THE DESIGN AND CONSTRUCTION OF A BOLOMETER

BY

TWIZERIMANA JULLIET

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A PROJECT PROPOSAL TO BE SUBMITTED TO THE DEPARTMENT OF PHYSICS IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD

OF THE DEGREE OF BACHELOR OF SCIENCE WITH EDUCATION

AT KABALE UNIVERSITY

NOVEMBR, 2020

I.

DECLARATION

I, JULLIET TWIZERIMANA declare that this is my original work and that from the best of my knowledge, this work has not been submitted anywhere, in any other University for an award or any academic purposes.

Signature ..-~-

Date:18/11/2020.

APPROVAL:

This project report on "THE DESIGNAND CONSTRUCTION OF A BOLOMETER will be

done under my supervision to be submitted to the department of physics with my approval as the student's

supervisor.

Name: **MR. HABAKWIHA VIANNEY**

Signature ……………………………………………………

Date 18/11/2020 ……………………………………………………

Acknowledgements:

1firstly thank the Almighty God for his love and protection. In this regard therefore. I would like to acknowledge the assistance both material and moral support received from individuals who contributed towards the completion of this project.

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Dedication:

dedicate this work to my parents: My Dad Mr. Late Haba Peter. My Mom Mrs. Haba SIi4 and Mr. Nyiringeri Julius.

Contents

ABSTRACT

This project on the design and construction of a bolometer is conducted in October *2020* at Kabale University in Kabale district, Southwestern Uganda.

A blackened platinum strip of a zigzag form as the heat sensitive element will be connected in a Wheatstone bridge with different resistors and a galvanometer will be used for the study aimed at investigating the effect of thermal /heat radiation on the resistance of the platinum strip or the bolometer. Galvanometer readings will be obtained and recorded.

CHAPTER ONE

INTRODUCTION

study

The first bolometer was invented by an American scientist Samuel P Langley in 1880 and they consisted of two steel, platinum or palladium foil strips covered with lampblack. One strip as shielded from radiation and one exposed to it. The strips formed two branches of a Wheatstone bridge which was fitted with a sensitive galvanometer which produced a deflection proportional to the intensity of radiation for small radiations, and connected to a battery. Electromagnetic radiation falling on the exposed strip would heat it and change its resistance.

In 1840, Sir John Herschel, son of William performed the first image of thermal radiation when focusing solar radiation with a lens into a suspension of carbon particles in alcohol The application of the tendency of electrical conductors to increase their electrical resistance with rising temperature was first described by Sir William Siemens at the Bakerian lecture or 1871 before the royal society of Great Britain. The necessary methods of construction were established by calendar, Griffiths, holborn and Wein between 1885 and 1900

A bolometer is a device used for detecting and measuring the heat and radiation of microwave energy by means of the rise in temperature of a blackened metal strip in one of the arms of a resistance bridge.

It uses the temperature sensitive resistive element whose resistance change with the temperature.

The thermistor and barrater are the examples of commonly used resistive elements and platinum strip is used as a sensitive element.

The term heat refers to a form of energy in a system as a result of the increase in temperature (Hotness or Coldness of the body) of the system. It is also a measure of the total kinetic energy of a particular body which is measured in joules (J). It can be transferred from a higher temperature to a lower temperature in three ways which include Radiation, Convection. and Conduction and in most cases through direct burning. A bolometer which is going to be designed and constructed will therefore be used in the heat and radiation detection in the learning and teaching of these three ways of heat transfer.

According to Uganda's technology today, the manufacturing of bolometers for heat radiation detection has not been started. The measurement of heat radiation is done but using the already made heat detectors like bolometers, thermocouples, thermopiles and others which are mainly imported from abroad. Because of this, the teaching and learning process of heat radiations in Uganda is more theoretical than practical which gives a difficulty to learners in the learning of heat radiation detection.

