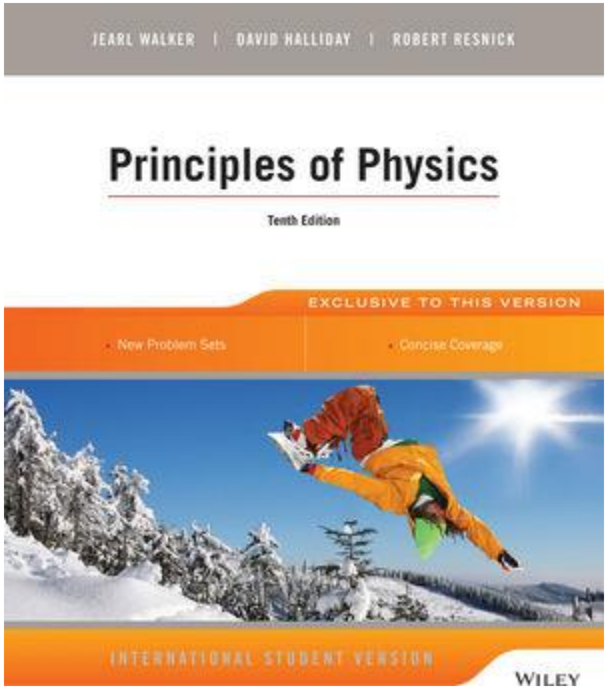
Text book

Principles of physics.

Tenth edition

Walker, Halliday
and Resnick



Chapter 1
Measurement

In this chapter we will explore the following concepts:

1. Measurement of a physical parameter

2. Units, systems of units

4. Changing units

5. Examples

What is physics?

- Science is based on measurements and comparisons.

Physics is the most interesting subject in the world

because

it is about how the world works

Chapter 1 : Measurements

- There are two kinds of physical quantities
- **Basic quantities:** length, time, mass, temperature, pressure, and electric current.
- **Derived quantities:** all other physical quantities
- For example, speed is defined in terms of length and time .
- The unit of each quantity is a unique name. **Example:** meter (m) for the quantity length.

Three Systems of Units (SI)

International system [SI]:

MKS: meter, Kg, second

French system: CGS:

centimeter, gram, second

British system: FPS:

foot, pound, second

The international system of units
SI

The Basic Physical quantities

1 Time

2 Length

3 Mass

4 Electric current

5 Amount of substance

6 Temperature

7 Luminous Intensity

The International System of Units (SI)

- Example of derived quantities: SI unit for power (watt W) is

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

(kilogram-meter squared per second cubic)

- Speed (velocity) v = distance / time = m/s
- Acceleration a = distance / time^2 = m/s^2

Standards and Units

The international system of units (SI)

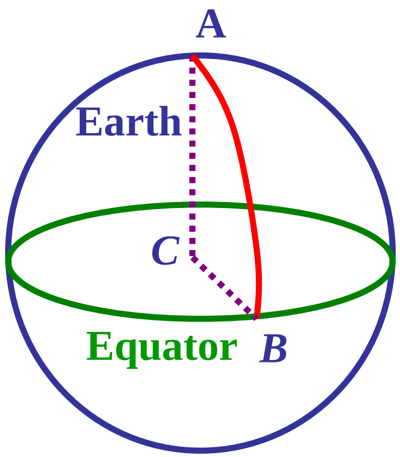
We need these in only

1 Time	seconds	s
2 Length	meter	m
3 Mass	kilogram	kg
4 Electric current	ampere	A
5 Amount of substance	mole	mol
6 Temperature	kelvin	K
7 Luminous Intensity	candela	cd

