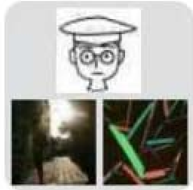
Introduction to Physics Experiments



群聊：周五上午-2023-2024 上

Xie Weiguang（谢伟广）

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§ Requirements and notes

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Groups

- Groups
- Rooms
- Time

Experiments

- **Mechanics**
  - EP05 Tuning fork frequency measurement with stand method (弦振动)
  - EP06 Young's modulus(杨氏模量)
- **Optics**
  - EP09 Measuring the curvature radius of lens using Newton（牛顿环）
  - EP13 Measurement of Angle of Prism --- Use of Spectrometer（分光计）
  - EP14 Michelson interferometer（迈克尔逊干涉）
- **Electronics**
  - EP04 the characteristic curve of the semiconductor diode (二极管)
  - EP10 Operation of a cathode ray oscilloscope (CRO)（示波器）
  - EP12 the Wheatstone bridge and specific resistance（直流电桥）
- **Electromagnetic**
  - EP11 Measuring the magnitude of the magnetic field using Hall effect（霍尔效应）

Scores

- Experiment (80)
  - Pre-lab preparation: 10%;
  - Operation: 50% (if no data processing: 90%)
  - Data processing & Question: 40%;
- Exam (20)

Pre-lab

- Read the lecture not of the experiment(you can refer to the corresponding Chinese book).
  - Be sure you understand the teaching materials before coming to the laboratory to avoid waste of valuable laboratory time, and figure out what should be done.

- The Pre-lab should include:

  1. Objective;
  2. Principle;
  3. Content and procedures with table(s)

Write them in your words based on your understanding of the materials. <u>Don’t copy the material directly (-10)</u>.

Pre-lab

- You must use the unified lab reports paper of Ji nan University
- The teacher will check you Pre-lab report when you come to the laboratory. (You are not allowed to do the experiments without the Pre-lab report)

Operation

After writing the Pre-lab report, you may do the due experiment following this procedure:

- Sign your name in the sign-in paper when you come into the lab.
- After the teacher introducing the experiment and the corresponding equipments, you may do the experiment according to the teaching material.
- Each experiment takes approximately two hours to complete.
- Write down the phenomena and your understanding during the experiment.

Operation

Be sure

- Keep original data
  - The teacher is interested in an original data sheet and is willing to see the direct recording of the actual data taken in the laboratory.
- Record all data in the blank table(s) in your Pre-lab report.
  - Do not use “scratch” data sheets from which data are to be transcribed onto the table in the pre-lab report.

Operation

- If you find something confusing, other students are often the most immediately available source of help, but do not hesitate to ask the teacher, and sooner rather than later.
- Complete some data processing in your Pre-lab report required by the teacher.
- Pre-lab report must be initialaled by your teacher before leaving.
- Put the equipments in order.
- Write down your leaving time in the sign-in paper

Final reports

- If the experiment requires no data processing, submit the lab report in the class.
- If data processing is required,
  - Give the data processing and estimate uncertainties (errors)
  - *Draw the graphs or diagrams.*
  - A summary or <u>discussion of the results</u>
    - The summary is included in tabular from under the data. It usually involves a comparison of the computed results with the accepted values together the percent uncertainty (error) involved. You are encouraged to add a brief discussion of the source of these errors and any other comments you would like to make about the working of the experiment.
  - Answers to the questions at the end of the experiment.

Final reports

- Hand in the lab report at the beginning of the next experiment. The report will be graded and returned as soon as possible.
- If your lab report is overdue, you will suffer a five or more points penalty
- All of the above together with your pre-lab will form the experimental report.

Requirements and notes

Time

- The class begins at 9:15, and you should come into the lab before that time. If you are late for over 15 minutes you may not be allowed to do the experiment, and you will not be allowed to make up for the experiment unless you are in special and pressing circumstances(On those occasions, approval must be in advance. E.g. you are ill and can be verified by a doctor's note.).
- If you are late for the class within 15 minutes the teacher deducts part of your score ,when your report is graded.

