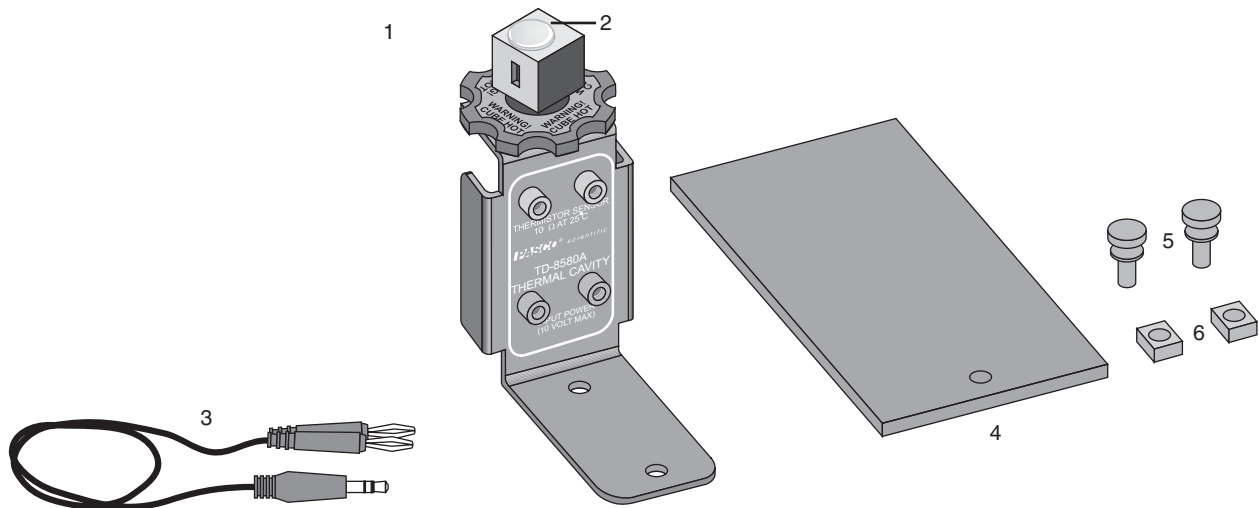


Thermal Cavity

TD-8580A



Included Equipment	Part Number
1. Thermal Cavity Assembly	TD-8580
2. Cavity Plug	699-122
3. Thermistor Cable	PS-2515
4. Base	ME-9205
5. Thumbscrews (qty. 2)	617-015
6. Square Nuts (qty. 2)	614-054
7. CD-ROM: Experiment Configuration Files for DataStudio	576-09345
Required Equipment ¹	
Power Supply, 10 V, 1 A	CI-6552A, PI-9877, SE- 9720a, SF-9584A, or similar
10 k Ω Thermistor-type Temperature Sensor or Resistance Meter	CI-6527A, PS-2125, or similar SE-9786A

¹See "Suggested Experiments" starting on page 3 for more information about the recommended equipment and additional equipment required for the experiments described in this manual.

Introduction

The TD-8580A Thermal Cavity can be used in studies of thermal radiation, the Stefan-Boltzmann law, and reflection and emission of light from different surfaces. The rotatable aluminum cube has a cavity and four different surface finishes: black, white, polished, and matte.

When powered by a stand-alone power supply or a Power Amplifier connected to a *ScienceWorkshop* interface, the built-in heating element can raise the temperature of the cube to 100 °C. A thermistor embedded in the cube allows the temperature to be measured with a PASPORT Temperature Sensor, a *ScienceWorkshop* Thermistor Sensor, or a resistance meter.

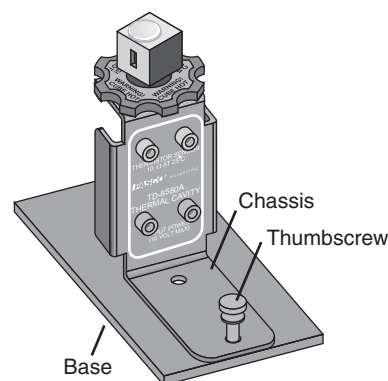
With an Infrared Sensor students can examine IR light emission from each of the cube's surfaces. The addition of a Light Sensor, Rotary Motion Sensor, Aperture Bracket, and Linear Translator allows students to scan the cavity and generate intensity versus position graphs for visible and infrared light.

