Part I

Revised Appendix D - Answers to Odd-Numbered Problems

R–2.1 The ground wire provides an alternate current path that carries more current.
R–2.3 (a) 0 A, 0 W. (b) 2 A, rightward, 20 W.
(c) 1 A, rightward, 5 W. (d) 1 A, leftward, 5 W.
(e) 2 A, leftward, 20 W.
R–2.5 These precautions prevent current from flowing through the torso of your body.
R–3.1 Computers, VCRs, microwave ovens, etc.
R–4.1 (a) 20 Ω. (b) 0.2 W. (c) 960 J. (d) 480 C.
R–5.1 (a) No. (b) The monitor can't work without power.
R–6.1 Her hair becomes charged and the strands repel each other.
R–6.3 The source provides a voltage, not a current.
R–6.5 You develop a charge by rubbing against the seat as you leave the car. Holding onto the outside surface as you exit allows the charge to leave gradually. Touching the outside surface only after you are outside forces the charge to leave all at once, shocking you.
R–8.1 (a) 3. (b) 3. (c) 3. (d) In the first case there is a collective effect; in the other cases there is an individual effect.
R–8.3 For an insulator a minus indicates an excess electron and a plus a deficit of an electron exactly at that spot. For a conductor they represent an excess or deficit in the average density of the conduction electrons in one mole.
R–8.5 (a) Assume that the extra charge carrier is a positive ion. The bulk of the liquid is neutral and all excess charge is due to ions distributed over its surface. (b) Assume that the extra charge carrier is an electron. The bulk is neutral and all excess charge, due to electrons, is distributed over its the surface.
R–8.7 (a) Yes. (b) In pure water electric current is entirely due to H^+ and OH^- ion movement. In salt water the current is dominated by the movement of Na^+ and Cl^- ions. In metal wire the current is due to the movement of electrons. In all cases a small average velocity is superimposed on the random motions of charge-carriers.
R–9.1 Only (d) would receive full credit.
R–9.3 "Show that" problem.
R–9.5 $(-2, 1, 0)$ and a 180° rotation about the y-axis
R–10.1 (a) "Show that" problem. (b) Use $\vec{a} = \hat{\imath}$, $\vec{b} = \hat{\imath}$, and $\vec{c} = \hat{\jmath}$.
R–10.3 (a) "Show that" problem. (b) The left side equals -2; the right side equals 0; the two sides are unequal.
R–10.5 (a) "Show that" problem. (b) Show that problem. (c) Show that problem.
R–10.7 "Show that" problem.
R–10.9 (a) Counterclockwise rotation of 53.1°.
(b) $(-3.60, 5.20, -1)$. (c) $(-10.40, -2.20, 26)$.
(d) $(-10.40, -2.20, 26)$. (e) they are the same. (f) 5.385, 6.403, 28.1. (g) 145.45° or 214.55°. (h) Yes.
R–10.11 $(10, 5, -3)$ N-m.
R–10.13 $(4.8 \times 10^{-3}, 9.6 \times 10^{-3}, 0)$ N.
R–10.15 "Show that" problem.
R–10.17 "Show that" problem.
R–10.19 $(0, 0, -d/c)$, $(a/e, b/e, c/e)$, where $e = \sqrt{a^2 + b^2 + c^2}$.
R–10.21 (a). $\hat{n} \equiv (0.254, -0.381, 0.889)$.
(b) $\dfrac{d\Phi_E}{dA} \equiv \vec{E} \cdot \hat{n} = -23.0$ volt/m.
(c) $d\Phi_E = \dfrac{d\Phi_E}{dA} dA = -1.195 \times 10^{-5}$ volt/m.

1–2.1 See Fig.2.1 and the accompanying discussion of the amber effect.
1–2.3 They will repel if the positive ends are brought near each other but attract if the positive end of one is brought near the neutral end of the other.
1–3.1 The mechanical motion would be identical, but the induced charge would be opposite the previous induced charge.
1–3.3 Either end would be attracted to an electrically charged object due to electrostatic induction.
1–4.1 (a) In the 17th century, the most common way to charge an object was to rub it or to touch it to a previously charged object. Water and iron cannot be charged in this manner. (b) Put object on insulator, charge by induction and either grounding or sparking or contact.
1–4.3 Conductors: your body, a penny. Insulators: your clothing, plastic, your comb, a styrofoam cup
1–4.5 When the person stands on the ground he is subject to the full voltage difference between the

charge source and ground, which produces a large enough current to cause the shock.
1–4.7 Watson's view would predict identical shocks in the two cases. Franklin's view (the correct view) would predict a greater shock in the first case.
1–4.9 A is a conductor and B is an insulator.
1–5.1 (a) "A Penny Saved Is a Penny Earned" implies money conservation in a situation where there is a flow of resource, both in and out. (b) Decreasing their energy bill with thermal insulation has the same effect as increasing their revenue by the same amount.
1–5.3 After the first connection, A has 4.8 units and B has 3.2 units. After the second connection, A has 0.96 units and B has 0.64 units.
1–5.5 (a) The jar cannot lose charge to the ground and losing it through the air could take hours or days. (b) As long as the top wire remains charged it will attract charge to the bottom, and thus the Leyden Jar remains charged. (c) As long as the bottom wire remains charged it will attract charge to the top, and thus very little charge can be drawn off the top wire. (d) The bottom retains its charge, since it is insulated. Once the top wire is connected to ground, the bottom wire will attract charge to the top and the Leyden Jar would regain its strength.
1–6.1 If the tube were left in place, electrostatic induction would occur. Then the experiment would be less reproducible, because the electrostatic induction would depend on the placement of the tube.
1–6.3 Rapid discharge of a nearby source causes a rapid decrease of the electrostatically induced charge in the human body.
1–6.5 The induced charge on each leaf will be of the same sign and hence the leaves will repel.
1–6.7 (a) Rubbing the balloons on clothing charges them up by friction. They are attracted to the wall by electrostatic induction and fall as they gradually lose their charge. (b) No. (c) The moisture in the air will draw off charge. The more moisture, the faster the charge will be drawn off.
1–6.9 When the negatively charged rod is brought near the grounded sphere, negative charge driven by electrostatic induction flows away from the sphere, leaving the sphere positively charged. When the ground connection is removed, the sphere remains positively charged, but also subject to electrostatic induction from the rod. When the rod is removed, the positive charge on the sphere redistributes.
1–7.1 $+2e$.
1–7.3 (a) Allowed. (b) Prohibited. (c) Allowed.
1–7.5 Electrons are transferred from the cloth to the rod. Protons generally cannot be transferred.
1–7.7 (a) The styrofoam partially discharges, after a diffusion time T across the tube the oven bag discharges, and after $2T$ the styrofoam completes its discharge. (b) No. (c) The oven bag discharges, then after T the styrofoam discharges.
1–8.1 People come in integer values; you are either alive or you are dead. There is no such thing as people conservation, as established by the phenomena of birth and death.
1–8.3 6.25×10^{19} electrons.
1–8.5 3.125×10^{9}.
1–9.1 "Show that" problem. A has units of C/m^3.
1–9.3 (a) The charge per unit length for rods 1 and 2 are q_1/l_1 and q_2/l_2, respectively. (b) $(q_1+q_2)/(l_1+l_2)$. (c) $(q_1+q_2)/l_2$. (d) $(q_1+q_2)/2l_2$.
1–9.5 (a) C has units of C/m^3 and B has units of C/m^4. (b) $(C+Br)(4\pi r^2 dr)$.
(c) $(4\pi C)(a^3/3)+(4\pi B)(a^4/4)$. (d) $C+(3/4)Ba$.
1–9.7 (a) C has units of C/m^3 and B has units of C/m^5. (b) $(C+Bz^2)\pi a^2 dz$. (c) $\pi a^2(Cl+Bl^3/3)$.
(d) $C+Bl^2/3$.
1–9.9 Show that problem.
1–10.1 When the tapes are pulled apart they develop a charge. Your finger is neutral. By electrostatic induction each will be attracted to your finger.
1–10.3 Use a versorium. It will respond at a greater separation to the tape with more charge.
1–10.5 (a) See Fig.4.24. (b) Smaller. (c) The same.
1–11.1 Moist wool is a conductor, and more easily transfer electrons on contacting the (conducting) sphere. The wool and the sphere then would have charge of the same sign, and would thus repel.
1–11.3 Since silk can be "grounded" here, it is acting like a conductor in this context. (In other contexts, silk acts like an insulator; most likely silk has a very low conductivity, so that for short times it behaves like an insulator, and for long time it behaves like a conductor). (1) Unelectrified and insulated silk is attracted to (charged) amber by electrostatic induction, or polarization, as in Figure 1.1. (2)

Electrified and insulated silk will repel amber only if it has charge of the same type as amber; the silk must have been electrified by placing it in contact with amber or something electrified like amber. (3) If the silk is attracted to the amber only when the silk is grounded, then again the silk is subject to electrostatic induction, or polarization. Wheeler clearly missed the possibility that silk could have "resinous" electricity (opposite to that of amber).

1–11.5 (a) Approximating a conducting disk by a uniform charge density and a line charge around its perimeter puts greater charge on the perimeter, thus causing greater electrical effects there. (b) For a charged needle, approximate the charge density as a uniform line density and one point charge at each end. (c) With an extra charge at the ends, electrical effects would be greater at the ends, thus providing a qualitative explanation for the "power of points".

1–11.7 It suggests there is no electricity on the inner surface of the cup.

1–11.9 (a) The amber is charged and the crumbs are uncharged. (b) Electrical attraction: one piece is charged and the other is uncharged (the amber effect), or one piece is charged and the other is charged oppositely. Magnetic atraction: one piece of silver contains iron (giving it has a permanent magnetic moment), and the other contains iron (without a permanent magnetic moment, but a large magnetic polarizability), so the magnetic analog of the amber effect occurs. (c) A magnet can attract silver electrically if the magnet is charged and the silver is uncharged (the amber effect) or if the magnet is charged and the silver is charged with electricity of the opposite sign. A magnet can attract silver magnetically if the silver is not pure, but rather contains iron within it.

1–11.11 The third of Newton's laws of motion is that to every force on one object due to a second, there is an equal and opposite force on the second due to the first; this is consistent with Fabri's observation that not only does electrified amber attract other (unelectrified) objects, but other (unelectrified) objects attract electrified amber.

1–11.13 (1) Levitation could have been due to repulsion between like charges, the feather having been charged by contact the already-charged globe. (2) The charged feather would go to the edges of materials because that is where materials are most polarizable (by the "power of points"). (3) A linen thread attached to the charged globe would be charged like the globe (it also could be polarized, but other results indicated that linen, relative to silk, is a conductor), and thus could attract chaff at the other end by the amber effect. (4) the crackle and glow can be due to atmospheric ions or electrons being attracted to the globe, and the associated electrons recombining and providing light, in a manner similar to phosphorescence.

1–11.15 Dufay's suspended, electrified people were charged up, and would discharge when touching someone on ground, releasing energy in the form of a spark.

1–11.17 According to Le Roy, conical discharges are associated with positive points. Thus, in Gray's 1708 conical discharge we conclude that his finger was charged positively relative to the globe.

1–11.19 (a) "Show that" problem. (b) "Show that" problem.

2–2.1 (a) "Show that" problem. (b) It decreases by a factor of $1/\sqrt{2}$. Yes. (c) 4.07×10^{-7} C. (d) $m_1 \to m_1 + M/2$.

2–3.1 4.77×10^{-6} N, attractive

2–3.3 0.626 mC

2–3.5 "Show that" problem. The maximum force will have magnitude $kQ^2/4r^2$.

2–3.7 48.5 μC.

2–3.9 (a) 3.33×10^{-10} C. (b) 4.8×10^{-10} sC.

2–4.1 $\theta = 60^\circ$, $q_{max} = 2l\sqrt{\frac{mg\tan\theta}{k}}$, $q_{max} = 4.76 \times 10^{-7}$ C.

2–4.3 θ.

2–4.5 (a) $\frac{kqQ}{4R^2\sin^2(\theta/2)}$. (b) $\frac{kqQ\cos(\theta/2)}{4R^2\sin^2(\theta/2)}$.

2–5.1 (a) 0 N. (b) 28.4 m. (c) 3.59×10^{-6} C.

2–5.3 $F = 9.53$ N, $\theta = -19^\circ$.

