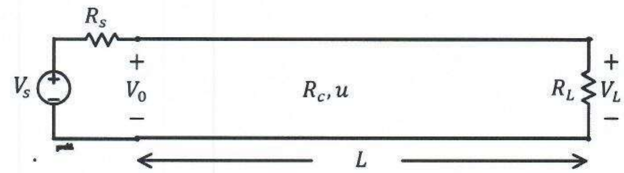
ELEC 353 – Final Exam 2019 – Solution

Question 1



1.A transmission line is L =14 cm long. It has speed-of-propagation u = 17 cm/ns, and characteristic resistance R_c = 73 ohms. The load resistor is R_L =200 ohms. The voltage generator V_S is a pulse function from 0 volts to 10 volts starting at t=0 and ending at t=1 ns. The internal resistance of the generator is R_S =100 ohms.

1.1)What is the voltage V_0 at the generator terminals at t=0.5 ns?

7.14 volts	8.89	6.67	4.22	None of these

1.2)What is the voltage V_L at the load terminals at t=1 ns?

6.18 volts	13.6	16.9	11.6	None of these

1.3)What is the voltage V_0 at the generator terminals at t=1.8 ns?

3.29 volts	2.27	3.69	1.79	None of these

1.4)What is the voltage V_L at the load terminals at t=2 ns?

1.96volts	8.04	0.00	6.46	None of these

1.5)What is the voltage V_L at the load terminals at t=2.6 ns?

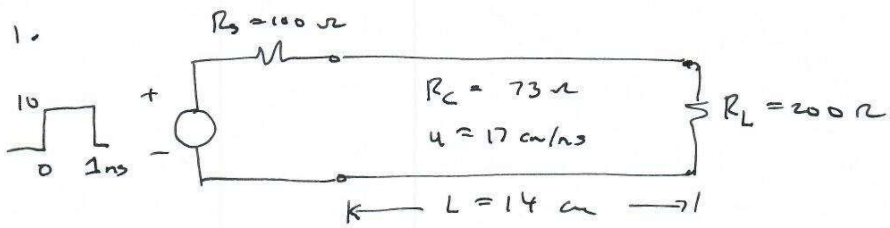
-11.9 volts	-2.86	0. 449	-5.28	None of these

1.6)What is the voltage V_0 at the generator terminals at t=3.4 ns?

-0.809 volts	-1.43	0.165	-1.26	None of these

ELEC 353 FINAL EXAM SOLUTION 2019

1.

