UNIT 1 SCIENTIFIC WORK. QUANTITIES AND UNITS

KEY CONCEPTS

- The stages in the scientific method are:
  - Making an observation and making questions.
  - Formulating hypotheses.
  - Testing through an experiment.
  - Getting results and drawing conclusions.
- Presenting results and formulating laws or theories.
- International system of units is used for measuring.
- Sometimes, multiples and fractions are used.

1. THE SCIENTIFIC METHOD

When you were little, you probably felt a certain curiosity about the two small holes in the wall at home. If this curiosity led you to put your fingers into them, the sharp electric shock, quickly followed by your crying, led you to an important conclusion: *do not put your fingers in any small holes in the wall that look like a socket*.

Without knowing it, your curiosity led you to experiment and then to a conclusion. You were applying the scientific method.

Human beings are naturally curious about everything that surrounds us. The Ancient Greeks wondered whether the Earth was flat or round and how they could measure the size of it. They also wondered if the stars orbited the Earth or if, on the other hand, the Earth and the other planets orbited the Sun.

These types of questions about things that we observe around us have led humans to create a series of stages for **observing, experimenting** and **drawing conclusions** that we call the **scientific method**.

1.1. What is the scientific method?

Although there isn't a set of strict rules that must be followed, we can say that every research process follows a set of stages:

1. **Making an observation and asking a question.** At this stage we look for information about the problem or similar problems.
2. **Formulating hypotheses.** Hypotheses are ideas we have about what factors will play a role in the problem we are investigating and what results we can expect.
3. **Testing and experimenting.** We test each hypothesis that we have formulated separately. We design an experiment which will let us measure each factor.

4. **Results and conclusions.** Once we have taken measurements, we organize them in tables and graphs, which will help us see the results more clearly and draw conclusions.
5. **Presenting and formulating laws or theories.** A law or theory gives us a general view of the problem and lets us predict what will happen in similar cases without having to repeat the whole process from the beginning.

2. PRESENTING RESULTS: TABLES AND GRAPHS

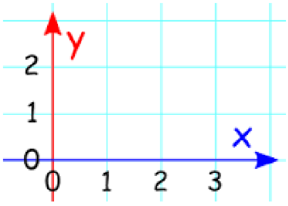
It's vital to organize the results you have obtained clearly so you can draw conclusions. We use **tables and graphs** to organize and present the results.

In **tables** we can show the measurements of one variable (dependent variable) that depends on other one's value (independent variable), giving the units of measurement. For example:

Distance (m)	4	7	10	13	16	19
Time (s)	0	2	4	6	8	10

A **graph** is a visual representation of the data in a table. On each axis of the graph, we mark the different values, keeping the following in mind:

- On the horizontal axis, or **x-axis**, we represent the **independent variable**, which is the variable whose value does not depend on another variable (for example, time).
- On the vertical axis, or **y-axis**, we put the **dependent variable**, whose value depends on what we have set as the independent variable (for example, distance).



Each pair of related values that we represent on the graph constitutes a point on the graph. Once we plot the graph we have to find the line (straight or curved) that goes through all the points.

3. MEASUREMENT

3.1. What is measurement?

Whenever we measure something, we make a comparison between the property we want to find out and the standard unit of measure chosen for this property. For example, when we say that a certain length is 10 metres, what we mean is that it has 10 standard units of the established measurement for distances, which is the metre.

Measuring is comparing a property with a standard of measurement defined for that property. This standard is called **unit of measurement**.

3.2. Quantities and units

We can measure many different properties of matter such as mass, length, volume and density. To do this, we need standard units of measurement and an appropriate instrument (for example a metre).

A **quantity** is any characteristic or property of an object that can be measured. A **unit of measurement** is the standard by which we measure a quantity.

3.3. The International System of Units

The internationalisation of trade and scientific thought during the 18th century, showed the need for a unified system of measurements. The first system, called the metric system, appeared in France during the revolution.

In Spain, this system was adopted in 1859, but it wasn't until 1960 that the **International System of Units (SI)** was established and adopted by most countries and especially by the scientific community.

Nowadays, this system is based on seven **fundamental** or **base quantities** which can be known only from direct measurements:

BASE QUANTITIES	
Name	**Symbol**
Length	*l*
Mass	*m*
Time	*t*
Temperature	*T*
Amount of substance	*n*
Electric current	*I*
Luminous intensity	*L*

UNIT OF MEASUREMENT	
Name	**Symbol**
Metre	*m*
Kilogram	*kg*
Second	*s*
Kelvin	*K*
Mole	*mol*
Ampere	*A*
Candele	*cd*

The rest of quantities are called **derived quantities** which can be known as mathematical combinations between the base quantities:

DERIVED QUANTIES	
Name	**Symbol**
Speed, velocity	*v*
Area	*A*
Volume	*V*
Force	*F*
Work	*W*
Energy	*E*
…	

UNIT OF MEASUREMENT	
Name	**Symbol**
Metre per second	*m/s*
Square metre	m^2
Cubic metre	m^3
Newton	*N*
Joule	*J*
Joule	*J*
…	

3.4. Multiples and submultiples of units

For some measurements, the SI units may be either too big or too small. Fortunately, SI units are part of the metric system and the units are categorized by factors of 10. Metric system has the advantage that conversions of units involve only powers of 10: there are 100 centimetres in a metre, 1.000 metres in a kilometre, and so on.

Depending on the order of magnitude of the property that we want to measure, we use multiples and submultiples (or fractions) of SI units. For example, distances in metres are suitable in construction, while distances in kilometres are appropriate for air travel, and the tiny measure of nanometres are convenient in optical design. With the metric system there is no need to invent new units for particular applications.

The table gives metric prefixes and symbols used to denote various factors of 10:

Prefix	Symbol	Value	Example (some are approximate)			
exa	E	10^{18}	exametre	Em	10^{18} m	distance light travels in a century
peta	P	10^{15}	petasecond	Ps	10^{15} s	30 million years
tera	T	10^{12}	terawatt	TW	10^{12} W	powerful laser output
giga	G	10^{9}	gigahertz	GHz	10^{9} Hz	a microwave frequency
mega	M	10^{6}	megacurie	MCi	10^{6} Ci	high radioactivity
kilo	k	10^{3}	kilometre	km	10^{3} m	about 6/10 mile
hecto	h	10^{2}	hectolitre	hL	10^{2} L	26 gallons
deka	da	10^{1}	dekagram	dag	10^{1} g	teaspoon of butter
—	—	10^{0} (=1)				
deci	d	10^{-1}	decilitre	dL	10^{-1} L	less than half a soda
centi	c	10^{-2}	centimetre	cm	10^{-2} m	fingertip thickness
milli	m	10^{-3}	millimetre	mm	10^{-3} m	flea at its shoulders
micro	µ	10^{-6}	micrometre	µm	10^{-6} m	detail in microscope
nano	n	10^{-9}	nanogram	ng	10^{-9} g	small speck of dust
pico	p	10^{-12}	picofarad	pF	10^{-12} F	small capacitor in radio
femto	f	10^{-15}	femtometre	fm	10^{-15} m	size of a proton
atto	a	10^{-18}	attosecond	as	10^{-18} s	time light crosses an atom

Remember:

- To go from **higher to lower units** you multiply by the conversion factor 10^{n}, *n* being the number of steps downwards on the scale from one unit to another.
- To go from lower to higher units you multiply by the conversion factor 10^{-n}, *n* being the number of steps downwards on the scale from one unit to another.