UNIT 2 Measurements and Calculations: NOTES
Part 1: Using Measurements Parts A-E

A. Accuracy vs. Precision Notes

B. Percent Error

A student determines the density of a substance to be 1.40 g/mL. Find the % error if the accepted value of the density is 1.36 g/mL. **SHOW ALL WORK!**

C. Significant Figures

► **Counting Sig Fig Examples**

- Calculating with Sig Figs

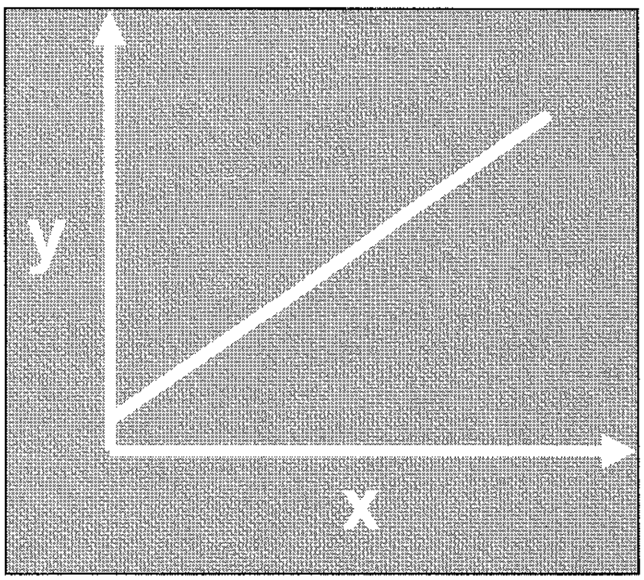
Practice Problems

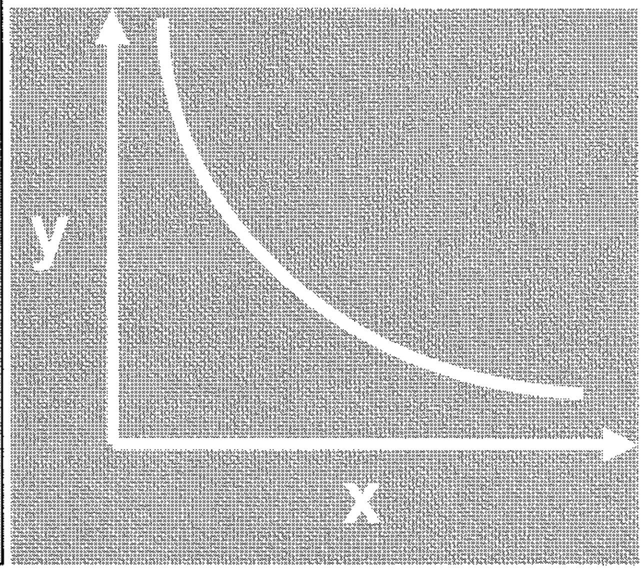
D. Scientific Notation

Practice Problems

- Calculating with Scientific Notation: CALCULATOR

E. Proportions





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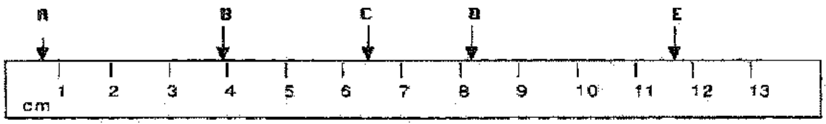
MATTER AND ENERGY Date ______________ Period _____

Measurement: Estimating One Place Beyond

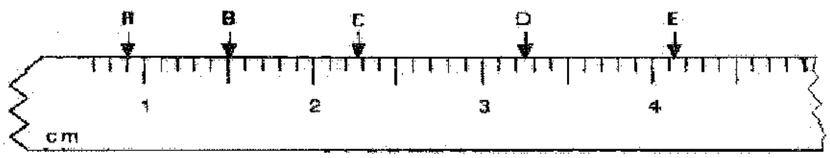
The accuracy of measurement is limited by the tools we use. If a clock doesn't have a second hand, we can estimate the number of seconds past the minute by looking at the minute hand. If a clock doesn't even have a minute hand, we can estimate time in hours and minutes, but certainly not seconds!!

