B.Sc Physics (Major)

Semester I

Physics Core Course 2

Mechanics

Laboratory Notebook

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Experiment No. 1 :

Determination of Acceleration due to Gravity ('g') using Kater's Pendulum

Theory: From the theory of compound pendulum we know that, $T = 2\pi\sqrt{\frac{k_{cm}^2+r^2}{gr}}$, where T is the time period of oscillation, k is the radius of gyration about the center of mass, r is the distance between point of suspension and the center of gravity.

In case of Kater's Pendulum, if the time period of oscillation for two different point of suspension be T_1 and T_2 and T_1 and T_2 are very close. If r_1 and r_2 be the distance between the point of suspension and the center of gravity in case of the previous two different point of suspension.

So, $T_1 = 2\pi\sqrt{\frac{k_{cm}^2+r_1^2}{gr_1}}$ and $T_2 = 2\pi\sqrt{\frac{k_{cm}^2+r_2^2}{gr_2}}$

We can deduct from the above equation that,

$g = 8\pi^2\left(\frac{T_1^2+T_2^2}{r_1+r_2}+\frac{T_1^2-T_2^2}{r_1-r_2}\right)^{-1}$, this the working formula for this experiment.

Apparatus: i) Kater's Pendulum, ii) Stop Watch, iii) Meter Scale, iv) Wedge, v) Telescope

Experiment:

a) Adjusting the cylindrical masses to get a nearly equal T_1 and T_2.

Table :

No.	Cylinder	No. of Oscillations considered	Total Time Period of oscillations (sec)	
			K_1	K_2
1.	D	5	8.81	8.87
2.	D	5	8.71	8.77
3.	D	10	18.01	17.09
4.	D	10	17.82	17.71
5.	D	20	35.50	35.42

b) Determining the final time period of oscillation T_1 and T_2

No.	Observed about the knife-edge	Time Period for 50 Oscillations (sec)	Mean Time Period for 50 Oscillations (sec)	Time Period (sec)
1.	K_1	88.05	87.48	1.7496 (T_1)
2.		87.40		
3.		86.99		
1.	K_2	86.89	87.47	1.7494 (T_2)
2.		87.47		
3.		88.05		

c) Determining the r_1 and r_2

No.	Distance between K_1 and C.G. r_1 (cm.)	Mean r_1 (cm.)	Distance between K_2 and C.G. r_2 (cm.)	Mean r_2 (cm.)
1.	44.2	44.1666	31.6	31.6333
2.	44.1		31.7	
3.	44.2		31.6	

Calculations :

$T_1 = 1.7496$ sec.; $T_2 = 1.7494$ sec.

$r_1 = 44.1666$ cm.; $r_2 = 31.6333$ cm.

$$g = 8\pi^2\left(\frac{T_1^2+T_2^2}{r_1+r_2}+\frac{T_1^2-T_2^2}{r_1-r_2}\right)^{-1}$$

$$\Rightarrow g = 8\pi^2\left(\frac{1.7496^2+1.7494^2}{44.1666+31.6333}+\frac{1.7496^2-1.7494^2}{44.1666-31.6333}\right)^{-1}$$

$$\Rightarrow g = 977.12$$

So we've calculated that the local acceleration due to gravity is 977.12 cm-s^{-2}

Conclusion: i) The plane on which the knife-edge is placed, must have to horizontal.

ii) This experiment is very sensitive as it seems. A small change results in a big difference in final result. So we need to take measurement more carefully and with more digital measuring instruments.

Experiment No. 2 :

Determination of Acceleration due to Gravity ('g') using Bar Pendulum

Theory: From the theory of compound pendulum we know that, $T = 2\pi\sqrt{\frac{k_{cm}^2+r^2}{gr}}$, where T is the time period of oscillation, k is the radius of gyration about the center of mass, r is the center of gravity. Where the term $\frac{k_{cm}^2+r^2}{r}$ is also known as Reduced Length. We can also show that this Reduced Length (L) is equal to the distance between the two specific points of suspension where the time period of oscillation is same.