The apparatus can be mounted on the included rectangular base or on a PASCO Basic Optics Bench.

Equipment Setup

Mounting on Included Base

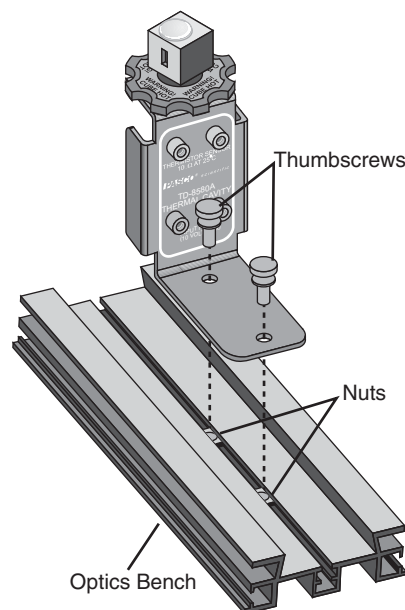
1. Place the apparatus upright with the chassis (horizontal support piece) on the base.
2. Align the outer hole in the chassis with the tapped hole in the base.
3. Insert a thumbscrew through the hole in the chassis and thread it into the base.



Mounting on an Optics Bench

Mount the apparatus on a Basic Optic Bench for use with a Linear Translator, Aperture Bracket, and other optics equipment.

1. Slide both nuts into the center slot of the optics bench.
2. Align the holes on the chassis of the Thermal Cavity apparatus with the nuts.
3. Insert the thumbscrews through the holes in the chassis and thread them loosely into the nuts.
4. Move the apparatus to the desired position on the optics bench.
5. Tighten the thumbscrews.



Thermistor Sensor Connection

Use the included cable to connect the white pair of jacks labeled “THERMISTOR SENSOR” to a *ScienceWorkshop* Thermistor Sensor, a PASPORT Temperature Sensor, or the temperature port of the Xplorer GLX interface.

You can also use a stand-alone resistance meter or multimeter to read the temperature. Measure the resistance between the white jacks and use the conversion formula on page 7 to calculate the temperature.

Power Supply Connection

The Thermal Cavity requires a power supply capable of 10 V and 1 A.

1. Use two banana patch cords to connect the power supply to the *red* pair of jacks labeled “INPUT POWER.”
2. Set the voltage as high as 10 V. The cube will reach 100 °C in about 30 minutes.

IMPORTANT: Do not apply voltage to the white thermistor jacks.

Safety



CAUTION: The cube can reach 100 °C (212 °F). Do not touch the cube while the apparatus is in use. Allow the apparatus to cool completely after use before handling. Do not apply more than 10 V to the apparatus. Always monitor the temperature when the apparatus is in use. Do not allow the cube to exceed 100 °C. This apparatus is intended for use by students only under instructor supervision.

Suggested Experiments

The configuration files called for in these activities can be found on the included CD-ROM. There are three folders, each containing different versions of the files. Refer to the table below to find the appropriate files for your equipment.

Equipment	Folder containing configuration files
PASPORT	<i>PASPORT</i>
<i>ScienceWorkshop</i> (without Power Amplifier)	<i>ScienceWorkshop</i>
<i>ScienceWorkshop</i> with Power Amplifier	<i>SW with Power Amp</i>

1. Infrared Light Intensity versus Temperature

In this experiment you will measure the IR intensity emitted by the cube as its temperature increases.

Required Equipment

Thermal Cavity	TD-8580A
For use with PASPORT	
Infrared Sensor	PS-2148
Temperature Sensor	PS-2125 or similar ¹
PASPORT interface or interfaces ²	See PASCO catalog or www.pasco.com
Power Supply, 10 V, 1 A	PI-9877, SE- 9720a, SF-9584A, or similar
For use with ScienceWorkshop	
Infrared Sensor	CI-6628
Thermistor Sensor (10 kΩ)	CI-6527A
<i>ScienceWorkshop</i> Interface	See PASCO catalog or www.pasco.com
Power Amplifier ³ or	CI-6552A
Power Supply, 10 V, 1 A	PI-9877, SE- 9720a, SF-9584A, or similar

¹Any PASPORT temperature sensor compatible with thermistor temperature probes can be used, including the Xplorer GLX's built-in temperature port.

²A multiple-port interface or combination of two single-port interfaces is required.

³The Power Amplifier requires a *ScienceWorkshop* 750 or 700 interface.

