هنـــاء فرحان

CHAPTER(1) Measurements(القياسات)

Physical Quantities الكميات الفيزيائية:

تقسم الكميات الفيزيائية بطريقتين

Physical Quantities

- **Base Quantities الكميات الأساسية**

  وهي التي لا يمكن التعبير عنها بدلالة كميات أخرى

  Ex: length (الطول), mass (الكتلة), time (الزمن)

- **Derived Quantities الكميات المشتقة**

  وهي التي يمكن التعبير عنها بدلالة الكميات الأساسية

  Ex: velocity (السرعة), Force (القوة), work (الشغل)

Physical Quantities

- **Vector Quantities الكميات المتجهة**

  لها مقدار واتجاه

- **Scalar Quantities الكميات القياسية**

  لها مقدار فقط

سيتم شرحه بالتفصيل في الفصل الثاني والثالث

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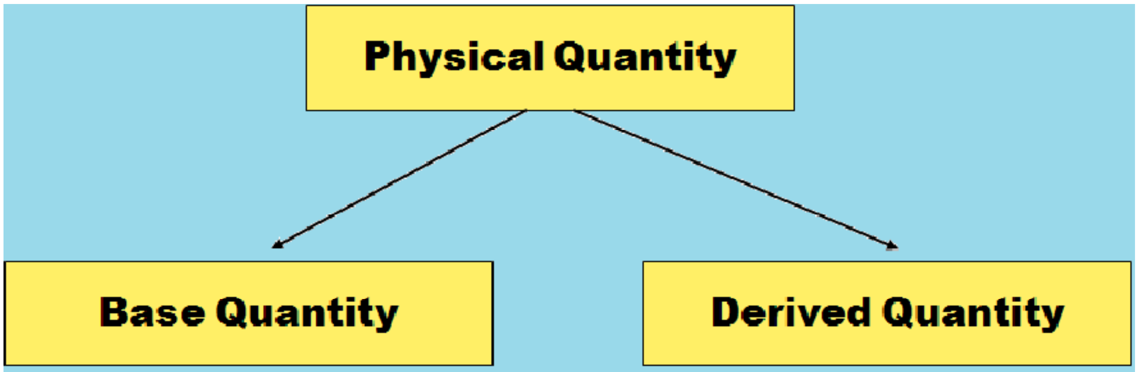

Basic Quantities

Base quantity		Symbol	SI unit	CGS unit
Length Other names: Distance, width, height, depth	الطول	*L* *D*	meter (m) متر	Centimeter (cm) سنتيمتر
Mass	الكتلة	*m*	kilogram (kg) كيلوجرام	gram (g) جرام
Time	الزمن	*t*	second (s) ثانية	second (s) ثانية

Derived Quantities

Quantity	Definition	Formula	Units
Velocity السرعة	$\frac{\text{distance}}{\text{time}}$	v = d/t	$\frac{\text{length}}{\text{time}}$ m/s, cm/s, km/h
Acceleration التسارع	$\frac{\text{velocity}}{\text{time}}$	a = v/t	$\frac{\text{length}}{(\text{time})^2}$ m/s^2, cm/s^2, km/h^2,

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Prefixes:

عبارة عن كلمة أو مقطع صغير من عدة حروف تضاف فى بداية كلمة ثانية فتغير معناها

Unit Name	Symbol	Multiple
Kilo (كيلو)	K	10^3
Mega (ميجا)	M	10^6
Giga (جيجا)	G	10^9
Centi (سنتي)	c	10^{-2}
Milli (ميلي)	m	10^{-3}
Micro (ميكرو)	µ	10^{-6}
Nano (نانو)	n	10^{-9}
Pico (بيكو)	p	10^{-12}

1- تضاف أي من هذه المقاطع الى الكميات الأساسية لتعطي وحدات جديدة
فمثلا عند أضافة كيلو (**k**) إلى وحدة المتر (**m**) يعطينا وحدة جديدة نسميها الكيلو متر(**km**) و هي عبارة عن 3 أضعاف المتر
ومن ثم يمكن كتابة العلاقة الجديدة بين الوحدتين

1 km= 10^3 m

مثال أخر

1 cm (سنتيمتر)= 10^{-2} m, 1 kg(كيلوجرام)= 10^3 g, , 1 ns (نانوسكند)= 10^{-9} s

2- يمكن أيجاد مضاعفاتها

$$1\ cm = 10^{-2}\ m \rightarrow (1\ cm)^3 = (10^{-2})^3\ (m)^3 \rightarrow 1\ cm^3 = 10^{-6}\ m^3$$

$$1\ km = 10^3\ m \rightarrow 1\ km^2 = 10^6\ m^2 \rightarrow 1\ km^3 = 10^9\ m^2$$

3- يمكن استخدامها في التعبيرات العلمية للأختصار. فمثلا
3560000000 m يمكن كتابته على شكل➔ 3.56x 10^9 m

نستبدل (10^9) بما يساويه من الجدول و هو (G)

3.56x 10^9 m = 3.56 Gm= 3.56 gigameter

0.00000492 s = 4.92 x 10^{-6} s

= 4.92 μ s = 4.92 microsecond

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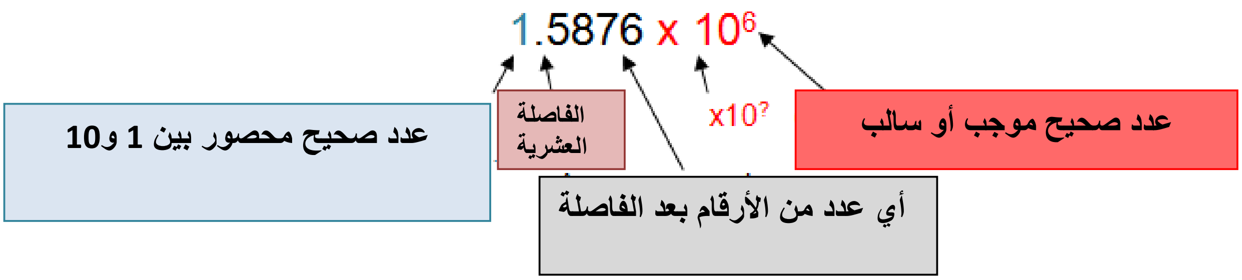
Scientific notation

هذا المفهوم(الكتابة العلمية) يستعمل لكتابة الأعداد الكبيرة جدا او الأجزاء الصغيرة. هذه الكتابه العلمية لعدد تقتضي أن نكتب هذا العدد على شكل عدد محصور بين 1و10 مضروبا في قوى 10ذات أس أما موجب أو سالب

$$a \times 10^n$$

حيث **n** عدد صحيح نسبي و **a** عدد عشري حيث: $1 \le a < 10$

مثال:



مثال لكتابة 3800 بشكل علمي نكتب

$3.8 \times 1000 = 3.8 \times 10^3$

امثلة اخرى $0{,}00006 = 6 \times 10^{-5}$

How to Convert Decimal to Scientific Notation: كيفية تحويل العدد العشري إلى التعبير العلمي للارقام

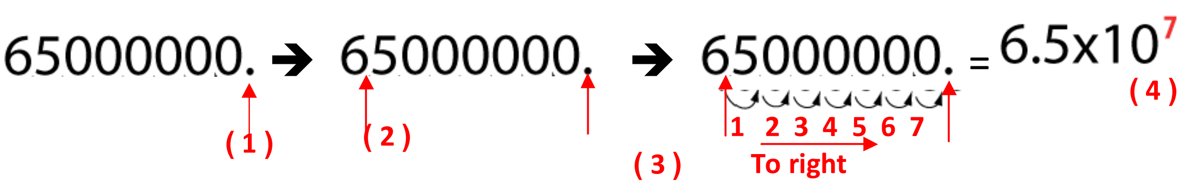
1- تحديد وضع الفاصلة في العدد المعطى في السؤال وإذا كان العدد لا يحتوي على فاصله فإننا نضعها على يمين العدد
254879 → 254879,

2- تحديد موضع الفاصله حسب المطلوب في السؤال

3- العد من موضع الفاصلة المطلوب إلى موضع الفاصله الأساسي:
إذا تحركنا لليمين نضع الإشارة موجبة وإذا تحركنا لليسار نضع الإشاره سالبه

4- نرفع العدد الناتج إلى أس 10

مثال (1)



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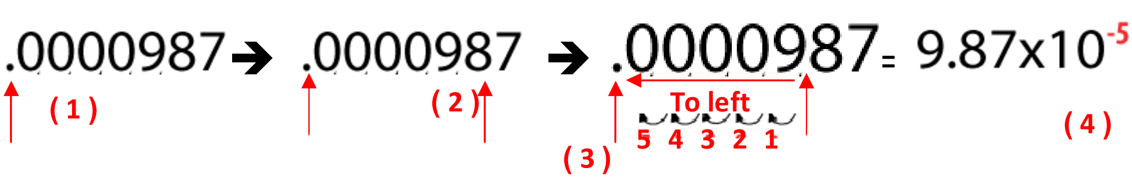

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8,790,000,000 = 8.79 x 10^9

8.790000000 ➔	8.7 9 0 0 0 0 0 0 0 1 2 3 4 5 6 7 8 9

===

32,500 = 3.25 x 10^4

3.2500 ➔	3.2 5 0 0 1 2 3 4

==

.000458 = 4.58 x 10^{-4}

.000458 ➔ .0 0 0 4 58
4 3 2 1

==

.00004945 = .0 0 0 0 4 9 4 5 = 4.945 x 10^{-5}
5 4 3 2 1

==

<u>How to Convert Scientific Notation to Decimal: كيفية تحويل عدد بالتعبير العلمي إلى عدد عشري</u>

1- تحديد موضع الفاصلة في العدد المعطى في السؤال وإذا كان العدد لا يحتوي على فاصله فإننا نضعها على يمين العدد.

