# Solutions to ECE 3065 Practice Test 2

1. **Short Answer Section**

   (a) false

   (b) true

   (c) boundary

   (d) open-short

   (e) filters (1) oscillators (2)

   (f) discrete RLC (1) transmission line (2) cavity resonator (3)

   (g) critical

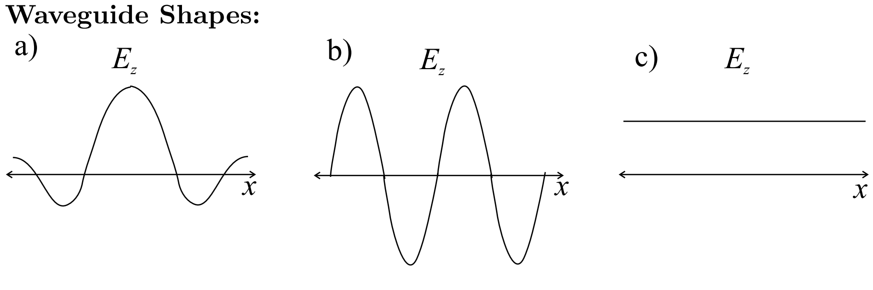
   (h) 0

   (i) loss (1) bandwidth (2)

2. **Descriptive Answer Section**
   Write a **concise** answer to each question in the spaces provided beneath each problem statement. **Note:** Correct answers that are extremely verbose will be penalized.

   (a) **Microwave Oven:** The electric field intensity of waveguide or cavity modes is not uniform in space. There are "hot spots" as well as "dead spots" in the chamber, so the food will not heat evenly unless rotated.

   (b) **Waveguide Shapes:**




   i. circular waveguide

   ii. rectangular waveguide

   iii. planar waveguide

iv. These are all TM modes (since $E_z$ is non-zero for each).

3. **Transmission Line Resonator:**

Here are the two equations for open-open transmission line resonators:

$$D = \frac{1}{\beta} \tan^{-1}(\sqrt{\alpha D})$$

$$\omega_0 C Z_0 = -\tan(\beta D)$$

Here are the pertinent parameters:

| | | | |
|---|---|---|---|
| $\alpha$ | 0.25 Nepers/m | $Z_0$ | 50 $\Omega$ |
| $f$ | 2.5 GHz | $\omega_0$ | $1.57 \times 10^{10}$ rad/s |
| $\lambda$ | 0.08 m | $v_p$ | $2 \times 10^8$ m/s |
| $\beta$ | 78.5 rad/m | | |

We must solve for resonant line length $D$ and coupling capacitor $C$. First, we solve for $D$ by iterating the first equation (see notes 24 for additional examples). Our initial guess is 0.04m (half a wavelength) and our final answer turns out to be 0.0388m (should always be pretty close). Then we solve for coupling capacitor: $C = 0.125$ pF.

To calculate unloaded $Q$-factor, we use the relationship:

$$Q_U = \frac{\beta}{2\alpha} = 157$$

Since this line is critically coupled, the loaded Q-factor is half $Q_U$: $Q_L = 78$.

4. **Nonstandard Waveguide:**

(a) Regardless of the cross-section, we know the following relationship holds for the velocity of a waveguide mode (which would be provided for you on a real test):

$$v_g = \frac{1}{\sqrt{\epsilon\mu}} \sqrt{1 - \left(\frac{f_c}{f}\right)^2} = \frac{D}{T}$$

where $D$ is the length of the waveguide and $T$ is the transit time measured by the device. At $f = 6$ GHz, a transit time of 6.68 ns is measured down the 1-meter waveguide. This gives us enough information to solve for the cut-off frequency for the dominant mode. The answer is 5.2 GHz, which is consistent with the fact that we know the dominant frequency cut-off is greater than 4 GHz.

(b) At 6 GHz, the waveguide supports a single mode. At 8 GHz, the waveguide supports two or more modes. Therefore, we know that the next-highest mode has a cut-off frequency between 6 and 8 GHz. Let's estimate this to be about 7 GHz. Plugging into our formula gives a $v_p = 2.6 \times 10^8$ m/s.

(c) In all types of waveguide, the cut-off frequency is inversely proportional to $\sqrt{\epsilon}$. If you repeated the transit time measurements at 4, 6, and 8 GHz, you would get indeterminate measurements for each case; all three frequencies should be well above the first several cut-off frequencies.