Setup

1. Mount the Thermal Cavity on the included base. Connect the Thermal Cavity to the Thermistor Sensor and power supply (but don't turn it on yet).
2. Connect both sensors to the interface (or interfaces).¹
3. Position the IR sensor on a stand or book so that its sensitive element is 2 cm from the black surface of the cube.

¹If you are using a *ScienceWorkshop* interface, connect the IR sensor to Channel A and the Thermistor sensor to Channel B; connect the Power Amplifier (if used) to Channel C; set the gain of the IR Sensor to 1.

4. Open the configuration file *IR_vs_Temp.ds*.

Procedure

Start with the cube below 40 °C.

1. Click Start.
2. Apply 10 V to the apparatus.

When the cube reaches 40 °C, data recording will automatically begin.

3. After the cube has reached 90 °C, click Stop. (If the cube reaches 100 °C, data recording will automatically stop.)
4. Turn off power to the apparatus.

Analysis

1. According to your data, how is measured IR intensity related to cube temperature?
2. The Stefan-Boltzmann law states that a surface's radiant intensity, I , is related to its absolute temperature, T , by

$$I = \epsilon \sigma T^4$$

where ϵ is the emissivity of the surface, and σ is the Stefan-Boltzmann constant. The measurement of I made by the IR sensor is proportional to the net power exchange, P_{net} , between the surface and the sensor. The net power is related to the surface's absolute temperature, T , and the sensor's own absolute temperature, T_0 , by

$$P_{\text{net}} = \epsilon k \sigma (T^4 - T_0^4)$$

where k is a constant related to the geometry of the surface and the sensor.²

Observe the graphs of I versus T and I versus T^4 . Does your data appear to support this relationship?

3. Repeat the experiment with the polished and white surfaces of the cube. How do the emissivities of the black, polished, and white surfaces compare?

$$\sigma = 5.670 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4$$

²The PASPORT IR sensor makes a direct measurement of T_0 , which you can use in your analysis.

2. Reflected Visible Light and Emitted Infrared Light

In this experiment you will measure the profile of visible light reflected by the cavity side of the cube and compare it to the profile of infrared light emitted by it.

Required Equipment

Thermal Cavity	TD-8580A
60 cm Optics Bench	OS-8541 or part of OS-8515A
Linear Translator	OS-8535
Aperture Bracket	OS-8534

For use with PASPORT

Light Sensor	PS-2106
Infrared Sensor	PS-2148
Temperature Sensor	PS-2125 or similar ¹
Rotary Motion Sensor	PS-2120
PASPORT Extension Cable ²	PS-2500
PASPORT interface or interfaces ³	See PASCO catalog or www.pasco.com
Power Supply, 10 V, 1 A	PI-9877, SE- 9720a, SF-9584A, or similar

For use with ScienceWorkshop

Light Sensor	CI-6504A
Infrared Sensor	CI-6628
Thermistor Sensor (10 k Ω)	CI-6527A
Rotary Motion Sensor	CI-6538
ScienceWorkshop Interface	See PASCO catalog or www.pasco.com
Power Amplifier ⁴ or	CI-6552A
Power Supply, 10 V, 1 A	PI-9877, SE- 9720a, SF-9584A, or similar

¹Any PASPORT temperature sensor compatible with thermistor temperature probes can be used, including the Xplorer GLX's built-in temperature port.

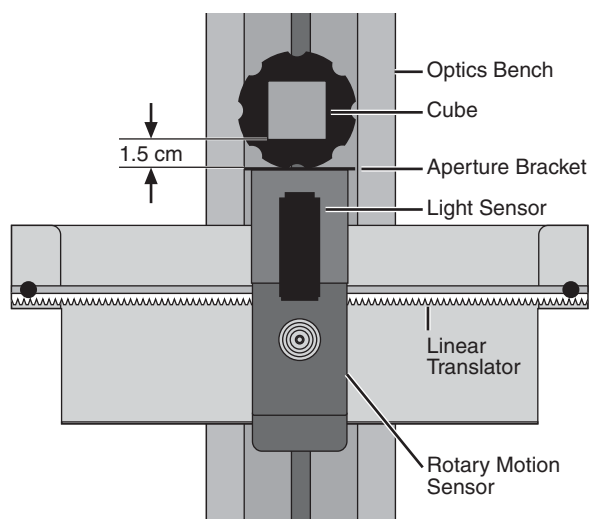
²Not required if the Light and IR sensors will be used with a USB Link.

