# ECE 391: Suggested Homework Problems

## Basic Relationships

1. Given a sinusoidal wave $v(z,t) = 5\sin(\pi/6 + 4\pi z - \pi 10^9 t)$ (V), where $z$ is measured in meters and $t$ is measured in seconds, determine:
   (a) the direction of wave propagation
   (b) the frequency of the wave
   (c) the wavelength of the wave
   (d) the phase velocity

2. A sinusoidal wave $f(z,t) = A\sin(\omega t + \beta z - \pi/3)$, with phase constant $\beta = 0.4\pi rad/m$ travels with phase velocity $v_p = 15cm/ns$. Determine:
   (a) the direction of wave propagation
   (b) the frequency of the wave
   (c) the wavelength of the wave

3. Given a transmission line with characteristic impedance $Z_0 = 75\Omega$ and distributed capacitance $c = 6pF/cm$, determine:
   (a) the distributed inductance of the transmission line in $nH/cm$
   (b) the velocity of propagation on the line

4. A transmission line has the following distributed parameters: $L = 1.3\mu H/m$ and $C = 14.5pF/m$. Determine:
   (a) the characteristic impedance
   (b) the velocity of propagation

5. A trace on a PCB with a dielectric constant of $\epsilon_r = 2.2$ has a flight time of 8ns. What would the flight time be on a board with $\epsilon_r = 4.5$?

6. A cable has an $\epsilon_r = 2.2$. Its capacitance per meter is $50pF$. What is its $Z_0$?

7. For an air-filled coaxial cable with negligible losses, and characteristic impedance of $75\Omega$, determine:
   (a) the velocity of propagation
   (b) the distributed capacitance of the cable
   (c) the distributed inductance of the cable

8. You just bought 100ft of coax cable on eBay. On the full length of cable, you have measured the flight time to be 175ns and the total capacitance to be 2000pF. What is the characteristic impedance $Z_0$, of the line?

9. Give the physical dimensions (diameter of center conductor and outer shield) of a coax cable with air dielectric that exhibits a $Z_0$ of $300\Omega$. You may choose an inner conductor diameter between

1.0 micron and 10 millimeters.

10. A certain communications system requires an element with signal delay of $2ns$. The system impedance is $50\Omega$. Design (i.e. determine the **physical** parameters of) a coaxial transmission line having the required delay and characteristic impedance. Make any assumptions that may be necessary.

11. Design a coaxial cable (specify the **physical** parameters) with characteristic impedance of $50\Omega$ using a polyethylene dielectric ($\epsilon_r = 2.3$) between the inner and outer conductor. The cable should provide a signal delay of $5ns$. Make any assumptions that may be necessary.

12. Find the component body dimensions of:
    (a) $1/4W$ axial leaded resistor
    (b) 1206 SMD resistor
    (c) 0402 SMD resistor
    Assume that these elements will be used in an RF circuit with sinusoidal excitation. Also, assume the velocity of propagation across the elements is equal to $0.6c$, where $c = 3\times10^8$ m/s. For each component, compute the frequency at which it can safely be considered to be a lumped element. Use the lambda versus component body size criterion.

13. The output from a digital chip has equal rise and fall times of 40ps. On a PCB utilizing a Teflon dielectric ($\epsilon_r = 2.2$), at what lengths (in mm) can transmission line effects be safely ignored?

14. What advantage does a board with a Teflon dielectric ($\epsilon_r = 2.2$) provide a digital circuit board designer?

15. A plumber and electrician decide to start a side business making $96\Omega$ coaxial transmission lines. Their first product uses an outer conductor made from copper water pipe with an inside diameter of 0.5 inch. The inner conductor is made from solid copper wire with an outside diameter of 0.1 inch. They will use air as a dielectric.

    a) Initially, they do not have enough 0.5 inch diameter water pipe. Having not taken ECE391, the plumber thought it would be fine to substitute copper water pipe with an inside diameter 0.625 inch. How will the current and voltage of an incident wave traveling down this transmission line change? Why? (give two reasons)

    b) The electrician thought they could save money and weight by using an inner conductor of hollow tubing with the same outside diameter of the solid copper wire. If they continue to use an outer conductor of 0.625 inch diameter copper pipe, how will the characteristic impedance of this new cable be different from the cable with the solid center conductor? Why?

    c) To help stabilize the inner conductor mechanically and to make use of all the Styrofoam packing peanuts they had accumulated, the plumber and electrician decide to replace the air dielectric with the peanuts. This changes the per unit length capacitance to 50pf/meter, and the $Z_o$ to $92\Omega$. For the packing peanut enhanced line, determine the lines:
    ii) inductance per meter
    ii) its velocity of propagation
    iii) its $\epsilon_r$

16. A lossless speaker cable 200m long, $\epsilon_r = 10$, $Z_o = 16\Omega$, is connected to a $16\Omega$ speaker. At a frequency of 32khz, are transmission line issues absolutely not a problem, possibly a problem, or absolutely a problem?

17. A lossless, $Z_o = 50\Omega$ transmission line is $1.0\times10^6$ meters long with $\epsilon_r = 1$. Its far end is shorted. At $t = 0$, an ohmmeter is connected to the near end. **Give the ohmmeter readings** at each time below. You may assume that the ohmmeter applies a voltage to measure resistance.

    (a) at time $t_{0-}$, ohmmeter reads:

    (b) at time $t_{0+}$, ohmmeter reads:

    (c) at time $t = 2_{td+}$, ohmmeter reads:

    (d) at time $t = \infty$, ohmmeter reads: