Prob. 10.6 (a) $\dfrac{\sigma}{\omega\varepsilon} = \tan 2\theta_\eta = \tan 60^o = \underline{\underline{1.732}}$

(b) $|\eta| = 240 = \dfrac{\dfrac{120\pi}{\sqrt{\varepsilon_r}}}{\sqrt[4]{1+3}} = \dfrac{120\pi}{\sqrt{2\varepsilon_r}} \longrightarrow \varepsilon_r = \dfrac{\pi^2}{8} = \underline{\underline{1.234}}$

(c) $\varepsilon_c = \varepsilon(1 - j\dfrac{\sigma}{\omega\varepsilon}) = 1.234 \times \dfrac{10^{-9}}{36\pi}(1 - j1.732) = \underline{\underline{(1.091 - j1.89)\times 10^{-11}}}$ F/m

(d)

$$\alpha = \frac{\omega}{c}\sqrt{\frac{\mu_r\varepsilon_r}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2} - 1\right]} = \frac{2\pi\times 10^6}{3\times 10^8}\sqrt{\frac{1}{2}\frac{\pi^2}{8}\left[\sqrt{1+3} - 1\right]} = \underline{\underline{0.0164}} \text{ Np/m}$$

Prob. 10.7

$$\frac{\sigma}{\omega\varepsilon} = \frac{4}{2\pi\times 10^5 \times 80 \times 10^{-9}/36\pi} = 9{,}000 >> 1$$

$$\alpha = \beta = \sqrt{\frac{\omega\mu\sigma}{2}} = \sqrt{\frac{2\pi\times 10^5}{2}\times 4\pi\times 10^{-7}\times 4} = 0.4\pi$$

(a) $u = \omega/\beta = \dfrac{2\pi\times 10^5}{0.4\pi} = \underline{\underline{5\times 10^5}}$ m/s

(b) $\lambda = 2\pi/\beta = \dfrac{2\pi}{0.4\pi} = \underline{\underline{5}}$ m

(c) $\delta = 1/\alpha = \dfrac{1}{0.4\pi} = \underline{\underline{0.796}}$ m

(d) $\eta = |\eta|\angle\theta_\eta, \theta_\eta = 45^o$

$$|\eta| = \frac{\sqrt{\dfrac{\mu}{\varepsilon}}}{\sqrt[4]{1+\left(\dfrac{\sigma}{\omega\varepsilon}\right)^2}} \cong \sqrt{\frac{\mu}{\varepsilon}\frac{\omega\varepsilon}{\sigma}} = \sqrt{\frac{4\pi\times 10^{-7}\times 2\pi\times 10^5}{4}} = 0.4443$$

Prob. 10.10 (a) $\gamma = \alpha + j\beta = \underline{\underline{0.05 + j2}}$ /m

(b) $\lambda = 2\pi / \beta = \pi = \underline{\underline{3.142}}$ m

(c) $u = \omega / \beta = \dfrac{2\times10^8}{2} = \underline{\underline{10^8}}$ m/s

(d) $\delta = 1/\alpha = \dfrac{1}{0.05} = \underline{\underline{20}}$ m

Prob. 10.11 (a) $\beta = \omega / c = \dfrac{2\pi x 10^6}{3x10^8} = \underline{\underline{0.02094}}$ rad/m,

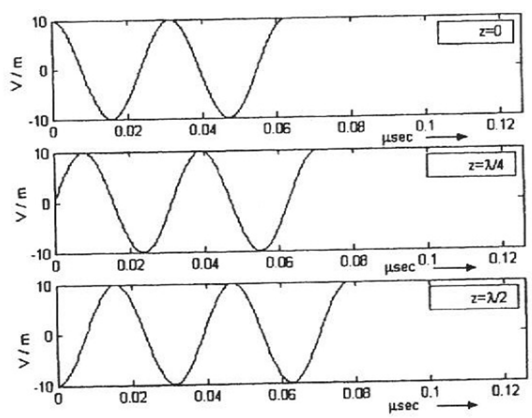
$\lambda = 2\pi / \beta = \underline{\underline{300}}$ m

(b) When $z = 0,\quad E_y = 10\cos\omega t$

$z = \lambda / 4,\quad E_y = 10\cos(\omega t - \dfrac{2\pi}{\lambda}\dfrac{\lambda}{4}) = 10\sin\omega t$

$z = \lambda / 2,\quad E_y = 10\cos(\omega t - \pi) = -10\cos\omega t$

Thus E is sketched below.



