Gokhale Memorial Girls' College

To whom it may concern

Subject: Completion of PHSA students of Semester III in 2021-22

The undersigned hereby certifies that the students mentioned in the table given below have completed their Scientific Writing Projects for the University of Calcutta B.A/B.Sc. Semester-III Examination, 2021 in SEC-A1 Course of Physics Honours. These students are mentioned in the modified template of Metric 1.3.2 (for DVV compliance) as PHSA with pdf link of their projects stated alongside.

SL.NO.	REGISTRATION NO.	COLLEGE ROLL NO.	NAME	SUBJECT
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2	013-1211-0233-20	20/BSCH/0104	Anwesha Das	PHSA
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Principal
Gokhale Memorial Girls' College

013/1801064693/0001 0130385

UNIVERSITY OF CALCUTTA
ADMIT

B.Sc. SEMESTER - III (HONOURS) Examination-2021
(UNDER CBCS)

Name of the Candidate :
VARSHA SUBBA

Father's/Guardian's Name :
SANAM SUBBA

Roll & No. :
203013-11-0092

Registration No.
013-1213-0232-20

Subjects Enrolled :
PHSA,MTMG

Name of the College :
GOKHALE MEMORIAL GIRLS' COLLEGE

SCHEDULE FOR EXAMINATION IN THEORETICAL PAPERS **

Examination Day & Date		Examination Starting Time	Subject Code ++	Course Code	Course Name	Number of Answer book(s) to be used	Signature of the invigilator on receipt of the answer script/s @
Saturday	15-01-2022	10 A.M.	PHSA	CC5	MATHEMATICAL PHYSICS - II	1	
Sunday	16-01-2022	10 A.M.	PHSA	CC6	THERMAL PHYSICS	1	
Monday	17-01-2022	10 A.M.	PHSA	CC7	MODERN PHYSICS	1	
Tuesday	18-01-2022	10 A.M.	PHSA	SEC-A1	SCIENTIFIC WRITING	1	
Friday	21-01-2022	2 P.M.	MTMG	GE3	MATHEMATICS-CC3/GE3	1	

Signature of the Principal/TIC/OIC of the College with Seal

Controller of Examinations (Actg.)

**** Subject to unavoidable changes**
++ In no circumstances subject/s to be altered

N.B. Please follow University Notification No. CE/ADM/18/229 Dated 04/12/2018 in www.cuexam.net for instruction of Examinee/Invigilator/Examination centre.

SEC A 1 PROJECT

"Verification of Stefan's Law of radiation by the measurement of Voltage and Current of a torch bulb by glowing it beyond the draper point."

NAME: VARSHA SUBBA
COLLEGE ROLL NO: 20/BSCH/0003
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UNIVERSITY ROLL NO: 203013-11-0092
EXAMINATION NAME: B.SC.SEMESTER III(HONOURS) PRACTICALEXAMINATION(CU),2021.

Contents

0.1 INTRODUCTION

Stefan-Boltzmann Law states that the total radiant heat power emitted from a surface is proportional to the fourth power of its absolute temperature.

Formulated in 1879 by Austrian physicist Joseph Stefan as a result of his experimental studies, the same law was derived in 1884 by Austrian physicist Ludwig Boltzmann from thermodynamic considerations, if E is the radiant heat energy emitted from a unit area in one second (that is, the power from a unit area) and T is the absolute temperature (in kelvins), then $E = \sigma T^4$, the Greek letter sigma (σ) representing the constant of proportionality, called the Stefan-Boltzmann constant. This constant has the value $5.670374419 * 10^{-8}$ watt per metre square per K^4.

The law applies only to black-bodies, theoretical surfaces that absorb all incident heat radiation.

0.2 THEORY: *To estimate the temperature of a torch bulb filament from resistance measurement and to verify Stefan's law*

The resistance of a torch bulb filament may be assumed to vary within the operating range of temperatures according to the equation,

$$R_t = R_0(1 + \alpha t + \beta t^2) \tag{1}$$

where R_t and R_0 are the resistances at $t^\circ C$ and $0^\circ C$ respectively, α and β are the temperature coefficients of resistance. If R_d is the resistance of the filament at the Draper point t_d at which the filament just starts showing a dull red glow, we can write,

$$\frac{R_t}{R_d} = \frac{1 + \alpha t + \beta t^2}{1 + \alpha t_d + \beta t_d^2} \tag{2}$$

For a tungsten filament $\alpha = 5.21 * 10^{-3 \circ}C^{-2}$, $\beta = 7.2 * 10^{-7 \circ}C^{-2}$ and the Draper point $t_d = 527^\circ C$. Hence putting these values of α, β, and t_d in equation(2) we can calculate R_t/R_d for different values of t in the usual operating range of temperatures of a torch bulb filament. Now we can draw a calibration curve by plotting R_t/R_d as a function of the absolute of the absolute temperature $T = t + 273$.

Resistance of the filament is measured by using the relation $R = V/I$ where I is the current through the filament and V is the voltage across it. In this way measuring R_t/R_d experimentally the corresponding temperature of the torch bulb filament can be found from the calibration curve.

According to Stefan's Law if a black body at absolute temperature T is surrounded by another black body at temperature T_0, the net amount of heat radiated per sec per unit area from the first body is

$$P = \alpha(T^4 - T_0^4) \tag{3}$$

where α is known as Stefan's constant.

In case of a torch bulb filament $T >> T_0$. Moreover, the filament cannot be taken as a black body. Thus we can approximately write,

$$p \approx AT^n \tag{4}$$

or,

$$log_{10}P = log_{10}A + nlog_{10}T \tag{5}$$

where A is some constant depending on the material and area of the filament and the power n is expected to be slightly different from 4.

The power P radiated by the filament is given by P = VI and the temperature T is obtained by resistance measurement as before.

Thus if the Stefan's Law [Eq.3] is valid, the graph between $log_{10}P$ and $log_{10}T$ must be a straight line of slope n.

0.3 APPARATUS: *Circuit Diagram*

(i) A tungsten filament torch bulb (6V, 6W),

(ii) A 6V dc supply,

(iii) A rheostat (100Ω, 1A),

(iv) A dc voltmeter (0-10V),

(v) A dc ammeter (0-1A).

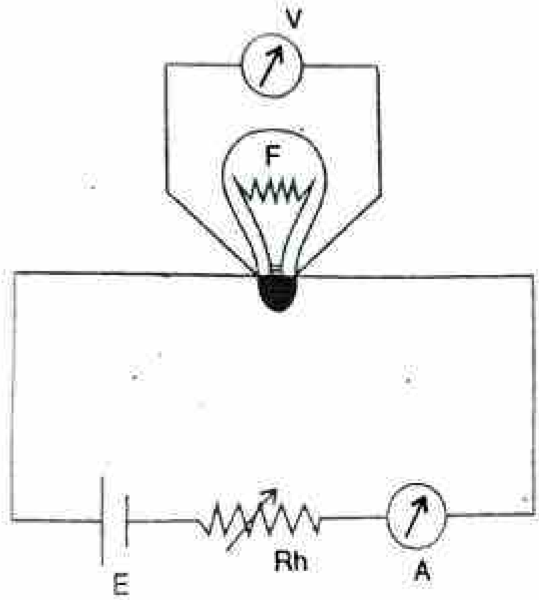

Figure 1: Circuit diagram

0.4 PROCEDURE

(1) Using $\alpha = 5.21 * 10^{-3} {}^\circ C^{-1}$, $\beta = 7.2 * 10^{-7} {}^\circ C^{-2}$ for tungsten and the Draper point $t_d = 527°C$ calculate R_t/R_d from equation(2) for several t in the range $100°C$ to $2500°C$. Draw a calibration curve by plotting R_t/R_d as a function of the absolute temperature $T = t + 273$. The curve comes out to be of the form as shown in Fig 2 (graph 1).

(2) Take a 6V, 6W tungsten filament torch bulb. Solder two wires directly to each of the base points of the bulb. Now make the circuit connections as shown in Fig 1.

(3) Keeping the resistance in the rheostat high, switch on the circuit. This time the bulb does not glow. Now slowly increase the current by adjusting the rheostat until the filament just shows a dull red glow (Draper point). Measure corresponding current I and voltage V and calculate $R_d = V/I$. Go to slightly higher current and then reduce it till the glow just ceases. Measure corresponding I and V and again calculate R_d. Repeat the whole operation a few times with increasing and decreasing currents and find mean R_d.

(4) Now increase the filament current I in small steps (say, 20 mA) from a value corresponding to the glow stage (Draper point) upto a current high enough to make the filament dazzling white. At each step note I and V and calculate power $P = VI$ and the resistance $R_t = V/I$. Compute $R - t/R_d$ and find the corresponding temperature T from the calibration curve of Fig 2 (graph 1).

(5) Draw a graph by plotting $log_{10}T$ along x-axis and $log_{10}P$ along y-axis (Fig 3, graph 2). Find the slope AB/AC of this curve in the high T region. This gives n.

0.5 GRAPHS

0.5.1 Graph 1:

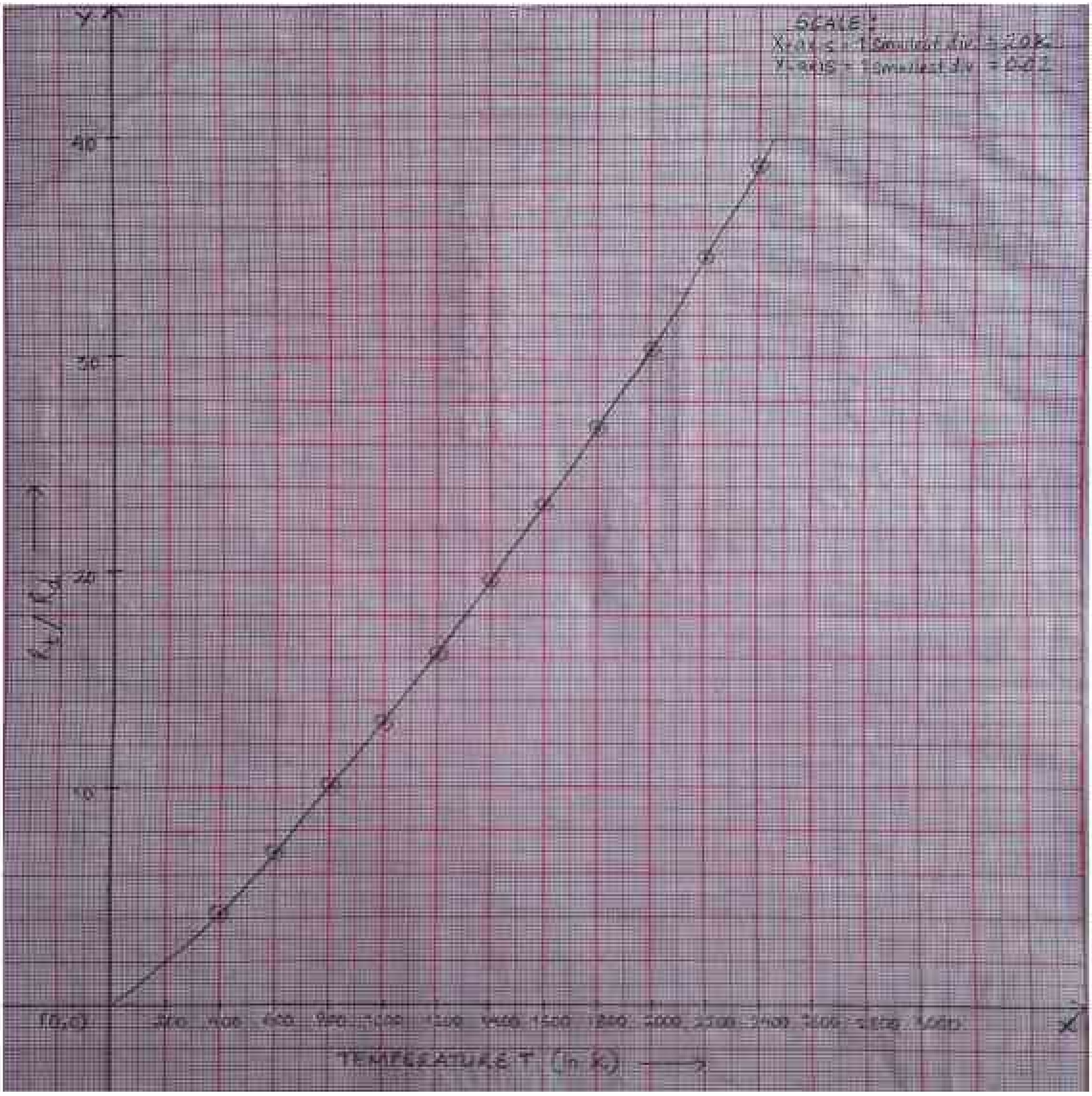

Figure 2: Calibration curve of a torch bulb filament

0.5.2 Graph 2:

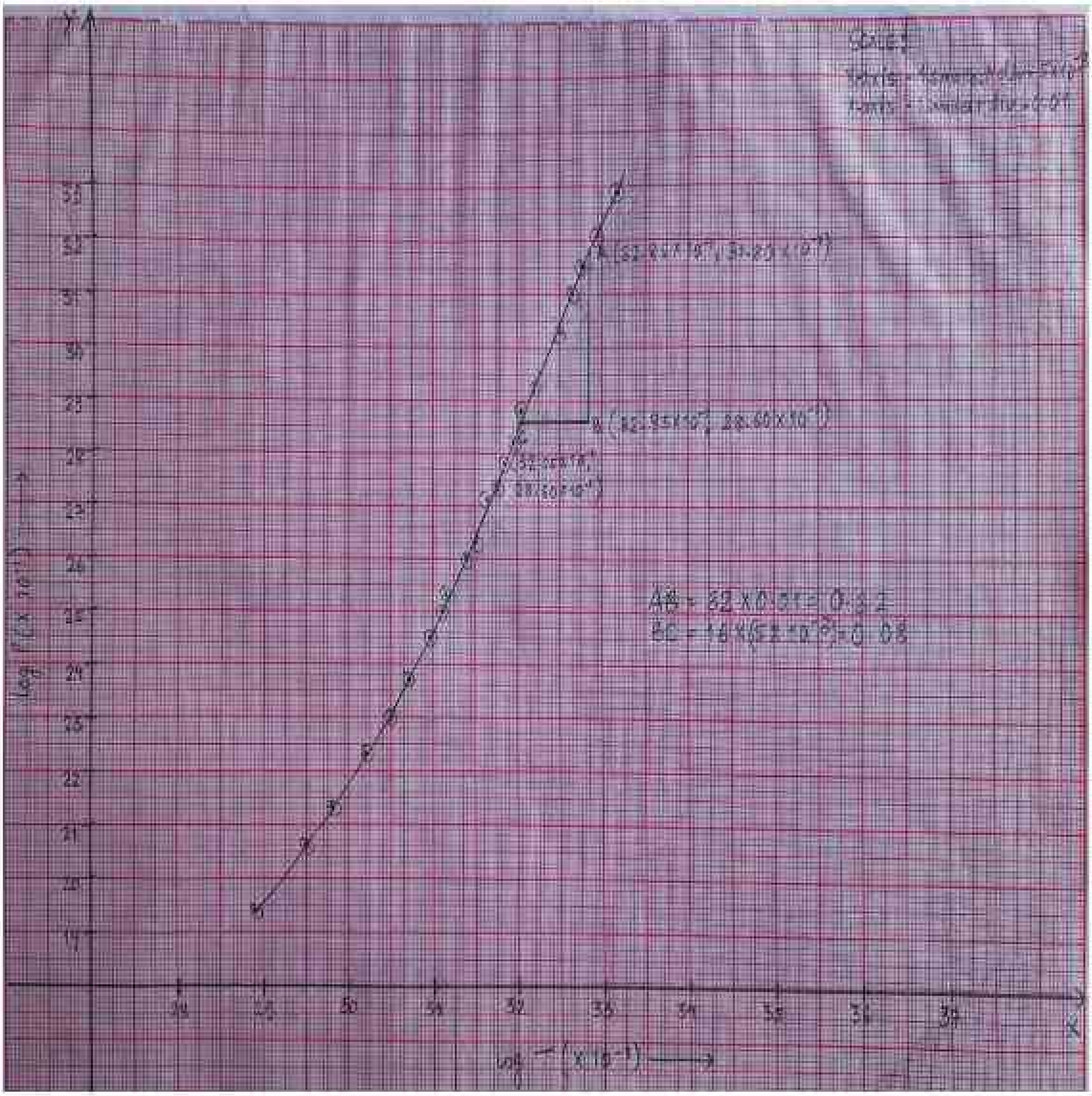

Figure 3: $log_{10}P$ vs $log_{10}T$

0.6 EXPERIMENTAL DATA

Bulb specification : 6V, 6W (Tungsten filament).

(A) To draw the calibration curve of the filament :

$\alpha = 5.21 * 10^{-3\circ}C^{-1}$, $\beta = 7.2 * 10^{-7\circ}C^{-2}$, $t_d = 527^\circ C$,

$$1 + \alpha t_d + \beta t_d^2 = 3.9456.$$

Temperature(t) in $^\circ C$	Temperature T=t+273 in K	R_t/R_d*
127	400	0.42
327	600	0.70
527	800	1.00
727	1000	1.31
927	1200	1.63
1127	1400	1.97
1327	1600	2.33
1527	1800	2.69
1727	2000	3.05
1927	2200	3.47
2127	2400	3.89

$^*R_t/R_d = 1 + \alpha t + \beta t^2 / 1 + \alpha t_d + \beta t_d^2$.

(B) Data for the Draper point :

No.of obs.	State of the filament	P.d(V) in Volt	Current(I) in mA	$R_d = V * 10^3/I$ in Ω
1(a)	Just glows	0.45	198	2.27
1(b)	Just ceases to glow	0.44	196	2.24
2(a)	Just glows	0.46	198	2.32
2(b)	Just ceases to glow	0.44	195	2.26
3(a)	Just glows	0.47	199	2.36
3(b)	Just ceases to glow	0.46	198	2.32
4(a)	Just glows	0.47	200	2.35
4(b)	Just ceases to glow	0.45	197	2.28
5(a)	Just glows	0.47	197	2.36
5(b)	Just ceases to glow	0.44	195	2.26

Mean R_d = [(2.26x2)+(2.36x2)+(2.32x2)+ 2.27 + 2.24 + 2.35 + 2.28]/10

= 2.30 Ω.

(C) Data for filament temperature and corresponding power dissipation :

No. of obs.	Current(I) in mA	P.d(V) in volt	$R_t = V * 10^3/\text{I}$ in Ω	R_t/R_d (R_d from table(B)	Temp.(T) from graph 1 in K	Power(P) = V.I in mW
1	196	0.44	2.24	0.974	780	86.24
2	208	0.55	2.64	1.148	900	114.40
3	217	0.62	2.86	1.243	960	134.54
4	231	0.73	3.16	1.374	1040	168.63
5	243	0.83	3.42	1.487	1120	201.69
6	255	0.93	3.65	1.587	1180	237.15
7	267	1.03	3.86	1.678	1240	275.01
8	278	1.13	4.06	1.765	1280	314.14
9	288	1.22	4.24	1.843	1340	351.36
10	301	1.33	4.42	1.922	1380	400.33
11	311	1.41	4.53	1.969	1400	438.51
12	321	1.51	4.70	2.043	1460	484.71
13	330	1.60	4.85	2.109	1480	528.00
14	345	1.70	4.93	2.143	1500	586.50
15	350	1.80	5.14	2.235	1560	630.00
16	361	1.90	5.26	2.287	1580	685.90
17	375	2.06	5.49	2.387	1620	772.50
18	380	2.10	5.53	2.404	1640	798.00
19	385	2.16	5.61	2.439	1660	831.60
20	400	2.32	5.80	2.522	1700	928.00
21	409	2.43	5.94	2.583	1740	993.87
22	418	2.53	6.05	2.630	1760	1057.54
23	426	2.63	6.17	2.683	1800	1120.38
24	440	2.84	6.45	2.804	1860	1249.60
25	451	2.93	6.50	2.830	1880	1321.43
26	464	3.08	6.64	2.887	1920	1429.12
27	493	3.44	6.98	3.035	2000	1695.92
28	511	3.66	7.16	3.113	2020	1870.26
29	525	3.85	7.33	3.187	2060	2021.25

(D) Data to draw $log_{10}P$ vs $log_{10}T$ graph :

Sl. No.	$log_{10}P$	$log_{10}T$
1	1.94	2.89
2	2.06	2.95
3	2.13	2.98
4	2.23	3.02
5	2.30	3.05
6	2.38	3.07
7	2.44	3.09
8	2.50	3.11
9	2.55	3.13
10	2.60	3.14
11	2.64	3.15
12	2.69	3.16
13	2.72	3.17
14	2.77	3.18
15	2.80	3.19
16	2.84	3.20
17	2.89	3.21
18	2.90	3.22
19	2.92	3.22
20	2.97	3.23
21	3.00	3.24
22	3.02	3.25
23	3.05	3.26
24	3.10	3.27
25	3.12	3.27
26	3.16	3.28
27	3.23	3.30
28	3.27	3.31
29	3.31	3.31

0.7 CALCULATIONS

(A) Calculations of n and verification of Stefan's Law :

From graph AB	From graph BC	Slope n= AB/BC	Remark
0.32	0.08	4	Stefan's Law is verified.

0.8 PRECAUTIONS AND DISCUSSIONS

(i) The potential leads must be soldered to the bulb base directly so that the lead resistances do not affect the measurement of the bulb resistance.

(ii) The Draper point(800 K) is near the middle of the usual operating range of the torch bulb filament (400-2000 K). So its use for calibration purpose is justified.

(iii) One could use ice point or steam point for calibration purpose. But that would require extra device and the process would be cumbersome.

(iv) The slope of the $log_{10}P$ vs $log_{10}T$ graph should be determined in the high T region. At lower temperatures the assumption $T >> T_0$ is less justified. Moreover, at lower T, the heat loss by conduction along the leads is not a negligible fraction of the heat loss by radiation.

(v) Slope of the curve $log_{10}P$ vs $log_{10}T$ does not depend on the units in which P and T are measured.

0.9 ERROR CALCULATION

0.9.1 Maximum proportional error :

$$n = \frac{\delta(log_{10}P)}{\delta(log_{10}T)} = \frac{AB}{BC} \tag{6}$$

$$\therefore \frac{\delta n}{n}|_{max} = \frac{\delta(AB)}{AB} + \frac{\delta(BC)}{BC} \tag{7}$$

where $\delta(AB)$= 1 smallest divisions of graph paper along y-axis.

$\delta(BC)$= 1 smallest divisions of graph paper along x-axis.

$$= (\frac{0.01}{0.32}) + (\frac{5 * 10^{-3}}{0.08}) = 0.093. \tag{8}$$

$$\therefore max\%error = 9.3\%. \tag{9}$$

0.10 ACKNOWLEDGEMENT

In the first place, I would like to thank God for being able to complete this project.

