1.1-Experimental Error

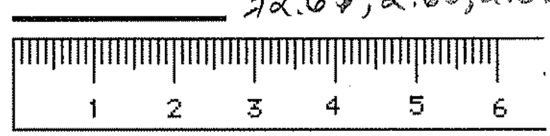
There is no such thing as an "exact" measurement in science. All measurements using any type of measuring instrument involve some error or uncertainty. In general, there are two types of errors in making measurements. These are 1) **instrument uncertainty** and 2) **human error**.

Instrument Uncertainty

Every measuring instrument, whether it be an inexpensive ruler or a multi-million dollar atomic mass spectrometer, has a limit to its precision.

2.64, 2.65, 2.66.

Consider the ruler segment shown at the right. How would you report the length of the line shown?



To properly read a measuring instrument with a scale you record as many "exact" digits as possible then end with one **"guess" digit**. The last digit in a measurement (the guess digit) locates the region of uncertainty of the device. For example, one person might read the length of the line in the above diagram as 2.65 cm while a second person might record the length as 2.66 cm. However, no one should read the length as 2.65**63**. The underlined numbers in the previous example have no scientific meaning. Why? – can't have 2 guess digits

Precision- is how close you can get to an exact value. This may be determined by the place of the guess digit in an observation. The ruler in the above diagram is precise to the nearest hundreth. of a cm.

Human Error

Using a precise stopwatch, try measuring the time it takes for a coin to drop from your eye level to the floor. Repeat this measurement several times. If you do, you might end up with data such as in the following table:

Trial #	Time	Trial #	Time
1	0.281 s	2	0.263 s
3	0.238 s	4	0.255 s

Note that the stopwatch is precise to a thousandth of a second, however, the measurements differ in the hundredth decimal place. In this case human error is greater than the instrument uncertainty. Human error usually involves "judgment calls" on the part of the person doing the measuring. For example, the stopwatch is started when the observer thinks the coin is just beginning to fall; it is clicked again when the observer hears the coin hit the floor.

Because of its complexity human error is difficult to define. The best way to handle human error in these types experimental situations is to assume that human error is random. That is, sometimes your measurement is too small, sometimes too large. This means that you should average your results.

Therefore, the best result for the coin drop experiment would be...

Best result = $\frac{0.281 + 0.238 + .263 + .255}{4} = 0.25925 = \boxed{0.26}$

* The above average was rounded to two decimal places because that was where the human error affected the data.

Note: there is a big distinction between human error and human mistakes. **Human error is unavoidable** no matter how careful the observations are made. **Mistakes are avoidable**. If a mistake is made during a series of measurements, then, disregard it. Do not include mistakes in the average.

For example, if a student recorded the following five times for an identical event to occur:
1.67 s, 1.69 s, 1.60 s, 2.21 s and 1.65 s, then the 2.21 s observation should be thrown out.

Best result = $\frac{1.67 + 1.69 + 1.60 + 1.65}{4} = 1.6525 = \boxed{1.65}$

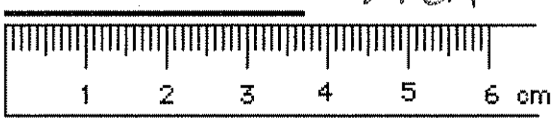
note: always record the error, but exclude from calc's.

Exercises (experimental error)

1. In the spaces provided below record the measurement for each measuring instrument.

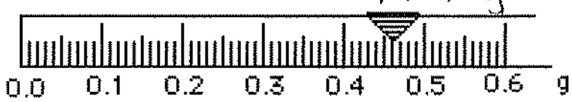
1a

3.74 cm



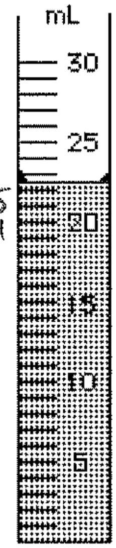
1b

,461 g



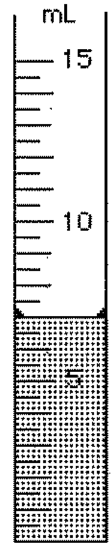
1c

22.5 ml



1d

7.0 mL ↙ guess #



	1a	1b	1c	1d
measurement -->	3.74cm	0.461g	22.5ml	7.0ml

2. Two types of balances are used to measure the mass of a nail. With one balance a mass of 2.0 g is recorded and a mass of 2.000 g is obtained from the second balance. Mathematically, these results are identical, but, scientifically they are not. Explain.

- the second scale is precise to the thousandth. while the 1st is only precise to the tenth.

3. A student wants to determine the time it takes for a cart to roll down an incline. An identical procedure is repeated four times and time measurements are made for each trial. The results are summarized in the table.