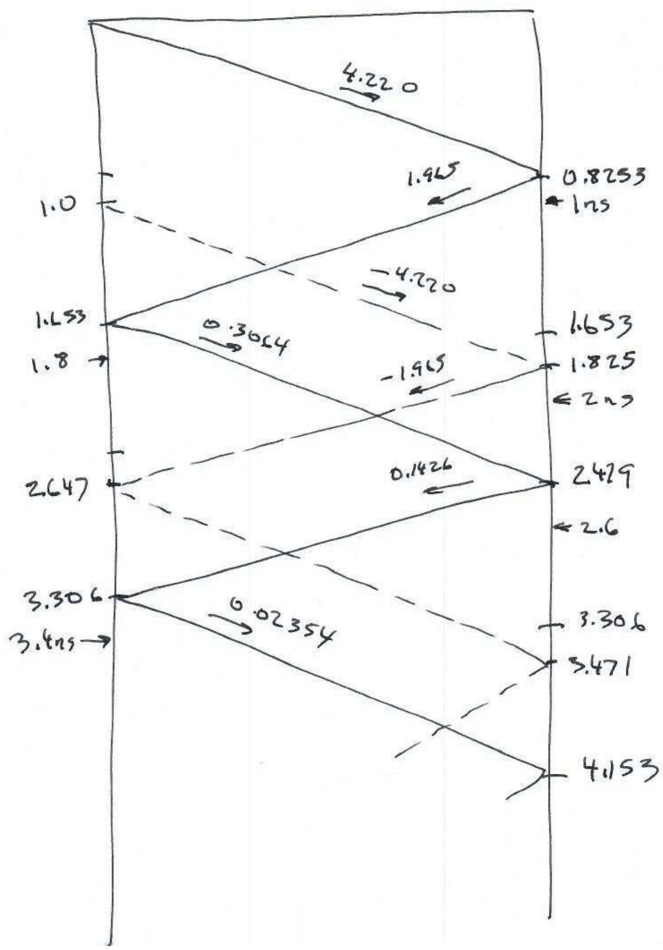


$$T = \frac{L}{u} = \frac{14}{17} = 0.8235 \text{ ns}$$

$$V^+ = \frac{R_c V_s}{R_s + R_c} = \frac{73 \times 10}{73 + 100} = 4.220 \text{ V.}$$

$$\Gamma_s = \frac{R_s - R_c}{R_s + R_c} = \frac{100 - 73}{100 + 73} = 0.1561$$

$$\Gamma_L = \frac{R_L - R_c}{R_L + R_c} = \frac{200 - 73}{200 + 73} = 0.4652$$



1.1) V_0 at 0.5 ns

$V_0 = 4.220$

1.2) V_L at 1 ns

$V_L = 4.220 + 1.965$
$= 6.185$

1.3) V_0 at 1.8 ns

$V_0 = 4.220 + 1.965 + 0.3064 - 4.220$
$= 6.491 - 4.220$
$= 2.271$

1.4) V_L at 2 ns

$V_L = 4.220 + 1.965 - 4.220 - 1.965$
$= 0$

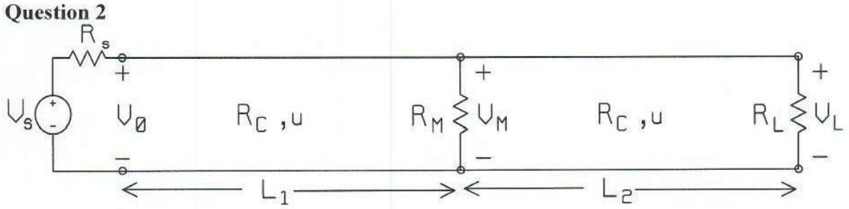
1.5) V_L at 2.6 ns

$V_L = 0 + 0.3064 + 0.1426$
$= 0.4490$

1.6) V_0 at 3.4 ns

$V_0 = 0.1426 + 0.02354$
$= 0.1661$

Question 2



The transmission-line circuit shown above has a step function generator starting at $t = 0$ of height $V_s = 10$ volts and internal resistance $R_s = 200$ ohms. The two transmission lines are identical, with characteristic resistance $R_c = 50$ ohms and speed of travel $u = 20$ cm/ns. The lengths are $L_1 = L_2 = 20$ cm. The load resistors are $R_M = 120$ ohms and $R_L = 5$ ohms.

2.1 What is the voltage V_0 across the generator terminals at $t = 0.4$ ns?

6.66 volts	3.33	9.80	2.00	None of these

2.2 What is transmission coefficient at the junction?

0.29	0.67	0.83	0.76	None of these

2.3 What is the voltage V_M across the junction at $t = 1.2$ ns?

2.80 volts	4.44	2.54	1.66	None of these

2.4 What is the voltage V_L across the load at $t = 2.4$ ns?

1.69 volts	4.48	5.93	0.30	None of these

2.5 What is the voltage V_0 across the generator at $t = 2.4$ ns?

1.45 volts	9.53	2.28	5.20	None of these

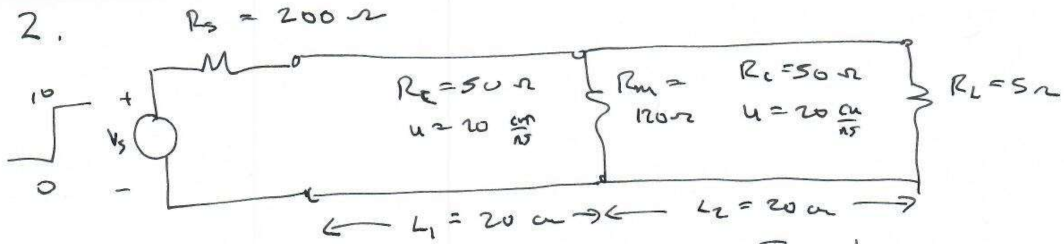
2.6 What is the voltage V_M at the junction at $t = 3.2$ ns?

