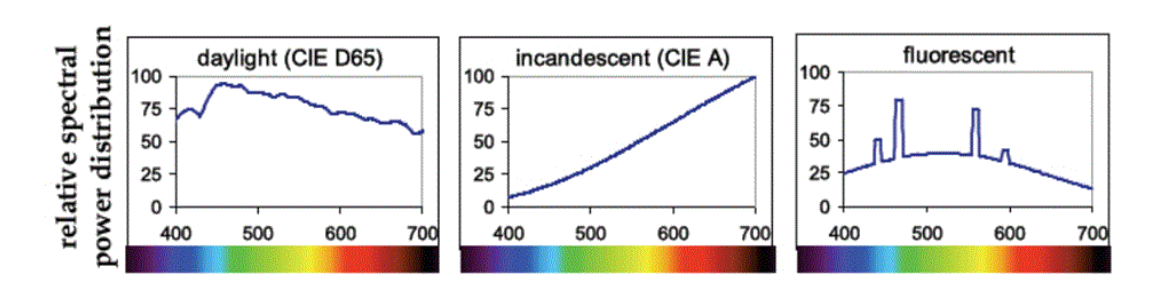
Mathematical Equations

Inverse Square Law:

E(d) ∝ 1/d2 , where E is the Irradiance and d is the distance .

Planck’s Blackbody Equation:

B_\lambda(\lambda, T) =\frac{2 hc^2}{\lambda^5}\frac{1}{ e^{\frac{hc}{\lambda k_\mathrm B T}} - 1}. , Where B is the spectral radiance, λ is the wavelength, h is Planck’s constant(6.625 x 10-34 J-s), T is the temperature, c is the speed of light in a vacuum, and k is Boltzman’s constant (1.38 x 10-23 J/K).

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**[**Figure 1: This shows a comparison between the different spectral power distributions of daylight, tungsten (incandescent) light, and fluorescent light.]

[Figure 2: A graph showing the spectral power distributions normalized to 1 at 560nm. The fluorescent light was normalized to 1 at 490nm]

**[**Figure 3: A graph showing the absolute values of the spectral power distribution of each of the different trials.]

[Figure 4: This shows the relationship between the tungsten trial and a Blackbody at a temperature of 3150 K]

[Figure 5: This graph shows the daylight power distribution and a Blackbody at 6500 K.]

[Figure 6: This shows the relationship between fluorescent light and a Blackbody at 7200 K.]

[Figure 7: this graph shows the values of tungsten light as the distance of the spectroradiometer was changed.]

[Figure 8: This graph shows the values of the tungsten light as the lamp was moved while the spectroradiometer and PRD were constant.]