2- نحرك موضع الفاصلة على حسب أس الـ 10

إذا كانت الإشارة موجبة فإن الفاصله تحرك لليمين
و إذا كانت الإشارة سالبه فإن الفاصله تحرك لليسار

1.4958 x 10^6 = 1.4 9 5 8 0 0 = 1,495,800
1 2 3 4 5 6

5 x 10^8 = 5.0 0 0 0 0 0 0 0 = 500,000,000
1 2 3 4 5 6 7 8

8.2 x 10^{-7} = 0 0 0 0 0 0 0 8.2 = .00000082
7 6 5 4 3 2 1

7 x 10^{-3} = . 0 0 7. = .007

9.87 x 10^5 = 9.8 7 0 0 0 = 987,000
1 2 3 4 5

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$9{,}243{,}000 = 9.2\,4\,3\,0\,0\,0 = 9.243 \times 10^6$

1 2 3 4 5 6

$124 = (1.24)(100) = 1.24 \times 10^2$	$0.000\,000\,000\,0436 = 4.36 \times 10^{-11}$
$93000000 = 9.3 \times 10^7$	$4.2 \times 10^{-7} = 0.000\,000\,42$
$3.6 \times 10^{12} = 3600000000000$	$0.000\,000\,005\,78 = 5.78 \times 10^{-9}$

General Rule

$(10^m) \times (10^n) = 10^{(m+n)}$	$(10^3) \times (10^2) = 10^5$
$(a \times 10^x)(b \times 10^y) = ab \times 10^{x+y}$	$(5.0 \times 10^4) \times (3.0 \times 10^{-6}) = 1.5 \times 10^{-1}$
$\frac{10^x}{10^y} = 10^{(x-y)}$	$\frac{10^{+7}}{10^{+2}} = 10^{+5}$, $\frac{10^{+7}}{10^{-2}} = 10^{+9}$
$(10^x)^y = 10^{xy}$	$(10^{-2})^3 = 10^{-6}$

Change units

عند تحويل الوحدات نضرب العدد بما يسمى معامل التحويل Conversion factor حيث أن النسبة بين الوحدات تساوي واحد مثلا

$1\ cm = 10^{-2}\ m$

Conversion factor = $\frac{1\ cm}{10^{-2}\ m} = \frac{10^{-2}\ m}{1\ cm} = 1$

وعلى حسب المطلوب في السؤال نحدد معامل التحويل

EX.(1) 5cm= ???? m

A. $5\ cm \times \frac{10^{-2}\ m}{1\ cm} = 5 \times 10^{-2}\ m$

Conversion factor to convert cm to m

EX.(2) 5 m= ???? cm

A. $5\ m \times \frac{1\ cm}{10^{-2}\ m} = 5 \times 10^{+2}\ m$

Conversion factor to convert m to cm

==

EX.(3) $6\ km/h^2$ = ... m/s^2

A.

$1\ km = 10^3\ m$, $1\ h = 3600\ s$

معامل التحويل لتحول km إلى m

$$6\ \frac{km}{h^2} \times \frac{10^3\ m}{1\ km} \times \frac{1\ h^2}{(3600)^2 s^2} = 4.6 \times 10^{-4}\ m/s^2$$

معامل التحويل لتحول h^2 إلى s^2

Phys 110

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Read the book

Think!

Ask questions

Attend the tutorials

Information is key

No pain no gain ☺

Important Information

- اسم الكتاب: Fundamentals of physics, by Halliday & Resnick 8^{th}/ Edition (موجود في مكتبة خوارزم تصوير أول 10 فصول لعدم توفر النسخة في المكتبات)
- توزيع المنهج: (موجود بالموقع) (الفصول 1-2-3-4-5-6-7-9)
- توزيع الدرجات:

  الدوري الاول 30 درجه + 3 درجات بونس (الفصول 1-2-3)

  نصفي 30 درجه + 3 درجات بونس (الفصول 4-5-6)

  النهائي 40 درجه + 4 درجات بونس (جميع الفصول)
- أهداف المنهج على موقع المنسقة
- مواعيد الاختبارات وأماكنها تحدد لاحقاً من قبل الشؤون التعليميه وستعلن في موقع المنسقه في حينه
- نظام الحضور والغياب هو نفس نظام الجامعه
- يمنع عملية التحويل والتنقل بين الشعب إلا لظروف قاهرة
- ضرورة مراجعة موقع المنسقه (hfarhan.kau.edu.sa) بشكل مستمر
- محاضرات حلول التمارين (السكاشن) ستعقد يومياً من الساعه 12-1 ما عدا يوم الاربعاء وستبدأ بمشيئة الله من يوم السبت 28/3 (الرجاء مراجعة الموقع لمعرفة المواعيد والغرف) (شعبتنا الأحد 12-1).
- ضرورة طباعة التمارين من الموقع وضرورة حلّها قبل الحضور لمحاضرة السيكشن ومناقشتها.

Chapter 1
Measurements

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Objectives

After this lecture you should be able to…

- **Differentiate** → Between base and derived quantities
- **Explain** → Standards of measurements
- **Define** → The International system of units
- **Convert** → Units using the chain-link method
- **Apply** → The scientific notation to numbers

Physical Quantities

Physics is based on measurement of **<u>Physical Quantities.</u>**

For example: length, time, mass, temperature, pressure.

Physical Quantities

Base quantities

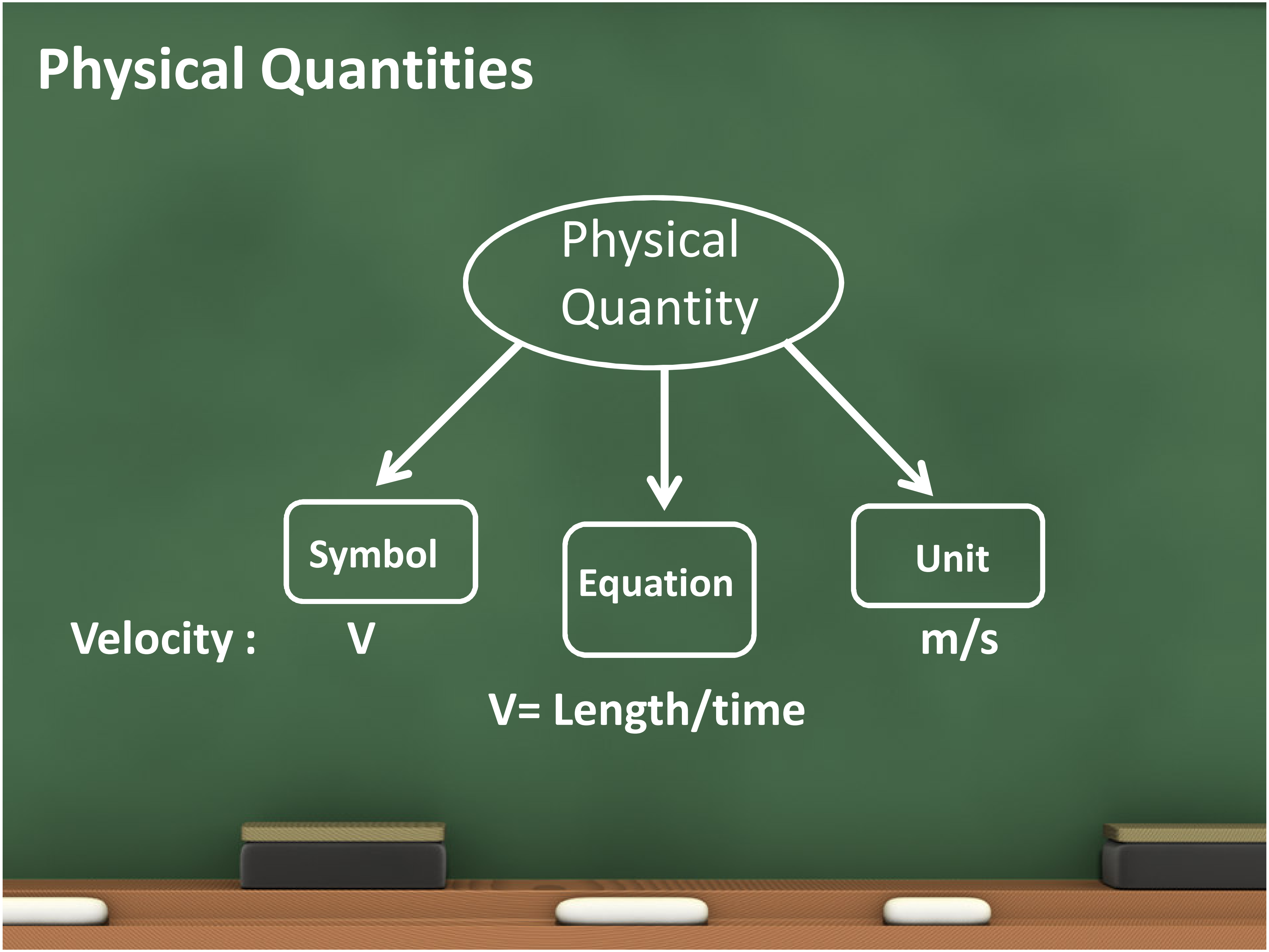
Assumed to be independent of each other.

Length, mass and time.

