# Unit-01 Basic Measurement I

## Objective：

1. Use vernier caliper to measure the length of an object, inner 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, cup, thin metal wire, single-slit, double-slit, slit holder, LED

## Principle：

In this experiment, we would learn how to use about vernier caliper, screw micrometer, and traveling micrometer, it was more precisely then ordinary ruler. All these three apparatuses include main-meter and sub-meter.

The deviation comes into existence when these apparatuses use for a long time, it means it cannot reset to zero, and it occurs on screw micrometer frequently. In here, we call that is zero error, and it should always consider when we use any measurement apparatuses.

**Length of object = main-ruler reading + sub-ruler reading – zero error**

### A. Vernier Caliper

### 1. The Construction

0.05 *mm* in accuracy for vernier caliper is shown in Fig.1. **F** is the main-ruler and **G** is the sub-ruler that is attached on main-ruler and 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. **H** is used for measuring the depth of a container. Nut **E** can fasten the sub-ruler on the main-ruler.

### 2. The Accuracy

By 0.05 mm vernier caliper in accuracy for example, the least graduation of the main-ruler is 1 mm. And length of 20 ticks on the sub-ruler as labeled on the main-ruler is equal to 39 mm, which means the length per tick on the sub-ruler is equal to 1.95 mm.

The difference between that value and two ticks (2 mm) on the main-ruler is 0.05 mm, and we utilize this feature for a more accurate measurement to 0.05 mm.

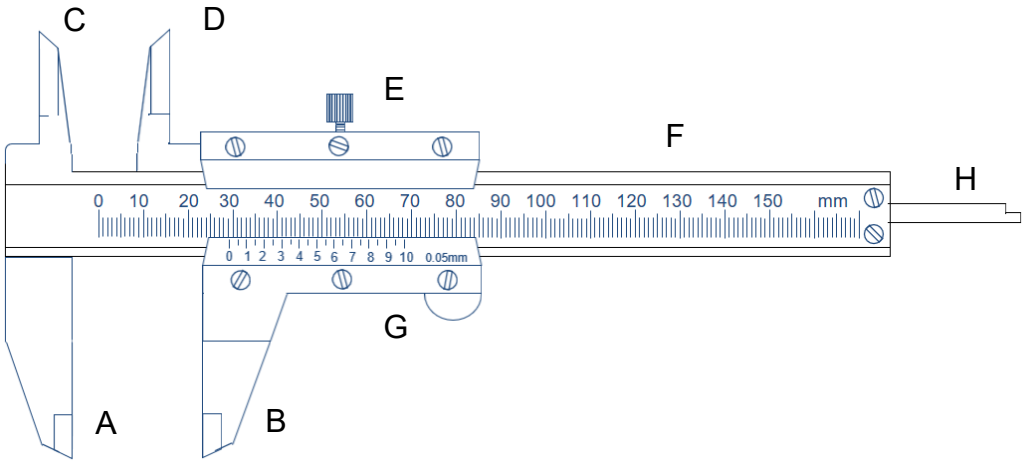


Figure 1. Vernier Caliper

## 3. The Measurement

Length of object = main-ruler readings + sub-ruler readings – zero error

(a) Zero error

When never grip an object, main-ruler and sub-ruler will be in alignment at the graduation of zero. If not, we should recording the zero error value $a_0$.

When sub-ruler's zero on the main-ruler's zero right, that is positive; on the other hand, that is negative.

(b) Main-ruler reading

Sub-ruler's zero falls between N and N+1 mm, the readings record N mm. As Fig.2 for example, sub-ruler's zero falls between 7 and 8 mm, so the readings should record 7 mm.

(c) Sub-ruler reading

Find out the ticks on sub-ruler which aligns to one of the tick on main-ruler, and multiply it by the accuracy value.

As Fig.2 for example, the scale 11 on sub-ruler aligns the scale 29 on main-ruler, so the readings could record 11 × 0.05 mm = 0.55 mm.If zero error is 0.00 mm, the length is measured as 7 mm + 0.55 mm – 0.00 mm = 7.55 mm. Significant figures below two digits of mm, and no estimate value.

