Mechanics
Units, Dimensional Analysis, and Unit Conversion

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Last time

- introduced the course
- basic ideas about science and physics

Overview

- introduce SI units
- unit conversion
- dimensional analysis

Quantities, Units, Measurement

If we want to make precise *quantitative* statements we need to agree on measurements: standard reference units.

We will mostly use SI (Système International) units:

Length	meter, m
Mass	kilogram, kg
Time	second, s

and many more!

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In all your answers, make sure you include the appropriate units!

Dimensional Analysis

All measurement values have associated units.

Equations relating measurable physical values also relate units.

This means units on each side of the equals sign must be equal.

Dimensional analysis allows us to:

- check our equation is correct
- check our calculation
- figure out the final units of an answer if we can't remember what they should be

This is very important!

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So,

$$[\mathrm{m}] = [\mathrm{m}] \quad \checkmark$$

Dimensional Analysis Examples

The other way to do dimensional analysis is directly in terms of the SI units that will be used.

$$v^2 = v_0^2 + 2ax$$

a is an acceleration, the rate of change of speed.
Units: meters per second squared, $\mathrm{m/s^2}$

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$$[\mathrm{m^2/s^2}] = [\mathrm{m^2/s^2}] + [\mathrm{m^2/s^2}] \quad \checkmark$$

Dimensional Analysis Question

Which of the following equations are dimensionally correct?
(1) $v_f = v_i + ax$
(2) $y = (2\text{ m})\cos(kx)$, where $k = 2\text{ m}^{-1}$.

A (1) only

B (2) only

C both

D neither

[1] Serway & Jewett, Page 16, # 9.

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B (2) only $\leftarrow$

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Dimensional Analysis Question

(1) Units of $v_f = v_i + ax$:

$$\begin{aligned} [\mathrm{ms}^{-1}] &= [\mathrm{ms}^{-1}] + [\mathrm{ms}^{-2}] \times [\mathrm{m}] \\ \left[\mathrm{ms}^{-1}\right] &= \left[\mathrm{ms}^{-1}\right] + \left[\mathrm{m}^2\ \mathrm{s}^{-2}\right] \end{aligned}$$

No. (1) is not dimensionally correct.

Dimensional Analysis Question

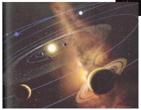
(2) Units of $y = (2\ \text{m})\cos(kx)$

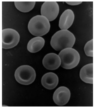
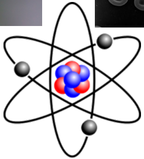
$$\begin{aligned} [\text{m}] &= [\text{m}] \times \cos([\text{m}^{-1}] \times [\text{m}]) \\ [\text{m}] &= [\text{m}] \end{aligned}$$

Yes. (2) is dimensionally correct.

Scale of Units

Scale	Prefix	Symbol
10^{21}	zetta	Z
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^{0}	—	—
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

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What is 3 $\mathrm{g/cm^3}$ in $\mathrm{kg/m^3}$?

$$(3\ \mathrm{g/cm^3}) \times \left(\frac{1\ \mathrm{kg}}{1000\ \mathrm{g}}\right) \times \left(\frac{100\ \mathrm{cm}}{1\ \mathrm{m}}\right)^3 = 3000\ \mathrm{kg/m^3}.$$

Scientific Notation

An alternate way to write numbers is in scientific notation.

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In scientific notation, we could write this as:

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This is the same thing.

$$10^8 = 100,000,000$$

so,

$$3.00 \times 100{,}000{,}000 = 300{,}000{,}000 \text{ m/s}$$

Scientific Notation: One digit only before decimal!

One reason to use scientific notation is to clearly convey the number of significant figures in a value.

There is **one digit**, followed by a decimal point, followed by more digits, if there is more than one significant figure.

Here there are two significant figures:

$$3.0 \times 10^8 \text{ m/s}$$

Here there are 4 significant figures:

$$\underset{\uparrow}{2}.998 \times 10^8 \text{ m/s}$$

one digit

one digit before the decimal + 3 digits after the decimal = 4 s.f.s

Scientific Notation vs Unit Scaling Prefixes

In scientific notation,

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Alternatively, we could write this with a unit prefix:

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where 1 Mm is one mega-meter,

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In scientific notation,

$$3.00 \times 10^8 \text{ m/s}$$

Alternatively, we could write this with a unit prefix:

$$300 \text{ Mm/s}$$

where 1 Mm is one mega-meter,
or use kilometers:

$$300,000 \text{ km/s}$$

or use a prefix with scientific notation:

$$3.00 \times 10^5 \text{ km/s}$$

Unit Conversion Examples

It may be necessary to change units several times to get to the unit you need.

What is 60.0 mi/hr in m/s? (mi is miles, hr is hours)

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1 mi = 1.609 km

Summary

- units and dimensional analysis
- scientific notation
- unit conversion

Quiz start of class this Thursday.

Homework

- Get the textbook: Fundamentals of Physics Extended, Halliday, Resnick, and Walker (9th Edition).
- Ch 1, Problems: 1, 3, 9, 23, 27.