- Please prepare for the due experiment and write pre-lab report. You will not permit to do the experiment if you haven’t the pre-lab report.
- The class will be over at 11:30, and you should finish the scheduled experiment before this time. You can prepare your experiments in the labs if you worry that you can’t finish the experiment during the scheduled time. The labs open from Monday to Friday during the course.

Others

- Please bring your calculator. You will have to process some data during experiments.
- Don't copy your classmate's results of experiments and reports. Both of you you will get zero regardless of how well you may be in the class.
- You can download the material from internet

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User: stu

Password: stu

Elementary knowledge of data processing

1. Uncertainty in measurement.
2. Significant figure
3. Data processing methods

Measurement.

- Direct measurement:
  - The value of some physical quantity can be directly obtained by measuring it using a proper instrument.
- Indirect measurement:
  - We can obtain the desired quantity using the function (or formula) that gives the relation between the direct measurement quantities and the desired quantity.
  - (e.g. measure the acceleration of gravity by using the period equation of single pendulum oscillation)

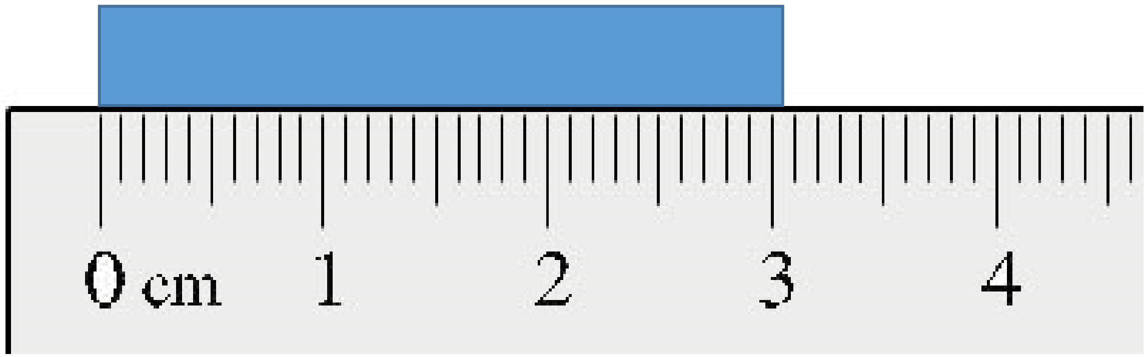
Uncertainties

- No measurement is absolutely accurate or exact. Human and instrumental limitations cause unavoidable deviations from the "true" values of the quantities we are measuring. The deviation of the value of a particular measurement from its "true" value is called the uncertainty (error) in that measurement.

Reliable digit

3.05cm?

3.06cm? or …



- In a scientific measurement, the result is meaningless if nothing is known about the uncertainty.

3.05cm;   3.05cm;

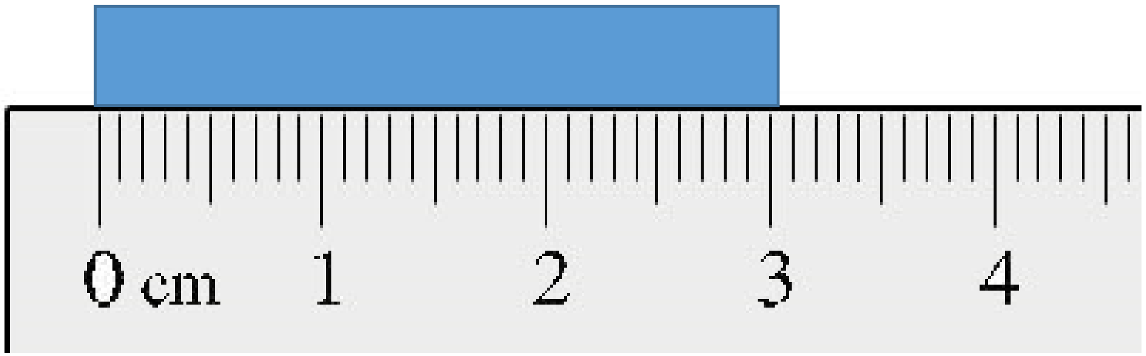
- We know nothing about the reliability of a result unless we know something about the probable uncertainties, which were used to obtain that result.
- So uncertainties are necessary in measurement results. The less the uncertainty is, the higher the reliability of the value for measurement is.

