Unit 1 Basic Measurement

I. Measurement of Length

Purpose:
1. Use vernier caliper to measure the length of an object, inter and outer
diameter, depth and capacity of a cup.
2. Use screw micrometer to measure the diameter of a metal wire, and the
thickness of a piece of object.
3. Use traveling micrometer to measure the width of a single-slit and
double-slit.

Apparatus:
Vernier caliper, screw micrometer, traveling micrometer, hollow metal
cylinder, thin metal wire, single-slit, and a double-slit.

Principle:
1. The construction of a vernier caliper (0.05 mm in accuracy for example) is
shown in Fig. 1. F is the main ruler and G, which is attached on F, is the
shifting ruler and is able to slide. Pincers A and B are used for measuring
the outer diameter of a cup; and pincers C and D are for measuring of the
inner diameter of a cup. T is used for measuring the depth of a container.
Nut S can fasten the shifting ruler F on the main ruler. Length of 20 ticks
on G is equal to 39 mm, as labeled on F, which means the length per tick
on G is equal to 1.95 mm. The difference between a tick on F and two
ticks (2 mm) on G is 0.05 mm, and we utilize this feature for a more accurate measurement.

Fig. 1. Vernier caliper

Example:
Take Fig. 2 for example. Pincers A and B grip an object and the 0th tick of G falls between 16 and 17 mm of the main ruler, we then have to find out the tick on G which matches (or being the closest) to one of the tick on F. As shown in the Fig., 1.5 (3rd tick) on G perfectly matches a tick on F, then the length is measured as 
\[(16 + 3 \times 0.05) \pm 0.025 = 16.15 \pm 0.025 \text{ mm} .\]
Q1: Design a vernier caliper of accuracy 0.1 mm.
Q2: Is it possible for one to read the measurement as 26.97±0.1 mm with the vernier caliper that you designed above?

2. Screw micrometer can get a more accurate measurement of the thickness of an object. The structure of a screw micrometer is shown in Fig. 3. A is a fixed end, and P is connected with K’ and installed through F and K. On the periphery of H (the left-end of K) are 50 ticks which functions as a sub-meter. P shifts 1 mm when K is screwed two rounds. Therefore, P shifts 0.01 mm when K is screwed by 1 tick. When measuring, put the object between A and P, screw K’ to clamp the item between A and P until 3 clicks. Find out the ticks on S (main meter) of which the edge of H falls between, and then read the ticks on the sub-meter H. Eventually, we can get the accurate measurement. As shown in Fig. 4, the thickness reads 7.374 mm (four significant figures).
3. The structure of a traveling micrometer is shown in Fig. 5. C is a platform with main meter on it. Pedestal D is installed on C and attached with a shifting meter, and the pedestal can be shifted by rotating knob A. On the stand L is a main meter, and E, a compartment with sub-meter, is assembled on L. Knob B controls the movement of E. A low-power microscope is also attached on E. The measurement principle is the same as a vernier caliper. D and C are used for horizontal measurement, and E and L are for vertical measurement.

Q3: The accuracy of the apparatus is 0.01 mm, and the approximate digit of the measurement is 0.001 mm. How to read the approximate digit?

Q4: What is the design of the main meter and sub-meter of the traveling micrometer you are using?
Instructions: (conduct each measurement over 5 times and take the average value)

A. Use of Vernier Caliper (measure the inner and outer diameter and depth of a cup, and calculate its capacity)
   1. Reset (Zero): Clamp pincers A and B, and check whether the measurement reads zero. If not, put down the recorded value, and remember to compensate it back after each measurement.
   2. Clamp the outer periphery of a cup with A and B, and measure the outer diameter.
   3. Put pincers C and D inside a cup and clamp it. Read the recorded value of the inner diameter.
   4. Measure the depth of the cup with T.

   **Q5:** When measuring the inner and outer diameter, and depth of a cup, you would find that the recorded value differs when you measure with different position. What are the difference between measurements at the same position and measurements at different positions?
   5. Get the average value and the standard deviation of outer diameter, inner diameter, and depth. Put them down in the form of \( X \pm \sigma \) with unit.
   6. Calculate the capacity of the cup.

