CHAPTER 01

Measurement and Physical Quantities

1.1 MEASUREMENT

Physics, like the other sciences, is all about explaining the natural world. Measurement is at its very heart. Ever since humans have been thinking about their place in the universe, they have been making measurements. Have you ever wondered about any of these:

- What would have been the first sort of measurement made by humans?
- When you use the unit of length, *foot*, whose foot was the standard?
- What is the shortest length of time that can exist? Is there no limit?
- Time passes but why can't it go backwards?
- Just how heavy is the universe? How did they weigh it?
- Is cream more dense than milk and, anyway, who invented *density*?

Questions like these have always intrigued people. As you study physics some of them will become clearer. But hopefully you will ask your own questions and make your own measurements, for this is what the study of physics is all about.

Activity 1.1 ESTIMATING

EI

1 Estimate the length of this page to the nearest millimetre. Now measure it. Were you over or under?

2 Now that you've had practice, estimate the length of this line:

Were you any more accurate?

3 How far is it from the floor to the ceiling? Write down your estimate and then find the actual value.

4 Can you estimate 30 seconds? Look at your watch, cover it and uncover it when you think 30 seconds is up. Repeat it until you are accurate to within 1 second. How did you count off the seconds? How did others in the class count off the seconds?

5 How good are you at estimating mass? Estimate the mass of this book in grams without lifting it and then again after lifting it. Did you lift it up and down to estimate mass? Why?

6 Feel the thickness of one page of this book. How many pages do you estimate this book has? Check.

NOVEL CHALLENGE

Here are a few 'Fermi' questions (named after US physicist Enrico Fermi, who used to drive his students nuts with them).

A How quickly does hair grow?
B How many piano tuners are there in your capital city?
C How many ping-pong balls can you fit in a suitcase?
D How quickly does grass grow?

NOVEL CHALLENGE

The four compass directions North, East, South, West are derived from old foreign words. Can you match up the original meanings with the compass directions:

A Indoeuropean *wes* = Sun goes 'down'.
B Italian *nerto* = 'to the left' as one faces the Sun.
C German *suntha* = region in which the 'Sun' appears in the Northern Hemisphere.
D Indoeuropean *aus* = Sun 'rises'.

NOVEL CHALLENGE

If you were transported in a time machine to an unknown date in Australian history, how could you work out the date? See our Web page for some suggestions.

Estimating measurements is important. You can see whether answers are reasonable or nonsense if you have a feeling for some of the common units of measurement in physics. The three quantities you've measured in the activity are the most basic measurements in physics: **length, time** and **mass**. But your estimates probably differed from others in your class and that's why standards were developed. The importance of measurement grew as human societies became more complex.

The first measurement the earliest humans are believed to have used was the 'day'. Hence, the 'day' became the first unit of measurement, well before any concept of length or mass. Which unit do you think came next? Perhaps the 'month' — from one new moon or full moon to the next; and then perhaps the 'year' when people noticed that the Sun rose again in the same constellation of stars after many new moons.

Neanderthal burial sites from 50 000 years ago suggest that people were conscious of the past, the present and the future — something that most other animals are believed to be unaware of.

As humans have progressed, so too has their need for new units of measurement. The need for a unit comes before a unit is invented. Only recently have units like the *barn* been invented. The size of a nucleus as seen by a high speed atomic particle is as big as the side of a barn, hence the name. One barn equals 10^{-28} m^2. There was no need for this unit until Einstein produced the 'theory of relativity' and physicists applied it to atomic structure.

PHYSICAL QUANTITIES 1.2

There are a number of things in the world we want to measure. As well as the three mentioned above (length, time and mass), there are others, such as temperature, electric current and weight. These measurable features are called **physical quantities**. There are also some non-physical quantities, for example intelligence, beauty and personality, that are difficult-to-measure. Attempts have been made to devise measurements for quantities such as these but have always ended up in disagreement and, in many cases, failure.

The **international system** of units called **SI** (from the French name for the system, *Système International d'Unités*), is now commonly used around the world. It is sometimes called the **metric system** (from the Greek *metron* to 'measure').

The seven fundamental (or base) units of this system are shown in Table 1.1.

Table 1.1 SI UNITS

PHYSICAL QUANTITY	SYMBOL OF QUANTITY	NAME OF UNIT	SYMBOL FOR UNIT
Length	l	metre	m
Mass	m	kilogram	kg
Time	t	second	s
Electric current	I	ampere	A
Temperature	T	kelvin	K
Amount of substance	n	mole	mol
Luminous intensity		candela	cd

To get multiples of the base units, prefixes are added. Table 1.2 lists some of these prefixes that will be used throughout your physics course. You should remember from nano to mega. Check with your teacher if you need any others.