³A multiple-port interface or combination of three single-port interfaces is required.

⁴The Power Amplifier requires a ScienceWorkshop 750 or 700 interface.

Setup

1. Mount the Thermal Cavity on the Optics Bench. Connect the thermistor sensor and power supply (but don't turn it on yet).
2. Mount the Linear Translator on the optics bench. Assemble the Linear Translator, Aperture Bracket, and Light Sensor (refer to the instructions accompanying the Linear Translator).
3. Arrange the apparatus so that the cavity side of the cube is about 1.5 cm from the front of the Aperture Bracket.
4. Turn the wheel on the Aperture Bracket to select aperture #6.
5. Open the configuration file *Reflected_and_Emitted_Light.ds*.



- Connect the Light, Thermistor, and Rotary Motion sensors to the interface (or interfaces).³ Leave the IR Sensor unconnected for now.
- In DataStudio, start data monitoring (open the Experiment menu and select Monitor Data). The measured cube temperature will appear in the digits display.
- Turn on the power supply and set the voltage to 10 V. When the cube temperature reaches about 80 °C, set the voltage to about 7 V. Allow the temperature to stabilize between 80 and 100 °C before proceeding.⁴

³If you are using a *ScienceWorkshop* interface, refer to the DataStudio configuration file for sensor gain settings and channel assignments.

⁴If you are using a Power Amplifier, the power turns on automatically whenever data is being monitored or recorded. The temperature is thermostatically set for 80 °C. Turn on data monitoring between data-recording runs to keep the cube hot.

Procedure

- Move the Light Sensor to one end of the Linear Translator.
- Click Stop to stop data monitoring, then Click Start to start data recording.
- Move the Light Sensor at a slow, steady pace across the Linear Translator to scan the cavity side of the cube. Click Stop.

Observe the graph of Visible Light Intensity versus Position. If necessary, delete the data⁵ and repeat this step to obtain a satisfactory graph.

- Remove the Light Sensor from the Aperture Bracket and replace it with the IR Sensor. Connect the IR Sensor to the interface.⁶
- Move the IR Sensor to one end of the Linear Translator.
- Click Start.
- Move the IR Sensor at a slow, steady pace across the Linear Translator to scan the cavity side of the cube. Click Stop.

Observe the graph of IR Light Intensity versus Position. If necessary, delete the data and repeat this step to obtain a satisfactory graph.

- Turn off power to the Thermal Cavity.

⁵Open the Experiment menu and select Delete Last Run.

⁶If you are using a Power Amplifier and a *ScienceWorkshop* interface, disconnect the Light Sensor from Channel A and replace it with the IR Sensor.

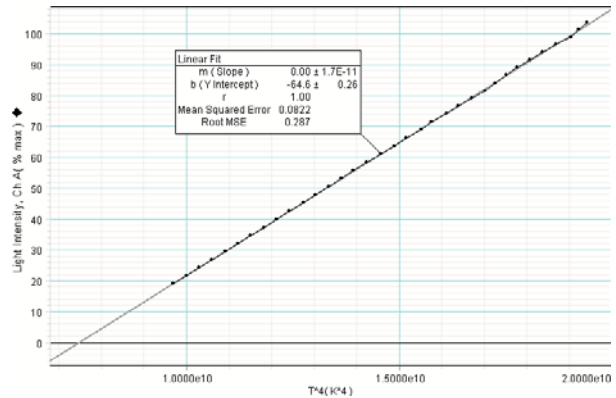
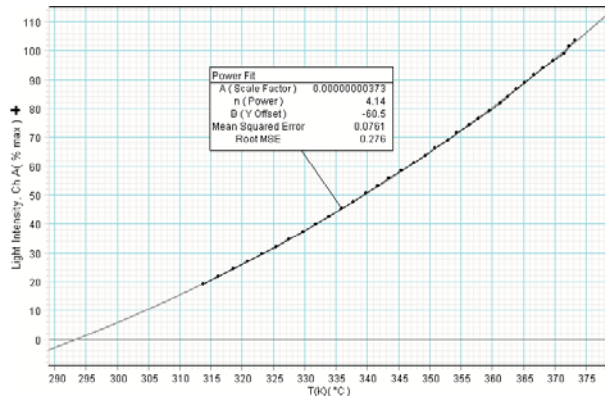
Analysis

- Compare the graphs of visible and IR light intensity. Which graph displays reflected light and which displays emitted radiation?
- When you look at the cavity, does it appear lighter or darker than the surrounding cube surface? How is the appearance of the cavity represented in the graph of visible light intensity?
- Allow the cube to cool to room temperature, then remove the cap from the top of the cube. Does the inner surface of the cavity appear lighter or darker than outer surface of the cube?
- In the infrared region of the spectrum, was the cavity brighter or darker than the cube surface?
- Compare the emitted radiation of the cavity and the cube surface. Which source of radiation has the higher emissivity?