- As this course is focused on getting experience using basic instrument, building circuits, etc, you do not need to do formal uncertainty (error) analysis. Still, this is a physics lab, and some attention must be paid to the uncertainties in your data and analysis.
- Uncertainty estimates come from consideration of the measurement itself, not from the comparison of theory and experiment. Uncertainties can be classified into two kinds: statistical uncertainty (Δ_A) and systematic uncertainty (Δ_B).

- Statistical uncertainty (Δ_A):

  You measure a quantity many times, but in the range of values for your measurement, you can't reliably state that one answer is better than the others. This is roughly the statistical uncertainty. And it can always be easily assigned.

x_1	x_2	x_3	x_n
3.06	3.07	3.08	…



- Systematical uncertainty (Δ_B):

  No mater how you actually measure something, the values for measurement are always different from what you are intending. This is roughly the systematical uncertainty. And it may require more thought to quantify.(Given in the device introduction)

- the resultant uncertainty(u)

$$u = \sqrt{{\Delta_A}^2 + {\Delta_B}^2}$$

Measurement result

- We should express the measurement result as following:

$$x = \overline{x} \pm u(units\ of\ \ x) \quad or$$
$$x = \overline{x}(1 \pm u_r)(units\ of\ \ x)$$

- Here *x* is the value of a quantity (measured many times or one time), $\overline{x}$ is the average value of the quantity, *u* is the resultant uncertainty, $u_r = u / \overline{x}$ is the percent uncertainty.
- How to calculate the uncertainty? Please refer to the appendix.

Measurement result

- We should express the measurement result as following:

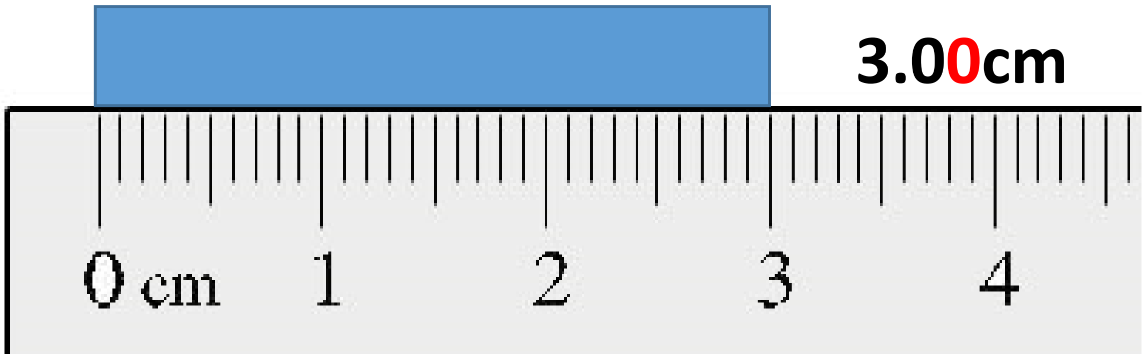
$$\bar{x} = \frac{x_1 + x_2 + \cdots + x_N}{\mathrm{N}} = \frac{\sum_{i=1}^{N} x_i}{N}$$

$$Absolute\ error$$
$$= \text{measured value} - \text{ conventional true value}$$

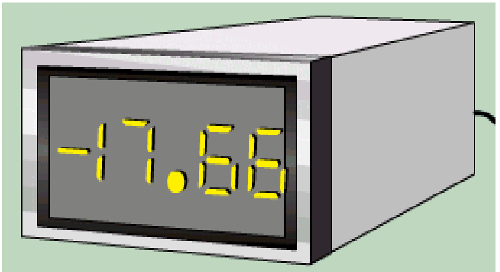
$$Relative\ error = \frac{\text{absolute error}}{\text{conventional true value}} \times 100\%$$

Significant figure

- Significant figures in a number are all of the figures that are obtained directly from the measuring process event the zero at the last digit(including the uncertainty).

