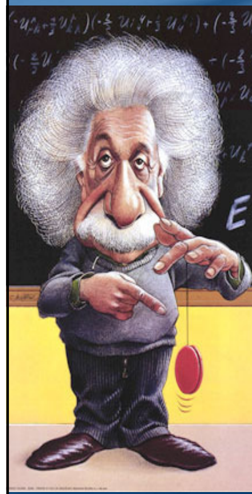
Chapter 1 – A Physics Toolkit

1.1, 1.2 Physics, Mathematics, and Measurement



What is Physics?

- the study of the physical world
- matter, energy, and how they are related

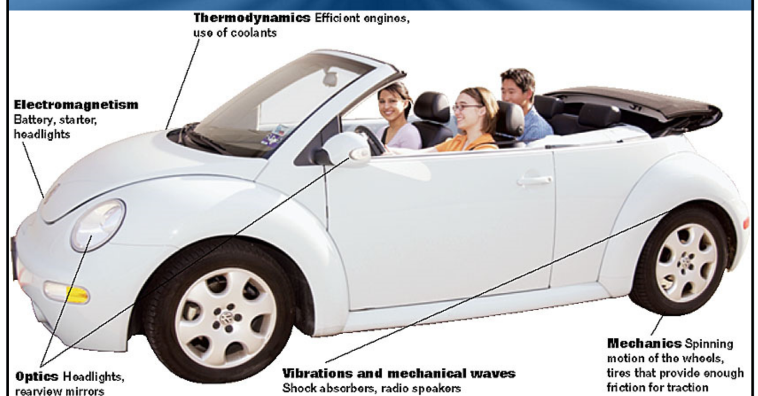
What is the goal of Physics?

- use a small number of basic concepts, equations, and assumptions to describe the physical world
- basically, to explain everything and be able to make accurate predictions

1.1, 1.2 Physics, Mathematics, and Measurement

Name	Subjects	Examples
Mechanics	motion and its causes, interactions between objects	falling objects, friction, weight, spinning objects
Thermodynamics	heat and temperature	melting and freezing processes, engines, refrigerators
Vibrations and wave phenomena	specific types of repetitive motions	springs, pendulums, sound
Optics	light	mirrors, lenses, color, astronomy
Electromagnetism	electricity, magnetism, and light	electrical charge, circuitry, permanent magnets, electromagnets
Relativity	particles moving at any speed, including very high speeds	particle collisions, particle accelerators, nuclear energy
Quantum mechanics	behavior of submicroscopic particles	the atom and its parts

1.1, 1.2 Physics, Mathematics, and Measurement



1.1, 1.2 Physics, Mathematics, and Measurement

$v_f = v_i + a\Delta t$	$\Delta d = v_i\Delta t + \frac{1}{2}a\Delta t^2$	$v_f^{\,2} = v_i^{\,2} + 2a\Delta d$	$F = ma$	$F_w = mg$
$F = G\frac{m_1 m_2}{d^2}$	$\mu = \frac{F_F}{F_N}$	$a_c = \frac{v^2}{r}$	$F_c = \frac{mv^2}{r}$	$v = \frac{2\Pi r}{T}$
$F_c = T + mg$	$F_c = T - mg$	$v = \sqrt{r\mu g}$	$v = \sqrt{rg}$	$W = F(\cos\Theta)d$
$W_{net} = \frac{1}{2}mv_f^{\,2} - \frac{1}{2}mv_i^{\,2}$	$PE_{grav} = mgh$	$\frac{1}{2}mv_i^{\,2} + mgh_i = \frac{1}{2}mv_f^{\,2} + mgh_f$	$P = \frac{W}{t}$	$P = Fv$
$KE = \frac{1}{2}mv^2$	$F\Delta t = mv_f - mv_i$	$m_1v_{i1} + m_2v_{i2} = m_1v_{f1} + m_2v_{f2}$	$F = -kx$	$PE_{sp} = \frac{1}{2}kx^2$
$f = \frac{1}{T}$	$T = \frac{1}{f}$	$T = 2\Pi\sqrt{\frac{l}{g}}$	$T = 2\Pi\sqrt{\frac{m}{k}}$	$v = f\lambda$

- In Physics, equations are important tools for modeling observations and making predictions

1.1, 1.2 Physics, Mathematics, and Measurement

SI Units (Le Systeme Internationale d'Unites)

- Physics involves the measurement of a variety of quantities

- SI System consists of 7 base units

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Base Quantity	Base Unit	Symbol
Length	meter	m
Mass		
Time		
Temperature		
Amount of Substance		
Electric Current		
Luminous Intensity		

1.1, 1.2 Physics, Mathematics, and Measurement

Originally, the meter was defined as one ten-millionth of the length of the earth's meridian extending from the north pole, through Paris, to the equator.

