Errors in Measuring

Any time someone makes a measurement there is an error in the measurement.

No one can measure perfectly.

This is widely known and perfectly acceptable in science.

What is unacceptable is not reporting the size of this error correctly.

Kinds of Errors

There are two basic kinds of errors

Systematic errors - like using a ruler that has one end “rounded off” so that what you think is a zero point is not really a zero point.

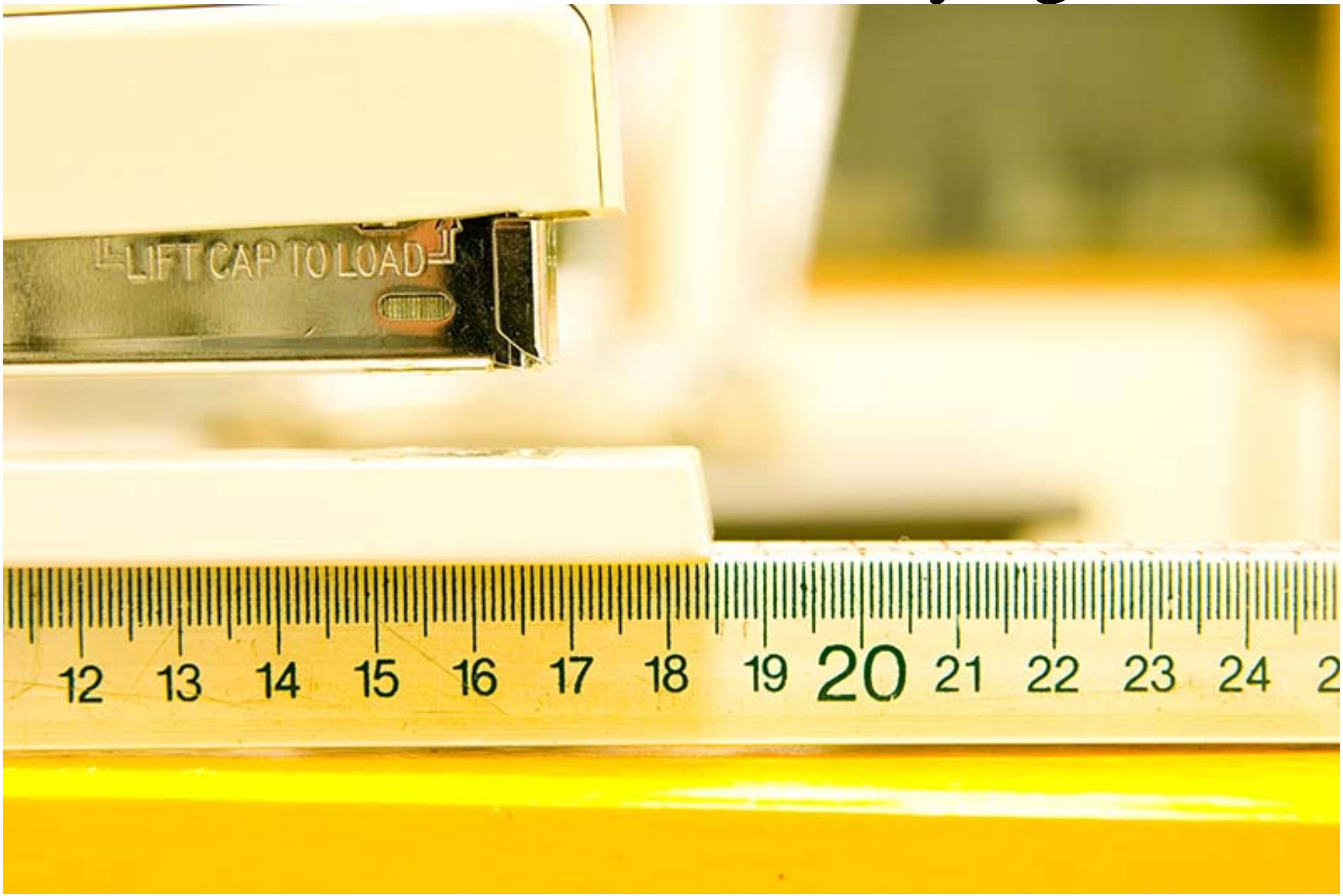
With good lab procedures systematic errors can be discovered and greatly reduced and sometimes even eliminated

Random errors - these are “noise” errors. Errors because of the limits of the measuring device.

