

TABLE A.3 (Continued)

Z	Element	Symbol	Chemical Atomic Mass (u)	Mass Number (^a Indicates Radioactive)	Atomic Mass (u)	Percentage Abundance	Half-Life (if Radioactive) $T_{1/2}$
82	Lead	Pb	207.2	204 ^a 206 207 208	203.973 020 205.974 440 206.975 871 207.976 627	1.4 24.1 22.1 52.4	$\geq 1.4 \times 10^{15}$ y 22.3 y 36.1 m 10.64 h 26.8 m
83	Bismuth	Bi	208.9803	209	208.980 374	100	2.14 m
84	Polonium	Po		211 ^a	210.987 254		138.38 d
85	Astatine	At		210 ^a	209.982 848		164 μ s
86	Radon	Rn		214 ^a	213.995 177		1.6 s
87	Francium	Fr		218 ^a	218.008 685		3.823 d
88	Radium	Ra		223 ^a	223.015 733		22 m
89	Actinium	Ac		226 ^a	226.025 402		1600 y
90	Thorium	Th		228 ^a	228.031 064		5.75 y
		Th		227 ^a	227.027 749		21.77 y
		Th	232.0381	228 ^a	228.028 716		1.913 y
91	Protactinium	Pa		232 ^a	232.038 051	100	1.40×10^{10} y
92	Uranium	U	238.0289	231 ^a	231.035 880		32 760 y
		U		232 ^a	232.037 131		69 y
		U		233 ^a	233.039 630	0.720	1.59×10^5 y
		U		235 ^a	235.043 924		7.04×10^8 y
		U		236 ^a	236.045 562		2.34×10^7 y
93	Neptunium	Np		237 ^a	237.048 168	99.2745	4.47×10^6 y
94	Plutonium	Pu		239 ^a	239.052 157		2.14×10^4 y
		Pu		242 ^a	242.058 737		24 120 y
		Pu		244 ^a	244.064 200		3.73×10^5 y 8.1×10^7 y

APPENDIX B

Mathematics Review

These mathematics appendices are intended as a brief review of operations and methods. Early in your course, you should be facile with basic algebraic techniques, analytic geometry, and trigonometry. The appendices on differential and integral calculus are more detailed and are intended for those students who have difficulty applying calculus concepts to physical situations. Mathematical symbols used in the text are given in the following table.

Mathematical Symbols Used in the Text and Their Meanings

Symbol	Meaning
=	is equal to
≡	is defined as
≠	is not equal to
∝	is proportional to
>	is greater than
<	is less than
≧ (≥)	is much greater (less) than
≈	is approximately equal to
~	is on the order of
Δx	the change in x
$\sum_{i=1}^N x_i$	the sum of all quantities x_i from $i = 1$ to $i = N$
$ x $	the magnitude of x (always a nonnegative quantity)
$\Delta x \rightarrow 0$	Δx approaches zero
$\frac{dx}{dt}$	the derivative of x with respect to t
$\frac{\partial x}{\partial t}$	the partial derivative of x with respect to t
$\int$	integral

B.1 • SCIENTIFIC NOTATION

Many quantities that scientists deal with often have very large or very small values. For example, the speed of light is about 300 000 000 m/s, and the ink required to make the dot over an i in this textbook has a mass of about 0.000 000 001 kg.

Obviously, it is very cumbersome to read, write, and keep track of numbers such as these. We avoid this problem by using the powers of the number 10:

$$10^0 = 1$$

$$10^1 = 10$$

$$10^2 = 10 \times 10 = 100$$

$$10^3 = 10 \times 10 \times 10 = 1000$$

$$10^4 = 10 \times 10 \times 10 \times 10 = 10\,000$$

$$10^5 = 10 \times 10 \times 10 \times 10 \times 10 = 100\,000$$

and so on. The number of zeros corresponds to the power to which 10 is raised, called the exponent of 10. For example, the speed of light, 300 000 000 m/s, can be expressed as 3×10^8 m/s.

For numbers less than one, we note the following:

$$10^{-1} = \frac{1}{10} = 0.1$$

$$10^{-2} = \frac{1}{10 \times 10} = 0.01$$

$$10^{-3} = \frac{1}{10 \times 10 \times 10} = 0.001$$

$$10^{-4} = \frac{1}{10 \times 10 \times 10 \times 10} = 0.0001$$

$$10^{-5} = \frac{1}{10 \times 10 \times 10 \times 10 \times 10} = 0.00001$$

In these cases, the number of places that the decimal point lies to the left of the digit 1 equals the value of the (negative) exponent. Numbers that are expressed as some power of 10 multiplied by another number between 1 and 10 are said to be in **scientific notation**. For example, the scientific notation for 5 943 000 000 is 5.943×10^9 , and that for 0.0000832 is 8.32×10^{-5} .

When numbers expressed in scientific notation are being multiplied, the following general rule is very useful:

$$10^n \times 10^m = 10^{n+m} \quad \text{[B.1]}$$

where n and m can be any numbers (not necessarily integers). For example, $10^2 \times 10^3 = 10^5$. The rule also applies if one of the exponents is negative. For example, $10^3 \times 10^{-8} = 10^{-5}$.

When dividing numbers expressed in scientific notation, note that

$$\frac{10^n}{10^m} = 10^n \times 10^{-m} = 10^{n-m} \quad \text{[B.2]}$$

EXERCISES With help from these rules, verify the answers to the following:

1. $86\,400 = 8.64 \times 10^4$
2. $9\,816\,762.5 = 9.8167625 \times 10^6$

3. $0.0000000398 = 3.98 \times 10^{-8}$
4. $(4 \times 10^7)(9 \times 10^9) = 3.6 \times 10^{18}$
5. $(3 \times 10^7)(6 \times 10^{-15}) = 1.8 \times 10^{-4}$
6. $\frac{75 \times 10^{-11}}{5 \times 10^{-3}} = 1.5 \times 10^{-7}$
7. $\frac{(3 \times 10^7)(8 \times 10^{-2})}{(2 \times 10^{12})(6 \times 10^5)} = 2 \times 10^{-18}$

B.2 • ALGEBRA

Some Basic Rules

When algebraic operations are performed, the laws of arithmetic apply. Symbols such as x , y , and z are usually used to represent quantities that are not specified — the **unknowns**.

First, consider the equation

$$8x = 32$$

If we wish to solve for x , we can divide (or multiply) each side of the equation by the same factor without destroying the equality. In this case, if we divide both sides by 8, we have

$$\frac{8x}{8} = \frac{32}{8}$$

$$x = 4$$

Next consider the equation

$$x + 2 = 8$$

In this type of expression, we can add or subtract the same quantity from each side. If we subtract 2 from each side, we get

$$x + 2 - 2 = 8 - 2$$

$$x = 6$$

In general, if $x + a = b$, then $x = b - a$.

Now consider the equation

$$\frac{x}{5} = 9$$

If we multiply each side by 5, we are left with x on the left by itself and 45 on the right:

$$\left(\frac{x}{5}\right)(5) = 9 \times 5$$

$$x = 45$$

In all cases, **whatever operation is performed on the left side of the equality must also be performed on the right side**.

The following rules for multiplying, dividing, adding, and subtracting fractions should be recalled, where a , b , and c are three numbers:

Example

Multiplying $\left(\frac{a}{b}\right)\left(\frac{c}{d}\right) = \frac{ac}{bd}$

Dividing $\frac{(a/b)}{(c/d)} = \frac{ad}{cb}$

Adding $\frac{a}{b} \pm \frac{c}{d} = \frac{ad \pm bc}{bd}$

EXERCISES In the following exercises, solve for x :

Answers

- $a = \frac{1}{1+x}$ $x = \frac{1-a}{a}$
- $3x - 5 = 13$ $x = 6$
- $ax - 5 = bx + 2$ $x = \frac{7}{a-b}$
- $\frac{5}{2x+6} = \frac{3}{4x+8}$ $x = -\frac{11}{7}$

Powers

When powers of a given quantity x are multiplied, the following rule applies:

$$x^a x^b = x^{a+b}$$

[B.3]

For example, $x^2 x^4 = x^{2+4} = x^6$.

When dividing the powers of a given quantity, the rule is

$$\frac{x^a}{x^b} = x^{a-b}$$

[B.4]

For example, $x^6/x^2 = x^{6-2} = x^4$.

A power that is a fraction, such as $\frac{1}{3}$, corresponds to a root as follows:

$$x^{1/3} = \sqrt[3]{x}$$

[B.5]

For example, $4^{1/3} = \sqrt[3]{4} = 1.5874$. (A scientific calculator is useful for such calculations.)

Finally, any quantity x^a that is raised to the m th power is

$$(x^a)^m = x^{am}$$

[B.6]

Table B.1 summarizes the rules of exponents.

TABLE B.1 Rules of Exponents

$$\begin{aligned} x^0 &= 1 \\ x^1 &= x \\ x^a x^b &= x^{a+b} \\ x^a/x^b &= x^{a-b} \\ x^{1/a} &= \sqrt[a]{x} \\ (x^a)^b &= x^{ab} \end{aligned}$$

EXERCISES Verify the following:

- $3^2 \times 3^3 = 243$
- $x^2 x^3 = x^5$
- $x^{10}/x^5 = x^5$
- $5^{1/3} = 1.709975$ (Use your calculator.)
- $60^{1/4} = 2.783158$ (Use your calculator.)
- $(x^4)^3 = x^{12}$

Factoring

Some useful formulas for factoring an equation are

$$\begin{aligned} ax + ay + az &= a(x + y + z) && \text{Common factor} \\ a^2 + 2ab + b^2 &= (a + b)^2 && \text{Perfect square} \\ a^2 - b^2 &= (a + b)(a - b) && \text{Difference of squares} \end{aligned}$$

Quadratic Equations

The general form of a quadratic equation is

$$ax^2 + bx + c = 0$$

[B.7]

where x is the unknown quantity and a , b , and c are numerical factors referred to as **coefficients** of the equation. This equation has two roots, given by

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

[B.8]

If $b^2 \geq 4ac$, the roots are real.

Example 1

The equation $x^2 + 5x + 4 = 0$ has the following roots, corresponding to the two signs of the square-root term:

That is,

$$x_+ = \frac{-5 + 3}{2} = -1 \quad x_- = \frac{-5 - 3}{2} = -4$$

where x_+ denotes the root corresponding to the positive sign and x_- denotes the root corresponding to the negative sign.

EXERCISES Solve the following quadratic equations:

Answers

- $x^2 + 2x - 3 = 0$ $x_+ = 1$ $x_- = -3$
- $2x^2 - 5x + 2 = 0$ $x_+ = 2$ $x_- = \frac{1}{2}$
- $2x^2 - 4x - 9 = 0$ $x_+ = 1 + \sqrt{22/2}$ $x_- = 1 - \sqrt{22/2}$

Linear Equations

A linear equation has the general form

$$y = ax + b$$

[B.9]

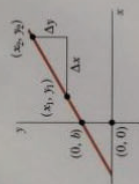


Figure B.1

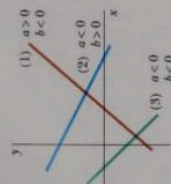


Figure B.2

where a and b are constants. This equation is referred to as linear because the graph of y versus x is a straight line, as shown in Figure B.1. The constant b , called the **intercept**, represents the value of y at which the straight line intersects the y axis. The constant a is equal to the slope of the straight line. If any two points on the straight line are specified by the coordinates (x_1, y_1) and (x_2, y_2) , as in Figure B.1, then the **slope** of the straight line can be expressed as

$$\text{Slope} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\Delta y}{\Delta x} \quad [\text{B.10}]$$

Note that a and b can have either positive or negative values. If $a > 0$, the straight line has a **positive** slope, as in Figure B.1. If $a < 0$, the straight line has a **negative** slope. In Figure B.1, both a and b are positive. Three other possible situations are shown in Figure B.2: $a > 0$, $b < 0$; $a < 0$, $b > 0$; and $a < 0$, $b < 0$.

EXERCISES

1. Draw graphs of the following straight lines:
(a) $y = 5x + 3$ (b) $y = -2x + 4$ (c) $y = -3x - 6$.
2. Find the slopes of the straight lines described in Exercise 1.

Answers: (a) 5 (b) -2 (c) -3

3. Find the slopes of the straight lines that pass through the following sets of points:

(a) (0, -4) and (4, 2); (b) (0, 0) and (2, -5); (c) (-5, 2) and (4, -2).

Answers: (a) 3/2 (b) -5/2 (c) -4/9

Solving Simultaneous Linear Equations

Consider an equation such as $3x + 5y = 15$, which has two unknowns, x and y . Such an equation does not have a unique solution. That is, $(x = 0, y = 3)$, $(x = 5, y = 0)$, and $(x = 2, y = 9/5)$ are all solutions to this equation.

If a problem has two unknowns, a unique solution is possible only if there are **two** independent equations. In general, if a problem has n unknowns, its solution requires n equations. In order to solve two simultaneous equations involving two unknowns, x and y , we solve one of the equations for x in terms of y and substitute this expression into the other equation.

Example 2

Solve the following two simultaneous equations:

- (1) $5x + y = -8$
- (2) $2x - 2y = 4$

Solution From (2), $x = y + 2$. Substitution of this into (1) gives

$$5(y + 2) + y = -8$$

$$6y = -18$$

$$y = -3$$

$$x = y + 2 = -1$$

Alternative Solution Multiply each term in (1) by the factor 2 and add the result to (2):

$$10x + 2y = -16$$

$$2x - 2y = 4$$

$$12x = -12$$

$$x = -1$$

$$y = x - 2 = -3$$

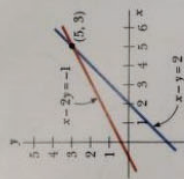


Figure B.3

Two linear equations with two unknowns can also be solved by a graphical method. If the straight lines corresponding to the two equations are plotted in a conventional coordinate system, the intersection of the two lines represents the solution. For example, consider the two equations

$$x - 2y = -1$$

$$x - y = 2$$

These are plotted in Figure B.3. The intersection of the two lines has the coordinates $x = 5, y = 3$. This represents the solution to the equations. You should check this solution by the analytical technique discussed earlier.

