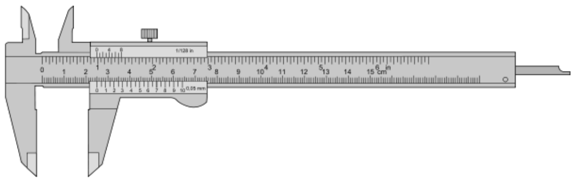
Vernier Calipers



A caliper (or calipers) is a device to measure the distance between opposite sides of an object. At its simplest, an outside caliper is just two arms (or jaws) and a sliding scale.

A Vernier Caliper uses a Vernier[1] scale to improve the precision of its measurement. This technique is simply a method to improve interpolation between two marks on the main scale.

To use calipers in our experiments:

i) Open the jaws by sliding the movable jaw. Place the jaws around the object (a "spindle" in the Angular Momentum lab) and close the jaws. Get the caliper tight and parallel for best reading.

ii) Slide the calipers off the object without changing the jaw opening.

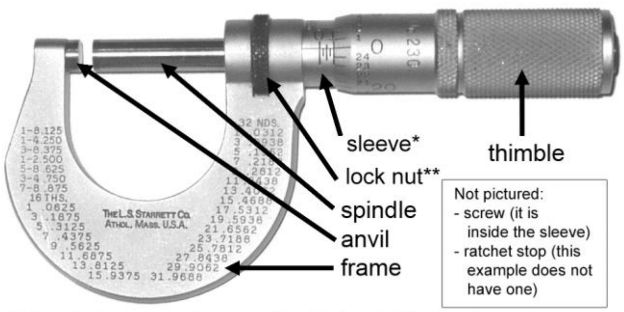
iii) Observe the main (cm) scale. Estimate the value by observing where 0 (zero) on the upper (mm) scale lines up with the upper scale. You can read cm and mm; plus you can estimate the 0.1mm.

iv) To use the vernier, see which mark on the mm scale lines up with a mark in the main scale. If you guessed 5 ¾ mm (for example) , then the 6, 7 or 8 marks are the ones which may line up.

The upper scale moves when you squeeze. In the image to left, the 0 (zero) of the upper scale is between 5 & 6 mm on the main scale. So, the measurement is 5 mm + something. The 8 lines up best, so your value is 5.8 mm.

1) https://en.wikipedia.org/wiki/Pierre_Vernier
Image from https://en.wikipedia.org/wiki/File:Vernier_Caliper_150mm.svg

Micrometer



*Sleeve is the most prevalent name. May also be called the *barrel* or *stock*.
**Aka *lock-ring*. Some mics have a *lock lever* instead.

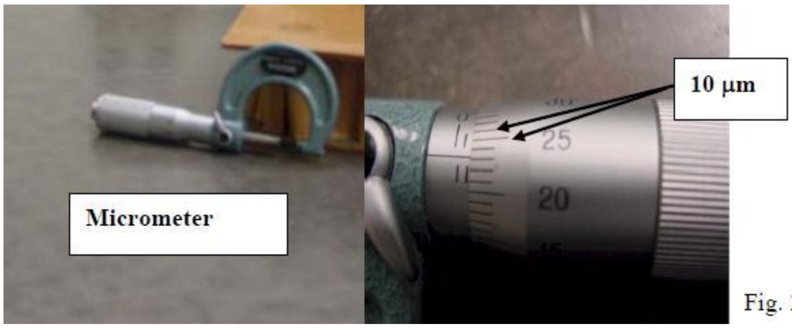


Fig. 2.

A screw micrometer allows you to use a carefully made, fine-pitch screw thread to measure dimensions (like the diameter of something) very carefully. The largest length it can measure is set by how big the open space, or gap, between the anvil and the end of the spindle can be. The right-hand image above shows a 0 to 1 inch micrometer made by Starrett. We use the name labels in that panel to describe the micrometer and its operation. Figure 2 shows a metric 0 to 25 mm micrometer, which we will use in our experiments.

