Chapter 1 - Measurement

> "There are two possible outcomes: if the result confirms the hypothesis, then you've made a *measurement*. If the result is contrary to the hypothesis, then you've made a discovery."
>
> \- *Enrico Fermi*

David J. Starling
Penn State Hazleton
PHYS 211

What is a Unit?

A **measurement** *is an assignment of numbers (with units) to objects or events, often including magnitude and uncertainty.*

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What are some examples of units that you are familiar with?

- Distance:
- Time:
- Mass:
- Volume:

What is a Unit?

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For length, you might choose:

- meter (m)
- inch (in)
- foot (ft)
- yard (yd)
- fathom (ftm)
- nautical mile (nmi)
- league
- astronomical unit (au)
- (this list goes on forever)

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Example: How many Jordans is the Empire State Building?

$$H = 1450 \text{ ft} \times \overbrace{\frac{1 \text{ jordan}}{6.5 \text{ ft}}}^{1} = 223 \text{ jordans}$$

What is a Unit?

Other examples:

(a) How many seconds are in 3.5 minutes?

(b) How many inches is Shaq's foot (1.25 ft)?

(c) How fast is a 35 mph kangaroo in m/s? (note, 1 mile $\approx$ 1609 m)

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(c) How fast is a 35 mph kangaroo in m/s? (note, 1 mile $\approx$ 1609 m) $\rightarrow$ 16 m/s

International System of Units

The standard set of units is known as the S.I. system, established in 1971.

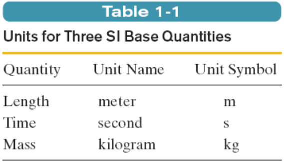

Table 1-1

Units for Three SI Base Quantities

Quantity	Unit Name	Unit Symbol
Length	meter	m
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Units in Mechanics

Significant Figures

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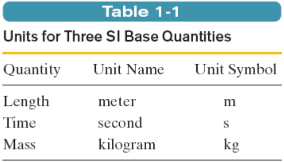

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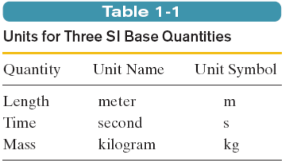

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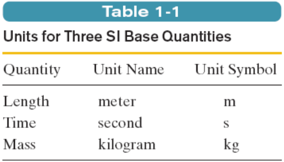

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- **1 kilogram** is the mass of a platinum-iridium cylinder kept under lock-and-key near Paris

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Examples of derived units:

- Speed (m/s)
- Momentum (kg m/s)
- Force (kg m/s^2)
- Torque (kg m^2/s^2)
- Energy (joule = kg m^2/s^2)
- Power (watt = joule/s = kg m^2/s^3)

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- That is, we reduce the number to the form

$$\mathrm{X.YZ} \times 10^N,$$

where N is how many places we moved the decimal point.

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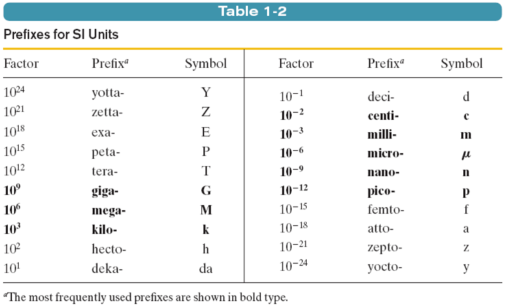

Table 1-2

Prefixes for SI Units

Factor	Prefix[a]	Symbol	Factor	Prefix[a]	Symbol
10^{24}	yotta-	Y	10^{-1}	deci-	d
10^{21}	zetta-	Z	**10^{-2}**	**centi-**	**c**
10^{18}	exa-	E	**10^{-3}**	**milli-**	**m**
10^{15}	peta-	P	**10^{-6}**	**micro-**	**μ**
10^{12}	tera-	T	**10^{-9}**	**nano-**	**n**
10^{9}	**giga-**	**G**	**10^{-12}**	**pico-**	**p**
10^{6}	**mega-**	**M**	10^{-15}	femto-	f
10^{3}	**kilo-**	**k**	10^{-18}	atto-	a
10^{2}	hecto-	h	10^{-21}	zepto-	z
10^{1}	deka-	da	10^{-24}	yocto-	y

[a] The most frequently used prefixes are shown in bold type.

