Name: ______________________

Date: ________________

Block: ________

Measurement and Uncertainty

Differentiated worksheet

Learning objectives:

I can use different mathematical skills to find the accuracy and precision in measurements

Success Criteria:

- Differentiate between accuracy and precision
- Apply the significant figures rules
- Develop a method to deal with scientific notation formula
- Solve mathematical equations
- Use the unit conversion method

Moderate achievers, High achievers, Gifted and talented

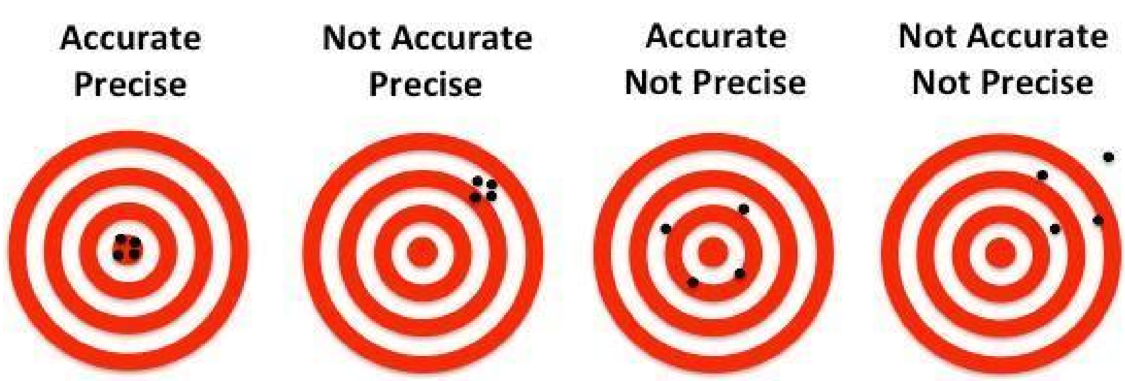
There is uncertainty in every measurement due to _________________________ of accuracy and precision.

Accuracy: how close the instrument measures to an accepted ____________________________________.

Precision: how closely two or more measurements of the same thing agree when ____________________

____

care by the same instrument.



Each instrument has its own actual uncertainty that can only be obtained by experiment (i.e. finding the variation in values from repeated measurements).

Summary

- Accuracy of a measured value refers to how close a measurement is to the correct value. The uncertainty in a measurement is an estimate of the amount by which the measurement result may differ from this value.
- Precision of measured values refers to how close the agreement is between repeated measurements.
- The precision of a *measuring tool* is related to the size of its measurement increments. The smaller the measurement increment, the more precise the tool.
- Significant figures express the precision of a measuring tool.
- When multiplying or dividing measured values, the final answer can contain only as many significant figures as the least precise value.
- When adding or subtracting measured values, the final answer cannot contain more decimal places than the least precise value.

SIGNIFICANT FIGURES

All ***Measurements*** have some degree of uncertainty to them (due to the instrument used.)

To indicate the degree of certainty in a measurement (or a number derived from a measurement), scientists use ***significant figures.*** Or numbers they know to be 100% accurate.

**** Significant figures are important in the way we report different kinds of data!**

A significant figure is a **measured** or **meaningful digit**

A. What is Not Significant?

Defined or counting numbers: A number which involves things which cannot realistically be subdivided.

Example:
1 book; 4 students (cannot have 1.5 books or 4.78 students)
Conversion factors are assumed to be an exact relationship (cannot have 1 kg = 1000.5 kg)

Rules for identifying # of sig figs:

a) An exact number (e.g. 25 students) has an infinite number of significant figures because the number was not rounded off. Exact numbers are not used to determine the significant digits.
b) For all measurements, the following rules apply to count the number of significant figures a number has.

