Answers to Selected Problems

Chapter 1

1-1 (a) $\sqrt{6}$ (b) $\mathbf{a}_x \frac{1}{\sqrt{6}} - \mathbf{a}_y \frac{1}{\sqrt{6}} + \mathbf{a}_z \frac{2}{\sqrt{6}}$ (c) 1 (d) $\frac{1}{\sqrt{6}}$ (e) 73.2°

(f) $-\mathbf{a}_x - \mathbf{a}_y 3 - \mathbf{a}_z$ (g) −7

1-3 (a) $5\sqrt{2}$ (b) $\mathbf{a}_x \frac{3}{5\sqrt{2}} - \mathbf{a}_y \frac{4}{5\sqrt{2}} + \mathbf{a}_z \frac{1}{\sqrt{2}}$ (c) 0 (d) 0 (e) 90°

(f) $\mathbf{a}_x 15 + \mathbf{a}_y 20 + \mathbf{a}_z 25$ (g) 50

1-6 For Problem 1-1, (a) $\mathbf{a}_x 7 - \mathbf{a}_y 3 - \mathbf{a}_z 5$ (b) $\mathbf{A}\cdot\mathbf{B} = 1$, $\mathbf{A}\cdot\mathbf{C} = -7$

For Problem 1-3, (a) $\mathbf{a}_x 80 - \mathbf{a}_y 60$ (b) $\mathbf{A}\cdot\mathbf{B} = 0$, $\mathbf{A}\cdot\mathbf{C} = -20$

1-7 $\sqrt{2}$ **1-12** (b) $\mathbf{a}_x \frac{2}{\sqrt{5}} - \mathbf{a}_y \frac{1}{\sqrt{5}}$

1-17 (a) $\phi = 0°$, $\mathbf{a}_\phi = \mathbf{a}_y$ (b) $\phi = 90°$, $\mathbf{a}_\phi = -\mathbf{a}_x$ (c) $\theta = 90°$, $\mathbf{a}_\theta = -\mathbf{a}_z$

1-18 (a) $\left(\sqrt{2}, 45°, 1\right), \left(\sqrt{3}, 55°, 45°\right)$ (c) $\left(1, 0°, 1\right), \left(\sqrt{2}, 45°, 0°\right)$

1-19 (a) $\left(\frac{1}{\sqrt{2}}, \frac{1}{\sqrt{2}}, 2\right), \left(\sqrt{5}, 27°, 45°\right)$ (c) $\left(0, -2, 3\right), \left(\sqrt{13}, 33.7°, 270°\right)$

1-20 (a) $\left(\frac{1}{2}, \frac{1}{2}, \frac{1}{\sqrt{2}}\right), \left(\frac{1}{\sqrt{2}}, 45°, \frac{1}{\sqrt{2}}\right)$ (c) $\left(-1.84, 1.84, -1.5\right), \left(\frac{3\sqrt{3}}{\sqrt{2}}, 135°, -\frac{3}{2}\right)$

1-24 (a) 0 (b) No **1-27** (a) 7 (b) 7. Yes **1-29** (a) πr_0^4 (b) $\frac{\pi}{2} r_0^4$. No

1-31 (a) $-\mathbf{a}_x e^{-x} \sin 2y \cos 3z + \mathbf{a}_y 2 e^{-x} \cos 2y \cos 3z - \mathbf{a}_z 3 e^{-x} \sin 2y \sin 3z$

(b) $\mathbf{a}_\rho 2\rho \sin 2\phi + \mathbf{a}_\phi 2\rho \cos 2\phi$ (c) $-\mathbf{a}_r 3r^{-4} \cos^2\theta - \mathbf{a}_\theta r^{-4} \sin 2\theta$

1-33 (a) $\nabla \cdot \mathbf{A} = z^2$, $\nabla \times \mathbf{A} = -\mathbf{a}_x 2yz + \mathbf{a}_y 2y - \mathbf{a}_z (2z + 6y)$

(b) $\nabla \cdot \mathbf{A} = -z^{-2} \cos\phi$, $\nabla \times \mathbf{A} = -\mathbf{a}_\rho \rho^{-1} z^{-1} \sin\phi$

(c) $\nabla \cdot \mathbf{A} = 4r \sin\theta - r \sin\phi \frac{\cos 2\theta}{\sin\theta}$,

$$\nabla \times \mathbf{A} = \mathbf{a}_r \frac{r}{\sin\theta}\left(\cos 2\theta + \cos\theta \cos\phi\right) - \mathbf{a}_\theta 3r \cos\theta - \mathbf{a}_\phi r \cos\theta \left(3 \sin\phi + 1\right)$$

1-35 (a) 1 km east, 4 km north (b) 576 m (c) 205 m/km

1-40 (a) $3/2$ (b) $3/2$ **1-43** (a) 0 (b) 0 (c) Yes

1-45 (a) $\pi/6$ (b) $\pi/6$ (c) No **1-47** (a) 2 (b) 2 (c) No

1-49 (a) $6\pi a^2$ (b) $6\pi a^2$ **1-51** (a) $-\frac{2}{3}a^3$ (b) $-\frac{2}{3}a^3$

Chapter 2

2-1 (a) $\frac{4\pi}{3}\left(b^3-a^3\right)\rho_{vo}$ **2-2** (b) $\frac{1}{9}\left(b^3-a^3\right)\left(d^3-c^3\right)\rho_{so}$

