11/24/2023

General Physics Lab

Radiation Experiment

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Purpose

The purpose of the experiment was to observe the thermal radiation phenomenon from the body and check heat radiation law by using thermal radiation measurement from the thermal radiation cube. Thermal radiation is the process by which energy, in the form of electromagnetic radiation, is emitted by a heated surface in all directions and travels directly to its point of absorption at the speed of light; thermal radiation does not require an intervening medium to carry it.

Introduction

1. Heat radiation:

An object has temperature which is above the absolute zero and it emits thermal radiation from its surface. The characteristic of this radiation is depending upon temperature of the body and its surface properties. Study of such object shows that the thermal radiation emitted by the body is nothing but electromagnetic radiation consists of a continuous distribution of the wavelength. As the temperature of the body increases it becomes red hot i.e., it emits light of wavelength of red colour.

The flux of the radiation released by an object is calculated by the Stefan-Boltzmann law which is stated as; the rate at which an object radiates energy is proportional to the fourth power of its absolute temperature. And it is given as,

$$R = \frac{P}{A} = e\sigma T^4$$

Whereupon is power in watts radiated from the surface, e is the emissivity, σ =5.67×10^8 W/m^2 .K^4 is the Boltzmann constant, A is the surface area of the object in m^2 , and T is surface temperature in Kelvin.

Materials/methods

Apparatus:

Thermal Radiation Cube (with Black side, white side, Polished aluminium side and Dull aluminium side) which is low temperature radiation object, Stefan-Boltzmann Lamp which is high temperature radiation object, Radiation Sensor, Thermometer, Ohmmeter, Millivoltmeter, Multimeter, Meter Stick.

Note:

1. The cube is heated by a 100-watt light bulb, it may be very hot, be careful.
2. To avoid heating of sensor, when remove the reflecting heat shield and read the data, as fast as possible.
3. When remove the reflecting heat shield you must put it back after read the data. If not, you should wait the sensor cooling to room temperature, and then you can continue with the experiment.
4. Take care that the position of the sensor with respect to the cube is the same for all measurements.

Procedure:

A. Stefan-Boltzmann Law (low temperature):

1. Set up the equipment as shown in Figure 2. The Radiation sensor should be pointed directly at the centre of the black surface. Ohmmeter is used to measure the temperature of the thermal radiation cube. Millivoltmeter is used to voltage by the radiation sensor.
2. With the Thermal Radiation Cube power off, measure the resistance of the thermistor r0 at room temperature T0 and record it.
3. Shield the sensor from the cube using the reflecting heat shield with the reflective side of the shield facing the cube.
4. Turn on the Radiation Cube and set the power switch to ‘10’. When the thermistor resistance indicated that the temperature is about 100 C above room temperature, turn the power down so the temperature is changing slowly. And remove the reflecting heat shield. Read and record the ohmmeter reading as r and the millivolt meter reading as v. The readings should be taken as nearly as possible and simultaneously too, while briefly removing the heat shield. When you will finish the experiment, put the reflecting heat shield back as fast as possible

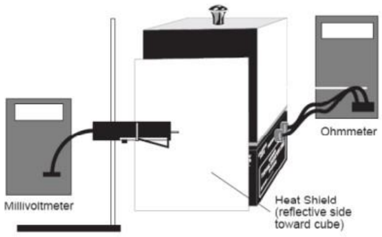


Figure 2 Equipment Setup

5. When the temperature has raised an additional 10℃, repeat the measurement of step 4 until the temperature of the radiation cube is around 1200

C. Take care that the position of the sensor with respect to the cube is the same for all measurements.

6. Using V as the y-axis and T^4-T0^4 as the x-axis, draw the graph, where T is in Kelvin (see Table 1) and is defined by the resistance. Then find out the slope of the line.

7. Turn on the Radiation Cube and set the power switch to ‘5’. When the cube reaches thermal equilibrium, the resistance of the thermistor is almost stable. Measure the radiation flux of each surface of the radiation Cube. Take care that the position of the sensor with respect to the cube is the same for all measurements.

8. According to the step 7, assuming the radiation flux of the black surface is similar to blackbody. Calculate the emissivity e of each surface of the radiation Cube.

B. Stefan-Boltzmann Law (high temperature):

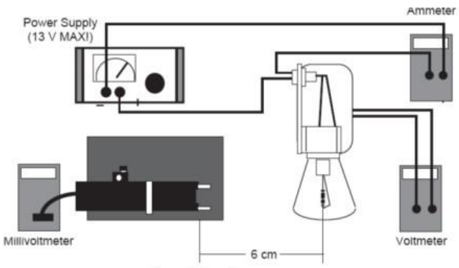


Figure 3 Equipment setup.

