ANSWERS TO ODD-NUMBERED PROBLEMS

Chapter 1

1.1. (a) $4\sqrt{3}$ units and directed 30° south of east (b) 0.51764 units and directed 45° north of east (c) 9.928 units and directed 30° south of east (d) $-6\sqrt{3}$ (e) 6 units and directed upwards (f) 0 (g) 0 (h) 2.784 (i) 1.607 units and directed upwards (j) 0 (k) 0 (l) 24 units and directed towards the north (m) 24 units and directed 30° north of east

1.3. $C^2 = A^2 + B^2 - 2AB\cos\theta$ where θ is the angle between $\mathbf{A}$ and $\mathbf{B}$.

1.5. (c) $d\mathbf{l} = \sqrt{u^2 + v^2}\, du\, \mathbf{i}_u + \sqrt{u^2 + v^2}\, dv\, \mathbf{i}_v + dz\, \mathbf{i}_z$ (d) $dv = (u^2 + v^2)\, du\, dv\, dz$

1.7. (c) $\alpha = 129.25°$, $\Delta = 29.38°$, $S = 38673$ Km (d) 208.97°, 25.17°

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

1.17. (a) Surfaces of constant magnitudes, T_0, are ellipsoids with intercepts on the x, y, and z axes at $\pm\sqrt{T_0}$, $\pm\sqrt{T_0/4}$, and $\pm\sqrt{T_0/9}$, respectively.
(b) Surfaces of constant magnitudes, U_0, are cylinders parallel to the z axis, having radii equal to $1/2U_0$ and with their axes passing through $x = \pm 1/2U_0, y = 0$.
(c) Surfaces of constant magnitudes, V_0, are toruses obtained by revolving, about the z axis, circles in the ϕ = constant plane with centers at $r_c = 1/2V_0$ and $z = 0$ and with radii equal to $1/2V_0$.

1.19. $\mathbf{F} = -(mMG/r^2)\mathbf{i}_r$ in the spherical coordinate system having its origin at the center of the earth. Constant magnitude surfaces are spheres concentric with the earth. Direction lines are radial lines converging towards the center of the earth.

1.23. (a) $\mathbf{v} = a\mathbf{i}_r + abt\,\mathbf{i}_\phi$, $\dfrac{d\mathbf{v}}{dt} = -ab^2t\,\mathbf{i}_r + 2ab\mathbf{i}_\phi$
(b) $\mathbf{v} = -\omega a \sin\omega t\, \mathbf{i}_x + \omega b\cos\omega t\,\mathbf{i}_y + c\mathbf{i}_z$
$\dfrac{d\mathbf{v}}{dt} = -\omega^2 a\cos\omega t\,\mathbf{i}_x - \omega^2 b\sin\omega t\,\mathbf{i}_y$

1.25. $(\mathbf{i}_r - \sqrt{3}\,\mathbf{i}_\phi)/2$

1.27.

Scalar function	x	y	z	r_c	ϕ	r_s	θ
Gradient	$\mathbf{i}_x$	$\mathbf{i}_y$	$\mathbf{i}_z$	$\mathbf{i}_{rc}$	$(1/r_c)\mathbf{i}_\phi$	$\mathbf{i}_{rs}$	$(1/r_s)\mathbf{i}_\theta$

1.29. 6.983

1.31. (a) 1/720 (b) $2\pi al$ (c) $\pi/16$

1.33. (a) 0 (b) $a^2l/2$

1.35. (a) $\pi/2$ (b) $\pi/2$ (c) $\pi/2$ (d) $\pi/2$

1.37. $-2/3$

1.39. $(e^{-1} - 1)\pi/2$

1.43.

Unit vector	$\mathbf{i}_x$	$\mathbf{i}_y$	$\mathbf{i}_z$	$\mathbf{i}_{rc}$	$\mathbf{i}_\phi$	$\mathbf{i}_{rs}$	$\mathbf{i}_\theta$
Divergence	0	0	0	$1/r_c$	0	$2/r_s$	$(\cot\theta)/r_s$

1.49. (a) 21/16 (b) 1/2 (c) 0 (d) 0

1.53. (a) $-y\mathbf{i}_x - z\mathbf{i}_y - x\mathbf{i}_z$ (b) $-2\mathbf{i}_z$ (c) $(2 + 2\sin\phi)\mathbf{i}_z$ (d) 0 except for $z = 0$
(e) $-(e^{-r}/r)\mathbf{i}_\phi$

1.63. (a) $6xyz^2 + 2x^3y$ (b) 0 (c) e^{-r}/r (d) $2(yz\mathbf{i}_x + zx\mathbf{i}_y + xy\mathbf{i}_z)$

Chapter 2

2.1. $-(mg/q)\mathbf{i}_r$, 55.7×10^{-12} N/C

2.3. (b) $y_L = qE_0L^2/2mv_0^2$, $\mathbf{v}_L = v_0\mathbf{i}_x + (qE_0L/mv_0)\mathbf{i}_y$
(c) $y_d = (qE_0L/mv_0^2)[(L/2) + d]$

2.5. $Q^2/\epsilon_0 l^2 mg = 4\pi/\sqrt{6}$

2.7. (a) $6Qd^2/4\pi\epsilon_0 z^4$ away from the quadrupole
(b) $3Qd^2/4\pi\epsilon_0 r^4$ towards the quadrupole

2.9. (a) $E_x = 0$, $E_y = 0$, $E_z = \rho_{L0}az/2\epsilon_0(a^2 + z^2)^{3/2}$
(b) $E_x = 0$, $E_y = -\rho_{L0}a^2/\pi\epsilon_0(a^2 + z^2)^{3/2}$, $E_z = 0$
(c) $E_x = -\rho_{L0}a^2/4\epsilon_0(a^2 + z^2)^{3/2}$, $E_y = 0$, $E_z = 0$
(d) $E_x = 0$, $E_y = -\rho_{L0}a^2/4\epsilon_0(a^2 + z^2)^{3/2}$, $E_z = 0$

2.11. (a) 0 for $|z| < a$, $\rho_{s0}a^2|z|/\epsilon_0 z^3$ for $|z| > a$
(b) $-\rho_{s0}/3\epsilon_0$ for $|z| < a$, $2\rho_{s0}a^3/3\epsilon_0|z^3|$ for $|z| > a$

2.13. $(\rho_0 r/2\epsilon_0)\mathbf{i}_r$ for $r < a$, and $(\rho_0 a^2/2\epsilon_0 r)\mathbf{i}_r$ for $r > a$, where the axis of the cylindrical charge is the z axis.

2.15. (a) $\mathbf{E} = (\rho_{L0}d/2\pi\epsilon_0 r^2)(\cos\phi\,\mathbf{i}_r + \sin\phi\,\mathbf{i}_\phi)$
(b) $x^2 + (y - c/2)^2 = (c/2)^2$, $z =$ constant; circles in planes normal to the z axis, with centers at $x = 0$ and $y = \pm c/2$, and having radii $c/2$.

