ME-21 - Sec(A)

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

Course Code : Phy-102

Determination of the Young's modulus by the bending method of a bar

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Level/Term : L-1, T-1

Course : Phy-102

Date of exp : 26-06-23

Date of sub : 10-06-23

Group : B1

Signature of Teacher :

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Experiment Name: Determination of the Young's Modulus by the bending method of a bar.

Abstract: The objective of this experimental study is to determine the Young's modulus of a bar using the bending method. The experiment aims to explore the connection between the applied load, bar span, height, and the resulting deflection. By placing the bar on two supports and applying a load at the center, the experiment investigates the relationship between these factors. Furthermore, it seeks to determine the coefficient of elasticity for stainless steel, brass and mild steel. By using the formula: $Y = \frac{mgl^3}{4bd^3y_0}$, the Young's modulus of the given bar is found to be 20.6×10^{11} dyne/cm^2 with an error of 2.89%.

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Introduction :

• Young's Modulus: Young's Modulus is a numerical constant. It characterizes the elastic properties of a solid when subjected to tension or compression in a single direction. Consider a metal rod that, upon being stretched or compressed lengthwise, returns to its original length. Young's Modulus quantifies a materials ability to withstand changes in length under lengthwise tension or compression. It is also known as the modulus of elasticity and is calculated by dividing the longitudinal stress by the strain. In the case of a metal bar under tension, stress is the ratio of the tensile force to the cross sectional area (F/A), while strain is the change in length divided by the original length ($\Delta L/L$). Therefore, young modulus can be mathematically expressed as $Y = \frac{F/A}{\Delta L/L}$, which is a specific form of Hooke's law of elasticity. [1]

It's important to note that young's modulus remains meaningful only within a range where stress and strain are directly proportional and the material returns to its original dimensions once the external force is removed.

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As stress increases, Young's modulus may no longer remain constant but decrease instead. The material may exhibit permanent deformation or eventually break. [1]

Theory:

When a rectangular beam of breadth b and depth d is supported near its two ends by two knife-edges separated by a distance l and if a load of mass m acting at a point of the beam equidistant from the knife-edges produces a depression y_0, then Y, the Young's modulus of the material, is given by

$$Y = \frac{mgl^3}{4bd^3 y_0} \quad \ldots\ldots (i)$$

where g is the acceleration due to gravity.

so,

Y = Young's modulus

m = mass of load

g = acceleration due to gravity

l = distance between two knife-edges.

b = breadth of the rectangular beam.

d = depth of the rectangular beam

y_0 = depression.

[2]

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Apparatus:

1. Rectangular beam.
2. Spherometer
3. Suitable weights
4. A screw gauge
5. Metre scale. etc.

Description of the apparatus: Setting of the apparatus is shown in figure-1.

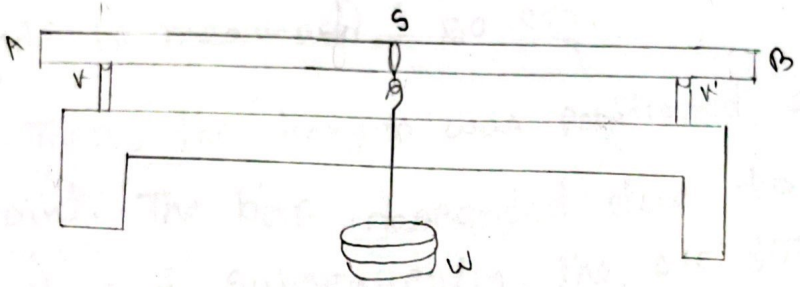


Fig: Schematic digram of the experimental setup.

A beam AB which is a metre long, composed of the experimental material and possessing a uniform cross-section, is affixed to two robust knife-edges, denoted as K and K', which are appropriately spaced apart. A hook is securely fastened to the midpoint(S) of KK', providing support for a hanger upon which weights labeled as W are meticulously positioned. [2]

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Procedure:

i) The depth of the given bar was determined using a screw gauge.

ii) The breadth of the given bar was determined using slide calipers.

iii) The distance between two knife edges of the bar was measured using a meter scale.

iv) The distances of the beam were provided. The middle point of the beam was determined and it measured 50 cm.

v) Then, the hanger was positioned at the middle point. The bar descended due to the added mass, and subsequently, the weights were added one by one. Readings were recorded for each weight.

vi) Afterwards, the weights were removed one by one, causing the bar to rise. Readings were again recorded for each weight.

vii) The average of the readings was calculated and using this mean value, the depression y_0 was determined.

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viii) Then, a graph was drawn where the mass(gm) of the loads was represented on the y-axis, and the depression (cm) was represented on the x-axis. From the graph, the slope was determined.

ix) After that, the Young's modulus was determined using the working formula. [2].

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Experimental data:

i) Table for measurement of Depth of the given Beam (d):

Least count of screw gauge = $\frac{\text{Pitch}}{\text{Total number of divisions in the circular scale}}$

$= \frac{0.05}{50}$ cm

$= 0.001$ cm

Table-1: Table to Determine depth.

NO of Obs	Linear Scale reading (cm)	Circular Scale Divisions (n)	Least Count (cm)	n×L.C (cm)	Total Reading (cm)	mean depth d (cm)	Instrumental error (cm)	Corrected depth
01.	0.55	16	0.001	0.016	0.566	0.565	0.002	0.563
02.	0.55	8		0.008	0.558			
03.	0.55	22		0.022	0.572			

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* Table for measurement of Breadth of the Given bar (b):

Vernier Constant of the slide calipers

$$= \frac{\text{value of one division of M.S(cm)}}{\text{Total no of divisions in V.S}}$$

$$= \frac{0.05}{10} = 0.005 \text{ cm}$$

Table-2: Table for determining breadth.

NO of obj	L.S.R (cm)	V.S.R (n)	V.C (cm)	V.S.R x V.C (cm)	Total Reading (cm)	mean Breadth	Instrumental error (cm)	Corrected breadth (cm)
01.	2.5	10	0.005	0.05	2.55	2.555	0	2.555
02.	2.5	12		0.06	2.56			
03.	2.5	11		0.055	2.555			

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* Table for measurement of deppession of the bar:

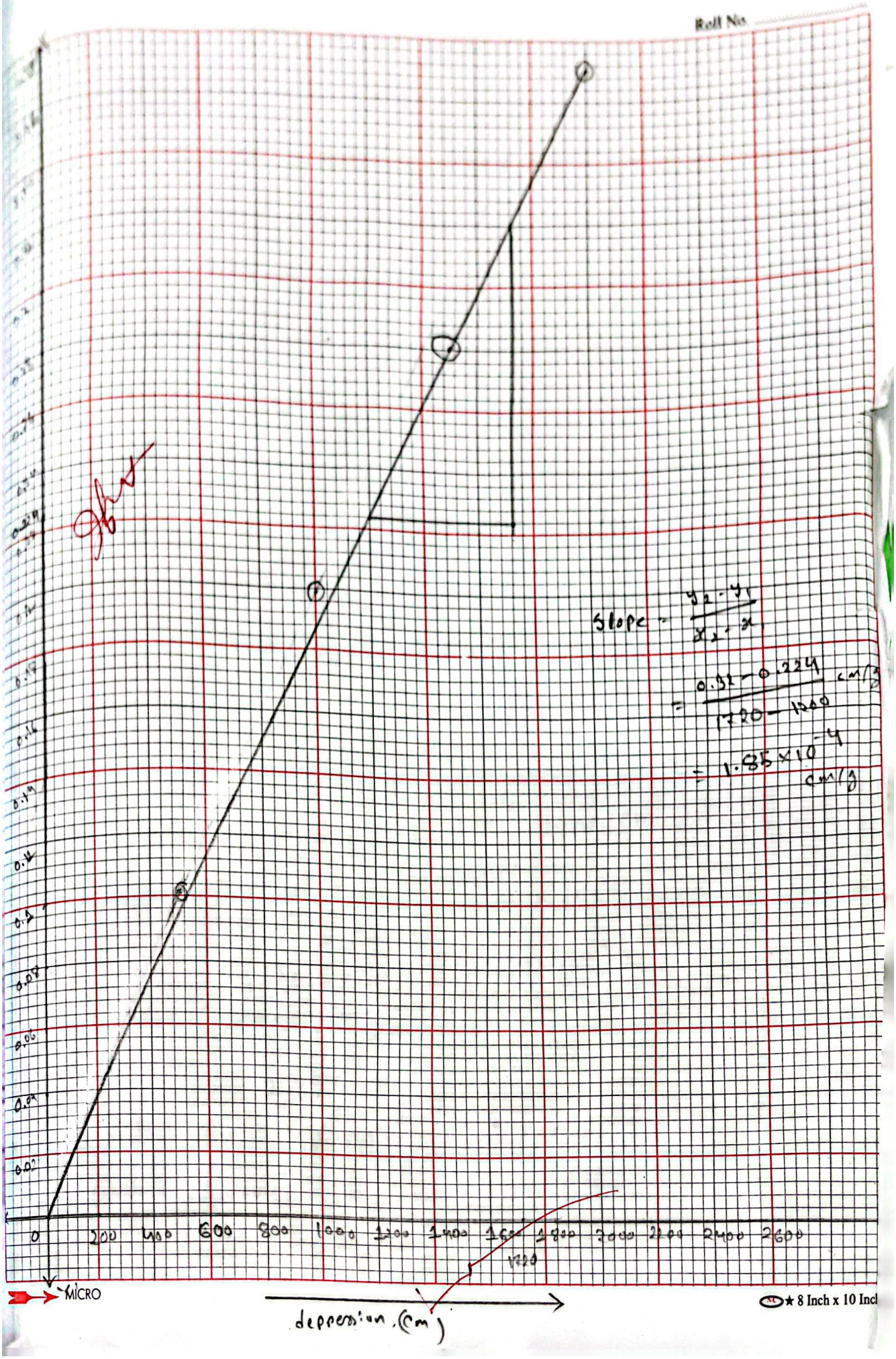
Table-3: ~~for~~ Table for determining the deppession.