EXERCISES Solve the following pairs of simultaneous equations involving two unknowns:

Answers

1. $x + y = 8$ $x = 5, y = 3$

2. $x - y = 2$ $x = 5, y = 3$

3. $98 - T = 10a$ $T = 65, a = 3.27$

4. $T - 49 = 5a$ $T = 65, a = 3.27$

5. $6x + 2y = 6$ $x = 2, y = -3$

6. $8x - 4y = 28$ $x = 2, y = -3$

Logarithms

Suppose that a quantity, x , is expressed as a power of some quantity a :

$$x = a^y \quad [\text{B.11}]$$

The number a is called the **base** number. The **logarithm** of x with respect to the base a is equal to the exponent to which the base must be raised in order to satisfy the expression $x = a^y$:

$$y = \log_a x \quad [\text{B.12}]$$

Conversely, the **antilogarithm** of y is the number x :

$$x = \text{antilog}_a y \quad [\text{B.13}]$$

In practice, the two bases most often used are base 10, called the **common** logarithm base, and base $e = 2.718 \dots$, called the **natural** logarithm base. When common logarithms are used,

$$y = \log_{10} x \quad (\text{or } x = 10^y) \quad [\text{B.14}]$$

When natural logarithms are used,

$$y = \log_e x = \ln x \quad (\text{or } x = e^y) \quad [\text{B.15}]$$

For example, $\log_{10} 52 = 1.716$, and so $\text{antilog}_{10} 1.716 = 10^{1.716} = 52$. Likewise, $\ln 52 = 3.951$, so $\text{antiln } 3.951 = e^{3.951} = 52$.

In general, note that you can convert between base 10 and base e with the equality

$$\ln x = (2.302585) \log_{10} x \quad [\text{B.16}]$$

Finally, some useful properties of logarithms are as follows:

$$\log(ab) = \log a + \log b$$

$$\log(a/b) = \log a - \log b$$

$$\log(a^n) = n \log a$$

$$\ln e = 1$$

$$\ln e^a = a$$

$$\ln\left(\frac{1}{a}\right) = -\ln a$$

B.3 • GEOMETRY

The **distance**, d , between two points the coordinates of which are (x_1, y_1) and (x_2, y_2) is

$$d = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \quad [\text{B.17}]$$

The arc length, s , of a circular arc (Fig. B.4) is proportional to the radius, r , for a fixed value of θ (in radians)—the **radian measure**:

$$s = r\theta$$

$$\theta = \frac{s}{r} \quad [\text{B.18}]$$

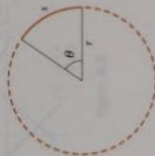


Figure B.4

Table B.2 gives the areas and volumes for several geometric shapes used throughout this book:

TABLE B.2 Useful Information for Geometry

Shape	Area or Volume	Shape	Area or Volume
Rectangle	Area = ℓw	Sphere	Surface area = $4\pi r^2$ Volume = $\frac{4\pi r^3}{3}$
Circle	Area = πr^2 (Circumference = $2\pi r$)	Cylinder	Lateral surface area = $2\pi r\ell$ Volume = $\pi r^2\ell$
Triangle	Area = $\frac{1}{2}bh$	Rectangular box	Area = $2(\ell h + \ell w + hw)$ Volume = ℓwh

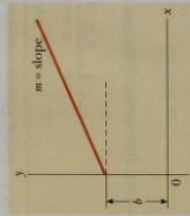


Figure B.5

The equation of a **straight line** (Fig. B.5) is

$$y = mx + b \quad [\text{B.19}]$$

where b is the y intercept and m is the slope of the line.

The equation of a **circle** of radius R centered at the origin is

$$x^2 + y^2 = R^2 \quad [\text{B.20}]$$

The equation of an **ellipse** with the origin at its center (Fig. B.6) is

$$\frac{x^2}{a^2} + \frac{y^2}{b^2} = 1 \quad [\text{B.21}]$$

where a is the length of the semimajor axis and b is the length of the semiminor axis.

The equation of a **parabola** the vertex of which is at $y = b$ (Fig. B.7) is

$$y = ax^2 + b \quad [\text{B.22}]$$

The equation of a **rectangular hyperbola** (Fig. B.8) is

$$xy = \text{constant} \quad [\text{B.23}]$$

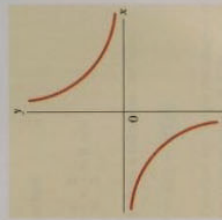


Figure B.8

B.4 • TRIGONOMETRY

That portion of mathematics based on the special properties of the right triangle is called trigonometry. By definition, a right triangle is one containing a 90° angle. Consider the right triangle in Figure B.9, where side a is opposite the angle θ , side b is adjacent to the angle θ , and side c is the hypotenuse of the triangle. The three basic trigonometric functions defined by such a triangle are the sine ($\sin$), cosine ($\cos$), tangent ($\tan$) functions. In terms of the angle θ , these functions are defined by

$$\sin \theta = \frac{\text{side opposite } \theta}{\text{hypotenuse}} = \frac{a}{c} \quad [\text{B.24}]$$

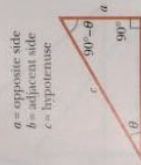


Figure B.9

$$\cos \theta = \frac{\text{side adjacent to } \theta}{\text{hypotenuse}} = \frac{b}{c} \quad [\text{B.25}]$$

$$\tan \theta = \frac{\text{side opposite } \theta}{\text{side adjacent to } \theta} = \frac{a}{b} \quad [\text{B.26}]$$

The Pythagorean theorem provides the following relationship between the sides of a right triangle:

$$c^2 = a^2 + b^2 \quad [\text{B.27}]$$

From the preceding definitions and the Pythagorean theorem, it follows that

$$\sin^2 \theta + \cos^2 \theta = 1$$

$$\tan \theta = \frac{\sin \theta}{\cos \theta}$$

The cosecant, secant, and cotangent functions are defined by

$$\csc \theta = \frac{1}{\sin \theta} \quad \sec \theta = \frac{1}{\cos \theta} \quad \cot \theta = \frac{1}{\tan \theta}$$

The following relations come directly from the right triangle shown in Figure B.9:

$$\begin{cases} \sin \theta = \cos(90^\circ - \theta) \\ \cos \theta = \sin(90^\circ - \theta) \\ \cot \theta = \tan(90^\circ - \theta) \end{cases}$$

Some properties of trigonometric functions are as follows:

$$\begin{cases} \sin(-\theta) = -\sin \theta \\ \cos(-\theta) = \cos \theta \\ \tan(-\theta) = -\tan \theta \end{cases}$$

$$\alpha + \beta + \gamma = 180^\circ$$

$$\text{Law of cosines} \quad \begin{cases} a^2 = b^2 + c^2 - 2bc \cos \alpha \\ b^2 = a^2 + c^2 - 2ac \cos \beta \\ c^2 = a^2 + b^2 - 2ab \cos \gamma \end{cases}$$

$$\text{Law of sines} \quad \frac{a}{\sin \alpha} = \frac{b}{\sin \beta} = \frac{c}{\sin \gamma}$$

Table B.3 lists a number of useful trigonometric identities.

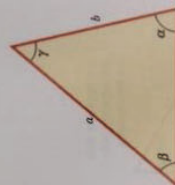


Figure B.10

TABLE B.3 Some Trigonometric Identities

$$\begin{aligned} \sin^2 \theta + \cos^2 \theta &= 1 & \csc^2 \theta &= 1 + \cot^2 \theta \\ \sec^2 \theta &= 1 + \tan^2 \theta & \sin^2 \frac{\theta}{2} &= \frac{1}{2}(1 - \cos \theta) \\ \sin 2\theta &= 2 \sin \theta \cos \theta & \cos^2 \frac{\theta}{2} &= \frac{1}{2}(1 + \cos \theta) \\ \cos 2\theta &= \cos^2 \theta - \sin^2 \theta & 1 - \cos \theta &= 2 \sin^2 \frac{\theta}{2} \\ \tan 2\theta &= \frac{2 \tan \theta}{1 - \tan^2 \theta} & \tan \frac{\theta}{2} &= \sqrt{\frac{1 - \cos \theta}{1 + \cos \theta}} \\ \sin(A \pm B) &= \sin A \cos B \pm \cos A \sin B \\ \cos(A \pm B) &= \cos A \cos B \mp \sin A \sin B \\ \sin A \pm \sin B &= 2 \sin \frac{1}{2}(A \pm B) \cos \frac{1}{2}(A \mp B) \\ \cos A + \cos B &= 2 \cos \frac{1}{2}(A + B) \cos \frac{1}{2}(A - B) \\ \cos A - \cos B &= 2 \sin \frac{1}{2}(A + B) \sin \frac{1}{2}(B - A) \end{aligned}$$

Example 3

Consider the right triangle in Figure B.11, in which $a = 2$, $b = 5$, and c is unknown. From the Pythagorean theorem, we have

$$\begin{aligned} c^2 &= a^2 + b^2 = 2^2 + 5^2 = 4 + 25 = 29 \\ c &= \sqrt{29} = 5.39 \end{aligned}$$

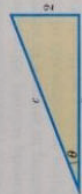


Figure B.11

$$\tan \theta = \frac{a}{b} = \frac{2}{5} = 0.400$$

From a table of functions or from a calculator, we have

$$\theta = \tan^{-1}(0.400) = 21.8^\circ$$

where $\tan^{-1}(0.400)$ is the notation for "angle the tangent of which is 0.400," sometimes written as $\arctan(0.400)$.

EXERCISES

- In Figure B.12, find (a) the side opposite θ , (b) the side adjacent to θ , (c) $\cos \theta$, (d) $\sin \theta$, and (e) $\tan \theta$.
Answers: (a) 3, (b) 3, (c) $\frac{4}{5}$, (d) $\frac{3}{5}$, (e) $\frac{3}{4}$
- In a certain right triangle, the two sides that are perpendicular to each other are 5m and 7m long. What is the length of the third side of the triangle?
Answer: 8.60 m
- A right triangle has a hypotenuse of length 3m, and one of its angles is 30° . What are the lengths of (a) the side opposite the 30° angle and (b) the side adjacent to the 30° angle?
Answers: (a) 1.5 m, (b) 2.60 m



Figure B.12

B.5 • SERIES EXPANSIONS

$$(a + b)^n = a^n + \frac{n}{1} a^{n-1} b + \frac{n(n-1)}{2!} a^{n-2} b^2 + \dots$$

$$(1 + x)^n = 1 + nx + \frac{n(n-1)}{2!} x^2 + \dots$$

$$e^x = 1 + x + \frac{x^2}{2!} + \frac{x^3}{3!} + \dots$$

$$\ln(1 \pm x) = \pm x - \frac{1}{2}x^2 \pm \frac{1}{3}x^3 - \dots$$

$$\sin x = x - \frac{x^3}{3!} + \frac{x^5}{5!} - \dots$$

$$\cos x = 1 - \frac{x^2}{2!} + \frac{x^4}{4!} - \dots$$

$$\tan x = x + \frac{x^3}{3} + \frac{2x^5}{15} + \dots \quad |x| < \pi/2$$

For $x \ll 1$, the following approximations can be used:

$$(1 + x)^n \approx 1 + nx \quad \sin x \approx x$$

$$e^x \approx 1 + x \quad \cos x \approx 1$$

$$\ln(1 \pm x) \approx \pm x \quad \tan x \approx x$$

B.6 • DIFFERENTIAL CALCULUS

In various branches of science, it is sometimes necessary to use the basic tools of calculus, first invented by Newton, to describe physical phenomena. The use of calculus is fundamental in the treatment of a variety of problems in newtonian mechanics, electricity, and magnetism. In this section, we simply state some basic properties and "rules of thumb," which should be a useful review.

First, a **function relation** must be specified that relates one variable to another (such as a coordinate as a function of time). Suppose one of the variables is called y (the dependent variable), and the other, x (the independent variable). We might have a function relation such as

$$y(x) = ax^3 + bx^2 + cx + d$$

If a , b , c , and d are specified constants, then y can be calculated for any value of x . We usually deal with continuous functions, that is, those for which y varies "smoothly" with x .

The **derivative** of y with respect to x is defined as the limit of the slopes of chords drawn between two points on the y versus x curve as Δx approaches zero. Mathematically, we write this definition as

$$\frac{dy}{dx} = \lim_{\Delta x \rightarrow 0} \frac{\Delta y}{\Delta x} = \lim_{\Delta x \rightarrow 0} \frac{y(x + \Delta x) - y(x)}{\Delta x} \quad [\text{B.28}]$$

where Δy and Δx are defined as $\Delta x = x_2 - x_1$ and $\Delta y = y_2 - y_1$ (see Fig. B.13).

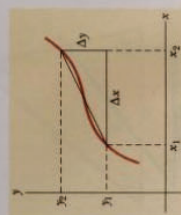


Figure B.13

A useful expression to remember when $y(x) = ax^n$, where a is a constant and n is any positive or negative number (integer or fraction), is

$$\frac{dy}{dx} = nax^{n-1} \quad [\text{B.29}]$$

If $y(x)$ is a polynomial or algebraic function of x , we apply Equation B.29 to each term in the polynomial and take $da/dx = 0$. It is important to note that dy/dx does not mean dy divided by dx but is simply a notation of the limiting process of the derivative, as defined by Equation B.28. In Examples 4 through 7, we evaluate the derivatives of several well-behaved functions.

