PH-211 Andres La Rosa

CHAPTER 1: MEASUREMENTS

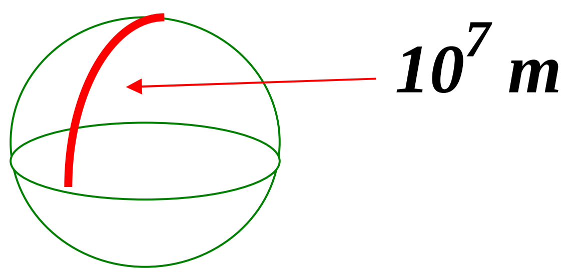
UNITS

INTERNATIONAL SYSTEM OF UNITS

1. **METER (m)** *length*
2. **KILOGRAM (kg)** *mass*
3. **SECOND (s)** *time*
4. **Kelvin (t*emperature*)** 5. **Mole**
6. **Candela** 7. **Ampere (*current*)**

1. How these units were initially defined?

The meter:



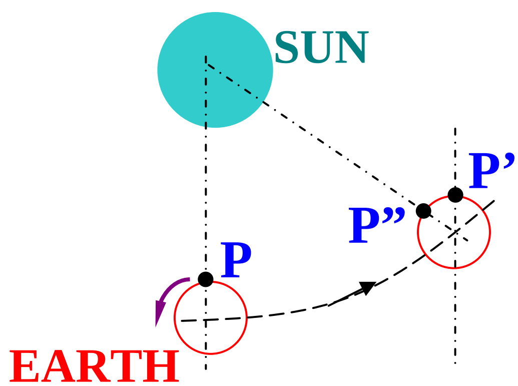
The *meter* was chosen in such a way that the distance from the Equator and the North Pole along the meridian through Paris would be 10 millions meters.

The second:

$$= \frac{1}{24}\left(\frac{1}{60}\right)\left(\frac{1}{60}\right) \textit{ mean solar day}$$

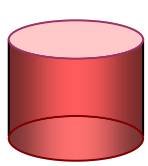
What is the difference between the *mean solar day* and the *sidereal day* ?

Mean solar day = 8.640×10^4 s (P=>P”)



Sidereal day = 8.616×10^4 s (P =>P’)

The kilogram = 1000 grams



Standard block kept in Paris

Other units:

cm = 10^{-2} m
in = 2.54 cm
mile = 1.609 Km
yard = 36 in =3 ft

1 foot =12 in

min = 60 s

yard = 0.9144 m

gram = 10^{-3} kg

Prefixes for SI units

10^{-9} nano (n)

10^{-6} micro (μ)

10^{-3} milli (m)

10^{9} giga (G)

10^{6} mega (M)

10^{3} kilo (k)

2. Changing units

Method: Chain-link conversion

Example 1:

V_{max} = 67 Km/s to miles/hour

$$67 \frac{Km}{s} = \frac{67\ Km}{s} \times 1 \times 1$$

mile = 1.609 Km ==> $1 = \dfrac{mile}{1.609\ Km}$

hour = 3600 s ==> $1 = \dfrac{3600\ s}{hour}$

$$67 \frac{Km}{s} = \frac{67\ Km}{s} \times \frac{mile}{1.609\ Km} \times \frac{3600\ s}{hour}$$

$$= 15 \times 10^{4}\ miles/h$$ answer

If we had punched all these numbers in our calculator, we would have obtained:

149906.7744 **Why not to use this more precise number then?**

Let's use this question as a motivation for the following Section 3.

