

Chapter 1

Measurement

القياس

Measuring Things

تجسید فیزیائی

و مقدار و عدد

5m

- To measure any physics quantity, we need magnitude and unit
- For example: the full day is 24 hours
- Each unit must be compared to a standard
- There are 3 Base Quantities (Length, Time, Mass).
کده زمان طول کمیت اساسیه
- We then define all other physical quantities in terms of these base quantities and their standards (called base standards).
اساسیه معیاره
- For example: volume is length × length × length, density is the ratio of mass to volume (volume is length × length × length) ...
الحجم
- Base standards must be both accessible and invariable

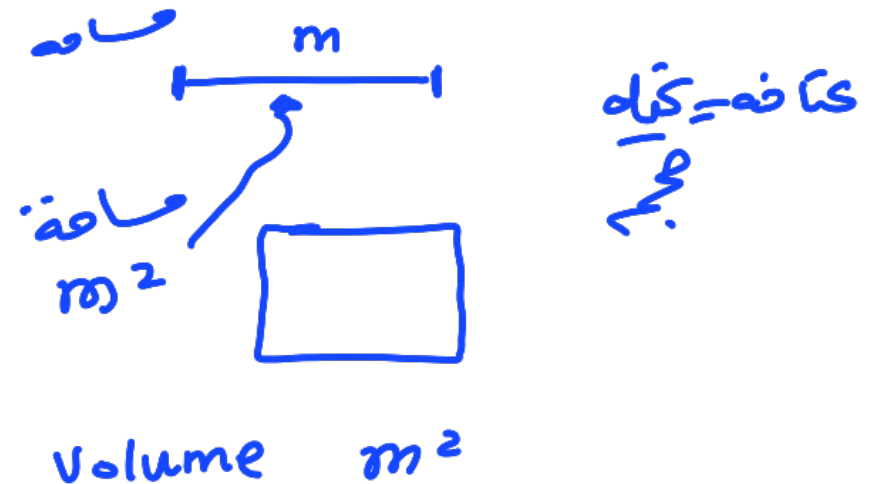
$$\text{Volume} = d \times d \times d$$

$$\text{density} = \frac{m}{V} = \frac{\text{kg}}{\text{m}^3}$$

Table 1-1 Units for Three SI

Base Quantities

Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg



The Physical Quantities

نوعين من الكميات الأساسية

There are two types of Physical Quantities

1

مخيمات اصليه

Basic Physical Quantity



كتلة Mass denoted as M (kg)

طول Length denoted as L (m)

زمن Time denoted as T (s)

2

مخيمات مشتقة

Derived Physical Quantity



It is any quantity that can be expressed by the basic quantity, such as area, volume, density, force, velocity, etc.

اي وحدة يمكن كتابتها باستخدام الكميات الأساسية

Systems of units

There are three common systems of units

- 1 International system of units (SI units) → النظام العالمي للقياس
SI unit
- 2 British system of units (UK units) → النظام البريطاني
(UK unit)
- 3 Gaussian system of units (cgs units) → النظام الغاوسي (مغز) (CGS unit)

كميات

القوة

	System		
Quantity	SI	British	CGS
Length	Meter (m) ✓	Foot (ft) قدم ✓	Centimetre (cm) ✓
Time	second (s) ✓	Second	second
Mass	Kilogram (kg) ✓	Pound_mass (lbm) ✓	Gram (g) ✓
Force	Newton (N) ✓	Pound_force (lbf) ✓	Dyne ✓

حفظ

The International System of Units (SI Units)

- The *International System* of units (abbreviated as SI units) has only seven quantities that are chosen internationally as base quantities. These units are used to derive any other unit in science.
 اي وحدة متباعدة اخرى غير السبع وحدات
 بقدر ممكن
- In this course we need only these three base quantities: length, time, mass to derive all other units we will study.
 هذه الاضاده
 درجتها

length ✓	meter	m
mass ✓	kilogram	kg
time ✓	second	s
electric current	ampere	<u>A</u>
thermodynamic temperature	kelvin	<u>K</u>
amount of substance	mole	<u>mol</u>
luminous intensity	candela	<u>cd</u>

For example:

السرعة = $\frac{\text{المسافة}}{\text{الزمن}}$
 Speed = $\frac{\text{Length}}{\text{Time}}$
 speed = $\frac{m}{s}$

