APPENDIX A Mathematical Formulas

A–1 Quadratic Formula

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

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

A–2 Binomial Expansion

$$(1 \pm x)^n = 1 \pm nx + \frac{n(n-1)}{2!}x^2 \pm \frac{n(n-1)(n-2)}{3!}x^3 + \cdots$$

$$(x+y)^n = x^n\left(1 + \frac{y}{x}\right)^n = x^n\left(1 + n\frac{y}{x} + \frac{n(n-1)}{2!}\frac{y^2}{x^2} + \cdots\right)$$

A–3 Other Expansions

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

$$\ln(1+x) = x - \frac{x^2}{2} + \frac{x^3}{3} - \frac{x^4}{4} + \cdots$$

$$\sin\theta = \theta - \frac{\theta^3}{3!} + \frac{\theta^5}{5!} - \cdots$$

$$\cos\theta = 1 - \frac{\theta^2}{2!} + \frac{\theta^4}{4!} - \cdots$$

$$\tan\theta = \theta + \frac{\theta^3}{3} + \frac{2}{15}\theta^5 + \cdots \qquad |\theta| < \frac{\pi}{2}$$

In general: $$f(x) = f(0) + \left(\frac{df}{dx}\right)_0 x + \left(\frac{d^2f}{dx^2}\right)_0 \frac{x^2}{2!} + \cdots$$

A–4 Exponents

$$(a^n)(a^m) = a^{n+m}$$

$$(a^n)(b^n) = (ab)^n$$

$$(a^n)^m = a^{nm}$$

$$\frac{1}{a^n} = a^{-n}$$

$$a^n a^{-n} = a^0 = 1$$

$$a^{\frac{1}{2}} = \sqrt{a}$$

A–5 Areas and Volumes

Object	Surface area	Volume
Circle, radius r	πr^2	—
Sphere, radius r	$4\pi r^2$	$\frac{4}{3}\pi r^3$
Right circular cylinder, radius r, height h	$2\pi r^2 + 2\pi r h$	$\pi r^2 h$
Right circular cone, radius r, height h	$\pi r^2 + \pi r\sqrt{r^2 + h^2}$	$\frac{1}{3}\pi r^2 h$

A–6 Plane Geometry

1. *Equal angles*:

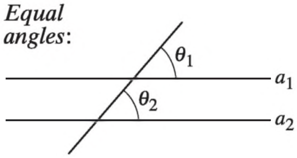


FIGURE A–1 If line a_1 is parallel to line a_2, then $\theta_1 = \theta_2$.

2. *Equal angles*:

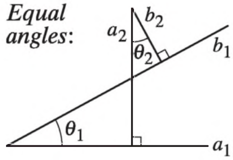


FIGURE A–2 If $a_1 \perp a_2$ and $b_1 \perp b_2$, then $\theta_1 = \theta_2$.

3. The sum of the angles in any plane triangle is 180°.
4. *Pythagorean theorem*:

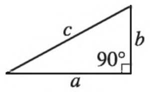


FIGURE A–3

In any right triangle (one angle = 90°) of sides a, b, and c:

$$a^2 + b^2 = c^2$$

where c is the length of the hypotenuse (opposite the 90° angle).

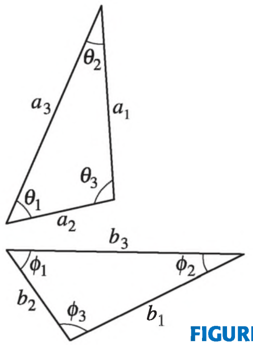


FIGURE A–4

5. *Similar triangles*: Two triangles are said to be similar if all three of their angles are equal (in Fig. A–4, $\theta_1 = \phi_1, \theta_2 = \phi_2$, and $\theta_3 = \phi_3$). Similar triangles can have different sizes and different orientations.
   (*a*) Two triangles are similar if any two of their angles are equal. (This follows because the third angles must also be equal since the sum of the angles of a triangle is 180°.)
   (*b*) The ratios of corresponding sides of two similar triangles are equal (Fig. A–4):

$$\frac{a_1}{b_1} = \frac{a_2}{b_2} = \frac{a_3}{b_3}.$$

6. *Congruent triangles*: Two triangles are congruent if one can be placed precisely on top of the other. That is, they are similar triangles and they have the same size. Two triangles are congruent if any of the following holds:
   (*a*) The three corresponding sides are equal.
   (*b*) Two sides and the enclosed angle are equal ("side-angle-side").
   (*c*) Two angles and the enclosed side are equal ("angle-side-angle").

A–7 Logarithms

Logarithms are defined in the following way:

$$\text{if} \quad y = A^x, \quad \text{then} \quad x = \log_A y.$$

That is, the logarithm of a number y to the base A is that number which, as the exponent of A, gives back the number y. For **common logarithms**, the base is 10, so

$$\text{if} \quad y = 10^x, \quad \text{then} \quad x = \log y.$$

The subscript 10 on $\log_{10}$ is usually omitted when dealing with common logs. Another important base is the exponential base $e = 2.718\ldots$, a natural number. Such logarithms are called **natural logarithms** and are written ln. Thus,

$$\text{if} \quad y = e^x, \quad \text{then} \quad x = \ln y.$$

For any number y, the two types of logarithm are related by

$$\ln y = 2.3026 \log y.$$

Some simple rules for logarithms are as follows:

$$\log(ab) = \log a + \log b, \qquad \textbf{(i)}$$

which is true because if $a = 10^n$ and $b = 10^m$, then $ab = 10^{n+m}$. From the definition of logarithm, $\log a = n$, $\log b = m$, and $\log(ab) = n + m$; hence, $\log(ab) = n + m = \log a + \log b$. In a similar way, we can show that

$$\log\left(\frac{a}{b}\right) = \log a - \log b \tag{ii}$$

and

$$\log a^n = n \log a. \tag{iii}$$

These three rules apply to any kind of logarithm.

If you do not have a calculator that calculates logs, you can easily use a **log table**, such as the small one shown here (Table A–1): the number N whose log we want is given to two digits. The first digit is in the vertical column to the left, the second digit is in the horizontal row across the top. For example, Table A–1 tells us that $\log 1.0 = 0.000$, $\log 1.1 = 0.041$, and $\log 4.1 = 0.613$. Table A–1 does not include the decimal point. The Table gives logs for numbers between 1.0 and 9.9. For larger or smaller numbers, we use rule (i) above, $\log(ab) = \log a + \log b$. For example, $\log(380) = \log(3.8 \times 10^2) = \log(3.8) + \log(10^2)$. From the Table, $\log 3.8 = 0.580$; and from rule (iii) above $\log(10^2) = 2\log(10) = 2$, since $\log(10) = 1$. [This follows from the definition of the logarithm: if $10 = 10^1$, then $1 = \log(10)$.] Thus,

$$\begin{aligned}\log(380) &= \log(3.8) + \log(10^2)\\ &= 0.580 + 2\\ &= 2.580.\end{aligned}$$

Similarly,

$$\begin{aligned}\log(0.081) &= \log(8.1) + \log(10^{-2})\\ &= 0.908 - 2 = -1.092.\end{aligned}$$

The reverse process of finding the number N whose log is, say, 2.670, is called "taking the **antilogarithm**." To do so, we separate our number 2.670 into two parts, making the separation at the decimal point:

$$\begin{aligned}\log N = 2.670 &= 2 + 0.670\\ &= \log 10^2 + 0.670.\end{aligned}$$

We now look at Table A–1 to see what number has its log equal to 0.670; none does, so we must **interpolate**: we see that $\log 4.6 = 0.663$ and $\log 4.7 = 0.672$. So the number we want is between 4.6 and 4.7, and closer to the latter by $\frac{7}{9}$. Approximately we can say that $\log 4.68 = 0.670$. Thus

$$\begin{aligned}\log N &= 2 + 0.670\\ &= \log(10^2) + \log(4.68) = \log(4.68 \times 10^2),\end{aligned}$$

so $N = 4.68 \times 10^2 = 468$.

If the given logarithm is negative, say, -2.180, we proceed as follows:

$$\begin{aligned}\log N = -2.180 &= -3 + 0.820\\ &= \log 10^{-3} + \log 6.6 = \log 6.6 \times 10^{-3},\end{aligned}$$

so $N = 6.6 \times 10^{-3}$. Notice that we added to our given logarithm the next largest integer (3 in this case) so that we have an integer, plus a decimal number between 0 and 1.0 whose antilogarithm can be looked up in the Table.

TABLE A–1 Short Table of Common Logarithms

N	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	000	041	079	114	146	176	204	230	255	279
2	301	322	342	362	380	398	415	431	447	462
3	477	491	505	519	531	544	556	568	580	591
4	602	613	623	633	643	653	663	672	681	690
5	699	708	716	724	732	740	748	756	763	771
6	778	785	792	799	806	813	820	826	833	839
7	845	851	857	863	869	875	881	886	892	898
8	903	908	914	919	924	929	935	940	944	949
9	954	959	964	968	973	978	982	987	991	996

A–8 Vectors

Vector addition is covered in Sections 3–2 to 3–5.
Vector multiplication is covered in Sections 3–3, 7–2, and 11–2.

A–9 Trigonometric Functions and Identities

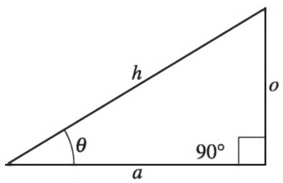


FIGURE A–5

The trigonometric functions are defined as follows (see Fig. A–5, o = side opposite, a = side adjacent, h = hypotenuse. Values are given in Table A–2):

$$\sin\theta = \frac{o}{h} \qquad \csc\theta = \frac{1}{\sin\theta} = \frac{h}{o}$$

$$\cos\theta = \frac{a}{h} \qquad \sec\theta = \frac{1}{\cos\theta} = \frac{h}{a}$$

$$\tan\theta = \frac{o}{a} = \frac{\sin\theta}{\cos\theta} \qquad \cot\theta = \frac{1}{\tan\theta} = \frac{a}{o}$$

and recall that

$$a^2 + o^2 = h^2 \qquad \text{[Pythagorean theorem].}$$

FIGURE A–6

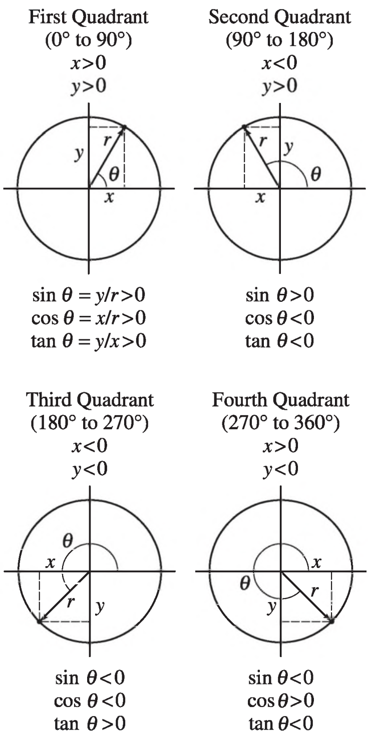


Figure A–6 shows the signs (+ or −) that cosine, sine, and tangent take on for angles θ in the four quadrants (0° to 360°). Note that angles are measured counterclockwise from the x axis as shown; negative angles are measured from *below* the x axis, clockwise: for example, $-30° = +330°$, and so on.

The following are some useful identities among the trigonometric functions:

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

$$\sec^2\theta - \tan^2\theta = 1, \quad \csc^2\theta - \cot^2\theta = 1$$

$$\sin 2\theta = 2\sin\theta\cos\theta$$

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

$$\tan 2\theta = \frac{2\tan\theta}{1 - \tan^2\theta}$$

$$\sin(A \pm B) = \sin A\cos B \pm \cos A\sin B$$

$$\cos(A \pm B) = \cos A\cos B \mp \sin A\sin B$$

$$\tan(A \pm B) = \frac{\tan A \pm \tan B}{1 \mp \tan A\tan B}$$

$$\sin(180° - \theta) = \sin\theta$$

$$\cos(180° - \theta) = -\cos\theta$$

$$\sin(90° - \theta) = \cos\theta$$

$$\cos(90° - \theta) = \sin\theta$$

$$\sin(-\theta) = -\sin\theta$$

$$\cos(-\theta) = \cos\theta$$

$$\tan(-\theta) = -\tan\theta$$

$$\sin\tfrac{1}{2}\theta = \sqrt{\frac{1-\cos\theta}{2}}, \quad \cos\tfrac{1}{2}\theta = \sqrt{\frac{1+\cos\theta}{2}}, \quad \tan\tfrac{1}{2}\theta = \sqrt{\frac{1-\cos\theta}{1+\cos\theta}}$$

$$\sin A \pm \sin B = 2\sin\left(\frac{A \pm B}{2}\right)\cos\left(\frac{A \mp B}{2}\right).$$

FIGURE A–7

For any triangle (see Fig. A–7):

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

$$c^2 = a^2 + b^2 - 2ab\cos\gamma. \qquad \text{[Law of cosines]}$$

Values of sine, cosine, tangent are given in Table A–2.

TABLE A–2 Trigonometric Table: Numerical Values of Sin, Cos, Tan

Angle in Degrees	Angle in Radians	Sine	Cosine	Tangent	Angle in Degrees	Angle in Radians	Sine	Cosine	Tangent
0°	0.000	0.000	1.000	0.000					
1°	0.017	0.017	1.000	0.017	46°	0.803	0.719	0.695	1.036
2°	0.035	0.035	0.999	0.035	47°	0.820	0.731	0.682	1.072
3°	0.052	0.052	0.999	0.052	48°	0.838	0.743	0.669	1.111
4°	0.070	0.070	0.998	0.070	49°	0.855	0.755	0.656	1.150
5°	0.087	0.087	0.996	0.087	50°	0.873	0.766	0.643	1.192
6°	0.105	0.105	0.995	0.105	51°	0.890	0.777	0.629	1.235
7°	0.122	0.122	0.993	0.123	52°	0.908	0.788	0.616	1.280
8°	0.140	0.139	0.990	0.141	53°	0.925	0.799	0.602	1.327
9°	0.157	0.156	0.988	0.158	54°	0.942	0.809	0.588	1.376
10°	0.175	0.174	0.985	0.176	55°	0.960	0.819	0.574	1.428
11°	0.192	0.191	0.982	0.194	56°	0.977	0.829	0.559	1.483
12°	0.209	0.208	0.978	0.213	57°	0.995	0.839	0.545	1.540
13°	0.227	0.225	0.974	0.231	58°	1.012	0.848	0.530	1.600
14°	0.244	0.242	0.970	0.249	59°	1.030	0.857	0.515	1.664
15°	0.262	0.259	0.966	0.268	60°	1.047	0.866	0.500	1.732
16°	0.279	0.276	0.961	0.287	61°	1.065	0.875	0.485	1.804
17°	0.297	0.292	0.956	0.306	62°	1.082	0.883	0.469	1.881
18°	0.314	0.309	0.951	0.325	63°	1.100	0.891	0.454	1.963
19°	0.332	0.326	0.946	0.344	64°	1.117	0.899	0.438	2.050
20°	0.349	0.342	0.940	0.364	65°	1.134	0.906	0.423	2.145
21°	0.367	0.358	0.934	0.384	66°	1.152	0.914	0.407	2.246
22°	0.384	0.375	0.927	0.404	67°	1.169	0.921	0.391	2.356
23°	0.401	0.391	0.921	0.424	68°	1.187	0.927	0.375	2.475
24°	0.419	0.407	0.914	0.445	69°	1.204	0.934	0.358	2.605
25°	0.436	0.423	0.906	0.466	70°	1.222	0.940	0.342	2.747
26°	0.454	0.438	0.899	0.488	71°	1.239	0.946	0.326	2.904
27°	0.471	0.454	0.891	0.510	72°	1.257	0.951	0.309	3.078
28°	0.489	0.469	0.883	0.532	73°	1.274	0.956	0.292	3.271
29°	0.506	0.485	0.875	0.554	74°	1.292	0.961	0.276	3.487
30°	0.524	0.500	0.866	0.577	75°	1.309	0.966	0.259	3.732
31°	0.541	0.515	0.857	0.601	76°	1.326	0.970	0.242	4.011
32°	0.559	0.530	0.848	0.625	77°	1.344	0.974	0.225	4.331
33°	0.576	0.545	0.839	0.649	78°	1.361	0.978	0.208	4.705
34°	0.593	0.559	0.829	0.675	79°	1.379	0.982	0.191	5.145
35°	0.611	0.574	0.819	0.700	80°	1.396	0.985	0.174	5.671
36°	0.628	0.588	0.809	0.727	81°	1.414	0.988	0.156	6.314
37°	0.646	0.602	0.799	0.754	82°	1.431	0.990	0.139	7.115
38°	0.663	0.616	0.788	0.781	83°	1.449	0.993	0.122	8.144
39°	0.681	0.629	0.777	0.810	84°	1.466	0.995	0.105	9.514
40°	0.698	0.643	0.766	0.839	85°	1.484	0.996	0.087	11.43
41°	0.716	0.656	0.755	0.869	86°	1.501	0.998	0.070	14.301
42°	0.733	0.669	0.743	0.900	87°	1.518	0.999	0.052	19.081
43°	0.750	0.682	0.731	0.933	88°	1.536	0.999	0.035	28.636
44°	0.768	0.695	0.719	0.966	89°	1.553	1.000	0.017	57.290
45°	0.785	0.707	0.707	1.000	90°	1.571	1.000	0.000	∞

APPENDIX B Derivatives and Integrals

B–1 Derivatives: General Rules

(See also Section 2–3.)

$$\frac{dx}{dx} = 1$$

$$\frac{d}{dx}[af(x)] = a\frac{df}{dx} \qquad [a = \text{constant}]$$

$$\frac{d}{dx}[f(x) + g(x)] = \frac{df}{dx} + \frac{dg}{dx}$$

$$\frac{d}{dx}[f(x)g(x)] = \frac{df}{dx}g + f\frac{dg}{dx}$$

$$\frac{d}{dx}[f(y)] = \frac{df}{dy}\frac{dy}{dx} \qquad [\text{chain rule}]$$

$$\frac{dx}{dy} = \frac{1}{\left(\frac{dy}{dx}\right)} \qquad \text{if } \frac{dy}{dx} \neq 0.$$

B–2 Derivatives: Particular Functions

$$\frac{da}{dx} = 0 \qquad [a = \text{constant}]$$

$$\frac{d}{dx}x^n = nx^{n-1}$$

$$\frac{d}{dx}\sin ax = a\cos ax$$

$$\frac{d}{dx}\cos ax = -a\sin ax$$

$$\frac{d}{dx}\tan ax = a\sec^2 ax$$

$$\frac{d}{dx}\ln ax = \frac{1}{x}$$

$$\frac{d}{dx}e^{ax} = ae^{ax}$$

B–3 Indefinite Integrals: General Rules

(See also Section 7–3.)

$$\int dx = x$$

$$\int a\,f(x)\,dx = a\int f(x)\,dx \qquad [a = \text{constant}]$$

$$\int [f(x) + g(x)]\,dx = \int f(x)\,dx + \int g(x)\,dx$$

$$\int u\,dv = uv - \int v\,du \qquad [\text{integration by parts: see also B–6}]$$

B–4 Indefinite Integrals: Particular Functions

(An arbitrary constant can be added to the right side of each equation.)

$$\int a\,dx = ax \qquad [a = \text{constant}]$$

$$\int x^m\,dx = \frac{1}{m+1}x^{m+1} \qquad [m \neq -1]$$

$$\int \sin ax\,dx = -\frac{1}{a}\cos ax$$

$$\int \cos ax\,dx = \frac{1}{a}\sin ax$$

$$\int \tan ax\,dx = \frac{1}{a}\ln|\sec ax|$$

$$\int \frac{1}{x}\,dx = \ln x$$

$$\int e^{ax}\,dx = \frac{1}{a}e^{ax}$$

$$\int \frac{dx}{\sqrt{x^2 \pm a^2}} = \ln\left(x + \sqrt{x^2 \pm a^2}\right)$$

$$\int \frac{dx}{\sqrt{a^2 - x^2}} = \sin^{-1}\left(\frac{x}{a}\right) = -\cos^{-1}\left(\frac{x}{a}\right) \qquad [\text{if } x^2 \leq a^2]$$

$$\int \frac{dx}{(x^2 \pm a^2)^{\frac{3}{2}}} = \frac{\pm x}{a^2\sqrt{x^2 \pm a^2}}$$

$$\int \frac{x\,dx}{(x^2 \pm a^2)^{\frac{3}{2}}} = \frac{-1}{\sqrt{x^2 \pm a^2}}$$

$$\int \sin^2 ax\,dx = \frac{x}{2} - \frac{\sin 2ax}{4a}$$

$$\int xe^{-ax}\,dx = -\frac{e^{-ax}}{a^2}(ax + 1)$$

$$\int x^2e^{-ax}\,dx = -\frac{e^{-ax}}{a^3}(a^2x^2 + 2ax + 2)$$

$$\int \frac{dx}{x^2 + a^2} = \frac{1}{a}\tan^{-1}\frac{x}{a}$$

$$\int \frac{dx}{x^2 - a^2} = \frac{1}{2a}\ln\left(\frac{x-a}{x+a}\right) \qquad [x^2 > a^2]$$

$$= -\frac{1}{2a}\ln\left(\frac{a+x}{a-x}\right) \qquad [x^2 < a^2]$$

B–5 A Few Definite Integrals

$$\int_0^\infty x^n e^{-ax}\,dx = \frac{n!}{a^{n+1}}$$

$$\int_0^\infty e^{-ax^2}\,dx = \sqrt{\frac{\pi}{4a}}$$

$$\int_0^\infty xe^{-ax^2}\,dx = \frac{1}{2a}$$

$$\int_0^\infty x^2e^{-ax^2}\,dx = \sqrt{\frac{\pi}{16a^3}}$$

$$\int_0^\infty x^3e^{-ax^2}\,dx = \frac{1}{2a^2}$$

$$\int_0^\infty x^{2n}e^{-ax^2}\,dx = \frac{1\cdot 3\cdot 5\cdots(2n-1)}{2^{n+1}a^n}\sqrt{\frac{\pi}{a}}$$

B–6 Integration by Parts

Sometimes a difficult integral can be simplified by carefully choosing the functions u and v in the identity:

$$\int u\,dv = uv - \int v\,du. \qquad \text{[Integration by parts]}$$

This identity follows from the property of derivatives

$$\frac{d}{dx}(uv) = u\frac{dv}{dx} + v\frac{du}{dx}$$

or as differentials: $d(uv) = u\,dv + v\,du$.

For example $\int xe^{-x}\,dx$ can be integrated by choosing $u = x$ and $dv = e^{-x}\,dx$ in the “integration by parts” equation above:

$$\int xe^{-x}\,dx = (x)(-e^{-x}) + \int e^{-x}\,dx$$

$$= -xe^{-x} - e^{-x} = -(x+1)e^{-x}.$$

APPENDIX C More on Dimensional Analysis

An important use of dimensional analysis (Section 1–7) is to obtain the *form* of an equation: how one quantity depends on others. To take a concrete example, let us try to find an expression for the period T of a simple pendulum. First, we try to figure out what T could depend on, and make a list of these variables. It might depend on its length ℓ, on the mass m of the bob, on the angle of swing θ, and on the acceleration due to gravity, g. It might also depend on air resistance (we would use the viscosity of air), the gravitational pull of the Moon, and so on; but everyday experience suggests that the Earth's gravity is the major force involved, so we ignore the other possible forces. So let us assume that T is a function of ℓ, m, θ, and g, and that each of these factors is present to some power:

$$T = C\ell^w m^x \theta^y g^z.$$

C is a dimensionless constant, and w, x, y, and z are exponents we want to solve for. We now write down the dimensional equation (Section 1–7) for this relationship:

$$[T] = [L]^w[M]^x[L/T^2]^z.$$

Because θ has no dimensions (a radian is a length divided by a length—see Eq. 10–1a), it does not appear. We simplify and obtain

$$[T] = [L]^{w+z}[M]^x[T]^{-2z}$$

To have dimensional consistency, we must have

$$\begin{aligned} 1 &= -2z \\ 0 &= w + z \\ 0 &= x. \end{aligned}$$

We solve these equations and find that $z = -\frac{1}{2}, w = \frac{1}{2},$ and $x = 0$. Thus our desired equation must be

$$T = C\sqrt{\ell/g}\, f(\theta), \qquad \textbf{(C–1)}$$

where $f(\theta)$ is some function of θ that we cannot determine using this technique. Nor can we determine in this way the dimensionless constant C. (To obtain C and f, we would have to do an analysis such as that in Chapter 14 using Newton's laws, which reveals that $C = 2\pi$ and $f \approx 1$ for small θ). But look what we *have* found, using only dimensional consistency. We obtained the form of the expression that relates the period of a simple pendulum to the major variables of the situation, ℓ and g (see Eq. 14–12c), and saw that it does not depend on the mass m.

How did we do it? And how useful is this technique? Basically, we had to use our intuition as to which variables were important and which were not. This is not always easy, and often requires a lot of insight. As to usefulness, the final result in our example could have been obtained from Newton's laws, as in Chapter 14. But in many physical situations, such a derivation from other laws cannot be done. In those situations, dimensional analysis can be a powerful tool.

In the end, any expression derived by the use of dimensional analysis (or by any other means, for that matter) must be checked against experiment. For example, in our derivation of Eq. C–1, we can compare the periods of two pendulums of different lengths, ℓ_1 and ℓ_2, whose amplitudes (θ) are the same. For, using Eq. C–1, we would have

$$\frac{T_1}{T_2} = \frac{C\sqrt{\ell_1/g}\, f(\theta)}{C\sqrt{\ell_2/g}\, f(\theta)} = \sqrt{\frac{\ell_1}{\ell_2}}.$$

Because C and $f(\theta)$ are the same for both pendula, they cancel out, so we can experimentally determine if the ratio of the periods varies as the ratio of the square roots of the lengths. This comparison to experiment checks our derivation, at least in part; C and $f(\theta)$ could be determined by further experiments.

APPENDIX D Gravitational Force due to a Spherical Mass Distribution

In Chapter 6 we stated that the gravitational force exerted by or on a uniform sphere acts as if all the mass of the sphere were concentrated at its center, if the other object (exerting or feeling the force) is outside the sphere. In other words, the gravitational force that a uniform sphere exerts on a particle outside it is

$$F = G\frac{mM}{r^2}, \qquad [m \text{ outside sphere of mass } M]$$

where m is the mass of the particle, M the mass of the sphere, and r the distance of m from the center of the sphere. Now we will derive this result. We will use the concepts of infinitesimally small quantities and integration.

First we consider a very thin, uniform spherical shell (like a thin-walled basketball) of mass M whose thickness t is small compared to its radius R (Fig. D–1). The force on a particle of mass m at a distance r from the center of the shell can be calculated as the vector sum of the forces due to all the particles of the shell. We imagine the shell divided up into thin (infinitesimal) circular strips so that all points on a strip are equidistant from our particle m. One of these circular strips, labeled AB, is shown in Fig. D–1. It is $R\,d\theta$ wide, t thick, and has a radius $R\sin\theta$. The force on our particle m due to a tiny piece of the strip at point A is represented by the vector $\vec{\mathbf{F}}_{\mathrm{A}}$ shown. The force due to a tiny piece of the strip at point B, which is diametrically opposite A, is the force $\vec{\mathbf{F}}_{\mathrm{B}}$. We take the two pieces at A and B to be of equal mass, so $F_{\mathrm{A}} = F_{\mathrm{B}}$. The horizontal components of $\vec{\mathbf{F}}_{\mathrm{A}}$ and $\vec{\mathbf{F}}_{\mathrm{B}}$ are each equal to

$$F_{\mathrm{A}}\cos\phi$$

and point toward the center of the shell. The vertical components of $\vec{\mathbf{F}}_{\mathrm{A}}$ and $\vec{\mathbf{F}}_{\mathrm{B}}$ are of equal magnitude and point in opposite directions, and so cancel. Since for every point on the strip there is a corresponding point diametrically opposite (as with A and B), we see that the net force due to the entire strip points toward the center of the shell. Its magnitude will be

$$dF = G\frac{m\,dM}{\ell^2}\cos\phi,$$

where dM is the mass of the entire circular strip and ℓ is the distance from all points on the strip to m, as shown. We write dM in terms of the density ρ; by density we mean the mass per unit volume (Section 13–2). Hence, $dM = \rho\,dV$, where dV is the volume of the strip and equals $(2\pi R\sin\theta)(t)(R\,d\theta)$. Then the force dF due to the circular strip shown is

$$dF = G\frac{m\rho 2\pi R^2 t\sin\theta\,d\theta}{\ell^2}\cos\phi. \qquad \textbf{(D–1)}$$

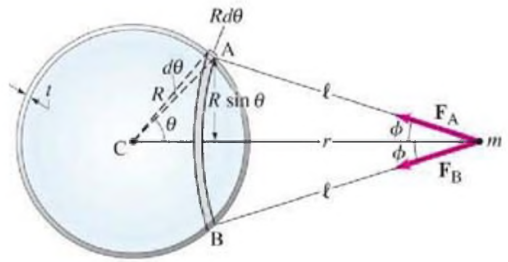
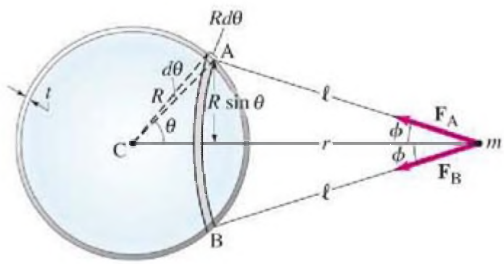


FIGURE D–1 Calculating the gravitational force on a particle of mass m due to a uniform spherical shell of radius R and mass M.

