重庆大学-辛辛那提大学联合学院

学生实验报告

CQU-UC Joint Co-op Institute (JCI)
Student Experiment Report

实验课程名称 Experiment Course Name 大学物理实验（I）

开课实验室（学院）Laboratory (School) JCI

学院 School CQU-UC 年级专业班 Student Group 18ME01

学生姓名 Student Name 易弘睿 学号 Student Number 20186103

学年 Academic Year 2019 学期 Semester Spring

成绩 Grade	
教师签名 Signature of Instructor	

批改说明 Marking instructions:

指导老师请用红色水笔批改，在扣分处标明所扣分数并给出相应理由，在封面的平时成绩处注明成绩。

Supervisors should mark the report with a **red ink pen**. Please write down **the points deducted** for each section when errors arise and specify the corresponding reasons. Please write down **the total grade** in the table on the cover page.

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JCI ____Experiment Report

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姓名 Name 易弘睿 学号 Student Number 20186103

开课学院、实验室 Academic School/ Laboratory CQU-UC

实验时间 Date of Experiment 2019 年 Year 03 月 Month 26 日 Day

报告时间 Date of Report 2019 年 Year 03 月 Month 27 日 Day

课程名称 Course Name		实验项目名称 Experiment Project		实验项目类型 Type of experiment project				
				验证 Verification	演示 Presentation	综合 Comprehensive	设计 Design	其他 Others
指导老师 Supervisor		成绩 Grade						

实验目的 Description/Instruction:

Young's modulus, which is along the longitudinal elastic modulus, is also a term in material mechanics. It was named in 1807 for the results of Thomas Young, a British physician and physicist. According to Hooke's law, within the elastic limit of an object, the stress is proportional to the strain. The ratio is called Young's modulus of a material. It is a physical quantity that characterizes the properties of a material and only depends on the physical properties of the material itself. The size of Young's modulus indicates the rigidity of the material. The larger Young's modulus, the less likely it is to be deformed. Young's modulus of elasticity is one of the basis for selecting materials for mechanical parts and is a commonly used parameter in engineering design. The determination of Young's modulus is of great significance to the study of mechanical properties of metal materials, optical fiber materials, semiconductors, nanomaterials, polymers, ceramics, rubber and other materials. It can also be used in mechanical parts design, biomechanics, geology and other fields. This experiment requires us to learn how to measure Young's modulus of wire by stretching method, master the principle and adjustment method of measuring tiny length change by optical lever method, and learn how to process data by gradual difference method.

原理和设计 Principle and Design:

The shape change of solid under the action of external force is called deformation, and the deformation that the object can completely restore its original shape after the external force is abandoned is called elastic deformation. The simplest deformation is the elongation and shortening of rod-shaped object after external force. If the wire (or rod) is L and the cross-section area is A, it will extend ΔL under the action of external force F along the length direction. According to Hooke's law, the elongation should be within the elastic limit. Variable ΔL/L is proportional to external stress F/A. We get:

$$\frac{\Delta L}{L} = \frac{1}{E}\frac{F}{A} \qquad (1.1)$$

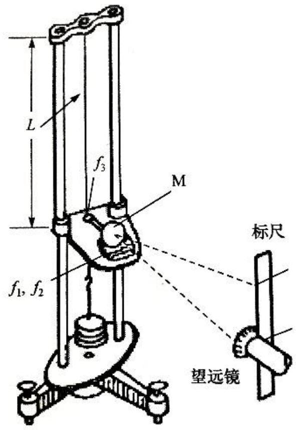


Figure 1： Diagram of Young's modulus device

As a result, it can be concluded that:

$$\mathrm{E} = \frac{\mathrm{F}}{\mathrm{A}}\frac{\mathrm{L}}{\Delta \mathrm{L}} \qquad (1.2)$$

In the formula, E is the Young's modulus of elasticity of the material, which is the force per unit area of a material when its elongation strain is 1.

In the international unit system, the unit of E is N/m^2 (i.e. Pa). F, A and L are easy to measure, but ΔL is a small change in length. It is difficult to measure by ordinary method. We use optical lever (mirror ruler group) amplification method to measure them.