Example 4

Suppose $y(x)$ (that is, y as a function of x) is given by

$$y(x) = ax^3 + bx + c$$

where a and b are constants. Then it follows that

$$\begin{aligned} y(x + \Delta x) &= a(x + \Delta x)^3 + b(x + \Delta x) + c \\ &= a(x^3 + 3x^2\Delta x + 3x\Delta x^2 + \Delta x^3) \\ &\quad + b(x + \Delta x) + c \end{aligned}$$

so

$$\Delta y = y(x + \Delta x) - y(x) = a(3x^2\Delta x + 3x\Delta x^2 + \Delta x^3) + b\Delta x$$

Substituting this into Equation B.28 gives

$$\begin{aligned} \frac{dy}{dx} &= \lim_{\Delta x \rightarrow 0} \frac{\Delta y}{\Delta x} = \lim_{\Delta x \rightarrow 0} [3ax^2 + 3x\Delta x + \Delta x^2] + b \\ &= 3ax^2 + b \end{aligned}$$

Example 5

$$y(x) = 8x^5 + 4x^3 + 2x + 7$$

Solution Applying Equation B.29 to each term independently and remembering that $d(\text{constant}) = 0$, we have

$$\frac{dy}{dx} = 8(5)x^4 + 4(3)x^2 + 2(1)x^0 + 0$$

$$\frac{dy}{dx} = 40x^4 + 12x^2 + 2$$

Special Properties of the Derivative

A. Derivative of the Product of Two Functions. If a function, y , is given by the product of two functions—say, $g(x)$ and $h(x)$ —then the derivative of y is defined as

$$\frac{d}{dx} [f(x)] = \frac{d}{dx} [g(x)h(x)] = g \frac{dh}{dx} + h \frac{dg}{dx} \quad [\text{B.30}]$$

B. Derivative of the Sum of Two Functions. If a function, y , is equal to the sum of two functions, then the derivative of the sum is equal to the sum of the derivatives:

$$\frac{d}{dx} [f(x)] = \frac{d}{dx} [g(x) + h(x)] = \frac{dg}{dx} + \frac{dh}{dx} \quad [\text{B.31}]$$

C. Chain Rule of Differential Calculus. If $y = f(x)$ and x is a function of some other variable, z , then dy/dz can be written as the product of two derivatives:

$$\frac{dy}{dx} = \frac{dy}{dx} \frac{dx}{dx}$$

[B.32]

D. The Second Derivative. The second derivative of y with respect to x is defined as the derivative of the function dy/dx (that is, the derivative of the derivative). It is usually written

$$\frac{d^2y}{dx^2} = \frac{d}{dx} \left(\frac{dy}{dx} \right)$$

[B.33]

Example 6

Find the first derivative of $y(x) = x^2/(x+1)^2$ with respect to x .

Solution We can rewrite this function in the alternate form $y(x) = x^2(x+1)^{-2}$ and apply Equation B.30 directly:

$$\frac{dy}{dx} = (x+1)^{-2} \frac{d}{dx} (x^2) + x^2 \frac{d}{dx} (x+1)^{-2}$$

$$\begin{aligned} &= (x+1)^{-2} 3x^2 + x^2(-2)(x+1)^{-3} \\ \frac{dy}{dx} &= \frac{3x^2}{(x+1)^2} - \frac{2x^3}{(x+1)^3} \end{aligned}$$

Example 7

A useful formula that follows from Equation B.30 is the derivative of the quotient of two functions. Show that the expression is given by

$$\frac{d}{dx} \left[\frac{g(x)}{h(x)} \right] = \frac{h \frac{dg}{dx} - g \frac{dh}{dx}}{h^2}$$

Solution We can write the quotient as gh^{-1} and then apply Equations B.29 and B.30:

$$\begin{aligned} \frac{d}{dx} \left(\frac{g}{h} \right) &= \frac{d}{dx} (gh^{-1}) = g \frac{d}{dx} (h^{-1}) + h^{-1} \frac{d}{dx} (g) \\ &= -gh^{-2} \frac{dh}{dx} + h^{-1} \frac{dg}{dx} \\ &= \frac{h \frac{dg}{dx} - g \frac{dh}{dx}}{h^2} \end{aligned}$$

TABLE B.4 Derivatives for Several Functions

$\frac{d}{dx} (a) = 0$	$\frac{d}{dx} (\cos ax) = -a \sin ax$	$\frac{d}{dx} (\sec x) = \tan x \sec x$
$\frac{d}{dx} (ax^n) = nax^{n-1}$	$\frac{d}{dx} (\tan ax) = a \sec^2 ax$	$\frac{d}{dx} (\csc x) = -\cot x \csc x$
$\frac{d}{dx} (e^{ax}) = ae^{ax}$	$\frac{d}{dx} (\cot ax) = -a \csc^2 ax$	$\frac{d}{dx} (\ln ax) = \frac{1}{x}$
$\frac{d}{dx} (\sin ax) = a \cos ax$		

Note: The letters a and n are constants.

Some of the most commonly used derivatives of functions are listed in Table B.4.

B.7 • INTEGRAL CALCULUS

We think of integration as the inverse of differentiation. As an example, consider the expression

$$f(x) = \frac{dy}{dx} = 3ax^2 + b$$

which was the result of differentiating the function

$$y(x) = ax^3 + bx + c$$

In Example 4, we can write the first expression, $dy = f(x) dx = (3ax^2 + b) dx$, and obtain $y(x)$ by "summing" over all values of x . Mathematically, we write this inverse operation as

$$y(x) = \int f(x) dx$$

For the function $f(x)$ already given,

$$y(x) = \int (3ax^2 + b) dx = ax^3 + bx + c$$

where c is a constant of the integration. This type of integral is called an *indefinite integral* because its value depends on the choice of the constant c .

A general **indefinite integral**, $I(x)$, is defined as

$$I(x) = \int f(x) dx \quad [\text{B.34}]$$

where $f(x)$ is called the *integrand* and $f(x) = \frac{dI(x)}{dx}$.

For a *general continuous* function $f(x)$, the integral can be described as the area under the curve bounded by $f(x)$ and the x axis, between two specified values of x —say, x_1 and x_2 —as in Figure B.14.

The area of the shaded element is approximately $f \Delta x$. If we sum all these area elements from x_1 to x_2 and take the limit of this sum as $\Delta x_i \rightarrow 0$, we obtain the *true* area under the curve bounded by $f(x)$ and x , between the limits x_1 and x_2 :

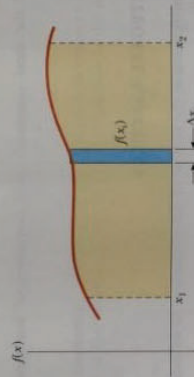


Figure B.14

$$\text{Area} = \lim_{\Delta x_i \rightarrow 0} \sum_{i=1}^n f(x_i) \Delta x_i = \int_{x_1}^{x_2} f(x) dx \quad [\text{B.35}]$$

Integrals of the type defined by Equation B.35 are called **definite integrals**. One of the common types of integrals that arise in practical situations has the form

$$\int x^n dx = \frac{x^{n+1}}{n+1} + c \quad (n \neq -1) \quad [\text{B.36}]$$

This result is obvious because differentiation of the right-hand side with respect to x gives $f(x) = x^n$ directly. If the limits of the integration are known, this integral becomes a *definite integral* and is written

$$\int_{x_1}^{x_2} x^n dx = \left[\frac{x^{n+1}}{n+1} \right]_{x_1}^{x_2} = \frac{x_2^{n+1} - x_1^{n+1}}{n+1} \quad (n \neq -1) \quad [\text{B.37}]$$

Examples

1. $\int_0^e x^2 dx = \left[\frac{x^3}{3} \right]_0^e = \frac{e^3}{3}$
2. $\int_0^8 x^{3/2} dx = \left[\frac{x^{5/2}}{5/2} \right]_0^8 = \frac{2}{5} \left[\frac{8^{5/2}}{2} \right] = \frac{2}{5} \cdot \frac{32\sqrt{2}}{2} = \frac{64\sqrt{2}}{5}$
3. $\int_3^5 x dx = \left[\frac{x^2}{2} \right]_3^5 = \frac{5^2 - 3^2}{2} = 8$

Partial Integration

Sometimes it is useful to apply the method of *partial integration* to evaluate certain integrals. The method uses the property that

$$\int u dv = uv - \int v du \quad [\text{B.38}]$$

where u and v are *carefully* chosen in order to reduce a complex integral to a simpler one. In many cases, several reductions have to be made. Consider the example

$$I(x) = \int x^2 e^x dx$$

This can be evaluated by integrating by parts twice. First, if we choose $u = x^2$, $v = e^x$, we get

$$\int x^2 e^x dx = \int x^2 d(e^x) = x^2 e^x - 2 \int e^x x dx + c_1$$

Now, in the second term, choose $u = x$, $v = e^x$, which gives

$$\int x^2 e^x dx = x^2 e^x - 2x e^x + 2 \int e^x dx + c_1$$

or

$$\int x^2 e^x dx = x^2 e^x - 2x e^x + 2e^x + c_2$$

The Perfect Differential

Another useful method to remember is the use of the *perfect differential*. That is, we should sometimes look for a change of variable such that the differential of the function is the differential of the independent variable appearing in the integrand. For example, consider the integral

$$I(x) = \int \cos^2 x \sin x dx$$

This becomes easy to evaluate if we rewrite the differential as $d(\cos x) = -\sin x dx$. The integral then becomes

$$\int \cos^2 x \sin x dx = - \int \cos^2 x d(\cos x)$$

If we now change variables, letting $y = \cos x$, we get

$$\int \cos^2 x \sin x dx = - \int y^2 dy = - \frac{y^3}{3} + c = - \frac{\cos^3 x}{3} + c$$

APPENDIX C

Periodic Table of the Elements

Group I	Group II	Transition elements									
H 1 1.0080 1s ¹											
Li 3 6.94 2s ¹	Be 4 9.012 2s ²										
Na 11 22.99 3s ¹	Mg 12 24.31 3s ²										
K 19 39.102 4s ¹	Ca 20 40.08 4s ²	Sc 21 44.96 3d ¹ 4s ²	Ti 22 47.88 3d ² 4s ²	V 23 50.94 3d ³ 4s ²	Cr 24 51.996 3d ⁵ 4s ¹	Mn 25 54.94 3d ⁵ 4s ²	Fe 26 55.85 3d ⁶ 4s ²	Co 27 58.93 3d ⁷ 4s ²			
Rb 37 85.47 5s ¹	Sr 38 87.62 5s ²	Y 39 88.91 4d ¹ 5s ²	Zr 40 91.22 4d ² 5s ²	Nb 41 92.91 4d ⁴ 5s ¹	Mo 42 95.94 4d ⁵ 5s ¹	Tc 43 98.91 4d ⁵ 5s ²	Ru 44 101.1 4d ⁷ 5s ¹	Rh 45 102.91 4d ⁸ 5s ¹			
Cs 55 132.91 6s ¹	Ba 56 137.34 6s ²										
Fr 87 (223) 7s ¹	Ra 88 (226) 7s ²										

* Lanthanide series

** Actinide series

† Atomic mass values given are averaged over isotopes in the percentages in which they exist in nature.
 ‡ For an unstable element, mass number of the most stable known isotope is given in parentheses.
 § The names for elements 104–109 are controversial. The names given here are those recommended by the discoverers.

Group III	Group IV	Group V	Group VI	Group VII	Group 0
B 5 10.81 2p ¹	C 6 12.011 2p ²	N 7 14.007 2p ³	O 8 15.999 2p ⁴	F 9 18.998 2p ⁵	Ne 10 20.18 2p ⁶
Al 13 26.98 3p ¹	Si 14 28.09 3p ²	P 15 30.97 3p ³	S 16 32.06 3p ⁴	Cl 17 35.453 3p ⁵	Ar 18 39.948 3p ⁶
Ga 31 69.72 4p ¹	Ge 32 72.59 4p ²	As 33 74.92 4p ³	Se 34 78.96 4p ⁴	Br 35 79.91 4p ⁵	Kr 36 83.80 4p ⁶
In 49 114.82 5p ¹	Sb 50 118.59 5p ²	Te 51 127.60 5p ³	I 52 126.90 5p ⁴	Xe 53 131.30 5p ⁵	
Tl 81 204.37 6p ¹	Pb 82 207.2 6p ²	Bi 83 208.98 6p ³	Po 84 (210) 6p ⁴	At 85 (218) 6p ⁵	Rn 86 (222) 6p ⁶

Eu 63 152.0 4f ⁷ 6s ²	Gd 64 157.25 4f ⁷ 5d ¹ 6s ²	Tb 65 158.93 4f ⁷ 6s ²	Dy 66 162.50 4f ⁹ 6s ²	Ho 67 164.93 4f ¹⁰ 6s ²	Er 68 167.26 4f ¹¹ 6s ²	Tm 69 168.93 4f ¹² 6s ²	Yb 70 173.04 4f ¹³ 6s ²	Lu 71 174.97 4f ¹⁴ 6s ²
Am 95 (243) 5f ⁷ 6d ¹ 7s ²	Cm 96 (247) 5f ⁷ 6d ² 7s ²	Bk 97 (247) 5f ⁷ 6d ³ 7s ²	Cf 98 (251) 5f ⁷ 6d ⁴ 7s ²	Es 99 (252) 5f ⁷ 6d ⁵ 7s ²	Fm 100 (253) 5f ⁷ 6d ⁶ 7s ²	Md 101 (258) 5f ⁷ 6d ⁷ 7s ²	No 102 (259) 5f ⁷ 6d ⁸ 7s ²	Lr 103 (260) 5f ⁷ 6d ⁹ 7s ²

SI Units

TABLE D.1 SI Base Units

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

TABLE D.2 Some Derived SI Units

Quantity	Name	Symbol	Expression in Terms of Base Units	Expression in Terms of Other SI Units
Plane angle	radian	rad	m/m	
Frequency	hertz	Hz	s ⁻¹	
Force	newton	N	kg·m/s ²	J/m
Pressure	pascal	Pa	kg/m·s ²	N/m ²
Energy/work	joule	J	kg·m ² /s ²	N·m
Power	watt	W	kg·m ² /s ³	J/s
Electric charge	coulomb	C	A·s	
Electric potential (emf)	volt	V	kg·m ² /A·s ³	W/A
Capacitance	farad	F	A ² ·s ⁴ /kg·m ²	C/V
Electric resistance	ohm	Ω	kg·m ² /A ² ·s ³	V/A
Magnetic flux	weber	Wb	kg·m ² /A·s ²	V·s
Magnetic field intensity	tesla	T	kg/A·s ²	Wb/m ²
Inductance	henry	H	kg·m ² /A ² ·s ²	Wb/A

Spreadsheet Problems

Overview

Students come to introductory physics courses with a wide variety of computing experience. Many are already accomplished programmers in one or more programming languages (BASIC, Pascal, FORTRAN, and so forth). Others have never even turned on a computer. To further complicate matters, a wide variety of hardware environments exists, although the vast majority can be classified as IBM/compatible (MS-DOS) or Macintosh environments. We have designed the spreadsheet problems and *Spreadsheet Investigations in Physics* to be usable by and useful to students in all these diverse situations. Our goal is to enable students to investigate a range of physical phenomena and obtain a feed for the physics. Merely "getting the right answer" by plugging numbers into a formula and comparing the result to the answer in the back of the book is discouraged.

