DeAnza College

Classical Mechanics
Lab 1
Measurement, Uncertainty, and Density

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De Anza College

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Overview

- Discussion of laboratory work
- Equipment
- Procedure

Why we do lab work

To confirm or disprove hypotheses

To get insights for new hypotheses

Integrity is very important.

Guidelines for lab books

- Put your name and section number on the outside front cover.
- Lab books stay in the lab.
- Save the first two pages for a table of contents.
- Number the rest of the pages of the lab book (one side only) in the top right corner for your table of contents; do this now! Complete your table of contents as the lab progresses.

Guidelines for lab books

- Write only in pen. Pencil can only be used to plot points on your graphs.
- Do not erase or white-out anything you have written in your lab book. If you think you've made a mistake, then cross out what you wrote (so you can still read it!) and re-write the correct version near it.
- If you need to cross out data, make a note next to it the correction explaining the change.
- No scratch paper is to be kept outside of your lab book.
- When a graph is required, it should be drawn while the data is taken.
- Plot **big** graphs.

Recording data in lab books

When you use a measuring device, record the what device is being used for each measurement **and** the unique device number in your lab book next to the measurement value.

Every measurement value should have units!

Where appropriate record your data in a table. This will make it easy for you to plot or analyze, and easy to refer to in your conclusions.

Conclusions

The point of doing labs is

- to learn good laboratory habits and
- to investigate the relationship between physical quantities for yourself.

This means that you must analyze your results to understand what your data means.

In your lab book, after you have gathered the data and done any plots required, you must write up conclusions.

Conclusions

Make sure to

- answer any questions posed in the lab instructions
- state any conclusions that you can draw from your data
- mention any effects that could have lead to errors in your data
- suggest improvements to lab procedure that could reduce errors
- suggest extensions to the lab using the same equipment or similar equipment, discussing what other questions could be investigated and why they are related / of interest in light of what you learned in your lab.

Safety

Occasionally during these labs you will use equipment that is heavy, long and awkward, and/or has fast-moving parts.

Please use your brain.

Communicate clearly with your partner what you are doing, so that you don't catch one another by surprise.

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You can also damage equipment if you are careless with it and we may not be able to replace it for many years.

Be careful not to drop equipment, not matter what it is.

If you are concerned about anything, ask me first!

Purpose of the Lab

To learn to use common measuring devices.

To learn to deal with uncertainties.

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To learn to use common measuring devices.

To learn to deal with uncertainties.

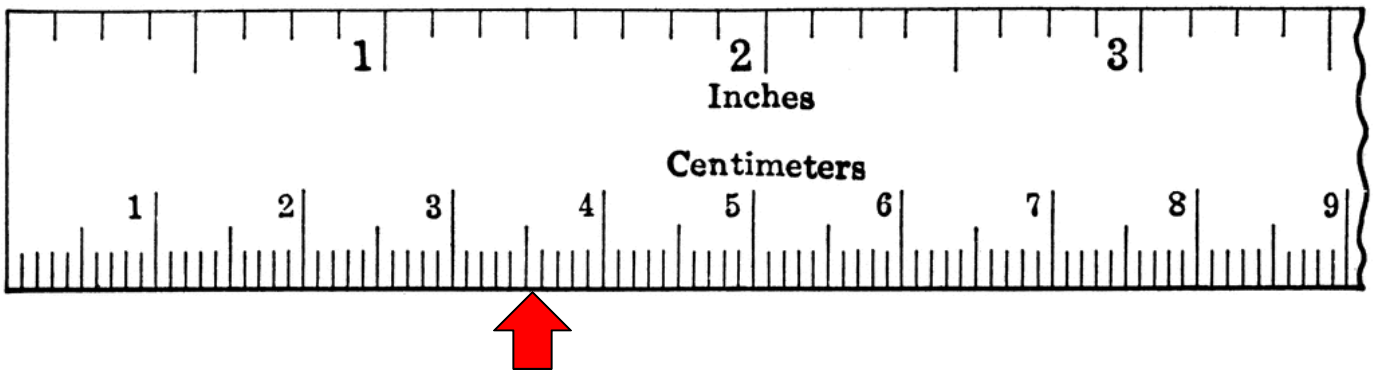
You will use various devices to measure the volume and mass of an aluminum block.

From those measurements you will deduce the density of the block and the uncertainty of your value.

Measurement Uncertainty and Significant Figures

All measuring devices are only so accurate.

For example, a ruler has millimeter (mm) marks, but not micrometer (μm) marks.



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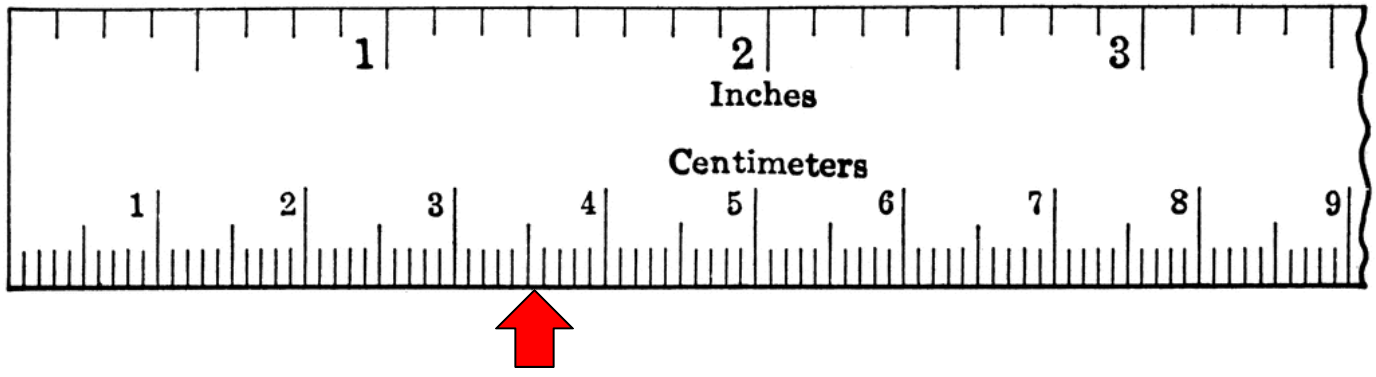

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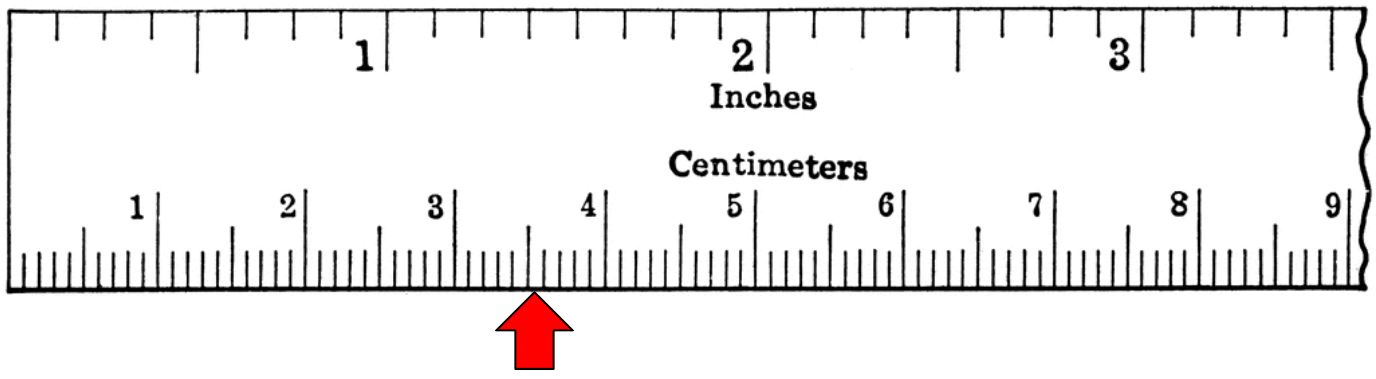

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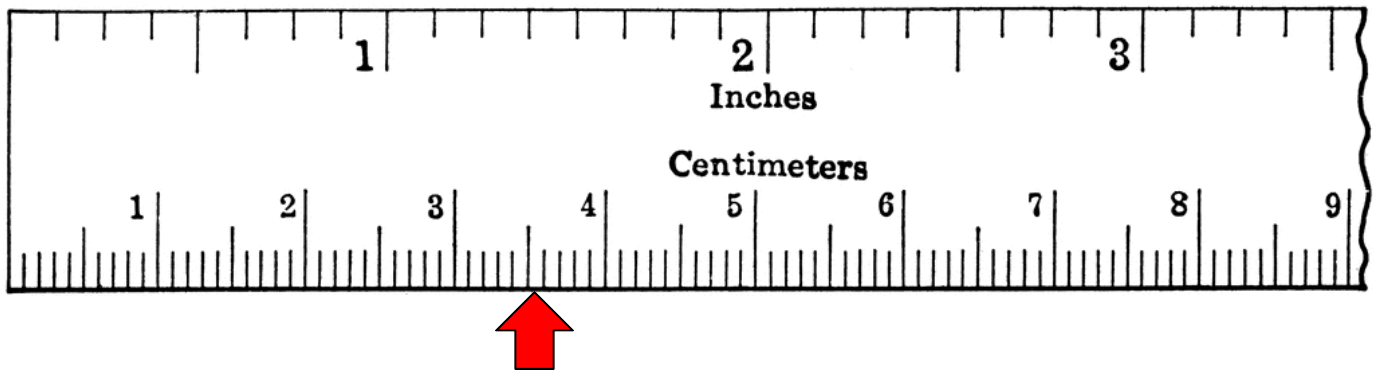

Does it make sense to report a ruler measurement to 5 decimal places? **No.**

If inputs to a problem or experiment are given to 3 significant figures, give the output to 3 significant figures.

Scientific Notation

An alternate way to write numbers is in scientific notation.

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For example, the speed of light in a vacuum is roughly:

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In scientific notation, we could write this as:

$$3.0 \times 10^8 \text{ m/s}$$

This is the same thing.

$$10^8 = 100,000,000$$

so,

$$3.0 \times 100{,}000{,}000 = 300{,}000{,}000 \text{ m/s}$$

Scientific Notation vs Unit Scaling Prefixes

In scientific notation,

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Alternatively, we could write this with a unit prefix:

$$300 \text{ Mm/s}$$

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In scientific notation,

$$3.0 \times 10^8 \text{ m/s}$$

Alternatively, we could write this with a unit prefix:

$$300 \text{ Mm/s}$$

where 1 Mm is one mega-meter,
or use kilometers:

$$300,000 \text{ km/s}$$

or use a prefix with scientific notation:

$$3.0 \times 10^5 \text{ km/s}$$

Significant Figures and Scientific Notation

One reason to use scientific notation is to clearly convey the number of significant figures in a value.

