

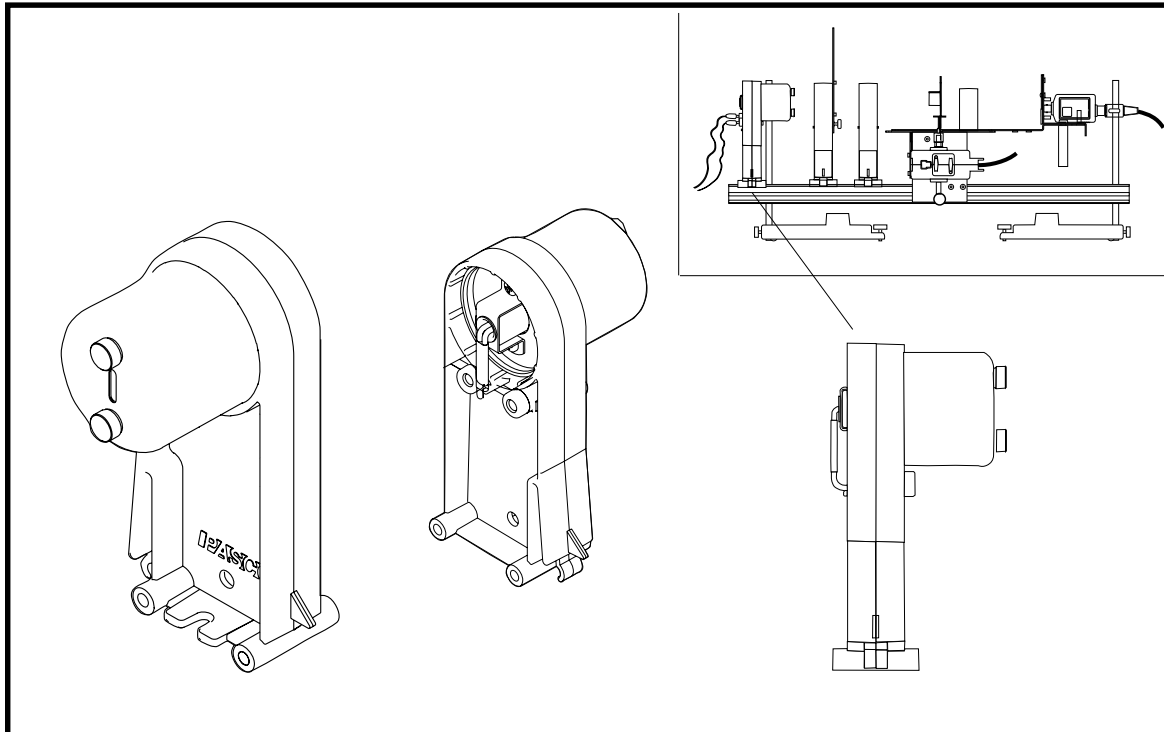
Includes
Teacher's Notes
and
Typical
Experiment Results



**Instruction Manual and
Experiment Guide for
the PASCO scientific
Model OS-8542**

012-07105B

BLACK BODY LIGHT SOURCE FOR THE OS-8539 EDUCATIONAL SPECTROPHOTOMETER





The exclamation point within an equilateral triangle is intended to alert the user of the presence of important operating and maintenance (servicing) instructions in the literature accompanying the device.

Table of Contents

Section	Page
Copyright, Warranty, and Equipment Return	ii
Introduction	1
Theory	2-4
Setup	5-8
Calibration	9
Procedures	9-10
Experiment	10-11
Data Collection and Analysis	12
Teacher's Guide	13-15
Troubleshooting	16
Parts and Replacements	17
Technical Support	Back Cover

Copyright, Warranty, and Equipment Return

Please—Feel free to duplicate this manual subject to the copyright restrictions below.

Copyright Notice

The PASCO scientific 012-07105A manual is copyrighted and all rights reserved. However, permission is granted to non-profit educational institutions for reproduction of any part of the manual providing the reproductions are used only for their laboratories and are not sold for profit. Reproduction under any other circumstances, without the written consent of PASCO scientific, is prohibited.

Limited Warranty

PASCO scientific warrants the product to be free from defects in materials and workmanship for a period of one year from the date of shipment to the customer. PASCO will repair or replace at its option any part of the product which is deemed to be defective in material or workmanship. The warranty does not cover damage to the product caused by abuse or improper use. Determination of whether a product failure is the result of a manufacturing defect or improper use by the customer shall be made solely by PASCO scientific. Responsibility for the return of equipment for warranty repair belongs to the customer. Equipment must be properly packed to prevent damage and shipped postage or freight prepaid. (Damage caused by improper packing of the equipment for return shipment will not be covered by the warranty.) Shipping costs for returning the equipment after repair will be paid by PASCO scientific.

Equipment Return

Should the product have to be returned to PASCO scientific for any reason, notify PASCO scientific by letter, phone, or fax BEFORE returning the product. Upon notification, the return authorization and shipping instructions will be promptly issued.

► **NOTE:** NO EQUIPMENT WILL BE ACCEPTED FOR RETURN WITHOUT AN AUTHORIZATION FROM PASCO.

When returning equipment for repair, the units must be packed properly. Carriers will not accept responsibility for damage caused by improper packing. To be certain the unit will not be damaged in shipment, observe the following rules:

- ① The packing carton must be strong enough for the item shipped.
- ② Make certain there are at least two inches of packing material between any point on the apparatus and the inside walls of the carton.
- ③ Make certain that the packing material cannot shift in the box or become compressed, allowing the instrument come in contact with the packing carton.