Directions: **Based on the diagrams below, make the best estimate for each of the measurements indicated by the arrows.**

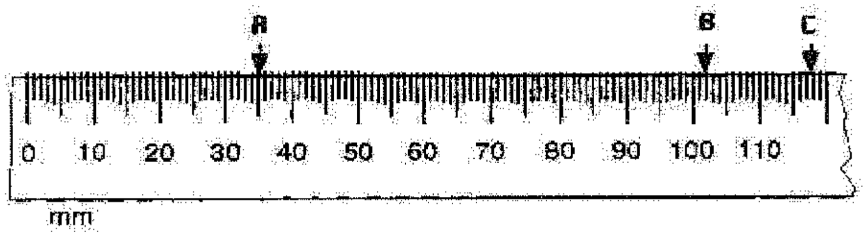
1. Estimate the number of centimeters indicated by each of the arrows below.



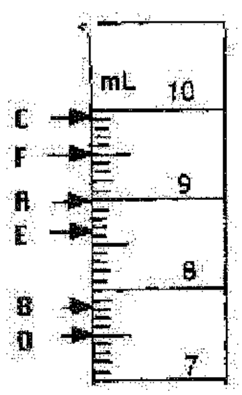
2. Estimate the number of centimeters indicated by each of the arrows below.



3. Estimate the number of millimeters and the number of centimeters indicated by each of the arrows below.



4. Estimate the number of milliliters indicated by each of the arrows below.



1. [a] ______________
[b] ______________
[c] ______________
[d] ______________
[e] ______________

2. [a] ______________
[b] ______________
[c] ______________
[d] ______________
[e] ______________

3. [a] ____________ mm
____________ cm
[b] ____________ mm
____________ cm
[c] ____________ mm
____________ cm

4. [a] ______________
[b] ______________
[c] ______________
[d] ______________
[e] ______________
[f] ______________

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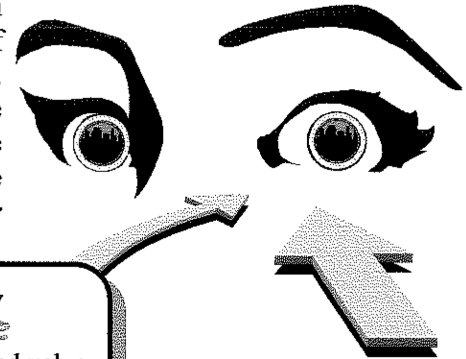
Calculating Errors of Measurement



If you are trying to get to New York City and you are 5 cm off course, you will still arrive in New York City. If you are trying to take some dirt out of your eye and you are 5 cm off course, you are working on the wrong eye. The size of the error is the same. The size of the error compared to the size of the target is not the same. The actual size of the error – the difference between the observed value and the true value – is known as the **absolute error**. The sign of the absolute error is not important. The size of the error is more important than whether the value is over or under.

- ★ **Observed value** - value based on laboratory measurements = Experimental Value
- ★ **True value** - most probable value or accepted value based on references = Accepted Value

Absolute error = |Observed value – True value|

The real measure of how far off a value is, is the percentage error. It is the size of the error, the absolute error, compared to the true value.

$$\text{Percent error} = \frac{|\text{observed value} - \text{true value}|}{\text{true value}} \times 100\%$$

Example: Aluminum has a density of 2.7 g/mL. A student measured the density to be 2.5 g/mL. What is the percentage error?

$$\text{Percent error} = \left|\frac{2.5\,{}^{g}/_{mL} - 2.7\,{}^{g}/_{mL}}{2.7\,{}^{g}/_{mL}}\right| \times 100\% = \left|\frac{-0.2\,{}^{g}/_{mL}}{2.7\,{}^{g}/_{mL}}\right| \times 100\% = 7.\overline{407}\% = 7\%$$

Answer the questions below based on your understanding of errors.