Derived quantity

base quantities

∴ Unit of speed = $\frac{\text{unit of length}}{\text{unit of time}} = \frac{m}{s}$

Table 1-1 Units for Three SI Base Quantities

Quantity	Unit Name	Unit Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

Prefixes for SI Units

البادئات

القياس العلمي

$$2.500 \times 10^3$$

$$300\ 000 = 3 \times 10^5$$

- To express the very large and very small quantities we often run into in physics, we use scientific notation, which employs powers of 10. In this notation,

$$3.560\ 000\ 000\ \text{m} = 3.56 \times 10^9\ \text{m}$$

$$0.000\ 000\ 492\ \text{s} = 4.92 \times 10^{-7}\ \text{s} = 492 \times 10^{-9}\ \text{s}$$

$$0.0041 = 4.1 \times 10^{-3}$$

$$0.00000001 = 1 \times 10^{-8}$$

- When dealing with very large or very small measurements, we use the prefixes listed in Table 1-2, For example:

$$1.27 \times 10^9 \times 10^{-9} = 1.27$$

$$1.27 \times 10^9\ \text{meter} = 1.27\ \text{gigameter} = 1.27\ \text{Gm}$$

$$2.35 \times 10^{-9}\ \text{s} = 2.35\ \text{nanoseconds} = 2.35\ \text{ns}$$

$$2.35 \times 10^{-9} \times 10^9 = 2.35\ \text{s}$$

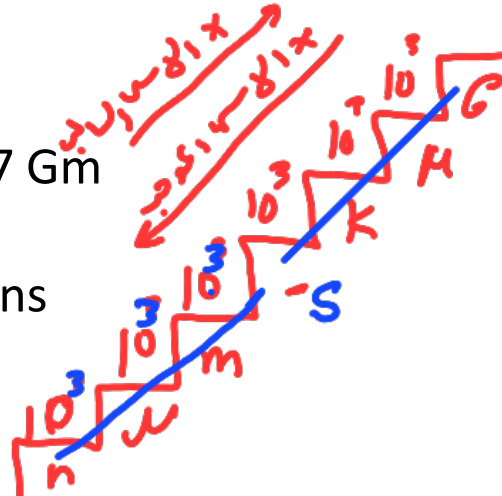
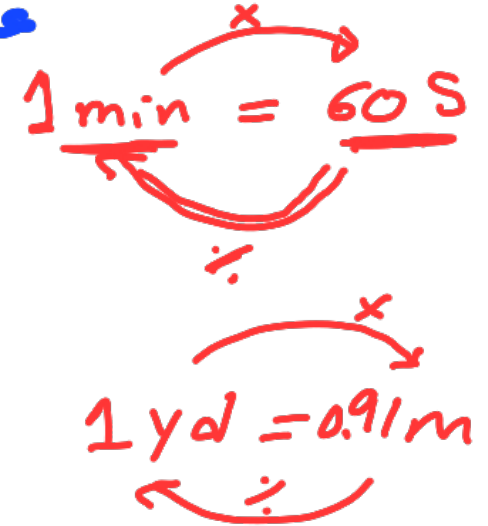


Table 1-2 Prefixes for SI Units

Factor	Prefix ^d	Symbol
10 ²⁴	yotta-	Y
10 ²¹	zetta-	Z
10 ¹⁸	exa-	E
10 ¹⁵	peta-	P
10 ¹²	tera-	T
10 ⁹	giga-	G
10 ⁶	mega-	M
10 ³	kilo-	k
10 ²	hecto-	h
10 ¹	deka-	da
10 ⁻¹	deci-	d
10 ⁻²	centi-	c
10 ⁻³	milli-	m
10 ⁻⁶	micro-	μ
10 ⁻⁹	nano-	n
10 ⁻¹²	pico-	p
10 ⁻¹⁵	femto-	f
10 ⁻¹⁸	atto-	a
10 ⁻²¹	zepto-	z
10 ⁻²⁴	yocto-	y

Changing Units

عند التحويل باستخدام معامل
تعبير أعف 1 تقريبا نحو 1 تقسم



- We often need to change the units in which a physical quantity is expressed.
- We multiply the original measurement by a conversion factor
- For example, because 1 min and 60 s are identical time intervals, we have:

