Name: ________________________

GTID: ________________________

ECE 4370: Antenna Engineering
TEST 1 (Fall 2012)

- 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. **Basic Radiating System:** Below is the far-field expression for the radiated electric field of an 8 GHz antenna with input current I. Answer the following questions based on this distribution.

$$\tilde{\vec{\mathrm{E}}}(r,\theta,\phi) = \begin{cases} \frac{\pi I \eta}{r}\exp(-jkr)\hat{\theta} & \text{for } -\frac{\pi}{8} \le \phi \le \frac{\pi}{8} \text{ and } \frac{\pi}{4} \le \theta \le \frac{3\pi}{4} \\ 0 & \text{elsewhere} \end{cases}$$

   (a) What is the value of wavenumber k for this antenna?

   (b) In the space below, write the far-field magnetic field solution, $\tilde{\vec{\mathrm{H}}}(r,\theta,\phi)$, that accompanies this electric field.

   (c) In the space below, write the far-field average Poynting vector, $\vec{\mathrm{S}}_{av}(r,\theta,\phi)$.

   (d) Compute the directivity, $D(r,\theta,\phi)$, for this antenna.

   (e) Compute the peak gain in dBi of this radiating system.

   (f) What are θ_{HPBW} and ϕ_{HPBW} (in degrees) for this antenna?

   (g) What is the radiation resistance for this antenna?

   (h) If the EIRP of this antenna used as a transmitter is 1 Watt, what power is received by a 0 dBi antenna 1 kilometer away?

   (i) The far field begins at least 50 cm away from this antenna. Estimate the size of the antenna's largest dimension.

   (j) Why is this radiation pattern not likely due to a z-directed radiating wire?

   (k) What is unrealistic about this radiation pattern and why?

Cheat Sheet

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

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

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

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

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

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

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

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

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

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

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

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