2.17.
$$\mathbf{E} = \frac{\rho_{L0}}{4\pi\epsilon_0 r}\left[\left(\frac{z + a}{\sqrt{(z + a)^2 + r^2}} - \frac{z - a}{\sqrt{(z - a)^2 + r^2}}\right)\mathbf{i}_r + \left(\frac{r}{\sqrt{(z - a)^2 + r^2}} - \frac{r}{\sqrt{(z + a)^2 + r^2}}\right)\mathbf{i}_z\right]$$
where the line charge is located along the z axis between $z = -a$ and $z = a$.
Direction lines are given by
$\sqrt{(z + a)^2 + r^2} - \sqrt{(z - a)^2 + r^2} =$ constant

2.19. (a) π (b) $2\pi/3$ (c) $\pi/6$ (d) 2π (e) $\pi/2$ (f) $\pi/2$

2.21. $Q/8\epsilon_0$

2.23. (a) $\dfrac{\rho_0 z}{\epsilon_0}\mathbf{i}_z$ for $|z| < a$, $\dfrac{\rho_0 a|z|}{\epsilon_0 z}\mathbf{i}_z$ for $|z| > a$

(b) $\dfrac{\rho_0}{\epsilon_0}(|z| - a)\,\mathbf{i}_z$ for $|z| < a$, 0 for $|z| > a$

(c) $\dfrac{z^3}{2\epsilon_0|z|}\mathbf{i}_z$ for $|z| < a$, $\dfrac{a^2|z|}{2\epsilon_0 z}\mathbf{i}_z$ for $|z| > a$

(d) $\dfrac{z^2 - a^2}{2\epsilon_0}\mathbf{i}_z$ for $|z| < a$, 0 for $|z| > a$

(e) $\dfrac{1}{\epsilon_0}\left(az - \dfrac{z^3}{2|z|}\right)\mathbf{i}_z$ for $|z| < a$, $\dfrac{a^2 z}{2\epsilon_0|z|}\mathbf{i}_z$ for $|z| > a$

2.25. (a) 0 for $r < a$, $\dfrac{\rho_0}{3\epsilon_0 r^2}(r^3 - a^3)\mathbf{i}_r$ for $a < r < b$, $\dfrac{\rho_0}{3\epsilon_0 r^2}(b^3 - a^3)\mathbf{i}_r$ for $r > b$

(b) $\dfrac{\rho_0 r^2}{4\epsilon_0 a}\mathbf{i}_r$ for $r < a$, $\dfrac{\rho_0 a^3}{4\epsilon_0 r^2}\mathbf{i}_r$ for $r > a$

(c) $\dfrac{\rho_0(5a^2r^3 - 3r^5)}{15\epsilon_0 a^2 r^2}\mathbf{i}_r$ for $r < a$, $\dfrac{2\rho_0 a^3}{15\epsilon_0 r^2}\mathbf{i}_r$ for $r > a$

2.27. $(\rho_0/2\epsilon_0)\mathbf{c}$ where $\mathbf{c}$ is the vector drawn from the axis of the cylindrical surface of radius a to the axis of the cylindrical surface of radius b.

2.31. (a) $\rho_s = \begin{cases} (2/3)\rho_{s0} & z = 0 \\ (4/3)\rho_{s0} & z = a \end{cases}$

(b) $\rho = e^{-r}/r$

(c) $\rho_s = \begin{cases} Q/4\pi a^2 & r = a \\ -Q/4\pi b^2 & r = b \end{cases}$

2.35. 1 unit of work done by the field.

2.39. $\dfrac{3Q(\Delta x)(\Delta z)}{4\pi\epsilon_0 r^3}\sin\theta\cos\theta\cos\phi$

2.41. (a) $\dfrac{5Q}{32\pi\epsilon_0 r} + \dfrac{Q(9\sin\theta\cos\phi + 3\sin\theta\sin\phi)}{32\pi\epsilon_0 r^2}$

(b) $-\dfrac{3}{4\pi\epsilon_0 r} - \dfrac{\sin\theta\cos\phi + \sin\theta\sin\phi + \cos\theta}{\pi\epsilon_0 r^2}$

(c) $\dfrac{Q(\sin\theta\cos\phi + \cos\theta)}{2\pi\epsilon_0 r^2}$

$$+\frac{Q(3\sin^2\theta\cos^2\phi + 3\cos^2\theta + 3\sin\theta\cos\theta\cos\phi - 2)}{4\pi\epsilon_0 r^3}$$

2.43. (a) $\dfrac{\rho_{L0}}{4\pi\epsilon_0}\ln\dfrac{\sqrt{r^2 + z_0^2} + z_0}{\sqrt{r^2 + z_0^2} - z_0}$

(b) $\dfrac{1}{2\pi\epsilon_0}(\sqrt{r^2 + z^2} - r)$

(c) 0

2.45. (a) $(\rho_{s0}/2\epsilon_0)(|z_0| - |z|)$

(b) $(\rho_{s0}/2\epsilon_0)(|\sqrt{r_0^2 + z^2}| - |\sqrt{r_0^2 + z_0^2}| - |z| + |z_0|)$

(c) $(\rho_{s0}/2\epsilon_0)(|\sqrt{r_0^2 + z_0^2}| - |\sqrt{r_0^2 + z^2}|)$

(d) 0

(e) 0

2.47. For the line charge lying along the z axis between $z = -a$ and $z = a$,

$$V = \frac{\rho_{L0}}{4\pi\epsilon_0}\ln\frac{\sqrt{r^2 + (z + a)^2} + (z + a)}{\sqrt{r^2 + (z - a)^2} + (z - a)}$$

Equipotential surfaces are given by

$$\frac{(c-1)^2}{4c}\left(\frac{r}{a}\right)^2 + \frac{(c-1)^2}{(c+1)^2}\left(\frac{z}{a}\right)^2 = 1$$

where c is constant.

2.49. $\frac{\rho_0}{2\epsilon_0}\left(a^2 - \frac{r^2}{3}\right)$ for $r < a$, $\frac{\rho_0 a^3}{3\epsilon_0 r}$ for $r > a$

2.51. (a) $\frac{\rho_0}{4\epsilon_0}(a^2 - r^2)$ for $r < a$, $\frac{\rho_0 a^2}{2\epsilon_0} \ln \frac{a}{r}$ for $r > a$

(b) 0 for $r < a$, $\frac{\rho_0}{2\epsilon_0}\left(\frac{a^2 - r^2}{2} - a^2 \ln \frac{a}{r}\right)$ for $a < r < b$,

$\frac{\rho_0}{2\epsilon^0}\left(\frac{a^2 - b^2}{2} - a^2 \ln \frac{a}{b}\right) + \frac{\rho_0(b^2 - a^2)}{2\epsilon_0} \ln \frac{b}{r}$ for $r > b$

(c) $\frac{\rho_0 a^2}{3\epsilon_0} \ln \frac{a}{r}$ for $r < a$, $\frac{\rho_0}{9\epsilon_0 a}(a^3 - r^3)$ for $r > a$

2.53. (a) $\frac{\rho_{s0} z}{\epsilon_0}$ for $|z| < a$, $\frac{\rho_{s0} a|z|}{\epsilon_0 z}$ for $|z| > a$

(b) $\frac{\rho_{s0} a}{\epsilon_0} \ln \frac{b}{a}$ for $r < a$, $\frac{\rho_{s0} a}{\epsilon_0} \ln \frac{b}{r}$ for $a < r < b$, 0 for $r > b$

(c) $\frac{\rho_{s0} a^2}{\epsilon_0}\left(\frac{1}{a} - \frac{1}{b}\right)$ for $r < a$, $\frac{\rho_{s0} a^2}{\epsilon_0}\left(\frac{1}{r} - \frac{1}{b}\right)$ for $a < r < b$, 0 for $r > b$

2.55. (a) $\pi a^2 \rho_{L0} \mathbf{i}_x$ (b) 0 (c) $(\rho_{L0} a^2/2)(-\pi \mathbf{i}_x + 2\pi^2 \mathbf{i}_y)$

Dipole moments for cases (a) and (b) about any point other than the origin are the same as the respective dipole moments about the origin.

