Chapter 1 A Physics Toolkit

1.1 Mathematics and Physics

Physics

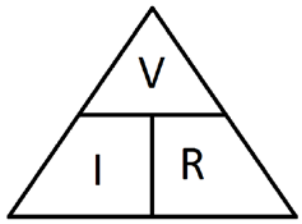
Is a branch of science that involves the study of the physical world: energy, matter, and how they are related

An electric current is a flow of electrons, in a wire

The potential difference, **or voltage, across a circuit**

Equals the current multiplied by the resistance in the circuit. That is,

V (volts) = I (amperes) X R (ohms).



I = V/R

V = IR

R = V/I

Q. What is the resistance of a lightbulb that has 0.75 amperes current when plugged into a 120-volt outlet?

1 Analyze the Problem

- Rewrite the equation.
- Substitute values.

Known:	Unknown:
$I = 0.75$ amperes	$R = ?$
$V = 120$ volts	

2 Solve for the Unknown

Rewrite the equation so the unknown is alone on the left.

$V = IR$

$IR = V$ Reflexive property of equality

$R = \frac{V}{I}$ Divide both sides by I.

$= \frac{120 \text{ volts}}{0.75 \text{ amperes}}$ Substitute 120 volts for V, 0.75 amperes for I.

$= 160$ ohms Resistance will be measured in ohms.

SI Units

The Système International d'Unités, or SI, uses seven base quantities

Table 1-1

SI Base Units

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

Derived units

Are created units by combining the base units in various ways.

Energy is measured in **joules**, where

1 joule equals one kilogram-meter squared per second squared,

Or **$1\ J = 1\ kg.m^2/s^2$**

Electric charge is measured in

coulombs, where **1 C = 1 A.s**

Prefixes Used with SI Units *ex. If we say one kilogram = 1 kg = 1 x 1000 g*

Table 1-2

Prefixes Used with SI Units

Prefix	Symbol	Multiplier	Scientific Notation	Example
femto-	f	0.000000000000001	10^{-15}	femtosecond (fs)
pico-	p	0.000000000001	10^{-12}	picometer (pm)
nano-	n	0.000000001	10^{-9}	nanometer (nm)
micro-	μ	0.000001	10^{-6}	microgram (μg)
milli-	m	0.001	10^{-3}	milliamps (mA)
centi-	c	0.01	10^{-2}	centimeter (cm)
deci-	d	0.1	10^{-1}	deciliter (dL)
kilo-	k	1000	10^{3}	kilometer (km)
mega-	M	1,000,000	10^{6}	megagram (Mg)
giga-	G	1,000,000,000	10^{9}	gigameter (Gm)
tera-	T	1,000,000,000,000	10^{12}	terahertz (THz)

Dimensional analysis

The method of treating the units as algebraic quantities, which can be cancelled

1 kg = 1000 g

you can construct the following conversion factors

$$\frac{1\ \text{kg}}{1000\ \text{g}} = 1 = \frac{1000\ \text{g}}{1\text{kg}}$$

For example, to convert 1.34 kg of iron ore to grams, do as shown below

$$\left(1.34\ \cancel{\text{kg}} \times \frac{1000\ \text{g}}{1\ \cancel{\text{kg}}}\right) = 1340\ \textbf{g}$$

To convert 43 km/h to m/s

$$\left(\frac{43\ \cancel{\text{km}}}{1\ \cancel{\text{h}}}\right)\left(\frac{1000\ \text{m}}{1\ \cancel{\text{km}}}\right)\left(\frac{1\ \cancel{\text{h}}}{60\ \cancel{\text{min}}}\right)\left(\frac{1\ \cancel{\text{min}}}{60\ \text{s}}\right) = 12\ \text{m/s}$$

Significant Digits or Significant figures.

Number	Number of s.f.	Reason	Scientific notation
504	3	in an integer all digits count (if last digit is not zero)	5.04×10^2
608 000	3	zeros at the end of an integer do not count	6.08×10^5
200	1	zeros at the end of an integer do not count	2×10^2
0.000 305	3	zeros in front do not count	3.05×10^{-4}
0.005 900	4	zeros at the end of a decimal count, those in front do not	5.900×10^{-3}

Arithmetic with significant digits

$$\underbrace{3.21}_{2\text{ d.p.}} + \underbrace{4.1}_{1\text{ d.p.}} = 7.32 \approx \underbrace{7.3}_{1\text{ d.p.}}$$ (the least number of d.p. is shown in red)

$$\underbrace{12.367}_{3\text{ d.p.}} - \underbrace{3.15}_{2\text{ d.p.}} = 9.217 \approx \underbrace{9.22}_{2\text{ d.p.}}$$

$$\underbrace{23}_{2\text{ s.f.}} \times \underbrace{578}_{3\text{ s.f.}} = 13\,294 \approx \underbrace{1.3 \times 10^4}_{2\text{ s.f.}}$$ (the least number of s.f. is shown in red)

$$\frac{\underbrace{6.244}_{4\text{ s.f.}}}{\underbrace{1.25}_{3\text{ s.f.}}} = 4.9952\ldots \approx \underbrace{5.00 \times 10^0}_{3\text{ s.f.}} = 5.00$$

A box has a length of 18.1 cm and a width of 19.2 cm, and it is 20.3 cm tall.

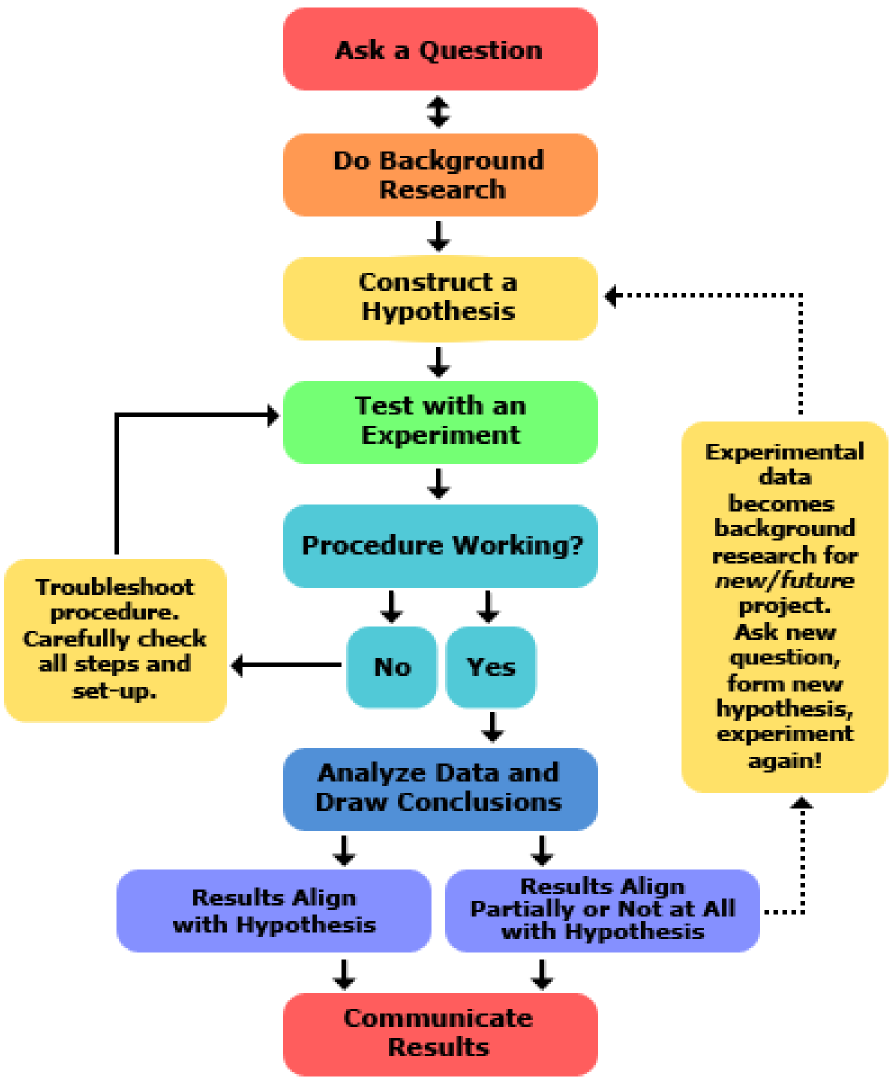
a. What is its volume?