1. The freezing point of water is 273.2 K, but it was measured at 250.1 K. What is the percentage error?

2. The mass of a penny is 2.67 g, but it was measured at 2.55 g. What is the percentage error?

3. The air pressure was 101.3 kPa, but the weatherman said it was 1001.3 kPa. What is the percentage error?

4. The amount of heat released when 1 mole of CO_2 forms is 393.5 kJ. but it was measured at 378.2 kJ. What is the percentage error?

Chemistry: Form WS1.4.2B Name ____________________

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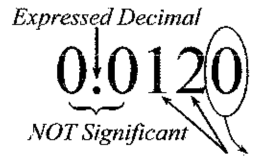
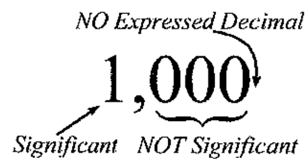
Counting Significant Digits

An index card is 12.65 cm long ... approximately. The last digit is estimated since the smallest space on the ruler is 0.1 cm. The same index card is also 126,500 μm long. The 5 is still the estimated digit. The zeros are only place holders. They are not significant. Significant digits are the ones that are measured and the one (and *only* one) that is estimated. All nonzero numbers are significant. Place holding zeros, the leading zeros between the decimal and the first nonzero digit or the trailing zeros in a number that has no expressed decimal, are not significant. One way of recognizing significant digits is the Atlantic-Pacific rule. When the decimal is absent, count from the first nonzero digit toward the Atlantic coast. When the decimal is present, count from the first nonzero digit toward the Pacific coast.





Pacific

Decimal **P**resent

Count toward the right from the first nonzero digit.

Atlantic

Decimal **A**bsent

Count toward the left from the first nonzero digit.

Tell the number of significant digits in each of the following measurements.

1. 48 cm ________
2. 306.2 g ________
3. 0.329 m ________
4. 83.9520 °C ________
5. 3700 mm ________
6. 400. cm^3 ________
7. 71.60 g ________
8. 0.00432 mm ________
9. 10.0 kg ________
10. 3.60×10^{15} sec ________
11. 6.24×10^{-4} m ________
12. 82.000 g ________

Name: ______________________________ Period: _____ Date: ____________

WS Scientific Notation, Accuracy, Precision & Error

Express the following numbers in scientific notation.

	Standard Notation	Scientific Notation	Sig. Figs.
1.	567		
2.	.003		
3.	.0467		
4.	14.77		
5.	3,000,000		
6.	4.879		
7.	0.0000123		
8.	45,082		
9.	602,300,000,000		
10.	16,430		
11.	0.16430		
12.	3,456,000		
13.	12		
14.	1978		
15.	0.03621		
16.	68.69		
17.	0.00000826		
18.	101.2		
19.	0.0091254		
20.	306,000,000		

Express the following numbers in standard notation.

	Scientific Notation	Standard Notation	Sig. Figs
21.	3.564×10^{3}		
22.	5.882×10^{1}		
23.	2.98×10^{-2}		
24.	3.7×10^{0}		
25.	9.439×10^{7}		
26.	6.7×10^{5}		
27.	1.0×10^{17}		
28.	7.0×10^{-2}		
29.	5.78×10^{6}		
30.	9.324×10^{-3}		
31.	1×10^{-6}		
32.	7.465×10^{2}		
33.	3.14×10^{3}		
34.	2.00×10^{-4}		
35.	4×10^{3}		
36.	5.13×10^{-5}		
37.	6.03×10^{-8}		
38.	6.68×10^{0}		
39.	7.24×10^{2}		
40.	3.8×10^{5}		

41. A measurement was taken three times. The correct measurement was 68.1 mL. Circle whether the set of measurements is accurate, precise, both, or neither.

a) 78.1 mL, 43.9 mL, 2 mL	accurate	precise	both	neither
b) 68.1 mL, 68.2 mL, 68.0 mL	accurate	precise	both	neither
c) 98.0 mL, 98.2 mL, 97.9 mL	accurate	precise	both	neither
d) 72.0 mL, 60.3 mL, 68.1 mL	accurate	precise	both	neither

42. Three students each weighed a copper cylinder four times. Describe the accuracy and the precision of each student's measurements if the correct (true) mass of the copper cylinder is 47.32 g.

