1. Consider the soil surface to be the $x$–$y$ plane at $z = 0$ and that $z$ increases as you travel farther away from the surface, deeper into the soil.

   (a) As the water content of soil increases, so does both the real and imaginary parts of the relative permittivity of the soil. Make a single MATLAB figure of the ratio $|S_{av}(z)|/|S_{av}(z = 0^+)|$ as a function of $z$ for two soils, one with $\epsilon_r = 5 - j$ and one with $\epsilon_r = 25 - j5$, at 1.4 GHz.

   (b) Create a duplicate figure with the ratio expressed in dB.

2. The power density $S_R(R, \theta, \phi)$ radiated by an isotropic antenna at $R = 50 \text{ m}$ is $3 \text{ mW m}^{-2}$.

   (a) What is the total power radiated by the antenna?
   (b) What is the radiation intensity $F(\theta, \phi)$ of this antenna?
   (c) What is the normalized antenna pattern $F_n(\theta, \phi)$ of this antenna?
   (d) Calculate the pattern solid angle, $\Omega_p$.
   (e) Find the directivity, $D(\theta, \phi)$.
   (f) Calculate the maximum directivity, $D_o$. Report in both “normal units” and dB.
   (g) If the power supplied to the antenna was 110 W, what is the maximum gain $G_o$ of the antenna? Report in both “normal units” and dB.
   (h) For what application would this antenna be useful?

3. The far-field electric field of an antenna is given by:
   \[
   \tilde{E}_\theta = \frac{e^{-jkr}}{R} \frac{8}{R^2} \cos^2(\theta), \quad 0 \leq \theta \leq \frac{\pi}{2} \\
   \tilde{E}_\phi = 0 \text{ elsewhere} \\
   \tilde{E}_z = 0
   \]

   Calculate:
   (a) the radiation intensity, $F(\theta, \phi)$;
   (b) the normalized pattern, $F_n(\theta, \phi)$;
   (c) the pattern solid angle, $\Omega_p$;
   (d) the main–beam solid angle, $\Omega_M$;
   (e) the main–beam efficiency;
   (f) the half–power beamwidths in the $xz$– and $yz$–planes;
   (g) the directivity, $D(\theta, \phi)$;
   (h) the maximum directivity, $D_o$, in dB;
   (i) the maximum directivity using the approximation $\Omega_p = \beta_{xz} \beta_{yz}$.
(j) Plot $F_n(\theta, \phi)$, in both “normal units” and dB.
(k) Plot $D(\theta, \phi)$, in both “normal units” and dB.
(l) For what application would this antenna be useful?

4. A picture of the the Hornbuckle research group’s L–band radiometer and the pattern of its horn antenna are on the course web page. Assume that the pattern is symmetrical in $\phi$.

(a) What is the 3 dB beamwidth of this antenna?
(b) Estimate the pattern solid angle, $\Omega_p$.
(c) Calculate the maximum directivity, $D_0$, in decibels.
(d) Qualitatively discuss the main beam efficiency of this antenna. Is the main beam efficiency high or low? Why?
(e) Give two reasons why this is a good antenna for microwave radiometry.

5. Use the m–file on the course website, ps4_5.m. This m–file plots the normalized pattern $F_n = \text{sinc}[(a/\lambda) \sin(\theta)]^2$ where $\text{sinc}(x) = \sin(\pi x)/\pi x$, $a$ is an antenna dimension, and $\lambda$ is the wavelength.

(a) Compare values of $A = a/\lambda$. $A$ is called the electrical size of the antenna. What happens when the electrical size increases?
(b) Find, graphically, the 3 dB beamwidth when $A = 1$.
(c) Find, graphically, the 3 dB beamwidth when $A = 5$. Readjust the axis using the axis command.
(d) Estimate the maximum directivity (in dB) when $A = 1$ using the approximation $\Omega_p = \beta_{xz}\beta_{yz}$.
(e) Estimate the maximum directivity (in dB) when $A = 5$ using the approximation $\Omega_p = \beta_{xz}\beta_{yz}$.
(f) For what application would this antenna be useful if $A = 5$?
(g) If you were designing an antenna with this pattern, what would $a$ need to be in order to have close to a 6° 3 dB beamwidth at a frequency of 3 GHz?


(a) Describe in your own words why using a constant $\tau = 6.28...$ instead of $\pi$ makes some sense.
(b) Argue mathematically why $\pi$ makes more sense than $\tau$ in some cases, and give an example.
(c) Do you think you will have a “conversion experience” and become “almost violently angry at $\pi$” and use profanity? Why or why not?
(d) Radian measure of angles is often difficult for students, but the definition is straightforward, $\theta = s/r$ where $s = \text{arc length}$ and $r = \text{radius}$. This doesn’t work with angles measured in degrees. In addition, the definition of degrees is nonsensical: why establish 360° for a full circle? Do you think radians will ever be commonly used instead of degrees? Why or why not?
(e) The US has tried to move away from English units to SI units in general. SI is the standard in scientific research, but besides some athletic contests (track and field, for example) the public by–in–large does not use SI units. Do you think at some point, as the “world gets smaller” the US public will use SI units in everyday life? Why or why not?