1.1, 1.2 Physics, Mathematics, and Measurement

In 1927, the meter was more precisely defined as the distance, at 0°, between the axes of the two central lines marked on the bar of platinum-iridium kept at the BIPM. This bar being subject to standard atmospheric pressure and supported on two cylinders of at least one centimeter diameter, symmetrically placed in the same horizontal plane at a distance of 571 mm from each other.

1.1, 1.2 Physics, Mathematics, and Measurement

In 1983 the CGPM replaced this latter definition by the following definition:

The meter is the length of the path traveled by light in a vacuum during a time interval of 1 / 299 792 458 of a second

1.1, 1.2 Physics, Mathematics, and Measurement

SI Units (Le Systeme Internationale d'Unites)

- Physics involves the measurement of a variety of quantities

- SI System consists of 7 base units

Base Quantity	Base Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time		
Temperature		
Amount of Substance		
Electric Current		
Luminous Intensity		

1.1, 1.2 Physics, Mathematics, and Measurement

At the end of the 18th century, a kilogram was the mass of a cubic decimeter of water. In 1889, the 1st CGPM sanctioned the international prototype of the kilogram, made of platinum-iridium.

The 3rd CGPM (1901), in a declaration intended to end the ambiguity in popular usage concerning the word "weight," confirmed that:

The kilogram is the unit of mass; it is equal to the mass of the international prototype of the kilogram.

1.1, 1.2 Physics, Mathematics, and Measurement

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SI Units (Le Systeme Internationale d'Unites)

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Base Quantity	Base Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature		
Amount of Substance		
Electric Current		
Luminous Intensity		

1.1, 1.2 Physics, Mathematics, and Measurement

The unit of time, the second, was defined originally as the fraction 1 / 86 400 of the mean solar day.

1.1, 1.2 Physics, Mathematics, and Measurement

Considering that a very precise definition of the unit of time is indispensable for the International System, the 13th CGPM (1967) decided to replace the definition of the second by the following:

The second is the duration of 9 192 631 770 periods of the radiation corresponding to the transition between the two levels of the ground state of the cesium 133 atom.

1.1, 1.2 Physics, Mathematics, and Measurement

SI Units (Le Systeme Internationale d'Unites)

- Physics involves the measurement of a variety of quantities

- SI System consists of 7 base units

Base Quantity	Base Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin	K
Amount of Substance	mole	mol
Electric Current	ampere	A
Luminous Intensity	candela	cd

1.1, 1.2 Physics, Mathematics, and Measurement

Derived Units

- Unit to measure the area of a room:

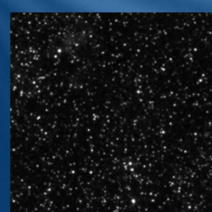
5 m x 6 m = 30 m^2

- Unit to measure velocity: m/s

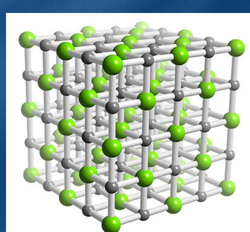
- Unit to measure weight: Newton (N) kg • m/s^2

1.1, 1.2 Physics, Mathematics, and Measurement

SI uses powers of 10 to accommodate extremes



- the distance between stars can be 100,000,000,000,000,000 m

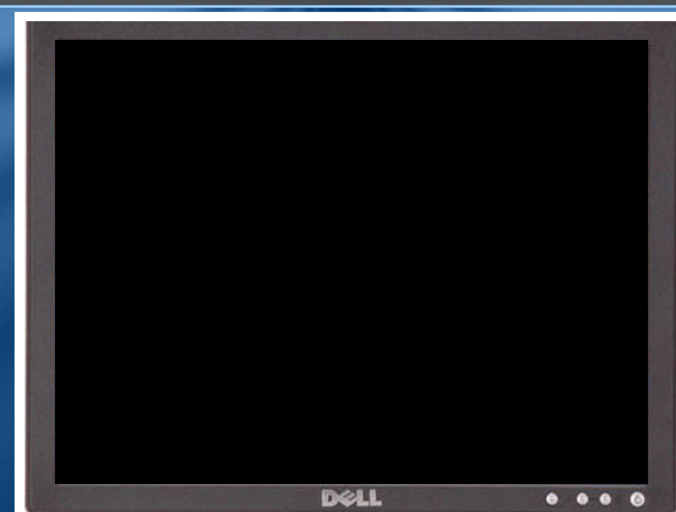


- the distance between atoms can be .000 000 001 m

- we can express these numbers in powers of 10

- 1 x 10^{17} m or 1 x 10^{-9} m

1.1, 1.2 Physics, Mathematics, and Measurement



1.1, 1.2 Physics, Mathematics, and Measurement

Scientific Notation

- a distance is 120,000,000 m

1. Place the decimal such that there is one non-zero digit to the left of the decimal point:

   1.2000000 m

2. Count the number of decimal places the decimal has been moved from the original number :

   moved 8

   (This becomes the power of 10)

