ECET 3410 – Fall 2016

High *f* Systems – Exam III **Print Name (LAST NAME FIRST):** Solutions

Instructions: Show all of your work, making sure that your work in legible and that your reasoning can be followed. No credit will be given for illegible or illogical work, or for final answers that are not justified by the work shown. Place all final answers in the spaces provided. This exam is closed book, except for a single 8.5"x11" sheet of handwritten notes which may **NOT** contain any numerically-solved problems.

Example Table 1.3 – Coaxial Cables

RG #	AWG Material	Insulation	# Shields	Jacket	Nom. O.D. (inch)	Nom. Imp. (Ohms)	Nom. Vel. Of Prop.	Nom. Cap. (pF/ft.)	Nom. Attenuation per 100' MHz	dB	Standard Spool Lengths
16A/U	18 Copper	Cellular Poly-ethylene	1	Black Vinyl	.195	50	66%	30.8	100 200 400	2.5 3.5 5.0	100,500 1000
18/U	18 Copper	Cellular Poly-ethylene	1	Black Vinyl	.280	75	78%	24	100 200 400	2.0 3.0 4.5	100,500 1000

Note: $\mu_o = 4\pi \cdot 10^{-7}$ H/m $\quad \varepsilon_r = \frac{1}{36\pi} \cdot 10^{-9}$ F/m

Problem #1) Given three waveguides having the following dimensions:

Waveguide A: 4.0cm x 1.0cm **Waveguide B: 3.5cm x 2.0cm** **Waveguide C: 3.0cm x 1.0cm**

You are asked to **choose one** of the waveguides for use in a communication system with the goal of operating the system at the lowest possible frequency.

Which waveguide (A, B, or C) would be the correct choice, and **above what minimum frequency** can the system theoretically operate? (Note – to get full credit for this problem, work must be shown in the space below that justifies your choice of waveguide.)

Lowest cutoff → $TE_{1,0}$

A: $f_{c_{10}} = \frac{c}{2a} = \frac{3\times10^8}{(0.04)(2)} = 3.75\ GHz$ ← "widest" waveguide

B: $f_{c_{10}} = \frac{c}{2a} = \frac{3\times10^8}{(0.035)(2)} = 4.29\ GHz$

C: $f_{c_{10}} = \frac{c}{2a} = \frac{3\times10^8}{(2)(0.03)} = 5\ GHz$

waveguide choice = A

minimum frequency of operation = 3.75 G Hz

Problem #2) Determine the **velocity of propagation** for a plane wave that is traveling through a lossless medium that has a relative permeability μ_r = **1**, and a relative permittivity of ε_r = **1**.

$v = \frac{c}{\sqrt{\varepsilon_r \mu_r}} = \frac{3\times10^8}{\sqrt{1\cdot1}} = 3\times10^8$

v = 3×10^8 m/sec

Problem #3) A **4.8GHz** uniform plane wave is traveling through salt water. If the salt water has the following material properties:

$\mu_r = 1, \quad \varepsilon_r = 1, \quad \sigma = 0.02$ S/m

a) Determine the **propagation constant**, $\gamma=\alpha+j\beta$, in rectangular form for the plane wave as it propagates through the salt water.

b) Determine the **intrinsic impedance**, η, of the salt-water in polar form.

$$\gamma = \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)}$$

$$j\omega\mu = j(2\pi)(4.8\times10^9)(1)(4\pi\times10^{-7}) = j37899$$

$$\sigma + j\omega\varepsilon = 0.02 + j(2\pi)(4.8\times10^9)(1)\left(\tfrac{1}{36\pi}\times10^{-9}\right) = 0.02 + j0.266$$

$$= \sqrt{j37899(0.02+j0.266)} = 3.767 + j100.6$$

$$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}} = \sqrt{\frac{j37899}{0.02+j0.266}} = 376.46 \angle 2.145^\circ \ \Omega$$

a) $\gamma =$ $3.767 + j100.6$

b) $\eta =$ $376.46 \angle 2.145^\circ$

Problem #4) A sheet of metal has a conductivity of $\sigma = 4.6\text{x}10^7$ **S/m**, a relative permeability $\mu_r = 1$, and a relative permittivity of $\varepsilon_r = 1$. Determine the **skin depth**, δ_s, for a 900MHz plane wave that is incident upon the metal sheet.

$$\delta_s = \sqrt{\frac{1}{\pi f \mu \sigma}} = \sqrt{\frac{1}{(\pi)(900\times10^6)(4\pi\times10^{-7})(4.6\times10^7)}}$$

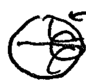
$$= 2.4735\times10^{-6} \text{ m}$$

$\delta_s =$ 2.47×10^{-6} m

Problem #5) Specify whether each statement is TRUE or FALSE.

TRUE — If two different loads connected to the receiving-end of a similar transmission-lines result in the same reflection coefficient magnitudes then they will also result in the same **VSWRs** on the lines. $VSWR = \frac{1+|\Gamma|}{1-|\Gamma|}$ ← magnitude ✓

false — The **circle** that provides the outer-boundary of the Smith Chart defines a set of impedance values all of which have an infinite magnitude (i.e. – an "open-circuit").



R = ∅ circle

false — Given a source connected to a coaxial line; if the **source frequency is decreased**, the **wavelength** on the line will also decrease.

$\lambda = v/f$ f↓ λ↑

false — Waveguides can only theoretically operate at their **cutoff frequency**.