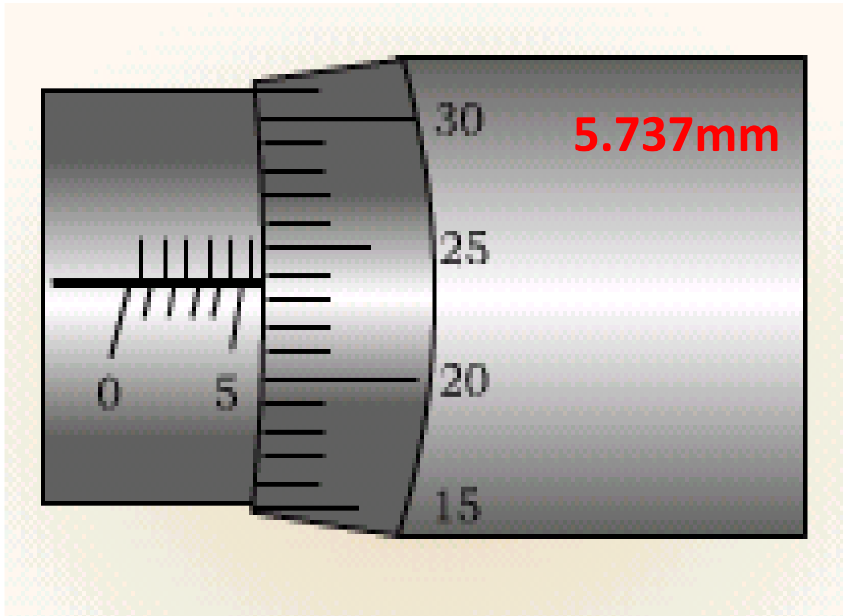


Digital meter



Resistance box

Micrometer caliper



Significant figure

- The measurement result should answer the precision of the device
- The significant figure exclude the zero that are included to locating the decimal point
- The last number is an estimate and we must not neglect it, even if it is zero.
- You must not change the significant figure when you make unit transform.

0.2580 cm≠0.258cm;

4 digit **3 digit**

0.120m ≠ 12cm

3 digit **2 digit**

Significant figures in calculations

- In addition or subtraction of experimental data it is a simple matter to determine what figures to carry and how many figures must be retained in the final result. The final result should contain the same accuracy as the *least accurate quantity* used in the calculation. (加、减法：诸量相加（相减）时，其和（差）数在小数点后所应保留的位数与诸数中小数点后位数最少的一个相同)。

$$
\begin{array}{r}
4.178 \\
+\ 21.3 \\
\hline
25.478 = 25.5
\end{array}
$$

- In multiplication, division and other mathematic operations with experimental data, things are not so obvious. The basic rule to be remembered when doing calculations with data is: The final result should contain the same significant figure as the least one entering into a calculation. (乘、除法：诸量相乘（除）后其积（商）所保留的有效数字，只须与诸因子中有效数字最少的一个相同)。

$$
\begin{array}{r}
4.178 \\
\times \quad 10.1 \\
\hline
4178 \\
4178 \\
\hline
421978 = 42.2
\end{array}
$$

Data processing methods

Data processing refers to the process in which we obtain a conclusion from the data got during labs. Data processing methods often used are the tabulation method, the graphical method, the successive difference method, etc.

1. The tabulation method

2. The graphical method

3. The successive difference method

The tabulation method

1) All tables must have a title.
2) All the data in the table(s) should be original.
3) Quantities and units should be showed.
4) Row or column sequence should answer the relation between independent variable and dependent variable.

Table1 measuring temperature dependent resistance curve

Temp(°C)	20	30	40	50	60	70
U_{RO}(V)						
I(mA)						
R(Ω)						

