Exercises

About the exercises.

Exercises are based on topics covered in modules. They are mainly used to supply missing steps in derivations and verify equations and concepts discussed in modules. The answers to most of the exercises is found in the modules itself. They will not be graded during the course.

E1. Using Internet, list as many applications as possible that utilize electromagnetic principles for operation.

E2. Using Internet, collect pictures of different transmission lines. Try to learn the application areas of each of these transmission lines.

E3. Derive the wave equation for current \( i(z, t) \) on a uniform lossless transmission line discussed in Module #2.

E4. Show that \( f(z, t) = V_0 \cos(\omega t - \beta z) \) is a solution of the voltage wave equation of the uniform lossless T-line.

E5. Show that \( g(z, t) = I_0 \sin(\omega t - \beta z) \) is a solution of the current wave equation of the uniform lossless T-line.

E6. What is the relation between \( \beta, \omega \) and \( \sqrt{LC} \) in E4 and E5?

E7. What is the definition of characteristic impedance of a uniform lossless transmission line?

E8. A certain lossless transmission line is terminated in (a) open circuit (b) short circuit (c) its own characteristic impedance. What is the reflection coefficient in all the cases?

E9. Sketch the voltage and current waveforms for the terminated transmission line of E8.

E10. Show from the units of \( L \) and \( C \) that the quantity \( 1/\sqrt{LC} \) has the units of velocity.

E11. Complete the steps leading to derivation of input impedance \( Z_{in} \) of a transmission line terminated in load \( Z_L \) as discussed in Module #5.

E12. [Programming] Write a Matlab function to determine input impedance of a lossless transmission line of length \( d_1 \) meters, propagation constant \( \beta_1 \), load impedance \( Z_{L1} \), and characteristic impedance \( Z_{01} \). Your function must take the above parameters as inputs and output the input impedance.
Assignments

About the assignments.

Assignments are used to reinforce concepts and techniques covered in the course. They are usually MCQ and/or programming. Answers to assignments will be given one week after they are posted on the website. We urge you to solve as many assignments as possible to get the best out of this course. For programming, we prefer MATLAB.

Some MCQs may have more than one correct answer. You have to select all the correct answers to get complete grade for the question.

1. Microstrip lines are mainly used in
   - printed circuit boards (PCBs)
   - laboratory to connect signal generator on one table to oscilloscope on the other table
   - very low frequency applications
   - optical wavelength range 400-800 nm

2. In the distributed circuit equivalent of the transmission line, it is assumed that
   - $\Delta z \gg \lambda_{\text{short}}$
   - $\Delta z \ll \lambda_{\text{short}}$
   - $\Delta z = \infty$
   - all of the above

3. On a uniform lossless transmission line, the voltage is given by $V_0 \cos(\omega t - \beta z)$. This indicates that the voltage is
   - independent of $z$ and $t$
   - wave travelling along $+z$ direction
   - wave travelling along $-z$ direction
   - zero at all times

4. In a lossless line, velocity of current wave is
   - directly proportional to frequency of the wave
   - depends only on line parameters $L$ and $C$
   - independent of frequency of the wave
   - inversely proportional to propagation constant

5. A uniform lossless transmission line is excited by a sinusoidal voltage at $z = 0$. Taking $\beta = 2$ rad/m, the phase of the voltage at $z = \pi/2$ meters from the source with respect to $z = 0$ is
   - $0$
   - $\pi/2$
   - $\pi$
   - $2\pi$
6. A lossless line extends from $z = 0$ to $z = \infty$. The line is excited by a voltage source at $z = 0$. On this line

- only +z travelling voltage wave exists
- only -z travelling voltage wave exists
- the ratio of voltage to current is constant
- the backward travelling current wave cancels forward travelling current wave

7. On a lossless transmission line

- the characteristic impedance is purely real
- the characteristic admittance is purely imaginary
- the characteristic impedance depends on frequency and propagation constant
- the characteristic impedance is $\sqrt{L/C}$

8. A transmission line is terminated in open circuit. Which of the following statement(s) is (are) correct?

- Voltage is maximum at the load
- Current is maximum at the load
- The magnitude of the reflection coefficient is unity
- A standing wave pattern exists on the transmission line

9. A transmission line is terminated in short circuit. Which of the following statement(s) is (are) correct?

- Voltage is maximum at the load
- Current is maximum at the load
- The magnitude of the reflection coefficient is unity
- A standing wave pattern exists on the transmission line

10. A transmission line is terminated in its own characteristic impedance. Which of the following statement(s) is (are) correct?

- Voltage is zero at the load
- The load can be replaced with an infinite length line of same characteristic impedance without affecting waves on the transmission line
- The magnitude of the reflection coefficient is zero
- A standing wave pattern does not exist on the transmission line
11. A lossless transmission line operating at 100 MHz is terminated in pure inductance of \( +jZ_0 \). The load reflection coefficient is
   a. \( +j \)
   b. \( -j \)
   c. 0
   d. 1

12. A lossless transmission line operating at 100 MHz is terminated in pure capacitance of \( -jZ_0 \). The load reflection coefficient is
   a. \( +j \)
   b. \( -j \)
   c. 0
   d. 1

13. In the circuit shown in Fig. 1, the load \( Z_L \) is 100 ohms. The transmission coefficient from line 1 to line 2 is

   \[
   \tau = \frac{Z_{L||} - Z_{01}}{Z_{L||} + Z_{01}} \quad \text{where} \quad Z_{L||} = Z_L || Z_{02}
   \]

   \( Z_{L||} = 20 \) ohms

   \( \tau = 0.5714 \)

14. In the circuit shown in Fig. 1, the reflection coefficient at the load \( Z_L = 200 \) ohms is

   \[
   \Gamma_L = \frac{Z_{L||} - Z_0}{Z_{L||} + Z_0} \quad \text{where} \quad Z_{L||} = Z_L || Z_{02}
   \]

   \( Z_{L||} = 22.22 \) ohms

   \( \Gamma_L = -0.384657 \)

15. For the transmission line problem discussed in Module #5, if the source and load resistances are interchanged, the amplitude \( V_0^+ \) is

   \[
   \text{Ans:} \quad Z_{in} = \frac{Z_0^2}{Z_L} = 100 \text{ ohms} ; \quad \Gamma_L = -\frac{1}{3} ; \quad |V_0^+| = 3.75 \text{ V}
   \]