

Thermal Radiation System

TD-8855A

Introduction

The Thermal Radiation System consists of three components: the Leslie's Cube (TD-8350); the Radiation Sensor (TD-8553); and the Stefan-Boltzmann Lamp (TD-8555).

Leslie's Cube

The Leslie's Cube (TD-8350) provides four different radiating surfaces that can be heated from room temperature to approximately 100 °C. The surface is uniformly heated by an embedded heater strip.

Heating the cube

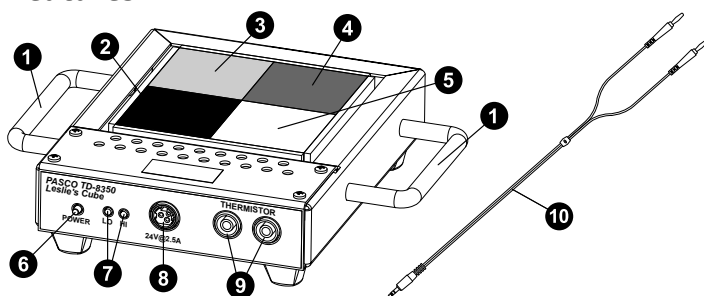
To heat the cube, first plug in the power cord, then press and hold the power button for one second. The device defaults to the higher temperature setting, which will be indicated by the **HI** LED illuminating. On this setting, the plate will heat up to 100 °C in about 20 minutes. If a lower temperature is desired, press the power button momentarily to switch to the low temperature setting. The **LO** LED will light up instead, and the plate will reach a final temperature of 70 °C in about 9 minutes.

Measuring temperature

To measure the plate temperature, plug the adapter cable into the banana plug connectors labeled THERMISTOR, then connect the 3.5 mm plug to a temperature sensor. Alternatively, you can plug an ohmmeter directly into the banana plug connectors labeled THERMISTOR. Using an ohmmeter requires converting ohms to degrees using Table 1. The thermistor is embedded in the aluminum plate.

CAUTION: Never touch the top surface of the Leslie's Cube, even if it is powered off and unplugged! The surface may remain hot for some time after being turned off. Use the handles to move the device.

Features



1 Handles

Use to move the device. **Never touch the top surface, as it may be very hot.**

2 Black surface

3 Polished silver surface

4 Silver surface

5 White surface

6 Power button

Push and hold button for one second to turn on power to the HI temperature setting. Push momentarily to switch to LO temperature setting. Push momentarily again to turn off power.

7 Temperature Indicator LEDs

The LED for the selected power level will blink green while heating up and turn solid green when the maximum temperature is reached. For the HI setting, this maximum is 100 °C. For the LO setting, this maximum is 70 °C.

8 Power adapter (24V @ 2.5A)

Connect to a standard wall outlet.

9 Thermistor banana jacks

Use to measure thermistor resistance, which can be converted to cube temperature via Table 1.

10 Adapter cable for PASCO temperature sensor

Plug the banana plugs into the thermistor banana jacks, then plug the 3.5 mm plug into a PASPORT Temperature Sensor (PS-2125) or Wireless Temperature Sensor Link (PS-3222) to measure the temperature directly.

Radiation Sensor

The Radiation Sensor (TD-8553) measures the relative intensities of incident thermal radiation. The sensing element, a miniature thermopile, produces a voltage proportional to the intensity of the radiation. The spectral response of the thermopile is essentially flat in the infrared region (from 0.5 to 40 μm), and the voltages produced range from the microvolt range up to around 100 millivolts (mV).

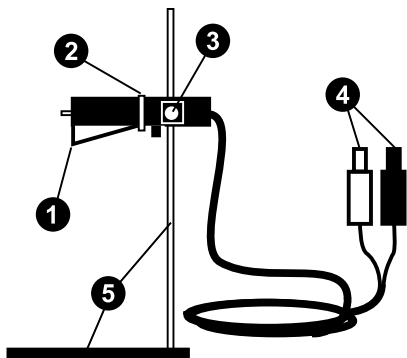
To read the voltage, connect the Radiation Sensor to a Voltage Sensor (UI-5100) or a PASPORT Galvanometer (PS-2160). A good millivoltmeter is also sufficient for most experiments.

The Radiation Sensor can be held in hand or mounted on its stand for more accurate positioning. A spring-clip shutter is opened and closed by sliding the shutter ring forward or back. During experiments, the shutter should be closed when measurements are not actively being taken. This helps reduce temperature shifts in the thermopile reference junction, which can cause the sensor response to drift.

NOTE: When opening and closing the shutter, you may inadvertently change the sensor position. For experiments where sensor position is critical, two small sheets of opaque insulating foam have been provided. Instead of closing the shutter, place this heat shield in front of the sensor when measurement is not actively being taken.