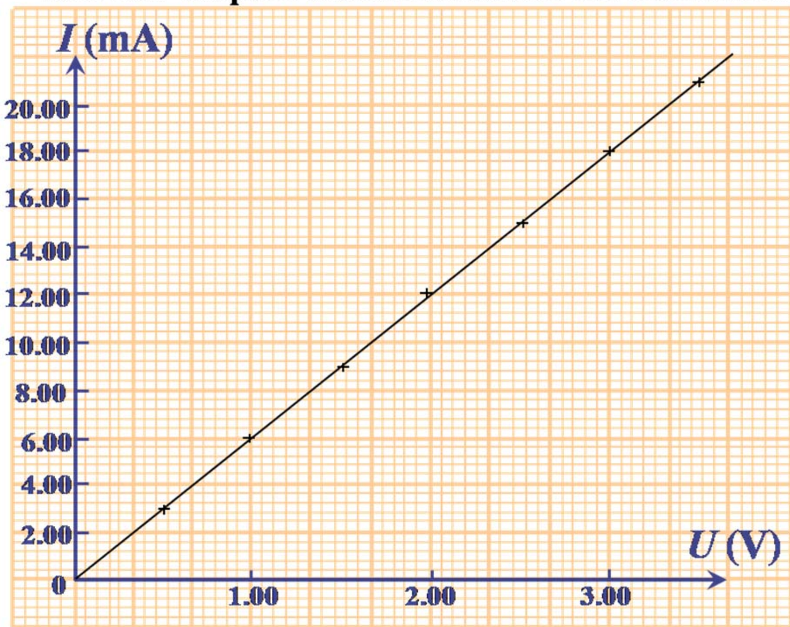
R=U/I

The graphical method

A purpose of many experiments is to find the relationship between measured variables. A good way to accomplish this task is to plot a graph of the data and then analyze the graph. These guidelines should be followed in plotting your data:

1. Use a sharp pencil. A broad-tipped pencil will introduce unnecessary inaccuracies.

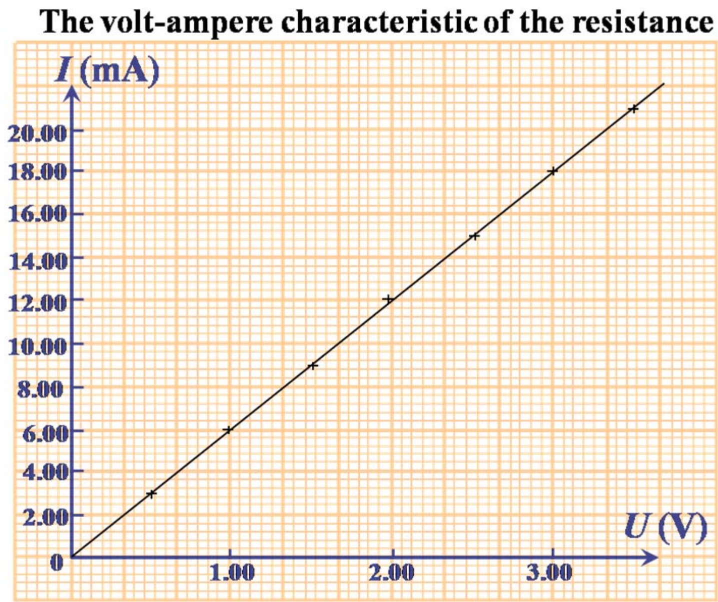
The volt-ampere characteristic of the resistance

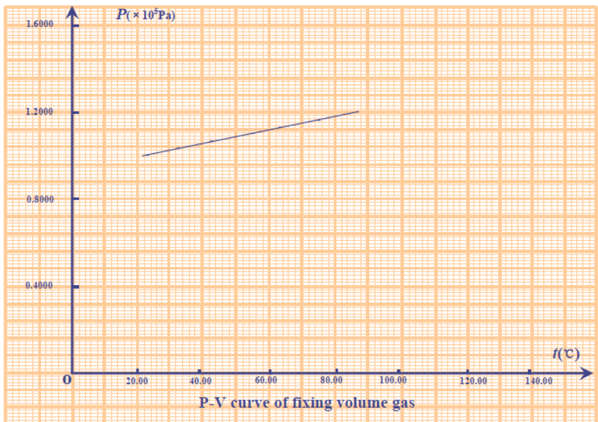


2.Draw your graph on a full page of graph paper. A compressed graph will reduce the accuracy of your graphical analysis.

3.Give the graph a concise title

4.The dependent variable should be plotted along the vertical(y) axis and the independent variable should be plotted along the horizontal(x) axis.