Chapter 3

3.1. $-e\mathbf{i}_x$

3.3. (b) $x_L = \frac{mv_0}{qB_0}\left[1 - \sqrt{1 - \left(\frac{qB_0 L}{mv_0}\right)^2}\right]$

$\mathbf{v}_L = \frac{qB_0 L}{m}\mathbf{i}_x + v_0 \sqrt{1 - \left(\frac{qB_0 L}{mv_0}\right)^2}\, \mathbf{i}_y$

(c) $x_d = x_L + \frac{qB_0 Ld}{mv_0}\left[1 - \left(\frac{qB_0 L}{mv_0}\right)^2\right]^{-1/2}$

3.5. mg/LB_0, 9800 amp from west to east

3.9. $\mathbf{F}_{21} = -(\mu_0/4\pi)I_1 I_2\, dl_1\, dl_2\, \mathbf{i}_z$, $\mathbf{F}_{12} = (\mu_0/4\pi)I_1 I_2\, dl_1\, dl_2\, \mathbf{i}_z$

$\mathbf{F}_{31} = (\mu_0/12\sqrt{3}\pi)I_1 I_2\, dl_1\, dl_3\, \mathbf{i}_y$, $\mathbf{F}_{13} = (\mu_0/12\sqrt{3}\pi)I_1 I_2\, dl_1\, dl_3\, \mathbf{i}_x$

$\mathbf{F}_{32} = (\mu_0/8\sqrt{2}\pi)I_2^2\, dl_2\, dl_3\, \mathbf{i}_y$, $\mathbf{F}_{23} = (\mu_0/8\sqrt{2}\pi)I_2^2\, dl_2\, dl_3\, \mathbf{i}_x$

3.11. $\frac{\mu_0 I_1 I_2 a}{2\pi}\left(\frac{1}{d} - \frac{1}{d+b}\right)$ towards the loop

$\frac{\mu_0 I_1 I_2 a}{2\pi}\left(\frac{1}{d} - \frac{1}{d+b}\right)$ towards the infinitely long wire

3.13. $\frac{d}{2}\sqrt{\frac{\pi W}{IL}}$

3.15. $\frac{\mu_0 n I a^2 \sin(2\pi/n)}{4\pi[(a \cos \pi/n)^2 + z^2](a^2 + z^2)^{1/2}}\, \mathbf{i}_z$

3.17. (a) $\frac{\mu_0 I a^2}{2}\left\{\frac{1}{[a^2 + (z-b)^2]^{3/2}} + \frac{1}{[a^2 + (z+b)^2]^{3/2}}\right\} \mathbf{i}_z$

3.19. (a) $\dfrac{\mu_0 n_0 I}{2}\left[\ln\dfrac{a+\sqrt{a^2+z^2}}{|z|} - \dfrac{a}{\sqrt{a^2+z^2}}\right]\mathbf{i}_z$

(b) $\dfrac{\mu_0 n_0 I}{2}\left[\dfrac{1}{|z|} - \dfrac{1}{\sqrt{a^2+z^2}}\right]\mathbf{i}_z$

(c) $\dfrac{\mu_0 n_0 I a}{z^2\sqrt{a^2+z^2}}\,\mathbf{i}_z$

3.21. (a) $(\mu_0 Id/2\pi r^2)(-\sin\phi\,\mathbf{i}_r + \cos\phi\,\mathbf{i}_\phi)$

(b) $(x - c/2)^2 + y^2 = (c/2)^2$, $z =$ constant; circles in planes normal to the z axis, with centers at $y = 0$ and $x = \pm c/2$, and having radii $c/2$.

3.23. (a) $3\mu_0 Ia^2 d/z^4$ away from the quadrupole

(b) $3\mu_0 Ia^2 d/2r^4$ towards the quadrupole

3.27. (a) $\dfrac{\mu_0 J_0 r}{2}\,\mathbf{i}_\phi$ for $r < a$, $\dfrac{\mu_0 J_0 a^2}{2r}\,\mathbf{i}_\phi$ for $r > a$

(b) 0 for $r < a$, $\dfrac{\mu_0 J_0}{2r}(r^2 - a^2)\mathbf{i}_\phi$ for $a < r < b$, $\dfrac{\mu_0 J_0}{2r}(b^2 - a^2)\mathbf{i}_\phi$ for $r > b$

(c) $\dfrac{\mu_0 J_0 a^2}{(n+2)r}\left(\dfrac{r}{a}\right)^{n+2}$ for $r < a$, $\dfrac{\mu_0 J_0 a^2}{(n+2)r}$ for $r > a$

3.29. (a) $-\mu_0 J_0 y\,\mathbf{i}_x$ for $|y| < a$, $-(\mu_0 J_0 a|y|/y)\mathbf{i}_x$ for $|y| > a$

(b) $\mu_0 J_0(|y| - a)\mathbf{i}_x$ for $|y| < a$, 0 for $|y| > a$

(c) $-(\mu_0 y^3/2|y|)\mathbf{i}_x$ for $|y| < a$, $-(\mu_0 a^2|y|/2y)\mathbf{i}_x$ for $|y| > a$

(d) $[\mu_0(a^2 - y^2)/2]\mathbf{i}_x$ for $|y| < a$, 0 for $|y| > a$

(e) $-\mu_0[ay - (y^3/2|y|)]\mathbf{i}_x$ for $|y| < a$, $-(\mu_0 a^2|y|/2y)\mathbf{i}_x$ for $|y| > a$

3.31. (a) $\mu_0 J_{s0}\mathbf{i}_x$ for $|y| < a$, 0 for $|y| > a$

(b) 0 for $r < a$, $(\mu_0 J_{s0} a/r)\mathbf{i}_\phi$ for $r > a$

(c) 0 for $r < a$, $(\mu_0 J_{s0} a/r)\mathbf{i}_\phi$ for $a < r < b$, 0 for $r > b$

3.33. 0 inside the sphere, $-(\mu_0 I/2\pi r_c)\mathbf{i}_\phi$ outside the sphere

3.37. (a) $\dfrac{2}{3}J_{s0}\mathbf{i}_z$ for $y = 0$, $\dfrac{4}{3}J_{s0}\mathbf{i}_z$ for $y = a$

(b) $3J_0 r\mathbf{i}_z$ for $r < a$, 0 for $a < r < b$, $-(J_0 a^3/b)\mathbf{i}_z$ for $r = b$, 0 for $r > b$

(c) $\dfrac{3}{2}J_{s0}\sin\theta\,\mathbf{i}_\phi$ for $r = a$

3.41. $\mathbf{A} = \dfrac{\mu_0 I}{4\pi}\ln\left[\dfrac{\sqrt{r^2+(z+a)^2}+(z+a)}{\sqrt{r^2+(z-a)^2}+(z-a)}\right]\mathbf{i}_z$