$7.05 \times 10^3\ cm^3$

b. How tall is a stack of 12 of these boxes?

243.6 cm

<u>Scientific Methods</u>



<u>Scientific theory</u>

Is an explanation based on many observations supported by experimental results.

- Theories may serve as explanations for laws.
- A theory is the best available explanation of why things work as they do.

  For example, the theory of universal gravitation states that all the mass in the universe is attracted to other mass. Laws and theories may be revised or discarded over time

Greek philosophers proposed that objects fall because they seek their natural places. The more massive the object, the faster it falls.

↓

Revision

Galileo showed that the speed at which an object falls depends on the amount of time it falls, not on its mass.

↓

Revision

Galileo's statement is true, but Newton revised the reason why objects fall. Newton proposed that objects fall because the object and Earth are attracted by a force. Newton also stated that there is a force of attraction between any two objects with mass.

↓

Revision

Galileo's and Newton's statements still hold true. However, Einstein suggested that the force of attraction between two objects is due to mass causing the space around it to curve.

1.2. Measurement

A measurement
is a comparison between an unknown quantity and a standard

Comparing Results

Precision:-

Precision is the degree of exactness with which a quantity is measured.

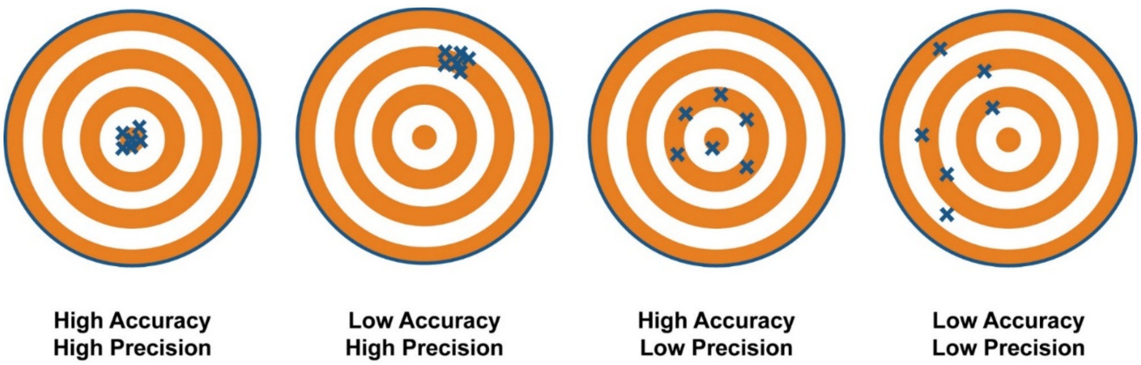
This refers to how close the measured values are to one another.

- Readings may be very precise, but wildly inaccurate.
- Precision relates to the reproducibility of results.

If a series of readings is taken with high precision, it indicates that the repeated values are all very close together and close to the mean (average) value.

Accuracy:-

is the extent to which a measurement matches the true value.



Repeatable:-

This is linked to *precision* in that if one person is conducting the same experiment and produces precise results the experiment is said to be repeatable.

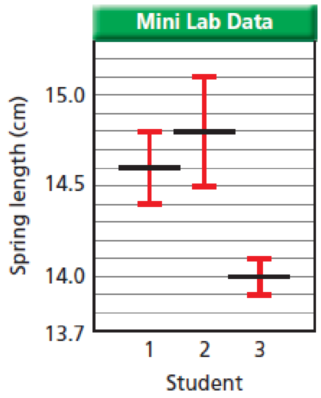
Reproducible:-

The is effectively the same as repeatable, *but for other groups*, *or studies* that produce the same precise results.

The significant digits in an answer show its precision.

A measure of 67.100 g is precise to the nearest thousandth of a gram

All measurements are subject to some uncertainty.



Student 1 (14.6 ± 0.2) cm.
Student 2 (14.8 ± 0.3) cm.
Student 3 (14.0 ± 0.1) cm.

Errors

1. Systemic error

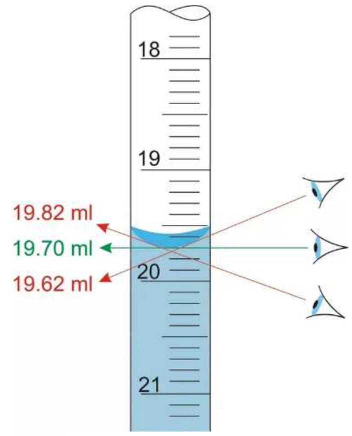
   Because of the measuring Device

2. Random error

   Because of the measuring person or surrounding environment

   Parallax error doesn't affect the precision of a measurement

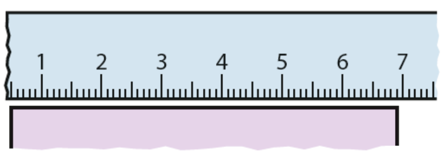
   Because it doesn't change the fineness of the divisions on its scale.



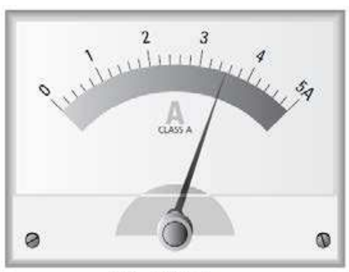
Parallax error

Reporting Uncertainty

Analogue instruments	Digital instruments
Instruments such as thermometers and measuring cylinders have various divisions	Digital readouts such as electronic balances have various precision levels
The uncertainty of an analogue scale is +/- half of the smallest division	The uncertainty of a digital scale is +/- the smallest scale division



Length = 6.90 ± 0.05 cm.



