You have mastered this topic when you can:
1) describe the imprecise nature of all measurements.
2) determine the number of significant figures in a measured quantity.
3) round calculated results to the appropriate number of significant figures.

QUANTITATIVE MEASURES

I) A Quantitative measure is any measurement consisting of a number and a unit. These are Quantitative measures: 25°C, 101.3 kPa, 948.73 g, 500.0 mL, etc.

II) **NUMBERS AND QUANTITIES**

A) ***A NUMBER is used to describe an amount of something.*** These are numbers: $^{-}$400.0, 0.501, 68, 321.5394, 4.76 x 10^{-3}, etc. ***Numbers*** only tell us how much, they do not tell us how much of what it is that you have, thus they are limited in their usefulness.

B) ***A QUANTITY consists of a number and a unit and is used to describe an amount of a specific property.*** The ***number*** describes the amount and the unit describes the property being measured.

e.g. Quantity	Amount	Unit	Property
25 °C	25	°C	temperature
454 g	454	g	mass
75.8 kg	75.8	kg	mass
341 mL	341	mL	volume
102.3 kPa	102.3	kPa	pressure
100 km	100	km	distance
100 km/h	100	km/h	speed

1) All branches of science rely heavily on ***quantities*** (numbers with units) because they convey specific information very clearly and concisely. Consider this situation: Your friend Chris rushes toward you excitedly yelling how he just won 250. What does the 250 mean? The amount of his win is known, but not what he won. He could have won 250 cows, 250 CDs, or 250 free trips on Skytrain. Chris used a number to describe his prize, had he used a ***quantity***, a number coupled with a unit, such as $250, you would have known instantly what he won and the amount of the prize.

SIGNIFICANT DIGITS

I) **PRECISION** AND **PLACE VALUES**. Numbers are composed of these digits 1, 2, 3, 4, 5, 6, 7, 8, 9 and 0 written in certain ***place values*** relative to the decimal. ***Place values*** indicate how large or small a number is. Larger ***place values*** equate to larger numbers while smaller ***place values*** equate to smaller numbers.

larger place values ← 1 234 567 890 . 123 456 789 0 → smaller place values

A) The number 123 000 is larger than the number 0.789 because the digits 123 occupy larger ***place values*** than the digits 789.

B) ***Place values*** have an important role in the ***precision*** of a ***quantity***. Consider the ***quantities*** 65.58 g and 655.8 g. The quantity 65.58 g is more precise than 655.8 g.

1) **Sample Problem 1:** In the quantity 65.58 g, the digit 8 occupies the second decimal place, the ***place value*** representing 100th of a gram while in the quantity 655.8 g, the digit 8 occupies the first decimal place, the ***place value*** representing 10th of a gram, thus 65.58 g is more precise.

2) ***PRECISION is a measure of the place value of the last measurable digit in a quantity.*** The more ***precise*** the number, the smaller the ***place value*** occupied by the number's last digit, or the smaller the ***place value*** of the number's last digit, the more ***precise*** the number.

3) **Required Practice 1. {Ans. on pg. 6}**

1. Which ***quantity*** is the most precise? a. 47 g or 47.68 g b. \$ 3 000 or \$3 100 c. 4.971 L or 0.001 46 L d. 147.5 km or 14.731 km
2. Arrange these numbers from most to least precise. 159 g, 83.2 g, 100 g, 89 750 g, 0.000 1 g

II) **PRECISION AND QUANTITIES**

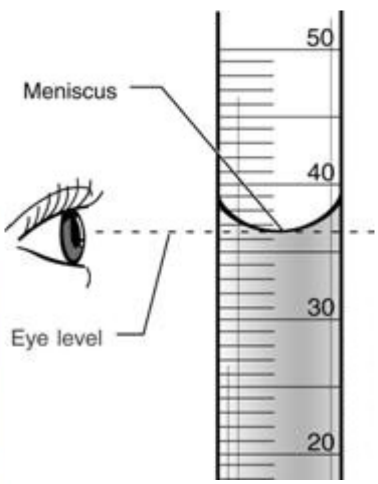
A) There are two types of ***quantities***, those that include **EXACT VALUES** and those that include **MEASURED VALUES**.