If a number is quoted as:

$$300{,}000{,}000 \text{ m/s}$$

is it accurate to 1 significant figure? Or to 9 significant figures?

It is not clear.

Significant Figures and Scientific Notation

One reason to use scientific notation is to clearly convey the number of significant figures in a value.

If a number is quoted as:

$$300{,}000{,}000 \text{ m/s}$$

is it accurate to 1 significant figure? Or to 9 significant figures?

It is not clear.

However, if we write:

$$3.00 \times 10^8 \text{ m/s}$$

this means that the value is given to 3 significant figures.

The speed of light to 4 significant figures is:

$$2.998 \times 10^8 \text{ m/s}$$

Error Propagation function (Random errors)

Suppose f is a function of the measured values x, y, and z.

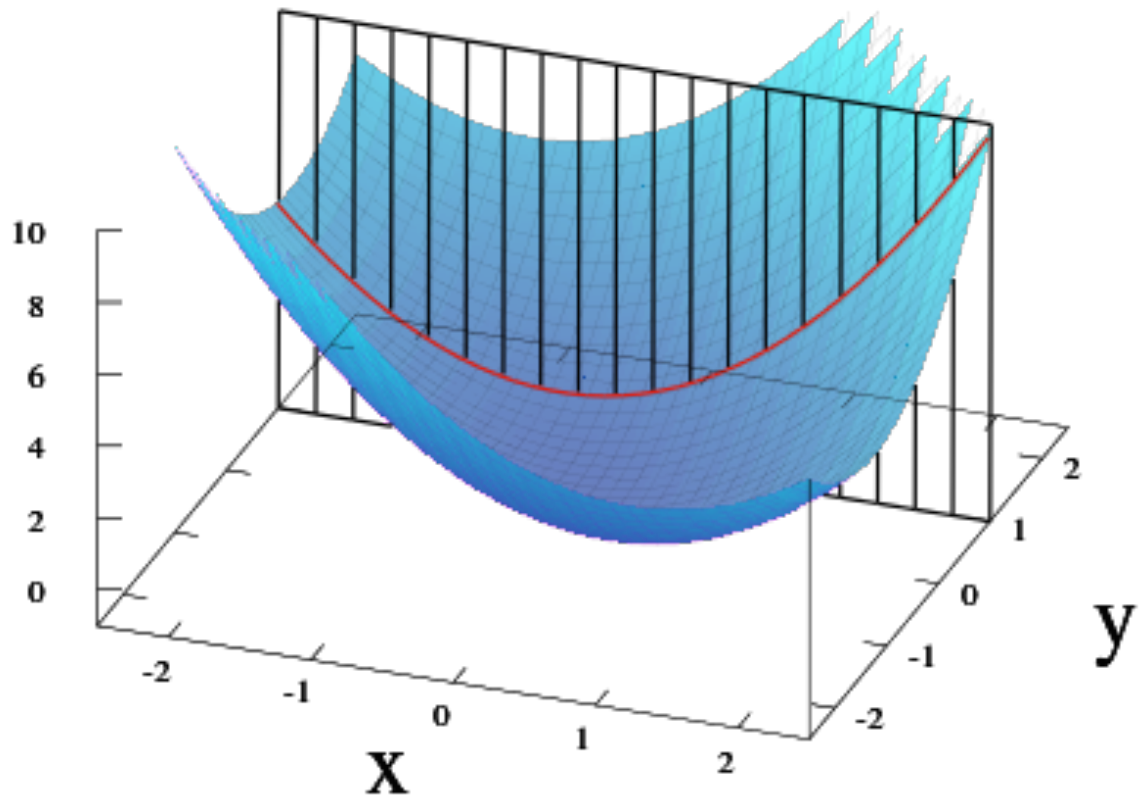
$$\delta f = \sqrt{\left(\frac{\partial f}{\partial x}\right)^2 (\delta x)^2 + \left(\frac{\partial f}{\partial y}\right)^2 (\delta y)^2 + \left(\frac{\partial f}{\partial f}\right)^2 (\delta z)^2}$$

δx, δy, and δz are uncertainties in x, y, and z respectively.

Partial Derivatives

Consider a scalar function $f(x, y)$:

$$f(x, y) = x^2 + xy + y^2$$



$$\frac{\partial}{\partial x} f(x, y) = 2x + y \qquad \frac{\partial}{\partial y} f(x, y) = x + 2y$$

[1] Figure from Wikipedia by IkamusumeFan.

Partial Derivatives

Consider a scalar function $f(x, y)$:

$$f(x, y) = x^2 + xy + y^2$$

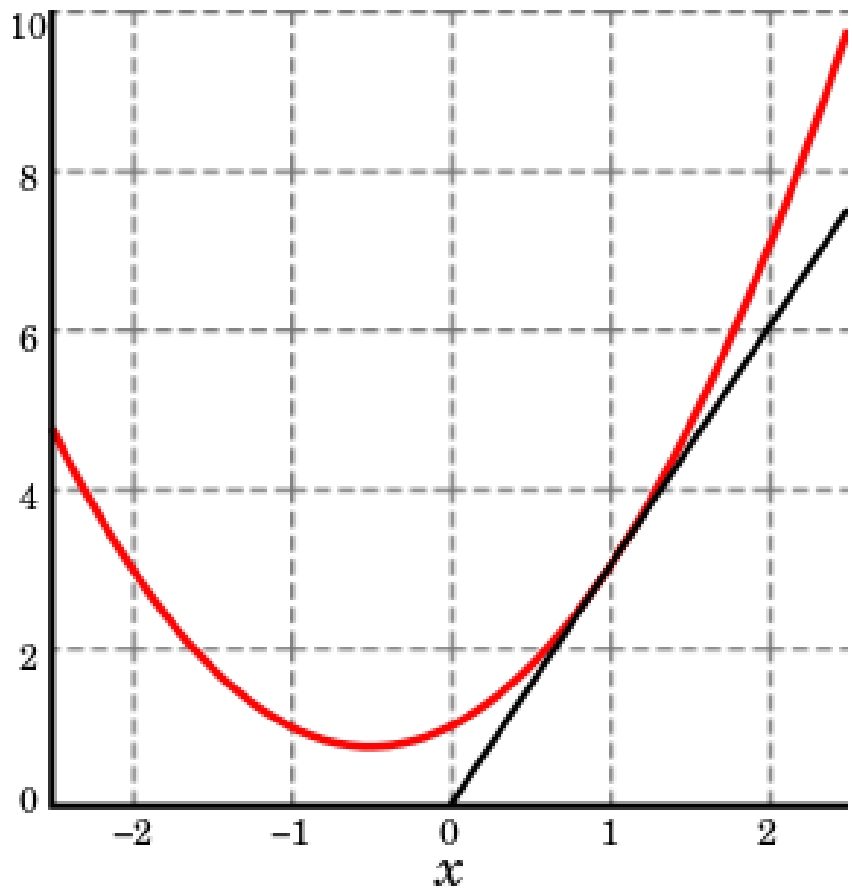
Set $y = 1$

$$f(x, 1) = x^2 + x + 1$$

Slope:

$$\left.\frac{\partial}{\partial x} f(x, y)\right|_{y=1} = \frac{\mathrm{df(x, 1)}}{\mathrm{dx}}$$

$$= 2x + 1$$



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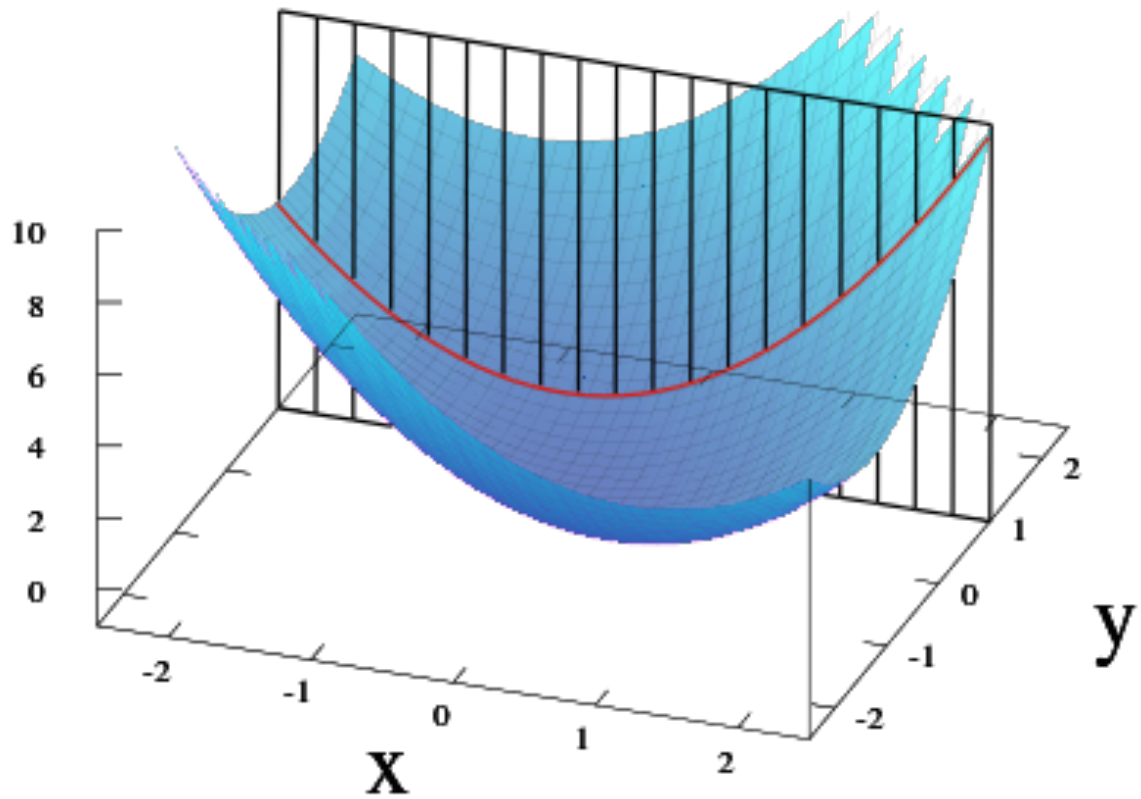