3.6 ± 0.1 A

A box has a length of 18.1 cm and a width of 19.2 cm, and it is 20.3 cm tall.

a. What is its volume?

7.05×10^3 cm^3

b. How precise is the measure of length? Of volume?

nearest tenth of a cm; nearest 10 cm^3

c. How tall is a stack of 12 of these boxes?

243.6 cm

d. How precise is the measure of the height of one box? Of 12 boxes?

nearest tenth of a cm; nearest tenth of a cm

Question

Determine who has the most accurate and precise value.

Ronald, Kevin, and Paul perform an experiment to determine the value of acceleration due to gravity on Earth (which most scientists agree is about 980 cm/s^2). The following results were obtained: Ronald — 961 ± 12 cm/s^2, Kevin — 953 ± 8 cm/s^2, and Paul — 942 ± 4 cm/s^2.

Ans.

Ronald's value is the most accurate, while Paul's value is the most precise.

1.3 Graphing Data

Graph the relationship between independent and dependent variables

Identifying Variables

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

It is the key ingredient when it comes to plotting data on a graph.

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

*Say that we are looking at the effect of changing **temperature on the pH of water.***

Independent variable: What you **change** (temperature) **X-axis**

Dependent variable: What changes because of the above. What you **measure** (pH) **Y-axis**

Controlled variables: Stuff that you keep (or should keep but don't really keep, but it doesn't matter) constant throughout your trials

Plotting Line Graphs

1. Identify the independent and dependent variables in your data.
The independent variable is plotted on the horizontal axis, the *x*-axis.
The dependent variable is plotted on the vertical axis, the *y*-axis.

2. Determine the range of the independent variable to be plotted.

3. Decide whether the origin (0, 0) is a valid data point.

4. Spread the data out as much as possible. Let each division on the graph paper stand for a convenient unit. This usually means units that are multiples of 2, 5, or 10.

5. Number and label the horizontal axis. The label should include the units, such as *Mass (grams).*

6. Repeat steps 2–5 for the dependent variable.

7. Plot the data points on the graph.

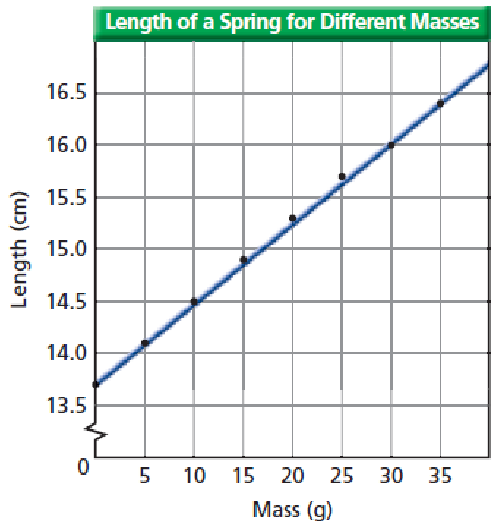
8. Draw the best-fit straight line or smooth curve that passes through as many data points as possible. This is sometimes called *eyeballing*.
the least-squares technique, that produces a unique best-fit line,

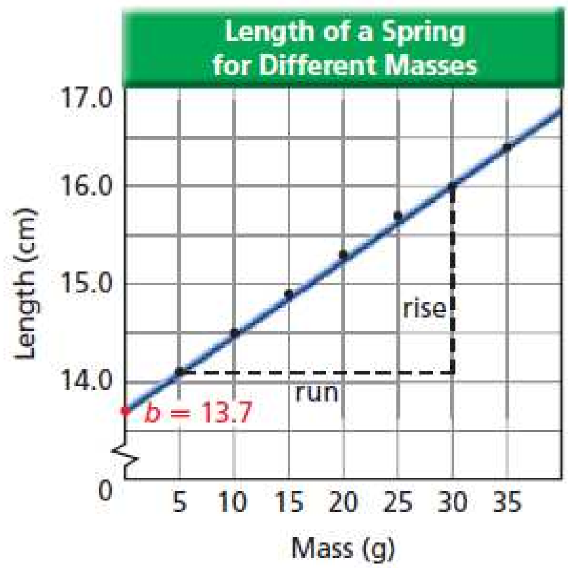
9. Give the graph a title that clearly tells what the graph represents.

Table 1-3

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





Linear Relationships

Linear Relationship Between Two Variables **y = mx + b**

b is the intercept with y-axis

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

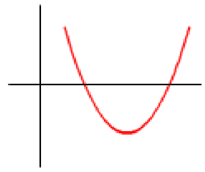
Nonlinear Relationships

Quadratic Relationship Between Two Variables

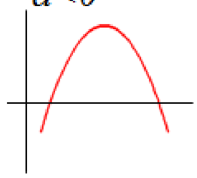
$$y = ax^2 + bx + c$$

y = ax² + bx + c

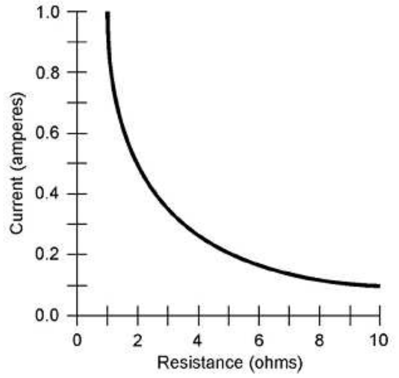
$a>0$

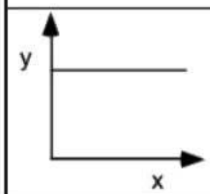
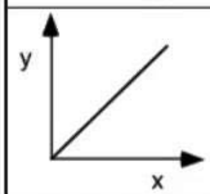
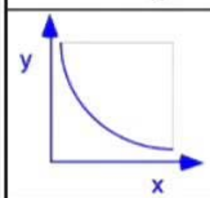
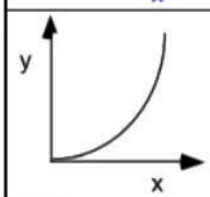
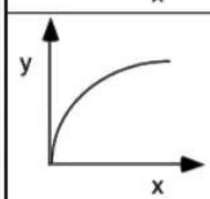


$a<0$



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



Graph shape	Written relationship	Modification required to linearize graph	Algebraic representation
	As x increases, y remains the same. There is no relationship between the variables.	None	$y = b$, or y is constant
	As x increases, y increases proportionally. Y is directly proportional to x.	None	$y = mx + b$
	As x increases, y decreases. Y is inversely proportional to x.	Graph y vs $\frac{1}{x}$, or y vs x^{-1}	$y = m\left(\frac{1}{x}\right) + b$
	Y is proportional to the square of x.	Graph y vs x^2	$y = mx^2 + b$
	The square of y is proportional to x.	Graph y^2 vs x	$y^2 = mx + b$

Chapter Test Practice /https://www.facebook.com/Physics-Way-585234978576403

1

The standard SI unit of mass is the ____________.