Length

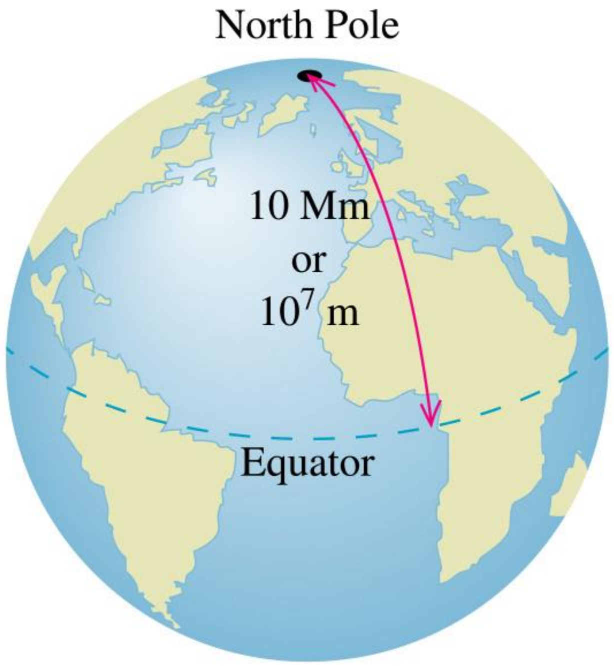
The Meter

Historical definition.

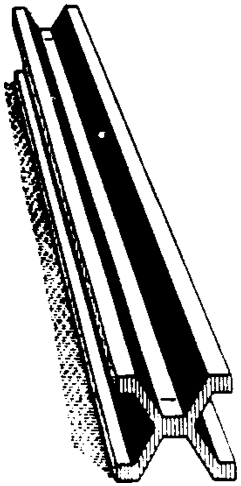


In 1792 the meter was defined to be one ten-millionth of the distance from the north pole to the equator.

$$1\ \mathrm{m} \equiv \frac{AB}{10^7}$$



For practical reasons the meter was later defined as the distance between two fine lines on a **standard meter bar** made of platinum-iridium.



The Meter

Present definition.

Since 1983 the meter is defined as **the length traveled by light in vacuum during the time interval of 1/299792458 of a second.** The reason why this definition was adapted was that the measurement of the speed of light had become extremely precise.

Since 1983 the speed of light in vacuum = 299,792,458 m/s exactly

Standard of Time

1- Earth's rotation has been used

$$1 \text{ second} \equiv \frac{1}{24 \times 60 \times 60}$$

of the time it takes the Earth to complete a full rotation about its axis.

The problem with this definition is that the length of the day is not constant.

2- Atomic clocks were then developed

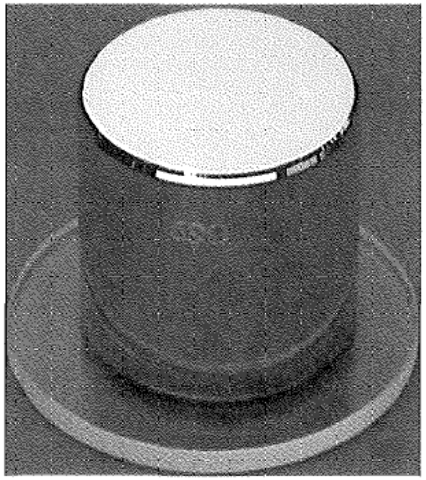
- A standard second based on the cesium clock is:

> 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.

Why are atomic clocks used to measure the most precise standard second?

Because these atoms are very consistent

Standard of Mass



- Kilogram (SI)
- The standard mass, the kilogram, is defined to be the mass of a particular cylinder of platinum-iridium alloy.
- It is kept at the international Bureau of weighs and measures at Sevres. Near Paris.
- Since 1889
- Accurate copies have been sent to other countries

Second Mass Standard

- The masses of atoms are measured by the mass of the carbon-12 atom
- This atom has a mass of 12 **atomic mass units** (u)
- The relation between the two units is

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

Density

Density ρ is the mass per unit volume

$$\rho = \frac{m}{V}.$$

- The units are kg/m^3 or gm/cm^3
- The density of water ($1.0\ gm/cm^3$) is often used as a comparison

Changing Units

- Units are changed by a method called ***chain-link conversion***
- We multiply the original measurement by a ***conversion factor*** (ratio of units equal to unity)