5.20 volts	5.93	0.363	1.69	None of these

2.7 What is the final value of the load voltage V_L as $t \to \infty$?

0.23 volts	9.05	1.60	5.71	None of these

2.



$T_1 = \frac{L_1}{u} = \frac{20}{20} = 1\,ns \qquad T_2 = 1\,ns$

$$V^+ = \frac{R_c V_s}{R_s + R_c} = \frac{50 \times 10}{50 + 200} = 2 \text{ volts}$$

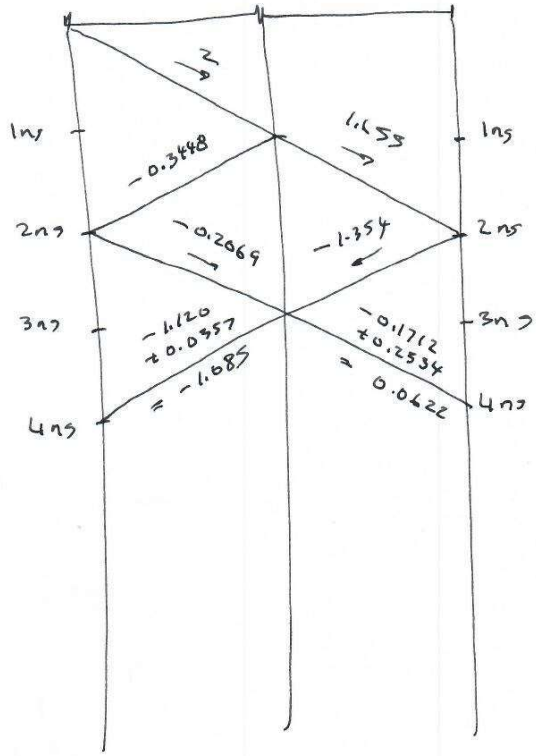
$$\Gamma_s = \frac{R_s - R_c}{R_s + R_c} = \frac{200 - 50}{200 + 50} = \frac{150}{250} = 0.6$$

$$\Gamma_L = \frac{R_L - R_c}{R_L + R_c} = \frac{5 - 50}{5 + 50} = -0.8182$$

$$R_p = R_m \parallel R_c = \frac{120 \times 50}{120 + 50} = 35.29$$

$$\Gamma_J = \frac{R_p - R_c}{R_p + R_c} = \frac{35.29 - 50}{35.29 + 50} = -0.1724$$

$$T_J = \frac{2R_p}{R_p + R_c} = \frac{2 \times 35.29}{35.29 + 50} = 0.8275.$$



2.1) V_o at 0.4 ns

$V_o = 2$ volts

2.2) $T_J = 0.8275$

2.3) V_m at 1.2 ns

$V_m = 2 - 0.3448$
$= 1.655$

2.4) V_L at 2.4 ns

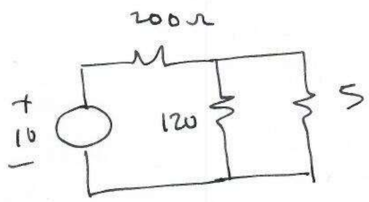
$V_L = 1.655 - 1.354$
$= 0.3012$

2.5) V_o at 2.4 ns

$V_o = 2 - 0.3448 - 0.2069$
$= 1.448$ v.