B. Use of Screw Micrometer (measure the diameter of a metal wire, and the thickness of an item)
   2. Reset (Zero): Screw K and make P contacts A smoothly, and then screw K’ until you hear three clicks.
   3. Conduct the measurement, and calculate the average value and standard deviation.

C. Use of Traveling Micrometer (measure the width of a single slit, double-slit, and the central dark fringe of diffraction)
   1. Adjust the horizontal level.

   **Q6:** Explain the effect if we don’t do the horizontal correction.
   2. Fasten the object on the platform, and adjust its position to get a clear image appears in the eyepiece.
   3. Adjust knob A to make the cross in the eyepiece overlap one end of the item under measurement. Put down the recorded position \( x_1 \). Repeat the procedure and record the position \( x_2 \) of the other end. Then the length of the object will be \( x_1 - x_2 \).
   4. Measure the width (ab) of the single-slit, and the width (ab and cd) of a double-slit in the same manners. The definitions of a,b,c,d are shown on the figure bellow.
Q7: In the measurement process, will the power of the microscope affect the accuracy of the experiment? Why?

Q8: How can we tell whether the single-slit and double-slit is perpendicular to the microscope? If they are not perpendicular, what will the effect be? Why?

Remarks:
1. When the experiments are done, separate the pincers of the vernier caliper, and the contacts (A and P) of the screw micrometer to avoid damage.
2. Do not over fasten the objects with the vernier caliper or screw micrometer.
3. Put down the results as the form of $\bar{X} \pm \sigma \tau$ with units. Deal them carefully with error propagation.
4. When measuring the width of the slits, the value provided on the slits are not accurate. They are only for reference.
II. Measurement of The Curvature of a Spherical Surface

Purpose:

Use spherometer to measure the curvature radius of a spherical surface.

Apparatus:

spherometer, glossy glass, convex lens, meter.

Principles:

1. Usage of spherometer:
   The structure of a spherometer is shown as Fig. 6. P is a tripod with three arms (D, E, and F) with equivalent length. The included angle of each two arms is 120°. M is the main meter and N the sub-meter. There are 100 ticks on the periphery of N. H shifts 1 mm when N is screwed one round, which means the length per tick is 0.01 mm. We can get the height of H from the main-meter and sub-meter. As shown in the figure, the circular plate falls between 6 and 7 mm on the main-meter, and the sub-meter reads 15.4. Hence, the height of H from plane DEF is $6 + 15.4 \times 0.01 = 6.154$ mm.

2. Measurement of the curvature radius:
   As shown in Fig. 7, the distance between each arm of the tripod is $S$, hence
D, E and F form an equilateral triangle. We then can make a circumscribed circle of radius \( r \). The extended line of H is sure to pass the center of the sphere O’. We assume that the line O’H intersects place DEF at O, then OD will be the radius of the circumscribed circle, and

\[
r = \frac{S}{\sqrt{3}}
\]

……………………………………………… (1).

Curvature radius \( R \) can be calculated by

\[
R = \frac{S^2}{6a} + \frac{a}{2}
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……………………………………………… (2).

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Instructions:

1. Adjust spherometer, making the tips of D, E, F, H contact the glossy glass. Check whether the main-meter M and sub-meter N overlaps at zero. If not, put down the recorded value and compensate it back after each measurement.

2. Screw H upwards, and put the object under measurement underneath it. Then screw H downwards smoothly until H contacts the surface of the object, and record the value \( a \) (the height of H from plane DEF).

3. Repeat the previous steps 5 times and calculate for the average value, and the standard deviation.

4. Measure the distance \( S \) (between each two arms) by a vernier caliper for 5 times, and get the average value.

5. Substitute \( S \) and \( a \) into Eq. 2, and calculate for \( R \).
Remarks:

All the measurement should be in the form of $\bar{X} \pm \sigma T$ with units. Also, be careful to the error propagation.