ANSWERS TO ODD-NUMBERED PROBLEMS

CHAPTER 1

1.1. (a) 2 m; (b) 0.8 m northward and 0.4 m eastward; (c) 0.8944 m

1.5. 21

1.7. $2\mathbf{i}_x + 2\mathbf{i}_y + \mathbf{i}_z$

1.9. $(4\mathbf{i}_x - 5\mathbf{i}_y + 3\mathbf{i}_z)/5\sqrt{2}$; $6\sqrt{2}$

1.11. $(4\mathbf{i}_x + 4\mathbf{i}_y + \mathbf{i}_z)\, dz$

1.13. $(4\mathbf{i}_x - \mathbf{i}_y)/\sqrt{17}$

1.15. $x + y + z = \text{constant}$

1.17. $\omega(-y\mathbf{i}_x + x\mathbf{i}_y)$

1.19. Traveling wave progressing in the negative z direction

1.21. (a) Linear; (b) circular; (c) elliptical

1.23. Elliptical polarization

1.25. $5 \cos (\omega t + 6.87°)$

1.27. $\sqrt{8\pi\epsilon_0 l^2\, mg}$

1.29. $\dfrac{0.0555Q}{\epsilon_0}(\mathbf{i}_x + \mathbf{i}_y + \mathbf{i}_z)$ N/C

1.31. $\dfrac{10^{-7}}{\pi\epsilon_0} \sum_{i=1}^{50} (2i - 1)[10^{-4}(2i - 1)^2 + 1]^{-3/2}\mathbf{i}_y$

1.33. $\dfrac{4 \times 10^{-7}}{\pi\epsilon_0} \sum_{i=1}^{50} \sum_{j=1}^{50} [10^{-4}(2i - 1)^2 + 10^{-4}(2j - 1)^2 + 1]^{-3/2}\mathbf{i}_z$

1.35. (a) $0.4485 \times 10^{-6} \sin 2\pi \times 10^7 t\, \mathbf{i}_x$ amp/m^2
(b) $0.4485 \times 10^{-8} \sin 2\pi \times 10^7 t$ amp

1.37. $d\mathbf{F}_1 = 0$; $d\mathbf{F}_2 = \dfrac{\mu_0}{4\pi} I_1 I_2\, dx\, dy\, \mathbf{i}_x$

1.39. (a) $(5 \times 10^{-5}\mu_0/\pi)\mathbf{i}_z$; (b) $-(10^{-4}\mu_0/4\pi)\mathbf{i}_z$

1.41. $0.179\mu_0\mathbf{i}_z$

1.43. $-v_0 B_0(14\mathbf{i}_y + 7\mathbf{i}_z)$

CHAPTER 2

2.1. 0.855

2.3. 1

2.7. 1/6

2.9. $\dfrac{(4n^2 - 1)(1 - e^{-1})}{12n^3(1 - e^{-1/n})} e^{-1/2n}$; 0.20825, 0.21009, 0.21070, 0.21071

2.11. 16π

2.13. 30 amp

2.15. $-B_0 b v_0\left(\dfrac{1}{x_0 + a} - \dfrac{1}{x_0}\right)$

2.17. $B_0 b\omega \ln \dfrac{x_0 + a}{x_0} \sin \omega t - B_0 b v_0\left(\dfrac{1}{x_0 + a} - \dfrac{1}{x_0}\right) \cos \omega t$

2.19. $2B_0\omega \sin \omega t$

2.21. 0

2.23. (a) 0; (b) $I_1 - I_2$

2.25. $\dfrac{J_0 r}{2}$ for $r < a$ and $\dfrac{J_0 a^2}{2r}$ for $r > a$, direction circular to the axis of the wire

2.27. (a) $I/4$; (b) $I/4$

2.29. 1/2

2.31. $\dfrac{\rho_{L0}}{2\pi\epsilon_0 r}$, direction radially away from the line charge

2.33. (a) $Q/8$; (b) $Q/8$

2.35. $-1/2$ amp

CHAPTER 3

3.1. $\omega B_0 \dfrac{z^2}{2} \sin \omega t\, \mathbf{i}_x$

3.3. (a) $z\mathbf{i}_x + x\mathbf{i}_y + y\mathbf{i}_z$; (b) 0

3.5. $\frac{1}{3} \times 10^{-7} \cos (6\pi \times 10^8 t - 2\pi z)\, \mathbf{i}_y$ Wb/m²