Spreadsheets are particularly valuable in exploratory investigations. Once you have constructed a spreadsheet, you can simply vary the parameters and see instantly how things change. Even more important is the ease with which you can construct accurate graphs of relations between physical variables. When you change a parameter, you can view the effects of the change upon the graphs simply by pressing a key or clicking a mouse button. "What if" questions can be easily addressed and depicted graphically.

How to Use the Templates

The computer spreadsheet problems are arranged by difficulty level. The least difficult problems are coded in black. For most of these problems, spreadsheets are provided on disk. Only the input parameters need to be changed. Problems of moderate difficulty are coded in blue. These require additional analysis and the provided spreadsheets will need to be modified to solve them. The most challenging problems are coded in magenta. For most of these, you must develop your own spreadsheets. The emphasis should be on understanding what the results mean rather than just getting an answer. For example, one spreadsheet problem explores the strategies for fuel burn rates in rocket propulsion. How long and at what rate should the rocket fuel be burned to obtain the highest velocity or the greatest distance?

Software Requirements

The spreadsheet template files are provided on a high-density (1.44 MB) 3.5" diskette, which can be obtained in either of two forms. The disk for the Macintosh environment will contain files in the file format used by the program Microsoft Excel 5.0 for the Macintosh.

Since there are many spreadsheet programs used in the IBM/compatible environment, the disk for Windows and DOS users will contain three different versions of the spreadsheet template files. These versions are chosen to allow the diskette to be usable by as many students as possible. The file **123WIN.EXE** contains templates in the format suitable for use in the program Lotus 1-2-3 for Windows. Release 4 or 5. Files in this format have filenames in the form *WK4, where * stands for a filename of eight letters or less. The file **EXCELWIN.EXE** contains templates in the format used by Microsoft Excel for Windows, Version 5.0; files in this format have the form *XLS. Finally, for students using an earlier version of Lotus 1-2-3 or Excel or using other popular spreadsheet programs (including non-Windows programs), a third file, **123DOS.EXE**, contains templates in the format introduced with the versions 2.x of DOS-based Lotus 1-2-3; files in this format have the form *WK1. The Lotus WK1 format can be read directly by almost all spreadsheet programs, including Lotus 1-2-3 (versions 2.0 and later), Excel, Microsoft Works, and Quattro Pro. The file Scholar program can also import WK1 spreadsheets; however, some minor format changes of the templates are needed.

To fit these versions of the template files onto one diskette, the diskette is supplied with the files in compressed form. These files are self-extracting; they can be decompressed by a simple procedure without using any external programs. Choose the version you want, copy the compressed file to a subdirectory on a hard disk, and execute the file. For example, to install the Lotus for Windows templates in the subdirectory C:\INVEST, do the following steps:

- A. Make sure that the subdirectory C:\INVEST exists. If it does not exist, make the subdirectory.
- B. Copy the file 123WIN.EXE from the distribution disk to the subdirectory C:\INVEST.
- C. Run or launch the file 123WIN.EXE. The templates will be extracted and are then ready to be used.

The templates on the Macintosh diskette are for Excel 5.0 for the Macintosh. The templates are not compressed. Copy these templates to a folder; they are ready to be used just as they are.

Hardware Requirements

You will need a microcomputer that can run one of the spreadsheet programs in one of their many versions. Your computer should be connected to a printer that can print text and graphics. Older versions of the software will run on a 8086/8088 MS-DOS system with just a single floppy disk drive or on a 512K Macintosh with two floppy drives. Newer versions require a more powerful computer to run effectively. For example, to run Excel For Windows, Version 5.0, you must have a hard disk with about 15 megabytes of disk memory available and 4 to 8 megabytes of RAM memory. Your software manuals will tell you exactly what you need to run the particular version of your spreadsheet program. However, all the problems require only a minimal computer system.

There are many different software versions and many different computer configurations. You might have one floppy drive, two floppy drives, a hard disk, a local area network, and so on. The combinations are almost endless. Our best suggestion is to read your software manual and ask your instructor or computer laboratory personnel how to start your spreadsheet program.

Spreadsheet Tutorial

Some students will have the needed computer and spreadsheet skills to start working with the templates immediately. Other students, who have not used a spreadsheet program before, will need some instruction. We have written *Spreadsheet Investigations in Physics* for both these groups of students. The first part contains a spreadsheet tutorial that the novice student can use *independently* to gain the required spreadsheet skills. A two- or three-hour initial session with the tutorial and the computer is all that most students need to get started. Once the students have mastered the basic operations of the spreadsheet program, they should try one or two of the easier problems.

Because very few introductory physics students have studied numerical methods, we have also included a brief introduction to numerical methods in *Spreadsheet Investigations in Physics*. This section covers numerical interpolation, differentiation, integration, and the solution of simple differential equations. The student should not try to master all of this material at one time; only study the sections that are needed to solve the currently assigned problems.

The templates supplied on the distribution diskettes with *Spreadsheet Investigations in Physics* constitute an outline. You must enter the appropriate data and parameters. The parameters must be adjusted to fit the needs of your problem. Feel free to change any parameters, to expand or decrease the number of rows of output, and to change the size of increments (for example, in time or distance). Most templates have graphs associated with them. You may have to adjust the ranges of variables plotted and the scales for the axes. See the tutorials for how to adjust the appearance of your graphs.

Answers to Odd-Numbered Problems

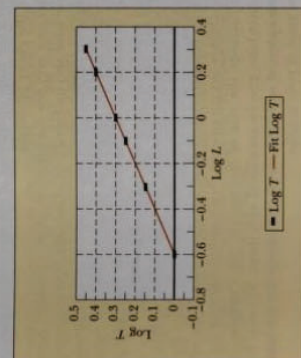
Chapter 1

- (a) 4.00 u = 6.64×10^{-24} g
(b) $55.9 \text{ u} = 9.28 \times 10^{-26}$ g
(c) $207 \text{ u} = 3.44 \times 10^{-22}$ g
- 2.86 cm
- (a) 623 kg/m^3
(b) Yes, because this is less than 1000 kg/m^3
- $0.579 \text{ t ft}^2/\text{s} + 1.19 \times 10^{-9} \text{ ft}^2/\text{s}^2$
- (a) $6.31 \times 10^4 \text{ AU}$ (b) $1.33 \times 10^{11} \text{ AU}$
- 151 μm
- (a) $1.609 \text{ km/h} = 1 \text{ mi/h}$ (b) 88 km/h (c) 16 km/h
- 1.19×10^{27}
- $\sim 10^7$ tuners
- (a) 797 (b) 11 (c) 18
- (a) $346 \text{ m}^2 \pm 13 \text{ m}^2$ (b) $(66.0 \pm 1.3) \text{ m}$
- $(-2.75, -4.76) \text{ m}$
- (a) $(2.17 \text{ m}, 1.25 \text{ m})$ and $(-1.90 \text{ m}, 3.29 \text{ m})$
(b) 4.55 m
- (a) 10.0 m (b) 15.7 m (c) 0
- (a) 5.2 m at 60° (b) 3.0 m at 330°
- (a) 3.0 m at 150° (b) 5.2 m at 300°
- 47.2 units at 122°
- 227 paces at 165°
- (a) $R_s = 49.5 \text{ units}$; $R_p = 27.1 \text{ units}$
(b) 56.4 units at 28.7°
- 240 m at 23°
- 196 cm at -14.7°
- 0.449%
- $5 \times 10^6 \text{ gal}$
- $6 \times 10^{26} \text{ kg}$
- $\sim 10^{11}$
- (a) A plot of $\log T$ versus $\log L$ for the given data shows an approximate linear relationship. Applying the least-squares method to the data yields 0.503 for the slope and 0.302 for the intercept of the straight line that best fits the data. The data points and the best-fit line, $\log T = 0.503 \log L + 0.302$ are shown in the figure at the top of the second column.

Chapter 2

- (a) 2.30 m/s (b) 16.1 m/s (c) 11.5 m/s
- (a) 5 m/s (b) 1.2 m/s (c) -2.5 m/s
(d) -3.3 m/s (e) 0

A.36



- (a) $2v_{0y}/(v_1 + v_2)$ (b) 0
- (a) -2.4 m/s (b) -3.2 m/s (c) 4 s
- (a) 5 m/s (b) -2.5 m/s (c) 0
- 5 m/s
- $1.34 \times 10^4 \text{ m/s}^2$
- (a) 2.0 m (b) -3.0 m/s (c) -2.0 m/s^2
- (a) 1.3 m/s^2 (b) 2 m/s^2 at 3 s
- (a) $t = 6 \text{ s}$ and for $t > 10 \text{ s}$ (d) -1.5 m/s^2 at 8 s
- -16.0 cm/s^2
- 160 ft
- (a) 20.0 s (b) no
- 3.10 m/s
- (a) -202 m/s^2 (b) 198 m
- (a) 10.0 m/s up (b) 4.68 m/s down
- (a) 29.4 m/s (b) 44.1 m
- (a) 7.82 m (b) 0.782 s
- (a) 5.00 m/s (b) 6.00 s (c) -0.300 m/s^2
- 2.05 m/s
- Yes, at 11.4 s and 212 m
- 0.509 s
- (a) 5.43 m/s^2 and 3.83 m/s^2 (c) Maggie by 2.62 m
- 10.9 m/s and 11.5 m/s
- -10^4 m/s^2
- (a) 2.99 s (b) -15.4 m/s
- (a) 31.3 m/s down and 34.9 m/s down
- (a) 26.4 m (b) 6.88%

Answer Section

A.37

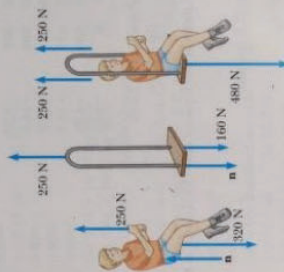
- (a) 5.46 s (b) 73.0 m (c) 26.7 m/s and 22.6 m/s
- (c) $v = 0$ and $a = v_0^2/h$ (d) $v = v_0$ and $a = 0$
- $v/\sqrt{3}$
- (a) At approximately $t = 37.0 \text{ s}$ after the police car starts, or 42.0 s after the first police officer sees the speeder.
(b) 74.0 m/s (c) 1370 m

Chapter 3

- (a) 4.87 km at 209° from east (b) 23.3 m/s
(c) 13.5 m/s at 209°
- (a) $18.04 + (4.00t - 4.90t^2) \text{ J}$ (b) -9.80 J
(c) -9.80 J (d) $18.04 - 25.4 \text{ J}$ (e) $(18.04 - 25.4 \text{ J}) \text{ m}$
- (a) $(2.00 + 3.00 \text{ J}) \text{ m/s}^2$
(b) $(3.00 + 4.00 \text{ J}) \text{ m/s}^2$ (c) -2.00 J (d) 3.00 J
- (a) $a_x = 0.800 \text{ m/s}^2$; $a_y = -0.300 \text{ m/s}^2$ (b) 339°
(c) $(3604 - 72.7 \text{ J}) \text{ m}$, -15.2°
- (a) 3.34 m/s (b) -50.9°
- 74.5 m/s
- 48.6 m/s
- 0.600 m/s^2
- (a) 2.67 s (b) 29.04 m/s (c) $(29.04 - 26.3 \text{ J}) \text{ m/s}$
- (a) The ball clears by 0.889 m (b) while descending
- 67.8°
- (a) 1.03 s (b) $(8.671 + 4.20 \text{ J}) \text{ m/s}$ (c) 25.8°
- 377 m/s^2
- (a) 6.00 rev/s (b) 1.52 km/s^2 (c) 1.28 km/s^2
- (a) 7.90 km/s (b) $5.07 \text{ ks} = 1.41 \text{ h}$
- 1.48 m/s^2
- (a) 13.0 m/s^2 (b) 5.70 m/s (c) 7.50 m/s^2
- (a) 4.004 m/s (b) $(4.004 + 6.00 \text{ J}) \text{ m}$
- (a) 41.7 m/s (b) 3.81 s
- (a) $v_x = 34.1 \text{ m/s}$; $v_y = -13.4 \text{ m/s}$; 36.6 m/s
- 8.94 m/s at -63.4°
- 20.0 m
- (a) 6.80 km (b) 3.00 km vertically above the impact point
- 66.2°
- (a) 46.5 m/s (b) -77.6° (c) 6.34 s
- (a) 20.0 m/s , 5.00 s (b) $(16.0\hat{x} - 27.1\hat{y}) \text{ m/s}$
- 6.34 s
- (a) 43.2 m (b) $v_x = 9.66 \text{ m/s}$; $v_y = -25.6 \text{ m/s}$
- Less than 265 m and more than 3.48 km
- There are an infinite number of solutions to the problem; however, there is one practical limitation. We can estimate that the maximum speed that the punter can give the ball is about 20 to 30 m/s . Use a speed in this range.
- There are an infinite number of solutions. For example if $v_0 = 22.32 \text{ m/s}$ at 45° , then the ball clears the crossbar in 3.01 s . Or if $v_0 = 24.60 \text{ m/s}$ at 30° , then the ball clears the crossbar in 2.23 s . The time it takes the ball to clear