(c)

$$H = \frac{10}{120\pi}\cos(2\pi\times10^6 t - 2\pi z/300)\boldsymbol{a}_x = \underline{\underline{26.53\cos(2\pi\times10^6 t - 0.02094z)\boldsymbol{a}_x}} \text{ mA/m}$$

(c) $u = c = \underline{\underline{3\times10^8 \text{ m/s}}}$

(d) Let $\quad \boldsymbol{E} = E_o \cos(\beta z + 40{,}000t)\boldsymbol{a}_E$

$$E_o = 25\times120\pi = 9.425\times10^3$$

$$\boldsymbol{a}_E x \boldsymbol{a}_H = \boldsymbol{a}_k \quad \longrightarrow \quad \boldsymbol{a}_E x \boldsymbol{a}_y = -\boldsymbol{a}_z \quad \longrightarrow \quad \boldsymbol{a}_E = -\boldsymbol{a}_x$$

$$\boldsymbol{E} = \underline{\underline{-9.425\cos(\beta z + 40{,}000t)\boldsymbol{a}_x \text{ kV/m}}}$$

Prob. 10.17

(a) along $+\mathbf{a}_x$

(b) $u = \dfrac{\omega}{\beta} = \underline{\underline{\dfrac{1}{3}\times10^8 \text{ m/s}}}$

(c) $\lambda = \dfrac{2\pi}{\beta} = \dfrac{2\pi}{3} = \underline{\underline{2.0944 \text{ m}}}$

Prob. 10.18

(a) $$\nabla\times\boldsymbol{E} = \begin{vmatrix} \boldsymbol{a}_x & \boldsymbol{a}_y & \boldsymbol{a}_z \\ \dfrac{\partial}{\partial x} & \dfrac{\partial}{\partial y} & \dfrac{\partial}{\partial z} \\ E_x(z,t) & E_y(z,t) & 0 \end{vmatrix} = -\frac{\partial E_y}{\partial z}\boldsymbol{a}_x + \frac{\partial E_x}{\partial z}\boldsymbol{a}_y$$

$$= -6\beta\cos(\omega t - \beta z)\boldsymbol{a}_x + 8\beta\sin(\omega t - \beta z)\boldsymbol{a}_y$$

But $\nabla\times\boldsymbol{E} = -\mu\dfrac{\partial \boldsymbol{H}}{\partial t} \quad \longrightarrow \quad \boldsymbol{H} = -\dfrac{1}{\mu}\int \nabla\times\boldsymbol{E}dt$

$$\boldsymbol{H} = \underline{\underline{\frac{6\beta}{\mu\omega}\sin(\omega t - \beta z)\boldsymbol{a}_x + \frac{8\beta}{\mu\omega}\cos(\omega t - \beta z)\boldsymbol{a}_y}}$$

(b) $\beta = \omega\sqrt{\mu\varepsilon} = \dfrac{2\pi f}{c}\sqrt{4.5} = \dfrac{2\pi\times40\times10^6}{3\times10^8}\sqrt{4.5} = \underline{\underline{1.777 \text{ rad/m}}}$

$$\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{1.777} = \underline{\underline{3.536 \text{ m}}}$$

$$\eta = \sqrt{\frac{\mu}{\varepsilon}} = \frac{120\pi}{\sqrt{4.5}} = \underline{\underline{177.72\ \Omega}}$$

$$u = \frac{1}{\sqrt{\mu\varepsilon}} = \frac{c}{\sqrt{4.5}} = \frac{3\times10^8}{\sqrt{4.5}} = \underline{\underline{1.4142\times10^8 \text{ m/s}}}$$

Prob. 10.19 $\beta = \omega\sqrt{\mu\varepsilon} = \frac{\omega}{c}\sqrt{\mu_r\varepsilon_r} = \frac{2\pi\times10^7}{3\times10^8}(10) = \underline{\underline{2.0943}}$ rad/m

$$H = -\frac{1}{\mu}\int \nabla\times \boldsymbol{E}dt$$

$$\nabla\times\boldsymbol{E} = \begin{vmatrix} \frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z} \\ 0 & E_y(x) & E_z(x) \end{vmatrix} = -\frac{\partial E_z}{\partial x}\boldsymbol{a}_y + \frac{\partial E_y}{\partial x}\boldsymbol{a}_z = -10\beta\sin(\omega t - \beta x)(a_y - a_z)$$

$$\boldsymbol{H} = -\frac{10\beta}{\omega\mu}\cos(\omega t - \beta x)(\boldsymbol{a}_y - \boldsymbol{a}_z) = -\frac{10\times 2\pi/3}{2\pi\times10^7\times50\times4\pi\times10^{-7}}\cos(\omega t - \beta x)(\boldsymbol{a}_y - \boldsymbol{a}_z)$$

$$\underline{\underline{\boldsymbol{H} = 5.305\cos(2\pi\times10^7 t - 2.0943x)(-\boldsymbol{a}_y + \boldsymbol{a}_z)}} \quad \text{mA/m}$$