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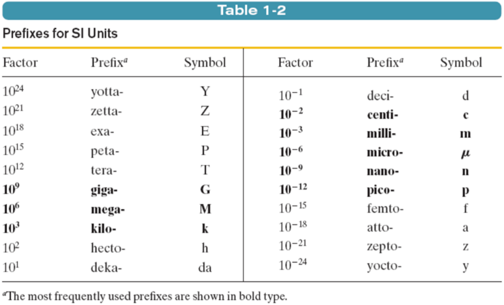

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Example: the distance to the moon is about

$$384,400,000 \text{ m} = 3.8 \times 10^8 \text{ m} = 0.38 \text{ Gm}.$$

Units in Mechanics

Approximate Lengths in Meters

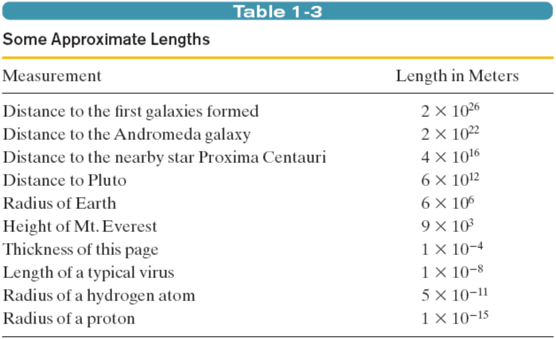

Table 1-3

Some Approximate Lengths

Measurement	Length in Meters
Distance to the first galaxies formed	2×10^{26}
Distance to the Andromeda galaxy	2×10^{22}
Distance to the nearby star Proxima Centauri	4×10^{16}
Distance to Pluto	6×10^{12}
Radius of Earth	6×10^{6}
Height of Mt. Everest	9×10^{3}
Thickness of this page	1×10^{-4}
Length of a typical virus	1×10^{-8}
Radius of a hydrogen atom	5×10^{-11}
Radius of a proton	1×10^{-15}

Units in Mechanics

Approximate Times in Seconds

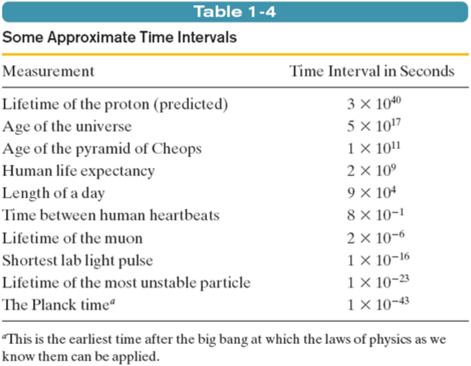

Table 1-4

Some Approximate Time Intervals

Measurement	Time Interval in Seconds
Lifetime of the proton (predicted)	3×10^{40}
Age of the universe	5×10^{17}
Age of the pyramid of Cheops	1×10^{11}
Human life expectancy	2×10^{9}
Length of a day	9×10^{4}
Time between human heartbeats	8×10^{-1}
Lifetime of the muon	2×10^{-6}
Shortest lab light pulse	1×10^{-16}
Lifetime of the most unstable particle	1×10^{-23}
The Planck time[a]	1×10^{-43}

[a] This is the earliest time after the big bang at which the laws of physics as we know them can be applied.

Units in Mechanics

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Significant Figures

Approximate Masses in Kilograms

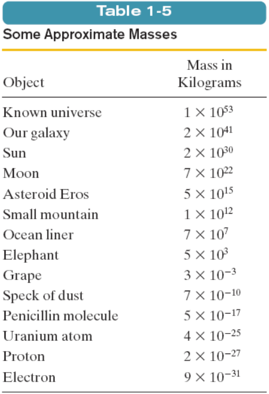


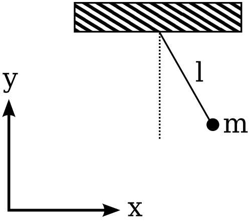
Table 1-5

Some Approximate Masses

Object	Mass in Kilograms
Known universe	1×10^{53}
Our galaxy	2×10^{41}
Sun	2×10^{30}
Moon	7×10^{22}
Asteroid Eros	5×10^{15}
Small mountain	1×10^{12}
Ocean liner	7×10^{7}
Elephant	5×10^{3}
Grape	3×10^{-3}
Speck of dust	7×10^{-10}
Penicillin molecule	5×10^{-17}
Uranium atom	4×10^{-25}
Proton	2×10^{-27}
Electron	9×10^{-31}

Units in Mechanics

The period of a pendulum's swing can be derived using only **dimensional analysis**.



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The period of a pendulum may depend on length l, mass m and gravitational acceleration g.

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What are a, b and c?

Answer: $a = 1/2$, $b = -1/2$ and $c = 0$, so $T \propto \sqrt{l/g}$

Significant Figures

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If uncertainty is unspecified, we assume an accuracy of about one or two units of the last digit.

$$8.8 \text{ cm} \rightarrow 8.8 \pm 0.1 \text{ or } 8.8 \pm 0.2 \text{ cm}$$

Significant Figures

How many significant figures are there?

number	sig figs
8.8	2
8.80	
0.8	
0.80	
8.0008	
80	
80.	
80.00	

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Why? Well...

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