ECET 3410 **Waveguides – Plane Waves – Wave Propagation**

High *f* Systems **Print Name (Last Name First):** **Sample Problems / Answers**

Problem #A) A variable frequency AC source is used to excite a 4cm x 2cm air-filled waveguide.

a) If the TE_{10} mode is setup within the guide, determine the **minimum possible source frequency**.
b) If the TE_{11} mode is setup within the guide, determine the **minimum possible source frequency**.

a) f_{c10} = ________3.75 G________ Hz
b) f_{c11} = ________8.385 G_______ Hz

Problem #B) A 1 GHz plane wave is propagating through a uniform medium ($\mu_r = 1$, $\varepsilon_r = 1$, $\sigma = .1$ S/m).

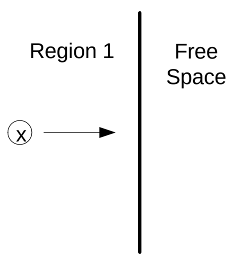
a) Determine the **velocity of propagation**, the **propagation constant** (in rectangular form), and the **intrinsic impedance** (in polar form) of the medium.
b) If the electric field strength ($\mathbf{E}^+$) found to be 10 V/m at a given reference point, determine the **magnetic field strength** at the same point.

a) **v** = _________2.43×10^8_____________ m/s
γ = _________15.24+j25.9____________
η = _________$262.7\angle 30.45°$__________ Ω
b) $\mathbf{H}^+$ = ______$0.038\angle -30.45°$________ A/m

Problem #D) A 1cm x 2cm waveguide is propagating an 8 GHz wave. What mode(s) may be propagating at this frequency? What is the cut-off frequency of the dominant mode?

(You would need to check the higher modes to prove this) → **mode(s)** ____TE_{10}__________
f_c = _______7.5 GHz_____

Problem #E) A 2GHz plane wave traveling in a region ($\varepsilon_r = 3$, $\mu_r = 1$) is normally incident upon an infinite region of free space. Determine the velocity and the wavelength in both regions.



v_1 = ___1.732×10^8 m/s _______
λ_1 = _________8.66 cm _____

v_{fs} = ____3×10^8 m/s_________
λ_{fs} = ______15 cm_________

Problem #I) A variable-frequency, AC source is used to excite a 2cm x 1cm air-filled waveguide.

a) Determine the **cutoff frequency** for the TE_{10} and TE_{11} modes of propagation.

a) f_{c10} = ____**7.5G**_____ Hz f_{c11} = ____**16.77G**_____ Hz

Problem #M) An air-filled, rectangular waveguide will be used within a 6.3 GHz communication system. The system components are designed to couple the TE_{10} mode. Determine the larger **dimension** of the waveguide in centimeters if the smaller dimension is ½ the length of the larger dimension. Justify your solution with a written statement describing the reasoning behind your answer.

a = ________**3**_______ cm

Justification: ***This gives a cutoff freq. of 5GHz. The cutoff needs to be lower than the operating frequency for the waveguide to function, but shouldn't be too close because losses will be too large, nor too large due to the possibility of multiple modes.***

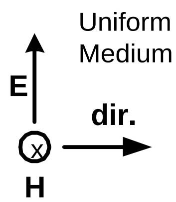
Problem #N) A 5.8 GHz plane wave is propagating through salt-water ($\mu_r = 1$, $\varepsilon_r = 1$, $\sigma = .01$ S/m). Determine the ***attenuation constant*** (from the propagation constant) as well as the velocity of propagation for the wave in the water. Do ***NOT*** assume that this is a good conductor.

α = ________**1.8847**_______Np/m
v = ____**2.99975×10^8**_____m/sec

Problem #O) A metal has a conductivity of $\sigma = 5.8\text{x}10^7$ S/m, and a relative permeability and permittivity of μ_r = 1.0 and ε_r = 1.0 respectively. Determine both the skin depth and the attenuation constant for the metal with respect to a 5.8GHz plane wave.

$\boldsymbol{\delta_s}$ = ______**0.868 x 10^{-6}**______m(/Np)
$\boldsymbol{\alpha}$ = ________**1152412**________Np/m

Problem #P) A 3 GHz plane wave is propagating in salt water (μ_r = 1.0, ε_r = 1.0, σ = 0.24 S/m).
Determine the **velocity of propagation** of the wave in this media.



(Hint – do NOT assume the media is lossless, instead use β)

v = _______**2.56x10^8**____________ m/s

Problem #Q) A highly conductive material has a conductivity of $\sigma = 5.0\text{x}10^7$ S/m and a relative permeability and permittivity of μ_r = 2500 and ε_r = 1.0 respectively. Determine the **skin depth** of this material at a frequency of 5.8 GHz. (Provide units)

δ_s = _____**1.87x10^{-8} m**_____________

Problem #R) A highly conductive material has a conductivity of $\sigma = 6.0\text{x}10^7$ S/m, and a relative permeability and permittivity of μ_r = 4.0 and ε_r = 1.0 respectively. Determine the **depth at which the wave may be assumed fully attenuated** (in terms of power density) in this material at a frequency of 4.8 GHz. (Provide units)

Depth for complete attenuation = ______**1.41 µm**______

Problem #S) A 1.8 GHz plane wave is propagating through salt-water (μ_r = 1, ε_r = 1, σ = .06 S/m).
Determine the ***propagation constant*** (in rectangular form) as well as the velocity of propagation for the wave in the water. Do ***NOT*** assume that this is a good conductor.

$\boldsymbol{\alpha}$ = ________**10.867 + j39.23**_______Np/m

v = __________**2.88 x 10^8**_________m/sec

Problem #T) Gold has a conductivity of $\sigma = 4.5\text{x}10^7$ S/m, and a relative permeability and permittivity of μ_r = 1.0 and ε_r = 1.0 respectively. Determine the minimum thickness of gold plating that will prevent a wave having a frequency of 800MHz or higher from passing through the gold (based upon remaining wave power as discussed in class). Be sure to provide units.

Thickness = _______**7.96 µm**________