Birzeit University

Physics department

Physics 211

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Experiment number: (4)

Experiment name: torsional torques and torsional modulus

Date: 3/2/2012

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Abstract:

The torsional pendulum is used to study the elastic properties of aluminum and steel rods the torsional constant is determined and its dependence on the rods geometry (n,m ) was studied also the shear modulus (G) was determined .

The results were:

I=0.0110± 0.002 Kg m2

m=0.90 ± 0.13🡪-1

 n= 4.3 ±0.5🡪4

G(avg) = (23.7± 1.0)x10^9 (N/m2)

Apparatus:

A massive dumbbell shaped object is fixed to a thin metallic rod (aluminum or steel ). The system is twisted and set in vibration . The period for small vibrations is measured and is related to the torsional constant

Theory:

The period for small oscillations is given by :

T= 2π$\sqrt{\frac{I}{K}}$

Where T is the period ,I is the moment of inertia of the system ,and k is the torsional constant .Note that the mass of the rod is small compared with that of the dumbbell , and I therefore is constant for the whole experiment and is determined once .(Irod is negligible )

For elastic twisting of the rod , the torque τ is related to the twist angle Ѳ by:

Τ=-ҡѲ

Where Ҡ itself is related to the dimensions of the rod by the following relation:

Ҡ= G$\frac{πL^{m}d^{n}}{32}$

In this last formula,G is the shear modulus , d is the rods diameter ,and L is the length .

Procedure:

Step one :Determine the moment of inertia of the apparatus as follows :

1. Using one rode (picked at random ), twist the system through six different angles Ѳ calculating τ each time .plot τ vs Ѳ and use the graph to determine Ҡ .(to calculate the torque the applied force should be read from spring used to pull the dumbbell object )
2. Set the dumbbell object into oscillation by pulling it with the spring and releasing it .Measure the period of oscillations for the system and determine I .
3. This value of I is constant throughout the experiment.

Step two: ҡ vs. d (the rods diameter).

1. Take the aluminum bars having the same length.
2. Perform small oscillation experiments on each determining the period for each rod.

Step three: repeat step two with fixed d and L varied.

Data analysis:

Part 1: determination of moment of inertia of the system:

|  |  |  |  |
| --- | --- | --- | --- |
| Ѳ (degres) | Ѳ(radians) | F (N) | τ(N) |
| 10 | 0.174533 | 0.5 | 0.025 |
| 20 | 0.349066 | 0.78 | 0.039 |
| 30 | 0.523599 | 1.2 | 0.06 |
| 40 | 0.698132 | 1.8 | 0.09 |
| 50 | 0.872665 | 2.45 | 0.1225 |

Diagram used to find the torsional constant ҡ:

Slope = ҡ, so ҡ =0.1409

Y intercept = 0.0065 experimentally while it ought to be zero theoretically.

∆Ѳ= 0.017453 rad

∆τ= 0.05 N

∆ ҡ= 0.001264

So ҡ =0.1409 ± 0.0013 (Nm/rad)

For determination of I

T= 2π$\sqrt{\frac{I}{K}}$ =1.8s

* I=(T/2π)2\* K

I=0.01157541 ± 0.0018851344

I= 0.011 ± 0.002 Kg m2 (same throughout the experiment)

Part 2: ҡ vs. d (the rods diameter). Determination of m and G1

The slope of the log K vs. log L diagram is m

m= -0.9007 ± 0.1254 🡪 m≈-1

Ҡ= G$\frac{πL^{m}d^{n}}{32}$

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| L(m) | T(s) | K(Nm/rad) | logL(m) | log K(Nm/rad) | G (N/m2) |
| 0.291 | 1.8245 | 0.130324 | -0.53611 | -0.88498 | 24155585785 |
| 0.398 | 2.0201 | 0.106308 | -0.40012 | -0.97343 | 26949434408 |
| 0.496 | 2.331 | 0.079841 | -0.30452 | -1.09777 | 25223738171 |

Part 3: calculation of the dependence of the torsional modulus on the diameter of the rod (n):

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **d(m)** | **T (s)** | **k** | **log d** | **log K** | **G N/m2** |
| **1** | **0.00405** | **0.5905** | **1.248833** | **-2.39254** | **0.096504** | **23746983305** |
| **2** | **0.0031** | **1.0273** | **0.412619** | **-2.50864** | **-0.38445** | **22857408615** |
| **3** | **0.00215** | **2.316** | **0.081183** | **-2.66756** | **-1.09053** | **19437365173** |

The slope of the diagram =4.3238 also = n

So n= 4.3238 ±0.514

n≈4

Results :

I=0.0110± 0.002 Kg m2

m=0.90 ± 0.13🡪-1

 n= 4.3 ±0.5🡪4

G(avg) = (23.7± 1.0)x10^9 (N/m2)

Discussion of results:

The sources of error : the aluminum bars we studied were not perfectly straight which could affect because they were bend which would lower the length affecting the torque

The timer also can give such systematic error, and the human eye too.

Conclusion :

the dependence of the torsional modulus on the diameter of the rod (n) is in the order of 4 and the dependence of the torsional modulus on the length of the rod (m) is in the order of -1

so the mathematic equation Ҡ= G$\frac{πL^{m}d^{n}}{32}$ *becomes* Ҡ= G$\frac{πL^{-1}d^{4}}{32}$