There are differences among micrometers. You can see there is a lock lever on the metric micrometer in the right panel, but the micrometer to the left has lock nut. These serve the same purpose: to prevent the gap from closing. Another difference is the metric micrometer has a ratchet stop, ie, a small, knurled knob that projects out from the larger thimble. When you apply a clockwise (CW) torque to the ratchet stop with your fingers, it slips and makes a ratcheting sound if the thimble is prevented from turning. This allows you to apply a reproducible, small torque when closing the micrometer gap onto an object being measured. Notice that the ratchet stop knob cannot be rotated counter-clockwise (CCW) with respect to the thimble; it only rotates one way, CW, if the thimble is kept from rotating.

On any screw micrometer, turning the thimble CW advances the spindle and closes the gap, while turning the knob CCW withdraws the spindle and opens the gap. Each division on the numbered end of the thimble represents an amount (right panel: 0.01 mm = 10^{-5} m) of spindle motion and, therefore, that much change in the gap. Each division along the sleeve (between the numbered end of the thimble and and the C-shaped frame) represents 0.50 mm). When measuring an object, open the gap (withdraw the spindle) by turning the thimble CCW until the object can just fit in the open gap. Then read the number of lines visible on the long part of the handle. They tell you number of integral (right panel: half-mm units) of distance that gap has. Next, find which marker on the thimble lines up with the long centerline parallel to the axis of the sleeve. Multiply this number by (right panel: 0.01 mm) and add that to the number of (right panel: half-mm units) to get a final reading. You can consider the measurement error on the micrometer to be equal to one of the divisions on the numbered end of the thimble (right panel: 10 microns).

You should clean the jaws of the micrometer before you try to make any careful measurement. Reason: Even a speck of dirt on one of the shiny ends (of either the spindle or the anvil) will spoil your distance measurement: the micrometer is that sensitive. The simplest way to clean them is to close the gap on a piece of paper until the paper is almost, but not quite, prevented from moving, and then pull out the paper against the friction of the almost-closed micrometer. If the gap is too small, the paper won't move. If the gap is too large, the paper won't rub enough to clean the the shiny surfaces. Try it a few times and you'll get it right. You want *just enough* friction on the paper to clean the surfaces.

After doing this cleaning procedure, try a test measurement as an example: Measure the diameter of a standard, yellow, wood pencil (or some other pencil or pen if you don't have a yellow pencil handy). Suppose, after closing the gap on the pencil, you see that there are 12 lines visible to the right of the 0 line on the sleeve. That's 12 times one-half mm, or 6 mm. Then suppose that on the numbered end of the thimble you find the 45-mark lines up with the long centerline along the sleeve. Multiplying 45 by 0.01 gives 0.45 mm. Adding this to the first number gives you a diameter of 6.45 ± 0.01 mm for the pencil. Try it, but don't expect whatever you're measuring to have exactly this diameter. For your test measurement just get the number of half-mm units and add the number of 0.01 mm units to it to get the final result.

Observing Diffraction Effects with a Micrometer

Now realize that 0.01 mm is only ~one order of magnitude greater than the wavelength of visible light (300-700 nm). You may wonder if the gap can be made sufficiently small for you to observe diffraction phenomena when visible light passes through the gap. The answer is, yes; indeed, you can, but you have to know what you're looking for. The observation is complicated by the shiny faces of the anvil and spindle. When close together, they do not create a slit with sharp edges. Rather, they're like two plane mirrors, so what you observe when light passes through them when they're close together will be some combination of direct transmission and reflected transmission diffraction effects interfering with each other.

