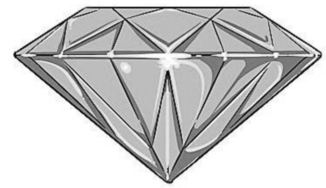
Measurement and Uncertainty

Name: ______________________

Date: ___________ Period: _____

I. OPENER: IS THE DIAMOND YOURS?

1. A friend asks to borrow your precious diamond for a day to show her family. You are a bit worried, so you carefully have your diamond weighed on a scale which reads 8.17 grams. The scale's accuracy is claimed to be $\pm$ 0.05 gram. The next day your friend returns the diamond and you weigh it again, getting 8.09 grams. Is this your diamond? Justify your answer.

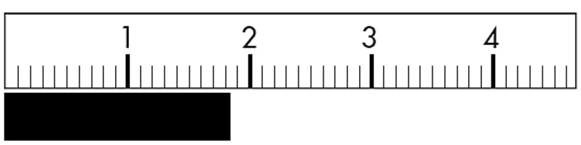


II. UNCERTAINTY

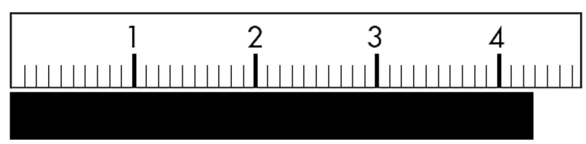
Accurate, precise measurements are an important part of physics. But no measure is absolutely precise. There is an uncertainty associated with every measurement. Among the most important sources of uncertainty, other than blunders, are the limited accuracy of every measuring instrument and the inability to read an instrument beyond some fraction of the smallest division shown. For example, if you were to use a centimeter ruler to measure the width of a board, the result could be claimed to be precise to about 0.1 cm, the smallest division on the ruler. The reason for this is that it is difficult for the observer to estimate between the smallest divisions. When giving the result of a measurement, it is important to state the **estimated uncertainty** in the measurement. For example, the width of a board might be written as 8.8 $\pm$ 0.1 cm. The $\pm$ 0.1 cm represents the estimated uncertainty in the measurement, so that the actual width most likely lies between 8.7 cm and 8.9 cm.

2. Measure the length of the solid black object using the centimeter ruler. Be sure to state your estimated uncertainty in the measurement.

(a)



(b)



Often the uncertainty in a measured value is not specified explicitly. In such cases, the uncertainty is generally assumed to be one or a few units in the last digit specified. For example, if a length is given as 8.8 cm, the uncertainty is assumed to be about 0.1 cm or 0.2 cm. It is important in this case that you do not write 8.80 cm, for this implies an uncertainty on the order of 0.01 cm; it assumes the length is probably between 8.79 cm and 8.81 cm, when actually you believe it is between 8.7 and 8.9 cm!

3. For the following measurements write the range that the measurement is most likely between.

(a) 50 cm (b) 5 cm (c) 5.0 cm (d) 5.00 cm

III. SIGNIFICANT FIGURES

The number of reliably known digits in a number is called the number of **significant figures**. Thus there are four significant figures in the number 23.21 cm and two in the number 0.062 cm (the zeros in the latter are merely place holders that show where the decimal point goes). The number of significant figures may not always be clear. Take, for example, the number 80. Are there one or two significant figures? If we say it is *about* 80 km between two cities, there is only one significant figure (the 8) since the zero is merely a place holder. If it is *exactly* 80 km within an accuracy of 1 or 2 km, then the 80 has two significant figures. If it is precisely 80 km, to within $\pm$ 0.1 km, then we write 80.0 km.

4. Write the number of significant figures in each measurement.

value	# of SFs
524	
5.24	
0.524	
52,400	
52,400.0	

value	# of SFs
52,400.	
5.240E+4	
5.24E+4	
52,401	
52.4	

value	# of SFs
52.400	
5,240	
5,240.	
1.000524	
52,400,100	

When making measurements, or when doing calculations, you should avoid the temptation to keep more digits in the final answer than is justified. As a rough general rule, we can say that *the final result of a multiplication or division should have only as many digits as the number with the least number of significant figures used in the calculation*.

5. Calculate each of the following and write the answer with the correct number of significant figures.
(a) 11.3 cm × 6.8 cm (b) 3.6 cm − 0.57 cm (c) 4.0 cm / 2.0 cm (d) 2.0 cm / 3.0 cm

IV. SCIENTIFIC NOTATION

We commonly write numbers in "powers of ten," or "scientific" notation—for instance 36,900 as 3.69×10^4, or 0.0021 as 2.1×10^{-3}. One advantage of scientific notation is that is allows the number of significant figures to be clearly expressed. For example, it is not clear whether 36,900 has three, four, or five significant figures. With powers of ten notation the ambiguity can be avoided: if the number is known to an accuracy of three significant figures, we write 3.69×10^4, but if it is known to four, we write 3.690×10^4.

V. PERCENT ERROR

The significant figures rule is only approximate, and in some cases may actually underestimate the precision of the answer. For example if you divide 97 by 92 a calculator shows the answer 1.05.

(a) What is the implied uncertainty in the numbers 97 and 92?

(b) Find the percent error in the implied uncertainty.

(d) According to the significant figure rule what is the result of 97 divided by 92?

(e) What is the percent error in this answer?

(f) What is the best way to write the result of 97 divided by 92?