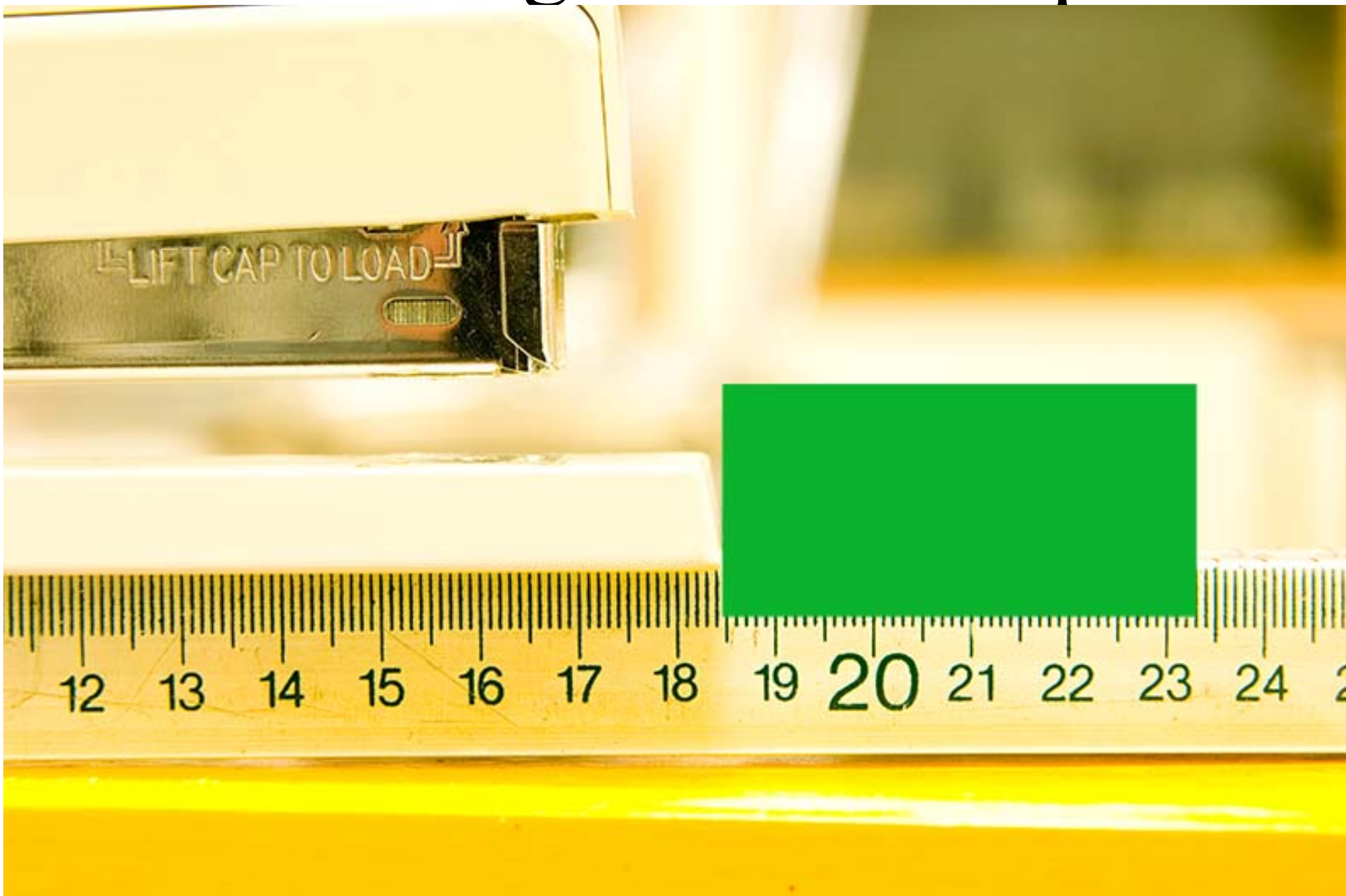
How long is the stapler?

How long is it now?