$\mathbf{B} = \dfrac{\mu_0 I}{4\pi r}\left[\dfrac{z+a}{\sqrt{r^2+(z+a)^2}} - \dfrac{z-a}{\sqrt{r^2+(z-a)^2}}\right]\mathbf{i}_\phi$

3.43. $\mathbf{A} = \dfrac{\mu_0 I\pi a^2\sin\theta}{4\pi r^2}\,\mathbf{i}_\phi$

$\mathbf{B} = \dfrac{\mu_0 I\pi a^2}{4\pi r^3}(2\cos\theta\,\mathbf{i}_r + \sin\theta\,\mathbf{i}_\theta)$

3.45. (a) $-\dfrac{\mu_0 J_0 y^2}{2}\,\mathbf{i}_z$ for $|y| < a$, $\left[-\dfrac{\mu_0 J_0 a^2}{2} - \mu_0 J_0 a(|y| - a)\right]\mathbf{i}_z$ for $|y| > a$

(b) $\mu_0 J_0\left(ay - \dfrac{y^3}{2|y|}\right)\mathbf{i}_z$ for $|y| < a$, $\dfrac{\mu_0 J_0 a^2 y}{2|y|}\,\mathbf{i}_z$ for $|y| > a$

(c) $-\dfrac{\mu_0|y^3|}{6}\,\mathbf{i}_z$ for $|y| < a$, $\dfrac{\mu_0(2a^3 - 3a^2|y|)}{6}\,\mathbf{i}_z$ for $|y| > a$

(d) $\dfrac{\mu_0(3a^2 y - y^3)}{6}\,\mathbf{i}_z$ for $|y| < a$, $\dfrac{\mu_0 a^3 y}{3|y|}\,\mathbf{i}_z$ for $|y| > a$

(e) $\frac{\mu_0(|y^3| - 3ay^2)}{6}\mathbf{i}_z$ for $|y| < a$, $\frac{\mu_0(a^3 - 3a^2|y|)}{6}\mathbf{i}_z$ for $|y| > a$

3.47. (a) $\mu_0 J_{s0} y \mathbf{i}_z$ for $|y| < a$, $(\mu_0 J_{s0}|y|/y)\mathbf{i}_z$ for $|y| > a$

(b) $\mu_0 J_{s0} a \ln \frac{b}{a}$ for $r < a$, $\mu_0 J_{s0} a \ln \frac{b}{r}$ for $a < r < b$, 0 for $r > b$

3.49. (a) $\mathbf{m} = (\pi n_0 I a^3/3)\mathbf{i}_z$ $\quad \mathbf{A} = (\mu_0 n_0 I a^3/12r^2)\sin\theta\,\mathbf{i}_\phi$

(b) $\mathbf{m} = (\pi n_0 I a^2/2)\mathbf{i}_z$ $\quad \mathbf{A} = (\mu_0 n_0 I a^2/8r^2)\sin\theta\,\mathbf{i}_\phi$

(c) $\mathbf{m} = \pi n_0 I a \mathbf{i}_z$ $\quad \mathbf{A} = (\mu_0 n_0 I a/4r^2)\sin\theta\,\mathbf{i}_\phi$

3.51. $(\mu_0 \rho_0 \omega_0 a^5/15r^2)\sin\theta\,\mathbf{i}_\phi$

3.53. $\left[x - \frac{d}{2}\left(\frac{c^2+1}{c^2-1}\right)\right]^2 + y^2 = \left(\frac{dc}{c^2-1}\right)^2$ where c is constant, $z = 0$

3.57. (a) Group (a) (b) Group (d) (c) Group (c) (d) Group (b) (e) Group (c)

Chapter 4

4.1. $\mathbf{E} = \mathbf{i}_x + \mathbf{i}_y$, $\mathbf{B} = \mathbf{i}_z$

4.3.
$$x = \frac{E_0}{\omega_c B_0}(\omega_c t - \sin\omega_c t) + \frac{v_0}{\omega_c}(1 - \cos\omega_c t)$$
$$y = \frac{E_0}{\omega_c B_0}(1 - \cos\omega_c t) + \frac{v_0}{\omega_c}\sin\omega_c t$$
$$z = 0$$

4.5.
$$x = \frac{qE_0}{m}\frac{\omega_c}{\omega_c^2 - \omega^2}\left(\frac{\sin\omega t}{\omega} - \frac{\sin\omega_c t}{\omega_c}\right)$$
$$y = \frac{E_0}{B_0}\frac{\omega_c}{\omega_c^2 - \omega^2}(\cos\omega t - \cos\omega_c t)$$
$$z = 0$$

4.7. $B_0 v_0 ab/y(y + a)$

4.9. $\left(B_0 b\omega \ln\frac{y+a}{y}\right)\sin\omega t + \frac{B_0 v_0 ab}{y(y+a)}\cos\omega t$

4.11. $\omega a B_0 \mathbf{i}_r$

4.15. $\frac{\mu_0 I}{2}\left(\frac{z+d}{\sqrt{a^2 + (z+d)^2}} - \frac{z-d}{\sqrt{a^2 + (z-d)^2}}\right)$

4.17. $\frac{\mu_0 I}{2}\left(\frac{z-a}{\sqrt{r^2 + (z-a)^2}} - \frac{z+a}{\sqrt{r^2 + (z+a)^2}}\right)$ for C outside the sphere

$\frac{\mu_0 I}{2}\left(2 + \frac{z-a}{\sqrt{r^2 + (z-a)^2}} - \frac{z+a}{\sqrt{r^2 + (z+a)^2}}\right)$ for C outside the sphere

4.19. $(7/8)\mu_0 I$

4.21. $1.0606\mu_0$

4.23. The magnetic field due to the moving charge is given by
$$\mathbf{B} = \frac{\mu_0 Q_0 v_0}{4\pi}\frac{r}{[r^2 + (v_0 t - z)^2]^{3/2}}\mathbf{i}_\phi$$
at an arbitrary point (r, ϕ, z).

4.25. $0.1471/\epsilon_0$ N-m

4.27. (a) $\frac{2\pi\rho_0^2}{15\epsilon_0}(2b^5 + 3a^5 - 5a^3b^2)$ N-m

(b) $\dfrac{\pi\rho_0^2 a^5}{7\epsilon_0}$ N-m

4.31. (a) $\dfrac{\mu_0 I_0^2}{4\pi}\left[\dfrac{c^4}{(c^2-b^2)^2}\ln\dfrac{c}{b}+\ln\dfrac{b}{a}-\dfrac{c^2}{2(c^2-b^2)}\right]$

(b) $\dfrac{\pi\mu_0 J_0^2}{9}\left(a^4\ln\dfrac{b}{a}+\dfrac{a^4}{6}\right)$

4.33. The energies associated with the current distributions of Problem 4.32 are
(a) $\mu_0 J_{s0}^2 a$ (b) $2\mu_0/15$

4.35. $\pi\mu_0(I_1^2\ln c/a + 2I_1I_2\ln c/b + I_2^2\ln c/b)$

4.37. $(V_0I_0/4)\sin 2\beta z$

4.39. $\dfrac{8\pi\beta E_0^2}{15\mu_0\omega}\cos^2(\omega t-\beta r)$

4.41. $4\cos(2t-96.87^\circ)$

4.43. (a) $\bar{E}_x = 2\underline{/135^\circ}$, $\bar{E}_y = 2\underline{/225^\circ}$

(b) The magnitude of the field vector is constant and equal to 2 units. The angle which the vector makes with the x axis varies as $(-\omega t + 135^\circ)$ with time. Hence, the field is circularly polarized.