1. Any digit between 1-9 is significant.
e.g. 234.566 has ***6*** sig figs
7.4586 has sig figs

2. A '0' at the beginning of a number is ***not significant*** because it only holds the decimal place. ***Leading zeros are NOT significant***

e.g. 0.00045 has ***2*** sig figs
0.02333 has sig figs

3. A '0' between two other sig figs is significant.
e.g. 50034.03 has ***7*** sig figs
e.g 534.034201 has sig figs

4. A '0' at the end of a number is only significant IF a decimal point occurs in the number otherwise it is not significant. ***Be careful with this one!***

e.g. 750000 has ***2*** sig figs
20000000 has sig fig
e.g. 750.000 has sig figs

Example:

If a balance gives a reading of 97.53 g when a beaker is placed on it, the reading is considered to have 4 significant figures. If the beaker is then put on a different balance and gives a reading of 97.5295 g, there are more significant figures to the measurement (6 significant figures).

How many significant figures do each of the following measurements have?

1. 1.25 kg ____________________
2. 1255 kg ____________________
3. 11s ____________________
4. 150 m ____________________
5. 1.283 cm ____________________
6. 365.249 days ____________________
7. 2 000 000 years ____________________
8. 17.25 L ____________________

B. <u>Scientific Notation</u>

Scientific Notation is a way of writing numbers for values too large or small to be conveniently written in standard decimal notation.

Example:

$10 = 1.0 \times 10^{1}$
$25 = 2.5 \times 10^{1}$
$250 = 2.5 \times 10^{2}$
$0.000\,0350\,000 = 3.5000 \times 10^{-5}$

Write the following numbers in scientific notation: 1.

3570 ____________________

2. 41.400 ____________________
3. 0.000 572 ____________________
4. 41.50×10^{-4} ____________________
5. $0.000\,410 \times 10^{7}$ ____________________

C. Adding or Subtracting Significant Figures

When adding or subtracting significant figures, round off the answer to the least number of decimal places contained in the calculation.

Example:

12.56 cm *(2 SF after decimal)* + 125.8 cm *(1 SF after decimal)* = 138.36 cm → 138.4 cm *(1 SF after decimal)*

Exercise:

1. 15.1 + 75.32

2. 178.904 56 – 125.8055

3. $4.55 \times 10^{-5} + 3.1 \times 10^{-5}$

4. $1.805 \times 10^{4} + 5.89 \times 10^{2}$

Multiplying or Dividing Significant Figure

When multiplying or dividing significant figures, round off the answer to the least number of significant figures contained in the calculation.

Example:

2.00 *(3 SF)* x 3.000 00 *(6 SF)* = 6.00 *(3 SF)*

Exercise:

1. 12.5 x 0.50

2. 0.15 x 0.0016

3. 40.0 / 30.000

4. 2.5 x 7.500 / 0.150

5. $(6.40 \times 10^{8}) \times (5 \times 10^{5})$

6. 4.37×10^{3} / 0.008 560 0

7. $0.51 \times 10^{-4} / 6 \times 10^{-7}$

8. 0.000 01 / 0.1000

Summary Practice Exercises:

In the following mixed calculations, perform multiplications and divisions before doing the additions and subtractions. Keep track of the number of significant figures at each stage of a calculation.

1. 25.00 x 0.100 – 15.87 x 0.1036

2. 35.0 x 1.525 + 50.0 x 0.975

3. (0.865 – 0.800) x (1.593 + 9.04)

4. (0.3812 - 0.4176) / (0.0159 – 0.0146)

5. 9.34 x 0.071 46 – 6.88 x 0.081 15

Significant Figures Worksheet

Significant Figures

1. Indicate how many significant figures there are in each of the following measured values.

246.32	______________	1.008	______________	700000	______________
107.854	______________	0.00340	______________	350.670	______________
100.3	______________	14.600	______________	1.0000	______________
0.678	______________	0.0001	______________	320001	______________