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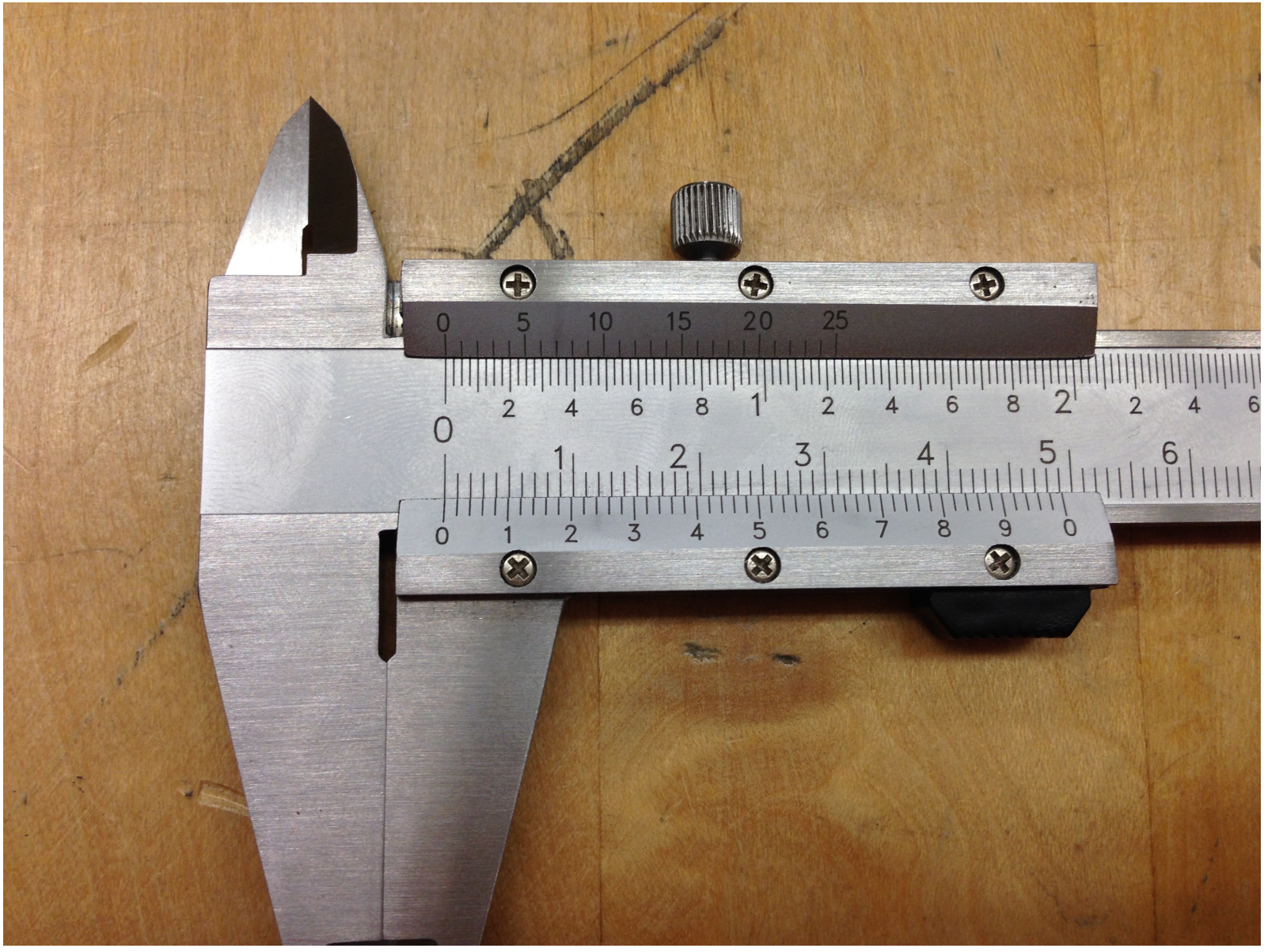
Vernier Calipers



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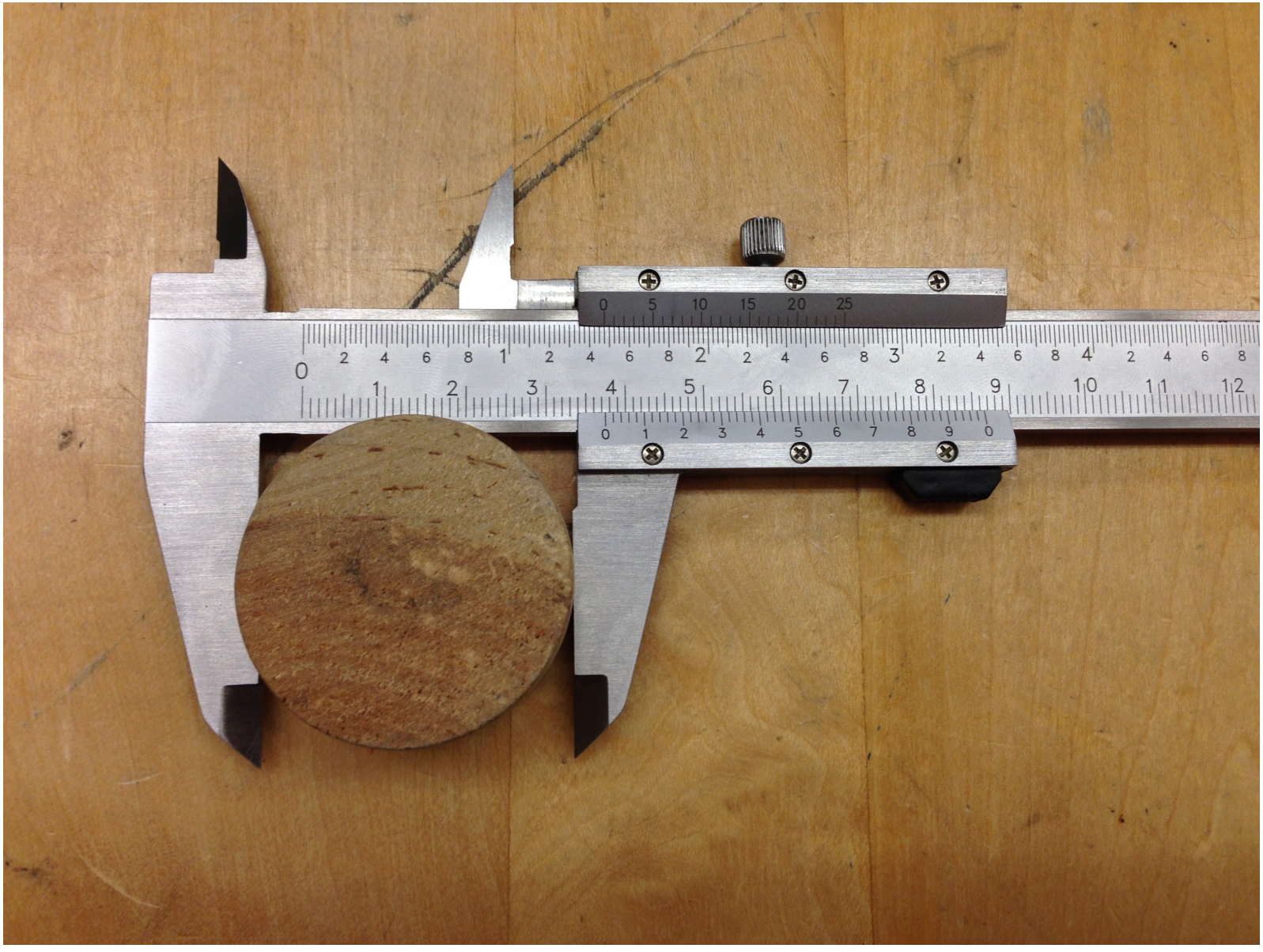

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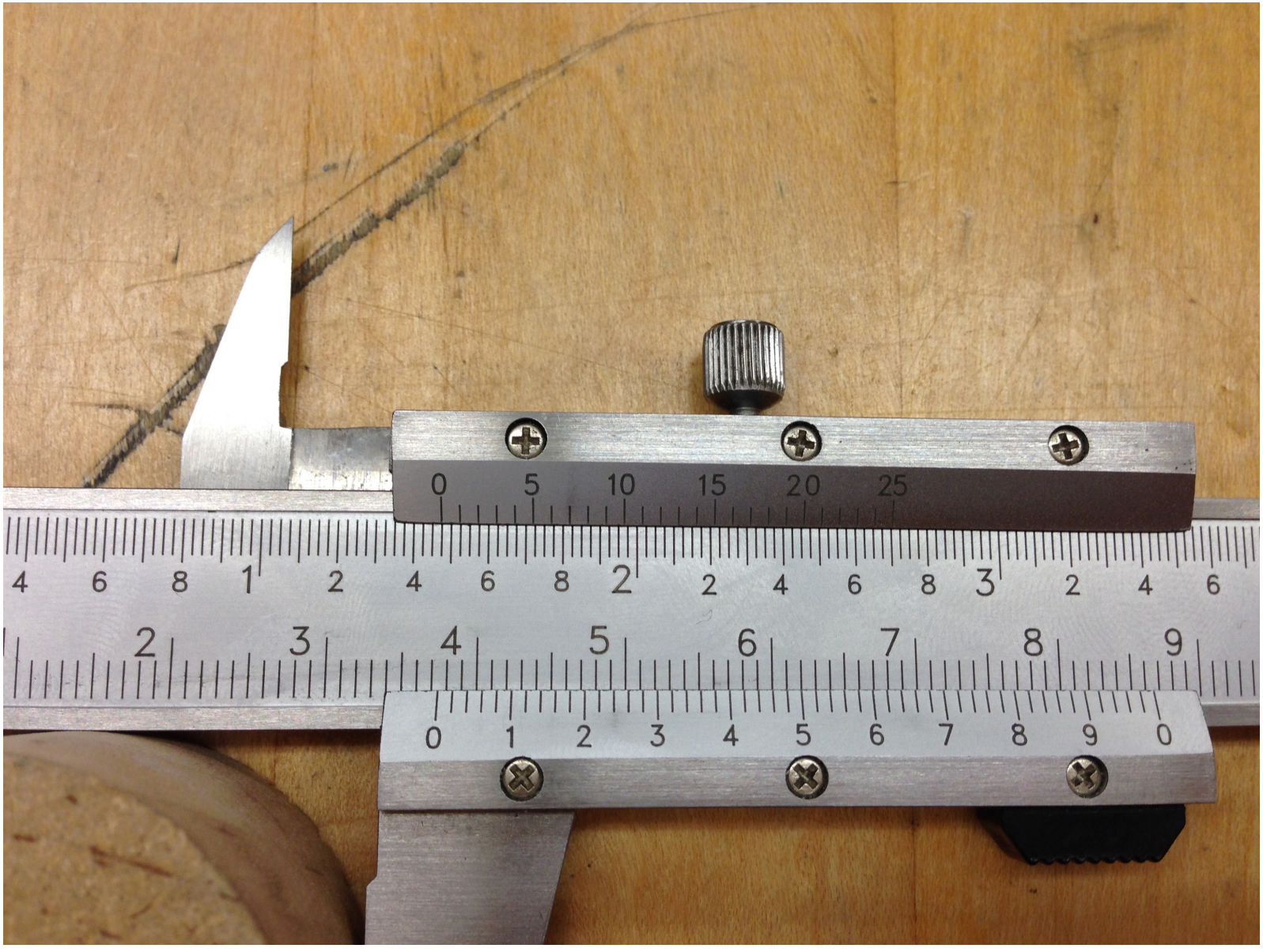