FIGURE D–1 (repeated) Calculating the gravitational force on a particle of mass m due to a uniform spherical shell of radius R and mass M.



To get the total force F that the entire shell exerts on the particle m, we must integrate over all the circular strips: that is, we integrate

$$dF = G\frac{m\rho 2\pi R^2 t \sin\theta\, d\theta}{\ell^2}\cos\phi \tag{D–1}$$

from $\theta = 0°$ to $\theta = 180°$. But our expression for dF contains ℓ and ϕ, which are functions of θ. From Fig. D–1 we can see that

$$\ell\cos\phi = r - R\cos\theta.$$

Furthermore, we can write the law of cosines for triangle CmA:

$$\cos\theta = \frac{r^2 + R^2 - \ell^2}{2rR}. \tag{D–2}$$

With these two expressions we can reduce our three variables (ℓ, θ, ϕ) to only one, which we take to be ℓ. We do two things with Eq. D–2: (1) We put it into the equation for $\ell\cos\phi$ above:

$$\cos\phi = \frac{1}{\ell}(r - R\cos\theta) = \frac{r^2 + \ell^2 - R^2}{2r\ell}.$$

and (2) we take the differential of both sides of Eq. D–2 (because $\sin\theta\, d\theta$ appears in the expression for dF, Eq. D–1), considering r and R to be constants when summing over the strips:

$$-\sin\theta\, d\theta = -\frac{2\ell\, d\ell}{2rR} \quad \text{or} \quad \sin\theta\, d\theta = \frac{\ell\, d\ell}{rR}.$$

We insert these into Eq. D–1 for dF and find

$$dF = Gm\rho\pi t\frac{R}{r^2}\left(1 + \frac{r^2 - R^2}{\ell^2}\right)d\ell.$$

Now we integrate to get the net force on our thin shell of radius R. To integrate over all the strips ($\theta = 0°$ to $180°$), we must go from $\ell = r - R$ to $\ell = r + R$ (see Fig. D–1). Thus,

$$\begin{aligned} F &= Gm\rho\pi t\frac{R}{r^2}\left[\ell - \frac{r^2 - R^2}{\ell}\right]_{\ell=r-R}^{\ell=r+R} \\ &= Gm\rho\pi t\frac{R}{r^2}(4R). \end{aligned}$$

The volume V of the spherical shell is its area $(4\pi R^2)$ times the thickness t. Hence the mass $M = \rho V = \rho 4\pi R^2 t$, and finally

$$F = G\frac{mM}{r^2}. \qquad \left[\begin{array}{c}\text{particle of mass } m \text{ outside a} \\ \text{thin uniform spherical shell of mass } M\end{array}\right]$$

This result gives us the force a thin shell exerts on a particle of mass m a distance r from the center of the shell, and *outside* the shell. We see that the force is the same as that between m and a particle of mass M at the center of the shell. In other words, for purposes of calculating the gravitational force exerted on or by a uniform spherical shell, we can consider all its mass concentrated at its center.

What we have derived for a shell holds also for a solid sphere, since a solid sphere can be considered as made up of many concentric shells, from $R = 0$ to $R = R_0$, where R_0 is the radius of the solid sphere. Why? Because if each shell has mass dM, we write for each shell, $dF = Gm\,dM/r^2$, where r is the distance from the center C to mass m and is the same for all shells. Then the total force equals the sum or integral over dM, which gives the total mass M. Thus the result

$$F = G\frac{mM}{r^2} \qquad \begin{bmatrix}\text{particle of mass } m \text{ outside}\\ \text{solid sphere of mass } M\end{bmatrix} \qquad \textbf{(D–3)}$$

is valid for a solid sphere of mass M even if the density varies with distance from the center. (It is not valid if the density varies within each shell—that is, depends not only on R.) Thus the gravitational force exerted on or by spherical objects, including nearly spherical objects like the Earth, Sun, and Moon, can be considered to act as if the objects were point particles.

This result, Eq. D–3, is true only if the mass m is outside the sphere. Let us next consider a point mass m that is located inside the spherical shell of Fig. D–1. Here, r would be less than R, and the integration over ℓ would be from $\ell = R - r$ to $\ell = R + r$, so

$$\left[\ell - \frac{r^2 - R^2}{\ell}\right]_{R-r}^{R+r} = 0.$$

Thus the force on any mass inside the shell would be zero. This result has particular importance for the electrostatic force, which is also an inverse square law. For the gravitational situation, we see that at points within a solid sphere, say 1000 km below the Earth's surface, only the mass up to that radius contributes to the net force. The outer shells beyond the point in question contribute zero net gravitational effect.

The results we have obtained here can also be reached using the gravitational analog of Gauss's law for electrostatics (Chapter 22).

APPENDIX

E Differential Form of Maxwell's Equations

Maxwell's equations can be written in another form that is often more convenient than Eqs. 31–5. This material is usually covered in more advanced courses, and is included here simply for completeness.

We quote here two theorems, without proof, that are derived in vector analysis textbooks. The first is called **Gauss's theorem** or the **divergence theorem**. It relates the integral over a surface of any vector function $\vec{\mathbf{F}}$ to a volume integral over the volume enclosed by the surface:

$$\oint_{\text{Area } A} \vec{\mathbf{F}} \cdot d\vec{\mathbf{A}} = \int_{\text{Volume } V} \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{F}}\, dV.$$

The operator $\vec{\boldsymbol{\nabla}}$ is the **del operator**, defined in Cartesian coordinates as

$$\vec{\boldsymbol{\nabla}} = \hat{\mathbf{i}}\frac{\partial}{\partial x} + \hat{\mathbf{j}}\frac{\partial}{\partial y} + \hat{\mathbf{k}}\frac{\partial}{\partial z}.$$

The quantity

$$\vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{F}} = \frac{\partial F_x}{\partial x} + \frac{\partial F_y}{\partial y} + \frac{\partial F_z}{\partial z}$$

is called the **divergence** of $\vec{\mathbf{F}}$. The second theorem is **Stokes's theorem**, and relates a line integral around a closed path to a surface integral over any surface enclosed by that path:

$$\oint_{\text{Line}} \vec{\mathbf{F}} \cdot d\vec{\boldsymbol{\ell}} = \int_{\text{Area } A} \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{F}} \cdot d\vec{\mathbf{A}}.$$

The quantity $\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{F}}$ is called the **curl** of $\vec{\mathbf{F}}$. (See Section 11–2 on the vector product.)

We now use these two theorems to obtain the differential form of Maxwell's equations in free space. We apply Gauss's theorem to Eq. 31–5a (Gauss's law):

$$\oint_A \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \int \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}}\, dV = \frac{Q}{\epsilon_0}.$$

Now the charge Q can be written as a volume integral over the charge density ρ: $Q = \int \rho\, dV$. Then

$$\int \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}}\, dV = \frac{1}{\epsilon_0}\int \rho\, dV.$$

Both sides contain volume integrals over the same volume, and for this to be true over *any* volume, whatever its size or shape, the integrands must be equal:

$$\vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}} = \frac{\rho}{\epsilon_0}. \qquad \textbf{(E–1)}$$

This is the differential form of Gauss's law. The second of Maxwell's equations, $\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$, is treated in the same way, and we obtain

$$\vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{B}} = 0. \qquad \textbf{(E–2)}$$

Next, we apply Stokes's theorem to the third of Maxwell's equations,

$$\oint \vec{\mathbf{E}} \cdot d\vec{\boldsymbol{\ell}} = \int \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = -\frac{d\Phi_B}{dt}.$$

Since the magnetic flux $\Phi_B = \int \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$, we have

$$\int \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = -\frac{\partial}{\partial t} \int \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}}$$

where we use the partial derivative, $\partial \vec{\mathbf{B}}/\partial t$, since B may also depend on position. These are surface integrals over the same area, and to be true over any area, even a very small one, we must have

$$\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}} = -\frac{\partial \vec{\mathbf{B}}}{\partial t}. \qquad \textbf{(E–3)}$$

This is the third of Maxwell's equations in differential form. Finally, to the last of Maxwell's equations,

$$\oint \vec{\mathbf{B}} \cdot d\vec{\boldsymbol{\ell}} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt},$$

we apply Stokes's theorem and write $\Phi_E = \int \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}}$:

$$\int \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = \mu_0 I + \mu_0 \epsilon_0 \frac{\partial}{\partial t} \int \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}}.$$

The conduction current I can be written in terms of the current density $\vec{\mathbf{j}}$, using Eq. 25–12:

$$I = \int \vec{\mathbf{j}} \cdot d\vec{\mathbf{A}}.$$

Then Maxwell's fourth equation becomes:

$$\int \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = \mu_0 \int \vec{\mathbf{j}} \cdot d\vec{\mathbf{A}} + \mu_0 \epsilon_0 \frac{\partial}{\partial t} \int \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}}.$$

For this to be true over any area A, whatever its size or shape, the integrands on each side of the equation must be equal:

$$\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}} = \mu_0 \vec{\mathbf{j}} + \mu_0 \epsilon_0 \frac{\partial \vec{\mathbf{E}}}{\partial t}. \qquad \textbf{(E–4)}$$

Equations E–1, 2, 3, and 4 are Maxwell's equations in differential form for free space. They are summarized in Table E–1.

TABLE E–1 Maxwell's Equations in Free Space†

Integral form	Differential form
$\oint \vec{\mathbf{E}} \cdot d\vec{\mathbf{A}} = \frac{Q}{\epsilon_0}$	$\vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}} = \frac{\rho}{\epsilon_0}$
$\oint \vec{\mathbf{B}} \cdot d\vec{\mathbf{A}} = 0$	$\vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{B}} = 0$
$\oint \vec{\mathbf{E}} \cdot d\vec{\boldsymbol{\ell}} = -\frac{d\Phi_B}{dt}$	$\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}} = -\frac{\partial \vec{\mathbf{B}}}{\partial t}$
$\oint \vec{\mathbf{B}} \cdot d\vec{\boldsymbol{\ell}} = \mu_0 I + \mu_0 \epsilon_0 \frac{d\Phi_E}{dt}$	$\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}} = \mu_0 \vec{\mathbf{j}} + \mu_0 \epsilon_0 \frac{\partial \vec{\mathbf{E}}}{\partial t}$

† $\vec{\boldsymbol{\nabla}}$ stands for the *del operator* $\vec{\boldsymbol{\nabla}} = \hat{\mathbf{i}}\frac{\partial}{\partial x} + \hat{\mathbf{j}}\frac{\partial}{\partial y} + \hat{\mathbf{k}}\frac{\partial}{\partial z}$ in Cartesian coordinates.

APPENDIX

F Selected Isotopes

(1) Atomic Number Z	(2) Element	(3) Symbol	(4) Mass Number A	(5) Atomic Mass†	(6) % Abundance (or Radioactive Decay‡ Mode)	(7) Half-life (if radioactive)
0	(Neutron)	n	1	1.008665	β^-	10.23 min
1	Hydrogen	H	1	1.007825	99.9885%	
	Deuterium	d or D	2	2.014082	0.0115%	
	Tritium	t or T	3	3.016049	β^-	12.312 yr
2	Helium	He	3	3.016029	0.000137%	
			4	4.002603	99.999863%	
3	Lithium	Li	6	6.015123	7.59%	
			7	7.016005	92.41%	
4	Beryllium	Be	7	7.016930	EC, γ	53.22 days
			9	9.012182	100%	
5	Boron	B	10	10.012937	19.9%	
			11	11.009305	80.1%	
6	Carbon	C	11	11.011434	β^+, EC	20.370 min
			12	12.000000	98.93%	
			13	13.003355	1.07%	
			14	14.003242	β^-	5730 yr
7	Nitrogen	N	13	13.005739	β^+, EC	9.9670 min
			14	14.003074	99.632%	
			15	15.000109	0.368%	
8	Oxygen	O	15	15.003066	β^+, EC	122.5 min
			16	15.994915	99.757%	
			18	17.999161	0.205%	
9	Fluorine	F	19	18.998403	100%	
10	Neon	Ne	20	19.992440	90.48%	
			22	21.991385	9.25%	
11	Sodium	Na	22	21.994436	β^+, EC, γ	2.6027 yr
			23	22.989769	100%	
			24	23.990963	β^-, γ	14.9574 h
12	Magnesium	Mg	24	23.985042	78.99%	
13	Aluminum	Al	27	26.981539	100%	
14	Silicon	Si	28	27.976927	92.2297%	
			31	30.975363	β^-, γ	157.3 min
15	Phosphorus	P	31	30.973762	100%	
			32	31.973907	β^-	14.284 days

† The masses given in column (5) are those for the neutral atom, including the Z electrons.

‡ Chapter 41; EC = electron capture.

(1) Atomic Number Z	(2) Element	(3) Symbol	(4) Mass Number A	(5) Atomic Mass	(6) % Abundance (or Radioactive Decay Mode)	(7) Half-life (if radioactive)
16	Sulfur	S	32	31.972071	94.9%	
			35	34.969032	β^-	87.32 days
17	Chlorine	Cl	35	34.968853	75.78%	
			37	36.965903	24.22%	
18	Argon	Ar	40	39.962383	99.600%	
19	Potassium	K	39	38.963707	93.258%	
			40	39.963998	0.0117%	
					β^-, EC, γ, β^+	1.265×10^9 yr
20	Calcium	Ca	40	39.962591	96.94%	
21	Scandium	Sc	45	44.955912	100%	
22	Titanium	Ti	48	47.947946	73.72%	
23	Vanadium	V	51	50.943960	99.750%	
24	Chromium	Cr	52	51.940508	83.789%	
25	Manganese	Mn	55	54.938045	100%	
26	Iron	Fe	56	55.934938	91.75%	
27	Cobalt	Co	59	58.933195	100%	
			60	59.933817	β^-, γ	5.2710 yr
28	Nickel	Ni	58	57.935343	68.077%	
			60	59.930786	26.223%	
29	Copper	Cu	63	62.929598	69.17%	
			65	64.927790	30.83%	
30	Zinc	Zn	64	63.929142	48.6%	
			66	65.926033	27.9%	
31	Gallium	Ga	69	68.925574	60.108%	
32	Germanium	Ge	72	71.922076	27.5%	
			74	73.921178	36.3%	
33	Arsenic	As	75	74.921596	100%	
34	Selenium	Se	80	79.916521	49.6%	
35	Bromine	Br	79	78.918337	50.69%	
36	Krypton	Kr	84	83.911507	57.00%	
37	Rubidium	Rb	85	84.911790	72.17%	
38	Strontium	Sr	86	85.909260	9.86%	
			88	87.905612	82.58%	
			90	89.907738	β^-	28.80 yr
39	Yttrium	Y	89	88.905848	100%	
40	Zirconium	Zr	90	89.904704	51.4%	
41	Niobium	Nb	93	92.906378	100%	
42	Molybdenum	Mo	98	97.905408	24.1%	
43	Technetium	Tc	98	97.907216	β^-, γ	4.2×10^6 yr
44	Ruthenium	Ru	102	101.904349	31.55%	
45	Rhodium	Rh	103	102.905504	100%	
46	Palladium	Pd	106	105.903486	27.33%	
47	Silver	Ag	107	106.905097	51.839%	
			109	108.904752	48.161%	
48	Cadmium	Cd	114	113.903359	28.7%	
49	Indium	In	115	114.903878	95.71%; β^-	4.41×10^{14} yr
50	Tin	Sn	120	119.902195	32.58%	
51	Antimony	Sb	121	120.903816	57.21%	

(1) Atomic Number Z	(2) Element	(3) Symbol	(4) Mass Number A	(5) Atomic Mass	(6) % Abundance (or Radioactive Decay Mode)	(7) Half-life (if radioactive)
52	Tellurium	Te	130	129.906224	34.1%; $\beta^-\beta^-$	$>9.7 \times 10^{22}$ yr
53	Iodine	I	127	126.904473	100%	
			131	130.906125	β^-, γ	8.0233 days
54	Xenon	Xe	132	131.904154	26.89%	
			136	135.907219	8.87%; $\beta^-\beta^-$	$>8.5 \times 10^{21}$ yr
55	Cesium	Cs	133	132.905452	100%	
56	Barium	Ba	137	136.905827	11.232%	
			138	137.905247	71.70%	
57	Lanthanum	La	139	138.906353	99.910%	
58	Cerium	Ce	140	139.905439	88.45%	
59	Praseodymium	Pr	141	140.907653	100%	
60	Neodymium	Nd	142	141.907723	27.2%	
61	Promethium	Pm	145	144.912749	EC, α	17.7 yr
62	Samarium	Sm	152	151.919732	26.75%	
63	Europium	Eu	153	152.921230	52.19%	
64	Gadolinium	Gd	158	157.924104	24.84%	
65	Terbium	Tb	159	158.925347	100%	
66	Dysprosium	Dy	164	163.929175	28.2%	
67	Holmium	Ho	165	164.930322	100%	
68	Erbium	Er	166	165.930293	33.6%	
69	Thulium	Tm	169	168.934213	100%	
70	Ytterbium	Yb	174	173.938862	31.8%	
71	Lutetium	Lu	175	174.940772	97.41%	
72	Hafnium	Hf	180	179.946550	35.08%	
73	Tantalum	Ta	181	180.947996	99.988%	
74	Tungsten (wolfram)	W	184	183.950931	30.64%; α	$>8.9 \times 10^{21}$ yr
75	Rhenium	Re	187	186.955753	62.60%; β^-	4.35×10^{10} yr
76	Osmium	Os	191	190.960930	β^-, γ	15.4 days
			192	191.961481	40.78%	
77	Iridium	Ir	191	190.960594	37.3%	
			193	192.962926	62.7%	
78	Platinum	Pt	195	194.964791	33.832%	
79	Gold	Au	197	196.966569	100%	
80	Mercury	Hg	199	198.968280	16.87%	
			202	201.970643	29.9%	
81	Thallium	Tl	205	204.974428	70.476%	
82	Lead	Pb	206	205.974465	24.1%	
			207	206.975897	22.1%	
			208	207.976652	52.4%	
			210	209.984188	β^-, γ, α	22.23 yr
			211	210.988737	β^-, γ	36.1 min
			212	211.991898	β^-, γ	10.64 h
			214	213.999805	β^-, γ	26.8 min
83	Bismuth	Bi	209	208.980399	100%	
			211	210.987269	α, γ, β^-	2.14 min
84	Polonium	Po	210	209.982874	α, γ, EC	138.376 days
			214	213.995201	α, γ	162.3 μs
85	Astatine	At	218	218.008694	α, β^-	1.4 s

(1) Atomic Number Z	(2) Element	(3) Symbol	(4) Mass Number A	(5) Atomic Mass	(6) % Abundance (or Radioactive Decay Mode)	(7) Half-life (if radioactive)
86	Radon	Rn	222	222.017578	α, γ	3.8232 days
87	Francium	Fr	223	223.019736	β^-, γ, α	22.00 min
88	Radium	Ra	226	226.025410	α, γ	1600 yr
89	Actinium	Ac	227	227.027752	β^-, γ, α	21.772 yr
90	Thorium	Th	228	228.028741	α, γ	698.60 days
			232	232.038055	100%; α, γ	1.405×10^{10} yr
91	Protactinium	Pa	231	231.035884	α, γ	3.276×10^{4} yr
92	Uranium	U	232	232.037156	α, γ	68.9 yr
			233	233.039635	α, γ	1.592×10^{5} yr
			235	235.043930	0.720%; α, γ	7.04×10^{8} yr
			236	236.045568	α, γ	2.342×10^{7} yr
			238	238.050788	99.274%; α, γ	4.468×10^{9} yr
			239	239.054293	β^-, γ	23.46 min
93	Neptunium	Np	237	237.048173	α, γ	2.144×10^{6} yr
			239	239.052939	β^-, γ	2.356 days
94	Plutonium	Pu	239	239.052163	α, γ	24,100 yr
			244	244.064204	α	8.00×10^{7} yr
95	Americium	Am	243	243.061381	α, γ	7370 yr
96	Curium	Cm	247	247.070354	α, γ	1.56×10^{7} yr
97	Berkelium	Bk	247	247.070307	α, γ	1380 yr
98	Californium	Cf	251	251.079587	α, γ	898 yr
99	Einsteinium	Es	252	252.082980	α, EC, γ	471.7 days
100	Fermium	Fm	257	257.095105	α, γ	100.5 days
101	Mendelevium	Md	258	258.098431	α, γ	51.5 days
102	Nobelium	No	259	259.10103	α, EC	58 min
103	Lawrencium	Lr	262	262.10963	α, EC, fission	$\approx$4 h
104	Rutherfordium	Rf	263	263.11255	fission	10 min
105	Dubnium	Db	262	262.11408	α, fission, EC	35 s
106	Seaborgium	Sg	266	266.12210	α, fission	$\approx$21 s
107	Bohrium	Bh	264	264.12460	α	$\approx$0.44 s
108	Hassium	Hs	269	269.13406	α	$\approx$10 s
109	Meitnerium	Mt	268	268.13870	α	21 ms
110	Darmstadtium	Ds	271	271.14606	α	$\approx$70 ms
111	Roentgenium	Rg	272	272.15360	α	3.8 ms
112		Uub	277	277.16394	α	$\approx$0.7 ms

Preliminary evidence (unconfirmed) has been reported for elements 113, 114, 115, 116 and 118.

Answers to Odd-Numbered Problems

CHAPTER 1

1. (*a*) 1.4×10^{10} y;
(*b*) 4.4×10^{17} s.
3. (*a*) 1.156×10^{0};
(*b*) 2.18×10^{1};
(*c*) 6.8×10^{-3};
(*d*) 3.2865×10^{2};
(*e*) 2.19×10^{-1};
(*f*) 4.44×10^{2}.
5. 4.6%.
7. 1.00×10^{5} s.
9. 0.24 rad.
11. (*a*) 0.2866 m;
(*b*) 0.000085 V;
(*c*) 0.00076 kg;
(*d*) 0.0000000000600 s;
(*e*) 0.0000000000000225 m;
(*f*) 2,500,000,000 V.
13. $5'10'' = 1.8$ m, 165 lbs $= 75.2$ kg.
15. (*a*) $1\ \text{ft}^2 = 0.111\ \text{yd}^2$;
(*b*) $1\ \text{m}^2 = 10.8\ \text{ft}^2$.
17. (*a*) 3.9×10^{-9} in.;
(*b*) 1.0×10^{8} atoms.
19. (*a*) 1 km/h $=$ 0.621 mi/h;
(*b*) 1 m/s $=$ 3.28 ft/s;
(*c*) 1 km/h $=$ 0.278 m/s.
21. (*a*) 9.46×10^{15} m;
(*b*) 6.31×10^{4} AU;
(*c*) 7.20 AU/h.
23. (*a*) $3.80 \times 10^{13}\ \text{m}^2$;
(*b*) 13.4.
25. 6×10^{5} books.
27. 5×10^{4} L.
29. (*a*) 1800.
31. 5×10^{4} m.
33. 6.5×10^{6} m.
35. $[M/L^3]$.
37. (*a*) Cannot;
(*b*) can;
(*c*) can.
39. (1×10^{-5})%, 8 significant figures.
41. (*a*) 3.16×10^{7} s;
(*b*) 3.16×10^{16} ns;
(*c*) 3.17×10^{-8} y.
43. 2×10^{-4} m.
45. 1×10^{11} gal/y.
47. 9 cm/y.
49. 2×10^{9} kg/y.
51. 75 min.
53. 4×10^{5} metric tons, 1×10^{8} gal.
55. 1×10^{3} days
57. 210 yd, 190 m.
59. (*a*) 0.10 nm;
(*b*) 1.0×10^{5} fm;
(*c*) 1.0×10^{10} Å;
(*d*) 9.5×10^{25} Å.
61. (*a*) 3%, 3%;
(*b*) 0.7%, 0.2%.
63. $8 \times 10^{-2}\ \text{m}^3$.
65. L/m, L/y, L.
67. (*a*) 13.4;
(*b*) 49.3.
69. 4×10^{51} kg.

CHAPTER 2

1. 61 m.
3. 0.65 cm/s, no.
5. 300 m/s, 1 km every 3 sec.
7. (*a*) 9.26 m/s;
(*b*) 3.1 m/s.
9. (*a*) 0.3 m/s;
(*b*) 1.2 m/s;
(*c*) 0.30 m/s;
(*d*) 1.4 m/s;
(*e*) -0.95 m/s.
11. 2.0×10^{1} s.
13. (*a*) 5.4×10^{3} m;
(*b*) 72 min.
15. (*a*) 61 km/h;
(*b*) 0.
17. (*a*) 16 m/s;
(*b*) $+5$ m/s.
19. 6.73 m/s.
21. 5 s.
23. (*a*) 48 s;
(*b*) 90 s to 108 s;
(*c*) 0 to 42 s, 65 s to 83 s, 90 s to 108 s;
(*d*) 65 s to 83 s.
25. (*a*) 21.2 m/s;
(*b*) $2.00\ \text{m/s}^2$.
27. $17.0\ \text{m/s}^2$.
29. (*a*) m/s, m/s^2;
(*b*) $2B\ \text{m/s}^2$;
(*c*) $(A + 10B)$ m/s, $2B\ \text{m/s}^2$;
(*d*) $A - 3Bt^{-4}$.
31. $1.5\ \text{m/s}^2$, 99 m.
33. $240\ \text{m/s}^2$.
35. $4.41\ \text{m/s}^2$, 2.61 s.
37. 45.0 m.
39. (*a*) 560 m;
(*b*) 47 s;
(*c*) 23 m, 21 m.
41. (*a*) 96 m;
(*b*) 76 m.
43. 27 m/s.
45. 117 km/h.
47. $0.49\ \text{m/s}^2$.
49. 1.6 s.
51. (*a*) 20 m;
(*b*) 4 s.
53. 1.16 s.
55. 5.18 s.
57. (*a*) 25 m/s;
(*b*) 33 m;
(*c*) 1.2 s;
(*d*) 5.2 s.
59. (*a*) 14 m/s;
(*b*) fifth floor.
61. 1.3 m.
63. 18.8 m/s, 18.1 m.
65. 52 m.
67. 106 m.
69. (*a*) $\frac{g}{k}(1 - e^{-kt})$;
(*b*) $\frac{g}{k}$.
71. 6.
73. 1.3 m.
75. (*b*) 10 m;
(*c*) 40 m.
77. $5.2 \times 10^{-2}\ \text{m/s}^2$.
79. 4.6 m/s to 5.4 m/s, 5.8 m/s to 6.7 m/s, smaller range of velocities.
81. (*a*) 5.39 s;
(*b*) 40.3 m/s;
(*c*) 90.9 m.

83. (*a*) 8.7 min;
(*b*) 7.3 min.

85. 2.3.

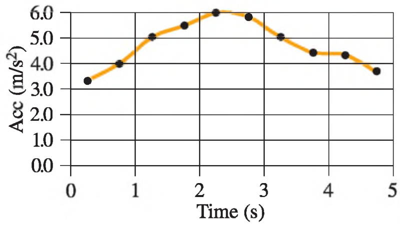
87. Stop.

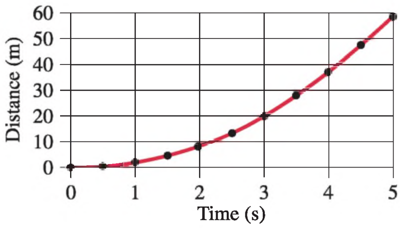
89. 1.5 poles.

91. 0.44 m/min, 2.9 burgers/min.

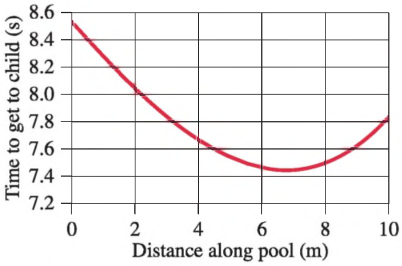
93. (*a*) Where the slopes are the same;
(*b*) bicycle A;
(*c*) when the two graphs cross; first crossing, B passing A; second crossing, A passing B;
(*d*) B until the slopes are equal, A after that;
(*e*) same.

95. (*c*)



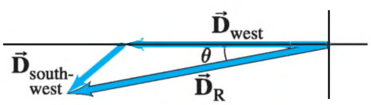


97. (*b*) 6.8 m.



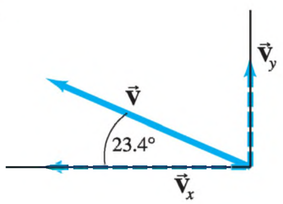
CHAPTER 3

1. 286 km, 11° south of west.



3. 10.1, −39.4°.

5. (*a*)



(*b*) −22.8, 9.85;
(*c*) 24.8, 23.4° above the $-x$ axis.

7. (*a*) 625 km/h, 553 km/h;
(*b*) 1560 km, 1380 km.

9. (*a*) 4.2 at 315°;
(*b*) $1.0\hat{\mathbf{i}} - 5.0\hat{\mathbf{j}}$ or 5.1 at 280°.

11. (*a*) $-53.7\hat{\mathbf{i}} + 1.31\hat{\mathbf{j}}$ or 53.7 at 1.4° above $-x$ axis;
(*b*) $53.7\hat{\mathbf{i}} - 1.31\hat{\mathbf{j}}$ or 53.7 at 1.4° below $+x$ axis, they are opposite.

13. (*a*) $-92.5\hat{\mathbf{i}} - 19.4\hat{\mathbf{j}}$ or 94.5 at 11.8° below $-x$ axis;
(*b*) $122\hat{\mathbf{i}} - 86.6\hat{\mathbf{j}}$ or 150 at 35.3° below $+x$ axis.

