# Maths skills – M0.2 Recognise and use expressions in decimal and standard form

### Tutorials

Learners may be tested on their ability to:

* use an appropriate number of decimal places in calculations, e.g. for a mean
* carry out calculations using numbers in standard and ordinary form, e.g. use of magnification
* understand standard form when applied to areas such as size of organelles
* convert between numbers in standard and ordinary form
* understand that significant figures need retaining when making conversions between standard and ordinary form, e.g. 0.0050 mol dm-3 is equivalent to 5.0 x 10-3 mol dm-3.

### Decimal places

You need to understand and use the appropriate number of decimal places or significant figures in calculations.

Decimal places are simply how many digits come after the decimal point.

For example, all of these numbers have the same number of decimal places but may have a different number of significant figures.

|  |  |  |
| --- | --- | --- |
| **Number** | **Decimal places** | **Significant figures** |
|  11.37 | 2 | 4 |
|  105.82 | 2 | 5 |
|  5.69 | 2 | 3 |
|  0.02 | 2 | 1 |

Significant figures (covered in detail in section M1.1) are numbers with meaning, starting from the first non-zero digit. For example.... now these numbers have the same number of significant figures but differ in the number of decimal places.

|  |  |  |
| --- | --- | --- |
| **Number** | **Decimal places** | **Significant figures** |
|  11.3 | 1 | 3 |
|  105 | 0 | 3 |
|  5.69 | 2 | 3 |
|  0.0200 | 4 | 3 |

When you are carrying out an experiment, you will be expected to record raw data to the same number of decimal places (rather than the same number of significant figures). These decimal places are used to tell the reader the resolution of your data collection. For example when measuring volumes 5.0, 5.5, 6.0 and 6.5 m*l* half a m*l* would be about right if you were using a 10 m*l* measuring cylinder. However, if you used a Gilson pipette you may be justified in using two decimal places.

|  |  |  |
| --- | --- | --- |
| **Measurement** | **Volume (m*l*)****X** | **Volume (m*l*)****✓** |
| 1 |  9 |  9.0 |
| 2 |  9.5 |  9.5 |
| 3 | 10 | 10.0 |
| 4 |  10.5 | 10.5 |

Processed data (i.e. what has been calculated), can be recorded up to one decimal place more than the raw data. For example, if you were asked to calculate the mean for the above example, from the data using a measuring cylinder the answer could be recorded as 9.75 m*l*. If you were using the data from the Gilson pipette, you could express the mean as 9.750 m*l*.

|  |  |  |
| --- | --- | --- |
| **Measurement** | **Volume (m*l*)****X** | **Volume (m*l*)****✓** |
| 1 |  9 |  9.0 |
| 2 |  9.5 |  9.5 |
| 3 | 10 | 10.0 |
| 4 |  10.5 | 10.5 |
|  |  | Mean = 9.75 |

When adding and subtracting decimals the answer should be given using the lowest number of decimal places used in the calculation. This is because you can’t claim your degree of resolution to be any higher than what your data say. This involves rounding off the number to a certain point depending on how many decimal places you are recording, with rounding up being required if the next number is 5 or above. For example, 25.5 – 8.31 = 17.19. The lowest number of decimal places in the calculation is one decimal place so the answer would therefore be 17.2.

This is particularly important when measuring quantities by difference such as mass, temperature and volume. The measurements made should be recorded to a specific number of decimal places, and when calculating the difference between the measurements, this number of decimal places should be maintained.

For example, if the following temperature measurements were recorded:

Initial temperature 22.5 °C

Final temperature 29.5 °C

The temperature difference would be 29.5 – 22.5 = 7.0 °C. This is given to 1 decimal place, to match the resolution of the measured values as this is the degree of accuracy of our data. The ‘0’ is significant, so must be included.

The number of decimal places you show in your collection of raw data or in your answer at the end of a calculation is communicating information about the degree of resolution you are claiming, and this is important information in a scientific context.

### Standard Form

Many numbers in biology, particularly with calculations involving large or small numbers, will be written in a scientific notation known as standard form. A number written in standard form is:

*a* × 10*n*

where *n* is a whole number (also known as an integer)

and *a* is between the values of 1 and 10

Standard form makes writing and reading long numbers easier. For example, 1 million in standard form is 1 x 106.

2 million would be 2 x 106.

You need to remember the “power laws” in order to deal with the value of *n*.

The multiplicative rule is where you add the powers

The division rule is where you subtract one power from the other

The power rule is where the powers are multiplied

The reciprocal rule is where the negative sign tells you it is the denominator

And the root rule is where the power is divided by the root

For example, for 2 × 104 × 8 × 103, we know that 2 x 8 = 16 so our *a* value is 16. For the *n* value we need to apply the multiplicative rule and add the powers, so 104 × 103 equals 107. Therefore the whole answer is 16 × 107.

However, be careful that you don’t make a mistake by forgetting that *a* must be between 1 and 10.

So here the multiplicative power rule has been applied and there is the correct numerical answer, the answer is not in standard form because the *a* value is not between 1 and 10. Therefore, 16 needs to be ‘scaled’ down by dividing by 10. Importantly - if we divide the numerical answer by 10, we have to increase the power by 1 in order to keep the numerical value the same. Therefore 16 × 107 becomes 1.6 × 108.

Here are some other examples of numbers written using standard form:

|  |  |
| --- | --- |
| **Number** | **Standard form** |
| 456000 | 4.56 x 105 |
| 2068567 | 2.068567 x 106 |
| 46 | 4.6 x 101 |
| 3789 | 3.789 x 103 |
| 4 | 4 x 100 |
| 0.0005 | 5 x 10-4 |
| 0.4678 | 4.678 x 10-1 |
| 0.000030006 | 3.0006 x 10-5 |
| 0.3040506 | 3.040506 x 10-1 |

You are expected to be able to express results in standard form and to also convert between standard and decimal forms. For example, the size of a cell may be 0.0001 m in ordinary (decimal) form. This would be written in standard form as 1 x 10-4 m.

In biology raw data is usually reported to the same number of decimal places rather than the same number of significant figures including when converting between standard and decimal forms.

By applying this to the data from the previous table, we get this third column:

|  |  |  |
| --- | --- | --- |
| **Number** | **Standard form** | **Standard form to 1 decimal place** |
| 456000 | 4.56 x 105 | 4.6 x 105 |
| 2068567 | 2.068567 x 106 | 2.1 x 106 |
| 46 | 4.6 x 101 | 4.6 x 101 |
| 3789 | 3.789 x 103 | 3.8 x 103 |
| 4 | 4 x 100 | 4.0 x 100 |
| 0.0005 | 5 x 10-4 | 5.0 x 10-4 |
| 0.4678 | 4.678 x 10-1 | 4.7 x 10-1 |
| 0.000030006 | 3.0006 x 10-5 | 3.0 x 10-5 |
| 0.3040506 | 3.040506 x 10-1 | 3.0 x 10-1 |

You have to be careful though because, by reducing the number of significant figures, you are altering your communication about the degree of resolution you are claiming to have.

In M0.1 we looked at converting between units to express a measurement clearly. An alternative is to keep units the same but use standard form. This is most useful in biology when you want to make a clear comparison between two things. You might want to show that a bacterium was 2 µm long and that an *Amoeba* was 1 mm. It would be better to communicate this as the bacterium being 2 x 10-3 mm and the *Amoeba* being 1 mm. Or you could say that the bacterium is 2 µm and the Amoeba is 1 x 103 µm. In this way you are using standard form to communicate clearly the difference in length.

**Document updates**

 v1.0 April 2017 Original version.

 v1.1 June 2019 Changed how the word accuracy and resolution were used in order to be in line with the ‘Language of measurement’

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