	Student 1	**Student 2**	**Student 3**
Trial 1	47.50 g	59.05 g	42.28 g
Trial 2	47.22 g	61.48 g	42.26 g
Trial 3	46.99 g	64.22 g	42.15 g
Trial 4	47.34 g	56.13 g	41.97 g
Average Mass	47.26 g	60.22 g	42.17 g

Accurate:	Yes or No	Yes or No	Yes or No
Precise:	Yes or No	Yes or No	Yes or No

% Error: $\frac{\text{(experimental – true)}}{\text{true}} \times 100$ = _______ % _______ % _______ % (show work below)

Chemistry: Form WS1.4.2C Name ______________________

MATTER Date ______________ Period ____

Calculating With Significant Digits

Every measurement has some error associated with it. Even if you are extremely careful, the best you can do is estimate the last digit beyond where your measuring tool measures. This causes some trouble with calculations. If you are finding the area of a piece of land, for example, when you multiply the length by the width, you are multiplying estimates by estimates. This can only multiply the uncertainty. There are rules to keep extra uncertain numbers from cropping up in your calculations.

★ **multiplication and division** - the number of significant figures in a product or quotient is the same as the measurement with the smaller number of significant figures

> *Problem*
> 3.1415 × 2.25 = 7.068375
>
> *Correct number of Significant Figures* = 3
>
> *Solution* 7.07

★ **addition and subtraction** - the number of decimal places in the sum or difference is equal to the number of decimal places in the measured quantity with the smallest number of decimal places

> *Problem*
> 6.357 - 2.4 = 3.957
> *Correct number of Decimal Places* = 1
>
> *Solution* 4.0

Perform each of the following calculations, expressing the answer with the correct number of significant digits.

1) 3.482 cm + 8.51 cm + 16.324 cm ______________
2) 48.0032 g + 9.17 g + 65.4321 g ______________
3) 80.4 cm - 16.532 cm ______________
4) 106.5mL - 30. mL ______________
5) 48.2 cm × 1.6 cm × 2.12 cm ______________
6) 8.3 m × 4.0 m × 0.9823 m ______________
7) 64.34 cm^3 ÷ 8.149 cm ______________
8) 4.93 mm^2 ÷ 18.71 mm ______________
9) $\mathbf{0.57\,mL \times \frac{760\,mm}{740\,mm} \times \frac{273\,K}{250\,K}}$ ______________
10) $\mathbf{5.13\,g \times \frac{44.962\,a.m.u.}{115.874\,a.m.u.}}$ ______________

Calculating: Significant Figures Name__________________

Perform the following calculations and report answer with the correct number of significant figures. You may use a calculator. ***Remember to use the correct rule for each calculation!***

1. 23×11.1
2. $45.0 \div 7.023$
3. 3.14×95
4. $(5.67 \times 10^{17}) \div (4.0 \times 10^{14})$
5. $(7.345 \times 10^{-14}) \times (1.2 \times 10^{30})$
6. $4.73 + 2.5$
7. $1.32 - 0.987$
8. $5{,}432 - 347.9$
9. $(5.43 \times 10^{15}) + (2.97 \times 10^{15})$
10. $(6.789 \times 10^{21}) - (3.2 \times 10^{20})$
11. $(3.79 \times 2.3) \div 4.678$
12. $(45.60 + 3.1) - 32.103$
13. $(14.67 \div 2.34) \times 8.7362$
14. $(9.563 + 3.12) \times 4.5$

15. A student made a series of measurements: 6.54 cm, 6.53 cm, 6.55 cm, 6.5 cm. Report the mean (average) of these measurements to the correct number of significant figures.

16. Which measurement in the above series did the student not report the true or correct number of significant figures when he read his ruler? ____________________

17. The distance from the school to a student's house is 2.7 miles according to their odometer. Convert this distance to inches and report the answer to the correct number of significant figures.

18. In the previous question what was the number produced by your calculator? Why is it misleading to write down all the digits displayed there?

