10.3

a) $\gamma = \alpha + j\beta$

$$\alpha = \frac{\omega}{c}\sqrt{\frac{\mu_r \epsilon_r}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2} - 1\right]} \quad \& \quad \beta = \frac{\omega}{c}\sqrt{\frac{\mu_r \epsilon_r}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2} + 1\right]}$$

$$\frac{\sigma}{\omega\epsilon} = \frac{0.08}{2\pi(50\times10^6)(3.6)\left(\frac{10^{-9}}{36\pi}\right)} = 8$$

$$\alpha = \frac{2\pi(50\times10^6)}{3\times10^8}\sqrt{\frac{(3.6)(2.1)}{2}\left[\sqrt{65} - 1\right]} = 5.411 \ [Np/m]$$

$$\beta = 6.129 \ [rad/m].$$

$$\gamma = 5.411 + j6.129 \quad [1/m]$$

b) $\lambda = \frac{2\pi}{\beta} = 1.025 \ [m]$

c) $u = \frac{\omega}{\beta} = 0.513\times10^8 \ [m/s]$

d) $$\eta = \eta_0\sqrt{\frac{\mu_r}{\epsilon_r\left(1 - j\frac{\sigma}{\omega\epsilon}\right)}} = 377\sqrt{\frac{2.1}{3.6(1-j8)}} = 287.94\frac{1}{\sqrt{1-j8}}$$

$$= \frac{287.94}{2.84\, e^{-j41.44^\circ}} = 101.39\, e^{j41.44^\circ} \ \Omega$$

e) $$\vec{H}_s = -\vec{a}_y \frac{6}{\eta} e^{-\gamma x} = -\vec{a}_y \frac{6\, e^{-(5.411 + j6.129)x}}{101.39\, e^{j41.44^\circ}}$$

$$= -\vec{a}_y\, 59.18\, e^{-5.411x}\, e^{-j6.129x - j41.44^\circ} \ [mA/m]$$

10.4

a) $\beta = 10 = \frac{\omega}{c}\sqrt{\frac{\mu_r \epsilon_r}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2}+1\right]}$

$$= \frac{2\pi \times 5\times 10^6}{3\times 10^8}\sqrt{\frac{(5)(2)}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2}+1\right]}$$

$$= 0.234\sqrt{\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2}+1}$$

$\therefore (42.706)^2 = \sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2}+1$

$\therefore \frac{\sigma}{\omega\epsilon} = 1822.8$

b) $\sigma = 1822.8\,\omega\epsilon = 1822.8\left(2\pi\times 5\times 10^6\right)\left(2\times\frac{10^{-9}}{36\pi}\right) = 0.203\ \left[\frac{S}{m}\right]$

c) $\epsilon_c = \epsilon + \frac{\sigma}{j\omega} = 2\epsilon_0 - j\,\frac{0.203}{2\pi\times 5\times 10^6} = 17.684\times 10^{-12} - j\,6.462\times 10^{-9}$ $[F/m]$

or

$$\epsilon_c = \epsilon\left(1-j\,\frac{\sigma}{\omega\epsilon}\right) = 2\epsilon_0\left(1-j\,1822.8\right)$$

$$= (2-j\,3645.6)\,\epsilon_0$$

d) $\alpha \simeq \beta = 10$ $[Np/m]$, because $\frac{\sigma}{\omega\epsilon} >> 1$ (good conductor)

e) since we have a good conductor

$$\eta = \sqrt{\frac{\omega\mu}{\sigma}}\,e^{j45°} = \sqrt{\frac{2\pi\times 5\times 10^6\times 5\times(4\pi\times 10^{-7})}{0.203}}\,e^{j45°}$$

$$= 31.18\,e^{j45°}\ [\Omega]$$

10.5

a) $\frac{\sigma}{\omega\epsilon} = \tan(2\times 30^\circ) = 1.732$

b) $\eta = \sqrt{\frac{\mu}{\epsilon(1-j\frac{\sigma}{\omega\epsilon})}}$ $\therefore |\eta| = \sqrt{\frac{\mu}{\epsilon\sqrt{1+(\frac{\sigma}{\omega\epsilon})^2}}} = 377\sqrt{\frac{\mu_r}{\epsilon_r\sqrt{1+(\frac{\sigma}{\omega\epsilon})^2}}}$

$\therefore 240 = 377\sqrt{\frac{1}{\epsilon_r\sqrt{1+1.732^2}}} = 377\sqrt{\frac{1}{\epsilon_r(\sqrt{4})}} = 377\sqrt{\frac{1}{2\epsilon_r}}$