I express my deep gratitude and appreciation to all my professors of physics department for guiding me throughout this semester and explaining critical topics related to the project without which I would not have been able to understand it or I would not have been able to conclude the project.

0.11 BIBLIOGRAPHY

(i) Advanced Practical Physics, Volume I, B.Ghosh, K.G.Mazumdar.

(ii) www.britannica.com>science>

(iii) Stefan,J.(1879),"Uber die Beziehung zwischen der Warmestrahlung und der Temperatur" [On the relationship between heat radiation and temperature](PDF), Sitzungsberichte der Mathematisch-naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften (in German),79:391-428

THE LATEX SOURCE CODE OF THIS PROJECT:

Main.tex file:

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\documentclass[11pt]{report}
\usepackage[utf8]{inputenc}
\usepackage[siunitx]{circuitikz}
\usepackage{graphicx}
\usepackage[a4paper]{geometry}
\usepackage{booktabs}
\usepackage{amsmath}
\usepackage{amssymb}
\begin{document}

\input{make title}

\tableofcontents

\newpage


\input{Chapters/introduction}

\input{Chapters/Theory}

\input{Chapters/Circuit Diagram}

\input{Chapters/Procedure}

\input{Chapters/Graphs}
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\newpage

\input{Chapters/Experimental data}

\input{Chapters/Calculations}

\input{Chapters/Precautions and Discussions}

\input{Chapters/Error Calculation}

\input{Chapters/Acknowledgement}

\input{Chapters/Bibliography}

\end{document}
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Make title page:

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\begin{title page}
  \begin{center}
    \vspace*{1cm}

    \Huge
    \textbf{SEC A 1 PROJECT}

    \vfill
   \vspace{1cm}
   \LARGE
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```
\textit{"Verification of Stefan's Law of radiation by the measurement of Voltage and Current of a torch bulb by glowing it beyond the draper point."}

\vspace{1.5cm}

\begin{figure}[h]

\centering

\includegraphics[height=4cm, width=4cm]{images/1.jpeg}

\end{figure}


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\begin{flushleft}

\LARGE

NAME: VARSHA SUBBA\\

COLLEGE ROLL NO: 20/BSCH/0003\\

UNIVERSITY REGISTRATION NO: 013-1213-0232-20\\

UNIVERSITY ROLL NO: 203013-11-0092\\

EXAMINATION NAME: B.SC.SEMESTER III(HONOURS) PRACTICALEXAMINATION(CU),2021.\\

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\end{title page}
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Introduction :

\section{INTRODUCTION}

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\paragraph{}

Stefan-Boltzmann Law states that the total radiant heat power emitted from a surface is proportional to the fourth power of its absolute temperature.

\paragraph{}

Formulated in 1879 by Austrian physicist Joseph Stefan as a result of his experimental studies, the same law was derived in 1884 by Austrian physicist Ludwig Boltzmann from thermodynamic considerations, if E is the radiant heat energy emitted from a unit area in one second (that is, the power from a unit area) and T is the absolute temperature (in kelvins), then $E=\sigma T^4$, the Greek letter sigma (σ) representing the constant of proportionality, called the Stefan-Boltzmann constant. This constant has the value $ 5.670374419*10^-^8$ watt per metre square per K^4.

\paragraph{}

The law applies only to black-bodies, theoretical surfaces that absorb all incident heat radiation.

\vspace{10cm}

Theory :

\section{THEORY: \textit{To estimate the temperature of a torch bulb filament from resistance measurement and to verify Stefan's law}}

\vspace{1cm}

\paragraph{}

\hspace{0.2cm} The resistance of a torch bulb filament may be assumed to vary within the operating range of temperatures according to the equation,&

\begin{equation} \label{eu_eqn}

R_{t} = R_{0} (1 + \alpha t + \beta t^2)

\end{equation} &

\hspace{0.5cm} where R_{t} and R_{0} are the resistances at $t^{\circ}C$ and $0^{\circ}C$ respectively, α and β are the temperature coefficients of resistance. If R_{d} is the resistance of the filament at the Draper point t_{d} at which the filament just starts showing a dull red glow, we can write,

\paragraph{}

\hspace{4.8cm}\begin{equation} \label{eu_eqn}

\frac{R_{t}}{R_{d}} = \frac{1+\alpha t +\beta t^2}{1+\alpha t_{d} + \beta t_{d}^2}

\end{equation}

\paragraph{}

\hspace{0.5cm} For a tungsten filament $\alpha = 5.21*10^-3^{\circ}C^-^2$, $\beta = 7.2*10^-^7^{\circ}C^-^2$ and the Draper point $t_{d}= 527^{\circ}C$. Hence putting these values of $\alpha, \beta,$ and t_{d} in equation(2) we can calculate R_{t}/R_{d} for different values of t in the usual operating range of temperatures of a torch bulb filament. Now we can draw a calibration curve by plotting R_{t}/R_{d} as a function of the absolute of the absolute temperature $T= t+273$.

\paragraph{}

\hspace{0.5cm} Resistance of the filament is measured by using the relation $R=V/I$ where I is the current through the filament and V is the voltage across it. In this way measuring R_{t}/R_{d} experimentally the corresponding temperature of the torch bulb filament can be found from the calibration curve.

\paragraph{}

\hspace{0.5cm} According to Stefan's Law if a black body at absolute temperature T is surrounded by another black body at temperature T_{0}, the net amount of heat radiated per sec per unit area from the first body is

\paragraph{}

\hspace{4.8cm} \begin{equation} \label{eu_eqn}

P= \alpha (T^4 - T_{0}^4)

\end{equation}

where α is known as Stefan's constant.

\paragraph{}

\hspace{0.5cm} In case of a torch bulb filament $T>>T_{0}$. Moreover, the filament cannot be taken as a black body. Thus we can approximately write,

\paragraph{}

\hspace{0.5cm} \begin{equation} \label{eu_eqn}

p \approx AT^n

\end{equation} &

\hspace{0.5cm} or,

\begin{equation} \label{eu_eqn}

log_{10}P = log_{10}A + n log_{10}T

\end{equation}

\paragraph{}

\hspace{0.5cm} where A is some constant depending on the material and area of the filament and the power n is expected to be slightly different from 4.

\paragraph{}

\hspace{0.5cm} The power P radiated by the filament is given by P = VI and the temperature T is obtained by resistance measurement as before.

\paragraph{}

\hspace{0.5cm} Thus if the Stefan's Law [Eq.3] is valid, the graph between $log_{10}P$ and $log_{10}T$ must be a straight line of slope n.

\vspace{15cm}

Circuit diagram :

\section{APPARATUS: \textit{Circuit Diagram}}

\vspace{1cm}

\paragraph{}

(i)\hspace{0.3cm}A tungsten filament torch bulb (6V, 6W),

\paragraph{}

(ii)\hspace{0.2cm}A 6V dc supply,

\paragraph{}

(iii)\hspace{0.1cm}A rheostat (100Ω, 1A),

\paragraph{}

(iv)\hspace{0.1cm}A dc voltmeter (0-10V),

\paragraph{}

(v)\hspace{0.2cm}A dc ammeter (0-1A).

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\paragraph{}

\begin{figure} [h]

\centering

\includegraphics[height=8cm, width=8cm]{images/3.jpeg}

\caption{Circuit diagram}

\label{fig:my_label}

\end{figure}

\vspace{10cm}

Procedure :

(1) \hspace{0.5cm} Using $\alpha = 5.21*10^-^3^{\circ}C^-^1$, $\beta = 7.2*10^-^7^{\circ}C^-^2$ for tungsten and the Draper point $t_{d}=527^{\circ}C$ calculate R_{t}/R_{d} from equation(2) for several t in the range $100^{\circ}C$ to $ 2500^{\circ}C$. Draw a calibration curve by plotting R_{t}/R_{d} as a function of the absolute temperature $T= t + 273$. The curve comes out to be of the form as shown in Fig 2 (graph 1).

\paragraph{}

(2) \hspace{0.5cm} Take a 6V, 6W tungsten filament torch bulb. Solder two wires directly to each of the base points of the bulb. Now make the circuit connections as shown in Fig 1.

\paragraph{}

(3) \hspace{0.5cm} Keeping the resistance in the rheostat high, switch on the circuit. This time the bulb does not glow. Now slowly increase the current by adjusting the rheostat until the filament just shows a dull red glow (Draper point). Measure corresponding current I and voltage V and calculate $R_{d}= V/I$. Go to slightly higher current and then reduce it till the glow just ceases. Measure corresponding I and V

and again calculate R_{d}. Repeat the whole operation a few times with increasing and decreasing currents and find mean R_{d}.

\paragraph{}

(4) \hspace{0.5cm} Now increase the filament current I in small steps (say, 20 mA) from a value corresponding to the glow stage (Draper point) upto a current high enough to make the filament dazzling white. At each step note I and V and calculate power $P=VI$ and the resistance $R_{t}=V/I$. Compute $R-{t}/R_{d}$ and find the corresponding temperature T from the calibration curve of Fig 2 (graph 1).

\vspace{0.5cm}

\paragraph{}

(5)\hspace{0.5cm} Draw a graph by plotting $log_{10}T$ along x-axis and $log_{10}P$ along y-axis (Fig 3, graph 2). Find the slope AB/AC of this curve in the high T region. This gives n.

\vspace{10cm}

Graphs :

\section{GRAPHS}

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\subsection{Graph 1:}

\paragraph{}

\begin{figure} [h]

\centering

\includegraphics[height=15cm, width=15cm]{images/4 (a).jpeg}

\caption{Calibration curve of a torch bulb filament}

\label{fig:my_label}

\end{figure}

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\subsection{Graph 2:}

\paragraph{}
\begin{figure} [h]
   \centering
   \includegraphics[height=15cm, width=15cm]{images/4.jpeg}
   \caption{$log_{10}P$ vs $log_{10}T$}
   \label{fig:my_label}
\end{figure}

Experimental Data:

\section{EXPERIMENTAL DATA}
\vspace{2cm}
\hspace{0.4cm} Bulb specification : 6V, 6W (Tungsten filament).
\vspace{1cm}
\paragraph{}
(a) \hspace{0.2cm} To draw the calibration curve of the filament :
\paragraph{}
\hspace{0.5cm} $\alpha= 5.21*10^-^3^{\circ}C^-^1$, $\beta= 7.2*10^-^7^{\circ}C^-^2$, $t_{d}=
527^{\circ}C$,
 \paragraph{}
 \hspace{2.5cm} $1+\alpha t_{d} + \beta t_{d}^2 = 3.9456$.
 \paragraph{}
\hspace{1.1cm} \begin{tabular}{|c|c|c|}
   \toprule
```

```
  Temperature(t)  & Temperature  & $R_{t}/R_{d}$*\\
  in $^{\circ}C$ & T=t+273 in K &              \\
  \midrule
  127 & 400 & 0.42\\
  327 & 600 & 0.70\\
  527 & 800 & 1.00\\
  727 & 1000 & 1.31\\
  927 & 1200 & 1.63\\
  1127 & 1400 & 1.97\\
  1327 & 1600 & 2.33\\
  1527 & 1800 & 2.69\\
  1727 & 2000 & 3.05\\
  1927 & 2200 & 3.47\\
  2127 & 2400 & 3.89\\
  \bottomrule
\end{tabular}
\paragraph{}
\hspace{1.1cm}*$R_{t}/R_{d}$ = $1+\alpha t+\beta t^2$/$1+\alpha t_{d}+\beta t_{d}^2$
\vspace{10cm}

(B) \hspace{0.5cm} Data for the Draper point :
\paragraph{}
\vspace{1cm}
\begin{tabular}{|c|c|c|c|c|}
  \toprule
  No.of & State of the & P.d(V)  & Current(I) & $R_{d}= V*10^3$/I\\
  obs.  & filament     & in Volt & in mA      &  in $\Omega$\\
  \midrule
  1(a)  & Just glows         & 0.45 & 198 & 2.27\\
```

```
    1(b)  & Just ceases to glow & 0.44 & 196 & 2.24\\
    \midrule
    2(a)  & Just glows         & 0.46 & 198 & 2.32\\
    2(b)  & Just ceases to glow & 0.44 & 195 & 2.26\\
    \midrule
    3(a)  & Just glows         & 0.47 & 199 & 2.36\\
    3(b)  & Just ceases to glow & 0.46 & 198 & 2.32\\
    \midrule
    4(a)  & Just glows         & 0.47 & 200 & 2.35\\
    4(b)  & Just ceases to glow & 0.45 & 197 & 2.28\\
    \midrule
    5(a)  & Just glows         & 0.47 & 197 & 2.36\\
    5(b)  & Just ceases to glow & 0.44 & 195 & 2.26\\
    \bottomrule
\end{tabular}
\paragraph{}
Mean $R_{d}$ = [(2.26x2)+(2.36x2)+(2.32x2)+ 2.27 + 2.24 + 2.35 + 2.28]/10
\paragraph{}
\hspace{1.6cm} = 2.30 $\Omega$.
\vspace{10cm}

(c) \hspace{0.5cm} Data for filament temperature and corresponding power dissipation :
\paragraph{}
\vspace{1cm}
\begin{tabular}{|c|c|c|c|c|c|c|}
  \toprule
No.  & Current(I) & P.d(V) & $R_{t}= V*10^3$/I & $R_{t}/R_{d}$ & Temp.(T) & Power(P)\\
of   & in     & in   & in $\Omega$      & ($R_{d}$ from & from graph & = V.I in\\
obs.  & mA     & volt &               &    table(B)   &  1 in K    & mW\\
```

```
\midrule
1 & 196 & 0.44 & 2.24 & 0.974 & 780 & 86.24\\
2 & 208 & 0.55 & 2.64 & 1.148 & 900 & 114.40\\
3 & 217 & 0.62 & 2.86 & 1.243 & 960 & 134.54\\
4 & 231 & 0.73 & 3.16 & 1.374 & 1040 & 168.63\\
5 & 243 & 0.83 & 3.42 & 1.487 & 1120 & 201.69\\
6 & 255 & 0.93 & 3.65 & 1.587 & 1180 & 237.15\\
7 & 267 & 1.03 & 3.86 & 1.678 & 1240 & 275.01\\
8 & 278 & 1.13 & 4.06 & 1.765 & 1280 & 314.14\\
9 & 288 & 1.22 & 4.24 & 1.843 & 1340 & 351.36\\
10 & 301 & 1.33 & 4.42 & 1.922 & 1380 & 400.33\\
11 & 311 & 1.41 & 4.53 & 1.969 & 1400 & 438.51\\
12 & 321 & 1.51 & 4.70 & 2.043 & 1460 & 484.71\\
13 & 330 & 1.60 & 4.85 & 2.109 & 1480 & 528.00\\
14 & 345 & 1.70 & 4.93 & 2.143 & 1500 & 586.50\\
15 & 350 & 1.80 & 5.14 & 2.235 & 1560 & 630.00\\
16 & 361 & 1.90 & 5.26 & 2.287 & 1580 & 685.90\\
17 & 375 & 2.06 & 5.49 & 2.387 & 1620 & 772.50\\
18 & 380 & 2.10 & 5.53 & 2.404 & 1640 & 798.00\\
19 & 385 & 2.16 & 5.61 & 2.439 & 1660 & 831.60\\
20 & 400 & 2.32 & 5.80 & 2.522 & 1700 & 928.00\\
21 & 409 & 2.43 & 5.94 & 2.583 & 1740 & 993.87\\
22 & 418 & 2.53 & 6.05 & 2.630 & 1760 & 1057.54\\
23 & 426 & 2.63 & 6.17 & 2.683 & 1800 & 1120.38\\
24 & 440 & 2.84 & 6.45 & 2.804 & 1860 & 1249.60\\
25 & 451 & 2.93 & 6.50 & 2.830 & 1880 & 1321.43\\
26 & 464 & 3.08 & 6.64 & 2.887 & 1920 & 1429.12\\
27 & 493 & 3.44 & 6.98 & 3.035 & 2000 & 1695.92\\
28 & 511 & 3.66 & 7.16 & 3.113 & 2020 & 1870.26\\
```

29 & 525 & 3.85 & 7.33 & 3.187 & 2060 & 2021.25\\

\bottomrule

\end{tabular}

\vspace{3cm}

(D) \hspace{0.5cm} Data to draw $log_{10}P$ vs $log_{10}T$ graph :

\paragraph{}

\hspace{2cm} \begin{tabular}{|c|c|c|}

\toprule

Sl. No. & $log_{10}P$ & $log_{10}T$\\

\midrule

1 & 1.94 & 2.89\\

2 & 2.06 & 2.95\\

3 & 2.13 & 2.98\\

4 & 2.23 & 3.02\\

5 & 2.30 & 3.05\\

6 & 2.38 & 3.07\\

7 & 2.44 & 3.09\\

8 & 2.50 & 3.11\\

9 & 2.55 & 3.13\\

10 & 2.60 & 3.14\\

11 & 2.64 & 3.15\\

12 & 2.69 & 3.16\\

13 & 2.72 & 3.17\\

14 & 2.77 & 3.18\\

15 & 2.80 & 3.19\\

16 & 2.84 & 3.20\\

17 & 2.89 & 3.21\\

18 & 2.90 & 3.22\\

```
    19 & 2.92 & 3.22\\
    20 & 2.97 & 3.23\\
    21 & 3.00 & 3.24\\
    22 & 3.02 & 3.25\\
    23 & 3.05 & 3.26\\
    24 & 3.10 & 3.27\\
    25 & 3.12 & 3.27\\
    26 & 3.16 & 3.28\\
    27 & 3.23 & 3.30\\
    28 & 3.27 & 3.31\\
    29 & 3.31 & 3.31\\
    \bottomrule
 \end{tabular}
 \vspace{5cm}
```

Calculations :

```
\section{CALCULATIONS}

\vspace{2cm}

\paragraph{}
(A)\hspace{0.5cm} Calculations of n and verification of Stefan's Law :
\vspace{1cm}
\paragraph{}