1.2 Statement of the problem

According to education sector in Uganda and in other countries, it is revealed that science subjects like physics are being poorly done and perceived to be difficult. It is wondered whether it is because of poor teaching methods based on theories rather than practical. It is therefore based on this that the researcher is going to design and construct a bolometer which wi II be used as a teaching material in areas like heat radiation such that it becomes more of practical for better physics results.

1.3. Objectives of the Project

1.3.1 The main objective of this project is to design and construct a bolometer.

1.3.2 Specific objectives of the study

I. To design and construct a bolometer
2. To enhance teaching and learning of radiation by using the bolometer as a teaching aid
3. To acquire more improvisational skills

1.4. Scope of the study

The scope of the study on design and construction of a bolometer will cover the content scope and time scope.

1.4.1 Content scope

This will involve exposing a blackened strip of platinum wire to radiation source. Ihe temperature of the wire will increase which also increase the resistance of the platinum wire. thus the galvanometer deflection.

1.4.2 Time Scope

The study will take six months for comprehensive and satisfactory information for the researcher to finish up the project successfully

1.5. Significance of the study

The study on the design and construction ofa heat sensor will be of immense benefit to the entire institution, the department, the students and other researchers who wish to carry out similar research on the above stated topic as the findings of the research work will educate people on how a bolometer detects heat radiations. The study finally will contribute to the existing I iterature review on the design and construction of a bolometer

CHAPTER TWO

J.

LITERATURE REVIEW

2.1. Bolometers

A bolometer is a very sensitive heat sensor whose electrical resistance varies with temperature and which is used in the detection and measurement of feeble thermal radiation.

Bolometer is a detector built from a material (sensing element) having a large temperature coefficient of electrical resistance. Absorption of radiation produce temperature change which gives rise to a change in electrical resistance. According to sensing element. the bolometers are classified as thermistor bolometers, semiconductor bolometers. and superconductor bolometers.

In the thermistor bolometer, as the sensing element is used as blackened thin layer of metal. whose electrical resistance varies with changes in temperature/ depends to a large extent on temperature of the heat radiation source. The working principle of a thermistor is that its resistance depends on its temperature and the relationship between a thermistor's temperature and resistance is nonlinear.

Sensitivity of a bolometer can be improved by using semiconductor or superconductor materials.

In general, semiconductor bolometers operate at cryogenic temperatures. i.e. under 4 K increased temperature is the sum of the heat sink temperature *TO* and the surface temperature of sensing element of bolometer Ti.e. AT = Ta+ T.

Usually the surface of sensing element of bolometer is covered with a black layer. in order to absorb as much as possible the incident radiation. The thermal mass of the detector should be small to increase sensitivity and to reduce its thermal time constant.

Bolometers are the best choice in modern astronomy for detection of electromagnetic radiation at wavelengths between 200 µm and 3 mm. They are directly sensitive to the energy left inside the absorber. from this reason, they can be used for not only for ionizing particles and photons but also for non-ionizing particles, any sort of radiation. and even to search for unknown forms of mass or energy (dark matter).on the other hand compared to more conventional particle detectors, they are extremely efficient in energy resolution and in sensitivity.

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K.

2.2. Theory of bolometers

Every object radiates if its temperature is above absolute zero. This means that all real objects radiate. This radiation includes the spectrum of infrared waves (0.77-1000 m). and if the radiant source temperature is quite high (above I 000 K), then a part of the emitted energy includes also visible light spectrum (0.39-0.77 m). To detect heat radiation we use Photo detectors. Photo detectors are optoelectronic devices that convert incident radiation, directly or indirectly. into equivalent electrical signals, and they are classified into two major classes: photon detectors and thermal detectors.

Operation principle of a bolometer

A bolometer consists of an absorptive element, such as a thin layer of metal connected to a thermal reservoir through a thermal link. The result is that any radiation impinging on the absorptive element raises its temperature above that of the reservoir due to absorption of the radiation by the sensing element. The intrinsic thermal time constant, which sets the speed of the sensor, is equal to the ratio of the heat capacity of the absorptive element to the thermal conductance between the absorptive element and the reservoir. The temperature change can be measured directly with an attached resistance thermometer, or the resistance of the absorptive element can be used as a thermometer. They are produced from thin foils or metal films, and they usually work without cooling.