As shown in Figure 1, an upright planar mirror M is mounted on a tripod with three toes in an isosceles triangle. The vertical distance $f_1 f_2$ between the hindfoot tip f_3 and the forefoot tip is b (called optical lever constant). When used, the forefoot tip f_1 and f_2 are placed in the fixing groove of the support platform, the hindfoot tip f_3 are placed on the cylinder which clamps the metal wire and can move freely up and down in the circular hole of the platform. The plane mirror surface is aligned with the telescope and the vertical ruler placed on the other support, and the telescope can be seen from the telescope at the same time. The clear image of the reference fork line and the ruler can be read out so that the position of the fork line on the ruler image can be obtained.

With the increase of external force and the elongation of wire, f_3 decreases, so that the plane mirror rotates an angle of θ on the axis of $f_1 f_2$, so that the angle between human rays and reflected rays is 2θ, which corresponds to the change of the position of the original fork line on the scale scale. As shown in Fig. 2, when θ angle is small, it can be seen from the graph:

$$\theta \approx \tan\theta = \frac{\Delta \mathrm{L}}{\mathrm{b}}, 2\theta \approx \tan 2 \approx = \frac{\mathrm{x}}{\mathrm{S}}$$

Hence,

$$\Delta \mathrm{L} = \mathrm{bx}/2\mathrm{S} \qquad (1.3)$$

Thus, the role of the optical lever is to amplify the small length change AL to the corresponding position change X of the original fork line on the scale, and its magnification is as follows:

$$\mathrm{K} = \frac{\mathrm{x}}{\Delta \mathrm{L}} = \frac{2\mathrm{S}}{\mathrm{b}} \qquad (1.4)$$

From formula (1.3), formula (1.4) and cross-sectional area $\mathrm{A} = \pi d^2/4$, and F = mg, it can be obtained that:

$$\mathrm{E} = \frac{8mgSL}{\pi d^2 bx} \qquad (1.5)$$

In the formula, d is the diameter of the wire and m is the weight added to the displacement x.

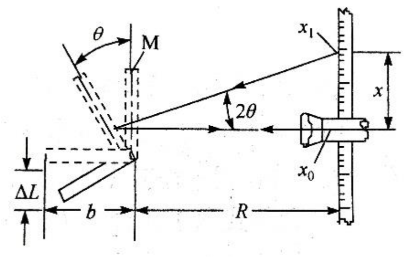


Figure 2： Principle diagram of optical lever amplification

实验器材 List of instruments and materials:

Young's modulus tester, mirror ruler set, tape ruler, vernier ruler, spiral micrometer.

实验步骤 Implementation:

1. Familiar with the use of various experimental instruments, self-designed relevant record forms.
2. Two weights are added to the weighting plate to straighten the steel wire, and the adjusting platform enables the steel wire to pass through the platform holes vertically. The cylinder clamping the steel wire can move freely in the holes.
3. Measure the length L between the two tightening points of the steel wire with a tape ruler, print the marks of the tips of the bare lever on the paper, and measure the bare rod constant B with a vernier ruler.
4. Measure diameter D at different parts of L segment of wire with spiral micrometer for five times, finding $\bar{d}$ andΔd, and showing the result completely.
5. Adjust the ruler group and optical lever, using the imaging principle of planar mirror, enables oneself to see the clear image of reference fork line and ruler in planar mirror at the same time from the ruler group telescope, and there is no relative position between them (i.e., when eyes move up and down, the fork image is not in relative position on the ruler). Shift).
(1) The front and rear toes of the light lever plane mirror are positioned in alignment, and the mirror surface is perpendicular to the platform surface.
(2) Adjust the telescope to make the telescope barrel level and on the same-level plane with the plane mirror;
(3) Move the ruler group left and right properly and adjust the horizontal orientation of the telescope barrel, and adjust the distance between the eyepiece and the objective (i.e. telescope focusing) so that it can see the clear image of the reel and the ruler.
6. Measuring S and X.

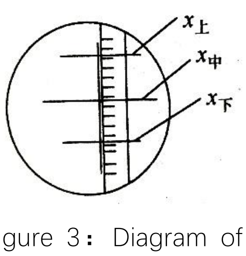


Figure 3：Diagram of fork line position

(1) When the image of a ruler in a telescope does not vibrate, record the position x_{up} and x_{down}. As shown in Figure 3, according to the magnification and distance relationship of the instrument, calculate S.