2-3 (c) $2\pi a \sin\theta_0 \; \rho_{\ell 0}$ **2-4** (a) $\pi a^2 \ell \rho_{vo}$

2-6 (a) $\frac{q}{4\pi\varepsilon_0 a^2}\left(1+\frac{1}{2\sqrt{2}}\right)\left(\mathbf{a}_x+\mathbf{a}_y\right)$ **2-7** $\frac{\sqrt{3}\,q^2}{4\pi\,\varepsilon_0\,a^2}$

2-9 (a) $\mathbf{E}=\mathbf{a}_r\frac{\rho_{vo}\,a^3}{12\varepsilon_0 r^2}\left(r\ge a\right);\;\mathbf{a}_r\frac{\rho_{vo}\,r}{\varepsilon_0}\left(\frac{1}{3}-\frac{r}{4a}\right)\left(r\le a\right)$

2-10 (a) $\mathbf{E}=0\left(r\le a\right);\;\mathbf{a}_r\frac{\rho_{vo}}{4\varepsilon_0 a}\frac{r^4-a^4}{r^2}\left(a\le r\le b\right);\;\mathbf{a}_r\frac{\rho_{vo}}{4\varepsilon_0 a}\frac{b^4-a^4}{r^2}\left(r\ge b\right)$

2-12 (a) $\mathbf{E}=0\left(r\le a\right);\;\mathbf{a}_r\frac{\rho_{s1}\,a^2}{\varepsilon_0 r^2}\left(a<r<b\right);\;\mathbf{a}_r\frac{\rho_{s1}\,a^2+\rho_{s2}b^2}{\varepsilon_0 r^2}\left(r>b\right)$

(b) $\rho_{s2}=-\rho_{s1}\frac{a^2}{b^2}$

2-16 $\mathbf{E}=\mathbf{a}_\rho\frac{-\rho_{vo}\left[e^{-k\rho^2}-1\right]}{2k\,\varepsilon_0\,\rho}\left(\rho<a\right);\;\mathbf{a}_\rho\frac{-\rho_{vo}\left[e^{-ka^2}-1\right]}{2k\varepsilon_0\,\rho}\left(\rho>a\right)$

2-18 $\mathbf{E}=0\;\left(\rho<a\right);\;\mathbf{a}_\rho\frac{1}{\varepsilon_0\rho}\left[\rho_{s1}a+\rho_{vo}\frac{\rho^2-a^2}{2}\right]\left(a<\rho<b\right);$

$=\mathbf{a}_\rho\frac{1}{\varepsilon_0\rho}\left[\left(\rho_{s1}a-\rho_{s2}b\right)+\rho_{vo}\frac{b^2-a^2}{2}\right]\left(\rho>b\right)$

2-20 (a) $\mathbf{E}=\mathbf{a}_x\frac{\rho_{vo}x}{\varepsilon_0}\left(|x|<\frac{d}{2}\right);\;\mathbf{a}_x\frac{\rho_{vo}d}{2\varepsilon_0}\left(x>\frac{d}{2}\right);\;-\mathbf{a}_x\frac{\rho_{vo}d}{2\varepsilon_0}\left(x<-\frac{d}{2}\right)$

2-25 (a) $\mathbf{a}_z\frac{\rho_{\ell 0}\,za}{2\varepsilon_0\left(z^2+a^2\right)^{3/2}}$ (b) $\frac{\rho_{\ell 0}\,a}{2\varepsilon_0\sqrt{z^2+a^2}}$ (c) $\mathbf{a}_z\frac{Q}{4\pi\varepsilon_0\,z^2}$ (d) $\frac{Q}{4\pi\varepsilon_0 z}$

2-31 (a) $\mathbf{a}_z\frac{\rho_{so}}{2\varepsilon_0}\left[\frac{z}{\sqrt{z^2+a^2}}-\frac{z}{\sqrt{z^2+b^2}}\right]$ (b) $\mathbf{a}_z\frac{Q}{4\pi\varepsilon_0 z^2}$

2-32 (a) $\frac{\rho_{so}}{2\varepsilon_0}\left[\sqrt{z^2+b^2}-\sqrt{z^2+a^2}\right]$ (c) $\frac{Q}{4\pi\varepsilon_0 z}$

2-34 $\mathbf{a}_z\frac{\rho_{so}z}{2\varepsilon_0 a}\left[\ln\left(\frac{a+\sqrt{z^2+a^2}}{|z|}\right)-\frac{a}{\sqrt{z^2+a^2}}\right]$

2-36 (a) $\mathbf{a}_z \dfrac{\rho_{\ell 0} a}{\pi\varepsilon_0} \dfrac{z}{\left(z^2+\dfrac{a^2}{4}\right)\sqrt{z^2+\dfrac{a^2}{2}}}$ **2-37** (a) $\dfrac{\rho_{\ell 0}}{\pi\varepsilon_0} \ln\left[\dfrac{\dfrac{a}{2}+\sqrt{z^2+\dfrac{a^2}{2}}}{-\dfrac{a}{2}+\sqrt{z^2+\dfrac{a^2}{2}}}\right]$