4.45. (a) $\sqrt{3}x - 2y - 3z = \text{constant}$.

(c) The direction of polarization makes an angle of 25.67° with its projection, on to the xy plane, which makes an angle of 73.9° with the x axis.

4.47. (a) $\sqrt{3}x + 3y + 2z = \text{constant}$.

(c) $\mathbf{B} = \dfrac{0.04\pi}{\omega}[(-1+j2\sqrt{3})\mathbf{i}_x + (-\sqrt{3}-j2)\mathbf{i}_y + 2\sqrt{3}\,\mathbf{i}_z]e^{-j0.02\pi(\sqrt{3}x+3y+2z)}$

The field is left circularly polarized.

4.49. $2\epsilon_0$

Chapter 5

5.3. $-50\epsilon_0 y$ for $x = 0$, $y > 0$; $-50\epsilon_0 x$ for $y = 0$, $x > 0$;
$(50\epsilon_0/x)\sqrt{x^4+4}$ for $xy = 2$

5.7. 0 for $r = a$, $\rho_{L1}/2\pi b$ for $r = b$, $-\rho_{L1}/2\pi c$ for $r = c$, and $(\rho_{L1}+\rho_{L2})/2\pi d$ for $r = d$

5.11. (c) $3\epsilon_0 E_0\cos\theta$

(d) $\mathbf{E}_a = E_0\mathbf{i}_z$

$$\mathbf{E}_s = \begin{cases} -E_0(\cos\theta\,\mathbf{i}_r - \sin\theta\,\mathbf{i}_\theta) \text{ for } r < a \\ \dfrac{E_0a^3}{r^3}(2\cos\theta\,\mathbf{i}_r + \sin\theta\,\mathbf{i}_\theta) \text{ for } r > a \end{cases}$$

5.17. (b) $\dfrac{Q}{4\pi\epsilon_0 r^2}\mathbf{i}_r$ for $r < a$, $\dfrac{Q}{4\pi\epsilon_0(1+\chi_{e0})r^2}\mathbf{i}_r$ for $a < r < b$, $\dfrac{Q}{4\pi\epsilon_0 r^2}\mathbf{i}_r$ for $r > b$

5.19. (b) $\mathbf{E}_a = E_0(\cos\theta\,\mathbf{i}_r - \sin\theta\,\mathbf{i}_\theta)$

$$\mathbf{E}_s = \begin{cases} -\dfrac{\chi_{e0}}{3+\chi_{e0}}E_0(\cos\theta\,\mathbf{i}_r - \sin\theta\,\mathbf{i}_\theta) \text{ for } r < a \\ \dfrac{\chi_{e0}}{3+\chi_{e0}}\dfrac{E_0a^3}{r^3}(2\cos\theta\,\mathbf{i}_r + \sin\theta\,\mathbf{i}_\theta) \text{ for } r > a \end{cases}$$

(d) $\dfrac{3\chi_{e0}}{3+\chi_{e0}}\epsilon_0E_0\cos\theta$

5.21. (a) $\rho_{s0}d/\epsilon_0$ (b) $\rho_{s0}d/4\epsilon_0$ (c) $\rho_{s0}(d+t)/4\epsilon_0$ (d) $\dfrac{\rho_{s0}d}{\epsilon_2-\epsilon_1}\ln\dfrac{\epsilon_2}{\epsilon_1}$

5.23. (a) $\epsilon_0E_0\mathbf{i}_z$ (b) $\epsilon_0E_0\mathbf{i}_z$ (c) $\dfrac{E_0}{4}\left(1+\dfrac{z}{d}\right)^2\mathbf{i}_z$ (d) $\epsilon_0E_0\left[1-\dfrac{1}{4}\left(1+\dfrac{z}{d}\right)^2\right]\mathbf{i}_z$

(e) $-\dfrac{3}{4}\epsilon_0E_0$ for $z=0$, 0 for $z=d$ (f) $\dfrac{\epsilon_0E_0}{2d}\left(1+\dfrac{z}{d}\right)$

5.29. (b) $\dfrac{\mu_0I}{2\pi r}\mathbf{i}_\phi$ for $r<a$, $\mu_0(1+\chi_{m0})\dfrac{I}{2\pi r}\mathbf{i}_\phi$ for $a<r<b$, $\dfrac{\mu_0I}{2\pi r}\mathbf{i}_\phi$ for $r>b$

5.31. (b) $\mathbf{B}_a=B_0(\cos\theta\,\mathbf{i}_r-\sin\theta\,\mathbf{i}_\theta)$

$$\mathbf{B}_s=\begin{cases}\dfrac{2\chi_{m0}}{3+\chi_{m0}}B_0(\cos\theta\,\mathbf{i}_r-\sin\theta\,\mathbf{i}_\theta)\text{ for } r<a\\[2mm] \dfrac{\chi_{m0}}{3+\chi_{m0}}\dfrac{B_0a^3}{r^3}(2\cos\theta\,\mathbf{i}_r+\sin\theta\,\mathbf{i}_\theta)\text{ for } r>a\end{cases}$$

(d) $\dfrac{3\chi_{m0}}{3+\chi_{m0}}\dfrac{B_0}{\mu_0}\sin\theta\,\mathbf{i}_\phi$

5.33. (a) $\mu_0J_{s0}d$ (b) $4\mu_0J_{s0}d$ (c) $\mu_0J_{s0}(4d-2t)$ (d) $[(\mu_1+\mu_2)/2]J_{s0}d$

5.35. (a) $(B_0/\mu_0)\mathbf{i}_y$ (b) $(B_0/\mu_0)\mathbf{i}_y$ (c) $\left(1+\dfrac{z}{d}\right)^2B_0\mathbf{i}_y$ (d) $\left[\left(1+\dfrac{z}{d}\right)^2-1\right]\dfrac{B_0}{\mu_0}\mathbf{i}_y$

(e) 0 for $z=0$, $(3B_0/\mu_0)\mathbf{i}_x$ for $z=d$ (f) $-2\left(1+\dfrac{z}{d}\right)\dfrac{B_0}{\mu_0d}\mathbf{i}_x$

5.37. $\mu_r=kH$, $\mu_{ir}=2kH$, $\chi_m=kH-1$, $\mathbf{M}=(kH-1)\mathbf{H}$

5.39. (a) $\rho_{s0}^2d/2\epsilon_0$ (b) $\rho_{s0}^2d/8\epsilon_0$

5.41. (a) $\mu_0J_{s0}^2d/2$ (b) $2\mu_0J_{s0}^2d$

5.43. $\dfrac{2}{3\sqrt{k\mu_0}}B_0^{3/2}$

5.47. $B_0(5\mathbf{i}_x+4\mathbf{i}_y+5\mathbf{i}_z)$ Wb/m²

5.49. (a) $\mathbf{H}_1=\sqrt{\dfrac{\epsilon_0}{\mu_0}}[E_i\cos\omega(t-\sqrt{\mu_0\epsilon_0}\,z)-E_r\cos\omega(t+\sqrt{\mu_0\epsilon_0}\,z)]\mathbf{i}_y$

$\mathbf{H}_2=2\sqrt{\dfrac{\epsilon_0}{\mu_0}}E_t\cos\omega(t-2\sqrt{\mu_0\epsilon_0}\,z)\,\mathbf{i}_y$