#______

Chapter 2 Part 1

Name ______________________________ Period ________ Date ____________

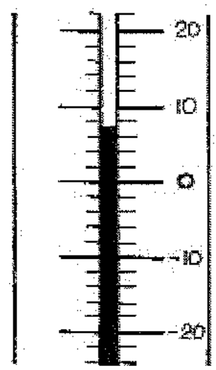
USING MEASUREMENTS TO IDENTIFY MATTER

PART A – ACCURACY, PRECISION, & PERCENT ERROR

1. Each of five students used the same ruler to measure the length of the same pencil. These data resulted: 15.33 cm, 15.34 cm, 15.33 cm, 15.33 cm, & 15.34 cm. The actual length of the pencil was 15.85 cm. Describe whether accuracy and precision are each good or poor for these measurements.

2. A chemistry student measured the boiling point of naphthalene ($C_{10}H_8$) at 231.0°C. What is the percent error for this measurement if the literature value is 217.9°C?

PART B – SIGNIFICANT FIGURES



3. ________________
   ▶ Using the thermometer on the right, record the temperature in degrees Celsius. Show the correct number of significant figures.

Determine the number of significant figures in each of the following:

4. 3.57 m ________
5. 20.040 g ________
6. 0.004 m^3 ________
7. 730 000 kg ________

Perform the following calculations and express your answers in the correct units and number of significant figures.

8. (5.14 cm)(6.742 cm) = ____________________
9. $\frac{2.8\ g}{6.86 \times 10^{-3}\ L}$ = ____________________
10. 45.68 g
    + 3.2 g
11. 1,423 mL
    - 40 mL

PART C – SCIENTIFIC NOTATION

Convert the following numbers into or out of scientific notation. Remember to keep the same number of significant figures.

12. 0.00003 cm ________________
13. 8,600,000 g ________________
14. 1.05×10^5 mm ________________
15. 1.00×10^{-3} m ________________

Name: ______________________________ **Uncertainty in Measurement Review**

1. **Define accuracy & precision in less than 4 words.**
   a. **Accuracy =**
   b. **Precision =**
2. **A technician determined the boiling point of octane to be 124.1°C. The actual boiling point of octane is 125.7°C. Calculate the percent error.**

3. **A student found the density of water to be 0.978 g/mL. The actual density is 1.00 g/mL. What is the percent error of this measurement?**

4. **Three students made multiple weighings of a copper cylinder, each using a different balance. Describe the accuracy and precision of each student's measurements if the correct mass of the cylinder is 27.32 g.**

Mass of Cylinder			
	Brian	Calvin	Evelyn
Weighing 1	**27.92**	**27.98**	**27.30**
Weighing 2	**26.99**	**27.96**	**27.33**
Weighing 3	**27.40**	**27.97**	**27.32**
Weighing 4	**27.50**	**27.99**	**27.31**

5. **Is percent error a measure of accuracy or precision?**

6. **Identify the number of significant figures in the following numbers:**
   a. 0.000086
   b. 600
   c. 4.000×10^{-8}
   d. 990.0
   e. 1,600
   f. 0.000000038900
   g. 22.0
   h. 8.6×10^{18}

7. **Round the following to 3 significant figures:**
   a. 87.073
   b. 4.23650×10^{8}
   c. 1.7777×10^{-8}
   d. 990.0
   e. 1,600
   f. 0.000000038900
   g. 9009
   h. 8.6×10^{18}

8. **Use a calculator to solve the following problems. ROUND YOUR ANSWERS to the proper number of significant figures.**
   a. $(1.2 \times 10^{4})(6.00 \times 10^{9}) =$
   b. 1,200 + 690 =
   c. 6.90 x 12,000 =
   d. 8 – 9.9 =
   e. 35.2 x 1/60 =
   f. 0.00798 ÷ 8 =
   g. 5.0 + 0.15111 =
   h. $(4.400 \times 10^{23}) * 3.4 =$
   i. 19.6 / 250 =
   j. 61.2 + 9.35 + 8.6 =