No of Obs.	Loads m (gm)	Reading for						Mean Reading (cm)	mean deppession y_0 (cm)
		Load increasing			Load decreasing				
		main scale	vernier scale	total (cm)	main scale	vernier scale	total (cm)		
1	0	0.6	30	0.63	06	41	0.641	0.6355	0
2	500	0.7	47	0.747	07	39	0.739	0.743	0.1075
3	1000	0.8	35	0.835	8	33	0.833	0.834	0.1985
4	1500	0.9	27	0.927	9	05	0.905	0.916	0.2805
5	2000	1.00	10	1.01	10	10	1.01	1.01	0.3745

* Length of the bar: $l = 90$ cm.

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Calculation:

From working formula ... (i),

$$Y = \frac{mgl^3}{4bd^3 y_0}$$

$$y_0 = \frac{mgl^3}{4bd^3 Y}$$

$$y_0 = m \times \frac{gl^3}{4bd^3 Y}$$

$$y_0 = m \times \text{slope}$$

$$\therefore \text{slope} = \frac{gl^3}{4bd^3 Y} = 1.85 \times 10^{-4} \text{ cm/g}$$

$$\therefore Y = \frac{gl^3}{4bd^3} \times \frac{1}{1.85 \times 10^{-4}} \text{ dyne/cm}^2$$

$$= \frac{981 \times 90^3}{4 \times 2.555 \times 0.563^3} \times \frac{1}{1.85 \times 10^{-4}} \text{ dyne/cm}^2$$

$$= 21.19 \times 10^{11} \text{ dyne/cm}^2$$

Error: $\frac{|\text{actual} - \text{determined}|}{\text{actual}} \times 100\%$

$$= \frac{|(20.6 \times 10^{11}) - (21.19 \times 10^{11})|}{20.6 \times 10^{11}} \times 100\%$$

$$= 2.89\%$$

Result: The Young's modulus of the bar was found to be 20.6×10^{11} dyne/cm^2 with an error of 2.89%.

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Discussion:

i) It is possible that the knife-edges were not rigidly fixed on a rigid support. ~~This may~~ An error may be caused by this.

ii) An error was caused by the knife edges not being positioned at an equal distance from the center of the bar.

iii) A backlash error may have beer caused by the circular scale of the screw gauge and spherometer not being moved in one direction.

iv) Some personal error may have been caused while taking the reading.

v) The load of the beam may have exceeded the elastic limit of the beam.

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Conclusion: A The Young modulus of the bar was found 21.19×10^{11} dyne/cm^2 by using the bending method. However, a significant error of 2.89% was observed in our experiment. The error could be attributed to various factors, including inddequate support and positioning of the knife-edges, improper handling of weights, exceeding the elastic limit of the bar. etc. future experiments should carefully consider and control these factors to enhance the accuracy and reliability of the measurements.

References:

[1] https://www.britannica.com/science/Youngs-modulus.

[2] Practical Physics for degree students, Dr. Oriasudding ahmed and Md. Shahabudding, page - (50-54).

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Experiment NO : 01

Name of the Experiment : Determination of the young's modulus by the bending method of a bar.

Working formula :

$$Y = \frac{mgl^3}{4bd^3 y_0} \quad \ldots (i)$$

Here,

b = breadth of rectangular beam

d = depth

l = distance

m = mass

y_0 = depression

Y = young's modulus.

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Experimental Data:

* Table for Measurement of Depth of the Given Beam (d):

Least count of screw gauge = $\frac{\text{Pitch}}{\text{Total no of divisions in the circular scale.}}$

$= \frac{0.05}{50}$ cm

$= 0.001$ cm

Table-1: Table to Determine depth:

No of obs	Linear scale Reading (cm)	Circular scale Divisions (n)	Least count	value of Circular scale Division (cm)	Total Reading (cm)	Head depth d (cm)	Instrumental Error (cm)	Corrected depth d (cm)
01.	0.55	16	0.001	0.016	0.566			
02.	0.55	8	0.001	0.008	0.558	0.565	0.002	0.563
03.	0.55	22	0.001	0.022	0.572			

* Table for measurement of Breadth of the given Bar (b)

vernier Constant of the slide calipers = $\frac{\text{value of one division of M.S (cm)}}{\text{Total no of division in V.S}}$

$= \frac{0.05}{10} = 0.005$ cm

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Table-2: Table for determining breadth

No of obs	L.S.R (cm)	V.S.R (n)	V.C (cm)	Value of vernier scale division formula	Total reading (cm)	Mean Breadth	Instrumental error (cm)	corrected b (cm)
1	~~0~~ 2.5	10	0.005	0.05	2.55			
2	2.5	12	0.005	0.06	2.56	2.555	0	2.555
3	2.5	11	0.005	0.055	2.555			

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Table-3: Table for measurement of depression of the bar.

No of obs.	Load m (gm)	Reading for						Mean Reading (cm)	Mean depression h (cm)
		Load increasing			Load decreasing.				
		Main Scale	Vernier Scale	total	main Scale	vernier Scale	total		
1	0	0.6	30	0.63	06	41	0.641	0.6355	0
2	500	0.7	47	0.747	07	39	0.739	0.743	0.1075
3	1000	0.8	35	0.835	8	33	0.833	0.834	0.1985
4	1500	0.9	27	0.927	9	05	0.905	0.915	0.280
5	2000	1.00	10	1.01	10	10	1.01	1.01	0.37

26.6.23

Length of the bar, l = 90 cm.

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Calculation:

From working formula ..(i),

$$Y = \frac{mgl^3}{4bd^3 y_0}$$

$$\therefore y_0 = \frac{mgl^3}{4bd^3 Y}$$

$$y_0 = m \times \text{slope}$$

$$\therefore \text{slope} = \frac{gl^3}{4bd^3 Y} = 1.85 \times 10^{-4}$$

$$\therefore Y = \frac{gl^3}{4bd^3 \times 1.85 \times 10^{-4}}$$

$$= \frac{981 \times 90^3}{4 \times 2.555 \times 0.563^3 \times 1.85 \times 10^{-4}} \text{ dyne/cm}^2$$

$$= 21.19 \times 10^{11} \text{ dyne/cm}^2$$

$$\% \text{ Error} = \frac{|\text{actual} - \text{determined}|}{\text{actual}} \times 100\%$$

~~= 2.89%~~

$$= \frac{|(20.6 \times 10^{11}) - (21.19 \times 10^{11})|}{20.6 \times 10^{11}} \times 100\%$$

$$= 2.89\%$$

26/06/2023

Result: The Young modulus of the bar was ~~found~~ found to be 20.6×10^{11} ~~dyne/cm²~~ with an error of 2.89%.

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ME-21-(Sec A)

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Course Code : PHY-102

Determination of the spring constant, effective mass and the rigidity modulus of the spring.

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Roll No : 202318058

Level/Term : L-1, T-1

Course : PHY-102

Date of exp : 12-06-23

Date of sub : 19-06-23

Group : B-1

Signature of Teacher :

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Experiment Name: Determination of the spring constant, effective mass and the rigidity modulus of the spring.