\begin{tabular}{|c|c|c|c|}
    \toprule
    From graph & From graph & Slope    & Remark \\
```

AB & BC & n= AB/BC & \\

\midrule

0.32 & 0.08 & 4 & Stefan's Law is verified.\\

\bottomrule

\end{tabular}

\vspace{15cm}

Precautions and Discussion:

\section{PRECAUTIONS AND DISCUSSIONS}

\vspace{2cm}

\paragraph{}

(i) \hspace{0.5cm} The potential leads must be soldered to the bulb base directly so that the lead resistances do not affect the measurement of the bulb resistance.

\paragraph{}

(ii) \hspace{0.4cm} The Draper point(800 K) is near the middle of the usual operating range of the torch bulb filament (400-2000 K). So its use for calibration purpose is justified.

\paragraph{}

(iii) \hspace{0.4cm} One could use ice point or steam point for calibration purpose. But that would require extra device and the process would be cumbersome.

\paragraph{}

(iv) \hspace{0.4cm} The slope of the $log_{10}P$ vs $log_{10}T$ graph should be determined in the high T region. At lower temperatures the assumption $T>>T_{0}$ is less justified. Moreover, at lower T, the heat loss by conduction along the leads is not a negligible fraction of the heat loss by radiation.

\paragraph{}

(v) \hspace{0.5cm} Slope of the curve $log_{10}P$ vs $log_{10}T$ does not depend on the units in which P and T are measured.

\vspace{12cm}

Error calculation:

\subsection{Maximum proportional error :}

\vspace{1cm}

\begin{equation}

n = \frac{\delta(log_{10}P)}{\delta(log_{10}T)} = \frac{AB}{BC}

\end{equation}

\begin{equation}

\therefore \frac{\delta n}{n} \rvert_{max} = \frac{\delta(AB)}{AB} + \frac{\delta(BC)}{BC}

\end{equation}

\paragraph{}

where $\delta (AB)$= 1 smallest divisions of graph paper along y-axis.

\paragraph{}

\hspace{1.1cm}$\delta (BC)$= 1 smallest divisions of graph paper along x-axis.

\paragraph{}

\begin{equation}

= (\frac{0.01}{0.32}) + (\frac{5*10^-^3}{0.08})

= 0.093.

\end{equation}

\paragraph{}

\begin{equation}

\therefore max \% error= 9.3 \%.

\end{equation}

\vspace{10cm}

Acknowledgement:

\section{ACKNOWLEDGEMENT}

\vspace{2cm}

\paragraph{}

In the first place, I would like to thank God for being able to complete this project.

\paragraph{}

I express my deep gratitude and appreciation to all my professors of physics department for guiding me throughout this semester and explaining critical topics related to the project without which I would not have been able to understand it or I would not have been able to conclude the project.

\vspace{18cm}

Bibliography:

\section{BIBLIOGRAPHY}

\vspace{2cm}

\paragraph{}

(i) \hspace{0.6cm} Advanced Practical Physics, Volume I, B.Ghosh, K.G.Mazumdar.

\paragraph{}

(ii) \hspace{0.5cm} www.britannica.com$>$science$>$

\paragraph{}

(iii) \hspace{0.4cm} Stefan,J.(1879),"Uber die Beziehung zwischen der Warmestrahlung und der Temperatur" [On the relationship between heat radiation and temperature](PDF), Sitzungsberichte der Mathematisch-naturwissenschaftlichen Classe der Kaiserlichen Akademie der Wissenschaften (in German),79:391-428

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UNIVERSITY OF CALCUTTA

ADMIT

B.Sc. SEMESTER - III (HONOURS) Examination-2021
(UNDER CBCS)

Name of the Candidate :

SOHINI MITRA

Father's/Guardian's Name :

KAUSIK MITRA

Roll & No. :

203013-11-0055

Registration No.

013-1211-0226-20

Subjects Enrolled :

PHSA,CEMG

Name of the College :

GOKHALE MEMORIAL GIRLS' COLLEGE

Sohini Mitra

SCHEDULE FOR EXAMINATION IN THEORETICAL PAPERS **

Examination Day & Date		Examination Starting Time	Subject Code ++	Course Code	Course Name	Number of Answer book(s) to be used	Signature of the invigilator on receipt of the answer script/s @
Saturday	15-01-2022	10 A.M.	PHSA	CC5	MATHEMATICAL PHYSICS - II	1	
Sunday	16-01-2022	10 A.M.	PHSA	CC6	THERMAL PHYSICS	1	
Monday	17-01-2022	10 A.M.	PHSA	CC7	MODERN PHYSICS	1	
Tuesday	18-01-2022	10 A.M.	PHSA	SEC-A1	SCIENTIFIC WRITING	1	
Saturday	22-01-2022	10 A.M.	CEMG	GE3	PAPER 3	1	

Signature of the Principal/TIC/OIC of the College with Seal

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Determination of Temperature Coefficient of Resistance using Carey Foster Bridge

Sohini Mitra

BSc.(Hons.) Semester III Practical Examination,(Calcutta University), 2021

CU Registration No.:- 013-1211-0226-20

CU Roll No. :- 203013-11-0055

Physics (PHSA)

SEC- A1 (Scientific Writing)(Project)

Date:-31/1/22

1 THEORY

(i) At first, to find the resistance per unit length (ρ) of the bridge, wire connections are made as shown in Figure.1a where connections are made with the resistance box X in the extreme left gap G_1, a copper strip Y of practically zero resistance in the extreme right gap G_4 and two equal resistances Q_1 and Q_2 in the two middle gaps. Let with certain resistance X in the resistance box X the null point be obtained at a distance l_1 from the left end. When the box X with resistance X and the copper strip Y are interchanged, let the null point be obtained at a distance l_2 from the left end.

If $\lambda_1\ \Omega$ and $\lambda_2\ \Omega$ are the end resistances at the left and right ends of the bridge wire then before interchanging X and Y we may write by employing *Wheatstone bridge principle*,

$$\frac{Q_1}{Q_2} = \frac{X + \lambda_1 + l_1\rho}{Y + \lambda_2 + (100 - l_1)\rho}$$

$$\text{or,}\quad \frac{Q_1}{Q_1 + Q_2} = \frac{X + \lambda_1 + l_1\rho}{X + Y + \lambda_1 + \lambda_2 + 100\rho}$$

After interchanging X and Y, if we proceed in the same manner as indicated above we again get,

$$\frac{Q_1}{Q_1 + Q_2} = \frac{Y + \lambda_1 + l_2\rho}{X + Y + \lambda_1 + \lambda_2 + 100\rho}$$

From the above two values of the ratio $Q_1/(Q_1 + Q_2)$ we get,

$$X + \lambda_1 + l_1\rho = Y + \lambda_1 + l_2\rho$$

Then it can be shown that

$$\rho = \frac{X - Y}{l_2 - l_1}$$

As the resistance Y of the copper strip is practically zero, therefore,

$$\rho = \frac{X}{l_2 - l_1} \tag{1}$$

(ii) Now, the connections are made as in Figure.1b by placing the given wire of resistance R in the extreme right gap G_4, a resistance box S in the extreme left gap G_1 and two equal resistances Q_1 and Q_2 in the two middle gaps G_2 and G_3 respectively. Let a null point be obtained at a distance l'_1 from the left end with a resistance S in the resistance box S. On interchanging the positions of the given wire R and the resistance box S, a new null point is obtained at a distance l'_2 from the left end.

Then it can be shown that

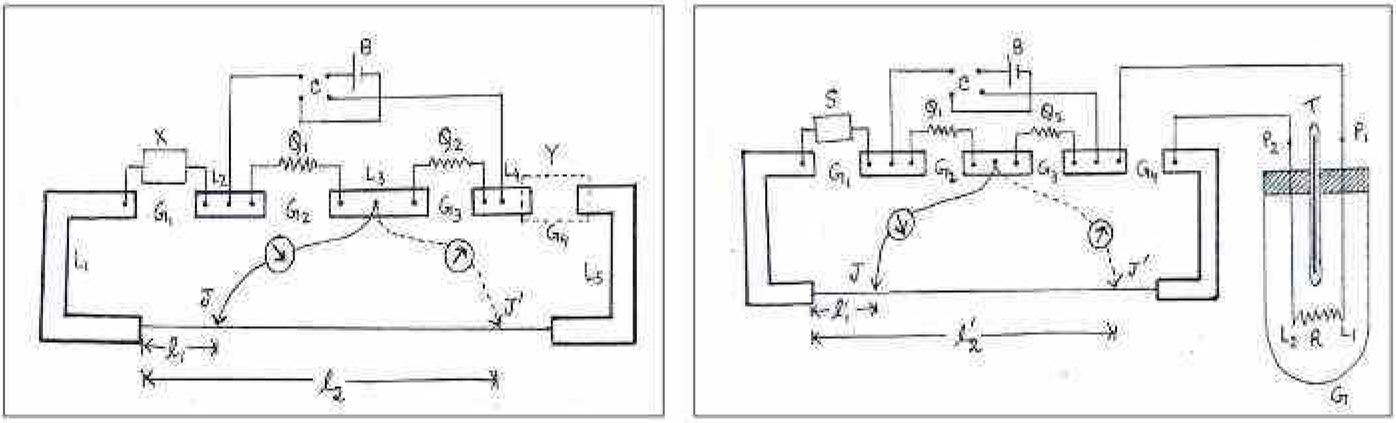
$$\rho = \frac{S - R}{l'_2 - l'_1}$$

$$\text{or,}\quad R = S - \rho\,(l'_2 - l'_1) \tag{2}$$

(iii) If the resistances R_1 and R_2 of the given wire at two different temperatures $t_1^\circ C$ (low) and $t_2^\circ C$ (high) are found out by using equation 1 and equation 2, then it can be shown that the temperature-coefficient (α) is given by

$$\alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1}\ \text{per}\ ^\circ C \tag{3}$$

2 CIRCUIT DIAGRAM



(a) Circuit Diagram to find ρ

(b) Circuit Diagram to find reistance $\boldsymbol{R}$ of the given wire

Figure 1: Experimental Setup

3 EXPERIMENTAL DATA

3.1 *Data for the measurement of* ρ *:*

Here,

$$Q_1 = Q_2 = 1\ \Omega$$

Table 1

No. of obs.		Resistances in Ω applied in		Null points in cm with			$(l_2 - l_1)$ in cm	$\rho = X/(l_2 - l_1)$ in Ω per cm	Mean ρ in Ω per cm
		Extreme left gap	Extreme right gap	Direct current	Reversed current	Mean			
1.	(a)	0.7	0.0	6.8	6.7	6.8	91.6	0.0076	0.00726
	(b)	0.0	0.7	98.4	98.5	98.4			
2.	(a)	0.6	0.0	12.8	12.6	12.7	79.5	0.0075	
	(b)	0.0	0.6	92.1	92.2	92.2			
3.	(a)	0.5	0.0	18.2	18.5	18.4	67.2	0.0074	
	(b)	0.0	0.5	85.5	85.6	85.6			
4.	(a)	0.4	0.0	23.8	24.1	24.0	56.2	0.0071	
	(b)	0.0	0.4	80.3	80.1	80.2			
5.	(a)	0.3	0.0	29.3	29.4	29.4	45.0	0.0067	
	(b)	0.0	0.3	74.4	74.5	74.4			

3.2 *Data for the measurement of R_1 and R_2*

Here,

$$Q_1 = Q_2 = 1\ \Omega$$

Table 2

Temperature	No. of obs.		Res. in the extreme left gap in Ω	Res. in the extreme right gap in Ω	Null points in cm with Direct current	Null points in cm with Reverse current	Null points in cm with Mean	Unknown resistance $R = S - \rho(\ell_2 - \ell_1)$ in Ω	Mean resistance in Ω
Room temp. (t_1) °C = 23 °C	1.	(a)	2.9	R	45.2	45.2	45.2	2.7	$R_1 = 3.0$
		(b)	R	2.9	77.8	77.9	77.8		
	2.	(a)	3	R	49.9	49.6	49.8	2.8	
		(b)	R	3	73.7	73.8	73.8		
	3.	(a)	3.1	R	56.0	55.9	56.0	3.0	
		(b)	R	3.1	67.8	67.7	67.8		
	4.	(a)	3.2	R	61.7	61.8	61.8	3.2	
		(b)	R	3.2	62.7	62.6	62.6		
	5.	(a)	3.3	R	68.0	67.8	67.9	3.4	
		(b)	R	3.3	56.9	56.6	56.8		
Steam temp. (t_2) °C = 100 °C	1.	(a)	5.1	R	88.8	88.8	88.8	5.4	$R_2 = 5.5$
		(b)	R	5.1	45.4	45.2	45.3		
	2.	(a)	5.2	R	92.8	88.1	90.4	5.5	
		(b)	R	5.2	51.8	52.0	51.9		
	3.	(a)	5.3	R	88.2	88.2	88.2	5.5	
		(b)	R	5.3	56.6	59.7	58.2		
	4.	(a)	5.4	R	77.7	77.0	77.4	5.5	
		(b)	R	5.4	62.1	63.3	62.7		
	5.	(a)	5.5	R	76.5	76.8	76.6	5.6	
		(b)	R	5.5	65.1	69.3	67.2		

4 CALCULATIONS

From Table 1 we obtained $\rho = 0.00726\ \Omega/\text{cm}$ and from Table 2 we obtained $R_1 = 3.0\ \Omega$ and $R_2 = 5.5\ \Omega$.

∴ The temperature-coefficient of resistance is given by,

$$\alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1}$$
$$= \frac{5.5 - 3.0}{3.0 \times 100 - 5.5 \times 23}$$
$$= \frac{2.5}{173.5}$$
$$= 0.0144 \text{ per } ^\circ C$$

$$\therefore \boxed{\alpha = 0.0144 \text{ per } ^\circ C}$$

5 PRECAUTIONS AND DISCUSSIONS

(i) At the beginning both X and Y should be made zero to see whether the null point is near the middle of the bridge wire (when $Q_1 = Q_2$).If the null point is found very near to 50 cm, it indicates that Q_1 is almost equal to Q_2.

(ii) In this experiment the effects of the end errors of the bridge wire are eliminated and hence this method using Carey Foster's bridge gives more accurate result than that obtained by using metre bridge.

(iii) For greater sensitiveness the resistances of the four arms should be of same order.

(iv) While determining ρ, the value of X should be adjusted to make $(l_2 - l_1)$ very nearly equal to the entire length of the bridge wire.This minimises the error due to non-uniformity of the bridge-wire.

(v) While measuring R_1 and R_2, S should be adjusted to make $\left(l_2' - l_1'\right)$ small. R=S-$\rho\left(l_2' - l_1'\right)$, where S is chosen from box and is fairly correct whereas ρ being a measured quantity may have some error. Therefore, the error in R is $\delta R_{max} = \delta\rho\left(l_2' - l_1'\right) + \rho \cdot 2\delta l$. Smaller is the value of $l_2' - l_1'$, δR_{max} will also be smaller.

6 MAXIMUM PERCENTAGE ERROR

We have,

$$\alpha = \frac{R_2 - R_1}{R_1 t_2 - R_2 t_1} \text{ per } ^\circ C$$
$$\therefore \left(\frac{\delta\alpha}{\alpha}\right)_{max} = \frac{2\delta R}{R_2 - R_1} + \frac{\delta R\,(t_1 + t_2) + \delta t\,(R_1 + R_2)}{R_1 t_2 - R_2 t_1} \tag{4}$$

where, $\delta t = 1$ div. of thermometer

and $$\delta R_{max} = \rho \left[\frac{l'_2 - l'_1}{l_2 - l_1} + 1 \right] \cdot 2\delta l$$

where, $\delta l = 0.1\text{cm}$ (1 div. of the metre scale)

$$l'_2 - l'_1 = -7.8\text{cm}$$
$$l_2 - l_1 = 67.9\text{cm}$$
and $\rho = 0.00726\ \Omega/\text{cm}$

$$\therefore\ \delta R_{max} = 0.00726 \left[\frac{-7.8}{67.9} + 1 \right] 2 \times 0.1$$
$$\delta R_{max} = 1.285 \times 10^{-3}\ \Omega$$

Therefore, from equation 4

$$\begin{aligned}
\left(\frac{\delta\alpha}{\alpha}\right)_{max} &= \frac{2\delta R}{R_2 - R_1} + \frac{\delta R\,(t_1 + t_2) + \delta t\,(R_1 + R_2)}{R_1 t_2 - R_2 t_1} \\
&= \frac{2 \times 1.285 \times 10^{-3}}{5.5 - 3.0} + \frac{1.285 \times 10^{-3} \times (23 + 100) + 0.1 \times (3.0 + 5.5)}{3.0 \times 100 - 5.5 \times 23} \\
&= 1.028 \times 10^{-3} + 5.810 \times 10^{-3} \\
&= 6.838 \times 10^{-3}
\end{aligned}$$

Therefore,

Maximum percentage error

$$\left(\frac{\delta\alpha}{\alpha}\right)_{max} \times 100\,\% = 6.838 \times 10^{-3} \times 100\,\%$$
$$= \pm\ 0.68\,\%$$

$\therefore$ Maximum percentage error in α is $\pm$ 0.68%

LATEX SOURCE CODE

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\documentclass[12pt]{article}

\usepackage[UTF8]{inputenc}

\usepackage{amsmath}

\usepackage{amssymb}

\usepackage{mathtools}

\usepackage{graphicx}

\usepackage{txfonts}

\usepackage{amsfonts}

\usepackage[T1]{fontenc}

\usepackage{mathdesign}

\usepackage{caption}

\usepackage{subcaption}

\usepackage{titling}

\usepackage{enumitem}

\usepackage{bm}

\usepackage{makecell}

\usepackage{geometry}

\usepackage{setspace}

\geometry{a4paper,margin=1.0in}

\graphicspath{E:\Latex practice files}

\def\nn{\nonumber}

\def\no{\noindent}
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\begin{document}

	\begin{titlepage}


		\title{\Huge\textbf{Determination of Temperature Coefficient of Resistance using Carey Foster Bridge}\vspace{2.4cm}}


		\author{{\LARGE {\hspace{-1.5cm}\vspace{2.5cm}\textbf{Sohini Mitra}}}\\

			\vspace*{1.5cm}\hspace{-1.5cm}

			\Large BSc.(Hons.) Semester III Practical Examination,(Calcutta University), 2021\\

			\hspace*{-1.5cm}

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			\Large  CU Registration No.:- 013-1211-0226-20 \\

			\vspace*{1.5cm}

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			\Large CU Roll No. :- 203013-11-0055\\

			\hspace*{-2cm}

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			\large Physics (PHSA)\\

			\hspace*{-2cm}

			\large  SEC- A1 (Scientific Writing)(Project)}

		\date{\hspace{-0.5cm}Date:-31/1/22}

		\maketitle
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\end{titlepage}


\section{\textsf{THEORY}}

\begin{enumerate} [label=(\roman*)]

\item At first, to find the resistance per unit length ($\rho$) of the bridge, wire connections are made as shown in Figure.\ref{fig:sub-first} where connections are made with the resistance box $\bm{X}$ in the extreme left gap $\bm{G_1}$, a copper strip $\bm{Y}$ of practically zero resistance in the extreme right gap $\bm{G_4}$ and two equal resistances $\bm{Q_1}$ and $\bm{Q_2}$ in the two middle gaps. Let with certain resistance $\bm{X}$ in the resistance box $\bm{X}$ the null point be obtained at a distance $\bm{l_1}$ from the left end. When the box $\bm{X}$ with resistance $\bm{X}$ and the copper strip $\bm{Y}$ are interchanged, let the null point be obtained at a distance $\bm{l_2}$ from the left end.\\

\hspace*{0.8cm}

If $\lambda_1$ $\Omega$ and $\lambda_2$ $\Omega$ are the end resistances at the left and right ends of the bridge wire then before interchanging $\bm{X}$ and $\bm{Y}$ we may write by employing \emph{Wheatstone bridge principle,}

\begin{align*}

\frac{Q_1}{Q_2}&=\frac{X+\lambda_1+l_1\rho}{Y+\lambda_2+{100-l_1)\rho} \\

\text{or,}\,\,\,\,\,\frac{Q_1}{Q_1+Q_2}&=\frac{X+\lambda_1+l_1\rho}{X+Y+\lambda_1+\lambda_2+100\rho}

\end{align*}

\hspace*{0.8cm}

After interchanging $\bm{X}$ and $\bm{Y}$, if we proceed in the same manner as indicated above we again get,

\vspace*{-0.8cm}

\begin{center}

\[\frac{Q_1}{Q_1+Q_2}=\frac{Y+\lambda_1+l_2\rho}{X+Y+\lambda_1+\lambda_2+100\rho}\]\\

\end{center}

\hspace*{0.8cm}
```

From the above two values of the ratio $Q_1/(Q_1+Q_2)$ we get,

\vspace*{-1cm}

\begin{center}

\[X+\lambda_1+l_1\rho=Y+\lambda_1+l_2\rho\]

\end{center}

\hspace*{0.8cm}

Then it can be shown that\\

\vspace*{-1.5cm}

\begin{center}

\[\rho = \frac{X-Y}{l_2-l_1}\]

\end{center}

\hspace*{0.8cm}

As the resistance $\bm{Y}$ of the copper strip is practically zero, therefore,

\begin{equation}\label{first}

\centering

\rho=\frac{X}{l_2-l_1}

\end{equation}

\item Now, the connections are made as in Figure.\ref{fig:sub-second} by placing the given wire of resistance $\bm{R}$ in the extreme right gap $\bm{G_4}$, a resistance box $\bm{S}$ in the extreme left gap $\bm{G_1}$ and two equal resistances $\bm{Q_1}$ and $\bm{Q_2}$ in the two middle gaps $\bm{G_2}$ and $\bm{G_3}$ respectively. Let a null point be obtained at a distance $\bm{l'_1}$ from the left end with a resistance $\bm{S}$ in the resistance box $\bm{S}$. On interchanging the positions of the given wire $\bm{R}$ and the resistance box $\bm{S}$, a new null point is obtained at a distance $\bm{l'_2}$ from the left end.\\

