SPH3U UNIVERSITY PHYSICS

REVIEW: MATH SKILLS

☞ Uncertainty in Measurements (P.650-652)

Uncertainty in Measurements

There are two types of quantities used in science: exact values and measurements. ***Exact values*** *include defined quantities (1 m = 100 cm) and counted values (5 beakers or 10 trials).* ***Measurements****, however, are not exact because there is always some uncertainty or error associated with every measurement. As such, there is an international agreement about the correct way to record measurements.*

Significant Digits

The certainty of any measurement is communicated by the number of significant digits in the measurement. In a measured or calculated value, ***significant digits*** *are the digits that are known reliably, or for certain, and include the last digit that is estimated or uncertain. As such, there are a set of rules that can be used to determine whether or not a digit is significant (refer to P.650 of your text).*

SIGNIFICANT DIGITS

- digits that are certain plus one estimated digit
- indicates the certainty of a measurement
- rules ☞ P.650

Significant Digits

WHEN DIGITS ARE SIGNIFICANT ✔

1. *All non-zero digits (i.e., 1-9) are significant.*

For example:	*259.69*	*has five significant digits*
	61.2	*has three significant digits*

Significant Digits

WHEN DIGITS ARE SIGNIFICANT ✔

2. *Any zeros between two non-zero digits are significant.*

For example:	*606*	*has three significant digits*
	6006	*has four significant digits*

Significant Digits

WHEN DIGITS ARE SIGNIFICANT ✔

3. *Any zeros to the right of both the decimal point and a non-zero digit are significant.*

For example:	*7.100*	*has four significant digits*
	7.10	*has three significant digits*

Significant Digits

WHEN DIGITS ARE SIGNIFICANT ✔

4. *All digits (zero or non-zero) used in scientific notation are significant.*

For example: *3.4×10^3 has two significant digits*
3.400×10^3 has four significant digits

Significant Digits

WHEN DIGITS ARE SIGNIFICANT ✔

5. *All counted and defined values have an infinite number of significant digits.*

For example: *16 students has ∞ significant digits*
π = 3.1415... has ∞ significant digits

Significant Digits

WHEN DIGITS ARE NOT SIGNIFICANT ✗

1. *If a decimal point is present, zeros to the left of other digits (i.e., leading zeros) are not significant – they are placeholders.*

For example: *0.22 has two significant digits*
0.000 22 has two significant digits

Significant Digits

WHEN DIGITS ARE NOT SIGNIFICANT ✗

2. *If a decimal point is not present, zeros to the right of the last non-zero digit (i.e., trailing zeros) are not significant – they are placeholders.*

For example:	*98 000 000*	*has two significant digits*
	25 000	*has two significant digits*

NOTE!

In most cases, the values you will be working with in this course will have two or three significant digits.

August 22, 2012 3UR - Uncertainty in Measurements 9

Significant Digits

PRACTICE

1. How many significant digits are there in each of the following measured quantities?

(a) 353 g	3
(b) 9.663 L	4
(c) 76 600 000 g	3
(d) 30.405 ml	5
(e) 0.3 MW	1
(f) 0.000 067 s	2
(g) 10.00 m	4
(h) 47.2 m	3
(i) 2.7×10^5 s	2
(j) 3.400×10^{-2} m	4

August 22, 2012 3UR - Uncertainty in Measurements 10

Significant Digits

PRACTICE

2. Express the following measured quantities in scientific notation with the correct number of significant digits.

(a) 865.7 cm	(4)	8.657×10^2 cm
(b) 35 000 s	(2)	3.5×10^4 s
(c) 0.05 kg	(1)	5×10^{-2} kg
(d) 40.070 nm	(5)	4.0070×10^1 nm
(e) 0.000 060 ns	(2)	6.0×10^{-5} ns