Abstract: The determination of the spring constant, effective mass and rigidity modulus of a spring was achieved through measurement and calculations. The diameter of the spring and wire were measured and the inner diameter and outer diameter of the spring was obtained. The spring was then subjected to vertical oscillations and the time for 30 oscillations was recorded. The collected data was used to plot a graph of T^2 versus m (mass). From the graph, the spring constant, e.g. was calculated. The effective mass and rigidity modulus of the spring were also determined using the obtained data. The error analysis was performed.

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Introduction: The spring constant, symbolized as 'k', reflects the stiffness of a spring. It signifies the proportionality between the applied force and the resulting displacement, as stated by Hooke's law ($F=-kx$). Here, 'F' is the force applied and 'x' is the displacement. [1]

The effective mass of an ideal spring with uniform linear density in a spring-mass system is one-third of its total mass. This value remains consistent regardless of the system's orientation (horizontal, vertical or oblique) due to the unaffected period of motion by external acceleration around the equilibrium point. Determining the effective mass involves calculating the spring's kinetic energy by summing the kinetic energies of its mass elements using an integral expression involving the velocity of each mass element.

$$K = \int_m \frac{1}{2} u^2 \, dm. \quad [2]$$

The modulus of rigidity, also known as the shear modulus, relates shear stress to shear strain. It is determined experimentally from the slope of a stress-strain curve obtained during tensile tests on a material sample. [3]

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Theory: If a spring be clamped vertically at the end P, and loaded with a mass m_0 at the other end A, then the period of vibration of the spring along a vertical line is given by,

$$T = 2\pi\sqrt{\frac{m_0+m}{k}} = 2\pi\sqrt{\frac{M}{k}} \quad \ldots (i)$$

Here, 'm' is a constant called the effective mass of the spring and 'k' is the spring constant. 'm_0' is the mass of the load. m is the mass of spring. [4]

At the instant under consideration let the load m_0 be moving with velocity v_0 as shown in Fig-1. At this same instant an element dm of the mass m of the spring will also be moving up but with a velocity 'v' and 'v_0' in just the ratio between y and y_0. Hence, $\frac{v}{y} = \frac{v_0}{y_0}$ i.e., $v = \frac{v_0}{y_0} y$. [4]

The kinetic energy of the spring alone will be $\int_0^9 \frac{1}{2} v^2 \, dm$.

But dm may be written as $\frac{m}{y_0} dy$, where m is the mass of the spring. Thus the integral equals to $\frac{1}{2}\left(\frac{m}{3}\right)v_0^2$. The total kinetic energy of the system will be: $\frac{1}{2}\left(m_0 + \frac{m}{3}\right)v_0^2$ and the effective mass of the system is, therefore,

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$m_0 + \frac{m}{3}$

Hence, $m' = \frac{1}{3} m$ ... (ii)

where, m' = effective mass of the spring

m = true mass of the spring.

The applied force $m_0 g$ is proportional to the extension x_0 within the elastic limit. Therefore, $m_0 g = k x_0$.

Hence, $k = \frac{m_0 g}{x_0}$ ... (iii)

If, η is the rigidity modulus of the material of the spring, then it can also be proved that,

$$\eta = \frac{4NR^3 k}{r^4} \quad \text{... (iv)}$$

where, N = number of turns in the spring

R = radius of the spring

r = radius of the wire of the spring

k = spring constant. [4]

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Figure :

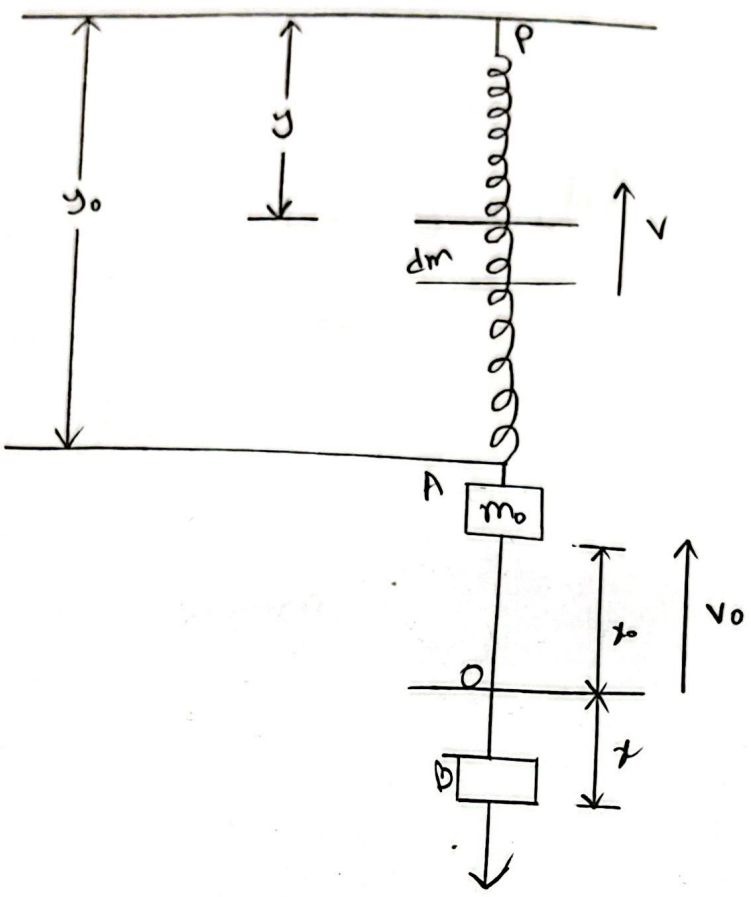


Figure-1: Figure of spring with load and extension.

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Apparatus:

i) A spiral spring.

ii) Convenient mass with hanging arrangement.

iii) Clamp or a hook attached to a rigid framework of heavy metal rods.

iv) weighing balance

v) stop clock.

vi) Scale

vii) A cathetometer.

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Procedure:

i) The number of turns in the spring was counted.

ii) The radius of the spring was determined. The inside and outside diameters of the spring were found out with the help of slide caliper. Several observations were made. Mean values were taken. If Dout was the outside diameter and Din was the inside diameter, then the mean radius of the spring was given by $\left(\frac{D_{out} + D_{in}}{4}\right)$. The radius of the wire of the spring was also measured very carefully with a screw gauge. A number of values were obtained at different points and the mean value was taken.

iii) Then the spring was clamped at one end at the edge of the working table or was suspended by a hook attached to a rigid framework of heavy metal rods.

iv) The length of the spring was measured with a meter scale. The arrangements were made to measure the extension of the spring.

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v) Suitable weight was added to the free end of the spring so that it extended. The extension was denoted as x_0 and the position was noted.

vi) The load was pulled for 2-3 cm and then let go. The spring was now set into motion, executing simple harmonic motion and vibrating up and down about the initial position. With a stopwatch, the time of 30 vibrations was taken. The vibrations were counted by observing the transits in one direction of the upper edge of the load at the initial position across the reference line. The period T in seconds per vibration was computed.

vii) The operation was repeated five times for (v) and (vi).

viii) Graphs were drawn with added loads (m_0) in grams plotted against the extension of the spring in centimeters. Additionally, graphs were drawn with T^2 as a function of m_0. Liners of best fit were drawn through the points on the graphs.

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ix) Graphs were drawn with added loads (m_o) in grams plotted against the extension of the spring in centimeters. From this graph, the slope of the line was determined by choosing two points on it. The slope was calculated as $\left(\frac{y_2 - y_1}{x_2 - x_1}\right)$ g m/cm. The spring constant (k) was obtained by multiplying this slope by the acceleration due to gravity (g).

x) The second graph T^2 vs m_o, did not pass through the origin due to the mass of the spring not being considered in its construction. The 'intercept of the resulting line on the mass-axis provided the effective mass of the spring (m').

xi) The mass of the spring was measured using a balance and it was shown that the effective mass (m') obtained from the graph was one-third (1/3) of the measured mass(m

xii) The rigidity modulus of the material of the spring was calculated with the help of equation (iv) using the obtained values. [4].