3.7. $\mathbf{B} = -\omega\mu_0\epsilon_0 E_0 \frac{z^3}{3} \cos \omega t\, \mathbf{i}_y$

$\mathbf{E} = -\omega^2\mu_0\epsilon_0 E_0 \frac{z^4}{12} \sin \omega t\, \mathbf{i}_x$

3.9. $\mathbf{E} = 10 \cos (6\pi \times 10^8 t - 2\pi z)\, \mathbf{i}_x$

$\mathbf{B} = \frac{10^{-7}}{3} \cos (6\pi \times 10^8 t - 2\pi z)\, \mathbf{i}_y$

3.11. $J_0(a + z)\mathbf{i}_y$ for $-a < z < 0$, $J_0(a - z)\, \mathbf{i}_y$ for $0 < z < a$, 0 otherwise

3.13. Curl will have a component in the y direction in addition to the x component

3.15. Curl has only a z component

3.17. $\oint_C \mathbf{A} \cdot d\mathbf{l} = 0$ for any C

3.19. (a) $3(x^2 + y^2 + z^2)$; (b) 0

3.21. (a) $-x\mathbf{i}_z$, y; (b) $-\mathbf{i}_z$, 0; (c) 0, 1; (d) 0, 0

3.23. $\frac{\rho_0}{2a\epsilon_0}(x^2 - a^2)\mathbf{i}_x$ for $-a < x < a$, 0 otherwise

3.25. (a) and (c)

3.27. $\nabla \cdot \mathbf{r} = 3$

3.29. $\oint_S \mathbf{A} \cdot d\mathbf{S} = 2\pi$, $\nabla \cdot \mathbf{A} = 3$

3.31. 0

CHAPTER 4

4.1. (a) 0.2 amp; (b) 0; (c) 0.2 amp

4.3. (a) $0.2 \cos \omega t$ amp; (b) $0.2 \sin \omega t$ amp; (c) $0.2828 \sin (\omega t + 45°)$ amp

4.5. (a) $\pm 0.0368 \cos \omega t\, \mathbf{i}_y$; (b) $\pm 0.0135 \cos \omega t\, \mathbf{i}_y$

4.7. $J_0 \frac{a}{2}\mathbf{i}_y$ for $z < -a$, $-J_0\left(z + \frac{z^2}{2a}\right)\mathbf{i}_y$ for $-a < z < 0$, $-J_0\left(z - \frac{z^2}{2a}\right)\mathbf{i}_y$ for $0 < z < a$, $-J_0 \frac{a}{2}\mathbf{i}_y$ for $z > a$

4.9. $-(\rho_0 a/\epsilon_0)\mathbf{i}_x$ for $x < -a$, $(\rho_0 x/\epsilon_0)\mathbf{i}_x$ for $-a < x < a$, $(\rho_0 a/\epsilon_0)\mathbf{i}_x$ for $x > a$

4.15. $(t - z\sqrt{\mu_0\epsilon_0})^2$ corresponds to a (+) wave; $(t + z\sqrt{\mu_0\epsilon_0})^2$ corresponds to a (−) wave

4.17. $C = \frac{\eta_0 J_{S0}}{2}$

For Problem 4.13, $E_x = \frac{\eta_0 J_{S0}}{2}(t \mp z\sqrt{\mu_0\epsilon_0})^2$ for $z \gtrless 0$ and

$H_y = \pm\frac{E_x}{\eta_0}$ for $z \gtrless 0$

4.19. $\mathbf{E} = [0.1\eta_0 \cos(6\pi \times 10^8 t \mp 2\pi z) + 0.05\eta_0 \cos(12\pi \times 10^8 t \mp 4\pi z)]\mathbf{i}_x$ for $z \gtrless 0$

