THE UNIVERSITY OF BRITISH COLUMBIA
Department of Electrical and Computer Engineering

ELEC 311 – Electromagnetic Fields & Waves
2025 W1

Drill Problems for
Chapter 11– Uniform Plane Waves

The purpose of the seven drill problems from Chapter 11 is to help you master fundamental techniques used to analyze uniform plane waves.

Answers should be short and to the point. Use sketches to explain your solution as required. Clarity, conciseness, and presentation all count. Solution = Intuition (strategy) + Execution (calculation). Make both explicit.

The numerical answers below are from the text. Do you agree with them?

D11.1 The electric field amplitude of a uniform plane wave propagating in the $\mathbf{a}_z$ direction is 250 V/m. If $\mathbf{E} = E_x\mathbf{a}_x$ and $\omega = 1.00$ Mrad/s, find: (*a*) the frequency; (*b*) the wavelength; (*c*) the period; (*d*) the amplitude of $\mathbf{H}$.

Answers: (*a*) 159 kHz; (*b*) 1.88 km; (*c*) 6.28 μs; (*d*) 0.663 A/m

D11.2 Let $H_s = (2\mathbf{4} - 40\mathbf{a}_x - 3\mathbf{4}20\mathbf{a}_y)e^{-j0.07z}$ A/m for a uniform plane wave traveling in free space. Find: (*a*) ω; (*b*) H_x at P (1, 2, 3) at $t = 31$ ns; (*c*) $|\mathbf{H}|$ at $t = 0$ at the origin.

Answers: (*a*) 21.0 Mrad/s; (*b*) 1.934 A/m; (*c*) 3.22 A/m

D11.3 A 9.375-GHz uniform plane wave is propagating in polyethylene (see Appendix C of the textbook for the details). If the amplitude of the electric field intensity is 500 V/m and the material is assumed to be lossless, find: (*a*) the phase constant; (*b*) the wavelength in the polyethylene; (*c*) the velocity of propagation; (*d*) the intrinsic impedance; (*e*) the amplitude of the magnetic field intensity.

Answers: (*a*) 295 rad/m; (*b*) 2.13 cm; (*c*) 1.99×10^8 m/s; (*d*) 251 Ω; (*e*) 1.99 A/m

D11.4 Given a nonmagnetic material having $\epsilon'_r = 3.2$ and $\sigma = 1.5 \times 10^{-4}$ S/m, find numerical values at 3 MHz for the (*a*) loss tangent; (*b*) attenuation constant; (*c*) phase constant; (*d*) intrinsic impedance.

Answers: (*a*) 0.28; (*b*) 0.016 Np/m; (*c*) 0.11 rad/m; (*d*) 207 $\angle 7.8°$ Ω

D11.5 Consider a material for which $\mu_r = 1$, $\epsilon'_r = 2.5$, and the loss tangent is 0.12. If these three values are constant with frequency in the range 0.5 MHz $\leq f \leq 100$ MHz, calculate: (a) σ at 1 and 75 MHz; (b) λ at 1 and 75 MHz; (c) v_p at 1 and 75 MHz.

Answers: (a) 1.67×10^{-5} and 1.25×10^{-3} S/m; (b) 190 and 2.53 m; (c) 1.90×10^8 m/s twice

D11.6 At frequencies of 1, 100, and 3000 MHz, the dielectric constant of ice made from pure water has values of 4.15, 3.45, and 3.20, respectively, while the loss tangent is 0.12, 0.035, and 0.0009, also respectively. If a uniform plane wave with an amplitude of 100 V/m at $z = 0$ is propagating through such ice, find the time-average power density at $z = 0$ and $z = 10$ m for each frequency.

Answers: 27.1 and 25.7 W/m²; 24.7 and 6.31 W/m²; 23.7 and 8.63 W/m²

D11.7 A steel pipe is constructed of a material for which $\mu_r = 180$ and $\sigma = 4 \times 10^6$ S/m. The two radii are 5 and 7 mm, and the length is 75 m. If the total current $I(t)$ carried by the pipe is $8 \cos \omega t$ A, where $\omega = 1200\pi$ rad/s, find: (a) the skin depth; (b) the effective resistance; (c) the dc resistance; (d) the time-average power loss.

Answers: (a) 0.766 mm; (b) 0.557 Ω; (c) 0.249 Ω; (d) 17.82 W