$1 \text{ min} = 60 \text{ s}$ ← Conversion factor between min and s

- If we need to convert 2 min to seconds:

$2 \text{ min} \times \left(\frac{60 \text{ s}}{1 \text{ min}} \right) = 120 \text{ s}$

$2 \text{ min} \left(\frac{60 \text{ s}}{1 \text{ min}} \right) = \frac{2 \text{ min} \times 60 \text{ s}}{1 \text{ min}} = 120 \text{ s}$

- Another example: we need to change the quantity 15 m/s to its equivalent in cm/min:

Conversion factors are: $1 \text{ min} = 60 \text{ s}$ and $1 \text{ m} = 100 \text{ cm}$, so,

$\frac{15 \text{ m}}{1 \text{ s}} \rightarrow \frac{15 \times 100}{\frac{1}{60}} \frac{\text{cm}}{\text{min}}$

$15 \frac{\text{m}}{\text{s}} \left(\frac{100 \text{ cm}}{1 \text{ m}} \right) \left(\frac{60 \text{ s}}{1 \text{ min}} \right) = \frac{15 \text{ m} \times 100 \text{ cm} \times 60 \text{ s}}{1 \text{ s} \times 1 \text{ m} \times 1 \text{ min}} = 90000 \text{ cm/min}$

$= 90000 \text{ cm/min}$

- By using this method, we can convert any unit to any other unit (even if we are not familiar with these units)

لو كان صناعه وده مركبه عن سبط ووقام حول لبط وده و الحتم و صره

Example 1: The speed of a car is 35 m/s. What was this speed in km/h?

Solution:

Conversion factor:

1 km = 1000 m

and

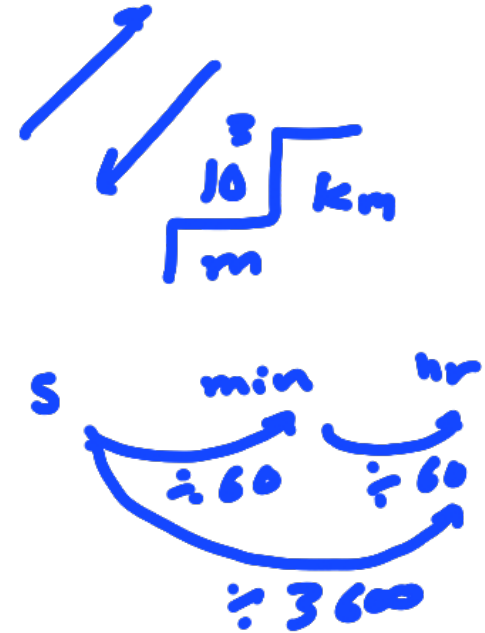
1 h = 3600 s

The speed is $v = 35 \frac{m}{s} = 35 \frac{m}{s} \times \left(\frac{1km}{1000 m}\right) \times \left(\frac{3600s}{1h}\right)$

$$= \frac{35 \times 1 \times 3600}{1000 \times 1} \frac{km}{h} = 126 km/h$$

$$\frac{35 \text{ m}}{1 \text{ s}} = \frac{35 \times 10^{-3}}{\frac{1}{3600}} \frac{\text{km}}{\text{hr}}$$

$$= 35 \times 10^{-3} \times 3600 = 126 \text{ km/hr}$$



Notes on unit conversion:

If there is a power in the unit, you must use the same power for the conversion factor.



1 m = 100 cm

1 m² = (100)² cm² ⇒ 1 m² = (10 000) cm²

1 m³ = (100)³ cm³ ⇒ 1 m³ = (1 000 000) cm³

For example, converting 5.3 m² to cm² unit will be:

$$5.3 \text{ m}^2 \times \left(\frac{10000 \text{ cm}^2}{1 \text{ m}^2} \right) = 53000 \text{ cm}^2$$

