Name: ________________________

GTID: ________________________

ECE 4370: Antenna Engineering
TEST 1 (Spring 2014)

- Please read all instructions before continuing with the test.

- This is a **closed** notes, **closed** book, **closed** friend, **open** mind test. On your desk you should only have writing instruments and a calculator. **No internet-enabled devices.**

- Show all work. (It helps me to give partial credit.) Work all problems in the spaces below the problem statement. If you need more room, use the back of the page. DO NOT use or attach extra sheets of paper for work.

- Work intelligently – read through the exam and do the easiest problems first. Save the hard ones for last.

- All necessary mathematical formulas are included either in the problem statements or the last page of this test.

- You have 80 minutes to complete this examination. When the proctor announces a "last call" for examination papers, he will leave the room in 5 minutes. The fact that the proctor does not have your examination in hand will not stop him.

- I will not grade your examination if you fail to 1) put your name and GTID number in the upper left-hand blanks on this page or 2) sign the blank below acknowledging the terms of this test and the honor code policy.

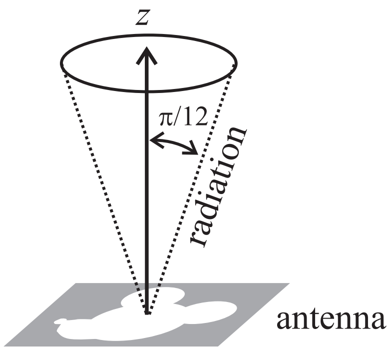
- Have a nice day!

Pledge Signature: ____

I acknowledge the above terms for taking this examination. I have neither given nor received unauthorized help on this test. I have followed the Georgia Tech honor code in preparing and submitting the test.

1. **Mystery Antenna:** Below is the far-field expression for the radiated Poynting vector for an antenna operating at 10 GHz. This antenna radiates a circular beam centered on the z-axis. Answer the following questions based on this distribution. (**35 points**)

$$\vec{S}_{av}(r, \theta, \phi) = \frac{500\,\text{mW}}{4\pi r^2}\hat{r} \quad \text{for}\,\theta \leq \frac{\pi}{12}, \qquad 0 \text{ elsewhere}$$

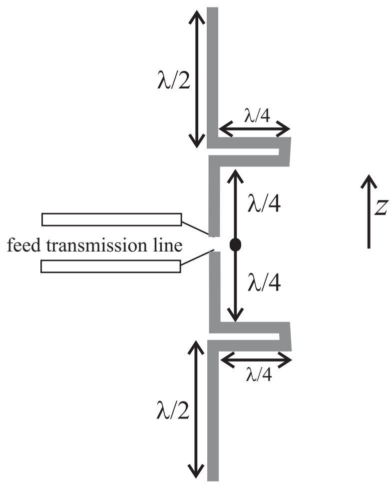


   (a) Write expressions for the E-field and H-field phasor-form solutions for the radiated waves in three-dimensions. Assume that the E-field polarization is in the $\hat{\theta}$ direction. (**20 points**)

   (b) What is the half-power beamwidth (in degrees) of this antenna? (**5 points**)

   (c) If this antenna is ideal and lossless, estimate its peak gain. (**10 points**)

2. **Wire Antenna:** Below is a diagram of a peculiar wire antenna. Base your answers to the following questions on this radiating structure. (**35 points**)



(a) Using the standard assumptions for wire antennas, sketch the magnitude and polarity of standing wave currents on this antenna. Sketch this directly on the diagram above. (**10 points**)

(b) Make a rough sketch of what you would expect to be the $\hat{\theta}$-pol, elevation-cut (at $\phi = 0$) of the gain pattern for this antenna. (**10 points**)

(c) Would you expect the horizontal segments of the wire antenna to radiate a significant $\hat{\phi}$-component of E-field? Why or why not? (**10 points**)

(d) You measure this radiating structure in an antennas range and find that it radiates a total of 400 mW when the input current is 5 mA peak. What is the radiation resistance of this antenna? (**5 points**)

