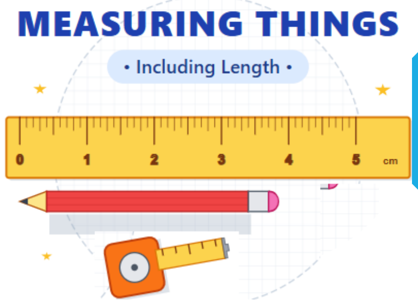
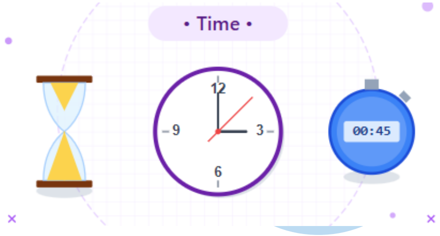
Chapter 1

Measurement

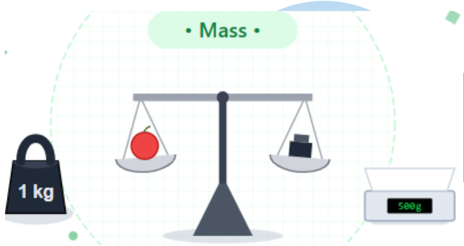
Units of Chapter 1



Section 1.1 Measuring Things - Including Length



Section 1.2 Time



Section 1.3 Mass

Section 1.1 Measuring Things - Including Length

What Is Physics?

Physics: the study of the fundamental laws of nature

- These laws can be expressed as mathematical equations
- Much complexity can arise from relatively simple laws

Section 1.1 Measuring Things - Including Length

Measuring Things

Physics and engineering are based on the precise measurement of physical quantities. To obtain precise measurements, we need:

1. Rules for measurement and comparison
2. Units for measurement

Definition of a **unit:**

- Is the unique name assigned to the measure of a quantity (mass, time, length, pressure, etc.)
- Corresponds to a **standard,** a physical quantity with value 1.0 unit (e.g. 1.0 m/s = one meter traveled every second)

Section 1.1 Measuring Things - Including Length

Measuring Things

To communicate the result of a measurement for a physical quantity, a **unit** must be defined.

With a few exceptions, all physical quantities have units. Examples:

- Mass: kilograms (kg)
- Speed: meters per second (m/s)
- Pressure: Pascal (Pa)
- Energy: joules (J)

Defining units allows everyone to relate to the same fundamental amount

Section 1.1 Measuring Things - Including Length

Physical quantities can be classified into two types:

1. **Fundamental/basic quantities:** These quantities do not depend on other physical quantities.
   There are only seven fundamental quantities: length, mass, time, temperature, luminous intensity, electric current, amount of a substance

2. **Derived quantities**: These quantities are defined in terms of fundamental quantities.
   Examples: Area, density, velocity, acceleration.

Section 1.1 Measuring Things - Including Length

The International System of Units

International system of units (SI-units):

- Established in 1960.
- Also known as the **mks** system, or the metric system.

Table 1.1.1 Units for Three SI Base Quantities

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

In the SI-system:

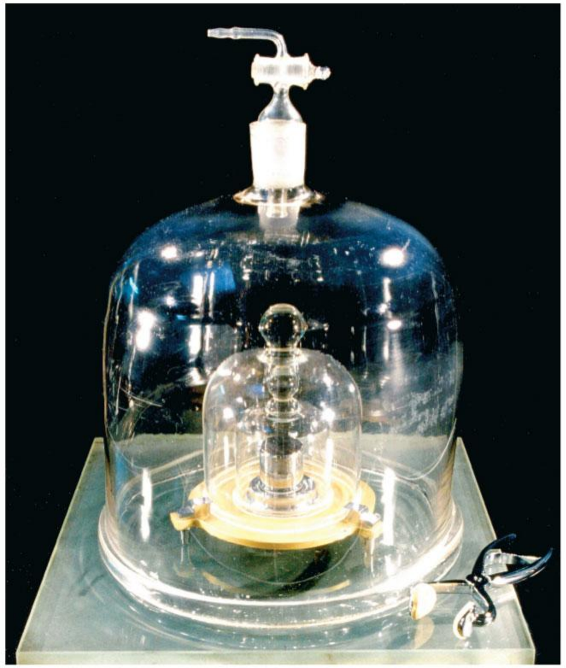
- Length is measured in **meter** (m)
- Mass is measured in **kilogram** (kg)
- Time is measured in **second** (s)

Units for other physical quantities in mechanics can be constructed from these fundamental units.