Derived quantities

Defined in terms of base quantities via equations.

$$\text{Velocity} = \frac{\text{Length}}{\text{Time}}$$


Physical Quantities
Physical Quantity
Symbol
Equation
Unit
Velocity :
V
m/s
V= Length/time

The International System of Units (SI)

Based on the General Conference on Weight and Measurements In 1971.

- Base Quantities
- Units of base quantities
- Standards of base quantities

Physical Quantity	Name of Unit	Abbreviation
Mass	***Kilogram***	***Kg***
Length	***Meter***	***m***
Time	***Second***	***s***
Temperature	Kelvin	K
Amount of substance	Mole	mol
Electric current	Ampere	A
Luminous intensity	Candela	cd

Standards of Base Quantities

__Length__:
A meter is the length of the path traveled by Light in a vacuum during a time interval of 1/299792458 of a second.

__Time__:
A Second is the time taken by 9192631770 oscillations of the light (of specified wavelength) emitted by cesium-133 atom.

__Mass__:
A kilogram is the mass of a paltinum-irradium cylinder 3.9 cm in height and diameter kept near Paris.

Scientific Notations

For large or small numbers

- $3560000000.0 \text{ m} = 3.56 \times 10^{+9} \text{ m}$
- $0.00000492 \text{ s} = 4.92 \times 10^{-6} \text{ s}$

Scientific Notations

- Example

Express 0.00592 in scientific notation.

a) 5.92×10^{3}

b) 5.92×10^{-3}

c) 5.92×10^{-2}

d) 5.92×10^{-5}

e) 5.92×10^{5}

Scientific Notations

- Example

Express 0.00592 in scientific notation.

a) 5.92×10^{3}

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c) 5.92×10^{-2}

d) 5.92×10^{-5}

e) 5.92×10^{5}

Scientific Notations

Using prefixes

10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	10^{1}	10^{2}	10^{3}	10^{6}	10^{9}
nano	micro	milli	centi	desi	deka	hecto	kilo	mega	giga
n	µ	m	c	d	da	h	k	M	G

3.56×10^{9} m giga → G 3.56 Gm

4.92×10^{-6} s $= 4.92\ \mu$ s

Conversion between units

Chain-link conversion

Convert 2 min to *s*?

$$1\,\text{min} = 60s$$

$$\frac{1\text{min}}{1\text{min}} = \frac{60\,s}{1\,\text{min}}$$

$$\Rightarrow \quad 1 = \frac{60s}{1\,\text{min}}$$

~~$1 = \frac{60}{1}$~~

<u>Conversion factor:</u>

is the ratio of units that equal unity

$$2\,\text{min} \times \frac{60\,\text{s}}{1\,\text{min}} = 120\,\text{s}$$

Unit Conversion

- Example

A section of a river can be approximated as a rectangle that is 20 m wide and 30 m long. Express the area of this river in square kilometers.

a) 600 km^2
b) 6 km^2
c) 6×10^{-2} km^2
d) 6×10^{-4} km^2
e) $6 \times 10^{+4}$ km^2

Unit Conversion

- Example

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Unit Conversion

- Example

Consider each of the following comparisons between various time units. Which one of these comparisons is false?

a) 84 600 s = 1 day
b) 1 h > 3000 s
c) 1 ns > 1000 μs
d) 1 s = 1000 ms
e) 1 y = 5.26×10^5 h

Unit Conversion

- Example

Consider each of the following comparisons between various time units. Which one of these comparisons is false?

a) 84 600 s = 1 day
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c) 1 ns > 1000 μs
d) 1 s = 1000 ms
e) 1 y = 5.26×10^5 h

The End

CHAPTER

1

MEASUREMENT

1-1 WHAT IS PHYSICS?

Science and engineering are based on measurements and comparisons. Thus, we need rules about how things are measured and compared, and we need experiments to establish the units for those measurements and comparisons. One purpose of physics (and engineering) is to design and conduct those experiments.

For example, physicists strive to develop clocks of extreme accuracy so that any time or time interval can be precisely determined and compared. You may wonder whether such accuracy is actually needed or worth the effort. Here is one example of the worth: Without clocks of extreme accuracy, the Global Positioning System (GPS) that is now vital to worldwide navigation would be useless.

1-2 Measuring Things

We discover physics by learning how to measure the quantities involved in physics. Among these quantities are length, time, mass, temperature, pressure, and electric current.

We measure each physical quantity in its own units, by comparison with a **standard.** The **unit** is a unique name we assign to measures of that quantity—for example, meter (m) for the quantity length. The standard corresponds to exactly 1.0 unit of the quantity. As you will see, the standard for length, which corresponds to exactly 1.0 m, is the distance traveled by light in a vacuum during a certain fraction of a second. We can define a unit and its standard in any way we care to. However, the important thing is to do so in such a way that scientists around the world will agree that our definitions are both sensible and practical.

Once we have set up a standard—say, for length—we must work out procedures by which any length whatever, be it the radius of a hydrogen atom, the wheelbase of a skateboard, or the distance to a star, can be expressed in terms of the standard. Rulers, which approximate our length standard, give us one such procedure for measuring length. However, many of our comparisons must be indirect. You cannot use a ruler, for example, to measure the radius of an atom or the distance to a star.

There are so many physical quantities that it is a problem to organize them. Fortunately, they are not all independent; for example, speed is the ratio of a length to a time. Thus, what we do is pick out—by international agreement—a small number of physical quantities, such as length and time, and assign standards to them alone. We then define all other physical quantities in terms of these *base quantities* and their standards (called *base standards*). Speed, for example, is defined in terms of the base quantities length and time and their base standards.

Base standards must be both accessible and invariable. If we define the length standard as the distance between one's nose and the index finger on an outstretched arm, we certainly have an accessible standard—but it will, of course, vary from person to person. The demand for precision in science and engineering pushes us to aim first for invariability. We then exert great effort to make duplicates of the base standards that are accessible to those who need them.

Table 1-1

Units for Three SI Base Quantities

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

1-3 The International System of Units

In 1971, the 14th General Conference on Weights and Measures picked seven quantities as base quantities, thereby forming the basis of the International System of Units, abbreviated SI from its French name and popularly known as the *metric system.* Table 1-1 shows the units for the three base quantities—length, mass, and time—that we use in the early chapters of this book. These units were defined to be on a "human scale."

Many SI *derived units* are defined in terms of these base units. For example, the SI unit for power, called the **watt** (W), is defined in terms of the base units for mass, length, and time. Thus, as you will see in Chapter 7,

$$1 \text{ watt} = 1 \text{ W} = 1 \text{ kg} \cdot \text{m}^2/\text{s}^3, \tag{1-1}$$

where the last collection of unit symbols is read as kilogram-meter squared per second cubed.

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,

$$3\,560\,000\,000 \text{ m} = 3.56 \times 10^9 \text{ m} \tag{1-2}$$

and

$$0.000\,000\,492 \text{ s} = 4.92 \times 10^{-7} \text{ s}. \tag{1-3}$$

Scientific notation on computers sometimes takes on an even briefer look, as in 3.56 E9 and 4.92 E–7, where E stands for "exponent of ten." It is briefer still on some calculators, where E is replaced with an empty space.

As a further convenience when dealing with very large or very small measurements, we use the prefixes listed in Table 1-2. As you can see, each prefix represents a certain power of 10, to be used as a multiplication factor. Attaching a prefix to an SI unit has the effect of multiplying by the associated factor. Thus, we can express a particular electric power as

$$1.27 \times 10^9 \text{ watts} = 1.27 \text{ gigawatts} = 1.27 \text{ GW} \tag{1-4}$$

or a particular time interval as

$$2.35 \times 10^{-9} \text{ s} = 2.35 \text{ nanoseconds} = 2.35 \text{ ns}. \tag{1-5}$$

Some prefixes, as used in milliliter, centimeter, kilogram, and megabyte, are probably familiar to you.

Table 1-2

Prefixes for SI Units

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

[a]The most frequently used prefixes are shown in bold type.

1-4 Changing Units

We often need to change the units in which a physical quantity is expressed. We do so by a method called *chain-link conversion.* In this method, we multiply the original measurement by a **conversion factor** (a ratio of units that is equal to unity). For example, because 1 min and 60 s are identical time intervals, we have

$$\frac{1 \text{ min}}{60 \text{ s}} = 1 \quad \text{and} \quad \frac{60 \text{ s}}{1 \text{ min}} = 1.$$

Thus, the ratios (1 min)/(60 s) and (60 s)/(1 min) can be used as conversion factors. This is *not* the same as writing $\frac{1}{60} = 1$ or $60 = 1$; each *number* and its *unit* must be treated together.

Because multiplying any quantity by unity leaves the quantity unchanged, we can introduce conversion factors wherever we find them useful. In chain-link conversion, we use the factors to cancel unwanted units. For example, to convert 2 min to seconds, we have

$$2 \text{ min} = (2 \text{ min})(1) = (2 \cancel{\text{min}})\left(\frac{60 \text{ s}}{1 \cancel{\text{min}}}\right) = 120 \text{ s}. \tag{1-6}$$

If you introduce a conversion factor in such a way that unwanted units do *not* cancel, invert the factor and try again. In conversions, the units obey the same algebraic rules as variables and numbers.

Appendix D gives conversion factors between SI and other systems of units, including non-SI units still used in the United States. However, the conversion factors are written in the style of "1 min = 60 s" rather than as a ratio. So, you need to decide on the numerator and denominator in any needed ratio.

1-5 Length

In 1792, the newborn Republic of France established a new system of weights and measures. Its cornerstone was the meter, defined to be one ten-millionth of the distance from the north pole to the equator. Later, for practical reasons, this Earth standard was abandoned and the meter came to be 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. Accurate copies of the bar were sent to standardizing laboratories throughout the world. These **secondary standards** were used to produce other, still more accessible standards, so that ultimately every measuring device derived its authority from the standard meter bar through a complicated chain of comparisons.