2-41 (a) $\mathbf{a}_z \dfrac{\rho_{\ell 0}\, a}{2\varepsilon_0}\left[\dfrac{1}{\sqrt{a^2+(z-\ell/2)^2}} - \dfrac{1}{\sqrt{a^2+(z+\ell/2)^2}}\right]$ (b) $\mathbf{a}_z \dfrac{Q}{4\pi\varepsilon_0 z^2}$

2-50 $\mathbf{E} = \mathbf{a}_\rho \dfrac{\rho_{\ell 0}}{2\pi\varepsilon_0\rho}\,(\rho < a,\ \rho > b);\ \ 0(a<\rho<b),\ \ \rho_s = -\dfrac{\rho_{\ell 0}}{2\pi a}\,(\rho = a);\ \dfrac{\rho_{\ell 0}}{2\pi b}\,(\rho = b)$

2-52 (a) $\rho_s = -\dfrac{a^3}{3b^2}\rho_{vo}\,(r=b);\quad \dfrac{a^3}{3c^2}\rho_{vo}\,(r=c)$

(b) $\mathbf{E} = \mathbf{a}_r \dfrac{\rho_{vo}}{3\varepsilon_0} r\ \ (r<a);\ \mathbf{a}_r \dfrac{\rho_{vo}\, a^3}{3\varepsilon_0 r^2}\ (a<r<b,\ r>c);\ 0\ (b<r<c)$

Chapter 3

3-1 (a) $\rho_{pv} = 0,\ \rho_{ps} = \pm P_0\ \ (\text{at } z = \pm\dfrac{\ell}{2})$ (b) $\rho_{pv} = 0,\ \rho_{ps} = P_0\cos\theta$

(c) $\rho_{pv} = -3P_0,\ \rho_{ps} = \dfrac{\ell}{2}P_0$ (on all six surfaces)

3-6 $\mathbf{E} = \mathbf{a}_z \dfrac{P_o}{2\varepsilon_o}\left[\dfrac{z+\ell/2}{\sqrt{(z+\ell/2)^2+a^2}} - \dfrac{z-\ell/2}{\sqrt{(z-\ell/2)^2+a^2}}\right]$

3-8 $\mathbf{E} = -\mathbf{a}_z \dfrac{P_0}{3\varepsilon_0}$ **3-9** $\mathbf{E} = -\mathbf{a}_r \dfrac{P_0 r}{\varepsilon_0 a}\,(r<a);\ 0\,(r>a),\ \mathbf{D} = 0$ everywhere

3-15 (a) $2\pi\left[\dfrac{1}{\varepsilon_1}\ln\dfrac{b}{a}+\dfrac{1}{\varepsilon_2}\ln\dfrac{c}{b}\right]^{-1}$ **3-17** (a) $\dfrac{\pi\varepsilon_1}{\ln\dfrac{c}{a}} + \dfrac{\pi\varepsilon_2\varepsilon_3}{\varepsilon_2\ln\dfrac{c}{b}+\varepsilon_3\ln\dfrac{b}{a}}$

3-18 (a) $w\ell\left[\dfrac{d_1}{\varepsilon_1}+\dfrac{d_2}{\varepsilon_2}\right]^{-1}$ (b) $\dfrac{w}{d}(\ell_1\varepsilon_1+\ell_2\varepsilon_2)$ **3-26** $W_e = \dfrac{4\pi\rho_0^2 a^5}{15\varepsilon_0}$

3-39 (a) $\mathbf{D} = \mathbf{a}_\rho \dfrac{\rho_{\ell 0}}{2\pi\rho}$ everywhere, $\mathbf{E} = \mathbf{a}_\rho \dfrac{\rho_{\ell 0}}{2\pi\varepsilon_0\varepsilon_r\rho}\,(\rho<a);\ \mathbf{a}_\rho \dfrac{\rho_{\ell 0}}{2\pi\varepsilon_0\rho}\,(\rho>a)$,

$\mathbf{P} = \mathbf{a}_\rho \dfrac{\rho_{\ell 0}}{2\pi\rho}\left(1-\dfrac{1}{\varepsilon_r}\right)(\rho<a);\ 0(\rho>a)$ (b) $\rho_{pv} = 0,\ \rho_{ps} = \dfrac{\rho_{\ell 0}}{2\pi a}\left(1-\dfrac{1}{\varepsilon_r}\right)$

Chapter 4

4-5 $V = V_0 \dfrac{\phi}{\phi_0}$, $\mathbf{E} = -\mathbf{a}_\phi \dfrac{V_0}{\phi_0}\dfrac{1}{\rho}$ **4-9** $V(r,\theta) = \dfrac{q(2d)\cos\theta}{4\pi\varepsilon_0 r^2}$

4-10 Seven image charges are needed.

4-11 An infinite number of image charges are needed.

4-13 $\rho_s = -\dfrac{\rho_\ell}{2\pi}\left\{\dfrac{a - s\cos\phi}{s^2 + a^2 - 2sa\cos\phi} - \dfrac{a - d\cos\phi}{d^2 + a^2 - 2ad\cos\phi}\right\}$

4-18 (b) Solve $\dfrac{q}{(d-a)} = -\dfrac{q^1}{(a-s)}$ and $\dfrac{q}{(a+d)} = -\dfrac{q^1}{(a+s)}$

4-23 $V(x,y) = \displaystyle\sum_{n=\text{odd}} \frac{4V_0}{n\pi} \frac{\cosh\left(\frac{n\pi}{b}x\right)}{\cosh\left(\frac{n\pi}{b}a\right)} \sin\left(\frac{n\pi}{b}y\right)$

4-25 $V(x,y) = V_0 \left\{ \sin\left(\dfrac{\pi}{a}x\right) \dfrac{\sinh\left(\frac{\pi}{a}y\right)}{\sinh\pi} + \sin\left(\dfrac{2\pi}{a}y\right) \dfrac{\sinh\left(\frac{2\pi}{a}x\right)}{\sinh(2\pi)} \right\}$

4-29 $V(\rho,\phi) = \displaystyle\sum_{n=\text{odd}} \frac{\left(-4V_0 \sin\frac{n\pi}{2}\right)}{n\pi} \left(\frac{\rho}{a}\right)^n \cos n\phi \ (\rho \le a);$

$\qquad = \displaystyle\sum_{n=\text{odd}} \frac{\left(-4V_0 \sin\frac{n\pi}{2}\right)}{n\pi} \left(\frac{a}{\rho}\right)^n \cos n\phi \ (\rho \ge a)$

4-31 $V(\rho,\phi) = \dfrac{\rho_{so}}{4\varepsilon_0 a}\rho^2 \sin 2\phi \ (\rho<a);\ \dfrac{\rho_{so} a^3}{4\varepsilon_0}\dfrac{1}{\rho^2}\sin 2\phi \ (\rho>a)$

4-32 $V(r,\theta) = -E_0 r\cos\theta + E_0 \dfrac{a^3}{r^2}\cos\theta$

4-36 (a) $\rho_{pv} = 0$, $\rho_{ps} = P_0\cos\theta$ (b) $\mathbf{E} = -\mathbf{a}_z \dfrac{P_0}{3\varepsilon_0}$

(c) $V(r,\theta) = \dfrac{P_0}{3\varepsilon_0} r\cos\theta \ (r<a);\ \dfrac{P_0}{3\varepsilon_0}\dfrac{a^3}{r^2}\cos\theta \ (r>a)$

Chapter 5

5-1 (b) $\mathbf{J} = \mathbf{a}_z \dfrac{3I_0}{2\pi \cancel{a^2}}\rho$

a^3

5-3 (a) $9\ \text{m}\Omega$ (b) 3.54×10^{7} S/m (c) 9×10^{-4} V/m (d) 8.78×10^{-5} W

5-4 (a) $1.27\times10^{6}\ \text{A/m}^2$ (b) 5.79×10^{7} S/m (c) 9.43×10^{-5} m/s (d) $4.29\times10^{-3}\ \text{m}^2/\text{sV}$

5-5 (a) 8.15 ps **5-6** $\dfrac{a}{\sigma_1 A}+\dfrac{b}{\sigma_2 A}$ **5-7** $\dfrac{d}{(\sigma_1\ell_1+\sigma_2\ell_2)w}$ **5-8** (b) $\dfrac{1}{4\pi\sigma}\left(\dfrac{1}{a}-\dfrac{1}{b}\right)$

5-10 $\dfrac{1}{2\pi}\dfrac{1}{\sigma_1+\sigma_2}\left(\dfrac{1}{a}-\dfrac{1}{b}\right)$ **5-12** $\dfrac{1}{2\pi\ell}\left\{\dfrac{1}{\sigma_1}\ln\dfrac{b}{a}+\dfrac{1}{\sigma_2}\ln\dfrac{c}{b}\right\}$

Chapter 6

6-2 (a) positive (b) $\dfrac{mv_0}{qB_0}$

6-3 $\mathbf{B}=\mathbf{a}_\phi\dfrac{\mu_0 I\rho}{2\pi a^2}\ (\rho<a);\ \mathbf{a}_\phi\dfrac{\mu_0 I}{2\pi\rho}\ (a<\rho<b);\ \mathbf{a}_\phi\dfrac{\mu_0 I}{2\pi\rho}\dfrac{c^2-\rho^2}{c^2-b^2}\ (b<\rho<c);\ 0\ (\rho>c)$

6-5 $\mathbf{B}=\mathbf{a}_\phi\mu_0 J_0\dfrac{e^{-\alpha a}}{\alpha^2}\dfrac{1}{\rho}\left(\alpha\rho e^{\alpha\rho}-e^{\alpha\rho}+1\right)\ (\rho<a);\mathbf{a}_\phi\mu_0 J_0\dfrac{1}{\alpha^2}\dfrac{1}{\rho}\left(\alpha a-1+e^{-\alpha a}\right)\ (\rho>a)$

6-8 $\mathbf{B}=0\ (\rho<a);\ \mu_0 J_0\dfrac{a}{\rho}(\rho-a)\ (a<\rho<b);\ \mu_0 J_0\dfrac{a}{\rho}(b-a)\ (\rho>b)$

6-10 $\mathbf{B}=\mathbf{a}_x\mu_0 J_0 z\left(|z|<\dfrac{d}{2}\right);\ \mathbf{a}_x\mu_0 J_0\dfrac{d}{2}\left(z>\dfrac{d}{2}\right);\ -\mathbf{a}_x\mu_0 J_0\dfrac{d}{2}\left(z<-\dfrac{d}{2}\right)$