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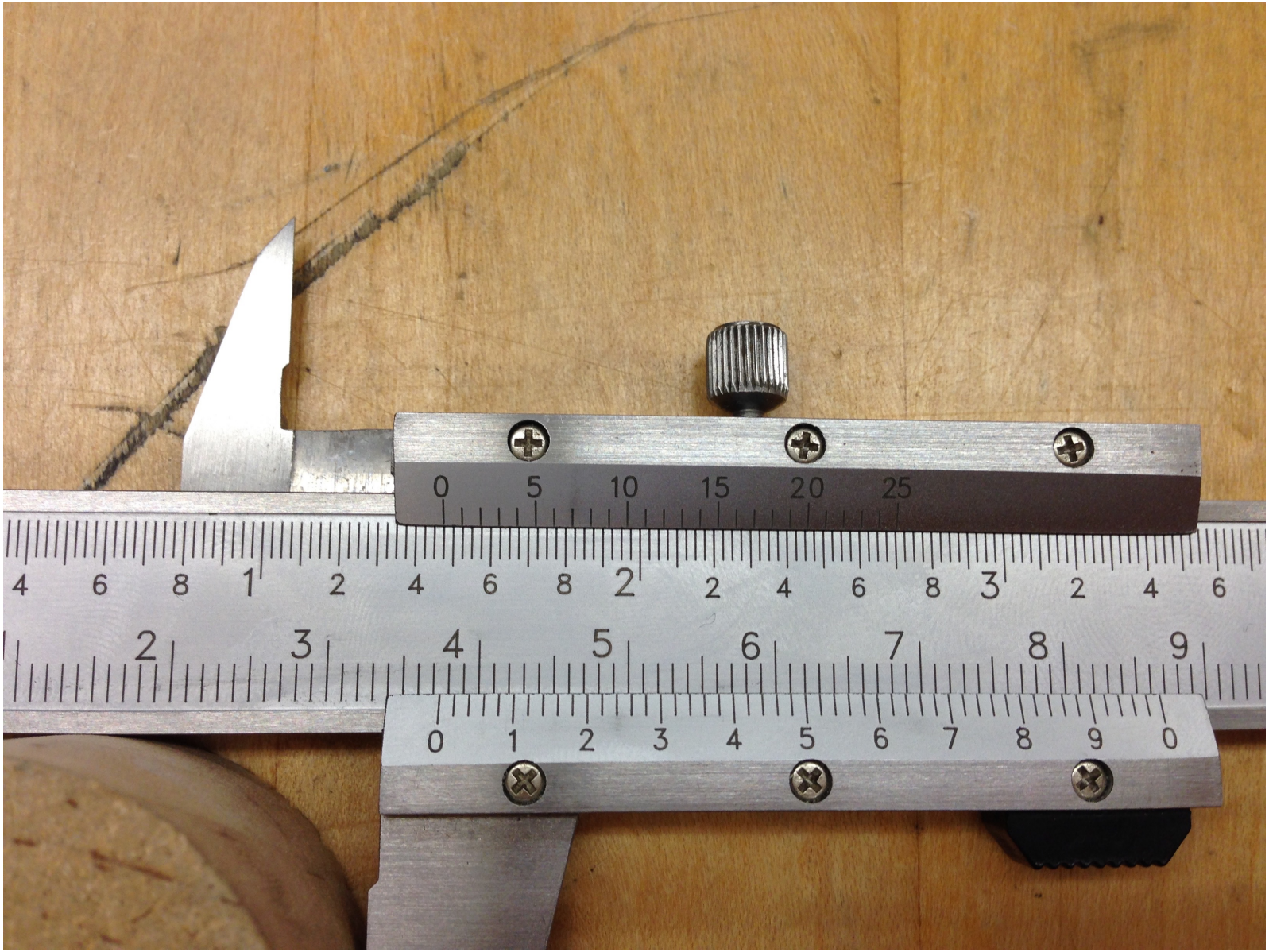
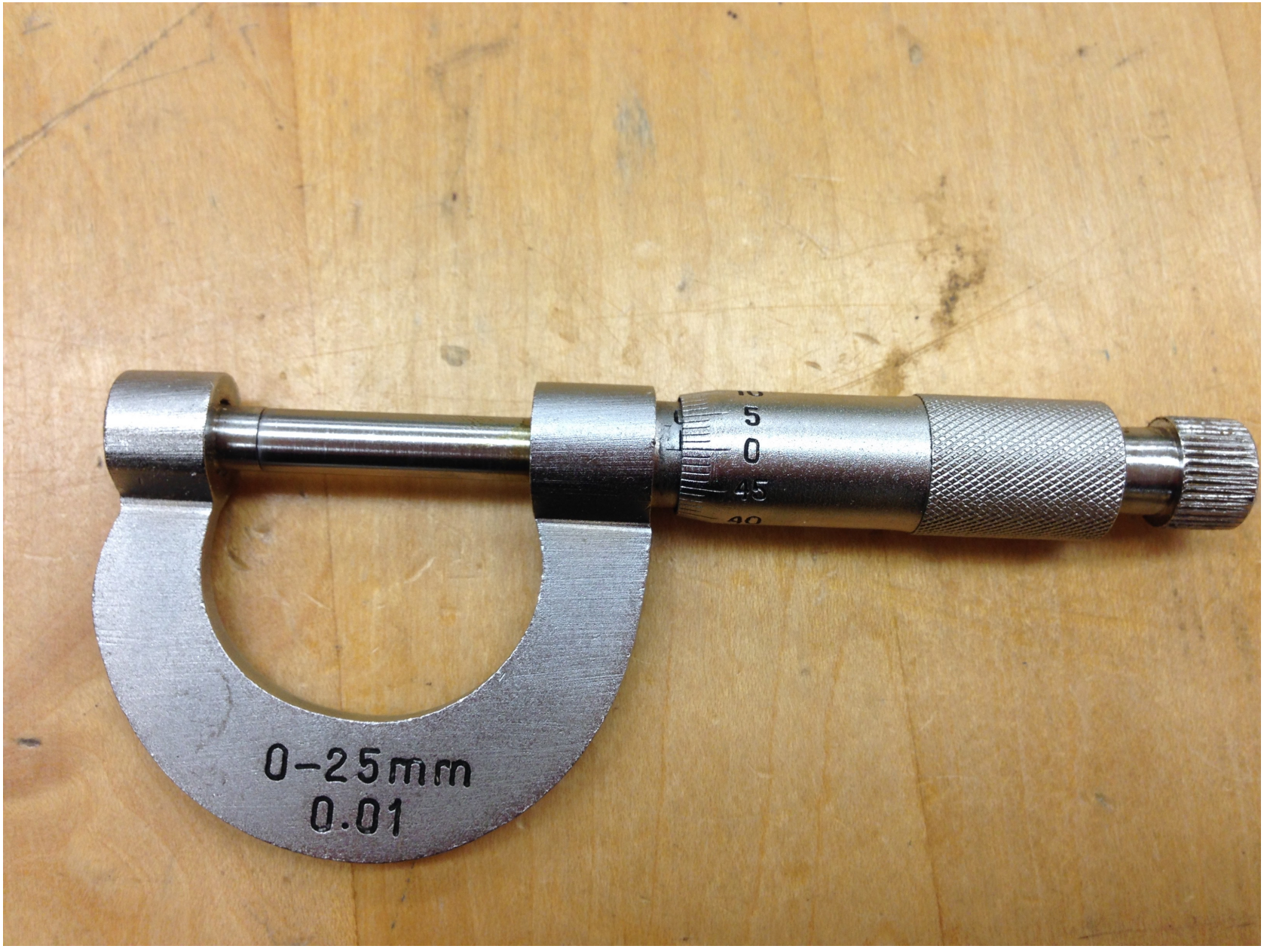


(3.752 cm $\pm$ 0.001 cm)