15. $(-2450\text{ m})\hat{\mathbf{i}} + (3870\text{ m})\hat{\mathbf{j}} + (2450\text{ m})\hat{\mathbf{k}}$, 5190 m.

17. $(9.60\hat{\mathbf{i}} - 2.00t\hat{\mathbf{k}})$ m/s, $(-2.00\hat{\mathbf{k}})$ m/s^2.

19. Parabola.

21. (*a*) $4.0t$ m/s, $3.0t$ m/s;
(*b*) $5.0t$ m/s;
(*c*) $(2.0t^2\hat{\mathbf{i}} + 1.5t^2\hat{\mathbf{j}})$ m;
(*d*) $v_x = 8.0$ m/s, $v_y = 6.0$ m/s, $v = 10.0$ m/s, $\vec{\mathbf{r}} = (8.0\hat{\mathbf{i}} + 6.0\hat{\mathbf{j}})$ m.

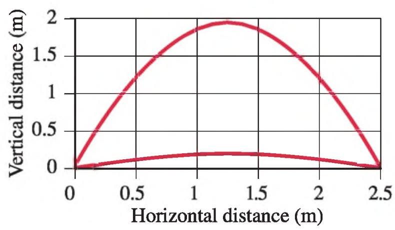
23. (*a*) $(3.16\hat{\mathbf{i}} + 2.78\hat{\mathbf{j}})$ cm/s;
(*b*) 4.21 cm/s at 41.3°.

25. (*a*) $(6.0t\hat{\mathbf{i}} - 18.0t^2\hat{\mathbf{j}})$ m/s, $(6.0\hat{\mathbf{i}} - 36.0t\hat{\mathbf{j}})$ m/s^2;
(*b*) $(19\hat{\mathbf{i}} - 94\hat{\mathbf{j}})$ m, $(15\hat{\mathbf{i}} - 110\hat{\mathbf{j}})$ m/s.

27. 414 m at −65.0°.

29. 44 m, 6.9 m.

31. 18°, 72°.



33. 2.26 s.

35. 22.3 m.

37. 39 m.

41. (*a*) 12 s;
(*b*) 62 m.

43. 5.5 s.

45. (*a*) $(2.3\hat{\mathbf{i}} + 2.5\hat{\mathbf{j}})$ m/s;
(*b*) 5.3 m;
(*c*) $(2.3\hat{\mathbf{i}} - 10.2\hat{\mathbf{j}})$ m/s.

47. No, 0.76 m too low; 4.5 m to 34.7 m.

51. $\tan^{-1} gt/v_0$.

53. (*a*) 50.0 m;
(*b*) 6.39 s;
(*c*) 221 m;
(*d*) 38.3 m/s at 25.7°.

55. $\dfrac{1}{2}\tan^{-1}\left(-\dfrac{1}{\tan\phi}\right) = \dfrac{\phi}{2} + \dfrac{\pi}{4}$.

57. $(10.5\text{ m/s})\hat{\mathbf{i}}$, $(6.5\text{ m/s})\hat{\mathbf{i}}$.

59. 1.41 m/s.

61. 23 s, 23 m.

63. (*a*) 11.2 m/s, 27° above the horizontal;
(*b*) 11.2 m/s, 27° below the horizontal.

65. 6.3°, west of south.

67. (*a*) 46 m;
(*b*) 92 s.

69. (*a*) 1.13 m/s;
(*b*) 3.20 m/s.

71. 43.6° north of east.

73. $(66\text{ m})\hat{\mathbf{i}} - (35\text{ m})\hat{\mathbf{j}} - (12\text{ m})\hat{\mathbf{k}}$, 76 m, 28° south of east, 9° below the horizontal.

75. 131 km/h, 43.1° north of east.

77. 7.0 m/s.

79. 1.8 m/s^2.

81. 1.9 m/s, 2.7 s.

83. (*a*) $\dfrac{Dv}{(v^2 - u^2)}$;
(*b*) $\dfrac{D}{\sqrt{v^2 - u^2}}$.

85. 54°.

87. $[(1.5\text{ m})\hat{\mathbf{i}} - (2.0t\text{ m})\hat{\mathbf{i}}] + [(-3.1\text{ m})\hat{\mathbf{j}} + (1.75t^2\text{ m})\hat{\mathbf{j}}]$, $(3.5\text{ m/s}^2)\hat{\mathbf{j}}$, parabolic.

89. Row at an angle of 24.9° upstream and run 104 m along the bank in a total time of 862 seconds.

91. 69.9° north of east.

93. (*a*) 13 m;
(*b*) 31° below the horizontal.

95. 5.1 s.

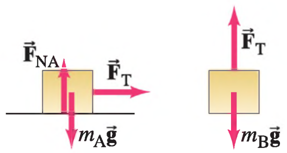
97. (*a*) 13 m/s, 12 m/s;
(*b*) 33 m.

99. (*a*) $x = (3.03t - 0.0265)$ m, 3.03 m/s;
(*b*) $y = (0.158 - 0.855t + 6.09t^2)$ m, 12.2 m/s^2.

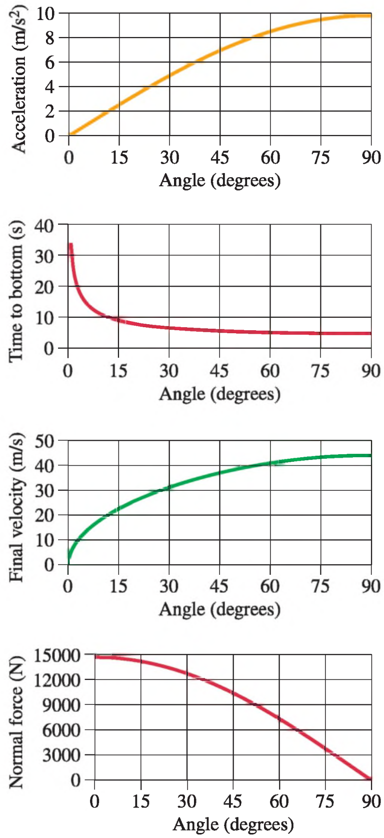
CHAPTER 4

1. 77 N.
3. (*a*) 6.7×10^2 N;
   (*b*) 1.2×10^2 N;
   (*c*) 2.5×10^2 N;
   (*d*) 0.
5. 1.3×10^6 N, 39%, 1.3×10^6 N.
7. 2.1×10^2 N.
9. $m > 1.5$ kg.
11. 89.8 N.
13. 1.8 m/s^2, up.
15. Descend with $a \geq 2.2$ m/s^2.
17. -2800 m/s^2, 280 g's, 1.9×10^5 N.
19. (*a*) 7.5 s, 13 s, 7.5 s;
    (*b*) 12%, 0%, -12%;
    (*c*) 55%.
21. (*a*) 3.1 m/s^2;
    (*b*) 25 m/s;
    (*c*) 78 s.
23. 3.3×10^3 N.
25. (*a*) 150 N;
    (*b*) 14.5 m/s.
27. (*a*) 47.0 N;
    (*b*) 17.0 N;
    (*c*) 0.
29. (*a*) (*b*)

31. (*a*) 1.5 m;
    (*b*) 11.5 kN, no.
33. (*a*) 31 N, 63 N;
    (*b*) 35 N, 71 N.
35. 6.3×10^3 N, 8.4×10^3 N.
37. (*a*) 19.0 N at 237.5°, 1.03 m/s^2 at 237.5°;
    (*b*) 14.0 N at 51.0°, 0.758 m/s^2 at 51.0°.
39. $\frac{5}{2}\frac{F_0}{m}t_0^2$.
41. 4.0×10^2 m.
43. 12°.
45. (*a*) 9.9 N;
    (*b*) 260 N.
47. (*a*) $m_E g - F_T = m_E a$;
    $F_T - m_C g = m_C a$;
    (*b*) 0.68 m/s^2, 10,500 N.
49. (*a*) 2.8 m;
    (*b*) 2.5 s.
51. (*a*)



    (*b*) $g\frac{m_B}{m_A + m_B}$, $g\frac{m_A m_B}{m_A + m_B}$.
53. $g\dfrac{m_B + \dfrac{\ell_B}{\ell_A + \ell_B}m_C}{m_A + m_B + m_C}$.
55. $(m + M)g \tan\theta$.
57. 1.52 m/s^2, 18.3 N, 19.8 N.
59. $\dfrac{(m_A + m_B + m_C)m_B}{\sqrt{(m_A^2 - m_B^2)}}g$.
61. (*a*) $\left(\frac{2y}{\ell} - 1\right)g$;
    (*b*) $\sqrt{2gy_0\left(1 - \frac{y_0}{\ell}\right)}$;
    (*c*) $\frac{2}{3}\sqrt{g\ell}$.
63. 6.3 N.
65. 2.0 s, no change.
67. (*a*) $g\dfrac{(m_A \sin\theta - m_B)}{(m_A + m_B)}$;
    (*b*) $m_A \sin\theta > m_B$ (m_A down the plane),
    $m_A \sin\theta < m_B$ (m_A up the plane).
69. (*a*) $\dfrac{m_B \sin\theta_B - m_A \sin\theta_A}{m_A + m_B}g$;
    (*b*) 6.8 kg, 26 N;
    (*c*) 0.74.
71. 9.9°.
73. (*a*) $41\,\frac{\text{N}}{\text{m/s}}$;
    (*b*) 1.4×10^2 N.
75. (*a*) $Mg/2$;
    (*b*) $Mg/2$, $Mg/2$, $3Mg/2$, Mg.
77. 8.7×10^2 N, 72° above the horizontal.
79. (*a*) 0.6 m/s^2;
    (*b*) 1.5×10^5 N.
81. 1.76×10^4 N.
83. 3.8×10^2 N, 7.6×10^2 N.
85. 3.4 m/s.
87. (*a*) 23 N;
    (*b*) 3.8 N.
89. (*a*) $g\sin\theta$, $\sqrt{\dfrac{2\ell}{g\sin\theta}}$, $\sqrt{2\ell g \sin\theta}$, $mg\cos\theta$;
    (*b*)



The graphs are all consistent with the results of the limiting cases.

CHAPTER 5

1. 65 N, 0.
3. 0.20.
5. 8.8 m/s^2.
7. 1.0×10^2 N, 0.48.
9. 0.51.
11. 4.2 m.
13. 1.2×10^3 N.
15. (*a*) 0.67;
    (*b*) 6.8 m/s;
    (*c*) 16 m/s.
17. (*a*) 1.7 m/s^2;
    (*b*) 4.3×10^2 N;
    (*c*) 1.7 m/s^2, 2.2×10^2 N.
19. (*a*) 0.80 m;
    (*b*) 1.3 s.
21. (*a*) A will pull B along;
    (*b*) B will eventually catch up to A;

(c) $\mu_A < \mu_B: a =$

$$g\left[\frac{(m_A + m_B)\sin\theta - (\mu_A m_A + \mu_B m_B)\cos\theta}{(m_A + m_B)}\right],$$

$$F_T = g\frac{m_A m_B}{(m_A + m_B)}(\mu_B - \mu_A)\cos\theta,$$

$\mu_A > \mu_B: a_A = g(\sin\theta - \mu_A\cos\theta)$,
$a_B = g(\sin\theta - \mu_B\cos\theta)$, $F_T = 0$.

23. (a) 5.0 kg;
(b) 6.7 kg.

25. (a) $\dfrac{v_0^2}{2dg\cos\theta} - \tan\theta$;
(b) $\mu_s \geq \tan\theta$.

27. (a) 0.22 s;
(b) 0.16 m.

29. 0.51.

31. (a) 82 N;
(b) 4.5 m/s^2.

33. $(M + m)g\dfrac{(\sin\theta + \mu\cos\theta)}{(\cos\theta - \mu\sin\theta)}$.

35. (a) 1.41 m/s^2;
(b) 31.7 N.

37. $\sqrt{rg}$.

39. 30 m.

41. 31 m/s.

43. 0.9 g's.

45. 9.0 rev/min.

47. (a) 1.9×10^3 m;
(b) 5.4×10^3 N;
(c) 3.8×10^3 N.

49. 3.0×10^2 N.

51. 0.164.

53. (a) 7960 N;
(b) 588 N;
(c) 29.4 m/s.

55. 6.2 m/s.

57. (b) $\vec{\mathbf{v}} = (-6.0\,\text{m/s})\sin(3.0\,\text{rad/s}\,t)\,\hat{\mathbf{i}} + (6.0\,\text{m/s})\cos(3.0\,\text{rad/s}\,t)\,\hat{\mathbf{j}}$,
$\vec{\mathbf{a}} = (-18\,\text{m/s}^2)\cos(3.0\,\text{rad/s}\,t)\,\hat{\mathbf{i}} + (-18\,\text{m/s}^2)\sin(3.0\,\text{rad/s}\,t)\,\hat{\mathbf{j}}$;
(c) $v = 6.0$ m/s, $a = 18$ m/s^2.

59. 17 m/s $\leq v \leq$ 32 m/s.

61. (a) $a_t = (\pi/2)$ m/s^2, $a_c = 0$;
(b) $a_t = (\pi/2)$ m/s^2,
$a_c = (\pi^2/8)$ m/s^2;
(c) $a_t = (\pi/2)$ m/s^2,
$a_c = (\pi^2/2)$ m/s^2.

63. (a) 1.64 m/s;
(b) 3.45 m/s.

65. m/b.

67. (a) $\dfrac{mg}{b} + \left(v_0 - \dfrac{mg}{b}\right)e^{-\frac{b}{m}t}$;
(b) $-\dfrac{mg}{b} + \left(v_0 + \dfrac{mg}{b}\right)e^{-\frac{b}{m}t}$.

69. (a) 14 kg/m;
(b) 570 N.

71. $\dfrac{mg}{b}\left[t + \dfrac{m}{b}\left(e^{-\frac{b}{m}t} - 1\right)\right], ge^{-\frac{b}{m}t}$.

75. 10 m.

77. 0.46.

79. 102 N, 0.725.

81. Yes, 14 m/s.

83. 28.3 m/s, 0.410 rev/s.

85. 3500 N, 1900 N.

87. 35°.

89. 132 m.

91. (a) 55 s;
(b) centripetal component of the normal force.

93. (a) $\theta = \cos^{-1}\dfrac{g}{4\pi^2 r f^2}$;
(b) 73.6°;
(c) no.

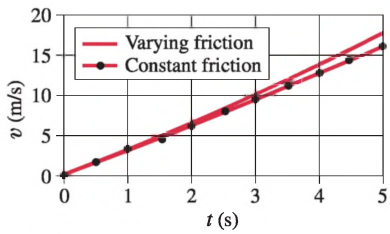
95. 82°.

97. (a) 16 m/s;
(b) 13 m/s.

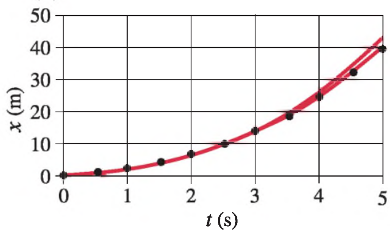
99. (a) 0.88 m/s^2;
(b) 0.98 m/s^2.

101. (a) 42.2 m/s;
(b) 35.6 m, 52.6 m.

103. (a)



(b)



(c) speed: −12%, position: −6.6%.

CHAPTER 6

1. 1610 N.

3. 1.9 m/s^2.

5. $\frac{2}{9}$.

7. 0.91 g's.

9. 1.4×10^{-8} N at 45°.

11. $Gm^2\left\{\left[\dfrac{2}{x_0^2} + \dfrac{3x_0}{(x_0^2 + y_0^2)^{3/2}}\right]\hat{\mathbf{i}} + \left[\dfrac{4}{y_0^2} + \dfrac{3y_0}{(x_0^2 + y_0^2)^{3/2}}\right]\hat{\mathbf{j}}\right\}$.

13. $2^{1/3} \approx 1.26$ times larger.

15. 3.46×10^8 m from the center of the Earth.

19. (b) g decreases as r increases;
(c) 9.42 m/s^2 approximate,
9.43 m/s^2 exact.

21. 9.78 m/s^2, 0.099° south of radially inward.

23. 7.52×10^3 m/s.

25. 1.7 m/s^2 upward.

27. 7.20×10^3 s.

29. (a) 520 N;
(b) 520 N;
(c) 690 N;
(d) 350 N;
(e) 0.

31. (a) 59 N, toward the Moon;
(b) 110 N, away from the Moon.

33. (a) They are executing centripetal motion;
(b) 9.6×10^{29} kg.

35. $\sqrt{\dfrac{GM}{\ell}}$.

37. 5070 s, or 84.5 min.

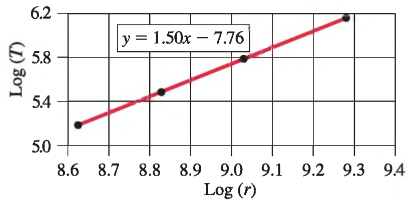
39. 160 y.

41. 2×10^8 y.

43. Europa: 671×10^3 km;
Ganymede: 1070×10^3 km;
Callisto: 1880×10^3 km.

45. (a) 180 AU;
(b) 360 AU;
(c) 360/1.

47. (a) $\log T = \frac{3}{2}\log r + \frac{1}{2}\log\left(\dfrac{4\pi^2}{Gm_J}\right)$,
slope $= \frac{3}{2}$,
y-intercept $= \frac{1}{2}\log\left(\dfrac{4\pi^2}{Gm_J}\right)$;
(b)



slope = 1.50 as predicted,
$m_J = 1.97 \times 10^{27}$ kg.

49. (a) 5.95×10^{-3} m/s^2;
(b) no, only by about 0.06%.

51. 2.64×10^6 m.

53. (a) 4.38×10^7 m/s^2;
(b) 2.8×10^9 N;
(c) 9.4×10^3 m/s.

55. $T_{\text{inner}} = 2.0 \times 10^4$ s,
$T_{\text{outer}} = 7.1 \times 10^4$ s.

57. 5.4×10^{12} m, it is still in the solar system, nearest to Pluto's orbit.

59. 2.3 g's.

61. 7.4×10^{36} kg, $3.7 \times 10^{6}\ M_{\text{Sun}}$.

65. 1.21×10^{6} m.

67. $V_{\text{deposit}} = 5 \times 10^{7}\ \text{m}^3$,
$r_{\text{deposit}} = 200$ m;
$m_{\text{deposit}} = 4 \times 10^{10}$ kg.

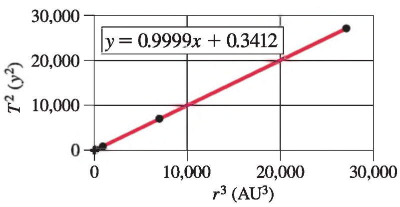
69. 8.99 days.

71. $0.44r$.

73. (*a*) 53 N;
(*b*) 3.1×10^{26} kg.

77. $1 \times 10^{-10}\ \text{m}^3/\text{kg}\cdot\text{s}^2$.

79. (*a*)



(*b*) 39.44 AU.

CHAPTER 7

1. 7.7×10^{3} J.

3. 1.47×10^{4} J.

5. 6000 J.

7. 4.5×10^{5} J.

9. 590 J.

11. (*a*) 1700 N;
(*b*) -6600 J;
(*c*) 6600 J;
(*d*) 0.

13. (*a*) 1.1×10^{7} J;
(*b*) 5.0×10^{7} J.

15. -490 J, 0, 490 J.

21. $1.5\hat{\mathbf{i}} - 3.0\hat{\mathbf{j}}$.

23. (*a*) 7.1;
(*b*) -250;
(*c*) 2.0×10^{1}.

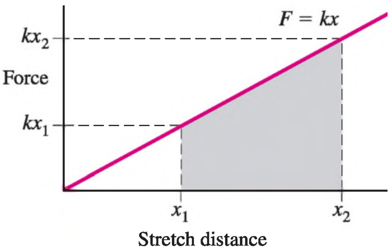
25. $-1.4\hat{\mathbf{i}} + 2.0\hat{\mathbf{j}}$.

27. 52.5°, 48.0°, 115°.

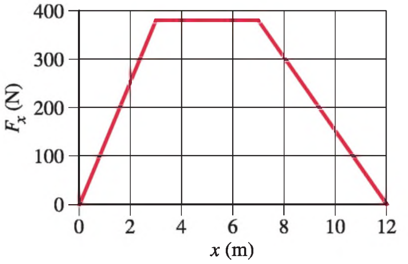
29. 113.4° or 301.4°.

31. (*a*) 130°;
(*b*) negative sign says that the angle is obtuse.

35. 0.11 J.



37. 3.0×10^{3} J.



39. 2800 J.

41. 670 J.

43. $\frac{1}{2}kX^2 + \frac{1}{4}aX^4 + \frac{1}{5}bX^5$.

45. 4.0 J.

47. $\dfrac{\sqrt{3}\pi RF}{2}$.

49. 72 J.

51. (*a*) $\sqrt{3}$;
(*b*) $\frac{1}{4}$.

53. -4.5×10^{5} J.

55. 3.0×10^{2} N.

57. (*a*) $\sqrt{\dfrac{Fx}{m}}$;
(*b*) $\sqrt{\dfrac{3Fx}{4m}}$.

59. 8.3×10^{4} N/m.

61. 1400 J.

63. (*a*) 640 J;
(*b*) -470 J;
(*c*) 0;
(*d*) 4.3 m/s.

65. 27 m/s.

67. (*a*) $\frac{1}{2}mv_2^2\left(1 + 2\dfrac{v_1}{v_2}\right)$;
(*b*) $\frac{1}{2}mv_2^2$;
(*c*) $\frac{1}{2}mv_2^2\left(1 + 2\dfrac{v_1}{v_2}\right)$ relative to Earth, $\frac{1}{2}mv_2^2$ relative to train;
(*d*) the ball moves different distances during the throwing process in the two frames of reference.

69. (*a*) 2.04×10^{5} J;
(*b*) 21.0 m/s;
(*c*) 2.37 m.

71. 1710 J.

73. (*a*) 32.2 J;
(*b*) 554 J;
(*c*) -333 J;
(*d*) 0;
(*e*) 253 J.

75. 12.3 J.

77. $\dfrac{A}{k}e^{-0.10k}$.

79. 86 kJ, 42°.

81. 1.5 N.

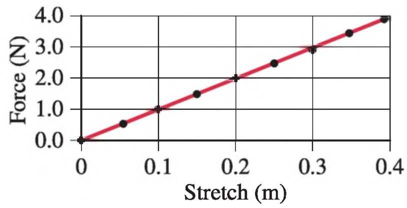
83. 2×10^{7} N/m.

85. 6.7°, 10°.

87. (*a*) 130 N, yes (≈29 lbs);
(*b*) 470 N, perhaps not (≈110 lbs).

89. (*a*) 1.5×10^{4} J;
(*b*) 18 m/s.

93. (*a*) $F = 10.0x$;
(*b*) 10.0 N/m;
(*c*) 2.00 N.



CHAPTER 8

1. 0.924 m.

3. 54 cm.

5. (*a*) 42.0 J;
(*b*) 11 J;
(*c*) same as part (*a*), unrelated to part (*b*).

7. (*a*) Yes, the expression for the work depends only on the endpoints;
(*b*) $U(x) = \frac{1}{2}kx^2 - \frac{1}{4}ax^4 - \frac{1}{5}bx^5 + C$.

9. $U(x) = -\dfrac{k}{2x^2} + \dfrac{k}{8\ \text{m}^2}$.

11. 49 m/s.

13. 6.5 m/s.

15. (*a*) 93 N/m;
(*b*) 22 m/s².

19. (*a*) 7.47 m/s;
(*b*) 3.01 m.

21. No, $D = 2d$.

23. (*a*) $\sqrt{v_0^2 + \dfrac{k}{m}x_0^2}$;
(*b*) $\sqrt{x_0^2 + \dfrac{m}{k}v_0^2}$.

25. (*a*) 2.29 m/s;
(*b*) 1.98 m/s;
(*c*) 1.98 m/s;
(*d*) 0.870 N, 0.800 N, 0.800 N;
(*e*) 2.59 m/s, 2.31 m/s, 2.31 m/s.

27. $k = \dfrac{12Mg}{h}$.

29. 3.9×10^{7} J.

31. (*a*) 25 m/s;
(*b*) 370 m.

33. 12 m/s.

35. 0.020.

37. 0.40.

39. (*a*) 25%;
(*b*) 6.3 m/s, 5.4 m/s;
(*c*) primarily into heat energy.

41. For a mass of 75 kg, the energy change is 740 J.

43. (*a*) 0.13 m;
(*b*) 0.77;
(*c*) 0.5 m/s.

45. (*a*) $\dfrac{GM_E m_s}{2r_s}$;
(*b*) $-\dfrac{GM_E m_s}{r_s}$;
(*c*) $-\frac{1}{2}$.

47. $\frac{1}{4}$.

49. (*a*) 6.2×10^5 m/s;
(*b*) 4.2×10^4 m/s, $v_{\text{esc at Earth orbit}} = \sqrt{2}v_{\text{Earth orbit}}$.

53. (*a*) 1.07×10^4 m/s;
(*b*) 1.16×10^4 m/s;
(*c*) 1.12×10^4 m/s.

55. (*a*) $-\sqrt{\dfrac{GM_E}{2r^3}}$;
(*b*) 1.09×10^4 m/s.

57. $\dfrac{GMm}{12r_E}$.

59. 1.12×10^4 m/s.

63. 510 N.

65. 2.9×10^4 W or 38 hp.

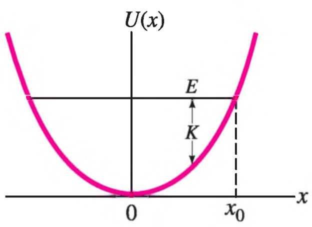
67. 4.2×10^3 N, opposing the velocity.

69. 510 W.

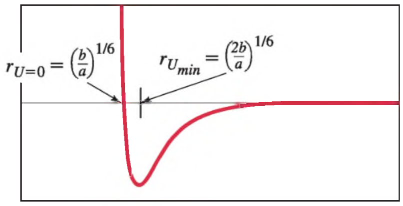
71. 2×10^6 W.

73. (*a*) -2.0×10^2 W;
(*b*) 3800 W;
(*c*) -120 W;
(*d*) 1200 W.

75. The mass oscillates between $+x_0$ and $-x_0$, with a maximum speed at $x = 0$.



77. (*a*) $r_{U\min} = \left(\dfrac{2b}{a}\right)^{\frac{1}{6}}$, $r_{U\max} = 0$;
(*b*) $r_{U=0} = \left(\dfrac{b}{a}\right)^{\frac{1}{6}}$;
(*c*)



(*d*) $E < 0$: bound oscillatory motion between two turning points, $E > 0$: unbounded;
(*e*) $r_{F>0} < \left(\dfrac{2b}{a}\right)^{\frac{1}{6}}$,
$r_{F<0} > \left(\dfrac{2b}{a}\right)^{\frac{1}{6}}$,
$r_{F=0} = \left(\dfrac{2b}{a}\right)^{\frac{1}{6}}$;
(*f*) $F(r) = \dfrac{12b}{r^{13}} - \dfrac{6a}{r^7}$.

79. 2.52×10^4 W.

81. (*a*) 42 m/s;
(*b*) 2.6×10^5 W.

83. (*a*) 28.2 m/s;
(*b*) 116 m.

85. (*a*) $\sqrt{2g\ell}$;
(*b*) $\sqrt{1.2g\ell}$.

89. (*a*) 8.9×10^5 J;
(*b*) 5.0×10^1 W, 6.6×10^{-2} hp;
(*c*) 330 W, 0.44 hp.

91. (*a*) 29°;
(*b*) 480 N;
(*c*) 690 N.

93. 5800 W or 7.8 hp.

95. (*a*) 2.8 m;
(*b*) 1.5 m;
(*c*) 1.5 m.

97. 1.7×10^5 m^3.

99. (*a*) 5220 m/s;
(*b*) 3190 m/s.

101. (*a*) 1500 m;
(*b*) 170 m/s.

103. 60 m.

105. (*a*) 79 m/s;
(*b*) 2.4×10^7 W.

107. (*a*) 2.2×10^5 J;
(*b*) 22 m/s;
(*c*) -1.4 m.

109. $x = \sqrt{\dfrac{a}{b}}$.

CHAPTER 9

1. 5.9×10^7 N.

3. $(9.6t\hat{\mathbf{i}} - 8.9\hat{\mathbf{k}})$ N.

5. 4.35 kg·m/s $(\hat{\mathbf{j}} - \hat{\mathbf{i}})$.

7. 1.40×10^2 kg.

9. 2.0×10^4 kg.

11. 4.9×10^3 m/s.

13. -0.966 m/s.

15. 1:2.

17. $\frac{3}{2}v_0\hat{\mathbf{i}} - v_0\hat{\mathbf{j}}$.

19. $(4.0\hat{\mathbf{i}} + 3.3\hat{\mathbf{j}} - 3.3\hat{\mathbf{k}})$ m/s.

21. (*a*) $(116\hat{\mathbf{i}} + 58.0\hat{\mathbf{j}})$ m/s;
(*b*) 5.02×10^5 J.

23. (*a*) 2.0 kg·m/s, forward;
(*b*) 5.8×10^2 N, forward.

25. 2.1 kg·m/s, to the left.

27. 0.11 N.

29. 1.5 kg·m/s.

31. (*a*) $\dfrac{2mv}{\Delta t}$;
(*b*) $\dfrac{2mv}{t}$.

33. (*a*) 0.98 N + (1.4 N/s)t;
(*b*) 13.3 N;
(*c*) $\left[(0.62\ \text{N/m}^{\frac{1}{2}}) \times \sqrt{2.5\ \text{m} - (0.070\ \text{m/s})t}\right] + (1.4\ \text{N/s})t$, 13.2 N.