3. If the original number is greater than 1, the exponent is positive. If the original number is less than 1, the exponent is negative :

   1.2×10^{8} m

1.1, 1.2 Physics, Mathematics, and Measurement

Scientific Notation

- a distance is .000789 m

1. Place the decimal such that there is one non-zero digit to the left of the decimal point:

   0007.89 m

2. Count the number of decimal places the decimal has been moved from the original number :

   moved 4

   (This becomes the power of 10)

3. If the original number is greater than 1, the exponent is positive. If the original number is less than 1, the exponent is negative :

   7.89×10^{-4} m

1.1, 1.2 Physics, Mathematics, and Measurement

Convert from standard notation to scientific notation

.00030 m
23,408 km
.00058 g
113 h
0.003005 g
23,000 kg
9,570,100 s
.004004 m

1.1, 1.2 Physics, Mathematics, and Measurement

Convert from standard notation to scientific notation

.00030 m	3.0×10^{-4} m
23,408 km	2.3408×10^{4} km
.00058 g	5.8×10^{-4} g
113 h	1.13×10^{2} h
0.003005 g	3.005×10^{-3} g
23,000 kg	2.3×10^{4} kg
9,570,100 s	9.5701×10^{6} s
.004004 m	4.004×10^{-3} m

1.1, 1.2 Physics, Mathematics, and Measurement

Convert from scientific notation to standard notation

4.56×10^{-6} m
1.58×10^{3} km
4.395×10^{5} g
2.5×10^{-3} h
5.8×10^{-4} g
1.28×10^{-2} kg
9.57×10^{4} s
1.06×10^{-5} m

1.1, 1.2 Physics, Mathematics, and Measurement

Convert from standard notation to scientific notation

.00030 m	3.0×10^{-4} m
23,408 km	2.3408×10^{4} km
.00058 g	5.8×10^{-4} g
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.004004 m	4.004×10^{-3} m

1.1, 1.2 Physics, Mathematics, and Measurement

SI uses prefixes to accommodate extremes
- combine prefixes with units that symbolize certain powers of 10

Power	Prefix	Abbreviation	Power	Prefix	Abbreviation
10^{-18}	atto-	a	10^{-1}	deci-	d
10^{-15}	femto-	f	10^{1}	deka-	da
10^{-12}	pico-	p	10^{3}	kilo-	k
10^{-9}	nano-	n	10^{6}	mega-	M
10^{-6}	micro-	µ (Greek letter *mu*)	10^{9}	giga-	G
			10^{12}	tera-	T
10^{-3}	milli-	m	10^{15}	peta-	P
10^{-2}	centi-	c	10^{18}	exa-	E

1.1, 1.2 Physics, Mathematics, and Measurement

Dimensional analysis (Factor-Label method)

- method of treating units as algebraic quantities
- build conversion factor from any equivalent relationship

Convert 2.0 meters to centimeters:

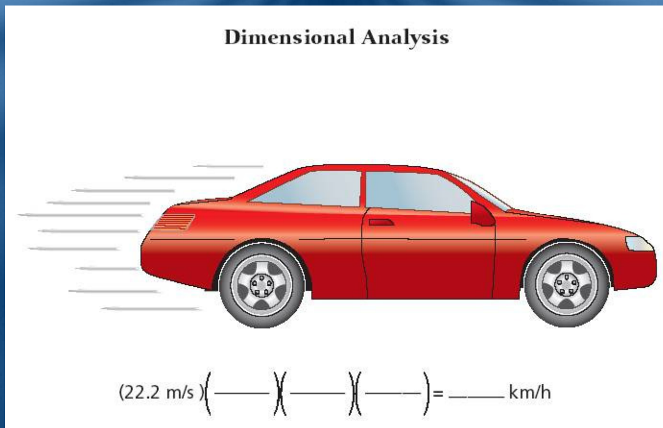
$$\frac{2.0\ \cancel{m}}{1} \times \boxed{\frac{100\ \text{cm}}{1\ \cancel{m}}} = 200\ \text{cm}$$

HAVE

CONVERSION FACTOR

WANT

1.1, 1.2 Physics, Mathematics, and Measurement



1.1, 1.2 Physics, Mathematics, and Measurement

Examples

- The mass of an average woman is 60,000,000 mg. Express this in grams and kilograms.

