# Appendix B

## Scientific conventions

# Scientific Conventions

Scientific information should be communicated according to accepted scientific conventions. These conventions include significant figures, formulae, units, and data (graphs, diagrams, tables). The Department of Education of Newfoundland and Labrador follows the conventions below in evaluating provincial science examinations in the province.

## Significant Figures

Any number used in a calculation should contain only figures that are considered reliable; otherwise, time and effort are wasted. Figures that are considered reliable are called significant figures. Scientific calculations generally involve numbers representing actual measurements. In a measurement, significant figures in a number consist of:

Figures (digits) definitely known + One estimated figure (digit)

They are often expressed as "all of the digits known for certain plus one that is uncertain."

### Significant Figure Rules

**(i) All non-zero digits are significant.**

**(ii) Zero Rules:**

- Trailing zeroes (i.e., at the end to the right) of a measurement may or may not be significant.
    - (i) If it represents a measured quantity, it is significant. For example: 25.0 cm - the zero is significant (the decimal is clearly indicated)
    - (ii) If it is immediately to the left of the decimal, it is not a significant figure. For example: 250 cm or 2500 cm - the zeroes are not significant (there is uncertainity whether the zeroes were measured values)
    - (iii) If the trailing zeroes in 250 cm and 2500 cm are significant, then the measurements must be written in scientific notation. For example: $2.50 \times 10^2$ cm or $2.500 \text{ x} 10^3$ cm - the zeroes are significant
- A zero, between two non-zero digits in a measurement, is significant. For example: 9.04 cm - the zero is significant
- Leading zeroes (i.e., at the beginning to the left) are never significant (they do not represent a measured quantity), they merely locate the decimal point. For example: 0.46 cm and 0.07 kg - the zeroes are not significant

**(iii) Rounding with Significant Figures**

In reporting a calculated measured quantity, rounding an answer to the correct number of significant figures is important if the calculated measurement is to have any meaning. The rules for rounding are:

– If the figure to be dropped is less than 5, eliminate it. For example:
  rounding 39.949 L to three significant figures results in 39.9 L
  rounding 40.0 g to two significant figures results in $4.0 \times 10^1$ g

– If the figure to be dropped is greater than or equal to 5, eliminate it and raise the preceding figure by 1. For example:
  rounding 39.949 L to four significant figures results in 39.95 L
  rounding 39.949 L to two significant figures results in $4.0 \times 10^1$ L

**(iv) Multiplying and Dividing with Significant Figures**

In determining the number of significant figures in a measurement that is calculated by multiplying or dividing, the measurement with the least number of significant figures should be identified. The final calculated measurement should contain the same number of significant figures as the measurement with the least number of significant figures. For example:

$$2.1 \text{ cm} \times 3.24 \text{ cm} = 6.8 \text{ cm}^2$$

Since 2.1 cm contains two significant figures and 3.24 contains three significant figures, the calculated measurement should contain no more than two significant figures.

**(v) Adding and Subtracting with Significant Figures**

In determining the number of significant figures in a measurement that is calculated by adding or subtracting, the measurement with the least number of decimal places should be identified. The final calculated measurement should contain the same number of decimal places as the measurement with the least number of decimal places. For example:

$$42.56 \text{ g} + 39.460 \text{ g} + 4.1 \text{ g} = 86.1 \text{ g}$$

Since 4.1 g only contains one decimal place, the calculated measurement must be rounded to one decimal place.

**(vi) Performing a Series of Calculations with Mixed Operations**

When a series of calculations is performed, it is important to remember that multiplication/division and addition/subtraction are governed by separate significant figure rules. Rounding only occurs at the last step.

When calculations involve both of these types of operations, the rules must be followed in the same order as the operations. Rounding still only occurs at the last step of the calculation. For example:

$$\frac{(0.428 + 0.0804)}{0.009800}$$

The addition is first, 0.428 + 0.0804 = 0.5084. Following the rules for addition/subtraction, the answer should have three significant figures, but rounding is the last step. Therefore, 0.5084 is used in the next step, 0.5084/0.009800 = 51.87755. Following the rules for multiplication/addition, the answer should have four significant figures (but rounding is the last step). The sum of the numerator has three significant figures, and the denominator has four, so the final answer is rounded to three significant figures, 51.9.

(vii) **Calculating with Exact Numbers**
Sometimes numbers used in a calculation are exact rather than approximate. This is true when using defined quantities, including many conversion factors, and when using pure numbers. Pure or defined numbers do not affect the accuracy of a calculation. You may think of them as having an infinite number of significant figures. Calculating with exact numbers is important when dealing with conversions or calculating molar ratios in chemistry.