In case of Bar Pendulum, $L = l_1 + l_2$ for two equal T_1 and T_2. So the equation reduces to the legendary form, $T = 2\pi\sqrt{L/g}$.

So, $= 4\pi^2 \, {}^{L}\!/_{T^2}$, these are the working formula for this experiment.

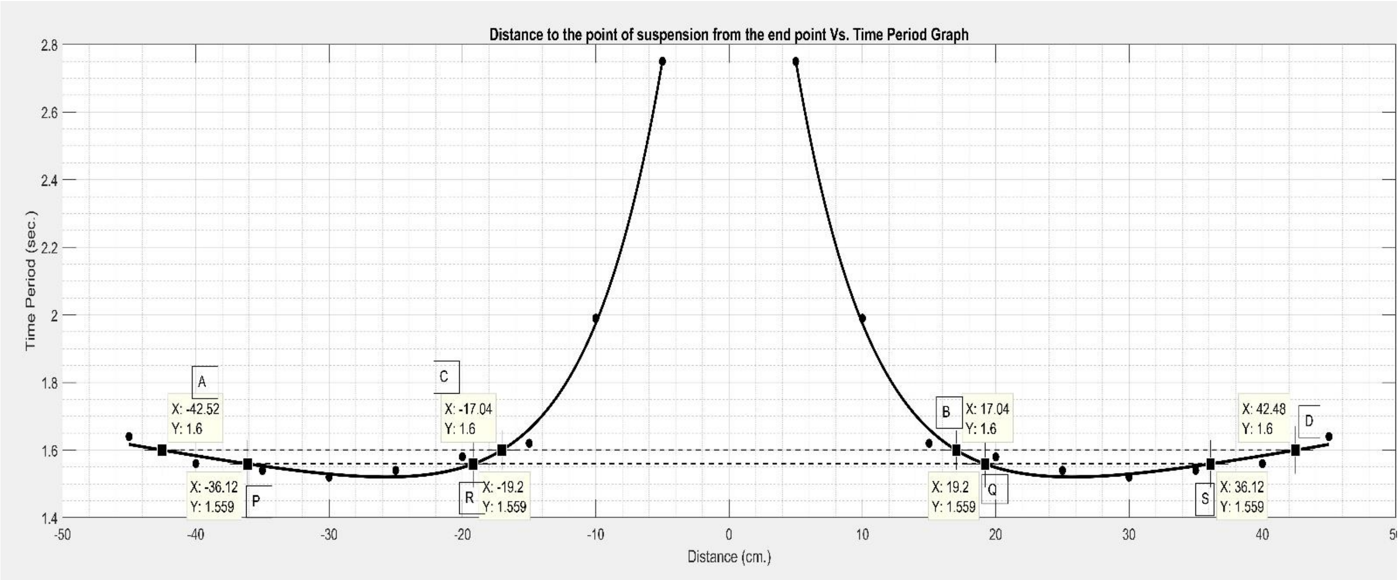
Apparatus: i) Bar Pendulum, ii) Stop Watch, iii) Meter Scale, iv) Knife-Edge

Experiment: Recording values of Time Period for different r.

Table :

No.	Which End	Distance to the point of suspension from the end point (cm.)	Total Time Period for 30 Oscillations (sec.)	Time Period (sec.)
1.	End 1	5	49.2	1.64
2.		10	46.8	1.56
3.		15	46.2	1.54
4.		20	45.6	1.52
5.		25	46.2	1.54
6.		30	47.4	1.58
7.		35	48.6	1.62
8.		40	59.7	1.99
9.		45	82.5	2.75
10.	End 2	5	82.5	2.75
11.		10	59.7	1.99
12.		15	48.6	1.62
13.		20	47.4	1.58
14.		25	46.2	1.54
15.		30	45.6	1.52
16.		35	46.2	1.54
17.		40	46.8	1.56
18.		45	49.2	1.64

Graph :



Calculation : Observation from the graph

Case 1 : Time Period = 1.6 sec.