- A human hair is approximately 50 μm. Express this diameter in meters (using scientific notation).

- The mass of a proton is 1.67×10^{-12} pg. Express this in g, mg, and kg (using scientific notation).

1.1, 1.2 Physics, Mathematics, and Measurement

Examples

- The mass of an average woman is 60,000,000 mg. Express this in grams and kilograms.

Ans: 60,000 g and 60 kg

- A human hair is approximately 50 μm. Express this diameter in meters (using scientific notation).

Ans: 5×10^{-5} m

- The mass of a proton is 1.67×10^{-12} pg. Express this in g, mg, and kg (using scientific notation).

Ans: 1.67×10^{-24}g; 1.67×10^{-21}mg; 1.67×10^{-27} kg

1.1, 1.2 Physics, Mathematics, and Measurement

Accuracy and Precision

Measurement – A comparison between an unknown quantity and a standard

- Must make a measurement in the correct units (e.g. – measure length use meters, NOT kilograms!!)

1.1, 1.2 Physics, Mathematics, and Measurement

Accuracy – how well the results of a measurement agree with the accepted value.

- No measurement is perfect due to various sources of error

Sources of Error

1. Human error

1.1, 1.2 Physics, Mathematics, and Measurement

Accuracy – how well the results of a measurement agree with the accepted value.

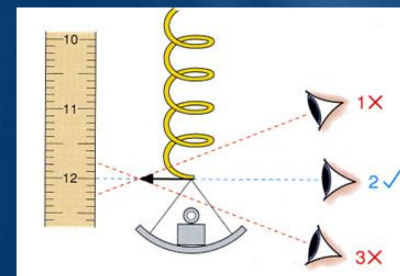
- No measurement is perfect due to various sources of error

Sources of Error

1. Human error

2. Method error

   Parallax – the apparent shift in the position of an object when viewed from different angles.



3. Instrument error

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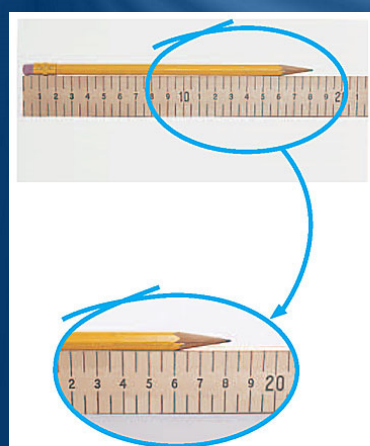
Precision – The degree of exactness of a measurement.

- The device that has the finest division on its scale produces the most precise measurement



What is the pencil's length?

1.1, 1.2 Physics, Mathematics, and Measurement

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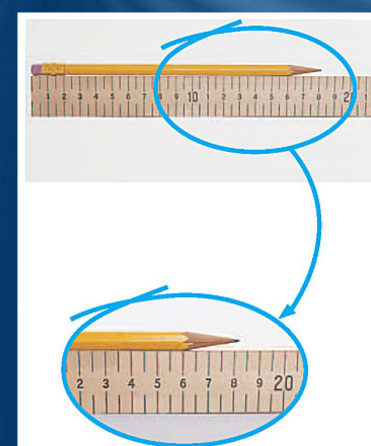
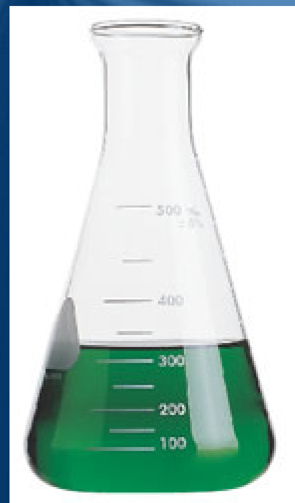


What is the pencil's length?

18.2 cm

1.1, 1.2 Physics, Mathematics, and Measurement

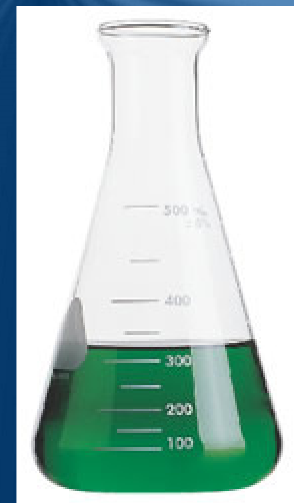
What is the volume of the green liquid?