\hspace*{0.8cm}

Then it can be shown that\\

\vspace*{-1.5cm}

\begin{center}

```
	\[\rho = \frac{S-R}{l'_2-l'_1}\]
\end{center}
\vspace*{-0.02cm}
\begin{equation}\label{second}
	\centering
\text{or}, \,\,\,\,\, R = S-\rho\left(l'_2-l'_1\right)
\end{equation}
\item If the resistances $\bm{R_1}$ and $\bm{R_2}$ of the given wire at two different temperatures $t_1^\circ C$ (low) and $t_2^\circ C$ (high) are found out by using equation \ref{first} and equation \ref{second}, then it can be shown that the temperature-coefficient ($\alpha$) is given by
\vspace*{0.2cm}
\begin{equation}\label{third}
	\centering
\alpha=\frac{R_2-R_1}{R_1t_2-R_2t_1}\,\,\text{per}\, ^\circ C
	\end{equation}
 \end{enumerate}
\newpage
\section{\textsf{CIRCUIT DIAGRAM}}
\begin{figure}[h]
	\hspace*{-1cm}
	\begin{subfigure}[t]{0.5\textwidth}
		\centering
	\framebox{\includegraphics[width=8.5cm,height=5.2cm]{Resistance.jpg}}
		\caption{Circuit Diagram to find $\rho$}
		\label{fig:sub-first}
	\end{subfigure}
```

```
\hspace*{1cm}

\begin{subfigure}[t]{0.5\textwidth}

	\centering

	\framebox{\includegraphics[width=9cm,height=5.2cm]{Unknown resistance.jpg}}

	\caption{Circuit Diagram to find reistance $\bm{R}$ of the given \hspace*{4cm}wire}

	\label{fig:sub-second}

\end{subfigure}

\caption{Experimental Setup}

\label{fig:fig}

\end{figure}

\vspace*{-0.8cm}

\section{\textsf{EXPERIMENTAL DATA}}

\subsection{\emph{Data for the measurement of $\rho$ :}}

\hspace*{2.5cm}

 Here,\\

 \hspace*{4.5cm}

  $\bm{Q_1}$ = $\bm{Q_2}$ = 1 $\Omega$

\begin{table}[h]

\caption{}

\vspace*{-0.2cm}

	\centering

	\begin{tabular}{||c c|c|c|c|c|c|c|c||}

		\hline \hline

		& &\multicolumn{2}{c|}{\makecell{Resistances in \\ $\Omega$ applied
in}}&\multicolumn{3}{c|}{\makecell{Null points in cm \\with}}&&& \\

	 \cline{3-7}
```

```
\multicolumn{2}{| |c|}{\raisebox{0.5cm}{\rotatebox{90}{\makecell{\hspace{1.2cm}No. of obs.}}}}&\raisebox{2.2cm}{\makecell{Extreme\\left gap}}&\raisebox{2.2 cm}{\makecell{Extreme\\right gap}}&\rotatebox{90}{\hspace{1.05cm}Direct current}&\rotatebox{90}{\hspace{0.8cm}Reversed current}&\rotatebox{90}{\hspace{1.7cm}Mean}&\rotatebox{90}{\hspace{1.8cm}

$\left(l_2-l_1\right)$} \rotatebox{90}{\hspace{2.4cm}in}\, \rotatebox{90}{\hspace{2.32cm}cm} &\rotatebox{90}{\hspace{1.3cm}$\rho=X/\left(l_2-l_1\right)$} \rotatebox{90}{\hspace{2.4cm}in} \rotatebox{90}{\hspace{1.8cm}$\Omega$ per cm}&\rotatebox{90}{\hspace{2cm}Mean $\rho$} \rotatebox{90}{\hspace{2.5cm}in} \rotatebox{90}{\hspace{1.8cm}$\Omega$ per cm}\\

\vspace*{-1.0cm}\\

\hline

& (a) &0.7 &0.0 &6.8&6.7&6.8& & &\\

\cline{3-7}\\[-0.8cm]

\vspace*{-0.6cm}

\raisebox{0.5cm}{1.}&&&&&&&\raisebox{0.4cm}{91.6}&\raisebox{0.4cm}{0.0076}&\\

& (b)&0.0&0.7&98.4&98.5&98.4&&&\\

\cline{1-9}

& (a) &0.6 &0.0 &12.8&12.6&12.7& & &\\

\cline{3-7}\\[-0.8cm]

\vspace*{-0.6cm}

\raisebox{0.5cm}{2.}&&&&&&&\raisebox{0.4cm}{79.5}&\raisebox{0.4cm}{0.0075}&\\

& (b)&0.0&0.6&92.1&92.2&92.2&&&\\

\cline{1-9}

& (a) &0.5 &0.0 &18.2&18.5&18.4& & &0.00726\\

\cline{3-7}\\[-0.8cm]

\vspace*{-0.6cm}

\raisebox{0.5cm}{3.}&&&&&&&\raisebox{0.4cm}{67.2}&\raisebox{0.4cm}{0.0074}&\\

& (b)&0.0&0.5&85.5&85.6&85.6&&&\\
```

```
    \cline{1-9}
    & (a) &0.4 &0.0 &23.8&24.1&24.0& & &\\
    \cline{3-7}\\[-0.8cm]
    \vspace*{-0.6cm}
    \raisebox{0.5cm}{4.}&&&&&&&\raisebox{0.4cm}{56.2}&\raisebox{0.4cm}{0.0071}&\\
    & (b)&0.0&0.4&80.3&80.1&80.2&&&\\
    \cline{1-9}
     & (a) &0.3 &0.0 &29.3&29.4&29.4& & &\\
    \cline{3-7}\\[-0.8cm]
    \vspace*{-0.6cm}
    \raisebox{0.5cm}{5.}&&&&&&&\raisebox{0.4cm}{45.0}&\raisebox{0.4cm}{0.0067}&\\
    & (b)&0.0&0.3&74.4&74.5&74.4&&&\\
    \hline\hline
            \end{tabular}
\label{table(A)}
\end{table}
\newpage
\subsection{\emph{Data for the measurement of $R_1$ and $R_2$}}
\hspace*{2.5cm}
Here,\\
\hspace*{4.5cm}
$\bm{Q_1}$ = $\bm{Q_2}$ = 1 $\Omega$
\begin{table}[h]
            \caption{}
            \vspace*{-0.2cm}
```

```latex
\centering
\begin{tabular}{||c|l c|c|c|c|c|c|c|c||}
	\hline \hline
	&&&&&\multicolumn{3}{c|}{Null points in cm with}&&\\
	\cline{6-8}
	\vspace*{-0.54cm}\\
\raisebox{1cm}{\rotatebox{90}{\makecell{\hspace{1.5cm}Temperature}}}&
\multicolumn{2}{c|}{\raisebox{1.5cm}{\rotatebox{90}{\makecell{\hspace{1.2cm}No. of obs.}}}}&\rotatebox{90}{\hspace{2cm}Res. in the extreme} \rotatebox{90}{\hspace{3cm} left gap} \rotatebox{90}{\hspace{3.6cm}in} \rotatebox{90}{\hspace{3.64cm}$\Omega$}&\rotatebox{90}{\hspace{2cm}Res. in the extreme} \rotatebox{90}{\hspace{3cm} right gap} \rotatebox{90}{\hspace{3.7cm}in} \rotatebox{90}{\hspace{3.74cm}$\Omega$}&\rotatebox{90}{\makecell{\hspace{2.4cm}Direct current}}&\rotatebox{90}{\makecell{\hspace{2.2cm}Reverse current}}&\raisebox{3.5 cm}{\makecell{Mean}}&\rotatebox{90}{\hspace{2cm}Unknown resistance} \rotatebox{90}{\hspace{2.3cm}$R = S-\rho\left(l'_2-l'_1\right)$}\rotatebox{90}{\hspace{3.5cm}in} \rotatebox{90}{\hspace{3.55cm}$\Omega$}&\rotatebox{90}{\hspace{2.4cm}Mean resistance} \rotatebox{90}{\hspace{3.5cm}in} \rotatebox{90}{\hspace{3.55cm}$\Omega$}
\vspace*{-1.7cm}\\
\hline
&&(a)&2.9&R&45.2&45.2&45.2&&\\
\cline{4-8}\\[-0.8cm]
\vspace*{-0.6cm}
&\raisebox{0.5cm}{1.}&&&&&&&\raisebox{0.4cm}{2.7}&\\
&&(b)&R&2.9&77.8&77.9&77.8&&\\
\cline{2-9}
Room temp. &&(a)&3&R&49.9&49.6&49.8&&\\
\cline{4-8}\\[-0.8cm]
\vspace*{-0.6cm}
&\raisebox{0.5cm}{2.}&&&&&&&\raisebox{0.4cm}{2.8}&\\
```

```
$\left(t_1\right)\,^\circ C$&&(b)&R&3&73.7&73.8&73.8&&\\

\cline{2-9}

= 23 $^\circ C $ & &(a)&3.1&R&56.0&55.9&56.0&&$R_1$ = 3.0\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{3.}&&&&&&&\raisebox{0.4cm}{3.0}&\\

&&(b)&R&3.1&67.8&67.7&67.8&&\\

\cline{2-9}

&&(a)&3.2&R&61.7&61.8&61.8&&\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{4.}&&&&&&&\raisebox{0.4cm}{3.2}&\\

&&(b)&R&3.2&62.7&62.6&62.6&&\\

\cline{2-9}

&&(a)&3.3&R&68.0&67.8&67.9&&\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{5.}&&&&&&&\raisebox{0.4cm}{3.4}&\\

&&(b)&R&3.3&56.9&56.6&56.8&&\\

\hline

&&(a)&5.1&R&88.8&88.8&88.8&&\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{1.}&&&&&&&\raisebox{0.4cm}{5.4}&\\

&&(b)&R&5.1&45.4&45.2&45.3&&\\
```

```
\cline{2-9}

Steam temp. &&(a)&5.2&R&92.8&88.1&90.4&&\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{2.}&&&&&&&\raisebox{0.4cm}{5.5}&\\

$\left(t_2\right)\,^\circ C$&&(b)&R&5.2&51.8&52.0&51.9&&\\

\cline{2-9}

= 100 $^\circ C $ & &(a)&5.3&R&88.2&88.2&88.2&&$R_2$ = 5.5\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{3.}&&&&&&&\raisebox{0.4cm}{5.5}&\\

&&(b)&R&5.3&56.6&59.7&58.2&&\\

\cline{2-9}

&&(a)&5.4&R&77.7&77.0&77.4&&\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{4.}&&&&&&&\raisebox{0.4cm}{5.5}&\\

&&(b)&R&5.4&62.1&63.3&62.7&&\\

\cline{2-9}

&&(a)&5.5&R&76.5&76.8&76.6&&\\

\cline{4-8}\\[-0.8cm]

\vspace*{-0.6cm}

&\raisebox{0.5cm}{5.}&&&&&&&\raisebox{0.4cm}{5.6}&\\

&&(b)&R&5.5&65.1&69.3&67.2&&\\

\hline \hline
```

```
	\end{tabular}

\label{table(B)}

\end{table}


\section{\textsf{CALCULATIONS}}

From Table {\ref{table(A)}} we obtained $\rho = 0.00726 \,\,\Omega/\text{cm}$ and from Table {\ref{table(B)}} we obtained $R_1 = 3.0\,\, \Omega$ and $R_2 = 5.5 \,\, \Omega$.\\

$\therefore$ The temperature-coefficient of resistance is given by,

\begin{align*}

	\alpha&=\frac{R_2-R_1}{R_1t_2-R_2t_1}\\

		&=\frac{5.5-3.0}{3.0 \times100-5.5\times23} \\

		&=\frac{2.5}{173.5}&\\

		&=0.0144 \,\, \text{per}\, ^\circ C

\end{align*}

 \hspace*{2.5cm}

$ \therefore$\,

 \framebox{$\alpha= 0.0144 \,\,\text{per} \,^\circ C$}


\section{\textsf{PRECAUTIONS AND DISCUSSIONS}}

\begin{enumerate}[label=(\roman*)]

	\item At the beginning both $\bm{X}$ and $\bm{Y}$ should be made zero to see whether the null point is near the middle of the bridge wire (when $\bm{Q_1}$ = $\bm{Q_2}$).If the null point is found very near to 50 cm, it indicates that $\bm{Q_1}$ is almost equal to $\bm{Q_2}$.

	\item In this experiment the effects of the end errors of the bridge wire are eliminated and hence this method using Carey Foster's bridge gives more accurate result than that obtained by using metre bridge.

	\item For greater sensitiveness the resistances of the four arms should be of same order.
```

\item While determining ρ, the value of $\bm{X}$ should be adjusted to make $\left(l_2-l_1\right)$ very nearly equal to the entire length of the bridge wire.This minimises the error due to non-uniformity of the bridge-wire.

\item While measuring R_1 and R_2, $\bm{S}$ should be adjusted to make $\left(l'_2-l'_1\right)$ small. R=S-$\rho\left(l'_2-l'_1\right)$, where $\bm{S}$ is chosen from box and is fairly correct whereas ρ being a measured quantity may have some error. Therefore, the error in $\bm{R}$ is $\delta R_{max} =\delta\rho\left(l'_2-l'_1\right)+\rho\cdot2\delta l$. Smaller is the value of $l'_2-l'_1$, δR_{max} will also be smaller.

\end{enumerate}

\section{\textsf{MAXIMUM PERCENTAGE ERROR}}

\hspace*{1.5cm}We have,

\begin{align}\label{fourth}

\alpha &=\frac{R_2-R_1}{R_1t_2-R_2t_1}\,\,\text{per}\, ^\circ C \nn\\

\therefore\left(\frac{\delta\alpha}{\alpha}\right)_{max}&=\frac{2\delta R}{R_2-R_1}+\frac{\delta R \left(t_1+t_2\right)+\delta t \left(R_1+R_2\right)}{R_1t_2-R_2t_1}

\end{align}

\begin{align*}

\text{where},\,\,\delta t & = \text{1 div. of thermometer}\\

\text{and} \,\,\delta R_{max} &=\rho\left[\frac{l'_2-l'_1}{l_2-l_1}+1\right]\cdot2\delta l\\

\text{where,}\,\,\delta l&=0.1\text{cm (1 div. of the metre scale)}\\

l'_2-l'_1 &=-7.8 \text{cm}\\

l_2-l_1 &= 67.9 \text{cm}\\

\text{and}\,\,\,\,\rho&=0.00726 \,\,\Omega/\text{cm}\\

\therefore \,\,\delta R_{max} & =0.00726\left[\frac{-7.8}{67.9}+1\right] 2\times0.1\\

\delta R_{max}&=1.285\times10^{-3}\,\,\Omega

\end{align*}

\hspace*{1.5cm} Therefore, from equation \ref{fourth}

\begin{align*}

```
\left(\frac{\delta\alpha}{\alpha}\right)_{max}&=\frac{2\delta R}{R_2-R_1}+\frac{\delta R \left(t_1+t_2\right)+\delta t \left(R_1+R_2\right)}{R_1t_2-R_2t_1}\\

&=\frac{2\times1.285\times10^{-3}}{5.5-3.0}+\frac{1.285\times10^{-3}\times\left(23+100\right)+0.1\times\left(3.0+5.5\right)}{3.0\times100-5.5\times23}\\

&=1.028 \times 10^{-3}+5.810\times10^{-3}\\

&=6.838\times10^{-3}\\

\end{align*}

\hspace*{1.5cm}Therefore,\\

\hspace*{2.5cm}

Maximum percentage error

\begin{align*}

\left(\frac{\delta\alpha}{\alpha}\right)_{max}\times100 \,\% &=6.838\times10^{-3}\times100 \, \% \\

&=\pm \,\, 0.68 \,\%

\end{align*}

\hspace*{1.5cm}

$\therefore$\,\,\framebox{Maximum percentage error in $\alpha$ is $\pm$ 0.68\%}

\end{document}
```

UNIVERSITY OF CALCUTTA
ADMIT

B.Sc. SEMESTER - III (HONOURS) Examination 2021
(UNDER CBCS)

Name of the Candidate :
NANDINI KARMAKAR

Father's/Guardian's Name :
BABLU KARMAKAR

Roll & No. :
203013-11-0060

Registration No. :
013-1211-0234-20

Subjects Enrolled :
PHSA,CEMG

Name of the College :
GOKHALE MEMORIAL GIRLS' COLLEGE

SCHEDULE FOR EXAMINATION IN THEORETICAL PAPERS **

Examination Day & Date		Examination Starting Time	Subject Code ++	Course Code	Course Name	Number of Answer book(s) to be used	Signature of the Invigilator on receipt of the answer scripts #
Saturday	15-01-2022	10 A.M.	PHSA	CC5	MATHEMATICAL PHYSICS - II	1	
Sunday	16-01-2022	10 A.M.	PHSA	CC6	THERMAL PHYSICS	1	
Monday	17-01-2022	10 A.M.	PHSA	CC7	MODERN PHYSICS	1	
Tuesday	18-01-2022	10 A.M.	PHSA	SEC-A1	SCIENTIFIC WRITING	1	
Saturday	22-01-2022	10 A.M.	CEMG	GE3	PAPER 3	1	

Signature of the Principal/TIC/OIC of the College with Seal

Controller of Examinations (Actg.)

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"Focus like a laser not a flashlight"

Michael Jordan

January 31, 2022

BSC SEMESTER III PRACTICAL EXAMINATION (CU)2021

- University Registration Number - 013-1211-0234-20
- University Roll Number - 203013-11-0060
- College Roll Number - 20/BSCH/0131
- SUBJECT-PHSA
- PAPER- SECA-1

Name - Nandini Karmakar

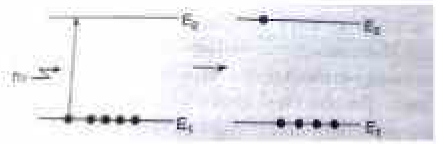

Figure 1:

Figure 2:

1 Introduction

Laser is one of the most exciting and fascinating development in physics of the relatively recent past. It is an acronym for Light Amplification by Stimulated Emission of Radiation (laser) and is a device for producing a highly monochromatic directional and coherent beam of light of high power density. It's working depends on the phenomena of stimulated emission of radiation, the theory of which was worked out as early as 1917 by Einstein. He observed that the absorption and emission processes alone cannot explain the equilibrium and predicted that there must be an additional process now termed as stimulated emission. The prediction attracted little attention until 1954 ,when 2 Russian physicist N.Basov and A.M. Prokhorov and the American physicist C.H.Townes discovered almost simultaneously and independently the phenomena of Microwave Amplification by Stimulated Emission of Radiation (MASER)

2 WORKING PRINCIPLE

2.1 Laser works on the princple: *interaction with radiation with matter.*

Laser action is preceded by three processes, namely, absorption, spontaneous emission and stimulated emission.

2.2 Absorption and emission: Goes hand in hand

Consider a system with v atoms(or molecules).An atom has a number of possible quantized energy states charactersed by its principal quantum number n (=1,2,3,....).For simplicity,we assume only 2 states.It remains in the ground state with minimum energy E_1 in the absence of external influences.On being subjected to some action, say irradiation by photons of right frequency n ,it transits to a higher energy state E_2,absorbing hn of the radiation.This process is called the stimulated absorption or excitation (figure 1)for which the appropriate frequency nis given by

$$v = E_2 - E_1/h$$

Absorption is necessarily a *stimulated* or *induced process*,the absorbed photon being the stimulating photon and the process may be represented symbolically as atom+photon →atom* where the (*) is used to indicate an excited state.

2.3 Spontaneous emission of radiation

Consider now an atom initially in the excited E_2 (figure 2).An atom stays in the excited state usually for a short period 10^{-8s},called its lifetime ,and returns,of its own,to the initial state E_1,hence emitting a a photon of frequency n.This process,opposite to excitation,is termed spontaneous emission or de-excitation.This is represented as atom* → atom +photon and the energy of the photon is given by,

$$h\nu = E_2 - E_1$$

If there is an assembly of atoms,the radiation (photons) emitted by each atom,due to spontaneous transition,has a random direction (no directivity) and a random phase.The emitted light is non-coherent in nature.

The quantum description of the above two processes however is identical-a transition between E_1 and E_2,no matter if it is an excitation or de-excitation.

2.4 Stimulated emission

When a photon of frequency precisely n or energy hν irradiates an atom,already in the excited state E_2,it cannot excite the atom which is already excited.It produces the equivalent effect : it de-excites the atom.So,under the influence of the electromagnetic field of a photon of frequency ν incident on it,it makes a transition to the lower energy state E_1,emitting an additional photon of the same frequency ν(figure3).So,now there are two photons,one original and the other emitted.This can be symbolically represented as; atom*+photon $\rightarrow$ atom +2photons They will be moving in phase in same direction.This type of transition is called stimulated emission of radiation in contrast to spontaneous one .If many such excited atoms are present,each of these two photons can go on to spontaneous one.If many such excited atoms are present,each of these two photons can go on to stimulate two more emissions and producing four photons.So long the majority of atoms one still in excited state.the process can continue in a cascade giving 1 photon$\rightarrow$ 2 photons$\rightarrow$4 photons$\rightarrow$8 photons$\rightarrow$ ... and so on in chains. The process of stimulated emission can thus produce a dramatic amplification of a beam of photons,the basic principle of laser,a device that explains the possibility to amplify light of a definite frequency.

The theory of stimulated emission was first put forward,as already stated ,by Albert Einstein in 1917.While in spontaneous emission,photons are emitted in random directions,in stimulated emission the photon always leaves the atom in the direction of the incident stimulating photon.The incident and stimulated photons are coherent and add to amplify the incident beam.If a large number of excited atoms is involved,the stimulated emission generates *an intense beam of high coherence and extreme directivity.* Transition between energy levels with absorption and emission of radiation are called *radiative transition* .But transitions that occur without absorption or emission of radiation are known as non-radiative transitions that occur mainly due to energy exchange between system and its environments.In laser material such transitions are rather common.

3 EINSTEIN'S THEORY AND A,B COEFFICIENTS

Transition between the various energy states is essentially a statistical process and one cannot predict which particular atom at a given instant will transit from one energy state to another. But if a very large number of atoms are involved,applying the probability theory,the rate of relative transitions between two energy states can be calculated with accuracy.One of the assumptions made were that the atomic system is in equilibrium with e.m.radiation. Let an assembly of atoms be in thermal equilibrium at a temperature T with radiation of frequencyν and energy density $u(\nu)$.Let $N_1$and N_2 be the number of atoms per unit volume at any instant in state 1 and 2 respectively.The probable rateP_{12} of absorption transition 1$\rightarrow$2 depends on the states 1 and 2 and is also proportional to the energy density of the radiation $u(\nu)$.

$$P_{12} = B_{12}u(\nu) \text{ ....(1)}$$

the proportionality constant B_{12} is called the Einstein's coefficient of absorption of radiation. Number of atoms in state 1 that absorbs a photon and rises thereby to state 2 per unit time i.e.,the time rate is given by

$$N_1P_{12} = N_1B_{12}u(n)\text{.............(2)}$$

The probable rate P_{21} of spontaneous transition 2$\rightarrow$1 depends on the states 1 and 2 and also on A_{21},the probability of spontaneous transition 2$\rightarrow$1. Number of atoms in state 2 that drops to state 1 by spontaneous transition per unit time i.e., the time rate is

$$N_2A_{21},\text{ ....(3)}$$

being independent of the energy density $u(v)$ of radiation. A_{21} is called Einstein's coefficient of spontaneous emission of radiation. There may again be a downward stimulated transition from state 2→state 1 due to the electromagnetic radiation field.The probability of such emission transition is proportional to the energy density $u(v)$ of radiation,apart from its dependence on states 1 and 2.It may thus be written as $B_{21}u(v)$,where B_{21} is the probability of stimulated emission. Number of atoms undergoing stimulated transition 2→1 per unit time,

$$N_2B_{21}u(v)................(4)$$

B_{21} is the Einstein's coefficient of spontaneous emission of radiation.

4 RELATION BETWEEN A AND B COEFFICIENTS

For equilibrium,the absorption and emission per unit time must occur equally.

$$N_1B_{12}u(v) = N_2A_{21} + N_2B_{21}u(v)$$

$$u(v) = \frac{N_2A_{21}}{(N_1B_{12} - N_2B_{21})} = \frac{A_{21}}{B_{21}}.\frac{1}{\frac{N_1}{N_2}.\frac{B_{12}}{B_{21}} - 1}$$

$$= \frac{A_{21}}{B_{21}}.\frac{1}{\frac{B_{12}}{B_{21}}e^{hv/kT} - 1]}...............(5)$$

$$[N_1/N_2 = e^{hv/kT}]$$

This relation for the energy density of radiation of frequency v must be in accordance with *Planck's radiation formula*:

$$u(v) = \frac{8hv^3}{c^3}.\frac{1}{e^{hv/kT} - 1}........(6)$$

Comparing (5) and(6) we get

$$B_{12} = B_{21} and A_{21}/B_{21} = 8hv^3/c^3$$

In general

$$B_{mn} = B_{nm}$$

$$and$$

$$A_{nm}/B_{nm} = 8hv^3/c^3(n > m)........(7)$$

Thus probabilities of stimulated absorption and stimulated emission are equal.Further, the second equality implies that the probabilities of spontaneous emission increases as v^3,i.e.,rapidly with energy difference between the involved states.It implies that the probability of spontaneous emission dominates over induced emission more and more as the energy difference between the two state increases.Laser action becomes more difficult at higher frequencies. The two relations in (7) are called Einstein's relations and the A's and the B's are referred to as EINSTEIN,S A AND B COEFFICIENTS. They cannot be determined by the classical electromagnetic theory. However,B can be calculated quantum mechanically using Dirac's theory and thence A can be obtained.

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ACTION: To cause population inversion, the medium A is fed with the pump energy E which is then released from the excited atom stimulates another it encounters in its path to release a second photon; the two coherent photons add completely to a beam of twice the intensity.As the beam courses through the medium,its amplitude rapidly increases more by more and more stimulated emissions.The total reflector T then reverses the beam allowing it another passage(in fact, multiple reversions may occur) through the excited medium for further amplification.On reaching P, a part L of the beam escapes as a *laser beam*. Stimulated photons that are emitted inclined to the axis are lost through the sides of the system so that the final emergent beam is always along the axis. Although Einstein's theory of stimulated emission is as old as 1917, the concept of population inversion however came much later,not before 1954, to make lasing possible.

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Solid dielectric lasers include ruby at 6940 A,Nd:YAG(Yttrium-Aluminium Garnet),i.e., YAG with Nd as impurity at l=1.064 mm and glass:Nd,i.e.,glass with Nd as impurity at l=1.064 mm.

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Gas-lasers include He-Ne at 6328A and argon ion and Krypton ion emitting in blue-green and red part.Another important gas laser is CO_2_ laser developed by C.K.N. Patel.

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Such lasers are made of a single crystal of a suitable impurity semiconductor such as GaAs(gallium arsenide) emitting near infrared(8300-8500A).

5.4 TUNABLE LASERS:

They are of two kinds:

1. Dye lasers(pumped by argon and nitrogen lasers)and
2. Parametric oscillators(where a non linear crystal,e.g.,$LiNbO_2$(lithium niobate) is pumped by Nd:YAG lasers). The dye lasers use active fluorescent material (organ dye),e.g.,fluorescin or rhodamine 6G or B in a solvent, emitting radiation ranging from 500-1000A.

6 Laser and its Applications

Laser generates ligh waves[$10^{14}Hz$].Since 1960,it opened up a completely new field of development in Optics.Although a source of light,it doesnot find itself useful in illumination purposes rather it shows a close resemblance with radio and microwave transmitters as like them it finds it's usage in generating a highly coherent and directional light beam of extreme monochromaticity. Owing to it's ability of providing lumious intensity of the order $10^{20}-10^{30}K$ with ease,it also finds it's use when it comes to the study of non-linear optical effects,optical beating,long distance interferenceand many other exhilarating phenomena.

Laser science or laser physics forms a link between quantum electronics and atomic and molecuar physics.It acquires a commanding position as it's study involves overlap of different branhes of physics namelyquantum computing,laser cooling,quantum chemistry and quantum cryptographyand many more which makes it a very engrossing subject.