A) kilometer

B) kilogram

C) pound

D) kilomole

2

If one were to divide 3.90 by 7.2, what would the answer be with the correct number of significant digits?

A) 0.54

B) 0.542

C) 1

D) 0.5417

3

The valid digits in a measurement are called _________.

A) uncertain digits

B) significant digits

C) powers of 10

D) valid digits

4

Solve the following problem and express the answer in scientific notation: 4.75×10^3 kg + 8.24×10^3 kg.

A) $1.299 \text{x} 10^3$ kg

B) 1.299×10^4 kg

C) 1299×10^3 kg

D) 12,990 kg

/https://www.facebook.com/Physics-Way-585234978576403

5

Convert 243 ng to its equivalent in kilograms.

A) 2.43×10^{-10} kg

B) 2.43×10^{-11} kg

C) 2.43×10^{9} kg

D) 2.43×10^{-7} kg

6

The multiplier for SI units with the prefix *pico* is __________.

A) 10^{-15}

B) 10^{-12}

C) 10^{-9}

D) 10^{-6}

7

The SI base unit of length is the __________.

A) foot

B) meter

C) kilometer

D) candela

8

In order to convert a quantity expressed in one unit into the same quantity in a different unit, use a(n) __________.

A) calculation coefficient

B) notation factor

C) conversion factor

D) algebraic quantity

9

The multiplier for SI units with the prefix *mega* is __________.

A) 106

B) 109

C) 1012

D) 1,015

10

Convert 57.7 kg to grams.

A) $5.77 \text{ x } 10^5$ g

B) 5.77×10^3 g

C) 5.77×10^4 g

D) 5.77×10^6 g

11

Combinations of SI base units are called __________.

A) significant units

B) base units

C) calculated units

D) derived units

12

Which of the following operations would yield an answer of 0.5417 to the correct number of significant digits?

A) 3.900/7.200

B) 3.9000/ 7.20

C) 3.900/7.20

D) 3.9000 / 7.2000

13

The multiplier for SI units with the prefix *micro* is __________.

A) 10-15

B) 10-12

C) 10-9

D) 10-6

14

Convert 1.45 km to meters.

A) 14.5×10^{3} m

B) 1.45×10^{-3} m

C) 0.145×10^{-3} m

D) 1.45×10^{3} m

15

The multiplier for SI units with the prefix *femto* is __________.

A) 10^{15}

B) 39733

C) 10^{-9}

D) 10^{-6}

16

The standard SI unit of time is the __________.

A) minute

B) hour

C) millisecond

D) second

17 The multiplier for SI units with the prefix *deci* is __________.

A) 101

B) 102

C) 10^{-1}

D) 10^{-2}

18 The apparent shift in the position of an object when it is viewed from different angles is caused by __________.

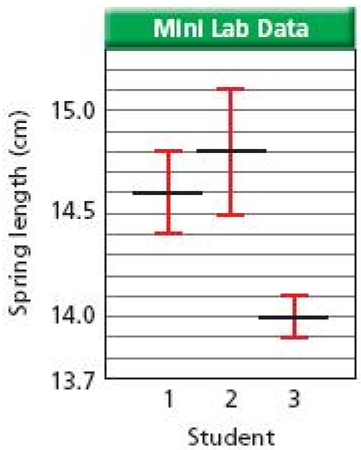
A) imprecise measurement

B) inaccuracy

C) parallax

D) faulty instruments

19 In the figure below, if a fourth student measured the spring's length to be 14.2 ± 0.2 cm, would this agree with any of the other students' measurements?



A) Yes, it agrees with only student 1.

B) Yes, it agrees only with student 3

C) Yes, it agrees with students 1 and 3.

D) No.

20

__________ describes how well the results of an experiment agree with the standard value.

A) Significance

B) Accuracy

C) Certainty

D) Precision

21

__________ describes the degree of exactness in a measurement.

A) Precision

B) Significance

C) Certainty

D) Accuracy

22

The property of a straight line on a graph that is the ratio of the vertical difference between two points to the horizontal difference between the same two points is the __________.

A) slope

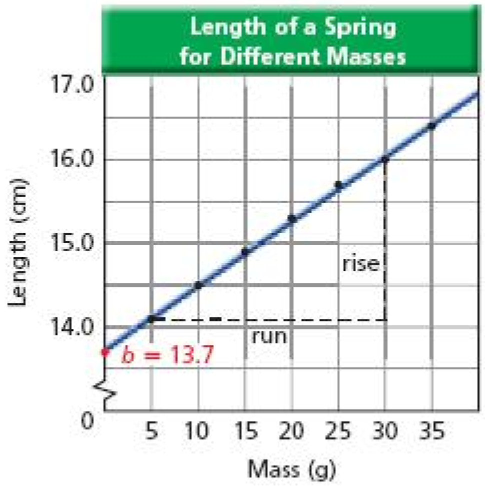
B) rise

C) intercept

D) tangent

23

Extrapolating from the figure below, if a mass of 45.0 g were hung on the spring, how long would the spring be?



A) 17.3 cm

B) 576 cm

C) 3.6 cm

D) 46.1 cm

24

What value is calculated by dividing rise by run?

A) acceleration of a moving object exhibiting uniform motion

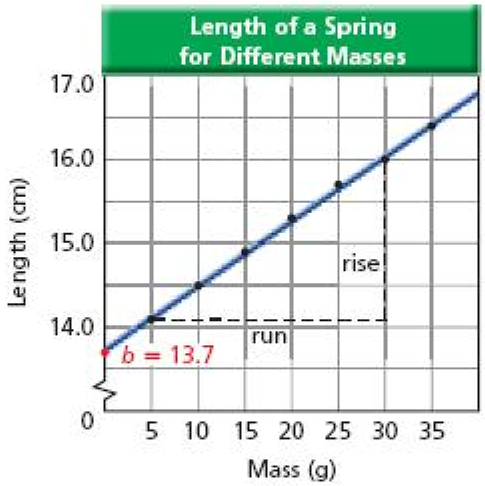
B) angular velocity

C) the slope of a straight line

D) the angle of a straight line

25

In the figure below, what is the physical meaning of the value for b?



A) It is the distance from the bottom of the spring to the suspended mass.

B) It is the length of the spring when no masses are suspended from it.

C) It is the length of the spring when the experiment is over.

D) It is the distance from the top of the spring to the suspended mass

Ans.