Address: PASCO scientific
10101 Foothills Blvd.
Roseville, CA 95747-7100

Phone: (916) 786-3800
FAX: (916) 786-3292
email: support@pasco.com
web: www.pasco.com

Introduction

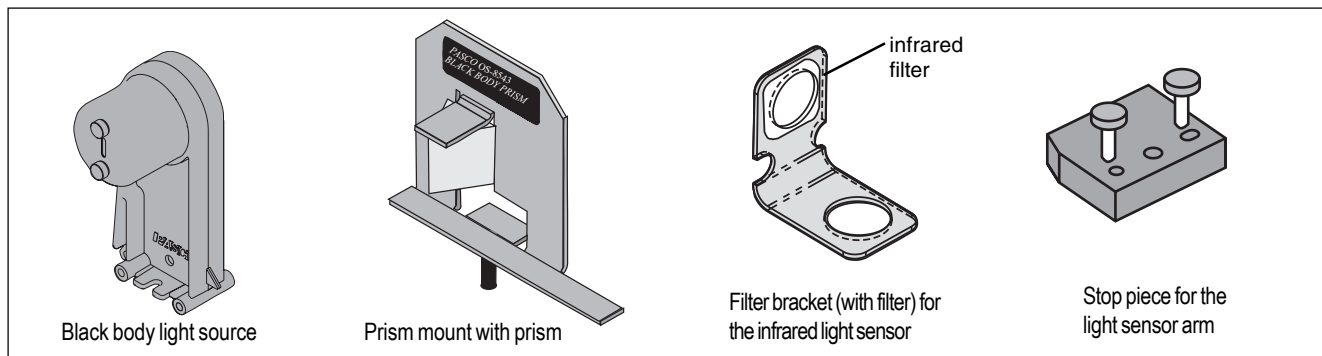
About this Manual

This manual describes setup, operational, and procedure guidelines for conducting a black body experiment using the OS-8537 Educational Spectrophotometer, OS-8542 Black Body Light Source and the OS-8543 Black Body Prism with Infrared Filter.

The Black Body Prism comes with the necessary accessories for mounting the prism onto the spectrophotometer table of the PASCO OS-8537 Educational Spectrophotometer. The Black Body Prism is designed to convert the PASCO Model OS-8539 Educational Spectrophotometer from a grating to a prism spectrophotometer. A prism spectrophotometer has two advantages over a grating spectrophotometer: a) it eliminates overlap of orders observed with a grating (When a grating is used, second order visible wavelengths overlap first order infrared wavelengths.), and b) the spectrum is brighter because it does not spread over several orders or in both directions.

Equipment Required:

- OS-8542 Black Body Light Source
- OS-8543 Black Body Prism with infrared filter, filter bracket and beveled stop piece



Also Required:

- Educational Spectrophotometer System (OS-8539)
- 0-10 VDC Power Supply (1 A) (SE-9720) *Or* Power Amplifier (CI-6552)
- Science Workshop Interface (Model 750 or 700)
- PASCO Infrared Sensor (CI-6628)* *Or* High Sensitivity Light Sensor (CI-604)**
- DataStudio™ software
- Setup CD for the Black Body experiment
- 1 package containing 10 tungsten light bulbs (9 for replacement in the black body light source)

*Use the infrared sensor for black body experiments or when you want to measure infrared wavelengths.

**Use the high sensitivity light sensor for experiments in which only visible wavelengths are desired and a linear response is not needed.

Theory

The 60-degree prism is mounted so that the back face is perpendicular to the incoming light, as shown in Figure 1. A schematic of the prism and the path of light is shown in Figure 2 below. Since the prism angle is 60 degrees, it can be shown that

$$(1) \theta_2 + \theta_3 = 60^\circ$$

And using Snell's law at each interface,

$$(2) \sin(60^\circ) = n \sin(\theta_2) \text{ and}$$

$$(3) \sin(\theta) = n \sin(\theta_3)$$

Combining equations (3) and (1) yields

$$(4) \sin(\theta) = n \sin(60^\circ - \theta_2)$$

which, using the double angle formula becomes

$$(5) \sin(\theta) = n \{ \sin(60^\circ) \cos(\theta_2) - \sin(\theta_2) \cos(60^\circ) \}$$

Now use a trig identity to change from cos to sin, and (5) becomes

$$(6) \sin \theta = n \sin(60^\circ) [1 - \sin^2(\theta_2)]^{\frac{1}{2}} - n \sin(\theta_2) \cos(60^\circ) = \sin(60^\circ) [n^2 - n^2 \sin^2(\theta_2)]^{\frac{1}{2}} - n \sin(\theta_2) \cos(60^\circ)$$

If we now use (2), equation 6 becomes

$$(7) \sin(\theta) = \sin(60^\circ) [n^2 - \sin^2(60^\circ)]^{\frac{1}{2}} - \sin(60^\circ) \cos(60^\circ)$$

Solving (7) for n gives

$$(8) n = \sqrt{\left[\left(\frac{\sin \theta}{\sin 60} + \cos 60 \right)^2 + \sin^2 60 \right]}$$

And finally, if we simplify,

$$(9) n = \sqrt{\left(\frac{2}{\sqrt{3}} \sin \theta + \frac{1}{2} \right)^2 + \frac{3}{4}}$$

The Cauchy equation gives the relationship between the wavelength and the index of refraction.

$$(10) n(\lambda) = \frac{A}{\lambda^2} + B$$

where A and B depend on the type of glass.

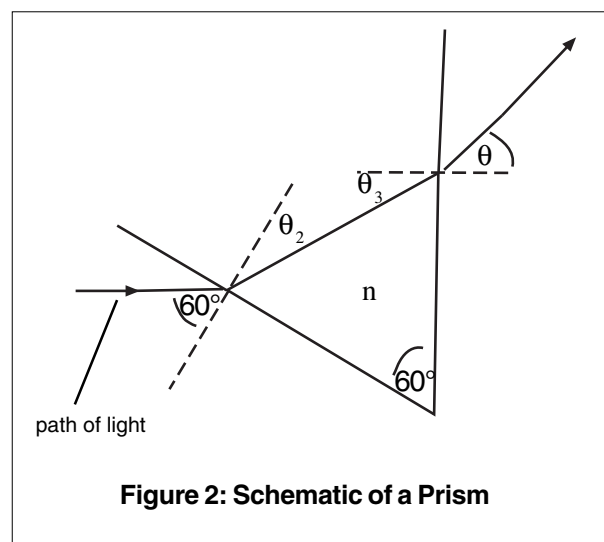
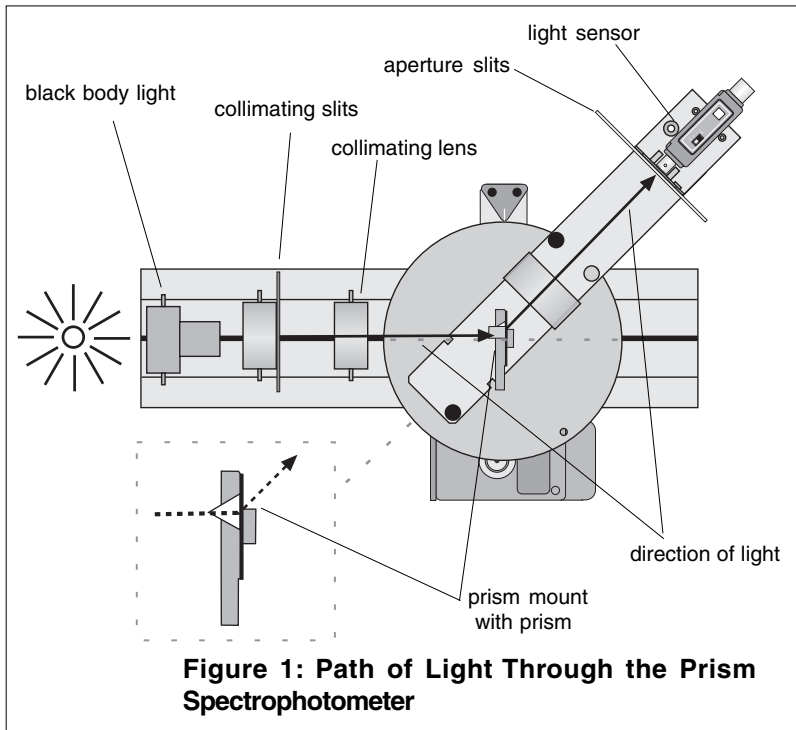