2. Calculate the answers to the appropriate number of significant figures.

$$\begin{array}{r} 32.567 \\ 135.0 \\ \underline{+\ \ 1.4567} \end{array} \qquad \begin{array}{r} 246.24 \\ 238.278 \\ \underline{+\ 98.3\ \ \ } \end{array} \qquad \begin{array}{r} 658.0 \\ 23.5478 \\ \underline{+\ \ 1345.29\ \ } \end{array}$$

3. Calculate the answers to the appropriate number of significant figures.

a) 23.7 x 3.8	=	______________	f) 1.678 / 0.42	=	______________
b) 45.76 x 0.25	=	______________	g) 28.367 / 3.74	=	______________
c) 81.04 g x0.010	=	______________	h) 4278 / 1.006	=	______________
d) 6.47 x 64.5	=	______________	i) (6.8 + 4.7) x 17.44	=	______________
e) 43.678 x 64.1	=	______________	j) (320. - 22.7) x 3.8	=	______________

k) $\dfrac{(14.86 + 13.7) \times (65.346 - 4.10)}{(43.888 - 32.888)}$ = ______________

AP Physics

Name_______________ Date _______________ Per. _______________

#

Sig Figs & Units Worksheet

1. How many significant figures are there in each of the following?

a. 273.16 ________ e. 2,000,000 ________ i. 5280. ________

b. 186,000 ________ f. 13.8 ________ j. 708.003 ________

c. 505 ________ g. 0.00928 ________ k. 0.0652 ________

d. 1000 ________ h. 60.080 ________ l. 3.040×10^5 -______

2. In the following, convert numbers in common notation to scientific notation, or vice versa.

a. 93,000,000 ________________________

b. 0.000019 ________________________

c. 606.39 ________________________

d. 2.997×10^{10} -________________________

e. 6.02×10^{-5} -________________________

f. 2.5359×10^2 -________________________

3. In the following, how many decimal places will the solution have? DO NOT SOLVE.

a. 6.0 m + 10.73 m + 111.250 m __________

b. 4050 L – 2.06 L __________

c. 96.75 km + 108.43 km + 77 km __________

d. 93.4 cm + 10.975 cm __________

e. 0.005070 cm + 6.90 cm + 2000.860 cm ______

f. 10.970 mL – 5.0 mL __________

4. In the following, how many digits should be in the solution to have the proper number of sig figs? DO NOT SOLVE.

a. (797.6 m)(54 m) _________

b. (851 cm)(24.3 cm) _________

c. 1075 kg ÷ 15 L _________

d. 93.4 m ÷ 10.975 m _________

e. $(6.02 \times 10^{23}$ m)(12.00 m)$(1.660 \times 10^{-24}$ m) ________________________

f. (453.6 m)$(9.050 \times 10^4$ m)(239.1 m) _________

Solve the following problems, expressing the answer in the proper number of sig figs.

5. Express the sum of 20.6 mm, 49.5 cm and 5.03 m in meters

6. If 22.5 L of gasoline is drawn from a tank originally containing 65 L of gasoline, what volume of gasoline remains in the tank?

7. What is the area of the bottom of a tank 30.0 cm long and 15.0 cm wide?

8. If the tank in Problem 7 has a volume of 2.25×10^4 cm^3, what is its height?

9. How many centimeters are there in 35.0 inches?

10. What is the distance, in kilometers, of a 2.5 mile cross-country course?

Math Review

Fill in the following table for the following quantities and their symbols:

Quantity	Unit	Symbol
length	meters	m
mass		
time		
force		
energy		
power		
speed		
frequency		

Complete the following conversions

1. 4 km = m
2. 54 mm = m
3. 0.394 Mg = g
4. 4000 ms = s
5. 4 dl = l
6. 70 dam (deka meters) = m
7. 4 Gg = cg
8. 9 000 000 µm = km
9. 4000 s = h
10. 67 m^2 = cm^2

Example 1:

3000 cm = km

$$3000\ cm \times \frac{1\ m}{100\ cm} \times \frac{1\ km}{1000\ m} = 0.03\ km$$

Example 2:

3 m^3 = ______ cm^3

$$3\ m^3 \cancel{\times \frac{(100\ cm)^3}{(1\ m)^3}} = 3\ m^3 \times \cancel{\frac{(1\,000\,000\ cm^3)}{(1\ m^3)}} = 3\,000\,000\ cm^3$$

Rounding:

5 and up → round up   4.55 → 4.6

4 and down → round down   4.54 → 4.5

Significant Figures:

All non-zero numbers count. Zeros to the left never count. Zeros in the middle always count.
Zeros to the right count only if there is a decimal in the number.

Example: 0.00050600 This number has 5 sig figs because the four zeros to the left of the 5 don't count. The 5 and 6 count. The 0 in the middle counts. The two zeros to the right of the 6 count because there is a decimal in the number.

Example: 567, 000 This number has 3 sig figs because the 5,6,and 7 count, but the zeros to the right do not count since there is no decimal in the number.

Round the following numbers to 2 sig figs:

1. 35.67 →	______________	6. 0.0102 →	______________
2. 0.0004567 →	______________	7. 99536 →	______________
3. 2.34 x 10^4 →	______________	8. 1.0326 →	______________
4. 4.777 x 10^{-6} →	______________	9. 156.21 →	______________
5. 23.333 →	______________	10. 9.75 →	______________

Multiplication / Division: This is the most common rule for sig figs we will be using. Use this for all multiplication or multifunction equations. Use the **lowest number of total sig figs** in your equation for your answer.

Example: 6.5 m x 687.3 m = 4467.645 m, but because of sig figs, your answer will be 4.5x10 [illegible] m
(2) (4) (7) (2)

Addition / Subtraction: If you have a situation where you are only using addition and / or subtraction you should use this rule for sig figs. Look at the number of **decimal places** and use the smallest number of decimal places in your answer.

Example: 3.456 s + 22.55 s = 26.006 s, but because of sig figs, your answer will be 26.0 1 s.
(3) (2) (3) (2)

Solve the following equations and leave the answers with the correct number of sig figs:

1. 23 + 4.8 = ______________
2. 234.67 x 34 = ______________
3. 4567 / 2.45 = _____________
4. 2.56 + 0.89 = _____________
5. 2345.8 x 23.2 = ______________

Percent Uncertainty:

If something is measured to be 12.3 cm +/- 0.5 cm. What is its percent uncertainty?

$\frac{0.5 \text{ cm}}{12.3 \text{ cm}}$ x 100% = 4% uncertainty

It is important to know how big the uncertainty is compared to the actual measurement. 0.5 cm error would be a lot if your measurement was only 2.1 cm! That would amount to an error of 24% instead of only 4%
(0.5 / 2.1) x 100% = 24%

To emphasize this point, consider this; 1 cm error when you are measuring 100 000 cm isn't much, therefore almost negligible. Your calculated % error would be low. 1 cm error when you are measuring only 10 cm is a concern. Your % error would be much higher.

Entering very big and very small numbers into your calculator.

Say this… " **…times ten to the…**".
Pressing [2nd] [EE] on your calculator is the equivalent of saying " times ten to the".

So, how do you enter 4 x 10^5 into your calculator.
You would say this in the following way " 4 times ten to the 5".
You would enter into your calculator the following….

[4] [2nd] [EE] [5]

Enter these problems into your calculator…

(3.9 x 10^7) x (2 x 10^2)

[3] [.] [9] [2nd] [EE] [7] [x] [2] [2nd] [EE] [2] [enter]

Your answer should be….?

$(3.9 \times 10^{-7}) \times (2 \times 10^{2})$

3	.	9	2nd	EE	(-)	7	x	2	2nd	EE	2	enter

Your answer should be….?