✗ above

TRUE — The **creation of a reflected wave** on a transmission-line may cause the steady-state voltage magnitude on the line to either increase or decrease depending on the magnitude of the load terminating the line. $V = V^+ + V^-$ ← may be positive or negative

false — The magnitude of the **reflection coefficient** for a "matched" load is equal to one (1). ✗

$\Gamma_R = \frac{Z_R - Z_0}{Z_R + Z_0} = \emptyset$ matched $(Z_R = Z_0)$

TRUE — For typical coaxial transmission-lines (like those shown in "Example Table 1-3"), the **relative permeability** of the insulating material between the conductors is assumed to equal one (1). ↑ True (Non-magnetic insulation) note $\epsilon_r > 1$ Typically (permittivity)

false — The **phase constant** (β) is assumed to be zero on a lossless transmission-line.

No ↑ $\alpha = \emptyset$, not β

TRUE — The **phase constant** (β) for a practical transmission-line will typically increase with increasing source frequency.

$\beta = \frac{2\pi}{\lambda} = \frac{2\pi f}{v}$ ✓

TRUE — The **attenuation constant** (α) on a transmission-line will typically increase with increasing source frequency.

false — The **sending-end** of a transmission-line is the end at which a reflected waveform is created.

↗ happens @ receiving-end (load)

TRUE — The **nominal velocity** (as given in table 1-3 of the text) defines the velocity of a wave on a coaxial-cable as a percent (%) of the speed of light in "air" (free-space).

TRUE — When expressed in decibels, attenuation on a 200m coaxial-cable will be 2x larger ~~that~~ Than that on a 100m cable of the same type when operating at the same frequency.

Problem #6) Multiple Choice – Write the letter corresponding to the best response to complete each statement in the blank preceding the statement.

<u>A (or B)</u> An **incident waveform** is:

A) a waveform traveling from the sending end to the receiving end of a transmission-line ✓ ← Best
B) a waveform that decreases in magnitude as it travels on a practical transmission-line ← True, but also true for a reflected wave
C) a waveform that increases in magnitude as it travels down a practical transmission-line
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

<u>~~X~~ A or B</u> A **matched load** terminating a lossless transmission-line: ← I'm sorry, this should have been "lossy"... I'll accept A or B

A) will not produce a reflected waveform ✓
B) will receive 100% of the power sent down the line by a source connected to the sending-end of the line ✓
C) will result in a infinite VSWR on the line ✓
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

<u>A</u> Given the **traveling wave equation** $E(x) = E_0^+ \cdot e^{-\gamma \cdot x} + \Gamma_R \cdot E_0^+ \cdot e^{-2\cdot\gamma\cdot L} \cdot e^{+\gamma \cdot x}$ for an AC transmission-line, the term "$\Gamma_R \cdot E_0^+ \cdot e^{-2\cdot\gamma\cdot L}$" is best described as:

A) the value of the reflected wave seen at the sending-end of the line ✓
B) the value of the incident wave seen at the receiving-end of the line ✗
C) the value of the reflected wave seen at the receiving-end of the line ✗
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

<u>D</u> The **standing wave pattern** on an ideal "short-circuited" transmission-line:

A) repeats every ½-wavelength of the traveling (incident and reflected) waveforms ✓
B) will have a "minimum" at the receiving end of the line ✓
C) is a repetitive pattern that always varies in magnitude from 0 → max → 0 → max → … ✓
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

<u>D</u> The **VSWR** on a lossless transmission-line:

A) will be 1 for a matched line ✓
B) is defined to be the ratio of the maximum RMS voltage in the standing-wave pattern on the line compared to the minimum RMS voltage in the standing-wave pattern on the line ✓
C) is not affected by velocity of the wave on the transmission-line ✓
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

<u>B</u> The **wavelength** of a steady-state AC wave propagating on a transmission-line:

A) is the distance between adjacent zero-voltage locations for a traveling wave on the line ✗
B) is the distance that the wave is able to travel in one period of the AC waveform ✓
C) will increase if the frequency of the AC wave is increased ✗
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

A Time Domain Reflectometry:

A) cannot be used to determine the length of a "matched line" ✓
B) cannot be used to determine the length of a "short-circuited line" ✗
C) cannot be used to determine the length of a "open-circuited line". ✗
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

C With respect to waveguides, the **Cutoff Frequency** for a given mode of operation:

A) will depend on the material from which the waveguide is constructed (i.e. – copper vs. aluminum, etc) ✗
B) will decrease with increasing source frequency ✗
C) will increase if the waveguide is decreased in size ✓
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

D With respect to coaxial-type transmission-lines, the **characteristic impedance** of a line:

A) provides a ratio of voltage over current for an incident wave traveling down the line ✓
B) will decrease if the material separating the conductors is replaced by a new material with a higher relative permittivity ✓
C) will not change if the magnitude of the load impedance terminating the line is increased ✓
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

B When using a **Smith Chart** to determine the input impedance of a lossy-line terminated with a known load:

A) the solution will require a rotation around the Smith Chart in the counter-clockwise direction ✗ Toward Gen
B) the input impedance will be closer to the center of the chart than the load impedance ✓
C) the solution point will be ½ way around the Smith Chart if the line is one (1) wavelength long. ✗
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

A A **single-stub tuner**:

A) is a matching device that can be used to match a "complex" load to a "real" impedance source
B) typically utilizes a short-circuited stub but would theoretically function with an open-circuited stub although the stub would have to be in series with the "line" section instead of in parallel. ✗
C) only operates above a cutoff frequency that is dependent on the length of the "stub" ✗
D) all of the above (A-C) are correct
E) none of the above (A-D) are correct

Do NOT Write Below This Line

1) ____ 2) ____ 3) ____ 4) ____ 5) ____ 6) ____ Total) ______/100