1. B	2. A	3. B	4. A	5. A	6. B	7. B	8. C	9. A	10. A
11. D	12. A	13. D	14. D	15. A	16. D	17. C	18. C	19. B	20. B
21. A	22. A	23. A	24. C	25.B					

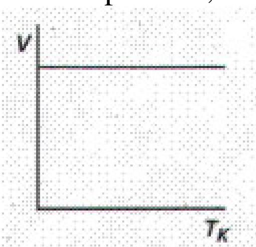
Standardized Test Practice

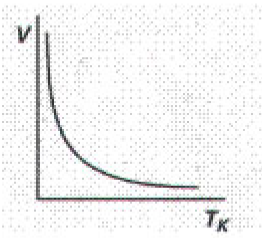
1

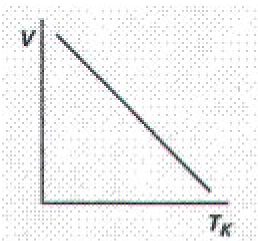
There is a linear relationship between volume, *V*, and absolute temperature, T_K, for an ideal gas at constant pressure:

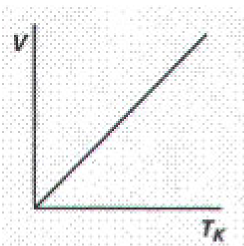
$$\frac{V}{T_K} = \text{constant}$$

If the constant is positive, which graph could represent this relationship?

A) 

B) 

C) 

D) 

2

A sprinter set a world record with a speed of 12.9 m/s. Using correct significant figures, what is this speed in km/hr?

A) 46.44 km/hr

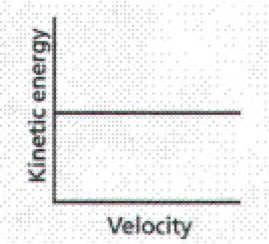
B) 46.4 km/hr

C) 47 km/hr

D) 46.8 km/hr

3

The relationship between kinetic energy of a moving object and its velocity is expressed as $KE = \frac{1}{2}mv^2$. Which of the following graphs represent this relationship?

A)


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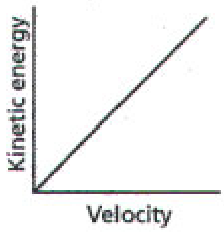

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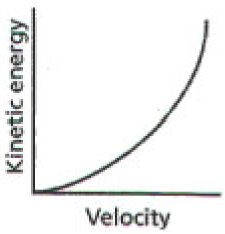
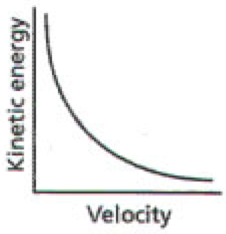


D)


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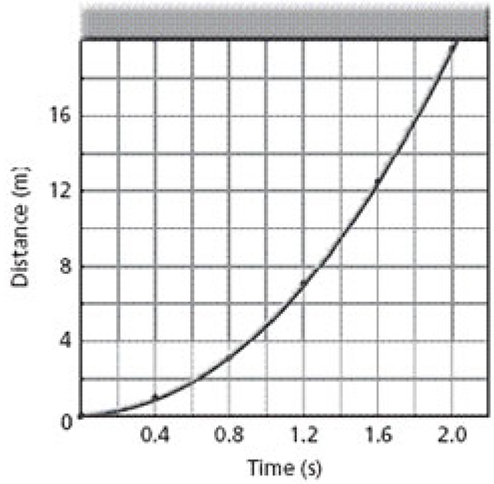


The graph above shows a nonlinear relationship. Which equation best represents the graph shown above?

- A) $m = \frac{\Delta y}{\Delta x}$
- B) $y = \frac{x}{a}$
- C) $y = ax^2 + bx + c$
- D) $m = \frac{\Delta y^2}{\Delta x^2}$

Ans.

1. D 2. B 3. C 4. C

Practice Problems

1.1 Mathematics and Physics

1. A lightbulb with a resistance of 50.0 ohms is used in a circuit with a 9.0-volt battery. What is the current through the bulb?

$$I = \frac{V}{R} = \frac{9.0\text{ volt}}{50.0\text{ ohms}} = 0.18\text{ ampere}$$

2. An object with uniform acceleration *a*, starting from rest, will reach a speed of *v* in time *t* according to the formula $v = at$. What is the acceleration of a bicyclist who accelerates from rest to 7 m/s in 4 s?

$$a = \frac{v}{t} = \frac{7\text{ m/s}}{4\text{ s}} = 1.75\text{ m/s}^2$$

3. How long will it take a scooter accelerating at 0.400 m/s^2 to go from rest to a speed of 4.00 m/s?

$$t = \frac{v}{a} = \frac{4.00\text{ m/s}}{0.400\text{ m/s}^2} = 10.0\text{ s}$$

4. The pressure on a surface is equal to the force divided by the area: $P = F/A$. A 53-kg woman exerts a force (weight) of 520 Newtons. If the pressure exerted on the floor is 32,500 N/m^2, what is the area of the soles of her shoes?

$$A = \frac{F}{P} = \frac{520\text{ N}}{32{,}500\text{ N/m}^2} = 0.016\text{ m}^2$$

5. How many megahertz is 750 kilohertz?

$$750\ \cancel{\text{kHz}}\left(\frac{1000\ \cancel{\text{Hz}}}{1\ \cancel{\text{kHz}}}\right)\left(\frac{1\text{ MHz}}{1{,}000{,}000\ \cancel{\text{Hz}}}\right) =$$

0.75 MHz

6. Convert 5021 centimeters to kilometers.

$$5021\ \cancel{\text{cm}}\left(\frac{1\ \cancel{\text{m}}}{100\ \cancel{\text{cm}}}\right)\left(\frac{1\text{ km}}{1000\ \cancel{\text{m}}}\right) =$$

5.021×10^{-2} km

7. How many seconds are in a leap year?

$$366\ \cancel{\text{days}}\left(\frac{24\ \cancel{\text{h}}}{1\ \cancel{\text{day}}}\right)\left(\frac{60\ \cancel{\text{min}}}{1\ \cancel{\text{h}}}\right)\left(\frac{60\text{ s}}{1\ \cancel{\text{min}}}\right) =$$

31,622,400 s

8. Convert the speed 5.30 m/s to km/h.

$$\left(\frac{5.30\ \cancel{\text{m}}}{1\ \cancel{\text{s}}}\right)\left(\frac{60\ \cancel{\text{s}}}{1\ \cancel{\text{min}}}\right)\left(\frac{60\ \cancel{\text{min}}}{1\text{ h}}\right)\left(\frac{1\text{ km}}{1000\ \cancel{\text{m}}}\right) =$$

19.08 km/h

9. **a.** 6.201 cm + 7.4 cm + 0.68 cm + 12.0 cm

$$\begin{array}{rl} 6.201 & \text{cm} \\ 7.4 & \text{cm} \\ 0.68 & \text{cm} \\ \underline{+\ 12.0} & \underline{\text{cm}} \\ 26.281 & \text{cm} \end{array}$$