35. 1.60 m/s (west), 3.20 m/s (east).

37. (*a*) 3.7 m/s;
(*b*) 0.67 kg.

39. (*a*) 1.00;
(*b*) 0.890;
(*c*) 0.286;
(*d*) 0.0192.

41. (*a*) 0.37 m;
(*b*) -1.6 m/s, 6.4 m/s;
(*c*) yes.

43. (*a*) $\dfrac{-M}{m + M}$;
(*b*) -0.96.

45. 3.0×10^3 J, 4.5×10^3 J.

47. 0.11 kg·m/s, upward.

49. (*b*) $e = \sqrt{\dfrac{h'}{h}}$.

51. (*a*) 890 m/s;
(*b*) 0.999 of initial kinetic energy lost.

53. (a) 7.1×10^{-2} m/s;
(b) -5.4 m/s, 4.1 m/s;
(c) 0, 0.13 m/s, reasonable;
(d) 0.17 m/s, 0, not reasonable;
(e) in this case, -4.0 m/s, 3.1 m/s, reasonable.

55. 1.14×10^{-22} kg·m/s, 147° from the electron's momentum, 123° from the neutrino's momentum.

57. (a) 30°;
(b) $v'_A = v'_B = \dfrac{v}{\sqrt{3}}$;
(c) $\frac{2}{3}$.

59. 39.9 u.

63. 6.5×10^{-11} m.

65. $(1.2\text{ m})\hat{\mathbf{i}} - (1.2\text{ m})\hat{\mathbf{j}}$.

67. $0\hat{\mathbf{i}} + \dfrac{2r}{\pi}\hat{\mathbf{j}}$.

69. $0\hat{\mathbf{i}} + 0\hat{\mathbf{j}} + \frac{3}{4}h\hat{\mathbf{k}}$.

71. $0\hat{\mathbf{i}} + \dfrac{4R}{3\pi}\hat{\mathbf{j}}$.

73. (a) 4.66×10^6 m from the center of the Earth.

75. (a) 5.7 m;
(b) 4.2 m;
(c) 4.3 m.

77. 0.41 m toward the initial position of the 85-kg person.

79. $v\dfrac{m}{m + M}$, upward, balloon also stops.

81. 0.93 hp.

83. -76 m/s.

85. Good possibility of a "scratch" shot.

87. 11 bounces.

89. 1.4 m.

91. 50%.

93. (a) $v = \dfrac{M_0 v_0}{M_0 + \dfrac{dM}{dt}t}$;
(b) 8.2 m/s, yes.

95. 112 km/h or 70 mi/h.

97. 21 m.

99. (a) 1.9 m/s;
(b) -0.3 m/s, 1.5 m/s;
(c) 0.6 cm, 12 cm.

101. $m < \frac{1}{3}M$ or $m < 2.33$ kg.

103. (a) 8.6 m;
(b) 40 m.

105. 29.6 km/s.

107. 0.38 m, 1.5 m.

109. (a) 1.3×10^5 N;
(b) -83 m/s^2.

111. 12 kg.

113. 0.2 km/s, in the original direction of m_A.

CHAPTER 10

1. (a) $\dfrac{\pi}{4}$ rad, 0.785 rad;
(b) $\dfrac{\pi}{3}$ rad, 1.05 rad;
(c) $\dfrac{\pi}{2}$ rad, 1.57 rad;
(d) 2π rad, 6.283 rad;
(e) $\dfrac{89\pi}{36}$ rad, 7.77 rad.

3. 5.3×10^3 m.

5. (a) 260 rad/s;
(b) 46 m/s, 1.2×10^4 m/s^2.

7. (a) 1.05×10^{-1} rad/s;
(b) 1.75×10^{-3} rad/s;
(c) 1.45×10^{-4} rad/s;
(d) 0.

9. (a) 464 m/s;
(b) 185 m/s;
(c) 328 m/s.

11. 36,000 rev/min.

13. (a) 1.5×10^{-4} rad/s^2;
(b) 1.6×10^{-2} m/s^2, 6.2×10^{-4} m/s^2.

15. (a) $-\hat{\mathbf{i}}, \hat{\mathbf{k}}$;
(b) 56.2 rad/s, 38.5° from $-x$ axis towards $+z$ axis;
(c) 1540 rad/s^2, $-\hat{\mathbf{j}}$.

17. 28,000 rev.

19. (a) -0.47 rad/s^2;
(b) 190 s.

21. (a) 0.69 rad/s^2;
(b) 9.9 s.

23. (a) $\omega = \frac{1}{3}5.0t^3 - \frac{1}{2}8.5t^2$;
(b) $\theta = \frac{1}{12}5.0t^4 - \frac{1}{6}8.5t^3$;
(c) $\omega(2.0\text{ s}) = -4$ rad/s, $\theta(2.0\text{ s}) = -5$ rad.

25. 1.4 m·N, clockwise.

27. $mg(\ell_2 - \ell_1)$, clockwise.

29. 270 N, 1700 N.

31. 1.81 kg·m^2.

33. (a) 9.0×10^{-2} m·N;
(b) 12 s.

35. 56 m·N.

37. (a) 0.94 kg·m^2;
(b) 2.4×10^{-2} m·N.

39. (a) 78 rad/s^2;
(b) 670 N.

41. 2.2×10^4 m·N.

43. 17.5 m/s.

45. (a) $14M\ell^2$;
(b) $\frac{14}{3}M\ell\alpha$;
(c) perpendicular to the rod and the axis.

47. (a) 1.90×10^3 kg·m^2;
(b) 7.5×10^3 m·N.

49. (a) R_0;
(b) $\sqrt{\frac{1}{2}R_0^2 + \frac{1}{12}w^2}$;
(c) $\sqrt{\frac{1}{2}}R_0$;
(d) $\sqrt{\frac{1}{2}(R_1^2 + R_2^2)}$;
(e) $\sqrt{\frac{2}{5}}r_0$;
(f) $\sqrt{\frac{1}{12}}\ell$;
(g) $\sqrt{\frac{1}{3}}\ell$;
(h) $\sqrt{\frac{1}{12}(\ell^2 + w^2)}$.

51. $a = \dfrac{(m_B - m_A)}{(m_A + m_B + I/R^2)}g$, compared to $a_{I=0} = \dfrac{(m_B - m_A)}{(m_A + m_B)}g$.

53. (a) 9.70 rad/s^2;
(b) 11.6 m/s^2;
(c) 585 m/s^2;
(d) 4.27×10^3 N;
(e) 1.14°.

57. (a) $5.3Mr_0^2$; (b) -15%.

59. (a) 3.9 cm from center along line connecting the small weight and the center;
(b) 0.42 kg·m^2.

61. (b) $\frac{1}{12}M\ell^2, \frac{1}{12}Mw^2$.

63. 22,200 J.

65. 14,200 J.

67. 1.4 m/s.

69. 8.22 m/s.

71. 7.0×10^1 J.

73. (a) 8.37 m/s, 32.9 rad/sec.
(b) $\frac{5}{2}$;
(c) the translational speed and the energy relationship are independent of both mass and radius, but the rotational speed depends on the radius.

75. $\sqrt{\frac{10}{7}g(R_0 - r_0)}$.

77. (a) 4.06 m/s;
(b) 8.99 J;
(c) 0.158.

79. (a) 4.1×10^5 J;
(b) 18%;
(c) 1.3 m/s^2;
(d) 6%.

81. (a) 1.6 m/s;
(b) 0.48 m.

83. $\frac{\ell}{2}, \frac{\ell}{2}$.

85. (*a*) 0.84 m/s;
(*b*) 96%.

87. 2.0 m·N, from the arm swinging the sling.

89. (*a*) $\frac{\omega_R}{\omega_F} = \frac{N_F}{N_R}$;
(*b*) 4.0;
(*c*) 1.5.

91. (*a*) 1.7×10^8 J;
(*b*) 2.2×10^3 rad/s;
(*c*) 25 min.

93. $\frac{Mg\sqrt{2Rh - h^2}}{R - h}$.

95. $\frac{\lambda_0 \ell^3}{6}$.

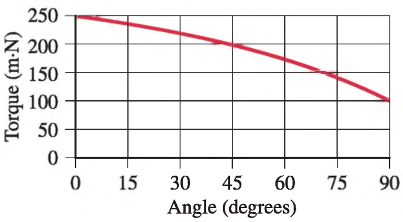
97. 5.0×10^2 m·N.

99. (*a*) 1.6 m;
(*b*) 1.1 m.

101. (*a*) $\frac{x}{y} g$;
(*b*) x should be as small as possible, y should be as large as possible, and the rider should move upward and toward the rear of the bicycle;
(*c*) 3.6 m/s^2.

103. $\sqrt{\frac{3g\ell}{4}}$.

105. $\tau =$
$[(0.300\text{ m})\cos\theta + 0.200\text{ m}](500\text{ N})$



CHAPTER 11

1. 3.98 kg·m^2/s.

3. (*a*) L is conserved: If I increases, ω must decrease;
(*b*) increased by a factor of 1.3.

5. 0.38 rev/s.

7. (*a*) 7.1×10^{33} kg·m^2/s;
(*b*) 2.7×10^{40} kg·m^2/s.

9. (*a*) $-\frac{I_W}{I_P}\omega_W$;
(*b*) $-\frac{I_W}{2I_P}\omega_W$;
(*c*) $\omega_W \frac{I_W}{I_P}$;
(*d*) 0.

11. (*a*) 0.55 rad/s;
(*b*) 420 J, 240 J.

13. 0.48 rad/s, 0.80 rad/s.

15. $\frac{1}{2}\omega$.

17. (*a*) 3.7×10^{16} J;
(*b*) 1.9×10^{20} kg·m^2/s.

19. -0.32 rad/s.

23. 45°.

27. $(25\hat{\mathbf{i}} \pm 14\hat{\mathbf{j}} \mp 19\hat{\mathbf{k}})$ m·kN.

29. (*a*) $-7.0\hat{\mathbf{i}} - 11\hat{\mathbf{j}} + 0.5\hat{\mathbf{k}}$;
(*b*) 170°.

37. $(-55\hat{\mathbf{i}} - 45\hat{\mathbf{j}} + 49\hat{\mathbf{k}})$ kg·m^2/s.

39. (*a*) $(\frac{1}{6}M + \frac{7}{9}m)\ell^2\omega^2$;
(*b*) $(\frac{1}{3}M + \frac{14}{9}m)\ell^2\omega$.

41. (*a*) $\left[(M_A + M_B)R_0 + \frac{I}{R_0}\right]v$;
(*b*) $\frac{M_B g}{M_A + M_B + \frac{I}{R_0^2}}$.

45. $F_A = \frac{(d + r_A\cos\phi)m_A r_A \omega^2 \sin\phi}{2d}$,
$F_B = \frac{(d - r_A\cos\phi)m_A r_A \omega^2 \sin\phi}{2d}$.

47. $\frac{m^2 v^2}{g(m + M)(m + \frac{4}{3}M)}$.

49. $\Delta\omega/\omega_0 = -8.4 \times 10^{-13}$.

51. $v_{\text{CM}} = \frac{m}{M + m}v$,
ω (about CM) $= \left(\frac{12m}{4M + 7m}\right)\frac{v}{\ell}$.

53. 8.3×10^{-4} kg·m^2.

55. 8.0 rad/s.

57. 14 rev/min, CCW when viewed from above.

59. (*a*) 9.80 m/s^2, along a radial line;
(*b*) 9.78 m/s^2, 0.0988° south from a radial line;
(*c*) 9.77 m/s^2, along a radial line.

61. Due north or due south.

63. $(mr\omega^2 - F_{\text{fr}})\hat{\mathbf{i}}$
$+ (F_{\text{spoke}} - 2m\omega v)\hat{\mathbf{j}}$
$+ (F_N - mg)\hat{\mathbf{k}}$.

65. (*a*) $(-24\hat{\mathbf{i}} + 28\hat{\mathbf{j}} - 14\hat{\mathbf{k}})$ kg·m^2/s;
(*b*) $(16\hat{\mathbf{j}} - 8.0\hat{\mathbf{k}})$ m·N.

67. (*b*) 0.750.

69. $v[-\sin(\omega t)\hat{\mathbf{i}} + \cos(\omega t)\hat{\mathbf{j}}]$,
$\vec{\boldsymbol{\omega}} = \left(\frac{v}{R}\right)\hat{\mathbf{k}}$.

71. (*a*) The wheel will turn to the right;
(*b*) $\Delta L/L_0 = 0.19$.

73. (*a*) 820 kg·m^2/s^2;
(*b*) 820 m·N;
(*c*) 930 W.

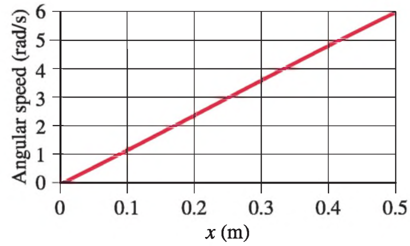
75. $\vec{\mathbf{a}}_{\tan} = -R\alpha\sin\theta\hat{\mathbf{i}} + R\alpha\cos\theta\hat{\mathbf{j}}$;
(*a*) $mR^2\alpha\hat{\mathbf{k}}$;
(*b*) $mR^2\alpha\hat{\mathbf{k}}$.

77. 0.965.

79. (*a*) There is zero net torque exerted about any axis through the skater's center of mass;
(*b*) $f_{\text{single axel}} = 2.5$ rad/s, $f_{\text{triple axel}} = 6.5$ rad/s.

81. (*a*) 17,000 rev/s;
(*b*) 4300 rev/s.

83. (*a*) $\omega = \left(12\,\frac{\text{rad/s}}{\text{m}}\right)x$;
(*b*)



CHAPTER 12

1. 528 N, (1.20×10^2)° clockwise from $\vec{\mathbf{F}}_A$.

3. 6.73 kg.

5. (*a*) $F_A = 1.5 \times 10^3$ N down, $F_B = 2.0 \times 10^3$ N up;
(*b*) $F_A = 1.8 \times 10^3$ N down, $F_B = 2.6 \times 10^3$ N up.

7. (*a*) 230 N;
(*b*) 2100 N.

9. -2.9×10^3 N, 1.5×10^4 N.

11. 3400 N, 2900 N.

13. 0.28 m.

15. 6300 N, 6100 N.

17. 1600 N.

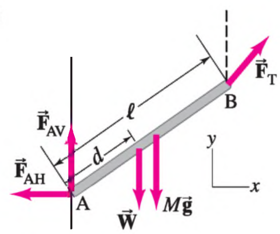
19. 1400 N, 2100 N.

21. (*a*) 410 N;
(*b*) 410 N, 328 N.

23. 120 N.

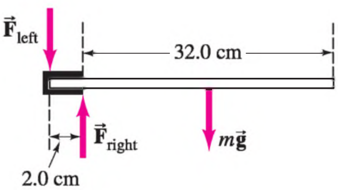
25. 550 N.

27. (*a*)

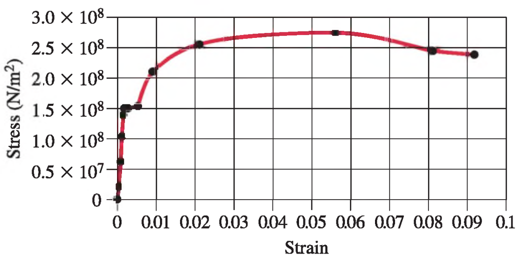


(*b*) $F_{AH} = 51$ N, $F_{AV} = -9$ N;
(*c*) 2.4 m.

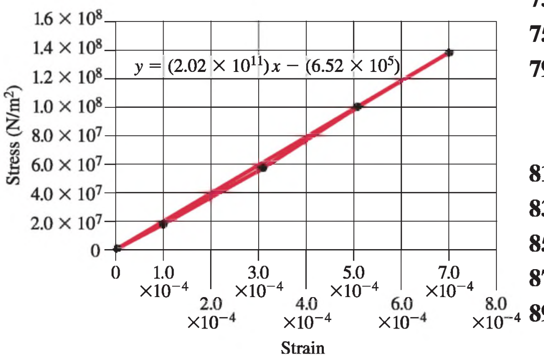
29. $F_{\text{top}} = 55.2\text{ N}$ right, 63.7 N up, $F_{\text{bottom}} = 55.2\text{ N}$ left, 63.7 N up.
31. 5.2 m/s^2.
33. 2.5 m at the top.
35. (*a*) $1.8 \times 10^5\text{ N/m}^2$;
(*b*) 3.5×10^{-6}.
37. (*a*) $1.4 \times 10^6\text{ N/m}^2$;
(*b*) 6.9×10^{-6};
(*c*) 6.6×10^{-5} m.
39. $9.6 \times 10^6\text{ N/m}^2$.
41. (*a*) $1.3 \times 10^2\text{ m}\cdot\text{N}$, clockwise;
(*b*) the wall;
(*c*) all three are present.
43. (*a*) 393 N;
(*b*) thicker.
45. (*a*) $3.7 \times 10^{-5}\text{ m}^2$;
(*b*) 2.7×10^{-3} m.
47. 1.3 cm.
49. (*a*) $F_T = 150$ kN;
$\mathbf{F}_A = 170$ kN, 23° above AC;
(*b*) $F_{DE} = F_{DB} = F_{BC} = 76$ kN, tension;
$F_{CE} = 38$ kN, compression;
$F_{DC} = F_{AB} = 76$ kN, compression;
$F_{CA} = 114$ kN, compression.
51. (*a*) $5.5 \times 10^{-2}\text{ m}^2$;
(*b*) $8.6 \times 10^{-2}\text{ m}^2$.
53. $F_{AB} = F_{BD} = F_{DE} = 7.5 \times 10^4$ N, compression;
$F_{BC} = F_{CD} = 7.5 \times 10^4$ N, tension;
$F_{CE} = F_{AC} = 3.7 \times 10^4$ N, tension.
55. $F_{AB} = F_{JG} = \dfrac{3\sqrt{2}}{2}F$, compression;
$F_{AC} = F_{JH} = F_{CE} = F_{HE} = \frac{3}{2}F$, tension;
$F_{BC} = F_{GH} = F$, tension;
$F_{BE} = F_{GE} = \dfrac{\sqrt{2}}{2}F$, tension;
$F_{BD} = F_{GD} = 2F$, compression;
$F_{DE} = 0$.
57. 0.249 kg, 0.194 kg, 0.0554 kg.
59. (*a*) $Mg\sqrt{\dfrac{h}{2R-h}}$;
(*b*) $Mg\dfrac{\sqrt{h(2R-h)}}{R-h}$.
61. (*a*)



(*b*) $mg = 65$ N, $F_{\text{right}} = 550$ N, $F_{\text{left}} = 490$ N;
(*c*) $11\text{ m}\cdot\text{N}$.
63. 29°.
65. 3.8.
67. 5.0×10^5 N, 3.2 m.
69. (*a*) 650 N;
(*b*) $F_A = 0$, $F_B = 1300$ N;
(*c*) $F_A = 160$ N, $F_B = 1140$ N;
(*d*) $F_A = 810$ N, $F_B = 490$ N.
71. He can walk only 0.95 m to the right of the right support, and 0.83 m to the left of the left support.
73. $F_{\text{left}} = 120$ N, $F_{\text{right}} = 210$ N.
75. $F/A = 3.8 \times 10^5\text{ N/m}^2 <$ tissue strength.
77. $F_A = 1.7 \times 10^4$ N, $F_B = 7.7 \times 10^3$ N.
79. 2.5 m.
81. (*a*) 6500 m;
(*b*) 6400 m.
83. 570 N.
85. 45°.
87. (*a*) $2.4w$;
(*b*) $2.6w$, 32° above the horizontal.
89. (*a*) $(4.5 \times 10^{-6})\%$;
(*b*) 9.0×10^{-18} m.
91. 150 N, 0.83 m.
93. (*a*) $mg\left(1 - \dfrac{r_0}{h}\cot\theta\right)$;
(*b*) $\dfrac{h}{r_0} - \cot\theta$.
95. (*b*) 46°, 51°, 11%.
97. (*a*)



(*b*)



Elastic Modulus $= 2.02 \times 10^{11}\text{ N/m}^2$.

CHAPTER 13

1. 3×10^{11} kg.
3. 6.7×10^2 kg.
5. 0.8547.
7. (*a*) 5510 kg/m^3;
(*b*) 5520 kg/m^3, 0.3%.
9. (*a*) $8.1 \times 10^7\text{ N/m}^2$;
(*b*) $2 \times 10^5\text{ N/m}^2$.
11. 13 m.
13. 6990 kg.
15. (*a*) 2.8×10^7 N, $1.2 \times 10^5\text{ N/m}^2$;
(*b*) $1.2 \times 10^5\text{ N/m}^2$.
17. 683 kg/m^3.
19. $3.35 \times 10^4\text{ N/m}^2$.
21. (*a*) 1.32×10^5 Pa;
(*b*) 9.7×10^4 Pa.
23. (*c*) $0.38h$, no.
27. 2990 kg/m^3.
29. 920 kg.
31. Iron or steel.
33. $1.1 \times 10^{-2}\text{ m}^3$.
35. 10.5%.
37. (*b*) Above.
39. 3600 balloons.
43. 2.8 m/s.
45. 1.0×10^1 m/s.
47. $1.8 \times 10^5\text{ N/m}^2$.
49. 1.2×10^5 N.
51. 9.7×10^4 Pa.
57. $\frac{1}{2}$.
59. (*b*) $h = \left[\sqrt{h_0} - t\sqrt{\dfrac{gA_1^2}{2(A_2^2 - A_1^2)}}\right]^2$
(*c*) 92 s.
63. $7.9 \times 10^{-2}\text{ Pa}\cdot\text{s}$.
65. 6.9×10^3 Pa.
67. 0.10 m.
69. (*a*) Laminar;
(*b*) turbulent.
71. 1.0 m.
73. 0.012 N.
75. 1.5 mm.
79. (*a*) 0.75 m;
(*b*) 0.65 m;
(*c*) 1.1 m.
81. 0.047 atm.
83. 0.24 N.
85. 1.0 m.
87. 5.3 km.
89. (*a*) 88 Pa/s;
(*b*) 5.0×10^1 s.
91. 5×10^{18} kg.

93. (*a*) 8.5 m/s;
(*b*) 0.24 L/s;
(*c*) 0.85 m/s.

95. $d\left(\dfrac{v_0^2}{v_0^2 + 2gy}\right)^{\frac{1}{4}}$.

97. 170 m/s.

99. 1.2×10^4 N.

101. 4.9 s.

CHAPTER 14

1. 0.72 m.

3. 1.5 Hz.

5. 350 N/m.

7. 0.13 m/s, 0.12 m/s^2, 1.2%.

9. (*a*) 0.16 N/m;
(*b*) 2.8 Hz.

11. $\dfrac{\sqrt{3k/M}}{2\pi}$.

13. (*a*) 2.5 m, 3.5 m;
(*b*) 0.25 Hz, 0.50 Hz;
(*c*) 4.0 s, 2.0 s;
(*d*) $x_A = (2.5\text{ m})\sin(\tfrac{1}{2}\pi t)$,
$x_B = (3.5\text{ m})\cos(\pi t)$.

15. (*a*) $y(t) = (0.280\text{ m})\sin[(34.3\text{ rad/s})t]$;
(*b*) $t_{\text{longest}} = 4.59 \times 10^{-2}\text{ s} + n(0.183\text{ s})$, $n = 0, 1, 2, \cdots$;
$t_{\text{shortest}} = 1.38 \times 10^{-1}\text{ s} + n(0.183\text{ s})$, $n = 0, 1, 2, \cdots$.

17. (*a*) 1.6 s, $\frac{5}{8}$ Hz;
(*b*) 3.3 m, −7.5 m/s;
(*c*) −13 m/s, 29 m/s^2.

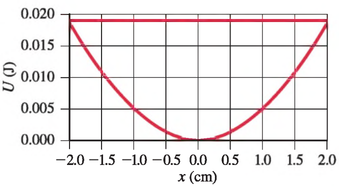
19. 0.75 s.

21. 3.1 s, 6.3 s, 9.4 s.

23. 88.8 N/m, 17.8 m.

27. (*a*) 0.650 m;
(*b*) 1.18 Hz;
(*c*) 13.3 J;
(*d*) 11.2 J, 2.1 J.

29.



(*a*) 0.011 J;
(*b*) 0.008 J;
(*c*) 0.5 m/s.

31. 10.2 m/s.

33. $A_{\text{high energy}} = \sqrt{5}A_{\text{low energy}}$.

35. (*a*) 430 N/m;
(*b*) 3.7 kg.

37. 309.8 m/s.

39. (*a*) 0.410 s, 2.44 Hz;
(*b*) 0.148 m;
(*c*) 34.6 m/s^2;
(*d*) $x = (0.148\text{ m})\sin(4.87\pi t)$;
(*e*) 2.00 J;
(*f*) 1.68 J.

41. 2.2 s.

43. (*a*) −5.4°;
(*b*) 8.4°;
(*c*) −13°.

45. $\frac{1}{3}$.

47. $\sqrt{2g\ell(1 - \cos\theta)}$.

49. 0.41 g.

51. (*a*) $\theta = \theta_0\cos(\omega t + \phi)$, $\omega = \sqrt{\dfrac{K}{I}}$.

53. 2.9 s.

55. 1.08 s.

57. Decreased by a factor of 6.

59. (*a*) (-1.21×10^{-3})%;
(*b*) 32.3 periods.

63. (*a*) 0°;
(*b*) 0, $\pm A$;
(*c*) $\frac{1}{2}\pi$ or 90°.

65. 3.1 m/s.

67. 23.7.

69. (*a*) 170 s;
(*b*) 1.3×10^{-5} W;
(*c*) 1.0×10^{-3} Hz on either side.

71. 0.11 m.

73. (*a*) $1.22f$;
(*b*) $0.71f$.

75. (*a*) 0.41 s;
(*b*) 9 mm.

77. 0.9922 m, 1.6 mm, 0.164 m.

79. $x = \pm\dfrac{\sqrt{3}A}{2} \approx \pm 0.866A$.

81. $\rho_{\text{water}}\,g(\text{area}_{\text{bottom side}})$.

83. (*a*) 130 N/m;
(*b*) 0.096 m.

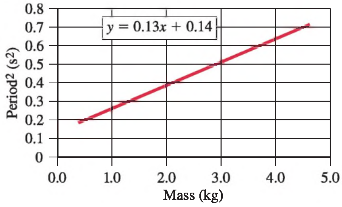
85. (*a*) $x = \pm\dfrac{\sqrt{3}x_0}{2} \approx \pm 0.866x_0$;
(*b*) $x = \pm\frac{1}{2}x_0$.

87. 84.5 min.

89. 1.25 Hz.

91. ~3000 N/m.

93. (*a*) $k = \dfrac{4\pi^2}{\text{slope}}$, *y*-intercept = 0;
(*b*) slope = 0.13 s^2/kg,
y-intercept = 0.14 s^2



(*c*) $k = \dfrac{4\pi^2}{\text{slope}} = 310$ N/m,
y-intercept $= \dfrac{4\pi^2 m_0}{k}$,
$m_0 = 1.1$ kg;
(*d*) portion of spring's mass that is effectively oscillating.

CHAPTER 15

1. 2.7 m/s.

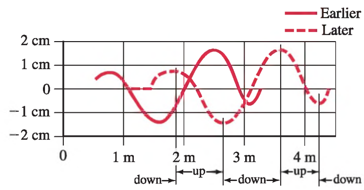
3. (*a*) 1400 m/s;
(*b*) 4100 m/s;
(*c*) 5100 m/s.

5. 0.62 m.

7. 4.3 N.

9. (*a*) 78 m/s;
(*b*) 8300 N.

11. (*a*)



(*b*) −4 cm/s.

13. 18 m.

15. $A_{\text{more energy}}/A_{\text{less energy}} = \sqrt{3}$.

19. (*a*) 0.38 W;
(*b*) 0.25 cm.

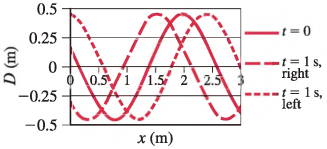
21. (*b*) 420 W.

23. $D = A\sin\left[2\pi\left(\dfrac{x}{\lambda} + \dfrac{t}{T}\right) + \phi\right]$.

25. (*a*) 41 m/s;
(*b*) 6.4×10^4 m/s^2;
(*c*) 35 m/s, 3.2×10^4 m/s^2.

27. (*b*) $D = (0.45\text{ m})\cos[2.6(x - 2.0t) + 1.2]$;

(*d*) $D = (0.45\text{ m})\cos[2.6(x + 2.0t) + 1.2]$.



29. $D = (0.020\text{ cm}) \times \sin\left[(9.54\text{ m}^{-1})x - (3290\text{ rad/s})t + \frac{3}{2}\pi\right]$

31. Yes, it is a solution.

35. Yes, it is a solution.

37. (*a*) 0.84 m;

(*b*) 0.26 N;

(*c*) 0.59 m.

39. (*a*) $t = \frac{2}{v}\sqrt{D^2 + \left(\frac{x}{2}\right)^2}$;

(*b*) slope $= \frac{1}{v^2}$,

y-intercept $= \frac{4}{v^2}D^2$.

41. (*a*)

(*b*)

(*c*) all kinetic energy.

43. 662 Hz.

45. $T_n = \frac{(1.5\text{ s})}{n}$, $n = 1, 2, 3, \cdots$,

$f_n = n(0.67\text{ Hz})$, $n = 1, 2, 3, \cdots$.

47. $f_{0.50}/f_{1.00} = \sqrt{2}$.

49. 80 Hz.