2.6) $V_m = 1.655 - 0.2069$
$- 1.085$
$= 0.3631$

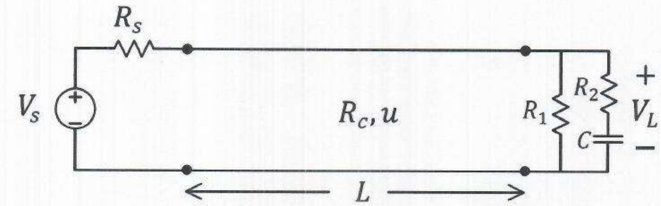
2.7) FINAL VALUE



$120 \| 5 = 4.8\ \Omega$

$V_L = 4.8 \times \frac{10}{200+4.8} = 0.2344$

Question 3



A transmission line has length L = 980 cm, characteristic resistance R_c=300 ohms and speed of travel u = 17 cm/ns. The generator is a step function starting at t = 0, of amplitude V_s =10 volts and internal resistance R_s =300 ohms. The line is terminated by a load as shown in the figure, with two resistors R_1=120 ohms and R_2=20 ohms, and a capacitor C =0.1636 pF. The capacitor is initially uncharged.

3.1 At ~~what time~~ does the exponential charging start?

57.7 ns	42.4	30.0	19.4	None of these

3.2 ~~What is the~~ time constant of the exponential charging?

9.00 ns	5.82	17.3	12.7	None of these

17.3 ps

3.3 What is the initial value of ~~the load~~ voltage V_L when the exponential charging starts?

1.42 volts	0.54	1.82	1.12	None of these

3.4 What is the final value of ~~the exponential~~ charging of the load voltage V_L?

3.41 volts	2.86	5.44	2.24	None of these

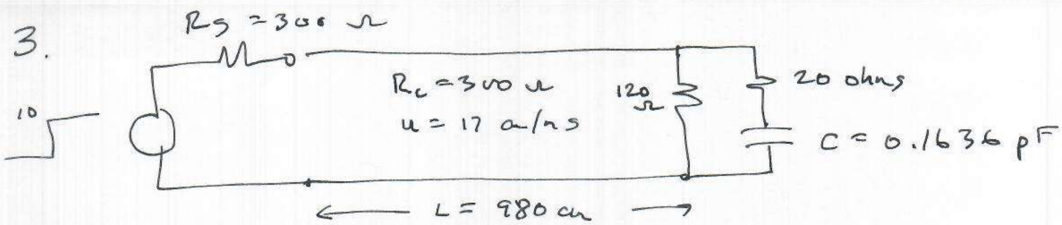
3.5 Write the formula for the ~~voltage~~ across the capacitor. (2 marks)

$$V_L(t) = 2.857 - 2.317\, e^{-\frac{t-57.65}{17.3\times 10^{-3}}} \quad (t \text{ in ns})$$

3.6 What is the value of the voltage V_L at t = 107.8 ns?

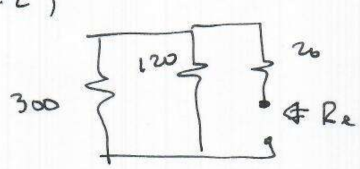
2.38 volts	4.43	2.73	1.83	None of these

3.



3.1) $T = \frac{L}{u} = \frac{980}{17} = 57.65$ ns

3.2)



$300 \parallel 120 = 85.714$

$R_e = 20 + 85.714$

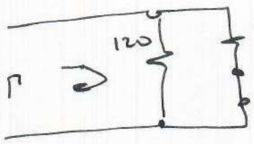
$= 105.714$

$T = R_e C = 105.714 \times 0.1636 \times 10^{-12}$

$= 17.295$ ps

Since the units of the answers on the exam paper were "ns" the correct answer is "none of these".

3.4) Initial value: C is a short circuit.