Prob. 10.20

$$0.4E_o = E_o e^{-\alpha z} \longrightarrow \frac{1}{0.4} = e^{2\alpha}$$

Or $\alpha = \frac{1}{2}\ln\frac{1}{0.4} = 0.4581 \longrightarrow \delta = 1/\alpha = \underline{\underline{2.183}}$ m

$$\lambda = 2\pi/\beta = 2\pi/1.6$$

$$u = f\lambda = 10^7\times\frac{2\pi}{1.6} = \underline{\underline{3.927\times10^7}} \quad \text{m/s}$$

Prob. 10.21

(a) $\boldsymbol{E} = \text{Re}[\boldsymbol{E}_s e^{j\omega t}] = (5\boldsymbol{a}_x + 12\boldsymbol{a}_y)e^{-0.2z}\cos(\omega t - 3.4z)$

At $z = 4$m, $t = T/8$, $\omega t = \frac{2\pi}{T}\frac{T}{8} = \frac{\pi}{4}$

$$\boldsymbol{E} = (5\boldsymbol{a}_x + 12\boldsymbol{a}_y)e^{-0.8}\cos(\pi/4 - 13.6)$$

$$|E| = 13e^{-0.8}|\cos(\pi/4 - 13.6)| = \underline{\underline{5.662}} \text{ V/m}$$

(b) loss $= \alpha\Delta z = 0.2(3) = 0.6$ Np. Since 1 Np = 8.686 dB,

loss = 0.6 x 8.686 = $\underline{5.212 \text{ dB}}$

(c) Let $x = \sqrt{1+\left(\dfrac{\sigma}{\omega\varepsilon}\right)^2}$

$$\frac{\alpha}{\beta} = \left(\frac{x-1}{x+1}\right)^{1/2} = 0.2/3.4 = \frac{1}{17}$$

$$\frac{x-1}{x+1} = 1/289 \quad \longrightarrow \quad x = 1.00694$$

$$\alpha = \omega\sqrt{\mu\varepsilon/2}\sqrt{x-1} = \frac{\omega}{c}\sqrt{\varepsilon_r/2}\sqrt{x-1}$$

$$\sqrt{\frac{\varepsilon_r}{2}} = \frac{\alpha c}{\omega\sqrt{x-1}} = \frac{0.2x3x10^8}{10^8\sqrt{0.00694}} = 7.2 \quad \longrightarrow \quad \varepsilon_r = 103.68$$

$$|\eta| = \frac{\sqrt{\dfrac{\mu_o}{\varepsilon_o}}.\dfrac{1}{\sqrt{\varepsilon_r}}}{\sqrt{x}} = \frac{120\pi}{\sqrt{103.68\times 1.00694}} = 36.896$$

$$\tan 2\theta_\eta = \frac{\sigma}{\omega\varepsilon} = \sqrt{x^2-1} = 0.118 \quad \longrightarrow \quad \theta_\eta = 3.365^o$$

$$\eta = 36.896\angle 3.365^o\ \Omega$$

$$\boldsymbol{H}_s = \boldsymbol{a}_k \times \frac{\boldsymbol{E}_s}{\eta} = \frac{\boldsymbol{a}_z}{\eta}\times(5\boldsymbol{a}_x + 12\boldsymbol{a}_y)e^{-\gamma z} = \frac{(5\boldsymbol{a}_y - 12\boldsymbol{a}_x)}{|\eta|}e^{-j3.365^o}e^{-\gamma z}$$

$$H = (-325.24a_x + 135.5a_y)e^{-0.2z}\cos(\omega t - 3.4z - 3.365^o)\ \text{mA}$$

$$\boldsymbol{P} = \boldsymbol{E}\times\boldsymbol{H} = \begin{vmatrix} \boldsymbol{a}_x & \boldsymbol{a}_y & \boldsymbol{a}_z \\ 5 & 12 & 0 \\ -325.24 & 135.5 & 0 \end{vmatrix} \times 10^{-3}e^{-0.4z}\cos(\omega t - 3.4z)\cos(\omega t - 3.4z - 3.365^o)$$

$$\boldsymbol{P} = 4.58e^{-0.4z}\cos(\omega t - 3.4z)\cos(\omega t - 3.4z - 3.365^o)\boldsymbol{a}_z$$

At z=4, t=T/4,

$$\boldsymbol{P} = 4.58e^{-1.6}\cos(\pi/4 - 13.6)\cos(\pi/4 - 13.6 - 0.0587)\boldsymbol{a}_z = \underline{\underline{0.8545\boldsymbol{a}_z\ \text{W/m}^2}}$$