Table 1 shows the values for the prism used. The graph in Figure 3 shows an inverse square fit of the data.

Thus, we get the values of A=13,900 and B=1.689 with the wavelength given by

$$(11) \lambda = \sqrt{\frac{A}{n - B}}$$

Thus, the final equation for the wavelength (in nanometers) is

$$(12) \lambda = \sqrt{\frac{13900}{\sqrt{\left(\frac{2}{\sqrt{3}}\sin\theta + \frac{1}{2}\right)^2 + \frac{3}{4}} - 1.689}}$$

Table 1: Prism Coefficients

Prism Coefficients, Data	
Wavelength (nm)	Refraction Index
404.700	1.776
435.800	1.762
480.000	1.748
486.100	1.746
546.100	1.734
587.600	1.728
643.800	1.722
656.300	1.721
706.500	1.717
852.100	1.709
1014.000	1.703

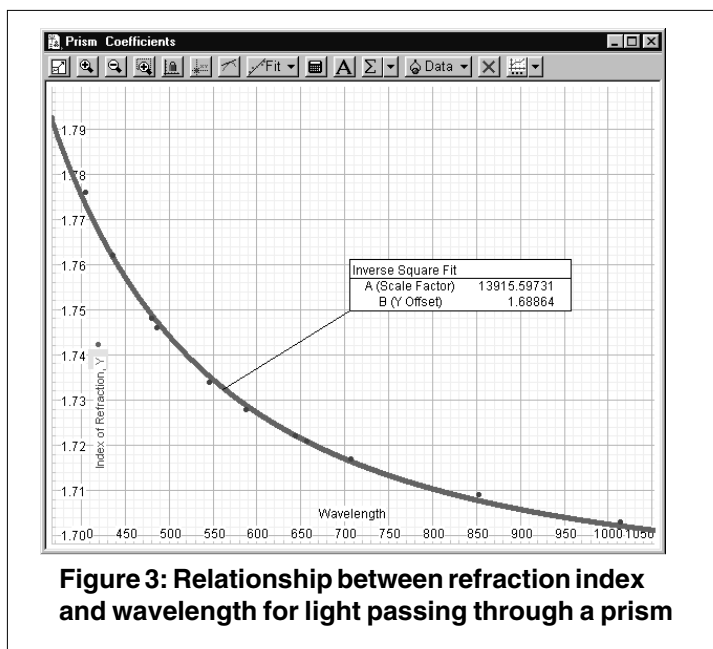


Figure 3: Relationship between refraction index and wavelength for light passing through a prism

Determination of the Wavelength from the Angle (using DataStudio)

In DataStudio, the equation for determining the wavelength is listed in the Definition box in the Calculator window, as follows:

$$\text{Wavelength} = \text{filter} (0,8000, (13900/(((1.1547*\sin ((\text{Init} - \text{Angle})/\text{Ratio}))^2 + 0.75)^{0.5} - 1.689))^{0.5})$$

where 0,8000 is the filtering range for the infrared light (0-8000 nm)

13,900 is constant A, as described above.

1.689 is constant B, as described above.

1.1547 is $\frac{2}{\sqrt{3}}$

Init - is the initial angle reading measured during data collection

Angle - is the angle measured by the rotary motion sensor

Ratio - is the ratio of the disk radius to the pin radius

B. Determining the Temperature of the Black Body Light Source

The temperature of a hot bulb can be calculated from a known resistance at room temperature. The resistance of the bulb is given by

$$(13) R = R_0 [1 - \alpha_0 (T - T_0)]$$

where α_0 is the thermal coefficient at room temperature. The bulb filament is made of tungsten, which has a coefficient of $\alpha_0 = 4.5 \times 10^{-3}/\text{K}$ at room temperature. Solving equation (13) for the hot temperature gives

$$(14) T = T_0 + \frac{\frac{R}{R_0} - 1}{\alpha_0}$$

The bulb has an approximate resistance of 0.84Ω at room temperature. For a more exact value, measure it yourself. You cannot measure the resistance of the bulb while it is still in the holder. Solder wire leads to one bulb to ensure a good contact, and use this bulb to determine the resistance.

To determine the resistance of the hot bulb, measure the voltage drop across the bulb and the current passing through it; use Ohm's law, where $V=IR$.

The current is determined from the power amplifier output from Channel C. Connect a voltage sensor to channel B, and place it directly across from the light source. The final equation for the temperature (in Kelvin) of the bulb becomes

$$(15) T = 300\text{K} + \frac{\frac{V}{I} - 0.84}{4.5 \times 10^{-3}/\text{K}}$$

Determining the Temperature of the Bulb Using DataStudio

In DataStudio, the temperature for the bulb in the black body light source can be viewed from the definition box in the Calculator. To view the equation for temperature, click on the calculator icon next to temperature (under the "Data" window). The equation is as follows:

$$\text{Temp (K)} = 300 + ((\text{voltage}/\text{current})/0.84 - 1)/.0045$$

where voltage is the voltage across the bulb

current is the current passing through the bulb

0.84 is the resistance of the bulb at room temperature

.0045 is 4.5×10^{-3}

Setup

This section describes the procedure for mounting the light sensor arm, prism mount and black body light source. For more detailed instructions about setting up the spectrophotometer table and rotary motion sensor, see the PASCO OS-9539 *Educational Spectrophotometer System Instruction Manual*. **Before proceeding, calibrate the rotary motion sensor, as described in the “Calibration” section on page 9 of this manual.**

1. Attach the Stop to the Light Sensor Arm

Attach the stop to the light sensor arm using the two screws provided (Figure 4). Note the orientation of the stop. Position the beveled corner of the stop so that it will hit against the angle indicator on the spectrophotometer table.