AB = 59.56 cm ; CD = 59.52

$L = \frac{AB+CD}{2}$

L = 59.54 cm

T = 1.6 sec

$g = 4\pi^2 L/_{T^2}$

g = 918.1816 cm.-sec.$^{-2}$

Case 2 : Time Period = 1.559 sec

PQ = 55.32 cm ; RS = 55.32 cm

L = 55.32 cm

T = 1.559 sec.

g = 898.5654 cm.-sec.$^{-2}$

So average $g = \frac{918.1816+898.5654}{2} = 908.3735$ cm-s^{-2}

So we’ve calculated that the local acceleration due to gravity is 908.3735 cm-s^{-2}

Conclusion: i) The plane on which the knife-edge is placed, must have to horizontal.
ii) Amplitude should be small.
iii) The Pendulum must not rotate about the vertical axis.
ii) This experiment is very sensitive as it seems. A small change results in a big difference in final result. So we need to take measurement more carefully and with more digital measuring instruments.

Experiment No. 3 :

Determination of the Young's Modulus of the Material of a wire by Searle's Method

Theory: We know that the Young's Modulus of a wire is given by,

$$Y = \frac{4mg}{\pi d^2} \Big/ \frac{\Delta l}{l} \qquad \text{............equation 1}$$

Where, Y = Young's Modulus

m = attached mass

g = acceleration due to gravity

d = diameter of the wire

l = initial length of the wire (before attaching mass)

Δl = change in length (after attaching mass)

$\Delta l = l_f - l_i$

$\frac{4mg}{\pi d^2} = Stress$

$\frac{\Delta l}{l} = Longitudinal\ Strain$

We can write equation 1 as,

$$\Delta l = \frac{4lg}{Y\pi d^2} m \qquad \text{................equation 2}$$

So, by plotting (Δl, m) and calculating the slope of the line, we can calculate Y as,

$Y = \frac{4lg}{\pi d^2 \tan(\theta)}$ where $\tan(\theta)$ is the slope. This will be the working formula of this experiment.

Apparatus: i) Experimental Wire, ii) Reference Wire, iii) Leveler, iv) Various Weights,

Experiment: Determining the slope of the equation 2

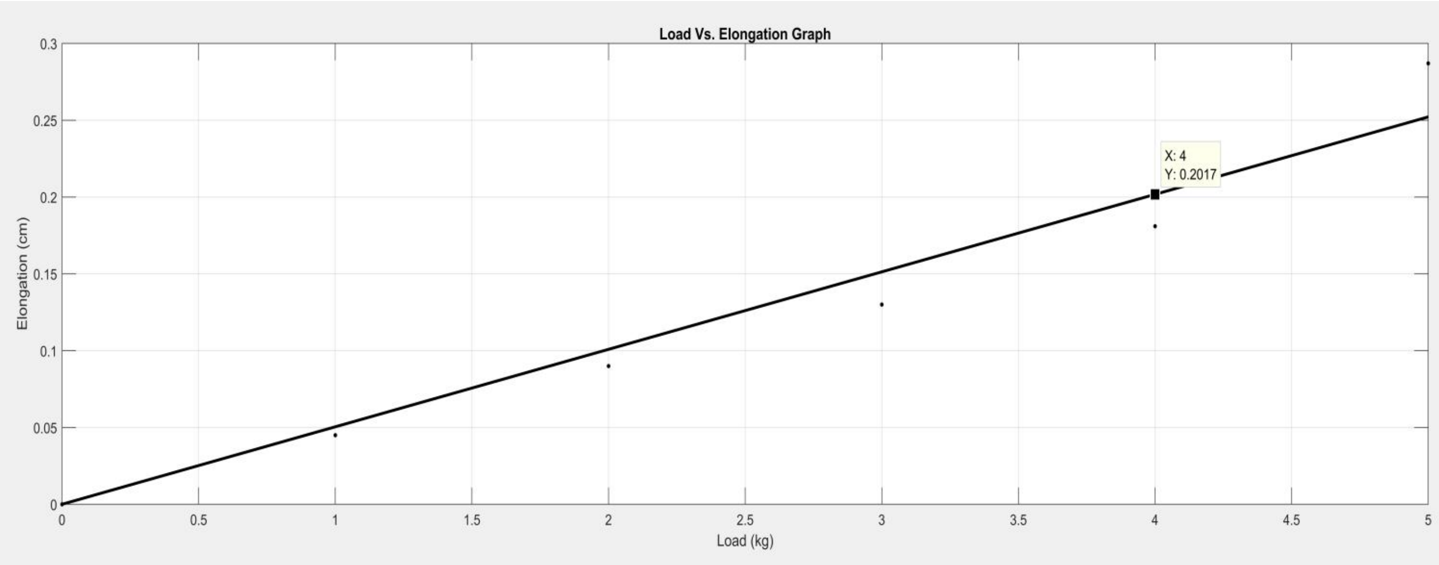
Table :