6-17 $\mathbf{B}=\mathbf{a}_z\mu_0 I_0\dfrac{\sqrt{3}a^2}{8\pi^2}\dfrac{1}{\left(z^2+\dfrac{a^2}{12}\right)\sqrt{z^2+\dfrac{a^2}{3}}}$

6-22 Assuming the strip is on the xz plane, $\mathbf{B}=\mathbf{a}_y\dfrac{\mu_0}{2\pi}\dfrac{I}{w}\ln\dfrac{x+w/2}{x-w/2}$ at points on the xz plane

6-24 $\mathbf{B}=\dfrac{\mu_0 I}{4\pi}\dfrac{d}{z^2+(d/2)^2}\left\{\mathbf{a}_z\left(1+\dfrac{\pi d/4}{\sqrt{z^2+(d/2)^2}}\right)-\mathbf{a}_x\dfrac{z}{\sqrt{z^2+(d/2)^2}}\right\}$

6-26 $\mathbf{B}=\mathbf{a}_z\dfrac{\mu_0 J_{so}}{2}\left\{\dfrac{-a}{\sqrt{z^2+a^2}}+\ln\dfrac{\left|\sqrt{z^2+a^2}+a\right|}{|z|}\right\}$

6-28 $\mathbf{B}=\mathbf{a}_z\dfrac{\mu_0 J_0}{2}\left\{\left(z+\dfrac{\ell}{2}\right)\ln\dfrac{a+\sqrt{a^2+\left(z+\ell/2\right)^2}}{\left|z+\ell/2\right|}-\left(z-\dfrac{\ell}{2}\right)\ln\dfrac{a+\sqrt{a^2+\left(z-\ell/2\right)^2}}{\left|z-\ell/2\right|}\right\}$

6-32 (a) $\mathbf{a}_z\mu_0 J_{so}\dfrac{\pi}{4}$ (b) $\dfrac{\mu_0 m}{4\pi r^3}\left(\mathbf{a}_r 2\cos\theta+\mathbf{a}_\theta\sin\theta\right)$; $m = J_{so}\dfrac{\pi^2 a^3}{2}$

6-33 (a) $\mathbf{a}_z\mu_0 J_{so}\dfrac{2}{3}$ (b) $m = \dfrac{4}{3}\pi J_{so}a^3$

6-39 $\dfrac{d\mathbf{F}_m}{dz}$ on the left top wire $= \dfrac{\mu_0 I^2}{4\pi a}\left(-\mathbf{a}_x+\mathbf{a}_y\right)$ **6-42** $\dfrac{dF_m}{dz} = \dfrac{\mu_0 I^2}{2\pi w}\ln\left|1+\dfrac{w}{d}\right|$

6-43 $\dfrac{dF_m}{dz} = \dfrac{\mu_0 I^2}{2\pi w^2}\left\{-2(w+d)\left[\ln(w+d)-1\right]+d(\ln d-1)+(2w+d)\left[\ln(2w+d)-1\right]\right\}$

Chapter 7

7-1 (a) $\mathbf{J}_m = 0$, $\mathbf{J}_{ms} = \mathbf{a}_z M_0\sin\phi$ (b) $\mathbf{J}_m = 0$, $\mathbf{J}_{ms} = \mp\mathbf{a}_y M_0$ at $z = \pm\dfrac{d}{2}$.

7-3 (a) $\mathbf{J}_m = -\mathbf{a}_\phi\dfrac{M_0}{a}$, $\mathbf{J}_{ms} = \mathbf{a}_\phi M_0$ (b) $\mathbf{J}_m = -\mathbf{a}_\phi M_0\sin\theta\dfrac{2r}{a^2}$, $\mathbf{J}_{ms} = \mathbf{a}_\phi M_0\sin\theta$

7-5 (a) $\mathbf{B} = \mathbf{a}_z\left(\dfrac{2}{3}\mu_0 M_0-\dfrac{2}{3}\mu_0 M_0\right) = 0$ (b) $\mathbf{B} = \mathbf{B}_m+\mathbf{B}_{ms} = -\mathbf{a}_z\dfrac{2}{3}\mu_0 M_0+\mathbf{a}_z\dfrac{2}{3}\mu_0 M_0 = 0$

7-7 (a) $\mathbf{B} = \mathbf{a}_\phi\dfrac{\mu_1 I}{2\pi\rho}\ (\rho<a)$; $\mathbf{a}_\phi\dfrac{\mu_2 I}{2\pi\rho}\ (\rho>a)$ (b) $\mathbf{J}_m = 0$, $\mathbf{J}_{ms} = \mathbf{a}_z\dfrac{I}{2\pi a}\dfrac{\mu_2-\mu_1}{\mu_0}$

7-9 (a) $\mathbf{B} = \mathbf{a}_\phi\dfrac{\mu I}{2\pi\rho}\ (a<\rho<b)$; $0\ (\rho<a,\ \rho>b)$ $\mathbf{H} = \mathbf{a}_\phi\dfrac{I}{2\pi\rho}\ (a<\rho<b)$; $0\ (\rho<a,\ \rho>b)$

$\mathbf{M} = \mathbf{a}_\phi\dfrac{I}{2\pi\rho}\left(\dfrac{\mu}{\mu_0}-1\right)\ (a<\rho<b)$; $0\ (\rho<a,\ \rho>b)$

7-10 $\mathbf{B} = \mathbf{a}_\phi\mu\dfrac{NI}{2\pi\rho}$ (in the core); 0 (outside the core)