2. Mount the Light Sensor arm to the Degree Plate

Align the Light Sensor arm over the bracketed markers and the edge holes displayed on the top surface of the degree plate. Use the thumb screws to secure the arm to the plate.

After securing the arm, check to ensure that the arm rotates throughout the full range between the zero mark and the stop.

3. Attach the Prism Mount to the Degree Plate and Spectrophotometer Table

Remove the wing nut and lock washer from the prism mount. Set the angle indicator on the spectrophotometer table to zero. Locate the hole in the center of the circular table on the spectrophotometer. Screw the prism mount into this center hole (Figure 6).

Note: Do not screw it down tight. The light sensor arm must be free to rotate under the prism without touching the prism mount.

Rotate the prism mount until it clears the light sensor arm and the prism is oriented with its apex pointed in the direction of the light source, and the prism mount bracket is aligned with the 0 and 180 degree lines on the plate. Check to see that the angle indicator on the degree plate is set to zero and the tab indicator on the prism mount is aligned parallel to the 180-degree line on the plate. From the bottom side of the degree plate, place a lock washer and wingnut on the threaded post to help secure the prism mount onto the table.

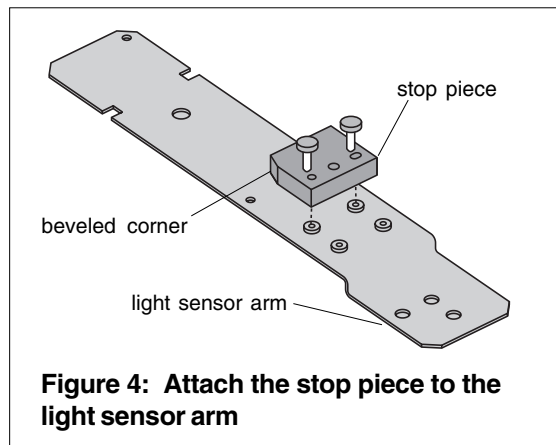


Figure 4: Attach the stop piece to the light sensor arm

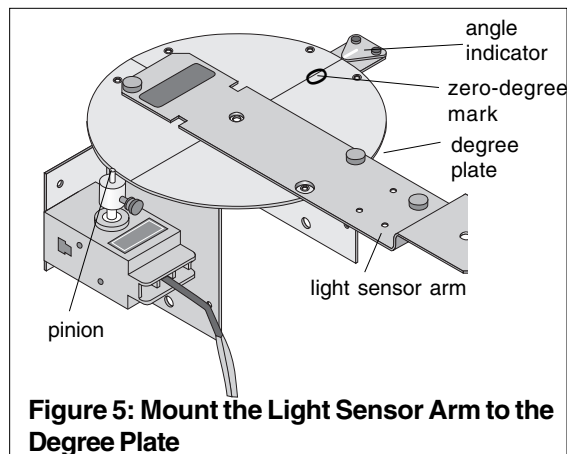


Figure 5: Mount the Light Sensor Arm to the Degree Plate

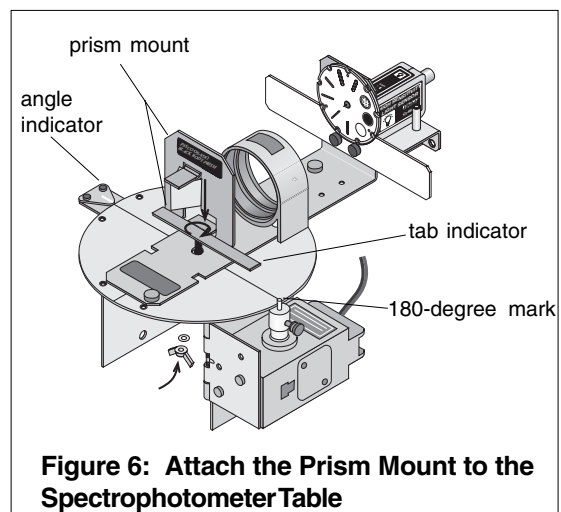
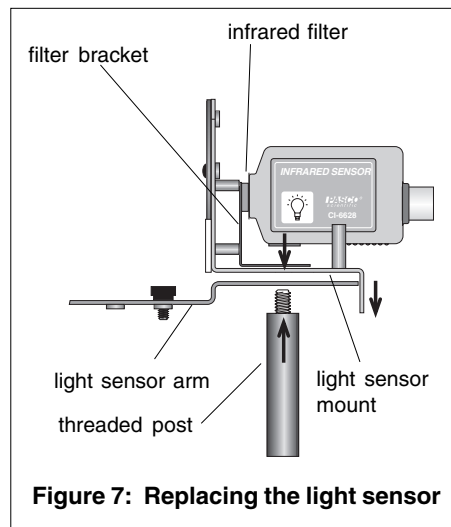


Figure 6: Attach the Prism Mount to the Spectrophotometer Table

4. Replace the Light Sensor with the Infrared Sensor and Infrared Filter

To observe infrared wavelengths, use the Infrared Sensor instead of the High Sensitivity Light Sensor. The filter prevents the infrared sensor from detecting objects in the room (such as people's hands), but still allows the sensor to detect hotter objects (such as a light source).

- To replace the High Sensitivity Light Sensor, rotate the threaded post clockwise to loosen the attachment and remove the light sensor.
- Place the base of the filter bracket over the front hole of the light sensor mount, such that the hole in the bracket base aligns over the front hole on the mount and the front hole of the light sensor arm.
- Place the Infrared Light Sensor over the base of the bracket. While holding the sensor in place with one hand, use your other hand to insert the threaded post from beneath the sensor. Rotate the post until the sensor holds firmly in place against the bracket and mount. The glass filter should fit snugly against the sensor, with the bracket under the case (Figure 8).