The metallic element bolometer has a positive temperature coefficient of resistance (resistance increases when temperature increases).the term temperature coefficient of resistance an in [K'] is defined. The electrical resistance of a bolometer varies with temperature as R (G)= R(lanl)

Where *Ro* is the strip resistance of sensing element when *AT* = 0 and a is the temperature coefficient of resistance. In metals *a* is positive, while in semiconductors it is negative. Raising the temperature of sensing element, as a result of the incident radiation, can be expressed by the
following relation:

$$C + G(T-T_O) = I^2R_O + \Phi^b{}_c + \eta\Delta\Phi_c$$

where: *C*- thermal capacity of the element; G -average thermal conductance from element to the heat sink at initial temperature To; Ta- detector temperature; I-bias current; <l>b c- background radiant energy; ~<l>c - signal radiant energy; *n*- emissivity; To- initial temperature of the detector and the temperature of the heat sink.

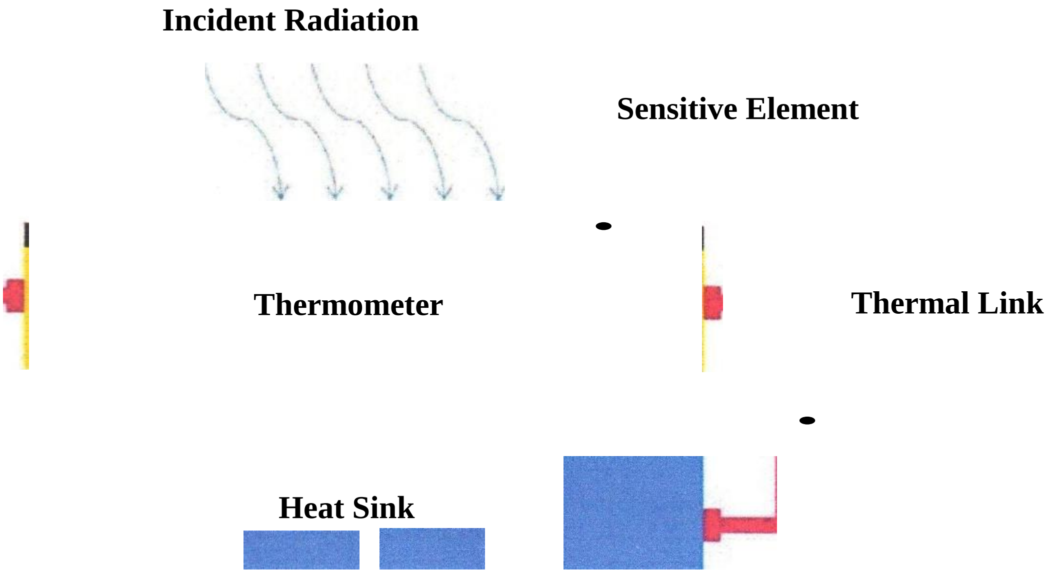

Figure 1

In Figure 1 is presenting a simple bolometer model. It consists of a bolometer weakly coupled to a heat sink by a thermal link. The bolometer is composed of an absorber attached to a thermistor of resistance *R* and at a temperature T To, where To is the heat sink temperature, which, in generally, is referred to as the stage temperature.

Heat equation for the bolometer

The resistance R (T) of the bolometer is a function of the temperature T, which for metals and semiconductors can be described by R (T)= Rs where *a* is a constant that depends on the material of the bolometer, and Rs is the resistance of the bolometer at the substrate temperature Ts.