August 22, 2012 3UR - Uncertainty in Measurements 11

Precision

*Measurements depend on the precision of the measuring instruments used, that is, the amount of information that the instruments can provide. For example, 2.861 cm is more precise than 2.86 cm because the three decimal places in 2.861 makes it precise to the nearest one-thousandth of a centimetre, while the two decimal places in 2.86 makes it precise only to the nearest one-hundredth of a centimetre. **Precision** is indicated by the number of decimal places in a measured or calculated value.*

PRECISION

- indicated by the number of decimal places in the number

Precision

RULES FOR PRECISION

1. *All measured quantities are expressed as precisely as possible. All digits shown are significant with any error or uncertainty in the last digit.*

   For example, in the measurement 87.64 cm the uncertainty is with the digit 4.

Precision

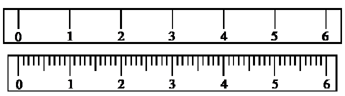
RULES FOR PRECISION

2. *The precision of a measuring instrument depends on its degree of fineness and the size of the unit being used.*

   For example, a ruler calibrated in millimetres (ruler #2) is more precise than a ruler calibrated in centimetres (ruler #1) because the ruler calibrated in millimetres has more graduations.

#1

#2



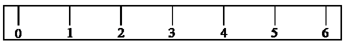
Precision

RULES FOR PRECISION

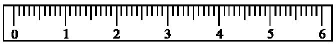
3. *Any measurement that falls between the smallest divisions on the measuring instrument is an estimate. We should always try to read any instrument by estimating tenths of the smallest division.*

   For example, with ruler #1 we would estimate to the nearest tenth of a centimetre (i.e. 3.2 cm); with ruler #2 we would estimate to the nearest tenth of a millimeter (i.e. 3.24 cm).

#1



#2



Precision

RULES FOR PRECISION

4. *The estimated digit is always shown when recording the measurement.*

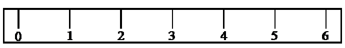
   For example, the 7 in the measurement 6.7 cm would be the estimated digit.

Precision

RULES FOR PRECISION

5. *Should the object fall right on a division mark, the estimated digit would be 0.*

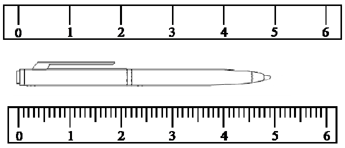
   For example, if we use a ruler calibrated in centimetres to measure a length that falls exactly on the 5 cm mark, the correct reading is 5.0 cm, not 5 cm.



Precision

PRACTICE

3. Use the two centimetre rulers to measure and record the length of the pen graphic.



(a) Child's ruler

~ 4.9 cm

(b) Ordinary ruler

~ 4.92 cm

Precision

PRACTICE

4. An object is being measured with a ruler calibrated in millimetres. One end of the object is at the zero mark of the ruler. The other end lines up exactly with the 5.2 cm mark. What reading should be recorded for the length of the object? Why?

5.20 cm should be recorded since the object falls right on division. Since the ruler is calibrated in millimetres, we need to estimate to the nearest tenth of the smallest division

Precision

PRACTICE

5. Which of the following values of a measured quantity is most precise?
   (a) 4.81 mm, 0.81 mm, 48.1 mm, 0.081 mm
   (b) 2.54 cm, 12.64 cm, 126 cm, 0.5400 cm, 0.304 cm

   (a) 0.081 mm – has 3 decimal places
   (b) 0.5400 cm – has 4 decimal places

Uncertainty in Measurements

PRACTICE

6. Copy and complete the following table.

	Measurement	Precision	# of Sig.Dig.		Measurement	
			now	needed	rounded	in sci.not.
	63.479 km (*example)*	3	5	3	63.5	6.35×10^1
a	46 597.2 cm	1	6	2	47 000	4.7×10^4
b	0.5803 L	4	4	1	0.6	6×10^{-1}
c	325 kg	0	3	2	320	3.2×10^2
d	0.067 80 mm	5	4	3	0.0678	6.78×10^{-2}
e	485.000 kW	3	6	4	485.0	4.850×10^2