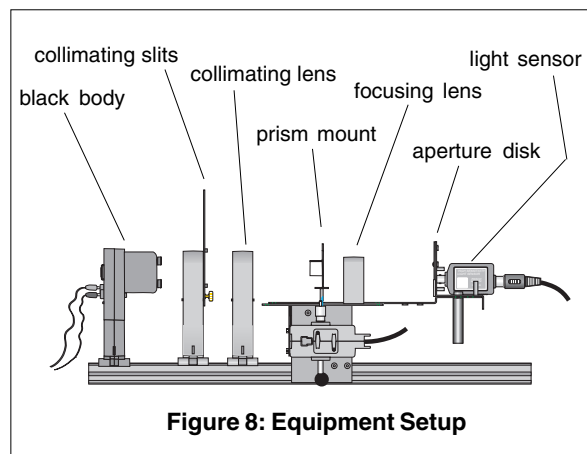


5. Position the Collimating Slits and Lenses on the Optics Track.

- Place the collimating lens close to but not touching the degree plate.
- Place the collimating slits exactly 10 cm from the collimating lens.

6. Mount the Black Body Light Source onto the Optics Track

Slide the black body light source onto the light end of the optics track. Place the light source as close as possible to the collimating slits. For added stability, use the screw and nut to secure the black body light source to the track (see Figure 8).



7. Connect the Power Supply to the Black Body Light Source

Use banana plugs to attach a power amplifier (used with a ScienceWorkshop interface) with signal generator capacity.

Note: A D.C. power supply can be used if a power amplifier is not available. However, the power amplifier is needed for displaying temperature and wavelength in DataStudio.

- With the amplifier turned off, attach the banana plugs on the black and red cables from the CI-6502 Power Amplifier to the connectors on the back side of the black body light source.
- Plug the DIN connector from the amplifier into analog channel C.

8. Science Workshop Interface Setup (for use with DataStudio™ software)

With the power on the interface turned off, connect the following:

- Rotary Motion Sensor - plug the yellow cable into digital channel 1 on the interface. Plug the black cable into digital channel 2.
- Light Sensor - plug the DIN connector into analog channel A
- Voltage Sensor - plug the DIN connector (extending from the black and red cables) into analog channel B and to the banana plug jacks in the back side of the Black Body light source.

9. Setup the Experiment in the DataStudio™ software

- 1) Insert the DataStudio Setup CD into the CD drive of your computer.

Note: You must have PASCO's DataStudio™ software loaded on your system to run the experiment with the DataStudio setup CD. The setup CD is not designed to be run with ScienceWorkshop® or other software. The following instructions apply to DataStudio and are subject to change with future updated releases of DataStudio software and/or DataStudio experiment setup CDs.

- 2) Click on the Experiment Setup window. Select from the list of sensors displayed in the sensors list. Drag each sensor icon to the corresponding channels on the *ScienceWorkshop* interface box display.
- 3) Verify or change (if desired) the voltage and current settings in the Signal Generator Box:
 - recommended voltage setting = 7 volts
 - recommended sampling rate = 50 Hz

Note: To view the Signal Generator dialog box, doubleclick on the Output icon located under the Signal Output drop down menu.

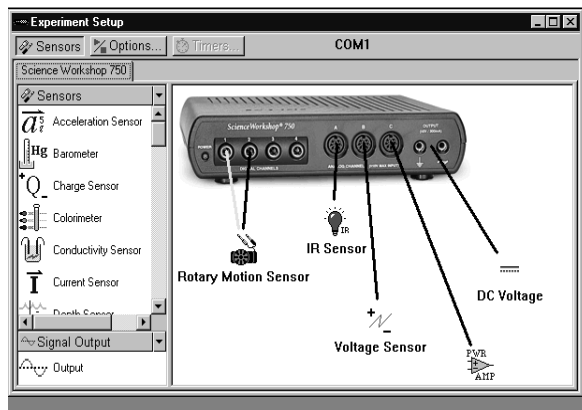


Figure 9: Experiment Setup Window

- 4) Prepare the graph displays in DataStudio.

Using DataStudio, you can view the following graphs when you create the appropriate horizontal (x) and vertical (y) axes:

- Light Intensity vs. Wavelength
- Light Intensity vs. Angular Position
- Voltage vs. Time
- Temperature vs. Time

Note: Prepare a graph display by dragging and dropping the appropriate run icons over the x and y axes in an open graph. You can also change a graph display by clicking on the Graph Settings button (the right most button on the top horizontal bar in the graph window.)

Example: Generate a graph display of light intensity vs. angular position.

From the “Displays” list, doubleclick on a graph icon. Drag and drop a voltage icon over the y-axis label on the graph. Drag and drop a angular position icon over the x-axis label on the graph. (For more detailed information about DataStudio, refer to the DataStudio online help guide listed under the HELP menu in the software.)

Note: If your graph displays negative angles, try reversing the position of the black and yellow cables you have inserted into channels 1 and 2.



****IMPORTANT OPERATIONAL NOTES****

The following notes are critical to maintaining the accuracy of the calibrations and experiment:

Setting the Collimating Slits - For best results, match the slit width size on the collimating lens to the same slit width size on the aperture. For example, if you select the number 4 width from the collimating slits, select the number 4 width on the aperture. (For more information about adjusting the collimating slits, see the Instructional Manual for the Model OS-8539 Educational Spectrophotometer.)

Ensure the slit opening on the aperture slides directly over the hole on the back of the aperture bracket; otherwise light will not reach the light sensor.

Adjusting the Voltage in the Black Body Light Source - In DataStudio, set the voltage in the Signal Generator box. The recommended voltage setting is 7 volts. The voltage can be varied from zero to 10V, but continuous operation of the bulb at 10V will result in a shorter bulb life.

In DataStudio, display the temperature graph and ensure the voltage increase corresponds to a temperature increase. The sampling rate is set to 50 Hz. Also, in DataStudio, ensure that you have selected DC voltage in the Signal Generator box; do not select sine wave or another function. The black body experiment requires direct and continuous current, not alternating or pulsating current.

To improve the voltage signal display on the graphs, increase the gain on the light sensor to 10 or 100. In the Signal Generator window, use the arrow keys to adjust the gain.

Checking the position of the prism - The prism mount and prism must remain fixed at all times. If not, your data will be in error. If the prism mount rotates at any time during the scanning, discard the data, recalibrate, and take another reading.