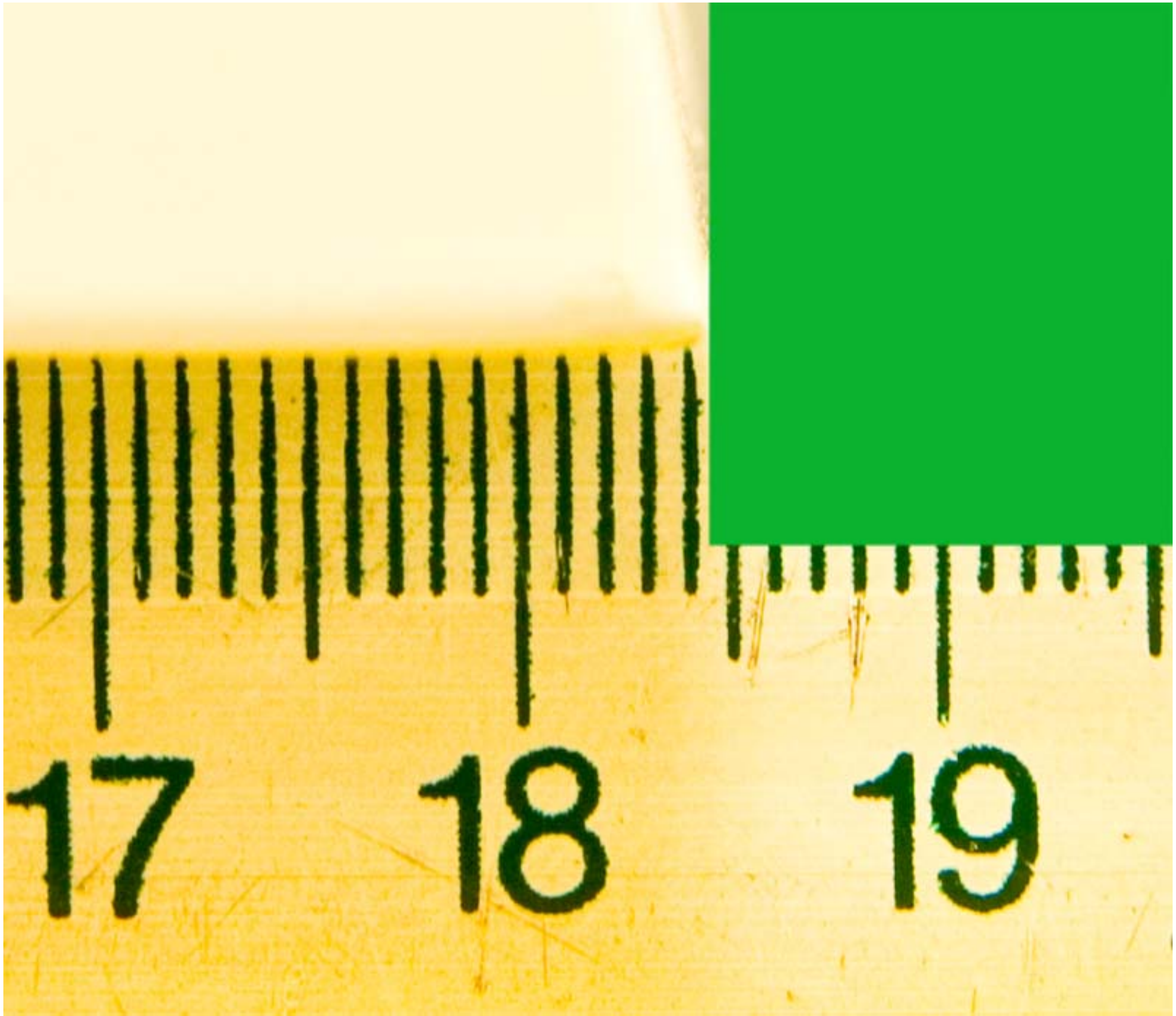
Get a better ruler and try again!



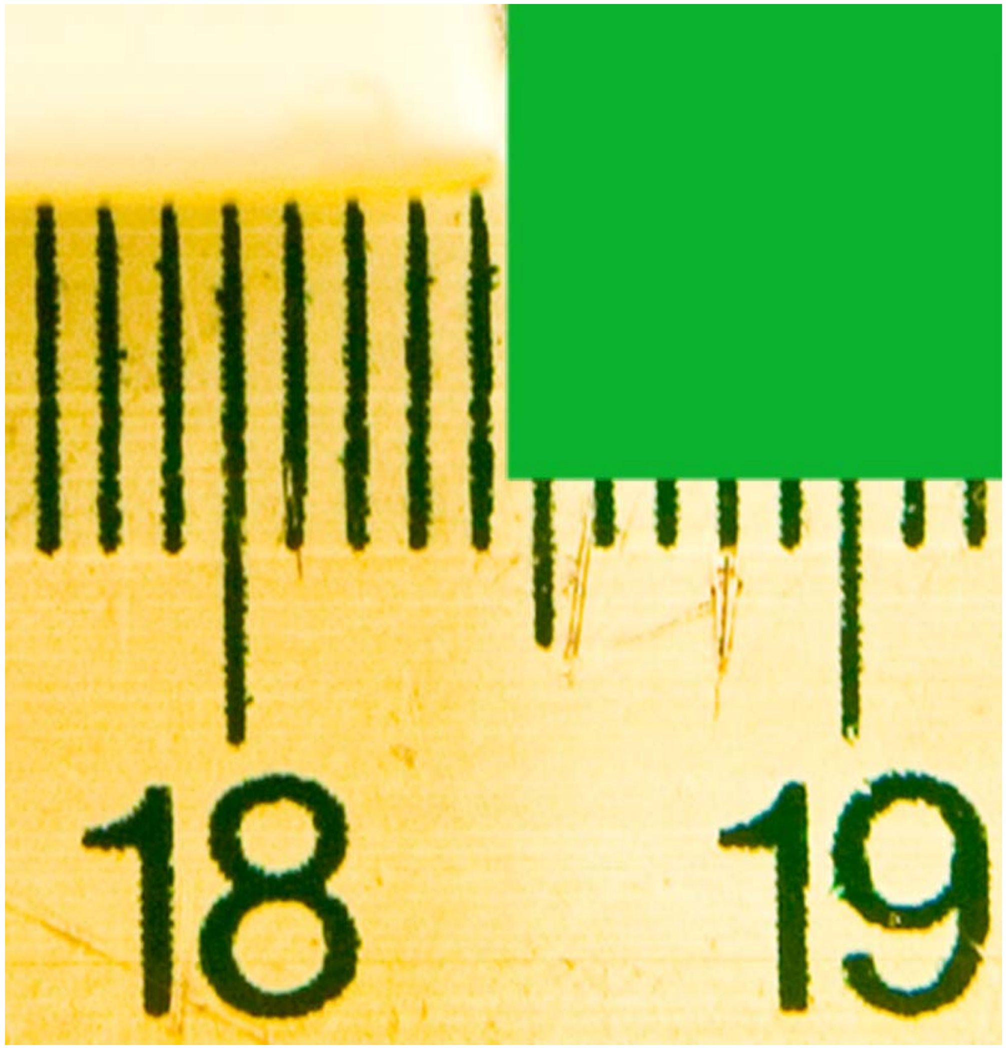
Did you think it was “exactly”… What if get a little help?