$(-3.9 \times 10^{-7}) \times (2 \times 10^{2})$

(-)	3	.	9	2nd	EE	(-)	7	x	2	2nd	EE	2	enter

Your answer should be….?

Use your calculator to answer the following….

$(3 \times 10^{3}) \times (2 \times 10^{2}) =$

$(3 \times 10^{3}) + (2 \times 10^{-2}) =$

$(-3 \times 10^{-3}) / (2 \times 10^{2}) =$

$(3 \times 10^{3}) - (2 \times 10^{2}) =$

$(3 \times 10^{3}) \times (2 \times 10^{-2}) =$

$(-3 \times 10^{-3}) \times (2 \times 10^{2}) =$

+

1. Conversion

Science uses the ***KMS*** system (***SI***: System Internationale). ***KMS*** stands for kilogram, meter, second. These are the units of choice of physics. The equations in physics depend on unit agreement. So you must convert to ***KMS*** in most problems to arrive at the correct answer.

kilometers (*km*) to meters (*m*) and meters to kilometers
centimeters (*cm*) to meters (*m*) and meters to centimeters
millimeters (*mm*) to meters (*m*) and meters to millimeters
nanometers (*nm*) to meters (*m*) and metes to nanometers
micrometers (μ*m*) to meters (*m*)
gram (*g*) to kilogram (*kg*)
Celsius (^oC) to Kelvin (*K*)
atmospheres (*atm*) to Pascals (*Pa*)
liters (*L*) to cubic meters (m^3)

Other conversions will be taught as they become necessary.

What if you don't know the conversion factors? Colleges want students who can find their own information (so do employers). Hint: Try a good dictionary and look under "measure" or "measurement". Or the Internet? Enjoy.

a. 4008 *g* =________________*kg*

b. 1.2 *km* =________________*m*

c. 823 *nm* =________________*m*

d. 298 *K* =________________^oC

e. 0.77 *m* =________________*cm*

f. $8.8\text{x}10^{-8}$ *m* =________________*mm*

g. 1.2 *atm* =________________*Pa*

h. 25.0 μ*m* =________________*m*

i. 2.65 *mm* =________________*m*

j. 8.23 *m* =________________*km*

k. 40.0 *cm* =________________*m*

l. $6.23\text{x}10^{-7}$ *m* =________________*nm*

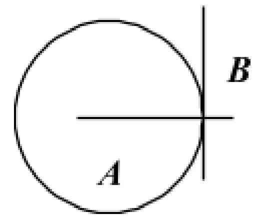
m. $1.5\text{x}10^{11}$ *m* =________________*km*

2. Geometry

Solve the following geometric problems.

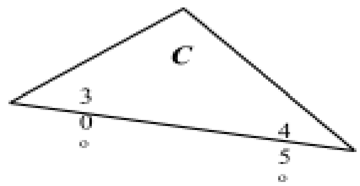
a. Line ***B*** touches the circle at a single point. Line ***A*** extends through the center of the circle.

   i. What is line ***B*** in reference to the circle?

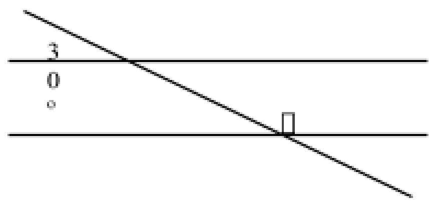


   ii. How large is the angle between lines ***A*** and ***B***?

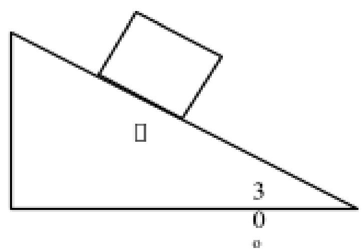
b. What is angle ***C***?



c. What is angle θ ?



d. How large is θ?



e. The radius of a circle is 5.5 *cm*,

   i. What is the circumference in <u>meters</u>?

   ii. What is its area in <u>square meters</u>?

f. What is the area under the curve at the right?