Eventually, a standard more precise than the distance between two fine scratches on a metal bar was required. In 1960, a new standard for the meter, based on the wavelength of light, was adopted. Specifically, the standard for the meter was redefined to be 1 650 763.73 wavelengths of a particular orange-red light emitted by atoms of krypton-86 (a particular isotope, or type, of krypton) in a gas discharge tube that can be set up anywhere in the world. This awkward number of wavelengths was chosen so that the new standard would be close to the old meter-bar standard.

By 1983, however, the demand for higher precision had reached such a point that even the krypton-86 standard could not meet it, and in that year a bold step was taken. The meter was redefined as the distance traveled by light in a specified time interval. In the words of the 17th General Conference on Weights and Measures:

> 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.

This time interval was chosen so that the speed of light c is exactly

$$c = 299\,792\,458 \text{ m/s}.$$

Measurements of the speed of light had become extremely precise, so it made sense to adopt the speed of light as a defined quantity and to use it to redefine the meter.

Table 1-3 shows a wide range of lengths, from that of the universe (top line) to those of some very small objects.

Table 1-3

Some Approximate Lengths

Measurement	Length in Meters
Distance to the first galaxies formed	2×10^{26}
Distance to the Andromeda galaxy	2×10^{22}
Distance to the nearby star Proxima Centauri	4×10^{16}
Distance to Pluto	6×10^{12}
Radius of Earth	6×10^{6}
Height of Mt. Everest	9×10^{3}
Thickness of this page	1×10^{-4}
Length of a typical virus	1×10^{-8}
Radius of a hydrogen atom	5×10^{-11}
Radius of a proton	1×10^{-15}

Sample Problem

Estimating order of magnitude, ball of string

The world's largest ball of string is about 2 m in radius. To the nearest order of magnitude, what is the total length L of the string in the ball?

KEY IDEA

We could, of course, take the ball apart and measure the total length L, but that would take great effort and make the ball's builder most unhappy. Instead, because we want only the nearest order of magnitude, we can estimate any quantities required in the calculation.

Calculations: Let us assume the ball is spherical with radius $R = 2$ m. The string in the ball is not closely packed (there are uncountable gaps between adjacent sections of string). To allow for these gaps, let us somewhat overestimate the cross-sectional area of the string by assuming the cross section is square, with an edge length $d = 4$ mm. Then, with a cross-sectional area of d^2 and a length L, the string occupies a total volume of

$$V = (\text{cross-sectional area})(\text{length}) = d^2L.$$

This is approximately equal to the volume of the ball, given by $\frac{4}{3}\pi R^3$, which is about $4R^3$ because π is about 3. Thus, we have

$$d^2L = 4R^3,$$

or

$$L = \frac{4R^3}{d^2} = \frac{4(2\text{ m})^3}{(4 \times 10^{-3}\text{ m})^2}$$
$$= 2 \times 10^6\text{ m} \approx 10^6\text{ m} = 10^3\text{ km}. \quad \text{(Answer)}$$

(Note that you do not need a calculator for such a simplified calculation.) To the nearest order of magnitude, the ball contains about 1000 km of string!

1-6 Time

Time has two aspects. For civil and some scientific purposes, we want to know the time of day so that we can order events in sequence. In much scientific work, we want to know how long an event lasts. Thus, any time standard must be able to answer two questions: "*When* did it happen?" and "What is its *duration*?" Table 1-4 shows some time intervals.

Table 1-4

Some Approximate Time Intervals

Measurement	Time Interval in Seconds
Lifetime of the proton (predicted)	3×10^{40}
Age of the universe	5×10^{17}
Age of the pyramid of Cheops	1×10^{11}
Human life expectancy	2×10^{9}
Length of a day	9×10^{4}
Time between human heartbeats	8×10^{-1}
Lifetime of the muon	2×10^{-6}
Shortest lab light pulse	1×10^{-16}
Lifetime of the most unstable particle	1×10^{-23}
The Planck time[a]	1×10^{-43}

[a]This is the earliest time after the big bang at which the laws of physics as we know them can be applied.

Any phenomenon that repeats itself is a possible time standard. Earth's rotation, which determines the length of the day, has been used in this way for centuries; Fig. 1-1 shows one novel example of a watch based on that rotation. A quartz clock, in which a quartz ring is made to vibrate continuously, can be calibrated against Earth's rotation via astronomical observations and used to measure time intervals in the laboratory. However, the calibration cannot be carried out with the accuracy called for by modern scientific and engineering technology.

To meet the need for a better time standard, atomic clocks have been developed. An atomic clock at the National Institute of Standards and Technology

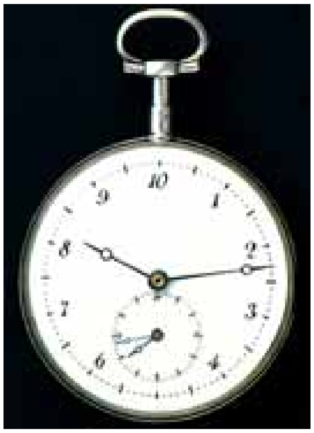

Fig. 1-1 When the metric system was proposed in 1792, the hour was redefined to provide a 10-hour day. The idea did not catch on. The maker of this 10-hour watch wisely provided a small dial that kept conventional 12-hour time. Do the two dials indicate the same time? *(Steven Pitkin)*

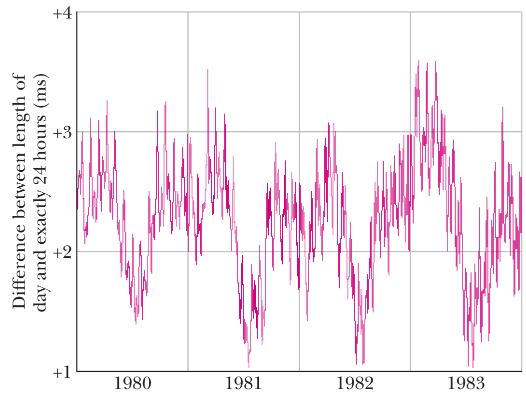

Fig. 1-2 Variations in the length of the day over a 4-year period. Note that the entire vertical scale amounts to only 3 ms (= 0.003 s).

(NIST) in Boulder, Colorado, is the standard for Coordinated Universal Time (UTC) in the United States. Its time signals are available by shortwave radio (stations WWV and WWVH) and by telephone (303-499-7111). Time signals (and related information) are also available from the United States Naval Observatory at website http://tycho.usno.navy.mil/time.html. (To set a clock extremely accurately at your particular location, you would have to account for the travel time required for these signals to reach you.)

Figure 1-2 shows variations in the length of one day on Earth over a 4-year period, as determined by comparison with a cesium (atomic) clock. Because the variation displayed by Fig. 1-2 is seasonal and repetitious, we suspect the rotating Earth when there is a difference between Earth and atom as timekeepers. The variation is due to tidal effects caused by the Moon and to large-scale winds.

The 13th General Conference on Weights and Measures in 1967 adopted a standard second based on the cesium clock:

> One second is the time taken by 9 192 631 770 oscillations of the light (of a specified wavelength) emitted by a cesium-133 atom.

Atomic clocks are so consistent that, in principle, two cesium clocks would have to run for 6000 years before their readings would differ by more than 1 s. Even such accuracy pales in comparison with that of clocks currently being developed; their precision may be 1 part in 10^{18}—that is, 1 s in 1×10^{18} s (which is about 3×10^{10} y).

1-7 Mass

The Standard Kilogram

The SI standard of mass is a platinum–iridium cylinder (Fig. 1-3) kept at the International Bureau of Weights and Measures near Paris and assigned, by international agreement, a mass of 1 kilogram. Accurate copies have been sent to standardizing laboratories in other countries, and the masses of other bodies can be determined by balancing them against a copy. Table 1-5 shows some masses expressed in kilograms, ranging over about 83 orders of magnitude.

Fig. 1-3 The international 1 kg standard of mass, a platinum–iridium cylinder 3.9 cm in height and in diameter. *(Courtesy Bureau International des Poids et Mesures, France)*

The U.S. copy of the standard kilogram is housed in a vault at NIST. It is removed, no more than once a year, for the purpose of checking duplicate copies that are used elsewhere. Since 1889, it has been taken to France twice for recomparison with the primary standard.

A Second Mass Standard

The masses of atoms can be compared with one another more precisely than they can be compared with the standard kilogram. For this reason, we have a second mass standard. It is the carbon-12 atom, which, by international agreement, has been assigned a mass of 12 **atomic mass units** (u). The relation between the two units is

$$1 \text{ u} = 1.660\,538\,86 \times 10^{-27} \text{ kg}, \tag{1-7}$$

with an uncertainty of ± 10 in the last two decimal places. Scientists can, with reasonable precision, experimentally determine the masses of other atoms relative to the mass of carbon-12. What we presently lack is a reliable means of extending that precision to more common units of mass, such as a kilogram.

Density

As we shall discuss further in Chapter 14, **density** ρ (lowercase Greek letter rho) is the mass per unit volume:

$$\rho = \frac{m}{V}. \tag{1-8}$$

Densities are typically listed in kilograms per cubic meter or grams per cubic centimeter. The density of water (1.00 gram per cubic centimeter) is often used as a comparison. Fresh snow has about 10% of that density; platinum has a density that is about 21 times that of water.