1. Set up the equipment as shown in Figure 3. Using the filament of Stefan-Boltzmann Lamp as the radiation object. During high temperature, the resistance r of the filament is equal to voltage divided by the current. Note: Adjust the height of the Radiation Sensor so that it is at the same height as the filament with the front face of the sensor approximately 6 cm away from the filament. Make sure that the entrance angle of the thermopile should include no “CLOSE” objects other than the lamp.
2. Before turning on the lamp, measure T0, the room temperature and the resistance of the filament r0 of the Stefan-Boltzmann Lamp.
3. Put the reflecting heat shield between the lamp and the sensor, the reflecting surface toward to the lamp. Turn on the power supply. Set the voltage of the filament to 1V according to the voltage meter. 4. Remove the reflecting heat shield, and record the ammeter reading (current) as I and the reading on the millivolt meter as V. Then, put the reflecting heat shield back as fast as possible.
5. Increase the voltage each time for 1V and no more than 12V. Repeat the step 4, and record the ammeter reading (current) as I and the reading on the millivolt meter as V.
6. Using V as the y-axis and T^4-T0^4as the x-axis to draw the graph, where T is in Kelvin (see Table 2) and is defined by the resistance. Then find out the slope of the line.

C. Inverse Square Law:

1. Set up the equipment as shown in Figure 3. Adjust the height of the radiation sensor such that it is at the same level as the filament of the Stefan-Boltzmann Lamp. The zero point of the meter stick should align with the centre of the lamp filament.

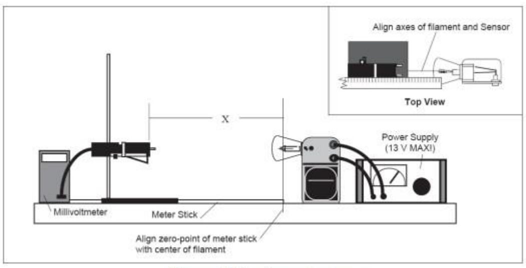


Figure 3 Equipment setup

2. Put the reflecting heat shield between the lamp and the sensor, the reflecting surface toward to the lamp. Turn on the power supply. Set the voltage of the filament to 10V.
3. Remove the reflecting heat shield, and record the ammeter reading (current) as I and the reading on the millivolt meter as V. Then, put the reflecting heat shield back as fast as possible.
4. Change the distance X between sensor and filament, for each time change 5cm no more than 50cm, and repeat the step 2.
5. Draw the graph by your experiment data and using voltage V to be the y-axis and distance X to be the x-axis.
6. Draw another graph by your experiment data and using voltage V to be the y-axis and the inverse square of the distance 1/X2 to be the x-axis.

D. Specific heat of liquid:

1. Set up the equipment as shown in Figure 4.
2. Take large containers filled with room temperature water, and insert a thermometer which scale is 50oC.
3. Measure the mass of two empty copper tubes A & B and marked as MA and MB. Tube A put into water and tube B put into the liquid you want test. Then measure the mass again, you can get the mass of water mA and the mass of the unknown liquid mB.
4. Measure the liquid volume when the thermometer immersed in liquid by Archimedes Method.
5. In both containers, insert one thermometer and put in the hot water. Heated the hot water to 500C.

(Note: The temperature can't over 50, otherwise it will break the thermometer)

When it reaches to the thermal equilibrium take them out of hot water and put into a large container which was filled with water. And record the initial temperature of the two tubes.

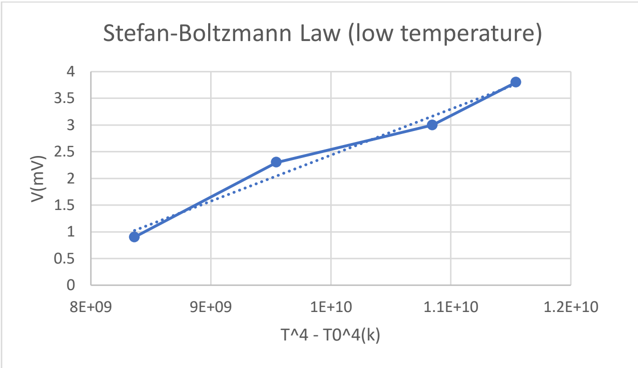
Figure 4 Equipment setup

6. Record the time and the temperature every 2 minutes until the temperature decrease to around 150C. Draw the graph between temperature vs. time, and then you can get the cooling curve.
7. Select the appropriate temperature range of ΔT, and find out the cooling time ΔtA and ΔtB from the curve. Calculate the specific heat of the liquid by the formula (*).
8. Choose more than two temperature difference ΔT, and repeat step 7. Find out the average value and standard deviation of the specific heat.

Results

Experiment 1

Low Temp						
	R(kΩ)	V(mV)	T(°C)	T(K)	T^4 - T0^4(k)	
	26.7	3.8	56	329.15	11543617695	
	32	3	51	324.15	10846504311	
	48	2.3	41	314.15	9545882241	
	75	0.9	31	304.15	8363708439	
0(T0)	118	0	X		0	