7-14 (a) $\mathbf{J}_m = 0$, $\mathbf{J}_{ms} = \mp\mathbf{a}_y M_0$ (at $z = \pm\dfrac{d}{2}$) (b) $\mathbf{B} = \mathbf{a}_x\mu_0 M_0\left(|z|<\dfrac{d}{2}\right)$; $0\left(|z|>\dfrac{d}{2}\right)$

(c) $\mathbf{H} = 0$ everywhere

7-26 $\dfrac{\mu N^2}{2\pi}c\ \ln\left[\dfrac{(a+b)(a+2b)}{a^2}\right]$ **7-27** $\mu_0 N_{\ell 1}N_{\ell 2}\pi a^2$

7-32 $L_{21}\approx\mu_0\dfrac{\pi(a_1 a_2)^2}{4d^3}$ **7-33** $L_{21} = \dfrac{\mu_0}{2\pi}N_1 N_2\, a_2\ln\left[1+\dfrac{a_2}{b+d}\right]$

7-36 $L_{21} = \dfrac{\mu_0}{\sqrt{3}\pi}\left[(d+b)\ln\left|1+\dfrac{b}{d}\right|-b\right]$

Chapter 8

8-1 (a) $\mathbf{E} = \mathbf{a}_\phi \dfrac{B_0\omega}{3a}\rho^2 \sin(\omega t)\ (\rho < a);\ \mathbf{a}_\phi \dfrac{B_0\omega a^2}{3\rho} \sin(\omega t)\ (\rho > a)$

(b) $V(t) = \dfrac{2\pi B_0\omega}{3a} b^3 \sin(\omega t),\ \ i(t) = \dfrac{V(t)}{R}$ (c) CCW

8-3 (b) $\mathbf{E} = \mathbf{a}_z \dfrac{\mu_0 I_0}{2\pi}\omega \sin(\omega t) \ln\dfrac{b}{a}\ (\rho < a);\ \mathbf{a}_z \dfrac{\mu_0 I_0}{2\pi}\omega \sin(\omega t) \ln\dfrac{b}{\rho}\ (a < \rho < b);\ 0\ (\rho > b)$

8-6 (a) $V(t) = -\mu_0 H_z\, \omega \cos(\omega t)\, ab$ (b) i(t) flows CW at $\omega t = \pi/4$

8-8 (a) $V_2(t) = -\dfrac{\mu_0 I_1}{2\pi}\omega \sin(\omega t)\ell \ln(1 + \dfrac{\ell}{d})$

8-11 (a) $V(t) = vB_0\ell\left[\omega(t + \dfrac{d}{v}) \sin\omega t - \cos\omega t\right]$ (b) $\mathbf{F} = \mathbf{a}_x \dfrac{V}{R} B_0 \ell$

8-12 $V(t) = -\omega B_0\, \ell\, d\, \sin\omega t$, i(t) CCW at $t = 0^+$

8-14 $V(t) = -N\pi a^2 B$ **8-16** (a) $\mathbf{H} = -\mathbf{a}_\phi \dfrac{\varepsilon}{2d}\dfrac{a^2}{\rho}\dfrac{\partial V}{\partial t}\ (\rho > a)$

8-17 (b) f > 676.3 kHz (c) No

8-19 (a) $\mathbf{E} = -\mathbf{a}_y \dfrac{kH_m}{\omega\varepsilon} \sin(\omega t - kz)$ (b) $k^2 = \omega^2\mu\varepsilon$

8-21 (a) $\mathbf{H} = \mathbf{a}_z \dfrac{0.06}{\omega\mu_0} \sin(\omega t - 0.02x)$ (b) $f \approx 955$ kHz

8-23 $E_{1x} = E_{1z} = 0,\ E_{1y} = \dfrac{\rho_s}{\varepsilon_0},\ H_{1x} = H_{1z} = 0,\ H_{1z} = J_{so}$

8-24 (a) $\mathbf{H} = -\mathbf{a}_\phi \dfrac{\rho}{2}\dfrac{V_0}{d}\left[\omega\varepsilon \cos\omega t + \sigma \sin\omega t\right]$ (b) $\mathbf{S} \,//\, -\mathbf{a}_\rho$ (c) $-P_{diss} = \dfrac{dW_e}{dt} + P_{f,out}$

8-26 (a) $\mathbf{B} = \mathbf{a}_z\, \mu_0 nKt,\ \mathbf{E} = -\mathbf{a}_\phi \dfrac{1}{2}\mu_0 nK\rho\ (\rho \le a)$ (b) $\mathbf{S} \,//\, -\mathbf{a}_\rho$ (c) $\dfrac{dW_m}{dt} + P_{f,out} = 0$

Chapter 9

9-3 $v = 1.88 \times 10^8$ m/s **9-5** $\underline{\mathbf{H}} = H_0\left\{\mathbf{a}_y\, e^{-j(5x + \frac{\pi}{2})} + \mathbf{a}_z\, e^{j5x}\right\}$

9-6 (a) $\mathbf{E}(z,t) = \mathbf{a}_x \cos(\omega t - 2z) - \mathbf{a}_y\, 2 \sin(\omega t - 2z)$