Micrometer



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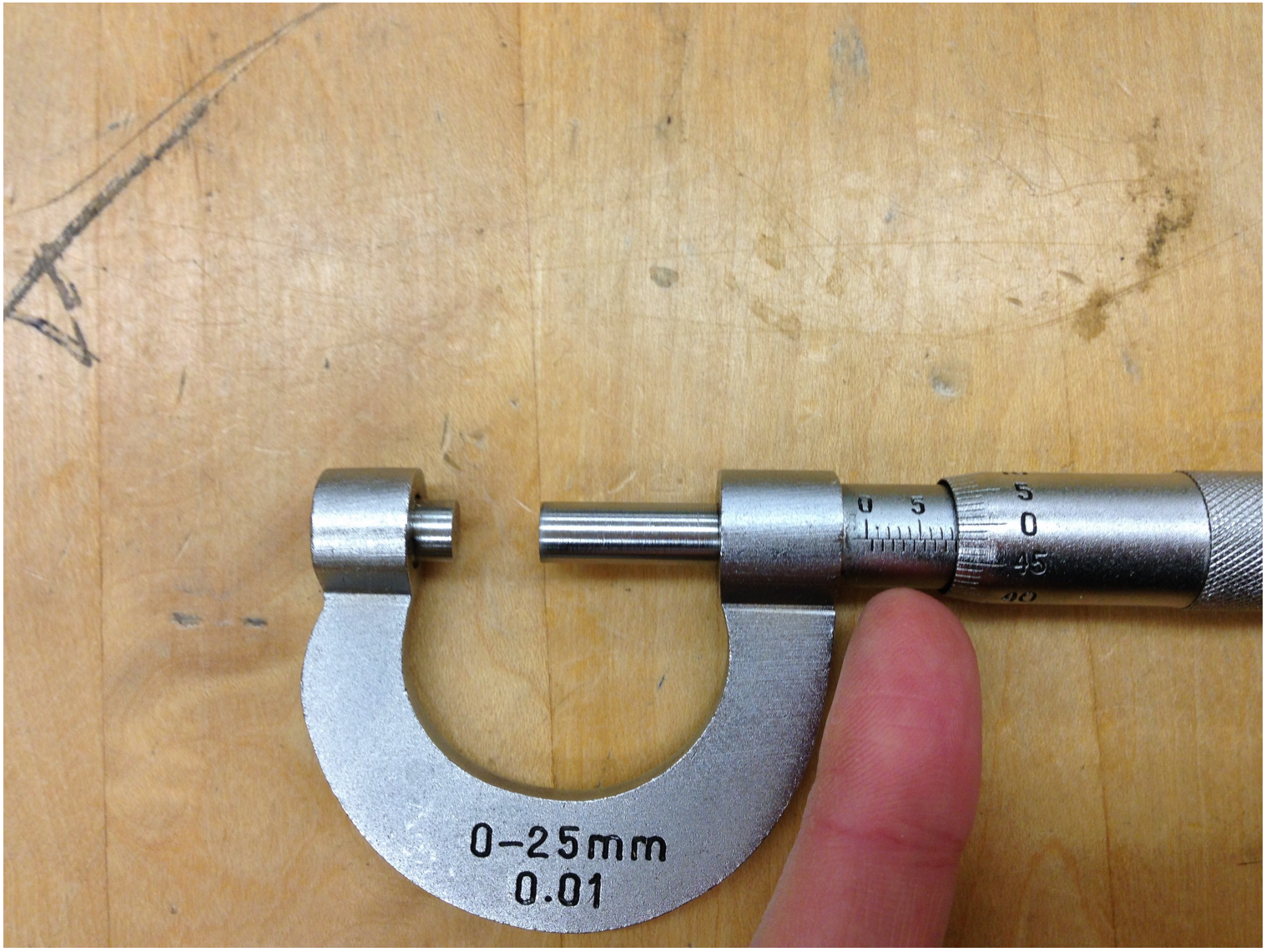
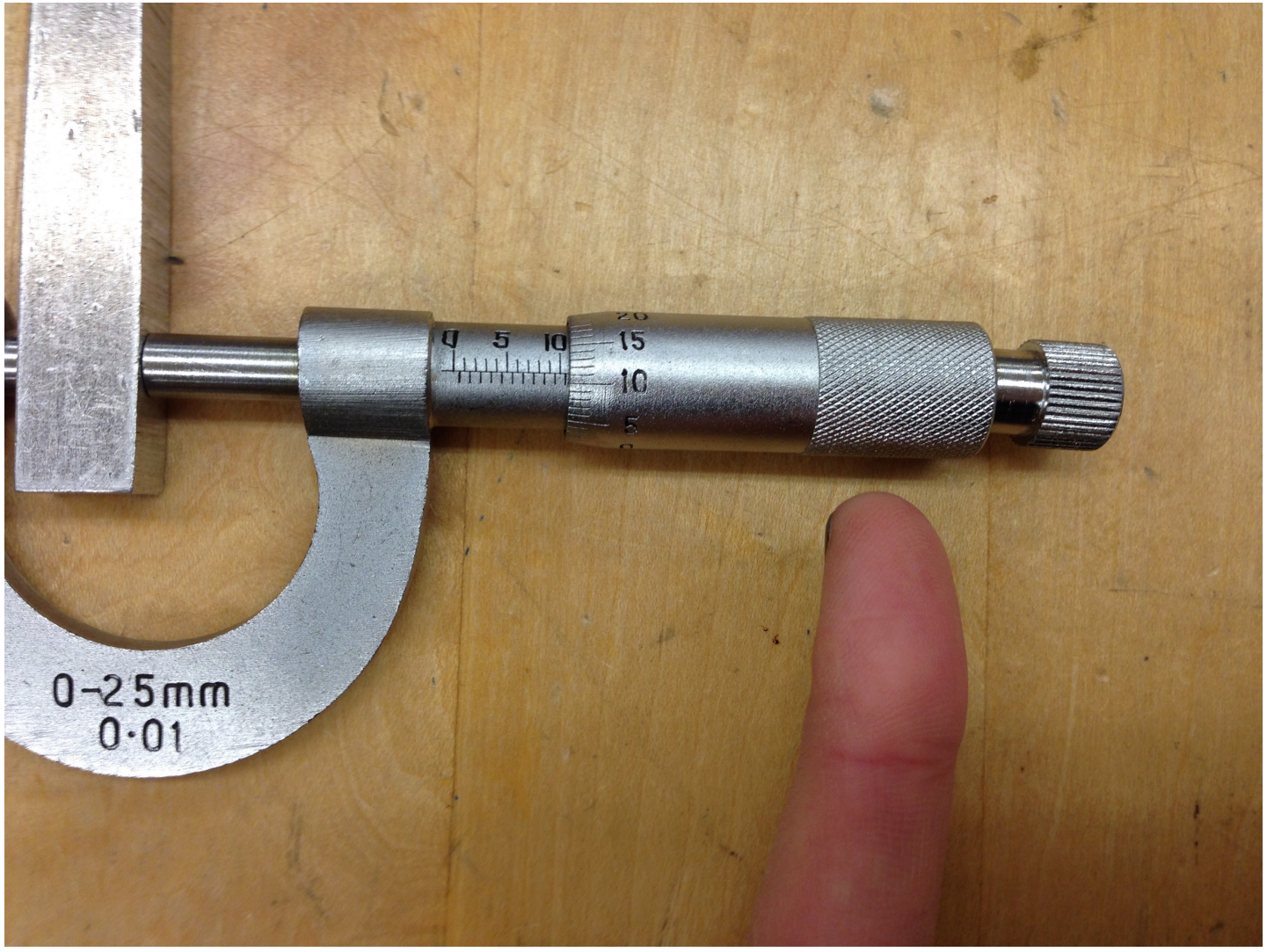


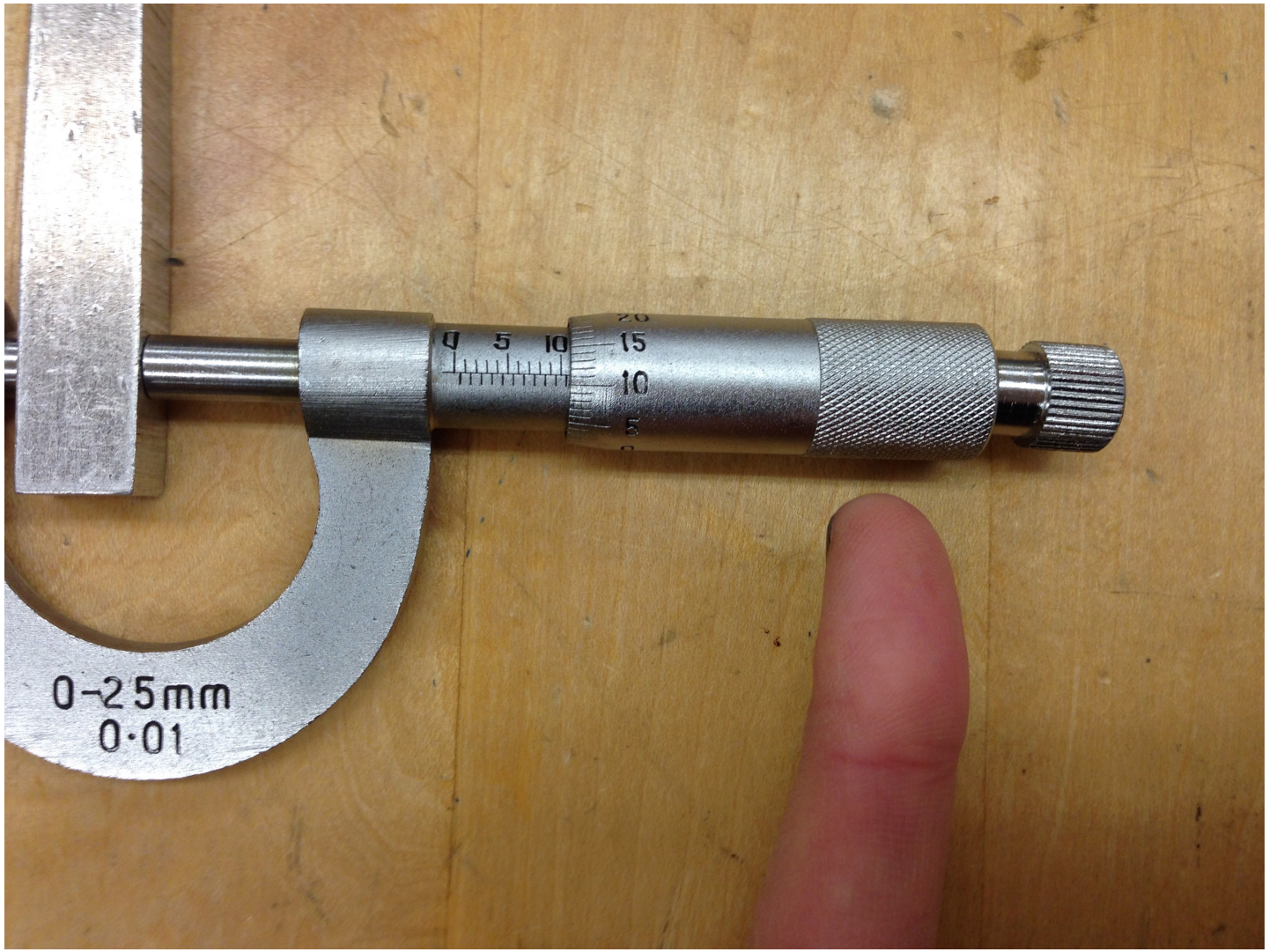
The "sleeve" (Coarse scale)

Micrometer



The “thimble” (Turn gently to close spindle towards anvil. Stop when you get a click!)

