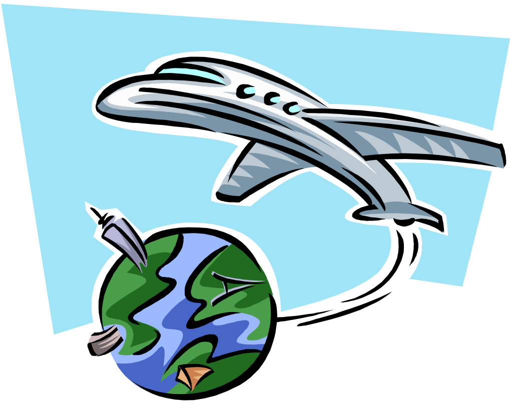
Physical Quantities- Measurements and Units

Key Words

to measure	base	length	depth	kilogram	metre
measurement (-s)	derived	width	volume	tonne	mass
magnitude	unit	area	intensive	extensive	matter
scientific notation					

We can state that Physics is based on measurements. When we investigate physical bodies, it is not enough to say that one body is "big" whereas another is "small". Concepts as "big" and "small" are relative. We have to have something, with which we can compare the characteristics of the bodies in an exact way. Since ancient times, man has used different measures to do this.



Imagine the following scenario: an aeroplane flying from Paris to Athens. The plane has taken 4 hours to cover the 3100 kilometres of distance that separates the two cities. During the flight, the outside temperature was 4˚ C below zero and the average velocity of the plane was 775 km/h.

1. Write a list of the measurements that have been made to describe the case above.

Length, time, temperature or velocity are characteristics we can **measure.** They are all **physical quantities.**

What are Physical Quantities?

A physical quantity is a measurable property of an object, a substance or a phenomenon (such as time).

Physical quantities allow us to describe our surroundings and the phenomena that take place in them.

A **physical quantity** is made up of two parts, a number and a unit. Physical quantities allow us to describe our surroundings and the phenomena that take place in them.

When you study mathematics, you usually use pure number (like 3 or 6.5 or π), or variables that represent pure numbers (such as x and y). **In science,** however, **numbers are used to represent** physical quantities: **quantities that correspond to something in the physical world**. It is therefore important to know what kind of quantity a number represents. So, how is that done? This is done by specifying units of measurements for each quantity. **Numbers that measure a physical quantity must always include the unit.**

For example, if you see the quantity "2.5 m" you know that it is the measurement of a distance, as distance is measured in metres. But if you see "2.5 m^2" instead, you know that is a surface area that has been measured.

You must always remember to include the unit of measurement when dealing with scientific data or express scientific quantities in any other context.

Base (or fundamental) and derived physical quantities

We can distinguish two types of physical quantities:

Base physical quantities	**Derived physical quantities**
- Can be **measured directly**, without calculations or mathematical operations.	- Are the **results of a mathematical operation** with base physical quantities.

So, **base physical quantities** are fundamental physical quantities that cannot be broken down into simpler ones therefore, that are not defined in terms of other physical quantities. Some examples are length, mass and time.

On the other hand, **derived physical quantities** are those that can be broken down into base physical quantities. Another way of saying is that derived magnitudes are a combination of base quantities by multiplication, division or both.

Please use full sentences and proper English to answer the following questions.

- Use a ruler to measure the length of your notebook. _________________.

- Is length a base or a derived quantity? Why?

- Calculate the area of your notebook. Explain whether area is a base or a derived quantity.

- Look for a definition of *speed* and *density*. Explain if they are base or derived quantities.

- Fill in the table.

Quantity	**Instrument(s) used**	**Do we need calculations?**	**Base or derived quantity?**
Length			
Area			
Volume			
Temperature			
Time			
Mass			

A system of units - The International System (SI)

The handspan was one of the first measuring units used by man. However, the handspan is a measure which varies from one person to another. Its use in commerce to measure objects (cloth, thread, land...) caused lots of problems. Therefore, in some places, like the Italian cities Pisa and Geneva, a standard handspan measure was established centuries ago, so that all salesmen of the city would use the same measure.

Nevertheless, later on it became clear that the standard handspan measure in different places was not exactly the same. Today we know, for example, that the handspan used in Pisa was 29.8 cm whereas the handspan used in Geneva was only 24.7 cm!

To finally resolve the problem with measures which varied from one person to the other and from one place to the other, the **International System** of measures (Système International d'Unités, SI) was established.

In order to establish the SI system, first of all, they determined the base quantities and the units used to measure them. And building on those base quantities, they defined the derived quantities and the units which corresponded to each quantity.

