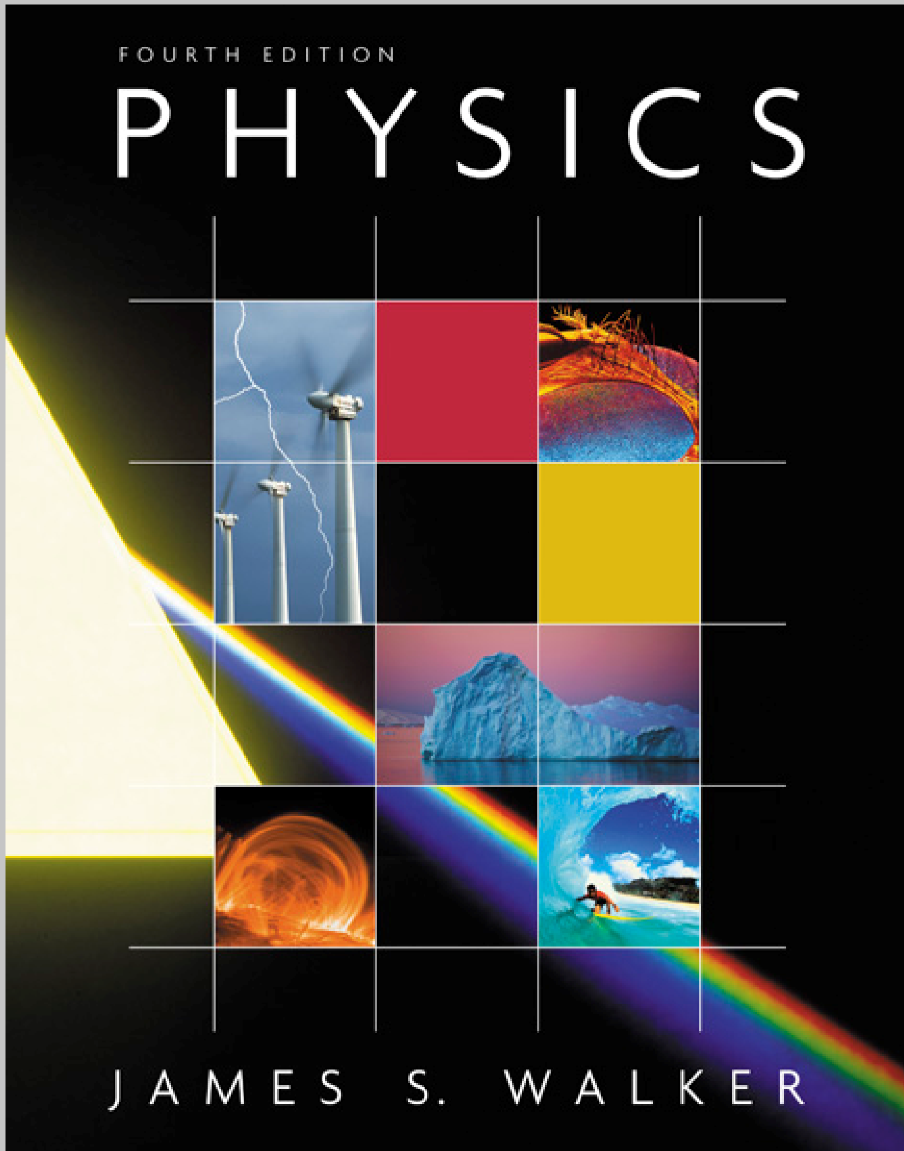


Lecture Outline

Chapter 1

Physics, 4th Edition

James S. Walker

Chapter 1
Introduction to Physics

Units of Chapter 1

- Physics and the Laws of Nature
- Units of Length, Mass, and Time
- Dimensional Analysis
- Significant Figures
- Converting Units
- Order-of-Magnitude Calculations
- Scalars and Vectors
- Problem Solving in Physics

1-1 Physics and the Laws of Nature

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**

1-2 Units of Length, Mass, and Time

Assume that you step on your bathroom scale and that it reads 120
The number alone is meaningless. It must be accompanied by the units
120 lb is a very different reading from 120 kg!

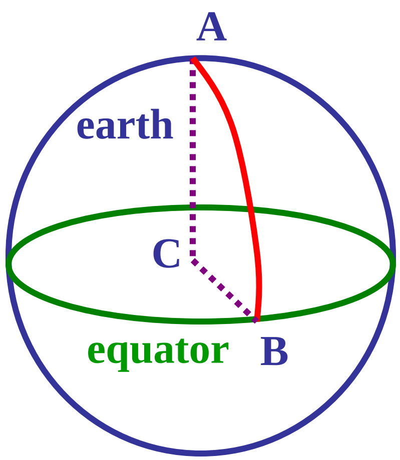
Conclusion: For every physical parameter we will need the appropriate units i.e. a standard by which we carry out the measurement by comparison to the standard. Does this mean that we have to define units for all parameters? The answer is no. In **mechanics** we need to define only three parameters:

These parameters are: **Length , Time, and Mass**
They are known as: **base quantities**

