

Blackbody Curves & UVB Filters – Student Guide

Background Material

Thoroughly review the “Spectra” and “Filters” background pages. The color index page may also be helpful to review.

Filters Simulator Overview

The filters simulator allows one to observe light from various sources passing through multiple filters and the resulting light that passes through to some detector. An “optical bench” shows the source, slots for filters, and the detected light. The wavelengths of light involved range from 380 nm to 825 nm which more than encompass the range of wavelengths detected by the human eye.

The upper half of the simulator graphically displays the source-filter-detector process. A graph of intensity versus wavelength for the source is shown in the leftmost graph. The middle graph displays the combined filter transmittance – the percentage of light the filters allow to pass for each wavelength. The rightmost graph displays a graph of intensity versus wavelength for the light that actually gets through the filter and could travel on to some detector such as your eye or a CCD. Color swatches at the far left and right demonstrate the effective color of the source and detector profile respectively.

The lower portion of the simulator contains tools for controlling both the light source and the filter transmittance.

- In the *source panel* perform the following actions to gain familiarity.
 - Create an **blackbody** source distribution – the spectrum produced by a light bulb which is a continuous spectrum. Practice using the **temperature** and **peak height** controls to control the source spectrum.
 - Create a **bell-shaped** spectrum. This distribution is symmetric about a peak wavelength. Practice using the peak **wavelength**, **spread**, and **peak height** controls to vary the source spectrum.
 - Practice creating **piecewise linear** sources. In this mode the user has complete control over the shape of the spectrum as control points can be dragged to any value of intensity.
 - Additional control points are created whenever a piecewise segment is clicked at that location.
 - Control points may be deleted by holding down the Delete key and clicking them.
 - Control points can be dragged to any location as long as they don’t pass the wavelength value of another control point.

- In the *filters panel* perform the following actions to gain familiarity.
 - Review the shapes of the preset filters (the B,V, and R filters) in the **filters list**. Clicking on them selects them and displays them in the graph in the *filters panel*.
 - Click the **add** button below the **filters list**.
 - Rename the filter from the default (“filter 4”).
 - Shape the piecewise linear function to something other than a flat line.
 - Click the **add** button below the **filters list**.
 - Select **bell-shaped** from the **distribution type** pull down menu.
 - Alter the features of the default and rename the filter.
 - If desired, click the **remove** button below the **filters list**. This removes the actively selected filter (can’t remove the preset B,V, and R filters). Filters are not saved anywhere. Refreshing the flash file deletes the filters.

Filters Simulator Questions

- Use the piecewise linear mode of the source panel to create a “flat white light” source at maximum intensity. This source will have all wavelengths with equal intensity.
- Drag the V filter to a slot in the beam path (i.e. place them in the **filter rack**).
- Try the B and the R filter one at a time as well. Dragging a filter anywhere away from the **filter rack** will remove it from the beam path.

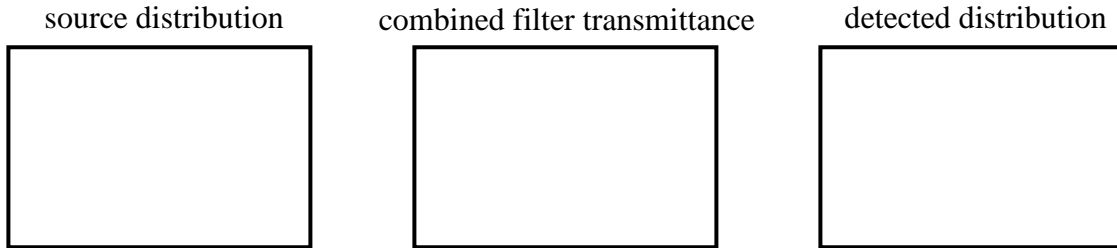
Question 1: Sketch the graphs for the flat white light and V filter in the boxes below. What is the effective color of the detected distribution? _____

source distribution	combined filter transmittance	detected distribution

Question 2: With the flat white light source, what is the relationship between the filter transmittance and the detected distribution? _____

- Add a new piecewise linear filter.
- Adjust the filter so that only large amounts of **green** light pass. This will require that addition of points.

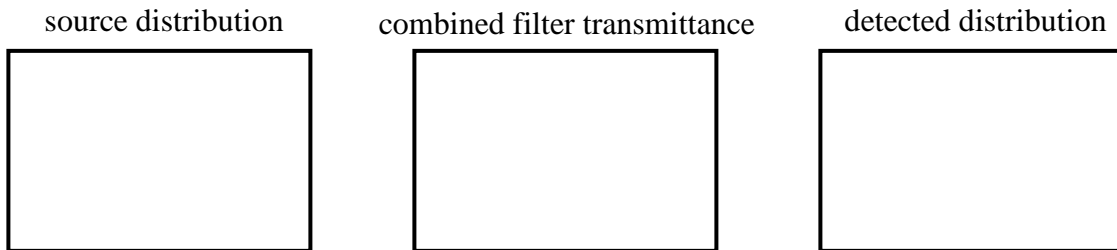
Question 3: Use this green filter with the flat white light source and sketch the graphs below.



Question 4: Use the **blackbody** option in the *source panel* to create a blackbody spectrum that mimics white light. What is the temperature of this blackbody you created? _____

- Add a new piecewise linear filter to the **filter list**.
- Modify the new filter to create a 40% “neutral density filter”. That is, create a filter which allows approximately 40% of the light to pass through at all wavelengths.
- Set up the simulator so that light from the “blackbody white light” source passes through this filter.

Question 5: Sketch the graphs created above in the boxes below. (This situation crudely approximates what sunglasses do on a bright summer day.)