Example 1 min and 60 s are identical time intervals

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

Thus, the ratios (1 min)/(60 s) and (60 s)/(1 min) can be used as conversion factors

Examples

to convert 2 min to seconds

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

to convert 15 inch to centimeters

$$15.0\ \text{in.} = (15.0\ \cancel{\text{in.}})\left(\frac{2.54\ \text{cm}}{1\ \cancel{\text{in.}}}\right) = 38.1\ \text{cm}$$

to convert 15 h to seconds

$$15\ \text{h} = 15\ \text{h}\ \text{X}\ 1 = 15\ \text{h}\ \ \text{X}\left(\frac{60\ \text{min}}{1\ \text{h}}\right) = 900\ \text{min}$$

$$= 900\ \text{min}\ \ \text{X}\ 1 = 900\ \text{min}\ \ \text{X}\left(\frac{60\ \text{s}}{1\ \text{min}}\right) = 54000\ s$$

to convert 10 km/h to m/s`

$$10\ \text{km/h} = 10\ \text{km/h}\left(\frac{1000\ \text{m/h}}{1\ \text{km/h}}\right) = 10000\ \text{m/h}$$

$$= 10000\ \text{m/h}\left(\frac{1\ \text{m/s}}{3600\ \text{m/h}}\right) = \frac{100}{36}\ \text{m/s} = \frac{100}{36}\ \text{m/s} = 2.78\ \text{m/s}$$

to convert 15 m/s to km/h

$$15\ \text{m/s} = 15\ \text{m/s}\left(\frac{1\ \text{km/s}}{1000\ \text{m/s}}\right) = 0.015\ \text{km/s}$$

$$= 0.015\ \text{km/s}\left(\frac{3600\ \text{km/h}}{1\ \text{km/s}}\right) = 54\ \text{km/h}$$

Scientific notation (powers of 10) is used to express the very large and very small quantities.

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

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

In computers

3.56 E9

4.92 E-7

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

Unit prefixes

- 1000 kilo k
- 10^6 mega M
- 10^9 giga G

- 10^{-2} centi c
- 10^{-3} mili m
- 10^{-6} micro μ
- 10^{-9} nano n
- 10^{-12} pico p

Examples:

1- A square with an edge of exactly 1 cm has an area of:

A) 10^{-6} m^2 B) 10^{-2} m^2 C) 10^{-4} m^2 D) 10^{2} m^2

$$\mathrm{L} = 1\,\mathrm{cm} = 1\times10^{-2}\,m$$

$$\mathrm{A} = 1\times10^{-2}\,m \mathrm{x} 1\times10^{-2}\,m$$

$$\mathrm{A} = 1\times10^{-4}\,\mathrm{m}^2 = 10^{-4}\,\mathrm{m}^2$$

(c)

2- 1.3 million second is approximately :

A) One day B) One year C) Two months D) 15 days

$$1.3\times10^{6}\,s$$

$$1.3\times10^{6}\,s = \frac{1.3\times10^{6}}{3600}\,h = 361.1h$$

$$1.3\times10^{6}\,s = \frac{361.1}{24}\,\mathrm{d}ays \approx 15 \qquad days$$

(D)

Example 5:

A 0.63 kg solid sphere has a radius 46 mm. Its density is :
(Volume of a sphere = = $4/3\pi r^3$)

$$\rho = \frac{m}{V}.$$

A) -0.55×10^3 kg/m^3

B) 0.25×10^3 kg/m^3

C) -0.55×10^3 kg/m^3

D) 1.55×10^3 kg/m^3

$$r = 46mm = 46\times10^{-3}m = 0.046m$$

$$\rho = \frac{m}{V} = \frac{mass}{volume} = \frac{0.63kg}{4/3\,\pi(0.046m)^3}$$

$$\rho = \frac{0.63kg}{4/3\,\pi(0.046m)^3} = \frac{0.63kg}{4/3\,\pi(0.046)^3 m^3}$$

$$\rho = 1.55\times10^3 kg/m^3$$

(D)