2–5.5 "Show that" problem. $F_x = -1.102 \times 10^{-6}$ N, $F_y = -0.995 \times 10^{-6}$ N, $F = 1.484 \times 10^{-6}$ N, $\theta' = -137.9^\circ$.

2–6.1 Rotating the rod about its perpendicular bisector does not change the configuration so it should not change F_y, but this rotation should reverse F_y. We conclude $F_y = 0$. Yes.

2–7.1 (a) $F_x = \frac{kqQ}{a(a+l)}$, $F_y = F_z = 0$. (b) $F_x \to \frac{kqQ}{a^2}$.
2–7.3 The y component of the force due to an arbitrary infinitesimal charge dQ between y and $y + dy$ is exactly cancelled by an equal charge dQ between $-y$ and $-y - dy$. Thus $F_y = 0$.
2–7.5 $F_x = \frac{kqQ}{L}\left[\frac{1}{a} - \frac{1}{\sqrt{L^2+a^2}}\right]$, $F_y = \frac{kqQ}{a\sqrt{L^2+a^2}}$.
2–7.7 $F_x = F_z = 0$, $F_y = -\frac{2kqQ}{\pi a^2}$.
2–7.9 The force will point directly away from the center of the arc, at an angle of $\alpha/2$. The force will have magnitude $F = \frac{2kqQ}{\alpha a^2}\sin(\frac{\alpha}{2})$.

3–2.1 (a) $F_e = 2.003 \times 10^{-17}$ N.
(b) $F_g = 2.935 \times 10^{-25}$ N. The force of gravity is much smaller than the electrostatic force.
3–2.3 (a) 6.12×10^{11} N/C. (b) 1.76×10^{13} m/s^2.
3–2.5 (a) $\theta = \tan^{-1}\left(\frac{|Q|E}{mg}\right)$. (b) $T = mg\sec\theta$.
(c) $\theta = 4.75 \times 10^{-4}$ degrees, $T = 0.412$ N.
3–2.7 No.
3–2.9 (a) $E = 2500$ N/C. (b) $|Q| = 0.11$ nC.
3–2.11 Scalar fields: pressure, density, temperature. Vector fields: flow velocity.
3–2.13 (a) Gravity is always attractive, so the field due to m_2 will point toward m_2, pulling m_1 toward m_2. (b) $\vec{g} = -\Sigma_i \frac{Gm_i}{R_i^2}\hat{R}_i$.
3–3.1 (a) 85,000 N/C $\hat{y}$. (b) $-85{,}000$ N/C $\hat{y}$.
3–4.1 Drag-dominated.
3–4.3 (a) The advantage is that a ball of charge creates field lines inside. (b) The disadvantage is that there are too many arrowheads if you want to sketch the field quickly. (c) The grass seed method has two problems: the grass seeds can align with the field in either direction and the density of the grass seeds gives only a qualitative representation of magnitude.
3–5.1 (a) 175 N/C $\downarrow$. (b) 1100 N/C $\uparrow$.
(c) 425 N/C $\downarrow$.
3–5.3 (a) Up $\uparrow$. (b) $\frac{kQ}{a^2}(1+\frac{q}{Q})(1+2\cos\theta)\uparrow$.
3–5.5 (a) $E_x = -47.0$ N/C, $E_y = -36.1$ N/C. (b) This calculation was relatively simple. Doing the calculation from scratch would have involved 23 separate calculations and than the addition of 23 vectors, a very involved calculation.
3–5.7 (a) $\vec{E} = kQ\left[\frac{1}{(x+a)^2} + \frac{1}{(x-a)^2} - \frac{2}{x^2}\right]\hat{x}$.
(b) $\vec{E} \to \frac{6kQa^2}{x^4}\hat{x}$.
3–5.9 "Show that" problem.
3–6.1 (a) $Q = \lambda L$. (b) $\vec{E} = \frac{k\lambda L}{x(x-L)}\hat{\rightarrow}$.
(c) $\vec{E} = \frac{k\lambda(2x-L)}{x(L-x)}\hat{\rightarrow}$.
3–6.3 $\vec{E} = -\frac{kQ(3-\sqrt{5})}{2a^2\sqrt{10}}\hat{y}$.
3–6.5 (a) Down. (b) $\vec{E} = -\frac{2k\lambda}{a}\hat{y}$.
3–6.7 (a) 0. (b) $\vec{p} = \frac{\pi}{2}\alpha R^2\hat{x}$. (c) $\vec{E} = -\frac{k\pi\alpha}{2R}\hat{x}$.
3–6.9 $\vec{E} = -\frac{\pi}{2}k\sigma\left(1 - \cos(2\alpha)\right)\hat{z}$.
3–6.11 (a) $\vec{E} = \frac{4k\lambda y}{y^2+a^2}\hat{y}$. (b) $\vec{E} = -\frac{4k\lambda a}{y^2+a^2}\hat{x}$.
3–6.13 (a) Place q at $(14.7, 0, 0)$ m. (b) Place λ in the xy plane, parallel to the y-axis, and intersecting the x-axis at $x = -288$ m. (c) Impossible.
3–6.15 (a) 20 N/C downward. (b) The upper sheet has charge density 0.442 nC/m^2 and the lower sheet has charge density -0.0884 nC/m^2.
3–7.1 Along.
3–7.3 $\vec{E}$ is zero 2/3 of the way from 2λ to λ.
3–7.5 Within an insulator we can arrange the charge however we please, but within a conductor the like charges would repel each other toward the surface disrupting the uniform volume charge distribution.
3–8.1 (a) 3.6×10^{-25} J. (b) 90°, 1.8×10^{-25} N-m.
3–8.3 (a) 2.5×10^{-25} N-m. (b) 1.17×10^{-25} N-m.
(c) -2.207×10^{-25} J.
3–8.5 (a) $\vec{F} = q(\frac{2kp}{x^3})\hat{\rightarrow}$. (b) $\vec{F} = -q(\frac{2kp}{x^3})\hat{\rightarrow}$.
(c) $p = 7.11 \times 10^{-25}$ C-m.
3–9.1 (a) $\vec{F} = pA\hat{x}$. (b) 2.37×10^{-9} N $\hat{x}$.
(c) 2.37×10^{-9} N $\hat{x}$.
3–10.1 (a) -2.59×10^6 m/s. (b) 4.64×10^{-8} s.
3–10.3 (a) -728 N/C (b) 6.44×10^{-9} C/m^2.
(c) 4.3×10^6 m/s, 21.8°.
3–10.5 2.01×10^{-5} m.
3–10.7 (a) The velocity v does not depend on the radius r. (b) $T = 2\pi r\sqrt{\frac{m_e}{2ek\lambda}}$.

4–2.1 (a) The flux will have the opposite sign.
(b) -34 N-m^2/C. (c) $\Phi_E = -\frac{1}{\epsilon_0}Q_{enc} = -4\pi kQ_{enc}$.
4–2.3 -7.68×10^{-6} N-m^2/C.
4–2.5 $E\pi R^2$.
4–2.7 $2\pi kQ\left[1 - \dfrac{d}{\sqrt{R^2+d^2}}\right]$.
4–3.1 (a) 0. (b) 679 N-m^2/C. (c) 0.
4–3.3 (a) $4\pi kQ$. (b) $(2/3)\pi kQ$.

4–3.5 (a) $(0.8, 0.48, -0.36)$. (b) 8.06 N/C. (c) 5.64 N/C. (d) $\pm 45.6°$. (e) 1.128×10^{-3} N-m^2/C. (f) 9.97×10^{-15} C.
4–4.1 1.77 nC/m^2.
4–4.3 -3.76×10^{-9} C.
4–5.1 (a) -1.94×10^{-12} C. (b) 2.59×10^5 N/C.
4–5.3 (a) 1.30×10^{-10} C/m^2. (b) 2.66×10^9 N/C.
4–5.5 (a) $\rho = \frac{\lambda}{\pi(b^2-a^2)}$. (b) 0, $\frac{2k\lambda(r^2-a^2)}{(b^2-a^2)r}$, $\frac{2k\lambda}{r}$.
4–5.7 (a) $\lambda_1 = -0.722$ nC/m, $\lambda_2 = 0.856$ nC/m. (b) 20.1 N/C.
4–5.9 Take mass density ρ. (a) $\vec{g} = \frac{\vec{F}_{grav}}{M}$, $\Phi_{gr} \equiv \oint \vec{g} \cdot \hat{n} dA = -4\pi G M_{enc}$. (b) $\vec{g} = -\frac{G\rho r}{3}\hat{r}$. (c) $T = 2\pi\sqrt{\frac{3}{4\pi G\rho}}$. (d) 5070 s.
4–6.1 No.
4–6.3 (a) 25 V. (b) The dipole moment on the conductor will point away from the point charge. The point charge will be attracted to the conductor.
4–6.5 (a) The inner surface has $-Q$ and the outer surface has $+Q$. (b) The inner surface has $-Q$ and the outer surface has zero charge.
4–6.7 Connecting the slats makes them behave almost like a solid conductor, which can screen out an external field.
4–7.1 -0.212 nC/m^2.
4–7.3 "Explain in your own words" problem.
4–7.5 (a) Starting to the left and proceeding to the right, the electric fields are $10\pi k\sigma\hat{\rightarrow}$, $18\pi k\sigma\hat{\rightarrow}$, $2\pi k\sigma\hat{\rightarrow}$, $10\pi k\sigma\hat{\leftarrow}$. (b) Starting with the left side of #1, going rightward the charge densities are $-(5/2)\sigma$ and $(9/2)\sigma$, $-(9/2)\sigma$ and $(1/2)\sigma$, $-(1/2)\sigma$ and $-(5/2)\sigma$.
4–7.7 (a) -7.96 nC/m^2. (b) -4.0×10^{-11} C. (c) $\vec{E} = \vec{0}$. (d) $E_r = -400$ N/C (radially inward).
4–7.9 (a) 0, kQ/r^2, $-kQ/r^2$ (radial component of field). (b) $Q_a^{inner} = 0$, $Q_a^{outer} = Q$. (c) $Q_b^{inner} = -Q$, $Q_b^{outer} = -Q$.
4–7.11 (a) 0, $4k\lambda/r$, $-2k\lambda/r$ (radial component of field). (b) $\lambda_a^{inner} = 0$, $\lambda_a^{outer} = 2\lambda$. (c) $\lambda_b^{inner} = -2\lambda$, $\lambda_b^{outer} = -\lambda$.
4–8.1 (a) All of the charge resides on the cups outer surface. (b) -3 μC. (c) 2 μC. (d) -0.4 μC.
4–9.1 $2\pi\left(1 - \dfrac{s}{\sqrt{s^2 + d^2/4}}\right)$.
4–10.1 3×10^3 C/m^2.
4–11.1 (a) $E_x = 0$, $E_y = -\frac{4k\lambda b}{x^2+b^2}$. (b) $\sigma = -\frac{\lambda b}{\pi(x^2+b^2)}$.
4–11.3 (a) $\frac{kQ^2}{8\pi r^4}$. (b) $\left(\frac{1}{b} - \frac{1}{a}\right)\frac{kQ^2}{2}$.

5–2.1 94.7 N.
5–3.1 (a) 2×10^{-8} J. (b) -2×10^{-8} J. In the first case we raise the electrical potential energy; in the second case we lower the electrical potential energy.
5–3.3 -2 V/cm, -2.2 V/cm, -2.4 V/cm.
5–3.5 2.7484 V.
5–4.1 5.69×10^{-14} m.
5–4.3 (a) 35.3 V; the electron goes toward the higher potential at the end point. (b) 883 N/C, along $-\hat{y}$ (downward).
5–4.5 (a) 4.8×10^{-5} J. (b) 20000 V, the starting point is at a lower potential than the endpoint. (c) 2500 V/cm.
5–4.7 (a) The 6 V plate, 1.78×10^6 m/s. (b) 1.44×10^{-18} J. (c) -1.44×10^{-18} J. (d) 9 V.
5–4.9 0.058%.
5–4.11 (a) 8.90×10^4 V. (b) 0.629×10^{-7} C. (c) 3.93×10^{-5} C/m^2.
5–5.1 The field is largest near the two bottom corners and smallest on the line directly between the two side plates.
5–5.3 The field is largest at the upper right and at the lower left corners and smallest at the center.
5–5.5 (a) "Show that" problem. (b) $-Q$.
5–5.7 (a) Spheres centered at the charge. (b) Yes. (c) Yes. (d) No.
5–5.9 The field must be zero at the crossing point.
5–6.1 -2.0 V.
5–6.3 $(2kq^2/a)(2 + 1/\sqrt{2})$.
5–6.5 (a) 480 kV. (b) 1920 kV. (c) 0 J.
5–6.7 (a) Halfway between them. (b) Yes. Take $V_\infty = -\frac{4kq}{a}$.
5–6.9 5.56×10^{-10} C.
5–6.11 -442 nC/m^2.
5–6.13 12.71 V.
5–7.1 (a) 0. (b) Yes. (c) $-\frac{a}{2}x^2 - bx$.
5–7.3 (a) $-b^2$. (b) $+b^2$. (c) $2b^2$. (d) No.
5–8.1 (a) The potential at the center is the same as on the surface. (b) The center.
5–8.3 2.02 nC/m.

