Lab Worksheet: Error Analysis

Check your work with your TA for completeness & credit

Determining the degree of uncertainty:

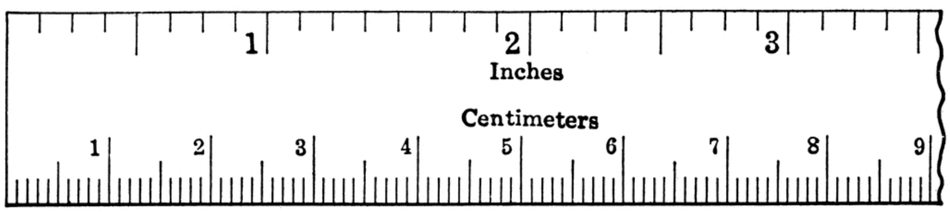
It is customary to report experimental results with the degree of uncertainty stated:

result = value measured ± uncertainty

This naturally raises the question of how do you estimate the uncertainty of a measured value? The answer to this question lies in determining the smallest fraction of the smallest division marked on a measuring device that can be estimated with reasonable accuracy.

Determining the least count and the Instrument Limit of Error (ILE):

The **least count** is the smallest division (graduation) that is marked on a measuring device. For example, the **ruler below has a least count of 0.125 (1/8) inches and 0.1 centimeters**. Notice the least count refers to the graduations (lines) on the measuring tool and not the numbers provided.



1) What is the least count for the following pieces of lab glassware in your locker? Include units.

a) 10 mL graduated cylinder: _________

b) 100 mL graduated cylinder: _________

c) 1 mL pluringe: _________

d) 3 mL pluringe: _________

e) 50 mL beaker: __________

f) 250 mL Erlenmeyer flask: _________

g) Consider the balances in the lab. Report the least count (smallest number) of the different types of balances below – choose any two with different digital readouts. You may need to go into the instrument room. Don't forget to include units!

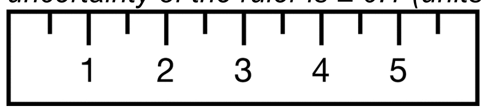
Balance #1 _______________

Balance #2 _______________

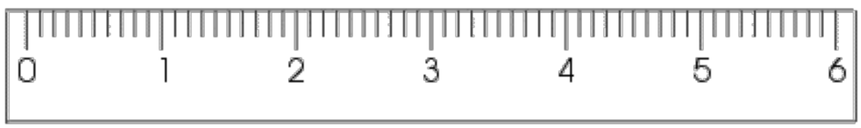
Read carefully and bring this worksheet to every lab.

The **<u>instrument limit of error (ILE)</u>** is the estimated accuracy to which a measuring device can be read. The ILE is a reflection of the uncertainty in measurements made with a particular device and is always equal to or smaller than the least count. The ILE is generally taken to be the least count or some fraction (1/2, 1/5, 1/10, etc.) of the least count. There are no set rules for which fraction of the least count to use in determining the ILE and different observers may report different ILE's.

- **If the space between the scale divisions is large**, you may be comfortable in estimating a fraction of 1/5 or 1/10 of the least count. A reader may estimate between the lines to 1/5 of the least count (0.5) in the figure below: 0.1, 0.2, 0.3, 0.4, or 0.5…
  (1/5 x 0.5 = 0.1). "*The uncertainty of the ruler is ± 0.1 (units not provided).*"



- **If the divisions are closer together**, you may only be able to estimate to the nearest 1/2 of the least count (0.1 cm). The reader may only estimate on the line or in between it in the centimeters ruler below: 0.05 cm or 0.10 cm…(1/2 x 0.1 cm = 0.05 cm). "*The uncertainty of the ruler is ± 0.05 cm.*"



- There are also situations where the divisions are so close to each other that you may only be able to estimate to the least count (smallest fraction = 1). The deciding factor is an evaluation of the smallest fraction of the least count that *you* can <u>accurately</u> estimate.
- **In digital readouts**, such as the balances, the reader has no say in determining the least fraction. *Consider how the last decimal place is determined*. There are many more sig figs than those provided so the <u>last decimal place was rounded either up or down</u>.

2) Estimate the ILE for the following instruments (include units for least count & ILE). If you are confused, carefully re-read the points above for examples. **Use distilled water to take one measurement with each device. Measure any amount within the capacity of the instrument. Report the measurement with proper sig figs and uncertainty (ILE).**

(Least Count) x (Fraction) = ILE

Table 1. Summary of Instrument Uncertainties

Equipment	**Least Count**	**Fraction**	**ILE**	**Measurement (value ± ILE with units)**
10 mL grad. Cylinder				
100 mL grad. Cylinder				
1 mL pluringe*				
3 mL pluringe*				
50 mL beaker				
250 mL Erlenmeyer flask				
Balance #1		**-**		
Balance #2		**-**		

Students will need to correctly identify **ILE**'s in the **lab reports** and the **exam.**

* Have your TA check your pluringe technique.

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B. Reporting the degree of uncertainty for individual measurements:

When discussing the systematic error of a particular measurement it is appropriate to express the standard error as a percentage of the volume being measured, percent intrinsic error (%IE).

% IE = (ILE / volume measured) x 100%

3) Calculate the % intrinsic error when a 10 mL graduated cylinder is used to measure the following volumes:

a) 1 mL:

b) 2.5 mL:

c) 5.0 mL:

d) 10.0 mL:

Which is the most practical volume to measure with a 10 mL graduated cylinder?

4) Calculate the % intrinsic error when 0.5 mL of liquid is measured using the following:

a) 10 mL graduated cylinder:

b) 1 mL pluringe:

c) 3 mL pluringe:

d) 50 mL beaker:

Which is best to use when measuring 0.5 mL?

5) General conclusions about when to use which piece of glassware:

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C. Vocabulary

In scientific research collecting and reporting quantitative data requires the experimenter to declare the extent to which they are certain that the results reported are due to the experimental conditions and not due to random chance or errors in data collection or analysis. In other words, scientists must state the degree of accuracy and reproducibility for the results reported. In reality, accuracy and reproducibility are actually expressed in terms of the level of uncertainty associated with the measurements used to generate data.

6. Experimental results may be described in terms of (write a definition for each term):

a) Accuracy:

b) Precision:

c) Reliability:

7. In the space provided, write brief definitions for the following sources of uncertainty in measurements:

a) Human (experimenter) error:

b) Intrinsic (systematic) error:

c) Indeterminate (random) error:

8. In general, an error analysis for an experiment does not include __________________ error because this type of error is usually the result of carelessness on the part of the experimenter.

9. The ____________ error can be assessed by making multiple measurements and reporting the average and standard deviation.

10. The ____________ error for a measuring device like a graduated cylinder can be assessed by determining the ILE from the least count.

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