SOURCE CODE

```
\documentclass{article}


\usepackage[english]{babel}


\usepackage[letterpaper,top=2cm,bottom=2cm,left=3cm,right=3cm,marginparwidth=1.75cm]{geometry
}


\usepackage{amsmath}
\usepackage{graphicx}
\usepackage[colorlinks=true, allcolors=blue]{hyperref}

\title{"Focus like a laser not a flashlight"}
\author{\textit{\textbf{Michael Jordan}}}

\begin{document}
\maketitle
```

{ BSC SEMESTER III PRACTICAL EXAMINATION (CU)2021 }

\begin{itemize}

\item {University Registration Number - 013-1211-0234-20}

\item {University Roll Number - 203013-11-0060}

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\end{itemize}

\pagebreak

\section{Introduction}

Laser is one of the most exciting and fascinating development in physics of the relatively recent past. It is an acronym for Light Amplification by Stimulated Emission of Radiation (laser) and is a device for producing a highly monochromatic directional and coherent beam of light of high power density. It's working depends on the phenomena of stimulated emission of radiation, the theory of which was worked out as early as 1917 by Einstein. He observed that the absorption and emission processes alone cannot explain the equilibrium and predicted that there must be an additional process now termed as stimulated emission. The prediction attracted little attention until 1954 ,when 2 Russian physicist N.Basov and A.M. Prokhorov and the American physicist C.H.Townes discovered almost simultaneously and independently the phenomena of Microwave Amplification by Stimulated Emission of Radiation (MASER)

\section{WORKING PRINCIPLE}

\subsection{Laser works on the princple:\textit{ interaction with radiation with matter.}}

Laser action is preceded by three processes, namely, absorption, spontaneous emission and stimulated emission.

\subsection{Absorption and emission: Goes hand in hand }

\begin{figure}

\centering

\includegraphics[width=0.4\textwidth]{1.jpg}

\caption{\label{fig:1}}

\end{figure}

Consider a system with \textit{v} atoms(or molecules).An atom has a number of possible quantized energy states charactersed by its principal quantum number n (=1,2,3,....,).For simplicity,we assume only 2 states.It remains in the ground state with minimum energy \(E_1\) in the absence of external influences.On being subjected to some action, say irradiation by photons of right frequency n ,it transits to a higher energy state \(E_2\),absorbing hn of the radiation.This process is called the stimulated absorption or excitation (figure 1)for which the appropriate frequency nis given by

\[{v} =E_2-E_1/h\]

Absorption is necessarily a \underline{\textit{stimulated}} or \underline{\textit{induced process}},the absorbed photon being the stimulating photon and the process may be represented symbolically as

atom+photon →atom*

where the (*) is used to indicate an excited state.

\begin{figure}

\centering

\includegraphics[width=0.4\textwidth]{2.jpg}

\caption{\label{fig:2}}

\end{figure}

\subsection{Spontaneous emission of radiation}

Consider now an atom initially in the excited E_2 (figure 2).An atom stays in the excited state usually for a short period ~10^{-8s},called its lifetime ,and returns,of its own,to the initial state E_1,hence emitting a a photon of frequency n.This process,opposite to excitation,is termed spontaneous emission or de-excitation.This is represented as

atom* → atom +photon

and the energy of the photon is given by,

$$h\textit{v}=E_2-E_1$$

If there is an assembly of atoms,the radiation (photons) emitted by each atom,due to spontaneous transition,has a random direction (no directivity) and a random phase.The emitted light is non-coherent in nature.

The quantum description of the above two processes however is identical-a transition between E_1 and E_2,no matter if it is an excitation or de-excitation.

\subsection{Stimulated emission}

When a photon of frequency precisely n or energy h\textit{v} irradiates an atom,already in the excited state \(E_2\),it cannot excite the atom which is already excited.It produces the \underline{equivalent effect} : it de-excites the atom.So,under the influence of the electromagnetic field of a photon of frequency \textit{v} incident on it,it makes a transition to the lower energy state \(E_1\),emitting an additional photon of the same frequency \textit{v}(figure3).So,now there are two photons,one original and the other emitted.This can be symbolically represented as;

atom*+photon → atom +2photons

They will be moving in phase in same direction.This type of transition is called \underline{stimulated emission} of radiation in contrast to spontaneous one .If many such excited atoms are present,each of these two photons can go on to spontaneous one.If many such excited atoms are present,each of these two photons can go on to stimulate two more emissions and producing four photons.So long the majority of atoms one still in excited state,the process can continue in a cascade giving

1 photon→ 2 photons→4 photons→8 photons→ ...

and so on in chains.

The process of stimulated emission can thus produce a dramatic amplification of a beam of photons,the basic principle of laser,a device that explains the possibility to amplify light of a definite frequency.

The theory of stimulated emission was first put forward,as already stated ,by Albert Einstein in 1917.While in spontaneous emission,photons are emitted in random directions,in stimulated emission the photon always leaves the atom in the direction of the incident stimulating photon.The incident and stimulated photons are coherent and add to amplify the incident beam.If a large number of excited atoms is involved,the stimulated emission generates \underline{\textit{an intense beam of high coherence and extreme}}

\underline{\textit directivity.}

Transition between energy levels with absorption and emission of radiation are called \underline{\textit{radiative transition}} .But transitions that occur without absorption or emission of radiation are known as non-radiative transitions that occur mainly due to energy exchange between system and its environments.In laser material such transitions are rather common.

EINSTEIN'S THEORY AND A,B COEFFICIENTS

Transition between the various energy states is essentially a statistical process and one cannot predict which particular atom at a given instant will transit from one energy state to another. But if a very large number of atoms are involved,applying the probability theory,the rate of relative transitions between two energy states can be calculated with accuracy.One of the assumptions made were that the atomic system is in equilibrium with e.m.radiation.

Let an assembly of atoms be in thermal equilibrium at a temperature T with radiation of frequency v and energy density $u(v)$.Let $N_1$and N_2 be the number of atoms per unit volume at any instant in state 1 and 2 respectively.The probable rate P_{12} of absorption transition 1→2 depends on the states 1 and 2 and is also proportional to the energy density of the

radiation $u(\textit{v})$.

$$\therefore P_{12}=B_{12}u(\textit{v}) \ \ldots\ldots\ldots(1)$$

the proportionality constant B_{12} is called the Einstein's coefficient of absorption of radiation.

∴Number of atoms in state 1 that absorbs a photon and rises thereby to state 2 per unit time i.e.,the time rate is given by

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For equilibrium,the absorption and emission per unit time must occur equally.

$$\therefore N_1B_{12}u(\textit{v})=N_2A_{21}+N_2B_{21}u(v)$$

$$u(\textit{v})= \frac{N_2A_{21}}{(N_1B_{12}-N_2B_{21})}$$

$$=\frac{A_{21}}{B_{21}}.\frac{1}{\frac{N_1}{N_2}.\frac{B_{12}}{B_{21}}-1}$$

$$=\frac{A_{21}}{B_{21}}.\frac{1}{\frac{B_{12}}{B_{21}}e^{hv/kT}-1} \qquad \text{...............}(5)$$

$$[\because N_1/N_2=e^{hv/kT}]$$

This relation for the energy density of radiation of frequency *v* must be in accordance with <u>*Planck's radiation formula*:</u>

$$u(\textit{v})= \frac{8\pi hv^3}{c^3}.\frac{1}{e^{hv/kT}-1} \qquad \text{........}(6)$$

Comparing (5) and(6) we get

$$B_{12}=B_{21} \text{ and } A_{21}/B_{21}=8\pi h\nu^3/c^3$$

In general

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\end{document}

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UNIVERSITY OF CALCUTTA

ADMIT

B.Sc. SEMESTER - III (HONOURS) Examination-2021

(UNDER CBCS)

Name of the Candidate :

BIDISHA DAS

Father's/Guardian's Name :

BIMAL KUMAR DAS

Roll & No. :

203013-11-0102

Registration No.

013-1214-0236-20

Subjects Enrolled :

PHSA,CEMG

Name of the College :

GOKHALE MEMORIAL GIRLS' COLLEGE

Bidisha Das

SCHEDULE FOR EXAMINATION IN THEORETICAL PAPERS **

Examination Day & Date		Examination Starting Time	Subject Code ++	Course Code	Course Name	Number of Answer book(s) to be used	Signature of the invigilator on receipt of the answer script/s @
Saturday	15-01-2022	10 A.M.	PHSA	CC5	MATHEMATICAL PHYSICS - II	1	
Sunday	16-01-2022	10 A.M.	PHSA	CC6	THERMAL PHYSICS	1	
Monday	17-01-2022	10 A.M.	PHSA	CC7	MODERN PHYSICS	1	
Tuesday	18-01-2022	10 A.M.	PHSA	SEC-A1	SCIENTIFIC WRITING	1	
Saturday	22-01-2022	10 A.M.	CEMG	GE3	PAPER 3	1	

Signature of the Principal/TIC/OIC of the College with Seal	[illegible] Controller of Examinations (Actg.)
** Subject to unavoidable changes ++ In no circumstances subject/s to be altered	N.B. Please follow University Notification No. CE/ADM/18/229 Dated 04/12/2018 in www.cuexam.net for instruction of Examinee/Invigilator/Examination centre.

MEASUREMENTS OF PLANCK'S CONSTANT USING LED

NAME- **BIDISHA DAS**

COLLEGE-**GOKHALE MEMORIAL GIRLS' COLLEGE , KOLKATA**

COLLEGE ROLL NO.-**20/BSCH/0180**

CALCUTTA UNIVERSITY REGISTRATION NO.-**013-1214-0236-20**

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STREAM-**PHSA**

PAPER CODE-**SEC-A1**

SEMESTER-**3**

EXAMINATION NAME- **BSc.HONOURS SEMESTER III PRACTICAL EXAMINATION(CU),2021**

DATE-**31STJANUARY, 2022**

1 AIM

To find the of Planck's Constant using the graph of voltage of the different coloured Led against their wavelength.

2 THEORY

An Led is a terminal semiconductor light source.In the unbiased condition a potential barrier developed across the p-n junction is reduced.At a particular voltage,the height of potential barrier becomes very low and the led starts glowing i.e. in the forward biased condition electron crossing the p-n junction are excited and when they return to their normal state,energy is emitted.This particular voltage is reached then the current may increase.

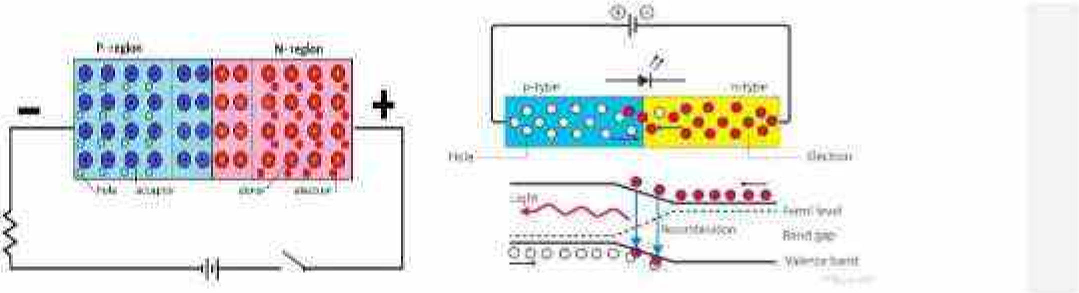

Figure 1: **P-N JUCTION DIODE**

The light energy emitted during forward biasing is given as :

$$E = h \times \nu \tag{1}$$

where,
E=The Emitted Energy.

ν = The Frequency of the emitted energy.

h = Planck's Constant.

or,

$$E = \frac{h \times c}{\lambda} \tag{2}$$

where,
c = Velocity of the Light.

λ = wavelength of the Light .

$\frac{1}{\lambda}$ = Wave Number.

If V is the forward voltage applied across the LED terminals that makes it emit light(it is also called forward knee voltage/threshold voltage) then the energy given to the LED is given by

$$E = e \times V \tag{3}$$

where,

e = Electronic Charge.

LEDs are very high efficiency diodes and hence this entire electrical energy is connected into light energy , then equation (2) and (3)

$$eV = \frac{h \times c}{\lambda} \tag{4}$$

From which Planck's Constant is given by

$$h = \frac{e \times \nu \times \lambda}{c} \tag{5}$$

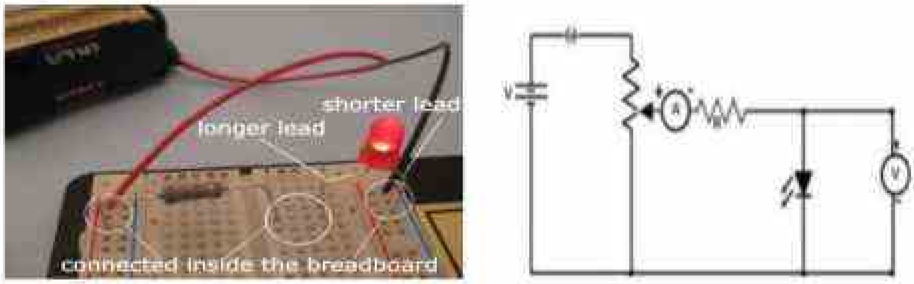

Figure 2: <u>**CIRCUIT DIAGRAM**</u>

3 EXPERIMENTAL DATAS

We know,
$c = 3 \times 10^8 \quad ms^{-1}$
$e = 1.6 \times 10^{-19} \ C$

Table 1: **CALCULATION OF PLANCK'S CONSTANT**

COLOUR	WAVELENGTH	$(1/\lambda)$	KNEE VOLTAGE	MEAN
GREEN	548 nm	$1.8248 \times 10^6 \ m^{-1} \approx 1.82 \times 10^6 \ m^{-1}$	a)2.05 V	2.00 V
			b)2.00 V	
			c)1.96 V	
YELLOW	576 nm	$1.7361 \times 10^6 \ m^{-1} \approx 1.73 \times 10^6 \ m^{-1}$	a)1.78 V	1.71 V
			b)1.66 V	
			c)1.71 V	
BLUE	450 nm	$2.2222 \times 10^6 \ m^{-1} \approx 1.73 \times 10^6 \ m^{-1}$	a)2.41 V	2.416 V
			b)2.42 V	
			c)2.42 V	
RED	620 nm	$1.6120 \times 10^6 \ m^{-1} \approx 1.61 \times 10^6 \ m^{-1}$	a)1.65 V	2.416 V
			b)1.73 V	
			c)1.63 V	

Table 2: **MEASUREMENTS OF VOLTAGE AND CURRENT OF LED'S AND KNEE VOLTAGE**

V(in volt)	RED(in mA)	Yellow (in mA)	Green(in mA)	Blue (in mA)
0	0	0	0	0
0.5	0	0	0	0
1	0	0	0	0
1.5	0	0	0	0
1.6	0	0	0	0
1.65	0.1	0	0	0
1.7	0.29	0.1	0	0
1.85	4.75	0.48	0	0
1.9	4	1.43	0	0
1.95		3.33	0	0
2.08			0.02	0
2.20			0.16	0
2.25			0.37	0
2.3			0.70	0
2.35			1.21	0
2.40			1.80	0.03
2.50			3.31	0.17

Table 3: **COMPARISON VALUE TABLE**

Colour	Experimental Values of Knee Voltage	Knee Voltage Values obtained from Graph
Red	1.65 V	1.65 V
Yellow	01.7 V	1.71 V
Green	2.08 V	1.9866 V
Blue	2.40 V	2.4166 V

4 CALCULATIONS

We know,
$c = 3 \times 10^8 \quad ms^{-1}$
$e = 1.6 \times 10^{-19} \ C$

From the Graph,

$$slope = \frac{hc}{e}$$

or,

$$h = \frac{e\,(V_2 - V_1)}{c\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right)}$$

$$= \frac{0.6 \times 1.6 \times 10^{-19}}{0.49 \times 3 \times 10^8}$$

$$= \ 6.53 \times 10^{-34} \ \ J - s$$

5 PERCENTAGE ERROR

$VALUE_{KNOWN} = 6.626 \times 10^{-34} J - s$
$VALUE_{EXPERIMENTAL} = 6.53 \times 10^{-34} J - s$
$PercentageError = \frac{VALUE_{KNOWN} - VALUE_{EXPERIMENTAL}}{VALUE_{KNOWN}} \times 100$

$$= \frac{6.626 \times 10^{-34} - 6.53 \times 10^{-34}}{6.626 \times 10^{-34}} \times 100$$

$$= 1.44\%$$

GRAPH

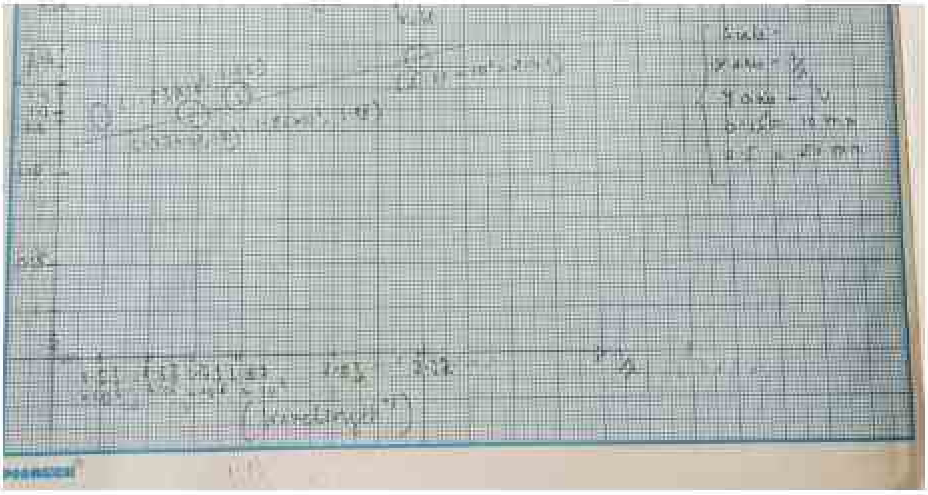

Figure 3: VOLTAGE vs WAVELENGTH^{-1}

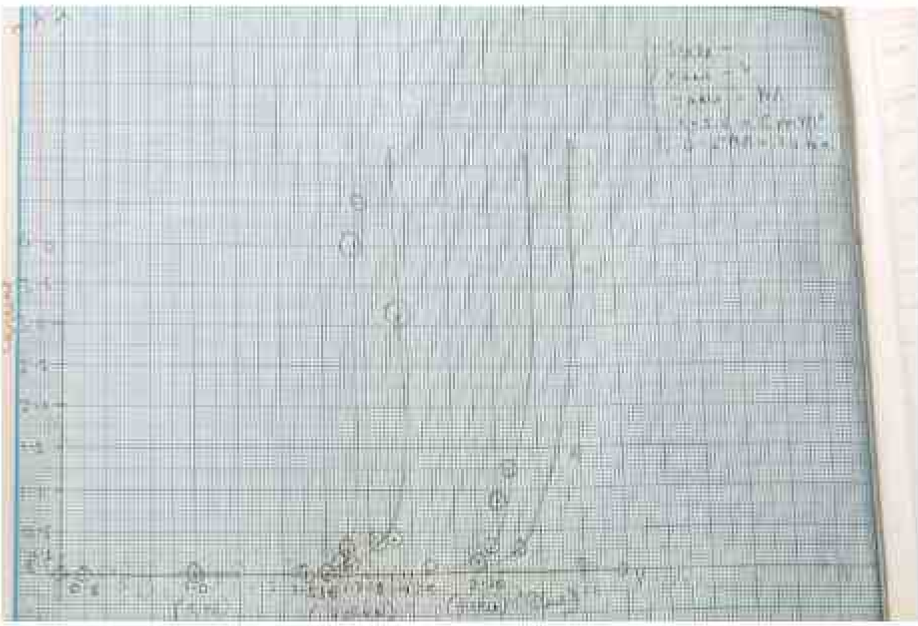

Figure 4: **VOLT vs CURRENT**

Figure 5:

6 ERRORS AND PRECAUTIONS

6.1 Systematic Error:

Since measurements are affected by the voltmeter such that the voltage is constantly lowered by some amount, the voltage reading attained is less than the actual stopping potential, especially at the lower intensities where the voltage is sustained at a lower rate. In addition, the time to attain the stopping voltage is greater because of this drain through the voltmeter. The static electricity of the observer in touching the h/e. Apparatus to reset the voltage reading can also affect the reading. Crossover of light from third order spectral lines to the second order affected the stopping potentials for that order.

6.2 Random Error:

A major component of random error was the variance in human response times between readings, and communication times between the observer and the recorder. Another source of random error was the adjustment of spectral lines on the aperture inside the h/e Apparatus, which we were not properly aware of until the third day. The data consistency is also affected by the connection to a voltmeter. The time to attain the stopping voltage is affected more strongly by the drain of voltage through the voltmeter at lower intensities because the charging rate is slower.

7 PRECAUTIONS

7.1 1

Reading should be taken just when the LED just start to emit light.

7.2 2

Voltmeter and ammeter should be at zero error.

7.3 3

We should note down the corresponding photocurrent with least error possible.