9-13 (a) $\underline{\mathbf{E}} = \mathbf{a}_z\, 5e^{-j(0.5x + \frac{\pi}{2})}$

(b) $\underline{\mathbf{H}} = -\mathbf{a}_y \dfrac{5}{2\omega\mu_0} e^{-j(0.5x + \frac{\pi}{2})},\ \mathbf{H}(x,t) = -\mathbf{a}_y \dfrac{2.5}{\omega\mu_0} \sin(\omega t - 0.5x)$

(c) $\omega = 1.06 \times 10^8$ rad/s (d) $\mathbf{S}_{av} = \mathbf{a}_x \dfrac{25}{\sqrt{2}\,\mu_0 c} = \mathbf{a}_x\, 0.047\ \text{W/m}^2$

9-15 (b) $\lambda = 1$ km **9-16** (b) f = 5.77 GHz

9-19 (b) $k_0 = 2\pi/3$ (c) $<\mathbf{S}> = \mathbf{a}_x\, 033\ \mathrm{W/m^2}$

9-20 (a) $f = 2.5$ GHz, $\varepsilon = 1.44\,\varepsilon_0$ (b) $n = 1.2$

(c) $\mathbf{E} = \mathbf{a}_z 2\sqrt{2}\, e^{jky}$, $\mathbf{H} = -\mathbf{a}_x \dfrac{2\sqrt{2}}{314} e^{jky}$, $H_{rms} = 6.37\,\mathrm{mA/m}$ (d) $314\ \Omega$

9-22 (a) $\mathbf{k} = 5.6\,(\mathbf{a}_x + \mathbf{a}_y 2 + \mathbf{a}_z 3)$ (b) $\mathbf{E} = \sqrt{5}\,(\mathbf{a}_x 2 - \mathbf{a}_y)\, e^{-j(5.6x+11.2y+16.8z)}$

(c) $\mathbf{H} = \dfrac{1}{\eta_0}\sqrt{\dfrac{5}{14}}\,(\mathbf{a}_x 3 + \mathbf{a}_y 6 - \mathbf{a}_z 5)\, e^{-j(5.6x+11.2y+16.8z)}$

9-24 (a) $\alpha = 37\,\mathrm{Np/m}$, $d_p = 2.7\,\mathrm{cm}$ (b) $4.77\ \mathrm{V/m}$

9-25 (a) $\alpha = 14.87\,\mathrm{Np/m}$, $d_p = 6.72\,\mathrm{cm}$ (b) L.T.= 0.09 (c) $\alpha = 1.86\times10^{-3}$, $d_p = 538.7$ m

9-27 $d_c > 3.3$ mm **9-31** $v_p = 1.58\times10^6$ m/s, $v_g = 3.16\times10^6$ m/s

9-32 (a) LP (b) LHCP (c) ~~L~~HEP R **9-33** (b) LHCP (c) RHEP

Chapter 10

10-3 $R = -0.8 + j0.002$, $T = 0.2 + j0.002$

10-5 $R = -0.514$, $T = 0.486$, $\mathbf{E} = \mathbf{a}_y T E_0\, e^{-j65.2x}\ e^{-0.067x}$

10-8 (a) $3x + 4z$ = const. (b) $\mathbf{k} = \mathbf{a}_x 3 + \mathbf{a}_z 4$ (c) $f = 238.7$ MHz

(d) $\mathbf{H} = \dfrac{1}{120\pi}(-\mathbf{a}_x 4 + \mathbf{a}_z 3)\, e^{-j(3x+4z)}$, $<\mathbf{S}> = \dfrac{25}{2\omega\mu_0}\mathbf{k}$

10-9 (a) $\theta_i = 36.9°$ (b) $\theta_r = 36.9°$, $\theta_t = 23.6°$

(c) $\mathbf{E}_r = \mathbf{a}_y R_\perp 5 e^{-j(3x-4z)}$, $\mathbf{H}_r = \dfrac{5}{\omega\mu_o} R_\perp (\mathbf{a}_x 4 + \mathbf{a}_z 3)\, e^{-j(3x-4z)}$, $R_\perp = -0.264$

(d) $\mathbf{E}_t = \mathbf{a}_y T_\perp 5 e^{-j(3x+6.87z)}$, $\mathbf{H}_t = \dfrac{5T_\perp}{\omega\mu_0}(-\mathbf{a}_x 6.87 + \mathbf{a}_z 3)\, e^{-j(3x+6.87z)}$, $T_\perp = 0.736$

(e) 6.99% (f) 93%

10-15 (a) $\theta_i = 67.4°$ (b) $\theta_r = 67.4°$, $\theta_t = 8.85°$ (c) $R_{\parallel} = -0.59$
(d) $T_{\parallel} = 0.41$ (e) 35% (f) 65%

10-19 Decompose the incident wave into a sum of a perpendicularly polarized wave and a parallel polarized wave.

10-21 (b) $\theta_B = 61°$ when $\alpha = 0.05$ (d) $\theta_B = 29°$, $\theta_c = 33.7°$ when $\alpha = 0.05$

10-24 65.37 m **10-31** (a) TE (b) Parallel **10-32** (a) Parallel (b) 33°

10-35 (a) $\mathbf{E}_r = -\mathbf{a}_y 5 e^{j(3x-4z)}$, $\mathbf{H}_r = \dfrac{1}{\eta_0}(\mathbf{a}_x 4 + \mathbf{a}_z 3)\, e^{j(3x-4z)}$ (b) 1

10-38 $f = 75\,\mathrm{MHz}$, $|\mathbf{E}| = \dfrac{\sqrt{3}}{2} E_{max}$ at 1m in front of the plate.