No.	Extra Load over Dead Load (kg)	While Increasing Load			While Decreasing Load			Average Length (cm)	Elongation (cm)
		Reading of Linear Scale (L) (cm)	Reading of Circular Scale (C) (div)	Total Length (L+C*S.P.) (cm)	Reading of Linear Scale (L) (cm)	Reading of Circular Scale (C) (div)	Total Length (L+C*S.P.) (cm)		
1	0	0	5	0	0	15	0.01	0.005	-
2	1	0	58	0.058	0	52	0.047	0.05	0.045
3	2	1	2	0.097	0	98	0.093	0.095	0.090
4	3	1	47	1.042	1	33	1.028	0.135	0.13
5	4	2	3	1.098	1	80	1.075	0.186	0.181
6	5	2	97	2.097	2	97	2.092	0.292	0.287

Graph:

Table for plotting the graph:

x axis (Load) [kg]	0	1	2	3	4	5
y axis (Elongation) [cm]	0	0.045	0.090	0.13	0.181	0.287



Calculation: The point specified in the graph is (40.2017)

Therefore, slope of the line is, $\tan(\theta) = \frac{0.2017}{4} = 0.050425$

Given data : Length of the wire (l) = 154 cm.

Diameter of the wire = 0.051 cm.

Therefore, $Y = \frac{4000lg}{\pi d^2 \tan(\theta)}$

$$Y = \frac{4000*154*981}{\pi 0.051^2 * 0.050425}$$

$= 14.6 \times 10^{11}$ dyne-cm^{-2}

So, we've calculated the Young's Modulus of the wire which is 14.6×10^{11} dyne-cm^{-2}

Conclusion: i) Sarle's Method is a very effective way to measure the Young's Modulus of the material of the wire.

ii) Since attached mass and elongation has a linear relationship, so we have a minimum instrumental error. Which is good.

Experiment No. 4 :

Determination of the Spring Constant of a given Spring

Theory: From Hook's Law we know that, within elastic limit, $F_{applied}\ \alpha\ \Delta l$, where $F_{applied}$ is the amount of Force applied on the spring and Δl is the change in length. The previous equation can be written as $F_{applied} = k\Delta l$. Here k is known as the Spring Constant of the spring which we have to find out.

$$F_{applied} = k\Delta l$$

$$\Rightarrow F_{applied} = Mg = k\Delta l\ ; \quad \text{M is the mass attached to the spring}$$

$$\Rightarrow k = \frac{M}{\Delta l} g$$

$$\Rightarrow k = \mu g; \quad \text{where } \mu = \frac{M}{\Delta l} \text{ i.e. mass needed for a unit elongation}$$

This formula will be the working formula for this experiment.