1-1 Units of Length, Mass, and Time

SI units of length (*L*), mass (*M*), time (*T*):

- Length: the meter
  - Was: one ten-millionth of the distance from the North Pole to the equator. Now: the distance traveled by light in a vacuum in 1/299,792,458 of a second
- Mass: the kilogram
  - The mass of a particular platinum-iridium cylinder kept at the International Bureau of Weights and Standards, Sèvres, France.
- Time: the second
  - The time for radiation from a cesium-133 atom to complete 9,192,631,770 oscillation cycles.



Section 1.1 Measuring Things - Including Length

DERIVED QUANTITIES

Derived Quantity	derived	Unit
Area	L×L	m^2
Volume	L×L×L	m^3
Density	Mass÷volume	kg/m^3
Speed	distance÷time	m/s
Acceleration	Δvelocity÷time	m/s^2
Force	mass×acceleration	N
Pressure	force÷area	N/m^2
work	force× displacement	J

FORCE=$KG.M/S^2$ = NEWTON

WORK= N.M={ $KG.(M/S^2)$}.M = J

Section 1.1 Measuring Things - Including Length

Systems of units and Standard Prefixes

Rules of writing units

Units named after scientists

Physical Quantity	Unit	Symbol
Force	newton	N
Energy	joule	J
Power	watt	W
Pressure	pascal	P
Charge	coulomb	C
Frequency	hertz	Hz
Potential	volt	V
current	ampere	A

Section 1.1 Measuring Things - Including Length

Prefixes are often used with units.

They correspond to specific multiples of powers of 10.

Examples:

10^3 meter = kilometer (km)

10^{-2} meter = 1/100 m = centimeter (cm)

10^{-3} second = millisecond

10^9 byte = 1* 1000000000 = gigabyte (GB)

10^{-9} meter = 1/1000000000 = nanometer (nm)

TABLE 1-4 Common Prefixes

Power	Prefix	Abbreviation
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

Section 1.1 Measuring Things - Including Length

Changing Units

- **Scientific notation** employs powers of 10 to write large or small numbers

$$3\,560\,000\,000\ \text{m} = 3.56\times10^{9}\ \text{m}$$
$$0.000\,000\,492\ \text{s} = 4.92\times10^{-7}\ \text{s}.$$

- A **conversion factor** is
  - A ratio of units that is equal to 1
  - Used to convert between units

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

- Units obey the same algebraic rules as variables and numbers

Section 1.1 Measuring Things - Including Length

Length

One should use **consistent units** (that belong to the same system); hence, conversion between different units is sometimes needed.

Units can be treated like algebraic quantities that can "cancel" each other

Example: Convert 316 feet to meters

1 m = 3.281 ft (this is the conversion factor)

Note that: $\frac{1\text{ m}}{3.281\text{ ft}} \neq \frac{3.281\text{ ft}}{1\text{ m}} \neq 1$

Therefore, to convert from ft to m:

$$316\text{ ft} \times \left(\frac{1\text{ m}}{3.281\text{ ft}}\right) = 96.3\text{ m}$$

Note that the units cancel properly—this is the key to using the conversion factor correctly!

Section 1.1 Measuring Things - Including Length

Changing Units

Example: Convert 3 mi/h to m/s, given 1 mile =1.609 km. (Ans: 1.34 m/s)

Convert : $3.00\, mi/h\ to\ m/s$ or $(3.00\frac{mi}{h}\ to\ \frac{m}{s})$

Ans: 1.34m/s

Example: A warehouse is 20 yards long, 10 yards wide, and 15 ft high. What is its volume in SI units? (1 yard = 3 ft, 1 m = 3.281ft) (Ans: 764 m^3)

$$V = \left[(20\ yards)\left(\frac{3ft}{1yard}\right)\left(\frac{1m}{3.281\ ft}\right)\right]\left[(10\ yards)\left(\frac{3ft}{1yard}\right)\left(\frac{1m}{3.281\ ft}\right)\right]\left[(15ft)\left(\frac{1m}{3.281\ ft}\right)\right]$$

$$V = 764\ m^3$$

Section 1.1 Measuring Things - Including Length

Changing Units

The world land speed record of 763.0 mi/h was set on October 15, 1997, by Andy Green in the jet-engine car *Thrust SSC*. Express this speed in meters per second.