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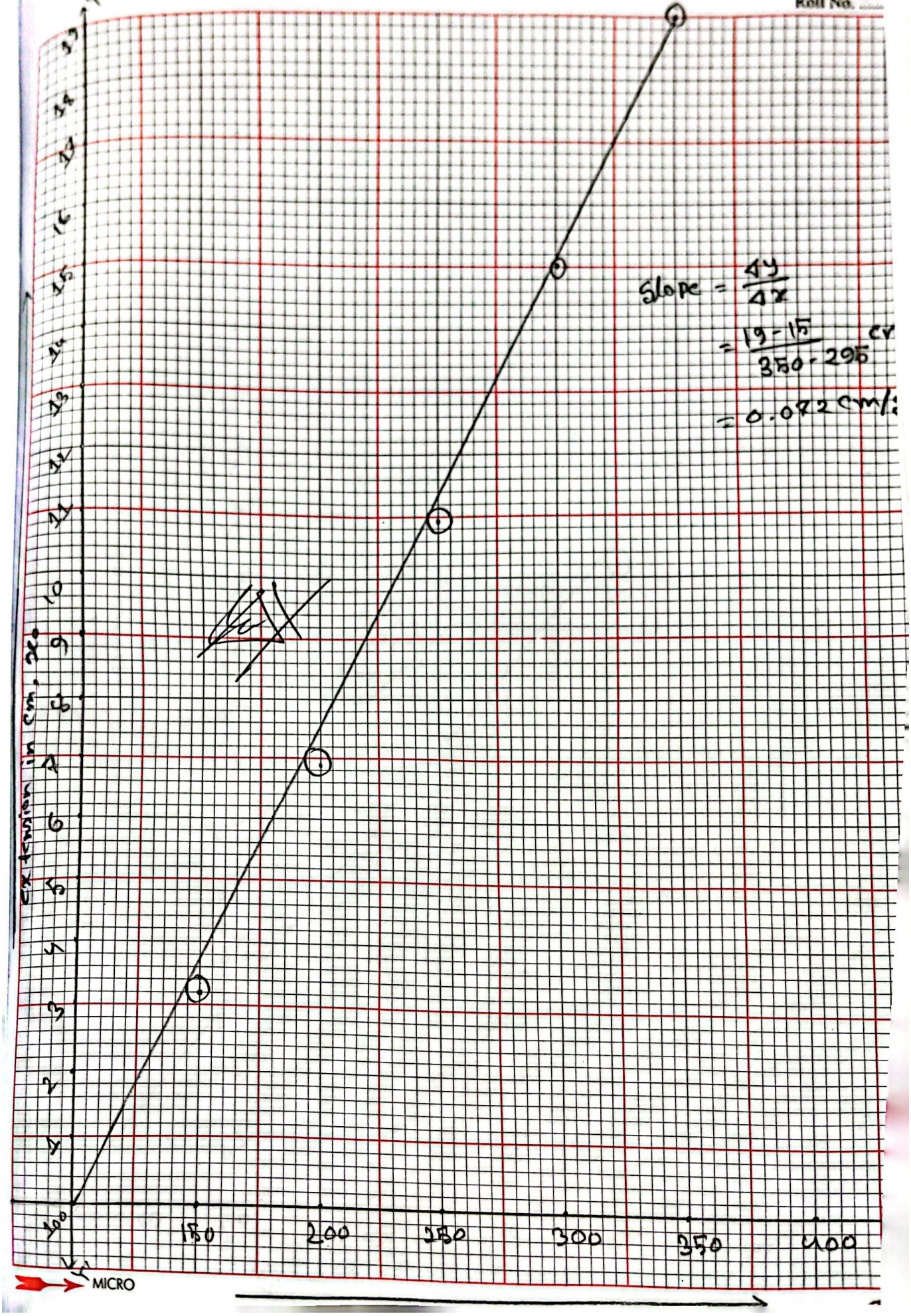
Experimental Data:

Table-1: Table to determine the square of period.

No of obs	Loads m_0 in (gm)	Extension x_0 (cm)	No of vibration	Total time (sec)	Period, T (sec)	T^2 (sec^2)
1	150	3.2	30	22.25	0.742	0.55
2	200	6.9		27	0.9	0.81
3	250	10.9		30.31	1.01	1.02
4	300	15		33.12	1.104	1.2188
5	350	19		34.9	1.163	1.353

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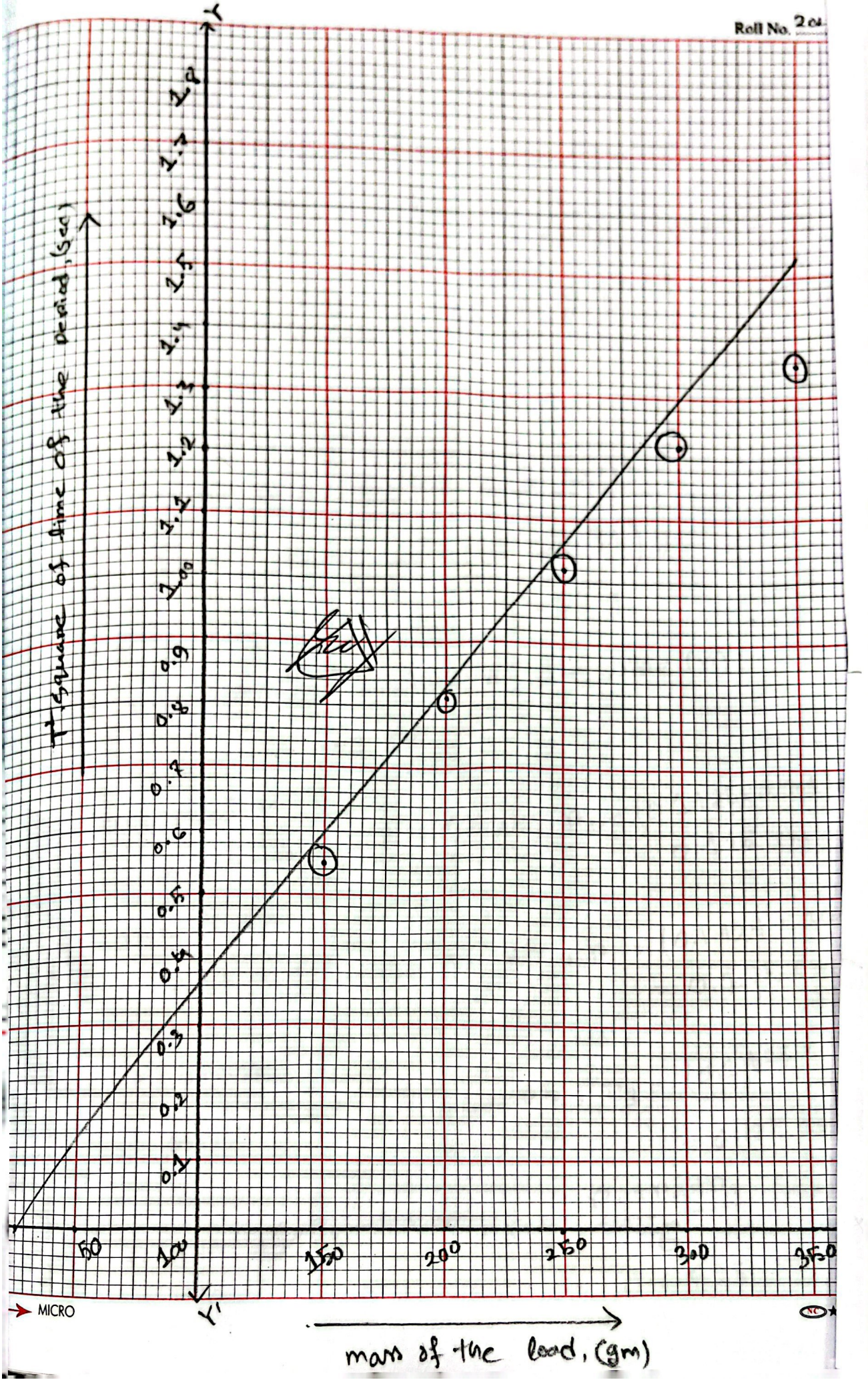
Slope $= \frac{\Delta y}{\Delta x}$

$= \frac{19-15}{350-295}$ cm

$= 0.082$ cm/

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calculation:

. Determining (k): From equation (iii)

$$k = \frac{m_0 g}{x_0} = \frac{g}{\frac{x_0}{m_0}} = \frac{g}{\text{slope}}$$

$$\therefore k = \frac{981}{0.072} = 13625 \text{ g/s}^2$$

$$\text{slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{19 - 15}{350 - 295} = 0.072 \text{ cm/gm}$$

. Determining effective mass. (m'):

from graph, $m' = (80 - 55.31)\text{ g}$

$= 24.69 \text{ g}$

. Determining radius of the wire (r):

L.C = 0.001 cm

observation -1,

M.S.R = 0.1, C.S.D = 25, $r_1 = (0.1 + 25 \times 0.001)$ cm

$= 0.125$ cm

observation -2,

M.S.R = 0.1, C.S.D = 25, $r_2 = (0.1 + 25 \times 0.001)$ cm

$= 0.125$ cm

observation-3,

M.S.R = 0.1, C.S.D = 25, $r_3 = (0.1 + 25 \times 0.001)$ cm

$= 0.125$ cm

radius of the wire, $r = \frac{r_1 + r_2 + r_3}{6}$ cm

$= 0.0625$ cm

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· Determining Radius of the spring (R):