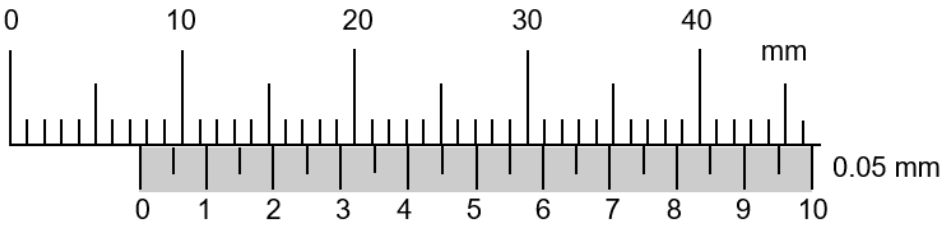


Figure 2. Example for Vernier Caliper

## B. Screw Micrometer

### 1. The Construction

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. **C** is main-meter and **D** is sub-meter that is attached on rough thimble **E**. **A** is a fixed end, and the spindle **B** is connected with thimble. **F** is lock nut that fix thimble on main-meter. Screw the rough thimble and clamp the object between **A** and **B**, and then screw fine thimble **H** slightly until you hear three clicks.

### 2. The Accuracy

At a general screw micrometer, the main-meter is divided into two parts about up and down, due to the horizontal line. Whatever up or down, one tick is 1 mm, and the adjacent graduation between up and down is 0.5 mm. On the periphery of sub-meter that the left-end is thimble are 50 ticks. When thimble is screwed one round, main-meter shifts 0.5 mm; it means per tick on sub-meter is 0.01 mm in accuracy.

### 3. The Measurement

Length of object = main-ruler readings + sub-ruler readings – zero error

(a) Zero error

Before grip an object, main-meter and sub-meter will be in alignment at the graduation of zero. If not, we should recording the zero error value $a_0$.

When the main-meter's horizontal line is under the sub-meter's zero that is positive; on the other hand, that is negative.

(b) Main-ruler reading

Find out the ticks on main-meter which the edge of sub-meter falls between, as Fig.3 for example, the readings could record 2.5 mm.

(c) Sub-ruler reading

Find out the ticks on sub-meter which the main-meter's horizontal line is extended to, it should include estimate value.

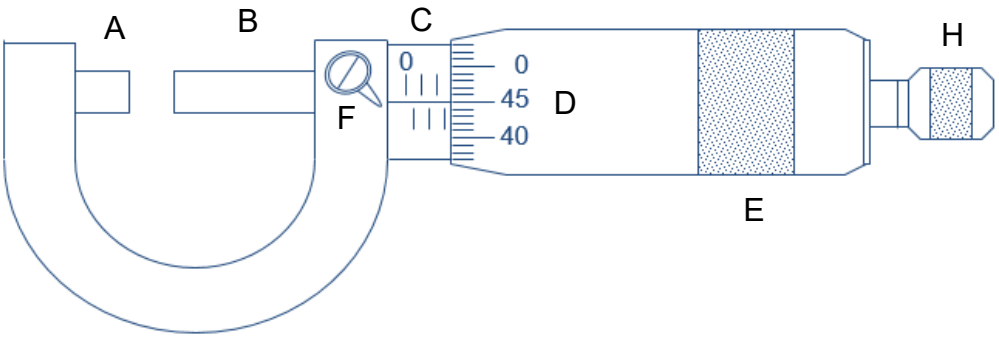


Figure 3. Screw Micrometer

As Fig.3 for example, the scale 45.0 on sub-meter corresponding main-meter's horizontal line, so the readings could record 45.0 × 0.01 mm = 0.450 mm. If zero error is 0 mm, the thickness is measured as 2.5 mm + 0.450 mm – 0 mm = 2.950 mm. Significant figures below three digits of mm, and the third digit is estimate value.

## C. Traveling Micrometer

### 1. The Construction

The structure of a traveling micrometer is shown in Fig.4. **A** is a platform with the set of vertical vernier caliper **B** and the set of horizontal vernier caliper **C** on it. **D** is a low-power microscope. The set of vernier caliper **B** are used for horizontal measurement; and the set of vernier caliper **C** are used for vertical measurement.