3. **Link Budget in Space:** A NASA orbiter is sent to Uranus to take images of the planet and other scientific data. The orbiter must send its data across a distance of 3×10^9 km to Earth. The spacecraft, powered by a radioisotope thermonuclear generator (RTG), transmits at a power of 200 W at 30 GHz using a dish antenna that has a gain of 46 dBi, pointed toward Earth. NASA uses its Deep Space Network dish receiver on Earth with 80 dBi of gain to receive the data signal. Answer the following questions based on this radio link. (**30 points**)

   (a) Based on the 80 dBi receive antenna gain, estimate the diameter of the presumably circular electromagnetic aperture of this antenna. Assume an ideal aperture efficiency of $\eta_A = 1$. (**10 points**)

   (b) What is the *effective isotropic radiated power* (EIRP) of the transmitter in this link in dBW? (**10 points**)

   (c) How much power, in dBm, is received on Earth from this transmission? (**10 points**)

Cheat Sheet

$\lambda f = c \qquad c = 3\times 10^8$ m/s $\qquad \mu_o = 4\pi\times 10^{-7}$ H/m $\qquad \epsilon_o = 8.85\times 10^{-12}$ F/m $\qquad k = \frac{2\pi}{\lambda}$

$$P_R = \underbrace{P_T + G_T}_{\text{EIRP}} + G_R - 20\log_{10}\left(\frac{4\pi}{\lambda}\right) - 20\log_{10}(r) \quad \text{Logarithmic Form}$$

$$P_R = \frac{P_T G_T G_R \lambda^2}{(4\pi r)^2} \quad \text{Linear Form} \qquad G = \eta_A \frac{4\pi}{\lambda^2} A_e$$

$$\text{Half-wave dipole current: } \tilde{I}_z(z) = I\cos(kz') \qquad \text{for } -\frac{\lambda}{4} \le z \le \frac{\lambda}{4}$$

$$\text{Directivity} = \frac{\text{Radiated Power Density in } (\phi,\theta)}{\text{Average Isotropically Radiated Power Density}} = \frac{\left\|\vec{\mathrm{S}}_{av}(r,\theta,\phi)\right\|}{P_T/(4\pi r^2)}$$

$$D(\phi,\theta) = \eta_{rad}\, G(\phi,\theta) \qquad P_T = \frac{1}{2} I^2 R_{rad}$$

$$\tilde{A}_z(\vec{\mathrm{r}}) = \frac{\mu}{4\pi r}\exp(-jkr)\int\int_{-\infty}^{+\infty}\int \tilde{J}_z(x',y',z')\exp(+jk[x'\sin\theta\cos\phi + y'\sin\theta\sin\phi + z'\cos\theta])\; dx'\, dy'\, dz'$$

$$\text{Line Current:} \quad \tilde{A}_z(r,\theta,\phi) = \frac{\mu}{4\pi r}\exp(-jkr)\int_{-\infty}^{+\infty} \tilde{I}_z(z')\exp(+jkz'\cos\theta)\; dz'$$

$$\tilde{\vec{\mathrm{H}}}(r,\phi,\theta) = \frac{1}{\mu}\nabla\times(\tilde{A}_z\hat{\mathrm{z}}) \approx \frac{jk\sin\theta}{\mu}\tilde{A}_z(r,\phi,\theta)\hat{\phi}$$

$$\tilde{\vec{\mathrm{E}}}(r,\phi,\theta) = \frac{1}{j2\pi f\mu\epsilon}\nabla\times\nabla\times(\tilde{A}_z\hat{\mathrm{z}}) \approx \frac{jk\eta\sin\theta}{\mu}\tilde{A}_z(r,\phi,\theta)\hat{\theta}$$

$$\eta = \sqrt{\frac{\mu}{\epsilon}} = 377\ \Omega \text{ for free space} \qquad \vec{\mathrm{S}}_{av} = \frac{1}{2}\text{Real}\left\{\tilde{\vec{\mathrm{E}}}\times\tilde{\vec{\mathrm{H}}}^*\right\} \approx \frac{1}{2}\left\|\tilde{\vec{\mathrm{E}}}\right\|\left\|\tilde{\vec{\mathrm{H}}}\right\|\hat{\mathrm{r}}$$

above approximations valid for far field, $r > D^2/\lambda$