$$S = \frac{|x_{up} - x_{down}|}{2} \times 100$$

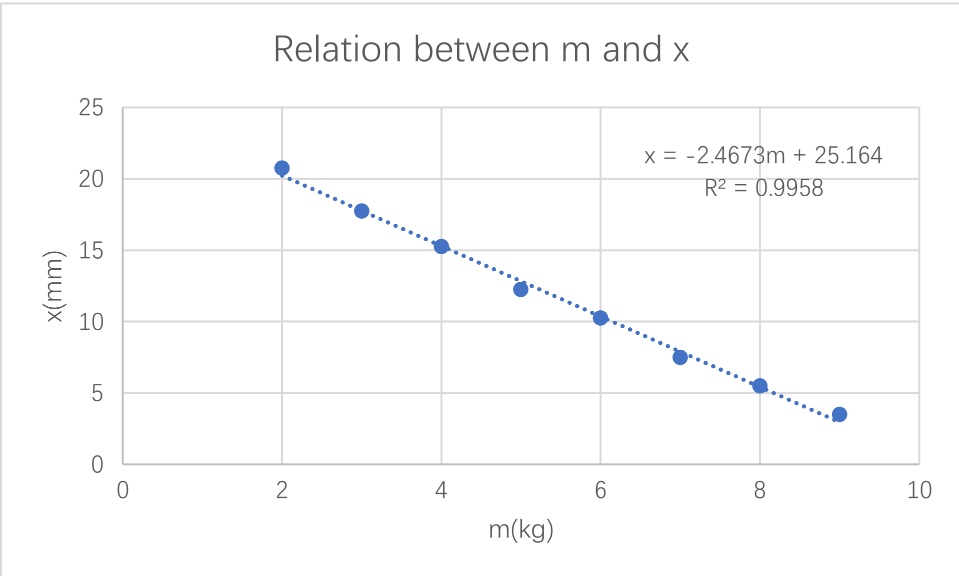
(2) When two weights are added, the position of the crosswise line of the intermediate fork x_{mid} is recorded every time a weight is added to record the position of the crosswise line pair of the intermediate fork x_{mid}, eight times in total, and then each weight is subtracted corresponds to the position of the sum, the position of the crosswise line under the same load is not averaged, and the position of the crosswise line is calculated by the method of gradual difference. This x corresponds to four weights.
7. Calculate E by formula (1.5) and write out the complete expression of E_C.
8. Compare the measured value with the accepted value.

实验结果和数据处理 Results and Data processing:

Results:

Measurement of Young's modulus using optical-lever method Data Recording Form									
d(mm)		0.591	0.601	0.600	0.610	0.595	0.605		
		Average: 0.600							
L(mm)		574.0		**b(mm)**			88.0		
x_{up} (mm)		29.0		**x(mm)**			-3.5		
i		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
m(kg)		**2.00**	**3.00**	**4.00**	**5.00**	**6.00**	**7.00**	**8.00**	**9.00**
x_{mid} (mm)	**Loading**	21.0	17.5	15.0	12.5	10.5	8.0	6.0	3.5
	Unloading	20.5	18.0	15.5	12.0	10.0	7.0	5.0	3.5
	Average	20.75	17.75	15.25	12.25	10.25	7.5	5.5	3.5

Form 1: Experiment Data



Graph 1: Relation between m and x

Calculation of Data:

$$S=\frac{|x_{up}-x_{down}|}{2}\times 100=\frac{|29.0-(-3.5)|}{2}\times 100=1625\text{mm}$$

$$\Delta\bar{x}=\frac{1}{4}\sum_{i=1}^{4}\Delta x_i=\frac{1}{4}(|x_5-x_1|+|x_6-x_2|+|x_7-x_3|+|x_8-x_4|)=9.8125\text{mm}$$

$$\dot{E}=\frac{8mgSL}{\pi d^2bx}=\frac{8\times1\times9.8\times1.625\times0.574}{3.14\times0.285^2\times0.088\times0.02\times10^{-6}}=1.66\times10^{11}\ \text{N/m}^2$$

$$\text{Error}=(E_C-\dot{E})/E_C\times 100\%=17.41\%$$

Calculation of Uncertainties:

1. U_A

For d:

$$U_{dA}=t_p\sqrt{\frac{\sum_{i=1}^{k}(d_i-\bar{d})^2}{k(k-1)}}=2.57\times\sqrt{\frac{(0.591-0.600)^2+(0.601-0.600)^2+(0.600-0.600)^2+(0.610-0.600)^2+(0.595-0.600)^2+(0.605-0.600)^2}{6\times5}}=0.007137\text{mm}$$