$$763.0\ \text{mi/h} = \left(763.0\,\frac{\text{mi}}{\text{h}}\right)\left(\frac{1\,609\ \text{m}}{1\ \text{mi}}\right)\left(\frac{1\ \text{h}}{3600\ \text{s}}\right)$$
$$= 341.0\ \text{m/s}$$

One of the world's largest cut diamonds is the First Star of Africa (mounted in the British Royal Sceptre and kept in the Tower of London). Its volume is 30.2 cubic centimeters. What is its volume in cubic meters?

$$30.2\ \text{cm}^3 = (30.2\ \text{cm}^3)\left(\frac{1\ \text{m}}{100\ \text{cm}}\right)^3$$
$$= (30.2)\left(\frac{1}{100}\right)^3 \frac{\text{cm}^3\ \text{m}^3}{\text{cm}^3} = 30.2 \times 10^{-6}\ \text{m}^3$$
$$= 3.02 \times 10^{-5}\ \text{m}^3$$

Section 1.1 Measuring Things - Including Length

Changing Units

Examples:

- $$1.3\text{ km}\times\frac{(1000\text{ m})}{(1\text{km})}=1300\text{m}=1.3\times10^{3}\text{m}$$

- $$0.8\text{ km}\times\frac{(1000\text{ m})}{(1\text{ km})}\times\frac{(100\text{cm})}{(1\text{ m})}=80\,000\text{ cm}$$
$$=8\times10^{4}\text{cm}$$

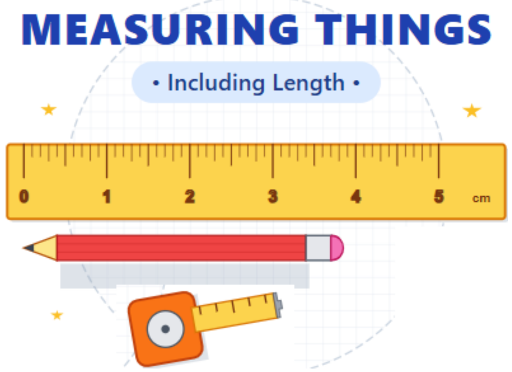
- $$2845\text{ mm}\times\frac{(1\text{ m})}{(1000\text{ mm})}\times\frac{(3.281\text{ ft})}{(1\text{ m})}=9.334\text{ ft}$$

Section 1.1 Measuring Things - Including Length

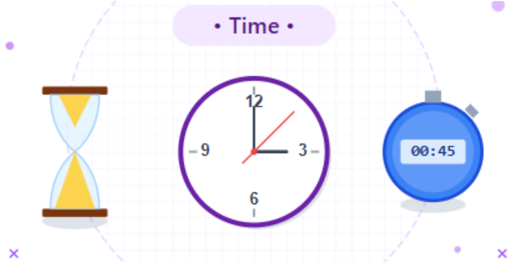
Changing Units

Length

- 1 mile = 1609 m $\frac{1\ mile}{1609\ m}$
- 1 m = 3.281 ft
- 1millimeter = 1mm = $10^{-3}\ m$
- 30 mm = 30 $\times 10^{-3}$ m = 0.03 m
- 1centimeter = 1cm = $10^{-2}\ m$
- 61 cm = 61 $\times 10^{-2}$ m = 0.61 m
- 1meter = 1m = 100cm
- 1kilometer = 1km = 1000 m = 10^3 m



Section 1.2 Time



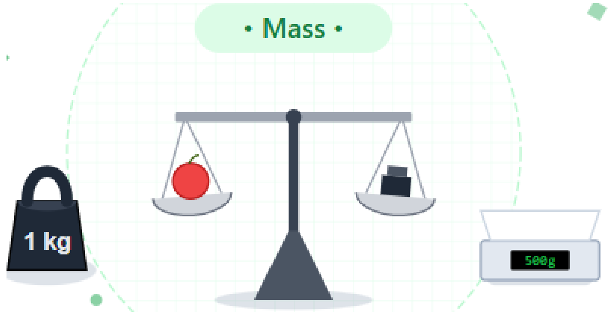
- 1millisecond $=10^{-3}$ s = 1 ms = $\frac{1ms}{10^{-3}\,s}$