Chapter 4

- (a) $1/3$ (b) 0.750 m/s^2
- $(6.00\hat{x} + 15.0\hat{y}) \text{ N}$; 16.2 N
- (a) 1.44 m (b) $(50.5\hat{x} + 1.40\hat{y}) \text{ N}$
- (a) $(2.50\hat{x} + 5.00\hat{y}) \text{ N}$ (b) 5.59 N
- (a) $3.64 \times 10^{-18} \text{ N}$
- $8.93 \times 10^{-30} \text{ N}$, which is 408 billion times smaller
- (a) 534 N down (b) 54.4 kg
- 5.00 m/s^2 at 36.9° (b) 6.08 m/s^2 at 25.3°
- (a) $\sim 10^{-22} \text{ m/s}^2$ (b) $\sim 10^{-23} \text{ m}$
- (a) 0.300 m/s^2 forward (b) 10.0 m (c) 2.00 m/s
- (a) 15.0 lb up (b) 5.00 lb up (c) 0
- (a) 31.5 N ; 37.5 N ; 49.0 N (b) 113 N ; 56.6 N ; 98.0 N
- (a) 514 N ; 557 N ; 323 N
- (a) 5.10 kN (b) 3620 kg
- 8.66 N east
- 3.73 m
- $a = F/(m_1 + m_2)$; $T = Fm_1/(m_1 + m_2)$
- (a) $a_1 = 2a_2$
(b) $T_1 = m_1 m_2 g / (2m_1 + \frac{1}{2}m_2)$ and $T_2 = m_1 m_2 g / (m_1 + \frac{1}{2}m_2)$
- (a) $a_1 = m_2 g / (2m_1 + \frac{1}{2}m_2)$ and $a_2 = m_2 g / (4m_1 + m_2)$
- (a) 706 N (b) 814 N (c) 706 N (d) 648 N
- (a) 3.00 s (b) $(18.0\hat{x} - 9.00\hat{y}) \text{ m}$ (c) 20.1 m
- 1.66 MN
- (a)



- (b) 0.408 m/s^2 (c) 83.3 N
- 1.18 kN
- $Mg/2$, $Mg/2$, $Mg/2$, $3Mg/2$, Mg
- $(M + m_1 + m_2)(m_2 g / m_1)$
- (a) 30.7° (b) 0.843 N

Chapter 5

1. $\mu_s = 0.306$; $\mu_k = 0.245$
3. (a) 256 m (b) 42.7 m
5. (d) 2.67 m/s (b) 0.368 (c) 9.37 N
7. (a) 0.161 (b) 1.01 m/s²
9. 37.8 N
11. (a) 0.931 m/s² (b) 6.10 cm
13. Any speed up to 8.08 m/s
15. (a) 9.13 $\times 10^{22}$ m/s² (b) 83.2 nN
17. (a) static friction (b) 0.0850
19. (a) 68.6 N toward the center of the circle and 784 N up
- (b) 0.857 m/s²
21. No. The jungle-ford needs a vine of minimal tensile strength 1.38 kN.
23. (a) 6670 N up (b) 20.3 m/s
25. 3.15 m/s
27. (a) 32.7 s⁻¹ (b) 9.80 m/s² down
- (c) 4.90 m/s² down
29. (a) 0.0347 s⁻¹ (b) 2.50 m/s (c) $a = -cv$
31. (a) 13.7 m/s down
- (b) (a) 0 (b) 0 (c) 0 (d) 0
- (e) 0 (f) 0 (g) 0 (h) 0 (i) 0 (j) 0 (k) 0 (l) 0 (m) 0 (n) 0 (o) 0 (p) 0 (q) 0 (r) 0 (s) 0 (t) 0 (u) 0 (v) 0 (w) 0 (x) 0 (y) 0 (z) 0

33. (a) 49.5 m/s down and 4.95 m/s down
- (b) (a) 0 (b) 0 (c) 0 (d) 0 (e) 0 (f) 0 (g) 0 (h) 0 (i) 0 (j) 0 (k) 0 (l) 0 (m) 0 (n) 0 (o) 0 (p) 0 (q) 0 (r) 0 (s) 0 (t) 0 (u) 0 (v) 0 (w) 0 (x) 0 (y) 0 (z) 0

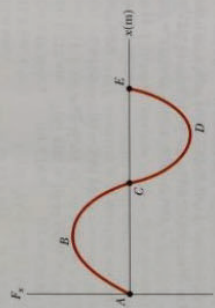
35. 2.97 nN
37. 0.612 m/s² toward the Earth
39. (a) 19.3° (b) 4.21 N
41. 2.14 rev/min
43. (b) 732 N down at the Equator and 735 N down at the poles
45. 20.1°
47. (b) 2.54 s; 23.6 rev/min
49. 12.8 N
51. 1.26 $\times 10^{22}$ kg
53. $\sim 10^{-7}$ N toward you

Chapter 6

1. 15.0 MJ
3. (a) 32.8 mJ (b) -32.8 mJ
5. 4.70 kJ

A.39

33. (a) -1.67×10^{-14} J (b) At the center
35. (a) + at B, - at D, 0 at A, C, and E
- (b) C stable, A and E unstable
- (c)



37. A/r^2
39. (a) 0.225 J (b) $W_{ac} = -0.363$ J (c) No; the normal force changes in a complicated way because of the curved slope.
41. 0.328
43. 0.115
45. 1.24 m/s
47. (a) 0.400 m (b) 4.10 m/s (c) The block stays on the track
49. 914 N/m
51. 2.06 m/s

53. If the particle has an initial energy less than 2471 J, it will be trapped in the potential well; for example, if $E_p = 1000$ J, it will be confined approximately to $-3.15 \text{ m} \leq x \leq 4.58 \text{ m}$.
55. $x = 0$ is a point of stable equilibrium; $x = 8.33 \text{ m}$ is a point of unstable equilibrium.

Chapter 9

5. 0.866c
7. 64.9/min; 10.6/min
9. 1.54 ns
11. 0.800c
13. (a) 2.18 μ s (b) 649 m
15. 0.696c
17. 0.900c
19. 0.0880
21. (a) 2.73×10^{-24} kg·m/s (b) 1.58×10^{-22} kg·m/s
- (c) 5.64×10^{-22} kg·m/s
23. (a) 0.850c (b) No change
25. 0.285c
27. (a) 939 MeV (b) 3.01 GeV (c) 2.07 GeV
29. (a) 0.582 MeV (b) 2.45 MeV
31. 10^{-15}
33. 42.1 g/cm³
37. 0.687%
39. (a) a few hundred seconds (b) $\sim 10^6$ km
41. (a) 83.3 ns (b) 23.7 m
43. Yes, with 18.8 m to spare
47. (b) For ϵ small compared to ϵ , the relativistic agrees with the classical expression. As ϵ approaches ϵ , the acceleration approaches zero, so the object can never reach or surpass the speed of light.
- (c) Perform $\int (1 - v^2/c^2)^{-3/2} dv = (dL/m) \int dt$ to obtain $v = gct/(mc^2 + g^2t^2/c^2)^{1/2}$ and then

Chapter 8

1. (9.004 - 12.0) kg·m/s; 15.0 kg·m/s
3. 6.25 cm/s west
5. (a) 6.00 m/s (b) 8.40 J
7. (a) 13.5 N·s (b) 9.00 kN (c) 18.0 kN
9. 260 N normal to the wall
11. 87.5 N
13. 301 m/s
15. (4M/m)(g²)^{1/2}
17. (a) 20.9 m/s east (b) 8.68 kJ into thermal energy
19. (a) 0.284 (b) 115 fJ and 45.4 fJ
21. 91.2 m/s
23. 0.556 m
25. (a) 2.88 m/s at 32.3° north of east (b) 783 J into thermal energy
27. 2.50 m/s at -60.0°
29. (a) 1.07 m/s at -29.7° (b) 0.318
31. (a) (-9.33 - 8.33j) Mm/s (b) 439 fJ
33. $\mathbf{r}_{CM} = (0 + 1.00j)$ m

Chapter 7

1. (a) 259 kJ, 0, 259 kJ (b) 0, -259 kJ, 259 kJ
3. (a) 80.0 J (b) 10.7 J (c) 0
5. (a) 40.0 J (b) -40.0 J (c) 62.5 J
7. (a) 22.0 J, 40.0 J (b) Yes
9. $v = (3g/0)^{1/2}$, 0.0980 N down
11. (a) 4.43 m/s (b) 5.00 m
13. 1.84 m
15. (a) 18.5 km, 51.0 km (b) 10.0 MJ
17. At $h = 2H/3$ or at $h = R$, whichever is smaller
19. 2.00 m/s, 2.79 m/s, 3.19 m/s
21. 3.74 m/s
23. (a) -160 J (b) 73.5 J (c) 28.8 N (d) 0.679
25. (a) 24.5 m/s (b) Yes (c) 206 m
- (d) unrealistic
29. 289 m
31. (a) 1.84×10^9 kg/m³ (b) 3.27 Mn/m²
- (c) -2.08×10^{15} J

A.40

$$\int dx = \int qEa(m^2c^2 + q^2E^2t^2)^{-1/2} dt \text{ to obtain}$$

- | Sl. | (a) | Z | 0.2 | 0.5 | 1.0 | 2.0 |
|-----|-----|-------|-------|-------|-------|-------|
| | | v/c | 0.180 | 0.385 | 0.600 | 0.800 |
- (b) For $Z = 3.8$, $v/c = 0.870$
 For $Z = 0.2$, $r = 2710$ Mly; $Z = 0.5$, $r = 5770$ Mly;
 $Z = 1.0$, $r = 9900$ Mly; and $Z = 2.0$, $r = 12\ 000$ Mly and
 $Z = 3.8$, $r = 13\ 800$ Mly

Chapter

1. (a) $5.99 \times 10^{-7} \text{ rad/s}$ (b) $2.65 \times 10^{-6} \text{ rad/s}$
 2. (a) 5.24*r* (b) 27.4 rad
 3. (a) 892 rad/s^2 (b) $4.21 \times 10^3 \text{ rad}$
 4. 7.50 rev
 5. (a) 25.0 rad/s (b) 39.8 rad/s² (c) 0.628*s*
 6. (a) 126 rad/s (b) 3.77 m/s² (c) 1.26 km/s²
 7. (d) 20.1 m
 8. 0.345
 9. (a) 143 kg·m² (b) 2.57 kJ
 10. 15.35
 11. 17. –3.52 N·m
 12. (a) –17.0*s*
21. No. The cross product must be perpendicular to each of its factors, having zero dot product with either of them.
22. 2.94 kN on each wheel and 4.41 kN on each front wheel
23. 1.46 kN, 1.33 kN (to the right) and 2.58 kN (upward)
24. (a) 24.0 N·m (b) 0.0356 rad/s² (c) 1.07 m/s²
25. 17.3 kJ kg·m²/s
26. 31. 60.0 kg·m²/s
27. –*m*²/g² cos ϕ
28. (a) 0.560 rad/s, counterclockwise (b) 99.9*s*
29. (a) $7.20 \times 10^{-3} \text{ kg}\cdot\text{m}^2/\text{s}$ (b) 9.47 rad/s
30. $-10^3 \text{ kg}\cdot\text{m}^2$ (c) 750*s*
31. (a) 500*s* (b) 250*s*
32. 5g/2*l* and 3g/2*l*
33. $2\pi/(6g/3)^{1/2}$ (b) $4(Rg/3)^{1/2}$ (c) $(Rg)^{1/2}$
34. $1.21 \times 10^{-4} \text{ kg}\cdot\text{m}^2$
35. (a) 118 N and 156 N (b) 1.17 kg·m²
36. (a) $(2mg \sin \theta + mR^2)^{1/2} (l + mR^2)^{-1/2}$ (c) 1.74 rad/s
37. 1.74 rad/s
38. (a) 3750 kg·m²/s (b) 1.88 kJ (c) 3750 kg·m²/s
39. (d) 10.0 m/s (e) 7.50 kJ (f) 5.62 kJ
40. 3*π*/8
41. The answer is not unique because the torque = *FR*.