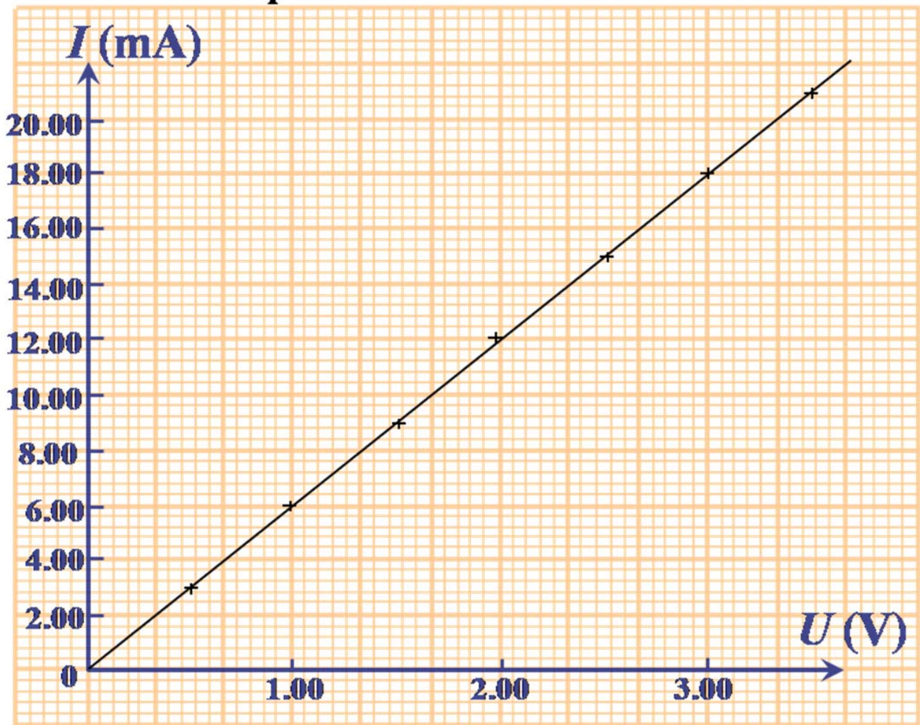




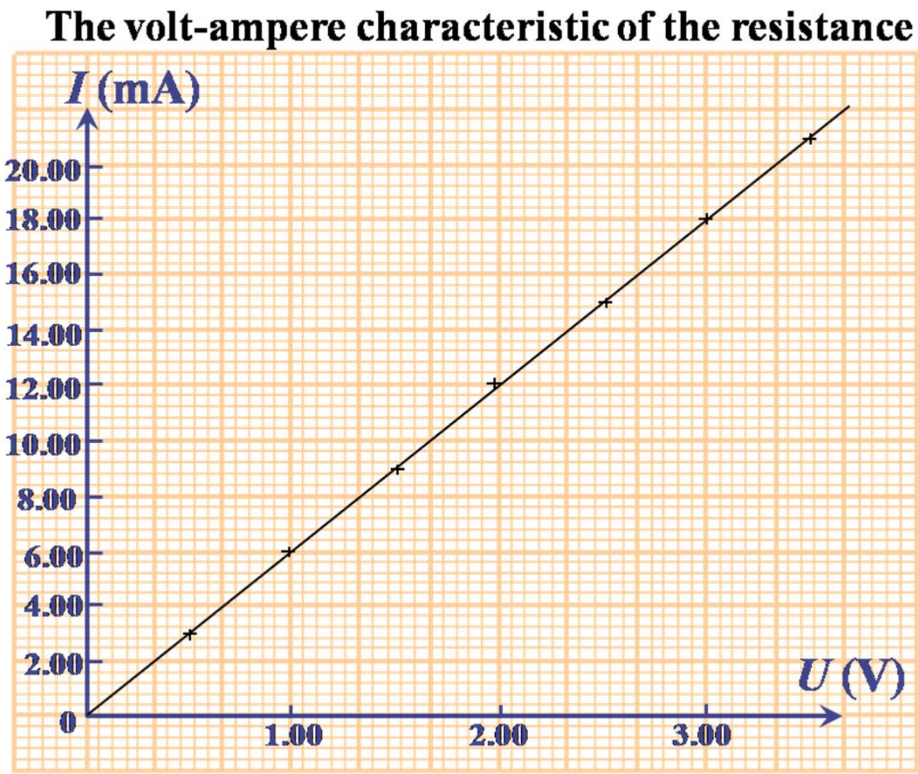
5.Label the axes and include units.