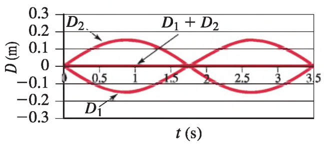
53. 11.

55. (*a*) $D_2 = 4.2\sin(0.84x + 47t + 2.1)$;

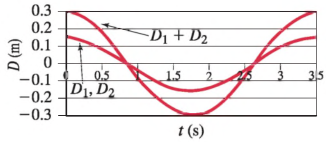
(*b*) $8.4\sin(0.84x + 2.1)\cos(47t)$.

57. 315 Hz.

59. (*a*)



(*b*)



61. $n = 4, n = 8$, and $n = 12$.

63. $x = \pm\left(n + \frac{1}{2}\right)\frac{\pi}{2}$ m, $n = 0, 1, 2, \cdots$.

65. 5.2 km/s.

67. $(3.0 \times 10^1)°$.

69. 44°.

71. (*a*) 0.042 m;

(*b*) 0.55 radians.

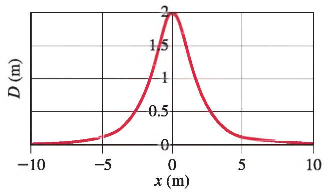
73. The speed is greater in the less dense rod, by a factor of $\sqrt{2.5} = 1.6$.

75. (*a*) 0.05 m;

(*b*) 2.25.

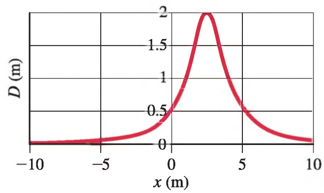
77. 0.69 m.

79. (*a*) $t = 0$ s;



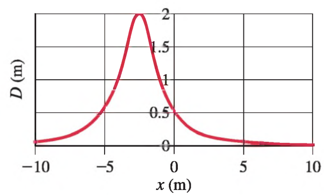
(*b*) $D = \frac{4.0\text{ m}^3}{(x - 2.4t)^2 + 2.0\text{ m}^2}$

(*c*) $t = 1.0$ s, moving right;



(*d*) $D = \frac{4.0\text{ m}^3}{(x + 2.4t)^2 + 2.0\text{ m}^2}$,

$t = 1.0$ s, moving left.



81. (*a*) G: 784 Hz, 1180 Hz, B: 988 Hz, 1480 Hz;

(*b*) 1.59;

(*c*) 1.26;

(*d*) 0.630.

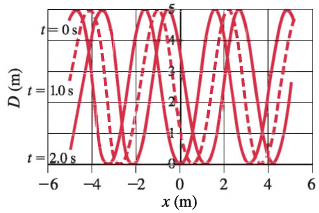
83. 6.3 m from the end where the first pulse originated.

85. $\lambda = \frac{4\ell}{2n - 1}$, $n = 1, 2, 3, \cdots$.

87. $D(x, t) = (3.5\text{ cm})\cos(0.10\pi x - 1.5\pi t)$, with x in cm and t in s.

89. 12 min.

93. speed $= 0.50$ m/s; direction of motion $= +x$, period $= 2\pi$ s, wavelength $= \pi$ m.



CHAPTER 16

1. 340 m.

3. (*a*) 1.7 cm to 17 m;

(*b*) 2.3×10^{-5} m.

5. (*a*) 0.17 m;

(*b*) 11 m;

(*c*) 0.5%.

7. 41 m.

9. (*a*) 8%;

(*b*) 4%.

11. (*a*) 4.4×10^{-5} Pa;

(*b*) 4.4×10^{-3} Pa.

13. (*a*) 5.3 m;

(*b*) 675 Hz;

(*c*) 3600 m/s;

(*d*) 1.0×10^{-13} m.

15. 63 dB.

17. (*a*) 10^9;

(*b*) 10^{12}.

19. 2.9×10^{-9} J.

21. 124 dB.

23. (*a*) 9.4×10^{-6} W;

(*b*) 8.0×10^6 people.

25. (*a*) 122 dB, 115 dB;

(*b*) no.

27. 7 dB.

29. (*a*) The higher frequency wave, 2.6;
(*b*) 6.8.

31. (*a*) 3.2×10^{-5} m;
(*b*) 3.0×10^{1} Pa.

33. 1.24 m.

35. (*a*) 69.2 Hz, 207 Hz, 346 Hz, 484 Hz;
(*b*) 138 Hz, 277 Hz, 415 Hz, 553 Hz.

37. 8.6 mm to 8.6 m.

39. (*a*) 0.18 m;
(*b*) 1.1 m;
(*c*) 440 Hz, 0.78 m.

41. -3.0%.

43. (*a*) 1.31 m;
(*b*) 3, 4, 5, 6.

45. 3.65 cm, 7.09 cm, 10.3 cm, 13.4 cm, 16.3 cm, 19.0 cm.

47. 4.3 m, open.

49. 21.4 Hz, 42.8 Hz.

51. 3430 Hz, 10,300 Hz, 17,200 Hz, relatively sensitive frequencies.

53. $\pm$ 0.50 Hz.

55. 346 Hz.

57. 10 beats/s.

59. (*a*) 221.5 Hz or 218.5 Hz;
(*b*) 1.4% increase, 1.3% decrease.

61. (*a*) 1470 Hz;
(*b*) 1230 Hz.

63. (*a*) 2430 Hz, 2420 Hz, difference of 10 Hz;
(*b*) 4310 Hz, 3370 Hz, difference of 940 Hz;
(*c*) 34,300 Hz, 4450 Hz, difference of 29,900 Hz;
(*d*) $f'_{\text{source moving}} \approx f'_{\text{observer moving}} = f\left(1 + \dfrac{v_{\text{object}}}{v_{\text{sound}}}\right)$.

65. (*a*) 1420 Hz, 1170 Hz;
(*b*) 1520 Hz, 1080 Hz;
(*c*) 1330 Hz, 1240 Hz.

67. 3 Hz.

69. (*a*) Every 1.3 s;
(*b*) every 15 s.

71. 8.9 cm/s.

73. (*a*) 93;
(*b*) 0.62°.

77. 19 km.

79. (*a*) 57 Hz, 69 Hz, 86 Hz, 110 Hz, 170 Hz.

81. 90 dB.

83. 11 W.

85. 51 dB.

87. 1.07.

89. (*a*) 280 m/s, 57 N;
(*b*) 0.19 m;
(*c*) 880 Hz, 1320 Hz.

91. 3 Hz.

93. 141 Hz, 422 Hz, 703 Hz, 984 Hz.

95. 22 m/s.

97. (*a*) No beats;
(*b*) 20 Hz;
(*c*) no beats.

99. 55.2 kHz.

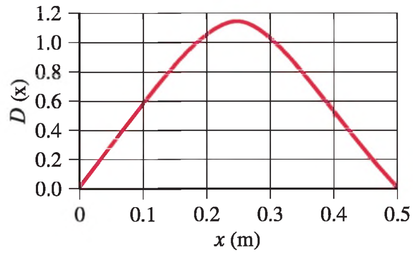
101. 11.5 m.

103. 2.3 Hz.

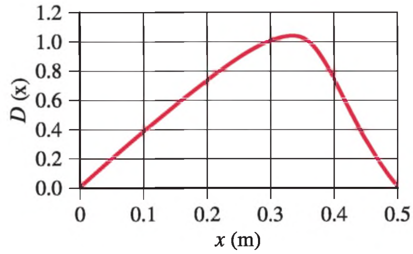
105. 17 km/h.

107. (*a*) 3400 Hz;
(*b*) 1.50 m;
(*c*) 0.10 m.

109. (*a*)



(*b*)



CHAPTER 17

1. $N_{\text{Au}} = 0.548 N_{\text{Ag}}$.

3. (*a*) 20°C;
(*b*) 3500°F.

5. 102.9°F.

7. 0.08 m.

9. 1.6×10^{-6} m for Super Invar™, 9.6×10^{-5} m for steel, steel is 60× as much.

11. 981 kg/m^3.

13. -69°C.

15. 3.9 cm^3.

17. (*a*) 5.0×10^{-5}/C°;
(*b*) copper.

21. (*a*) 2.7 cm;
(*b*) 0.3 cm.

23. 55 min.

25. 3.0×10^{7} N/m^2.

27. (*a*) 27°C;
(*b*) 5500 N.

29. -459.67°F.

31. 1.35 m^3.

33. 1.25 kg/m^3.

35. 181°C.

37. (*a*) 22.8 m^3;
(*b*) 1.88 atm.

39. 1660 atm.

41. 313°C.

43. 3.49 atm.

45. -130°C.

47. 7.0 min.

49. Ideal = 0.588 m^3, actual = 0.598 m^3 (nonideal behavior).

51. 2.69×10^{25} molecules/m^3.

53. 4×10^{-17} Pa.

55. 300 molecules/cm^3.

57. 19 molecules/breath.

59. (*a*) 71.2 torr;
(*b*) 180°C.

61. 223 K.

63. (*a*) Low;
(*b*) 0.025%.

65. 20%.

67. 9.9 L, not advisable.

69. (*a*) 1100 kg;
(*b*) 100 kg.

71. (*a*) Lower;
(*b*) 0.36%.

73. 1.1×10^{44} molecules.

75. 3.34 nm.

77. 13 h.

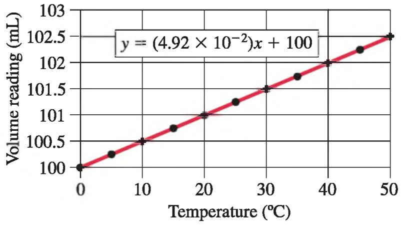
79. (*a*) 0.66×10^{3} kg/m^3;
(*b*) -3%.

81. $\pm$ 0.11 C°.

83. 3.6 m.

85. 3% increase.

87.



Slope of the line: 4.92×10^{-2} ml/°C,
relative β: 492×10^{-6}/°C,
β for the liquid: 501×10^{-6}/°C,
which liquid: glycerin.

CHAPTER 18

1. (*a*) 5.65×10^{-21} J;
(*b*) 3.7×10^{3} J.

3. 1.29.

5. 3.5×10^{-9} m/s.

7. (*a*) 4.5;
(*b*) 5.2.

9. $\sqrt{3}$.

13. (*b*) 5.6%.

15. 1.004.

17. (*a*) 493 m/s;
(*b*) 28 round trips/s.

19. Double the temperature.

21. (*a*) 710 m/s;
(*b*) 240 K;
(*c*) 650 m/s, 240 K, yes.

23. Vapor.

25. (*a*) Vapor;
(*b*) solid.

27. 3600 Pa.

29. 355 torr or 4.73×10^{4} Pa or 0.466 atm.

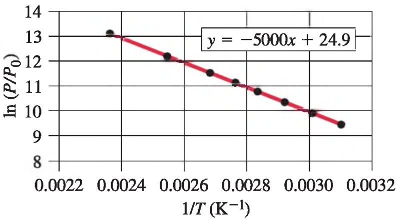
31. 92°C.

33. 1.99×10^{5} Pa or 1.97 atm.

35. 70 g.

37. 16.6°C.

39. (*a*) Slope $= -5.00 \times 10^{3}$ K,
y intercept = 24.9.
Let P_0 = 1 Pa in this graph:



41. (*a*) 3.1×10^{6} Pa;
(*b*) 3.2×10^{6} Pa.

43. (*b*) $a = 0.365\ \mathrm{N \cdot m^4/mol^2}$,
$b = 4.28 \times 10^{-5}\ \mathrm{m^3/mol}$.

45. (*a*) 0.10 Pa;
(*b*) 3×10^{7} Pa.

47. 2.1×10^{-7} m, stationary targets, effective radius of $r_{H_2} + r_{\mathrm{air}}$.

49. (*b*) $4.7 \times 10^{7}\ \mathrm{s^{-1}}$.

51. $\frac{1}{40}$.

53. 3.5 h, convection is much more important than diffusion.

55. (*b*) 4×10^{-11} mol/s;
(*c*) 0.6 s.

57. 260 m/s, 3.7×10^{-22} atm.

59. (*a*) 290 m/s;
(*b*) 9.5 m/s.

61. 50 cm.

63. Kinetic energy $= 6.07 \times 10^{-21}$ J, potential energy $= 5.21 \times 10^{-25}$ J, yes, potential energy can be neglected.

65. 0.07%.

67. 1.5×10^{5} K.

69. (*a*) 2800 Pa;
(*b*) 650 Pa.

71. 2×10^{13} m.

73. 0.36 kg.

75. (*b*) 4.6×10^{9} Hz,
2.3×10^{5} times larger.

77. 0.21.

CHAPTER 19

1. 10.7°C.

3. (*a*) 1.0×10^{7} J;
(*b*) 2.9 kWh;
(*c*) $0.29 per day, no.

5. 4.2×10^{5} J, 1.0×10^{2} kcal.

7. 6.0×10^{6} J.

9. (*a*) 3.3×10^{5} J;
(*b*) 56 min.

11. 6.9 min.

13. 39.9°C.

15. 2.3×10^{3} J/kg·C°.

17. 54 C°.

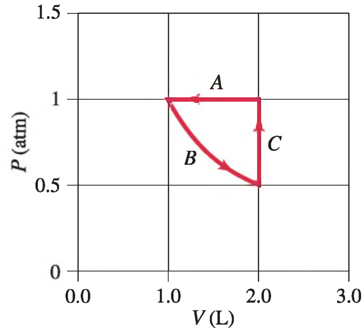
19. 0.31 kg.

21. (*a*) 5.1×10^{5} J;
(*b*) 1.5×10^{5} J.

23. 4700 kcal.

25. 360 m/s.

27.



29. (*a*) 0;
(*b*) −365 kJ.

31. (*a*) 480 J;
(*b*) 0;
(*c*) 480 J into gas.

33. (*a*) 4350 J;
(*b*) 4350 J;
(*c*) 0.

35. -4.0×10^{2} K.

37. 236 J.

39. (*a*) 3.0×10^{1} J;
(*b*) 68 J;
(*c*) −84 J;
(*d*) −114 J;
(*e*) −15 J.

41. $RT \ln \dfrac{(V_2 - b)}{(V_1 - b)} + a\left(\dfrac{1}{V_2} - \dfrac{1}{V_1}\right)$.

43. 43 C°.

45. 83.7 g/mol, krypton.

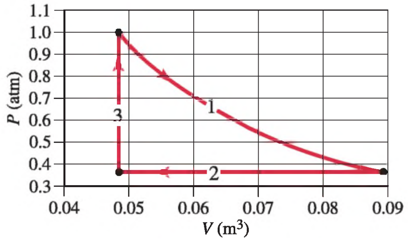
47. 48 C°.

49. (*a*) 6230 J;
(*b*) 2490 J;
(*c*) 8720 J.

51. 0.457 atm, −39°C.

53. (*a*) 404 K, 195 K;
(*b*) -1.59×10^{4} J;
(*c*) 0;
(*d*) -1.59×10^{4} J.

55. (*a*)



(*b*) 209 K;

(*c*) $Q_{1\to2} = 0$,
$\Delta E_{1\to2} = -2480$ J,
$W_{1\to2} = 2480$ J,
$Q_{2\to3} = -3740$ J,
$\Delta E_{2\to3} = -2240$ J,
$W_{2\to3} = -1490$ J,
$Q_{3\to1} = 4720$ J,
$\Delta E_{3\to1} = 4720$ J,
$W_{3\to1} = 0$;

(*d*) $Q_{\text{cycle}} = 990$ J,
$\Delta E_{\text{cycle}} = 0$,
$W_{\text{cycle}} = 990$ J.

57. (*a*) 5.0×10^1 W;
(*b*) 17 W.

59. 21 h.

61. (*a*) Ceramic: 14 W, shiny: 2.0 W;
(*b*) ceramic: 11 C°, shiny: 1.6 C°.

63. (*a*) 1.73×10^{17} W;
(*b*) 278 K or 5°C.

65. 28%.

67. (*b*) 4.8 C°/s;
(*c*) 0.60 C°/cm.

69. 6.4 Cal.

71. 4×10^{15} J.

73. 1 C°.

75. 3.6 kg.

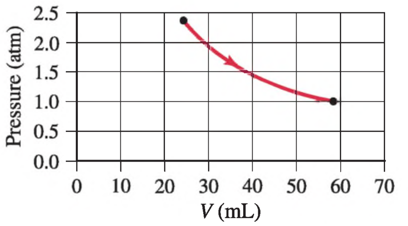
77. 0.14 C°.

79. (*a*) 800 W;
(*b*) 5.3 g.

81. 1.1 days.

83. (*a*) 4.79 cm;

(*b*)



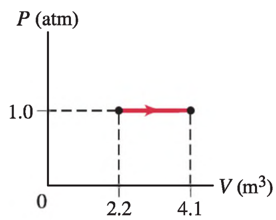
(*c*) $Q = 4.99$ J, $\Delta E = 0$, $W = 4.99$ J.

85. 110°C.

87. 305 J.

89. (*a*) 1.9×10^5 J;
(*b*) 4.4×10^5 J;

(*c*)



91. 2200 J.

CHAPTER 20

1. 0.25.

3. 0.16.

5. 0.21.

7. (*b*) 0.55.

9. 0.74.

13. 1.4×10^{13} J/h.

15. 1400 m.

17. 660°C.

19. (*a*) 4.1×10^5 Pa, 2.1×10^5 Pa;
(*b*) 34 L, 17 L;
(*c*) 2100 J;
(*d*) −1500 J;
(*e*) 600 J;
(*f*) 0.3.

21. 8.55.

23. 5.4.

25. (*a*) −4°C;
(*b*) 29%.

27. (*a*) 230 J;
(*b*) 390 J.

29. (*a*) 3.1×10^4 J;
(*b*) 2.7 min.

31. 91 L.

33. 0.20 J/K.

35. 5×10^4 J/K.

37. $5.49 \times 10^{-2} \dfrac{\text{J/K}}{\text{s}}$.

39. 9.3 J/K.

41. (*a*) 93 *m* J/K, yes;
(*b*) −93 *m* J/K, no; *m* in kg (SI).

43. (*a*) 1010 J/K;
(*b*) 1020 J/K;
(*c*) -9.0×10^2 J/K.

45. (*a*) Adiabatic;
(*b*) $\Delta S_{\text{adiabatic}} = 0$,
$\Delta S_{\text{isothermal}} = -nR\ln 2$;
(*c*) $\Delta S_{\text{environment adiabatic}} = 0$,
$\Delta S_{\text{environment isothermal}} = nR\ln 2$.

47. (*a*) All processes are reversible.

49. $\dfrac{T}{nC_V}$.

53. 2.1×10^5 J.

55. (*a*) $\frac{5}{16}$;
(*b*) $\frac{1}{64}$.

57. (*a*) 2.47×10^{-23} J/K;
(*b*) -9.2×10^{-22} J/K;
(*c*) these are many orders of magnitude smaller, due to the relatively small number of microstates for the coins.

59. (*a*) 1.79×10^6 kWh;
(*b*) 9.6×10^4 kW.

61. 12 MW.

63. (*a*) 0.41 mol;
(*b*) 396 K;
(*c*) 810 J;
(*d*) −700 J;
(*e*) 810 J;
(*f*) 0.13;
(*g*) 0.24.

65. (*a*) 110 kg/s;
(*b*) 9.3×10^7 gal/h.

67. (*a*) 18 km³/days;
(*b*) 120 km².

69. (*a*) 0.19;
(*b*) 0.23.

71. (*a*) 5.0 C°;
(*b*) 72.8 J/kg·K.

73. 1700 J/K.

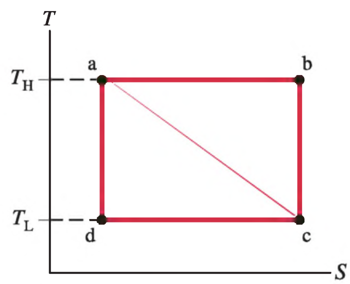
75. 57 W or 0.076 hp.

77. $e_{\text{Sterling}} =$

$$\left(\frac{T_{\text{H}} - T_{\text{L}}}{T_{\text{H}}}\right)\left[\frac{\ln\left(\dfrac{V_{\text{b}}}{V_{\text{a}}}\right)}{\ln\left(\dfrac{V_{\text{b}}}{V_{\text{a}}}\right) + \dfrac{3}{2}\left(\dfrac{T_{\text{H}} - T_{\text{L}}}{T_{\text{H}}}\right)}\right],$$

$e_{\text{Sterling}} < e_{\text{Carnot}}$.

79. (*a*)



(*b*) W_{net}.

81. 16 kg.

83. 3.61×10^{-2} J/K.

CHAPTER 21

1. 2.7×10^{-3} N.

3. 7200 N.

5. $(4.9 \times 10^{-14})\%$.

7. 4.88 cm.

9. -5.8×10^{8} C, 0.

11. (*a*) $q_1 = q_2 = \frac{1}{2}Q_T$;

(*b*) $q_1 = 0, q_2 = Q_T$.

13. $F_1 = 0.53$ N at 265°,

$F_2 = 0.33$ N at 112°,

$F_3 = 0.26$ N at 53°.

15. $F = 2.96 \times 10^{7}$ N, away from center of square.

17. 1.0×10^{12} electrons.

19. (*a*) $\pi\sqrt{\dfrac{md^3}{kQq}}$;

(*b*) 0.2 ps.

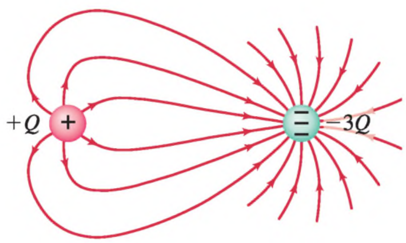
21. 3.08×10^{-16} N west.

23. 1.10×10^{7} N/C up.

25. $(172\,\hat{\mathbf{j}})$ N/C.

27. 1.01×10^{14} m/s^2, opposite to the field.

29.



31. $(-4.7 \times 10^{11}\,\hat{\mathbf{i}})$ N/C

$-\,(1.6 \times 10^{11}\,\hat{\mathbf{j}})$ N/C;

or

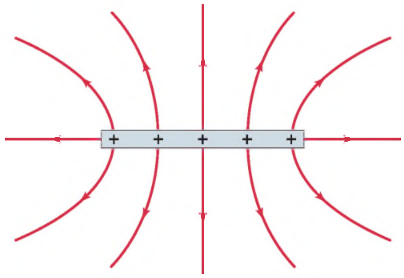
5.0×10^{11} N/C at 199°.

33. $E = 2.60 \times 10^{4}$ N/C, away from the center.

35. $\dfrac{4kQxa}{(x^2 - a^2)^2}$, left.

37. $\dfrac{\lambda}{2\pi\varepsilon_0}\sqrt{\dfrac{1}{x^2} + \dfrac{1}{y^2}}$, $\tan^{-1}\dfrac{x}{y}$.

39.



41. $\frac{1}{4}$.

43. (*a*) $\dfrac{Qy}{2\pi\varepsilon_0(y^2 + \ell^2)^{3/2}}$.

45. 1.8×10^{6} N/C, away from the wire.

47. $\dfrac{8\lambda\ell z}{\pi\varepsilon_0(\ell^2 + 4z^2)\sqrt{4z^2 + 2\ell^2}}$, vertical.

49. $-\dfrac{2\lambda \sin\theta_0}{4\pi\varepsilon_0 R}\hat{\mathbf{i}}$.

51. (*a*) $\dfrac{\lambda}{4\pi\varepsilon_0 x(x^2 + \ell^2)^{1/2}}$

$\times\,(\ell\hat{\mathbf{i}} + [x - (x^2 + \ell^2)^{1/2}]\hat{\mathbf{j}})$.

53. $\dfrac{Q}{4\pi\varepsilon_0 x(x + \ell)}$.

55. $\dfrac{Q(x\hat{\mathbf{i}} - \frac{2a}{\pi}\hat{\mathbf{j}})}{4\pi\varepsilon_0(x^2 + a^2)^{3/2}}$.

57. (*a*) $(-3.5 \times 10^{15}\ \text{m/s}^2)\,\hat{\mathbf{i}}$

$-\,(1.41 \times 10^{16}\ \text{m/s}^2)\,\hat{\mathbf{j}}$;

(*b*) 166° counterclockwise from the initial direction.

59. −23°.

61. (*b*) $2\pi\sqrt{\dfrac{4\pi\varepsilon_0 mR^3}{qQ}}$.

63. (*a*) 3.4×10^{-20} C;

(*b*) no;

(*c*) 8.5×10^{-26} m·N;

(*d*) 2.5×10^{-26} J.

65. (*a*) θ very small;

(*b*) $\dfrac{1}{2\pi}\sqrt{\dfrac{pE}{I}}$.

67. (*a*) In the direction of the dipole.

69. 3.5×10^{9} C.

71. 6.8×10^{5} C, negative.

73. 1.0×10^{7} electrons.

75. 5.71×10^{13} C.

77. 1.6 m from Q_2, 3.6 m from Q_1.

79. $\dfrac{1.08 \times 10^{7}}{[3.00 - \cos(13.9t)]^2}$ N/C (upwards).

81. 5×10^{-9} C.

83. 8.0×10^{-9} C.

85. 18°.

87. $E_A = 3.4 \times 10^{4}$ N/C, to the right;

$E_B = 2.3 \times 10^{4}$ N/C, to the left;

$E_C = 5.6 \times 10^{3}$ N/C, to the right;

$E_D = 3.4 \times 10^{3}$ N/C, to the left.

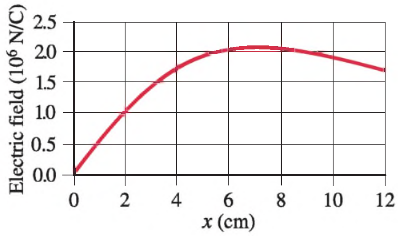
89. -7.66×10^{-6} C, unstable.

91. (*a*) 9.18×10^{6} N/C, down;

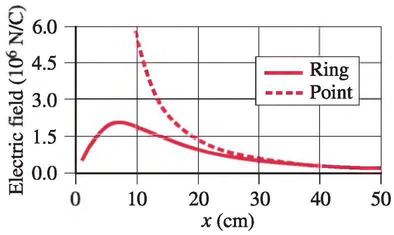
(*b*) 1.63×10^{-4} C/m^2.

93. (*a*) $\dfrac{a}{\sqrt{2}} = 7.07$ cm;

(*b*) yes;



(*c*) and (*d*)



(*e*) 37 cm.

CHAPTER 22

1. (*a*) 31 N·m^2/C;

(*b*) 22 N·m^2/C;

(*c*) 0.

3. (*a*) 0;

(*b*) 0, 0, 0, 0, $E_0\ell^2$, $-E_0\ell^2$.

5. 1.63×10^{-8} C.

7. (*a*) -1.1×10^{5} N·m^2/C;

(*b*) 0.

9. -8.3×10^{-7} C.

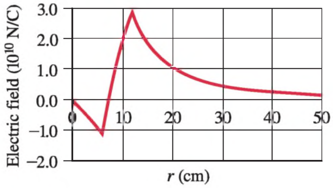
11. 4.3×10^{-5} C/m.

13. -8.52×10^{-11} C.

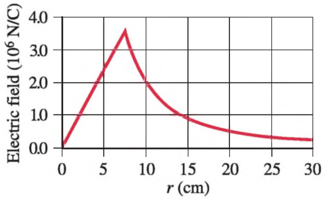
15. (*a*) -2.6×10^{4} N/C (toward wire);

(*b*) -8.6×10^{4} N/C (toward wire).

17. (a) $-(1.9 \times 10^{11}\ \text{N/C}\cdot\text{m})r$;
(b) $-(1.1 \times 10^{8}\ \text{N}\cdot\text{m}^2/\text{C})/r^2 + (3.0 \times 10^{11}\ \text{N/C}\cdot\text{m})r$;
(c) $(4.1 \times 10^{8}\ \text{N}\cdot\text{m}^2/\text{C})/r^2$;
(d) yes.



19.



21. (a) 5.5×10^{7} N/C (outward);
(b) 0;
(c) 5.5×10^{5} N/C (outward).

23. (a) $-8.00\ \mu$C;
(b) $+1.90\ \mu$C.

25. (a) 0;
(b) $\dfrac{\sigma}{\varepsilon_0}$ (outward, if both plates are positive);
(c) same.

27. (a) 0;
(b) $\dfrac{r_1^2\sigma_1}{\varepsilon_0 r^2}$;
(c) $\dfrac{(r_1^2\sigma_1 + r_2^2\sigma_2)}{\varepsilon_0 r^2}$;
(d) $\sigma_1 = -\left(\dfrac{r_2}{r_1}\right)^2 \sigma_2$;
(e) $\sigma_1 = 0$, or place $Q = -4\pi\sigma_1 r_1^2$ inside r_1.

29. (a) 0;
(b) $\dfrac{Q}{4\pi\varepsilon_0}\left(\dfrac{1}{r_0^3 - r_1^3}\right)\left(\dfrac{r^3 - r_1^3}{r^2}\right)$;
(c) $\dfrac{kQ}{r^2}$.

31. (a) $-q$;
(b) $Q + q$;
(c) $\dfrac{kq}{r^2}$;
(d) 0;
(e) $\dfrac{k(q+Q)}{r^2}$.

33. (a) $\dfrac{\sigma R_0}{\varepsilon_0 R}$, radially outward;
(b) 0;
(c) same for $R > R_0$ if $\lambda = 2\pi R_0\sigma$.

35. (a) 0;
(b) $\dfrac{1}{2\pi\varepsilon_0}\dfrac{(Q/\ell)}{r}$;
(c) 0;
(d) $\dfrac{e}{4\pi\varepsilon_0}\left(\dfrac{Q}{\ell}\right)$.

37. (a) 1.9×10^{7} m/s;
(b) 5.5×10^{5} m/s.

