

Lecture PowerPoints

Chapter 1

Physics: Principles with Applications, 6th edition

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Chapter 1

Introduction, Measurement, Estimating



Units of Chapter 1

- **The Nature of Science**
- **Physics and Its Relation to Other Fields**
- **Models, Theories, and Laws**
- **Measurement and Uncertainty; Significant Figures**
- **Units, Standards, and the SI System**
- **Converting Units**
- **Order of Magnitude: Rapid Estimating**
- **Dimensions and Dimensional Analysis**

1-1 The Nature of Science

Observation: important first step toward scientific theory; requires imagination to tell what is important.

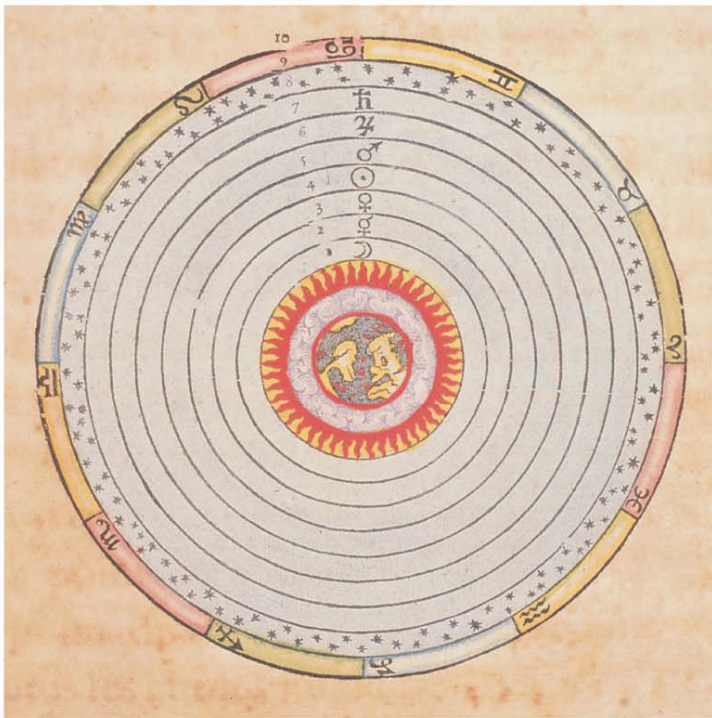
Theories: created to explain observations; will make predictions.

Observations will tell if the prediction is accurate, and the cycle goes on.

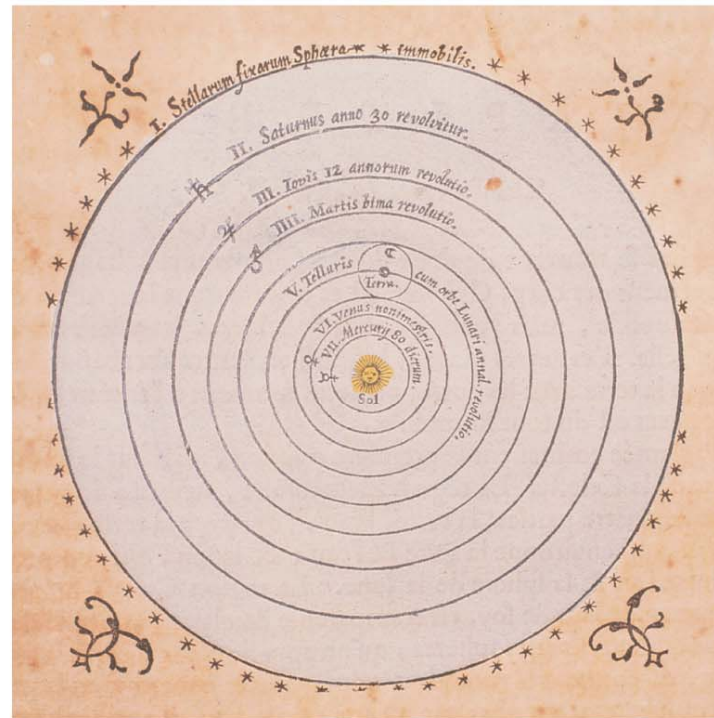
1-1 The Nature of Science

How does a new theory get accepted?