Checking the angular display against the reading on the degree plate - DataStudio allows you to adjust the angle units to either degree or radians. If you set the units to rads in DataStudio, remember that the number on the degree plate will not correspond to the number on the display. You will need to mathematically convert degrees to radians.

If you have negative angle readings, you may have reversed the colored cables for the rotary motion sensor, rotated the degree plate in the wrong direction, or improperly mounted the light sensor arm and lenses. While taking a reading, the degree plate must rotate clockwise. For more information about the rotary motion sensor or the light sensor arm, see the instruction manual for the Educational Spectrophotometer.

Calibration

1. Calibrate the Rotary Motion Sensor

Determining the wavelength from the prism spectrophotometer requires an exact measurement of the angle. To calibrate the rotary motion sensor, determine the ratio of the disk radius to the pin radius (approximately 60:1) as follows:

- Remove the prism mount and the light sensor bracket from the degree plate by unscrewing the two small thumbscrews. Start the DataStudio program and select a rotary motion sensor. Make a digits display of the angular position, and turn the degree plate so that the zero degree mark is exactly aligned with the index mark.
- Start recording data. Slowly and continuously turn the degree plate clockwise for exactly one complete rotation.
- Stop recording data. Record the maximum value of the angle. Divide this number by 360 (or 2π if it is in radians mode). This is the ratio of the radii. Record this number in the calculator in DataStudio.

2. Tare the Light Sensor

Note: For best results and to avoid measurement drift, tare the light sensor before scanning the spectrum and/or before each experiment run. To turn the light source on, click the **On** button in DataStudio's Signal Generator box.

- Rotate the light sensor arm until it hits the stop against the angle indicator on the spectrophotometer table.
- Block the light source by placing your hands between the collimating slits and the collimating lens.
- While the light is blocked, press the tare button on the light sensor to zero the sensor.

Procedures

A. Scanning a Spectrum

- Tare the light sensor (as described in the section above).
- Remove your hand to unblock the light and start recording data (Click the **Start** button in the DataStudio setup window) on the computer. Slowly rotate the light sensor arm through the spectrum.
- To determine the initial angle from the light source, continue to rotate the arm until the light sensor has passed through the white light that passes under the prism (i.e the degree plate has rotated past the zero degree mark).

4. Stop recording data. The initial angle (when the stop is against the angle indicator) is required to calculate the wavelength.
5. In DataStudio, make a graph of intensity vs. angular position. Measure the angle to the white light that passes directly through the spectrophotometer and under the prism. This angle is subtracted from all angles, so that all angles are referenced from the *reference line* (the parallel beams that travel in a straight line through the spectrophotometer).
6. Enter the initial angle as “Init” into the wavelength calculation in the DataStudio calculator.

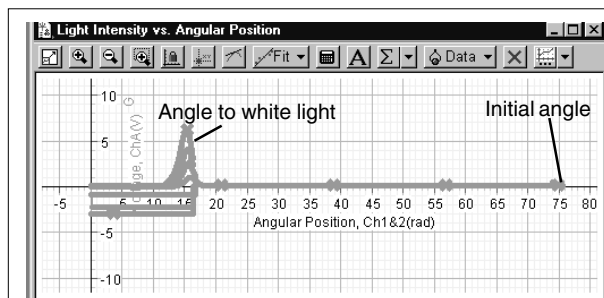


Figure 10: Measuring the Angle of the Refracted Light (Using DataStudio)

Experiment

A. Black Body Spectrum: Scanning Nested Curves from Black Bodies of Different Temperatures

Note: Before running the experiment, perform the rotary motion sensor calibration, as described in the “Calibration” section on page 9. Enter this calibration as “Ratio” into the DataStudio calculator, and click the **Accept** button.

1. Rotate the light sensor arm until it hits the stop against the angle indicator on the circular table.

Note: Before proceeding, the black body light source must be turned on and emitting light. If not, click the **On** button in DataStudio’s Signal Generator dialog box.

2. Block the light source by placing your hand between the collimating slits and the collimating lens. While the light is blocked, press the tare button on the light sensor to zero the sensor.
3. Remove your hand to unblock the light and start recording data on the computer. Click the **Start** button in the DataStudio setup window, and slowly rotate the light sensor arm through the spectrum.
4. After you have scanned through the spectrum, stop rotating the arm, continue recording and push the tare button again. Place your hand between the collimating slits and the collimating lens to block the light and return the light sensor arm to its original position against the stop. Blocking the light during this time causes the return scan to be below the axis of the graph, so it does not trace back over the black body data.
5.
 - a) Change the temperature of the bulb by changing the voltage applied to the bulb. You get temperature from current and voltage, as shown by

$$\text{Temp. (K)} = 300 + ((\text{voltage}/\text{current})/0.84 - 1/0.0045).$$
 - b) For each temperature, determine the maximum peak (λ_{max}) of the wavelength. Use the Wien displacement law, where $\lambda_{\text{max}} T = 2898 \mu\text{m} \cdot \text{K}$, to calculate the λ_{max} .

Experiment (Continued)

- Repeat steps 1 through 5 to get nested curves. On the last scan, continue the scan to the zero-degree mark so that you can obtain an exact determination of the initial angle. When you have finished all 5 runs, click the **Stop** button in Data Studio.

Note: To avoid measurement drift, you must tare the light sensor (steps 1 and 2) before each subsequent scan through the spectrum.

EXPERIMENT NOTES AND OBSERVATIONS:

(Use the following space to perform calculations and make note of your observations during the experiment.)

Data Collection and Analysis

When you are ready to scan the spectrum, click the **Start** button in the DataStudio setup window. Data Studio records the results and automatically performs the calculations for you. When you have finished collecting your data, click the **Stop** button and view your results in either a graph or a table. If necessary, you can view voltage, wavelength, angle and temperature data points all in the same run. To view individual data points in a table, doubleclick to open a table icon, click on a colored data run icon, and drag and drop the colored data run into the table. (For more information about data analysis using DataStudio, refer to the DataStudio online help guide.)