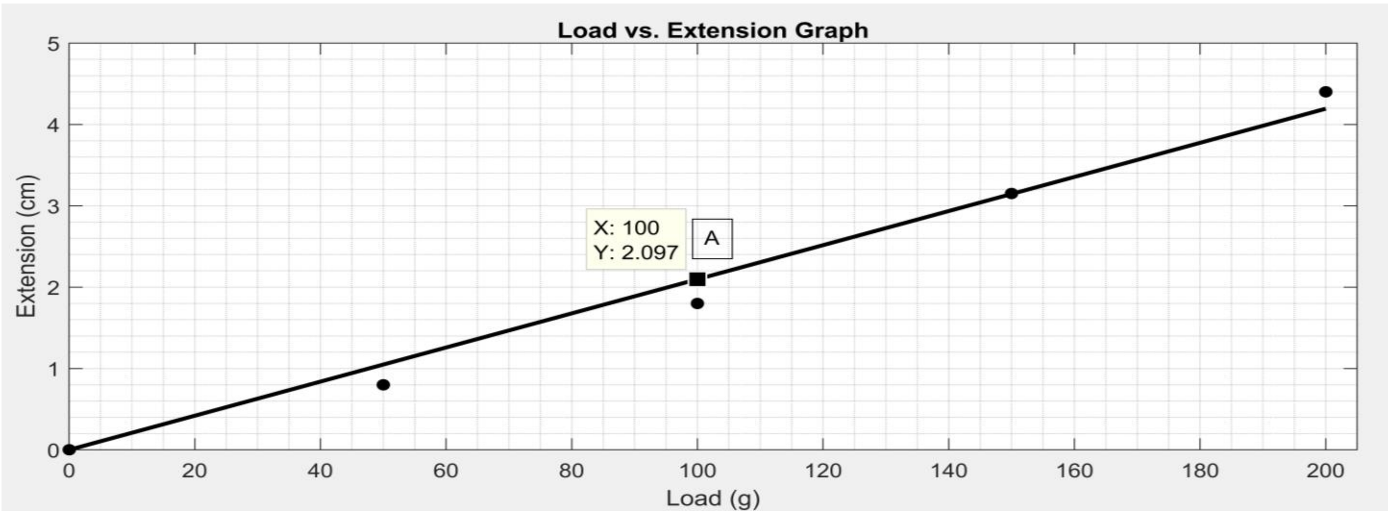
Apparatus: i) Spring, ii) Mass Scale, iii) Meter Scale, iv) Weights

Experiment:

Table:

No.	Attached Load (g)	Elongated Length (cm)			Elongation (cm)
		While Loading	While Unloading	Mean	
1.	0	23	23	23	-
2.	50	23.8	23.8	23.8	.8
3.	100	24.8	24.8	24.8	1.8
4.	150	26.1	26.2	26.15	3.15
5.	200	27.4	27.4	27.4	4.4

Graph:



Calculation: Observation from graph

The graph is between M and Δl. The straight line follows the equation $k = \mu g$.

The point A on the graph is (100,2.097)

Therefore the slope of the graph is = $\frac{100}{2.097}$

So, $\mu = \frac{100}{2.097}$

Therefore, $k = \mu g$

$\Rightarrow k = \frac{100}{2.097} * 981$; g=981 cm-$s^{-2}$

$\Rightarrow k = 46781.11$

So we've calculated the spring constant to be around 46781.11 dyne-cm^{-2}

Conclusion: i) While performing the experiment the spring must not be oscillating.

ii) A simple linear relationship makes this measurement very immune to instrumental errors.

Experiment No. 5 :

Measuring the length of a given rod using Vernier Calipers

Theory: To measure a length using Vernier Calipers, we need to record two consecutive readings, one is the Main Scale Reading and the other one is the Vernier Scale Reading. Every Vernier Calipers has a characteristic parameter called Vernier Constant which is the difference between one main scale division and one Vernier scale division.

VC = 1MSD – 1VSD

Now, the final reading is, MSR + VSR * VC, where MSR stands for Main Scale Reading, VSR stands for Vernier Scale Reading.

Apparatus: i) Vernier Calipers

Experiment:

a) Calculating Vernier Constant

1 MSD = 0.1 cm.

10 VSD = 9 MSD
= 0.9 cm.
1 VSD = 0.09 cm.

VC = 0.1 – 0.09 cm.
= 0.01 cm

b) Measuring the Length
Table:

No.	MSR (cm)	VSR (div)	Length (cm)	Mean Length (cm)
1.	9.8	9	9.89	9.238
2.	8.7	8	8.78	
3.	9.1	7	9.17	
4.	9.2	9	9.29	
5.	9.3	8	9.38	

So we've measured the length to be 9.238 ± 0.01cm.

Conclusion: i) The Vernier Calipers has an absolute error of 0.01 cm.

ii) The Vernier Calipers has no zero error.

iii) We've executed the experiment several times to get more accurate results.