5–8.5 $-(1/3)Ar^3$, the equipotential surfaces are concentric cylinders centered on the z-axis.
5–8.7 $2\pi k\sigma(\sqrt{z^2+a^2}-z)$.
5–9.1 (a) $V(z)=\frac{kQ}{\sqrt{R^2+z^2}}$. (b) $E_z=\frac{kQz}{(R^2+z^2)^{3/2}}$. (c) No. (d) E_x and E_y will in general change under rearrangement.
5–9.3 Qualitatively similar to Figure 5.10(b), but skewed with 2λ dominating λ.
5–9.5 (a) 0. (b) $V(x)=ka\left[x\ln(\frac{x+l/2}{x-l/2})-l\right]$. (c) "Show that" problem. (d) "Show that" problem.
5–9.7 (a) $V=-kQ/b$. (b) $V(a)=-0.9kQ/b<0$. (c) For $q>0.1Q$.
5–10.1 (a) 24.85 V, 29.25 V. (b)$E_x\approx -22$ V/m. (c)$E_x=-22$ V/m.
5–10.3 (a) $V(x)=\frac{kQ}{l}\left[\ln|x+l|-\ln|x|\right]$. (b) $E_x=\frac{kQ}{l}\left[\frac{1}{x}-\frac{1}{x+l}\right]$. (c) $E_x=\frac{kQ}{l}\left[\frac{1}{x}-\frac{1}{x+l}\right]$.
5–10.5 "Show that problem".
5–10.7 (a) 3.28 V, 7.32 V. (b) -20.2 V/m. (c) $-20r^3$, -20 V/m.
5–10.9 $(-2y+8x)\hat{x}+(-2x+10y)\hat{y}$.
5–10.11 (a) $E_x=-\frac{4}{3}\frac{V_a}{d}(\frac{x}{d})^{1/3}$. (b) In units of V/m: 0, -0.84×10^4, -1.06×10^4, -1.2×10^4, -1.33×10^4. (c) $-\frac{V_a}{9\pi k}(\frac{1}{xd^2})^{2/3}$. Total charge per unit area from 0 to d is $E_x(d)/4\pi k=-1.18\times10^{-7}$ C/m^2.
5–11.1 (a) 6300 V, -1125 V. (b) 3.15×10^5 N/C outward, 2.81×10^4 N/C inward. (c) 3×10^{-9} C, 6×10^{-9} C, 1350 V, 1350 V. (d) 6.75×10^4 N/C outward, 3.375×10^4 N/C outward.
5–11.3 No.
5–11.5 $Q_{10R}=10Q_R$, $\sigma_{10R}=\frac{1}{10}\sigma_R$, $V_R=V_{10R}$, $E_{10R}=\frac{1}{10}E_R$.
5–11.7 (a) 9.09 V. (b) 100 V. (c) $100\left[1-(\frac{10}{11}^n\right]$ V.
5–12.1 1.114×10^6 N/C.
5–12.3 1.323×10^{10} N/C.

6–2.1 (a) 23.6 nF. (b) 2.12×10^2m.
6–2.3 Excess charge affects the structure of the solid sphere less than the structure of the shell.
6–2.5 4.50×10^{-8} m.
6–3.1 (a) 0.143 nF. (b) 1.25 nC. Larger sphere has larger charge.
6–3.3 (a) 5.79×10^{-11} F. (b) 1.736×10^{-12} C.
6–3.5 (a) By how close the plates can be kept without touching each other. (b) B how large the plates can be without making the capacitor unusable.
6–3.7 (a) 1250 V. (b) 0.0905 m^2. (c) 6.25×10^5 N/C. (d) 5.53×10^{-6} C/m^2.
6–3.9 This problem involves dielectrics, which are discussed in section 5. (a) 4.73 cm. (b) 0.775 nF. (c) 5.89×10^{-6} C.
6–3.11 (a) 19.24 pF. (b) 4.62 nC. (c) 28.8×10^3 N/C.
6–4.1 (a) Make three parallel arms, each with three 2 μF capacitors in series. (b) Put two units from part (a) in parallel.
6–4.3 $A/4\pi k(d_1+d_2)$. $C=Q/\Delta V$ has ΔV increase by the factor $(d_1+d_2)/d$.
6–4.5 (a) 3.428 μF, 14 μF. (b) 41.14 μC, 5.143 V, 6.857 V. (c) 12 V, 96 μC, 72 μC.
6–4.7 154 nF.
6–4.9 4 nF.
6–4.11 7 μF.
6–4.13 (a) 9 μC on each capacitor, $\Delta V_1'=3$ V, $\Delta V_2'=1.5$ V. (b) Yes. (c) No.
6–5.1 $d=2.67\times10^{-4}$ m, $A=242$ m^2.
6–5.3 3.91.
6–5.5 Above about one volt, electrolysis occurs at the plates and an ion current would flow. The capacitor would not be able to hold charge in this circumstance.
6–5.7 (a) 4.24 cm^2. (b) 120 pF, 3.5 kV.
6–5.9 "Show that" problem.
6–5.11 "Show that" problem.
6–5.13 (a) 2.22×10^{-17} F $=22.2$ aF. (b) 0.00721 V.
6–5.15 $C_{total}=\frac{1+\kappa}{2}\frac{ab}{k(a-b)}$.
6–6.1 (a) 6.67×10^{-8} F, 3.32×10^{-6} m. (b) 4.8×10^{-4} J. (c) 3.61×10^7 V/m. (d) 5761 J/m^3.
6–6.3 4×10^{-6} F.
6–6.5 (a) $Q_A=Q_B=160$ nC, $\Delta V_A=4$ V, $\Delta V_B=8$ V, $U_A=0.32$ μJ, $U_B=0.64$ μJ. (b) $\Delta V_A=\Delta V_B=5.333$ V, $Q_A=213.3$ nC, $Q_B=106.7$ nC, $U_A=0.568$ μJ, $U_B=0.284$ μJ. (c) 0.108 μJ. (d) $\Delta V_A=\Delta V_B=1.777$ V, $Q_A=71.1$ nC, $Q_B=35.6$ nC, $U_A=0.063$ μJ, $U_B=0.032$ μJ. (e) 0.757 μJ.
6–6.7 (a) $U=\dfrac{kQ^2}{2R}$. (b) $dU=-\dfrac{kQ^2}{2R^2}dR$, $P_{el}=\dfrac{E^2}{8\pi k}$.
6–6.9 In left branch of Figure 6.33, set $C_1=6$ μF, C_2=12 μF; in right branch set C_3=12 μF, $C_4=6$ μF. (a) $Q_1=Q_2=Q_3=Q_4=360\,\mu$C, $\Delta V_1=\Delta V_4=60$V, $\Delta V_2=\Delta V_3=30$V. (b) 32.4 mJ. (c) $Q_1=Q_4=240$ μC,

$Q_2 = Q_3 = 480\ \mu$C, $\Delta V_1 = \Delta V_2 = \Delta V_3 = \Delta V_4 = 40$ V.
(d) 28.8 mJ. (e) $-240\ \mu$C.
6–6.11 1.128×10^{12} J.
6–7.1 (a) $|\vec{E}_{diel}|/|\vec{E}_0| = 1/5$. (b) $V_{diel}/V_0 = 1/5$, $V_{diel} = 1.2$ V. (c) $Q_{diel}/Q_0 = 1$. (d) $C_{diel}/C_0 = 5$. (e) $U_{diel}/U_0 = 1/5$.
6–7.3 In the first case, U gives all of the energy. In the second case the capacitor energy must be included.
6–7.5 "Show that" problem.
6–7.7 Take $C = 12\ \mu$F initially.
(a) $U_{cap} = (1/2)CV^2$, $\Delta U_{batt} = -CV^2$,
$U_{heat} = (1/2)CV^2$; $U'_{cap} = CV^2$,
$W'_{hand} = (1/2)CV^2$; $U''_{cap} = (1/4)CV^2$,
$\Delta U''_{batt} = (1/2)CV^2$, $U''_{heat} = (1/4)CV^2$.
(b) $U'_{cap} = (1/4)CV^2$, $\Delta U'_{batt} = (1/2)CV^2$,
$W'_{hand} = (1/4)CV^2$.
6–8.1 (a) $0.2233\ \mu$C. (b) 191.4 V.
(c) $Q_a = 0.0106\ \mu$C, $Q_b = 0.2127\ \mu$C.
6–8.3 "Show that" problem.
$V_1 - V_2 = Q_1(p_{11} - p_{21}) + Q_2(p_{12} - p_{22}) + Q_3(p_{13} - p_{23})$. The term $Q_3(p_{13} - p_{23})$ is the effect of Q_3.
6–8.5 (a) Charge will distribute over the surface of a conductor, so that the material is is irrelevant and only the shape of the surface is important. Polarization of an insulator depends on the dielectric constant and thus the material. (b) The spheres induced dipole moment, due to polarization, is relatively small for $r \gg a$.
6–9.1 (a) Along the length of the molecule.
(b) α would need to change depending on the direction of $\vec{E}$. In most cases $\vec{E}$ and $\vec{p}$ would not even point in the same direction.
6–9.3 "Show that" problem.
6–10.1 "Show that" problem.
6–10.3 $\dfrac{k\lambda^2}{a}$.

7–1.1 (a) No current. (b) No current. (c) 5 mA.
7–2.1 10,800 C, 3.75×10^{19} electrons/s.
7–2.3 (a) 35,840 C. (b) 2.39×10^3 s, or about 66.4 hrs.
7–2.5 5.09×10^{-11} A.
7–2.7 (a) 133.3 A. (b) 4.76×10^5 A/m^2.
(c) $J_x = 4.47 \times 10^5$ A/m^2, $J_y = -1.629 \times 10^5$ A/m^2, $J_z = 0$. (d) 0.612 A.
7–2.9 No. Opposite directions.
7–2.11 $J_r = -995$ A/m^2.
7–3.1 (a) 4 Ω, 5 Ω. (b) Non-ohmic.
7–3.3 (a) 2 A. (b) −2 A.
7–3.5 (a) 3.13×10^{-5} Ω/m. (b) 0.125 Ω.
7–3.7 8.45 Ω-m.
7–3.9 0.086 mm.
7–3.11 (a) 7 mA. (b) 8.4 nV. (c) 20 nΩ.
7–3.13 (a) 240 Ω, 2.4 Ω. (b) Resistance of the bulb for home use.
7–3.15 (a) 5 kV. (b) 250 Ω.
7–3.17 (a) 3.6×10^4 J. (b) 0.833 A. (c) 6000 C.
7–3.19 (a) 28.8 Ω. (b) 28.8×10^6/m.
7–3.21 (a) 23.9 horsepower. (b) 1000%. (c) No. It cannot exceed 100%.
7–4.1 (a) 0.28 V/m rightward. (b) 0.532 V. Higher voltage on left, lower voltage on right.
7–4.3 (a) 2.79×10^{-8} Ω-m. (b) Aluminum.
7–4.5 (a) For $d = 0.04$ cm, $R_{Cu} = 0.01547$ Ω, $R_{steel} = 8.27 \times 10^{-6}$ Ω. (b) $\Delta V_{Cu} = 0.0309$ V, $\Delta V_{steel} = 16.54 \times 10^{-6}$ V.
7–4.7 Charge on the surface of the circuit, including the wire, makes an electric field that drives the current through the wire.
7–4.9 $\vec{E}$ points from regions of higher potential to regions of lower potential. The local form of Ohm's Law, $\vec{J} = \sigma\vec{E}$, says that $\vec{J}$ is in the same direction as $\vec{E}$. Therefore $\vec{J}$ points from regions of higher potential to regions of lower potential.
7–5.1 (a) 13 Ω. (b) $\Delta V_2 = 27$ V, $\Delta V_1 = 12$ V.
(c) 39 V. (d) 3 A. (e) 3 A.
7–5.3 (a) 6 Ω. (b) 3.5 A. (c) 35 V. (d) 3.5 A.
(e) 10 Ω.
7–5.5 (a) 1.5 Ω. (b) Both are 12 V. (c) 12 V.
(d) 11 A. (e) 1.09 Ω.
7–5.7 (a) $R_1 = 4$ Ω, $R_2 = 2.67$ Ω, $R_3 = 1.2$ Ω.
(b) $I_3 = 10$ A, $I_2 = 6$ A. (c) 16 V. (d) 28 V. (e) 2.8 Ω.
7–5.9 One has a parallel combination of two resistors in series with another parallel combination of two resistors. The other has a series combination of two resistors in parallel with another series combination of two resistors.
7–5.11 96 Ω, 144 Ω, 100 W.
7–5.13 (a) $I_A = 3$ A, $\mathcal{P}_A = 0.9$ W. (b) $I_A = I_B = 3$ A, $\mathcal{P}_A = \mathcal{P}_B = 0.9$ W. (c) $I_A = I_B = 1.5$ A,

$\mathcal{P}_A = \mathcal{P}_B = 0.225$ W. (d) $I_B = 2$ A, $\mathcal{P}_B = 0.4$ W, $I_A = I_C = 1$ A, $\mathcal{P}_A = \mathcal{P}_C = 0.1$ W.

