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Develop a Black Body and Analyze its Emission characteristic w.r.t. Temperature variation

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Abstract – *A blackbody is a fundamental concept in thermodynamic and radiation. A perfect model of blackbody is characterized by emissivity =1 which is difficult to be obtained. A blackbody is an object that absorb electromagnetic radiation totally regardless of its direction and wavelength. The blackbody has also ability to emit the energy thus it is considered as a perfect radiator. There are laws of radiation which require emissivity characteristics of a body which is measured with respect to a perfect black body. But in order to validate these laws; developing and constructing a black body is a key thing. The main purpose of this paper is to develop an experimental setup an approximate blackbody to analyze emissivity characteristics and to validate laws of radiation.*

Key Words: **Blackbody Radiation, Emissivity, Heat Transfer, Thermodynamics, Radiation, Experimental setup**

1.INTRODUCTION

The revolutionary thinking that started at the beginning of the twentieth century was centered around the concept of Blackbody whose experimental implications could not be explained by the theories then in use now called classic mechanics. Eventually the results from the blackbody led to the development of quantum mechanics and brought the geniuses of Einstein, Planck, and others to the spotlight of modern physics. Experimental setups of blackbodies have been extensively studied in the last hundred years by numerous groups and its modern applications are vast, ranging from measurements of star surface temperatures up to radiometer calibrators.

Currently, blackbodies are typically used for calibration purposes of imagining and sensing instruments such as infrared thermometers, metrology, spectrographs, and other industrial processes. Although much experimental work has been carried out with blackbodies, most modern physicists and physics students do not ever step in front of a tangible blackbody. This is due in great part to the fact that they are difficult to design and build, and are operated at high temperatures. The term blackbody refers to a hypothetic object that completely absorbs all wavelengths of electromagnetic radiation incident to it. Such a body does not reflect light, and therefore appears black if its temperature is low enough so as not to be self- luminous. When the blackbody is heated to a given temperature it emits radiation at all wavelengths. For a blackbody, both the emissivity and absorptivity are unity. Hence, for validating every law of radiation; blackbody setup plays very important role. Designing and developing a blackbody is very difficult task in which analyzing the emissivity characteristics with temperature variation is main objective. So, we are designing a setup of a spherical body which is used as a blackbody. This setup is very useful for the various experiments used to validate laws of radiation, analyzing emissivity characteristics, etc. this setup can also be useful for students to understand concepts like radiation transfer and behavior of blackbody.

2. DEVELOPMENT OF BLACKBODY

2.1 Construction of Blackbody

Developing a blackbody setup is actually creating physical conditions like orientation, shape, size and selection of coating material which together can be suitable to act as a blackbody. The setup consists of two spheres of different dimensions, one sphere of diameter 100 mm with thickness of 2 mm and another hollow sphere having diameter 200 mm and thickness 5 mm. second sphere of bigger diameter encloses the smaller diameter sphere inside it. Both the spheres are acting as a blackbody for the calculation of emissivity characteristics.

Table -1: Specifications

Component	Specifications
Inner Sphere	Diameter – 104 mm
Outer Sphere	Diameter – 210 mm
Clamp Heater	250 Watt
Air Heater	1000 Watt

The selection of sphere as a shape of the body is highly feasible for the radiation heat transfer on the basis of 'View factor' [View factor is the fraction of the radiation leaving surface 1 that strikes surface 2 directly]. In a setup that

consists of two concentric spheres, the view factorF1 → 2 is equal to 1 since the entire radiation leaving the surface of the smaller sphere will be intercepted by the larger sphere. the inner sphere consist of a heater and outer sphere is heated by the means of air heater which is in the chamber in which the spheres are located.

Fig -1: Inner and outer sphere as a Blackbody

Both the spheres used are made up of copper, copper is the good conductor of heat and also thermal diffusivity of the copper is good which is an essential property required for this setup. the outer sphere is made as two hemispherical halves which are later joined with the bolts. Both spheres are manufactured using hammering manually by gradually giving shape of curvature required for sphere. As copper is ductile material and easy to deform hence for a given thickness of outer sphere it was suitable.

The coating on the inner surface of the outer sphere is supposed to act as a blackbody. Hence, to meet the requirements of the ideal blackbody i.e. Absorptivity and emissivity should be approximately 1; coating material is selected accordingly. '**Heat Resistant Black Matte Finish Paint'** is used for coating material. It has emissivity and absorptivity as around of 0.95 and also it can sustain the temperature around 750 degree Celsius.

There are other measuring and controlling instruments mounted on the setup like Thermocouple (K- Type), Temperature Indicators (12 Channels) and Dimmer stat (2000W for both heaters).

2.2 Validation of Emissivity

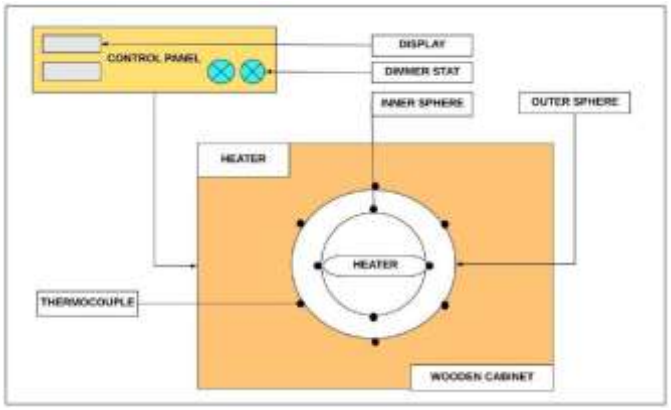

Fig -2: Schematic of Setup

The emissivity of the material used for coating is known but, in this setup, the coating is applied on the copper surface. For the better results and as there is radiation involved, there is vacuum maintained between two spheres. Hence, for the validation of heat transfer laws there is need to calculate the actual emissivity of coating, the process used is as follows,

First the outer sphere is heated and maintained to a steady state temperature (T_o).

$$\mathbf{Mo \times C \times (\Delta T \text{ in time } t) = \varepsilon \times \sigma \times T_0^{\,4} \times Ac \times (t)}$$

$\Delta T = T_{final} - T_{initial}$
$T_{initial}$ – Temperature at start of time 't'.
T_{final} – Temperature after time 't'.
Mo – mass of inner sphere
C – Heat required to raise the temperature of Copper per unit mass by 1°C
ε – Emissivity of blackbody
Ac – curved surface area of surface

'$\boldsymbol{\varepsilon}$' can be found here

3. RESULTS

Table -2: Result table for Emissivity

Temperatures (Celsius)	Emissivity ($\boldsymbol{\varepsilon}$)
60	0.84
65	0.85
70	0.86

3. CONCLUSION

This setup is an attempt to develop a body which will act as a blackbody i.e. the body should have emissivity and absorptivity near to 1. In this attempt a blackbody is developed considering all the factors like size, shape, orientation and materials. Hence, blackbody developed in this setup can give around 0.85 value of emissivity and absorptivity. There are some errors due to which the results are affected because of human errors in measurement, possibility of poor vacuum and environmental conditions etc. This setup is very useful in validating all the laws of heat transfer as in every heat transfer experiment blackbody plays an important role.

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