The two posts extending from the front end of the sensor protect the thermopile and provide a reference for positioning the sensor a repeatable distance from a radiation source.

Features



1 Shutter

2 Shutter ring

Slide forward to open shutter.

3 Thumbscrew

Loosen to reposition the Radiation Sensor, or to remove the sensor from the stand.

4 Banana connectors

Use to connect the sensor to a millivoltmeter, or to a voltage sensor using an adapter cable.

5 Mounting rod and base

6 2× insulating foam boards (not pictured)

Stefan-Boltzmann Lamp

The Stefan-Boltzmann Lamp (TD-8555) is a high temperature source of thermal radiation. The lamp can be used for high temperature investigations of the Stefan-Boltzmann Law. The high temperature simplifies the analysis because the fourth power of the ambient temperature is negligibly small compared to the fourth power of the high temperature lamp filament. When properly oriented, the filament also provides a good approximation to a point source of thermal radiation. It therefore works well for investigations into the inverse square law.

By adjusting the power into the lamp (13 V max, 2 A min, 3 A max), filament temperatures up to approximately 3,000 °C can be obtained. The filament temperature is determined by carefully measuring the voltage and current into the lamp. The voltage divided by the current gives the resistance of the filament, which can in turn be used to find temperature using Table 2.

⚠ IMPORTANT: The voltage into the lamp **should NEVER** exceed 13 V. Higher voltages will burn out the filament.

For small temperature changes, the temperature of the tungsten filament can be accurately calculated using the following equation:

$$T = \frac{R - R_{\text{ref}}}{\alpha R_{\text{ref}}} T_{\text{ref}}$$

where:

- T = filament temperature
- R = filament resistance at temperature T
- T_{ref} = reference temperature (usually room temperature)
- R_{ref} = resistance at temperature T_{ref}
- α = temperature coefficient of resistivity for the filament (has a value of $4.5 \times 10^{-3} \text{ K}^{-1}$ for tungsten)

For large temperature differences, however, α is not constant and the previous equation is not always accurate. Therefore, **for large temperature differences**, determine the temperature of the filament using the following procedure:

1. Accurately measure the resistance R_{ref} of the tungsten filament at room temperature (about 300 K). Accuracy is important here, as a small error in R_{ref} will cause a large error in your result for the filament temperature.
2. When the filament is hot, measure the voltage and current into the filament, then divide the voltage by the current to obtain the resistance R_T .
3. Divide R_T by R_{ref} to obtain the relative resistance (R_T/R_{ref}).
4. Using your measured value for the relative resistance of the filament, as well as Table 2 on the following page or the associated graph in Figure 1, determine the temperature T .

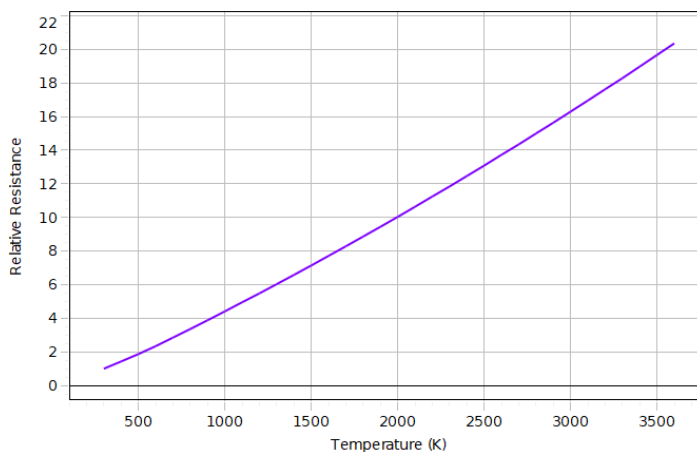
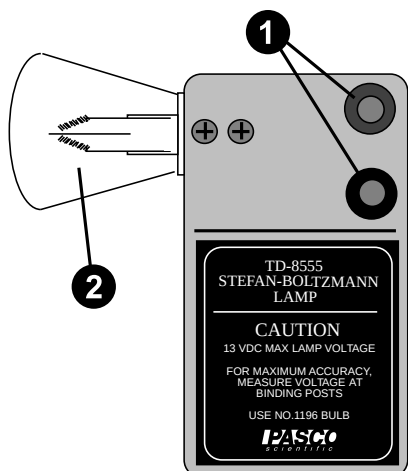


Figure 1: Relative resistance (R_T/R_{ref}) versus temperature for tungsten.

Features



1 Banana connectors

Use banana plug cables to connect the lamp to a power supply.
13 V max, 2 A min, 3 A max.

2 Bulb

Can produce temperatures of up to about 3,000 °C.