8 CONCLUSION

It is determined experimentally that the value of Planck's Constant $h = 6.53 \times 10^{-34}\ \ J - s$ which is within acceptable limits as compared to the Known value h = 6.626x1034J - s with a difference of 1.44%. Regarding random error and measurement uncertainty, total differentials proved to bein-significant with regard to the the final precision of the experimental value of h as evident by the magnitude of in the final experimental value.Further investigation and refinement of experimental execution and techniques would most likely decrease random error. Furthermore the acquisition of additional data for a variety of LEDs within each color group would also help to decrease random error by statistical elimination of inherent manufacturing inconsistencies in the LEDs.

```
\documentclass{article}

\usepackage[utf8]{inputenc}

\usepackage{setspace}

\usepackage[a4paper ,total={6in, 8in}]{geometry}

\usepackage{stackengine,graphicx}

\parindent0px

\setcounter{footnote}{0}

\date{}

\begin{document}

\maketitle

\begin{center}

\title{\bf\Large\underline{MEASUREMENTS OF PLANCK'S CONSTANT USING LED}}


\vspace{6mm}

\title{ \Large{NAME- \bf {BIDISHA DAS}}} \\

\vspace{6mm}

\title{\Large{COLLEGE-\bf GOKHALE MEMORIAL GIRLS' COLLEGE , KOLKATA}}\\

\vspace{6mm}

\title{\Large{COLLEGE ROLL NO.-\bf {20/BSCH/0180}}}\\

\vspace{6mm}

\title{\Large{CALCUTTA UNIVERSITY REGISTRATION NO.-\bf {013-1214-0236-20}}}\\

\vspace{6mm}

\title{\Large{CALCUTTA UNIVERSITY ROLL NO.-\bf{203013-11-0102}}}\\

\vspace{6mm}

\title{\Large{STREAM-\bf PHSA}}\\
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\vspace{6mm}

\title{\Large{PAPER CODE-\bf SEC-A1}}\\

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\title{\Large{SEMESTER-\bf 3}}\\

\vspace{6mm}

\title{\Large{EXAMINATION NAME- \bf {BSc.HONOURS SEMESTER III PRACTICAL
EXAMINATION(CU),2021}}} \\

\vspace{6mm}

\date{\Large {DATE-\bf{31^{\bf ST} \bf{JANUARY , 2022}}}\\


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\section{AIM}

To find the of Planck's Constant using the graph of voltage of the different coloured Led against their
wavelength.

\section{THEORY}

An Led is a terminal semiconductor light source.In the unbiased condition a potential barrier developed
across the p-n junction is reduced.At a particular voltage,the height of potential barrier becomes very
low and the led starts glowing i.e. in the forward biased condition electron crossing the p-n junction are
excited and when they return to their normal state,energy is emitted.This particular voltage is reached
then the current may increase.\\


\begin{figure}[h!]

   \centering
```

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  \includegraphics[width=\linewidth]{1.jpg}

  \caption{\bf \underline{P-N JUCTION DIODE}}

  \label{fig:my_label}

\end{figure}

The light energy emitted during forward biasing is given as :

\begin{equation}

\label{eu_eqn}

E = h \times \nu

\end{equation}\\

where,

\vspace{1mm}

\\E=The Emitted Energy.\\

\\ $\displaystyle \nu$ = The Frequency of the emitted energy.\\

\\ h = Planck's Constant.\\


or, \begin{equation}

 \label{eu_eqn}

 E = \frac{h \times c}{\lambda}

\end{equation}

where,

\vspace{1mm}

\\c = Velocity of the Light.\\

\\  $\displaystyle\lambda$ = wavelength of the Light .\\

\\ $\displaystyle \frac{1}{\lambda}$ = Wave Number. \\

\vspace{2mm}\\
```

If V is the forward voltage applied across the LED terminals that makes it emit light(it is also called forward knee voltage/threshold voltage) then the energy given to the LED is given by

\begin{equation}

\label{eq_eqn}

E = e\times V

\end{equation}

where,

\vspace{1mm}

\\e = Electronic Charge.\\

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LEDs are very high efficiency diodes and hence this entire electrical energy is connected into light energy , then equation (2) and (3)

\begin{equation}

\label{eq_eqn}

e V = \frac{h \times c}{\lambda}

\end{equation}

From which Planck's Constant is given by

\begin{equation}

\label{eq_eqn}

h = \frac{e \times \nu \times \lambda}{c}

\end{equation} \\

\vspace{2mm}

\begin{figure}[h!]

\centering

\includegraphics[width=\linewidth]{2.jpg}

```
   \caption{\bf \underline {CIRCUIT DIAGRAM}}

   \label{fig:my_label}

\end{figure}

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\section{EXPERIMENTAL DATAS}

We know,\\

$c = 3\times 10^{8} \hspace{4mm} \si{ms^{-1}$ \\

$e = 1.6 \times 10^{-19} \hspace{2mm}\si{C}$


\vspace{3mm}

\begin{table}[h]

\caption{\bf \underline{CALCULATION OF PLANCK'S CONSTANT}}

\vspace{2mm}

 \begin{tabular}{||c|c|c|c|c||} \hline\hline


COLOUR & WAVELENGTH & $(1/\lambda)$ & KNEE VOLTAGE & MEAN \\

\hline\hline

GREEN & $548 \hspace{2mm}\si{nm}$ & $1.8248\times 10^6\hspace{2mm} \si{m^{-1}}$ {{\approx}}
1.82 \times 10^{6}\hspace{2mm} \si{m^{-1}}$ & a)$2.05\hspace{2mm}\si{V}$ &
$2.00\hspace{2mm}\si{V}$\\

\hline

& & & b)$2.00 \hspace{2mm}\si{V}$ & \\

\hline

& & & c)$1.96\hspace{2mm} \si{V}$ & \\

\hline
```

```
YELLOW & $576\hspace{2mm} \si{nm}$ & $1.7361\times 10^6\hspace{2mm} \si{m^{-1}}$
${\displaystyle{\approx}} 1.73 \times 10^{6}\hspace{2mm} \si{m^{-1}}$ & a)$1.78\hspace{2mm}\si{V}$
& $1.71\hspace{2mm}\si{V}$\\

\hline

& & & b)$1.66\hspace{2mm}\si{V}$ & \\

\hline

& & & c)$1.71\hspace{2mm}\si{V}$ & \\

\hline

BLUE & $450\hspace{2mm} \si{nm}$ & $2.2222\times 10^6 \hspace{2mm}\si{m^{-1}$
${\displaystyle{\approx}} 1.73 \times 10^{6} \hspace{2mm}\si{m^{-1}}$ & a)$2.41\hspace{2mm}\si{V}$
& $2.416\hspace{2mm}\si{V}$\\

\hline

& & & b)$2.42\hspace{2mm}\si{V}$ & \\

\hline

& & & c)$2.42\hspace{2mm}\si{V}$ & \\

\hline

RED & $620\hspace{2mm} \si{nm}$ & $1.6120\times 10^6 \hspace{2mm}\si{m^{-1}}$
${\displaystyle{\approx}} 1.61 \times 10^{6} \hspace{2mm}\si{m^{-1}}$ & a)$1.65\hspace{2mm}\si{V}$
& $2.416\hspace{2mm}\si{V}$\\

\hline

& & & b)$1.73\hspace{2mm}\si{V}$ & \\

\hline

& & & c)$1.63\hspace{2mm}\si{V}$ & \\

\hline\hline

\end{tabular}


\end{table}

\begin{center}
```

```
\begin{table}

\caption{\bf \underline{MEASUREMENTS OF VOLTAGE AND CURRENT OF LED'S AND KNEE VOLTAGE }}
\vspace{2mm}
\begin{tabular}{||c|c|c|c|c||} \hline\hline
\si{V}(in volt) & RED(in \si{mA}) & Yellow (in \si{mA}) & Green( in \si{mA} }& Blue (in \si{mA}) \\
\hline
$0$ & $0$ & $0$ & $0$ & $0$ \\
\hline
$0.5$ & $0$ & $0$ & $0$ & $0$ \\
\hline
$1$ & $0$ & $0$ & $0$ & $0$ \\
\hline
$1.5$ & $0$ & $0$ & $0$ &$0$
\\
\hline
$1.6$ & $0$ & $0$ & $0$ & $0$ \\
\hline
$1.65$ & $0.1$ & $0$ & $0$ & $0$ \\
\hline
$1.7$ & $0.29$ & $0.1$ & $0$ & $0$ \\
\hline
$1.85$ & $4.75$ & $0.48$ & $0$ & $0$ \\
\hline
$1.9$ & $4$ & $1.43$ & $0$ & $0$ \\
```

```
\hline
$1.95$ & & $3.33$ & $0$ & $0$ \\
\hline
$2.08$ & & & $0.02$ & $0$ \\
\hline
$2.20$ & & & $0.16$ & $0$ \\
\hline
$2.25$ & & & $0.37$ & $0$ \\
\hline
$2.3$ & & & $0.70$ & $0$ \\
\hline
$2.35$ & & & $1.21$ & $0$ \\
\hline
$2.40$ & & & $1.80$ & $0.03$ \\
\hline
$2.50$ & & & $3.31$ & $0.17$ \\
\hline\hline
\end{tabular}

\end{table}
\end{center}

\newpage
\begin{table}[h!]
\caption{\bf \underline{COMPARISON VALUE TABLE}}
```

```
\vspace{2mm}

\begin{tabular}{||c|c|c||}

\hline\hline


Colour  &  Experimental Values of Knee Voltage & Knee Voltage Values obtained from Graph \\

\hline\hline

Red & $1.65 \hspace{2mm}\si{V}$ & $1.65 \hspace{2mm}\si{V}$ \\

\hline

Yellow & $01.7 \hspace{2mm} \si{V} & $1.71 \hspace{2mm}\si{V}$ \\

\hline

Green & $2.08 \hspace{2mm}\si{V}$ & $1.9866 \hspace{2mm}\si{V} \\

\hline

Blue & $2.40 \hspace{2mm}\si{V}$ & $2.4166 \hspace{2mm}\si{V}$ \\

\hline\hline


\end{tabular}

\end{table}

\newpage


\begin{figure}[H]

\section*{GRAPH}

\centering

  \begin{subfigure}

  \includegraphics[width=0.8\textwidth]{3.jpg}

  \caption{{VOLTAGE vs WAVELENGTH^{-1}}}
```

```
  \label{fig:Ng1}
\end{subfigure}
\vspace{6mm}
\begin{subfigure}
  \includegraphics[width=0.8\textwidth]{4.jpg}
  \caption{{\bf \underline{VOLT vs CURRENT }}}
  \label{fig:Ng2}
\end{subfigure}
\caption{}
\end{figure}
\newpage



\section{CALCULATIONS}
We know,\\
$c = 3\times 10^{8} \hspace{4mm} \si{ms^{-1}$ \\
$e = 1.6 \times 10^{-19} \hspace{2mm}\si{C}$


\vspace{3mm}
From the Graph, \\
$$slope=\displaystyle \frac{hc}{e}$$ \\
\vspace{2mm}
or,$$\displaystyle h = \frac{c  \left(V_2_- V_1 \right) }{c \left( \frac{1}{\lambda_2}-\frac{1}{\lambda_1}
\right) }$$ \\
\vspace{2mm}
```

$$=\frac{0.6 \times 1.6 \times 10^{-19}}{0.49 \times 3 \times 10^8}$$

\vspace{2mm}

$$=\hspace{2mm}6.53\times 10^{-34}\hspace{2mm}\si{J-s}$$

\vspace{4mm}

\section{PERCENTAGE ERROR}

$VALUE_{KNOWN} = 6.626 \times 10^{-34} \si{J-s}$ \\

\vspace{1mm}

$VALUE_{EXPERIMENTAL} = 6.53 \times 10^{-34} \si{J-s}$ \\

\vspace{6mm}

\displaystyle {$$Percentage Error = \displaystyle \frac{VALUE_{KNOWN} - VALUE_{EXPERIMENTAL}}{VALUE_{KNOWN}} \times 100 $$}

\vspace{2mm} \\

$$=\frac{6.626 \times 10^{-34}-6.53 \times 10^{-34}}{6.626 \times 10^{-34}} \times 100$$ \\

\

\vspace{2mm}

$$=1.44 \%$$

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\section{ERRORS AND PRECAUTIONS}

\subsection{Systematic Error:}Since measurements are affected by the voltmeter such that the voltage is constantly lowered by some amount, the voltage reading attained is less than the actual stopping potential, especially at the lower intensities where the voltage is sustained at a lower rate. In addition, the time to attain the stopping voltage is greater because of this drain through the voltmeter. The static electricity of the observer in touching the h/e. Apparatus to reset the voltage reading can also affect the reading. Crossover of light from third order spectral lines to the second order affected the stopping potentials for that order.

\subsection{Random Error:}A major component of random error was the variance in human response times between readings, and communication times between the observer and the recorder. Another source of random error was the adjustment of spectral lines on the aperture inside the h/e Apparatus, which we were not properly aware of until the third day.

The data consistency is also affected by the connection to a voltmeter. The time to attain the stopping voltage is affected more strongly by the drain of voltage through the voltmeter at lower intensities because the charging rate is slower.

\section{PRECAUTIONS}

\subsection{1}

Reading should be taken just when the LED just start to emit light.

\subsection{2}

Voltmeter and ammeter should be at zero error.

\subsection{3}

We should note down the corresponding photocurrent with least error possible.

\vspace{4mm}

\section{CONCLUSION}

It is determined experimentally that the value of Planck's Constant $h = 6.53 \times 10^{-34} \hspace{2mm}\si{J-s}$ which is within acceptable limits as compared to the Known value h = 6.626x10−34J · s with a difference of 1.44%. Regarding random error and measurement uncertainty, total differentials proved to beinsignificant with regard to the the final precision of the experimental value of h as evident by the magnitude of in the final experimental value.Further investigation and refinement of experimental execution and techniques would most likely decrease random error. Furthermore the acquisition of additional data for a variety of LEDs within each color group would also help to decrease random error by statistical elimination of inherent manufacturing inconsistencies in the LEDs.

\end{document}

013/1801103009/0001 0130386

UNIVERSITY OF CALCUTTA

ADMIT

B.Sc. SEMESTER - III (HONOURS) Examination-2021

(UNDER CBCS)

Name of the Candidate :

ANWESHA DAS

Father's/Guardian's Name :

JHANTU CHARAN DAS

Roll & No. :

203013-11-0059

Registration No.

013-1211-0233-20

Subjects Enrolled :

PHSA,MTMG

Anwesha Das

Name of the College :

GOKHALE MEMORIAL GIRLS' COLLEGE

SCHEDULE FOR EXAMINATION IN THEORETICAL PAPERS **

Examination Day & Date		Examination Starting Time	Subject Code ++	Course Code	Course Name	Number of Answer book(s) to be used	Signature of the invigilator on receipt of the answer script/s @
Saturday	15-01-2022	10 A.M.	PHSA	CC5	MATHEMATICAL PHYSICS - II	1	
Sunday	16-01-2022	10 A.M.	PHSA	CC6	THERMAL PHYSICS	1	
Monday	17-01-2022	10 A.M.	PHSA	CC7	MODERN PHYSICS	1	
Tuesday	18-01-2022	10 A.M.	PHSA	SEC-A1	SCIENTIFIC WRITING	1	
Friday	21-01-2022	2 P.M.	MTMG	GE3	MATHEMATICS-CC3/GE3	1	

Signature of the Principal/TIC/OIC of the College with Seal	Controller of Examinations (Actg.)
** Subject to unavoidable changes ++ In no circumstances subject/s to be altered	N.B. Please follow University Notification No. CE/ADM/18/229 Dated 04/12/2018 in www.cuexam.net for instruction of Examinee/Invigilator/Examination centre.

Calibration of a thermocouple by direct measurement of thermo-emf using potentiometer and the constants

31st January, 2022

Anwesha Das

University Registration No: 013-1211-0233-20

University Roll No: 203013-11-0059

Examination Name: BSc Honours Semester III Practical Examination(CU), 2021

Subject : PHSA
Paper: SEC-A-1

0.1 *Theory*

When one junction of a thermocouple is kept at $0°C$ while its other junction is maintained at a higher temperature, thermo-emf e will be developed in the couple. If this e.m.f e be balanced against the potential difference existing at the ends of a length l of potentiometer wire of total length L having the potential drop ρ per unit length then,

$$e = \rho l \tag{1}$$

If E be the e.m.f of the storage battery B,R the resistance of the potentiometer wire of length L and R_1 be the resistance applied in the resistance box kept in the potentiometer circuit then,

$$\rho = \frac{ER}{(R + R_1)L} \tag{2}$$

From Eq.(1) and Eq.(2) we get,

$$e = \frac{ERl}{(R + R_1)L} \tag{3}$$

By measuring thermo-e.m.f e with the help of Eq.(1) for different temperatures of the hot junction, a curve may be drawn by plotting temperature ($t°C$) of the hot junction along $x-$axis, while the corresponding thermo-e.m.f e along $y-$axis. within a small range of temperatures (which is far away from **neutral temperature**) the curve would be a **straight line** as is shown in Figure 1. This curve is called the ***calibration curve*** of the given thermocouple.

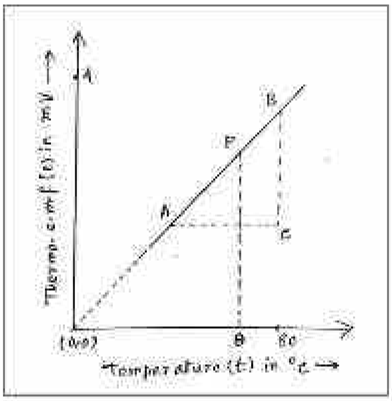

Figure 1: **Theorectical calibration curve of thermo-couple.**

To find the thermo-electric power $P = \frac{de}{dt}$ at a given temperature $\theta°C$ of the hot junction a tangent is drawn to the curve at the point corresponding to $\theta°C$ of the hot unction. By measuring the slope (BC/AC in Figure 1) of this tangent line, $P = \frac{de}{dt}$ can be determined at $\theta°C$. If e is measured in μV and t in $\theta°C$ then P will be given in units of $\mu V/°C$.

0.2 *Circuit Diagram*

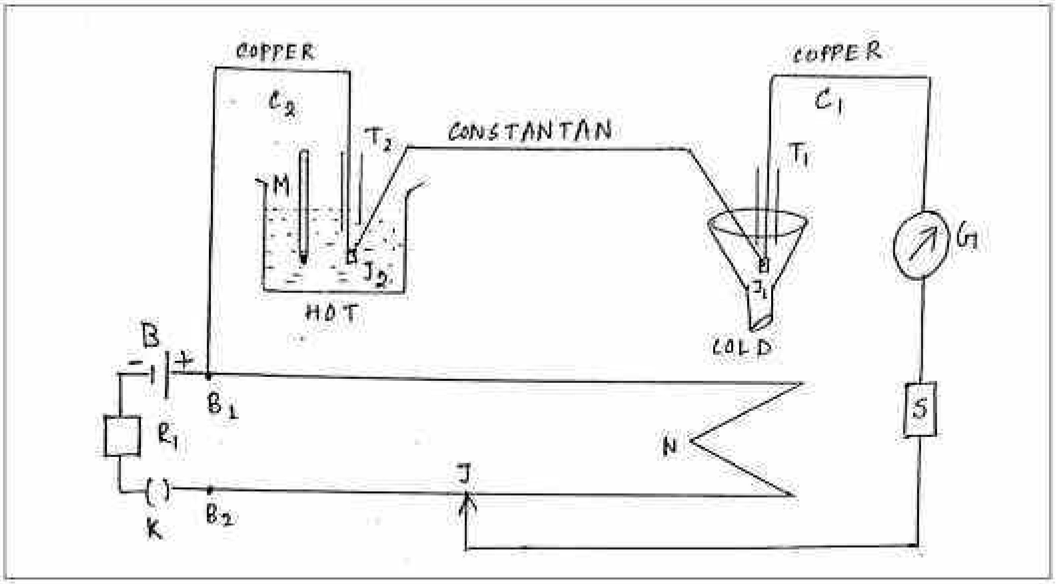

Figure 2: **Circuit Diagram.**

The arrangements shown in the above figure (Figure 2) consists of two circuits -

(i) **thermo-couple circuit**

(ii) **potentiometer circuit**

These two circuits are interlinked. Here,

$\mathbf{J_1}$, $\mathbf{J_2}$ are two cold and hot junctions respectively,
M is the thermometer,
$\mathbf{B_1NB_2}$ is the potentiometer wire,
K is plug key,
$\mathbf{R_1}$ is resistance box,
B is battery,
J is jockey,
G is galvanometer and
S is a high resistance.

0.3 *Experimental Data*

0.3.1 Resistance(R) of potentiometer wire:

Resistance of the Pot. (potentiometer) wire: 20Ω

0.3.2 Noting of the E.M.F(E) of the cell B:

Stage of Expt.	E.M.F of cell B in V	Mean E.M.F in V	Remark
Before Expt	2V	2V	The E.M.F of battery is remaining constant
After Expt.	2V		

Table 1:

0.3.3 Calculation of R_1:

From Eq. (2),

$$R_1 = \frac{ER}{\rho L} - R$$

Now putting $\rho = 5 \times 10^{-6} V/cm$ (for copper-constantan couple), $L = 1000cm$, E.M.F of the cell,$E = 2V$ and the resistance in the pot wire,$R = 20\Omega$,We get

$$R_1 = \left[\left(\frac{2 \times 20}{5 \times 10^{-6} \times 10^3}\right) - 20\right]\Omega$$

$$= [(8 \times 1000) - 20]\Omega$$

$$= 7980\Omega \simeq 8k\Omega$$

0.3.4 Temperature-Null point record:

- Temperature of cold junction = $0°C$.
- E.M.F of battery (B), E = $2V$.
- Resistance of the Pot. wire, R = 20Ω.
- Length of the Pot. wire, L = $1000cm$

No. of obs.	Temp.of hot junction in $°C$ (t)	Resitance in the pot. circuit $\Omega(R)$	null point		Total length in cm regd for balance	Thermo-e.m.f $e = \frac{ERl \times 10^3}{(R+R_1)L}$ in mV
			on wire no.	At the scale reading in cm		
1.	$23°C$	20	2nd	79.6	120.4	0.6004
2.	$33°C$	20	3rd	47.5	252.5	1.2594
3.	$43°C$	20	4th	27.8	372.2	1.8564
4.	$53°C$	20	6th	51.4	548.6	2.7362
5.	$63°C$	20	7th	60.6	639.4	3.1890
6.	$73°C$	20	8th	22.7	777.3	3.8768
7.	$83°C$	20	9th	92.4	807.6	4.0279
8.	$93°C$	20	10th	45.4	954.6	4.761

Table 2:

0.4 *Calculation*

Calculation of thermo-e.m.f using the experimental data:

- For observation (1), thermo-e.m.f,

  $e = \frac{2V \times 20\Omega \times 120.4cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 0.6004\, mV$

- For observation (2), thermo-e.m.f,

  $e = \frac{2V \times 20\Omega \times 252.5cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 1.2594\, mV$

- For observation (3), thermo-e.m.f,

  $e = \frac{2V \times 20\Omega \times 372.2cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 1.8564\, mV$

- For observation (4), thermo-e.m.f,

  $e = \frac{2V \times 20\Omega \times 548.6cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 2.7362\, mV$

- For observation (5), thermo-e.m.f,

  $e = \frac{2V \times 20\Omega \times 639.4cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 3.1890\, mV$

- For observation (6), thermo-e.m.f,

  $e = \frac{2V \times 20\Omega \times 777.3cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 3.8768\, mV$

- For observation (7), thermo-e.m.f,

  $e = \frac{2V \times 20\Omega \times 807.6cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 4.0279\, mV$

- For observation (8), thermo-e.m.f.

$$e = \frac{2V \times 20\Omega \times 954.6cm \times 10^3}{(20+8000)\Omega \times 1000cm} = 4.761\, mV$$

0.5 *Graph*

0.5.1 Drawing of (e-t) curve (Calibration Curve):

To draw this curve, the temperature (t) of the hot junction in $°C$ is plotted along $x - axis$ while the corresponding thermo-e.m.f (e) in milli-volts is plotted along $y - axis$. As the range of temperature is small and the highest temperature applied at the hot junction is far below the neutral temperature, the curve would be a straight line (straight portion of a parabola).

The nature of the curve is shown in the Figure 3.

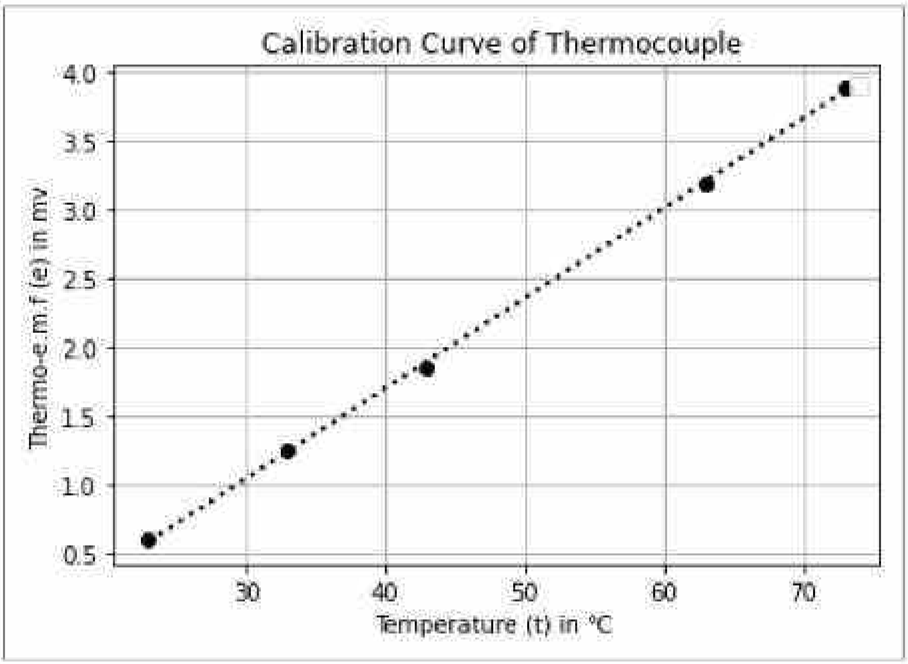

Figure 3: **Experimental calibration curve of thermocouple.**

0.6 *Precautions and Discussions*

(*i*) The cold junction should be carefully guarded throughout the experiment, so that its temperature may remain at $0°C$. To prevent the presence of air between ice particles, particularly around the soldered junction, the ice is to be pierced from time to time during the observation with the help of a wooden or glass rod. The ice in the funnel is thus pressed and the cold junction is kept well inside the ice. If necessary, ice may be added from time to time.

(*ii*) The water taken in the beaker (in which hot junction J_2 is introduced) should be large and it should be heated slowly so that the temperature may remain constant for an appreciable time.

(*iii*) The junctions (J_1 and J_2) should be kept at the middle region of the baths so that temperatures of the junctions may not change due to a small variation of the temperature of the surroundings.

(*iv*) The experiment should be performed within a small range of temperature so that the $(e - t)$ curve within that range may be approximately a straight line.

(*v*) To guard against the fall of potential of the battery B, during the experiment, its e.m.f should be measured several times during the experiment.

(*vi*) The precalculation of R_1 is not must but we can change it to obtain null point at the $10th$ wire for each temperature of the hot junction. However, if R_1 is precalclated and kept fixed, the potentiometer becomes directly calibrated .The process of null point-determination becomes easier and at the same time the order of accuracy in the measurement of null point remains of the same order as involved in the measurement of other quantities.

0.7 *Error calculation*

$$e = \frac{ERl}{(R+R_1)L}$$

$$\therefore \frac{\delta e}{e}\Big|_{max} = \frac{\delta E}{E} + \frac{\delta R}{R} + \frac{\delta R}{R+R_1} + \frac{\delta l}{l} \tag{4}$$

Here we assume that the face value of R_1 is correct and L is given. Now,

$\delta E = 1$; smallest division of voltameter or $0.001V$ (if measured by a digital multimeter)

$\delta R = 0.001\Omega$ (as R is measured by a P.O. box)

δl = range of values of l over which no detectable deflection of the galvanometer is obtained. It may range from $0.1cm$ to $0.5cm$ depending on the galvanometer sensitivity.

Since $(R+R_1)$ is fairly large we can neglect the term $\frac{\delta R}{R+R_1}$. Now putting a set of observed values of E, R, and l we can calculate the maximum percentage error in e as $\frac{\delta e}{e}\Big|_{max} \times 100\%$

Maximum percentage error calculation:

$\frac{\delta e}{e}\Big|_{max} \times 100\% = (\frac{1}{2} \times \frac{0.001}{20} \times \frac{0.1}{120.4}) \times 100\%$=$2.076 \times 10^{-6}$

LaTeX Source Code