Sample Data

▲ Voltage, ChA Run #1		* wavelength Run #1		Angular Position, Ch1 & 2 Run #1		◆ temperature (K) Run #1	
Time (s)	Voltage (V)	Time (s)	Y	Time (s)	Angular Posi (rad)	Time (s)	Y
3.5600	0.007	3.5600	335.527	3.5600	0.009	3.5600	2770.774
3.5800	0.007	3.5800	335.527	3.5800	0.009	3.5800	2768.867
3.6000	0.008	3.6000	335.560	3.6000	0.013	3.6000	2769.620
3.6200	0.009	3.6200	335.560	3.6200	0.013	3.6200	2769.832
3.6400	0.009	3.6400	335.593	3.6400	0.017	3.6400	2767.526
3.6600	0.008	3.6600	335.625	3.6600	0.022	3.6600	2766.372
3.6800	0.007	3.6800	335.658	3.6800	0.026	3.6800	2767.137
3.7000	0.008	3.7000	335.724	3.7000	0.035	3.7000	2767.510
3.7200	0.009	3.7200	335.789	3.7200	0.044	3.7200	2767.143
3.7400	0.009	3.7400	335.953	3.7400	0.065	3.7400	2767.146
3.7600	0.009	3.7600	336.217	3.7600	0.100	3.7600	2767.705
3.7800	0.009	3.7800	336.515	3.7800	0.140	3.7800	2768.665
3.8000	0.009	3.8000	336.881	3.8000	0.188	3.8000	2767.705
3.8200	0.011	3.8200	337.249	3.8200	0.236	3.8200	2768.867
3.8400	0.012	3.8400	337.585	3.8400	0.279	3.8400	2769.620
3.8600	0.011	3.8600	337.821	3.8600	0.310	3.8600	2769.237
3.8800	0.011	3.8800	338.160	3.8800	0.353	3.8800	2768.863
3.9000	0.012	3.9000	338.433	3.9000	0.388	3.9000	2770.000
3.9200	0.012	3.9200	338.604	3.9200	0.410	3.9200	2769.825
3.9400	0.013	3.9400	338.878	3.9400	0.445	3.9400	2769.243

Teacher's Guide

Theory of the Black Body Experiment

An incandescent light source that emits light through a small cavity is a “perfect emitter.” By definition, a perfect light emitter is one that emits light rays throughout an infinite number of frequencies in the visible and invisible electromagnetic spectrum. When light from the black body is cast through a prism, the observed spectrum is continuous, and no overlapping of the spectral lines occurs.

In this experiment, parallel light rays travel through the collimating lens, which allows the light rays to remain parallel. Passing through the prism, the light rays refract and project in front of the aperture slit over the light sensor. The light sensor detects and records the light intensity as voltage.

Unlike other light sources, changes in light intensity from an incandescent black body is solely dependent on temperature. Increasing the temperature of the black body light source increases the light intensity. For any given temperature, there appears to be an optimal wavelength for reaching a maximum light intensity.

The angle of the emitted light depends upon the refraction index of the prism and the wavelength of the rays. Shorter wavelengths show more “bend” than longer wavelengths and therefore exhibit higher indices of refraction.

Notes:

1. See the Operational Notes section of this manual for important setup reminders.
2. Before beginning the experiment, have students do the following:
 - a) Set the collimating and aperture slits.
 - b) Check the position of the prism.
 - c) Ensure the cables from the rotary motion sensor are properly inserted into ScienceWorkshop.
 - d) Check to see that the black body light is turned on and is emitting steady light.

Students can turn the bulb on from the Signal Generator box in DataStudio. If the bulb does not turn on or emits intermittent bursts of light, see the Troubleshooting section of this manual.

Sample Data

Calibration:

Init Angle: 76.8 degrees (1.33 rads)

Ratio of plate to pin radius: 59.740

Procedure: Scanning a Spectrum

Spectrum Color	(deg)	θ (rads)	n	λ
Red	58	1.01	1.714	746
Yellow	59	1.03	1.717	705
Green	60	1.05	1.732	569
Blue	61	1.06	1.741	517
Violet	62	1.08	1.749	481

Teacher's Guide (Continued)

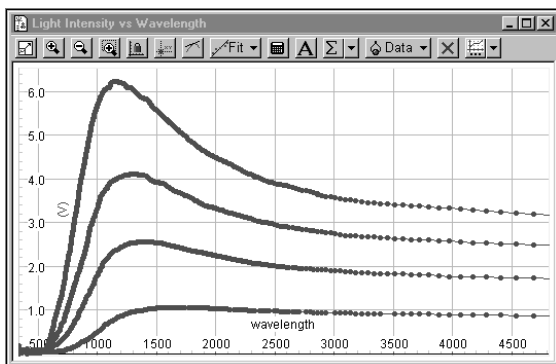
Activity 1: Black Body Temperatures

Data Run	Time (s)	Volts	ΔV	Temp. (K)	ΔT	λ	(rads)
1	12.06	1	1	2762.983	-----	661	12.9
	13.40	2	1	2764.252	2.269	741	13.6
	14.56	3	1	2764.464	0.212	803	14.0
	14.56	4	1	2766.554	2.090	862	14.3
	17.14	5	1	2767.513	0.959	933	14.7
	19.90	6	1	2771.716	4.203	1046	15.0

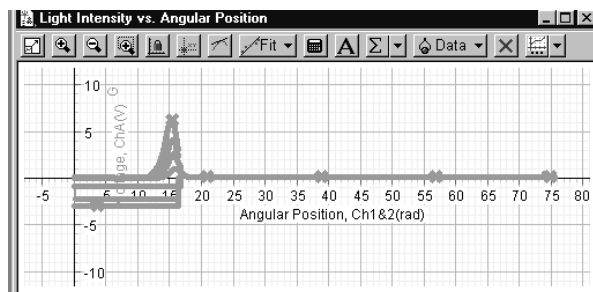
Black Body Experiment - Sample Graphs (Data Studio)

Note: The window appearances in the following graphs are subject to change with updated versions of the DataStudio software.

Light Intensity vs. Wavelength



Light Intensity vs. Angular Position



Questions/Exercise for Students:

- 1) How does changing the temperature of the bulb affect the wavelength or light intensity? Do you notice a pattern with increasing temperature?
- 2) From what you remember from the lesson on the grating spectrophotometer, what differences have you observed between using a prism and a grating?
- 3) On a piece of paper, draw a diagram showing the position of the reference angle, measured angle and spectral lines. Do the spectral lines converge or diverge? Do the light rays overlap?
- 4) What would happen if you removed the collimating lens?
- 5) What is the relationship between the light's angle, wavelength and intensity?
- 6) What differences do you notice between the black body and other types of light sources you have used?
- 7) Replace the infrared light sensor with the high sensitivity light sensor. What differences do you notice in the graph displays?