45 ms = 45ms $\times$ $\frac{10^{-3}\,s}{1ms}$ = 45 $\times$ 10^{-3} s

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

- 1 hour = 3600 s $\quad \frac{1\,h}{3600s}$
- 1 day = 24 hr = 24x60x60 = 86400 s
- 1 year = $3\text{x}10^{7}$ s

Section 1.2 Mass



- 1 milligram = 1mg = $10^{-3}\,g$
- 1 gram = 1g = $10^{-3}\,kg$
- 1kilogram = 1kg = 1000 g = 10^{3} g
- 30 g to be in kg = $30\,g \times \frac{1\,kg}{1000\,g}$ = $30*10^{-3}$ kg

Units

LENGTH

1 meter= 100 cm

1kilometer= 1000 meter

1 meter = 1000 millimeter

MASS

1 kilogram= 1000 gram

1 milligram = 10^{-3} gram

Time

1 minute = 60 seconds

1 hour = 60 minutes

1 hour = 60×60 = 3600 seconds

Section 1.2 Mass

Mass vs. Density

- Mass per unit volume is called **density**

$$\rho = \frac{m}{v}$$

- **Equation (1.3.2)**

Examples Calculate . . .

- Density of material : $\dfrac{(18\ \text{kg})}{(0.032\ \text{m}^3)} = 560\ \text{kg/m}^3$
- Mass of object: $(380\ \text{kg/m}^3) \times (0.0040\ \text{m}^3) = 1.5\ \text{kg}$

  Volume of object: $\dfrac{(250\ \text{kg})}{(1280\ \text{kg/m}^3)} = 0.20\,\text{m}^3$

Summary of Chapter 1

Physics is based on a small number of laws and principles

Units of length are meters; of mass, kilograms; and of time, seconds

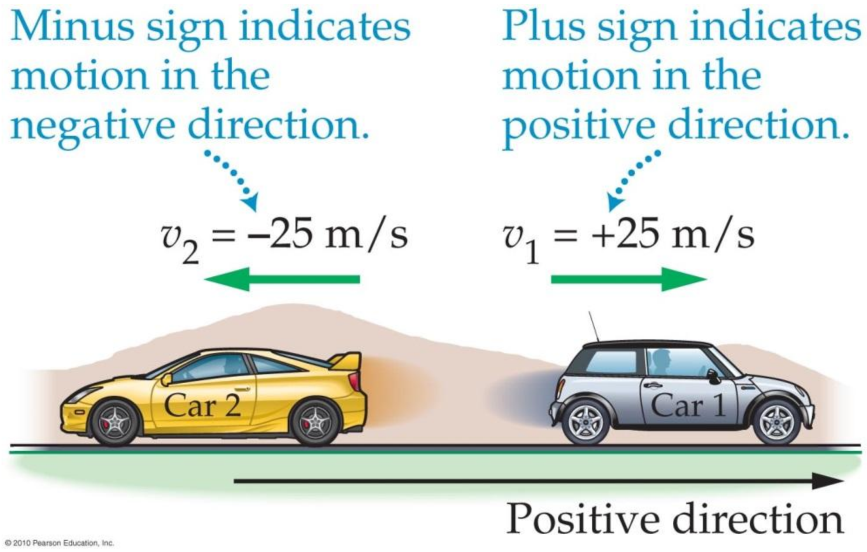
Convert one unit to another by multiplying by their ratio

Scalars and Vectors

Some physical quantities are scalar quantities, and some are vector quantities:

- A **scalar** quantity: has only a **numerical value.** May be positive or negative. Examples: temperature, speed, height

- A **vector** quantity: has both a **magnitude** *and* a **direction.** Examples: displacement (e.g., 10 feet north), force, magnetic field. A symbol representing a vector quantity is usually written in bold face ($\mathbf{v}$) or using a vector sign above its symbol ($\vec{v}$).



Problem Solving in Physics

No recipe or plug-and-chug works all the time, but here are some guidelines:

1. Read the problem carefully. (direct/indirect information in question?)
2. Sketch the system
3. Visualize the physical process
4. Strategize
5. Identify appropriate equations
6. Solve the equations (use symbols, convert units)
7. Check your answer (dimensions?, reasonable/order of magnitude?
8. Explore limits/special cases