(b) $\dfrac{E_r}{E_i}=-\dfrac{1}{3}\quad\dfrac{E_t}{E_i}=\dfrac{2}{3}$

Chapter 6

6.1. (a) $\dfrac{3a^2z-z^3}{6\epsilon}$ for $|z|<a$, $\dfrac{a^3|z|}{3\epsilon z}$ for $|z|>a$

(b) $\dfrac{\rho_0}{4\epsilon}(a^2-r^2)$ for $r<a$, $-\dfrac{\rho_0a^2}{2\epsilon}\ln\dfrac{r}{a}$ for $r>a$

(c) $\dfrac{\rho_0}{2\epsilon}(b^2-a^2)$ for $r<a$, $-\dfrac{\rho_0}{6\epsilon}\left(r^2+\dfrac{2a^3}{r}-3b^2\right)$ for $a<r<b$,

$\dfrac{\rho_0}{3\epsilon r}(b^3-a^3)$ for $r>b$

(d) $-\dfrac{\rho_0}{\epsilon}\left(\dfrac{r^2}{6}-\dfrac{r^4}{20a^2}-\dfrac{a^2}{4}\right)$ for $r<a$, $\dfrac{2\rho_0a^3}{15\epsilon r}$ for $r>a$

6.5. $V=\dfrac{V_0}{\ln\epsilon_2/\epsilon_1}\ln\dfrac{\epsilon_1d+(\epsilon_2-\epsilon_1)x}{\epsilon_1d}$

$$\mathbf{E} = -\frac{V_0}{\ln \epsilon_2/\epsilon_1} \frac{\epsilon_2 - \epsilon_1}{\epsilon_1 d + (\epsilon_2 - \epsilon_1)x} \mathbf{i}_x$$

6.7. (a) $\rho_s = \epsilon M_0 \cos\theta$ for $r = a$

(b) $\mathbf{E} = \begin{cases} -(M_0/3)\mathbf{i}_z & \text{for } r < a \\ (M_0 a^3/3r^3)(2\cos\theta\, \mathbf{i}_r + \sin\theta\, \mathbf{i}_\theta) & \text{for } r > a \end{cases}$

(c) $\mathbf{H} = \begin{cases} -(M_0/3)\mathbf{i}_z & \text{for } r < a \\ (M_0 a^3/3r^3)(2\cos\theta\, \mathbf{i}_r + \sin\theta\, \mathbf{i}_\theta) & \text{for } r > a \end{cases}$

$\mathbf{B} = \begin{cases} (2\mu_0 M_0/3)\mathbf{i}_z & \text{for } r < a \\ (\mu_0 M_0 a^3/3r^3)(2\cos\theta\, \mathbf{i}_r + \sin\theta\, \mathbf{i}_\theta) & \text{for } r > a \end{cases}$

6.9. $$V = V_1 \frac{\sinh(\pi x/b)}{\sinh(\pi a/b)} \sin(\pi y/b) + V_2 \frac{\sinh(3\pi x/b)}{\sinh(3\pi a/b)} \sin(3\pi y/b)$$

$$V = \frac{3V_1}{4} \frac{\sinh(\pi x/b)}{\sinh(\pi a/b)} \sin(\pi y/b) - \frac{V_1}{4} \frac{\sinh(3\pi x/b)}{\sinh(3\pi a/b)} \sin(3\pi y/b)$$

6.11. (a) $$V = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_0}{n\pi} \frac{\sinh[n\pi(x - a/2)/b]}{\sinh(n\pi a/2b)} \sin(n\pi y/b)$$

$$\mathbf{J}_c = -\frac{4V_0\sigma_0}{b} \sum_{n=1,3,5,\ldots}^{\infty} \frac{1}{\sinh(n\pi a/2b)} \times \left[\cosh\frac{n\pi}{b}\left(x - \frac{a}{2}\right) \sin\frac{n\pi y}{b}\, \mathbf{i}_x + \sinh\frac{n\pi}{b}\left(x - \frac{a}{2}\right) \cos\frac{n\pi y}{b}\, \mathbf{i}_y\right]$$

(b) $$V = \sum_{n=1,3,5,\ldots}^{\infty} \frac{4V_0}{n\pi} \frac{\cosh[n\pi(x - a/2)/b]}{\cosh(n\pi a/2b)} \sin(n\pi y/b)$$

$$\mathbf{J}_c = -\frac{4V_0\sigma_0}{b} \sum_{n=1,3,5,\ldots}^{\infty} \frac{1}{\cosh(n\pi a/2b)} \times \left[\sinh\frac{n\pi}{b}\left(x - \frac{a}{2}\right) \sin\frac{n\pi y}{b}\, \mathbf{i}_x + \cosh\frac{n\pi}{b}\left(x - \frac{a}{2}\right) \cos\frac{n\pi y}{b}\, \mathbf{i}_y\right]$$

(c) $$V = \sum_{n=1,3,5,\ldots}^{\infty} \left[\frac{4V_1}{n\pi} \frac{\sinh(n\pi x/b)}{\sinh(n\pi a/b)} \sin(n\pi y/b) + \frac{4V_2}{n\pi} \frac{\sinh(n\pi y/a)}{\sinh(n\pi b/a)} \cos(n\pi x/a)\right]$$

$$\mathbf{J}_c = -\sigma_0 \sum_{n=1,3,5,\ldots}^{\infty} \left\{\left[\frac{4V_1}{b} \frac{\cosh(n\pi x/b)}{\sinh(n\pi a/b)} \sin(n\pi y/b) + \frac{4V_2}{a} \frac{\sinh(n\pi y/a)}{\sinh(n\pi b/a)} \cos(n\pi x/a)\right]\mathbf{i}_x + \left[\frac{4V_1}{b} \frac{\sinh(n\pi x/b)}{\sinh(n\pi a/b)} \cos(n\pi y/b) + \frac{4V_2}{b} \frac{\cosh(n\pi y/a)}{\sinh(n\pi b/a)} \sin(n\pi x/a)\right]\mathbf{i}_y\right\}$$

6.13. The image charge is an infinitely long line charge of uniform density $-\rho_{L0}$ C/m situated parallel to the actual line charge and at a distance d from the grounded conductor on the side opposite to that of the actual line charge.

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

(b) $-\dfrac{\epsilon_1\epsilon_2 V_0}{\epsilon_2 t + \epsilon_1(d - t)}$ for $x = 0$, $\dfrac{\epsilon_1\epsilon_2 V_0}{\epsilon_2 t + \epsilon_1(d - t)}$ for $x = d$

6.21. $\mu/12\pi$

6.23. $\pi a^2 \mu N^2$

6.25. $\pi a^2 \mu N_1 N_2$

6.27. 1257

6.31. For f slightly larger than $1/2\pi l\sqrt{\mu\epsilon}$, the input behaviour of the structure is equivalent to a series combination of $C = \epsilon wl/d$ and $\frac{1}{3}L$ where $L \doteq \mu dl/w$. For still higher frequencies, the input behaviour of the structure is equivalent to C in series with the parallel combination of $\frac{1}{3}L$ and $\frac{1}{5}C$.