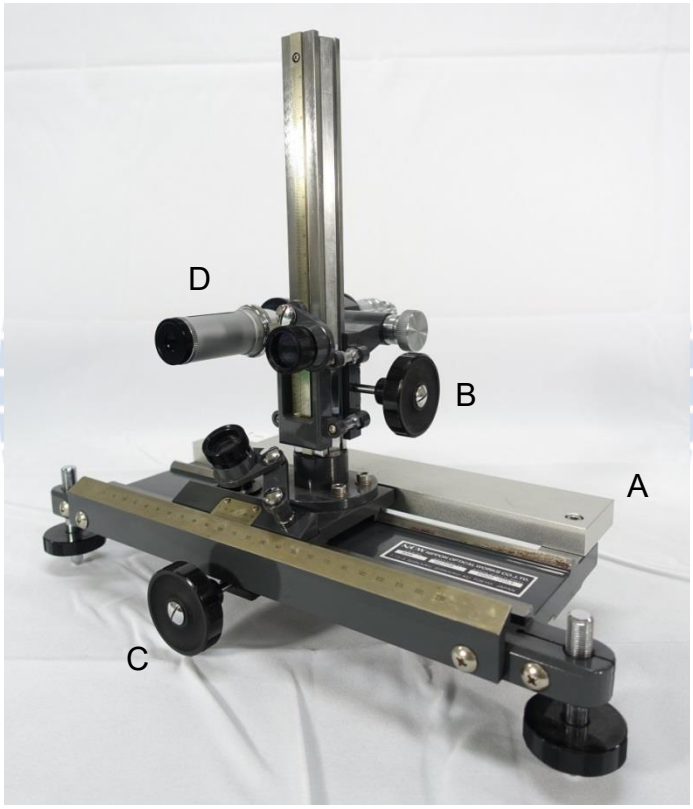


Figure 4. Traveling Micrometer

### 2. The Accuracy

The least graduation of the main-ruler is 0.5 mm. Before grip an object, align the zero grid of main-ruler with the zero grid of the sub-ruler. We fund that the $50^{th}$ grid of the sub-ruler will align with $49^{th}$ grid of the main-ruler. It means that the former aligns with 24.5 mm on the latter. So per tick on the sub-ruler is 0.49 mm. The difference between that value and one tick (0.5 mm) on the main-ruler is 0.01 mm, and we utilize this feature for a more accurate measurement to 0.01 mm.

**3. The Measurement**

Length of object = main-ruler readings + sub-ruler readings – zero error

(a) Zero error

Before fasten an object, main-ruler and sub-ruler will be in alignment at the graduation of zero. If not, we should recording the zero error value $a_0$.

(b) Both main-meter and sub-meter readings are the same as vernier caliper.

## Remarks：

1. When the experiments are done, separate the contacts of the screw micrometer to avoid damage.
2. Do not over fasten the objects with the verner caliper or screw micrometer. Then screw fine thimble **H** slightly until you hear three clicks.

## Procedure：

**Length of object = main-ruler reading + sub-ruler reading – zero error**

**A. Use of vernier caliper measure the inner diameter, outer diameter and depth of a cup; and then calculate its capacity**.

1. Record the zero error $a_0$ of the vernier caliper.
2. Clamp the outer periphery of a cup with **A** and **B**, and measure the outer diameter $2R$.
3. Put pincers **C** and **D** inside a cup and clamp it. Read the recorded value of the inner diameter $2r$.
4. Measure the depth $h$ of the cup with **H**.
5. Get the average value and the standard deviation of the mean.
6. Calculate the capacity of the cup. (Consider the error transfer.)

[Note] Capacity of the cup $V = \bar{V} \pm \sigma_V$

$$\bar{V} = \pi \bar{r}^2 \bar{h} \qquad \sigma_V = \sqrt{\sigma_r^2 \left(2\pi \bar{r}\bar{h}\right)^2 + \sigma_h^2 \left(\pi \bar{r}^2\right)^2}$$

**B. Use of screw micrometer measure the diameter of a metal wire, and the thickness of an item.**

1. Record the zero error $a_0$ of the screw micrometer.
2. Screw the rough thimble and clamp the thin metal wire or optional object between **A** and **B**.
3. Measure the diameter of thin metal wire and thickness of optional object respectively.
4. Calculate the average value and the standard deviation of the mean respectively.

**C. Use of traveling micrometer measure the width of single slit, double-slit, and the central dark fringe of diffraction.**

1. Adjust the horizontal level.
2. Fasten the object on the platform, and adjust its position to get a clear image appears in the eyepiece.
3. For example with single-slit, the definitions of a and b are shown in the Fig.5. Adjust horizontal knob on **C** 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 $x_2$ on the other end. Then the length of the object will be

   $\Delta x = |x_2 - x_1|$.

4. Measuring the width of a double-slit and the center of dark fringe by the same way.
5. Calculate the average value and the standard deviation of the mean respectively.


Figure 5. Single slit and Double slit

## Questions：

1. 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?
2. According to characteristics of the screw micrometer, What is the restriction about the sample we want to measure? Why?
3. If will the power of the microscope is change, does the accuracy be affected of the experiment? Why?
4. 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?