39. (a) $\dfrac{\rho_E r}{3\varepsilon_0}$;
(b) $\dfrac{\rho_E r_0^3}{3\varepsilon_0 r^2}$;
(c) 0;
(d) $\left(\dfrac{\rho_E r_0^3}{3\varepsilon_0} + \dfrac{Q}{4\pi\varepsilon_0}\right)\dfrac{1}{r^2}$.

41. (a) 0;
(b) $\dfrac{Q}{2500\pi\varepsilon_0 R_0^2}$.

43. (a) $\dfrac{\rho_E d}{2\varepsilon_0}$ away from surface.

45. (a) 13 N (attractive);
(b) 0.064 J.

47. (a) 0;
(b) $-\dfrac{\rho_0(d - x)}{\varepsilon_0}\hat{\mathbf{i}}$;
(c) $-\dfrac{\rho_0(d + x)}{\varepsilon_0}\hat{\mathbf{i}}$.

49. $\dfrac{Q}{4\pi\varepsilon_0}\dfrac{r^2}{r_0^4}$, radially outward.

51. $\Phi = \oint \vec{\mathbf{g}} \cdot d\vec{\mathbf{A}} = -4\pi G M_{\text{enc}}$.

53. $a\ell^3\varepsilon_0$.

55. 475 $\text{N}\cdot\text{m}^2/\text{C}$, 475 $\text{N}\cdot\text{m}^2/\text{C}$.

57. (a) 0;
(b) $E_{\max} = \dfrac{Q}{\pi\varepsilon_0 r_0^2}$, $E_{\min} = \dfrac{Q}{25\pi\varepsilon_0 r_0^2}$;
(c) no;
(d) no.

59. (a) 1.1×10^{-19} C;
(b) 3.5×10^{11} N/C.

61. (a) $\dfrac{\rho_E r_0}{6\varepsilon_0}$, right;
(b) $\dfrac{17}{54}\dfrac{\rho_E r_0}{\varepsilon_0}$, left.

63. (a) 0;
(b) 5.65×10^{5} N/C, right;
(c) 5.65×10^{5} N/C, right;
(d) $-5.00 \times 10^{-6}\ \text{C/m}^3$;
(e) $+5.00 \times 10^{-6}\ \text{C/m}^3$.

65. (a) On inside surface of shell.
(b) $r < 0.10$ m, $E = \left(\dfrac{2.7 \times 10^4}{r^2}\right)$ N/C;
$r > 0.10$ m, $E = 0$.

67. $-46\ \text{N}\cdot\text{m}^2/\text{C}$, -4.0×10^{-10} C.

CHAPTER 23

1. −0.71 V.

3. 3280 V, plate B has a higher potential.

5. 30 m.

7. 1.4 μC.

9. 1.2 cm, 46 nC.

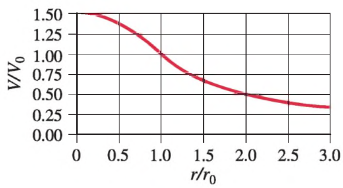
11. (a) 0;
(b) −29.4 V;
(c) −29.4 V.

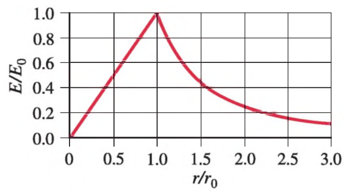
13. (a) -9.6×10^{8} V;
(b) 9.6×10^{8} V.

15. (a) They are equal;
(b) $Q\left(\dfrac{r_2}{r_1 + r_2}\right)$.

17. (a) 10–20 kV;
(b) 30 $\mu\text{C/m}^2$.

19. (a) $\dfrac{Q}{4\pi\varepsilon_0 r}$;
(b) $\dfrac{Q}{8\pi\varepsilon_0 r_0}\left(3 - \dfrac{r^2}{r_0^2}\right)$;
(c) Let $V_0 = V$ at $r = r_0$, and $E_0 = E$ at $r = r_0$:





21. $\dfrac{\rho_0}{\varepsilon_0}\left(\dfrac{r_0^2}{4} - \dfrac{r^2}{6} + \dfrac{r^4}{20r_0^2}\right)$.

23. (a) $\dfrac{R_0\sigma}{\varepsilon_0}\ln\left(\dfrac{R_0}{R}\right) + V_0$;
(b) V_0;
(c) no, from part (a) $V \to -\infty$ due to length of wire.

25. (a) 29 V;
(b) -4.6×10^{-18} J.

27. 0.34 J.

29. 4.2 MV.

31. 9.64×10^5 m/s.

33. (*a*) 0;
(*b*) $E_x = 0$,
$E_y = \dfrac{Q}{4\pi\varepsilon_0}\dfrac{R}{(x^2 + R^2)^{3/2}}$, looks like a dipole.

35. $\dfrac{\sigma}{2\varepsilon_0}\left(\sqrt{R_2^2 + x^2} - \sqrt{R_1^2 + x^2}\right)$.

37. 29 m/s.

39. $\dfrac{Q}{8\pi\varepsilon_0 \ell}\ln\left(\dfrac{x + \ell}{x - \ell}\right)$.

41. $\dfrac{a}{6\varepsilon_0}(R^2 - 2x^2)\sqrt{R^2 + x^2} + \dfrac{a|x|^3}{3\varepsilon_0}$.

43. 2 mm.

45. (*a*) 2.6 mV;
(*b*) 1.8 mV;
(*c*) −1.8 mV.

49. -7.1×10^{-11} C/m^2 on $x = 0$ plate, 7.1×10^{-11} C/m^2 on other plate.

51. $(-2.5y + 3.5yz)\hat{\mathbf{i}} + (-2y - 2.5x + 3.5xz)\hat{\mathbf{j}} + (3.5xy)\hat{\mathbf{k}}$.

53. (*a*) $\dfrac{Q}{4\pi\varepsilon_0}\left(\dfrac{1}{y\sqrt{\ell^2 + y^2}}\right)\hat{\mathbf{j}}$;
(*b*) $\dfrac{Q}{4\pi\varepsilon_0}\left(\dfrac{1}{x^2 - \ell^2}\right)\hat{\mathbf{i}}$.

55. −62.5 kV.

57. 1.3 eV.

59. (*a*) $\dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{Q_1Q_2}{r_{12}} + \dfrac{Q_1Q_3}{r_{13}} + \dfrac{Q_1Q_4}{r_{14}} + \dfrac{Q_2Q_3}{r_{23}} + \dfrac{Q_2Q_4}{r_{24}} + \dfrac{Q_3Q_4}{r_{34}}\right)$;
(*b*) $\dfrac{1}{4\pi\varepsilon_0}\left(\dfrac{Q_1Q_2}{r_{12}} + \dfrac{Q_1Q_3}{r_{13}} + \dfrac{Q_1Q_4}{r_{14}} + \dfrac{Q_1Q_5}{r_{15}} + \dfrac{Q_2Q_3}{r_{23}} + \dfrac{Q_2Q_4}{r_{24}} + \dfrac{Q_2Q_5}{r_{25}} + \dfrac{Q_3Q_4}{r_{34}} + \dfrac{Q_3Q_5}{r_{35}} + \dfrac{Q_4Q_5}{r_{45}}\right)$.

61. (*a*) 1.33 keV;
(*b*) $v_e/v_p = 42.8$.

63. 250 MeV, same order of magnitude as observed values.

65. 1.11×10^5 m/s, 3.5×10^5 m/s.

67. 0.26 MV/m.

69. 600 V.

71. 1.5 J.

73. Yes, 2.0 pV.

75. 1.03×10^6 m/s.

77. $-\dfrac{\sqrt{3}Q}{2\pi\varepsilon_0\ell}, \dfrac{Q}{\pi\varepsilon_0\ell}\left(\dfrac{\sqrt{3}}{6} - 2\right)$,
$-\dfrac{Q}{\pi\varepsilon_0\ell}\left(1 + \dfrac{\sqrt{3}}{6}\right)$.

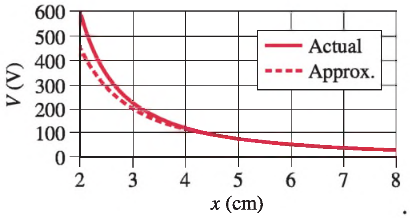
79. (*a*) 1.2 MV;
(*b*) 1.8 kg.

81. (*a*) $\dfrac{\rho_E(r_2^3 - r_1^3)}{3\varepsilon_0 r}$;
(*b*) $\dfrac{\rho_E}{\varepsilon_0}\left(\dfrac{r_2^2}{2} - \dfrac{r^2}{6} - \dfrac{r_1^3}{3r}\right)$;
(*c*) $\dfrac{\rho_E}{2\varepsilon_0}(r_2^2 - r_1^2)$; yes.

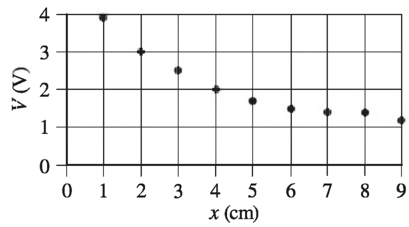
83. $\vec{\mathbf{E}} = \dfrac{\lambda}{2\pi\varepsilon_0 R}$, radially outward.

85. (*a*) 23 kV;
(*b*) $\dfrac{4Bx\hat{\mathbf{i}}}{(x^2 + R^2)^3}$;
(*c*) $(2.3 \times 10^5 \text{ N/C})\hat{\mathbf{i}}$.

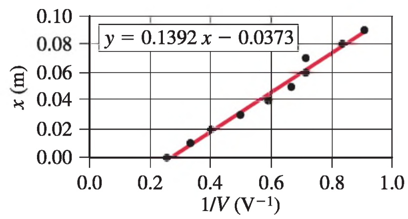
87. (*a*) and (*b*)



89. (*a*) Point charge;



(*b*) 1.5×10^{-11} C;



(*c*) $x = -3.7$ cm.

CHAPTER 24

1. 3.0 μF.

3. 3.1 pF.

5. 56 μF.

7. 1.1 C.

9. 83 days.

11. 130 m^2.

13. 7.10×10^{-4} F.

15. 18 nC.

17. 5.8×10^4 V/m.

19. (*a*) 0.22 μm $\leq x \leq$ 220 μm;
(*b*) $\dfrac{x^2\,\Delta C}{\varepsilon_0 A}$;
(*c*) 0.01%, 10%.

21. 3600 pF, yes.

23. 1.5 μF in series with the parallel combination of 2.0 μF and 3.0 μF, 2.8 V.

25. Add 11 μF connected in parallel.

27. $C_{max} = 1.94 \times 10^{-8}$ F, all in parallel, $C_{min} = 1.8 \times 10^{-9}$ F, all in series.

29. (*a*) $\frac{3}{5}C$;
(*b*) $Q_1 = Q_2 = \frac{1}{5}CV, Q_3 = \frac{2}{5}CV$,
$Q_4 = \frac{3}{5}CV, V_1 = V_2 = \frac{1}{5}V$,
$V_3 = \frac{2}{5}V, V_4 = \frac{3}{5}V$.

31. $Q_1 = \dfrac{C_1C_2}{C_1 + C_2}V_0, Q_2 = \dfrac{C_2^2}{C_1 + C_2}V_0$.

33. (*a*) $Q_1 = 23\,\mu$C, $Q_2 = Q_4 = 46\,\mu$C;
(*b*) $V_1 = V_2 = V_3 = V_4 = 2.9$ V;
(*c*) 5.8 V.

35. 2.4 μF.

37. (*a*) $C_1 + \dfrac{C_2C_3}{C_2 + C_3}$;
(*b*) $Q_1 = 8.40 \times 10^{-4}$ C,
$Q_2 = Q_3 = 2.80 \times 10^{-4}$ C.

39. $C = \dfrac{\varepsilon_0 A}{d}\left(1 - \dfrac{\theta\sqrt{A}}{2d}\right)$.

41. 6.8×10^{-3} J.

43. 2.0×10^3 J.

45. 1.70×10^{-3} J.

47. (*a*) $\dfrac{U_f}{U_i} = \dfrac{\ln\left(\dfrac{3R_a}{R_b}\right)}{\ln\left(\dfrac{R_a}{R_b}\right)} > 1$, work done to enlarge cylinder;
(*b*) $\dfrac{U_f}{U_i} = \dfrac{\ln\left(\dfrac{R_a}{R_b}\right)}{\ln\left(\dfrac{3R_a}{R_b}\right)} < 1$, charge moved to battery.

49. (*a*) $-\dfrac{\varepsilon_0 A\ell V_0^2}{2d(d - \ell)}$;
(*b*) $\dfrac{\varepsilon_0 A\ell V_0^2}{2(d - \ell)^2}$.

53. 2200 batteries, no.

55. 1.1×10^{-4} J.

57. (*a*) 0.32 μm^2;

(*b*) 59 megabytes.

59. $\frac{\varepsilon_0 A}{2d}(K_1 + K_2)$.

61. $\frac{\varepsilon_0 A K_1 K_2}{(d_1 K_2 + d_2 K_1)}$.

63. (*a*) $\frac{\varepsilon_0 \ell^2}{d}\left[1 + (K-1)\frac{x}{\ell}\right]$;

(*b*) $\frac{V_0^2 \varepsilon_0 \ell^2}{2d}\left[1 + (K-1)\frac{x}{\ell}\right]$;

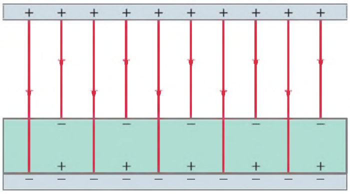
(*c*) $\frac{V_0^2 \varepsilon_0 \ell}{2d}(K-1)$, left.

67. $\frac{\varepsilon_0 A}{d - \ell + \frac{\ell}{K}}$.

69. $E_{air} = 2.69 \times 10^4$ V/m,

$E_{glass} = 4.64 \times 10^3$ V/m,

$Q_{free} = 0.345\ \mu C$, $Q_{ind} = 0.286\ \mu C$.



71. 43 μF.

73. 15 V.

75. 840 V.

77. 3.76×10^{-9} F, 0.221 m^2.

79. $\frac{1}{2K}$, work done by the electric field, $\frac{1}{K}$.

81. 1.2.

83. (*a*) 25 J;

(*b*) 940 kW.

85. (*a*) Parallel;

(*b*) 7.7 pF to 35 pF.

87. 5.15 pF.

89. $Q_1 = 11\ \mu C$, $Q_2 = 13\ \mu C$,

$Q_3 = 13\ \mu C$, $V_1 = 11$ V,

$V_2 = 6.3$ V, $V_3 = 5.2$ V.

91. $\frac{Q^2 x}{2\varepsilon_0 A}$.

93. 9×10^{-16} m, no.

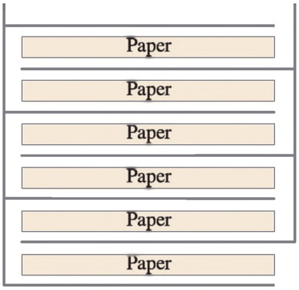
95. (*a*) 0.27 μC, 15 kV/m, 5.9 nF, 6.0 μJ;

(*b*) 0.85 μC, 15 kV/m, 19 nF, 19 μJ.

97. (*a*) 32 nF;

(*b*) 14 μC;

(*c*) 7.0 mm;



(*d*) 450 V.

CHAPTER 25

1. 8.13×10^{18} electrons/s.

3. 5.5×10^{-11} A.

5. (*a*) 28 A;

(*b*) 8.4×10^4 C.

7. 1.1×10^{21} electrons/min.

9. (*a*) $2.0 \times 10^1\ \Omega$;

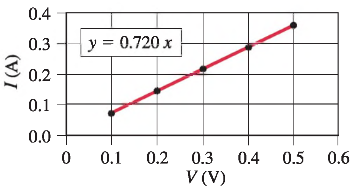
(*b*) 430 J.

11. 0.47 mm.

13. 0.64.

15. (*a*) Slope $= 1/R$, *y*-intercept $= 0$;

(*b*) yes, $R = 1.39\ \Omega$;



(*c*) $1.0 \times 10^{-6}\ \Omega \cdot m$, nichrome.

17. At 1/5.0 of its length, 2.0 Ω, 8.0 Ω.

19. 2400°C.

21. $\sqrt{2}$.

23. 44.1°C.

25. One-quarter of the original.

27. $\frac{1}{4\pi\sigma}\left(\frac{1}{r_1} - \frac{1}{r_2}\right)$.

29. (*a*) 0.14 Ω;

(*b*) 0.60 A;

(*c*) $V_{Al} = 52$ mV, $V_{Cu} = 33$ mV.

31. 0.81 W.

33. 29 V.

35. (*b*) As large as possible.

37. (*a*) 0.83 A;

(*b*) 140 Ω.

39. 0.055 kWh, 7.9 cents/month.

41. 0.90 kWh $= 3.2 \times 10^6$ J.

43. 24 lightbulbs.

45. 11 kW.

47. 0.15 kg/s = 150 mL/s.

49. 0.12 A.

51. (*a*) ∞;

(*b*) 96 Ω.

53. (*a*) 930 V;

(*b*) 3.9 A.

55. (*a*) 1.3 kW;

(*b*) max = 2.6 kW, min = 0.

57. (*a*) 5.1×10^{-10} m/s;

(*b*) 6.9 A/m^2;

(*c*) 1.2×10^{-7} V/m.

59. 2.5 A/m^2, north.

61. 35 m/s, delay time from stimulus to action.

63. 11 hr.

65. 1.8 m, it would generate 540 W of heat and could start a fire.

67. 0.16 S.

69. (*a*) \$35/month;

(*b*) 1300 kg/year.

71. (*a*) −19% change;

(*b*) % change would be slightly less.

73. (*a*) 190 Ω;

(*b*) 15 Ω.

75. (*a*) 1500 W;

(*b*) 12 A.

77. 2:1.

79. (*a*) 21 Ω;

(*b*) 2.0×10^1 s.

(*c*) 0.17 cents.

81. 36.0 m, 0.248 mm.

83. (*a*) 1200 W;

(*b*) 100 W.

85. 1.4×10^{12} protons.

87. (*a*) 3.1 kW;

(*b*) 24 W;

(*c*) 15 W;

(*d*) 38 cents/month.

89. (*a*) \$55/kWh;

(*b*) \$280/kWh, D-cells and AA-cells are 550× and 2800×, respectively, more expensive.

91. $1.34 \times 10^{-4}\ \Omega$.

93. $\dfrac{4\ell\rho}{ab\pi}$.

95. $f = 1 - \dfrac{V}{V_0}$.

CHAPTER 26

1. (*a*) 5.93 V;
(*b*) 5.99 V.

3. 0.060 Ω.

5. 9.3 V.

7. (*a*) 2.60 kΩ;
(*b*) 270 Ω.

9. Connect nine 1.0-Ω resistors in series with battery; then connect output voltage circuit across four consecutive resistors.

11. 0.3 Ω.

13. 450 Ω, 0.024.

15. Solder a 1.6-kΩ resistor in parallel with 480-Ω resistor.

17. 120 Ω.

19. $\frac{13}{8}R$.

21. $R = r$.

23. (*a*) V_{left} decreases,
V_{middle} increases,
$V_{\text{right}} = 0$;
(*b*) I_{left} decreases,
I_{middle} increases,
$I_{\text{right}} = 0$;
(*c*) terminal voltage increases;
(*d*) 8.5 V;
(*e*) 8.6 V.

25. (*a*) V_1 and V_2 increase, V_3 and V_4 decrease;
(*b*) I_1 and I_2 increase, I_3 and I_4 decrease;
(*c*) increases;
(*d*) before: $I_1 = 117$ mA, $I_2 = 0$,
$I_3 = I_4 = 59$ mA;
after: $I_1 = 132$ mA,
$I_3 = I_3 = I_4 = 44$ mA, yes.

27. 0.38 A.

29. 0.

31. (*a*) 29 V;
(*b*) 43 V, 73 V.

33. $I_1 = 0.68$ A left, $I_2 = 0.33$ A left.

37. 0.70 A.

39. 0.17 A.

41. (*a*) $\dfrac{R(5R' + 3R)}{8(R' + R)}$;
(*b*) $\dfrac{R}{2}$.

43. 1 – 15 MΩ.

45. 5.0 ms.

47. 44 s.

49. (*a*) $I_1 = \dfrac{2\mathscr{E}}{3R}$, $I_2 = I_3 = \dfrac{\mathscr{E}}{3R}$;
(*b*) $I_1 = I_2 = \dfrac{\mathscr{E}}{2R}$, $I_3 = 0$;
(*c*) $\dfrac{\mathscr{E}}{2}$.

51. (*a*) 8.0 V;
(*b*) 14 V;
(*c*) 8.0 V;
(*d*) 4.8 μC.

53. 29 μA.

55. (*a*) Place in parallel with 0.22-mΩ shunt resistor;
(*b*) place in series with 45-kΩ resistor.

57. 100 kΩ.

59. $V_{44} = 24$ V, $V_{27} = 15$ V;
−15%, −15%.

61. 0.960 mA, 4.8 V.

63. 12 V.

65. Connect a 9.0-kΩ resistor in series with human body and battery.

67. 2.5 V, 117 V.

69. 92 kΩ.

71. (*a*) $\dfrac{R_2 R_3}{R_1}$;
(*b*) 121 Ω.

73. Terminal voltage of mercury cell (3.99 V) is closer to 4.0 V than terminal voltage of dry cell (3.84 V).

75. 150 cells, 0.54 m^2, connect in series; connect four such sets in parallel to total 600 cells and deliver 120 V.

77. Counterclockwise current: −24 V, clockwise current: +48 V.

79. 10.7 V.

83. 9.0 Ω.

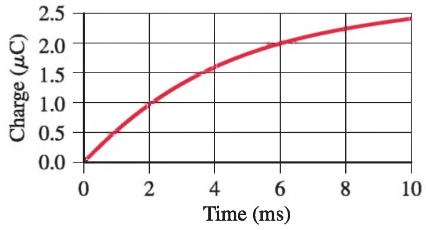
85. (*b*) 1.39 V;
(*c*) 0.42 mV;
(*d*) no current from "working" battery is needed to "power" galvanometer.

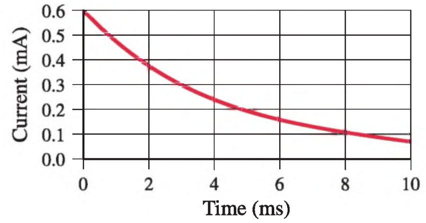
87. 1.0 mV, 2.0 mV, 4.0 mV, 10.0 mV.

89. (*a*) 6.8 V, 15 μC;
(*b*) 48 μs.

91. 200 MΩ.

93. 4.5 ms.





CHAPTER 27

1. (*a*) 8.5 N/m;
(*b*) 4.9 N/m.

3. 2.6×10^{-4} N.

5. (*a*) South pole;
(*b*) 3.41 A;
(*c*) 7.39×10^{-2} N.

7. 2.13 N, 41.8° below negative *y* axis.

9. $(-2IrB_0 \sin\theta_0)\hat{\mathbf{j}}$.

13. 6.3×10^{-14} N, north.

15. 1.8 T.

17. (*a*) Downward;
(*b*) into page;
(*c*) right.

19. (*a*) 0.031 m;
(*b*) 3.8×10^{-7} s.

23. 1.8 m.

25. $(0.78\hat{\mathbf{i}} - 1.0\hat{\mathbf{j}} + 0.1\hat{\mathbf{k}}) \times 10^{-15}$ N.

27. $L_{\text{final}} = \frac{1}{2}L_{\text{initial}}$.

29. (*a*) Negative;
(*b*) $qB_0\left(\dfrac{\ell^2 + d^2}{2d}\right)$.

31. 1.3×10^8 m/s, yes.

33. (*a*) 45°;
(*b*) 2.3×10^{-3} m.

35. (*a*) $2NIAB$;
(*b*) 0.

37. (*a*) 4.85×10^{-5} m·N;
(*b*) north.

39. (*a*) $(-4.3\,\hat{\mathbf{k}})$ A·m^2;
(*b*) $(2.6\hat{\mathbf{i}} - 2.4\hat{\mathbf{j}})$ m·N;
(*c*) −2.8 J.

41. 12%.

43. 39 μA.

45. 6 electrons.

47. (*b*) 0.05 nm, about $\frac{1}{6}$ the size of a typical metal atom;
(*c*) 10 mV.

49. 0.820 T.

51. 70 u, 72 u, 73 u, and 74 u.

53. 1.5 mm, 1.5 mm, 0.77 mm, 0.77 mm.

55. ${}^{2}_{1}\mathrm{H}$, ${}^{4}_{2}\mathrm{He}$.

57. 2.4 T, upwards.

59. (*a*) $\dfrac{IBd}{m}t$;
(*b*) $\left(\dfrac{IBd}{m} - \mu_k g\right)t$;
(*c*) east.

61. 1.1×10^{-6} m/s, west.

63. 3.8×10^{-4} m·N.

65. $\pi\left[\dfrac{mb(3a+b)}{3NIBa(a+b)}\right]^{1/2}$.

67. They do not enter second tube, 12°.

69. 1.1 A, down.

71. 7.3×10^{-3} T.

73. -6.9×10^{-20} J.

75. 0.083 N, northerly and 68° above the horizontal.

77. (*a*) Downward;
(*b*) 28 mT;
(*c*) 0.12 T.

CHAPTER 28

1. 0.37 mT, 7.4 times larger.

3. 0.15 N, toward other wire.

7. 0.12 mT, 82° above directly right.

9. 3.8×10^{-5} T, 17° below the horizontal to north.

11. (*a*) $(2.0 \times 10^{-5})(25 - I)$ T;
(*b*) $(2.0 \times 10^{-5})(25 + I)$ T.

15. Closer wire: 0.050 N/m, attractive, farther wire: 0.025 N/m, repulsive.

17. 17 A, downward.

19. $\dfrac{\mu_0 I}{2\pi}\left(\dfrac{d - 2x}{x(d-x)}\right)\hat{\mathbf{j}}$.

21. 46.6 μT.

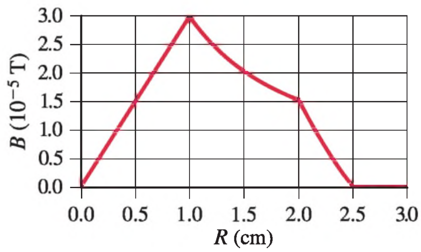
23. (*b*) $\dfrac{\mu_0 I}{2\pi y}$, yes, looks like B from long straight wire.

25. 0.160 A.

27. (*a*) 5.3 mT;
(*b*) 3.2 mT;
(*c*) 1.8 mT.

29. (*a*) 0.554 m;
(*b*) 10.5 mT.

31. (*a*) $\dfrac{\mu_0 I_0 R}{2\pi R_1^2}$;
(*b*) $\dfrac{\mu_0 I_0}{2\pi R}$;
(*c*) $\dfrac{\mu_0 I_0}{2\pi R}\left(\dfrac{R_3^2 - R^2}{R_3^2 - R_2^2}\right)$;
(*d*) 0;
(*e*)



33. 3.6×10^{-6} T.

35. $0.075\,\mu_0 I/R$.

37. (*a*) $\dfrac{\mu_0 I}{4}\left(\dfrac{1}{R_1} + \dfrac{1}{R_2}\right)$, into the page;
(*b*) $\dfrac{\pi I(R_1^2 + R_2^2)}{2}$, into the page.

39. (*a*) $\dfrac{Q\omega R^2}{4}\hat{\mathbf{i}}$;
(*b*) $\dfrac{\mu_0 Q\omega}{2\pi R^2}\left(\dfrac{R^2 + 2x^2}{\sqrt{R^2 + x^2}} - 2x\right)\hat{\mathbf{i}}$;
(*c*) yes.

41. (*b*) $\dfrac{\mu_0 I}{4\pi y}\left(\dfrac{d}{\sqrt{d^2 + y^2}}\right)\hat{\mathbf{k}}$.

43. (*a*) $\dfrac{n\mu_0 I \tan(\pi/n)}{2\pi R}$, into the page.

45. $\dfrac{\mu_0 I}{4\pi}\left[\dfrac{\sqrt{x^2 + y^2}}{xy} + \dfrac{\sqrt{y^2 + (b-x)^2}}{(b-x)y} + \dfrac{\sqrt{(a-y)^2 + (b-x)^2}}{(a-y)(b-x)} + \dfrac{\sqrt{(a-y)^2 + x^2}}{x(a-y)}\right]$, out of page.

47. (*a*) 16 A·m^2;
(*b*) 13 m·N.

49. 2.4 T.

51. $(\vec{\mathbf{F}}/\ell)_{\mathrm{M}} = 6.3 \times 10^{-4}$ N/m at 90°,
$(\vec{\mathbf{F}}/\ell)_{\mathrm{N}} = 3.7 \times 10^{-4}$ N/m at 300°,
$(\vec{\mathbf{F}}/\ell)_{\mathrm{P}} = 3.7 \times 10^{-4}$ N/m at 240°.

53. 170 A.

55. (*a*) 2.7×10^{-6} T;
(*b*) 5.3×10^{-6} T;
(*c*) no, no Newton's third-law-type of relationship;
(*d*) both 1.1×10^{-5} N/m, yes, Newton's third law holds.

57. $\dfrac{\mu_0 tj}{2}$, to the left above sheet (with current coming toward you).

61. (*a*) $\dfrac{N\mu_0 IR^2}{2} \times \left(\dfrac{1}{(R^2 + x^2)^{3/2}} + \dfrac{1}{(R^2 + (x-R)^2)^{3/2}}\right)$;
(*b*) 4.5 mT.

63. 3×10^9 A.

