

1.1.4: Measurements and Exact Numbers

Measurement

Measurements have three parts to them:

1. Numeric Value
2. Unit
3. Uncertainty

For example, if a certain length is measured as 45.2 cm, the numerical value is 45.2 and the unit is cm (centimeter). The last significant digit reported communicates the level of uncertainty. Since the last digit in this example is 2, that is the uncertain digit. The 2 is uncertain and could possibly be 1 or 3. So this length is somewhere between 45.1 cm and 45.3 cm.

If instead the length had been reported as 45 cm, the 5 would be the uncertain digit, and the measurement is between 44 cm and 46 cm.

Both of these measurements might have been taken of the same length, but one of them was taken with a more precise instrument and one was taken with a less precise instrument. Reporting one of these measurements tells us not only the length itself, but how certain we are of the measurement and the precision of the instrument used to take the measurements.

Note

Any measured value has a component of uncertainty, no matter how precise the instrument used. The convention used is that the last significant digit reported should represent the place value of the uncertainty. That is, the last (right-most) digit is the uncertain one!

Exact Numbers

Exact numbers have no uncertainty. You can think of them as having an infinite number of significant digit. This is not possible for any measurement, but it is possible in these cases:

1. Counted items
2. Defined values

For example, if you pour a substance into four beakers, the number 4 is exact. There is no uncertainty in the number of beakers you have. Also, if you measure the diameter of a circle, and you calculate the radius by dividing the diameter by 2, the number 2 is exact. There are exactly two radii in the diameter.

Also, some values are exact because one unit is defined as being exactly equal to another. Any metric relationship is exact. There are exactly 1000 m in 1 km. For some relationships, it is not as obvious that the relationship is exact, and you will be informed in the textbook or in the problem. For example, the inch is defined as being equal to 2.54 cm exactly.

[Note that not all relationships we will use are exact. Some are approximations that have some uncertainty. One example is the use of the relationship "1 kg = 2.20 lb". The kilogram is not defined as 2.20 pounds. It is not exactly 2.20 pounds. This is an approximation. If we want to use a more precise approximation, we would use "1 kg = 2.2046 lb". If we wanted to be even more precise, we could use "1 kg = 2.2046226 lb". We could even look in a reference book to find more digits than that, but these approximations are good enough for our purposes.]

Exercise 1.1.4.1

Determine whether each number is exact or measured:

- (a) The homework assignment has 8 questions.
- (b) The assignment took 15 minutes to complete.
- (c) There are 60 minutes in an hour.
- (d) Therefore the homework assignment took 0.25 hours.

Answer (a)

Exact.

Answer (b)

Measured.

Answer (c)

Exact.

Answer (d)

Measured.

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