7–5.15 (a) Resistors in parallel add as inverses and capacitors in parallel add directly. (b) Resistors in series add directly and capacitors in series add as inverses. (c) The formulas for total resistance and capacitance take the same form if $R \leftrightarrow \frac{1}{C}$ and $I \leftrightarrow Q$. Then $R = \frac{\Delta V}{I} \leftrightarrow \frac{1}{C} = \frac{\Delta V}{Q}$.

7–5.17 If a person stands on only one foot, then most current would pass through the foot touching the ground. If the person were to stand on both feet, there would be a path for current into the torso of the body where current is most dangerous.

7–6.1 (a) 1 mV. (b) 20000 Ω/V.

7–6.3 (a) 1.98 kΩ. (b) 0.5526 Ω. (c) 83.99 mV.

7–6.5 (a) 6.505 V. (b) 0.0769%.

7–7.1 The ion density is high near the plates, but low farther from the plates.

7–7.3 Starting a car four times a day consumes 0.667% of the chemical charge every day: about the same amount as the non-current-producing sulfation reaction does.

7–7.5 1662 s = 27.7 min.

7–8.1 1.36 V, 0.3 Ω.

7–8.3 (a) The filling, aluminum foil and saliva in the mouth. (b) The chemical energy of the voltaic cell (the foil and filling are the electrodes and the saliva is the electrolyte).

7–9.1 (a) 432,000 C. (b) 60 hr. (c) 24 hr.

7–9.3 (a) 2880 C = 0.8 A-hr. (b) 0.1 A. (c) 8 hr.

7–10.1 (a) Voltage gains of 0.6 V and 1.2 V across electrodes, voltage losses $Ir = 0.3$ V and $IR = 1.5$ V across resistances. (b) 0.6 hr. (c) 7776 J.

7–10.3 (a) 2 A. (b) Voltage loss of 0.3 V and voltage gain of 1.3 V across electrodes; and voltage losses $Ir = 0.4$ V and $IR = 0.6$ V across resistances.

7–11.1 (a) $\vec{F}_- = 1.59 \times 10^{-17}$ N $\hat{y}$,
$\vec{F}_+ = -1.61 \times 10^{-17}$ N $\hat{y}$.
(b) $\vec{v}_- = 3.18 \times 10^{-6}$ m/s $\hat{y}$,
$\vec{v}_+ = -3.22 \times 10^{-6}$ m/s $\hat{y}$.

7–11.3 (a) "Show that" problem.
(b) 11.2×10^6 s/m^2. (c) 9.54×10^{-7} m.

7–12.1 1.846×10^6 s.

7–12.3 $n = 3.84 \times 10^{13}/\text{m}^3$, $v_d = 9000$ m/s.

7–12.5 (a) $dI = \omega\Sigma r dr$. (b) $I = \omega\Sigma a^2/2$.

7–12.7 2.415 μC/m^2.

7–12.9 "Show that" problem.

7–13.1 Insulators, semiconductors, conductors.

7–13.3 $J = nev$. If the critical velocities v_c are not too different for semiconductors and metals, then the densities n mostly determine the J_cs.

8–3.1 (a) $\mathcal{E} = 24$ V; (b) $r = 0.024$ Ω;
(c) 105.0 A-hr.

8–3.3 (a) 30 days; (b) 22.2 days.

8–3.5 $\mathcal{E} = 10.72$ V; $r = 0.0245$ Ω.

8–3.7 (a) $I = 5.2$ A charging the battery;
(b) 1.352 W heating;
(c) 10.72 W charging; (d) 88.98% efficiency.

8–3.9 (a) $R = 0.75$ Ω. (b) $I = 3$ A.

8–4.1 (a) 40 hr. (b) 12 cents.

8–5.1 $\mathcal{E} = 0.6$ V, $r = 600$ Ω; (b) 4.02%; (c) 5.14%.

8–5.3 $I = 2.25$ A.

8–5.5 (a) $R = 3.264$ Ω; (b) $\Delta V = 261$ V;
(c) $M = 1.190 \times 10^4$ kg; (d) 78.6%.

8–5.7 (a) $R = 2.4$ Ω; (b) 99.59%; (c) 96%.

8–6.1 (a) $I_1 = I + I_2$; (b) $I_1 = -\dfrac{\Delta V}{R_1}$, $I_2 = \dfrac{\Delta V}{R_2}$, $I = \dfrac{\Delta V - \mathcal{E}}{r}$.

8–6.3 $R = 788$ Ω.

8–6.5 (a) $0.05 \le r/R \le 0.55$;
(b) $0.033 \le r/R \le 0.367$.

8–6.7 $R = 15$ Ω, $\mathcal{E} = 120$ V.

8–7.1 (a) $I = I_1 = -I_2 = 22.22$ A;
(b) $\Delta V_1 = -\Delta V_2 = 11.778$ V; (c) $\mathcal{P}_1 = 266.7$ W discharge, $\mathcal{P}_2 = -222.2$ W charge. (d) $I_1^2 r_1 = 4.9$ W, $I_2^2 r_2 = 39.5$ W. To our numerical accuracy, energy is conserved.

8–7.3 (a) Reverse the direction of positive I_2 relative to Figure 8.13(b). Then $I_1 = I + I_2$,
$I_1 = \frac{\mathcal{E}_1 - \Delta V}{r_1} = 600 - 100\Delta V$,
$I_2 = \frac{\mathcal{E}_2 + \Delta V}{r_2} = 500 - 50\Delta V$, $I = \frac{\Delta V}{R} = 100\Delta V$.
(b) $\Delta V = 0.4$ V. (c) $I = 40$ A, $I_1 = 560$ A, $I_2 = 520$ A. (d) $\mathcal{P}_R = 16$ W, $\mathcal{P}_{r_1} = 3136$ W, $\mathcal{P}_{r_2} = 5408$ W, $\mathcal{P}_1 = 3360$ W discharge, $\mathcal{P}_2 = 5200$ W discharge.

8–7.5 (a) B_1 off, B_2 off. (b) B_1 dim, B_2 dim.
(c) B_1 bright, B_2 off. (d) B_1 bright, B_2 off.

8–7.7 $R = (-1 + \sqrt{3})30$ Ω = 21.96 Ω.

8–7.9 $0.5R$.

8–7.11 $R = 7.2\ \Omega$.
8–7.13 "Show that" problem.
8–7.15 "Show that" problem.
8–7.17 (a) All positive currents and ΔV are as in Fig.8.39, so that $I_1 = \dfrac{\mathcal{E} - \Delta V}{r_1}$, etc. Also, $I = \Delta V/R$ and $I = I_1 + I_2 + I_3$. (b) $\Delta V = 4.963\ \Omega$.
(c) $I = 496.3$ A, $I_1 = 103.7$ A, $I_2 = 251.8$ A, $I_3 = 140.7$ A. (d) current is conserved.
8–8.1 (a) $Q_2 = 0$, $I_1 = 0$, $I = 6$ A. (b) $I_2 = 0$, $I = I_1 = 1.5$ A, $Q_2 = 40.5\ \mu$C.
8–8.3 (a) $Q = 0$, $I_1 = 4/3$ A, $I_2 = 2/3$ A, $I_3 = 2/3$ A, $I_4 = 4/3$ A. $I = I_1 - I_2 = 2/3$ A goes to the capacitor. (b) $I_1 = I_3 = 0.8$ A, $I_2 = I_4 = 1.0$ A, $I = 0$, $Q = 14.4\ \mu$C.
8–8.5 (a) $I_R = 0$. (b) $I_R = I_0$.
8–9.1 (a) $\tau_{RC} = 12$ s. (b) $I_0 = 0.84\ \mu$A, $I_\infty = 0$. (c) $Q_0 = 0$, $Q_\infty = 10.08\ \mu$C. (d) $U_{heat} = 15.88\ \mu$J. (e) $U_{heat} = 21.17\ \mu$J.
8–9.3 (a) "Show that" problem. (b) 96 μJ.
(c) "Show that" problem.
8–9.5 (a) $R = 5.09 \times 10^{15}\ \Omega$. (b) $\tau_{RC} = 2.04 \times 10^7$ s. (c) $C = 1.965 \times 10^{-13}$ F.
8–10.1 More turns through small angles require less surface charge but are more expensive to make. Two 45° might be adequate.
8–10.3 (a) $r/R \to \infty$. (b) Let $R_{eq}^{-1} = r^{-1} + R^{-1}$. Then $Q_{C_p} = (\mathcal{E}/R)(r + R)C_p[1 - e^{-t/R_{eq}C}]$, $I_R = Q_{C_p}/RC_p$.
8–10.5 (a) $2\Sigma_s$. (b) Charge will actually flow from one part of the surface through the bulk to another part of the surface. (c) A combination of bulk and surface current would provide the least resistance, but in practice the resistance to surface current is very large because of the associated small cross-sectional area.
8–10.7 (a) If $\sigma_1 < \sigma_2$, then the electric field is larger in material 1 than in material 2, so a larger field enters than leaves the surface.
(b) $\Sigma_S = J(\sigma_1 - \sigma_2)/4\pi k\sigma_1\sigma_2$.
8–11.1 Many choices are possible. For $R_1 = R_3 = 0$, (9.65′) gives $I_1 = I_3 = 0$, whereas (9.65) gives nonzero I_1 and I_3.
8–12.1 $n = 0.862 \times 10^{24}/\text{m}^3$.