Prob. 10.22 For a good conductor, $\dfrac{\sigma}{\omega\varepsilon} >> 1$, say $\dfrac{\sigma}{\omega\varepsilon} > 100$

(b) $R_{ac} = \dfrac{l}{\sigma\, 2\pi a\delta}$. At 100 MHz, $\delta = 6.6x10^{-3}$ mm for copper (see Table 10.2).

$$R_{ac} = \frac{600}{5.8\times10^{7}\times2\pi\times(1.2\times10^{-3})\times6.6\times10^{-3}} = \underline{\underline{0.2079\ \Omega}}$$

(c) $\dfrac{R_{ac}}{R_{dc}} = \dfrac{a}{2\delta} = 1 \longrightarrow \delta = a/2 = \dfrac{66.1\times10^{-3}}{\sqrt{f}}$

$$\sqrt{f} = \frac{66.1\times2\times10^{-3}}{a} = \frac{66.1\times2}{1.2} \longrightarrow f = \underline{\underline{12.137}}\ \text{kHz}$$

Prob. 10.25

(a) $\tan\theta = \dfrac{\sigma}{\omega\varepsilon} = \dfrac{3.5\times10^{7}}{2\pi\times150\times10^{6}\times\dfrac{10^{-9}}{36\pi}} = \dfrac{3.5\times18\times10^{9}}{15} >> 1$

$$\alpha = \beta = \sqrt{\frac{\omega\mu\sigma}{2}} = \sqrt{\pi f \mu\sigma} = \sqrt{150\pi\times10^{6}\times4\pi\times10^{-7}\times3.5\times10^{7}} = 143{,}965.86$$

$\gamma = \alpha + j\beta = \underline{\underline{1.44(1+j)x10^{5}\ /\text{m}}}$

(b) $\delta = 1/\alpha = \underline{\underline{6.946\times10^{-6}\ \text{m}}}$

(c) $u = \dfrac{\omega}{\beta} = \dfrac{150\times2\pi\times10^{6}}{1.44\times10^{5}} = \underline{\underline{6547\ \text{m/s}}}$

Prob. 10.26

$\omega = 10^{6}\pi = 2\pi f \longrightarrow f = 0.5\times10^{6}$

$$\delta = \frac{1}{\sqrt{\pi f\sigma\mu}} = \frac{1}{\sqrt{\pi\times0.5\times10^{6}\times3.5\times10^{7}\times4\pi\times10^{-7}}} = \underline{\underline{0.1203}}\ \text{mm}$$

$$R_{ac} = \frac{l}{\sigma\delta w}$$

since δ is very small, $w = 2\pi\rho_{outer}$

$$R_{ac} = \frac{l}{\sigma2\pi\rho_{outer}\delta} = \frac{40}{3.5\times10^{7}\times2\pi\times12\times10^{-6}\times0.1203} = \underline{\underline{0.126\Omega}}$$

$$\mathscr{P}_{ave} = \frac{1}{2}\ \text{Re}(\boldsymbol{E}_s \times \boldsymbol{H}_s^*)$$

as required.

Prob. 10.31

(a) $\boldsymbol{P} = \boldsymbol{E} \times \boldsymbol{H} = \dfrac{V_o I_o}{2\pi\rho^2 \ln(b/a)} \cos^2(\omega t - \beta z)\boldsymbol{a}_z$

(b) $\boldsymbol{P}_{ave} = \dfrac{1}{T}\displaystyle\int_0^T \boldsymbol{E} \times \boldsymbol{H} dt = \dfrac{V_o I_o}{4\pi\rho^2 \ln(b/a)}\boldsymbol{a}_z$

Prob. 10.32

(a) $\quad \boldsymbol{H}_s = \dfrac{j30\beta I_o dl}{120\pi r} \sin\theta e^{-j\beta r}\boldsymbol{a}_H$

where $\quad \boldsymbol{a}_E \times \boldsymbol{a}_H = \boldsymbol{a}_k \quad \longrightarrow \quad \boldsymbol{a}_\theta \times \boldsymbol{a}_H = \boldsymbol{a}_r \quad \longrightarrow \quad \boldsymbol{a}_H = \boldsymbol{a}_\phi$

$$\boldsymbol{H}_s = \frac{j\beta I_o dl}{4\pi r} \sin\theta e^{-j\beta r}\boldsymbol{a}_\phi$$