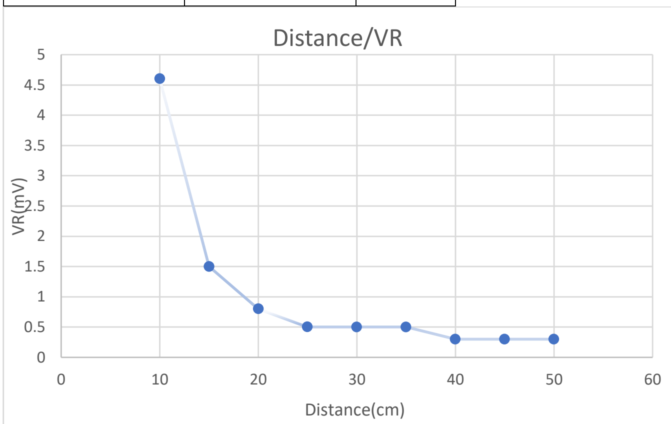


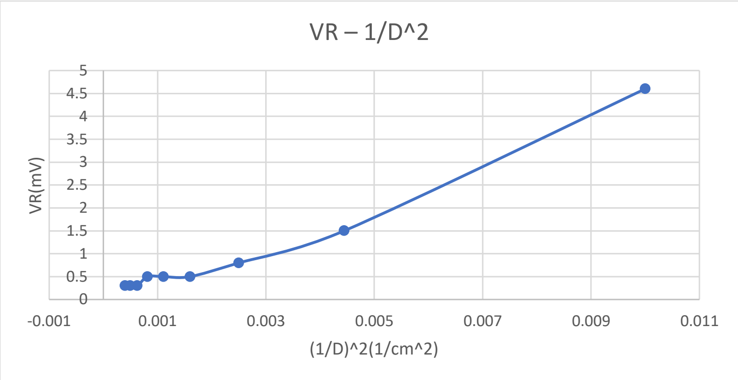
Experiment 2(high temp)

High Temp								
Vin(V)	Volt(V)	I(A)	R(Ω)	VR(mV)	R/R30∘	T(K)	T^4 - T0^4(k)	
0	x	x	0.8	x				
1	0.11	0.07	1.571429	0.2	0.509090909		-193877776	
2	1.42	0.28	5.071429	0.3	1	300	8100000000	
3	2.76	0.36	7.666667	0.5	3.227272727	410.5383734	28406323534	
4	3.71	0.4	9.275	0.8	4.878787879	479.9003322	52846206121	
5	4.52	0.43	10.51163	1.1	5.902272727	539.7299325	84860583921	
6	5.32	0.48	11.08333	1.5	6.689217759	576.4458465	1.10417E+11	
7	6.68	0.53	12.60377	2.21	7.053030303	624.4092614	1.52012E+11	
8	7.76	0.57	13.61404	2.1	8.02058319	673.1899408	2.05376E+11	
9	8.29	0.58	14.2931	3.1	8.663476874	706.516925	2.49167E+11	
10	9.7	0.63	15.39683	4.1	9.095611285	749.9037999	3.16244E+11	

Inverse Square Law

Inverse Square Law		
Distance(cm)	(1/D)^2(1/cm^2)	VR(mV)
10	0.01	4.6
15	0.004444444	1.5
20	0.0025	0.8
25	0.0016	0.5
30	0.001111111	0.5
35	0.000816327	0.5
40	0.000625	0.3
45	0.000493827	0.3
50	0.0004	0.3





Experiment 4(emission)

EMISSION	mv
black	3.6
white	3.6
right	0.1
left	1.6

Commented [SD1]:

Discussion

As we increase the voltage applied the temperature should also be increased gradually by 10 degrees up until 120 degrees. The voltage (mV) is directly proportional to T^4-To^4(k). The linearity of this graph indicates that the Stefan Boltzmann equation is correct, even at low temperatures. The graph should be straight, with some statistical variations

Any other thermal source in the room would influence the results, including the warm body of the experimenter and the room itself. These introduce some error, but it is small as long as the temperature of the lamp is high compared to the temperature of these other sources. This inaccuracy in the low temperature points is due to absorption of the infrared by the glass lamp bulb. (See experiment 1) This absorption is more significant at the lower temperatures, where the infrared makes up a larger percentage of the entire output.

The graph of radiation versus 1/x2 is more linear, but not over the entire range. There is a distinct falloff in intensity at the nearer distances, due to the non-point characteristics of the lamp. (A graph of radiation versus 1/x2 using only data points from 10cm or more is nearly linear.) If we use data from distances that are large compared to the size of the lamp filament—so that the filament is effectively a "point"—then this data supports the hypothesis. The Stefan-Boltzmann Lamp is not truly a point source. If it were not, then there would be a falloff in light level for measurements taken close to the lamp. This falloff can be seen in our data.

Conclusion

The investigation into thermal radiation phenomena and heat radiation laws using the thermal radiation cube revealed notable insights. The experiment, while extensive, acknowledged the potential for errors, attributing them to the prolonged duration. The results demonstrated the expected relationship between voltage and temperature, validating the Stefan-Boltzmann equation even at lower temperatures. External factors, such as infrared absorption by the lamp bulb, contributed to slight inaccuracies, emphasizing the need for meticulous experimental conditions. The findings supported the hypothesis that the Stefan-Boltzmann Lamp, while not a perfect point source, exhibited characteristic falloffs in intensity at closer distances. Despite potential errors, the experiment provided valuable data for understanding thermal radiation, contributing to the broader body of knowledge in this field.

Reference

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