1) ***EXACT VALUES are counting numbers and defined values, which are perfect and exact therefore they have infinite precision.***

a) Precision of ***counting numbers***: **e.g.** If Peter has 5 loonies, he has **exactly** 5 loonies, not 5.6 loonies or 5.000 08 loonies, he has **exactly** 5 loonies. The precision of a ***counting number*** is perfect and **exact**, and can be written with an infinite number of zeros: **i.e.** 5.000 000... loonies.

b) ***Defined values are created by scientists and are purposely created to be perfect and exact so they have infinite precision.*** By definition 1 dozen = 12. This means 1 dozen is perfect and **exact**, has infinite precision, and can be written with an infinite number of zeros. By definition 10 mm = 1 cm. This means 10 mm is perfect, **exact**, and has infinite precision, and 1 cm is perfect, **exact** and has infinite precision, both can be written with an infinite number of zeros.

2) ***MEASURED VALUES*** are created by reading a measurement instruments.



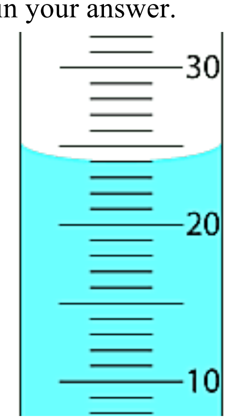
a) Numbers obtained from these instruments have limited precision. **e.g.** A centigram balance is used to measure the mass of an object. The mass of an average loonie is 7.130 g. This mass was recorded to 3 decimal places because we have confidence in the balance scale to that level of precision. Recording digits smaller than the 1 000th place value (the third decimal place) would be speculation: this is unacceptable. This limits the confidence a scientist has with quantities created using measurement tools. Scientists record all quantities to the correct number of ***significant digits*** to reflect the precision of the instrument used to measure it.

i) When we read volume of a liquid from the graduated cylinder we are making an estimate of the last digit. Because this last digit is an estimate made by humans, there is error involved. There is also error involved in the graduated cylinder itself. Typically the error of the graduated cylinder is ± 0.1 mL. This means that the volume of the above graduated cylinder could be read as 36.6 mL ± 0.1 mL. This means the actual volume is somewhere between 36.5 mL and 36.7 mL.

ii) The electronic balances typically have an error of ± 1 of whatever the place value of the last digit seen on the screen. If the mass of a substance is read as 6.24 g, it should be recorded as 3.24 g ± 0.01 g. If the mass of a substance is read as 159.240 g, it should be recorded as 159.240 g ± 0.001 g.

3) **Sample Problems 2:** Record the volume of liquid in these graduated cylinders. Be sure you include the error in your answer.

1.



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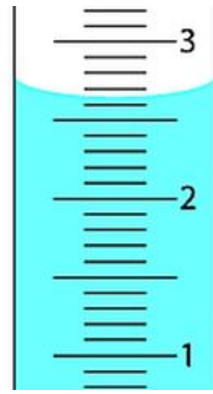
2.



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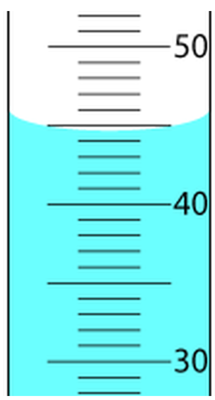
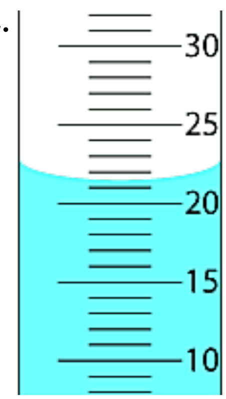
4) **Required Practice 2:** Record the volume of liquid in these graduated cylinders. Be sure you include the error in your answer. **{Ans. on pg. 6}**

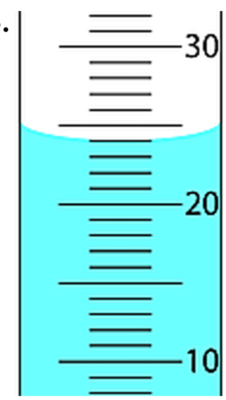
1.



2.



3.



III) ***Significant digits are a scientist's way of recording the precision of a quantity, thus they are extremely important.*** In a measured or calculated number, ***significant digits*** are those digits with which a scientist has the utmost confidence, plus one estimated digit.