Chapter 11

11-5 (a) 0, 6, 12,18, 24 GHz (b) TM_0, TM_1, TM_2, TM_3

11-8 $k_z = 471.2$ rad/m, $\lambda_g = 13.3$ mm, $v_p = 2 \times 10^8$ m/s, $Z_{TM} = 90.5\ \Omega$,

$\mathbf{S}_{av} = \mathbf{a}_z\, 3\,|E_0|^2 \cos^2(200\pi\, x)$ mW/m^2

11-11 (a) $0 < f < 1.88$ kHz (b) $1.88 < f < 3.75$ kHz

11-17 (a) 2.39×10^6 W/cm (b) 7.89×10^5 W/cm (c) 7.89×10^5 W/cm

11-19 (a) TE_{10}, TE_{01}, TE_{20}, TE_{11}, TM_{11} (b) $k_z = 124.5$ rad/m, $f_c = 6.95$ GHz,

$v_p = 4.04 \times 10^8$ m/s, $\lambda_g = 5.05$ cm, $Z_{TM} = 124.3\ \Omega$ (c) $2.87 < f < 5.74$ GHz

(d) $5.23 < \lambda < 10.45$ cm

11-21 (a) TE_{10}, TE_{20}, TE_{01}, TE_{11}, TM_{11} (c) $11.7 < f < 23.4$ GHz

11-27 (a) No (b) Yes **11-28** a = 3.2 cm, b = 1.8 cm

11-30 a = 1.5 cm, b = 0.75 cm **11-32** $k_z = -j24.9$, -4.32 dB

11-34 $f_r = 10.6$ GHz, $Q \approx 6.2\times10^3$ **11-35** (a) a = 21.2 cm (b) a = 13.3 cm

11-37 The first three are 10.6 GHz, 16.8 GHz, 18.4 GHz

11-39 $\mathbf{J}_s = \mathbf{a}_z \dfrac{K_0}{\eta a} e^{-jkz}$ (at $\rho = a$), $I_0 = \dfrac{2\pi K_0}{\eta}$

11-46 $v = 1.875 \times 10^8$ m/s, $L = 0.569$ μH/m, $Z_o = 106.7\ \Omega$, $G = 2.21 \times 10^{-14}$ S/m

11-47 $\Gamma_L = \dfrac{1}{3}$, $Z_{in} = 49 - j35\,\Omega$ **11-48** $10 + j30\ \Omega$

11-52 $\Gamma_L = 0.34\, e^{-j126°}$, $Z_L = 59 - j36\ \Omega$, $z_{max} = -10$ cm

Chapter 12

12-1 (a) $\mathbf{E} = \begin{cases} \mathbf{a}_x\, 2K(|z| - vt), & |z| < vt \\ 0, & |z| > vt \end{cases}$ $\mathbf{H} = \begin{cases} \mathbf{a}_y \dfrac{2K}{\eta}(z - vt), & 0 < z < vt \\ \mathbf{a}_y \dfrac{2K}{\eta}(z + vt), & -vt < z < 0 \\ 0, & |z| > vt \end{cases}$

(c) $\rho_v = \rho_s = 0$, $\mathbf{J} = 0$, $\mathbf{J}_s = \mathbf{a}_x \dfrac{4K}{\mu} t$ at $z = 0$

12-4 (a) $\mathbf{A} = \mathbf{a}_z \dfrac{\mu I_0 \Delta\ell}{8\pi r} e^{-jkr}$ (b) $\mathbf{E} = \mathbf{a}_\theta \dfrac{I_0 \Delta\ell}{8\pi} j\omega\mu \dfrac{e^{-jkr}}{r} \sin\theta$

12-5 0.039 W **12-7** (a) 0.067 V/m (b) 0.071 V/m

12-9 (a) $\dfrac{I_0 \Delta\ell\, j\omega\mu}{4\pi r}\, e^{-jkr}\left\{\mathbf{a}_\theta\,(\sin\theta + j\cos\theta\cos\phi) - \mathbf{a}_\phi\, j\sin\phi\right\}$

12-13 $P_r = \dfrac{4}{3}\eta\pi^5\left(\dfrac{a^2}{\lambda^2}\right)^2 I_0^2$ **12-17** $R_r = 36.5\ \Omega$, $D_{max} = 3.3$

12-18 14.64 kW **12-19** $|E_\theta| = 1.404$ V/m, $|H_\phi| = 3.72$ mA/m

12-21 $R_r = 199\ \Omega$, $D_{max} = 2.41$ **12-23** $e_r = 0.382$

12-25 (i) 90° (ii) 78° (iii) 47°

12-26 (i) $AF = \cos\left(\dfrac{\pi}{2}\cos\phi + \dfrac{\pi}{4}\right)$ (iii) $AF = \cos\left(\pi\cos\phi + \dfrac{\pi}{2}\right)$

12-28 $F(\theta,\phi) = \sqrt{1 - \sin^2\theta\cos^2\phi}\ \cos\left(\dfrac{\pi}{2}\sin\theta\cos\phi\right)$

12-31 SLL = −12 dB for N=5