(b) $\boldsymbol{P}_{ave} = \dfrac{1}{2}\text{Re}[\boldsymbol{E}_s \times \boldsymbol{H}_s^*] = \dfrac{1}{2}\text{Re}[\dfrac{30\beta^2 I_o^2 dl^2 \sin^2\theta}{4\pi r^2}\boldsymbol{a}_r] = \dfrac{15\beta^2 I_o^2 dl^2 \sin^2\theta}{4\pi r^2}\boldsymbol{a}_r$

Prob. 10.33

(a) $P_{ave} = \dfrac{1}{2}\text{Re}(E_s H_s^*) = \dfrac{1}{2}\text{Re}(\dfrac{|E_s|}{|\eta|}) = \dfrac{8^2}{2|\eta|}e^{-0.2z}$

$$\alpha = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2} - 1\right]}$$

$$\beta = \omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2} + 1\right]}$$

Let $\quad x = \sqrt{1+\left(\dfrac{\sigma}{\omega\varepsilon}\right)^2}$

$$\frac{\alpha}{\beta}=\frac{\sqrt{x-1}}{\sqrt{x+1}}=0.1/0.3=1/3$$

$$\frac{x-1}{x+1}=\frac{1}{9} \longrightarrow x=5/4$$

$$\frac{5}{4}=\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2} \longrightarrow \frac{\sigma}{\omega\varepsilon}=3/4$$

$$|\eta|=\frac{\sqrt{\frac{\mu}{\varepsilon}}}{\sqrt[4]{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}}=\frac{120\pi/\sqrt{81}}{\sqrt{\frac{5}{4}}}=37.4657$$

$$P_{ave}=\frac{64}{2(37.4657)}e^{-0.2z}=\underline{\underline{0.8541e^{-0.2z}\ \text{W/m}^2}}$$

(b) $20dB=10\log\frac{P_1}{P_2} \longrightarrow \frac{P_1}{P_2}=100$

$$\frac{P_2}{P_1}=e^{-0.2z}=\frac{1}{100} \longrightarrow e^{0.2z}=100$$

$$z=5\log 100=\underline{\underline{23\text{ m}}}$$

Prob.10.34

(a)

$$\alpha=\omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\varepsilon}\right)^2}-1\right]}$$

$$\tan\theta=\frac{\sigma}{\omega\varepsilon}=10^{-2}$$

$$\alpha=\omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+10^{-4}}-1\right]}=\frac{2\pi\times2\times10^9}{3\times10^8}\sqrt{\frac{2.5}{2}}\sqrt{0.00005}=0.3311$$

$$\beta=\omega\sqrt{\frac{\mu\varepsilon}{2}\left[\sqrt{1+10^{-4}}+1\right]}=\frac{2\pi\times2\times10^9}{3\times10^8}\sqrt{\frac{2.5}{2}}\sqrt{2.00005}=66.23$$

(In this case, $\beta=\omega\sqrt{\mu\varepsilon}$.)

$$(1-0.2)E_o=E_oe^{-\alpha z} \longrightarrow 0.8E_o=E_oe^{-\alpha z}$$

$$e^{\alpha z}=1.25 \longrightarrow z=\frac{1}{\alpha}\ln 1.25=\underline{\underline{0.674\text{ m}}}$$

(b) $\beta z = 180^o = \pi \longrightarrow z = \dfrac{\pi}{\beta} = \underline{\underline{0.04743 \text{ m}}}$

(c) $P = P_o e^{-2\alpha z} \longrightarrow 0.9P_o = P_o e^{-2\alpha z}$

$e^{2\alpha z} = 1/0.9 = 1.111 \longrightarrow z = \dfrac{1}{2\alpha}\ln 1.111 = \underline{\underline{0.159 \text{ m}}}$

Prob. 10.35

(a) $u = \omega / \beta \longrightarrow \omega = u\beta = \dfrac{\beta c}{\sqrt{4.5}} = \dfrac{2\times 3\times 10^8}{\sqrt{4.5}} = \underline{\underline{2.828\times 10^8}}$ rad/s

$$\eta = \frac{120\pi}{\sqrt{4.5}} = 177.7\Omega$$

$$\boldsymbol{H} = \boldsymbol{a}_k \times \frac{\boldsymbol{E}}{\eta} = \frac{\boldsymbol{a}_z}{\eta} \times \frac{40}{\rho}\sin(\omega t - 2z)\boldsymbol{a}_\rho = \underline{\underline{\frac{0.225}{\rho}\sin(\omega t - 2z)\boldsymbol{a}_\phi}} \text{ A/m}$$

(b) $\mathscr{P} = \boldsymbol{E}\times\boldsymbol{H} = \underline{\underline{\dfrac{9}{\rho^2}\sin^2(\omega t - 2z)\boldsymbol{a}_z \text{ W/m}^2}}$

(c) $\mathscr{P}_{\text{ave}} = \dfrac{4.5}{\rho^2}\boldsymbol{a}_z$, $\text{dS} = \rho \text{d}\phi \text{d}\rho \boldsymbol{a}_z$

$$\text{P}_{\text{ave}} = \int \mathbf{P}_{\text{ave}} \bullet dS = 4.5 \int_{2\text{mm}}^{3\text{mm}} \frac{\text{d}\rho}{\rho}\int_0^{2\pi} \text{d}\phi = 4.5\ln(3/2)(2\pi) = \underline{\underline{11.46 \text{ W}}}$$

Prob. 10.36 (a) $P_{i,ave} = \dfrac{E_{io}^{\ 2}}{2\eta_1}, \qquad P_{r,ave} = \dfrac{E_{ro}^{\ 2}}{2\eta_1}, \qquad P_{t,ave} = \dfrac{E_{to}^{\ 2}}{2\eta_2}$

$$R = \frac{P_{r,ave}}{P_{i,ave}} = \frac{E_{ro}^{\ 2}}{E_{io}^{\ 2}} = \Gamma^2 = \underline{\underline{\left(\frac{\eta_2 - \eta_1}{\eta_2 + \eta_1}\right)^2}}$$

$$R = \left(\frac{\sqrt{\dfrac{\mu_o}{\varepsilon_2}} - \sqrt{\dfrac{\mu_o}{\varepsilon_1}}}{\sqrt{\dfrac{\mu_o}{\varepsilon_2}} + \sqrt{\dfrac{\mu_o}{\varepsilon_1}}}\right)^2 = \left(\frac{\sqrt{\mu_o\varepsilon_1} - \sqrt{\mu_o\varepsilon_2}}{\sqrt{\mu_o\varepsilon_1} + \sqrt{\mu_o\varepsilon_2}}\right)^2$$

Since $n_1 = c\sqrt{\mu_1\varepsilon_1} = c\sqrt{\mu_o\varepsilon_1}, \qquad n_2 = c\sqrt{\mu_o\varepsilon_2},$

$$\eta_1 = \sqrt{\frac{\mu_1}{\varepsilon_1}} = \frac{120\pi}{\sqrt{4}} = 60\pi, \qquad \eta_2 = \eta_o = 120\pi$$

$$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \frac{120\pi - 60\pi}{180\pi} = \frac{1}{3}, \qquad \tau = \frac{2\eta_2}{\eta_1 + \eta_2} = \frac{2x120\pi}{180\pi} = \frac{4}{3}$$

$$E_{io} = 10, \qquad E_{ro} = \Gamma E_{io} = 10/3, \qquad E_{to} = \tau E_{io} = 40/3$$

$$\boldsymbol{P}_1 = \boldsymbol{P}_i + \boldsymbol{P}_r = \frac{E_{io}^2}{2\eta_1}\boldsymbol{a}_z + \frac{E_{ro}^2}{2\eta_1}(-\boldsymbol{a}_z) = \frac{100}{2\times 60\pi}\boldsymbol{a}_z - \frac{100}{92\times 60\pi}\boldsymbol{a}_z = \underline{\underline{0.2358\boldsymbol{a}_z \text{ W/m}^2}}$$

$$\boldsymbol{P}_2 = \boldsymbol{P}_t = \frac{E_{to}^2}{2\eta_2}\boldsymbol{a}_z = \frac{1600}{9\times 2\times 120\pi}\boldsymbol{a}_z = \underline{\underline{0.2358\boldsymbol{a}_z \text{ W/m}^2}}$$

Prob. 10.40

(a) $$\eta_2 = \sqrt{\frac{\mu}{\varepsilon}} = \frac{120\pi}{\sqrt{4}} = 60\pi, \qquad \eta_1 = \eta_o = 120\pi$$

$$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \frac{60\pi - 120\pi}{180\pi} = -\frac{1}{3}, \qquad \tau = \frac{2\eta_2}{\eta_1 + \eta_2} = \frac{120\pi}{180\pi} = \frac{2}{3}$$

$$s = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+1/3}{1-1/3} = \underline{\underline{2}}$$

(b) $$\lambda_1 = c/f = \frac{3\times 10^8}{10^8} = \underline{\underline{3 \text{ m}}}$$

$$\lambda_2 = u/f = \frac{\frac{c}{\sqrt{\varepsilon_r}}}{f} = \frac{3}{\sqrt{4}} = \underline{\underline{1.5 \text{ m}}}$$

(c) $$P_i = \frac{E_{oi}^2}{2\eta_1}, \qquad P_r = \frac{E_{or}^2}{2\eta_1} = \frac{\Gamma^2 E_{oi}^2}{2\eta_1}$$

$$\frac{P_r}{P_i} = \Gamma^2 = \frac{1}{9} = 0.1111 \text{ or } \underline{\underline{11.11\%}}$$

Prob. 10.41 $\eta_1 = \eta_o = 120\pi, \qquad \eta_2 = \sqrt{\frac{\mu_2}{\varepsilon_2}}$

$$\frac{E_{ro}}{E_{io}} = \Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} \qquad (1)$$

But $$E_{ro} = \eta_o H_{ro} \qquad (2)$$

Combining (1) and (2),

Prob. 10.43 (a) Medium 1 is free space. Given that $\beta = 1$,

$$\beta = 1 = \frac{\omega}{c} \longrightarrow \omega = c = \underline{\underline{3\times10^8 \text{ rad/s}}}$$

(b) $$\eta_1 = \eta_o, \qquad \eta_2 = \eta_o\sqrt{\frac{\mu_r}{\varepsilon_r}} = \eta_o\sqrt{\frac{3}{12}} = \eta_o/2$$

$$\Gamma = \frac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = -1/3, \qquad \tau = 1 + \Gamma = 2/3$$

$$s = \frac{1+|\Gamma|}{1-|\Gamma|} = \frac{1+1/3}{1-1/3} = \underline{\underline{2}}$$

(c) Let $H_r = H_{or}\cos(\omega t + z)\boldsymbol{a}_H$, where

$$\boldsymbol{E}_r = -\frac{1}{3}(30)\cos(\omega t + z)\boldsymbol{a}_y = -10\cos(\omega t + z)\boldsymbol{a}_y, \qquad H_{or} = \frac{10}{\eta_o} = \frac{10}{120\pi}$$

$$\boldsymbol{a}_E \times \boldsymbol{a}_H = \boldsymbol{a}_k \longrightarrow -\boldsymbol{a}_y \times \boldsymbol{a}_H = -\boldsymbol{a}_z \longrightarrow \boldsymbol{a}_H = -\boldsymbol{a}_x$$

$$\boldsymbol{H}_r = -\frac{10}{120\pi}\cos(3\times10^8 t + z)\boldsymbol{a}_x \text{ A/m} = \underline{\underline{-26.53\cos(3\times10^8 t + z)\boldsymbol{a}_x \text{ mA/m}}}$$

(d) $$\boldsymbol{P}_t = \frac{E_{ot}^2}{2\eta_2}\boldsymbol{a}_z, \qquad E_{ot} = \tau E_{oi} = \frac{2}{3}(30) = 20, \qquad \eta_2 = 60\pi$$

$$\boldsymbol{P}_t = \frac{20^2}{120\pi}(\boldsymbol{a}_z) = \underline{\underline{1.061\boldsymbol{a}_z \text{ W/m}^2}}$$

Prob. 10.44

(a) In air, $\beta_1 = 1, \lambda_1 = 2\pi/\beta_1 = 2\pi = \underline{\underline{6.283 \text{ m}}}$

$$\omega = \beta_1 c = \underline{\underline{3x10^8 \text{ rad/s}}}$$

In the dielectric medium, ω is the same .

$$\omega = \underline{\underline{3x10^8 \text{ rad/s}}}$$

$$\beta_2 = \frac{\omega}{c}\sqrt{\varepsilon_{r2}} = \beta_1\sqrt{\varepsilon_{r2}} = \sqrt{3}$$

$$\boldsymbol{a}_E x \boldsymbol{a}_H = \boldsymbol{a}_k \longrightarrow \boldsymbol{a}_z x \boldsymbol{a}_H = \boldsymbol{a}_y \longrightarrow \boldsymbol{a}_H = \boldsymbol{a}_x$$

$$\boldsymbol{H}_t = \underline{\underline{35.37\cos(\omega t - 16\pi y)\boldsymbol{a}_x \text{ mA/m}}}$$

Prob. 10.47 (a) $\omega = \beta c = 3\times 3\times 10^8 = \underline{\underline{9\times 10^8 \text{ rad/s}}}$

(b) $\lambda = 2\pi / \beta = 2\pi / 3 = \underline{\underline{2.094 \text{ m}}}$