$R_L = 120 \| 20 = 17.14$

$$\Gamma = \frac{R_L - R_C}{R_L + R_C} = \frac{17.14 - 300}{17.14 + 300}$$

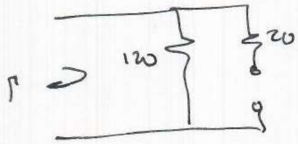
$$= -0.8919$$

$V^+ = 5$

$V^- = \Gamma V^+ = 5 \times (-0.8919) = -4.460$

$V_L = V^+ + V^- = 5 - 4.460 = 0.540$

3.5) Final Value: C is an open circuit



$$\Gamma = \frac{120 - 300}{120 + 300} = -0.4286$$

$V^+ = 5$

$V^- = 5\,\Gamma = -2.143$

$V_L = V^+ + V^- = 5 - 2.143$

$= 2.857$

3.6) $V_L(t) = V_{final} + (V_{initial} - V_{final})\, e^{-\frac{t - T}{\tau}}$

$$= 2.857 + (0.5400 - 2.857)\, e^{-\frac{t - 57.65}{17.295 \times 10^{-3}}}$$

with t in ns.

$$V_L(t) = 2.857 - 2.317\, e^{-\frac{t - 57.65}{17.295 \times 10^{-3}}}$$

3.7) $t = 107.8$ ns

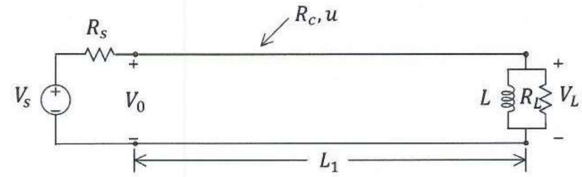
$$V_L(107.8) = 2.857 - 2.317\, e^{-\frac{107.8 - 57.65}{17.295 \times 10^{-3}}}$$

$$= 2.857 - 2.317\, e^{-2900}$$

$= 2.857$ volts

The correct answer is “none of these”.

Question 4



A transmission line circuit operates at a frequency of 2450 MHz. The transmission line has characteristic resistance $R_c = 55$ ohms and speed of travel $u = 14$ cm/ns. The length of the transmission line is $L_1 = 1.375\lambda$ where λ is the wavelength on the transmission line. The load impedance consists of an inductance of $L = 14$ nanoHenries in parallel with a resistance R_L=30 ohms. The A.C. generator has R.M.S. value V_s=5 volts. The internal resistance is R_s=25 ohms.

4.1 Find the impedance of the inductance in parallel with the load resistance at the operating frequency.

55.68+j15.50 ohms	67.37+j29.17	29.43+j4.10	70.32+j45.68	None of these

4.2 What is the length of the transmission line in cm?

7.86 cm	6.43	5.00	3.57	None of these

4.3 What is the magnitude and angle of the reflection coefficient at the load?

$0.139\angle 79.5°$	$0.252\angle 53.6°$	$0.306\angle 168.1°$	$0.361\angle 51.4°$	None of these

4.4 What is the standing-wave ratio (SWR) on the transmission line?

2.13	1.67	1.89	1.32	None of these

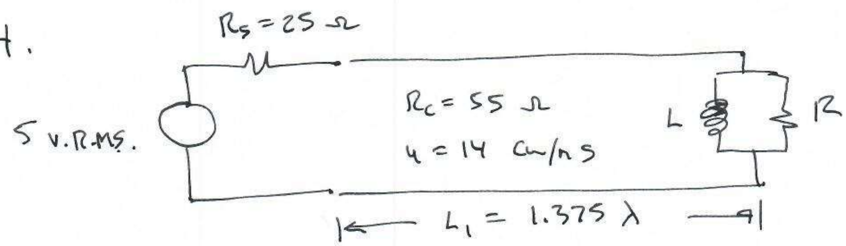
4.5 Find the input impedance of the transmission line circuit.

78.30-j24.98 ohms	41.74+j2.15	84.55-j43.80	40.85-j27.03	None of these

4.6 Find the R.M.S. value of the voltage V_0 at the input to the transmission line.

4.04 volts	3.44	3.87	3.13	None of these

4.



