(4.1) TM modes: Consider transverse magnetic modes propagating along the axis (z) of a rectangular wave guide of dimensions $a \times b$. Follow the logic of the derivation for TE modes and find the normal modes and their cutoff frequencies. Show clearly that $E_z$ determines all the other fields. Assuming that the core of the wave guide is air (approximate as vacuum) use $a = 7.21\text{cm}$ and $b = 3.4\text{cm}$ find the numerical values of the lowest cutoff frequency for the $TE_{10}$, $TE_{01}$, and $TM_{11}$ modes. What happens to the $TM_{10}$ mode? (10 points)

(4.2) Write down all four Maxwell’ equations for linear material media both in differential form and in Fourier space. Describe in words (but precisely) the content of each of the equations and each of the terms with as little mathematical terminology as possible. (Einstein: “Everything should be made as simple as possible, but not simpler.”) State some important implications of the equations and add comments on any important aspects. For example, does Gauss’ Law have the same content as Coulomb’s law or what is the difference between high school and this course? (8 points)

(4.3) Griffiths 9.28 and 9.29. The latter is a (mildly) tedious problem algebraically; you can present the solution just for the 10 mode. Those who are going to graduate school might wish to do the general case. (3 + 5 points)

(4.4) Recapitulation This is given to remind you of Faraday’s law and some elementary (not necessarily obvious!) physics. A thin Copper ring of radius $a$ rotates about an axis perpendicular to a magnetic field of $200G = 0.02T$ along the $z$-axis. Its initial frequency of rotation is $\omega_0$. Calculate the time $\tau$ (in seconds) it takes for the angular frequency to decrease by a factor of $e$ assuming that the bearings are frictionless. State clearly any other assumptions you make and write down any numerical values you looked up explicitly. What is the dependence of $\tau$ on the cross-sectional area of the ring and the radius of the ring? (8 points)