9–2.1 $q_{m1} = 22.56$ A-m, $q_{m2} = 15.95$ A-m.
9–2.3 $\mu = 1.64$ A-m^2.
9–2.5 $B = 0.0259$ T.
9–2.7 $\vec{F} = q_m\vec{B}$, q_m due to one pole of a long magnet and $\vec{B} = k_m[-\vec{\mu} + 3(\vec{\mu}\cdot\hat{R})\hat{R}]/R^3$ due to a short magnet. The force on the distant pole of the long magnet is neglected.
9–2.9 (a) The magnet is strongly attracted to the soft iron rod when the soft iron is brought up to the magnet's poles, but only weakly attracted when the rod brought up to the magnet's center. (b) The soft iron is strongly attracted to the magnet when the magnet is brought to any part of the soft magnet.
9–2.11 "Show that" problem.
9–3.1 (a) $q_m = 5.12$ A-m, $\sigma_m = 3.2 \times 10^5$ A/m, $\mu = 0.256$ A-m^2. (b) 0.201 T, 1.28×10^{-3} T, 2.84×10^{-9} T.
9–3.3 $M = 3.99 \times 10^5$ A/m.
9–3.5 (a) $r \ll a$, no r-dependence. (b) $a \ll r \ll l$, $|\vec{B}| \sim r^{-2}$. (c) $l \ll r$, $|\vec{B}| \sim r^{-4}$.
9–4.1 Discontinuity in $\vec{C}$ is $\mu_0(\alpha - 1)\vec{M}$.
9–5.1 Put a rod of soft magnet in a line between a pole of a permanent magnet and the region where the field is to be intensified.
9–5.3 When field lines are expelled (concentrated), the object that is their source is repelled (attracted).
9–5.5 (a) $H = 1481$ A/m, $\chi = 1.688$.
(b) $M_{emu} = 2.50$ mmu/cm^3, $B_{emu} = 50$ G, $H_{emu} = 18.6$ Oe, $\chi_{emu} = 0.1344$.
9–6.1 M_r and M_s are too far in value; the magnet would not retain its magnetization.
9–7.1 (a) $|\vec{H}| = 485$ A/m, $|\vec{B}| = 0.98$ T. (b) small, except perhaps near the poles.
9–7.3 By keeping in the field lines, the keeper magnet lets the magnetization of one pole of the magnet magnetize the other end, and vice-versa.
9–8.1 In Figure 9.19a there are no poles because $\vec{M}$ is normal to $\hat{n}$; hence $\vec{H} \approx \vec{0}$. In Figure 9.19b the poles produce a demagnetization field $\vec{H} \approx -\vec{M}$ that makes $\vec{B} = \mu_0(\vec{H} + \vec{M}) \approx \vec{0}$.
9–9.1 $|\vec{B}| = 6.63 \times 10^{-6}$ T.
9–9.3 72.8° dip angle.
9–9.5 "Show that" problem.
9–10.1 If the Fe and Nd interaction were ferromagnetic, the net magnetic moment would be larger than

when they are antiferromagnetic: $7\mu_{Fe} + \mu_{Nd}$ rather than $7\mu_{Fe} - \mu_{Nd}$.

10–1.1 (a) $\vec{B} = -0.056\hat{x}$ T. (b) $\vec{B} = 0.056\hat{x}$ T.
10–1.3 (a) $B_{1x} = -0.0371$ T. $B_{1y} = 0.01486$ T.
(b) $B_{2x} = -0.0743$ T. $B_{2y} = -0.0297$ T.
(c) $B_x = 0.1114$ T. $B_y = -0.01486$ T.
10–2.1 (a) South pole up. (b) Uptward force on loop. (c) Downward force on magnet. (d) No torque on magnet.
10–2.3 (a) Left magnet has moment into page, right has moment out of page. (b) Attracted to loop on left.
10–2.5 The wire moves leftward, along $-x$.
10–2.7 (a) $\vec{\mu} = [-3.157\hat{i} - 0.476\hat{j} + 6.156\hat{k}]$ A-m^2.
(b) $\vec{\tau} = (0.209\ \hat{j} + 0.0162\ \hat{k})$ N-m.
10–2.9 (a) Attractive. (b) Repulsive. (c) Wires carrying parallel currents will attract.
10–3.1 (a) $\vec{\mu} = -4.52 \times 10^{-4}\hat{z}$ A-m^2.
(b) $\vec{\tau} = -1.810 \times 10^{-6}\hat{y}$ N-m.
(c) $\vec{\tau} = -1.666 \times 10^{-6}\hat{y}$ N-m.
10–3.3 (a) $\mu = 1.024 \times 10^{-4}$ A-m^2.
$q_m = 8.53 \times 10^{-4}$ A-m, (b) $|\vec{B}| = 94.8$ nT.
(c) 0.521 nT. (d) $|\vec{B}| = 10.24$ nT.
10–3.5 (a) $M = 9.27 \times 10^6$ A/m. (b) For a good magnet, $M \approx 10^5$-10^6 A/m.
10–4.1 (a) $|\vec{F}| = 81.6\ \mu$N. (b) Reversing the current or field reverses the force, pumping the blood the opposite way. (c) Reversing both current and field does not change the direction of the force.
10–4.3 Compress.
10–4.5 $\vec{F} = -2Ia|\vec{B}|\hat{y}$.
10–4.7 (a) $\vec{F} = -2\pi Na^2 AI\hat{z}$. (b) $\vec{F} = -0.253\hat{z}$ N.
10–4.9 (a) "Show that" problem. (b) $\vec{F} = 0.049\hat{y}$ N.
10–4.11 No current was specified. For $I = 1$ A, we have (a) $\vec{F}_{bot} = 0.010\hat{y}$ N. $\vec{F}_{top} = -0.005\hat{y}$ N. (b) $\vec{F}_{left} = 0.0045\hat{x}$ N. $\vec{F}_{right} = -0.0045\hat{x}$ N.
(c) $\vec{F}_{net} = 0.005\hat{y}$ N, compress.
10–4.13 (a) $a = 10^7$ m/s^2. (b) $|\vec{F}| = 1.4 \times 10^5$ N.
(c) $I = 2.8 \times 10^6$ A.
10–4.15 $\vec{F} = [2\pi k_m q_m I a^2/(r^2 + a^2)^{3/2}]\hat{y}$.
10–5.1 (a) Force is out of the page.
(b) $|\vec{F}| = 2.206 \times 10^{-17}$ N. (c) $a = 2.47 \times 10^{12} g$, where $g = 9.8$ m/s^2.
10–5.3 $|\vec{B}| = 6.65 \times 10^{-17}$ T.
10–5.5 $\vec{F} = (-0.399\hat{x} - 0.908\hat{y} - 1.167\hat{z}) \times 10^{-14}$ N, $|\vec{F}| = 1.532 \times 10^{-14}$ N.
10–5.7 $\vec{B} = (0.0286\hat{j} - 0.0755\hat{k})$ T.
10–5.9 "Show that" problem.
10–6.1 (a) Electron moves on a semicircle that bends left, and comes back out of the field region. (b) Proton moves on a semicircle that bends right, and comes back out of the field region.
10–6.3 (a) It initially deflects along $-\hat{y}$.
(b) $v = 1.655 \times 10^4$ m/s.
10–6.5 The period and radius are independent. The mechanics student is wrong.
10–6.7 (a) $T = 1.725 \times 10^{-8}$ s. (b) $|\vec{B}| = 7.62$ T.
(c) 4.17×10^4 V.
10–6.9 Deuteron, 2.55 cm; Triton, 3.12 cm; ^{3}He nucleus, 1.56 cm; ^{4}He nucleus, 1.80 cm.
10–6.11 (a) 26.1 T. (b) 30.1 T.
10–6.13 (a) $\vec{F}$ is perpendicular to $\vec{B}$.
(b) $v_\perp^2 = v^2 - v_\parallel^2 = \sqrt{2mE} - v_\parallel^2$, and both E and $v_\parallel$ do not change. (c), (d), (e) are "show that" problems.
10–6.15 (a) $\theta = 107.6°$. (b) $R = 1.768$ cm.
(c) $p = 3.53$ cm.
10–6.17 (a) circle centered at $x = z = mv_0/qB$, $y = 0$, with radius $R = \sqrt{2}mv_0/qB$. (b) penetration is $(\sqrt{2} - 1)mv_0/qB$. (c) time in field is $(\pi/2)(m/qB)$. (d) Exits at $x_0 = 2mv_0/qB$.
10–6.19 (a) "Show that" problem. (b) "Show that" problem. (c) The two formulae coincide.
10–6.21 (a) "Show that" problem. (b) "Show that" problem.
10–7.1 Because the charge carriers move to the side of the wire, the force does act on the charge carriers themselves (i.e. the current). Thus Maxwell was in error here – "to err is human."
10–7.3 (a) Positive. (b) $v_d = 0.882$ mm/s.
10–7.5 (a) $R_H = 7.35 \times 10^{-11}$ m^3/C.
(b) $R_t = -10.5 \times 10^{-9}\ \Omega$. (c) $l = 1.22\ \mu$m.
10–7.7 (a) Top is negative. (b) $\vec{E}_{mot} = -vB\hat{y}$, $\vec{E}_{es} = vB\hat{y}$. (c) $\Delta V = vBl$. (d) $\Delta V = vBl\cos\theta$.
10–8.1 $dW_{emf} = -dW_{pmf} = -0.084$ J.

11–2.1 $d\vec{B} = 2.72 \times 10^{-10}(2\hat{i} + \hat{k})$ T.
11–3.1 "Show that" problem.
11–4.1 (a) 5.29 m. (b) 281 turns.

11–4.3 2.81 mm.
11–4.5 (a) $d\vec{B} = (k_m I ds/a^2)\hat{\otimes}$.
(b) $\vec{B} = (\pi k_m I/a)\hat{\otimes}$.
11–4.7 3.67 mA.
11–4.9 $B_x = 6 \times 10^{-5}$ T.
11–5.1 (a) $\vec{B} = \vec{0}$, $\vec{B} = 4\pi k_m K\hat{i}$, $\vec{B} = 12\pi k_m K\hat{i}$.
(b) $|\vec{B}| = 0.00314$ T.
11–5.3 (a) Two close coils behave like a single coil, with a single maximum at their midpoint. (b) Two distant coils behave like two independent coils, with a local minimum at their midpoint.
(c) $B_y = 2\pi k_m I R^2 [\frac{1}{[(y+\frac{s}{2})^2+R^2]^{3/2}} + \frac{1}{[(y-\frac{s}{2})^2+R^2]^{3/2}}]$.
(d) $s = R$.
11–5.5 "Show that" problem.
11–5.7 "Show that" problem.
11–5.9 (a) $|\vec{B}| = 168.4\hat{z}$ μT, into page. (b) $|\vec{B}| = 49.1\hat{z}$ μT, out of page. (c) $|\vec{B}| = 0.678\hat{z}$ μT, into page.
11–5.11 $\vec{B} = -2k_m K \ln(\dfrac{x + w/2}{x - w/2})\hat{y}$.
11–5.13 (a) $I = Kd$, $K = M$, counterclockwise.
(b) $\vec{B} = k_m M d \frac{ab}{\sqrt{z^2+(a^2+b^2)/4}}\left[\frac{1}{z^2+a^2/4} + \frac{1}{z^2+b^2/4}\right]\hat{z}$.
11–5.15(a)$B_x = \frac{2\pi k_m NI}{L}\left[\frac{x+\frac{L}{2}}{\sqrt{(x+\frac{L}{2})^2+a^2}} - \frac{x-\frac{L}{2}}{\sqrt{(x-\frac{L}{2})^2+a^2}}\right]$.
(b) For $L/a \to 0$, $B_x \to \dfrac{2\pi k_m N I a^2}{(x^2+a^2)^{3/2}}$. For $L/a \to \infty$, $B_x \to 4\pi k_m NI/L$.
11–5.17 (a) $dI/dr = \sigma\omega r$. (b) $I = \sigma\omega(a^2/2)$.
(c) $B_x = 2\pi k_m \sigma\omega[\sqrt{x^2+a^2} - 2x + \dfrac{x^2}{\sqrt{x^2+a^2}}]$.
11–6.1 (a) $\vec{F} = 3.04 \times 10^{-21}\hat{y}$ N.
(b) $\vec{F} = -3.04 \times 10^{-21}\hat{x}$ N. (c) $\vec{F} = \vec{0}$.
11–6.3 $\vec{F} = \dfrac{2evk_m I}{r}\hat{i}$.
11–6.5 (a) $|\vec{F}| = 2k_m I^2 \ln(a/r)$, to the left, and expansive. (b) $|\vec{F}| = 9.15 \times 10^{-5}$ N.
11–6.7 Take solenoid current clockwise as viewed from above. (a) $\vec{B}_{of\ loop} = \dfrac{2\pi k_m I_2}{b}\hat{\uparrow}$.
(b) $\vec{F}_{on\ solenoid} = \dfrac{2\pi^2 k_m I_1 I_2 n a^2}{b}\hat{\uparrow}$.
(c) $\vec{B} = 2.51 \times 10^{-4}\hat{\uparrow}$ T, $\vec{F} = 1.18 \times 10^{-5}\hat{\uparrow}$ N.
11–6.9 $F/l = k_m I^2/a$.
11–7.1 (a) $\Gamma_B = 1.721 \times 10^{-5}$ T-m. (b) $\Gamma_B = 0$.
11–7.3 (a) $I_{enc} = 19{,}900$ A. (b) $\Gamma_B = 0.05$ T-m. (c) $\Gamma_B = 0$ T-m.
11–7.5 (a) Field circulates counterclockwise.
(b) $\Gamma_B/s = 0.04$ T. (c) $I_{enc} = 636.6$ A. (d) Current flows out of the page.
11–8.1 "Show that" problem. Deformation doesn't affect circulation if no current passes through the deforming circuit.
11–8.3 (a) and (b) For both a physical circuit and an Ampèrian circuit, $d\vec{s}$ is defined, but only for a physical circuit does it point along the local current direction.
11–9.1 Take $d\vec{s}$ to be clockwise, so $I_{enc} > 0$ is into the page. (a) $\Gamma_B = -120$ T-m. (b) $I_{enc} = -9.55 \times 10^7$ A (out of page). (c) $\vec{J} \cdot \hat{n} = 7.96 \times 10^6$ A/m^2.
11–9.3 (a) $\Gamma_B = 10ydydx$.
(b) $I_{enc} = 5ydydx/2\pi k_m$. (c) $I/A = 5y/2\pi k_m$.
11–9.5 (a) $\Gamma_B = 5.6 \times 10^{-6}$ T-m.
(b) $B = 3.56 \times 10^{-5}$ T. (c) $I_{enc} = 4.45$ A,
$I_{enc}/A = 2266$ A/m^2. (d) Into the page.
11–10.1 (a) $|\vec{B}| = 9.60$ mT. (b) $|\vec{B}| = 15$ mT.
(c) counterclockwise.
11–10.3 (a) $r < a$ and $a < r < b$ counterclockwise, $c < r$ clockwise. (b) concentric circle of radius $r > c$.
(c) $\Gamma_B = 2\pi r|\vec{B}|$. (d) $\Gamma_B = 12\pi k_m I$.
(e) $|\vec{B}| = 6k_m I/r$.
11–10.5 Take I_{inner} to be out of the page, and $\hat{\phi}$ to indicate the counterclockwise tangent.
(a) $J_{core} = \dfrac{I}{\pi a^2}$, $J_{sheath} = \dfrac{I}{\pi(c^2 - b^2)}$. (b) For $r < a$, $\vec{B} = \dfrac{2k_m I}{a^2} r\hat{\phi}$; for $a < r < b$, $\vec{B} = \dfrac{2k_m I}{r}\hat{\phi}$; for $b < r < c$, $\vec{B} = \dfrac{2k_m I}{r}(1 - \dfrac{r^2 - b^2}{c^2 - b^2})\hat{\phi}$; for $c < r$, $\vec{B} = \vec{0}$.
11–10.7 (a) $d\vec{B}' = -k_m(nIz)(d\vec{s} \times \vec{\rho})/R^3$.
(b) $d\vec{B} = \int d\vec{B}' = \dfrac{-2k_m\,(nI)\,(d\vec{s} \times \vec{\rho})}{\rho^2}$.
(c) "Show that" problem.
11–11.1 Use $q_M = \dfrac{\mu}{l}$. (a) $|\vec{F}| = \dfrac{k_m q_m^2}{4h^2}$, repelled.
(b) $h = \dfrac{q_m}{2}\sqrt{\dfrac{k_m}{Mg}}$.
11–11.3 (a) "Show that" problem.
(b) $B_y = \dfrac{k_m q_m}{(-y+h)^2}$ for $y < 0$.