$f = 2450$ MHz $\quad \omega = 2\pi f = 1.539 \times 10^{10}$

$L = 14$ nH

$R_L = 30\ \Omega$

4.1) $Z_L = j\omega L = j\ 1.539 \times 10^{10} \times 14 \times 10^{-9} = j215.5\ \Omega$

$Z_{LOAD} = 30 \| j215.5 = 29.43 + j4.096\ \Omega$

4.2) $\lambda = \frac{u}{f} = \frac{14}{2.450} = 5.714$ cm

$L = 1.375\ \lambda = 7.857$ cm

4.3) $\Gamma_L = \dfrac{Z_{LOAD} - R_C}{Z_{LOAD} + R_C} = \dfrac{(29.43 + j4.096) - 55}{(29.43 + j4.096) + 55}$

$= -0.29979 + j\,0.06305$

$= 0.3063 \angle 168.1^\circ$

4.4) $SWR = \dfrac{1 + |\Gamma_L|}{1 - |\Gamma_L|} = 1.883$

4.5) $\beta = \dfrac{2\pi}{\lambda} = \dfrac{360}{0.05714} = 6300 \text{ deg/m}$

$\beta L = \dfrac{2\pi}{\lambda} 1.375\lambda = 360 \times 1.375 = 495^\circ$

$\tan \beta L = -1$

$Z_{IN} = R_C \dfrac{Z_{LOAD} + jR_C \tan \beta L}{R_C + j Z_{LOAD} \tan \beta L}$

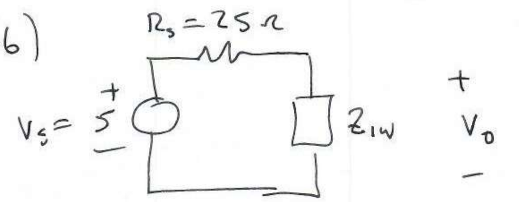
$Z_{IN} = 55 \dfrac{29.43 + j4.096 + j55(-1)}{55 + j(29.43 + j4.096)(-1)}$

$= 55 \dfrac{58.80 \angle -59.976}{66.02 \angle -26.47}$

$= 48.985 \angle -33.5$

$= 40.85 - j\,27.04$

4.6)



$V_o = Z_{IN} \dfrac{V_S}{Z_{IN} + R_S} = \dfrac{48.985 \angle -33.5 \times 5}{48.985 \angle -33.5 + 25}$

$= 3.441 \angle -11.18^\circ$

V_o RMS is 3.441 V.

Question 5

A plane wave travels in the z direction in a material at 1500 MHz. The relative permittivity of the material is $\varepsilon_r = 51$ and the loss tangent is 0.05. The electric field is oriented parallel to the x axis. The amplitude of the electric field at $z = 0$ is 5 volts/meter and the phase is zero degrees. The material is non-magnetic.

5.1 What is the value of the conductivity?

63.8 mS/m	8.68	267	213	None of these

5.2 ~~What is the phase~~ constant?

224.6 rad/meter	71.7	14.4	53.6	None of these

5.3 What is the penetration depth?

1.40 m	0.250	0.178	0.113	None of these

5.4 What is the amplitude of the electric field at $z = 3.743$ cm?

1.36 V/m	0.913	0.612	1.12	None of these

5.5 What is the magnitude of the intrinsic impedance of the material?

124.9 ohms	164.8	65.1	52.7	None of these

5.6 What is the amplitude of the magnetic field at $z = 0$?

40.04 mA/m	30.34	76.22	94.84	None of these

5) $f = 1500$ MHz $\quad \omega = 2\pi f = 9.424 \times 10^9$ r/s

$\epsilon_r = 51$

$\tan\delta = 0.05$

$E_0 = 5$ V/m

5.1) $\tan\delta = \dfrac{\sigma}{\omega\epsilon}$

$\sigma = \omega\epsilon\tan\delta = 9.424\times10^9 \times 51 \times 8.854\times10^{-12} \times 0.05$

$= 0.2128 = 212.8$ mS/m

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

$= \sqrt{j\, 9.424\times10^9 \times 4\pi\times10^{-7}\,(0.2128 + j\,9.424\times10^9 \times 51 \times 8.854\times10^{-12})}$