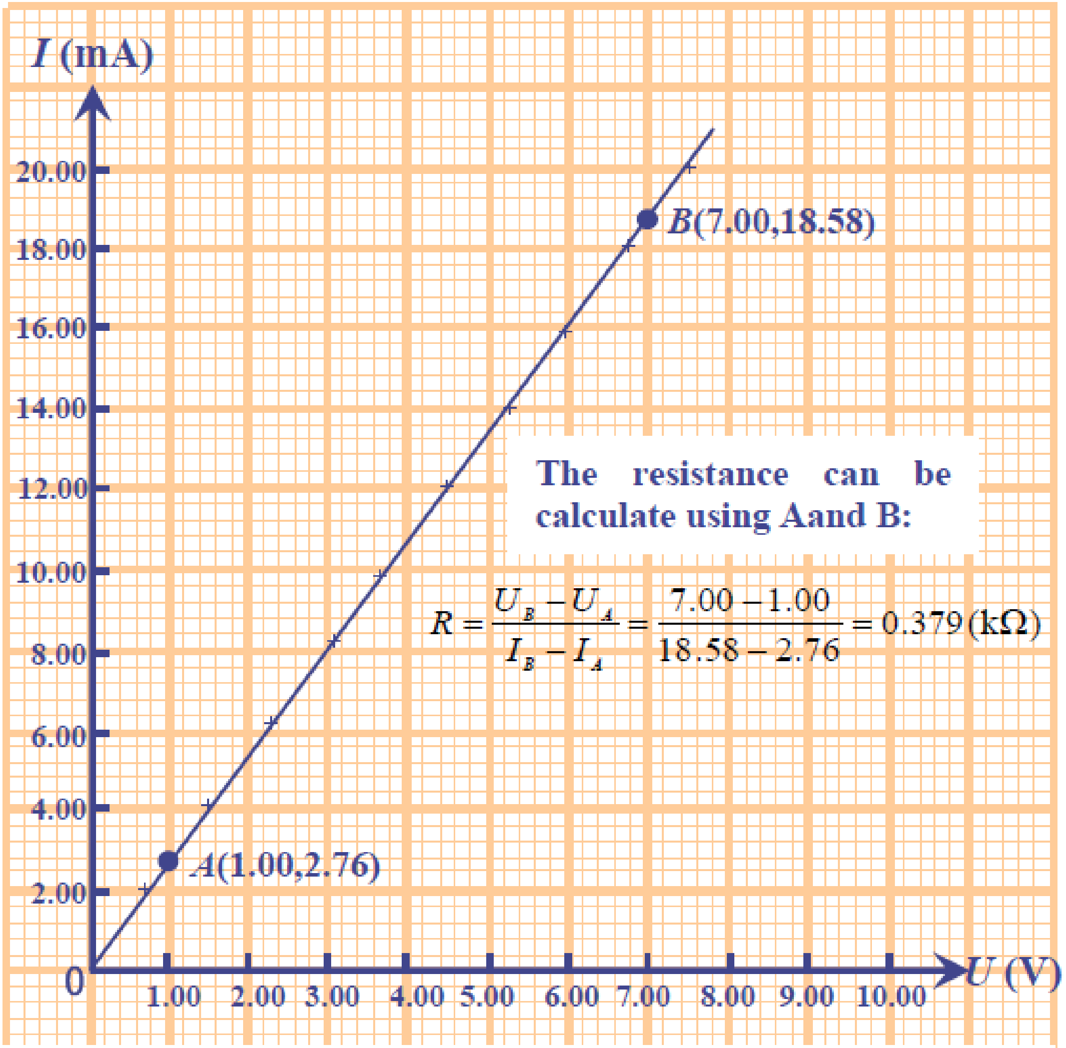
6.Select a scale for each axis so that the curve extends over most of the graph sheet and so that decimal parts of units are easily determined. This can be done if each small division is made equal to one, two, five, or ten units.

