Teacher's Signature: _____
Date: 28/3/22

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Section: E Group: 2 Date: 28/03/2022

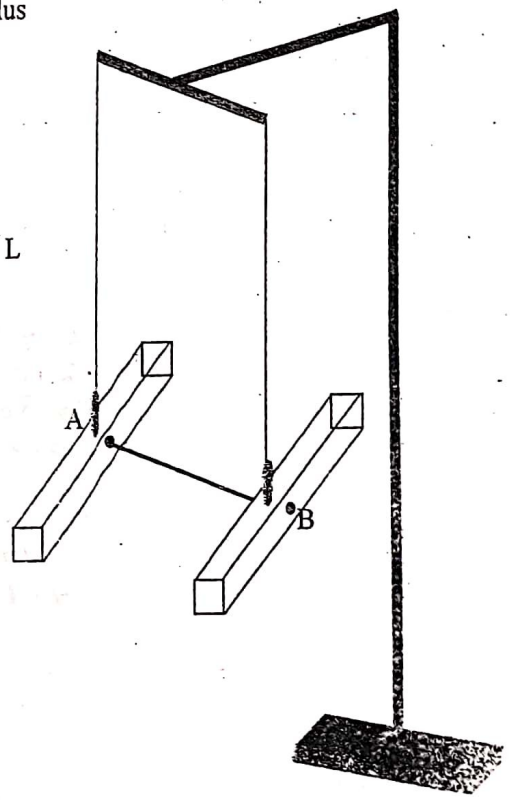
Experiment No. 06

Name of the Experiment: Determination of the Young's modulus of the material of a wire by Searle's dynamic method.

Theory:

If a wire specimen is fastened to two identical bars at their mid-points from which they are supported by threads and if the ends of the bars are drawn together and released, the bars oscillate with a period T. In that case, Young's modulus is given by the formula, $Y = \frac{8\pi I}{T^2 r^4} l$

Where l is the length and r is the radius of the wire.
I is the moment of inertia of one of the bars about its supporting thread.



Note: For a rectangular object having mass M, length L and width b, the moment of inertia is given as,

$$I = \frac{M}{12}(L^2 + b^2)$$

Apparatus:

- Searle's apparatus
- Screw gauge
- Stopwatch
- Slide calipers
- Meter scale etc.

Experimental Data:

(A) Table for the width of a bar, b

No. of obs.	MSR, x (cm.)	VSR	Vernier Constant (cm.)	Value of VSR, y (cm.)	Total reading, x+y (cm.)	Mean Width (cm.)	Instrumental error	Correct width, b (cm.)
1	0.7	10	0.005	0.	0.75	0.725	0	0.725
2	0.7	2		0.01	0.71			
3	0.7	3		0.015	0.715			

(B) Table for the moment of inertia of the bar, I

Length of the bar, L (cm)	Mass of one bar, M (gm)	Moment of Inertia of one bar, $I=\frac{M}{12}[L^2+b^2]$ (gm-cm^2)
30.5	145	11246.87

(C) Length of the wire = 27 cm [the horizontal wire AB in figure 1]

(D) Table for the radius of the wire, r

No. of obs.	LSR, x (cm.)	CSR	Least Count (cm.)	Value of CSR, y (cm.)	Total reading, x+y (cm.)	Mean Diameter (cm.)	Instrumental error	Correct diameter (cm.)	Radius, r = D/2 (cm.)
1	0.15	14	0.001	0.014	0.164	0.162	0	0.162	0.081
2	0.15	10		0.01	0.16				
3	0.15	13		0.013	0.163				

(E) Table for the time period, T

No. of obs.	No. of vibrations	Time taken to complete the vibrations (sec.)	Total time taken to complete the vibrations $t=\frac{t_1+t_2}{2}$ (sec.)	Period of oscillation, T (sec.)	Mean T (sec.)
1	10	t_1= 2.72 t_2= 2.87	2.795	0.2795	0.273
2	15	t_1= 3.88 t_2= 3.92	3.9	0.26	
3	20	t_1= 5.77 t_2= 5.82	5.79	0.289	
4	25	t_1= 6.17 t_2= 7.17	6.67	0.267	

Calculation:

The Young's modulus of the wire is,

$$Y=\frac{8\pi Il}{T^2r^4}=\frac{8\times\pi\times 11246.87}{(0.273)^2\times(0.081)^4}\times 27$$

$$=2.37\times10^{12}\ \text{Dynes/cm}^2$$

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Result:

The Young's modulus of the wire is, $Y=2.37\times10^{12}$ Dynes/cm^2

Discussions:

Q: What is stress and strain? Define longitudinal stress and longitudinal strain. How are they related to Young's Modulus? Derive the unit of Young's Modulus.

Stress: When some amount of deforming force is applied to an object the object deforms. In response, a restoring force is generated inside the object that want to restore the object to its original shape.

Strain: Strain refers to the ratio deformation and initial size. Or we can simply say, deformation per unit initial length.

Longitudinal Stress: When the deforming force are perpendicular to the surface of application, the stress produced is called Longitudinal stress. If length increases, it is tensile stress.

Longitudinal Strain: Strain produced due to longitudinal stress is called longitudinal strain.

Youngs modulus: the amount of longitudinal stress required to produce 1 unit of longitudinal strain in a body is called the youngs modulus of the material that the body is mad of. $Y = \frac{\sigma}{\epsilon}$.

Q: In determining the Young's Modulus of the wire using the formula given which quantities you think should be measured with caution and why?

the time period, the radius and length of the bar, and the radius of the wire should be measured with caution. The reason is that these quantities have higher exponents in the given formula and so slight mistake in taking a measurement will produce a large mistake in the final result.

Q: On what factors does the value of Y depend?

For Young's modulus is a property of the material that the object is made of, not of the object itself. Therefore, the size, shape, or time period of osillation doesn't affect this value. But it is dependent upon temperature and pressure.

Q: Suppose, you are provided with two wires both made of copper but they are of different length and diameter. What do you think about their Young's Modulus? Will they be different or same? Why?

No, Young's modulus will be the same because they are made of the same material.

Q: Is it possible to determine the *Rigidity Modulus* of elasticity using this apparatus? Explain.

No; it is not. The reason is that rigidity modulus is related to shear stress and shear strain. Searle's apparatus is not constructed to apply shear force on the wire.

Q: Why have we used a short length wire in the experiment?

Because if we use a long wire, there will be unwanted vibration in the middle of the wire which will produce faulty time period data.

Q: What is the standard value of the *Young's Modulus* of the material used to perform the experiment?

The standard value of young's modulus of steel (we can assume that the wire is made of regular steel) is between 19×10^{11} and 21.5×10^{11} dyne/cm^2.