For Din: V.C = 0.005 cm

M.S.R = 2.3, V.S.R = 7, $R_1 = (2.3 + 7 \times 0.005)$ cm
$= 2.335$ cm

M.S.R = 2.3, V.S.R = 2, $R_2 = (2.3 + 2 \times 0.005)$ cm
$= 2.310$ cm

M.S.R = 2.3, V.S.R = 8, $R_3 = (2.3 + 8 \times 0.005)$ cm
$= 2.34$ cm

$\therefore$ Din = $\frac{R_1 + R_2 + R_3}{3} = 2.328$

For Dout: V.C = 0.005 cm

M.S.R = 2, V.S.R = 2, $R_4 = (2 + 2 \times 0.005)$ cm
$= 2.01$ cm

M.S.R = 2.1, V.S.R = 7, $R_5 = (2.1 + 2 \times 0.005)$ cm
$= 2.135$ cm

M.S.R = 2, V.S.R = 6, $R_6 = (2 + 6 \times 0.005)$ cm
$= 2.03$ cm

$\therefore$ Dout = $\frac{R_4 + R_5 + R_6}{3} = 2.058$ cm

$\therefore R = \frac{Din + Dout}{4} = \frac{2.328 + 2.058}{4} = 1.0965$ cm

Number of turn, N = 122

· Determining Rigidity modulus (η):

From equation (iv): $\eta = \frac{4NKR^3}{nu} =$ ~~$4 \times 122 \times 13625 \times (1.096$~~

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$$\therefore \eta = \frac{4 \times 122 \times 13625 \times (1.0965)^3}{(0.0625)^4}$$

$$= 5.745 \times 10^{11} \text{ gm/cm/s}^2$$

. Error:

$$\frac{|\text{actual value} - \text{measured value}|}{\text{actual value}} \times 100\%$$

$$= \frac{|(7.7 \times 10^{11}) - (5.745 \times 10^{11})|}{7.7 \times 10^{11}} \times 100\%$$

$$= 25.39\%$$

. Result: The value of the rigidity modulus was found to be 7.7×10^{11} gm/cm/s^2 with an error of 25.39%.

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Discussion:

i) An instrumental error could arise if the main scale zero did not coincide with the circular scale zero. This was taken care of by adjusting for the error.

ii) If the wire was not uniform, readings had to be taken at different points and the mean of these readings was considered the most accurate.

iii) During the experiment the weights were supposed to hang along the axis of the spring. However, this condition was not met.

iv) Initially, the measurement of the time period was not accurate due to errors in personal observation.

v) The oscillations were expected to occur in the vertical plane but they also exhibited slight oscillations in the horizontal plane.

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Conclusion: The experiment aimed to determine the spring constant and effective mass of a given spiral spring. Deviations from ideal conditions were observed and errors were accounted for, such as, instrumental errors, deviation from ideal conditions. Inaccuracies in time period measurement etc. The calculated rigidity modulus was 7.7×10^{11} gm/cms^2 with an error of 25.39%. Further improvements are needed for more accurate results.

Reference:

[1] https://en.m.wikipedia.org/wiki/Hooke%27s_law

[2] https://en.m.wikipedia.org/wiki/Effective_mass_(spring%E2%80%93mass_system)#:~:text=The%20effective%20mass%20of%20the%20spring%20in%20a%20spring%2Dmass,have%20the%20same%20effective%20mass).

[3] https://mainulgub.files.wordpress.com/2016/06/scan0002.pdf.

[4] Practical Physics for degree students by Dr. Giasuddin Ahmad & md. Shahabuddin. Page: (68-73).

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Name of Experiment:

DETERMINATION OF THE SPRING CONSTANT, EFFECTIVE MASS AND THE RIGIDITY MODULUS OF THE SPRING.

WORKING FORMULA:

$$T = 2\pi \sqrt{\frac{m_0 + m'}{k}}$$

$$= 2\pi \sqrt{\frac{M}{k}} \quad \text{---(i)}$$

and,

$$\eta = \frac{4NR^3K}{r^4} \quad \text{---(ii)}$$

and,

$$Kx_0 = m_0 g$$

$$K = \frac{m_0 g}{x_0} \quad \text{---(iii)}$$

~~and,~~

~~$AA' = \frac{AA}{3}$~~

where,

T = Time period of the spring.

x_0 = distance travelled after adding

m_0 = mass of the load.

m' = effective mass of the spring.

M = Total mass of the spring.

K = Spring constant

N = number of turns in the spring

R = radius of the spring.

r = radius of the wire of the spring.

η = rigidity modulus of the spring.

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Apparatus:

i) A spiral spring.

ii) convenient mass with hanging arrangement.

iii) clamp or a hook attached to a rigid framework of heavy metal rods.

iv) weighing balance.

v) stop clock

vi) scale.

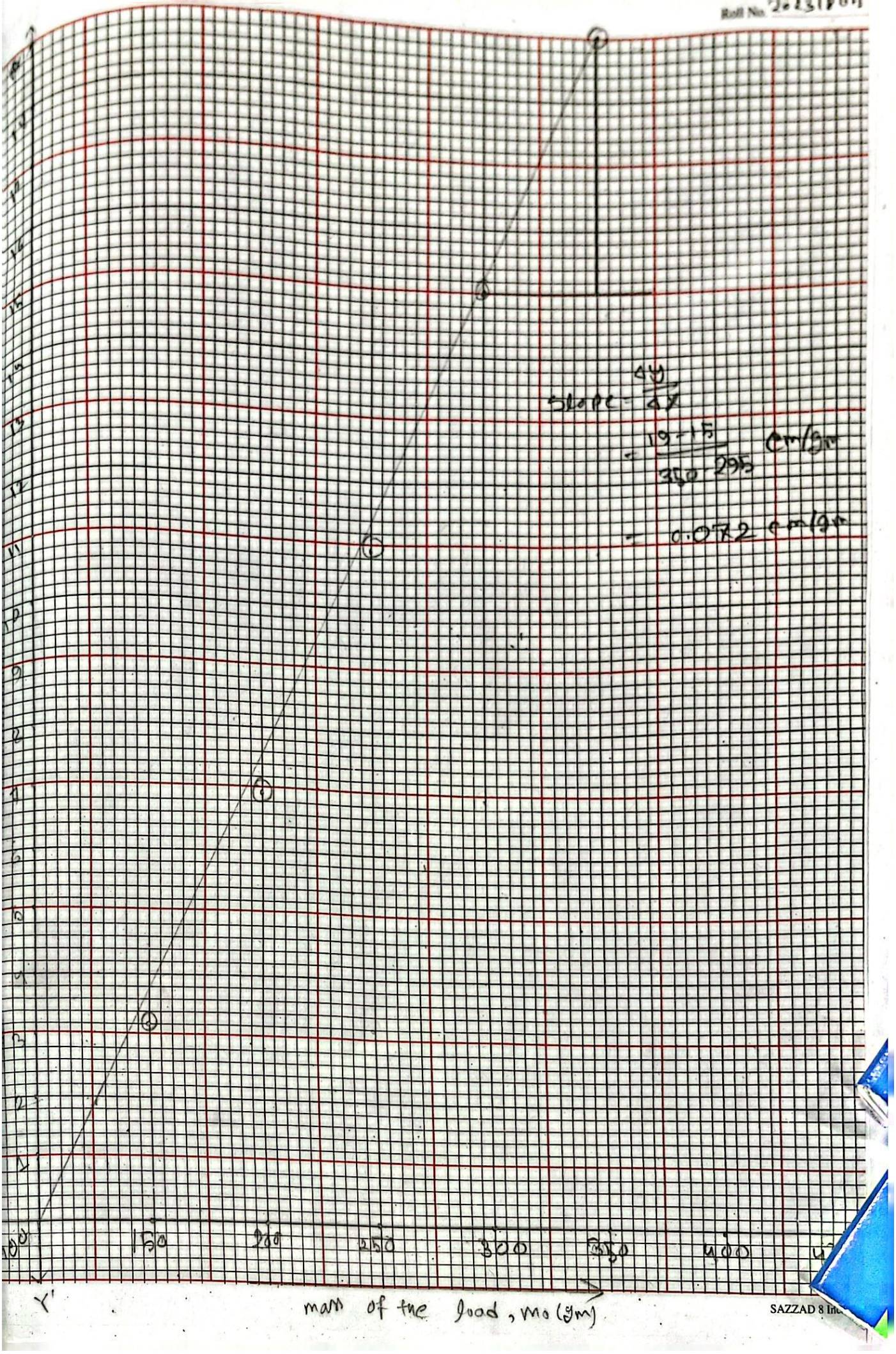
vii) A cathetometer.