Micrometer

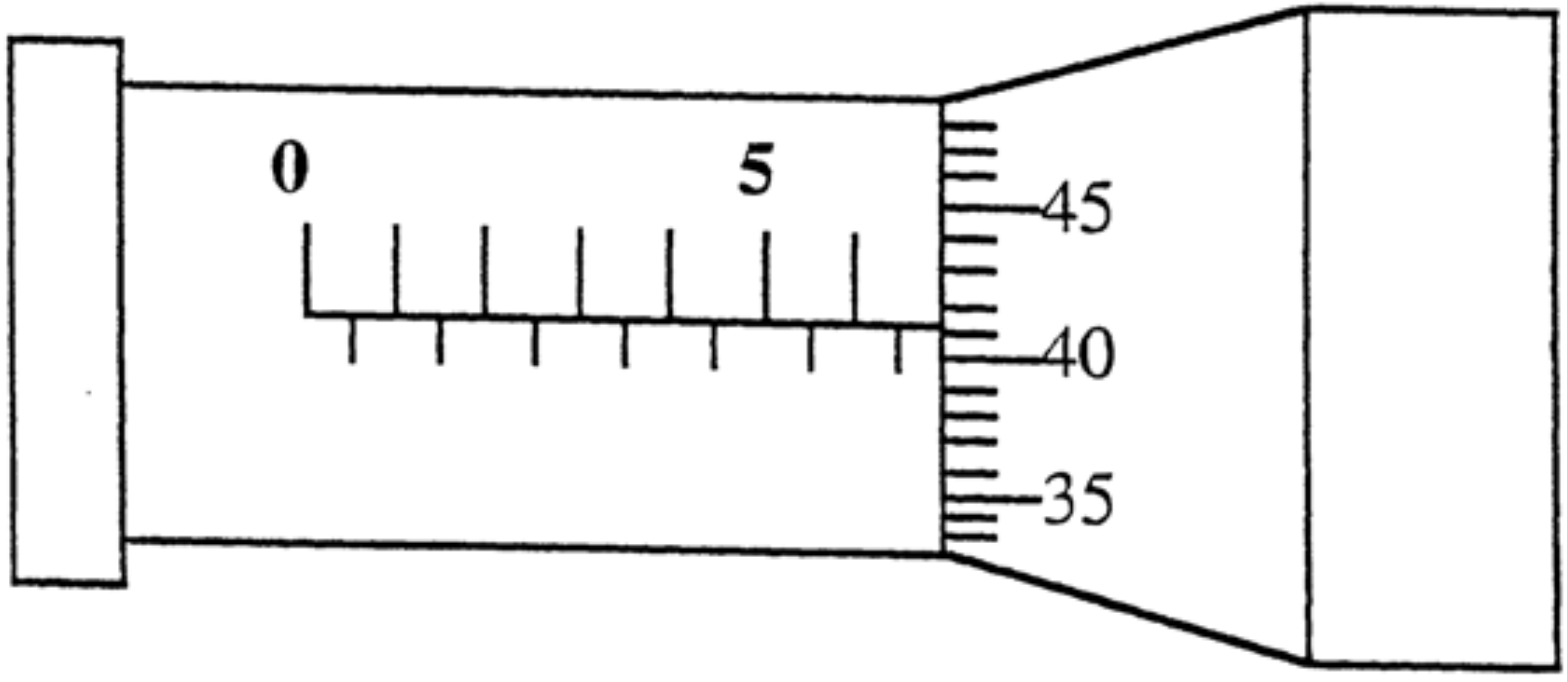


The "thimble" (Turn gently to close spindle towards anvil. Stop when you get a click!) (10.610 mm $\pm$ 0.005 mm)

Micrometer

The thimble-lock lever.

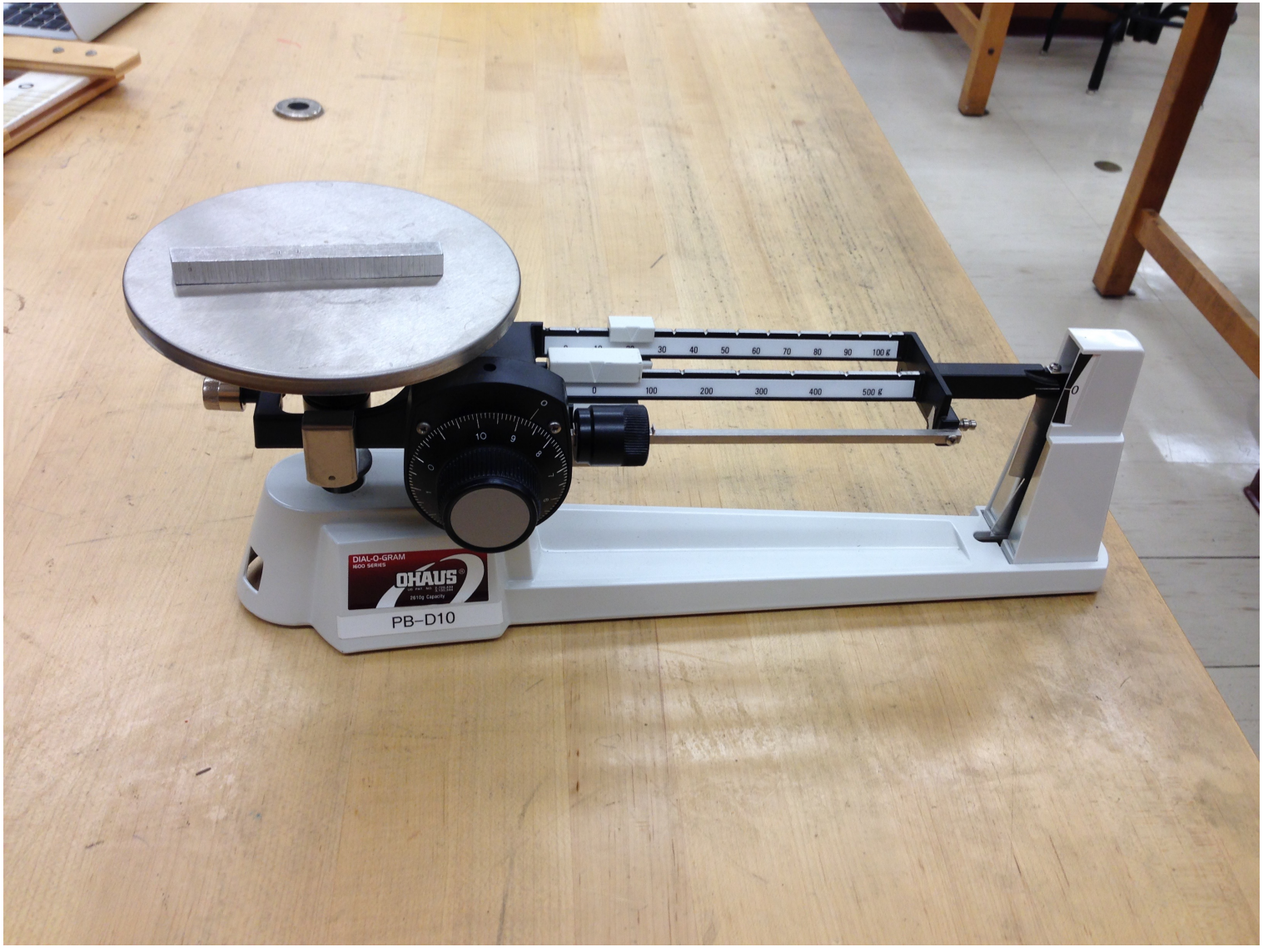
Micrometer



Coarse scale: see the 6.5 mm line.
Fine scale: sleeve scale is just past the 41 line: 0.41(2) mm

Best final reading: 6.5 mm + 0.412 mm = 6.912 mm
(when reporting answer include uncertainty)

Pan Balance



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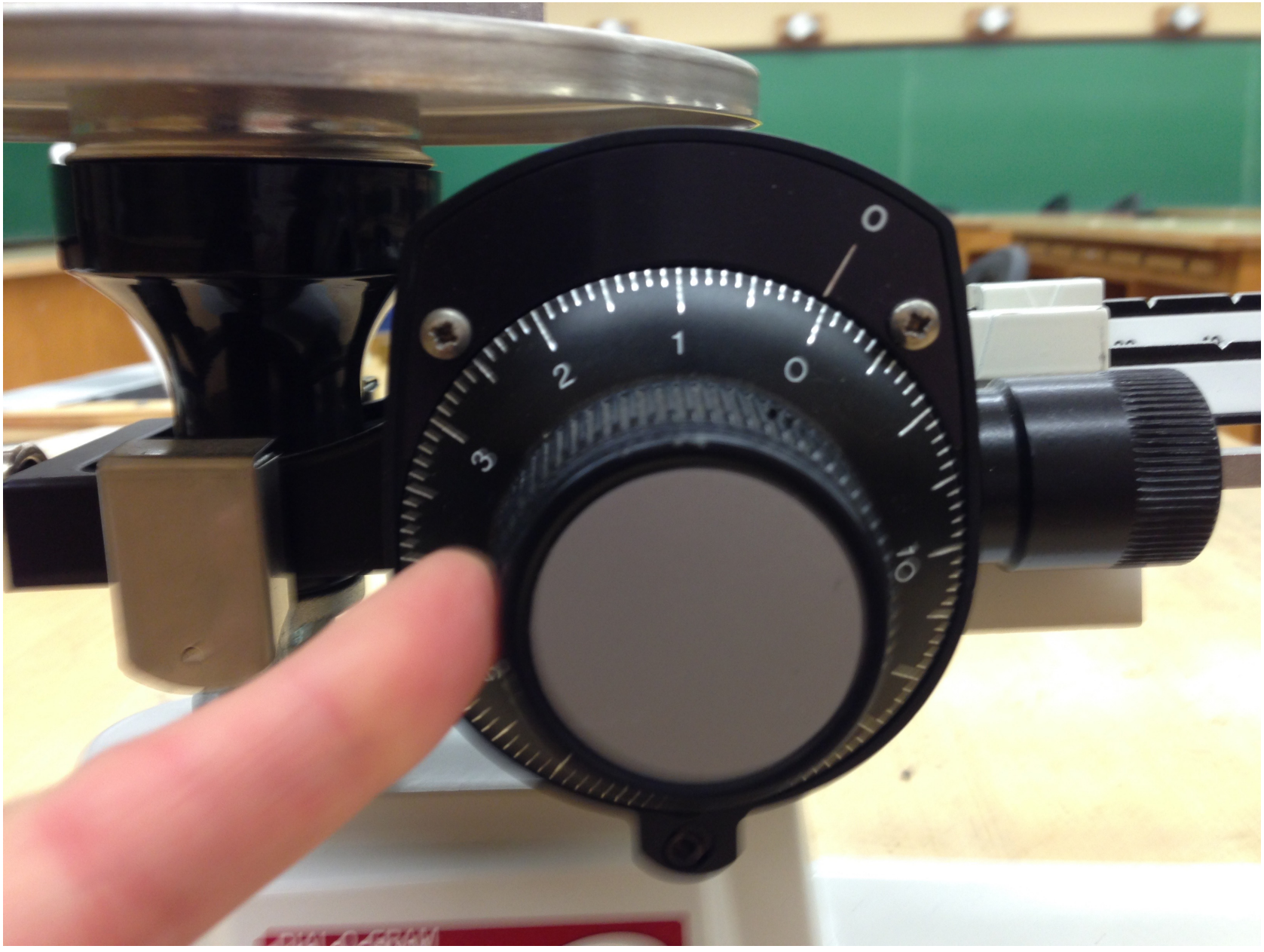