Table 1-5

Some Approximate Masses

Object	Mass in Kilograms
Known universe	1×10^{53}
Our galaxy	2×10^{41}
Sun	2×10^{30}
Moon	7×10^{22}
Asteroid Eros	5×10^{15}
Small mountain	1×10^{12}
Ocean liner	7×10^{7}
Elephant	5×10^{3}
Grape	3×10^{-3}
Speck of dust	7×10^{-10}
Penicillin molecule	5×10^{-17}
Uranium atom	4×10^{-25}
Proton	2×10^{-27}
Electron	9×10^{-31}

Sample Problem

Density and liquefaction

A heavy object can sink into the ground during an earthquake if the shaking causes the ground to undergo *liquefaction,* in which the soil grains experience little friction as they slide over one another. The ground is then effectively quicksand. The possibility of liquefaction in sandy ground can be predicted in terms of the *void ratio* e for a sample of the ground:

$$e = \frac{V_{\text{voids}}}{V_{\text{grains}}}. \tag{1-9}$$

Here, V_{grains} is the total volume of the sand grains in the sample and V_{voids} is the total volume between the grains (in the *voids*). If e exceeds a critical value of 0.80, liquefaction can occur during an earthquake. What is the corresponding sand density ρ_{sand}? Solid silicon dioxide (the primary component of sand) has a density of $\rho_{SiO_2} = 2.600 \times 10^3$ kg/m^3.

KEY IDEA

The density of the sand ρ_{sand} in a sample is the mass per unit volume—that is, the ratio of the total mass m_{sand} of the sand grains to the total volume V_{total} of the sample:

$$\rho_{\text{sand}} = \frac{m_{\text{sand}}}{V_{\text{total}}}. \tag{1-10}$$

Calculations: The total volume V_{total} of a sample is

$$V_{\text{total}} = V_{\text{grains}} + V_{\text{voids}}.$$

Substituting for V_{voids} from Eq. 1-9 and solving for V_{grains} lead to

$$V_{\text{grains}} = \frac{V_{\text{total}}}{1 + e}. \tag{1-11}$$

(continues on the next page)

From Eq. 1-8, the total mass m_{sand} of the sand grains is the product of the density of silicon dioxide and the total volume of the sand grains:

$$m_{sand} = \rho_{SiO_2} V_{grains}. \tag{1-12}$$

Substituting this expression into Eq. 1-10 and then substituting for V_{grains} from Eq. 1-11 lead to

$$\rho_{sand} = \frac{\rho_{SiO_2}}{V_{total}} \frac{V_{total}}{1+e} = \frac{\rho_{SiO_2}}{1+e}. \tag{1-13}$$

Substituting $\rho_{SiO_2} = 2.600 \times 10^3$ kg/m^3 and the critical value of $e = 0.80$, we find that liquefaction occurs when the sand density is less than

$$\rho_{sand} = \frac{2.600 \times 10^3 \text{ kg/m}^3}{1.80} = 1.4 \times 10^3 \text{ kg/m}^3.$$

(Answer)

A building can sink several meters in such liquefaction.

REVIEW & SUMMARY

Measurement in Physics Physics is based on measurement of physical quantities. Certain physical quantities have been chosen as **base quantities** (such as length, time, and mass); each has been defined in terms of a **standard** and given a **unit** of measure (such as meter, second, and kilogram). Other physical quantities are defined in terms of the base quantities and their standards and units.

SI Units The unit system emphasized in this book is the International System of Units (SI). The three physical quantities displayed in Table 1-1 are used in the early chapters. Standards, which must be both accessible and invariable, have been established for these base quantities by international agreement. These standards are used in all physical measurement, for both the base quantities and the quantities derived from them. Scientific notation and the prefixes of Table 1-2 are used to simplify measurement notation.

Changing Units Conversion of units may be performed by using *chain-link conversions* in which the original data are multiplied successively by conversion factors written as unity and the units are manipulated like algebraic quantities until only the desired units remain.

Length The meter is defined as the distance traveled by light during a precisely specified time interval.

Time The second is defined in terms of the oscillations of light emitted by an atomic (cesium-133) source. Accurate time signals are sent worldwide by radio signals keyed to atomic clocks in standardizing laboratories.

Mass The kilogram is defined in terms of a platinum–iridium standard mass kept near Paris. For measurements on an atomic scale, the atomic mass unit, defined in terms of the atom carbon-12, is usually used.

Density The density ρ of a material is the mass per unit volume:

$$\rho = \frac{m}{V}. \tag{1-8}$$

PROBLEMS

Tutoring problem available (at instructor's discretion) in *WileyPLUS* and WebAssign
SSM Worked-out solution available in Student Solutions Manual
• – ••• Number of dots indicates level of problem difficulty
Additional information available in *The Flying Circus of Physics* and at flyingcircusofphysics.com
WWW Worked-out solution is at
ILW Interactive solution is at
http://www.wiley.com/college/halliday

sec. 1-5 Length

•1 SSM Earth is approximately a sphere of radius 6.37×10^6 m. What are (a) its circumference in kilometers, (b) its surface area in square kilometers, and (c) its volume in cubic kilometers?

•2 A *gry* is an old English measure for length, defined as 1/10 of a line, where *line* is another old English measure for length, defined as 1/12 inch. A common measure for length in the publishing business is a *point,* defined as 1/72 inch. What is an area of 0.50 gry^2 in points squared (points^2)?

•3 The micrometer (1 μm) is often called the *micron.* (a) How many microns make up 1.0 km? (b) What fraction of a centimeter equals 1.0 μm? (c) How many microns are in 1.0 yd?

•4 Spacing in this book was generally done in units of points and picas: 12 points = 1 pica, and 6 picas = 1 inch. If a figure was misplaced in the page proofs by 0.80 cm, what was the misplacement in (a) picas and (b) points?

•5 SSM WWW Horses are to race over a certain English meadow for a distance of 4.0 furlongs. What is the race distance in (a) rods and (b) chains? (1 furlong = 201.168 m, 1 rod = 5.0292 m, and 1 chain = 20.117 m.)

••6 You can easily convert common units and measures electronically, but you still should be able to use a conversion table, such as those in Appendix D. Table 1-6 is part of a conversion table for a system of volume measures once common in Spain; a volume of 1 fanega is equivalent to 55.501 dm^3 (cubic decimeters). To complete the table, what numbers (to three significant figures) should be entered in (a) the cahiz column, (b) the fanega column, (c) the cuartilla column, and (d) the almude column, starting with the top blank? Express 7.00 almudes in (e) medios, (f) cahizes, and (g) cubic centimeters (cm^3).

Table 1-6

Problem 6

	cahiz	fanega	cuartilla	almude	medio
1 cahiz =	1	12	48	144	288
1 fanega =		1	4	12	24
1 cuartilla =			1	3	6
1 almude =				1	2
1 medio =					1

••7 ILW Hydraulic engineers in the United States often use, as a unit of volume of water, the *acre-foot,* defined as the volume of water that will cover 1 acre of land to a depth of 1 ft. A severe thunderstorm dumped 2.0 in. of rain in 30 min on a town of area 26 km^2. What volume of water, in acre-feet, fell on the town?

••8 Harvard Bridge, which connects MIT with its fraternities across the Charles River, has a length of 364.4 Smoots plus one ear. The unit of one Smoot is based on the length of Oliver Reed Smoot, Jr., class of 1962, who was carried or dragged length by length across the bridge so that other pledge members of the Lambda Chi Alpha fraternity could mark off (with paint) 1-Smoot lengths along the bridge. The marks have been repainted biannually by fraternity pledges since the initial measurement, usually during times of traffic congestion so that the police cannot easily interfere. (Presumably, the police were originally upset because the Smoot is not an SI base unit, but these days they seem to have accepted the unit.) Figure 1-4 shows three parallel paths, measured in Smoots (S), Willies (W), and Zeldas (Z). What is the length of 50.0 Smoots in (a) Willies and (b) Zeldas?

Fig. 1-4 Problem 8.

••9 Antarctica is roughly semicircular, with a radius of 2000 km (Fig. 1-5). The average thickness of its ice cover is 3000 m. How many cubic centimeters of ice does Antarctica contain? (Ignore the curvature of Earth.)

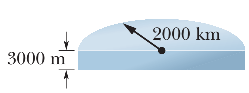

Fig. 1-5 Problem 9.

sec. 1-6 Time

•10 Until 1883, every city and town in the United States kept its own local time. Today, travelers reset their watches only when the time change equals 1.0 h. How far, on the average, must you travel in degrees of longitude between the time-zone boundaries at which your watch must be reset by 1.0 h? (*Hint:* Earth rotates 360° in about 24 h.)

•11 For about 10 years after the French Revolution, the French government attempted to base measures of time on multiples of ten: One week consisted of 10 days, one day consisted of 10 hours, one hour consisted of 100 minutes, and one minute consisted of 100 seconds. What are the ratios of (a) the French decimal week to the standard week and (b) the French decimal second to the standard second?

•12 The fastest growing plant on record is a *Hesperoyucca whipplei* that grew 3.7 m in 14 days. What was its growth rate in micrometers per second?

•13 Three digital clocks *A, B,* and *C* run at different rates and do not have simultaneous readings of zero. Figure 1-6 shows simultaneous readings on pairs of the clocks for four occasions. (At the earliest occasion, for example, *B* reads 25.0 s and *C* reads 92.0 s.) If two events are 600 s apart on clock *A,* how far apart are they on (a) clock *B* and (b) clock *C*? (c) When clock *A* reads 400 s, what does clock *B* read? (d) When clock *C* reads 15.0 s, what does clock *B* read? (Assume negative readings for prezero times.)