$\mathbf{H} = \pm\frac{E_x}{\eta_0}\mathbf{i}_y$ for $z \gtrless 0$

4.21. (a) Same as in Fig. 4.17, except displaced to the left by 1/3 μs; (b) 75.4 V/m for $300(n - 1/3) < |z| < 300n$ and -37.7 V/m for $300(n - 1) < |z| < 300(n - 1/3)$, $n = 1, 2, 3, \ldots$; (c) $0.2z/|z|$ amp/m for $300(n - 1) < |z| < 300(n - 2/3)$ and $-0.1z/|z|$ amp/m for $300(n - 2/3) < |z| < 300n$, $n = 1, 2, 3, \ldots$

4.23. (a) 0; (b) $\eta_0 J_{S0} \sin\omega t \sin\beta z\, \mathbf{i}_x$; (c) 0

4.25. (a) $\frac{\eta_0 J_{S0}}{2}[\cos(\omega t + \beta z)\,\mathbf{i}_x - \cos(\omega t + \beta z)\,\mathbf{i}_y]$, linear;

(b) $\frac{\eta_0 J_{S0}}{2}[\cos(\omega t - \beta z)\,\mathbf{i}_x - \cos(\omega t + \beta z)\,\mathbf{i}_y]$, elliptical except at $z = 0$, $\lambda/8$, $\lambda/4$, $3\lambda/8$, and $\lambda/2$;

(c) $\frac{\eta_0 J_{S0}}{2}[\cos(\omega t - \beta z)\,\mathbf{i}_x - \cos(\omega t - \beta z)\,\mathbf{i}_y]$, linear

4.27. (a) 0; (b) -3.00 kHz; (c) 1.732 kHz

4.31. (a) $-\frac{E_0}{\eta_0}\sin(\omega t - \beta z)\,\mathbf{i}_x + \frac{E_0}{\eta_0}\cos(\omega t - \beta z)\,\mathbf{i}_y$; (b) $\frac{E_0^2}{\eta_0}\mathbf{i}_z$

CHAPTER 5

5.1. (a) 0.1724×10^{-4} V/m, 0.1724×10^{-6} V, 0.1724×10^{-5} ohms; (b) 0.2857×10^{-4} V/m, 0.2857×10^{-6} V, 0.2857×10^{-5} ohms; (c) 250 V/m, 2.5 V, 25 ohms

5.3. 1.5245×10^{-19} s

5.5. (a) $-8.667 \times 10^{-7} \sin 2\pi \times 10^9 t$ amp; (b) $-2.778 \times 10^{-6} \sin 2\pi \times 10^9 t$ amp; (c) $-4.444 \times 10^{-5} \sin 2\pi \times 10^9 t$ amp

5.7. (a) $\epsilon_0 E_0(4\mathbf{i}_x + 2\mathbf{i}_y + 2\mathbf{i}_z)$; (b) $8\epsilon_0 E_0(\mathbf{i}_x + \mathbf{i}_y + \mathbf{i}_z)$; (c) $0.5E_0(3\mathbf{i}_x - \mathbf{i}_y - \mathbf{i}_z)$

5.9. $|e|^2 B_0 a^2/2m$, 0.7035×10^{-18} amp-m²

5.11. $0.5 \times 10^{-6} \sin 2\pi z$ amp

5.13. $\frac{\partial^2 \bar{H}_y}{\partial z^2} = \bar{\gamma}^2 \bar{H}_y$

5.15. 0.00083 nepers/m, 4.7562×10^{-3} rad/m, 1.32105×10^8 m/s, 1321.05 m, $(161.102 + j28.115)$ ohms

5.17. $\mathbf{E} = 3.736e^{\mp 0.0404z}\cos\left(2\pi \times 10^6 t \mp 0.0976z + \frac{\pi}{8}\right)\mathbf{i}_x$ for $z \gtrless 0$

$\mathbf{H} = \pm 0.05\, e^{\mp 0.0404z}\cos(2\pi \times 10^6 t \mp 0.0976z)\,\mathbf{i}_y$ for $z \gtrless 0$

5.19. 16.09 m, 1.917:1, 90° out of phase

5.21. (a) 30 MHz; (b) 5 m; (c) 1.5×10^8 m/s; (d) $4\epsilon_0$;
(e) $\frac{1}{6\pi}\cos(6\pi \times 10^7 t - 0.4\pi z)\,\mathbf{i}_y$ amp/m

