1. Write the integral and differential form of Maxwell’s equations for the following cases:
   1) Electric field is obtained from a source which produces a single short pulse in a linear dielectric medium of permittivity $\varepsilon$ and permeability $\mu_0$. One possible case of this is referred to as EMP (electromagnetic pulse) and usually results from certain types of high-energy explosions, especially a nuclear explosion, or from a suddenly fluctuating magnetic field. Find example values and durations of such fields, state your source(s) and explain in one to two sentences why it is relevant to understand these types of fields.
   2) The fields are a result of time-harmonic currents in a good conductor of conductivity $\sigma$ situated in a linear uniform good dielectric of permittivity $\varepsilon$. Both conductor and dielectric are non-magnetic.
   3) Same as above with a non-uniform dielectric of permittivity $\varepsilon(x,y,z)$.
   4) Same as above with a nonlinear uniform dielectric.
   5) Time-constant current in a good conductor of conductivity $\sigma$ situated in a linear uniform good dielectric of permittivity $\varepsilon$. Both conductor and dielectric are non-magnetic.

2. Assume a uniform plane wave is propagating in the $z$-direction in air, and the electric field has only an $E_y$ component, i.e. $\mathbf{E} = E_y \mathbf{u}_y$, where $|E_y| = 754 \text{V/m}$.
   1) Find the magnitude of all H-field components and the power density carried by the wave, and make sure you explain how you obtained the expressions for the field components.
   2) Compare this to the power density of the broadband Sun spectrum at various parts of the planet and under various cloud cover, and to the electric field of TV broadcasting stations, which is $\sim 0.1 \text{V/m}$ rms. Summarize in a table and state your sources.
   3) Is this field intensity or power density considered to be harmful to humans at (a) 2GHz, (b) 300 THz, (c) 120 Hz (harmonic of the power frequency)? State your source and provide a brief discussion if needed.

Here is an example of measured TV broadcast signals in Tokyo, Japan (from R. Vias et al. “A Battery-Less, Energy Harvesting Device for Long Range Scavenging of Wireless Power from Terrestrial TV Broadcasts,” *IEEE 2012 IMS Digest*, June 2012). This is measured with a NARDA SRM-3000 radiation meter in isotropic mode, courtesy Prof. Kawahara from Japan.
3. For the same E-field value given in Problem 2, find the magnitude of all relevant H-field components and the power density for the following cases, and summarize in a table:
   1) wave propagates through fresh water, with a real-valued relative permittivity of 80
   2) wave propagates through glass, with a real-valued relative permittivity of 4
   3) wave at f=1GHz propagates through lossy ground with a relative permittivity of 20 and a conductivity of 4S/m. Assume the ground is uniform. The value of the field is given at z=0, find the magnitudes of E and H for z=10cm, z=1m and z=10m.

4. Next we will review Faraday’s law to see how we can receive power from a plane wave with a simple type of antenna.
   1) A circular wire loop of radius 1cm is situated in a vacuum in the electromagnetic field of the plane wave with rms strength given in problem 2 at the cellular frequency of 2GHz. Discuss the size of the loop relative to the wavelength. How should the loop be positioned in order that the emf induced in it be maximal? Determine the rms value of the emf in that case.
   2) The inductance of the loop is about 10nH and the resistance is 1Ω. What is the rms value of the current approximately? What is the assumption you used to calculate this current?
   3) Under what condition(s) will this type of antenna deliver the maximum power carried from the wave into a load?

5. Design a metal shield in the shape of a closed box for a piece of sensitive equipment at 100 MHz. The shield must ensure that any signal penetrating the shield will be 100 dB weaker than the one incident on the shield. The material at your disposal is Aluminum, and the box needs to enclose a device that measures 12cm by 8cm by 4cm. The interior dielectric and exterior dielectric environments can be assumed to be air. Compute the shielding effectiveness of your design, defined as

\[ SE = 20 \log \left( \frac{E_{\text{transmitted}}}{E_{\text{incident}}} \right) \]