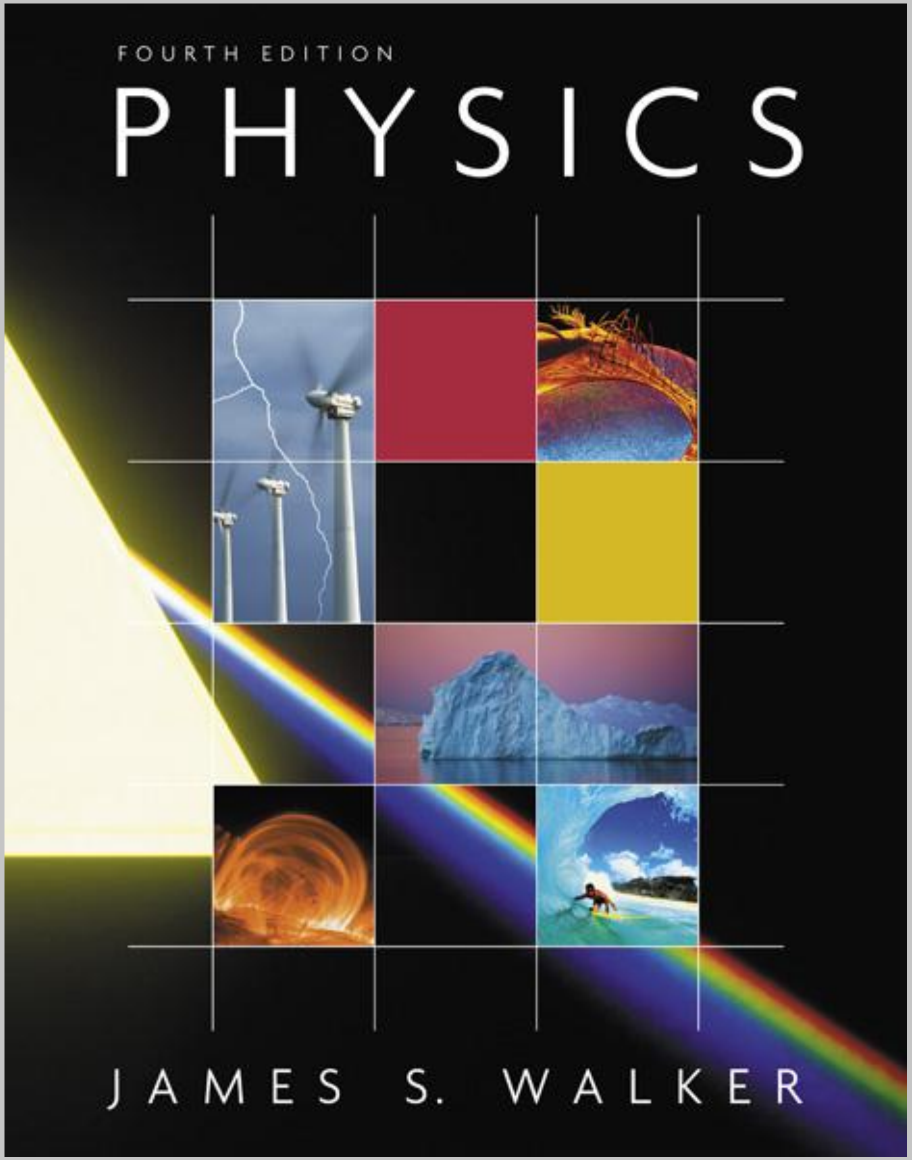

Chapter 1

Physics, 4th Edition

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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
- Problem Solving in Physics

1-1 Physics and the Laws of Nature

Physics: the study of the fundamental laws of nature

- **Physicists strive to find the most simple, general laws**
- **these laws are expressed as mathematical equations**

$$R_{ik} - \frac{1}{2} g_{ik} R = \frac{8\pi G}{c^4} T_{ik}$$

- **much complexity can arise from relatively simple laws**

1-2 Units of Length, Mass, and Time

SI units of length [L], mass [M], time [T]:

Length: the meter (m)

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 (kg)

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 (s)

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 1–1 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
Height of a person	2 m
Diameter of a CD	0.12 m
Diameter of the aorta	0.018 m
Diameter of a period in a sentence	5×10^{-4} m
Diameter of a red blood cell	8×10^{-6} m
Diameter of the hydrogen atom	10^{-10} m
Diameter of a proton	2×10^{-15} m

1-2 Units of Length, Mass, and Time

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

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

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

Other physical quantities have composite units.