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Experimental Data:

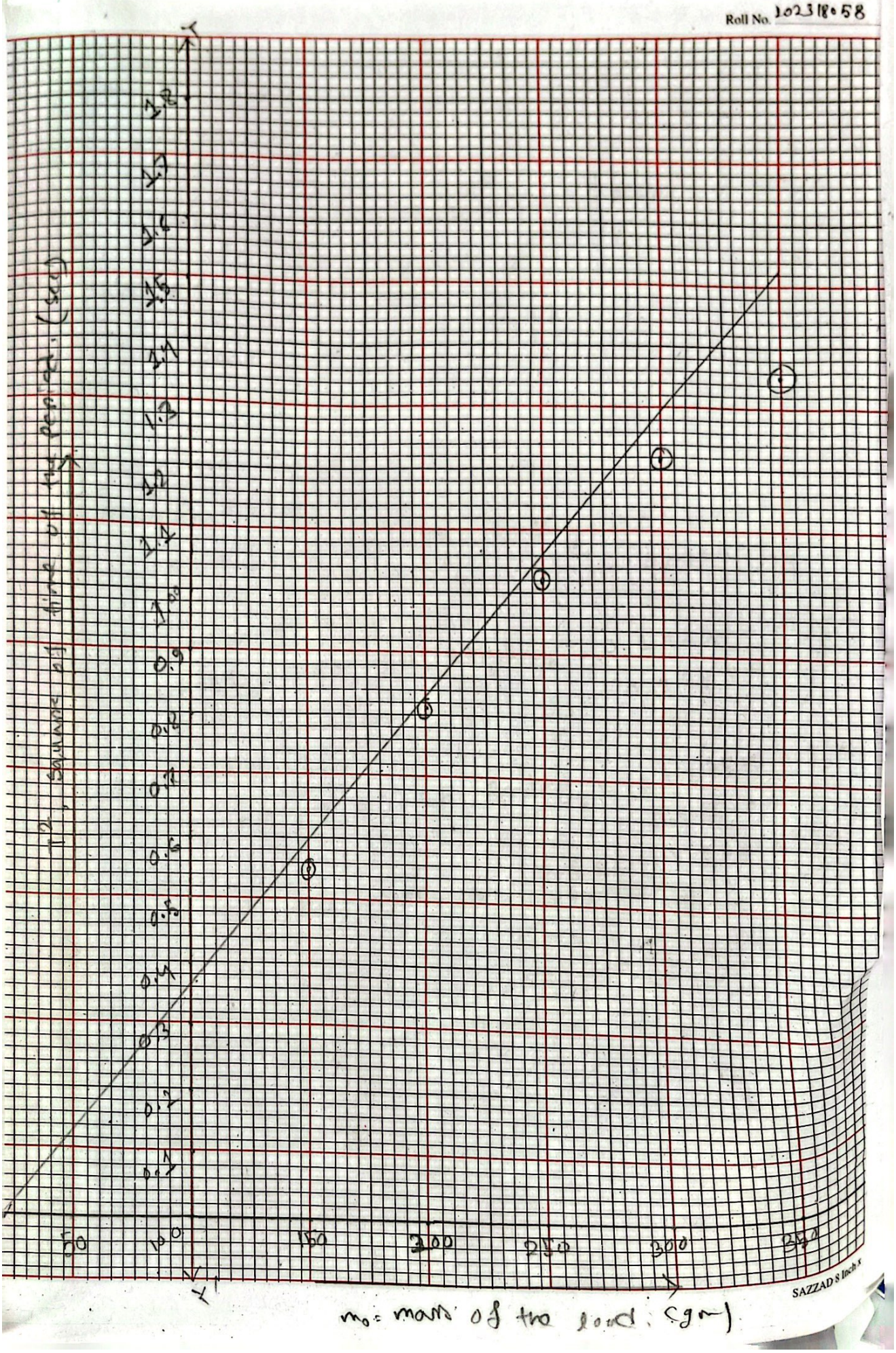
No of obs	Loads m_0 in gms	Extension (cm)	No of vibration	Total Time (sec)	Period T (sec)	T^2
1	150	3.2		22.25	0.742	0.55
2	200	6.9		27	0.9	0.81
3	250	10.9	30	30.31	1.01	1.02
4	300	15		33.12	1.104	1.2188
5	350	19		34.9	1.163	1.353

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Calculation: For K,

$$K = \frac{m_0 g}{x_0} = \frac{g}{\frac{x_0}{m_0}} = \frac{g}{\text{slope}}$$

$$\therefore K = \frac{981}{0.072} = 13625 \text{ g cm/s}^2 \quad | \text{ slope} = 0.072$$

For effective mass, (m')

From graph, $m' = (80 - 55.31)\,g$

$= 24.69\,g$

For wire, L.C = 0.001 cm

Observation - 1,

M.S.R = 0.1, C.S.D = 25, $\text{Reading}_1 = (0.1 + 25 \times 0.001)$ cm

$= 0.125$ cm

observation - 2,

m.s.R = 0.1, C.S.D = 25, $\text{Reading}_2 = (0.1 + 25 \times 0.001)$ cm

$= 0.125$ cm

observation - 3,

M.S.R = 0.1, C.S.D = 25, $\text{Reading}_3 = (0.1 + 25 \times 0.001)$ cm

$= 0.125$ cm

radius of the wire, $r = \frac{0.125 + 0.125 + 0.125}{6}$ cm

$= 0.0625$ cm

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for spring,

Din : V.C = 0.005 cm

M.S.R = 2.3, V.S.R = 7, R_1 = (2.3 + 7 × 0.005) cm
= 2.335 cm

M.S.R = 2.3, V.S.R = 2, R_2 = (2.3 + 2 × 0.005) cm
= 2.310 cm

M.S.R = 2.3, V.S.R = 8, R_3 = (2.3 + 8 × 0.005) cm
= 2.34 cm

∴ Din = $\frac{R_1 + R_2 + R_3}{3}$ = 2.328

Dout: M.S.R = 2, V.S.R = 2, R_4 = (2 + 2 × 0.005) cm
= 2.01 cm

M.S.R = 2.1, V.S.R = 7, R_5 = (2.1 + 2 × 0.005)
= 2.135 cm

M.S.R = 2, V.S.R = 6, R_6 = (2 + 6 × 0.005) cm
= 2.03 cm

∴ Dout = $\frac{R_4 + R_5 + R_6}{3}$ = 2.058 cm

∴ R = $\frac{Din + Dout}{4}$ = $\frac{2.328 + 2.058}{4}$ = 1.0965 cm

Number of turn, N = 122

∴ Rigidity modulus : $\eta = \frac{4NKR^3}{r^4} = \frac{4 \times 122 \times 13625 \times (1.096}{(0.0625)^4}$

= 5.745 × 10^{11}

= dm/cm/s^2

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Error:

$$\frac{|\text{actual value} - \text{measured value}|}{\text{actual value}} \times 100\%$$

$$= \frac{|(7.7 \times 10^{11}) - (5.745 \times 10^{11})|}{7.7 \times 10^{11}} \times 100\%$$

$$= 25.39\%$$

Result: The value of the rigidity modulus was found to be 7.7×10^{11} dm/cm^2 with an error of 25.39%.

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ME-21-(Sec.A)

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ME-21(A)

MILITARY INSTITUTE OF SCIENCE AND TECHNOLOGY

Course Code : Phy-102

Determination of Resistance of a Galvanometer by Half Deflection Method and a High Resistance By the method of Deflection.

Name : A.K.M Tazbin Ahmed

Roll No : 202318058

Level/Term : L-1, T-1

Course : Phy-102

Date of exp : 29.05.23

Date of sub : 05.06.23

Group : B1

Signature of Teacher :

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Abstract: The resistance of a galvanometer was determined using the half deflection method and a high resistance was measured using the method of deflection. Mutiple measurements were conducted to ensure accuracy and average values were recorded. The galvanometer resistance was found to be 650Ω with an error of 21.579%. The high resistance was determined to be 10000Ω with an error of 0.926%. The effectiveness and usefulness of both methods for resistance determination were demonstrated providing valuable insights into galvanometry principles and measurement techniques.

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Introduction :

The half deflection technique is a method used to assess the internal resistance of a cell, which helps in determining a high-value resistance. In this technique, the deflection of the galvanometer at half its maximum value is considered as a measurement solely attributable to the cell itself. To achieve this, a high resistance box is usually connected to the battery to adjust the circuit and ensure that the galvanometer's deflection falls within the scale. [1].