For $\Delta\bar{x}$:

$$U_{\Delta\bar{x}A}=t_p\sqrt{\frac{\sum_{i=1}^{k}(\Delta\bar{x}_i-\bar{x})^2}{k(k-1)}}=3.18\times\sqrt{\frac{(10.5-9.8125)^2+(10.25-9.8125)^2+(9.75-9.8125)^2+(8.75-9.8125)^2}{4\times3}}=1.230539\text{mm}$$

2. U_B

Uncertainties	U_B	
	U_I	U_E
卷尺(mm)	0.5	0.5
游标卡尺(mm)	0.02	0.02
千分尺(mm)	0.001	0.004
标尺	0.1	0.5

3. U

$U_L=\sqrt{U_I^2+U_E^2}=0.7\text{mm}$ $L=(574.0\pm0.7)$ mm (P=95%)

$U_b=\sqrt{U_I^2+U_E^2}=0.03\text{mm}$ $b=(88.0\pm0.03)$ mm (P=95%)

$U_S=50\sqrt{U_I^2+U_E^2}=26\text{mm}$ $S=(1625\pm26)$ mm (P=95%)

$$\left\{\begin{array}{l}U_{dB}=\sqrt{U_I^2+U_E^2}=0.0042\text{mm}\\ U_d=\sqrt{U_{dA}^2+U_{dB}^2}=0.0082\text{mm}\end{array}\right\}$$ $d=(0.6\pm0.0082)$mm (P=95%)

$$\left\{\begin{array}{l}U_{\Delta\bar{x}B}=\sqrt{U_I^2+U_E^2}=0.51\text{mm}\\ U_{\Delta\bar{x}}=\sqrt{U_{\Delta\bar{x}A}^2+U_{\Delta\bar{x}B}^2}=1.332\text{mm}\end{array}\right\}$$ $\Delta\bar{x}=(9.8125\pm1.332)$mm (P=95%)

$$\frac{U_{\dot{E}}}{\dot{E}}=\sqrt{(\frac{U_S}{S})^2+(\frac{U_L}{L})^2+(\frac{2U_d}{d})^2+(\frac{U_b}{b})^2+(\frac{U_{\Delta\bar{x}}}{\Delta\bar{x}})^2}=1.08$$

$$U_{\dot{E}}=\text{E}\times\frac{U_{\dot{E}}}{\dot{E}}=1.79\times10^{11}\ \text{N/m}^2$$

$$E=(1.66\pm1.79)\times10^{11}\ \text{N/m}^2$$

实验讨论 Discussions:

1. Why the error of this lab is up to 17.41%? How to make it decrease?

Reason:

From the percentage of errors in the total errors of the direct measurements, the average value n of steel wire diameter a and scale readings in telescopes obtained by successive difference method have the greatest influence on the total relative errors.

Methods:

(1) Because the same force is applied to the steel wire, the elongation of the steel wire should be equal, but the difference of the scale readings of the telescope calculated by the author is as follows: $\Delta n_1=3.00cm$ $\Delta n_2=2.50cm$ $\Delta n_3=2.00cm$. The values of Δn_1 and Δn_2 , Δn_3 differ greatly because the steel wire is too thick and the weight plate is too light to straighten the steel wire. Therefore, it is necessary to pre-add weight to straighten the steel wire in order to reduce the error of scale reading.

(2) When the diameter of steel wire is measured at different locations, the diameter of steel wire is uneven because the steel wire is not straight or rusty, and the measured value at the uneven or rusty place is larger than the actual value. Therefore, the error of diameter measurement can be reduced by increasing the measuring times and eliminating the data with large deviation from a set of data.

2. Why can the optical lever play the role of light amplification, and what factors are related to the magnification?

The principle of amplification is to use the reflection of light to magnify the change of light path angle caused by small displacement when small displacement occurs, and display it on projection. Because the geometric relationship of projection is satisfied, it can also be calibrated to read quantitatively.

Assuming that the elongation of the steel wire is L and the angle of the planar mirror is a, the moving distance C of the horizontal fork wire can be seen in the fixed telescope. Assuming that the incident and reflected light of the optical lever coincide, when the planar mirror turns an angle a, the light incident on the optical lever mirror will deflect 2a, and a is very small. It can be considered that the distance D from the planar mirror to the scale is from the telescope to the deflected optical lever plane mirror. The distance of the center is tan2a = 2A = C/D, a = C/2D, and because Tana = a = L/b, B is the vertical distance between the hind foot of the optical lever and the forefoot, it becomes the optical lever constant. So 1/W = 2 D/b is the optical lever magnification factor. From this we can see what the magnification is related to, both B C and D.