Experiment No. 6 :

Measuring the Diameter and Radius of a given rod using Screw Gauge

Theory: To measure a length using Screw Gauge, we need to record two consecutive readings, one is the Main Scale Reading and the other one is the Circular Scale Reading. Every Screw Gauge has a characteristic parameter called Screw Pitch and Least Count.

Reading = MSR + CSR*LC, where MSR stands for Main Scale Reading, CSR stands for Circular Scale Reading and LC stands for Least Count

Apparatus: i) Screw Gauge

Experiment:

Screw Pitch = 1mm

Total Number of divisions in the Circular Scale = 100 div

So, Least Count = 1/100 mm./div.

= 0.01 mm./div.

Table:

No.	MSR (mm)	CSR (div)	Total Reading (mm)	Average Diameter (mm)
1.	9	34	9.34	9.347
2.	9	35	9.35	
3.	9	35	9.35	

So, we've calculated the diameter of the rod is 9.347 ± 0.01 mm.

So, the radius of the rod is 4.6735 ± 0.01 mm.

Conclusion: i) The Screw Gauge has an absolute error of 0.001 cm.

ii) The Screw Gauge has no zero error.

iii) We've executed the experiment several times to get more accurate results.

Experiment No. 7:

Measuring the Diameter and Radius of a given rod using Traveling Microscope Tube

Theory: Its principal of operation is based on that of the Vernier Calipers. To measure a small length, we need to record two consecutive readings, one is the Main Scale Reading and the other one is the Vernier Scale Reading. Every Vernier Calipers has a characteristic parameter called Vernier Constant which is the difference between one main scale division and one Vernier scale division.

$$VC = 1MSD - 1VSD$$

Now, the final reading is, MSR + VSR * VC, where MSR stands for Main Scale Reading, VSR stands for Vernier Scale Reading.

Apparatus: i) Traveling Microscope Tube

Experiment:

1 MSD = 0.05 cm.

50 VSD = 49 MSD

1 VSD = 49/50 MSD

= 0.049 cm.

VC = 0.05-0.049 cm.

= 0.001 cm.

Table:

a) Measuring the diameter horizontally

No.	Right Side			Left Side			Diameter (cm)	Average (cm)
	MSR (cm)	VSR (div)	Reading (cm)	MSR (cm)	VSR (div)	Reading (cm)		
1.	5.4	0	5.40	4.45	22	4.472	0.928	0.9823
2.	5.4	3	5.403	4.45	20	4.470	0.933	
3.	5.4	5	5.405	4.45	19	4.469	0.936	

a) Measuring the diameter vertically

No.	Up			Down			Diameter (cm)	Average (cm)
	MSR (cm)	VSR (div)	Reading (cm)	MSR (cm)	VSR (div)	Reading (cm)		
1.	8.2	10	8.210	7.25	30	7.280	0.930	0.9327
2.	8.2	8	8.208	7.25	27	7.277	0.931	
3.	8.2	12	8.212	7.25	25	7.275	0.937	

Average Diameter = (0.9823+0.9327)/2

= 0.9325 cm.

= 9.325 mm.

Therefore the Radius of the rod, 4.663±0.01 mm.

Conclusion: i) The Traveling Microscope Tube has an absolute error of 0.001 cm.

ii) Since we've subtracted two readings to get the final reading, the Traveling Microscope Tube has no zero error.

iii) We've executed the experiment several times to get more accurate results.

Experiment No. 8:

Measuring the Diameter and Radius of a Capillary Tube using Traveling Microscope Tube

Theory: Its principal of operation is based on that of the Vernier Calipers. To measure a small length, we need to record two consecutive readings, one is the Main Scale Reading and the other one is the Vernier Scale Reading. Every Vernier Calipers has a characteristic parameter called Vernier Constant which is the difference between one main scale division and one Vernier scale division.

VC = 1MSD – 1VSD

Now, the final reading is, MSR + VSR * VC, where MSR stands for Main Scale Reading, VSR stands for Vernier Scale Reading.