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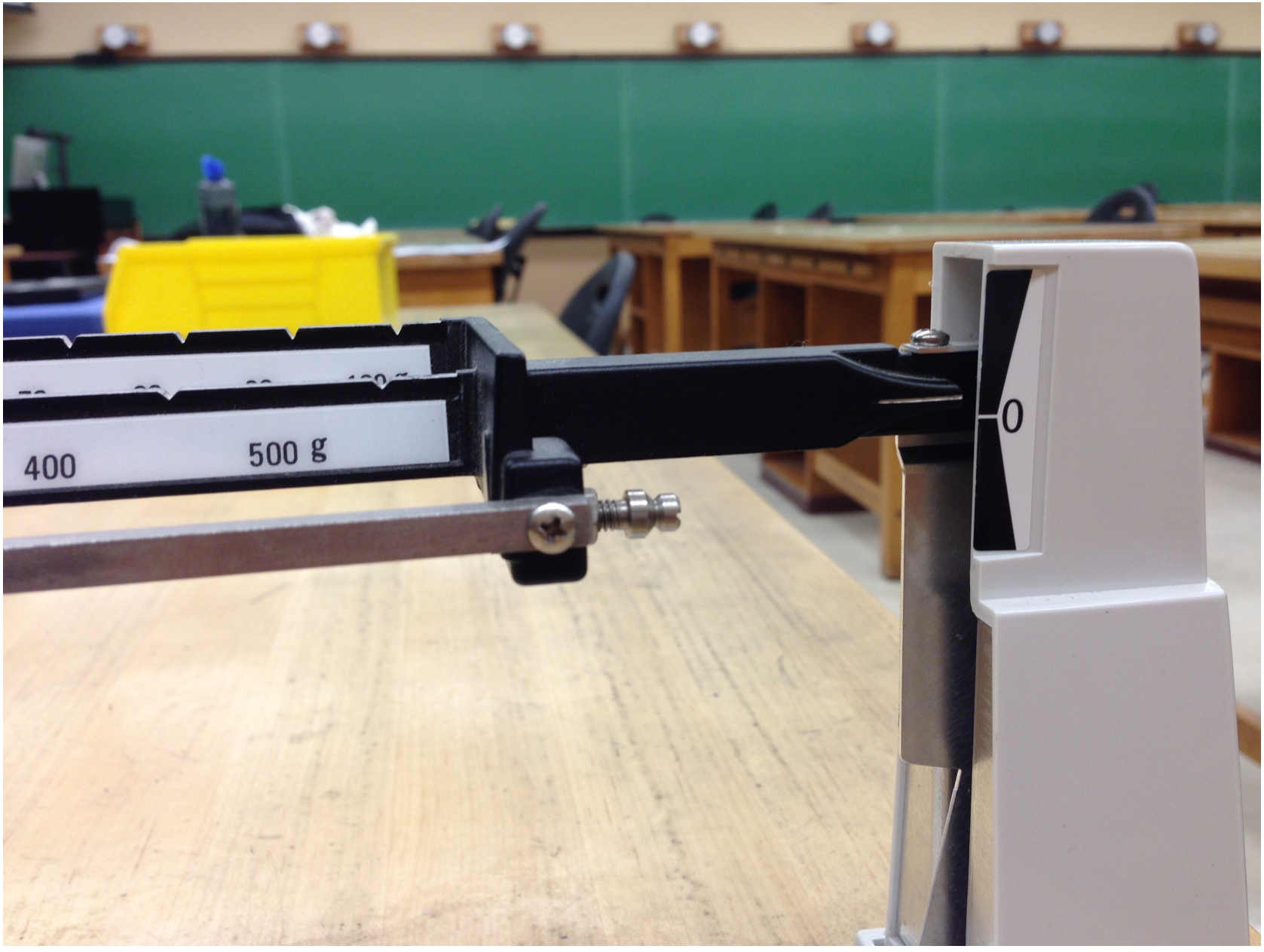

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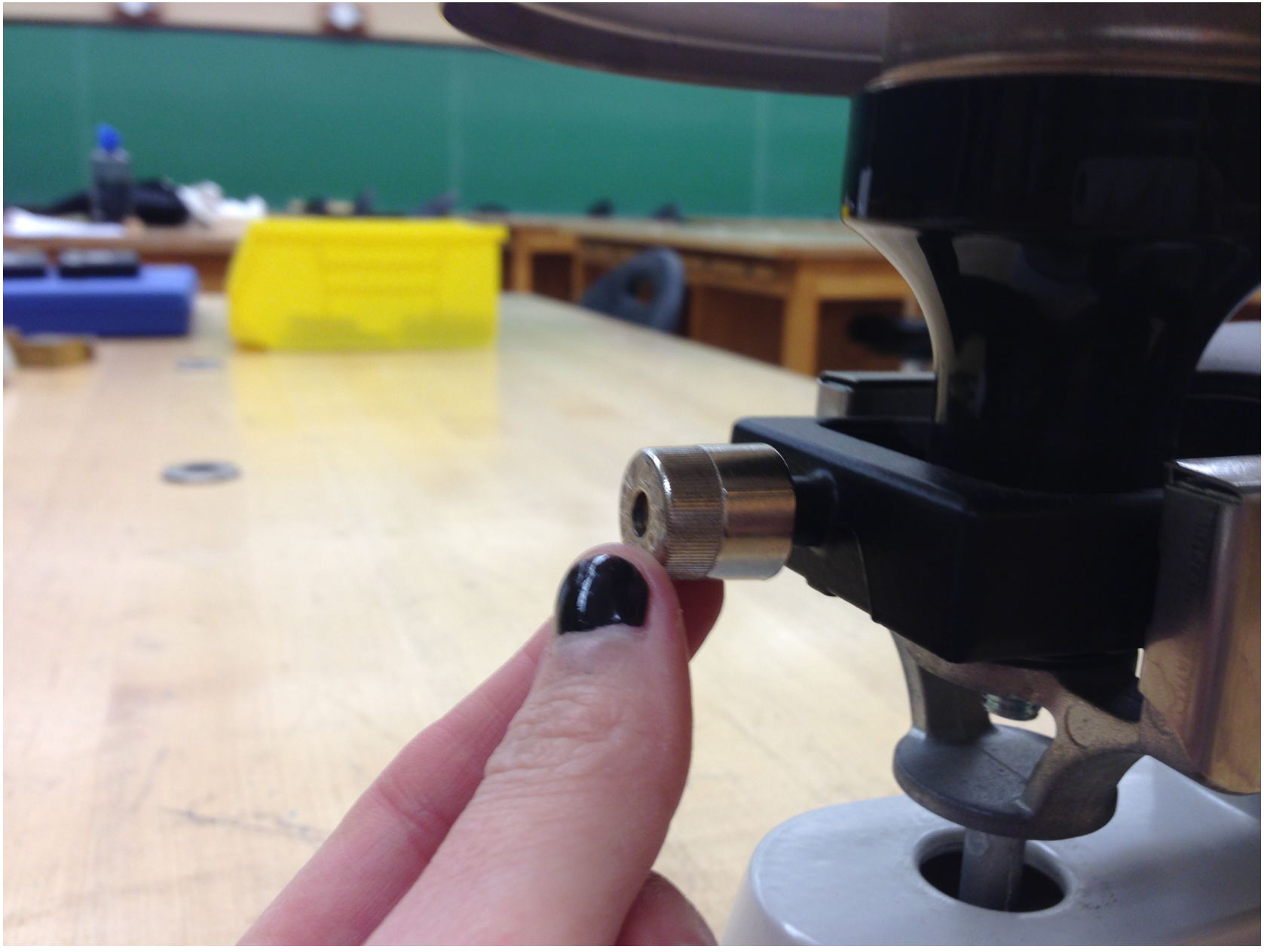