A) **RULES FOR COUNTING *SIGNIFICANT DIGITS*.** ← **MEMORIZE THESE RULES!!**

(1) Non-zero digits are always significant.

(2) Captured zeros, zeros between non-zero digits, are significant.

(3) Leading (beginning) zeros are never significant because their only role is to place the decimal relative to the significant digits.

(4) Trailing (ending) zeros: Are significant if a decimal is present.
Are not significant if a decimal is not present.

(5) All digits in numbers written in scientific notation are significant.

(6) Exact values have infinite significant digits.

B) Applying the rules for counting ***significant digits***.

1) **Sample Problems 3:** Determine the number of significant digits in each quantity. Justify your answer.

1. 4.76 kL has ______ ***significant digits*** because the three non-zero digits are significant.

2. 4.0744 g has ______ ***significant digits*** because the four non-zero digits are significant; the zero is captured so it is also significant.

3. 0.0054 g has _____ ***significant digits*** because the two non-zero digits are significant; the leading zeros are not significant.

Continued on the next page.

4. 1 468 000 km has ______ ***significant digits*** because the four non-zero digits are significant; a decimal is absent so the three trailing zeros are not significant.

5. 200. m has _____ ***significant digits*** because the one non-zero digit is significant; a decimal is present so the two trailing zeros are significant.

6. 0.004 580 0 g has _____ ***significant digits*** because the four non-zero digits are significant, the three leading zeros are not significant, a decimal is present so the two trailing zeros are significant.

2) **Required Practice 3:** Determine the number of ***significant digits*** in these numbers. **{Ans. on pg. 6}**

1. 4.56	6. 8 014	11. 1.86×10^{-2}
2. 1.4	7. 0.001 49	12. 4.014×10^{15}
3. 4.60	8. 0.001 080 3	13. $1.450\ 00 \times 10^{8}$
4. 81 700	9. 0.000 080 0	14. $9.909\ 000 \times 10^{-3}$
5. 916.00	10. 1.000 45	15. 0.000 100 0

C) **RULES FOR DETERMINING *SIGNIFICANT DIGITS* IN CALCULATIONS**

1) **RULES FOR ROUNDING NUMBERS** ← **MEMORIZE THESE RULES!!**

(1) ROUND YOUR FINAL ANSWER ONLY.

(2) If the first digit to be dropped is greater than 5, increase the last digit kept digit by 1.
e.g. Round to one decimal place: 1.**36** = 1.**4**, 34.**6**78 = 34.**7**, 0.**0**93 568 = 0.**1**

(3) If the first digit to be dropped is less than 5, the last digit kept remains unchanged.
e.g. Round to one decimal place: 1.**32** = 1.**3**, 34.**6**48 = 34.**6**, 0.**1**35 68 = 0.**1**

(4) If the only digit to be dropped is a 5 (there are no digits after the 5), round the last digit kept to the nearest even digit.
e.g. Round to one decimal place: 1.**25** = 1.**2**; 1.**35** = 1.**4**; 52.**65** = 52.**6**

(5) If the first digit to be dropped is a 5 (there are digits after the 5), increase the last digit kept by 1.
e.g. Round to one decimal place: 1.**2**501 = 1.**3**; 1.**35**111 = 1.**4**; 52.**6**50000001 = 52.**7**

2) **Required Practice 4:** Round these quantities to two decimal places. **{Ans. on pg. 7}**

1. 0.145 7 mL	3. 87.211 1 m	5. 6 821.400 0 L	7. 214.675 g
2. 197.317 62 g	4. 86.219 kg	6. 82.131 4 µg	8. 87.651 L

3) ***FOR MULTIPLICATION AND DIVISION, RECORD THE RESULT TO THE LEAST NUMBER OF SIGNIFICANT DIGITS POSSIBLE.***

a) **Sample Problems 5:** Complete these calculations.

