Name _____ Date _____

GRCI PHYSICS

Significant Figures

The **precision** is determined by how finely divided the instrument's scale is. Precision is **plus or minus (±) half of the smallest unit** on the instrument's scale. (Engineers and machinists call precision "the tolerance"). The finer (smaller) the divisions the greater the precision is. If the mass had been recorded as 1.3 g then the precision was ±0.05 g.

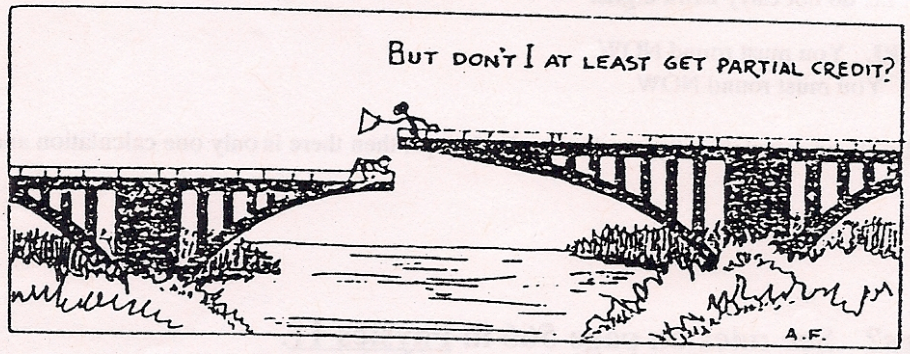
When measuring, a person must not to estimate between the lines on the scale. The last digit is "rounded" to the nearest line. Thus the last digit in a measurement is always doubtful.

Accuracy concerns itself with the truth of digits in a measurement. Does the person trust the digits that are shown? Errors that affect the accuracy of a measurement are called systematic errors. Examples of such errors are:

(a) balance not zeroed correctly,
(b) warped instrument,
(c) markings on instrument were made incorrectly.
(d) parallax and
(e) dirty instruments.

Systematic errors have no place in well-done laboratory work. They can always be minimized by careful work.

Precise but not Accurate!



Addition and Subtraction

WHEN ADDING OR SUBTRACTING, ADD OR SUBTRACT, THEN ROUND OFF THE ANSWER TO THE LEAST NUMBER OF COLUMNS CONTAINED IN THE MEASUREMENTS.

Example:

27.8 h	3500 ± 50 m	- 35XX
1.364 h	141 ± 0.5 m	- 141
0.6 h	830 ± 5 m	- 83
29.764 h	4471 m	- 45XX
~29.8 h	~4500 m or 4.5×10^3 m	

Multiplication and Division

WHEN MULTIPLYING OR DIVIDING, THE ANSWER HAS THE SAME NUMBER OF SIGNIFICANT FIGURES AS THE MEASUREMENT WITH THE LEAST NUMBER OF SIGNIFICANT FIGURES.

Thus if you multiply a 2-significant digit measurement by a 3-significant digit measurement the answer should have two significant figures.

Examples:

$0.12 \text{ m} \times 0.345 \text{ m} = 0.0414 \text{ m}^2$
$\sim 0.041 \text{m}^2$

$0.345 \text{ kg} / 0.12 \text{ m}^3 = 2.875 \text{ kg/m}^3$
$\sim 2.9 \text{ kg/m}^3$

Combinations of the Above Rules

If one must do an addition (or subtraction) before doing a division (or multiplication) in one larger calculation, them one must round after the addition before doing the division. Then using the rounded number do the division to the proper significant digits

$$\text{Percent} = \frac{32\,g + 21\,g + 85\,g}{598\,g} \times 100 \qquad \text{Percent} = \frac{84.9\,m - 85.8\,m}{85.8\,m} \times 100$$

$$\text{Percent} = \frac{138}{598} \times 100 \qquad \text{Percent} = \frac{-0.9}{85.8} \times 100$$

$$\text{Percent} = 23.1 \qquad \text{Percent} = -1$$

Multiple Step Calculations

If a calculation takes 2 separate steps, using the same rounding rules, then you must still round after the first step. Do not carry all the digits on the calculator display. i.e. do not carry extra digits.

e.g. Step 1 $\lambda = 4 \times RL$ You must round NOW.
Step 2 $f = v/\lambda$ You must round NOW.

