Qualifying exam questions for Electromagnetics Fall 2017

1. What is the lowest cutoff frequency for a square waveguide whose cross-section is 1.5 cm by 1.5 cm? **(2 pts)** Why are square waveguides a bad idea / not an industry standard? **(2 pts)**

2. Design an 80 Ohm coaxial transmission line using copper wire/tubes and polyethylene (relative permittivity is 2.25) Draw a picture and show all dimensions. **(3 pts)** If a 100 kW average power, 2 GHz wave is placed on the transmission line from problem 2, what is the peak electric field on the line? **(3 pts)** Is that a reasonable value of electric field and why? **(1 pt)**

3. What is the significance of Brewster's angle, why is it important? **(2 pts)** When there is a boundary between two different dielectrics, for what type of wave is the Brewster's angle relevant? (Describe the polarization of the wave in terms of the plane of incidence.) **(2 pts)**

4. There is a current loop in the z = –4 plane with a center of (x,y,z) = (0,0,–4). There is another current loop in the x = –4 plane with a center of (x,y,z) = (–4,0,0). Find the center location and orientation of a third loop that cancels the magnetic field at the origin. All coils have a radius of 3 cm and a current of 1 A. **(5 pts)**

Solutions:

1) Cutoff frequency f = c/(2a) = 10 GHz. The lowest frequency is degenerate f(TE10) = f(TE01), waveguides are typically designed for a frequency range where only one mode can propagate.

2) The impedance of a coaxial transmission line is approximately Z=80=60*ln(b/a)/(epsilon_r)^0.5. So ln(b/a)=80/40=2. So b=a exp(2). There are an uncountable number of solutions. For example, Let a=1cm and b=exp(2) cm. Power =Vmax*Vmax/(2Z). Vmax=(2*80*100000)^0.5=4000 V. The peak electric field is on inner conductor. So, Emax = Vmax/(ln(b/a)/a = 4000/2/.01 = 200,000 V/m = 2 kV/cm. This electric field is well below any threshold for breakdown, so it is reasonable. [If someone chooses and a smaller than ½ mm, the value will NOT be reasonable.

3) Brewster's Angle is the angle for which there is no reflected wave from a boundary for a particular type of polarization (100% transmission). If the electric field is in the plane of incidence, there is no reflection at Brewster's angle. If the polarization is perpendicular to the plane of incidence, there will be refection at Brewster's angle.

4) The coil has to be placed in the x+z=constant plane since the field magnitudes for the first two coils are equal and in the z and x directions. Solving, the distance from the origin to cancel field is d = (25/2^0.33333 – 9)^0.5. The center of the coil is at y=0, x=z=d/2^0.5. The equation of the plane that contains the coil is x+z=d*2^0.5. Of course, there is another solution for x=z=-d/2^0.5 in the plane x+z = -d*2^0.5.