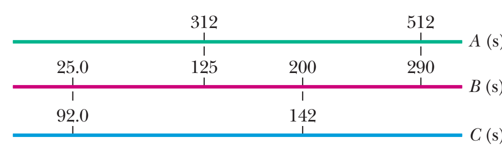

Fig. 1-6 Problem 13.

•14 A lecture period (50 min) is close to 1 microcentury. (a) How long is a microcentury in minutes? (b) Using

$$\text{percentage difference} = \left(\frac{\text{actual} - \text{approximation}}{\text{actual}}\right)100,$$

find the percentage difference from the approximation.

•15 A fortnight is a charming English measure of time equal to 2.0 weeks (the word is a contraction of "fourteen nights"). That is a nice amount of time in pleasant company but perhaps a painful string of microseconds in unpleasant company. How many microseconds are in a fortnight?

•16 Time standards are now based on atomic clocks. A promising second standard is based on *pulsars,* which are rotating neutron stars (highly compact stars consisting only of neutrons). Some rotate at a rate that is highly stable, sending out a radio beacon that sweeps briefly across Earth once with each rotation, like a lighthouse beacon. Pulsar PSR 1937+21 is an example; it rotates once every 1.557 806 448 872 75 ± 3 ms, where the trailing ±3 indicates the uncertainty in the last decimal place (it does *not* mean ±3 ms). (a) How many rotations does PSR 1937+21 make in 7.00 days? (b) How much time does the pulsar take to rotate exactly one million times and (c) what is the associated uncertainty?

•17 SSM Five clocks are being tested in a laboratory. Exactly at noon, as determined by the WWV time signal, on successive days of a week the clocks read as in the following table. Rank the five clocks according to their relative value as good timekeepers, best to worst. Justify your choice.

Clock	Sun.	Mon.	Tues.	Wed.	Thurs.	Fri.	Sat.
A	12:36:40	12:36:56	12:37:12	12:37:27	12:37:44	12:37:59	12:38:14
B	11:59:59	12:00:02	11:59:57	12:00:07	12:00:02	11:59:56	12:00:03
C	15:50:45	15:51:43	15:52:41	15:53:39	15:54:37	15:55:35	15:56:33
D	12:03:59	12:02:52	12:01:45	12:00:38	11:59:31	11:58:24	11:57:17
E	12:03:59	12:02:49	12:01:54	12:01:52	12:01:32	12:01:22	12:01:12

••18 Because Earth's rotation is gradually slowing, the length of each day increases: The day at the end of 1.0 century is 1.0 ms longer than the day at the start of the century. In 20 centuries, what is the total of the daily increases in time?

•••19 Suppose that, while lying on a beach near the equator watching the Sun set over a calm ocean, you start a stopwatch just as the top of the Sun disappears. You then stand, elevating your eyes by a height $H = 1.70$ m, and stop the watch when the top of the Sun again disappears. If the elapsed time is $t = 11.1$ s, what is the radius r of Earth?

sec. 1-7 Mass

•20 The record for the largest glass bottle was set in 1992 by a team in Millville, New Jersey—they blew a bottle with a volume of 193 U.S. fluid gallons. (a) How much short of 1.0 million cubic centimeters is that? (b) If the bottle were filled with water at the leisurely rate of 1.8 g/min, how long would the filling take? Water has a density of 1000 kg/m^3.

•21 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?

•22 Gold, which has a density of 19.32 g/cm^3, is the most ductile metal and can be pressed into a thin leaf or drawn out into a long fiber. (a) If a sample of gold, with a mass of 27.63 g, is pressed into a leaf of 1.000 μm thickness, what is the area of the leaf? (b) If, instead, the gold is drawn out into a cylindrical fiber of radius 2.500 μm, what is the length of the fiber?

•23 SSM (a) Assuming that water has a density of exactly 1 g/cm^3, find the mass of one cubic meter of water in kilograms. (b) Suppose that it takes 10.0 h to drain a container of 5700 m^3 of water. What is the "mass flow rate," in kilograms per second, of water from the container?

••24 Grains of fine California beach sand are approximately spheres with an average radius of 50 μm and are made of silicon dioxide, which has a density of 2600 kg/m^3. What mass of sand grains would have a total surface area (the total area of all the individual spheres) equal to the surface area of a cube 1.00 m on an edge?

••25 During heavy rain, a section of a mountainside measuring 2.5 km horizontally, 0.80 km up along the slope, and 2.0 m deep slips into a valley in a mud slide. Assume that the mud ends up uniformly distributed over a surface area of the valley measuring 0.40 km $\times$ 0.40 km and that mud has a density of 1900 kg/m^3. What is the mass of the mud sitting above a 4.0 m^2 area of the valley floor?

••26 One cubic centimeter of a typical cumulus cloud contains 50 to 500 water drops, which have a typical radius of 10 μm. For that range, give the lower value and the higher value, respectively, for the following. (a) How many cubic meters of water are in a cylindrical cumulus cloud of height 3.0 km and radius 1.0 km? (b) How many 1-liter pop bottles would that water fill? (c) Water has a density of 1000 kg/m^3. How much mass does the water in the cloud have?

••27 Iron has a density of 7.87 g/cm^3, and the mass of an iron atom is 9.27×10^{-26} kg. If the atoms are spherical and tightly packed, (a) what is the volume of an iron atom and (b) what is the distance between the centers of adjacent atoms?

••28 A mole of atoms is 6.02×10^{23} atoms. To the nearest order of magnitude, how many moles of atoms are in a large domestic cat? The masses of a hydrogen atom, an oxygen atom, and a carbon atom are 1.0 u, 16 u, and 12 u, respectively. (*Hint:* Cats are sometimes known to kill a mole.)

••29 On a spending spree in Malaysia, you buy an ox with a weight of 28.9 piculs in the local unit of weights: 1 picul = 100 gins, 1 gin = 16 tahils, 1 tahil = 10 chees, and 1 chee = 10 hoons. The weight of 1 hoon corresponds to a mass of 0.3779 g. When you arrange to ship the ox home to your astonished family, how much mass in kilograms must you declare on the shipping manifest? (*Hint:* Set up multiple chain-link conversions.)

••30 Water is poured into a container that has a small leak. The mass m of the water is given as a function of time t by $m = 5.00t^{0.8} - 3.00t + 20.00$, with $t \geq 0$, m in grams, and t in seconds. (a) At what time is the water mass greatest, and (b) what is that greatest mass? In kilograms per minute, what is the rate of mass change at (c) $t = 2.00$ s and (d) $t = 5.00$ s?

•••31 A vertical container with base area measuring 14.0 cm by 17.0 cm is being filled with identical pieces of candy, each with a volume of 50.0 mm^3 and a mass of 0.0200 g. Assume that the volume of the empty spaces between the candies is negligible. If the height of the candies in the container increases at the rate of 0.250 cm/s, at what rate (kilograms per minute) does the mass of the candies in the container increase?

Additional Problems

32 In the United States, a doll house has the scale of 1:12 of a real house (that is, each length of the doll house is $\frac{1}{12}$ that of the real house) and a miniature house (a doll house to fit within a doll house) has the scale of 1:144 of a real house. Suppose a real house (Fig. 1-7) has a front length of 20 m, a depth of 12 m, a height of 6.0 m, and a standard sloped roof (vertical triangular faces on the ends) of height 3.0 m. In cubic meters, what are the volumes of the corresponding (a) doll house and (b) miniature house?

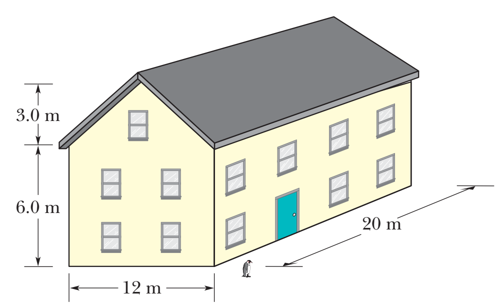

Fig. 1-7 Problem 32.

33 SSM A ton is a measure of volume frequently used in shipping, but that use requires some care because there are at least three types of tons: A *displacement ton* is equal to 7 barrels bulk, a *freight ton* is equal to 8 barrels bulk, and a *register ton* is equal to 20 barrels bulk. A *barrel bulk* is another measure of volume: 1 barrel bulk = 0.1415 m^3. Suppose you spot a shipping order for "73 tons" of M&M candies, and you are certain that the client who sent the order intended "ton" to refer to volume (instead of weight or mass, as discussed in Chapter 5). If the client actually meant displacement tons, how many extra U.S. bushels of the candies will you erroneously ship if you interpret the order as (a) 73 freight tons and (b) 73 register tons? (1 m^3 = 28.378 U.S. bushels.)

34 Two types of *barrel* units were in use in the 1920s in the United States. The apple barrel had a legally set volume of 7056 cubic inches; the cranberry barrel, 5826 cubic inches. If a merchant sells 20 cranberry barrels of goods to a customer who thinks he is receiving apple barrels, what is the discrepancy in the shipment volume in liters?

35 An old English children's rhyme states, "Little Miss Muffet sat on a tuffet, eating her curds and whey, when along came a spider who sat down beside her. . . ." The spider sat down not because of the curds and whey but because Miss Muffet had a stash of 11 tuffets of dried flies. The volume measure of a tuffet is given by 1 tuffet = 2 pecks = 0.50 Imperial bushel, where 1 Imperial bushel = 36.3687 liters (L). What was Miss Muffet's stash in (a) pecks, (b) Imperial bushels, and (c) liters?