Trial #	Time	Trial #	Time
1	11.5 s	2	10.3 s
3	10.3 s	4	10.1 s

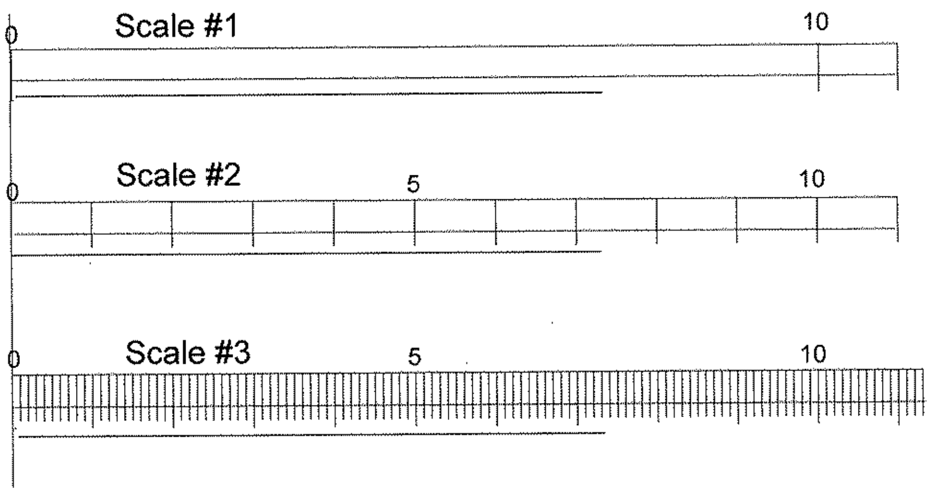
Explain the variation in the times and calculate the average time to the correct precision

- human error in trials 2-4, human mistake for trial #1 ∴ throw out that data.

Avg = $\frac{1}{3}(10.3 + 10.3 + 10.1)$ = $10.2\overline{3}$ = 10.2

Instrument Precision

A)



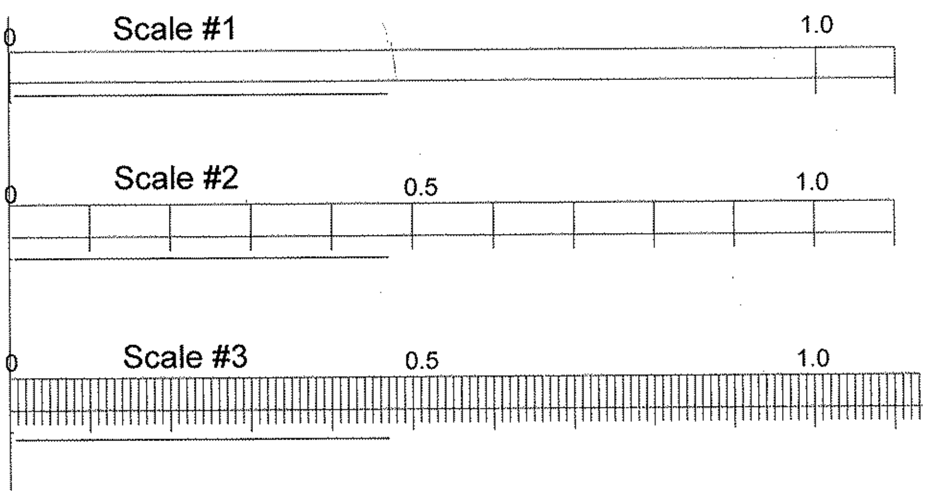
Length of Line

Scale #1
7

Scale #2
7.3

Scale #3
7.35

B)



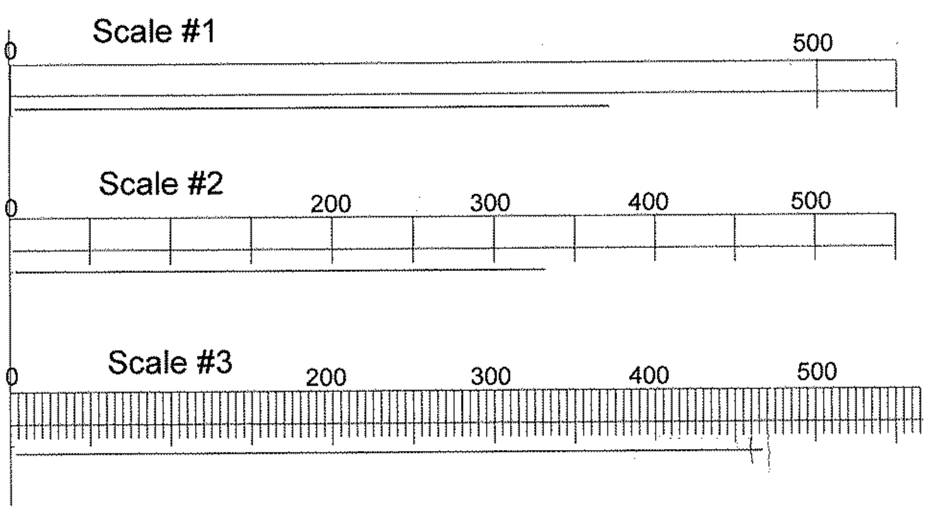
Length of Line

Scale #1
0.5 / 0.4

Scale #2
0.48

Scale #3
0.475

C)



Length of Line

Scale #1
400

Scale #2
340

Scale #3
469