(c) $F = q_m B = \dfrac{k_m q_m^2}{4h^2}$.

11–12.1 (a) Induced surface current K circulates clockwise as seen from above.
(b) $K = \dfrac{q_m}{2\pi}\dfrac{\rho}{(\rho^2+h^2)^{3/2}}$. (c) $\vec{F} = \dfrac{k_m q_m^2}{(2h)^2}(-\hat{z})$.
11–13.1 See Section 11.13.
11–14.1 (a) $B_{gap} = 17.2$ mT,
$B_{in} = B_{gap} = 17.2$ mT. (b) $A_{gap}/A = 45.5$.
11–14.3 (a) $B_{in} = 1.29$ T. (b) $B_{gap} = 1.29$ T.

For Chapter 12 Food for Thought questions on pp.512-513, 515, and 517, see last page.
12–3.1 (a) Calico is an insulator. (b) The greater the current, the greater the deflection. (c) Counterclockwise.
12–3.3 (a) Counterclockwise. (b) To increase the response.
12–3.5 (a) Smaller. (b) Clockwise.
12–3.7 (a) Ssource of magnetic field. (b) Counterclockwise.
12–4.1 (a) Increases out of the page. (b) Into the page. (c) Clockwise. (d) Clockwise. (e) Up.
(f) Compress. (g) No tendency to rotate.
12–4.3 No current.
12–4.5 If R increases, (a) decrease. (b) to observer. (c) same direction as primary. (d) same direction as primary. (e) loops attract and expand. (f) If R decreases, all answers reverse.
12–4.7 (a) Increase out of the page. (b) Into the page. (c) Clockwise. (d) Clockwise. (e) Leftward, compressive. (f) If the field is reversed, then the responses in parts (a-d) reverse, but are the same for part (e). (g) If the field is tilted, the effects decrease.
12–4.9 (a) Counterclockwise. (b) Move foil away and compress the foil.
12–4.11 See last page of Answers.
12–4.13 See last page of Answers.
12–5.1 (a) $\vec{E}$ and $\vec{B}$ are vectors; $\mathcal{E}$, Φ_B, and $d\Phi_B/dt$ are scalars. (b) $\vec{E}$, $\mathcal{E}$, and $d\Phi_B/dt$ do not change; $\vec{B}$ and Φ_B reverse. (c) $\mathcal{E}$ and $d\Phi_B/dt$.
12–5.3 (a) $\Phi_B = -(16t + 32\times 10^3 t^2)\times 10^{-4}$ Wb.
(b) $d\Phi_B/dt = -(16 + 64\times 10^3 t)\times 10^{-4}$ Wb/s.
(c) $\mathcal{E} = (16 + 64\times 10^3 t)\times 10^{-4}$ V, counterclockwise as seen from above.
(d) $|\vec{F}| = 2.56(t + 6\times 10^3 t^2 + 8\times 10^6 t^3)\times 10^{-8}$ N.
(e) 3.03 s.
12–5.5 (a) -2.39 mV. (b) -2.47 mV, a 3.57% change. (c) -0.646 mA.
12–5.7 (a) 0.008 V counterclockwise. (b) 0.32 mA counterclockwise. (c) 4.43×10^{-5} N pushing the loop into the field region. (d) 1.536×10^{-6} N-m, tending to decrease the angle below 60 degrees.
12–5.9 (a) 0.096 T into the page. (b) 0.00144 Wb/s. (c) 0.036 mA clockwise. (d) 6.912×10^{-8} N drawing the circuit into the solenoid.
12–5.11 (a) $2NBA$. (b) $2NBA/R$.
12–5.13 (a) $\mathcal{E} = -(2\pi r)(dr/dt)B$, $I = \mathcal{E}/R$.
(b) $dF/ds = (2\pi r)(dr/dt)B^2/R$. (c) 144 N/m.
12–6.1 (a) 0.2 H. (b) 27 A/s.
12–6.3 $-(32.4 + 32.4t)$ mV.
12–6.5 (a) $\dfrac{2k_m N_1 N_2 ha}{\rho}$. (b) $\dfrac{2k_m N_1 N_2 ha}{\rho}$.
12–6.7 (a) $\dfrac{2\pi^2 k_m a^2 b^2}{R^3}$. (b) 1.599×10^{-10} H.
12–6.9 (a) $4\pi^2 k_m N_c N_s I_s a^2/l$. (b) counterclockwise. (c) $|\mathcal{E}| = d\Phi_B/dt = 4\pi^2 k_m N_c N_s (dI_s/dt)a^2/l$.
(d) 0.1263 mH.
12–7.1 (a) $-0.08\hat{y}$ V/m. (b) bottom is higher, by 18.35 mV.
12–7.3 (a) $\Delta V_{right} = 0$. (b) $\Delta V_{left} = 0$.
(c) $\Delta V_{top} = 0$.
12–7.5 East wing is higher by 0.135 V.
12–7.7 1.42 μV, clockwise viewed from above.
12–7.9 (a) $\omega r B b$, radially out. (b) $b/\sigma c d$. (c) Force $r\omega B^2 bcd\sigma$ opposing motion, torque $r^2\omega B^2 bcd\sigma$ opposing motion. (d) "Show that" problem.
12–8.1 (a) Middle arm. (b) Before, $I_J = 0.048$ A, $I_w = 1.2$ A, both right to left, (c) After, I_w is unchanged and $I_J = 1.2$ A, left to right. (d) $\Delta V_w = 24$ V, $\Delta V_J = 600$ V, both clockwise, and $\Delta V_L = 624$ V counterclockwise. (e) See Fig.12.24.
12–9.1 2.703 mH.
12–9.3 $-61{,}300$ A/s, the sign meaning that I_2 and I_1 are changing in opposite senses.
12–9.5 (a) On average, the equivalent ring and solenoid magnets are opposed. (b) On average, the ring and solenoid currents are opposed. (c) An increase in I_{sol} is accompanied by a decrease in I_{ring}. This corresponds to out-of-phase magnets, which repel.

12–10.1 (a) 72 turns. (b) -1.55 mV.
12–10.3 (a) N^2L. (b) 0.1382 mH.
12–10.5 $L = 2k_m N^2 a \ln[(a+b)/b]$.
12–11.1 (a) $dI/dt = 2.21 \times 10^5$ A/s, $V_R = 0.966$ V, $V_L = 1.434$ V. (b) $I = 6.52$ A, $dI/dt = 1.38 \times 10^5$ A/s, $V_R = 1.5$ V.
12–11.3 (a) $dI/dt = 5.78 \times 10^5$ A/s, 4.8 V.
(b) 37.25 ns.
12–11.5 (a) 6.73 mH. (b) 0.410 ms. (c) 19.8 mA.
12–11.7 Let $V_L = LdI/dt + IR_L$. (a) At $t = 0^+$, $V_L = LdI/dt = 12$ V across the inductance part of the inductor. At $t = 25$ μs, $V_L = IR_L = 0.293$ V across the resistance part of the inductor. (b) At $t = 0^+$, a sketch would show voltage changes of 12 V across the emf and $V_L = LdI/dt = 12$ V across the inductance part of the inductor. At $t = 25$ μs, a sketch would show voltage changes of 12 V across the emf and voltage drops $IR_L = 0.293$ V and $IR = 11.707$ V. (c) At $t = 0^+$ the electric field is electromagnetically induced. At $t = 25$ μ the field is electrostatic.
12–12.1 (a) 0.1568 J. (b) 2.306×10^8 J/m^3.
(c) 24.1 T.
12–12.3 0.416 μH/m.
12–12.5 (a) 0.008 s. (b) See Figure 12.23.
(c) At $t = 0$, $I = 0$ and $dI/dt = 3 \times 10^3$ A/s. At $t = 0.002$ s, $I = 5.31$ A and $dI/dt = 2.34 \times 10^3$ A/s. At $t = \infty$, $I = 24$ A and $dI/dt = 0$. (d) Battery provides 0, 63.7 W, and 288 W. (e) Resistor uses 0, 14.1 W, and 288 W. (f) Inductor builds up energy at rate 0, 49.7 W, and 0. (g) Except for negligible parasitic capacitance, there is no electrical energy. (h) $\mathcal{P}_{batt} = \mathcal{P}_L + \mathcal{P}_R$.
12–13.1 (a) 1.1 N/C. (b) 1.76 N/C.
12–13.3 (a) The problem statement should have asked you to show that $|E_z/E_\theta| = l/2\pi Na$, not $2\pi Na/l$. (b) 0.00398. (c) $|E_\theta| = 0.0329$ V/m,
$E_z = 0.1309$ mV/m. Note: $\Delta V_L = E_z l = 0.0262$ mV. (d) E_θ is electromagnetically induced. (e) E_z is electrostatic.
12–13.5 Let $\tilde{R}^2 = R_r R_l + R_r R_m + R_l R_m$. If $\mathcal{E}_r > 0$, then $I_l = \mathcal{E}_r R_m/\tilde{R}^2$ goes up the left arm and
$I_r = \mathcal{E}_r (R_m + R_l)/\tilde{R}^2$ goes down the right arm.
(a) $I_r R_r$. (b) $I_l R_l$. (c) $\mathcal{E}_r = -0.787$ mV, so
$I_r R_r = -0.562$ mV (voltmeter bottom is positive) and $I_l R_l = -0.225$ mV (voltmeter top is positive).
12–13.7 (a) 4 A clockwise. (b) 8 V across left, 0 V across top, 4 V across right, 0 V across bottom.
(c) $V_A = -5$ V, $V_B = -2$ V, $V_C = -3$ V, $V_D = 0$ V.
(d) 5 V, -3 V, 1 V, -3 V.
12–14.1 (a) $I_1 = I_2 = 6$ A, right to left.
(b) $I = 1.714$ A in both arms, circulating clockwise; $I = 0.968$ A in both arms, circulating clockwise.
12–14.3 (a) $I_1 = I_2 = 0$. (b) $I_1 = I_2 = 0$.
(c) $I_1 = 0.545$ A, $I_2 = 0.15$ A. (d) $I = 0.346$ A, circulating counterclockwise. (e) 68.6 μs, 0.193 A.