Question 6: Remove all filters in the filters rack. Place a B filter in the beam path with the flat white light source. Then add a second B filter and then a third. Describe and explain what happens when you add more than one of a specific filter. _____

Question 7: Place a B filter in the beam path with the 40% neutral density filter. Then add a V filter into the beam path. Describe and explain what happens when you add more than one filter to the filter rack. _____

Question 8: Create a piecewise linear filter that when used with the flat white light source would allow red and blue wavelengths to pass and thus effectively allowing purple light to pass. Draw the filter in the box to the right.

purple filter



- Remove all filters from the **filters rack**.
- Create a very narrow **bell-shaped** source distribution that is peaked at green wavelengths (somewhere close to 550 nm). Notice the color.
- Expand the spread of the source distribution to maximum. Notice how the color changes.
- Change the distribution source to an **blackbody source** peaked at green wavelengths (a temperature close to 5270 K). Again notice the color.

Question 9: Using observations from the above actions, explain why we don't observe "green stars" in nature, though there are indeed stars which emit more green light than other wavelengths. _____

Blackbody – Curves Mode Familiarization

The Blackbody Curve Simulator has two main modes – the *curves mode* and the *filters mode*. The curves mode allows the exploration of blackbody curves including their peak wavelength and the area under the curve which is related to their total energy production.

- Learn how to add and remove curves and change their temperatures.
 - Click the **add curve** button one or more times.
 - Change the temperature slider. Notice which curve changes.
 - Select a second curve and change temperature.
 - Remove all but 1 or 2 extra curves.
- Learn the **vertical scale** options. Have 2 or 3 curves in the explorer.
 - Change temperature with the **auto scale all curves** mode.
 - Change temperature with the **auto scale to selected curve** mode.
 - Change temperature with the **lock scales** mode.
- Learn the **horizontal scale** options. Select the horizontal scale tab.
 - Note how changing the rightmost limit changes the view.
- Use, if desired, the **indicate peak wavelength** and **highlight area under curve** options.

Blackbody Curves – Questions

Question 10: Create a blackbody curve of temperature 6000 K and draw the shape in the box to the right. Does it have a peak? Is it symmetric about this peak? _____



Question 11: Create a second curve using the **add curve** button and use the temperature slider to vary its temperature. Can you find a blackbody curve of another temperature that intersects the 6000 K curve? Do you believe this would be true for two curves of any temperature? _____

Question 12: Make sure that there is only one curve and check **indicate peak wavelength**. Vary the temperature of the curve and note how the peak wavelength changes. Formulate a general statement relating the peak wavelength to temperature. Then compare this statement with Wien's Law discussed in the background pages. _____

Question 13: Select the **highlight area under curve** option and lock the vertical scale. Vary the temperature of the curve and note how the area under the curve changes. Formulate a general statement relating the area under curve to temperature. _____

Question 14: (Calculator Required) Complete the following table below. The "Area Ratio" is the area for the curve divided by the area for the curve in the row above. This will tell you many times greater the new ratio is compared to the previous one.

Curve Temperature	Area Under Curve (W/m^2)	Area Ratio
3000 K		
6000 K		
12000 K		
24000 K		

Can you specify a more precise statement relating the area under curve to temperature. Is this consistent with what was referred to as the Stefan-Boltzmann Law in the background pages?

Blackbody Explorer – Filters Mode

The second mode is the *filters mode* and explores the use of UBVR filters with blackbody curves.

- Unselect **highlight area under curve** and **indicate peak wavelength**. Select the **filters** tab.

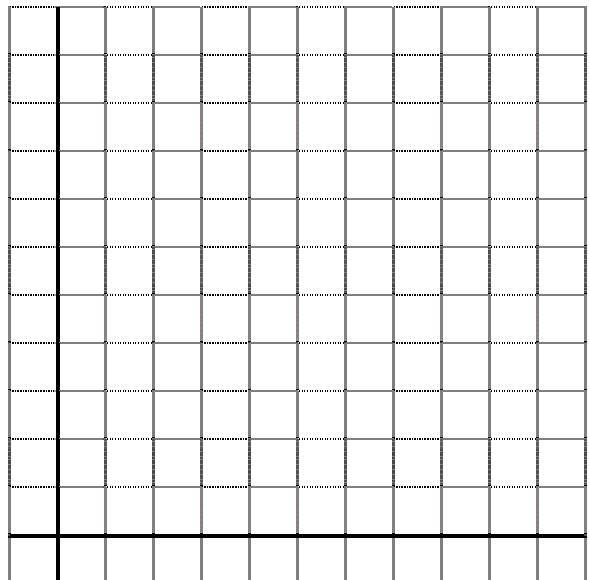
The light from a blackbody curve that passes through the UBVR filters are shown as colored areas under the curve. *It is this area which is later translated into a number for color magnitude. Remember that a magnitude is a logarithmic version of the flux (i.e. the amount of light) that passes through a filter and that lower numbers reflect larger fluxes.* Note that this area depends on both the source and the filter. What is listed as a V value is the apparent magnitude of a star (assumed to blackbody which isn't exactly true) through the V filter.

Question 15: Vary the temperature and in the table to the right note the temperature in at which each filter peaks. Where are the filters most sensitive, i.e. which temperature will give the strongest response in a detector?

Curve	Peak Temperature
U	
B	
V	
R	

Question 16: Use the color index feature to create a B-V index. This will compare the apparent magnitude of a star through the B filter to that through the V filter. Plot temperature on the vertical axis and B-V on the horizontal.

Temperature	B-V
3000 K	
4000 K	
5000 K	
6000 K	
8000 K	
10,000 K	
15,000 K	
20,000 K	
25,000 K	



Question 17: Use your graph to estimate the B-V value of a 12,000 K blackbody. _____