Here is a procedure that will work. Go into the hallway outside the lab and look up at one of the lamp fixtures in the ceiling. Direct your attention to one of the (relatively) thin fluorescent tubes, which you will use as a source of white light. Hold the micrometer close to one of your eyes so that you're looking through a, say, 0.1 mm gap directly at a fluorescent tube lengthwise. If you carefully orient the micrometer gap, you will both directly see the lamp and an image of it reflected off the shiny faces that delimit the gap. Adjust your aim so that the images coincide. Now, without moving the aim too much, turn the thimble CW to close the gap. At some closure you'll start to see whitish and blackish bands, and their thickness and separation will vary with the width of the gap. This pattern is too complicated to understand without great care. However, if you keep closing the gap, at about 5 small units or so, which corresponds to about 0.05 mm, you should see colors of the rainbow. This is a clear sign that wavelength-dependent diffraction effects are occurring. See if you notice how the colors separate, and then try to figure out if this is what you would expect for single-slit diffraction[2]. You are not looking through a single slit, though; you are looking through a deep, reflective gap, but maybe what you see is qualitatively similar to what you'd expect for the simpler case of a single slit. What happens to the colors as you close the gap further?

PLEASE: Throughout this lab (and later in life if you use a screw micrometer again), though it looks a lot like a small C-clamp • used to hold pieces of wood or metal together, this device is NOT a C-clamp. It is a finely made, delicate instrument. If you close the gap too tightly on a trapped object, you'll damage the fine thread that is the heart of the device.

2) See Knight, Jones, and Field, College Physics: A Strategic Approach, 2nd. ed. Chap. 17.5

You are treating it carefully if you NEVER drop it and you NEVER try to close the gap too tightly on an object by rotating the thimble with too much torque. Use the thimble to go most of the way, but then use the ratchet stop at the end of the thimble to go the final distance. The slippage built into the ratchet knob gives you a reproducible way to apply the small, final torque for your distance measurement, thereby preventing you from over-tightening the micrometer on whatever it is you're measuring. If for some reason your micrometer doesn't have a ratchet stop, you'll have to get used to applying the final torque *carefully* with your finger tips by feel. Practice helps.

Measurement of the hair diameter with a Micrometer

First, you must determine the zero reading of the micrometer so you have a clear reference point when measuring the diameter of the hair. After cleaning spindle-end and anvil, and without the hair between them, close the micrometer with the same, small final torque you will use later when measuring the hair. (Because neither the frame nor the internal, fine-thread screws are perfectly rigid, the micrometer will show different zero readings according to whether you close it gently, just right, or too much. What distance value do you read with micrometer when it's closed just right? This will be your closed value. It would be nice if it were zero, but for any slight mis-adjustment, it won't be zero. That doesn't mean the micrometer is broken; it just means that you have to correct for the zero shift. (This is a simple example of a systematic error that you correct for.) When measuring the diameter of the hair remember to start counting from your measured zero shift, whatever it is. Record this zero shift.

Now insert a hair, which you can supply from your own head. But be careful which hair you choose. According to information on the internet, the diameter of human hair can vary a lot according to the person it's taken from and according to which part of the head or body it's taken from. Moreover, all human hair is not cylindrical. The hair making up a man's mustache is noticeably flattened, like a belt. Since it's not circular in cross section, it doesn't have a diameter, and, besides, it would be hard to know just how you mounted it on the frame used to hold it in the experimental setup. So make sure you choose a proper hair from your head or your partner's head.

Bring the jaws together with a CW rotation of the ratchet stop and record the reading you get with the final torque just right. Subtract the zero reading from the reading with the hair to obtain the hair diameter. Include the dimensional unit and your estimate of the uncertainty in measuring the hair diameter.

Ruler

As of this writing, the internet search engine "Google" offers more than 40 million web pages in response to the query "instructions use ruler".

Convenient Tools

Hand width ≈ 4 inches, used to measure horses
Thumb width ≈ 1 inch
Hand Span ≈ 9 inches
Cubit ≈ 18 inches, often used when building arks
Fist width at arms length ≈ 10^{o}, useful in making astronomical observations
Length of a foot ≈ 1 foot, length and width of many floor tiles in lab rooms
Pint of water (16 ounces) = 1 lb (16 ounces)

Nota bene: These values are *very* approximate!