5.23. (a) $\mathbf{H} = 0.1\cos(3\pi \times 10^7 t - 0.4\pi z)\,\mathbf{i}_y$, $\mathbf{B} = 2\mu_0\mathbf{H}$, $\mathbf{M} = \mathbf{H}$, $\mathbf{J}_m = -0.04\pi \cdot \sin(3\pi \times 10^7 t - 0.4\pi z)\,\mathbf{i}_x$; (b) $\mathbf{E} = 6\pi\cos(3\pi \times 10^7 t - 0.4\pi z)\,\mathbf{i}_x$, $\mathbf{D} = 8\epsilon_0 E$, $\mathbf{P} = 7\epsilon_0\mathbf{E}$, $\mathbf{J}_p = -0.035\pi\sin(3\pi \times 10^7 t - 0.4\pi z)\,\mathbf{i}_x$

5.25. (a) 0.0211 nepers/m, 18.73 rad/m, 0.3354×10^8 m/s, 0.3354 m, 42.15 ohms; (b) $2\pi \times 10^{-3}$ nepers/m, $2\pi \times 10^{-3}$ rad/m, 10^7 m/s, 1000 m, $2\pi(1 + j)$ ohms

5.27. 1 Hz

CHAPTER 6

6.1. $\pm(\mathbf{i}_x + 2\mathbf{i}_y + 3\mathbf{i}_z)/\sqrt{14}$

6.3. $H_0(2\mathbf{i}_x - \mathbf{i}_y)/\sqrt{5}$

6.5. $\rho_S = 3\,|D_0|$, $\mathbf{J}_S = H_0(2\mathbf{i}_x + \mathbf{i}_y - 2\mathbf{i}_z)\,D_0/|D_0|$

6.7. (a) $2\pi\cos(2\pi \times 10^6 t - 0.02\pi z)$ V; (b) $0.25\cos(2\pi \times 10^6 t - 0.02\pi z)$ amp; (c) $0.5\pi\cos^2(2\pi \times 10^6 t - 0.02\pi z)$ W

6.11. Exact values are $\mathcal{L} = 0.1994\mu$, $\mathcal{C} = 5.0155\epsilon$, and $\mathcal{G} = 5.0155\sigma$

6.13. (a) $\mathcal{L} = 0.278 \times 10^{-6}$ H/m, $\mathcal{G} = 4.524 \times 10^{-16}$ mho/m;
(b) $(52.73 + j0)$ ohms

6.17. (a) $\frac{\partial \bar{V}}{\partial z} = -\mathcal{Z}\bar{I}$, $\frac{\partial \bar{I}}{\partial z} = -\mathcal{Y}\bar{V}$; (c) $\bar{\gamma} = \sqrt{\frac{\mathcal{L}_1}{\mathcal{L}_2} - \omega^2\mathcal{L}_1\mathcal{C}}$

6.19. $1667\frac{\lambda}{4}$ at $f = 50.01$ MHz

6.21. $2.25\epsilon_0$

6.23. 4.7746 cm

6.25. $\mathbf{E}_2 = E_0(4\mathbf{i}_x + 2\mathbf{i}_y - 6\mathbf{i}_z)$, $\mathbf{H}_2 = H_0(4\mathbf{i}_x - 3\mathbf{i}_y)$

6.27. All boundary conditions are satisfied

6.29. (a) $\frac{1}{16}P_i$; (b) $\frac{9}{16}P_i$; (c) $\frac{3}{8}P_i$

6.31. 150 ohms

CHAPTER 7

7.1. $0.05\pi(\sqrt{3}\,\mathbf{i}_x + \mathbf{i}_y)$

7.3. $\frac{1}{2\sqrt{2}}\mathbf{i}_x + \frac{\sqrt{3}}{2}\mathbf{i}_y + \frac{1}{2\sqrt{2}}\mathbf{i}_z$

7.5. (a) Yes; (b) $\frac{1}{24\pi}(\sqrt{3}\,\mathbf{i}_y - \mathbf{i}_z)\cos[6\pi \times 10^7 t - 0.1\pi(y + \sqrt{3}\,z)]$