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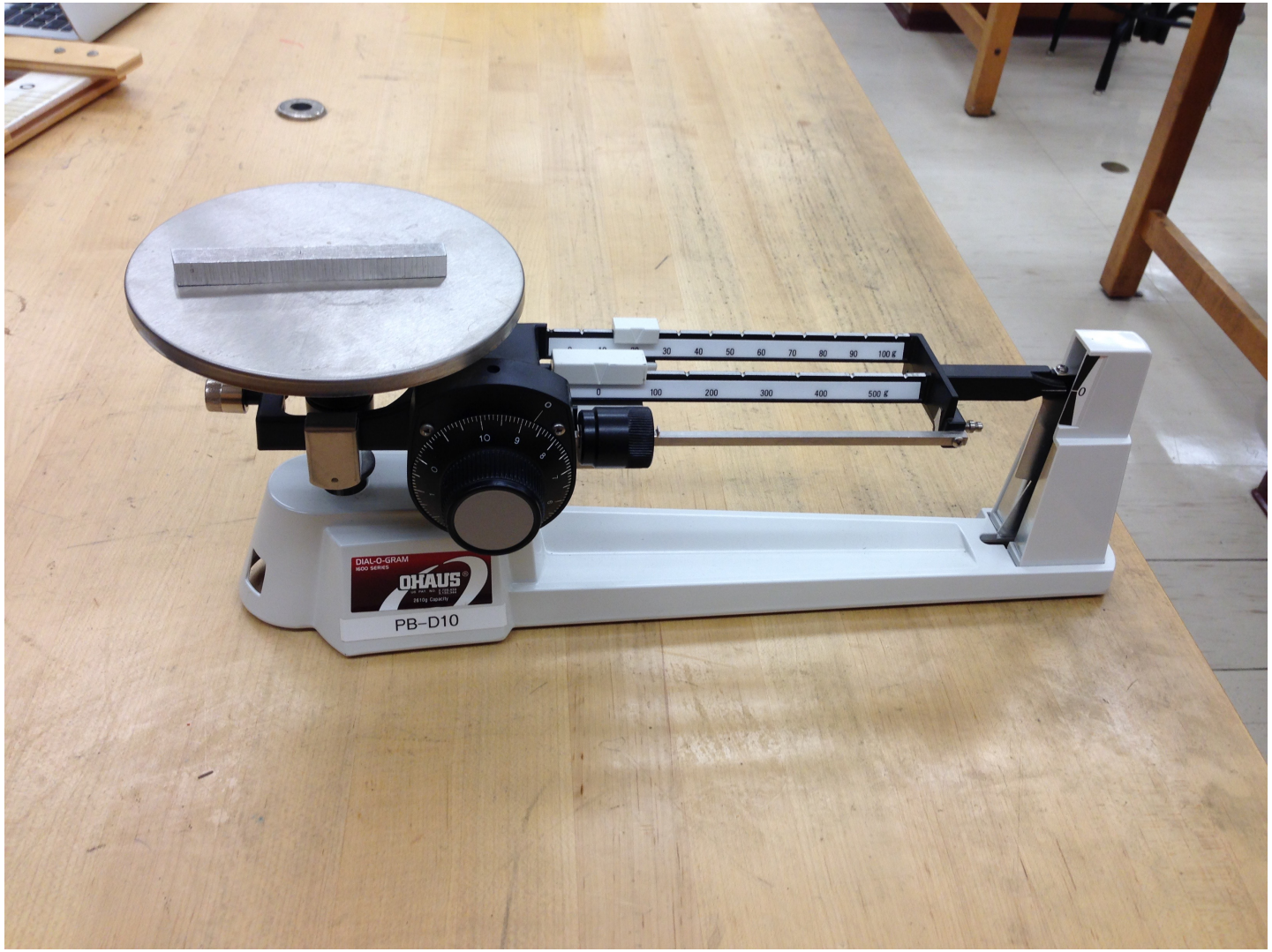
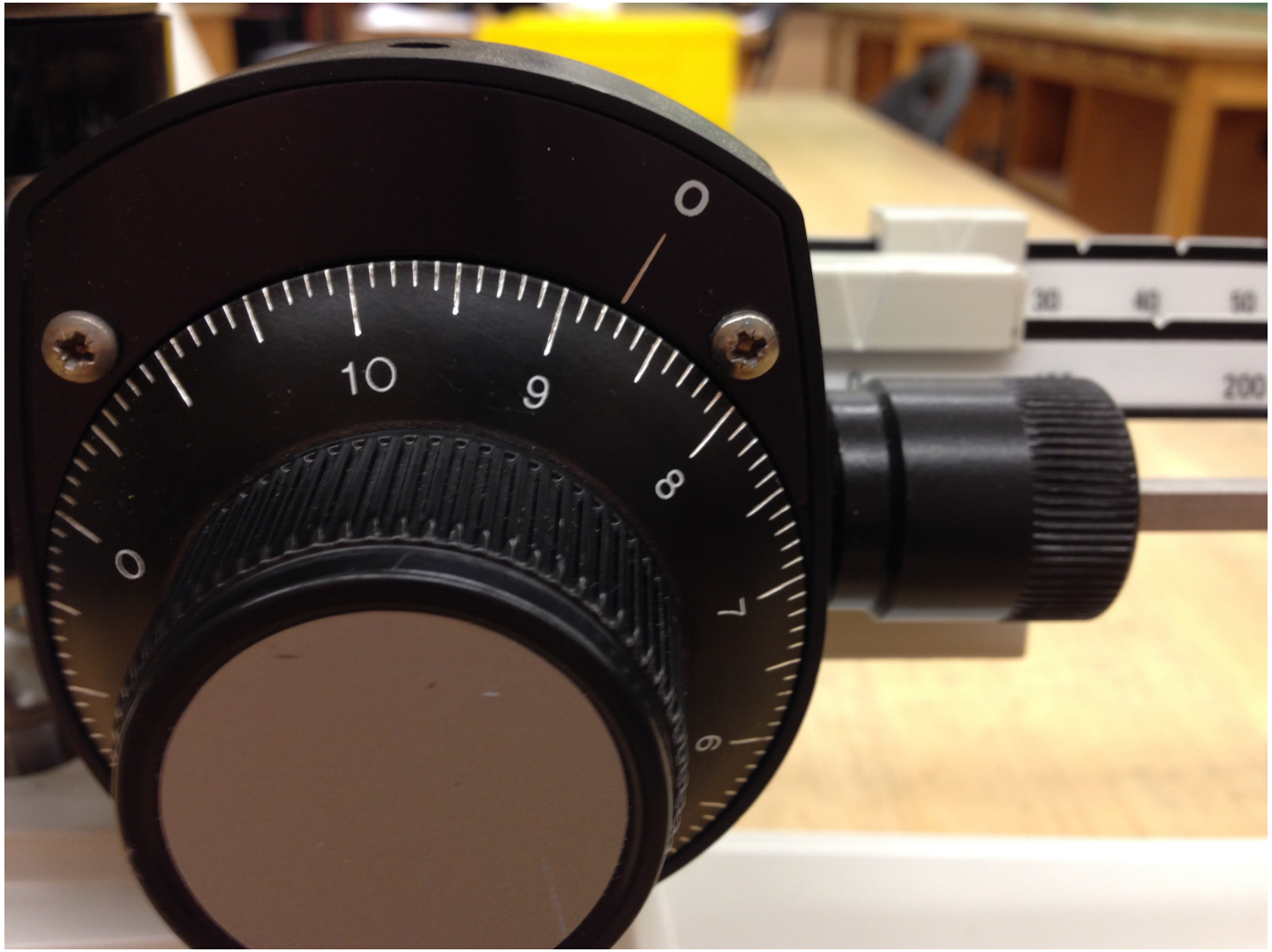


Course scale: 20 g

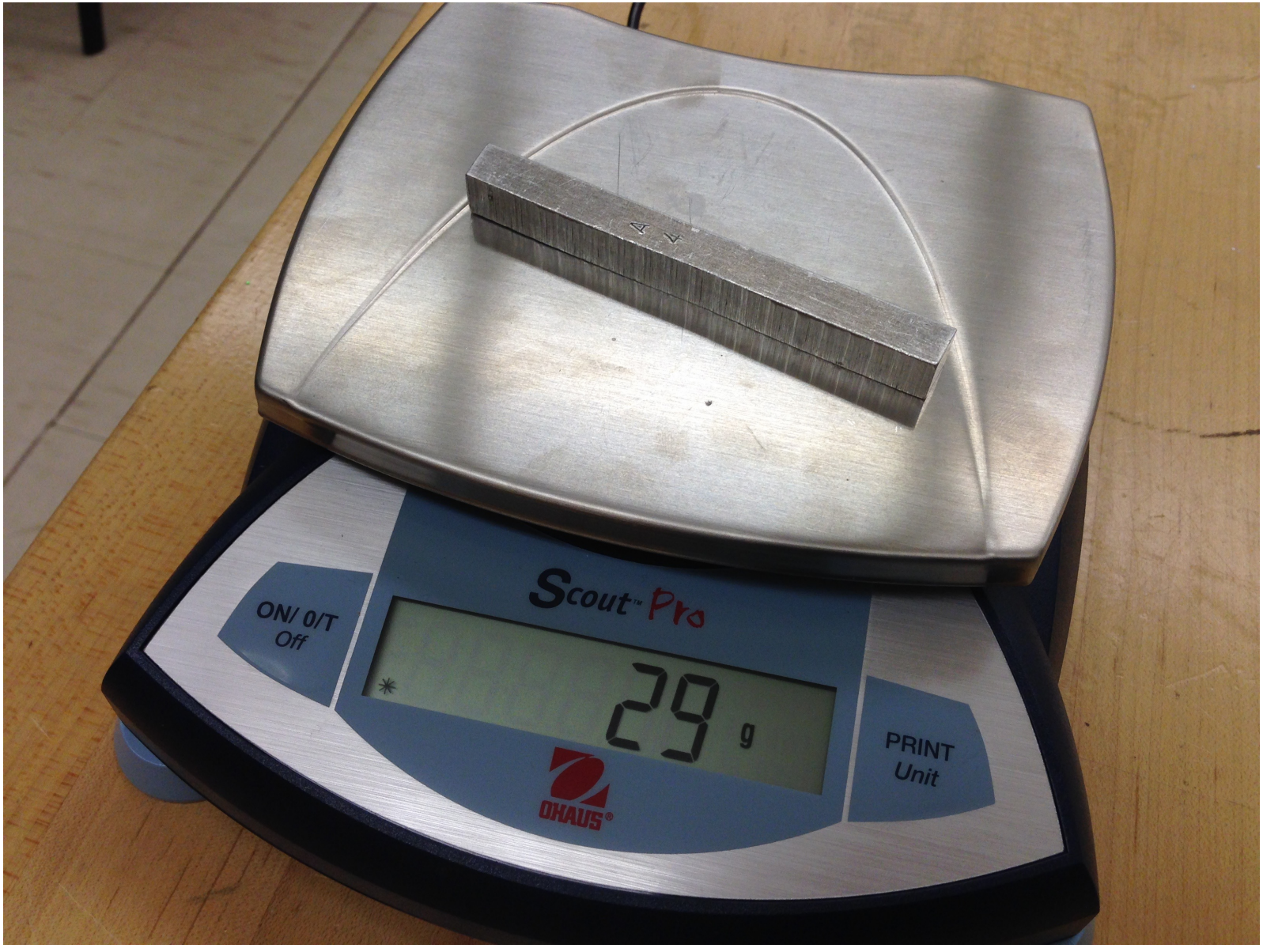
Pan Balance



Fine scale: 8.7(3) g

Best final answer: 28.73 g $\pm$ (uncertainty)

Digital Balance



Purpose of the Lab

You will use a ruler, vernier calipers, and micrometers, as well as a pan-balance and a digital balance, to measure the volume and mass of an aluminum block.

From those measurements you will deduce the density of the block and the uncertainty of your value.