Chapter 1

1. The sun; 5.90 mN versus 33.3 μ N
3. 2/3
5. 346 Mm
7. 1.97

Chapter

1. (a) 150 Hz, 0.667 s (b) 4.00 m (c) π rad
2. (a) 2.83 m (b) 0.350 m (c) 0.350 m
3. 18.8 m/s, 7.11 km^2/s^2
4. (a) 18.8 cm/s, 0.333 s (b) 178 cm^2/s^2 , 0.500 s
5. (a) 12.0 cm (b) 46.0 J
6. (a) 575 N/m (b) 46.0 J
7. (a) 40.0 cm/s, 160 cm/s (b) 40.0 cm/s, 160 cm/s
8. (a) 32.0 cm/s, -96.0 cm^2/s^2 (b) 32.0 cm/s, -96.0 cm^2/s^2
9. (a) 0.232 s (b) 0.232 s
10. 0.628 m/s
11. (a) 6.28 m/s (b) 0.178 m
12. (a) 126 m (b) 1.02 m/s
13. 2.23 m/s
14. (a) 25.0 m (b) 1.02 m/s
15. (a) 25.0 m (b) 1.02 m/s
16. (a) 15.8 m (b) 6.06 s
17. (a) 1.35 m
18. (a) 1.35 m
19. (a) 1.35 m

Chapter

1. $y = 6[(x - 4.5\pi)^2 + 3]^{-1}$
3. (a) left (b) 5.00 m/s
5. 0.319 m
7. (a) $y = (8.00 \text{ cm})\sin(7.85x + 6.00\pi t)$
(b) $y = (8.00 \text{ cm})\sin(7.85x + 6.00\pi t - 0.785)$
(c) 2.00 cm, 2.98 m, 0.576 Hz, 1.72 m/s
9. (a) 2.15 cm (b) 1.95 rad (c) 541 cm/s
(d) $y = (2.15 \text{ cm})\sin(8.38x + 80\pi t + 1.95)$
11. (a) -73.3° (b) 0.858 cm
13. (a) 80.0 N (b) 15.8 m/s
15. 80.0 N
17. 631 N
19. 1.64 m, s^{-2}
21. 55.1 Hz
23. $(\sqrt{2})P_0$
25. 7.82 m
27. 2.94 m, 5.81 m
29. 2.94 m
31. (a) A drop by 75.7 Hz (b) 0.948 m
33. (a) 33.3 m/s (b) 33.3 m/s
35. 430 Hz to 441 Hz
37. (a) 30.2 N (b) 0.892 m (c) 83.6 m/s
39. (a) 3.338 m/s (b) -5.48 cm (c) 0.667 m, 5.00 Hz
41. (a) 11.0 m/s (b) 6.01 km
43. (a) 55.8 m/s (b) 2500 Hz
45. 47. But is exiting at 1.69 m

Chapter

1. (a) 9.24 m (b) 600 Hz
3. 5.66 cm
5. At 0.0891 m, 0.303 m, 0.518 m, 0.732 m, 0.947 m, 1.16 m from one speaker
9. (a) $x = \pi, 3\pi, 5\pi, \dots$ (b) 0.0294 m
11. 150 Hz

Chapter

1. 6.24 MPa
3. 5.27×10^{18} kg
5. 1.62 m
7. $7.74 \times 10^{-3} \text{ m}^2$
9. 98.6 kPa
11. 10.5 m; no
13. $m/[(\rho_w - \rho_b)h]$
15. 7.00 cm
17. 1250 kg/m³ and 500 kg/m³
19. 1450 m³

- S5. The dipole approximation of the electric field $E = 2k_p/x^3$ is within 20% of the actual value when $x > 6.2$ cm. It is within 5% when $x > 12.6$ cm.

Chapter 20

1. (a) $-600 \mu\text{J}$ (b) -50.0 V
3. (a) 132 km/s (b) 6.40 Mm/s
5. (a) 81.6 Mm/s (b) 83.9 Mm/s , too large by 2.91%
7. (a) 59.0 V (b) 4.56 Mm/s
9. 260 V
11. (a) 144 nV (b) -71.9 nV (c) -144 nV and 71.9 nV
13. -11.0 MV
15. (a) -27.3 eV (b) -6.81 eV (c) 0
19. (a) 10.8 m/s and 1.55 m/s (b) Larger
21. $\mathbf{E} = (-5 + 6x)\mathbf{i} + (3x^2 - 8.2)\mathbf{j} - 4.5x\mathbf{k}$, 7.08 N/C
23. $-0.533 k_Q R$
25. (a) C/m^2 (b) $k_Q[L - d \ln(1 + L/d)]$
27. (a) 45.0 MV/m away and 30.0 MV/m away
29. (a) $1.00 \mu\text{F}$ (b) 100 V
31. (a) 11.1 kV/m (b) 98.3 nC/m^2 (c) 3.74 pF
33. (d) 74.8 pF
35. (a) $17.0 \mu\text{C}$ (b) 9.00 V (c) $45.0 \mu\text{C}$ and $108 \mu\text{C}$
37. $6.00 \mu\text{F}$ and 3.00 pF
39. (a) $5.96 \mu\text{F}$ (b) $89.5 \mu\text{C}$ on $20.0 \mu\text{F}$, $63.2 \mu\text{C}$ on $6.00 \mu\text{F}$, $26.3 \mu\text{C}$ on $15.0 \mu\text{F}$ and on $3.00 \mu\text{F}$
41. $120 \mu\text{C}$, $80.0 \mu\text{C}$ and $40.0 \mu\text{C}$
43. (a) $216 \mu\text{J}$ (b) $54.0 \mu\text{J}$
45. (a) circuit diagram: 100 V $25.0 \mu\text{F}$ $5.00 \mu\text{F}$

energy stored: 150 mJ (b) potential difference: 268 V

circuit diagram:

49. (a) $4.00 \mu\text{F}$ (b) $8.40 \mu\text{F}$ (c) 5.71 V and $48.0 \mu\text{C}$
51. $\sim 10^{-6} \text{ F}$ and $\sim 10^4 \text{ V}$ for two 40-cm by 100-cm sheets of aluminum foil sandwiching a thin sheet of plastic
53. 253 MeV
55. (a) 488 V (b) $7.81 \times 10^{-17} \text{ J}$ (c) 306 km/s
57. (d) $3.90 \times 10^{13} \text{ m/s}^2$ (e) $6.51 \times 10^{-16} \text{ N}$
59. (a) $13.5 \mu\text{C}$ (b) 0.290 m
61. (a) $40.0 \mu\text{J}$ (b) 500 V
63. $e_0 A/(s-d)$

(b) Result Number of draws

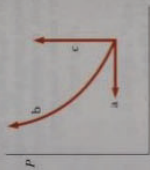
- | | |
|-------|----|
| 5R | 1 |
| 4R 1G | 5 |
| 3R 2G | 10 |
| 2R 3G | 10 |
| 1R 4G | 5 |
| 5G | 1 |

33. 8.36 MJ/K
35. 32.9 kJ
37. (a) 5.00 kW (b) 763 W
39. 77.8 W
41. $5.97 \times 10^4 \text{ kg/s}$
43. 29.3 J
45. (a) $2nRT_0 \ln 2$ (b) 0.273

Chapter 19

1. (a) $21.6 \mu\text{N}$ toward the other (b) $0.899 \mu\text{N}$ away from the other
3. The force is $\sim 10^{38} \text{ N}$
5. 2.51×10^{-4}
7. K/d in the direction of motion
9. 1.82 m to the left of the negative charge
11. $-k_A A/d$
13. (a) at the center (b) $1.73 k_Q d^2/\epsilon^2$
15. 1.59 MN/C toward the rod
17. -21.6 MN/C
19. 4.14 MN/C
21. $226 \text{ kN}\cdot\text{m}^2/\text{C}$
23. (a) $+Q/2\epsilon_0$ (b) $-Q/2\epsilon_0$
25. $2.33 \times 10^{11} \text{ N/C}$ radially outward
27. $\mathbf{E} = 0$ inside and $\mathbf{E} = k_Q Q/r^2$ radially away, outside
29. $\mathbf{E} = \rho r/2\epsilon_0$ away from the axis
31. (a) 0 (b) 5400 N/C outward (c) 540 N/C outward
33. (a) $+708 \text{ nC/m}^2$ and -708 nC/m^2
35. 2.90 N
37. (a) 496 nC/m^2 (b) 248 nC/m^2
39. $5.25 \mu\text{C}$
41. (a) 10.9 nC (b) 5.43 mN
43. (a) $\rho r/3\epsilon_0$; $Q/4\pi\epsilon_0 r^2$; 0; $Q/4\pi\epsilon_0 r^2$, all radially outward
45. For $r < a$, $\mathbf{E} = \lambda/2\pi\epsilon_0 r$ radially outward. For $a < r < b$, $\mathbf{E} = [\lambda + \rho\pi(r^2 - a^2)]/2\pi\epsilon_0 r$ radially outward. For $r > b$, $\mathbf{E} = [\lambda + \rho\pi(b^2 - a^2)]/2\pi\epsilon_0 r$ radially outward
47. (a) σ/ϵ_0 away from both plates (b) 0
49. 205 nC
51. -707 J/mN

19. 1.18 MJ
21. (a) $4P_0 V_0$ (b) $T = (P_0/nR V_0) V^2$
23. (a) -567 J (b) 167 J
25. (a) 12.0 kJ (b) -12.0 kJ
27. (a) 7.50 kJ (b) 900 K
29. 3.10 kJ ; 37.6 kJ
31. (a) 0.0410 m^3 (b) -5.48 kJ (c) -5.48 kJ
33. 2.47 L
37. 51.9°C
39. 1.94 kW
41. 47.5 g
43. (a) 16.8 L (b) 0.351 L/s
45. (a) $-P_0 V_0/2$ (b) $-P_0 V_0 \ln 4$ (c) 0



47. (a) $4P_0 V_0$ (b) $4P_0 V_0$ (c) 9.08 kJ
49. 5.31 h
51. 466 J
53. By varying h until $T = 45^\circ\text{C}$ at $t = 180 \text{ s}$, one finds $h = 0.010 \text{ 855 cal/s}\cdot\text{cm}^2\cdot^\circ\text{C}$. Examine the associated graph for each choice of h .
55. (b) $\Delta U = 4669 \text{ J}$

Chapter 18

1. (a) 6.94% (b) 335 J
3. (a) 10.7 MJ (b) 0.533 s
5. (a) 67.2% (b) 38.8 kW
7. (a) 26.8% (b) 42.3%
9. (a) 741 J (b) 499 J
11. (a) 5.12% (b) 5.27 TJ/h
13. 453 K
17. (a) 24.0 J (b) 144 J
19. -610 J/K
21. 195 J/K
23. 1.02 MJ/K
25. 716 J/K
27. 5.76 J/K ; temperature is constant if the gas is ideal
29. (a) 1 (b) 6

Chapter 17

1. 0.165°C
3. $0.234 \text{ kJ/kg}\cdot^\circ\text{C}$
5. 29.6°C
7. (a) $0.435 \text{ cal/g}\cdot^\circ\text{C}$ (b) beryllium
9. (a) 25.8°C (b) No
11. 59.4°C
13. 0.414 kg
15. (a) 0°C (b) 114 g
17. Liquid lead at 805°C , if the specific heat is constant

A.42

21. (a) 4.24 m/s (b) 17.0 m/s
23. (a) 17.7 m/s (b) 1.73 mm
25. (a) $1 \text{ atm} + 15.0 \text{ MPa}$ (b) 2.98 m/s
27. 68.0 kPa
29. 105 m/s
31. (b) $2\sqrt{h(h_0 - h)}$
33. 0.258 N
35. 1.91 m
37. 8.01 km/yes
39. 709 kg/m^3
41. 2.00 MN
43. 90.04%
45. 4.43 m/s
47. 4.43 m/s
51. (b) 1.40 s

Chapter 16

1. (a) $37.0^\circ\text{C} = 310 \text{ K}$ (b) $-20.6^\circ\text{C} = 253 \text{ K}$
3. (a) -27°C (b) 1.27 atm (c) 1.74 atm
5. (a) -320°F (b) 77.3 K
9. From 40.6°C to -31.6°C
11. 3.27 cm
13. 55.0°C
15. 0.109 cm^2
17. (a) 1.76 mm (b) $8.78 \mu\text{m}$ (c) 0.0930 cm^3
19. (a) 3.00 mol (b) 1.80×10^{23} molecules
21. 1.50×10^{23} molecules
23. 471 K
25. (a) 400 kPa (b) 449 kPa
27. Between 10 kg and 100 kg
29. $(P_0 V M/R)(1/T_1 - 1/T_2)$
31. $6.64 \times 10^{-27} \text{ kg}$
33. (a) $8.76 \times 10^{-31} \text{ J}$ for both (b) 1.62 km/s for helium and 514 m/s for argon
35. 17.6 kPa
37. $1.51 \times 10^{-20} \text{ J}$
39. 575°F
41. 0.522 kg
43. 3.35 cm
45. $\alpha\Delta T$ is much less than 1.
47. (a) Expansion makes density drop. (b) $5 \times 10^{-5}/^\circ\text{C}$
49. (a) $h = nRT/(mg + P_{\text{atm}}A)$ (b) 0.661 m

Chapter 17

1. 0.165°C
3. $0.234 \text{ kJ/kg}\cdot^\circ\text{C}$
5. 29.6°C
7. (a) $0.435 \text{ cal/g}\cdot^\circ\text{C}$ (b) beryllium
9. (a) 25.8°C (b) No
11. 59.4°C
13. 0.414 kg
15. (a) 0°C (b) 114 g
17. Liquid lead at 805°C , if the specific heat is constant