7.7. (a) $\frac{1}{2}(\mathbf{i}_x + \sqrt{3}\,\mathbf{i}_z)$; (b) $8\sqrt{3}$ m, 24 m

7.9. 1 cm

7.11. 3600 MHz, 5400 MHz

7.13. $\text{TE}_{1,0}$ mode; $10 \sin 20\pi x \sin\left(10^{10}\pi t - \frac{80\pi}{3}z\right)\mathbf{i}_y$

7.15. $\Gamma = -0.3252$, $\tau = 0.6748$

7.17. (a) 0; (b) -5 m/s

7.19. 2.4×10^8 m/s

7.23. $\text{TE}_{1,0}$, $\text{TE}_{0,1}$, $\text{TE}_{2,0}$, $\text{TE}_{1,1}$, and $\text{TM}_{1,1}$

7.25. 6.5 cm, 3.5 cm

7.27. 3535.5 MHz ($\text{TE}_{1,0,1}$, $\text{TE}_{0,1,1}$), 4330.1 MHz ($\text{TE}_{1,1,1}$, $\text{TM}_{1,1,1}$), 5590.2 MHz ($\text{TE}_{2,0,1}$, $\text{TE}_{0,2,1}$, $\text{TE}_{1,0,2}$, $\text{TE}_{0,1,2}$)

7.29. (a) 41.81°; (b) 48.6°

CHAPTER 8

8.1. $0.2\pi \cos 2\pi \times 10^7 t$ amp

8.5. 0.2λ

8.7. (a) 1.257×10^{-3} V/m; (b) $R_{\text{rad}} = 0.0351$ ohm, $\langle P_{\text{rad}} \rangle = 1.7546$ W

8.9. 1.111 W

8.11. $\sqrt{(D_2 R_{\text{rad}2})/(D_1 R_{\text{rad}1})}$

8.13. $1\frac{7}{8}$

8.15. 0.60943

8.17. 1.015 W

8.19. (a) $E_\theta = -\frac{\eta\beta L I_0 \sin\theta}{8\pi r}\sin(\omega t - \beta r)$, $H_\phi = \frac{E_\theta}{\eta}$;
(b) $R_{\text{rad}} = 20\pi^2(L/\lambda)^2$, $D = 1.5$

8.21. $-\frac{\pi}{4}$, $\cos\left(\frac{\pi}{4}\cos\psi - \frac{\pi}{8}\right)$

8.23. $\cos^2\left(\frac{\pi}{2}\cos\psi\right)$

8.25. $\left|\cos\psi \cos\left(\frac{\pi}{4}\cos\psi - \frac{\pi}{4}\right)\right|$

8.27. $\left[\cos\left(\frac{\pi}{2}\cos\theta\right)\right]/\sin\theta$, where θ is the angle from the vertical, $D = 3.284$

8.29. 4

8.31. 0.00587 V

CHAPTER 9

9.1. (a) $\dfrac{x\mathbf{i}_x + y\mathbf{i}_y + z\mathbf{i}_z}{\sqrt{x^2 + y^2 + z^2}}$; (b) $yz\mathbf{i}_x + zx\mathbf{i}_y + xy\mathbf{i}_z$

9.3. $\dfrac{1}{3\sqrt{5}}(5\mathbf{i}_x + 2\mathbf{i}_y + 4\mathbf{i}_z)$

9.5. 2.121

9.7. $Q/30\pi\epsilon_0$

9.9. $V = \dfrac{10^{-5}}{\pi\epsilon_0}\sum_{i=1}^{50}[10^{-4}(2i - 1)^2 + y^2]^{-1/2}$

$\mathbf{E} = \dfrac{10^{-5}}{\pi\epsilon_0}\sum_{i=1}^{50}[10^{-4}(2i - 1)^2 + 1]^{-3/2}\mathbf{i}_y$

9.11. (a) $-\dfrac{4\epsilon_0 V_0}{9d^2}\left(\dfrac{x}{d}\right)^{-2/3}$; (b) $[\rho_s]_{x=0} = 0$, $[\rho_s]_{x=d} = \dfrac{4\epsilon_0 V_0}{3d}$

9.13. $V = -\dfrac{kx^3}{6\epsilon} + \dfrac{kd^2x}{8\epsilon}$ for $-\dfrac{d}{2} < x < \dfrac{d}{2}$