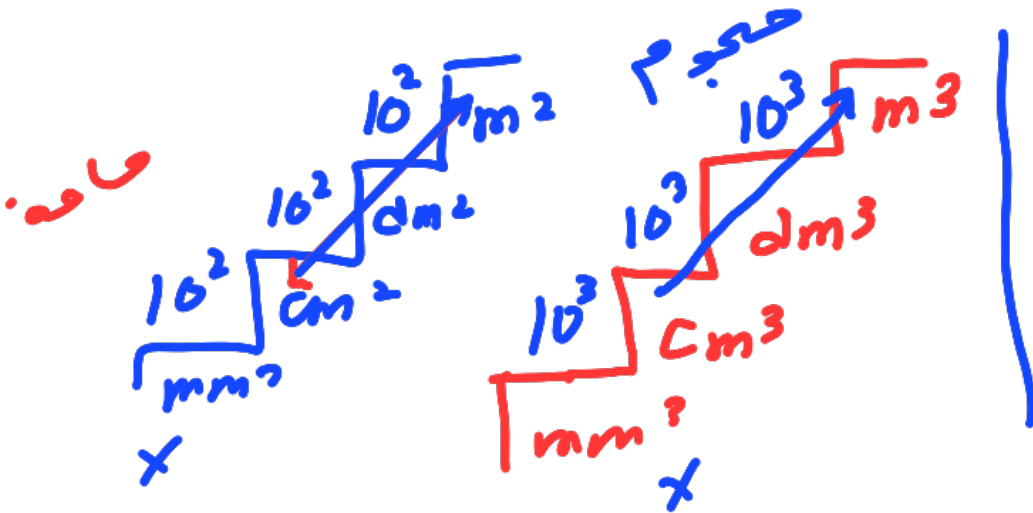
1 cm = 10⁻² m

1 cm² = (10⁻²)² m² ⇒ 1 cm² = (10⁻⁴) m²

1 cm³ = (10⁻²)³ m³ ⇒ 1 cm³ = (10⁻⁶) m³

For example, converting 5.3 cm² to m² unit will be:

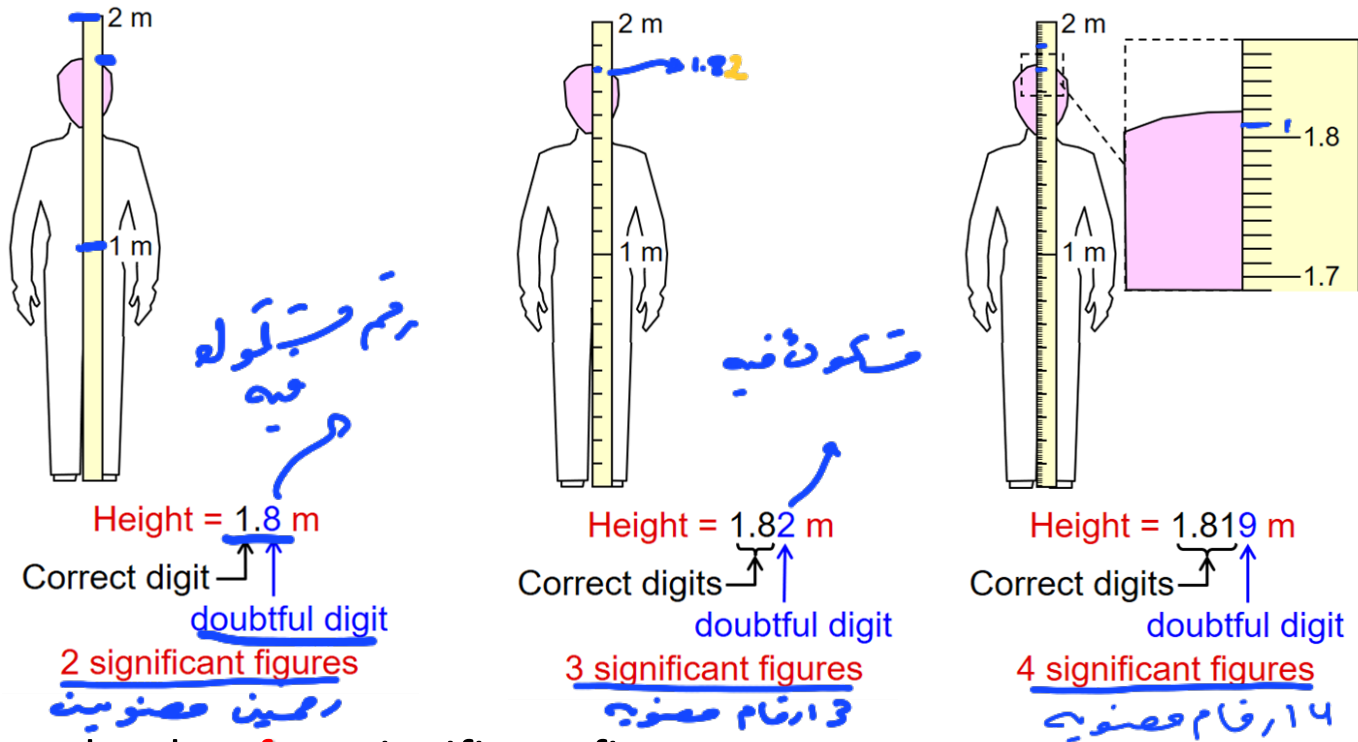
$$5.3 \text{ cm}^2 \times \left(\frac{10^{-4} \text{ m}^2}{1 \text{ cm}^2} \right) = 5.3 \times 10^{-4} \text{ m}^2 = 0.00053 \text{ m}^2$$