Required equipment:

- Power supply capable of providing 13 V @ 3 A max

Replacement parts:

- GE Lamp No. 1196, available at most auto parts stores

 **NOTE:** When replacing the bulb, the leads should be soldered to minimize resistance.

Software help

The SPARKvue, PASCO Capstone, and Chemvue Help provide information on how to use this product with the software. You can access the help from within the software or online.

SPARKvue

Software: Main Menu  > Help

Online: help.pasco.com/sparkvue

PASCO Capstone

Software: Help > PASCO Capstone Help

Online: help.pasco.com/capstone

Experiment files

Download one of several student-ready activities from the PASCO Experiment Library. Experiments include student handouts and teacher notes. Visit pasco.com/freelabs/TD-8855A.

Technical support

Need more help? Our knowledgeable and friendly Technical Support staff is ready to answer your questions or walk you through any issues.

-  Chat pasco.com
-  Phone 1-800-772-8700 x1004 (USA)
+1 916 462 8384 (outside USA)
-  Email support@pasco.com

Limited warranty

For a description of the product warranty, see the Warranty and Returns page at www.pasco.com/legal.

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Product end-of-life disposal



This electronic product is subject to disposal and recycling regulations that vary by country and region. It is your responsibility to recycle your electronic equipment per your local environmental laws and regulations to ensure that it will be recycled in a manner that protects human health and the environment. To find out where you can drop off your waste equipment for recycling, please contact your local waste recycle or disposal service, or the place where you purchased the product. The European Union WEEE (Waste Electronic and Electrical Equipment) symbol on the product or its packaging indicates that this product must not be disposed of in a standard waste container.

CE statement

This device has been tested and found to comply with the essential requirements and other relevant provisions of the applicable EU Directives.

FCC statement

This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions:

- (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Appendix: Resistance tables

Table 1: Thermistor resistance vs. temperature for the Thermal Radiation Cube.

Therm. Res. (Ω)	Temp. ($^{\circ}\text{C}$)	Therm. Res. (Ω)	Temp. ($^{\circ}\text{C}$)	Therm. Res. (Ω)	Temp. ($^{\circ}\text{C}$)	Therm. Res. (Ω)	Temp. ($^{\circ}\text{C}$)
55,142	-10	13,676	18	4,204	46	1,531	74
52,235	-9	13,068	19	4,045	47	1,480	75
49,499	-8	12,491	20	3,892	48	1,432	76
46,924	-7	11,941	21	3,745	49	1,386	77
44,500	-6	11,418	22	3,601	50	1,341	78
42,215	-5	10,921	23	3,471	51	1,298	79
40,057	-4	10,450	24	3,342	52	1,256	80
38,025	-3	10,000	25	3,219	53	1,216	81
36,107	-2	9,572	26	3,101	54	1,178	82
34,298	-1	9,166	27	2,988	55	1,141	83
32,590	0	8,778	28	2,880	56	1,105	84
30,974	1	8,409	29	2,776	57	1,071	85
29,448	2	8,058	30	2,677	58	1,038	86
28,007	3	7,724	31	2,580	59	1,006	87
26,645	4	7,405	32	2,489	60	975	88
25,357	5	7,100	33	2,401	61	945	89
24,138	6	6,810	34	2,317	62	917	90
22,984	7	6,534	35	2,236	63	889	91
21,892	8	6,271	36	2,158	64	862	92
20,858	9	6,019	37	2,084	65	837	93
19,880	10	5,778	38	2,012	66	812	94
18,953	11	5,549	39	1,942	67	788	95
18,074	12	5,329	40	1,877	68	765	96
17,242	13	5,120	41	1,814	69	742	97
16,452	14	4,920	42	1,753	70	721	98
15,704	15	4,729	43	1,694	71	700	99
14,992	16	4,546	44	1,637	72	680	100
14,317	17	4,371	45	1,583	73		

Table 2: Relative resistance, temperature, and resistivity for tungsten.

R_T/R_{ref}	Temperature (K)	Resistivity ($\mu\Omega \text{ cm}$)
1.0	300	5.65
1.43	400	8.06
1.87	500	10.56
2.34	600	13.23
2.85	700	16.09
3.36	800	19.00
3.88	900	21.94
4.41	1000	24.93
4.95	1100	27.94
5.48	1200	30.98
6.03	1300	34.08
6.58	1400	37.19
7.14	1500	40.36
7.71	1600	43.55
8.28	1700	46.78
8.86	1800	50.05
9.44	1900	53.35
10.03	2000	56.67
10.63	2100	60.06
11.24	2200	63.48
11.84	2300	66.91
12.46	2400	70.39
13.08	2500	73.91
13.72	2600	77.49
14.34	2700	81.04
14.99	2800	84.70
15.63	2900	88.33
16.29	3000	92.04
16.95	3100	95.76
17.62	3200	99.54
18.28	3300	103.3
18.97	3400	107.2
19.66	3500	111.1
20.35	3600	115.0