However if you choose to do the above calculation by combining the 2 steps, then there is only one calculation and one rounding operation.

e.g. $f = v/4 \times RL$

Problems with Zeroes? See rules on page 566 in Physics 11.

1009 s - 4 significant figures
0.180 s - 3 significant figures
0.0019 s - 2 significant figures
0.0190 s - 3 significant figures
7000 g - ambiguous and should be avoided. Use scientific notation or state precision.
7.0×10^3 g - 2 significant digits
7.00×10^3 g - 3 significant digits
7000 ± 5 g - 3 significant digits
7000 ± 50 g - 2 significant digits

Exact Numbers

Exact numbers do not affect the number of significant figures. Exact numbers have an infinite number of digits.

In science there are many examples of exact numbers:

Converting units does not change the number of significant digits. All the prefixes in System International are exact numbers.

The number of protons and neutrons in a nucleus are exact. It is impossible to have a fraction of either particle. Thus if you say there are 6 protons in a carbon atom you mean that there are 6.0000...(with an infinite number of zeroes.)

The "100", when multiplying by 100 to get percent, is exact and does not affect the number of significant figures.

The denominator when calculating an average is exact and does not affect the number of significant figures.

The "2" in "$2\pi r$" when calculating circumference is exact.

Constants

Calculators, encyclopedias, online resources and other textbooks will give values with different numbers of significant figures for the same measured constants such as Avogadro's constant, the speed of light, the gravitational constant, the specific heat capacity of substances etc.

You are expected to use the constants as given to you by your teacher. The number of significant figures given with a constant reflects what a person is able to measure in the labs at GRCI.

Rounding Rules

1. If the number dropped is greater than 5, then add 1 to the digit to its immediate left. **eg. 88.6 becomes 89**
2. If the number dropped is less than 5, then do NOT change the digit to its immediate left. **eg. 71.3 becomes 71**
3. If the number dropped is a 5 then always round the digit to its immediate left so that the digit is always an even number.
   eg. 6.35 becomes 6.4 and 2.65 becomes 2.6

QUESTIONS Answer on lined note paper.

1. (a) Explain the difference between accuracy and precision in your own words.
   (b) What are the significant digits in a measurement?

2. Suppose that you have just taken the last ruler for a lab exercise and its markings are worn off at the edges. You have to do the lab. What should you do? What kind of error is this?

3. How many significant figures do each of the following measurements have?
   (a) 60 003 h
   (b) 600 ± 5 m
   (c) 0.000 93 s
   (d) 930 400 ± 0.5 g
   (e) 23 000 ± 500 h
   (f) 925 000 km

4. Please add or subtract the following, to the correct number of significant figures:
   (a) 637.415 g + 21.21 g + 7435.1 g
   (b) 95.2 s + 9.25 s + 915 s
   (c) 7.43 g - 1.6 g
   (d) 0.452 m - 0.3 m
   (e) 12.043 5 m - 4.241 m + 76.21 m

5. Please multiply or divide to the correct number of significant figures:
   (a) 2.5 cm^2 x 491 cm
   (b) 17.5 m/s / 5 s
   (c) 6314 m x 8.1 m
   (d) 12.5 kg x 1014 m x 13 m/s^2
   (e) 9672 m^3 / 301 m^2

6. Please do the following calculations to the correct number of significant figures.
   (a) (4.26 - 4.31)/4.31
   (b) ((5.11 x 3.49)/2 - s
   (c) 6314 m x 8.1 m
   (d) 12.5 kg x 1014 m x 13 m/s^2
   (e) 9672 m^3 / 301 m^2

7. What are exact numbers and how many significant digits do they have?