= 26.3 cm after rounding

b. 1.6 km + 1.62 m + 1200 cm

$$\begin{array}{rcr} 1.6\text{ km} & = & 1600\text{ m} \\ 1.62\text{ m} & = & 1.62\text{ m} \\ 1200\text{ cm} & = & \underline{+\ 12\text{ m}} \\ & & 1613.62\text{ m} \end{array}$$

= 1600 m or 1.6 km after rounding

10. **a.** 10.8 g − 8.264 g

$$\begin{array}{rl} 10.8 & \text{g} \\ \underline{-\ 8.264} & \underline{\text{g}} \\ 2.536 & \text{g} \end{array}$$

= 2.5 g after rounding

Chapter 1 continued

b. 4.75 m − 0.4168 m

$$\begin{array}{r} 4.75\ \ \ \ \ \text{m} \\ -0.4168\ \text{m} \\ \hline 4.3332\ \text{m} \end{array}$$

= 4.33 m after rounding

11. a. 139 cm × 2.3 cm

320 cm^2 or 3.2×10^2 cm^2

b. 3.2145 km × 4.23 km

13.6 km^2

12. a. 13.78 g ÷ 11.3 mL

1.22 g/mL

b. 18.21 g ÷ 4.4 cm^3

4.1 g/cm^3

Section Review

1.1 Mathematics and Physics pages 3–10

page 10

13. Math Why are concepts in physics described with formulas?

The formulas are concise and can be used to predict new data.

14. Magnetism The force of a magnetic field on a charged, moving particle is given by $F = Bqv$, where F is the force in kg·m/s^2, q is the charge in A·s, and v is the speed in m/s. B is the strength of the magnetic field, measured in teslas, T. What is 1 tesla described in base units?

$$F = Bqv, \text{ so } B = \frac{F}{qv}$$

$$\text{T} = \frac{\text{kg·m/s}^2}{(\text{A·s})(\text{m/s})} = \frac{\text{kg}}{\text{A·s}^2}$$

1 T = 1 kg/A·s^2

15. Magnetism A proton with charge 1.60×10^{-19} A·s is moving at 2.4×10^5 m/s through a magnetic field of 4.5 T. You want to find the force on the proton.

a. Substitute the values into the equation you will use. Are the units correct?

$$F = Bqv$$

$$= (4.5\ \text{kg/A·s}^2)(1.60\times10^{-19}\ \text{A·s})(2.4\times10^5\ \text{m/s})$$

Force will be measured in kg·m/s^2, which is correct.

b. The values are written in scientific notation, $m\times10^n$. Calculate the 10^n part of the equation to estimate the size of the answer.

$10^{-19}\times10^5 = 10^{-14}$; the answer will be about 20×10^{-14}, or 2×10^{-13}.

c. Calculate your answer. Check it against your estimate from part **b.**

1.7×10^{-13} kg·m/s^2

d. Justify the number of significant digits in your answer.

The least-precise value is 4.5 T, with 2 significant digits, so the answer is rounded to 2 significant digits.

16. Magnetism Rewrite $F = Bqv$ to find v in terms of F, q, and B.

$$v = \frac{F}{Bq}$$

17. Critical Thinking An accepted value for the acceleration due to gravity is 9.801 m/s^2. In an experiment with pendulums, you calculate that the value is 9.4 m/s^2. Should the accepted value be tossed out to accommodate your new finding? Explain.

No. The value 9.801 m/s^2 has been established by many other experiments, and to discard the finding you would have to explain why they were wrong. There are probably some factors affecting your calculation, such as friction and how precisely you can measure the different variables.

Section Review

1.2 Measurement pages 11–14

page 14

18. **Accuracy** Some wooden rulers do not start with 0 at the edge, but have it set in a few millimeters. How could this improve the accuracy of the ruler?

As the edge of the ruler gets worn away over time, the first millimeter or two of the scale would also be worn away if the scale started at the edge.

19. **Tools** You find a micrometer (a tool used to measure objects to the nearest 0.01 mm) that has been badly bent. How would it compare to a new, high-quality meterstick in terms of its precision? Its accuracy?

It would be more precise but less accurate.

20. **Parallax** Does parallax affect the precision of a measurement that you make? Explain.

No, it doesn't change the fineness of the divisions on its scale.

21. **Error** Your friend tells you that his height is 182 cm. In your own words, explain the range of heights implied by this statement.

His height would be between 181.5 and 182.5 cm. Precision of a measurement is one-half the smallest division on the instrument. The height 182 cm would range ± 0.5 cm.

22. **Precision** A box has a length of 18.1 cm and a width of 19.2 cm, and it is 20.3 cm tall.

a. What is its volume?

7.05×10^3 cm^3

b. How precise is the measure of length? Of volume?

nearest tenth of a cm; nearest 10 cm^3

c. How tall is a stack of 12 of these boxes?

243.6 cm

d. How precise is the measure of the height of one box? Of 12 boxes?

nearest tenth of a cm; nearest tenth of a cm

23. **Critical Thinking** Your friend states in a report that the average time required to circle a 1.5-mi track was 65.414 s. This was measured by timing 7 laps using a clock with a precision of 0.1 s. How much confidence do you have in the results of the report? Explain.

A result can never be more precise than the least precise measurement. The calculated average lap time exceeds the precision possible with the clock.

Practice Problems

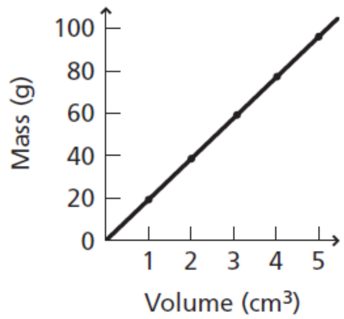
1.3 Graphing Data pages 15–19

page 18

24. The mass values of specified volumes of pure gold nuggets are given in **Table 1-4.**

Table 1-4	
Mass of Pure Gold Nuggets	
Volume (cm^3)	Mass (g)
1.0	19.4
2.0	38.6
3.0	58.1
4.0	77.4
5.0	96.5

a. Plot mass versus volume from the values given in the table and draw the curve that best fits all points.



Chapter 1 continued

b. Describe the resulting curve.

a straight line

c. According to the graph, what type of relationship exists between the mass of the pure gold nuggets and their volume?

The relationship is linear.

d. What is the value of the slope of this graph? Include the proper units.

$$\text{slope} = \frac{\Delta y}{\Delta x} = \frac{96.5\text{ g} - 19.4\text{ g}}{5.0\text{ cm}^3 - 1.0\text{ cm}^3}$$

$$= 19.3\text{ g/cm}^3$$

e. Write the equation showing mass as a function of volume for gold.

$m = (19.3\text{ g/cm}^3)V$

f. Write a word interpretation for the slope of the line.

The mass for each cubic centimeter of pure gold is 19.3 g.