```
\documentclass[12pt]{report}

\usepackage{geometry,amsmath,amssymb,graphicx}

\usepackage{xcolor}

\usepackage{gensymb}

\usepackage{amsmath}

\usepackage{tikz}

\usepackage{float}

\restylefloat{table}


\definecolor{titlepagecolor}{cmyk}{1,.60,0,.40}


\DeclareFixedFont{\titlefont}{T1}{ppl}{b}{it}{0.5in}


\makeatletter

\def\printauthor{%

        {\large \@author}}

\makeatother

\author{%

        \Huge{ \texttt{Anwesha Das}} \vspace{10pt}\\

        {\Large \textbf{University Registration No:} \textbf{\color{teal}013-1211-0233-20}} \\

        {\Large \textbf{University Roll No:} \textbf{\color{teal}203013-11-0059}}\\

        {\Large \textbf{Examination Name:} \textbf{\color{teal}BSc Honours Semester III Practical
Examination(CU),  2021}}\\

        {\Large \textbf{Subject :}} \textbf{\color{teal} {\large PHSA}}\\

        {\Large \textbf{Paper:}} \textbf{\color{teal} {\Large SEC-A-1}}}
```

```
\newcommand\titlepagedecoration{%
	\begin{tikzpicture}[remember picture,overlay,shorten >= -10pt]

		\coordinate (aux1) at ([yshift=-15pt]current page.north east);
		\coordinate (aux2) at ([yshift=-410pt]current page.north east);
		\coordinate (aux3) at ([xshift=-4.5cm]current page.north east);
		\coordinate (aux4) at ([yshift=-150pt]current page.north east);

		\begin{scope}[titlepagecolor!40,line width=12pt,rounded corners=12pt]
			\draw
			(aux1) -- coordinate (a)
			++(225:5) --
			++(-45:5.1) coordinate (b);
			\draw[shorten <= -10pt]
			(aux3) --
			(a) --
			(aux1);
			\draw[opacity=0.6,titlepagecolor,shorten <= -10pt]
			(b) --
			++(225:2.2) --
			++(-45:2.2);
		\end{scope}
		\draw[titlepagecolor,line width=8pt,rounded corners=8pt,shorten <= -10pt]
		(aux4) --
		++(225:0.8) --
		++(-45:0.8);
		\begin{scope}[titlepagecolor!70,line width=6pt,rounded corners=8pt]
			\draw[shorten <= -10pt]
			(aux2) --
			++(225:3) coordinate[pos=0.45] (c) --
			++(-45:3.1);
```

```
\draw
(aux2) --
(c) --
++(135:2.5) --
++(45:2.5) --
++(-45:2.5) coordinate[pos=0.3] (d);
\draw
(d) -- +(45:1);
\end{scope}
\end{tikzpicture}%
}

\begin{document}
\begin{titlepage}

\noindent
\titlefont \centering  Calibration of a thermocouple by direct measurement of thermo-emf using potentiometer and the constants\par%

\centering
\vspace{1cm}
{\LARGE \textbf{\textit{31st January, 2022}}}

\null\vfill
\vspace*{1cm}
\noindent
\hfill
\begin{minipage}{0.75\linewidth}
\begin{flushright}
\printauthor
```

```latex
\end{flushright}

\end{minipage}

\titlepagedecoration

\centering

\end{titlepage}

\newgeometry{left=3cm}

\section{\textit{Theory}}

When one junction of a thermocouple is kept at $ 0^{\circ}C $ while its other junction is maintained at a higher temperature, thermo-emf $ e $ will be developed in the couple. If this e.m.f $ e $ be balanced against the potential difference existing at the ends of a length  $ l $ of potentiometer wire of total length \uppercase{l} having the potential drop $\rho $ per unit length then,

\begin{equation} \label{eq1}

e=\rho l

\end{equation}

If \uppercase{e} be the e.m.f of the storage battery \uppercase{b,r} the resistance of the potentiometer wire of length \uppercase{l} and ${R_1}$  be the resistance applied in the resistance box kept in the potentiometer circuit then,

\begin{equation}

\rho = \frac{ER}{(R+R_1)L}

\end{equation}

From Eq.(1) and Eq.(2) we get,

\begin{equation}

e=\frac{ERl}{(R+R_1)L}

\end{equation}

By measuring thermo-e.m.f $e$ with the help of Eq.(1) for different temperatures of the hot junction, a curve may be drawn by plotting temperature ($ t^{\circ}C $) of the hot junction along $x-$axis, while the corresponding thermo-e.m.f $e$ along $y-$axis. within a small range of temperatures (which is far away from \textbf{neutral temperature}) the curve would be a \textbf{straight line} as is shown in Figure 1. This curve is called the \textbf{\textit{calibration curve}} of the given thermocouple.
```

```
\begin{figure}[ht]
	\centering
	\framebox{{\includegraphics[width=5.0cm]{Theoretical calibration curve.jpeg}}}
	\caption{\textbf{Theorectical calibration curve of thermo-couple.}}
	\label{fig:sg}
\end{figure}
\newline
To find the thermo-electric power $P=\frac{de}{dt}$ at a given temperature $\theta ^{\circ}C $ of the hot junction a tangent is drawn to the curve at the point corresponding to $\theta ^{\circ}C $ of the hot unction. By measuring the slope
(BC/AC in Figure 1)	of this tangent line, $P=\frac{de}{dt}$ can be determined at $\theta ^{\circ}C $. If $e$ is measured in $\mu V$ and $t$  in $\theta ^{\circ}C $ then P will be given in units of  $\mu V/^{\circ}C$.


   \section{\textit{Circuit Diagram}}
   \begin{figure}[!htpb]
    \centering
    \framebox{{\includegraphics[width=14.0cm]{Circuit diagram.jpeg}}}
    \caption{\textbf{Circuit Diagram.}}
    \label{fig:sg}
   \end{figure}
  The arrangements shown in the above figure (Figure 2) consists of two circuits -
  \begin{enumerate}
    \item [(i)] \textbf{thermo-couple circuit}
    \item [(ii)] \textbf{potentiometer circuit}
    \end{enumerate}
  These two circuits are interlinked. Here,\\


  \begin{minipage}{0.5\linewidth}
  \begin{flushleft}
    $\textbf{J}_\textbf{1}$, $\textbf{J}_\textbf{2}$ are two cold and hot  junctions
respectively,\\
```

```
\textbf{M} is the thermometer,\\
$\textbf{B}_\textbf{1}\textbf{N}\textbf{B}_\textbf{2}$ is the potentiometer wire,\\
\textbf{ K} is plug key,\\
\end{flushleft}
\end{minipage}
\begin{minipage}{0.95\linewidth}
\begin{flushleft}
$\textbf{R}_\textbf{1}$ is resistance box,\\
\textbf{B} is battery,\\
\textbf{J} is jockey,\\
\textbf{ G} is galvanometer and\\ \textbf{S} is a high resistance.
\end{flushleft}
\end{minipage}



\newpage
\section{\textit{Experimental Data}}

\subsection{ Resistance(R) of potentiometer wire:}
\hspace{2.0cm} Resistance of the Pot. (potentiometer) wire: \hspace{1mm}$20 \Omega$
\vspace{5mm}
\subsection{Noting of the E.M.F(E) of the cell B:}


\begin{table}[H]
\caption{}
\begin{tabular}{|c|c|c|c|}
\hline\\ [-0.5cm]
\centering
Stage of& E.M.F of cell & Mean E.M.F & Remark\\
```

```
Expt.   & B in V       & in V      &       \\
\hline
        &    &    &                  \\
Before Expt & 2V  &    & The E.M.F of  battery \\
\cline{1-2}
        &    & 2V &  is remaining \\

After Expt. & 2V  &    &     constant\\
\hline

\end{tabular}

\end{table}
\subsection{Calculation of $R_1$:}

\hspace{2.0cm}From Eq. (2),

\[R_1=\frac{ER}{\rho L}-R\]

Now putting $\rho=5\times10^{-6} V/cm$  (for copper-constantan couple), $L=1000 cm$, E.M.F
of the cell,$E=2V$ and the resistance in the pot wire,$R=20\Omega$,We get
\[R_1=\Bigg[\Bigg(\frac{2\times20}{5\times10^{-6}\times10^{3}}\Bigg)-20\Bigg]\Omega\]
\[=[(8\times1000)-20]\Omega\]
\[=7980\Omega\simeq8k\Omega\]
\newpage
\subsection{Temperature-Null point record:}
\begin{itemize}
    \item Temperature of cold junction = $0^{\circ}C$.
    \item E.M.F of battery (B), E = $2V$.
    \item Resistance of the Pot. wire, R = $20\Omega$.
    \item Length of the Pot. wire, L = $1000 cm$
```

```
\end{itemize}

\begin{table}[H]
    \caption{}

    \begin{tabular}{|c|c|c|c|c|c|c|c|}
        \hline\\ [-0.5cm]
        \centering
        No.& Temp.of hot & Resitance in the &\multicolumn{2}{c|}{null point}&Total &
Thermo-e.m.f\\
        \cline{4-5}
        of & junction & pot. circuit&on& At the&length in &$e=\frac{ERl\times
10^3}{(R+R_1)L}$\\
        obs. & in $^{\circ}C$ & $\Omega(R)$ &wire &scale &cm regd& in mV\\
          & (t)   &           &no.  &reading&for& \\
          &    &           &     &in cm &balance& \\
        \hline\\ [-0.5cm]

        1.& $23^{\circ}C$& 20 &2nd&79.6&120.4&0.6004 \\
  \hline
        2.& $33^{\circ}C$& 20 &3rd&47.5&252.5&1.2594 \\
        \hline
        3.& $43^{\circ}C$& 20 &4th&27.8&372.2&1.8564 \\
        \hline
        4.& $53^{\circ}C$& 20 &6th&51.4&548.6&2.7362 \\
        \hline
        5.& $63^{\circ}C$& 20 &7th&60.6&639.4&3.1890 \\
        \hline
        6.& $73^{\circ}C$& 20 &8th&22.7&777.3&3.8768 \\
        \hline
        7.& $83^{\circ}C$& 20 &9th&92.4&807.6&4.0279 \\
```

```
\hline
8.& $93^{\circ}C$& 20 &10th&45.4&954.6&4.761 \\
\hline

\hline

\end{tabular}
\end{table}

\newpage
\section{\textit{Calculation}}
\textbf{Calculation of thermo-e.m.f using the experimental data:}\\
\begin{itemize}
\item For observation (1), thermo-e.m.f,\\

$e$ = $\frac{2 V\times20 \Omega\times120.4 cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $0.6004 \hspace{1mm}mV$\\

\item For observation (2), thermo-e.m.f,\\

$e$ = $\frac{2 V\times20 \Omega\times252.5 cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $1.2594 \hspace{1mm}mV$\\
\item For observation (3), thermo-e.m.f,\\

$e$ = $\frac{2 V\times20 \Omega\times372.2 cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $1.8564 \hspace{1mm}mV$\\

\item For observation (4), thermo-e.m.f,\\

$e$ = $\frac{2 V\times20 \Omega\times548.6 cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $2.7362 \hspace{1mm}mV$\\
```

\item For observation (5), thermo-e.m.f,\\

e = $\frac{2 V\times20 \Omega\times639.4 cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $3.1890 \hspace{1mm}mV$\\

\item For observation (6), thermo-e.m.f,\\

e = $\frac{2 V\times20 \Omega\times777.3cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $3.8768 \hspace{1mm}mV$\\

\item For observation (7), thermo-e.m.f,\\

e = $\frac{2 V\times20 \Omega\times807.6 cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $4.0279 \hspace{1mm}mV$\\

\item For observation (8), thermo-e.m.f,\\

e = $\frac{2 V\times20 \Omega\times954.6 cm\times 10^3}{(20+8000) \Omega \times 1000 cm}$ = $4.761 \hspace{1mm}mV$\\

\end{itemize}

\newpage

\section{\textit{Graph}}

\subsection{Drawing of (e-t) curve (Calibration Curve):}

\hspace{2.0cm}To draw this curve, the temperature (t) of the hot junction in $^{\circ}C $ is plotted along $x-axis$ while the corresponding thermo-e.m.f (e) in milli-volts is plotted along $y-axis$. As the range of temperature is small and the highest temperature applied at the hot junction is far below the neutral temperature, the curve would be a straight line (straight portion of a parabola).

\begin{center}

The nature of the curve is shown in the Figure 3.

\end{center}

\begin{figure}[!htpb]

\centering

\framebox{{\includegraphics[width=12.0cm]{Calibration curve.png}}}

\caption{ \textbf{Experimental calibration curve of thermocouple.}}

\end{figure}

\newpage

\section{\textit{Precautions and Discussions}}

\begin{enumerate}

\item [(i)] The cold junction should be carefully guarded throughout the experiment, so that its temperature may remain at

$0 ^{\circ}C $. To prevent the presence of air between ice particles, particularly around the soldered junction, the ice is to be pierced from time to time during the observation with the help of a wooden or glass rod. The ice in the funnel is thus pressed and the cold junction is kept well inside the ice. If necessary, ice may be added from time to time.

\item[(ii)]The water taken in the beaker (in which hot junction J_2 is introduced) should be large and it should be heated slowly so that the temperature may remain constant for an appreciable time.

\item[(iii)]The junctions (J_1 and J_2) should be kept at the middle region of the baths so that temperatures of the junctions may not change due to a small variation of the temperature of the surroundings.

\item[(iv)]The experiment should be performed within a small range of temperature so that the $(e-t)$ curve within that range may be approximately a straight line.

\item[(v)]To guard against the fall of potential of the battery B, during the experiment, its e.m.f should be measured several times during the experiment.

\item[(vi)]The precalculation of R_1 is not must but we can change it to obtain null point at the $10th$ wire for each temperature of the hot junction. However, if R_1 is precalclated and kept fixed, the potentiometer becomes directly calibrated .The process of null point-determination becomes easier and at the same time the order of accuracy in the measurement of null point remains of the same order as involved in the measurement of other quantities.

\end{enumerate}

\newpage

```latex
\section{\textit{Error calculation}}
\begin{equation*}
	e=\frac{ERl}{(R+R_1)L}
\end{equation*}

\begin{equation}
\therefore \frac {\delta e}{e} \Big\vert_{max}=\frac{\delta E}{E}+
\frac{\delta R}{R}+\frac{\delta R}{R+R_1}+\frac{\delta l}{l}
\end{equation}

\noindent Here we assume that the face value of $R_1$ is correct and $L$ is given. Now,\\
\indent $\delta E =1$; smallest division of voltameter or $0.001V$ (if measured by a digital multimeter)\\
\indent$\delta R=0.001\Omega$ (as $R$ is measured by a P.O. box)\\
\indent$\delta l$ = range of values of $l$ over which no detectable deflection of the galvanometer is obtained. It may range from $0.1 cm$ to $0.5 cm$ depending on the galvanometer sensitivity.\\
\indent Since $(R+R_1)$ is fairly large we can neglect the term $\frac{\delta R}{R+R_1}$. Now putting a set of observed values of $E, R,$ and $l$ we can calculate the maximum percentage error in e as $\frac {\delta e}{e}\big\vert_{max}\times100\%$\\

\textbf{Maximum percentage error calculation:}\\

$\frac {\delta e}{e}\big\vert_{max}\times100\%$ = $(\frac{1}{2}\times\frac{0.001}{20}\times\frac{0.1}{120.4})\times100\%$=$2.076\times10^{-6}$