Sample Data

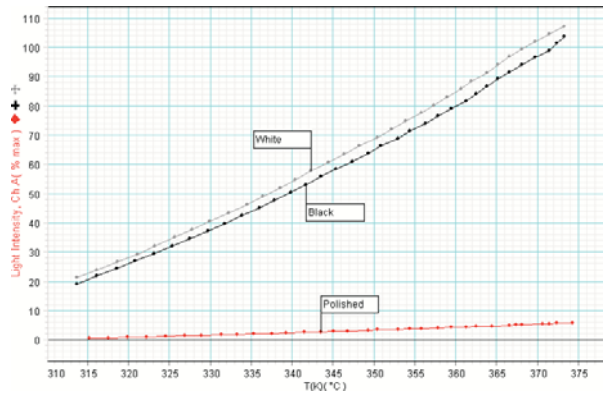
DataStudio files containing these data can be found on the included CD-ROM.

Infrared Light Intensity versus Temperature



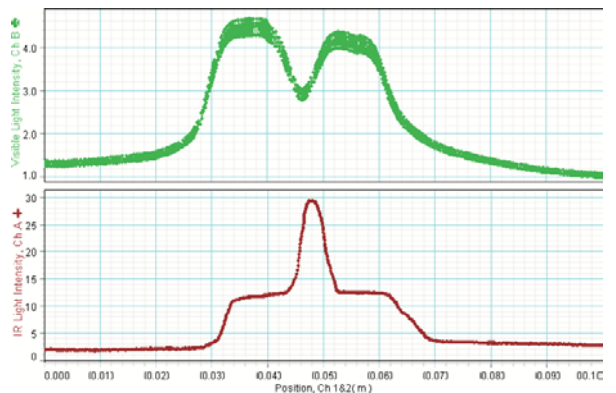
The graphs above show I versus T (above left) and I versus T^4 (above right) for the black surface. The curve fit applied to I versus T is $I = A \times T^n + B$; note that the curve intersects the horizontal axis at $T = 294 \text{ K} = 21^\circ \text{C}$, the approximate temperature of the sensor.

The graphs of I versus T for the different surfaces of the cube (right) show that the black and white surfaces have similar emissivities in the IR region of the spectrum, and the emissivity of the polished surface is much lower.



Reflected Visible Light and Emitted Infrared Light

These graphs show visible light intensity versus position (top right) and IR light intensity versus position (bottom right) at 92°C . In the visible region of the spectrum, the cavity is darker than the surrounding cube surface; in the IR region the cavity is brighter.



Resistance to Temperature Conversion

To find the temperature (T) measured in kelvin based on the resistance (R) of the embedded thermistor measured in $\text{k}\Omega$, use the formula:

$$\frac{1}{T} = A + B \cdot \ln\left(\frac{R}{10}\right) + C \cdot \left(\ln\frac{R}{10}\right)^2 + D \cdot \left(\ln\frac{R}{10}\right)^3$$

where $A = 3.35 \times 10^{-3}$, $B = 2.56 \times 10^{-4}$, $C = 2.38 \times 10^{-6}$, and $D = 8.37 \times 10^{-8}$.

Specifications

Power requirement	10 V, 1 A
Maximum input voltage	10 V
Heating resistor	10 Ω , 10 W max
Thermistor	10 k Ω at 25 °C
Maximum temperature	100 °C
Cube	Aluminum, 3 × 3 × 3 cm

Technical Support

For assistance with any PASCO product, contact PASCO at:

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

Phone: 916-786-3800 (worldwide)
800-772-8700 (U.S.)

Fax: (916) 786-3292

Web: www.pasco.com

Email: support@pasco.com

Limited Warranty

For a description of the product warranty, see the PASCO catalog.

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