5.3 m² → 5.3 × 10⁴ cm² = 53000 cm²
 5.3 cm² → 5.3 × 10⁻⁴ m² = 0.00053 m²

Significant Figures and Decimal Places الأرقام المعنوية تعتمد على أداة القياس

Number of the significant figures depends on the instrument used



15.07 This number has **four** significant figures

10.68 The **8** is called the **least significant figure**

0.00064 This number has **two** significant figures

12.000 This number has **five** significant figures

RULES FOR SIGNIFICANT FIGURES

قواعد الأرقام المهمة

- 1. All non-zero numbers ARE significant.** The number 33.2 has THREE significant figures because all of the digits present are non-zero.
- 2. Zeros between two non-zero digits ARE significant.** 2051 has FOUR significant figures. The zero is between a 2 and a 5.
- 3. Leading zeros are NOT significant.** They're nothing more than "place holders." The number 0.54 has only TWO significant figures. 0.0032 also has TWO significant figures. All of the zeros are leading.
- 4. Trailing zeros to the right of the decimal ARE significant.** There are FOUR significant figures in 92.00. 92.00 is different from 92: a scientist who measures 92.00 milliliters knows his value to the nearest 1/100th milliliter; meanwhile his colleague who measured 92 milliliters only knows his value to the nearest 1 milliliter. It's important to understand that "zero" does not mean "nothing." Zero denotes actual information, just like any other number. You cannot tag on zeros that aren't certain to belong there.
- 5. Trailing zeros in a whole number with the decimal shown ARE significant.** Placing a decimal at the end of a number is usually not done. By convention, however, this decimal indicates a significant zero. For example, "540." indicates that the trailing zero IS significant; there are THREE significant figures in this value.
- 6. Trailing zeros in a whole number with no decimal shown are NOT significant.** Writing just "540" indicates that the zero is NOT significant, and there are only TWO significant figures in this value.
- 7. For a number in scientific notation: $N \times 10^x$, all digits comprising N ARE significant by the first 6 rules; "10" and "x" are NOT significant.** 5.02×10^4 has THREE significant figures: "5.02." "10 and "4" are not significant.

قواعد الأرقام المصنوية

① كل الأعداد غير المصنوية هي أرقام مصنوية

$$23.6 \Rightarrow 3 \text{ SF}$$

② كل الأرقام ذات العدد وحيث الفاصلة تصير أرقام المصنوية

$$1005 \Rightarrow 4 \text{ SF}$$

$$1.00 \Rightarrow 3 \text{ SF}$$

③ الأرقام التي لا تعد أرقام مصنوية

$$0.0008 \Rightarrow 1 \text{ SF}$$

④ الأرقام التي ليست بدون لا تعد أرقام مصنوية

$$1000 \quad 1 \text{ SF}$$

$$\underline{1000.0} \quad 5 \text{ SF}$$

⑤ الرقم المكتوب بالصيغة العلمية لا تعد الأرقام في الأس

$$5.3 \times 10^6 = 2 \text{ SF}$$

المطول

Length

- In 1792, the meter (m) was selected to be the standard unit of length.

المعرف القديم

- The old definition of the meter: the meter, defined to be one ten-millionth of the distance from the north pole to the equator.

تعريف

- Later, the meter was defined as the distance between two fine lines engraved near the ends of a platinum-iridium bar, the standard meter bar, which was kept at the International Bureau of Weights and Measures near Paris.

تعريف حديث

- New definition of the meter: The meter is the length of the path traveled by light in a vacuum during a time interval of 1/299 792 458 of a second.