1. 6.954 x 1.2 = 8.344 8 =
___ **sig figs** ___ **sig figs** _____ **sig figs**

2. 255 ÷ 185.34 = 1.375 84 =
___ **sig figs** ___ **sig figs** _____ **sig figs**

B) **Required Practice 5:** Complete these calculations. **{Ans. on pg. 7}**

1. 21.3 ÷ 1.3	5. (25.0)(0.2)	9. (25.0)(3.0)
2. $\frac{6.34 \times 1.2}{1.217}$	6. $\frac{21.500}{8.50}$	10. $\frac{(43.84)(1.2)}{8.1466}$
3. 0.21 x 61.5	7. 150.0 ÷ 8.0	11. (8 572.0)(10.0)
4. 12.34 x 2.34	8. 81 ÷ 27.0	12. 4.12 ÷ 8.169 x 2.0

4) ***FOR ADDING AND SUBTRACTING, RECORD THE RESULT TO THE LEAST PRECISE PLACE VALUE POSSIBLE.***
REMEMBER: Large left hand place values are less precise then small right hand place values. This means when adding and subtracting we round as far left as possible.
a) **Sample Problems 6:** Complete these calculations.

1. 6.75 cm + 184.1 cm = 190.85 cm =
___ decimal ___ **decimal** ___ **decimal**

2. 42.125 g + 56.376 7 g = 98.501 7 g =
___ **decimal** ___ decimal ___ **decimal**

NOTE: For non-decimal numbers, record the result to the largest (most left hand) place value of the last non-zero digit.

3. 125 774 g – 115 000 g = 125 77**4** g
– 11**5** 000 g
1**0** 774 g = ________________

4. 84 913 g + 5 240 000 g = 84 91**3** g
+ 5 2**4**0 000 g
5 3**2**4 913 g = ______________

5) **Required Practice 6:** Complete these calculations. **{Ans. on pg. 7}**

1. 42.1 g + 56.37 g
2. 4.13 g – 2.2 g
3. 248.768 s – 37.53 s
4. 60.0 m – 12 m
5. 60 m – 12 m
6. 820 m + 13 m
7. 653.08 s – 14.2 s
8. 19.077 h – 6.1 h
9. 27.5 g – 3.16 g + 150.000 1 g
10. 15.060 8 g + 3.00 g + 0.08 g
11. 4.621 s – 52.618 s + 99 s
12. 82 301 m + 44 000 m – 65 300 m

SCIENTIFIC NOTATION

I) Science often uses ***quantities*** with extremely large or small numbers.

e.g. The mass of 1 proton = 0.000 000 000 000 000 000 000 001 67 g

The mass of 1 electron = 0.000 000 000 000 000 000 000 000 000 911 g

A) These and other numbers like them are written in decimal notation requiring a large amount of time and space to write them. To simplify these numbers, **SCIENTIFIC NOTATION** was developed. ***Scientific notation*** is a method of writing very large or very small numbers in a compact form by eliminating the zeros whose only purpose is to place the decimal in its proper location. Numbers written in ***scientific notation*** follow the pattern of a single digit followed by a decimal then all other significant digits and "x 10^n" where n = a positive or negative exponent: **i.e.** 1.2345 x 10^n.

1) **e.g.**

Decimal Notation		***Scientific Notation***
0.000 000 000 000 000 000 000 001 67 g	=	1.67 x 10^{-24} g
0.000 000 000 000 000 000 000 000 000 911 g	=	9.11 x 10^{-28} g
49 860 000 000 000 km	=	4.986 x 10^{13} km
602 000 000 000 000 000 000 000 atoms K	=	6.02 x 10^{23} atoms K

a) 1.67 x 10^{-24} g, 9.11 x 10^{-28} g, 4.986 x 10^{13} km, and 6.02 x 10^{23} atoms K are written in ***scientific notation*** and are much more practical to use.

B) **CONVERTING TO AND FROM *SCIENTIFIC NOTATION***

1) **USE THESE STEPS TO CONVERT DECIMAL NOTATION TO SCIENTIFIC NOTATION**

(1) Count the number of places the decimal must move to have one non-zero digit to its left. This is n = the exponent on the "x 10^n ".

- ***If the decimal moves right, n is negative.***
- ***If the decimal moves left, n is positive.***

(2) Write the number in the form 1.2345 x 10^n.

2) **Sample Problems 7:** Convert these to scientific notation.