65. (*a*) 46 turns;
(*b*) 0.83 mT;
(*c*) no.

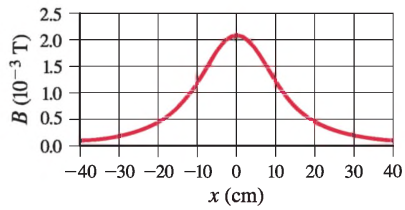
67. $\dfrac{\mu_0 I\sqrt{5}}{2\pi a}$, into the page.

69. 0.10 N, south.

71. $\frac{2}{3}$.

73. (*c*) 1.5 A.

75.



CHAPTER 29

1. −460 V.

3. Counterclockwise.

5. 1.2 mm/s.

7. (*a*) 0.010 Wb;
(*b*) 55°;
(*c*) 5.8 mWb.

9. Counterclockwise.

11. (*a*) Clockwise;
(*b*) 43 mV;
(*c*) 17 mA.

13. (*a*) 8.1 mJ;
(*b*) 4.2×10^{-3} C°.

15. (*a*) 0.15 A;
(*b*) 1.4 mW.

17. 8.81 C.

19. 21 μJ.

21. 23 mV, 26 mV.

23. (*a*) 0;
(*b*) 0.99 A, counterclockwise.

25. (*a*) $\dfrac{\mu_0 I a}{2\pi}\ln\left(1+\dfrac{a}{b}\right)$;
(*b*) $\dfrac{\mu_0 I a^2 v}{2\pi b(a+b)}$;
(*c*) clockwise;
(*d*) $\dfrac{\mu_0^2 I^2 a^4 v}{4\pi^2 b^2 (a+b)^2 R}$.

27. 1.0 m/s.

29. (*a*) 0.11 V;
(*b*) 4.1 mA;
(*c*) 0.36 mN.

31. 0.39 m/s.

33. (*a*) Yes;
(*b*) $v_0\, e^{-B^2\ell^2 t/mR}$.

35. (*a*) $\dfrac{v\mu_0 I}{2\pi}\ln\left(1+\dfrac{a}{b}\right)$;
(*b*) $-\dfrac{v\mu_0 I}{2\pi}\ln\left(1+\dfrac{a}{b}\right)$.

37. 57.2 loops.

41. 150 V.

43. 13 A.

45. (*a*) 2.4 kV;
(*b*) 190 V.

47. 50, 4.8 V.

49. (*a*) Step-up;
(*b*) 3.5.

51. (*a*) R;
(*b*) $\left(\dfrac{N_P}{N_S}\right)^2 R$.

53. 98 kW.

55. (*b*) Clockwise;
(*c*) increase.

57. (*a*) $\dfrac{IR}{\ell}$;
(*b*) $\dfrac{\mathscr{E}_0}{\ell}\, e^{-B^2\ell^2 t/mR}$.

59. 10.1 mJ.

61. 0.6 nC.

63. (*a*) 41 kV;
(*b*) 31 MW;
(*c*) 0.88 MW;
(*d*) 3.0×10^7 W.

65. (*a*) Step-down;
(*b*) 2.9 A;
(*c*) 0.29 A;
(*d*) 4.1 Ω.

67. 46 mA, left to right through resistor.

69. 2.3×10^{17} electrons.

71. (*a*) 25 A;
(*b*) 98 V;
(*c*) 600 W;
(*d*) 81%.

73. $\frac{1}{2}B\omega\ell^2$.

77. $B\omega R$, radially in toward axis.

79. (*a*) $\dfrac{\pi d^2 B^2 \ell v}{16\rho}$;
(*b*) $16\rho\rho_m g/B^2$;
(*c*) 3.7 cm/s.

CHAPTER 30

1. (*a*) 31.0 mH;
(*b*) 3.79 V.

3. $\dfrac{\mu_0 N_1 N_2 A_2 \sin\theta}{\ell}$.

5. 12 V.

7. 0.566 H.

9. 11.3 V.

11. 46 m, 21 km, 0.70 kΩ.

15. 18.9 J.

17. 1.06×10^{-3} J/m^3.

19. $\dfrac{\mu_0 N^2 I^2}{8\pi^2 r^2}, \dfrac{\mu_0 N^2 I^2 h}{4\pi}\ln\left(\dfrac{r_2}{r_1}\right)$.

21. $\dfrac{\mu_0 I^2}{16\pi}$.

23. 3.5 time constants.

25. (*a*) $\dfrac{LV_0^2}{2R^2}\left(1-e^{-t/\tau}\right)^2$;
(*b*) 7.6 time constants.

27. (*b*) 6600 V.

29. $(12\text{ V})e^{-t/8.2\,\mu\text{s}}$, 0, 12 V.

31. (*a*) 0.16 nF;
(*b*) 62 μH.

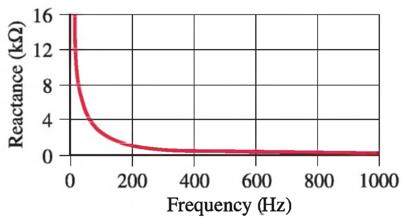
33. (*c*) (2×10^{-4})%.

35. (*a*) $\dfrac{Q_0}{\sqrt{2}}$;
(*b*) $\frac{1}{8}T$.

37. $\dfrac{L}{R}\ln\left(\frac{4}{3}\right) = (0.29)\dfrac{L}{R}$.

39. 3300 Hz.

41.



43. (*a*) $R + R'$;
(*b*) R'.

45. (*a*) 2800 Ω;
(*b*) 660 Hz, 11 A.

47. 2190 W.

49. (*a*) 0.40 kΩ;
(*b*) 75 Ω.

51. 1600 Hz.

53. 240 Hz, voltages are out of phase.

55. (*a*) 0.124 A;
(*b*) 5.02°;
(*c*) 14.8 W;
(*d*) 0.120 kV, 10.5 V.

57. 7.8 μF.

59. $I_0 V_0 \sin\omega t \sin(\omega t + \phi)$.

61. 130 Ω, 0.91.

63. 265 Hz, 324 W.

65. (*b*) 130 Ω.

67. (*a*) $\dfrac{V_0^2 R}{2\left[R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2\right]}$;
(*b*) $\dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC}}$;
(*c*) $\dfrac{R}{L}$.

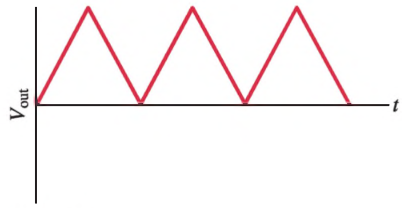
69. 37 loops.

71. (*a*) 0.040 H;
(*b*) 28 mA;
(*c*) 16 μJ.

73. 2.4 mA, 0, 2.4 mA.

77. (*a*) $\dfrac{Q_0^2}{2C}e^{-Rt/L}$;
(*b*) $\dfrac{dU}{dt} = -I^2 R$.

79.

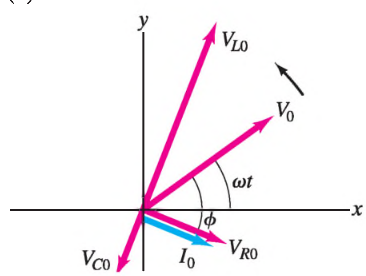


81. (*a*) 0;
(*b*) 0, 90° out of phase.

83. 2.2 kHz.

85. 69 mH, 18 Ω.

89. (*a*)



(*b*) $\dfrac{V_0}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}}\sin(\omega t - \phi)$,

$\phi = \tan^{-1}\dfrac{\omega L - \dfrac{1}{\omega C}}{R}$.

91. (*a*) $\left(\dfrac{V_{20}}{\omega L - \dfrac{1}{\omega C}}\right)\sin\left(\omega t - \tfrac{1}{2}\pi\right)$;

(*b*) $\left(\dfrac{V_{20}}{\omega^2 LC - 1}\right)\sin(\omega t - \pi)$;

(*c*) $\dfrac{1}{\omega^2 LC}$;

(*d*) $V_{1\,\text{out}} = V_1$.

93. (*a*) $\dfrac{V_0}{R}\sin\omega t$;

(*b*) $\dfrac{V_0}{X_L}\sin\left(\omega t - \tfrac{1}{2}\pi\right)$;

(*c*) $\dfrac{V_0}{X_C}\sin\left(\omega t + \tfrac{1}{2}\pi\right)$

(*d*) $\dfrac{V_0}{R}\sqrt{1+\left(R\omega C - \dfrac{R}{\omega L}\right)^2}\sin(\omega t+\phi)$,

$\phi = \tan^{-1}\left(R\omega C - \dfrac{R}{\omega L}\right)$;

(*e*) $\dfrac{R}{\sqrt{1 + \left(R\omega C - \dfrac{R}{\omega L}\right)^2}}$;

(*f*) $\dfrac{1}{\sqrt{1 + \left(R\omega C - \dfrac{R}{\omega L}\right)^2}}$.

95. 0.14 H.

97. 54 mH, 22 Ω.

99. $\sqrt{6.0}\,f_0 = 2.4 f_0$.

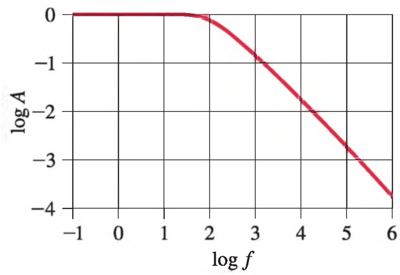
101. (*a*) 7.1 kHz, V_{rms};

(*b*) 0.90.

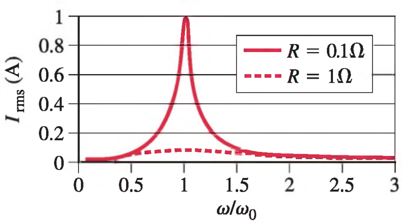
103. (*b*) For $f \to 0$ $A \to 1$;

for $f \to \infty$, $A \to 0$;

(*c*) f is in s^{-1}:



105.



CHAPTER 31

1. 110 kV/m·s.

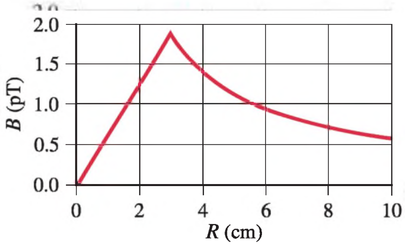
3. 1.2×10^{15} V/m·s.

7. (*b*) With R in meters, for $R \le R_0$,

$B_0 = (6.3 \times 10^{-11}\ \text{T/m})R$;

for $R > R_0$, $B_0 = \dfrac{5.7 \times 10^{-14}\ \text{T}\cdot\text{m}}{R}$.

(*c*)



9. 3.75 V/m.

11. (*a*) $-\hat{\mathbf{k}}$;

(*b*) $\dfrac{E_0}{c}$, $-\hat{\mathbf{j}}$.

13. 2.00×10^{10} Hz.

15. 5.00×10^2 s = 8.33 min.

17. (*a*) 3.00×10^5 m;

(*b*) 34.1 cm;

(*c*) no.

19. (*a*) 261 s;

(*b*) 1260 s.

21. 3.4 krad/s.

23. 2.77×10^7 s.

25. 4.8 W/m², 42 V/m.

27. 4.50 μJ.

29. 3.80×10^{26} W.

31. (*a*) 5 cm², yes;

(*b*) 20 m², yes;

(*c*) 100 m², no.

33. (*a*) 2×10^8 ly;

(*b*) 2000 times larger.

35. 8×10^6 m/s².

37. 27 m².

39. 16 cm.

41. 3.5 nH to 5.3 nH.

43. 6.25×10^{-4} V/m;

1.04×10^{-9} W/m².

45. 3 m.

47. 1.35 s.

49. 34 V/m, 0.11 μT.

51. Down, 2.2 μT, 650 V/m.

53. (*a*) 0.18 nJ;

(*b*) 8.7 μV/m, 2.9×10^{-14} T.

57. 4×10^{10} W.

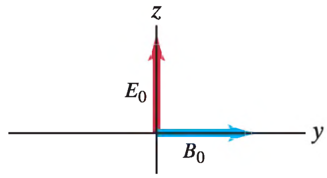
59. 5 nodes, 6.1 cm.

61. (*a*) $+x$;

(*b*) $\beta = \alpha c$;

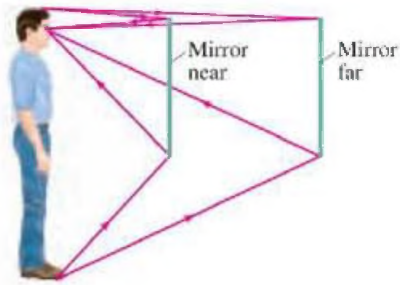
(*c*) $\dfrac{E_0}{c}e^{-(\alpha x - \beta t)^2}$.

63. (*d*) Both $\vec{\mathbf{E}}$ and $\vec{\mathbf{B}}$ rotate counterclockwise.



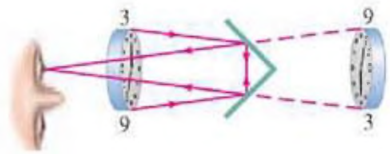
CHAPTER 32

1.



3. 7°.

7.



9. 37.6 cm.

11. 1.0 m.

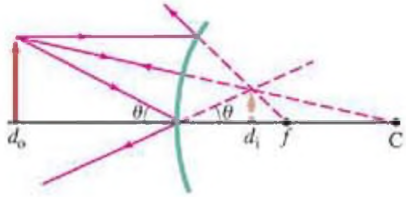
13. 2.1 cm behind front surface of ball; virtual, upright.

15. Concave, 5.3 cm.

17. −6.0 m.

19. Convex, −32.0 cm.

21.



23. -3.9 m.

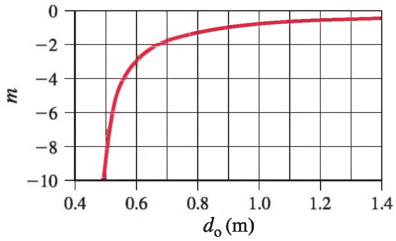
25. (*a*) Convex;

(*b*) 20 cm behind mirror;

(*c*) -91 cm;

(*d*) -1.8 m.

27. (*b*)



(*c*) 0.90 m;

(*d*) just beyond focal point.

31. Because the image is inverted.

33. (*a*) 2.21×10^8 m/s;

(*b*) 1.99×10^8 m/s;

(*c*) 1.97×10^8 m/s.

35. 8.33 min.

37. 3 m.

39. 35°.

41. 38.6°.

43. 2.6 cm.

45. 4.4 m.

47. 3.2 mm.

49. 38.9°.

53. 0.22°.

55. 0.80°.

57. 33.3°, diamond.

59. 82.1 cm.

61. $n \geq 1.5$.

63. (*a*) 2.3 μs;

(*b*) 17 ns.

65. $n \geq 1.72$.

67. 17.3 cm.

71. 0.25 m, 0.50 m.

73. (*a*) 3.0 m, 4.4 m, 7.4 m;

(*b*) toward, away, toward.

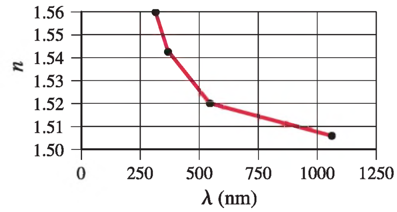
75. 3.80 m.

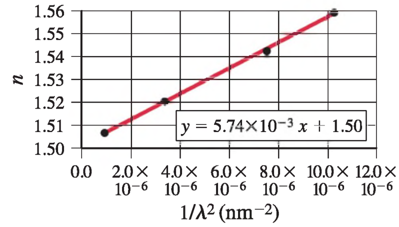
77. 31 cm for real image, 15 cm for virtual image.

83. $\dfrac{d}{n-1}$.

85. The light would totally internally reflect only if $\theta_i \leq 32.5°$.

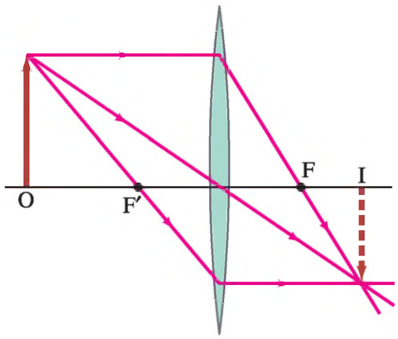
87. $A = 1.5005$, $B = 5740\ \text{nm}^2$.





CHAPTER 33

1. (*a*)



(*b*) 508 mm.

3. (*a*) 4.26 D, converging;

(*b*) -14.8 cm, diverging.

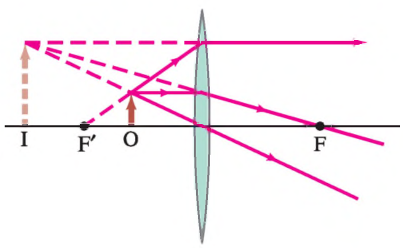
5. (*a*) 106 mm;

(*b*) 109 mm;

(*c*) 117 mm;

(*d*) an object 0.513 m away.

7. (*a*) Virtual, upright, magnified;



(*b*) converging;

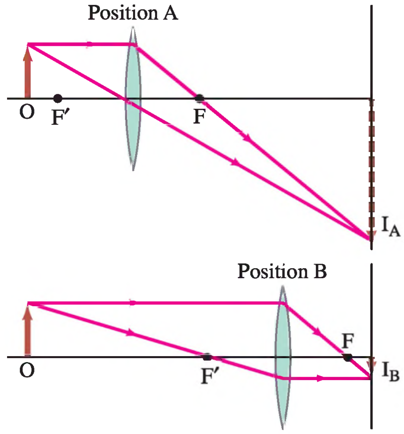
(*c*) 6.7 D.

9. (*a*) 0.02 m;

(*b*) 0.004 m.

11. 50 cm.

13. 21.3 cm, 64.7 cm.



15. (*c*) Real, upright; (*d*) real, upright.

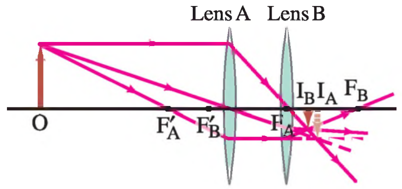
17. 0.107 m, 2.2 m.

19. (*b*) 182 cm; (*c*) 182 cm.

21. 18.5 cm beyond second lens, $-0.651\times$.

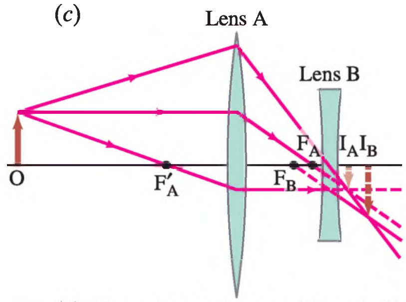
23. (*a*) 7.14 cm beyond second lens;

(*b*) $-0.357\times$; (*c*)

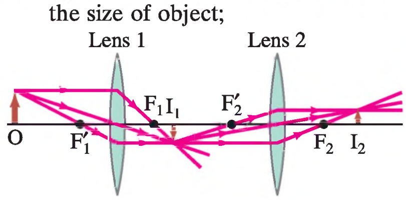


25. (*a*) 0.10 m to right of diverging lens; (*b*) $-1.0\times$;

(*c*)



27. (*a*) 30 cm beyond second lens, half the size of object;



(*b*) 29 cm beyond second lens, 0.46 times the size of object.

29. 1.54.

31. 8.6 cm.

33. 34 cm.

35. $f/2.8$.

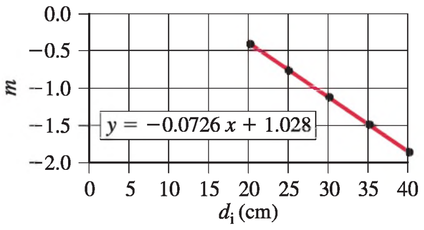
37. $\frac{1}{6}$ s.

39. 41 mm.

41. $+2.5$ D.

43. 41 cm, yes.

45. (*a*) -1.3 D;
(*b*) 37 cm.
47. -24.8 cm.
49. 18.4 cm, 1.00 m.
51. 6.6 cm.
53. (*a*) 13 cm;
(*b*) 8.3 cm.
55. (*a*) -234 cm;
(*b*) $4.17\times$.
57. (*a*) -66 cm;
(*b*) $3.0\times$.
59. 4 cm, toward.
61. 2.5 cm, 91 cm.
63. $-26\times$.
65. $16\times$.
67. 3.7 m, 7.4 m.
69. $-9\times$.
71. $8.0\times$.
73. 1.6 cm.
75. (*a*) $754\times$;
(*b*) 1.92 cm, 0.307 cm;
(*c*) 0.312 cm.
77. (*a*) 0.85 cm;
(*b*) $250\times$.
79. $410\times$, $25\times$.
81. 79.4 cm, 75.5 cm.
83. $6.450\text{ m} \le d_0 \le \infty$.
85. 116 mm, 232 mm.
87. -19.0 cm.
89. 3.1 cm, 25 cm.
91. (*a*) 0.26 mm;
(*b*) 0.47 mm;
(*c*) 1.3 mm;
(*d*) $0.56\times$, $2.7\times$.
93. 20.0 cm.
95. 47 m.
97. $2.8\times$, $3.9\times$, person with normal eye.
99. $1.0\times$.
101. $+3.4$ D.
103. $-19\times$.
105. (*a*) 28.6 cm;
(*b*) 120 cm;
(*c*) 15 cm.
107. -6.2 cm.
109. (*a*) $-1/f$, 1;
(*b*) 14 cm, yes, y-intercept $= 1.03$;



(*c*) $f = -1/\text{slope}$.

CHAPTER 34

3. 3.9 μm.
5. 0.2 mm.
7. 660 nm.
9. 3.5 cm.
11. Inverted, starts with central dark line, and every place there was bright fringe before is now dark fringe and vice versa.
13. 2.7 mm.
15. 2.94 mm.
17. $\frac{1}{4}$.
21. $I_0\left[\dfrac{3 + 2\sqrt{2}\cos\left(\dfrac{2\pi d\sin\theta}{\lambda}\right)}{3 + 2\sqrt{2}}\right]$.
23. 634 nm.
25. (*a*) 180 nm;
(*b*) 361 nm, 541 nm.
27. (*b*) 290 nm.
29. 8.68 μm.
31. 113 nm, 225 nm.
35. 1.32.
37. (*c*) 571 nm.
39. 0.191 mm.
41. 80.1 μm.
43. 0.3 mm.
45. (*a*) 17 lm/W;
(*b*) 160 lamps.
47. (*a*) Constructive;
(*b*) destructive.
49. 440 nm.
51. $I_0\cos^2\left(\dfrac{2\pi x}{\lambda}\right)$.
53. (*a*) 81.5 nm;
(*b*) 0.130 μm.
55. $\theta = \sin^{-1}\left(\sin\theta_i \pm \dfrac{m\lambda}{d}\right)$.
57. 340 nm, 170 nm.
59. Constructive: 90°, 270°; destructive: 0°, 180°; exactly switched.
61. 240 nm.
63. 0.20 km.
65. 126 nm.

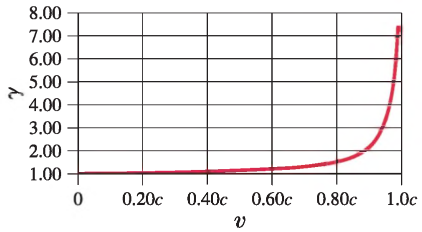
CHAPTER 35

1. 37.3 mrad = 2.13°.
3. 2.35 m.
5. Entire pattern is shifted, with central maximum at 23° to the normal.
7. 4.8 cm.
9. 953 nm.
11. (*a*) 63°;
(*b*) 30°.
13. 0.15.
15. $d = 5D$.
17. 265 fringes.
19. (*a*) 1.9 cm;
(*b*) 12 cm.
21. 0.255.
23. (*a*) $I_\theta = I_0\left(\dfrac{1 + 2\cos\delta}{3}\right)^2$.
25. 1.5×10^{11} m.
27. 1.0×10^4 m.
29. 730 lines/mm, 88 lines/mm.
31. 0.40 μm, 0.50 μm, 0.52 μm, 0.62 μm.
33. Two full orders, plus part of a third order.
35. 556 nm.
37. 24°.
39. $\lambda_2 > 600$ nm overlap with $\lambda_3 < 467$ nm.
41. $\lambda_1 = 614$ nm, $\lambda_2 = 899$ nm.
43. 7 cm, 35 cm, second order.
45. (*c*) $-32°$, 0.9°.
47. (*a*) 16,000 and 32,000;
(*b*) 26 pm, 13 pm.
49. 14.0°.
51. No.
53. 45°.
55. 61.2°.
57. (*a*) 35.3°;
(*b*) 63.4°.
59. 36.9°, smaller than both angles.
61. $I = \dfrac{I_0}{4}\sin^2(2\theta)$, 45°.
63. 28.8 μm.
65. 580 nm.
67. 0.6 m.
69. 658 nm, 853 lines/cm.
71. (*a*) 18 km;
(*b*) 23″, atmospheric distortions make it worse.
73. 5.79×10^5 lines/m.
75. 36.9°.
77. (*a*) 60°;
(*b*) 71.6°;
(*c*) 84.3°.
79. 0.4 m.
81. 0.245 nm.
83. 110 m.
85. -0.17 mm.
87. Use 24 polarizers, each rotated 3.75° from previous axis.

CHAPTER 36

1. 72.5 m.

3. 1.00, 1.00, 1.01, 1.02, 1.05, 1.09, 1.15, 1.25, 1.40, 1.67, 2.29, 7.09.



5. 2.42×10^8 m/s.

7. 27 yr.

9. $(6.97 \times 10^{-8})\%$.

11. (*a*) $0.141c$;
(*b*) $0.140c$.

13. (*a*) 3.4 yr;
(*b*) 7.4 yr.

15. $0.894c$.

17. Base: 0.30ℓ, sides: 1.94ℓ.

19. $0.65c$.

21. (*a*) (820 m, 20 m, 0);
(*b*) (2280 m, 20 m, 0).

23. (*a*) $0.88c$;
(*b*) $-0.88c$.

25. (*a*) $0.97c$;
(*b*) $0.55c$.

27. $0.93c$ at 35°.

29. (*a*) $\ell_0\sqrt{1 - \frac{v^2}{c^2}\cos^2\theta}$;
(*b*) $\tan^{-1}\left[\frac{\tan\theta}{\sqrt{1 - \frac{v^2}{c^2}}}\right]$.

31. $t'_B - t'_A = -\dfrac{v\ell}{c^2\sqrt{1 - \frac{v^2}{c^2}}}$,
B is turned on first.

33. Not possible in boy's frame of reference.

35. (*a*) -0.5%;
(*b*) -20%.

37. $0.95c$.

39. 8.20×10^{-14} J, 0.511 MeV.

41. 900 kg.

43. 1.00 MeV/c^2, or 1.78×10^{-30} kg.

45. 9.0×10^{13} J, 9.2×10^9 kg.

47. $0.866c$.

49. 1670 MeV, 2440 MeV/c.

51. $0.470c$.

53. $0.32c$.

55. $0.866c$, $0.745c$.

57. (*a*) 2.5×10^{19} J;
(*b*) -2.4%.

59. 237.04832 u.

61. 240 MeV.

65. 230 MHz.

67. (*a*) 1.00×10^2 km/h;
(*b*) 67 Hz.

69. 75 μs.

71. 8.0×10^{-8} s.

73. (*a*) $0.067c$;
(*b*) $0.070c$.

75. (*a*) $\tan^{-1}\sqrt{\frac{c^2}{v^2} - 1}$;
(*c*) $\tan^{-1}\frac{c}{v}$, $u = \sqrt{c^2 + v^2}$.

77. (*a*) 0.77 m/s;
(*b*) 0.21 m.

79. 1.022 MeV.

83. (*a*) 4×10^9 kg/s;
(*b*) 4×10^7 yr;
(*c*) 1×10^{13} yr.

85. 28.32 MeV.

87. (*a*) 2.86×10^{-18} kg·m/s;
(*b*) 0;
(*c*) 3.31×10^{-17} kg·m/s.

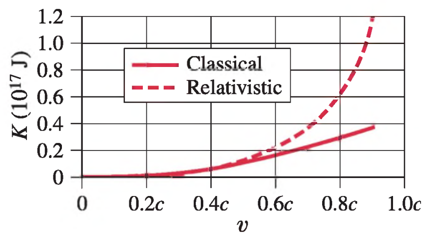
89. 3×10^7 kg.

91. $0.987c$.

93. 5.3×10^{21} J, 53 times as great.

95. (*a*) 6.5 yr;
(*b*) 2.3 ly.

99.



CHAPTER 37

1. (*a*) 10.6 μm, far infrared;
(*b*) 829 nm, infrared;
(*c*) 0.69 mm, microwave;
(*d*) 1.06 mm, microwave.

3. 5.4×10^{-20} J, 0.34 eV.

5. (*b*) 6.62×10^{-34} J·s.

7. $2.7 \times 10^{-19}\text{ J} < E < 4.9 \times 10^{-19}$ J,
$1.7\text{ eV} < E < 3.0$ eV.

9. 2×10^{13} Hz, 1×10^{-5} m.

11. 7.2×10^{14} Hz.

13. 3.05×10^{-27} m.

15. Copper and iron.

17. 0.55 eV.

19. 2.66 eV.

21. 3.56 eV.

23. (*a*) 1.66 eV;
(*b*) 3.03 eV.

25. (*a*) 1.66 eV;
(*b*) 3.03 eV.

27. 0.004, or 0.4%.

29. (*a*) 2.43 pm;
(*b*) 1.32 fm.

31. (*a*) 8.8×10^{-6};
(*b*) 0.049.