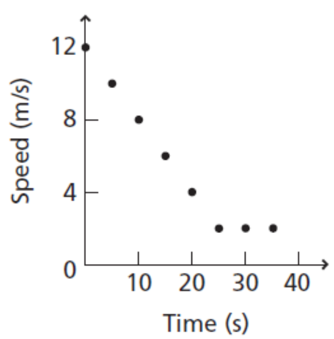
Section Review

1.3 Graphing Data pages 15–19

page 19

25. Make a Graph Graph the following data. Time is the independent variable.

Time (s)	0	5	10	15	20	25	30	35
Speed (m/s)	12	10	8	6	4	2	2	2



26. Interpret a Graph What would be the meaning of a nonzero *y*-intercept to a graph of total mass versus volume?

There is a nonzero total mass when the volume of the material is zero. This could happen if the mass value includes the material's container.

27. Predict Use the relation illustrated in Figure 1-16 to determine the mass required to stretch the spring 15 cm.

16 g

28. Predict Use the relation in Figure 1-18 to predict the current when the resistance is 16 ohms.

7.5 A

29. Critical Thinking In your own words, explain the meaning of a shallower line, or a smaller slope than the one in Figure 1-16, in the graph of stretch versus total mass for a different spring.

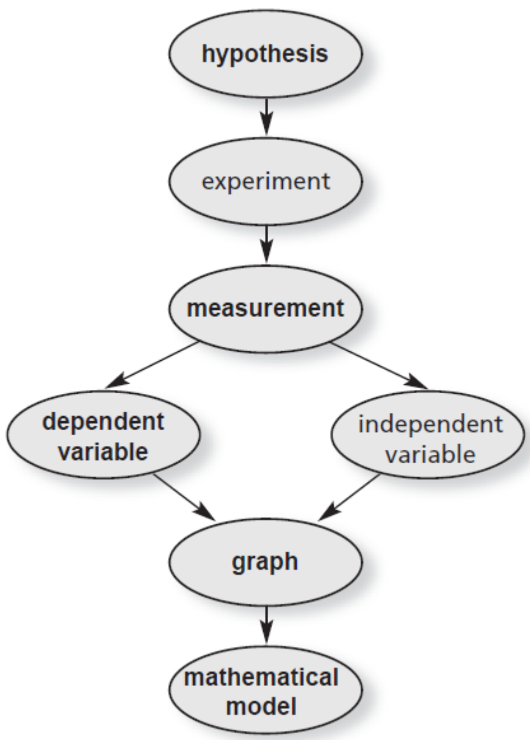
The spring whose line has a smaller slope is stiffer, and therefore requires more mass to stretch it one centimeter.

Chapter Assessment

Concept Mapping

page 24

30. Complete the following concept map using the following terms: *hypothesis, graph, mathematical model, dependent variable, measurement.*



Chapter 1 continued

Mastering Concepts

page 24

31. Describe a scientific method. (1.1)

Identify a problem; gather information about it by observing and experimenting; analyze the information to arrive at an answer.

32. Why is mathematics important to science? (1.1)

Mathematics allows you to be quantitative, to say "how fast," not just "fast."

33. What is the SI system? (1.1)

The International System of Units, or SI, is a base 10 system of measurement that is the standard in science. The base units are the meter, kilogram, second, kelvin, mole, ampere, and candela.

34. How are base units and derived units related? (1.1)

The derived units are combinations of the base units.

35. Suppose your lab partner recorded a measurement as 100 g. (1.1)

a. Why is it difficult to tell the number of significant digits in this measurement?

Zeros are necessary to indicate the magnitude of the value, but there is no way of knowing whether or not the instrument used to measure the values actually measured the zeros. The zeros may serve only to locate the 1.

b. How can the number of significant digits in such a number be made clear?

Write the number in scientific notation, including only the significant digits.

36. Give the name for each of the following multiples of the meter. (1.1)

a. $\frac{1}{100}$ m

centimeter

b. $\frac{1}{1000}$ m

millimeter

c. 1000 m

kilometer

37. To convert 1.8 h to minutes, by what conversion factor should you multiply? (1.1)

$\frac{60\ \text{min}}{1\ \text{h}}$, **because the units will cancel correctly.**

38. Solve each problem. Give the correct number of significant digits in the answers. (1.1)

a. 4.667×10^4 g $+ 3.02\times10^5$ g

3.49×10^5 g

b. $(1.70\times10^2\ \text{J}) \div (5.922\times10^{-4}\ \text{cm}^3)$

2.87×10^5 J/cm^3

39. What determines the precision of a measurement? (1.2)

the precision of a measuring device, which is limited by the finest division on its scale

40. How does the last digit differ from the other digits in a measurement? (1.2)

The final digit is estimated.

41. A car's odometer measures the distance from home to school as 3.9 km. Using string on a map, you find the distance to be 4.2 km. Which answer do you think is more accurate? What does *accurate* mean? (1.2)

The most accurate measure is the measure closest to the actual distance. The odometer is probably more accurate as it actually covered the distance. The map is a model made from measurements, so your measurements from the map are more removed from the real distance.

42. How do you find the slope of a linear graph? (1.3)

The slope of a linear graph is the ratio of the vertical change to the horizontal change, or rise over run.

Chapter 1 continued

43. For a driver, the time between seeing a stoplight and stepping on the brakes is called reaction time. The distance traveled during this time is the reaction distance. Reaction distance for a given driver and vehicle depends linearly on speed. (1.3)

a. Would the graph of reaction distance versus speed have a positive or a negative slope?

Positive. As speed increases, reaction distance increases.

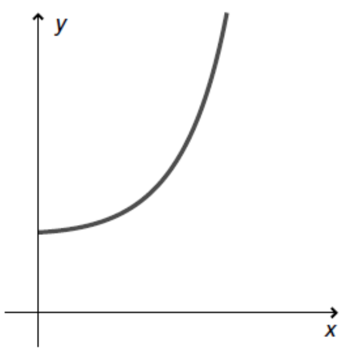
b. A driver who is distracted has a longer reaction time than a driver who is not. Would the graph of reaction distance versus speed for a distracted driver have a larger or smaller slope than for a normal driver? Explain.

Larger. The driver who was distracted would have a longer reaction time and thus a greater reaction distance at a given speed.

44. During a laboratory experiment, the temperature of the gas in a balloon is varied and the volume of the balloon is measured. Which quantity is the independent variable? Which quantity is the dependent variable? (1.3)

Temperature is the independent variable; volume is the dependent variable.