13–1.1 "Verify that" problem.
13–2.1 From best to worst: iron rods, iron, plastic (either rods or solid). Iron rods have a large magnetization, but a relatively large resistance.
13–3.1 The motor is an external source of mechanical power, and the generator uses the electrical power.
13–4.1 (a) 10 Ω. (b) 100 V.
13–4.3 (a) 92.31 A. (b) 5.94 N, 10.24 m/s^2.
(c) 0.01481 V. (d) 92.08 A. (e) 0.224 s.
13–5.1 (a) 429 s. (b) 7.33 A, 0.0703 N.
13–5.3 (a) 228 s. (b) 2.89×10^4 m/s. (c) 771 A.
13–6.1 0.0403 s.
13–6.3 88.7%
13–7.1 (a) 80 s. (b) 0.08 N, 1.667 m/s^2.
(c) 69.1 m/s, 1.97 m/s.
13–8.1 2.69×10^6 m/s, 2.69×10^5 m/s,
2.69×10^2 m/s, 2.69×10^1 m/s,
13–8.3 "Show that" problem.
13–8.5 (a) opposite source current. (b) same as source current.

14–1.1 $V_{rms} = 1/\sqrt{3}$, $\overline{V} = 0$.
14–1.3 (a) 0.0127 s per radian and 0.08 s per period.
(b) 12.5 s^{-1} and 78.5 rad/s. (c) 12.5 s^{-1} is f and 78.5 rad/s is ω.
14–1.5 $V_{rms} = V_m/\sqrt{3}$; $\overline{\Delta V} = V_m/2$.
14–1.7 $V_{rms} = V_m/\sqrt{3}$; $\overline{\Delta V} = 0$.
14–2.1 Decrease either L or C by a factor of 4.
14–2.3 (a) 2.093×10^{-9} F to 0.264×10^{-9} F.
(b) 5.23×10^{-12} J and 0.660×10^{-12} J.
14–2.5 16.24 pF.
14–3.1 (a) Current starts at zero but with finite slope, going through some damped oscillations until it is zero at long times. (b) Charge starts at zero and

with zero slope, going through some damped oscillations until it is finite at long times.
14–3.3 "Show that" problem.
14–3.5 (a) $\omega_0 = 2.49 \times 10^4$ rad/s, $f_0 = 3.97 \times 10^3$ Hz, $R_c = 1197\ \Omega$. (b) For $R = 5\ \Omega$, we have $R < R_c$; very underdamped. A sketch would show that the voltage initially rises quadratically in time, and then goes to a slowly damped oscillation around the applied emf.
14–4.1 (a) 29.4 cm^2. (b) 800 turns.
14–5.1 (a) 5.86 Ω, 56.1°. (b) energy is absorbed.
14-5.3 (a) B provides power, A receives power. (b) $-55°$.
14–5.5 (a) 500 Ω, 6.37 μF, $-90°$. (b) 510 mJ.
14–5.7 (a) Scalar. (b) The y-component of the rotating vector, or phasor, gives a scalar that equals the voltage.
14–5.9 (a) At low f capacitors serve as open circuits (finite voltage), at high f capacitors serve as closed (or short) circuits (zero voltage). (a) At low f inductors serve as closed (or short) circuits (zero voltage), at high f inductors serve as open circuits (finite voltage).
14–6.1 5 ms was a misprint. The intended time lag was 0.5 ms. This gives $Z = 40\ \Omega$, $\phi = 0.1885$ rad $= 10.80°$, $R = 39.3\ \Omega$, $X_L = 7.50\ \Omega$, $L = 0.0199$ H.
14–6.3 $X_L = 1.57\ \Omega$, $Z = 20.06\ \Omega$, $\phi = 0.0784$ rad $= 4.49°$, $t_{lead} = 0.250$ ms, $I_m = 4.23$ A.
14–6.5 $X_C = 3.02 \times 10^4\ \Omega$, $R = 1.433 \times 10^5\ \Omega$, $Z = 1.464 \times 10^5\ \Omega$, $\phi = -11.86°$.
14–6.7 $Z = 160\ \Omega$, $X_L = 30.14\ \Omega$, $R = 157.1\ \Omega$, $\phi = -0.1894$ rad $= -10.85°$, $t_{lag} = 6.85 \times 10^{-5}$ s.
14–6.9 $\phi = 0.1520$ rad, $X_L = 1.839\ \Omega$, $L = 0.665$ mH, $Z = 12.14\ \Omega$.
14–6.11 (a) $I_{rms} = 4.87$ A for all circuit elements. (b) $\Delta V_{R,rms} = 116.8$ V, $\Delta V_{L,rms} = 27.5$ V. (c) $\mathcal{P}_{R,rms} = 569$ W, $\mathcal{P}_{L,rms} = 0$. (d) $\phi = 0.231$ rad, $t_{lag} = 0.614$ ms.
14–6.13 (a) Inductor, with $X_L = 39.25\ \Omega$, $L = 0.1041$ H. (b) $\overline{\mathcal{P}} = 148.4$ W.
14–7.1 (a) $f = 62.5$ kHz. (b) $Z_R = R = 200\ \Omega$, $Z_L = X_L = 3571\ \Omega$. (c) power surges have high frequencies, for which inductors have a high impedance.
14–7.3 Units misprint: capacitance is in μF, not μH. (a) Capacitor. (b) Resistor. (c) $V_{R,m} = 2.40$ V, $V_{C,m} = 24.9$ V. (d) $V_{R,m} = 17.35$ V, $V_{C,m} = 18.00$ V.
14–7.5 "Show that" problem.
14–8.1 (a) Yes. (b) No. (c) Yes.
14–8.3 (a) $X_L = 6.283\ \Omega$, $X_C = 0.796\ \Omega$, $Z = 6.79\ \Omega$, $\phi = 53.9°$. (b) $I_m = 3.53$ A, $V_{L,m} = 22.2\ \Omega$, $V_{R,m} = 14.14\ \Omega$, $V_{C,m} = 2.81\ \Omega$. (c) Voltage leads current by 0.374×10^{-3} s. (d) 14.41 V, voltage lags current by 0.781×10^{-4} s. (e) 26.3 V, voltage leads current by 3.99×10^{-4} s. (f) 19.39 V, voltage leads current by 6.25×10^{-4} s.
14–8.5 (a) 1340 Hz, $I_{rms} = 0.05$ A. (b) $V_{L,rms} = 6.316$ V, $V_{R,rms} = 1.20$ V, $V_{C,rms} = 6.316$ V. (c) $Z = 191\ \Omega$, $\phi = 82.8°$, $I_{rms} = 0.00628$ A. (d) $V_{L,rms} = 1.587$ V, $V_{R,rms} = 0.1507$ V, $V_{C,rms} = 0.397$ V. (e) $R_c = 252.6\ \Omega$. Definitely a resonance, but rather broad, since $\mathcal{Q} = 5.625$ is fewer than the 6.26 radians that correspond to a full period.
14–8.7 "Show that" problem.
14–9.1 For water, a valve permits a small force to control a large flow of water; for electricity, a valve permits a small voltage to control a large flow of electricity.
14–9.3 See Figure 14.14b. The grid voltage determines whether or not electrons are drawn off the cathode; once off the cathode, they go to the anode.
14–10.1 Neither of them can dissipate energy, and on average neither of them can store energy.
14–10.3 (a) $\mathcal{P} > 0$ when refinery is buying power. (b) $\mathcal{P} < 0$ when refinery is selling power.
14–10.5 (a) $\cos\phi_0 = 0.423$. (b) Add capacitor with $C = 1.957\ \mu$F. (c) $Z = 1215\ \Omega$.
14–11.1 (a) 6.25 turns. (b) 62.5 turns.
14–11.3 100 V.
14–11.5 (a) $N_s/N_p = 1/10$. (b) Lower voltage side has higher current; thicker wire decreases the Joule heating rate.
14–11.7 (a) $\mathcal{P}_{gen} = 4800$ W. (b) $\mathcal{P} = \mathcal{P}_{gen} = 4800$ W. (c) $\mathcal{P}_{wires} = 2.56$ W. (d) $\mathcal{P}_{load} = 4797.44$ W.
14–11.9 See Section 14.11.3.
14–11.11 (a) $R = 1\ \Omega$. (b) $R_c/R = 50$. (c) $L = 13.37$ mH, $C = 21.39\ \mu$F. (d) $N_s/N_p = 100$.
14–12.1 Toaster.
14–12.3 (a) $\mathcal{E}_m = 0.400$ V. (b) $Z = 20.8\ \Omega$, $\phi = 54.8°$. (c) $I_m = 8.16$ A. (d) $F = -0.1011$ N.

14–12.5 Use the geometry of Figure 14.18a, with an inductor and capacitor in series with the circuit. (a) $IR + LdI/dt + Q/C = \mathcal{E}_m \sin\omega t$, $\mathcal{E}_m = \omega B_m lx$. (b) $I = (\mathcal{E}_m/Z)\sin\omega t$, Z and ϕ as in (14.71) and (14.72). (c) $\overline{F} = -(\mathcal{E}_m b B_m/2Z)\sin\phi$. (d) If $\omega > \omega_0$, L dominates; if $\omega < \omega_0$, C dominates.
14–13.1 (a) 23.9 μm. (b) $d = 0.001$ inch is 25.4 μm, so that the field will penetrate, but down by a factor of $e^{-d/\delta} = 0.346$.
14–13.3 "Show that" problem.

