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Lab Report – 04

Name of the Experiment	: Determination of shear modulus using dynamic method.
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Instructor's comments:

Data Tables:

Vernier Constant (V.C.) of the slide calipers,

$$V.C = \frac{\text{The value of one smallest division of the main scale}}{\text{Total number of divisions in the vernier scale}} = \frac{0.1\,cm}{20} = 0.005\,cm$$

Least Count (L.C.) of the Screw Gauge

$$L.C. = \frac{\text{Pitch}}{\text{Total number of divisions in the circular scale}} = \frac{0.5\,mm}{50} = 0.01\,mm$$
$$= 0.001\,cm$$

Table-1: Data for the radius of the cylinder, *a*

No. of obs.	Main scale reading, x (cm)	Vernier scale division, d	Vernier constant V_C (cm)	Diameter $y = x + V_c \times d$ (cm)	Mean diameter, D (cm)	Radius, $a = \frac{D}{2}$ (cm)
1	4.4	12	0.005	4.46	4.464	2.232
2	4.4	14		4.47		
3	4.4	13		4.465		
4	4.4	12		4.46		
5	4.4	13		4.465		

Here, For main scale reading 4.4;

$y = x + V_e \times d$

$= 4.4 + 0.005 \times 12$

$= 4.46\,cm$

$x = 4.4\,cm$

$V_e = 0.005\,cm$

$d = 12$

Mean diameter, $D = 4.464\,cm$ $\left[\frac{4.46+4.47+4.465+4.46+4.465}{5}\right]$

Radius, $a = 2.232\,cm$

Vernier constant, $V_e = \frac{0.1\,cm}{20} = 0.005\,cm$

Table-2: Data for the radius of the wire, r

No. of obs.	Linear scale reading, x (cm)	Circular scale division, d	Least count, L_c (cm)	Diameter $y = x + d \times L_c$ (cm)	Mean diameter, D (cm)	Instru-mental error (cm)	Corrected diameter, D (cm)	Radius $r = \frac{D}{2}$ (cm)
1	0.05	5	0.001	0.055	0.054	$+2 \times L_c$ $= (+2 \times 0.001)$ $= +0.002$	0.056	0.028
2	0.05	3		0.053				
3	0.05	5		0.055				
4	0.05	4		0.054				
5	0.05	3		0.053				

Table-3: Data for the time period

No. of obs.	Time for 10 oscillations, t (sec)	Time period, T= t/10 (sec)	Mean T (sec)
1	22.87	2.287	2.2846
2	22.97	2.297	
3	22.72	2.272	
4	22.89	2.289	
5	22.78	2.278	

Length of the wire, l: (i) 46 cm (ii) 46 cm (iii) 46 cm

Average length of the wire, l = 46 cm

Mass of the cylinder, M= 0.9174 kg

$$L_c = \frac{\text{Pitch}}{\text{TNDCS}} = \frac{0.5\,\text{mm}}{50} = 0.01\,\text{mm} = 0.001\,\text{cm}$$

Diameter, $y = x + d \times L_c$ (For, $d=5$)

$x = 0.05$ cm

$d = 5$

$L_c = 0.001$ cm

$= 0.05 + 5 \times 0.001$

$= 0.055$ cm

Mean, diameter, $D = \frac{(0.055+0.053+0.055+0.051+0.053)\,cm}{5}$

$= 0.054$ cm

Instrumental error $= \pm 2 \times Lc$

$= \pm 2 \times 0.001$

$= \pm 0.002$ cm

corrected diameter, $D = (0.054 + 0.002)$ cm

$= 0.056$ cm

Radius, $r = \frac{D}{2} = \frac{0.056}{2} = 0.028$ cm

Calculations:

Moment of Inertia of the cylinder, $I = \frac{1}{2}Ma^2 = \frac{1}{2} \times 0.9174 \times (0.0223)^2$

$a = 2.232\,cm = 0.0223\,m$

$= 2.2815 \times 10^{-4}\,kgm^2$

Modulus of rigidity of the wire, $\eta = \frac{8\pi I l}{T^2 r^4}$ (SI unit)

$$= \frac{8\pi \times 2.285 \times 10^{-4}\,kgm^2 \times 0.46\,m}{(2.2846)^2 \times (2.8 \times 10^{-4}\,m)^4}$$

$= 8.234 \times 10^{10}\,kg\,s^{-2}\,m^{-1}$

$l = 46\,cm = 0.46\,m$

$r = 0.028\,cm = 2.8 \times 10^{-4}\,m$

Error Calculation:

Standard value of the modulus of rigidity of the material of the wire = 7.7×10^{10} SI Unit.

Percentage error = $\frac{\textit{Standard value} - \textit{Experimental value}}{\textit{Standard value}} \times 100$

$$= \left| \frac{7.7 \times 10^{10} - 8.234 \times 10^{10}}{7.7 \times 10^{10}} \right| \times 100$$

$= 6.935\%$

Results:

$\eta = 8.234 \times 10^{10}$ ~~Pa~~ $kg\,s^{-2}\,m^{-1}$

Percentage error $= 6.935\%$

Questions:

1. How will the period of oscillation be affected if the cylindrical mass of the pendulum be made heavy?

We know,

$$T = 2\pi\sqrt{I/c} = 2\pi\sqrt{\frac{\frac{1}{2}Ma^2}{c}} \quad \therefore T \propto \sqrt{M}$$

$T \propto \sqrt{M} \propto \sqrt{I}$;

Here, time period (T) is propotional to square root term of mass and inertia. If the mass and inertia increase for 4 time; the time period will increase for 2 times.

2. Discuss about the sensitivity of the calculation of the radius of the wire and hence its effect on the resultant modulus of the rigidity.

We know,

$$\eta = \frac{8\pi I \lambda}{T^2 r^4}$$

$$\therefore \eta \propto \frac{1}{r^4}$$

From the equation we can say that η is inversely proportional to the fourth power of the wire radius. This means, it is very sensitive to change. A very small change in measuring radius can cause a large change in the calulated value of η. So, the calculation of η is extremely sensitive to the radius of the wire.

Discussion:

Today our experiment was to know how a torsional pendulum work, to determine the shear modulus of the element of wire by the method oscillation. Throughout our experiment we used, a very thin wire and a heavy mass connected to the very end of the wire. As the wire was so thin, and to get high precised value we used a slide calipher and screw gadge; which helps us to calculate as accurate as possible. But as the wire has some deformation from previous, there was some drawback in our calculation. And then we have to calculate the time period (T) of oscillation, as the total system create a simple harmonic motion. In this process, we use our own eye to observe the oscillation. So, there was also some drawback, if we can do it with laser vision, or using slo-motion technology, the we could get a more accurate reading. But we could do the whole experiment with a less error 6.935%. Finally, we can learn the whole process practically and understand the shear Modulus of the wire.

For Inertia, $I = \frac{1}{2} M a^2$, where a = radius $I \propto r^2$

So, I is dependent on radius a.

Period, $T = 2\pi \sqrt{I/C}$

So, $T \propto \sqrt{I}$

As I is dependent to radius, $T \propto \sqrt{r^2}$

$\Rightarrow T \propto r$

So, $T \propto \sqrt{I} \propto r$

$\therefore$ If one of the term increases both will increase.

Again, $\eta = \frac{8\pi I l}{T^2 r^4}$

Here, $\eta \propto \frac{1}{r^4}$ and $\eta \propto I$; $\eta \propto l$

So, rigidity is dependent on l.

Also, If material changes then η also change. Because it dependent on I and I is dependent on mass.