المسار الذي يعطيه الضوء في الفراغ خلال فترة زمنية $\frac{1}{299792458}$ ثانية

The standard meter

It is a bar of Platinum-Iridium kept at a constant temperature
The meter is defined as the distance between the two scratch marks



Example: The micrometer ($1 \mu\text{m}$) is often called the micron. (a) How many microns make up 1 km? (b) What fraction of a centimeter equals 1 μm ? (c) How many microns are in 1 yd?

Solution: a) $\text{km} \rightarrow \mu\text{m}$ $1 \text{ km} = \underline{1 \times 10^9 \mu\text{m}}$

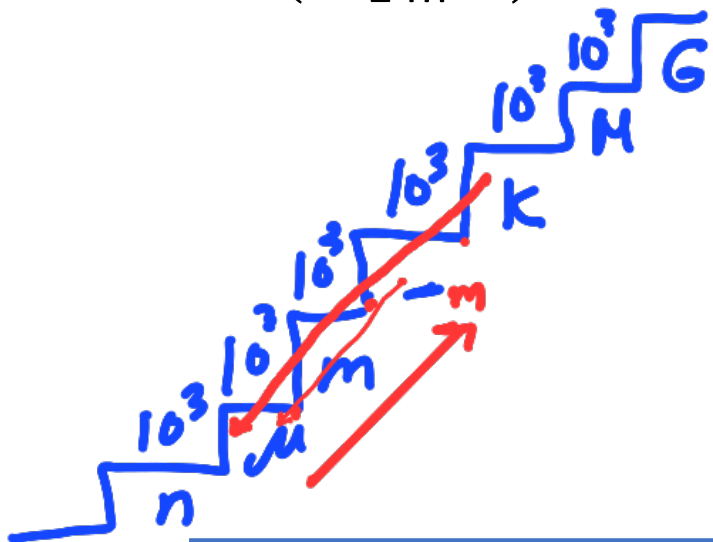
(a) Conversion factors:

$$1 \text{ km} = 1 \times 10^3 \text{ m and } 1 \text{ m} = 1 \times 10^6 \mu\text{m},$$

$$\Rightarrow 1 \text{ km} = 10^3 \text{ m}$$

Now we convert 10^3 m to μm :

$$10^3 \text{ m} \times \left(\frac{1 \times 10^6 \mu\text{m}}{1 \text{ m}} \right) = \boxed{10^9 \mu\text{m}}$$



(c) Conversion factors:

$$1 \text{ yd} = 0.91 \text{ m and } 1 \text{ m} = 1 \times 10^6 \mu\text{m},$$

$$\Rightarrow 1 \text{ yd} = 0.91 \text{ m}$$

Now we convert 0.91 m to μm :

$$0.91 \text{ m} \times \left(\frac{1 \times 10^6 \mu\text{m}}{1 \text{ m}} \right) = 9.1 \times 10^5 \mu\text{m}$$

$1 \mu\text{m} \rightarrow \text{cm}$

(b) Conversion factors:

$$1 \text{ cm} = 1 \times 10^{-2} \text{ m and } 1 \mu\text{m} = 1 \times 10^{-6} \text{ m},$$

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

Now we convert $1 \times 10^{-6} \text{ m}$ to cm :

$$1 \times 10^{-6} \text{ m} \times \left(\frac{1 \text{ cm}}{1 \times 10^{-2} \text{ m}} \right) = \underline{1 \times 10^{-4} \text{ cm}}$$

$$\begin{aligned} 1 \mu\text{m} &\rightarrow 1 \times 10^{-6} \text{ m} \\ 1 \times 10^{-6} \text{ m} &\rightarrow 1 \times 10^{-6} \times 100 \\ &= 1 \times 10^{-4} \checkmark \\ &= 0.0001 \checkmark \text{ cm} \end{aligned}$$



Example: In printing some books, a length unit of “points” and “picas” are used: 12 points = 1 pica, and 6 picas = 1 inch. What is 0.8 cm in (a) picas and (b) points?

cm → inch → Picas → Point

Solution:

$$1 \text{ inch} = 2.54 \text{ cm}$$

$$1 \text{ inch} = 6 \text{ picas}$$

$$1 \text{ pica} = 12 \text{ point}$$

We need first to convert cm to inch:

Conversion factor:

$$1 \text{ in} = 2.54 \text{ cm}$$

$$0.8 \text{ cm} \times \left(\frac{1 \text{ in}}{2.54 \text{ cm}} \right) = 0.315 \text{ in}$$

Now we convert in to picas and points:

① التحويل من cm إلى inch

$$\frac{0.8 \text{ cm}}{2.54} = 0.315 \text{ inch}$$

② التحويل من inch إلى Picas

$$0.315 \text{ inch} \times 6 = 1.9 \text{ Picas}$$

a) Conversion factor:

$$6 \text{ picas} = 1 \text{ inch}$$

$$0.315 \text{ in} \times \left(\frac{6 \text{ picas}}{1 \text{ in}} \right) = 1.9 \text{ picas}$$

b) Conversion factor:

$$12 \text{ points} = 1 \text{ pica}$$

$$1.9 \text{ picas} \times \left(\frac{12 \text{ points}}{1 \text{ pica}} \right) = 22.8 \text{ points}$$

③ التحويل من Picas إلى Points

$$1.9 \text{ Picas} \times 12 = 22.8 \text{ Points}$$

Time

الزمن

- Any phenomenon that repeats itself is a possible time standard, for example, Earth's rotation, which determines the length of the day, has been used in this way for centuries
- However, the accuracy of measuring time this way is not good enough for science and engineering technology.
- To meet the need for a better time standard, atomic clocks have been developed
- One **second** is defined as the time taken by 9 192 631 770 oscillations of the light emitted by the cesium atom.
- Atomic clocks are so consistent and accurate.

الساعات الذرية

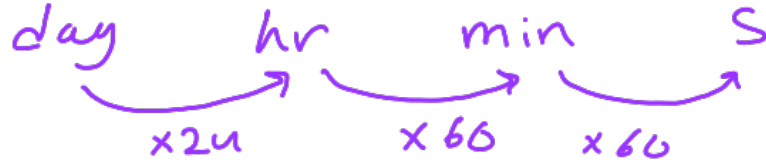
دقيقه ثابتة

الزمن الذي تقوله 919 2631 770 اهتزازاته
صادرة عن ذره سيزيوم



Example: A plant can grow 3.7 m in 14 days. What was its growth rate in micrometers per second?

Solution:



Conversion factor:

$$1 \text{ m} = 1 \times 10^6 \mu\text{m} \quad \text{and} \quad 1 \text{ day} = 86400 \text{ s}$$

$$\text{The growth rate in m/days} = \frac{3.7 \text{ m}}{14 \text{ day}} = 0.26 \text{ m/day}$$

Now, convert 0.26 m/day to $\mu\text{m/s}$:

$$0.26 \left(\frac{\text{m}}{\text{day}} \right) \times \left(\frac{1 \times 10^6 \mu\text{m}}{1 \text{ m}} \right) \times \left(\frac{1 \text{ day}}{86400 \text{ s}} \right) = \left(\frac{0.26 \text{ m} \times 1 \times 10^6 \mu\text{m} \times 1 \text{ day}}{1 \text{ day} \times 1 \text{ m} \times 86400 \text{ s}} \right) = 3 \mu\text{m/s}$$

$\mu\text{m/s}$

growth rate $\frac{\mu\text{m}}{\text{s}}$

$$= \frac{3.7 \text{ m}}{14 \text{ day}} = \frac{3.7 \times 10^6 \mu\text{m}}{14 \times 60 \times 60 \times 24 \text{ s}}$$

$$= 3 \mu\text{m/s}$$

Mass

كتلة

تقاس الكتلة من خلال مقارنة كتلة صناعية

- Mass used to be measured by making a comparison to the “standard kilogram”
- The **Standard Kilogram: The SI standard of mass is a cylinder of platinum and iridium that is kept at the International Bureau of Weights and Measures near Paris**
- The masses of atoms can be compared with one another more precisely than they can be compared with the standard kilogram. For this reason, **the mass of carbon atom is used as a second mass standard.** By agreement,



mass of carbon atom = 12 atomic mass unit (u).

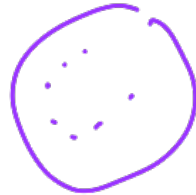
$$1 \text{ u} = 1.66054 \times 10^{-27} \text{ kg}$$

تعريف جديد

- In 2019, the kilogram definition has changed (it is defined now **based on some universal physics constants**).