9.15. (a) $\dfrac{\epsilon_2 x}{\epsilon_2 t + \epsilon_1(d - t)}V_0$ for $0 < x < t$, $\dfrac{\epsilon_2 t + \epsilon_1(x - t)}{\epsilon_2 t + \epsilon_1(d - t)}V_0$ for $t < x < d$

(b) $\dfrac{\epsilon_2 t}{\epsilon_2 t + \epsilon_1(d - t)}V_0$

9.17. (a) $V_0\dfrac{\sinh(\pi x/b)}{\sinh(\pi a/b)}\sin\dfrac{\pi y}{b} + \dfrac{V_0}{3}\dfrac{\sinh(3\pi x/b)}{\sinh(3\pi a/b)}\sin\dfrac{3\pi y}{b}$

(b) $0.1963V_0$

9.19. $\sum_{n=1,3,5,\ldots}^{\infty}\dfrac{4V_0}{n\pi}\cos\dfrac{n\pi}{4}\dfrac{\sinh(n\pi x/b)}{\sinh(n\pi a/b)}\sin\dfrac{n\pi y}{b}$

9.21. (a) 16.91 V; (b) 16.92 V; (c) 15.53 V. Exact value = 15.17 V

9.23. 90.886 V

9.25. (b) $\bar{Z}_{in} = \dfrac{j\omega\mu dl}{w}\left(1 - \dfrac{j\omega\mu\sigma l^2}{3}\right)$; equivalent circuit consists of an inductor L in parallel with a resistor $3R$ where $L = \mu dl/w$ and $R = d/\sigma lw$

9.27. $\bar{Y}_{in} = \dfrac{j\omega\epsilon wl}{d}\left(1 + \dfrac{\omega^2\mu\epsilon l^2}{3}\right)$; equivalent circuit consists of a capacitor C in series with an inductor $(1/3)L$ where $C = \epsilon wl/d$ and $L = \mu dl/w$

9.29. 5×10^5 amp-turns/Wb

9.31. 8.4×10^{-4} Wb

CHAPTER 10

10.1. (a) 240 km; (b) 6 MHz; (c) 10 MHz

10.3. (a) 0.9475 Hz; (b) 0.0347 Hz

10.5. 15 cm

10.7. 45.39°

10.11. -0.00533 mho, 1.667

10.13. 0.14λ, 0.192λ

10.15. (a) $0.0359E_0(-\sqrt{3}\,\mathbf{i}_x - \mathbf{i}_z)\cos[6\pi \times 10^9 t - 10\pi(-x + \sqrt{3}\,z)]$;
(b) $0.5359E_0(\mathbf{i}_x - \mathbf{i}_z)\cos[6\pi \times 10^9 t - 17.32\pi(x + z)]$

10.17. 50.77°; perpendicular to the plane of incidence

10.19. (a) 8.02 m, 20; (b) 25.38 m, 52

10.21. 1.645

10.25. (a) 0.1654×10^{-3} V/m; (b) $R_{\text{rad}} = 0.6077 \times 10^{-3}$ ohms, $\langle P_{\text{rad}} \rangle = 0.0304$ W

APPENDIX A

A.1. $-3\,\mathbf{i}_x + \sqrt{3}\,\mathbf{i}_y + \mathbf{i}_z$

A.3. Equal

A.5. $-\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}\mathbf{i}_z$

A.7. $13\mathbf{i}_r + 6\mathbf{i}_z$

APPENDIX B

B.1. (a) $-\sin\phi\,\mathbf{i}_z$, $\cos\phi$; (b) 0, 0 except at $r = 0$; (c) 0 except at $r = 0$, 0

B.3. $\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial \Phi}{\partial r}\right) + \frac{1}{r^2}\frac{\partial^2 \Phi}{\partial \phi^2} + \frac{\partial^2 \Phi}{\partial z^2}$

B.5. (a) $-\frac{1}{r^2}(\sin\theta\,\mathbf{i}_r - \cos\theta\,\mathbf{i}_\theta)$; (b) $\cos\theta\,\mathbf{i}_r - \sin\theta\,\mathbf{i}_\theta$