We use [ ] to designate unit type (called dimensionality) of the physical quantity, i.e in what units it is measured

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 × $(\text{velocity})^2$

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

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Acceleration	[L]/[T^2]
Energy	[M][L^2]/[T^2]

Let us try iClicker
Frequency is D A

From the table, which relation is incorrect

A. **Distance = velocity x time**

B. **Velocity = acceleration / time**

C. **Energy = mass × (velocity)^2**

D. **mass x acceleration x distance = Energy**

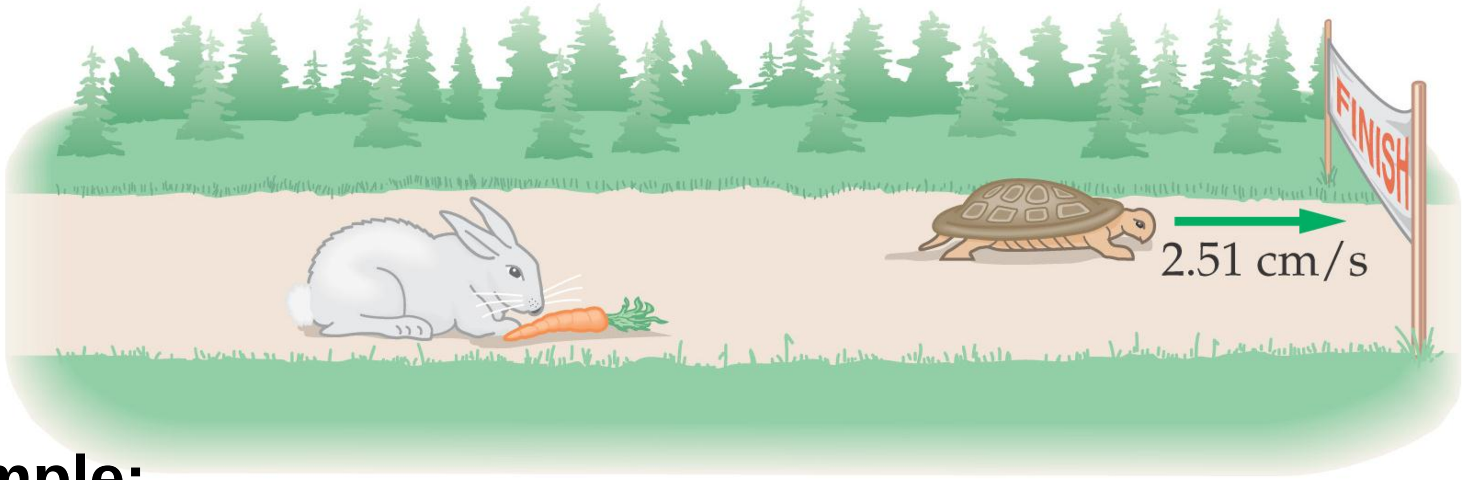
1-4 Significant Figures

Is my height 2m, 1.8 m, 1.82 m or 1.8165 m ?

- **accuracy of measurements is limited**
- **significant figures: the number of digits in a quantity that are known with certainty – for example human height is usually measured to three significant figures**
- **number of significant figures after multiplication or division is the number of significant figures in the least-known quantity**

1-4 Significant Figures

number of significant figures after multiplication or division is the number of significant figures in the least-known quantity



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

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 \$1.49

Sum: \$2.39 + \$1.49 = \$3.88

\$2.21 + \$1.35 = \$3.56

\$3.56 + 8% tax = \$3.84

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

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

1-5 Converting Units

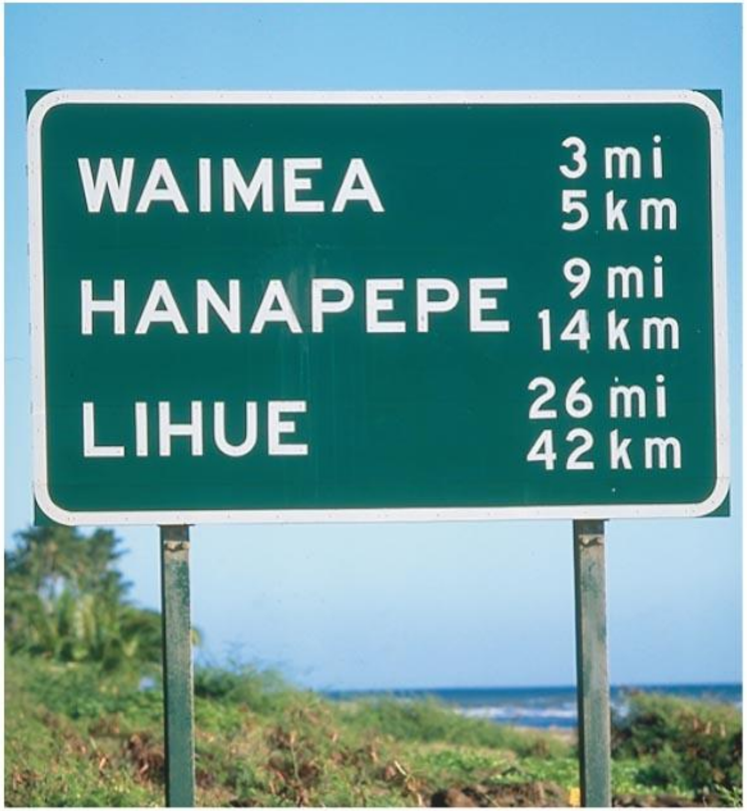
Converting feet to meters:

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!



Let us try iClicker

What is the most accurate conversion factor from km to miles that you can deduce from this picture ?

A. 1.6
B. 1.8
C. 1.56
D. 1.615
E. 0.81

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

1-6 Order-of-Magnitude Calculations Example:

Approximately how many times does an average human heart beat in a lifetime?

A) 3×10^{11}
B) 3×10^{10}
C) 3×10^{9}
D) 3×10^{8}
E) 4×10^{7}

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