6.33. (a) $-480\pi^2 \times 10^{-7} \sin 300\pi t$ volts (b) 0 volts

6.39. (a) For the region $r < (a - b)$, $\mathbf{E} = 0$ for all t.
For the region $(a - b) < r < (a + b)$,
$\mathbf{E}$ is zero for $\cos 2\pi t > (r - a)/b$ and $(Q/4\pi\epsilon_0 r^2)\mathbf{i}_r$ for $\cos 2\pi t < (r - a)/b$.
For the region $r > (a + b)$, $\mathbf{E} = (Q/4\pi\epsilon_0 r^2)\mathbf{i}_r$ for all t.
(b) No wave propagation

6.41. (a) $10 \cos 2\pi \times 10^7 t$, $10 \sin 2\pi \times 10^7 t$, 10^7 Hz
(b) $10 \cos 0.1\pi z$, $10 \sin 0.1\pi z$, 20 m
(c) 2×10^8 m/sec
(d) $\dfrac{1}{8\pi} \cos (2\pi \times 10^7 t - 0.1\pi z)$

6.43. (a) The given $\bar{\mathbf{E}}$ represents the electric field of a uniform plane wave
(b) Direction of propagation is along the unit vector $\frac{1}{4}(\sqrt{3}\,\mathbf{i}_x + 3\mathbf{i}_y + 2\mathbf{i}_z)$.
$\lambda = 25$ m
$f = 12$ MHz
$\lambda_x = 57.7$ m, $\lambda_y = 33.3$ m, $\lambda_z = 50$ m
$v_{px} = 6.928 \times 10^8$ m/sec, $v_{py} = 4 \times 10^8$ m/sec, $v_{pz} = 6 \times 10^8$ m/sec
The polarization is left circular
$$\bar{\mathbf{H}} = \frac{1}{240\pi}[(-1 + j2\sqrt{3})\mathbf{i}_x + (-\sqrt{3} - j2)\mathbf{i}_y + 2\sqrt{3}\,\mathbf{i}_z]e^{-j0.02\pi(\sqrt{3}x+3y+2z)}$$

6.47. (a)
$$[E_x]_{t=0.015} = \begin{cases} 2/3 & -1.5 < z < 0.75 \\ 0 & \text{otherwise} \end{cases}$$
$$[E_x]_{t=0.035} = \begin{cases} -1/3 & -7.5 < z < 4.5 \\ -8/45 & -1.5 < z < 0.75 \\ 8/15 & 2 < z < 3 \\ 0 & \text{otherwise} \end{cases}$$
(b)
$$\eta_0[H_y]_{z=-3} = \begin{cases} 1 & 0 < t < 0.01 \\ 1/3 & 0.02 < t < 0.03 \\ 8/45 & 0.04 < t < 0.05 \\ -8/675 & 0.06 < t < 0.07 \\ 8/1025 & 0.08 < t < 0.09 \\ \cdots & \end{cases}$$
$$\eta_0[H_y]_{z=2.5} = \begin{cases} 24/15 & 0.03 < t < 0.04 \\ -8/75 & 0.05 < t < 0.06 \\ 8/1125 & 0.07 < t < 0.08 \\ \cdots & \end{cases}$$
$$\eta_0[H_y]_{t=0.035} = \begin{cases} 4/3 & -1.5 < z < 0.75 \\ 0 & \text{otherwise} \end{cases}$$
$$\eta_0[H_y]_{t=0.035} = \begin{cases} 1/3 & -7.5 < z < 4.5 \\ 8/45 & -1.5 < z < 0.75 \\ 24/15 & 2 < z < 3 \\ 0 & \text{otherwise} \end{cases}$$
E_x in volts/m, H_y in amps/m, t in μ sec, and z in m.

6.51. $V(0, t) = 0$ $\qquad I(0, t) = 2(|\bar{V}^+|/Z_0) \cos \omega t$
$V(\lambda/8, t) = -\sqrt{2}\,|\bar{V}^+| \sin \omega t$ $\qquad I(\lambda/8, t) = \sqrt{2}(|\bar{V}^+|/Z_0) \cos \omega t$
$V(\lambda/4, t) = -2|\bar{V}_+| \sin \omega t$ $\qquad I(\lambda/4, t) = 0$

$V(3\lambda/8, t) = -\sqrt{2}\,|\bar{V}^+|\sin\omega t$ $\qquad I(3\lambda/8, t) = -\sqrt{2}(|\bar{V}^+|/Z_0)\cos\omega t$

$V(\lambda/2, t) = 0$ $\qquad I(\lambda/2, t) = -2(|\bar{V}^+|/Z_0)\cos\omega t$

6.53. (a) ∞, $|\bar{V}(d)| = 10\sin(\pi d/2l)$, $|\bar{I}(d)| = 0.2\cos(\pi d/2l)$

(b) 0, $|\bar{V}(d)| = 2.5\sin(\pi d/l)$, $|\bar{I}(d)| = 0.05\,|\cos(\pi d/l)|$

(c)

d	0	$l/2$	l
Voltage, volts	0	5.303	7.07
Current, amps	0.1458	0.1	0.03535

6.57. No standing waves in medium 3.
In medium 2, standing wave ratio is 1.5. Standing wave patterns consist of minima for $|\bar{E}_x|$ and maxima for $|\bar{H}_y|$ at either end of medium 2. Both patterns contain three wavelengths.
In medium 1, standing wave ratio is 3. Standing wave patterns consist of minimum for $|\bar{E}_x|$ and maximum for $|\bar{H}_y|$ at the right end of medium 1.
Fraction of incident power transmitted into medium 3 = $\frac{3}{4}$.

6.59. 2.5 cm, $4\epsilon_0$

6.61.

Z_0 of stub	stub location	stub length
50 ohms	0.033λ	0.0811λ
50 ohms	0.167λ	0.4189λ
100 ohms	0.033λ	0.0434λ
100 ohms	0.167λ	0.4566λ

6.63. (a) $0.75e^{j0.264\pi}$ (b) 7 (c) 0.316λ (d) $(220 - j310)$ ohms
(e) $(0.0015 + j0.00215)$ mhos (f) 0.258λ

6.67.

Propagating mode	$TE_{1,0}$	$TE_{2,0}$	$TE_{3,0}$
f_c, MHz	1875	3750	5625
θ_i, degrees	71.79	51.32	20.37
λ_g, cm	2.631	3.203	7.184
v_{pz}, m/sec	1.5783×10^8	1.9215×10^8	4.3104×10^8
η_g, ohms	198.35	241.47	541.68

6.69. (a) $\bar{H}_y = 2\bar{H}_0\cos(\beta x\cos\theta_i)\,e^{-j\beta z\sin\theta_i}$

$\bar{E}_x = 2\sqrt{\mu/\epsilon}\,\bar{H}_0\sin\theta_i\cos(\beta x\cos\theta_i)\,e^{-j\beta z\sin\theta_i}$

$\bar{E}_z = j2\sqrt{\mu/\epsilon}\,\bar{H}_0\cos\theta_i\sin(\beta x\cos\theta_i)\,e^{-j\beta z\sin\theta_i}$

(c) $\lambda_c = 2a/m$, $f_c = m/2a\sqrt{\mu\epsilon}$, $\lambda_g = \lambda/\sqrt{1-(\lambda/\lambda_c)^2}$,
$v_{pz} = v_p/\sqrt{1-(\lambda/\lambda_c)^2}$, $m = 1, 2, 3, \ldots$

(d) $\bar{H}_y = 2\bar{H}_0\cos(m\pi x/a)\,e^{-j(2\pi/\lambda_g)z}$

$\bar{E}_x = 2\eta\bar{H}_0(\lambda/\lambda_g)\cos(m\pi x/a)\,e^{-j(2\pi/\lambda_g)z}$

$\bar{E}_z = j2\eta\bar{H}_0(\lambda/\lambda_c)\sin(m\pi x/a)\,e^{-j(2\pi/\lambda_g)z}$

(e) $\eta_g = \bar{E}_x/\bar{H}_y = \eta\sqrt{1-(\lambda/\lambda_c)^2}$
Transmission-line equivalent consists of $\bar{V}\longleftrightarrow\bar{E}_x$, $\bar{I}\longleftrightarrow\bar{H}_y$, $Z_0\longleftrightarrow\eta_g$, and $v_p\longleftrightarrow v_{pz}$.