- Predictions agree better with data
- Explains a greater range of phenomena

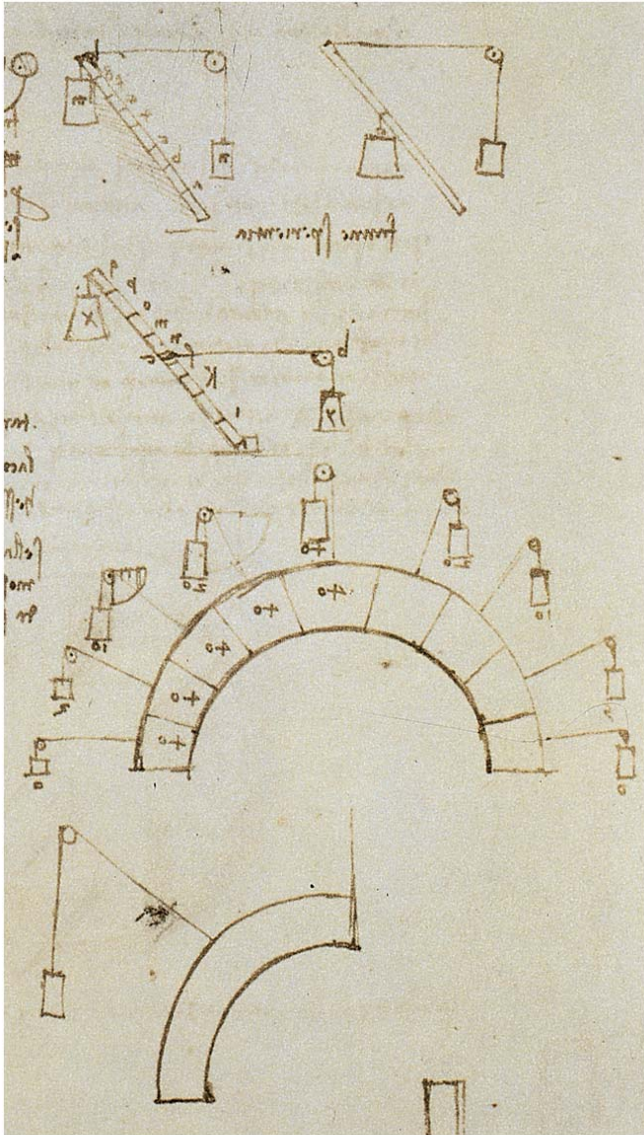


(a)



(b)

1-2 Physics and Its Relation to Other Fields



Physics is needed in both architecture and engineering.

Other fields that use physics, and make contributions to it: physiology, zoology, life sciences, ...

1-2 Physics and Its Relation to Other Fields

Communication between architects and engineers is essential if disaster is to be avoided.



(a)



(b)

1-3 Models, Theories, and Laws

Models are very useful during the process of understanding phenomena. A model creates mental pictures; care must be taken to understand the limits of the model and not take it too seriously.

A theory is detailed and can give testable predictions.

A law is a brief description of how nature behaves in a broad set of circumstances.

A principle is similar to a law, but applies to a narrower range of phenomena.

1-4 Measurement and Uncertainty; Significant Figures

No measurement is exact; there is always some **uncertainty** due to limited instrument accuracy and difficulty reading results.



The photograph to the left illustrates this – it would be difficult to measure the width of this 2x4 to better than a **millimeter**.