(c) $\dfrac{\sigma}{\omega\varepsilon} = \dfrac{4}{9\times 10^8 \times 80\times 10^{-9} / 36\pi} = 2\pi = \underline{\underline{6.288}}$

$$\tan 2\theta_\eta = \frac{\sigma}{\omega\varepsilon} = 6.288 \longrightarrow \theta_\eta = 40.47^o$$

$$|\eta_2| = \frac{\sqrt{\mu_2/\varepsilon_2}}{\sqrt[4]{1+\left(\dfrac{\sigma_2}{\omega\varepsilon_2}\right)^2}} = \frac{377/\sqrt{80}}{\sqrt[4]{1+4\pi^2}} = 16.71$$

$$\eta_2 = \underline{\underline{16.71\angle 40.47^o\ \Omega}}$$

(d) $\Gamma = \dfrac{\eta_2 - \eta_1}{\eta_2 + \eta_1} = \dfrac{16.71\angle 40.47^o - 377}{16.71\angle 40.47^o + 377} = 0.935\angle 179.7^o$

$$E_{or} = \Gamma E_{oi} = 9.35\angle 179.7^o$$

$$\boldsymbol{E}_r = \underline{\underline{9.35\sin(\omega t - 3z + 179.7)\boldsymbol{a}_x \text{ V/m}}}$$

$$\alpha_2 = \frac{\omega}{c}\sqrt{\frac{\mu_{r2}\varepsilon_{r2}}{2}\left[\sqrt{1+\left(\frac{\sigma_2}{\omega\varepsilon_2}\right)^2} - 1\right]} = \frac{9\times 10^8}{3\times 10^8}\sqrt{\frac{80}{2}\left[\sqrt{1+4\pi^2} - 1\right]} = 43.94 \text{ Np/m}$$

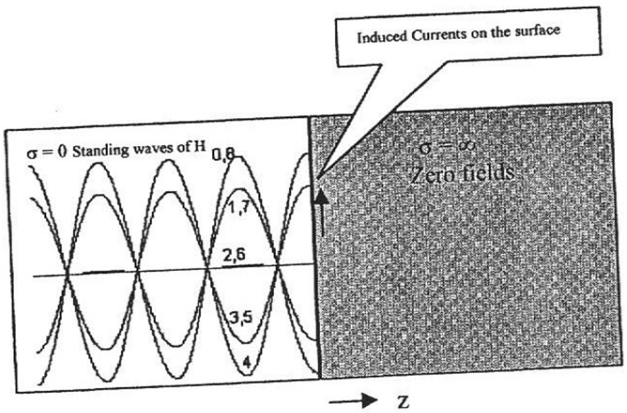
$$\beta_2 = \frac{9\times 10^8}{3\times 10^8}\sqrt{\frac{80}{2}\left[\sqrt{1+4\pi^2} + 1\right]} = 51.48 \text{ rad/m}$$

$$\tau = \frac{2\eta_2}{\eta_2 + \eta_1} = \frac{2\times 16.71\angle 40.47^o}{16.71\angle 40.47^o + 377} = 0.0857\angle 38.89^o$$

$E_{ot} = \tau E_o = 0.857\angle 38.89^o$

$$E_t = 0.857 e^{43.94z} \sin(9\times10^8 t + 51.48z + 38.89^o) \text{ V/m}$$

Prob. 10.48



Curve 0 is at t = 0; curve 1 is at t = T/8; curve 2 is at t = T/4; curve 3 is at t = 3T/8, etc.

Prob. 10.49 Since $\mu_o = \mu_1 = \mu_2$,

$$\sin\theta_{t1} = \sin\theta_i \sqrt{\frac{\varepsilon_o}{\varepsilon_1}} = \frac{\sin 45^o}{\sqrt{4.5}} = 0.3333 \longrightarrow \underline{\underline{\theta_{t1} = 19.47^o}}$$

$$\sin\theta_{t2} = \sin\theta_{t1}\sqrt{\frac{\varepsilon_1}{\varepsilon_2}} = \frac{1}{3}\sqrt{\frac{4.5}{2.25}} = 0.4714 \longrightarrow \underline{\underline{\theta_{t2} = 28.13^o}}$$

Prob. 10.50

$$\boldsymbol{E}_s = \frac{20(e^{jk_x x} - e^{-jk_x x})}{j2}\frac{(e^{jk_y y} + e^{-jk_y y})}{2}\boldsymbol{a}_z$$

$$= -j5\left[e^{j(k_x x + k_y y)} + e^{j(k_x x - k_y y)} - e^{-j(k_x x - k_y y)} - e^{-j(k_x x + k_y y)}\right]\boldsymbol{a}_z$$

which consists of four plane waves.

$$\nabla\times\boldsymbol{E}_s = -j\omega\mu_o\boldsymbol{H}_s \longrightarrow \boldsymbol{H}_s = \frac{j}{\omega\mu_o}\nabla\times\boldsymbol{E}_s = \frac{j}{\omega\mu_o}\left(\frac{\partial E_z}{\partial y}\boldsymbol{a}_x - \frac{\partial E_z}{\partial x}\boldsymbol{a}_y\right)$$