**PRECISION MEASURING INSTRUMENTS**

Several measuring devices and techniques are standard tools of mechanics. They will be introduced here so that you will understand them well enough to use them when the need arises in this course.

**THE VERNIER CALIPER**

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| https://www.lhup.edu/%7Edsimanek/scenario/labman1/vernier2.gif |
| **Fig. 1. Vernier Caliper.** |

In 1631 the French mathematician-inventor Pierre Vernier invented the measurement principle which bears his name. The Vernier scale has a beautiful simplicity, neatly solving the problem of reading fractions of small divisions on a measuring scale.

Suppose the main scale of a length measuring instrument is divided so that its engraved marks are one millimeter apart. The distance between these marks is so small that it would not be practical to divide them into tenths of millimeters. Even if such small divisions could be engraved accurately, they could not be easily read without a magnifying lens.

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| **Fig. 2. Use of the Vernier Caliper.** |

Parallel to the main scale is a movable scale with a number of engraved marks This is the *Vernier scale*. One of these, the *index mark*, points to a position on the main scale indicating the length reading. For example, if the index mark was lined up exactly with the 3.7 mark on the main scale, the length reading is approximately 3.7 mm. But we want to do better than this!

The metric Vernier scale has *ten or more equally spaced marks*. Their spacing is not the same as that of the marks on the main scale. If you look at these closely you will see that ten divisions of the Vernier scale occupy a length interval equal to *nine* of the smallest main scale divisions (millimeters). Obviously, in this case, the Vernier scale markings are engraved 9/10 millimeter apart.

A *metric* Vernier scale usually has ten divisions, requiring 11 engraved marks (ten plus the index mark). In general, a Vernier scale will have at least one more mark than it has divisions. Sometimes they have a few more marks at one or both ends, just for convenience. An *English* metric length scale, with the main scale marked in 1/16 inch intervals, may use a Vernier scale with 8 divisions, capable of measuring to (1/8)(1/16) = 1/128 inch.

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| **Fig. 3. Principle of the Vernier scale.** |

In the instrument called the *Vernier caliper* a movable jaw slides linearly along the main scale. The main scale is rigidly attached to the other jaw. To make a measurement, the jaws are gently closed down upon the object being measured.

On most Vernier instruments the scale divisions are not labeled in any way. The index mark may be labeled 0, "zero." If the "zero" mark is not labeled, it may be easily identified as follows:

When the instrument's jaws are fully closed, the Vernier scale mark which lines up with the main scale "zero" mark is the index mark. This index mark is to be considered the "zero" Vernier mark, and the other vernier marks are numbered in order from it, one through ten.

Now if the jaws are opened just 1/10 mm, the Vernier marks all move together that far, which brings the first vernier mark into coincidence with the main scale's 1 mm mark. Each time the jaws are moved 1/10 mm wider, the next higher valued Vernier mark lines up with a main scale mark.

This illustrates the principle of the Vernier scale and tells us how to read a Vernier caliper. The jaws are first gently closed on the object to be measured. Observe where the index mark points to the main scale, and write down this reading, rounded down to the next smaller main scale mark. Finally, to read the actual fraction of the main scale division, observe which of the *Vernier* marks lines up best with a main scale mark. The number of that vernier mark represents the fraction of a main scale division which must be added.

It doesn't matter which *main scale* mark lines up best with a Vernier mark. It is the *Vernier mark* number which you record.

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| https://www.lhup.edu/%7Edsimanek/scenario/labman1/vernscl1.gif |
| **Fig. 4. A centimeter Vernier scale.** |

Here's an example. Fig. 4 shows a Vernier scale for measuring on a centimeter scale to ten fractions of a millimeter.

The index mark (zero) falls between main scale marks 4.5 and 4.6. Mentally remember (or write down) 4.5. The vernier mark which lines up best with a main scale mark is 6. Therefore the actual reading is 4.5 + 0.06 = 4.56.

Fig. 5 shows another setting of the same scale. What is its reading?

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| **Fig. 5. A metric example.** |

Not all Vernier scales have ten divisions (11 marks). The smallest main scale division can be divided into any number of smaller divisions. Angle-measuring Vernier scales are often built with the main scale divided to half-degree intervals. The Vernier then has 30 divisions, dividing each half-degree into minutes of arc. [60 minutes of arc equal one degree of arc.] The *principle* underlying this is obviously the same as that described above.

Here's a puzzle for you. Consider the Vernier scale shown in Fig. 6.

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| **Fig. 6. English Vernier scale.** |

We'll give you this much hint. The main scale reads in inches, the smallest divisions are 1/16 inch. (The illustration is enlarged.)

a) Which scale (upper or lower) is the Vernier scale? How did you determine this?

b) What is the smallest fraction of an inch which can be read on the Vernier scale?

c) What is the reading of the instrument?

**THE MICROMETER CALIPER**

Fig. 8 shows a typical micrometer caliper. The object to be measured is placed between the fixed jaw (A) and the movable jaw (R) and the jaw is gently closed on the object. The movable jaw (R) of the micrometer caliper is driven by a precise and uniform screw. A typical metric instrument has the main scale marked to 1/2 millimeter. The circumference of the rotating handle (the thimble, T) is subdivided into 50 equal subdivisions. One rotation of the handle carries the screw a distance of 1/2 mm along the main scale (S). Therefore the markings on the thimble allow one to read hundredths of millimeters.

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| **Fig. 7. Principle of the micrometer.** |

In Fig. 7 the reading on the main scale is more than 5.5 mm but less than 5.6 mm. The thimble reading is 27.5, so the instrument's length reading is 5.5 + 0.275 = 5.775 mm.

You must practice so that you are *sure* whether the reading lies in the lower or upper half of a millimeter. If it is in the upper half, be sure to include the extra half millimeter in the final value.

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| **Fig. 8. Micrometer caliper.** |

On most micrometers, the half-mm marks are on the opposite side of the line from the mm marks. This makes the scale easier to read. Fig. 7 shows this style.

Special care must be exercised when using this instrument. Close the jaws on an object, then tighten the jaws using the slip clutch (H) only. This ensures sufficiently snug closure, but prevents the jaws being closed so forcefully that the instrument might be bent, and the jaws thrown out of alignment.

***Zero correction*.** Always check whether full closure of the jaws actually gives a zero reading. Special wrenches are available to set the zero reading exactly. Alternatively, the zero reading may be treated as a correction value to be added to (or subtracted from) all readings made with the instrument. This value is called a "zero correction."

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**PARALLAX**

Whenever a pointer or index mark must be read against a scale, it is best to have the two in exactly the same plane. Good quality instruments are designed to ensure this. But in some cases this is not possible, as with the movable needle on a voltmeter or ammeter. The needle must be slightly above the calibrated scale, to avoid the needle touching the scale. The marks around the thimble of a micrometer caliper can not touch the scale on the main shaft, for the same reason.

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| **Fig. 10. Parallax in reading a scale.** |

Whenever the index mark and scale lie in different planes, the "reading" you observe can change as you move your head to different positions. This effect is called "parallax." To eliminate its effect on measurements, be certain that your line of sight is exactly perpendicular to the scale.

Some electrical meters have a mirror beneath the scale so that you can first line up your eye so that the pointer and its image seem to coincide. This ensures that your line of sight is perpendicular to the scale.