1-4 Measurement and Uncertainty; Significant Figures

Estimated uncertainty is written with a \pm sign; for example: 8.8 ± 0.1 cm

Percent uncertainty is the ratio of the uncertainty to the measured value, multiplied by 100:

$$\frac{0.1}{8.8} \times 100\% \approx 1\%$$

1-4 Measurement and Uncertainty; Significant Figures

The number of **significant figures** is the number of reliably known digits in a number. It is usually possible to tell the number of significant figures by the way the number is written:

23.21 cm has 4 significant figures

0.062 cm has 2 significant figures (the initial zeroes don't count)

80 km is ambiguous – it could have 1 or 2 significant figures. If it has 3, it should be written 80.0 km.

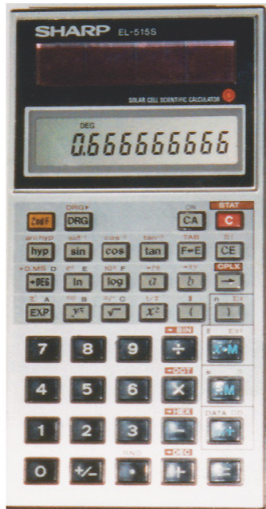
1-4 Measurement and Uncertainty; Significant Figures

When multiplying or dividing numbers, the result has as many significant figures as the number used in the calculation with the fewest significant figures.

Example: $11.3 \text{ cm} \times 6.8 \text{ cm} = 77 \text{ cm}$

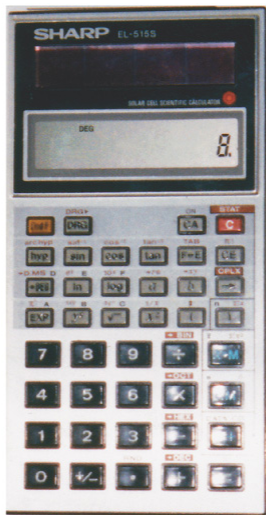
When adding or subtracting, the answer is no more accurate than the least accurate number used.

1-4 Measurement and Uncertainty; Significant Figures



(a)

Calculators will not give you the right number of significant figures; they usually give too many but sometimes give too few (especially if there are trailing zeroes after a decimal point).



(b)

The top calculator shows the result of $2.0 / 3.0$.

The bottom calculator shows the result of 2.5×3.2 .

1-5 Units, Standards, and the SI System

Quantity	Unit	Standard
Length	Meter	Length of the path traveled by light in $1/299,792,458$ second.
Time	Second	Time required for 9,192,631,770 periods of radiation emitted by cesium atoms
Mass	Kilogram	Platinum cylinder in International Bureau of Weights and Measures, Paris

TABLE 1–4
Metric (SI) Prefixes

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

[†] μ is the Greek letter “mu.”

1-5 Units, Standards, and the SI System

These are the standard SI prefixes for indicating powers of 10. Many are familiar; Y, Z, E, h, da, a, z, and y are rarely used.

1-5 Units, Standards, and the SI System

We will be working in the SI system, where the basic units are kilograms, meters, and seconds.

TABLE 1–5 SI Base Quantities and Units

Quantity	Unit	Unit Abbreviation
Length	meter	m
Time	second	s
Mass	kilogram	kg
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Other systems: cgs; units are grams, centimeters, and seconds.

British engineering system has force instead of mass as one of its basic quantities, which are feet, pounds, and seconds.