The temperature of the bolometer as a function of time (and the incoming IR radiation) can be described by the heat equation, the Stefan-Boltzmann law and the Joule heating law

C= +e(P+ P- 2A,oT)-G (T-Ts)

ta

T(0)= Ts

Here V(t) is the input voltage, "e is the material specific emissivity of the bolometer. Pis the radiation power from the scene, Ps is the radiation power from the substrate. 2As is the total surface area of the bolometer (upside and downside). _ is the Boltzmann constant. and G is thermal conductivity of the supporting legs. The term VA(t-=R(T) is the power resulting from Joule heating, that is the power induced by the bias voltage over the bolometer. and 2Aso-T 4 represents the radiation power emitted from the bolometer according to Stefan-Boltzmann's law. The latter also relates P, to the target temperature T of a scene object.

In bolometers, absorbed energy of the incident radiation increases the temperature of detector. which in turn causes the change of some temperature-dependent parameter. e.g. electrical
conductivity (resistivity),

Bolometer is a detector built from a material (sensing element) having a large temperature coefficient of electrical resistance

2.3. The working principle of a Wheatstone bridge

A Wheatstone bridge was invented by Samuel hunter Christie 111 1833. but it was later popularized by Sir Charles Wheatstone in 1843.

A Wheatstone bridge also known as the resistance bridge is used to calculate the unknown resistances by balancing the two arms of the bridge circuit of which one arm includes the component of unknown resistance.

The circuit consists of a galvanometer, two known resistors, one unknown resistor. one variable resistor and an electromotive force source (the battery) connected in the form of a bridge.

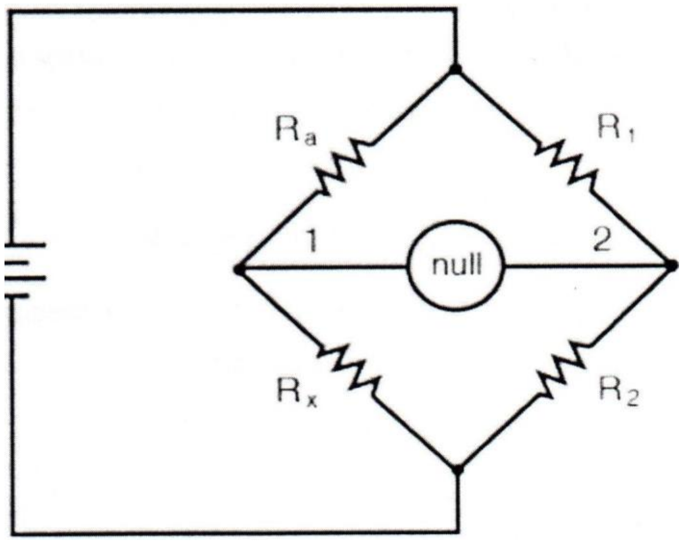

Figure 2

Bridge circuit is balanced when R/R,=RI/R>

The Wheatstone bridge works on the principle of **null** deflection that is the ratio of their resistances is equal and no current flows through the circuit.

The bridge is said to be in unbalanced condition when there is galvanometer deflection which implies that there is some current passing through **it** and the bridge is said to be in balanced condition when there is no galvanometer deflection implying that no current is flowing through the galvanometer, that is the galvanometer is center zero. This condition can be achieved by adjusting the known and the variable resistors.

2.4. Applications of bolometers

Some of the major applications of bolometers include. in thermal cameras. in particle detectors. detection of forest fire, air surveillance , in fingerprint scanners, astronomical applications. and detection of concealed weapons (journal of applied physics 76(1). 1-24. 1994)

2.5. Examples of bolometers

Langley bolometer. This was the first bolometer to be invented and it consists of two steel platinum or palladium foil strips covered with lampblack. One strip was shielded from radiation while one exposed to it. The strips formed two branches of a Wheatstone bridge which was titted with a sensitive galvanometer and connected to the battery. Electromagnetic radiation falling on the exposed strip would heat it and change its resistance. (S.P. Langley, nature 25. (14 (1981) .Google scholars.

Hot electron bolometer.

This operates at cryogenic (low) temperatures, typically within a few degrees of absolute zero. At these very low temperatures, the electron system in a metal is weakly coupled to the phonon system.