Chapter 21

1. 7.50×10^{15} electrons
3. (a) $0.6324e^{-t}$ (b) $0.99995I_0e^{-t}$ (c) I_0e^{-t}
5. 0.130 mm/s
7. 6.43 A
9. 1.33 A
11. 1.38 A
13. 14.40°C
15. 0.180 V/m
17. 5.00 A ; 24.0 A
19. 28.9 A
21. 36.1%
23. (a) 0.660 kWh (b) 3.966
25. (a) 6.73 A (b) 1.97 A
27. Put the three resistors in parallel
29. (a) 227 mA (b) 5.08 V
31. (a) 75.0 V (b) 25.0 V ; 6.25 W ; and 6.25 W ; 37.5 W
33. 846 mA down in the $8.00\text{-}\Omega$ resistor; 462 mA down in the middle branch; 1.31 A up in the right-hand branch
35. (a) -222 J and 1.88 kJ (b) 687 J ; 128 J ; 25.6 J ; 0.16 J ; 205 J (c) 1.66 kJ
37. (a) 0.385 mA ; 3.08 mA ; 2.69 mA (b) e is higher by 69.2 V
39. (a) 5.00 s (b) $150 \text{ }\mu\text{C}$ (c) $4.06 \text{ }\mu\text{A}$
41. (a) 6.00 V (b) $8.25 \text{ }\mu\text{s}$
43. 25.5 y
45. 1.36 cm
47. (a) either 3.84 A or 0.375 A (b) impossible
49. (a) 12.5 A ; 6.25 A ; 8.33 A (b) No; together they would require 27.1 A
51. Experimental resistivity = $1.47 \text{ }\mu\Omega\cdot\text{m} \pm 4\%$; in agreement with $1.50 \text{ }\mu\Omega\cdot\text{m}$
53. (a) $\mathbf{E} = V_0\mathbf{j}/\ell$ (b) $R = 4\rho\ell/\pi d^2$
- (c) $I = V_0\pi d^2/4\rho\ell$ (d) $\mathbf{J} = V_0\mathbf{j}/\rho\ell$
51. (c) The savings are $\$254.02$.
53. Kirchhoff's equations for this circuit can be written as

$$\begin{aligned} \mathcal{E}_1 - I_1R_1 - I_4R_4 &= 0 \\ \mathcal{E}_2 - I_2R_2 - I_4R_4 &= 0 \\ \mathcal{E}_3 - I_3R_3 - I_4R_4 &= 0 \end{aligned}$$

and

$$I_1 + I_2 + I_3 = I_4$$

In matrix form, they are

$$\begin{bmatrix} R_1 & 0 & 0 & R_4 \\ 0 & R_2 & 0 & R_4 \\ 0 & 0 & R_3 & R_4 \\ 1 & 1 & 1 & -1 \end{bmatrix} \begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ I_4 \end{bmatrix} = \begin{bmatrix} \mathcal{E}_1 \\ \mathcal{E}_2 \\ \mathcal{E}_3 \\ 0 \end{bmatrix}$$

In Lotus 1-2-3 use the /DataMatrixInsert and /DataMatrixMultiply commands and in Excel use the array

formulas = MINVERSE(array) and = MMULT(array1, array2) to carry out the calculations. Using the data given in the problem, we find

$$I_1 = -1.26 \text{ A}, I_2 = 0.87 \text{ A}, I_3 = 1.08 \text{ A}, \text{ and } I_4 = 0.69 \text{ A}.$$

Chapter 22

1. (a) up (b) toward you, out of the plane of the paper (c) no deflection (d) into the plane of the paper
3. -20.9 mT
5. $8.93 \times 10^{-30} \text{ N}$ down, $1.60 \times 10^{-17} \text{ N}$ up, $4.80 \times 10^{-17} \text{ N}$ down
7. 3.00 T
9. 0.245 T east
11. $2\pi R B \sin \theta$ up
13. $9.98 \text{ N}\cdot\text{m}$ clockwise as seen looking down from above
15. (a) 3.97° (b) $3.39 \text{ mN}\cdot\text{m}$
17. (a) $28.5 \text{ }\mu\text{T}$ into the paper
- (b) $24.7 \text{ }\mu\text{T}$ into the paper
19. $\mu_0 I/4\pi$ into the paper
21. $-27.0 \text{ }\mu\text{N}$
23. $20.0 \text{ }\mu\text{T}$ toward the bottom of the page
25. (a) 3.60 T (b) 1.94 T
27. (a) 6.34 mN/m inward (b) greater
29. 31.8 mA
31. 464 mT
33. (a) 8.63×10^{16} electrons (b) $4.01 \times 10^{20} \text{ kg}$
35. $20.0 \text{ }\mu\text{T}$
37. 2.00 GA west
39. (a) 30.0 A (b) $88.8 \text{ }\mu\text{T}$ out of the paper
41. $\mu_0 I \ln(1 + \pi r/b)/2\pi w$
43. 143 pT away along the axis
45. (a) The electric current feels a magnetic force.
47. 12 layers, 120 m
49. (a) $-8.00 \times 10^{-21} \text{ kg}\cdot\text{m/s}$ (b) 8.90°
53. This problem is somewhat similar to Problem S11.4, which dealt with gravitation and orbits, except that here the acceleration is velocity dependent. The equation of motion is

$$\mathbf{F} = q\mathbf{E} + q(\mathbf{v} \times \mathbf{B}) = m\mathbf{a} = q(\mathbf{E}_0 - v\mathbf{B}_0)\mathbf{i} + qv\mathbf{B}_0\mathbf{k}$$

The acceleration in the y direction is zero, so the y component of the velocity of the electron is constant.

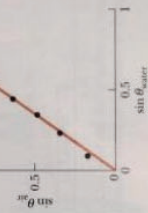
Chapter 23

1. 160 A
3. (a) 1.60 A (b) $20.1 \text{ }\mu\text{T}$ (c) up
5. $(-87.1 \text{ mV}) \cos(200\pi t + \phi)$
7. 1.00 m/s
9. 0.763 V
11. 2.83 mV
13. 9.82 mV

15. (b) Larger R makes current smaller, so the loop must travel faster to maintain equality of magnetic force and weight. (c) The magnetic force is proportional to the product of field and current, whereas the current is itself proportional to field. If B gets two times smaller, the speed must get four times larger to compensate.
17. 1.80 mN/C upward and to the left, perpendicular to $\mathbf{v}_1$
19. $22.3 \text{ }\mu\text{N/C}$
21. 19.5 mV
23. 18.8 V cos $377t$
29. (a) 0.139 s (b) 0.461 s
31. (a) 0.890 (b) 0
33. 30.0 mH
35. (a) 1.00 A (b) 12.0 V , 1.20 kV , 1.21 kV
- (c) 7.62 ms
37. (a) 8.06 MJ/m^3 (b) 6.32 kJ
39. 44.2 nJ/m^3 for the $\mathbf{E}$ field and $995 \text{ }\mu\text{J/m}^3$ for the $\mathbf{B}$ field
41. $2\pi R^2 I_0^2 / \mu_0 = 2.70 \times 10^8 \text{ J}$
43. (a) 7.54 kV (b) The plane of the coil is parallel to $\mathbf{B}$
47. 6.00 A
51. (a) 62.5 GJ (b) 2000 N
53. (a) $L = \pi \mu_0 N^2 R/2$ (c) $\sim 1 \text{ ms}$
- (b) $\sim 100 \text{ nH}$
- (c) $\tau = 0.35 \text{ ms}$
55. (a) $I_{\text{avg}} = 0.24 \text{ ms} = 0.686\tau$; and (c) $I_{\text{avg}} = 0.80 \text{ ms} = 2.29\tau$; $I_{\text{avg}} = 1.6 \text{ ms} = 4.57\tau$.

Chapter 24

1. 1.85 aT up
3. 733 nT
5. (a) 6.00 MHz (b) $(-73.3\text{ k}) \text{ nT}$
- (c) $\mathbf{B} = (-73.3 \text{ k nT}) \cos(0.126x - 3.77 \times 10^7 t)$
7. They are, so long as $k = \omega(\mu_0\epsilon_0)^{1/2}$; that is, so long as $\lambda = c/f$
9. 1.09 pF to 1.64 pF
11. (a) $2\pi r^2 B_{\text{max}} \cos \theta$, where θ is the angle between the magnetic field and the normal to the loop
- (b) The loop should be in the vertical plane containing the line of sight to the transmitter.
13. (a) away along the perpendicular bisector of the line segment joining the antennas
- (b) along the extensions of the line segment joining the antennas
15. $307 \text{ }\mu\text{W/m}^2$
17. $3.33 \times 10^5 \text{ m}^2$
19. (a) 332 kW/m^2 radially inward
- (b) 1.88 kV/m and $222 \text{ }\mu\text{T}$
21. (a) $\mathbf{E} \cdot \mathbf{B} = 0$ (b) $(11.4 - 28.6\text{ g}) \text{ W/m}^2$
23. (a) 2.53 mT (b) 650 MW/m^2 (c) 510 W
25. 83.3 nPa
27. (a) 1.90 kN/C (b) 50.0 pJ
- (c) $1.67 \times 10^{-19} \text{ kg}\cdot\text{m/s}$
29. 545 THz



Chapter 25

1. 25.5° , 442 nm
3. 19.5° above the horizon
5. 30.0° and 19.5° at entry; 19.5° and 30.0° at exit
7. 3.39 m
9. times from mirror 1 and 5 times from mirror 2
11. 3.88 mm
13. 30.4° and 23.3°
15. 24.7°
17. 0.171°
19. 4.61°
21. (a) 27.9° (b) 48.6°
23. 59.8° for both; 0.0422°
25. 1.00008
27. 67.2°
29. 4.74 cm
31. 22.0°
33. 2.27 m
35. 77.5°
39. greater than 66.5°
41. 62.2°
43. 82 reflections
45. 27.5°
47. slope = $1.328 \pm 0.8\%$

49. (a) It always happens
(b) 30.3°
(c) It cannot happen
51. 2.37 cm
- S1. Using Snell's Law and plane geometry, the following relationships can be derived:

$$\sin \theta_1 = n \sin \rho_1$$

$$\rho_2 = \phi - \rho_1$$

$$n \sin \rho_2 = \sin \theta_2$$

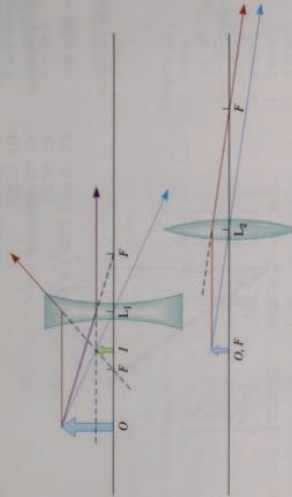
$$\delta = \theta_1 + \theta_2 - \phi$$

These equations are used to find ρ_1 , ρ_2 , θ_1 , θ_2 , and δ in the spreadsheet. IF statements are used in the calculation of θ_2 and δ so that error messages are not printed when ρ_2 exceeds the critical angle for total internal reflection.

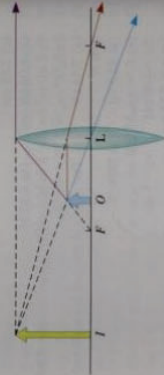
Chapter 26

1. $\sim 10^{-9}$ s younger
3. 2.11°
5. 10.0 ft, 30.0 ft, 40.0 ft
7. 0.267 m behind the mirror; virtual, upright, diminished;
 $M = 0.0267$
9. (a) -12.0 cm; 0.400
(b) -15.0 cm; 0.250
(c) upright
11. (a) a concave mirror with radius of curvature 2.08 m
(b) 1.25 m from the object

45. 8.00 cm



13. 30.0 cm
15. 38.2 cm below the top surface of the ice
17. 8.57 cm
19. 3.88 mm
21. (a) 16.4 cm (b) 16.4 cm
23. (a) 650 cm from the lens on the opposite side from the object; real, inverted, enlarged
(b) 600 cm from the lens on the same side as the object; virtual, upright, enlarged
25. 2.84 cm
27. 7.50 cm
29. (a) 3.40, upright
(b)



33. (a) 39.0 mm (b) 39.5 mm
35. 160 cm to the left of the lens; inverted; $M = -0.800$
37. -40.0 cm
39. 5.71 cm in front of the mirror; real
41. -25.0 cm
43. 0.107 m to the right of the vertex of the hemispherical face

47. 1.50 m in front of the mirror; 1.40 cm (inverted)
49. (a) 30.0 cm and 120 cm (b) 24.0 cm
(c) real, inverted, diminished
S1. See Figure 36.13. Applying the law of sines to triangle OPC , one finds $R \sin \theta_1 = (R + \rho) \sin \alpha$. Snell's law gives $n_1 \sin \theta_1 = n_2 \sin \theta_2$. Applying plane geometry gives $\gamma = \theta_1 - \alpha = \theta_2$. Applying the law of sines to triangle POC gives $q - R = R \sin \theta_2 / \sin \gamma$. These equations are used to calculate θ_1 , θ_2 , γ , and q in the spreadsheet. The maximum angle α for which the error in the image distance is 3% or less is 2.35° . (b) 2.25° (d) No. (For a plot of the percent error versus α , just call up the associated graph.)