3. Precision, accuracy, significant figures

Math: Interested in the logic of symbolic algebraic expression and numbers

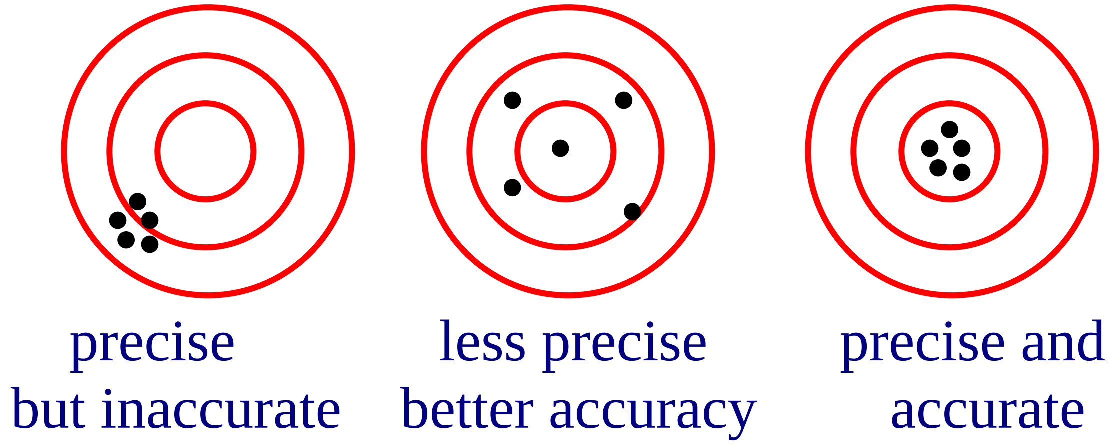
Physics: Deals with **measurements**

Numbers (math) represent real values of measurements

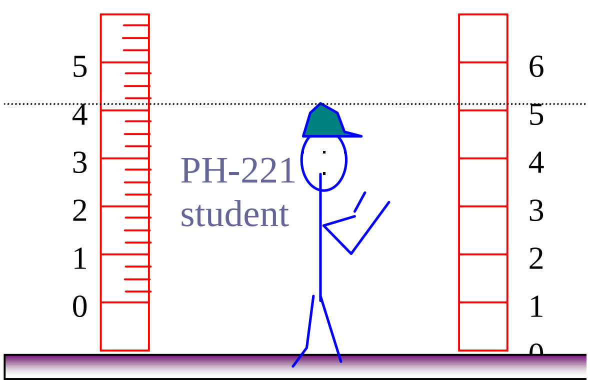
Measurements have **uncertainties** (random errors, systematic errors, etc)

The use of **significant figures** is one way (although no the best method) to express the ***precision*** of a measurement

Example-1 About precision and accuracy



Example-1 About precision and accuracy



If we do not notice the offset on the left-side ruler: the ruler on the right will provide a more accurate measurement of the student's height (h_1=5 f). The ruler at the left would provide a more precise measurement (more decimal points, h_2=4.1 f) but it would be inaccurate.

About significant figures

- By convention
  When an experimental measurement is given as **h = 5 cm** it **means**

  4.5 cm **<** h **<** **5.5** cm.

  Similarly **x = 2.4 µm** means

  2.35 µm < x < **2.45** µm

- **Exponential notation** provides a convenient way to identify the order of magnitude of a quantity and the number of significant figures (precision of the measurement).

  By convention:

  $y = 2.0 \times 10^1$ means 19.5 < y < 20.5

$y = 2 \times 10^1$ means $15 < y < 25$

- **How to deal with significant figures**

$$67\ \frac{Km}{s} = \frac{67\ Km}{s}\ x\ \frac{mile}{1.609\ Km}\ x\ \frac{3600\ s}{hour}$$

Two significant figures (67)

3.600×10^3 (3600)

1.609×10^0 (1.609)

four significant figures (1.609, 3600)

Procedure-1: all quantities reduced to 2 significant. figures

$$67\ \frac{Km}{s} = 6.7\ \text{x}10^1\ \frac{3.6\text{x}10^3}{1.6\text{x}10^0}\ \frac{miles}{hour} =$$

$$= 15\text{x}10^4\ \frac{miles}{hour}$$

Procedure-2: keep all the significant figures during the calculation and take the 2 significant figures only at the end.

- **Justification for throwing out significant figures**

In the example below let’s consider, for the sake of the argument, that the only magnitude introducing uncertainties in the calculation is the value of 67 (its values is somewhere between 66.5 and 67.5)

The value of $67\mathbf{x}\frac{3600}{1.609}$ **is, then, between:**

maximum value $67.5\ \frac{3600}{1.609} =$ **151025**

and

minimum value $66.5\frac{3600}{1.609} =$ **148788**

Notice there is a difference of about 2000 between the max and min values. So to provide 149906.7744 as an answer (suggested at the end of Section 2), which has precision over the decimal point, does not make ant sense. We do not know the number with such decimal point precision.

The answer that we obtained before 15×10^4, by keeping only two significant

figures throughout the calculation, was close enough.

Final note: Keep in mind that significant figures is just one way to express the precision of a measurement (in some cases it may provide ambiguous result.) Is for that reason that more powerful methods of error analysis have been developed (you’ll be exposed to that in physics lab courses.)

change of units

How many km in 1 μm ?

$$1\,\mu m = 10^{-6} m$$

$$= 10^{-6} m \times 1$$

$$1 = \frac{1\,Km}{1000\,m}$$

$$= 10^{-6} \cancel{m} \times \frac{1\,Km}{1000\,\cancel{m}}$$

$$= 10^{-9}\,Km$$

Significant figures ← one way to provide **precision** of our measurements

- $x = 1.1 \Leftrightarrow 1.05 < x < 1.15$
- 0.03

$0.03 = 3 \times 10^{-2}$ ← scientific notation recommended

- $y = 100$ ← sometimes we are not sure what does it mean ← How many sig. fig. ?

the ambiguity is removed if we use scientific notation:

Use 10×10^{1} to indicate → $95 < y < 105$

use 1.00×10^{2} to indicate → $99.5 < y < 100.5$

the scientific notation: provide ORDER of MAGNITUDE & explicitly specifies the number of significant figures.