36 Table 1-7 shows some old measures of liquid volume. To complete the table, what numbers (to three significant figures) should be entered in (a) the wey column, (b) the chaldron column, (c) the bag column, (d) the pottle column, and (e) the gill column, starting with the top blank? (f) The volume of 1 bag is equal to 0.1091 m^3. If an old story has a witch cooking up some vile liquid in a cauldron of volume 1.5 chaldrons, what is the volume in cubic meters?

Table 1-7

Problem 36

	wey	chaldron	bag	pottle	gill
1 wey =	1	10/9	40/3	640	120 240
1 chaldron =					
1 bag =					
1 pottle =					
1 gill =					

37 A typical sugar cube has an edge length of 1 cm. If you had a cubical box that contained a mole of sugar cubes, what would its edge length be? (One mole = 6.02×10^{23} units.)

38 An old manuscript reveals that a landowner in the time of King Arthur held 3.00 acres of plowed land plus a livestock area of 25.0 perches by 4.00 perches. What was the total area in (a) the old unit of roods and (b) the more modern unit of square meters? Here, 1 acre is an area of 40 perches by 4 perches, 1 rood is an area of 40 perches by 1 perch, and 1 perch is the length 16.5 ft.

39 SSM A tourist purchases a car in England and ships it home to the United States. The car sticker advertised that the car's fuel consumption was at the rate of 40 miles per gallon on the open road. The tourist does not realize that the U.K. gallon differs from the U.S. gallon:

$$1 \text{ U.K. gallon} = 4.546\,090\,0 \text{ liters}$$
$$1 \text{ U.S. gallon} = 3.785\,411\,8 \text{ liters.}$$

For a trip of 750 miles (in the United States), how many gallons of fuel does (a) the mistaken tourist believe she needs and (b) the car actually require?

40 Using conversions and data in the chapter, determine the number of hydrogen atoms required to obtain 1.0 kg of hydrogen. A hydrogen atom has a mass of 1.0 u.

41 SSM A *cord* is a volume of cut wood equal to a stack 8 ft long, 4 ft wide, and 4 ft high. How many cords are in 1.0 m^3?

42 One molecule of water (H_2O) contains two atoms of hydrogen and one atom of oxygen. A hydrogen atom has a mass of 1.0 u and an atom of oxygen has a mass of 16 u, approximately. (a) What is the mass in kilograms of one molecule of water? (b) How many molecules of water are in the world's oceans, which have an estimated total mass of 1.4×10^{21} kg?

43 A person on a diet might lose 2.3 kg per week. Express the mass loss rate in milligrams per second, as if the dieter could sense the second-by-second loss.

44 What mass of water fell on the town in Problem 7? Water has a density of 1.0×10^3 kg/m^3.

45 (a) A unit of time sometimes used in microscopic physics is the *shake*. One shake equals 10^{-8} s. Are there more shakes in a second than there are seconds in a year? (b) Humans have existed for about 10^6 years, whereas the universe is about 10^{10} years old. If the age of the universe is defined as 1 "universe day," where a universe day consists of "universe seconds" as a normal day consists of normal seconds, how many universe seconds have humans existed?

46 A unit of area often used in measuring land areas is the *hectare*, defined as 10^4 m^2. An open-pit coal mine consumes 75 hectares of land, down to a depth of 26 m, each year. What volume of earth, in cubic kilometers, is removed in this time?

47 SSM An astronomical unit (AU) is the average distance between Earth and the Sun, approximately 1.50×10^8 km. The speed of light is about 3.0×10^8 m/s. Express the speed of light in astronomical units per minute.

48 The common Eastern mole, a mammal, typically has a mass of 75 g, which corresponds to about 7.5 moles of atoms. (A mole of atoms is 6.02×10^{23} atoms.) In atomic mass units (u), what is the average mass of the atoms in the common Eastern mole?

49 A traditional unit of length in Japan is the ken (1 ken = 1.97 m). What are the ratios of (a) square kens to square meters and (b) cubic kens to cubic meters? What is the volume of a cylindrical water tank of height 5.50 kens and radius 3.00 kens in (c) cubic kens and (d) cubic meters?

50 You receive orders to sail due east for 24.5 mi to put your salvage ship directly over a sunken pirate ship. However, when your divers probe the ocean floor at that location and find no evidence of a ship, you radio back to your source of information, only to discover that the sailing distance was supposed to be 24.5 *nautical miles*, not regular miles. Use the Length table in Appendix D to calculate how far horizontally you are from the pirate ship in kilometers.

** View All Solutions Here **

51 The cubit is an ancient unit of length based on the distance between the elbow and the tip of the middle finger of the measurer. Assume that the distance ranged from 43 to 53 cm, and suppose that ancient drawings indicate that a cylindrical pillar was to have a length of 9 cubits and a diameter of 2 cubits. For the stated range, what are the lower value and the upper value, respectively, for (a) the cylinder's length in meters, (b) the cylinder's length in millimeters, and (c) the cylinder's volume in cubic meters?

52 As a contrast between the old and the modern and between the large and the small, consider the following: In old rural England 1 hide (between 100 and 120 acres) was the area of land needed to sustain one family with a single plough for one year. (An area of 1 acre is equal to 4047 m^2.) Also, 1 wapentake was the area of land needed by 100 such families. In quantum physics, the cross-sectional area of a nucleus (defined in terms of the chance of a particle hitting and being absorbed by it) is measured in units of barns, where 1 barn is 1×10^{-28} m^2. (In nuclear physics jargon, if a nucleus is "large," then shooting a particle at it is like shooting a bullet at a barn door, which can hardly be missed.) What is the ratio of 25 wapentakes to 11 barns?

53 SSM An *astronomical unit* (AU) is equal to the average distance from Earth to the Sun, about 92.9×10^6 mi. A *parsec* (pc) is the distance at which a length of 1 AU would subtend an angle of exactly 1 second of arc (Fig. 1-8). A *light-year* (ly) is the distance that light, traveling through a vacuum with a speed of 186 000 mi/s, would cover in 1.0 year. Express the Earth–Sun distance in (a) parsecs and (b) light-years.

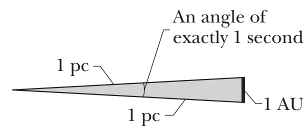

Fig. 1-8 Problem 53.

54 The description for a certain brand of house paint claims a coverage of 460 ft^2/gal. (a) Express this quantity in square meters per liter. (b) Express this quantity in an SI unit (see Appendices A and D). (c) What is the inverse of the original quantity, and (d) what is its physical significance?

Chapter 1: MEASUREMENT

Choose the correct answer:

1. We can write the speed of light **(c = 299,000,000 m/s)** using the **scientific notation as:**

(a) 2.99×10^{8} (b) 29.9×10^{8} (c) 0.299×10^{8} (d) 299×10^{8}

---

2. A car moving with a speed of **100 km/h**, what is its speed in **m/s**?

(a) 27.8 m/s (b) 16.7 m/s (c) 277.8 m/s (d) 167.7 m/s

---

3. We can express the very small number (**0.000 000 004 56**) using the scientific notation as:

(a) 4.56×10^{-8} (b) 4.56×10^{-9} (c) 4.56×10^{-10} (d) 4.56×10^{-11}

---

4. The conversion factor to convert **3 min to seconds** is

(a) $\frac{3600s}{3\min}$ (b) $\frac{60s}{3\min}$ (c) $\frac{3600s}{1\min}$ (d) $\frac{60s}{1\min}$

---

5. Which of the following is **not a base quantity** ?

(a) speed (b) mass (c) length (d) time

---

6. How many **centimeters in 1 km**?

(a) 10^{5} cm (b) 10^{2} cm (c) 10 cm (d) 10^{4} cm

---

7. The **conversion factor** to convert **hours to seconds** is:

(a) $\frac{1\ s}{3600\ h}$ (b) $\frac{3600\ h}{1\ s}$ (c) $\frac{1\ h}{3600\ s}$ (d) $\frac{3600\ s}{1\ h}$

---

8. (**1 m = 3.281 ft**) then **1.5 ft/h** equals:

(a) 1.37×10^{-3} m/s (b) 1.27×10^{-4} m/s (c) 1645.8 m/s (d) 17717.4 m/s

---

9. A **square** with an **edge** of **1 cm** has an area of: (area = edge^2)

(a) $10^{2}\ m^{2}$ (b) $10^{4}\ m^{2}$ (c) $10^{-4}\ m^{2}$ (d) $10^{-6}\ m^{2}$

---

10. **10^3 gigawatts** is:

(a) 10^{12} watts (b) 10^{9} watts (c) 10^{-6} watts (d) 10^{-3} watts

---

11. The **conversion factor** to convert **10 kg to g** is:

(a) $\frac{10^{3}\ g}{1kg}$ (b) $\frac{10^{3}\ g}{10kg}$ (c) $\frac{1kg}{10^{3}\ g}$ (d) $\frac{10kg}{10^{3}\ g}$

---

12. Which prefix is **true**?

(a) milli = 10^3 (b) micro = 10^{-9} (c) mega = 10^6 (d) pico = 10^9

13. **1 mm^2** =

(a) 10^{-3} m^2 (b) 10^{-6} m^2 (c) 10^{-9} m^2 (d) 10^{-12} m^2

14. If the **length, height, and width** of a **rectangular block** are **3 cm, 4 cm, and 5 cm** respectively, then the **volume** is