Teacher's Guide (Continued)

Answers to Questions from Page 14

- 1) The intensity of the light is related to the temperature of the bulb by $I \propto T^4$. The higher the bulb temperature, the higher the intensity that the light ray becomes. The peak wavelength is shifted to higher frequencies (and shorter wavelengths) at higher temperatures.
- 2) A prism spectrophotometer has two advantages over a grating spectrophotometer: a) it eliminates overlap of orders observed with a grating. (When a grating is used, second order visible wavelengths overlap first order infrared wavelengths.), and b) the spectrum is brighter because it does not spread over several orders or in both directions.
- 3) The spectral lines converge at a point in front of the light sensor. However, beyond the light sensor, light rays diverge. The light rays do not overlap.
- 4) The collimating lens allows the light rays to travel parallel to one another before passing through the prism. The parallel lines serve as a reference to compare to when measuring the angle of refraction.

If you remove the collimating lens, the waves will refract and reflect off of the various objects in the room before reaching the prism. These waves would bend at various angles, and would make it difficult to determine a reference line for the path of light travel through the prism. You would not be able to obtain an accurate measurement of the refracted angle.

- 5) The angle of a wave is directly related to its ability to refract. The larger the angle, the greater the “bend” or refraction, and the shorter the resulting wavelength. For any given temperature, there appears to be an optimal wavelength for reaching a maximum light intensity.
- 6) Unlike other light sources, changes in light intensity from an incandescent black body is solely dependent on temperature. The spectra of an incandescent light source are continuous and rainbow colored. Gas light sources display discrete spectra.
- 7) The graphs display waves between 400-700 nm because the high sensitivity light sensor detects light in the visible region of the electromagnetic spectrum. With the high sensitivity light sensor, you will not be able to observe waves of infrared light, which are typically greater than 750 nm and lie in the invisible region of the electromagnetic spectrum.

Troubleshooting

Problem: *The light sensor arm does not rotate throughout the full range of motion.*

Solution: Loosen the screw underneath the prism mount and/or the screws on the top of the degree plate. Check that the diameter of the screw is the proper fit. If not, use a different size screw.

Problem: *The angle readings on the graph display are negative.*

Solution: Check to ensure that you have properly inserted the colored cables into digital channels on the ScienceWorkshop interface box. (For instructions, see “Setup” in this manual).

Problem: *The stop on the light sensor arm does not touch the angle indicator.*

Solution: Loosen the wing nut from below the spectrophotometer table. If necessary, also loosen the thumb screws on the top of the degree plate.

Problem: *The graph does not display a voltage reading or voltage readings are negative.*

Solution: Check to ensure the following: a) The power amplifier is connected to the ScienceWorkshop interface. b) The banana plugs are properly inserted into the back side of the black body light source. c) The DIN connector extending from the black and red cables is properly inserted into channel B of the ScienceWorkshop interface. d) In DataStudio, the “on” button in the Signal Generator Box is depressed. (For more instructions, see “Setup” in this manual.) e) Ensure you have the signal set to DC voltage in the Signal Generator box in DataStudio. f) If steps a-e fail to correct the problem, you may have a faulty light sensor. To order a new light sensor, see the “Parts and Replacements” section of this manual.

Problem: *The black body light does not turn on.*

Solution: Check to ensure the following: a) The connections of the banana plugs tightly fit into the female connector holes on the back side of the black body b) The DIN connector extending from the red and black cables is properly inserted into the ScienceWorkshop interface c) In DataStudio, the “on” button in the Signal Generator box is depressed. If your connections are set properly and the bulb still does not turn on, replace the bulb.



To avoid the risk of burns or shock, do not try to replace the bulb while the light source is turned on. Before replacing the bulb, turn the power supply off, and click the Off button in DataStudio’s Signal Generator box.

Problem: *The black body emits pulsating, rather than steady light.*

Solution: In DataStudio, open the Signal Generator box window and change the setting to DC voltage. If the you already have the signal set to DC voltage, you may need to replace the bulb.

Problem: *The graph does not show a wavelength reading.*

Solution: Check to ensure that the aperture slit opening on the aperture slides directly over the hole on the back of the aperture bracket; otherwise light will not reach the sensor to record a reading. If necessary, you can adjust the gain of the signal using the gain switch on top of the infrared sensor.

Parts and Replacements

To order replacements, call 1-800-772-8700 (inside the U.S.A.) or (916) 786-3800 (outside the U.S.A.)

1. **Black Body Light Source** - A package of 10 replacement bulbs (526-040) comes included in the Prism Spectrophotometer Kit. To replace the bulb, loosen the two screws from the front face of the light source and remove the slotted cover. To order more bulbs, use part no. 012-07105.



To avoid the risk of burns or shock, do not try to replace the bulb while the light source is turned on. Before replacing the bulb, turn the power supply off, and click the Off button in DataStudio's Signal Generator box.

2. **Infrared Filters** - To order a replacement glass filter, use part no. 636-06912.
3. **Infrared Light Sensor** - In the event you have received a malfunctioning sensor, see the Warranty and Equipment Return section described in the front of this manual.

Notes

Technical Support

Feedback

If you have any comments about the product or manual, please let us know. If you have any suggestions on alternate experiments or find a problem in the manual, please tell us. PASCO appreciates any customer feedback. Your input helps us evaluate and improve our product.

To Reach PASCO

For technical support, call us at 1-800-772-8700 (toll-free within the U.S.) or (916) 786-3800.

fax: (916) 786-3292

e-mail: techsupp@pasco.com

web: www.pasco.com

Contacting Technical Support

Before you call the PASCO Technical Support staff, it would be helpful to prepare the following information:

- If your problem is with the PASCO apparatus, note:
 - Title and model number (usually listed on the label);
 - Approximate age of apparatus;
 - A detailed description of the problem/sequence of events (in case you can't call PASCO right away, you won't lose valuable data);
 - If possible, have the apparatus within reach when calling to facilitate description of individual parts.

- If your problem relates to the instruction manual, note:
 - Part number and revision (listed by month and year on the front cover);
 - Have the manual at hand to discuss your questions.



The exclamation point within an equilateral triangle is intended to alert the user of important operating and safety instructions that will help prevent damage to the equipment or injury to the user.