\end{document}
```

013/1801145474/0001 0130423

UNIVERSITY OF CALCUTTA
ADMIT

B.Sc. SEMESTER - III (HONOURS) Examination-2021
(UNDER CBCS)

Name of the Candidate :
PRANGYA PARAMITA ROY

Father's/Guardian's Name :
SUBHENDU BIKASH ROY

Roll & No. :
203013-11-0072

Registration No.
013-1211-0254-20

Subjects Enrolled :
PHSA,MTMG

Name of the College :
GOKHALE MEMORIAL GIRLS' COLLEGE

SCHEDULE FOR EXAMINATION IN THEORETICAL PAPERS **

Examination Day & Date		Examination Starting Time	Subject Code ++	Course Code	Course Name	Number of Answer book(s) to be used	Signature of the invigilator on receipt of the answer script/s @
Saturday	15-01-2022	10 A.M.	PHSA	CC5	MATHEMATICAL PHYSICS - II	1	
Sunday	16-01-2022	10 A.M.	PHSA	CC6	THERMAL PHYSICS	1	
Monday	17-01-2022	10 A.M.	PHSA	CC7	MODERN PHYSICS	1	
Tuesday	18-01-2022	10 A.M.	PHSA	SEC-A1	SCIENTIFIC WRITING	1	
Friday	21-01-2022	2 P.M.	MTMG	GE3	MATHEMATICS-CC3/GE3	1	

Signature of the Principal/TIC/OIC of the College with Seal

Controller of Examinations (Actg.)

** Subject to unavoidable changes
++ In no circumstances subject/s to be altered

N.B. Please follow University Notification No. CE/ADM/18/229 Dated 04/12/2018 in www.cuexam.net for instruction of Examinee/Invigilator/Examination centre.

Done by Prangya Paramita Roy College roll no. 20/BSCH/0250 CU Registration no. 013-1211-0254-20 CU Roll no. 203013-11-0072 Name of the examination; BSC honors Semester III Practical examination(CU), 2021 Paper : PHSA-SEC-A1

1 To estimate the temperature of a torch bulb filament from resistance measurement and to verify Stefan's Law.

2 Theory:

The resistance of a torch bulb filament maybe assumed to vary with the operating range of temperatures according to the equation,

$R_t = R_0(1 + \alpha t + \beta t^2)$

where R_t *and* R_0 *are the resistances at* $t°c$ *and* $0°c$ *respectively;* α *and* β *are the temperature coefficients of resistance. If* R_d *is the resistance of the filament at which the filament just starts showing a dull red glow, we can write* $\frac{R_t}{R_d} = \frac{(1+\alpha t+\beta t^2)}{(1+\alpha t_d+\beta t_d^2)}$

For a tungsten filament $\alpha = 5.21\times10^-3c$, $\beta = 7.2\times10^-7c$ *and the Draper point* $t_d = 527c$. *Hence putting these values of* α, β *and* t_d, *in previous expression we can calculate* R_t/R_d *for different values of t in the usual operating range of temperatures of a torch bulb filament. Now we can draw a calibration curve by plotting* R_t/R_d *as a function of the absolute temperature* $T = t + 273$.

Resistance of the filament is measured by using the relation $R = V/I$ *where* I *is the current through the filament and* V *is the voltage across it. In this way bulb filament can be found from the calibration curve.*

According to Stefan's Law if a black body at absolute temperature T *is surrounded by another black body at temperature* T_0, *the net amount of heat radiated per second per unit area from the first body is*

$P = \sigma(T^4 - T_0^4)$

where σ *is known as Stefan's constant. In case of a torch bulb filament* $T >> T_0$. *Moreover, the filament cannot be taken as a black body. Thus we can approximately write*

$P\ AT^n$

or $\log_1 0P = \log_1 0A + n\log_1 0$

where A *is some constant depending on the material and area of the filament and the power* n *is expected to be slightly different from 4. The power* P *radiated by the filament is given by* $P = VI$ *and temperature* T_0 *is obtained by resistance measurement as before. Thus if the Stefan's Law is valid the graph between* $\log_1 0P$ *and* $\log_1 0T$ *must be a straight line of slope* n.

3 Experimental data:

Bulb specification : 6V, 6W (Tungsten filament)

(A)To draw the calibration curve of the filament:

$\alpha = 5.21 \times 10^{-3} C^{-1}$
$\beta = 7.2 \times 10^{-7} C^{-2}$
$t_d = 527C$
$1 + \alpha t_d + \beta t_d^2 = 3.9454$
$\log_1 0P \ Vs \log_1 0T \ curve$

Temperature T in °c	**Temperature $T = t + 273$ in K**	$\frac{R_t}{R_d} = \frac{1+\alpha t+\beta t^2}{1+\alpha t_d+\beta t_d^2}$
127	*400*	*0.42*
327	*600*	*0.72*
527	*800*	*1.00*
727	*1000*	*1.31*
927	*1200*	*1.63*

(B)Data for the Draper point.

No. of obs.	**Current (I) in mA**	**Potential difference (V) in volt**	$R_t = \frac{V \times 10}{I}$	R_t/R_d	**Ten**

(C)To draw $log_{10}P$ Vs log_T graph

Temperature T in K	$log_1 0T$	**Power P in mW**	$log_1 0P$

(E) Calculation of n and verification of Stefan's Law:

From graph	**Slope** $n = AB/BC$	**Remark**

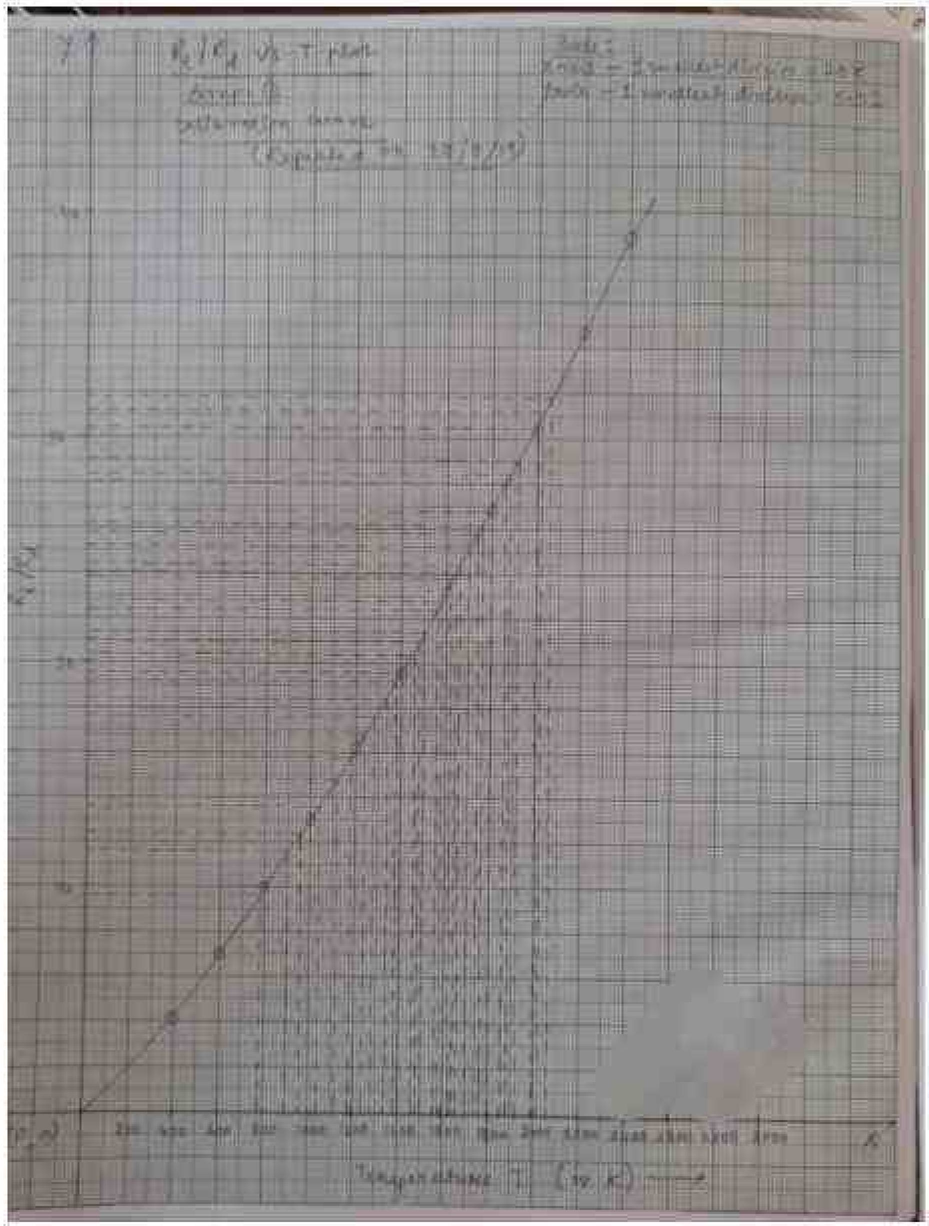

Figure 1: $\underline{\mathbf{R}_t/R_d vs T Graph}$

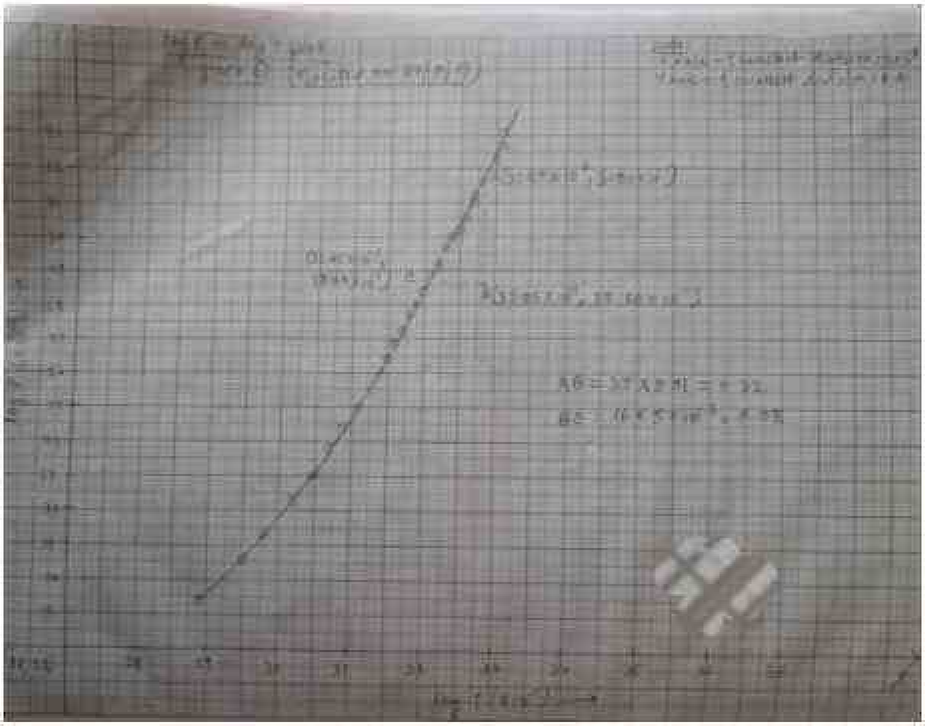

Figure 2: log P VS log T

4 Precautions and Discussions:

The potential leads must be soldered to the bulb directly so that the lead resistance do not affect the measurements of the bulb resistances.

```
\documentclass{article}

\usepackage{graphicx}

% Comment the following line to NOT allow the usage of umlauts

\usepackage[utf8]{inputenc}

% Uncomment the following line to allow the usage of graphics (.png, .jpg)

%\usepackage{graphicx}


% Start the document

\begin{document}


% Create a new 1st level heading


\title{Verification of Stefan's Law of radiation by measurement of voltage and current of a point}
\noindent

\it {Done by Prangya Paramita Roy

  College roll no. 20/BSCH/0250

  CU Registration no. 013-1211-0254-20

  CU Roll no. 203013-11-0072

  Name of the examination; BSC honors Semester III Practical examination(CU), 2021

  Paper : PHSA-SEC-A1}
```

To estimate the temperature of a torch bulb filament from resistance measurement and to verify Stefan's Law.

Theory:

The resistance of a torch bulb filament maybe assumed to vary with the operating range of temperatures according to the equation,

$R_t = R_0(1 + {\alpha}t + {\beta}t^2)$

where R_t and R_0 are the resistances at t°c and 0°c respectively; ${\alpha}$ and ${\beta}$ are the temperature coefficients of resistance. If R_d is the resistance of the filament at which the filament just starts showing a dull red glow, we can write

$\frac{R_t} {R_d} = \frac{(1 + {\alpha}t + {\beta}t^2)} {(1 + {\alpha}t_d + {\beta}t_d^2)}$

For a tungsten filament ${\alpha} = 5.21{\times}10^{-3}$°c, ${\beta} = 7.2{\times}10^{-7}$°c and the Draper point $t_d = 527$°c. Hence putting these values of ${\alpha}$, ${\beta}$ and t_d, in previous expression we can calculate R_t/R_d for different values of t in the usual operating range of temperatures of a torch bulb filament. Now we can draw a calibration curve by plotting R_t/R_d as a function of the absolute temperature $T = t + 273$.

Resistance of the filament is measured by using the relation $R = V/I$ where I is the current through the filament and V is the voltage across it. In this way bulb filament can be found from the calibration curve.

According to Stefan's Law if a black body at absolute temperature T is surrounded by another black body at temperature T_0, the net amount of heat radiated per second per unit area from the first body is

$P = {\sigma}(T^4 - T_0^4)$

where ${\sigma}$ is known as Stefan's constant. In case of a torch bulb filament $T>>T_0$. Moreover, the filament cannot be taken as a black body. Thus we can approximately write

$P ~ AT^n$

or $\log_10P = \log_10A + n\log_10$

where A is some constant depending on the material and area of the filament and the power n is expected to be slightly different from 4.

The power P radiated by the filament is given by $P = VI$ and temperature T_0 is obtained by resistance measurement as before.

Thus if the Stefan's Law is valid the graph between $\log_10P$ and $\log_10T$ must be a straight line of slope n.

\section{Experimental data:}

Bulb specification : 6V, 6W (Tungsten filament)

(A)To draw the calibration curve of the filament: \\

$\alpha = 5.21 \times 10^{-3}{\si{°C^{ -1}}$\\

$\beta=7.2\times 10^{-7}{\si{°C^{-2}}$\\

$t_d = 527\si{°C}$\\

$1 + {\alpha}t_d + {\beta}t_d^2 = 3.9454$ \\

$\log_10P$ Vs $\log_10T$ curve \\

\begin{tabular}{|c|c|c|}

\hline

\bf{Temperature T in °c} & \bf{Temperature $T = t + 273$ in K} & \bf{$\frac{R_t} {R_d} =

\frac{1 + {\alpha}t + {\beta}t^2} {1 + {\alpha}t_d + {\beta}t_d^2}$} \\ \hline

\hline

127&400&0.42\\

327&600&0.72\\

527&800&1.00\\

727&1000&1.31\\

927&1200&1.63\\

\hline

\end{tabular}

(B)Data for the Draper point.

\begin{tabular}{|c|c|c|c|c|c|c|}

\hline

\bf{No. of obs.} & \bf{Current (I) in mA} & \bf{Potential difference (V) in volt} & \bf{$R_t =

\frac{V{\times}10} {I}$} & \bf{$R_t/R_d$} & \bf{Temperature (T) from graph} & \bf{Power$P = V/I$ in mW} \\

\hline

\end{tabular}

(C)To draw $log_{10}P$ Vs log_{T} graph

\begin{tabular}{|c|c|c|c|}

\hline

```
\bf{Temperature T in K} & \bf{$log_10T$} & \bf{Power P in mW} & \bf{$log_10P$} \\


\hline
\end{tabular}
```

(E) Calculation of n and verification of Stefan's Law:

```
\hline
\bf{From graph} & \bf{Slope $n = AB/BC$} & \bf{Remark} \\


\hline
\end{tabular}
\newpage


 \begin{figure}[h!]
   \centering
   \includegraphics[width=\linewidth]{pragya1.jpg}
   \caption{\bf \underline{{{R_t}/{R_d}} vs{ T Graph}}}
   \label{fig:my_label}
\end{figure}
\begin{figure}[h!]
   \centering
   \includegraphics[width=\linewidth]{pragya2.jpg}
   \caption{\bf \underline{{log P VS log T}}}
```

```
  \label{fig:my_label}
\end{figure}
\newpage
\section{Precautions and Discussions:}
```

The potential leads must be soldered to the bulb directly so that the lead resistance do not affect the measurements of the bulb resistances.

```
% Uncomment the following two lines if you want to have a bibliography %\bibliographystyle{alpha}
%\bibliography{document}

\end{document}
```

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UNIVERSITY OF CALCUTTA
ADMIT

B.Sc. SEMESTER - III (HONOURS) Examination-2021

(UNDER CBCS)

Name of the Candidate :

SIRSHA MUKHERJEE

Father's/Guardian's Name :

SUBRATA MUKHERJEE

Roll & No. :

203013-11-0061

Registration No.

013-1211-0237-20

Subjects Enrolled :

PHSA,MTMG

Sirsha Mukherjee

Name of the College :

GOKHALE MEMORIAL GIRLS' COLLEGE

SCHEDULE FOR EXAMINATION IN THEORETICAL PAPERS **

Examination Day & Date		Examination Starting Time	Subject Code ++	Course Code	Course Name	Number of Answer book(s) to be used	Signature of the invigilator on receip of the answer script/ @
Saturday	15-01-2022	10 A.M.	PHSA	CC5	MATHEMATICAL PHYSICS - II	1	
Sunday	16-01-2022	10 A.M.	PHSA	CC6	THERMAL PHYSICS	1	
Monday	17-01-2022	10 A.M.	PHSA	CC7	MODERN PHYSICS	1	
Tuesday	18-01-2022	10 A.M.	PHSA	SEC-A1	SCIENTIFIC WRITING	1	
Friday	21-01-2022	2 P.M.	MTMG	GE3	MATHEMATICS-CC3/GE3	1	

Signature of the Principal/TIC/OIC of the College with Seal	Controller of Examinations (Actg.)
** Subject to unavoidable changes ++ In no circumstances subject/s to be altered	N.B. Please follow University Notification No. CE/ADM/18/229 Dated 04/12/2018 in www.cuexam.net for instruction of Examinee/Invigilator/Examination centre.

UNIVERSITY OF CALCUTTA :

FINAL EXAMINATION

SEM - 3 (PHSA) - 2022

C U ROLL NO. - 203013-11-0061

C U REGISTRATION NO. - 013-1211-0237-20

EXAMINATION NAME - BSc HONOURS SEMESTER III PRACTICAL

EXAMINATION(CU) , 2021

PAPER CODE : PHSA - SEC - A-1

DATE - 31.01.2022

The tunneling effect in tunnel diode using I-V characteristics

Sirsha Mukherjee

31 January 2022

1 Theory

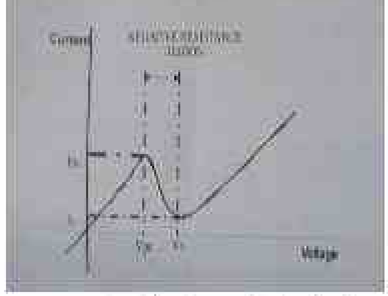
tunneling is an effect that is caused by quantum mechanical effects when electrons pass through the energy barrier.
The tunneling only occurs under certain conditions,it occurs within tunnel diodes because of the very high doping levels employed.
At reverse bias,the electrons tunnel from the valence band in the p type material,and the level of the current increase monotonically.
For the forward bias situation there are a number of different areas.
For voltage up to

$$V_{pe}$$

,electrons from the conduction band find increasing availability of empty states in the valence band and the level of current increase up to a point where the current equals

$$I_{pe}$$

.
Once the point is reached,it is found that number of empty states available for electrons with the level of energy they are given by increase voltage level starts to fall.This means that the current level falls in line with this.The overall current level falls away relatively swiftly,dropping to near zero.



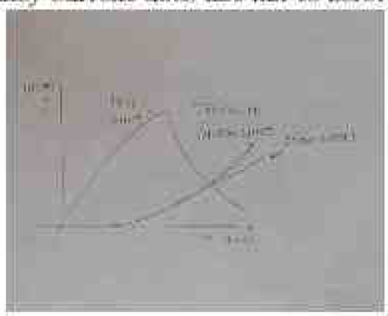
the characteristics curve for the tunnel diode is made up from several different elements.

As the current from the tunneling effect falls,so the diffusion current which is the same action as occur in a normal PN junction diode starts to increase and steadily becomes the dominant mechanism.

Normal diode current: This is the normal or expected current that would flow through a PN junction diode.

Tunneling current: This is the current that arises as a result of the tunneling effect.

Excess current: This is a third element of current that contributes to overall current within the diode.It results from what may be termed excess current that results from tunneling though bulk states in the energy gap,and means that the valley current does not fall to zero.



The three constituents of the tunnel diode current sum together to give the overall characteristic curve that is seen in explanation of tunnel diode theory.

2 Apparatus required

A tunnel-diode,Millie-ammeter(50mA),Millie-voltmeter(600/60mV),variable D.C.supply.

3 Circuit

The voltage is increased in the forward direction across the diode.

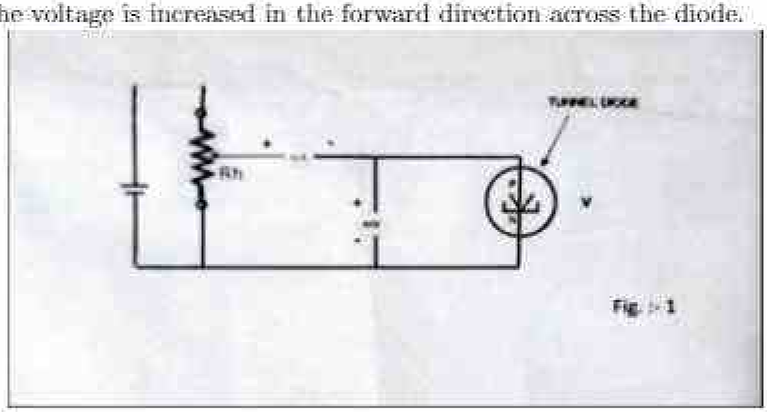


Fig. :- 1

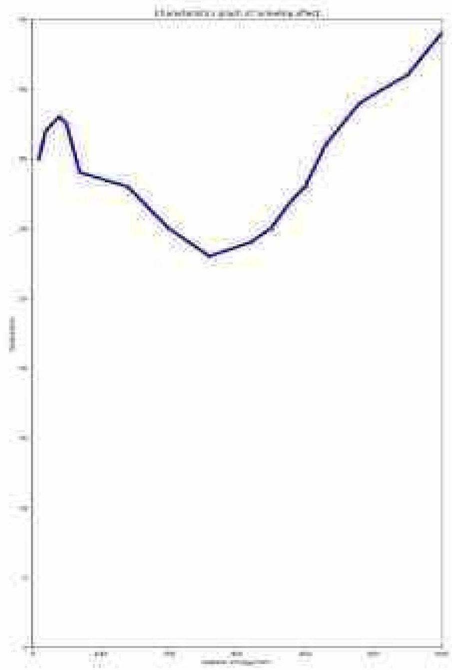
4 Observation

observation table

Serial no.	Millie-voltmeter reading.	Millie-ammeter reading.
1	0	0
2	10	35
3	20	37
4	40	38
5	50	37.5
6	70	34
7	140	33
8	160	32
9	180	31
10	200	30
11	230	29
12	260	28
13	320	29
14	350	30
15	380	32
16	400	33
17	430	36
18	480	39
19	550	41
20	600	44

5 Result

plot a graph in current(I)(mA) and applied voltage(V)(mV)



6 Precautions

(i) Tunnel Diode is be used in forward bias condition.
(ii) Ratings of the diode are to be taken into considerations.

```
\documentclass{article}
\usepackage{setspace}
\usepackage[utf8]{inputenc}
\usepackage{graphicx}
\graphicspath{{c:/user/downloads/}}
\usepackage{tikz}

\title{The tunneling effect in tunnel diode using I-V characteristics}
\author{Sirsha Mukherjee}
\date{31 January 2022}

\begin{document}
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\begin{centering}
\includegraphics[width=13cm,height=18cm]{admit.jpg}
\end{centering}
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SEM - 3 (PHSA) - 2022\\
C U ROLL NO. - 203013-11-0061\\
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DATE - 31.01.2022\\
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\end{doublespace}

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\maketitle

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\begin{centering}

\includegraphics[width=5cm,height=4cm]{tunnel.jpg}\\

\end{centering}

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```
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\includegraphics[width=5cm,height=4cm]{charecteristc curve.jpg}\\

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\end{centering}

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\begin{centering}

\includegraphics[width=10cm,height=5cm]{circuit.jpg}\\

\end{centering}

\section{Observation}

\begin{center}

\begin{tabular}{|p{2cm}||p{4cm}||p{4cm}|}

\hline

\multicolumn{3}{c}{observation table}\\

\hline

Serial no. & Millie-voltmeter reading. & Millie-ammeter reading.\\

\hline

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9 & 180 & 31 \\

10 & 200 & 30 \\
```

```
11 & 230 & 29 \\
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16 & 400 & 33 \\
17 & 430 & 36 \\
18 & 480 & 39 \\
19 & 550 & 41 \\
20 & 600 & 44 \\
\hline
\end{tabular}
\end{center}
\section{Result}
plot a graph in current(I)(mA) and applied voltage(V)(mV)\\
\begin{centering}
\includegraphics[width=7cm,height=10cm]{graph.jpg}
\end{centering}

\section{Precautions}
(i) Tunnel Diode is be used in forward bias condition.\\
(ii) Ratings of the diode are to be taken into considerations.\\
\end{document}
```