15–2.1 (a) 2011 m/s. (b) 2 min. (c) 70 min. (d) 60 flagmen.
15–3.1 2.83×10^{16} N/C-s.
15–4.1 0.01096/m.
15–4.3 (a) $dy/dx = x/(a-y)$, $d^2y/dx^2 = a^2/(a-y)^3$. (b) $1/a$. (c) $d^2y/dx^2 = 1/R$, where $R = a$ is the radius of curvature.
15–5.1 120 m/s.
15–5.3 3 N.
15–5.5 (a) Energy flowing along the string is more concentrated. (b) Yes. (c) 3361 N. (d) It corresponds to hanging a mass of 342.6 kg; unlikely.
15–5.7 "Show that" problem.
15–5.9 (a) 2.048 m/s. (b) 0.36 m. (c) -0.653 m/s. (d) -0.626 m/s^2.
15–5.11 The large phases require high accuracy. (a) 251.3274 m^{-1}. (b) 2010.6193 s^{-1}. (c) 320 Hz. (d) 0.003125 s. (e) -8048.23 rad$\equiv$0.527 rad. (f) In cm, $y(x,t) = 0.03\sin[251.3274x + 2010.6193t + 0.527]$. (g) -0.0200 cm.
15–5.13 (a) 3.0 kg/m. (b) 0.72 N.
15–5.15 (a) 147.3 m/s. (b) 170 cm and 85 cm. (c) 86.6 Hz and 173.3 Hz.
15–5.17 (a) 7.48 m. (b) 18.70 m. (c) 0.01282 s. (d) 78.0 Hz. (e) 0.0358 m, -2.65 m/s, -8600 m/s^2.
15–5.19 (a) $\frac{d^2y}{dx^2} = v^2(\frac{d^2y}{dt^2})$ and $\frac{d^2z}{dx^2} = v^2(\frac{d^2z}{dt^2})$. (b) $v = \sqrt{\frac{F}{\mu}}$. (c) $f_1 = \frac{v}{2L}$.
15–6.1 $-12000\ \hat{x}$ V/m.
15–6.3 (a) $(D/c)\sin(qx-\omega t)$. (b) $(D/c)\sin(qy-\omega t)$.
15–6.5 (a) 0.009375 m. (b) 670.2 m^{-1}. (c) 2.01×10^{10} s^{-1}. (d) $0.15\sin(qy-\omega t)$ mT.
15–7.1 (a) 303 m. (b) 3.367 m.
15–8.1 (a) r^{-1}. (b) $r^{-1/2}$.
15–8.3 1.584×10^5 V/m; 0.528 mT.
15–9.1 (a) 4.17×10^{-8} m/s^2. (b) 19,200 s. (c) 8×10^{-4} m/s. (d) 7.68 m.
15–9.3 (a) $u_E = u_B = 8.95\sin^2(qy-\omega t)$ mJ/m^3. (b) $\vec{S} = 5.37 \times 10^6 \sin^2(qy-\omega t)\ \hat{y}$ W/m^2. (c) $\mathcal{P} = 0.0179\sin^2(qy-\omega t)$ N/m^2.
15–9.5 (a) $\vec{S} = -2\pi k_m n^2 r I \frac{dI}{dt}\hat{r}$. (b) $\mathcal{P}/l = 4\pi^2 k_m n^2 r^2 I|\frac{dI}{dt}|$, flowing radially inward. (c) $d\mathcal{P}/l = 8\pi^2 k_m n^2 r dr I|\frac{dI}{dt}|$. (d) $d(dU_B/dt)/l = 8\pi^2 k_m n^2 r dr I|\frac{dI}{dt}|$. This equals $\mathcal{P}/l$, so $d\mathcal{P} = d(dU_B/dt)$.
15–10.1 (a) 3.93 m, (b) 1.132, (c) 1.282.
15–10.3 (a) 5.07×10^{14} Hz. (b) 5.07×10^{14} Hz. (c) 443.7 nm. (d) $\theta_{refl} = 23°$, $\theta_{refr} = 17.04°$.
15–10.5 (a) $\theta_c^{crownglass} = 41.14°$, $\theta_c^{diamond} = 24.41°$. (b) Crown glass. (c) Diamond.
15–11.1 2.3 W/m^2, polarized vertically.
15–11.3 (a) 0. (b) 0.134 W/m^2, at 35° to the x axis.
15–11.5 2.58 W/m^2, polarized vertically.
15–11.7 (a) 53.1°. (b) 36.9°.
15–12.1 (a) and (b) See Section 15.12.
15–12.3 $-2881\ \hat{x}$ A/m.
15–13.1 "Show that" problem.
15–14.1 (a) 2.4 m. (b) 2.4 m.
15–14.3 $R/R_c \approx 0.25$. This corresponds to $\mathcal{Q} = R_c/2R \approx 2.0$ radians, or 0.32 of a full oscillation. It damps out very quickly.
15–15.1 (a) $\delta L = (\pi A/2L)^2 L$. (b) "Show that" problem.
15–15.3 (a) 5.09×10^3 m/s. (b) 1.964×10^{-3} s.
15–15.5 24.9 m.
15–15.7 Using (15.82), so $v_{water} = 1.432 \times 10^3$ m/s, gives 114.8 Hz. (Using $v_{water} \approx 4.3 v_{air}$, as in example 15.7, so $v_{water} \approx 1.475 \times 10^3$ m/s, gives 118.3 Hz.)

16–2.1 (a) 76.6 mm. (b) 287 Hz.
16–2.3 $4(d^2 - m^2\lambda^2)y^2 - 4m^2\lambda^2 D^2 = m^2\lambda^2(d^2 - m^2\lambda^2)$.
16–2.5 (a) 0.212 m. (b) 1604 Hz.
16–2.7 (a) one line of maxima, no lines of minima. (b) one line of maxima, two lines of minima. (c) five lines of maxima, six lines of minima.
16–2.9 (a) See Fig.16.6a. (b) See Fig.16.7a. (c) See Fig.16.8a.
16–2.11 Use $\tan\theta \approx \sin\theta$. (a) 4.08 m. (b) 12.53°.
16–3.1 "Show that" problem.

16–3.3 (a) $\phi = 2\pi + 2\theta - 6\theta'$. (b) $\sin^2\theta = \frac{1-(n/3)^2}{1-(1/3)^2}$. (c) For $n = 4/3$, $\phi - 180° = 51.0°$.
16–4.1 See Section 16.4.
16–4.3 See Section 16.4.
16–4.5 At 90° (top of circle) get maximum increase in period; At 270° (bottom of circle) get maximum decrease in period;
16–4.7 Grimaldi's experiment showing light within the geometrical shadow, and bright and dark fringes just outside the geometrical shadow.
16–4.9 Birefringent crystals, unless oriented properly, will give two images.
16–5.1 (a) "Show that" problem. (b) v_s. (c) v_p.
16–5.3 For small amplitude disturbances the equations are linear, which leads to an amplitude-independent sound velocity. Hence the relative amounts of reflection and refraction are amplitude-independent.
16–6.1 (a) 109.87 Hz. Out of tune by 0.12%. (b) Tone at $(f_A - f'_E)^{-1}$.
(c) 7.5 s.
16–6.3 $\lambda'/\lambda = v/c$. Since the experiments indicate that λ' in the film is less than λ in air, we deduce that $v < c$.
16–6.5 (a) The sources have a coherence time much shorter than the measuring time of the eye. (b) The sources have a coherence time longer than the measuring time of the ear.
16–6.7 (a) No. (b) No.
16–6.9 (a) 489.44 nm. (b) 611.8 nm and 407.9 nm.
16–6.11 (a) 691.3 nm, 518.5 nm, and 414.8 nm.
(b) 592.6 nm and 460.9 nm.
16–6.13 (a) 912 nm. (b) 606.5 nm, 485.2 nm, and 404.3 nm.
16–6.15 113.1 nm.
16–6.17 Correct for the misprint of 1575, rather than 1515, lines at atmospheric pressure.
(a) $n_1 = 1.000293$. (b) $\lambda_{vac} = 690.2$ nm.
(c) $d = 0.4998$ m.
16–6.19 (a) $N = 2\Delta D/\lambda$. (b) 600 nm.
16–6.21 (a) 409 nm. (b) 0.422 degrees, 8.1 mm. (c) 611.
16–6.23 (a) 858 nm. (b) 613 nm.
16–7.1 "Show that" problem.
16–7.3 (a) 1.536 mm. (b) 0.541 mm.
16–7.5 Break up the illuminated part of the plane into tiny strip-shaped sources parallel to the finite opaque strip (or into tiny annulus-shaped sources concentric with the finite opaque disk). At the center of the geometrical shadow, wavelets from all strips (or annuli) add in phase, giving an interference maximum.
16–7.7 366.5 nm.
16–7.9 (a) 162.5 μm. (b) 0.220°, 0.660°.
16–7.11 (a) 0.0766°. (b) 0.0321 cm.
16–7.13 For $m = \pm 1$ minima: (a) 184.7 μm.
(b) 0.428°, 0.486 cm.
16–7.15 197.1 μm.
16–7.17 (a) "Show that" problem. (b) "Show that" problem.
16–7.19 (a) 3.93 mm. (b) 1.5×10^{-8} radians.
(c) 150 radians – unresolvable.
16–7.21 (a) 2.16×10^{12} m. (b) 3100 times the radius of the sun. (c) 6.79×10^{14} m.
16–7.23 (a) 0.671 mm. (b) 0.0419 mm. (c) 3.5 m. (d) 5.75 m.
16–8.1 (a) $2d = (m + \frac{1}{2})\lambda/n_{\mathrm{O,E}}$. (b) O-beam has 520 nm ($m = 3$) and 404.4 nm ($m = 4$); E-beam has 557.1 nm ($m = 3$) and 433.3 nm ($m = 4$).
16–8.3 (a) 63 nm. (b) 0.00451°.
16–9.1 (a) maxima out to $m = \pm 6$. (b) $m = 0$ at 0°; $m = \pm 1$ at $\pm 9.04°$; $m = \pm 2$ at $\pm 18.32°$; $m = \pm 3$ at $\pm 28.13°$; $m = \pm 4$ at $\pm 38.94°$; $m = \pm 5$ at $\pm 51.79°$; $m = \pm 6$ at $\pm 70.54°$. (c) maxima out to $m = \pm 4$.
(d) 0.0212 rad = 1.213°. (e) 43.9 nm.
16–9.3 Interpret third maximum to be third order ($m = 3$). (a) 513.4 nm. (b) $m_{max} = 10$.
(c) $\theta_6 = 36.3°$.
16–9.5 400 nm $\leq \lambda \leq$595 nm.
16–9.7 4030 lines.
16–9.9 1216 slits.
16–9.11 (a) "Show that" problem. (b) "Show that" problem. (c) Multiples of three.
16–10.1 [scattering angle, angle of incidence relative to normal]: (a) [20°, 80°]. (b) [160°, 10°].
16–10.3 0.16 nm.
16–10.5 $m = 4$ gives $\lambda = 0.01139$ nm, $m = 5$ gives $\lambda = 0.00911$ nm.
16–10.7 (a) 0.205 nm, 1.467×10^{18} Hz. (b) 0.270 nm, 1.111×10^{18} Hz.

16–10.9 $2d\sin\theta = m\lambda$ and $n_V = n_A/d =$ constant relates the volume and area densities and the plane separation. Higher n_A means smaller d and thus larger θ and larger scattering angle 2θ.

Chapter 12 Food for Thought questions on pp.512-513, 515, and 517

pp.512-513 See Figure 12.6.

1. Primary moves leftward, with I_P counterclockwise as seen from the right. Then $\vec{B}_{ext}$ is along $\hat{\rightarrow}$, $d\vec{B}_{ext}/dt$ is along $\hat{\leftarrow}$, and $\vec{B}_{ind}$ is along $\hat{\rightarrow}$.
2. Primary moves rightward, with I_P clockwise as seen from the right. Then $\vec{B}_{ext}$ is along $\hat{\leftarrow}$, $d\vec{B}_{ext}/dt$ is along $\hat{\leftarrow}$, and $\vec{B}_{ind}$ is along $\hat{\rightarrow}$.
3. Primary moves leftward, with I_P clockwise as seen from the right. Then $\vec{B}_{ext}$ is along $\hat{\leftarrow}$, $d\vec{B}_{ext}/dt$ is along $\hat{\rightarrow}$, and $\vec{B}_{ind}$ is along $\hat{\leftarrow}$.
4. There is no general correlation between $\vec{B}_{ext}$ and $\vec{B}_{ind}$; There is a general correlation whereby $\vec{B}_{ind}$ opposes $d\vec{B}_{ext}/dt$.

p.515 See Figure 12.8(a). In all cases, the observer is to the right.

Situation	$\frac{d\vec{B}_{ext}}{dt}$	$\vec{B}_{ind}$	$\mathcal{E}_{ind}, I_{ind}$	$\vec{F}_{net}$	Compress or Expand
pull magnet from loop	$\otimes$	$\odot$	Counterclockwise	$\otimes$	Expand
push loop to magnet	$\odot$	$\otimes$	Clockwise	$\odot$	Compress
pull loop from magnet	$\otimes$	$\odot$	Counterclockwise	$\otimes$	Expand
push reversed magnet to loop	$\otimes$	$\odot$	Counterclockwise	$\odot$	Compress

p.517 See Figure 12.9(a). The observer is to the right.

Situation	$\frac{d\vec{B}_{ext}}{dt}$	$\vec{B}_{ind}$	$\mathcal{E}_{ind}, I_{ind}$	$\vec{F}_{net}$	Compress or Expand
reverse primary	$\otimes$	$\odot$	Counterclockwise	$\odot$	Compress

Table problems 12-4.11 and 12-4.13

12–4.11

Observer	$\frac{d\vec{B}_{ext}}{dt}$	$\vec{B}_{ind}$	$\mathcal{E}_{ind}, I_{ind}$	$\vec{\tau}$	Compress or Expand
reader	$\otimes$	$\odot$	Counterclockwise	opposite $\vec{\omega}$	Expand

12–4.13 See Figure 12.32.

Observer	$\frac{d\vec{B}_{ext}}{dt}$	$\vec{B}_{ind}$	$\mathcal{E}_{ind}, I_{ind}$	$\vec{F}_{net}$	Compress or Expand
from above	$\otimes$	$\odot$	Counterclockwise	$\odot$	Compress