6.73. (b) $\bar{V}(z) = e^{-(1/2)az}[\bar{A}e^{(1/2)\sqrt{a^2-4\omega^2\mathcal{L}_0\mathcal{C}_0}\,z} + \bar{B}e^{-(1/2)\sqrt{a^2-4\omega^2\mathcal{L}_0\mathcal{C}_0}\,z}]$

$$\bar{I}(z) = \frac{e^{(1/2)az}}{j\omega\mathcal{L}_0}\Big[\frac{1}{2}(a - \sqrt{a^2-4\omega^2\mathcal{L}_0\mathcal{C}_0})\bar{A}e^{(1/2)\sqrt{a^2-4\omega^2\mathcal{L}_0\mathcal{C}_0}\,z}$$
$$+ \frac{1}{2}(a + \sqrt{a^2-4\omega^2\mathcal{L}_0\mathcal{C}_0})\bar{B}e^{-(1/2)\sqrt{a^2-4\omega^2\mathcal{L}_0\mathcal{C}_0}\,z}\Big]$$

$f_c = a/4\pi\sqrt{\mathcal{L}_0\mathcal{C}_0}$

6.75.

Frequency	α, nepers/m	β, rad/m	$\bar{\eta}$, ohms	λ, m
100 MHz	0.0211	18.73	42.4	0.3354
10 KHz	$2\pi \times 10^{-3}$	$2\pi \times 10^{-3}$	$(1+j)2\pi$	1000

6.77. (a) $\bar{E}_x(d) = \bar{E}_x^+ e^{\bar{\gamma}d} + \bar{E}_x^- e^{-\bar{\gamma}d}$

$$\bar{H}_y(d) = \frac{1}{\bar{\eta}}[\bar{E}_x^+ e^{\bar{\gamma}d} - \bar{E}_x^- e^{-\bar{\gamma}d}]$$

6.79. (a) $\dfrac{\partial \bar{V}}{\partial z} = -[2\mathcal{R}_i + j\omega(2\mathcal{L}_i + \mathcal{L})]\bar{I}(z)$

$$\frac{\partial \bar{I}}{\partial z} = -(\mathcal{G} + j\omega\mathcal{C})\bar{V}(z)$$

(b) $\bar{\gamma} = [2\mathcal{R}_i + j\omega(2\mathcal{L}_i + \mathcal{L})](\mathcal{G} + j\omega\mathcal{C})$

$$Z_0 = \sqrt{\frac{2\mathcal{R}_i + j\omega(2\mathcal{L}_i + \mathcal{L})}{\mathcal{G} + j\omega\mathcal{C}}}$$

(c) $\sqrt{2\mathcal{R}_i\mathcal{G}}$

6.81. (b) 1824.42, 4175.58, 7824.42 MHz

6.83. (a) $f_{1,0,1} = 5303.4$ MHz, $f_{2,0,1} = f_{1,0,2} = 8385.4$ MHz, $f_{2,0,2} = 10606.5$ MHz.

(b) $\bar{E}_y = \bar{E}_0 \sin\dfrac{\pi x}{a} \sin\dfrac{\pi z}{d}$

$$\bar{H}_x = -j\frac{\bar{E}_0}{\eta}\frac{\lambda}{2d}\sin\frac{\pi x}{a}\cos\frac{\pi z}{d}$$

$$\bar{H}_z = j\frac{\bar{E}_0}{\eta}\frac{\lambda}{2a}\cos\frac{\pi x}{a}\sin\frac{\pi z}{d}$$

$$Q = \frac{\pi\sigma\delta\eta}{4}\frac{(a^2 + d^2)^{3/2}}{(a^3 + d^3)}$$

6.87. 56.3°

6.89. For currents equal in magnitude and phase: (a) linearly polarized in the z direction, (b) linearly polarized in the x direction, (c) linearly polarized parallel to the vector $(\mathbf{i}_x + \mathbf{i}_z)$, and (d) linearly polarized parallel to the vector $(-\mathbf{i}_x + \frac{1}{2}\mathbf{i}_y - \frac{1}{2}\mathbf{i}_z)$. For currents equal in magnitude but different in phase by $\pi/2$: (a) linearly polarized in the z direction, (b) linearly polarized in the x direction, (c) circularly polarized normal to the y axis, and (d) elliptically polarized with major axis along $\mathbf{i}_x$ and minor axis along $(\mathbf{i}_y - \mathbf{i}_z)$ and with the ratio of the major to the minor axis equal to $\sqrt{2}$.

6.91. (a) $I_1(t) = I_0 \cos\omega t$, $I_2(t) = -I_0 \cos\omega t$, where $I_0 = \omega Q_0$.

(b) $\bar{\mathbf{A}} = \dfrac{\mu\omega Q_0(dl)^2\cos\theta}{4\pi r}\left(j\dfrac{\omega}{v} + \dfrac{1}{r}\right)e^{-j\omega r/v}\mathbf{i}_z$

(c)
$$\bar{\mathbf{E}} = -\frac{Q_0(dl)^2\sin\theta\cos\theta}{4\pi\epsilon r}\left[\left(\frac{\omega}{v}\right)^3 - j\frac{3}{r}\left(\frac{\omega}{v}\right)^2 - \frac{6\omega}{vr^2} + j\frac{6}{r^3}\right]e^{-j\omega r/v}\mathbf{i}_\theta + \frac{Q_0(dl)^2(3\cos^2\theta - 1)}{4\pi\epsilon r^2}\left[j\left(\frac{\omega}{v}\right)^2 + \frac{3\omega}{vr} - j\frac{3}{r^2}\right]e^{-j\omega r/v}\mathbf{i}_r$$

$$\bar{\mathbf{H}} = \frac{\omega Q_0(dl)^2\sin\theta\cos\theta}{4\pi r}\left[-\left(\frac{\omega}{v}\right)^2 + j\frac{3\omega}{vr} + \frac{3}{r^2}\right]e^{-j\omega r/v}\mathbf{i}_\phi$$

(d)
$$\bar{\mathbf{E}} = -\frac{Q_0(dl)^2\omega^3\sin\theta\cos\theta}{4\pi\epsilon r v^3}e^{-j\omega r/v}\mathbf{i}_\theta$$

$$\bar{\mathbf{H}} = -\frac{Q_0(dl)^2\omega^3\sin\theta\cos\theta}{4\pi\epsilon\eta r v^3}e^{-j\omega r/v}\mathbf{i}_\phi$$

6.93. (c) $U_n = \dfrac{\cos^2[(\pi/2)\cos\theta]}{\sin^2\theta}$