Solutions

Marking: **M1** a correct method, **A1** the correct answer, **B1** an independent mark.

Each answer shows the steps, then the **result**.

2.1

$B_0 = \dfrac{E_0}{c} = \dfrac{50}{3.0 \times 10^8} = \mathbf{167\ nT}$; $\lambda = \dfrac{c}{f} = \mathbf{3.0\ m}$; $S = \dfrac{50^2}{2 \times 377} = \mathbf{3.3\ W/m^2}$

2.2

$S = \dfrac{P}{4\pi r^2} = \dfrac{1.0}{4\pi \times 10^2} = \mathbf{8.0 \times 10^{-4}\ W/m^2}$; $E_0 = \sqrt{2\eta_0 S} = \mathbf{0.77\ V/m}$

2.3

$\delta = \dfrac{1}{\sqrt{\pi f \mu_0 \sigma}}$; at 10 MHz $\delta = \mathbf{21\ \mu m}$; $\delta \propto \dfrac{1}{\sqrt{f}}$, so at 3.0 GHz it is $\dfrac{21}{\sqrt{300}} = \mathbf{1.2\ \mu m}$

2.4

$\eta_2 = \dfrac{377}{1.5} = \mathbf{251}\ \Omega$; $\lambda = \dfrac{c}{f\sqrt{\varepsilon_r}} = \mathbf{6.7\ cm}$; $\Gamma = \dfrac{251 - 377}{251 + 377} = -0.20$, so **4**% reflects

3.1

$\eta_2 = \dfrac{377}{3} = \mathbf{126}\ \Omega$

$\Gamma = \dfrac{126 - 377}{126 + 377} = \mathbf{-0.50}$, $\tau = \mathbf{0.50}$

$E_r = -100$ V/m, $E_t = \mathbf{100\ V/m}$; $\lambda_2 = \dfrac{1.0\text{ m}}{3} = \mathbf{0.33\ m}$

$S_i = \dfrac{200^2}{754} = 53.1$ W/m^2, $S_r = 0.25 \times 53.1 = 13.3$ W/m^2, $S_t = \dfrac{100^2}{2 \times 126} = 39.8$ W/m^2, and $13.3 + 39.8 = 53.1$

3.2

$\delta = \dfrac{1}{\sqrt{\pi \times 10^3 \times 4\pi \times 10^{-7} \times 3.5 \times 10^7}} = \mathbf{2.7\ mm}$

$e^{-1.0/2.7} = 0.69$, a loss of only $8.69 \times \dfrac{1.0}{2.69} = \mathbf{3.2\ dB}$

at 1.0 MHz $\delta = \dfrac{2.7}{\sqrt{1000}} = 85$ µm, so $\dfrac{t}{\delta} = 11.8$ and the loss is **102 dB**

aluminium blocks radio frequencies well but hardly touches a 1 kHz magnetic field; use a high-permeability material such as mu-metal or steel, whose large μ makes δ small

3.3

(a) $\Gamma = \dfrac{188.5 - 377}{188.5 + 377} = -\dfrac{1}{3}$, so **11**% reflects; loss $-10\log(1 - 0.11) = \mathbf{0.51\ dB}$

(b) $\lambda_d = \dfrac{c}{f\sqrt{\varepsilon_r}} = \dfrac{10\text{ cm}}{2} = 5.0$ cm; $d = \dfrac{\lambda_d}{2} = \mathbf{2.5\ cm}$

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(c) the half-wave sheet is strong and reflects almost nothing at the design frequency, but only near that frequency; the thin skin is light and works over a wide band, because it is too thin to reflect much at any frequency, but it is weaker

(d) $\eta_w = \dfrac{377}{\sqrt{80}} = 42\ \Omega$, so $\Gamma = \dfrac{42 - 377}{42 + 377} = -0.80$; about **64**% of the power reflects: the surface must shed water (a water-repellent coating, or a sloped cover)