In the following table, you can see some **base quantities** which make up the International System, the **base unit** of each one, and the **unit abbreviations or symbol** used to represent them.

In order to make communication between scientist around the world easier, most scientists use the international system (SI units).

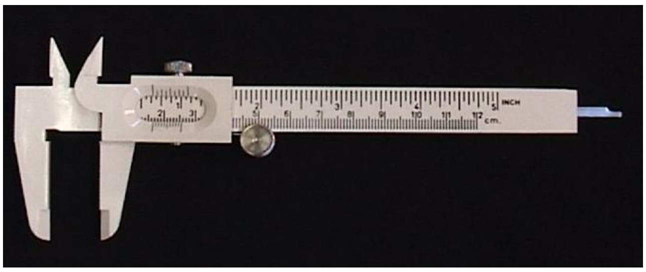
Base Quantity	SI unit name	SI unit symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Of these seven base quantities length, mass and time are the ones used more often in our everyday life. Therefore, we will define them in greater detail.

Length

The SI unit of length is the metre (m). There are larger and smaller units of length based on the metre: (km, cm, mm, nm, etc).

To measure length, we use a **metre** or a **ruler**. For smaller lengths, we can use **Vernier caliper** (picture 1) or even a **micrometer** (picture 2).



Picture 1. Vernier caliper

Picture 2. Micrometer

Mass

Mass is the amount of substance or matter in an object.

The SI unit of mass is the kilogram (kg).

To measure mass, we use a **balance**. A beam or mechanical balance is the simplest and probably the oldest way to measure mass. However, you will most always use an electronic balance when working in the laboratory.

(“Google, 2016)

Length and mass use the decimal system

Sometimes we need to measure something very big, like the distance between the Sun and Earth, or something very small, like the mass of a pollen grain. In these cases, the base units are not the most adequate. Instead, we use the **decimal system** to make **multiples** and **submultiples** of the base units. In the decimal system (deci = ten), the units are multiples of ten. Each multiple equals to ten units of the closest smaller unit, and each submultiple equals to one tenth of the closest bigger unit.

The multiples and submultiples are indicated with **prefixes**. The closest submultiple of a metre is a *deci*metre (1 m = 10 dm). And a gram is the equivalent of one thousandth of a *kilo*gram (multiple) or 1000 *milli*grams (submultiple).

In the following table, you can see the prefixes and their abbreviations.

Prefix	**Abbreviation**	**Example: length**	**Example: mass**
Milli- (= one thousandth)	m-	millimetre (mm)	milligram (mg)
Centi- (= one hundredth)	c-	centimetre (cm)	centigram (cg)
Deci- (= one tenth)	d-	decimetre (dm)	decigram (dg)
-	-	metre (m) **(base SI unit)**	gram (g)
Deca- (= ten)	Da-	decametre (dam)	decagram (dag)
Hecto- (= hundred)	h-	hectometre (hm)	hectogram (hg)
Kilo- (= thousand)	k-	kilometre (km)	kilogram (kg) **(base SI unit)**

1 tonne (t) = 1000 kg

Time: The decimal system is not used for all quantities

When we are working with units of time, we notice that they are built up on a different system. Time units were based on observations of astronomic phenomena such as the position of the Sun on the sky, the phases of the Moon and the seasons. This way, the **day**, the **month** and the **year** were defined. Based on these units, the most commonly used time units were calculated: the **hour**, the **minute** and the **second**. In the International system, the **second** has been established as base unit for time.

The units which are bigger than the second do not follow the decimal system!

► Calculate the following quantities. **Do not use a calculator**!

1 .... = 365.2 days = 31 553 280 s

1 day = ... hours = 86 400 s

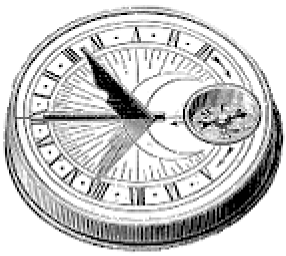
1 hour = ... minutes = ... s

1 min = ... s

However, when we are talking about time units which are **smaller** than the second, we use the decimal system. For example, in a sprinter race we talk about tenths and hundredths of seconds. In some case we even use thousandths of seconds.

Measuring time

Time is measured with **clocks** or **stopwatches**. The first clocks were sundials.