(viii) **Significant Figures in Logarithms**
When determining the number of significant figures from a logarithm function, only the digits to the right of the decimal should be counted as significant figures. For example:

– What is the pH of a sample of orange juice that has $2.5 \times 10^{-4}$ mol/L hydronium ions? The measurement $2.5 \times 10^{-4}$ mol/L has two significant figures. The power of ten indicates where the decimal is located (i.e. 0.00025). The pH of the sample is $-\log(2.5 \times 10^{-4}) = 3.602\,059$. The digit to the left of the decimal is derived from the power of ten. Therefore, it is not significant. Only two digits to the right of the decimal are significant. The answer should be recorded as 3.60.

– What is the hydronium ion concentration of orange juice with pH = 2.25? The pH 2.25 has two significant figures. The hydronium ion concentration is equal to the antilog of -2.25. This value is 0.0056234 mol/L, which, when rounded to two significant figures, becomes 0.0056 mol/L or $5.6 \times 10^{-3}$ mol/L.

## Formulae and Units

A constructed response question that requires numerical calculations often uses formulae or equations as the starting point to its solution. Proper use of formulae and units in science indicates a thorough understanding of the logic to solve a problem. For any solution that requires the mathematical manipulation of a formula, the formula should be stated at the beginning, followed by workings that clearly indicate the mathematical computations necessary to find the solution.

For most cases in science, a S.I. unit follows a measured value because it describes the value. Three exceptions to this are pH, equilibrium constants, and index of refraction. The final answer of a solution for a constructed response question that requires the mathematical manipulation of a formula always has a unit with the value. The workings of a solution that lead to the final answer do not have to show units.

# Data

Data is generally presented in the form of graphs, tables, and drawings. When these formats are used several scientific conventions should be followed.

## Graphs

Graphs represent relationships between numerical information in a pictorial form. Two kinds of graphs are commonly used in science courses in Newfoundland and Labrador:

(i) Line graph

- used to display the relationship between continuous data
- demonstrates a progression of values or shows how one variable changes in relation to another variable; for example, growth of a child with age

Note: When equations are graphed, a line or curve of best-fit must be drawn.

(ii) Bar graph

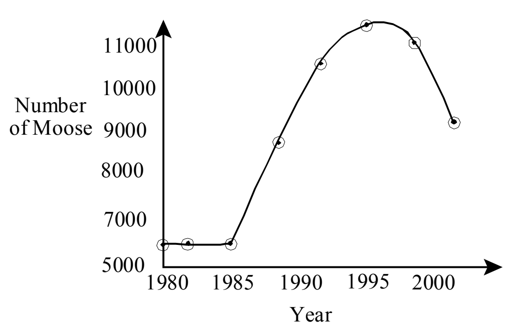
- used to display discrete or discontinuous data
- consists of parallel bars whose lengths are proportional to quantities given in a set of data. The items compared are plotted along the horizontal axis and appropriate measurement is plotted along the vertical axis. The numbers and types of protists in a lake may be illustrated in a bar graph.

**Graphing Rules:**

1. The graph must have a title. The title represents the relationship between the two variables.
2. The manipulated (independent) variable is on the horizontal *x*-axis.
3. The responding (dependent) variable is on the vertical *y*-axis.
4. Each axis is specifically labelled with units (if applicable) according to the variable it represents and values are provided with equal increments. The scale does not have to be the same on both axes, but the scales must accommodate the ranges of the two variables (i.e., the graph line or series of bars must fill out the majority ($\geq 75\%$) of the available space).

   Note: It is not necessary that both axes start at zero. See example below.
5. When data are plotted, a circle should be placed around each point to indicate a degree of error. The graph may show exact numbers or a general relationship. A best-fit line or curve must be used in line and scatter graphs.
6. A legend may be used to identify individual lines on a multi-line graph.

Moose Population in Newfoundland and Labrador (1980 - 2000)



**(i) Tables**

Tables represent numerical or textual information in an organized format. They show how different variables are related to one another by clearly labelling data in a horizontal or vertical format. As with graphs, tables must have a title that represent the relationship between the variables. For example:

Moose Population in Newfoundland and Labrador (1980 - 2000)

| Year | Number of Moose |
|---|---|
| 1980 | 5789 |
| 1985 | 6057 |
| 1990 | 8823 |
| 1995 | 11 156 |
| 2000 | 9315 |

**(ii) Drawings**

Biological drawings that indicate a scale are not required for the level three science course public examinations in Newfoundland and Labrador. Diagrams, however, may often be used to aid in the explanation of a constructed response question. These should be clear and properly labelled to indicated important aspects of the diagram.

The example below is a sketch of the geological conditions necessary for an artesian well: