Nail IB

P H Y S I C S

Physics and physical measurement

The realm of physics

1.1.1 State and compare quantities to the nearest order of magnitude.

Throughout the study of physics we deal with a wide range of magnitudes. We will use minuscule values such as the mass of an electron and huge ones such as the mass of the (observable) universe. In order to easily understand the magnitude of these quantities we need a way to express them in a simple form, to do this, we simply write them to the nearest power of ten (rounding up or down as appropriate).

That is, instead of writing a number such as 1000, we write 10^3 .

The use of orders of magnitude is generally just to get an idea of the scale and differences in scale of values. It is not an accurate representation of a value. For example, if we take 400, it's order of magnitude is 10^2 , which when we calculate it gives 10 x 10 = 100. This is four times less than the actual value, but that does not matter. The point of orders of magnitude is to get a sense of the scale of the number, in this case we know the number is within the 100s.

1.1.2 State the ranges of magnitude of distances, masses and times that occur in the universe, from smallest to greatest.

Distances:

- sub-nuclear particles: 10^{-15} m
- extent of the visible universe: 10^{+25} m

Masses:

- mass of electron: 10^{-30} kg
- mass of universe: 10^{+50} kg

Times:

- passage of light across a nucleus: 10^{-23} s
- age of the universe : 10^{+18} s

1.1.3 State ratios of quantities as differences of orders of magnitude.

Using orders of magnitude makes it easy to compare quantities, for example, if we want to compare the size of an an atom (10^{-10} m) to the size of a single proton (10^{-15} m) we would take the difference between them to obtain the ratio. Here, the difference is of magnitude 10^{5}meaning that an atom is 10^{5} or 100000 times bigger than a proton.

1.1.4 Estimate approximate values of everyday quantities to one or two significant figures and/or to the nearest order of magnitude.

Significant figures

To express a value to a certain amount of significant figures means to arrange the value in a way that it contains only a certain amount of digits which contribute to its precision.

For example, if we were asked to state the value of an equation to three significant figures and we found the result of that value to be 2.5423, we would state it as 2.54.

Note that 2.54 is accurate to three significant figures as we count both the digits before and after the point.

The amount of significant figures includes all digits except:

- leading and trailing zeros (such as **0.00**24 (2 sig. figures) and 24**000** (2 sig. figures)) which serve only as placeholders to indicate the scale of the number.
- extra "artificial" digits produced when calculating to a greater accuracy than that of the original data, or measurements reported to a greater precision than the equipment used to obtain them supports.

Rules for identifying significant figures:

- All non-zero digits are considered significant (such as 14 (2 sig. figures) and 12.34 (4 sig. figures)).
- Zeros placed in between two non-zero digits (such as 1**0**4 (3 sig. figures) and 1**00**4 (4 sig. figures))
- Trailing zeros in a number containing a decimal point are significant (such as 2.34**00** (5 sig. figures) note that a number 0.000**23400** also has 5 sig. figures as the leading zeros are not significant).

Note that a number such as 0.230 and 0.23 are technically the same number, but, the former (0.230) contains three significant figures, which states that it is accurate to three significant figures. On the other hand, the latter (0.23) could represent a number such as 2.31 accurate to only two significant figures. The use of trailing zeros after a decimal point as significant figures is is simply to state that the number is accurate to that degree.

Another thing to note is that some numbers with no decimal point but ending in trailing zeros can cause some confusion. For example, the number 200, this number contains one significant figure (the digit 2). However, this could be a number that is represented to three significant figures which just happens to end with trailing zeros.

Typically these confusions can be resolved by taking the number in context and if that does not help, one can simply state the degree of significance (for example “200 (2 s.f.)” , means that the two first digits are accurate and the second trailing zero is just a place holder.

Expressing significant figures as orders of magnitude:

To represent a number using only the significant digits can easily be done by expressing it’s order of magnitude. This removes all leading and trailing zeros which are not significant.

For example:

0.000**34** contains two significant figures (34) and fours leading zeros in order to show the magnitude. This can be represented so that it is easier to read as such: 3.4×10^{-4}.

Note that we simply removed the leading zeros and multiplied the number we got by 10 to the power of negative the amount of leading zeros (in this case 4). The negative sign in the power shows that the zeros are leading.

A number such as **34**000 (2 s.f.) would be represented as 34×10^{3}.

Again, we simply take out the trailing zeros, and multiply the number by 10 to the power of the number of zeros (3 in this case).

There are a couple of cases in which you need to be careful:

- A number such as 0.003400 would be represented as 3.400×10^{-3} . Remember, trailing zeros after a decimal point **are** significant.
- 56000 (3 s.f.) would be represented as 560×10^{2} . This is because it is stated that the number is accurate the 3 significant zeros, therefor the first trailing zero is significant and must be included. Note that this can be used as another way to express a value such as 56000 to three significant figures (as opposed to writing "56000 (3 s.f.)").

Rounding

When working with significant figures you will often have to round numbers in order to express them to the appropriate amount of significant figures.

For example:

State 2.342 to three significant figures: would be written 2.34.

When representing the number 2.342 to three significant figures we rounded it down to 2.34. This means that when we removed the excess digit, it was not high enough to affect the last digit that we kept.

Whether to round up or down is a simple decision:

If the first digit in the excess being cut off is lower than 5 we do not change the last digit which we are keeping. If the first digit in the excess which is being cut off is 5 or higher we increment the last digit that we are keeping (and the rest of the number if required).