The high resistance means those resistors which have more than 10kΩ of resistance. In this method of deflection, it involves using a highly sensitive and high-resistance galvanometer which is connected in series with the resistance under measurement and a battery. By observing the deflection of the galvanometer, the unknown resistance can be determined. [2].

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Theory: In the arrangement, the shunt resistance S is very small compared to the galvanometer resistance G, then the total potential difference between the ends of the shunt resistance S remains nearly constant for all values of R_1.

Thus when, $R_1 = 0$ then the galvanometer current I_g is given by $\frac{V}{G} = Kd$ ... (i).

also, $I_g' = \frac{V}{G+R_1} = K\frac{d}{2}$ ... (ii)

where, I_g' is the new galvanometer current in the changed circumstances.

Dividing (i) by (ii), we get

$$\frac{G+R_1}{G} = 2$$

$\Rightarrow G + R_1 = 2G$

or, $G = R_1$ ... iii)

Hence by simply measuring R_1, G can be found.

In two determine a high Resistance by the method of deflection, the current I_g flowing through the galvanometer is given by,

$$I_g = \frac{ES_1}{x(S_1+G)+S_1G} = Kd_1 \quad \text{...(iv)}$$

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The galvanometer current I_g is given by

$$I_g = \frac{\varepsilon S_2}{R(S_2 + G_1) + S_2 G_1} = k d_2 \quad \text{--- (v)}$$

Hence we get,

$$x = R \frac{S_1}{S_2} \frac{(S_2 + G_1)}{(S_1 + G_1)} \times \frac{d_2}{d_1} \quad \text{... (vi)}$$

and, $$x = R \frac{S_2 + G_1}{S_2} \times \frac{d_2}{d_1} \quad \text{--- (vii)} \quad [3]$$

circuit figure:

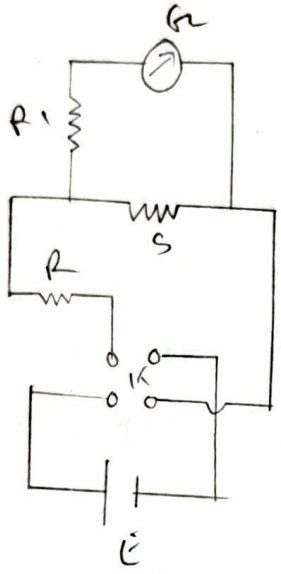


Figure-1 : Figure to determine the resistance of a galvanometer by half deflection method.

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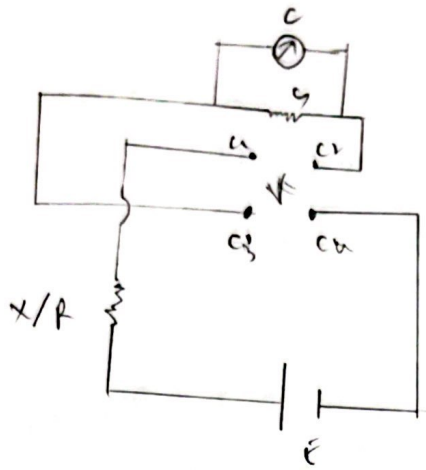


Figure-2: Figure to determine A High resistance By the method of Deflection..

Apparatus: Suspended coil galvanometer, shunt box S, resistance R and R_1, commutator K, cell E, connecting wires, battery, A high resistance to be measured, two way plug key etc.

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Description of the apparatus:

* Galvanometer: In a suspended coil galvanometer, a coil is mounted on a pivot between magnetic poles. when a current flows through the coil, it generates a magnetic field that interacts withe the magnetic field of the poles, causing the coil to rotate. The amount of rotation is proportional to the current. [4].

* Commutator: A commutator is a rotary switch found in electric motors and generators. It reverses the current direction between the rotor and external circuit. It consists of metal contact segments on the rotating armature. Brushes made of carbon press against the commutator, establishing contact with each segment. The commutator connects the armature windings to ensure proper current flow for motor or generator Operation. [5]

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Procedure: Procedure of half deflection method:

i) The connection was made as shown in figure 1. One sharp edge of the spot of light was brought to the zero mark of the scale.

ii) A resistance of the order of 1000 Ω was inserted into the battery circuit. The resistance R_1 was set to zero by putting all plugs in the box. Starting with the smallest value of the shunt resistance S, S was gradually increased until a deflection of about 10 cm was obtained on the scale. This deflection was noted.

iii) The resistance R was kept constant, and the value of the resistance R_1 was adjusted until the deflection was reduced to half of the previous value. The value of R_1, which represents the galvanometer resistance G was recorded.

iv) The current in the circuit was stopped and an examination was conducted to determine if the same sharp edge of the spot of light remained at zero on the scale. If it was not at zero, the scale was adjusted to bring it back to zero. The value of R1 was set to zero while

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keeping R unchanged. Then, the current was reversed using the commutator K. The entire operation was repeated to obtain another value of G_2.

v) The value of the resistance R was kept the same and the value of the shunt resistance S was changed to achieve a different deflection of approximately 10 cm. The value of G_2 was determined accordingly. The operation was repeated three times with different values of R in the battery circuit and two values of S for each R.

*Procedure to determine a high resistance by the method of deflection:

i) The connection was made as shown in Figure 2. The unknown resistance was inserted into the circuit as X.

ii) Two difflection were noted: one in the direct connection and another in the reverse connection. The mean of the two deflection was calculated.

iii) The high resistance, which should not be less than 10000 ohms, was joined in the circuit as R. The deflections were noted, one in the direct connection and another in the reverse

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connection. The mean of the two deflections was calculated.

iv) The operation was repeated alternately to obtain three sets of values for different values of S. The value of X was calculated from each set of observations. The mean of the three values of X was then determined. [3]

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Experimental data:

Table-1: Table to determine the Resistance of a Galvanometer by half-deflection method.

No. of obs.	Current	Resistance R in ohms (Ω)	Shunt Resistance S in ohms (Ω)	Resistance R_1 in ohms (Ω)	Deflections	$G_t = R_1$ ohms (Ω)	mean G in ohms (Ω)
1	Direct	1300	39	500	10 05	500	291.667
	Reverse	1300	39	700	10 05	700	
2	Direct	1400	40	500	10 05	500	
	Reverse	1400	40	700	10 05	700	
3	Direct	1200	37	1200	10 05	1200	
	Reverse	1200	37	1150	10 05	1150	

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Table-2: Table to Determine A High Resistance by the method of deflection.

NO of obs	Series Resistance in (Ω)	Shunt resistance in (Ω)	Deflections in cm for current			unknown Resistance X in (Ω)	Mean X in (Ω)
			Direct	Reverse	mean		
1	X	S_1 = 500	14	15	14.5	10000	9907.04
	R=10000	S_2 = 500	14	15	14.5		
2	X	S_1 = 700	17	17	16.5	10000	
	R=10000	S_2 = 700	16	17	16.5		
3	X	S_1 = 800	17	19	18	9722.26	
	R=10000	S_2 = 800	17	18	17.5		

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Calculation:

for table-1,

$G_2 = R_1$

$G_{21} = 1200\Omega$

$G_{22} = 1150\Omega$

$G_{23} = 500\Omega$

$G_{24} = 700\Omega$

$G_{25} = 500\Omega$

$G_{26} = 700\Omega$

$$\text{Avg} = \frac{1200 + 1150 + 500 + 700 + 500 + 700}{6}$$

$$= 791.667\Omega.$$

$$\text{Error} : \frac{|\text{standard} - \text{obtained}|}{\text{standard}} \times 100\%.$$

$$= \frac{|650 - 791.667|}{650} \times 100\%$$

$$= 21.79\%$$

Result: The resistance of the galvanometer was found to be 650Ω with an error of 21.79%

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For table-2,

If, $S_1 = S_2 = 500\Omega$

$$x_1 = \frac{14.5}{14.5} \times 10000$$
$$= 10000\Omega$$

$$x_2 = \frac{16.5}{16.5} \times 10000$$
$$= 10000\Omega$$

$$x_3 = \frac{17.5}{18} \times 10000$$
$$= 9722.22\Omega$$

$$\text{Avg} = \frac{10000 + 10000 + 9722.22}{3}\ \Omega$$
$$= 9907.4\Omega$$

Error:

$$\frac{|\text{standard} - \text{obtained}|}{\text{standard}} \times 100\%$$

$$= \frac{|10000 - 9907.4|}{10000} \times 100\%$$

$$= 0.926\%$$

Result: The high resistance was to be found 10000Ω with an error of 0.926%.

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Discussion:

i) The connection was failed, and no deflection was obtained by the galvanometer. As a result, the circuit had to be reconnected. consequently, an error occured in the circuit.

ii) During the reading, a mistake occured, resulting in an error. However, after rechecking multiple times, the error was partially resolved.

iii) The pointer of the galvanometer was not functioning properly, frequently getting stuck and causing imperfect readings. As a result errors occurred in the measurements. However, by repeating the experiment multiple times, the error was gradually reduced.

iv) The wire wasn't connected properly, resulting in imperfect deflection. The mistake was realized and the wire was reconnected correctly, which led to a decrease in the error.

v) The series resistance R should never be made equal to zero when the circuit is closed otherwise the galvanometer will be damaged.

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vi) For a steady deflection a storage battery should be used.

vii) The pair of deflections, d_1 and d_2 for x and R in each set were made nearly equal.

Conclusion: The resistance of a galvanometer was determined using the half deflection method, ensuring that the deflection was halved by adjusting the value of resistance R_1. Furthermore, the method of deflection was utilized to measure a high resistance by observing the diflection of the galvanometer. The results obtained through these methods contribute to a better understanding of galvanometer behaviour and enhance their usefulness in a wide range of applications. Efforts were made to rectify the error. Despite the attempts, the result obtained for the resistance of the galvanometer using the half deflection method yielded 650 ohms with an error of 21.79%. Additionally, the high resistance was determined to be 10000 ohms with an error of 0.926%.

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References:

[1] https://byjus.com/question-answer/what-is-half-deflection-method/

[2] tutorialspoint.com/how-to-measure-high-resistances-resistance-measurement-methods.

[3] Dr. Gias uddin Ahmad and Md. Shahabuddin "Practical Physics for Degree students", Page 382-389.

[4] https://unacademy.com/content/neet-ug/study-material/physics/moving-coil-galvanometer-types-working-principle-and-the-moving-coil/

[5] https://en.wikipedia.org/wiki/commutator-(electric)

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Name: A.K.M Tazbir Ahmed
ID : 202318058

Name of the experiment:

DETERMINATION OF RESISTANCE OF A GALVANOMETER BY HALF DEFLECTION METHOD AND A HIGH RESISTANCE BY THE METHOD OF DEFLECTION

Working formula:

$$\frac{V}{G_2} = Kd \quad \text{---(i)}$$

$$C'g = \frac{V}{G_2+R_1} = K\frac{d}{2} \quad \text{---(ii)}$$

$$G_2 = R_1 \quad \text{---(iii)}$$

Here,

V = The potential difference between the ends of the shunt resistance.

G_2 = Galvanometer resistance.

Cg = Galvanometer current.

K = Galvanometer constant

R_1 = Resistance

$C'g$ = new galvanometer current

also,

$$Cg = \frac{ES_1}{x(S_1+G_2)+S_1G_2} = Kd_1 \quad \text{---(i)}$$

$$Cg = \frac{ES_2}{R(S_2+G_2)+S_2G_2} = Kd_2 \quad \text{---(ii)}$$

$$x = R\frac{S_1(S_2+G_2)}{S_2(S_1+G_2)} \times \frac{d_2}{d_1} \quad \text{---(iii)}$$

$$x = R\frac{S_2+G_2}{S_2} \times \frac{d_2}{d_1} \quad \text{---(iv)}.$$

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Here,

K = Constant of proportionality

R = Known Resistance.

S_2 = Shunt resistance

d_2 = deflection $\simeq d_1$

C_g = The galvanometer current

x = Unknown high resistance to be measured

Apparatus: Suspended coil galvanometer, shunt box S, resistance R and R_1, commutator K, cell E, connecting wires, battery, high resistance to be measured, Ordinary resistance box containing resistances from 1 to 1000 ohms, plug commutator, two-way plug key.

Figure.

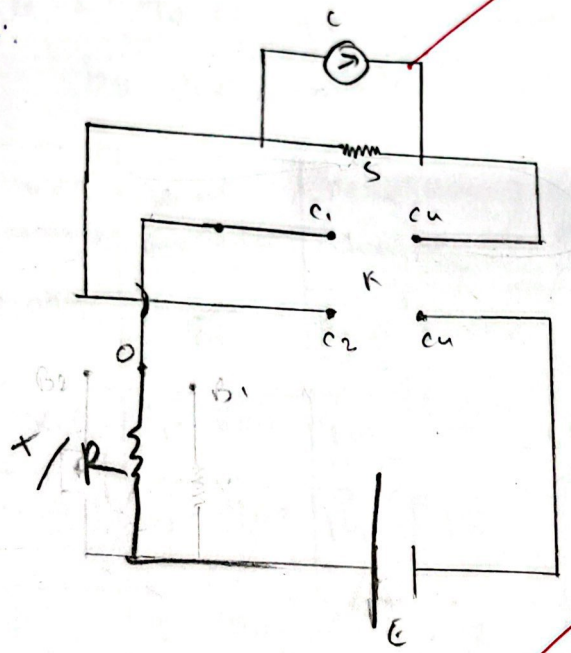


Figure 1. diagram to determine A High resistance By the method of Deflection.

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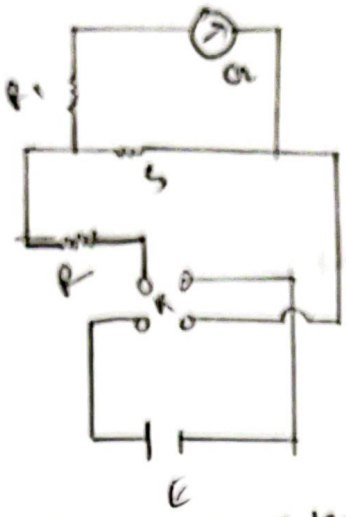


Figure2: Figure to determine the resistance of a galvanometer By half - deflection method.

Table :

EMF of the battery:

Galvanometer resistance (given), G=

Table-1 : Table to determine A High Resistance by the method of deflection

No of obj	Series Resistance in ohm,	Shunt Resistance in ohm	Deflections in cm for current.			Unknown resistance X in Ω	mean X in Ω
			Direct	Reverse	mean		
1	X	$S_1 = 500$	14	15	14.5	10000	
	R=10000	$S_2 = 500$	14	15	14.5		
2	X	$S_1 = 700$	17	17	16.5	10000	9907.0
	R=10000	$S_2 = 700$	16	17	16.5		
3	X	$S_1 = 800$	17	19	18	9722.26	
	R=10000	$S_2 = 800$	17	18	17.5		

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Table 1: Table to determine the resistance of a Galvanometer by half-deflection method.

No. of obs.	Position	Resistance R in ohms	Shunt resistance S in ohms	Resistance R in ohms	Deflection	G = R ohms	Mean G in ohms
1	Direct	1300	39	600	10 05	1300	
	Reverse	1300	39	700	10 05	700	
2	Direct	1400	40	500	10 05	500	791.66
	Reverse	1400	40	700	10 05	700	
3	Direct	1200	37	1200	10 05	1200	
	Reverse	1200	37	1150	10 05	1150	
4							
5							

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Calculation: (for table-2)

$G = R_1$

$G_1 = 1200\ \Omega$

$G_2 = 1150\ \Omega$

$G_3 = 500\ \Omega$

$G_4 = 700\ \Omega$

$G_5 = 500\ \Omega$

$G_6 = 700\ \Omega$

$$\text{Avg} = \frac{1200 + 1150 + 500 + 700 + 500 + 700}{6}$$

$$= 791.667\ \Omega$$

Error calculation:

$$\frac{|\text{standard} - \text{obtained}|}{\text{standard}} \times 100\%$$

$$= \frac{|650 - 791.667|}{650} \times 100\%$$

$$= 21.79\%$$

Result: The resistance of the galvanometer was found to be $650\ \Omega$ with an error of 21.79%

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Calculation: (For table-1)

If, $S_1 = S_2 = 500\Omega$

$$R_1 = \frac{14.5}{14.5} \times 10000$$

$$= 10000\ \Omega$$

$$R_2 = \frac{16.5}{16.5} \times 10000$$

$$= 10000\ \Omega$$

$$R_3 = \frac{17.5}{18} \times 10000$$

$$= 9722.22\ \Omega$$

$$\text{Avg} = \frac{10000 + 10000 + 9722.22}{3}$$

$$= 9907.4\ \Omega$$

Error:

$$\frac{|\text{Standard} - \text{obtained}|}{\text{Standard}} \times 100\%$$

$$= \frac{|10000 - 9907.4|}{10000} \times 100\%$$

$$= 0.926\%$$

Result: The high resistance was to be found $10000\ \Omega$ with an error of 0.926%

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