Table 1.2 PREFIXES

PREFIX	SYMBOL	MEANING	VALUE	FACTOR
Pico	p	one million-millionth	0.000 000 000 001	10^{-12}
Nano	n	one thousand-millionth	0.000 000 001	10^{-9}
Micro	µ	one millionth	0.000 001	10^{-6}
Milli	m	one thousandth	0.001	10^{-3}
Centi	c	one hundredth	0.01	10^{-2}
Deci	d	one tenth	0.1	10^{-1}
Kilo	k	one thousand	1 000	10^{3}
Mega	M	one million	1 000 000	10^{6}
Giga	G	one thousand million	1 000 000 000	10^{9}
Tera	T	one million million	1 000 000 000 000	10^{12}

Example of using a prefix with a unit: 1 millimetre = 10^{-3} metre = 0.001 metre.

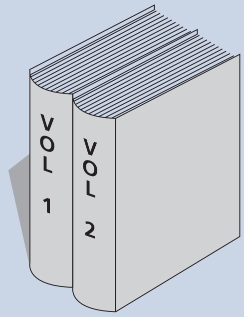
Rarely used prefixes are:

- 10^{-15} femto (f) — radius of a proton is 1 fm
- 10^{-21} zepto (z) — charge on the electron is 160 zC
- 10^{-24} yocto (y) — mass of the hydrogen atom is 1.66 yg
- 10^{-27} xenno (x) — magnetic moment of a proton is 14 xJ T^{-1}
- 10^{21} zetta (Z) — distance to Andromeda galaxy is 20 Zm
- 10^{24} yotta (Y) — mass of the Earth is 5977 Yg.

Others you'd never use are vendeko (v) 10^{-33} and vendeka (V) 10^{33}. Can you think of any practical use of these prefixes? Mathematicians also use the term *googol* to represent 10^{100} and *googolplex* for 10 raised to the power of a googol: $10^{10^{100}}$. The biggest number in the world (apart from infinity) is Grahams' number. If all the material in the world was turned into paper there still wouldn't be enough paper to write it down. Now that's big!

NOVEL CHALLENGE

You have two 100-page volumes of a dictionary on your shelf. A worm eats its way from Volume 1 page 1 through to Volume 2 page 100.
How many pages does it eat through?



Standards

Standards have to be agreed upon for units to be useful throughout the world. For instance, the temperatures in different countries couldn't be compared until a universal temperature scale was devised. The following shows how some of these units have developed.

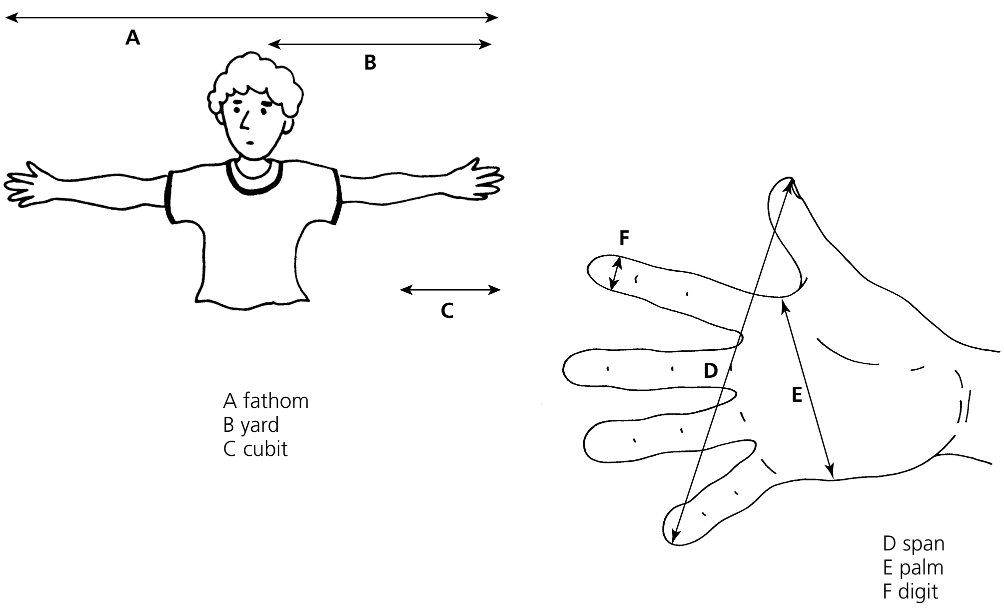


Figure 1.1
Body measurements.