In this book we use the **International System of Units (SI)**

In this system the units for the base quantities are:

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



The meter

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

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

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

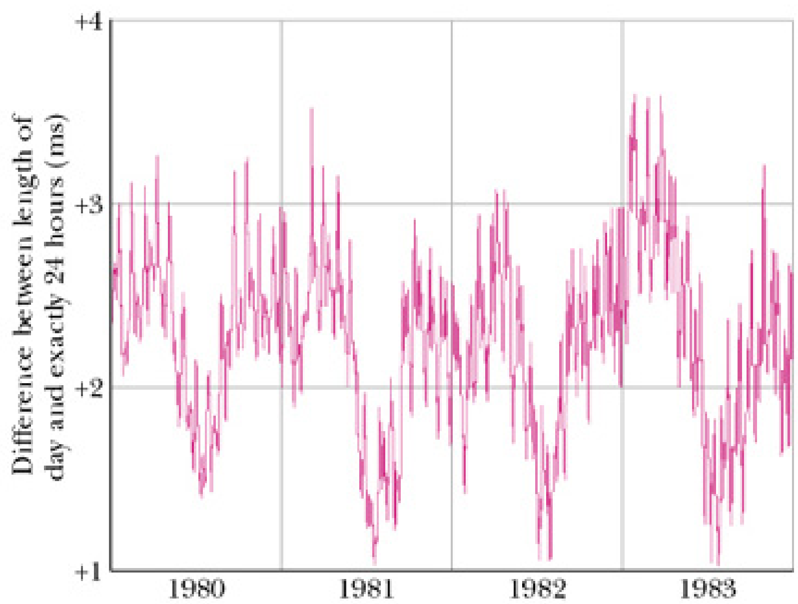
The Second

(1-5)

Initially the second was defined as follows:

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

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 as is shown in the figure. For this reason since 1967 the second is defined as **the time taken by 9192631770 light oscillations of a particular wavelength emitted by a cesium-133 atom**. This definition is so precise that it would take two cesium clocks 6000 years before their readings would differ more than 1 second.

The kilogram

The SI standard of mass is a platinum-iridium cylinder shown in the figure. The cylinder is kept at the International Bureau of Weights and Measures near Paris and assigned a mass of 1 kilogram. Accurate copies have been sent to other countries.

(1-6)

A Second Mass Standard

The carbon-12 atom, by international agreement, has been assigned a mass of 12 **atomic mass units** (u). The relation between the two units is: $1u = 1.66053886 \times 10^{-27}$Kg

Summary

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
One kilogram is the mass of a particular platinum-iridium cylinder kept at the International Bureau of Weights and Standards, Sèvres, France.

Time: the second
One second is the time for radiation from a cesium-133 atom to complete 9,192,631,770 oscillation cycles.

1-2 Units of Length, Mass, and Time

TABLE 1–3 Typical Times

Age of the universe	5×10^{17} s
Age of the Earth	1.3×10^{17} s
Existence of human species	6×10^{13} s
Human lifetime	2×10^{9} s
One year	3×10^{7} s
One day	8.6×10^{4} s
Time between heartbeats	0.8 s
Human reaction time	0.1 s
One cycle of a high-pitched sound wave	5×10^{-5} s
One cycle of an AM radio wave	10^{-6} s
One cycle of a visible light wave	2×10^{-15} s

TABLE 1–2 Typical Masses

Galaxy (Milky Way)	4×10^{41} kg
Sun	2×10^{30} kg
Earth	5.97×10^{24} kg
Space shuttle	2×10^{6} kg
Elephant	5400 kg
Automobile	1200 kg
Human	70 kg
Baseball	0.15 kg
Honeybee	1.5×10^{-4} kg
Red blood cell	10^{-13} kg
Bacterium	10^{-15} kg
Hydrogen atom	1.67×10^{-27} kg
Electron	9.11×10^{-31} kg

Q: What is the typical life time of a dog in SI units?

20 years= ? s

TABLE 1–1 Typical Distances

Distance from Earth to the nearest large galaxy (the Andromeda galaxy, M31)	2×10^{22} m
Diameter of our galaxy (the Milky Way)	8×10^{20} m
Distance from Earth to the nearest star (other than the sun)	4×10^{16} m
One light year	9.46×10^{15} m
Average radius of Pluto's orbit	6×10^{12} m
Distance from Earth to the Sun	1.5×10^{11} m
Radius of Earth	6.37×10^{6} m
Length of a football field	10^{2} m

1-2 Units of Length, Mass, and Time

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

1-3 Dimensional Analysis

- **Any valid physical formula must be dimensionally consistent – each term must have the same dimensions**

TABLE 1–5 Dimensions of Some Common Physical Quantities

Quantity	Dimension
Distance	[L]
Area	$[L^2]$
Volume	$[L^3]$
Velocity	[L]/[T]
Acceleration	$[L]/[T^2]$
Energy	$[M][L^2]/[T^2]$

From the table:

Distance = velocity × time

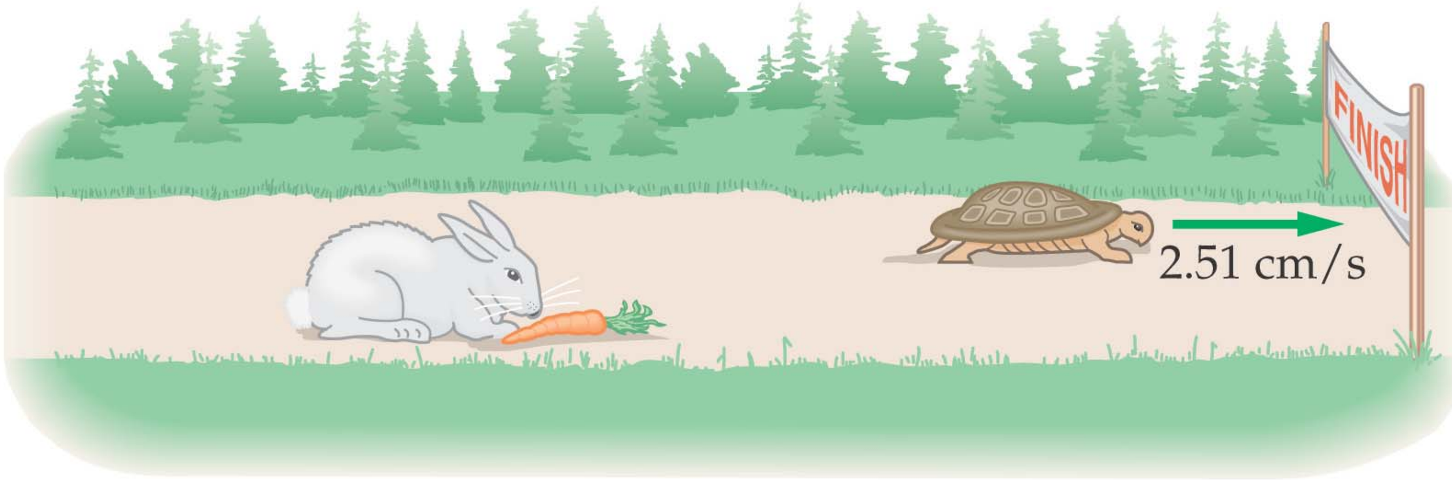
Velocity = acceleration × time

Energy = mass × (velocity)^2

1-4 Significant Figures

- accuracy of measurements is limited
- significant figures: the number of digits in a quantity that are known with certainty
- number of significant figures after multiplication or division is the number of significant figures in the least-known quantity

1-4 Significant Figures



Example:

A tortoise travels at 2.51 cm/s for 12.23 s. How far does the tortoise go?

Answer: 2.51 cm/s × 12.23 s = 30.7 cm (three significant figures)

1-4 Significant Figures

Scientific Notation

• **Leading or trailing zeroes can make it hard to determine number of significant figures: 2500, 0.000036**

• **Each of these has two significant figures**

• **Scientific notation writes these as a number from 1-10 multiplied by a power of 10, making the number of significant figures much clearer:**

$2500 = 2.5 \times 10^3$

If we write 2.50×10^3, it has three significant figures

$0.000036 = 3.6 \times 10^{-5}$

1-4 Significant Figures

Round-off error:

The last digit in a calculated number may vary depending on how it is calculated, due to rounding off of insignificant digits

Example:

$2.21 + 8% tax = $2.3868, rounds to $2.39

$1.35 + 8% tax = $1.458, rounds to $1.46

Sum: $2.39 + $1.46 = $3.85

$2.21 + $1.35 = $3.56

$3.56 + 8% tax = $3.84

1-5 Converting Units

Converting feet to meters:

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

Or: 1 = 1 m / 3.281 ft

316 ft × (1 m / 3.281 ft) = 96.3 m

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

1-6 Order-of-Magnitude Calculations

Why are estimates useful?

1. **as a check for a detailed calculation – if your answer is very different from your estimate, you've probably made an error**

2. **to estimate numbers where a precise calculation cannot be done**

Q: What is the weight of your classmate sitting to your left?

1-7 Scalars and Vectors

Scalar – a numerical value. May be positive or negative.
Examples: temperature, speed, height

Vector – a quantity with both magnitude and direction.
Examples: displacement (e.g., 10 feet north), force, magnetic field

1-8 Problem Solving in Physics

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

1. Read the problem carefully
2. Sketch the system
3. Visualize the physical process
4. Strategize
5. Identify appropriate equations
6. Solve the equations
7. Check your answer
8. Explore limits and special cases

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
- All terms in an equation must have the same dimensions
- The result of a calculation should have only as many significant figures as the least accurate measurement used in it

Summary of Chapter 1

•Convert one unit to another by multiplying by their ratio

• Order-of-magnitude calculations are designed to be accurate within a power of 10

• Scalars are numbers; vectors have both magnitude and direction

• Problem solving: read, sketch, visualize, strategize, identify equations, solve, check, explore limits