$\therefore \epsilon_r = 1.234$

c) $\epsilon_c = \epsilon\left(1-j\frac{\sigma}{\omega\epsilon}\right) = 1.234\epsilon_0(1-j1.732)$

$= (10.91 - j18.89)\times 10^{-12}$ [F/m]

d) $\alpha = \frac{\omega}{c}\sqrt{\frac{\mu_r\epsilon_r}{2}\left[\sqrt{1+(\frac{\sigma}{\omega\epsilon})^2} - 1\right]}$

$= \frac{2\pi\times 10^6}{3\times 10^8}\sqrt{\frac{(1)(1.234)}{2}\left[\sqrt{1+1.732^2} - 1\right]}$

$= 16.45\times 10^{-3}$ [Np/m]

10.7

a) $\frac{\sigma}{\omega\epsilon} = \frac{4}{2\pi \times 10^8 (80 \times 10^{-9}/36\pi)} = 9$

$$\beta = \frac{2\pi \times 10^8}{3 \times 10^8} \sqrt{\frac{(1)(80)}{2}\left[\sqrt{1+9^2}+1\right]} = 42 \ [\text{rad/m}]$$

$$u = \omega/\beta = \frac{2\pi \times 10^8}{42} = 14.96 \times 10^6 \ [\text{m/s}]$$

b) $\lambda = \frac{2\pi}{\beta} = 0.15 \ [\text{m}]$

c) $\alpha = \frac{2\pi \times 10^8}{3 \times 10^8} \sqrt{\frac{(1)(80)}{2}\left[\sqrt{1+9^2}-1\right]} = 37.595 \ [\text{Np/m}]$

$$\delta = \frac{1}{\alpha} = 0.0266 \ [\text{m}].$$

The skin depth in Seawater is very short, this explains why radar cannot be used in submarine communication.

d) $\eta = \eta_o \sqrt{\frac{\mu_r}{\epsilon_r\left(1-j\frac{\sigma}{\omega\epsilon}\right)}} = 377\sqrt{\frac{1}{80(1-j9)}} = \frac{42.15}{\sqrt{1-j9}}$

$$= \frac{42.15}{\sqrt{9.05\, e^{-j83.66^\circ}}} = 14.011\, e^{j41.83^\circ} \ [\Omega]$$

10.8

a) $T = \frac{2\pi}{\omega} = \frac{2\pi}{\pi 10^8} = 2 \times 10^{-8}$ [S]

b) $\alpha = 0.1 = \frac{\omega}{c}\sqrt{\frac{\mu_r \epsilon_r}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2} - 1\right]}$

$$0.1 = \frac{\pi 10^8}{3 \times 10^8}\sqrt{\frac{(1)(4)}{2}\left[\sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2} - 1\right]}$$

$\therefore \sqrt{1+\left(\frac{\sigma}{\omega\epsilon}\right)^2} = 1.0046 \qquad \left(\frac{\sigma}{\omega\epsilon} = 0.096\right)$

$$\beta = \frac{\pi 10^8}{3 \times 10^8}\sqrt{\frac{(1)(4)}{2}\left[1.0046 + 1\right]} = 2.097 \text{ [rad/m]}$$

$$\lambda = \frac{2\pi}{\beta} = 2.997 \text{ [m]}$$

c) $\eta = 377\sqrt{\frac{\mu_r}{\epsilon_r\left(1 - j\frac{\sigma}{\omega\epsilon}\right)}} = 377\sqrt{\frac{1}{4(1-j0.096)}} = \frac{188.5}{\sqrt{1-j0.096}}$

$$= 188.07 e^{j2.742°} \ [\Omega]$$

$$\vec{E} = \vec{a}_z \, 12(188.07) e^{-0.1y} \sin(\pi \times 10^8 t - 2.097y + 2.742°) \ [\text{V/m}].$$

$$= \vec{a}_z \, 2256.8 \, e^{-0.1y} \sin(\pi \times 10^8 t - 2.097y + 2.742°) \left[\frac{\text{V}}{\text{m}}\right]$$

d) $\vec{E}$ leads $\vec{H}$ by $2.742°$.

10.19

a) $\frac{\sigma}{\omega\epsilon} = \frac{10^{-2}}{2\pi \times 8 \times 10^{6}\left(15 \times \frac{10^{-9}}{36\pi}\right)} = 1.5$ [not conducting]

b) $\frac{\sigma}{\omega\epsilon} = \frac{0.025}{2\pi \times 8 \times 10^{6}\left(16 \times \frac{10^{-9}}{36\pi}\right)} = 3.5$ [" "]

c) $\frac{\sigma}{\omega\epsilon} = 694.44$ [conducting].