1. Write 0.000 000 000 000 000 000 160 2 C in scientific notation.

(1) 0.000 000 000 000 000 000 160 2 C

The decimal must be moved **19** spaces **right**, so the exponent n = ⁻19

(2) 1.602 x 10^{-19} C

0.000 000 000 000 000 000 160 2 C = 1.602 x 10^{-19} C

2. Write 8 500 000 000 000 m in scientific notation.

(1) 8 500 000 000 000. m — The decimal must be moved **12** spaces **left**, so the exponent n = 12

(2) 8.5 x 10^{12} m — 8 500 000 000 000 m = 8.5 x 10^{12} m

3) **Required Practice 7:** Convert these to scientific notation. **{Ans. on pg. 7}**

1. 1 240 000
2. 128
3. 1 000 000 000 000 000 000
4. 0.000 124
5. 0.000 000 000 214
6. 0.000 000 001

C) **USE THESE STEPS TO CONVERT SCIENTIFIC NOTATION TO DECIMAL NOTATION**

(1) Write the number without the "x 10^n "

(2) Move the decimal n places: (a) left if n is negative.

(b) right if n is positive.

1) **Sample Problems 8:** Convert these to decimal notation.

1. Write 1.75 x 10^{-5} in decimal notation.

(1) 1.75 → *(2a)* 0.000 017 5 ∴ 1.75 x 10^{-5} = 0.000 017 5

2. Write 5.129 x 10^{10} in decimal notation.

(1) 5.129 → *(2b)* 51 290 000 000. ∴ 5.129 x 10^{10} = 51 290 000 000

2) **Required Practice 8:** Convert these numbers to decimal notation. **{Ans. on pg. 7}**

1. 1.32 x 10^{10}
2. 2.64 x 10^{3}
3. 1.32 x 10^{-3}
4. 6.02 x 10^{23}
5. 3.45 x 10^{-5}
6. 8.793 x 10^{-11}

ANSWERS TO THE REQUIRED PRACTICE

Required Practice 1 from page 2

1a. 47.68 g **b.** \$3 100 **c.** 0.001 46 L **d.** 14.731 km **2.** 0.000 1 g, 83.2 g, 159 g, 89 750 g, 100 g

Required Practice 2 from page 3

1. 39.8 mL ± 0.1 mL **2.** 21.4 mL ± 0.1 mL **3.** 24.0 mL ± 0.1 mL

Required Practice 3 from page 4

1. 3 **2.** 2 **3.** 3 **4.** 3 **5.** 5 **6.** 4 **7.** 3 **8.** 5 **9.** 3 **10.** 6 **11.** 3 **12.** 4 **13.** 6 **14.** 7 **15.** 4

Required Practice 4 from page 4

1. 0.15 mL **2.** 197.32 g **3.** 87.21 m **4.** 86.22 kg **5.** 6 821.40 L **6.** 82.13 µg **7.** 214.68 g **8.** 87.65 L

Required Practice 5 from page 4

1. 16 **2.** 6.3 **3.** 13 **4.** 28.9 **5.** 5 **6.** 2.53 **7.** 19 **8.** 3.0 **9.** 75 **10.** 6.5 **11.** 85 700 **12.** 1.0

Required Practice 6 from page 5

1. 98.5 g **2.** 1.9 g **3.** 211.24 s **4.** 48 m **5.** 50 m **6.** 830 m **7.** 638.9 s **8.** 13.0 h **9.** 174.3 g **10.** 18.14 g
11. 51 s **12.** 61 000 m

Required Practice 7 from page 6

1. 1 240 000 = 1.24×10^{6} **2.** 128 = 1.28×10^{2} **3.** 1 000 000 000 000 000 000 = 1×10^{18}
4. 0.000 124 = 1.24×10^{-4} **5.** 0.000 000 000 214 = 2.14×10^{-10} **6.** 0.000 000 001 = 1×10^{-9}

Required Practice 8 from page 6

1. 1.32×10^{10} = 13 200 000 000 **2.** 2.64×10^{3} = 2 640 **3.** 1.32×10^{-3} =0.001 32
4. 6.02×10^{23} = 602 000 000 000 000 000 000 000 **5.** 3.45×10^{-5} = 0.000 034 5
6. 8.793×10^{-11} = 0.000 000 000 087 93

BE SURE YOU PREPARE FOR MEMORY CHALLENGE-5 ON T30 – T37!!