The volt-ampere characteristic of the resistance



7. Each point should be plotted as "+", "*", or a dot surrounded by a small circle. Draw a beeline or curve using a Square or a French curve. The beeline or curve need not get across every point, but it must be smooth and the points not on it must distribute equably besides it.
8. Show the character value of the beeline or curve by graphic solution.





The volt-ampere characteristic of the resistance

The successive difference method

- Successive difference method can be used under the condition that the independent variable equably changes, and the relation between two physical quantities is liner.

  e.g. K=Δl/ΔP

- Suppose l_1, l_2, l_3…l_6 are the values of l measured 6 times, then,

$$\overline{l} = \frac{1}{5}\left[(l_2 - l_1) + (l_3 - l_2) + (l_4 - l_3) + (l_5 - l_4) + (l_6 - l_5)\right]$$

$$= \frac{1}{5}(l_6 - l_1)$$

$$P=\frac{1}{5}\left(P_6-P_1\right) \qquad k=\frac{\overline{l}}{\overline{P}}=\frac{l_6-l_1}{P_6-P_1}$$

- Here, we can see that l_2, l_3, l_4, l_5 haven't be used. If we divide these values to two groups, that is (l_1, l_2, l_3) and (l_4, l_5, l_6),then

$$k=\frac{1}{3}\left\{\frac{l_4-l_1}{p_4-p_1}+\frac{l_5-l_2}{p_5-p_2}+\frac{l_6-l_3}{p_6-p_3}\right\}$$

Any Questions?

Appendix: calculating uncertainty in measurement

The rigorous calculation is very complicated. For the beginner, we simplify the calculation as following:

Calculating the uncertainty of quantity directly measured

i) If the quantity is measured many times the uncertainty include Δ_A and Δ_B , but we only calculate Δ_A and neglect Δ_B that is, $u = \Delta_A$

Suppose x_1, x_2, x_3…x_n are the values of a quantity measured *n* times, $\overline{x}$ is the average of the values, then

$$\overline{x} = \frac{1}{n}(x_1 + x_2 + x_3 + \cdots + x_n) = \frac{1}{n}\sum_{i=1}^{n} x_i$$

$$u_A = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})^2}{n(n-1)}}$$

statistical uncertainty $\Delta_A = t_p u_A$ t_p **can be looked up in table1.**

Table1 the relation between t and n

t \ n / p	3	4	5	6	7	8	9	10	15	20	∞
0.68	1.32	1.20	1.14	1.11	1.09	1.08	1.07	1.06	1.04	1.03	1
0.90	2.92	2.35	2.13	2.02	1.94	1.86	1.83	1.76	1.73	1.71	1.65
0.95	4.30	3.18	2.78	2.57	2.46	2.37	2.31	2.26	2.15	2.09	1.96
0.99	9.93	5.84	4.60	4.03	3.71	3.50	3.36	3.25	2.98	2.86	2.58

Then the uncertainty can be obtained:

$$u = \Delta_A = t_p u_A \qquad (2)$$

When the uncertainty is obtained the probability should be given at the same time. (e.g. p=0.683)

Exercises：

- **One quantity has been measured 10 times, and the values are：1.57, 1.55, 1.56, 1.58, 1.54, 1.55, 1.59, 1.57, 1.55, 1.58. Please calculate the average and the uncertainty.**
- **Correct errors：**

  6.674±0.03 , 56800±200, 1.1m=1100mm

The significant figure of uncertainty

- **We only retain one significant figure in the uncertainty of the final result .**

For example

When u=0.548mm， the uncertainty should be quoted as u =0.6mm.

When u=1.17 Ω， the uncertainty should be quoted as u=2Ω.

(round up after the decimal point)

The significant figure in the result expression

- **A measurement and its experimental uncertainty should have their last significant digits in the same location (relative to the decimal point).**

- **Examples are 54.1 ± 0.1mm, 121 ± 3 s, 8.674 ± 0.002 kg, and $(5.67 \pm 0.01) \times 10^3 \Omega$**