$= \sqrt{j\, 11{,}842.5\,(0.2128 + j\,4.2554)}$

$= \sqrt{11{,}842.5\angle 90\,(4.261\angle 87.13)}$

$= \sqrt{50{,}461\angle 177.13}$

$= 224.635\angle 88.565$

$= 5.651 + j\,225.56$

$\beta = 225.56$ r/2

5.3) $\delta = \frac{1}{\alpha} = \frac{1}{5.65} = 0.17699 = 17.7$ cm

5.4) $E(37.43 \text{ cm}) = 5e^{-\alpha z} = 5e^{-5.65 \times 0.3743}$

$= 5 \times 0.1207$

$= 0.6033$ V/m

5.5) $\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}} = \sqrt{\frac{11{,}842.5 \angle 90}{4.261 \angle 87.13}}$

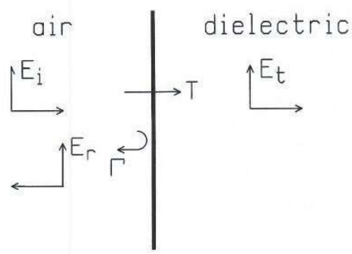
$= \sqrt{2779 \angle 2.87} = 52.72 \angle 1.44°$

$|\eta| = 52.72$

5.6) $|H| = \frac{|E|}{|\eta|} = \frac{5}{52.72} = 0.09484$ A/m

$= 94.84$ mA/m

Question 6



6. A plane wave in air at 3.20 GHz has amplitude $E_i = 12.0$ mV/m and travels in the $+z$ direction. The xy plane is the interface between air for $z < 0$ and plastic for $z > 0$. The plastic material has $\varepsilon_r = 7.1$ and is lossless and non-magnetic. The observer is in the air at z=-1.56 cm.

6.1) What is the intrinsic impedance of the plastic material?

104 ohms	248	281	141	none of these

6.2) What is the reflection coefficient at the surface of the plastic?

-0.567	-0.205	-0.146	-0.454	none of these

6.3) What is the amplitude and phase of the incident electric field strength at the observer?

8.00 mV/m ∠-135°	42.5 mV/m ∠ 135°	12.0 mV/m ∠ 60°	14.0 mV/m ∠ -45°	none of these

6.4) What is the amplitude and phase of the reflected electric field strength at the observer?

2.04 mV/m ∠-135°	5.45 mV/m ∠120°	8.72 mV/m ∠ 45°	4.54 mV/m ∠-45°	none of these

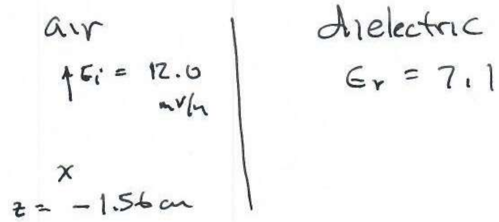
6.5) What is the amplitude of the electric field strength at the observer?

9.20 mV/m	43.4	15.5	14.1	none of these

6.6) What is the power density transmitted into the plastic?

57.6 nanoW/m^2	255	152	2230	none of these

6)



$f = 3.20$ GHz

6.1) $\eta_2 = \dfrac{\eta_0}{\sqrt{\epsilon_r}} = \dfrac{377}{\sqrt{7.1}} = 141.5\ \Omega$

6.2) $\Gamma = \dfrac{\eta_2 - \eta_0}{\eta_2 + \eta_0} = \dfrac{141.5 - 377}{141.5 + 377} = -0.4542$

6.3) $E_i = 12\, e^{-j\beta z}$

$\lambda = \dfrac{u}{f} = \dfrac{3\times10^8}{3.20\times10^9} = 0.09375$ m

$\beta = \dfrac{360}{\lambda} = 3{,}840$ deg/m

$\beta z = 3{,}840 \times (-0.0156) = -59.9^\circ$

$E_i = 12\, e^{-j\beta z} = 12\, e^{-j(-59.9^\circ)} = 12 \measuredangle 59.9^\circ$

6.4) $E_r = \Gamma E_i\, e^{+j\beta z} = -0.4542 \times 12 \times e^{-j59.9^\circ}$