Apparatus: i) Traveling Microscope Tube

Experiment:

1 MSD = 0.05 cm.

50 VSD = 49 MSD

1 VSD = 49/50 MSD

= 0.049 cm.

VC = 0.05-0.049 cm.

= 0.001 cm.

Table:

b) Measuring the diameter horizontally

No.	Right Side			Left Side			Diameter (cm)	Average (cm)
	MSR (cm)	VSR (div)	Reading (cm)	MSR (cm)	VSR (div)	Reading (cm)		
1.	6.1	2	6.102	5.9	3	5.903	0.199	0.199
2.	6.1	3	6.103	5.9	5	5.905	0.198	
3.	6.1	2	6.102	5.9	2	5.902	0.200	

b) Measuring the diameter vertically

No.	Up			Down			Diameter (cm)	Average (cm)
	MSR (cm)	VSR (div)	Reading (cm)	MSR (cm)	VSR (div)	Reading (cm)		
1.	8.7	48	8.748	8.5	48	8.548	0.200	0.201
2.	8.7	49	8.749	8.5	47	8.547	0.202	
3.	8.7	47	8.747	8.5	45	8.545	0.202	

Average Diameter = (0.199+0.201)/2

= 0.200 cm.

= 2 mm.

Therefore the Radius of the rod, 1±0.01 mm.

Conclusion: i) The Traveling Microscope Tube has an absolute error of 0.001 cm.

ii) Since we've subtracted two readings to get the final reading, the Traveling Microscope Tube has no zero error.

iii) We've executed the experiment several times to get more accurate results.

Experiment No. 9 :

Determining the Modulus of Rigidity of the Material of a wire by Maxwell's Needle

Theory: If η is the Modulus of Rigidity or Shear Modulus, l is the length of the wire, r is the radius of the wire, D is the length of the hollow container pipe, m_1 and m_2 is the masses of the external hollow and solid brass rod, and T_1 and T_2 is the time period of oscillation of the torsion pendulum in the two specified condition (i.e. hollow rods in the middle, solid rods at the sides and solid rods in the middle, hollow rods at the sides) then it can be shown that,

$\eta = \frac{2l\pi D^2}{r^4}\left(\frac{m_1 - m_2}{T_1^2 - T_2^2}\right)$; this is the working formula for this experiment.

Apparatus: i) Maxwell's Needle Apparatus, ii) Thin Wire, iii) Screw Gauge, iv) Mass Scale, v) Stop Watch

Experiment:

a) Measuring the radius of the wire

Screw Pitch = 0.1 cm.
LC = 0.01 mm. = 0.0001 cm.

No.	MSR (mm)	CSR (div)	Diameter Reading (mm)	Diameter (mm)	Radius (cm)
1.	0	46	0.46	0.45	0.0225
2.	0	45	0.45		
3.	0	46	0.46		

So, the radius r=0.0225 cm.

b) Measuring the time periods

Table:

No.	SHHS Configuration			HSSH Configuration		
	Total Time for 20 Oscillation (sec)	Mean time for 20 Oscillation (sec)	T_1 (sec)	Total time for 20 Oscillation (sec)	Mean Time for 20 Oscillation (sec)	T_2 (sec)
1.	889.4	889.86	44.49	648.2	648.6	32.43
2.	890.4			649.2		
3.	889.8			648.6		

So, T_1 =44.49 sec., T_2 = 32.43 sec.

c) l=114 cm; m_1 = 247.165 g.; m_2 = 62.575 g.; D=40 cm.

Calculation:

$$\eta = \frac{2l\pi D^2}{r^4}\left(\frac{m_1 - m_2}{T_1^2 - T_2^2}\right)$$

$$\eta = \frac{2*114*\pi*40^2}{0.0225^4}\left(\frac{247.165-62.575}{44.49^2-32.43\text{^}2}\right)$$

$= 8.89 \times 10^{11}$ dyne-cm.$^{-2}$

So, we've calculated the value of the Modulus of Rigidity or the Shear Modulus to be 8.89×10^{11} dyne-cm.$^{-2}$

Conclusion: i) Since most of the variables are in more than one degree polynomial form, we must take the readings very carefully.