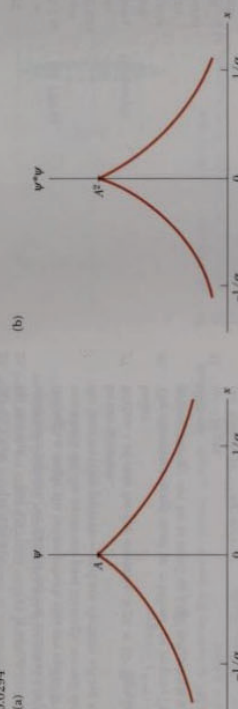
Chapter 27

1. 1.58 cm
3. (a) 55.7 m (b) 124 m
5. 1.54 mm
7. 0.0480 mm
9. 612 nm
11. (a) green (b) purple
13. 435 nm
15. 0.290 mm
17. 91.2 cm
19. 1.00 mrad
21. 3.09 m
23. 61.0 mm
25. 105 m
27. 5.91° in first order, 13.2° in second order, 26.5° in third order
29. (a) 478.7 nm, 647.6 nm, and 696.6 nm
(b) 20.31° , 28.30° , and 30.66°
31. (a) 12 000, 24 000, 36 000
(b) 0.0111 nm
33. 0.0934 nm
35. 14.4°
37. (a) $\sim 10^{-3}$ degree
(b) $\sim 10^{11}$ Hz, microwave
39. 2.50 mm
41. 3.58°
43. 2.52 cm
45. 115 nm
47. (b) 266 nm
49. (a) 25.6° (b) 19.0°
51. $\gamma' = (n - 1) d/d$
S1. (a) 9:1 (b) 1:9

Chapter 28

1. 5.18 kK
3. (a) 2.57 eV (b) $12.8 \mu\text{eV}$ (c) 191 neV
(d) 484 nm, 9.68 cm, 6.52 m
5. 5.71×10^5 photons

7. (a) 296 nm, 1.01 PHz
(b) 2.71 V
9. 2.22 eV, 3.70 eV
11. 1.78 eV, 9.47×10^{-28} kg·m/s
13. 70.1°
15. (a) 43.0° (b) 602 keV, 3.21×10^{-22} kg·m/s
(c) 278 keV, 3.21×10^{-22} kg·m/s
17. (a) 0.174 nm (b) 5.49 pm
19. (a) 124 MeV or more (b) With kinetic energy much larger than the magnitude of its negative electric potential energy, the electron would immediately escape.
21. (a) 3.91×10^4 , 1.07×10^{-17} kg·m/s (b) 62.2 am, much smaller than 10^{-14} m
23. (a) 13.1 keV (b) 124 keV
25. (a) 993 nm (b) 4.97 nm (c) If we detect the interference pattern, we cannot say the neutron has passed through a single slit because both slits are open. If we test which slit the neutrons pass through, we will destroy the interference pattern—and are thereby asking a different question.
27. Within 1.16 nm for the electron, 5.28×10^{-32} m for the bullet
29. The electron energy must be $\sim 100 m_e c^2$ or larger. The proton energy can be as small as $1.001 m_p c^2$, which is quite classical.
31. (a) 126 pm (b) 5.28×10^{-24} kg·m/s
(c) $K = 95.5$ eV
33. 0.500
35. (a)
37. 0.793 nm
39. 202 fm, 6.14 MeV, a gamma ray
43. (a) 0.0103 (b) 0.990
45. By 0.959 nm, to 1.91 nm
47. 1.36 eV
49. 0.143 nm. This is of the same order of magnitude as the spacing between atoms in a crystal, so Bragg diffraction will occur.

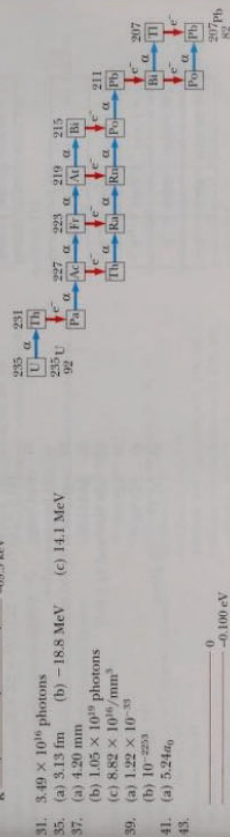


(c) It is continuous, finite, and can be normalized.
(d) $A = \sqrt{\alpha}$ (e) 0.682

Chapter 23		(b) 520 km/s		(b) 1312 nm	
		(a) n	(a) m_ℓ	(b) n	(b) m_ℓ
1.	(a) 3	3	2	3	1
2.	(a) 3	3	2	3	1
3.	(a) 1312 nm	3	2	3	1
4.	(a) 3	3	2	3	1
5.	(a) 3	3	2	3	1

7. $4a_0$
9. It does, with $E = -k_f^2/2a_0$

11. $L = \sqrt{6h} = 2.58 \times 10^{-34} \text{ J}\cdot\text{s}$
13. $L_z = -2h, -1h, 0, 1h, \text{ or } 2h$
14. $\theta = 145^\circ; 114^\circ; 90.0^\circ; 65.5^\circ; \text{ or } 35.3^\circ$
15. (a) 2 (b) (c) (d) (e) 50
17. (a) $3.99 \times 10^{11} \text{ kg}\cdot\text{m}^3$ (b) $8.17 \times 10^{-10} \text{ m}$
18. (a) 1.77 Tm/s (d) $5.91 \times 10^{-4} \text{ e}$
19. (a) $5.05 \times 10^{-47} \text{ J}\cdot\text{s}$ (b) 31.6 meV/T
20. Here μ_B is 1836 times smaller than μ_p , as a proton is 1836 times more massive than an electron. The electron has a bigger charge-to-mass ratio than anything else, which gives it a greater relative ability for a magnetic field to twist it.
21. $1.29 \times 10^{22} \text{ g} \cdot 3.5/3 \cdot 3.03 \times 10^8 \text{ kg} \cdot 4.49 \times 10^{14} \text{ s}^{-1} \cdot 5.25 \times 10^{15} \text{ J} \cdot 1.60 \times 10^{19} \text{ C} \cdot 7.62 \times 10^{-17} \text{ s}^2$
23. (1) 1, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s
- (2) Element 15 should have valence +3 or -5, and it does. Element 47 should have valence -1, but it has valence +1. Element 86 should be inert, and it is.



_____ 0
 _____ -0.100 eV
 _____ -1.00 eV

29. 4.28 MeV
(a) $e^- + p \rightarrow n + \nu$
(b) $^{16}\text{O atom} \rightarrow ^{16}\text{N atom} + \nu$
(c) 2.75 MeV
 33. -2.64 MeV
(a) For nuclei, $^{192}\text{Au} + p_n \rightarrow ^{193}\text{Hg} + {}_0^1e^- + \bar{\nu}$
(b) 7.89 MeV
(c) 2.75 MeV
 35. (a) ^{13}C , (b) ^{10}B
(c) 2.52×10^{24}
 37. (a) 2.52×10^{24}
(b) 2.31×10^{12} Bq
(c) 1.07 MeV
 41. 4.45×10^{18} h
(a) 4.45×10^{18} Bq
(b) 152 N
(c) 2.62 MeV
 43. 6.25×10^{19} Bq
(a) 0.68 MeV
(b) 4.62 MeV and 13.9 MeV
(c) 1.03×10^7 kWh
 45. (a) 2.75 fm, 379 N, 17.6 MeV
(b) 4.62 MeV and 13.9 MeV
(c) 1.03×10^7 kWh
 47. (a) 0.68 MeV
(b) 4.62 MeV and 13.9 MeV
(c) 1.03×10^7 kWh
 49. (a) 4.79 MeV
(b) 1.02 MeV
(c) 5.94 Gy
 51. 1.02 MeV
(a) 0.68 MeV
(b) 4.62 MeV and 13.9 MeV
(c) 1.03×10^7 kWh
 53. 5.94 Gy
(a) 0.68 MeV
(b) 4.62 MeV and 13.9 MeV
(c) 1.03×10^7 kWh

81. The following tables give the number of parent nuclei (N1) and the number of daughter nuclei (N2) present:

(a)

	N1	N2
$t = 1$ min	4349	478
$t = 2$ min	5782	648
$t = 5$ min	2488	587
$t = 30$ min	76	19

(b)

	N1	N2
$t = 1$ min	3514	1391
$t = 2$ min	2470	2187
$t = 5$ min	857	2718
$t = 30$ min	zero	126

(c)

	N1	N2
$t = 1$ min	4997	3
$t = 2$ min	4993	5
$t = 5$ min	4983	8
$t = 30$ min	4897	9

Chapter 31

- 4.53×10^{23} Hz, 662 am
- 118 MeV
- $\sim 10^{-23}$ s
- 67.5 MeV, 67.5 MeV/c, 1.63×10^{22} Hz
- $\Omega^+ \rightarrow \bar{\Lambda}^0 + K^+$, $\bar{K}_S^0 \rightarrow \pi^+ + \pi^-$, $\bar{\Lambda}^0 \rightarrow \bar{p} + \pi^+$
- $\bar{n} \rightarrow \bar{p} + e^+ + \nu_e$
- (b) The second violates strangeness conservation.
- (a) $\bar{p}_s$, (b) ν_p , (c) $\bar{\nu}_s$, (d) ν_s , (e) ν_p
- (f) $\bar{e}^+ + \nu_e$
- (a), (c), and (f) violate baryon number conservation; (b), (d), and (e) can occur; (f) violates muon-lepton number conservation.
- (b) and (c) conserve strangeness; (a), (d), (e), and (f) violate strangeness conservation.
- (a) $\bar{d}u + u\bar{u}d \rightarrow \bar{d}s + u\bar{s}$
(b) $\bar{d}u + u\bar{u}d \rightarrow \bar{u}s + u\bar{s}$
(c) $us + u\bar{u}d \rightarrow \bar{u}s + \bar{d}s + s\bar{s}$
(d) $u\bar{u}d + u\bar{u}d \rightarrow \bar{d}s + u\bar{d} + u\bar{d} + u\bar{d}; \Lambda^0$
- (a) 590.07 nm, (b) 597 nm, (c) 661 nm
- (a) $\nu = c(\lambda^2 + 2Z)/(\lambda^2 + 2Z + 2)$, (b) $\nu = c(H)(Z^2 + 2Z)/(Z^2 + 2Z + 2)$
- (a) charge, (b) energy, (c) baryon number
- one part in 50 000 000
- 3.5 MeV and 32.3 MeV
- 9.26 cm
- 29.7 MeV
- (a) Z^+ , (b) gluon

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Solar System Data

Body	Mass (kg)	Mean Radius (m)	Period (s)	Distance from Sun (m)
Mercury	3.18×10^{23}	2.43×10^6	7.60×10^6	5.79×10^{10}
Venus	4.88×10^{24}	6.06×10^6	1.94×10^7	1.08×10^{11}
Earth	5.98×10^{24}	6.37×10^6	3.156×10^7	1.496×10^{11}
Mars	6.42×10^{23}	3.37×10^6	5.94×10^7	2.28×10^{11}
Jupiter	1.90×10^{27}	6.99×10^7	3.74×10^8	7.78×10^{11}
Saturn	5.68×10^{26}	5.85×10^7	9.35×10^8	1.43×10^{12}
Uranus	8.68×10^{25}	2.33×10^7	2.64×10^9	2.87×10^{12}
Neptune	1.03×10^{26}	2.21×10^7	5.22×10^9	4.50×10^{12}
Pluto	$\approx 1.4 \times 10^{22}$	$\approx 1.5 \times 10^6$	7.82×10^9	5.91×10^{12}
Moon	7.36×10^{22}	1.74×10^6	—	—
Sun	1.991×10^{30}	6.96×10^8	—	—

Physical Data Often Used*

Average earth-moon distance	3.84×10^8 m
Average earth-sun distance	1.496×10^{11} m
Average radius of the earth	6.37×10^6 m
Density of air (20°C and 1 atm)	1.29 kg/m^3
Density of water (20°C and 1 atm)	$1.00 \times 10^3 \text{ kg/m}^3$
Free-fall acceleration	9.80 m/s^2
Mass of the earth	$5.98 \times 10^{24} \text{ kg}$
Mass of the moon	$7.36 \times 10^{22} \text{ kg}$
Mass of the sun	$1.99 \times 10^{30} \text{ kg}$
Standard atmospheric pressure	$1.013 \times 10^5 \text{ Pa}$

*These are the values of the constants as used in the text.

Some Prefixes for Powers of Ten

Power	Prefix	Abbreviation	Power	Prefix	Abbreviation
10^{-18}	atto	a	10^3	deka	da
10^{-15}	femto	f	10^2	hecto	h
10^{-12}	pico	p	10^1	kilo	k
10^{-9}	nano	n	10^0	mega	M
10^{-6}	micro	μ	10^6	giga	G
10^{-3}	milli	m	10^{12}	tera	T
10^{-2}	centi	c	10^{15}	peta	P
10^{-1}	deci	d	10^{18}	exa	E

Conversions*

Length	Force
1 in. = 2.54 cm	1 N = 10^5 dyne = 0.2248 lb
1 m = 39.37 in. = 3.281 ft	1 lb = 4.448 N
1 ft. = 0.3048 m	1 dyne = 10^{-5} N = 2.248×10^{-6} lb
12 in. = 1 ft	
3 ft = 1 yd	
1 yd = 0.9144 m	
1 km = 0.621 mi	
1 mi = 1.609 km	
1 mi = 5280 ft	
1 Å = 10^{-10} m	
1 Å = $1 \mu = 10^{-6}$ m = 10^3 Å	
1 lightyear = 9.461×10^{15} m	
Area	Volume
1 m ² = 10^4 cm ² = 10.76 ft^2	1 m ³ = 10^6 cm ³ = $6.102 \times 10^4 \text{ in.}^3$
1 ft ² = 0.0929 m ² = 1.44 in. ²	1 ft ³ = 1728 in. ³ = $2.83 \times 10^{-2} \text{ m}^3$
1 in. ² = 6.452 cm ²	1 liter = 1000 cm ³ = 1.0576 qt = 0.0353 ft ³
	1 ft ³ = 7.481 gal = 28.32 liters = $2.832 \times 10^{-2} \text{ m}^3$
	1 gal = 3.786 liters = 231 in. ³
Mass	Power
1000 kg = 1 t (metric ton)	1 hp = 550 ft·lb/s = 0.746 kW
1 slug = 14.59 kg	1 W = 1 J/s = 0.738 ft·lb/s
1 u = 1.66×10^{-27} kg	1 Btu/h = 0.293 W

*See Table A.1 of Appendix A for a more complete list.

The Greek Alphabet

Alpha	A	α	Iota	ι	Rho	ρ
Beta	B	β	Kappa	κ	Sigma	σ
Gamma	Γ	γ	Lambda	λ	Tau	τ
Delta	Δ	δ	Mu	μ	Upsilon	υ
Epsilon	Ε	ε	Nu	ν	Phi	φ
Zeta	Ζ	ζ	Xi	ξ	Chi	χ
Eta	Η	η	Omicron	ο	Psi	ψ
Theta	Θ	θ	Pi	π	Omega	ω