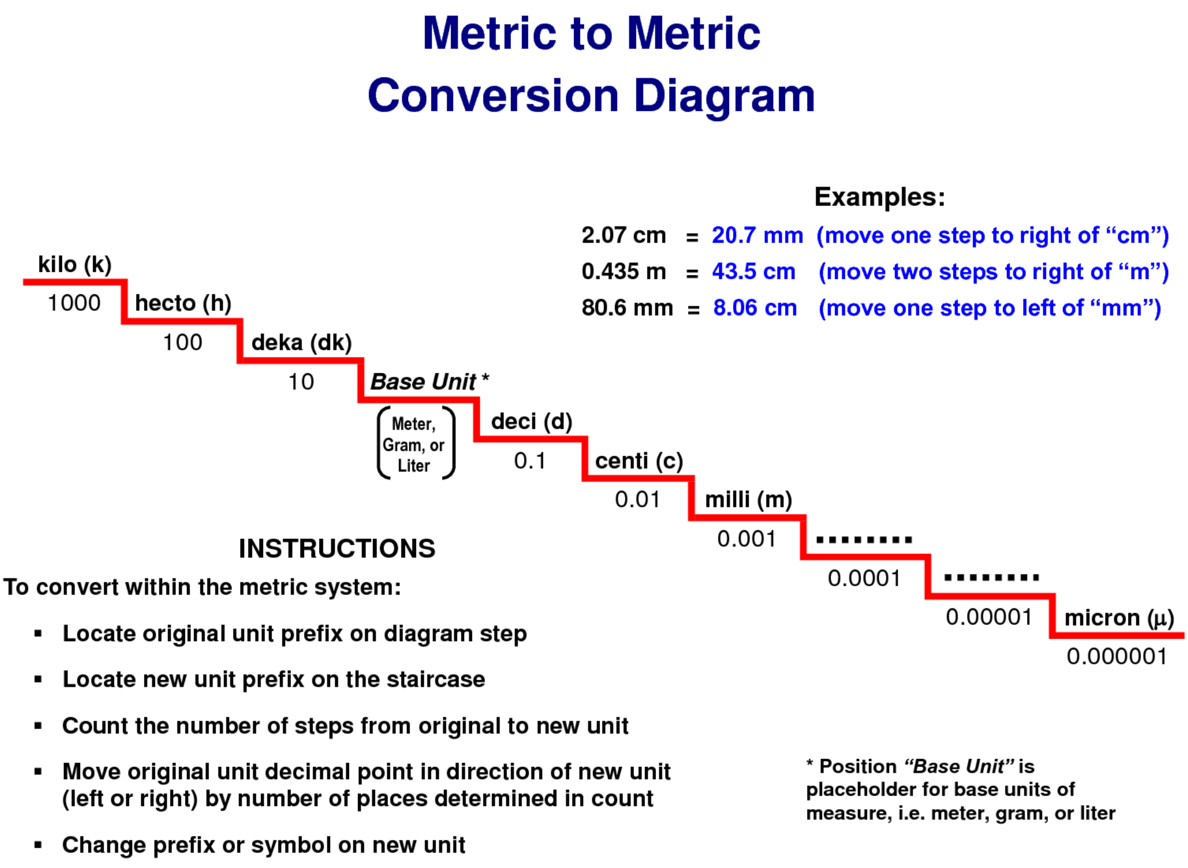


1500-1300 BC

The sundial was first used in Egypt to measure the time of day by the Sun's shadow. Hours are shorter in winter and longer in summer.

Decimal System - How can we easily change the unit?

Changing the place of the decimal separator in a measured value one or various steps right or left, we can easily change the unit to the most adequate multiple or submultiple.



(HubPages, 2015)

<u>You must know the SI unit of the different physical quantities we study throughout the year and be able to use the decimal system.</u> In science SI units are often used, and always when a physical constant is present. You will see what a physical constant is in later units.

➢ Change the units of the following values.

20 kg = ... mg	653 cg = ... hg	3 dL = ... hL
500 mL= .... dl	0.5 daL= cl	110 cg = ... mg
46 dam= .... km	8 t = ... g	0.01 m =....................... cm

Significant Figures

Significant figures (sig figs) are the figures in a number that allows us to appreciate the precision in a measurement.

So, what do we mean by ‘the precision in an instrument’ then? Well, we could spend quite some time explaining precision of instruments and the corresponding errors. However, at this level, it is enough for you to understand that the greater the number of divisions in an instrument the greater its precision will be. So if you can measure more decimals, your measurement will be more precise.

Rules for determining Significant Figures

- Figures that do not contain zeros are always significant → 134.76
- All figures to the right of a decimal place are significant, including zeros → 12.30
- Zeros at the beginning of a number are not significant → 0.00025 or 0.89
- Zeros at the end of a number without a decimal are not significant → 14500

We will talk more about significant figures throughout the year, especially in the laboratory, as it is very important when dealing with the precision of a measurement and the instrument with which it was recorded.

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