(a) 60 m^3 (b) 60 cm^3 (c) 60 m (d) 60 cm

15. If **1 mi = 1609 m** then **55 mi/h** is

(a) 15.4 m/s (b) 24.6 m/s (c) 66.3 m/s (d) 88.1 m/s

16. A **nanosecond** is:

(a) 10^{9} s (b) 10^{-9} s (c) 10^{10} s (d) 10^{-10} s

17. A **gram** is**:**

(a) 10^{-6} kg (b) 10^{-3} kg (c) 10^{6} kg (d) 10^{3} kg

18. The **SI base unit** for **mass** is**:**

(a) gram (b) pound (c) kilogram (d) kilopound

19. There are **1000 meters** in

(a) 1 kilometer (b) 10 kilometer (c) 100 cm (d) 10,000 cm

20. How many **centimeters in 1 km**?

(a) 10^5 cm (b) 10^2 cm (c) 10 cm (d) 10^4 cm

21. The **conversion factor** to convert **hours to seconds** is:

(a) $\frac{1\ s}{3600\ h}$ (b) $\frac{3600\ h}{1\ s}$ (c) $\frac{1\ h}{3600\ s}$ (d) $\frac{3600\ s}{1\ h}$

22. If **1m = 3.281 ft**, then **3.375 ft^3 =**

(a) 1.2×10^2 m^3 (b) 9.6×10^{-2} m^3 (c) 10.5 m^3 (d) 0.21 m^3

23. 10^{-9} second is

(a) millisecond (b) microsecond (c) nanosecond (d) gigasecond

24. A **10 kilogram** =

(a) 10^{6} g (b) 10^{3} g (c) 10^{4} g (d) 10^{2} g

25. The SI units of the base quantities (Length, Mass, Time) are:

(a) m, kg, s (b) cm, g, s (c) km, g, s (d) km, kg, s

26. (0.000 000 00636) is equal to:

(a) 6.36×10^{-7} (b) 6.36×10^{-8} (c) 6.36×10^{-9} (d) 6.36×10^{-10}

27. 50 km =

(a) 5×10^{5} cm (b) 5×10^{6} cm (c) 5×10^{7} cm (d) 5×10^{8} cm

28. 100 g/cm^{3} =

(a) 10^{3} kg/m^{3} (b) 10^{4} kg/m^{3} (c) 10^{5} kg/m^{3} (d) 10^{6} kg/m^{3}

29. a microsecond is:

(a) 10^{6} s (b) 10^{-6} s (c) 10^{9} s (d) 10^{-9} s

30. The **conversion factor** to convert **6 m to mm** is:

(a) $\frac{10^3 mm}{1m}$ (b) $\frac{10^3 mm}{6m}$ (c) $\frac{1m}{10^3 mm}$ (d) $\frac{6m}{10^3 mm}$

Are the following statements (**True** ✓) or (**False** ×) ?

31. The SI base unit for mass is gram.

(a) True (b) False

32. There are 1209600 seconds in one week.

(a) True (b) False

CH 1

قاعدة / إذا كانت الفاصلة يمين ← الأس موجب
يسار ← الأس سالب .

1- 2,99,000,000 (1 2 3 4 5 6 7 8)

2.99×10^8

قاعدة / من كبير لصغير ← نضرب .
من صغير لكبير ← نقسم

2- 100 km/h → m/s

$100 \times \frac{10^3}{3600} = 27.77$ m/s

3- 0,000 000 004 56 (1 2 3 4 5 6 7 8 9)

4.56×10^{-9}

معامل التحويل / ① أكتب العلاقة الأساسية .
② الشي اللي ما ابغا اشوفو أقسم عليه عشان اطيرو .

4- $\frac{1\ min}{1\ min} = \frac{60\ s}{1\ min}$

5- [speed] ← * مين من الاثنين إن هو كمية أساسية ؟

6- 1 km $\xrightarrow{10^3}$ m $\xrightarrow{10^2}$ cm ⇒ 10^5 cm

7- $\frac{1h}{1h} = \frac{3600\ s}{1\ h}$

8- 1 m = 3,281 ft

?? = 1,5 ft

$= \frac{1.5}{3.281} = 0.457 \div 3600 = 1.269 \times 10^{-4}$ m/s

عشان نحول من ساعة إلى ثانية .

9- 1 cm $\xrightarrow{\times 10^{-2}}$ m

$cm^2 \xrightarrow{(\times 10^{-2})^2} m^2$

$= 10^{-4}\ m^2$

10- 10^3 GW $\xrightarrow{\times 10^9}$ W

$= 10^{12}$ watt

تابع CH 1

11- $\frac{1\,kg}{1\,kg} = \frac{10^3\,g}{1\,kg}$

12- milli = 10^3 ✗ خطأ , milli = 10^{-3} ✓

micro = 10^{-9} ✗ خطأ , micro = 10^{-6} ✓

mega = 10^6 ✓ صح

pico = 10^9 ✗ خطأ , pico = 10^{-12} ✓

13- $1\,mm \xrightarrow{(\times 10^{-3})} m$

$1\,mm^2 \xrightarrow{(\times 10^{-3})^2} m^2 \Rightarrow 10^{-6}\ m^2$

14- الحجم = الطول x العرض x الارتفاع

$= 3 \times 4 \times 5 = 60\ cm^3$

15- $55 \times \frac{1609}{3600} = 24.58\ m/s$

16- $1\ ns \xrightarrow{\times 10^{-9}} s$

17- 1 gram = 10^{-3} kg

18- mass ⟶ kilogram. الوحدة الأساسية للكتلة ← الكيلو جرام .

19- 1000 meters = 1 kilometer

20- $1\,km \xrightarrow{\times 10^3} m \xrightarrow{\times 10^2} cm \Rightarrow 10^5\ cm$

21- $\frac{1\,h}{1\,h} = \frac{3600\ s}{1\,h}$

22- 1 m = 3.281 ft

$1\ m^3 = (3.281)^3\ ft^3$

$1\ m^3 = 35.31\ ft^3$

$1\ m^3 = 35.31\ ft^3$

?? = $3.375\ ft^3$

$= 0.0955\ m^3 = 9.6 \times 10^{-2}\ m^3$

23- $\boxed{10^{-9}}$ second = nonosecond
↓ nano

24- 10 kg $\xrightarrow{\times 10^3}$ g = $10^1 \times 10^3 = 10^4$ g "إذا الأساسات متساوية نجمع الأسس"

25- Length = m , Mass = kg , Time = s .

26- 0.000 000 006 36
1 2 3 4 5 6 7 8 9
6.36×10^{-9}

27- 50 km $\xrightarrow{\times 10^5}$ cm
$= 5 \times 10^6$ cm

28- $100 \ g/cm^3 = 100 \times \frac{10^{-3}}{10^{-6}} = 100000 = 10^1 \times 10^4 = 10^5 \ kg/m^3$
4 3 2 1

29- (micro) second = 10^{-6} s
↓ 10^{-6}

30- $\frac{1 \ m}{1 \ m} = \frac{10^3 \ mm}{1 \ m}$

31- الوحدة الأساسية للكتلة هي الكيلو جرام
(gram) X خطأ

32- في الساعة فيه 3600 ثانية
يعني في اليوم بيكون 24 x 3600 = 86400
يعني في الأسبوع بيكون 7 x 86400 =
604800 ثانية.

Fundamentals of Physics

8^{th} Edition

HALLIDAY * RESNICK

Chapter 1

Measurement

1-2 Measuring Physical quantities

Base quantities

- Length
- Mass
- Time
- Temperature

Derived quantities

Quantities are defined in term of base quantities

- Area
- Volume
- Density

1-3 Units

A unique name we assign to measures of that quantity

Systems of units

	SI		FR		BR
Length	m	Length	cm	Length	feet
Time	s	Time	s	Time	s
Mass	Kg	Mass	g	Mass	slug

To express the very large and very small quantity

We use Scientific notation

Scientific notation

Power of ten

For example:

1. 3560000000 m = 3.56×10^{9} m

2. 0.000000492 s = 4.92×10^{-7} s

Exponent of ten

For example:

3.56 E 9 m

4.92 E -7 s

When we dealing with very large or very small measurements we use Prefixes Listed

Prefixes of units

Factor	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}	10^{-1}	1	10^{1}	10^{2}	10^{3}	10^{6}	10^{9}	10^{12}
Prefix	pico	nano	micro	milli	centi	deci		deka	hecto	kilo	mega	giga	tera
symbol	p	n	μ	m	c	d		da	h	k	M	g	T

For example,

1) a microsecond is 10^{-6} s

2) 1.27 x 10^{9} watts = 1.27 gw

3) 1.2 x 10^{6} m = 1.2 Mm

1-4 Changing Units

We often need to change the units in the physical quantity by a method called chain link conversion

In this method we multiply the original measurement by A conversion Factor

** **conversion Factor is (a ratio of units that is equal to unity)**

1 min = 60 s

$$\frac{1\ \text{min}}{60\ \text{s}} = 1 \qquad \frac{60\ \text{s}}{1\ \text{min}} = 1$$

1) For example, the conversion factor to convert 6 m to mm is

1 m → 10^{3} mm

6 m → ?

$$6\ \text{m} \times \frac{10^{3}\ \text{mm}}{1\ \text{m}}$$

→ Conversion factor

معامل التحويل

2) Convert 2 mins to seconds

1-5 Length

The unit of Length –the meter- is defined as the length of the path traveled by light in vacuum during a time interval 1/229 792 458 of a second

1-6 Time

The unit of Time –the second- is defined in terms of the oscillations of light emitted by an atomic source (cesium-133) .

1-7 Mass

The unit of mass –one Kilogram - is defined in terms of a platinum-iridium cylinder kept near Paris.

Atomic mass units $1u = 1.660\ 538\ 86 \times 10^{-27}$ **kg**

Density

The density ρ of a material is the mass per unit volume

$$\rho = \frac{m}{v} = \frac{\text{mass}}{\text{Volume}} \quad \frac{Kg}{m^3}$$