- $z = 6.7 \times 10 \times \frac{3.600 \times 10^{3}}{1.609}$ → very likely the result will have 2 significant figures.

(6.7: 2 s.f.; 3.600: 4 s.f.; 1.609: 4 s.f.)

$z = 15 \times 10^{4}$

$145000 < z < 155000$

- Number written in scientific notation

→ $9 = 9 \times 10^0$ $\quad <8.5, 9.5>$

→ $90 = 9 \times 10^1$ Indicates that 90 had only ONE significant figure $<85, 95>$

$90 = 9.0 \times 10^1$ To emphasize that the number has 2 significant figures

$<89.5, 90.5>$

→ Notice above that

9×10^1 and 9.0×10^1

have different meaning

update

COUNTING UP TO 100 MILLION.

The science of measurement, metrology, has been moving ***away*** from ➔**standards based** on artifacts such as **a meter** stick and

toward ➔ the use of quantum phenomena

to provide reliable, accurate and, if possible, portable calibrations that can be used by researchers in the field.

Examples are:

a) Resistance ==> defined in terms of the quantum Hall effect

b) voltage ==>in terms of the Josephson effect.

c) Consider capacitance, the measure of how well a tiny reservoir can store electrical charge.

  c-1) NIST already has the best capacitance **standard**, accurate to 0.02 parts per million (ppm). But this device is cumbersome and, more importantly, its accuracy is frequency dependent. For rendering the value of capacitance in circuits operating outside a certain frequency range, the standard is no better than 2 ppm.

  c-2) A promising **new approach to capacitance (pioneered at** NIST; contact Mark Keller, 303-497-5430) **uses a** **single-electron transistor (SET)**, which contains at its heart a tiny refuge for electrons where the arriving charges can be counted one at a time, all the way up to **100 million** or more. When combined with an accurate voltage measurement this becomes an accurate capacitance standard (C=Q/V). The SET approach has now achieved a measurement accuracy of about 2 ppm, and the NIST researchers hope soon to reach 0.1 ppm. The setup is relatively portable and its output is largely independent of frequency. (Keller et al., Science 10 Sept.)

http://lw1fd.hotmail.msn.com/cgi-bin/getmsg?disk=209.185.130.55_d1393&login=a_larosa&f=33792&curmbox=ACTIVE&_lang=&msg=MSG938435611.8&start=546729&len=4303

THE UNIVERSE MAY BE YOUNGER THAN PREVIOUSLY THOUGHT

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NOTE TO EDITORS: 99-58

NASA RESEARCHER FINDS EVIDENCE THAT THE UNIVERSE MAY BE YOUNGER THAN PREVIOUSLY THOUGHT

Dr. Eyal Maoz of NASA Ames Research Center, Moffett Field, CA, and astrophysicists from a variety of U.S. and Canadian institutions have found evidence suggesting that the universe may be younger than scientists had previously thought, and that it is expanding faster than expected. Their findings are reported in the Sept. 23 issue of Nature magazine.

Current estimates put the age of the universe at about 15 billion years. Maoz' research indicates the universe may be as young as 12 billion years, nearly the same age as its oldest stars. This implied relatively low age of the universe revives an old paradox in the field of astrophysics that the universe seems to be younger than some of the stars in it. The finding suggests that a revision of the cosmological model may be required.

Maoz and his team used the Hubble Space Telescope to observe the pulsing of giant stars called 'Cepheid variables' in the galaxy NGC4258. Researchers used a standard "Cepheid measurement" technique that allowed them to measure the distance from Earth to the galaxy. However, this measurement was different from another independent, highly accurate distance determination to that galaxy made using masers (the microwave equivalent of lasers), which are located at the galaxy center and orbiting a supermassive black hole.

A revision of the standard Cepheid measurement method would mean that estimates for the age of the Universe would have to be revised downwards by 10-15%, experts say.

Measuring galactic distances using Cepheid variables has been a standard since 1929. They are useful because their rate of pulsation is closely linked to their brightness. This means that a galaxys' apparent brightness can be used to gauge its distance from Earth.-more-
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Maoz and his colleagues used the Cepheid method to estimate the distance from Earth to the benchmark NGC4258 galaxy as 8.1 megaparsecs (Mpc), significantly farther than the geometric estimates derived by recent estimates. (One Mpc is equivalent to approximately three million light years.)

"We discovered a considerable discrepancy between the maser-based and Cepheid-based distance," Maoz said. "The bottom line is that it seems that galaxy distances may have been consistently overestimated by about 12%. This would imply that the universe is expanding faster than expected, and the age of the universe is lower by a similar factor."