How about a closer look?



Even closer - what happens to the “lines” on the ruler?



Reporting Errors

We need to report accurately how much of the measurement is a "guess".

This is not too important in homework or test problems but is of extreme importance in lab reports.

In the example of the ruler we should be able to say 18.44 cm ± 0.02 cm.

This means that we can report with confidence the stapler is between 18.42 and 18.46 cm long.

Quality of Measurements

The quality of the measurement can be expressed with precision and accuracy.

Accuracy is a measure of how close a measurement is to the true value.

Accuracy is often expressed as a percent error from an accepted standard.

$\%$ error $= |A-O|/A \times 100$

A = accepted value

O = observed value

Quality of Measurements

Precision is the agreement between a set of numbers.

Measure the same event with a bunch of stopwatches.

How close together are each of the time measurements? Why are they not all the same?

When repeated measurements of the same object or event give results that are close together it is good precision, even if the value is not close to the true answer.

Quality of Measurements

During a 100 m race 5 timers measure 10.12 s, 10.14 s, 10.11 s, 10.13 s and 10.11 s. The "acutrack" timer measures 10.023 s.

This is good precision - the timers all have times that are grouped close together.

This is poor accuracy (depending on your perspective) because the timers are all off by about 1% from the "standard" timer.

Quality of Measurements

During another 100 m race the timers measure 10.15 s, 10.04 s, 10.26 s, 10.01 s and 10.35 s. The “acutrack” timer measures 10.152 s.

This is poor precision even though the accuracy if all the timers measurements are averaged. For good precision there should be no more deviation than ± 5 in the last recorded digit.

Quality of Measurements

Good precision and good accuracy mean that all of the measured numbers have only small variations.

Significant Figures

Significant Figures or Significant Digits are digits that are actually measured.

Digits that are not significant are those that only keep a place value.

Significant digits are important in correctly reporting the answers to calculations made in the lab (unless one does a full statistical error analysis).

The general rule is that the answer to a calculation must not have more significant digits than the term with in the calculation with the smallest number of significant digits.

Significant Figures

If you find the density of an object by dividing a measured mass of 12.45 g by a volume of 15.2 ml and report an answer of 0.819079 g/ml you are reporting an incorrect answer even though the calculations are correct.

The answer implies that you could measure 6 digits in both the mass and the volume but you did not.

The answer should be reported as 0.819 g/ml because it reports 3 digits - the same number of digits as the volume measurement.

Significant Figures

Which digits are significant?

If you do the measurements then every digit that you measure is significant.

The trouble often arises in looking at an other’s data.

Significant Figures

General rules:

1) If the digit is not a zero it is assumed to be actually measured.
2) If the digit is a zero and the **only** purpose of the zero is to hold a decimal place it is not considered significant unless some other notation is given.

Significant Figures

Examples:

350,000   2 significant digits - the trailing zeros give no indication of being measured.

$350{,}\overline{0}00$ 4 significant digits - the line over the zero indicates the last digit that was measured.

0.0035   2 significant digits - the leading zeros are only “place holders”

2.5600   5 significant digits - the trailing zeros do not need to be present to give value so the observer must have taken the time to measure them to be zero.