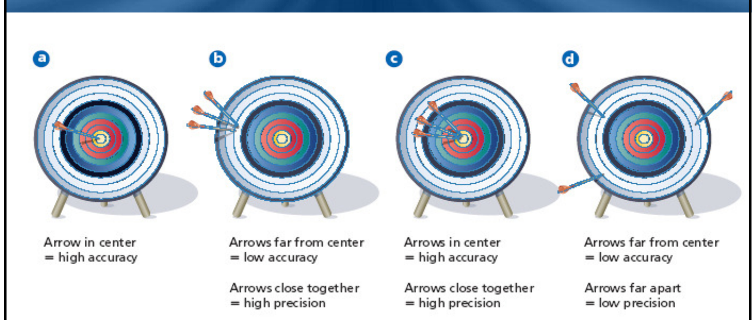
1.1, 1.2 Physics, Mathematics, and Measurement

What is the volume of the green liquid?

320 mL



1.1, 1.2 Physics, Mathematics, and Measurement



1.1, 1.2 Physics, Mathematics, and Measurement

Significant Figures – those digits in a measurement that are known with certainty plus the first digit that is uncertain (estimated).

Significant figures are significant because they SIGNIFY something!!!!

- Significant figures are an indicator of precision

- Our pencil measure 18.2 cm

-How many significant figures (sig figs) are there?

-How many digits are known with certainty?

-How many estimated digits are there?

1.1, 1.2 Physics, Mathematics, and Measurement

Significant Figures – those digits in a measurement that are known with certainty plus the first digit that is uncertain (estimated).

Significant figures are significant because they SIGNIFY something!!!!

- Significant figures are an indicator of precision

- Our pencil measure 18.2 cm

-How many significant figures (sig figs) are there? 3

-How many digits are known with certainty? 2

-How many estimated digits are there? 1

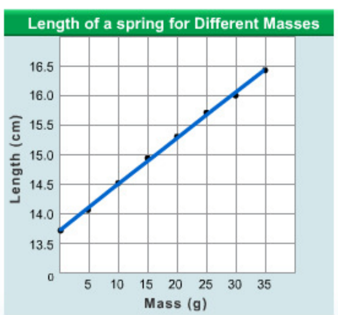
1.3 Graphing Data

- A variable is any factor that might affect the behavior of an experimental setup

- The independent variable is the factor that is changed or manipulated during the experiment.

- The dependent variable is the factor that depends on the independent variable.

1.3 Graphing Data



Length of a spring for Different Masses

Mass Attached to Spring (g)	Length of Spring (cm)
0	13.7
5	14.1
10	14.5
15	14.9
20	15.3
25	15.7
30	16.0
35	16.4

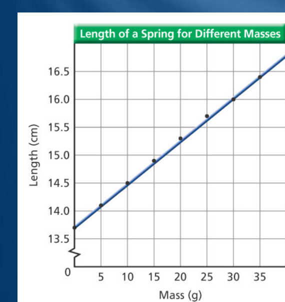
1.3 Graphing Data

Linear Relationships

When the line of best fit is a straight line, as in the figure, the dependent variable varies linearly with the independent variable. This relationship between the two variables is called a linear relationship.

The relationship can be written as an equation:

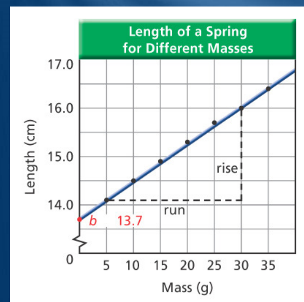
$$y = mx + b$$



1.3 Graphing Data

Linear Relationships

The slope is the ratio of the vertical change to the horizontal change. To find the slope, select two points, A and B, far apart on the line. The vertical change, or rise, Δy, is the difference between the vertical values of A and B. The horizontal change, or run, Δx, is the difference between the horizontal values of A and B.



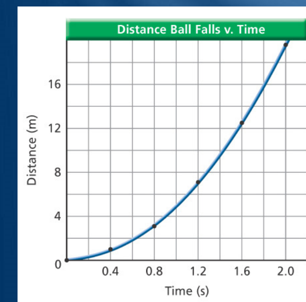
Slope $m = \frac{rise}{run} = \frac{\Delta y}{\Delta x}$

1.3 Graphing Data

Nonlinear Relationships

A quadratic relationship exists when one variable depends on the square of another.

$y = ax^2 + bx + c$



1.3 Graphing Data

Nonlinear Relationships

The graph in the figure shows how the current in an electric circuit varies as the resistance is increased. This is an example of an inverse relationship.

In an inverse relationship, a hyperbola results when one variable depends on the inverse of the other.

$y = \frac{a}{x}$