1-6 Converting Units

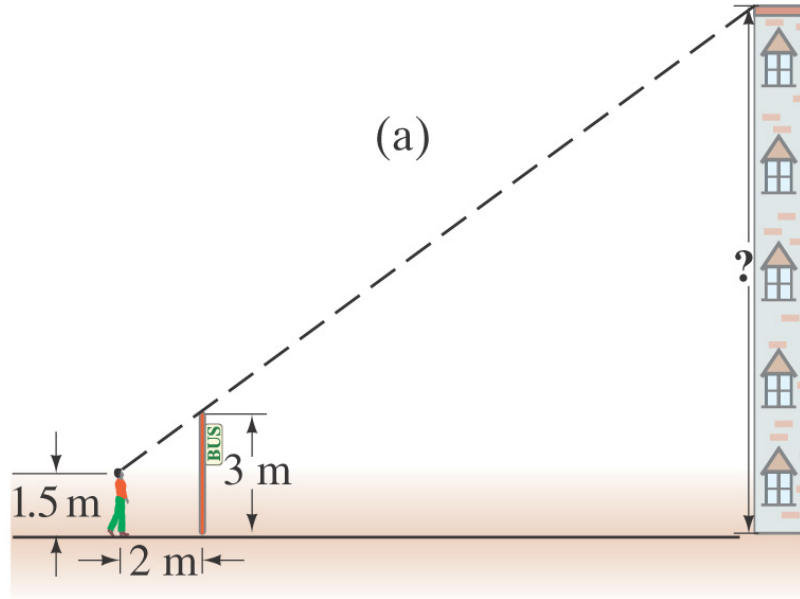
Converting between metric units, for example from kg to g, is easy, as all it involves is powers of 10.

Converting to and from British units is considerably more work.

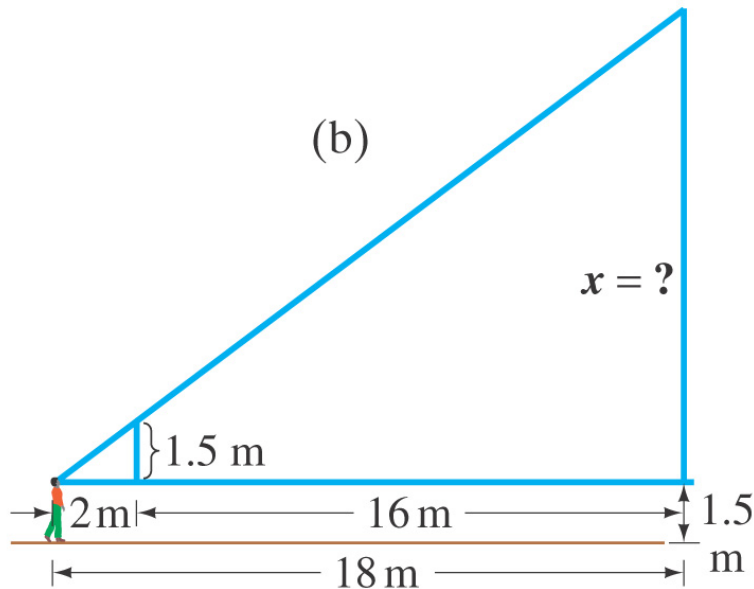


For example, given that $1 \text{ m} = 3.28084 \text{ ft}$, this 8611-m mountain is 28251 feet high.

1-7 Order of Magnitude: Rapid Estimating



A quick way to estimate a calculated quantity is to round off all numbers to **one significant figure** and then calculate. Your result should at least be the right **order of magnitude**; this can be expressed by rounding it off to the nearest power of 10.



Diagrams are also very useful in making estimations.

1-8 Dimensions and Dimensional Analysis

Dimensions of a quantity are the base units that make it up; they are generally written using square brackets.

Example: Speed = distance / time

Dimensions of speed: [L/T]

Quantities that are being added or subtracted must have the same dimensions. In addition, a quantity calculated as the solution to a problem should have the correct dimensions.

Summary of Chapter 1

- Theories are created to explain observations, and then tested based on their predictions.
- A model is like an analogy; it is not intended to be a true picture, but just to provide a familiar way of envisioning a quantity.
- A theory is much more well-developed, and can make testable predictions; a law is a theory that can be explained simply, and which is widely applicable.
- Dimensional analysis is useful for checking calculations.

Summary of Chapter 1

- **Measurements can never be exact; there is always some uncertainty. It is important to write them, as well as other quantities, with the correct number of significant figures.**
- **The most common system of units in the world is the SI system.**
- **When converting units, check dimensions to see that the conversion has been done properly.**
- **Order-of-magnitude estimates can be very helpful.**