45. What type of relationship is shown in **Figure 1-20?** Give the general equation for this type of relation. (1.3)



■ **Figure 1-20**

quadratic; $y = ax^2 + bx + c$

46. Given the equation $F = mv^2/R$, what relationship exists between each of the following? (1.3)

a. F and R

inverse relationship

b. F and m

linear relationship

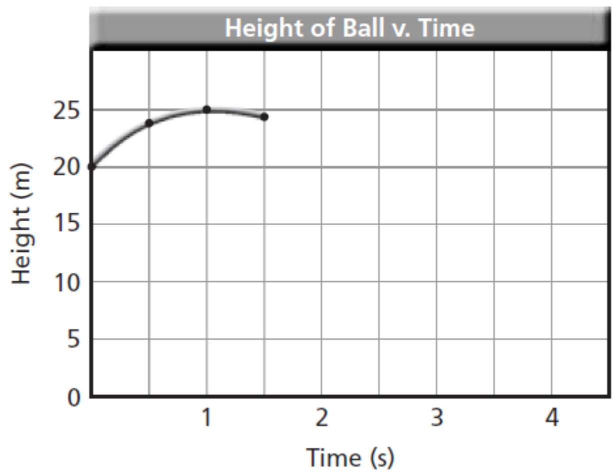
c. F and v

quadratic relationship

Applying Concepts

pages 25–26

47. **Figure 1-21** gives the height above the ground of a ball that is thrown upward from the roof of a building, for the first 1.5 s of its trajectory. What is the ball's height at $t = 0$? Predict the ball's height at $t = 2$ s and at $t = 5$ s.



■ **Figure 1-21**

When $t = 0$ and $t = 2$, the ball's height will be about 20 m. When $t = 5$, the ball will have landed on the ground so the height will be 0 m.

48. Is a scientific method one set of clearly defined steps? Support your answer.

There is no definite order of specific steps. However, whatever approach is used, it always includes close observation, controlled experimentation, summarizing, checking, and rechecking.

Chapter 1 continued

49. Explain the difference between a scientific theory and a scientific law.

A scientific law is a rule of nature, where a scientific theory is an explanation of the scientific law based on observation. A theory explains why something happens; a law describes what happens.

50. Density The density of a substance is its mass per unit volume.

a. Give a possible metric unit for density.

possible answers include g/cm^3 or kg/m^3

b. Is the unit for density a base unit or a derived unit?

derived unit

51. What metric unit would you use to measure each of the following?

a. the width of your hand

cm

b. the thickness of a book cover

mm

c. the height of your classroom

m

d. the distance from your home to your classroom

km

52. Size Make a chart of sizes of objects. Lengths should range from less than 1 mm to several kilometers. Samples might include the size of a cell, the distance light travels in 1 s, and the height of a room.

sample answer:
radius of the atom, 5×10^{-11} m; virus, 10^{-7} m; thickness of paper, 0.1 mm; width of paperback book, 10.7 cm; height of a door, 1.8 m; width of town, 7.8 km; radius of Earth, 6×10^{6} m; distance to the Moon, 4×10^{8} m

53. Time Make a chart of time intervals. Sample intervals might include the time between heartbeats, the time between presidential elections, the average lifetime of a human, and the age of the United States. Find as many very short and very long examples as you can.

sample answer:
half-life of polonium-194, 0.7 s; time between heartbeats, 0.8 s; time to walk between physics class and math class, 2.4 min; length of school year, 180 days; time between elections for the U.S. House of Representatives, 2 years; time between U.S. presidential elections, 4 years; age of the United States, (about) 230 years

54. Speed of Light Two students measure the speed of light. One obtains $(3.001 \pm 0.001)\times10^{8}$ m/s; the other obtains $(2.999 \pm 0.006)\times10^{8}$ m/s.

a. Which is more precise?

$(3.001 \pm 0.001)\times10^{8}$ m/s

b. Which is more accurate?

$(2.999 \pm 0.006)\times10^{8}$ m/s

55. You measure the dimensions of a desk as 132 cm, 83 cm, and 76 cm. The sum of these measures is 291 cm, while the product is 8.3×10^{5} cm^3. Explain how the significant digits were determined in each case.

In addition and subtraction, you ask what place the least precise measure is known to: in this case, to the nearest cm. So the answer is rounded to the nearest cm. In multiplication and division, you look at the number of significant digits in the least precise answer: in this case, 2. So the answer is rounded to 2 significant digits.

56. Money Suppose you receive \$5.00 at the beginning of a week and spend \$1.00 each day for lunch. You prepare a graph of the amount you have left at the end of each day for one week. Would the slope of this graph be positive, zero, or negative? Why?

negative, because the change in vertical distance is negative for a positive change in horizontal distance

Chapter 1 continued

57. Data are plotted on a graph, and the value on the y-axis is the same for each value of the independent variable. What is the slope? Why? How does y depend on x?

Zero. The change in vertical distance is zero. y does not depend on x.

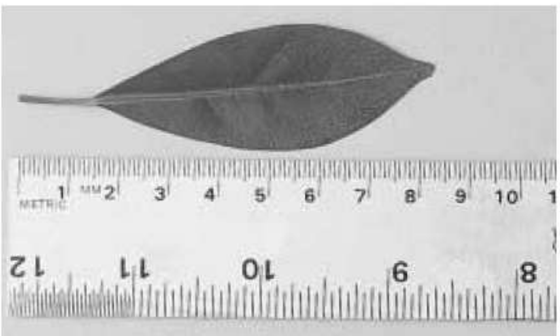
58. Driving The graph of braking distance versus car speed is part of a parabola. Thus, the equation is written $d = av^2 + bv + c$. The distance, d, has units in meters, and velocity, v, has units in meters/second. How could you find the units of a, b, and c? What would they be?

The units in each term of the equation must be in meters because distance, d, is measured in meters.

$av^2 = a(\text{m/s})^2$, so a is in s^2/m;

$bv = b(\text{m/s})$, so b is in s^{-1}.

59. How long is the leaf in **Figure 1-22?** Include the uncertainty in your measurement.



■ **Figure 1-22**

8.3 cm ± 0.05 cm, or 83 mm ± 0.5 mm

60. The masses of two metal blocks are measured. Block A has a mass of 8.45 g and block B has a mass of 45.87 g.

a. How many significant digits are expressed in these measurements?

A: three; B: four

b. What is the total mass of block A plus block B?

54.32 g

c. What is the number of significant digits for the total mass?

four

d. Why is the number of significant digits different for the total mass and the individual masses?

When adding measurements, the precision matters: both masses are known to the nearest hundredth of a gram, so the total should be given to the nearest hundredth of a gram. Significant digits sometimes are gained when adding.

61. History Aristotle said that the speed of a falling object varies inversely with the density of the medium through which it falls.

a. According to Aristotle, would a rock fall faster in water (density 1000 kg/m^3), or in air (density 1 kg/m^3)?

Lower density means faster speed, so the rock falls faster in air.

b. How fast would a rock fall in a vacuum? Based on this, why would Aristotle say that there could be no such thing as a vacuum?

Because a vacuum would have a zero density, the rock should fall infinitely fast. Nothing can fall that fast.

62. Explain the difference between a hypothesis and a scientific theory.

A scientific theory has been tested and supported many times before it becomes accepted. A hypothesis is an idea about how things might work—it has much less support.

63. Give an example of a scientific law.

Newton's laws of motion, law of conservation of energy, law of conservation of charge, law of reflection