Thermistor or thermal resistor: Is the resistor whose electrical resistance varies with changes in temperature. The working principle of a thermistor is that its resistance depends on its temperature and the relationship between a thermistor's temperature and resistance is nonlinear.

There are two types of thermistors i.e. Negative temperature coefficient whose resistance decreases with increase in temperature and the positive temperature coefficient whose resistance increases with increase in temperature.

Pyrometer. This is a type of remote sensing thermometer used to measure temperature of distant objects or higher temperatures like the temperature of a furnace. It has both optical and detector systems and is based on the principle that the intensity of light received by the observer depends on the distance of the observer from the source and the temperature of the distant source.

Radiometer is a device for measuring radiant flux (power) of electromagnetic radiation. It is generally an infrared radiation detector which operates in microwave wavelengths. Journal of applied physics (76 (1), 1-24, 1994)

Infrared bolometers. These consist of an energy absorbing material connected to a thermometer with a weak thermal connection to a constant temperature heat sink.

Other examples include cryogenic bolometer, thermocouple, scintillating bolometer. micro bolometers, pryheliometer, tasimeter etc

Johnston, Hamish (5october 2020) new microwave bolometer could boost quantum computers. Archived from original on (8 October 2020)

CHAPTER THREE

METHODS AND MATERIALS

3.1. Introduction

This chapter will present and describe the materials and methods/procedures the researcher will use to design and construct a heat sensor.

3.2. Materials

Resistors to reduce current flow

Galvanometer to test the device by measuring current flowing through the circuit

A blackened platinum wire to act as a bolometer in the gaps of a Wheatstone bridge

A Wheatstone bridge to calculate the unknown resistance by balancing two arms of the ridge circuit

Batteries/Dry cells to produce current for the circuit

3.3. Methods

A blackened strip of platinum wire of a zigzag form as the heat sensitive element will he connected to the gaps of a Wheatstone bridge with two different resistors of different resistances and a rheostat.

The batteries will then be connected to the Wheatstone bridge to complete the circuit. The rheostat will be adjusted until the galvanometer shows zero deflection.

The sensing element will be exposed to the radiation source.

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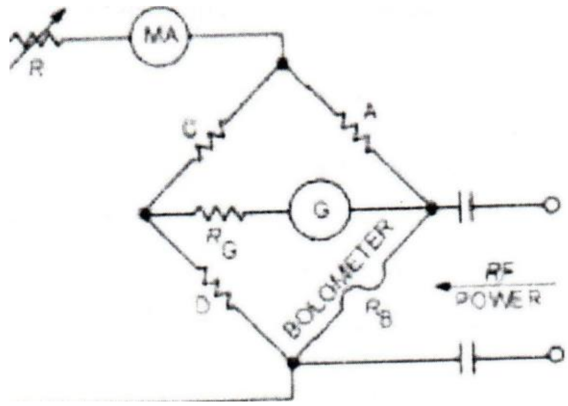
3.4. Schematic representation of a bolometer



CHAPTER FOUR.

RESULTS AND DISCUSSION

This mainly consist of the results obtained while designing and testing the bolometer. explanation of the procedure used and how the methods and materials can improved.

4.1. Results

when the blackened strip of platinum wire of zigzag form was exposed to heat source/ to heat radiation produced by the power supplier, the galvanometer showed zero deflection showing balance and when resistor one(r I) set to 45ohmns.resistor two(r2) set to 35ohms and the rheostat adjusted, the milliammeter readings started rising continuously.

Analysis of the results. The strip of platinum of about 4em was made in a zigzag form and blackened for good absorption of incident radiations and emission by the sensitive element. Two batteries of 3.0 v were used to produce measurable and sufficient current for the circuit.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.0. Conclusion

Considering all the procedures and the available materials, i conclude that a simple bolometer which can be used as a teaching aid on heat radiation for the betterment of physics was designed.

5.1. Recommendations

I highly recommend that a similar research can be carried out over a long period of time.

Other wires like Nichrome having the same form, and length and a power supply instead of batteries could be used in the future projects to improve on the current flow through the circuit.

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