لصيغة التعريف الجديد للكيلوغرام العالمية

Example: Earth has a mass of 5.98×10^{24} kg. The average mass of the atoms that make up Earth is 40 u. How many atoms are there in Earth?



Solution:

Conversion factor:

$$1 \text{ u} = 1.66054 \times 10^{-27} \text{ kg}$$

$$\Rightarrow \text{mass of one atom} = 40 \text{ u} \times \left(\frac{1.66054 \times 10^{-27} \text{ kg}}{1 \text{ u}} \right) = 6.64 \times 10^{-26} \text{ kg}$$

$$\text{Number of atoms in Earth} = \left(\frac{\text{mass of Earth}}{\text{mass of one atom}} \right) = \left(\frac{5.98 \times 10^{24} \text{ kg}}{6.64 \times 10^{-26} \text{ kg}} \right) = 9 \times 10^{49} \text{ atoms}$$

$$\text{atom mass} = 40 \text{ u} = 40 \times 1.66054 \times 10^{-27} \text{ kg} = 6.64 \times 10^{-26} \text{ kg}$$

$$\text{Number of atoms} = \frac{\text{mass of earth}}{\text{mass of atom}} = \frac{5.98 \times 10^{24}}{6.64 \times 10^{-26}} = 9 \times 10^{49} \text{ atoms}$$

$$5.98 \times 10^{24} \text{ kg} \quad \text{كتلة الارض}$$

$$40 \text{ u} \quad \text{كتلة الذرة}$$

$$\frac{\text{كتلة الارض}}{\text{كتلة الذرة}} = \text{عدد الذرات}$$

کتابہ ص ۵۱

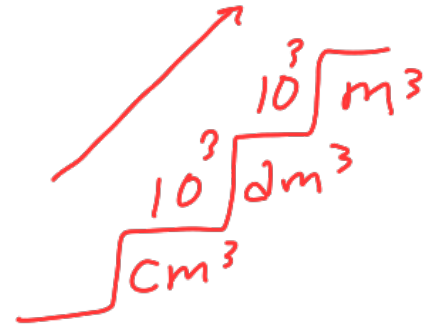
Example: Assuming that water has a density of exactly 1 g/cm³, find the density of water in kg/m³.

Solution:

Conversion factor:

$$1 \text{ g} = 1 \times 10^{-3} \text{ kg}$$

and $1 \text{ cm}^3 = 10^{-6} \text{ m}^3$



$$\frac{1 \text{ g}}{1 \text{ cm}^3} = \frac{1 \times 10^{-3} \text{ kg}}{1 \times 10^{-6} \text{ m}^3}$$

$$= 1000 \text{ kg/m}^3$$

$$1 \left(\frac{\text{g}}{\text{cm}^3} \right) \times \left(\frac{1 \times 10^{-3} \text{ kg}}{1 \text{ g}} \right) \times \left(\frac{1 \text{ cm}^3}{10^{-6} \text{ m}^3} \right) = \left(\frac{10^{-3}}{10^{-6}} \right) \text{ kg} = 10^3 \text{ kg/m}^3 = 1000 \text{ kg/m}^3$$

المسافة التي يقطعها الضوء في سنة

قول

A light-year is a measure of length (not a measure of time) equal to the distance that light travels in 1 year. $3 \times 10^8 m$
Compute the conversion factor between light-years and meters.

Solution:

The conversion factor from years to second is

$$1y = 1y \times \frac{365.25d}{1y} \times \frac{24h}{1d} \times \frac{60min}{1h} \times \frac{60s}{1min} = 3.16 \times 10^7 s$$

The speed of light is $3.00 \times 10^8 m/s$.

Thus in 1 year, light travels a distance of

$$(3.00 \times 10^8 m/s) (3.16 \times 10^7 s) = 9.48 \times 10^{15} m$$

So that

$$1 ly = 9.48 \times 10^{15} m$$

$$\begin{aligned} 1 \text{ light year} &= \text{speed} \times \text{time} \\ &= 3 \times 10^8 m \times 365 \times 24 \times 60 \times 60 \end{aligned}$$

$$1 \text{ light year} = 9.46 \times 10^{15} m$$

1 light year $\rightarrow m$

المسافة = السرعة \times الزمن