$= -5.45 \times e^{-j59.9^\circ} = 5.45\, e^{j180}\, e^{-j59.9}$

$= 5.45\, e^{j120.1^\circ} = 5.45 \measuredangle 120.1^\circ$

6.5) $E = E_i + E_r = 12 \measuredangle 59.9 + 5.45 \measuredangle 120.1$

$= 3.285 + j\,15.097$

$= 1.545 \measuredangle 77.7^\circ$

$|E| = 1.545$

6.6) $E_t = T E_i$

$$T = \frac{2\eta_2}{\eta_2 + \eta_0} = \frac{2 \times 141.5}{141.5 + 377} = 0.5458$$

$$E_t = 0.5458 \times 12 = 6.55 \text{ mV/m}$$

$$S_{av} = \frac{|E_t|^2}{2\eta} = \frac{(0.00655)^2}{2 \times 141.5}$$

$$= 1.516 \times 10^{-7} = 0.1516 \times 10^{-6} \text{ W/m}^2$$

$$= 151.6 \text{ nW/m}^2$$

Question 7

A wireless link is set up at 14 GHz between a transmit antenna of gain $G_T = 8$ dB, and a receive antenna of gain $G_R = 9$ dB. The antennas are 4 km apart. The input power to the transmitter is 1 kW. The antennas are lossless.

7.1 What is the spreading factor for the wireless link?

-135 dB	-127	-141	-147	None of these

7.2 What is the power flow density S_{av} in microwatts per square meter at the location of the receiver?

31.38 microWatts/m^2	6.17	0.32	12.37	None of these

7.3 What is the effective area of the receive antenna?

0.000290 m^2	0.000145	0.000578	0.000365	None of these

7.4 The receive antenna is terminated in a matched load. What is the power delivered to the matched load?

9.10 nW	1.80	2.25	0.18	None of these

7.5 The system designer is considering a different antenna separation of 14 km apart. What gain G_R is needed for the receive antenna so that the received power remains the same as in question 7.4?

7.82 dB	6.89	12.02	19.88	None of these

7. $f = 14$ GHz

$G_T = 8$ dB $\rightarrow 10^{8/10} = 6.31$

$G_R = 9$ dB $\rightarrow 10^{9/10} = 7.94$

$R = 4$ km

$P_t = 1$ kW

7.1) $L_t = \left(\frac{\lambda}{4\pi R}\right)^2$

$\lambda = \frac{c}{f} = \frac{3\times10^8}{14\times10^9} = 0.02143$ m

$L_t = \left(\frac{0.02143}{4\times\pi\times 4000}\right)^2$

$= (4.263\times10^{-7})^2$

$= 1.817\times10^{-13}$

$= -127.4$ dB

7.2) $S_{av} = G_T \frac{P_t}{4\pi R^2} = 6.31 \frac{1000}{4\pi(4000)^2}$

$= 3.138\times10^{-5} = 31.38\ \mu W/m^2$

7.3) $A_e = \frac{\lambda^2}{4\pi} G_R = \frac{(0.02143)^2}{4\pi} \times 7.94$

$= 2.902\times10^{-4}\ m^2$

$= 0.0002902\ m^2$

7.4) $P_R = A_e S_{av} = 9.106\times10^{-3}\ \mu W = 9.106$ nW

7.5) $P_R = \left(\frac{\lambda}{4\pi R}\right)^2 G_R G_T P_t$

$R = 14$ km

$G_R = \frac{P_R}{\left(\frac{\lambda}{4\pi R}\right)^2 G_T P_t}$

$\left(\frac{\lambda}{4\pi R}\right)^2 = \left(\frac{0.02143}{4\pi\times 14000}\right)^2 = (1.218\times10^{-7})^2$

$= 1.484\times10^{-14}$

$$G_R = \frac{9.106 \times 10^{-9}}{1.484 \times 10^{-14} \times 6.31 \times 1000}$$

$$= 97.24 \rightarrow 19.88\ dB$$