33. (*a*) 229 eV;
(*b*) 0.165 nm.

35. 1.65 MeV.

37. 212 MeV, 5.86 fm.

39. 1.772 MeV, 702 fm.

41. 4.7 pm.

43. 4.0 pm.

45. 1840.

47. (*a*) 1.1×10^{-24} kg·m/s;
(*b*) 1.2×10^6 m/s;
(*c*) 4.2 V.

51. 590 m/s.

53. 20.9 pm.

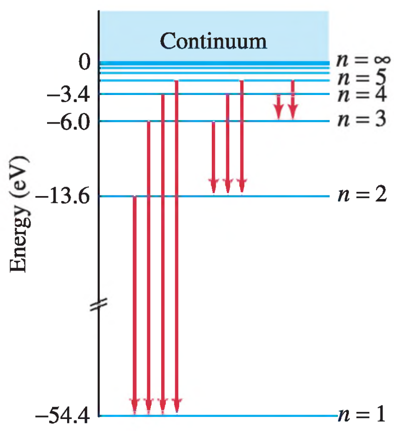
55. 1.51 eV

57. 122 eV.

59. 91.4 nm.

61. 37.0 nm.

63.



65. -27.2 eV, 13.6 eV.

67. Yes: $v = 7 \times 10^{-3}\,c$;
$1/\gamma = 0.99997$.

69. 97.23 nm, 102.6 nm, 121.5 nm, 486.2 nm, 656.3 nm, 1875 nm.

71. Yes.

73. 3.28×10^{15} Hz.

75. 5.3×10^{26} photons/s.

77. 6.2×10^{18} photons/s.

79. 0.244 MeV for both.

81. 28 fm.

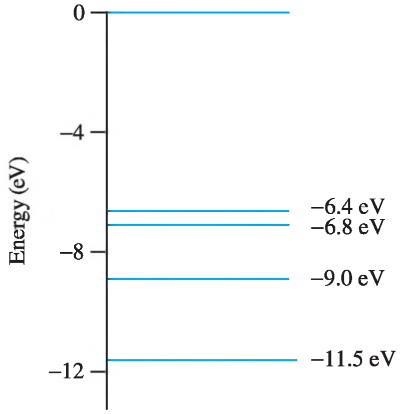
83. 4.4×10^{-40}, yes.

85. 2.25 V.

87. 9.0 N.

89. 1.2 nm.

91. (*a*)



(*b*) Ground state, 0.4 eV, 2.2 eV, 2.5 eV, 2.6 eV, 4.7 eV, 5.1 eV.

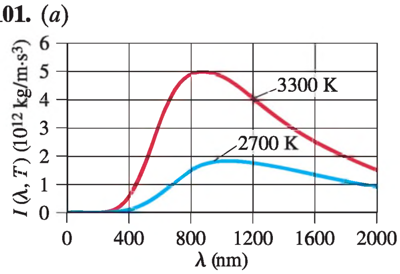
93. (*a*) $E_n = -\dfrac{2.84 \times 10^{165}\ \mathrm{J}}{n^2}$,
$r_n = n^2(5.17 \times 10^{-129}\ \mathrm{m})$;
(*b*) no, because $n \approx 10^{68}$ so $\Delta n = 1$ is negligible compared to n.

95. 1.0×10^{-8} N.

97. (*a*) $\sqrt{\dfrac{Gh}{c^5}}$; (*b*) 1.34×10^{-43} s;
(*c*) $\sqrt{\dfrac{Gh}{c^3}}$; (*d*) 4.05×10^{-35} m.

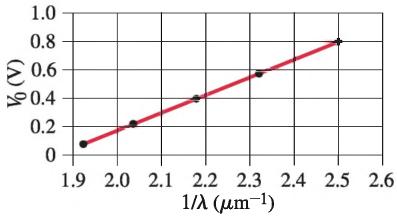
99. (*a*) 6.0×10^{-3} m/s;
(*b*) 1.2×10^{-7} K.

101. (*a*)



(*b*) 4.8 times more intense.

103. (*a*) $\dfrac{hc}{e}, -\dfrac{W_0}{e}$;
(*b*)



(*c*) 1.2×10^{-6} V·m, -2.31 V;
(*d*) 2.31 eV;
(*e*) 6.63×10^{-34} J·s.

CHAPTER 38

1. 2.8×10^{-7} m.

3. 5.3×10^{-11} m.

5. 4500 m/s.

7. 1.0×10^{-14}.

9. $\Delta x_{\mathrm{electron}} \geq 1.4 \times 10^{-3}$ m,
$\Delta x_{\mathrm{baseball}} \geq 9.3 \times 10^{-33}$ m,
$\dfrac{\Delta x_{\mathrm{electron}}}{\Delta x_{\mathrm{baseball}}} = 1.5 \times 10^{29}$.

11. 1.3×10^{-54} kg.

13. (*a*) 10^{-7} eV;
(*b*) $1/10^8$;
(*c*) 100 nm, 10^{-6} nm.

19. (*a*) $A \sin[(2.6 \times 10^9\ \mathrm{m}^{-1})x] + B \cos[(2.6 \times 10^9\ \mathrm{m}^{-1})x]$;
(*b*) $A \sin[(4.7 \times 10^{12}\ \mathrm{m}^{-1})x] + B \cos[(4.7 \times 10^{12}\ \mathrm{m}^{-1})x]$.

21. 1.8×10^6 m/s.

23. (*a*) 46 nm;
(*b*) 0.20 nm.

25. $\Delta p\, \Delta x \approx h$, which is consistent with the uncertainty principle.

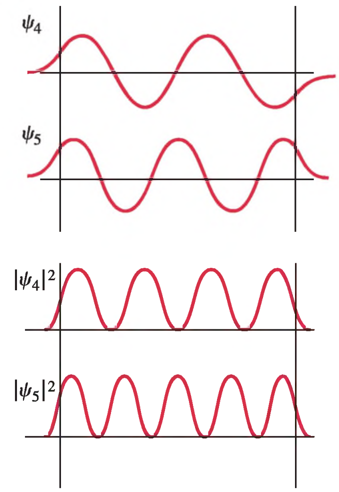
27. $n = 1$: 0.094 eV, $(1.0\ \mathrm{nm}^{-1/2}) \sin[(1.6\ \mathrm{nm}^{-1})x]$;
$n = 2$: 0.38 eV, $(1.0\ \mathrm{nm}^{-1/2}) \sin[(3.1\ \mathrm{nm}^{-1})x]$;
$n = 3$: 0.85 eV, $(1.0\ \mathrm{nm}^{-1/2}) \sin[(4.7\ \mathrm{nm}^{-1})x]$;
$n = 4$: 1.5 eV, $(1.0\ \mathrm{nm}^{-1/2}) \sin[(6.3\ \mathrm{nm}^{-1})x]$.

29. (*a*) 940 MeV;
(*b*) 0.51 MeV;
(*c*) 0.51 MeV.

31. (*a*) 4.0×10^{-19} eV;
(*b*) 2×10^8;
(*c*) 1.4×10^{-10} eV.

33. n odd:
$\psi = [(-1)^{(n-1)/2}]\sqrt{\dfrac{2}{\ell}} \cos\left(\dfrac{n\pi x}{\ell}\right)$,
$E_n = \dfrac{n^2h^2}{8m\ell^2}$;
n even:
$\psi = [(-1)^{n/2}]\sqrt{\dfrac{2}{\ell}} \sin\left(\dfrac{n\pi x}{\ell}\right)$,
$E_n = \dfrac{n^2h^2}{8m\ell^2}$.

35.



37. 0.020 nm.

39. 17 eV.

41. (*a*) 6.1%;
(*b*) 93.9%.

43. (*a*) 12% decrease;
(*b*) 6.2% decrease.

45. (*a*) 32 MeV;
(*b*) 57 fm;
(*c*) 1.4×10^7 m/s, 8.6×10^{20} Hz, 7×10^9 yr.

47. 14 MeV.

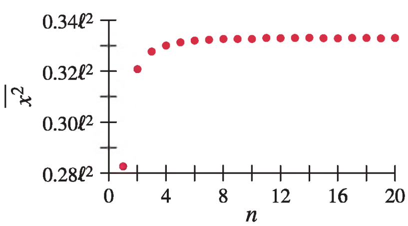
49. 25 nm.

51. $\Delta x = r_1$ (the Bohr radius).

53. 0.23 MeV, 3.3×10^6 m/s.

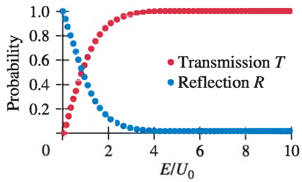
55. 27% decrease.

57.



59. (*a*) $\Delta\phi > 0$ so $\phi \neq 0$ exactly;
(*b*) 4 s.

61. (*a*)



(*b*) 10%: $E/U_0 = 0.146$;
20%: $E/U_0 = 0.294$;
50%: $E/U_0 = 0.787$;
80%: $E/U_0 = 1.56$.

CHAPTER 39

1. 0, 1, 2, 3, 4, 5, 6.

3. 18 states, $(3, 0, 0, -\frac{1}{2})$, $(3, 0, 0, +\frac{1}{2})$, $(3, 1, -1, -\frac{1}{2})$, $(3, 1, -1, +\frac{1}{2})$, $(3, 1, 0, -\frac{1}{2})$, $(3, 1, 0, +\frac{1}{2})$, $(3, 1, 1, -\frac{1}{2})$, $(3, 1, 1, +\frac{1}{2})$, $(3, 2, -2, -\frac{1}{2})$, $(3, 2, -2, +\frac{1}{2})$, $(3, 2, -1, -\frac{1}{2})$, $(3, 2, -1, +\frac{1}{2})$, $(3, 2, 0, -\frac{1}{2})$, $(3, 2, 0, +\frac{1}{2})$, $(3, 2, 1, -\frac{1}{2})$, $(3, 2, 1, +\frac{1}{2})$, $(3, 2, 2, -\frac{1}{2})$, $(3, 2, 2, +\frac{1}{2})$.

5. $n \geq 6$; $m_\ell = -5, -4, -3, -2, -1, 0, 1, 2, 3, 4, 5$; $m_s = -\frac{1}{2}, +\frac{1}{2}$.

7. (*a*) 7;
(*b*) -0.278 eV;
(*c*) 4.72×10^{-34} J·s, 4;
(*d*) $-4, -3, -2, -1, 0, 1, 2, 3, 4$.

11. $n \geq 7$, $\ell = 6$, $m_\ell = 2$.

13. (*a*) $\dfrac{1}{\sqrt{\pi r_0^3}} e^{-1.5}$;
(*b*) $\dfrac{1}{\pi r_0^3} e^{-3}$;
(*c*) $\dfrac{4}{r_0} e^{-3}$.

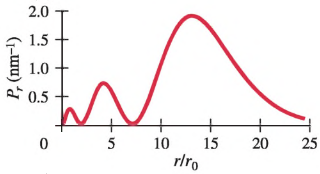
15. 1.85.

17. (*a*) $1.3r_0$;
(*b*) $2.7r_0$;
(*c*) $4.2r_0$.

21. $\dfrac{r^4}{24 r_0^5} e^{-r/r_0}$.

23. 1.1%.

27. (*a*) $\dfrac{4r^2}{27r_0^3}\left(1 - \dfrac{2r}{3r_0} + \dfrac{2r^2}{27r_0^2}\right) e^{-2r/3r_0}$;
(*b*)



(*c*) $13.1r_0$.

29. (*a*) $(1, 0, 0, -\frac{1}{2})$, $(1, 0, 0, +\frac{1}{2})$, $(2, 0, 0, -\frac{1}{2})$, $(2, 0, 0, +\frac{1}{2})$, $(2, 1, -1, -\frac{1}{2})$, $(2, 1, -1, +\frac{1}{2})$;
(*b*) $(1, 0, 0, -\frac{1}{2})$, $(1, 0, 0, +\frac{1}{2})$, $(2, 0, 0, -\frac{1}{2})$, $(2, 0, 0, +\frac{1}{2})$, $(2, 1, -1, -\frac{1}{2})$, $(2, 1, -1, +\frac{1}{2})$, $(2, 1, 0, -\frac{1}{2})$, $(2, 1, 0, +\frac{1}{2})$, $(2, 1, 1, -\frac{1}{2})$, $(2, 1, 1, +\frac{1}{2})$, $(3, 0, 0, -\frac{1}{2})$, $(3, 0, 0, +\frac{1}{2})$, $(3, 1, -1, -\frac{1}{2})$.

31. $n = 3$, $\ell = 2$.

33. (*a*) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$;
(*b*) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^1$;
(*c*) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10}$-$4f^{14} 5s^2 5p^6 5d^{10} 6s^2 6p^6 5f^3 6d^1 7s^2$.

35. 5.75×10^{-13} m, 115 keV.

39. 0.0383 nm, 1 nm.

41. 0.194 nm.

43. Chromium.

47. 2.9×10^{-4} eV.

49. (*a*) 0.38 mm; (*b*) 0.19 mm.

51. (*a*) $\frac{1}{2}, \frac{3}{2}$; (*b*) $\frac{5}{2}, \frac{7}{2}$; (*c*) $\frac{3}{2}, \frac{5}{2}$;
(*d*) 4*p*: $\frac{\sqrt{3}}{2}\hbar, \frac{\sqrt{15}}{2}\hbar$; 4*f*: $\frac{\sqrt{35}}{2}\hbar, \frac{\sqrt{63}}{2}\hbar$;
3*d*: $\frac{\sqrt{15}}{2}\hbar, \frac{\sqrt{35}}{2}\hbar$.

53. (*a*) 0.4 T;
(*b*) 0.5 T.

55. 4.7×10^{-4} rad; (*a*) 180 m;
(*b*) 1.8×10^5 m.

57. 634 nm.

59. 3.7×10^4 K.

61. (*a*) 1.56;
(*b*) 1.36×10^{-10} m.

63. (*a*) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^2$;
(*b*) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^4$;
(*c*) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^1 5s^2$.

65. (*a*) 2.5×10^{74};
(*b*) 5.1×10^{74}.

67. $5.24r_0$.

69. (*a*) 45°, 90°, 135°;
(*b*) 35.3°, 65.9°, 90°, 114.1°, 144.7°;
(*c*) 30°, 54.7°, 73.2°, 90°, 106.8°, 125.3°, 150°;
(*d*) 5.71°, 0.0573°, yes.

71. (*b*) $\overline{K} = -\frac{1}{2}\overline{U}$.

73. (*a*) Forbidden; (*b*) allowed;
(*c*) forbidden; (*d*) forbidden;
(*e*) allowed.

75. 4, beryllium.

77. (*a*) 3×10^{-171}, 1×10^{-202};
(*b*) 1×10^{-8}, 6×10^{-10};
(*c*) 7×10^{15}, 4×10^{14};
(*d*) 4×10^{22} photons/s, 7×10^{23} photons/s.

CHAPTER 40

1. 5.1 eV.

3. 4.7 eV.

5. 1.28 eV.

9. (*a*) 18.59 u;
(*b*) 8.00 u;
(*c*) 0.9801 u.

11. 1.10×10^{-10} m.

13. (*a*) 1.5×10^{-2} eV, 0.082 mm;
(*b*) 3.0×10^{-2} eV, 0.041 mm;
(*c*) 4.6×10^{-2} eV, 0.027 mm.

15. (*a*) 6.86 u;
(*b*) 1850 N/m, $k_{CO}/k_{H_2} = 3.4$.

17. 2.36×10^{-10} m.

19. $m_1 x_1 = m_2 x_2$.

21. 0.2826 nm.

23. 0.34 nm.

25. (*b*) -6.9 eV;
(*c*) -11 eV;
(*d*) -2.8%.

27. 9.0×10^{20}.

29. (*a*) 6.96 eV;
(*b*) 6.89 eV.

31. 1.6%.

33. 3.2 eV, 1.1×10^6 m/s.

39. (*a*) $\dfrac{h^2 N^2}{32 m\ell^2}$;
(*b*) $\dfrac{h^2 (N+1)}{8 m\ell^2}$;
(*c*) $\dfrac{4}{N}$.

43. 1.09 μm.

45. (*a*) $2N$;
(*b*) $6N$;
(*c*) $6N$;
(*d*) $2N(2\ell + 1)$.

47. 4×10^6.

49. 1.8 eV.

51. 8.6 mA.

53. (*a*) 1.7 mA; (*b*) 3.4 mA.

55. (*a*) 35 mA; (*b*) 70 mA.

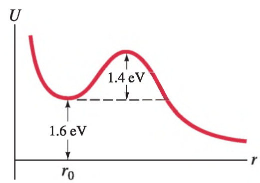
57. 3700 Ω.

59. 0.21 mA.

61. $I_B + I_C = I_E$.

63. (*a*) 3.1×10^4 K;
(*b*) 930 K.

65.



67. (*a*) 0.9801 u;
(*b*) 482 N/m, $k_{HCl}/k_{H_2} = 0.88$.

71. Yes, 1.09 μm.

73. 1100 J/mol.

75. 5.50 eV.

77. 3×10^{25}.

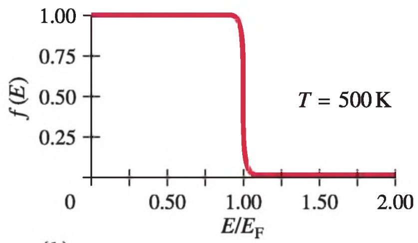
79. 6.47×10^{-4} eV.

81. 1.1 eV.

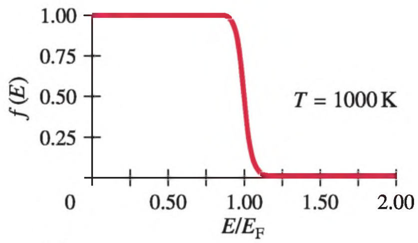
83. (*a*) 0.094 eV; (*b*) 0.63 nm.

85. (*a*) 150 V $\leq V \leq$ 486 V;
(*b*) 3.16 k$\Omega \leq R_{load} < \infty$.

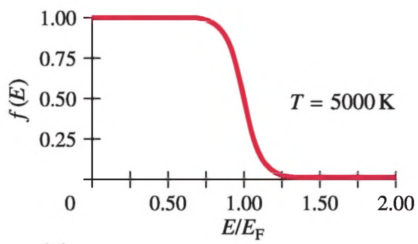
87. (*a*)



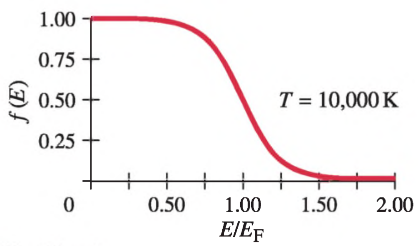
(*b*)



(*c*)



(*d*)



89. 32 mA.

CHAPTER 41

1. 0.149 u.

3. 0.85%.

5. 3727 MeV/c^2.

7. (*b*) 180 m; (*c*) 2.58×10^{-10} m.

9. 30 MeV.

11. 6×10^{26} nucleons, no, mass of all nucleons is approximately the same.

13. 550 MeV.

15. 7.94 MeV.

17. ${}^{23}_{11}$Na: 8.11 MeV/nucleon;
${}^{24}_{11}$Na: 8.06 MeV/nucleon.

19. (*b*) Yes, binding energy is positive.

21. 0.782 MeV.

23. 2.6×10^{-12} m.

25. (*a*) β^-;
(*b*) ${}^{24}_{11}\text{Na} \rightarrow {}^{24}_{12}\text{Mg} + \beta^- + \bar{\nu}$, 5.52 MeV.

27. (*a*) ${}^{234}_{90}$Th; (*b*) 234.04367 u.

29. 0.078 MeV.

31. (*a*) ${}^{32}_{16}$S;
(*b*) 31.97207 u.

33. 0.862 MeV.

35. 0.9612 MeV, 0.9612 MeV, 0, 0.

37. 5.31 MeV.

39. (*a*) $1.5 \times 10^{-10}\ \text{yr}^{-1}$;
(*b*) 6.0 h.

41. 0.16.

43. 0.015625.

45. 6.9×10^{19} nuclei.

47. (*a*) 3.59×10^{12} decays/s;
(*b*) 3.58×10^{12} decays/s;
(*c*) 9.51×10^{7} decays/s.

49. 0.76 g.

51. 2.30×10^{-11} g.

53. 4.3 min.

55. 2.98×10^{-2} g.

57. 35.4 d.

59. ${}^{228}_{88}$Ra, ${}^{228}_{89}$Ac, ${}^{228}_{90}$Th, ${}^{224}_{88}$Ra, ${}^{220}_{86}$Rn;
${}^{231}_{90}$Th, ${}^{231}_{91}$Pa, ${}^{227}_{89}$Ac, ${}^{227}_{90}$Th, ${}^{223}_{88}$Ra.

61. $N_D = N_0(1 - e^{-\lambda t})$.

63. 2.3×10^{4} yr.

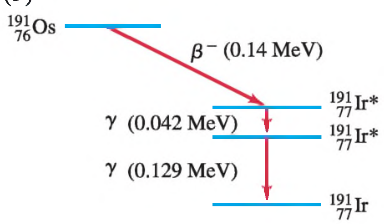
65. 41 yr.

69. $6.64T_{1/2}$.

71. (*b*) 98.2%.

73. 1 MeV.

75. (*a*) ${}^{191}_{77}$Ir;
(*b*)



(*c*) The higher excited state.

77. 550 MeV, 2.5×10^{12} J.

79. 2.243 MeV.

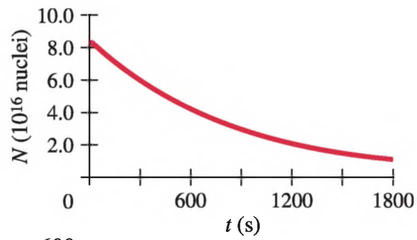
81. (*a*) 2.4×10^{5} yr;
(*b*) no significant change, maximum age is on the order of 10^5 yr.

83. 5.49×10^{-4}.

85. (*a*) 1.6%;
(*b*) 0.66%.

87. 1.3×10^{21} yr.

89. 8.33×10^{16} nuclei,



600 s.

CHAPTER 42

1. ${}^{28}_{13}$Al, β^-, ${}^{28}_{14}$Si.

3. Yes, because $Q = 4.807$ MeV.

5. 5.701 MeV released.

7. (*a*) Yes;
(*b*) 20.8 MeV.

9. 4.730 MeV.

11. $\text{n} + {}^{14}_{7}\text{N} \rightarrow {}^{14}_{6}\text{C} + \text{p}$, 0.626 MeV.

13. (*a*) The He has picked up a neutron from the C;
(*b*) ${}^{11}_{6}$C;
(*c*) 1.856 MeV, exothermic.

15. 18.000938 u.

17. 0.671 MeV.

19. $\pi(R_1 + R_2)^2$.

21. 10 cm.

23. 173.3 MeV.

25. 6×10^{18} fissions/s.

27. 0.34 g.

29. 5×10^{-5} kg.

31. 25 collisions.

33. 0.11.

35. 3000 eV.

39. (*a*) 5.98×10^{23} MeV/g,
4.83×10^{23} MeV/g,
2.10×10^{24} MeV/g;
(*b*) 5.13×10^{23} MeV/g; Eq. 42–9a gives about 17% more energy per gram, 42–9b gives about 6% less, and 42–9c gives about 4× more.

41. 0.35 g.

43. 6100 kg/h.

45. 2.46×10^{9} J, 50 times more than gasoline.

47. (*b*) 26.73 MeV;
(*c*) 1.943 MeV, 2.218 MeV, 7.551 MeV, 7.296 MeV, 2.752 MeV, 4.966 MeV;
(*d*) larger Coulomb repulsion to overcome.

49. 4.0 Gy.

51. 220 rad.

53. 280 counts/s.

55. 1.6 days.

57. (*a*) ${}^{131}_{53}\text{I} \rightarrow {}^{131}_{54}\text{Xe} + \beta^- + \bar{\nu}$;
(*b*) 31 d;
(*c*) 8×10^{-12} kg.

59. 8.3×10^{-7} Gy/d.

61. (*a*) ${}^{218}_{84}\text{Po}$;
(*b*) radioactive, alpha and beta decay, 3.1 min;
(*c*) chemically reactive;
(*d*) 9.1×10^6 Bq, 4.0×10^4 Bq.

63. 7.041 m, radio wave.

65. (*a*) ${}^{12}_{6}\text{C}$;
(*b*) 5.701 MeV.

67. 1.0043 : 1.

69. 6.5×10^{-2} rem/yr.

71. 4.4 m.

73. (*a*) 920 kg;
(*b*) 3×10^6 Ci.

75. (*a*) 3.7×10^{26} W;
(*b*) 3.5×10^{38} protons/s;
(*c*) 1.1×10^{11} yr.

77. 8×10^{12} J.

79. (*a*) 3700 decays/s;
(*b*) 4.8×10^{-4} Sv/yr, yes (13% of the background rate).

81. 7.274 MeV.

83. 79 yr.

85. 2 mCi.

CHAPTER 43

1. 5.59 GeV.

3. 2.0 T.

5. 13 MHz.

7. Alpha particles, $\lambda_\alpha \approx d_{\text{nucleon}}$, $\lambda_p \approx 2d_{\text{nucleon}}$.

9. 5.5 T.

11. 1.8×10^{-19} m.

15. 33.9 MeV.

17. 1879.2 MeV.

19. 67.5 MeV.

21. (*a*) 178.5 MeV;
(*b*) 128.6 MeV.

23. (*a*) Charge, strangeness;
(*b*) energy;
(*c*) baryon number, strangeness, spin.

25. (*b*) The photon exists for such a short time that the uncertainty principle allows energy to not be conserved during the exchange.

27. 69.3 MeV.

29. $K_{\Lambda^0} = 8.6$ MeV, $K_{\pi^-} = 57.4$ MeV.

31. 52.3 MeV.

33. 9 keV.

35. 7.5×10^{-21} s.

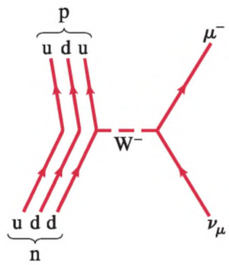
37. (*a*) 700 eV;
(*b*) 70 MeV.

39. (*a*) uss;
(*b*) dss.

41. (*a*) Proton;
(*b*) $\overline{\Sigma^-}$;
(*c*) K^-;
(*d*) π^-;
(*e*) $D_{\bar{S}}^-$.

43. $c\bar{s}$.

45.



47. (*a*) 0.38 A;
(*b*) 1.0×10^2 m/s.

49. 2.1×10^9 m, 7.1 s.

51. (*a*) Possible, strong interaction;
(*b*) possible, strong interaction;
(*c*) possible, strong interaction;
(*d*) not possible, charge is not conserved;
(*e*) possible, weak interaction.

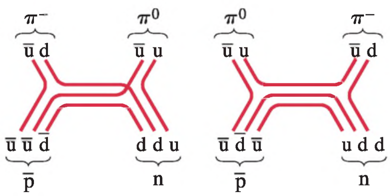
55. 64.

57. (*b*) 10^{29} K.

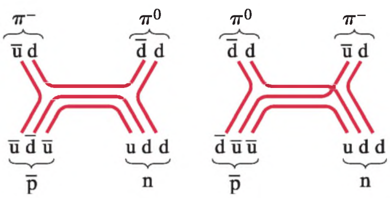
59. 798.7 MeV, 798.7 MeV.

61. 16 GeV, 7.8×10^{-17} m.

63. Some possibilities:

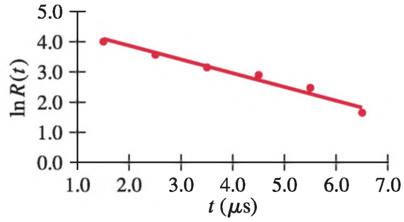


or [see Example 43–9b]



65. $v/c = 1 - (9.0 \times 10^9)$.

67.



2.3 μs, 3.1%.

CHAPTER 44

1. 3.1 ly.

3. 0.050″, 20 pc.

5. Less than, a factor of 2.

7. 0.037.

9. 2×10^{-3} kg/m^3.

11. -0.092 MeV, 7.366 MeV.

13. 1.83×10^9 kg/m^3, 3.33×10^5 times.

15. $D_1/D_2 = 0.15$.

19. 540°.

21. 3.1×10^{-16} m.

23. 200 Mly.

25. (*a*) 656 nm;
(*b*) 659 nm.

27. 0.0589 *c*.

31. 1.1×10^{-3} m.

33. 6 nucleons/m^3.

35. (*a*) 10^{-5} s;
(*b*) 10^{-7} s;
(*c*) 10^{-4} s.

37. (*a*) 6380 km, 20 km, 8.85 km;
(*b*) 700 : 2 : 1.

39. 8×10^9.

41. A: Temperature increases, luminosity stays the same, and size decreases;
B: Temperature stays the same, and luminosity and size decrease;
C: Temperature decreases, and luminosity and size increase.

43. 2×10^{28} N.

45. $d_{480}/d_{660} = 1.7$.

47. 2×10^{16} K, hadron era.

49. (*a*) 13.93 MeV;
(*b*) 4.7 MeV;
(*c*) 5.5×10^{10} K.

51. $R_{\text{min}} = GM/c^2$.

53. $\approx 10^{-15}$ s.

55. Venus, $b_{\text{Venus}}/b_{\text{Sirius}} = 16$.

57. $\dfrac{h^2}{4m_n^{8/3}\,GM^{1/3}}\left(\dfrac{9}{4\pi^2}\right)^{2/3}$.

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Note: The abbreviation *defn* means the page cited gives the definition of the term; *fn* means the reference is in a footnote; *pr* means it is found in a Problem or Question; *ff* means "also the following pages."

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