Name: _____

GTID: _____

ECE 6390: Satellite Communications and Navigation Systems
TEST 1 (Fall 2005)

- 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.

- 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 50 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. **Short Answer Section** (**35 points**)

(a) ———————— (1) ———————— (2) ———————— (3) ———————— (4)
The Helmholtz (scalar) wave equation holds for a medium that has the following four properties: $\boxed{Answer\ 1}$, $\boxed{Answer\ 2}$, $\boxed{Answer\ 3}$, and $\boxed{Answer\ 4}$.

(b) ————————
Earth $\boxed{Answer}$ cause gravitational irregularities in an otherwise ideal orbit.

(c) ———————— (1) ———————— (2)
A satellite in elliptical orbit is furthest away from a planet at $\boxed{Answer\ 1}$ and closest at $\boxed{Answer\ 2}$.

(d) ————————
A transmitter sends 100 mW into an antenna with peak *linear* gain of 4 with respect to an isotropic radiator; the EIRP of this system is $\boxed{Answer}$ dBm.

(e) ————————
The cheapest location on earth from which to launch a satellite is the $\boxed{Answer}$.

(f) ———————— (1) ———————— (2) ———————— (3) ———————— (4)
List 4 types of power supplies for a satellite.

(g) **Famous Dates:** Match the dates below to the events.

———— 1630   a) First satellite *Sputnik* launched by USSR

———— 1945   b) I started taking ECE 6390

———— 1957   c) Arthur C. Clarke publishes "Extra-Terrestrial Relays"

———— 1958   d) Telestar I and II launched by Bell Labs

———— 1962   e) *Explorer I*, first US satellite is launched

———— 1969   f) First mobile satellite telephone networks launched

———— 1980s   g) Johannes Kepler born

———— 2000   h) Moon landing

———— 2005   i) Global Positioning System launched

2

2. **Conspiracy Theory:** An engineer files a complaint with the FCC claiming that it may be possible to interrogate RFID tags from an LEO satellite (500 km overhead), violating the privacy of anyone who happens to be wearing a Wal-Mart shirt with an inventory tag still attached or driving their car with an automatic toll-paying tag on the windshield. There are two types of proposed RFID tags for inventory control, tollway payments, and other identification purposes. The first type is a *battery-assisted* tag that uses a small, internal battery to drive its modulating circuitry; all power backscattered by this type of tag is due to the partial reflection of an incident wave. Highway toll tags are a common example of this type of tag. The second type is a *purely passive* tag that actually powers its modulating circuitry from the incident radio wave. Inventory tags are a common example of purely passive RFID tags. Both types of RFID tags operate in the 915 MHz ISM band and have antenna gains of approximately 0 dBi. Assume that a 915 MHz satellite interrogator can transmit and receive with 10 dBi of antenna gain. Based on this scenario, answer the following questions. (**30 points**)
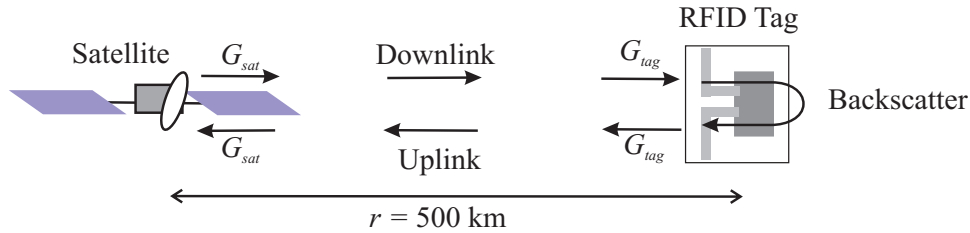
(a) For a passive tag, at least $1\mu W$ must be received by the tag from the satellite interrogator in order for the tag to power-up. How much transmit power must be sent by the interrogating satellite to make this happen? Does this seem reasonable? (**15 points**)

(b) At least -110 dBm of back-scattered power must be received by the satellite in order to read *any* RFID tag's data. How much transmit power must be sent by the interrogating satellite to make this happen? Does this seem reasonable? Hint: In a backscatter radio link, power is transferred from satellite to RFID tag for the first leg of the link; the received power then becomes the transmit power for the tag (assuming no internal losses) and is send back to the satellite on a second link. (**15 points**)

3. **Launch a GPS Satellite!:**   The US Air Force is planning to launch another replacement GPS satellite into space. The first stage of the launch rocket places the satellite into a low-earth orbit (LEO) exactly 1000 km above the surface of the earth with an inclination that matches the final orbit (see diagram below). To make the jump to final orbit, a smaller second-stage rocket fires for a very brief time at Point A to increase the velocity and place the satellite into an elliptical transit orbit. At Point B the thrusters of the second stage fire briefly for the last time, transferring the satellite to its final circular orbit of 20,200 km above the Earth's surface. Answer the questions below based on this scenario. (**35 points**)

$R_E = 6380$ km

$r_1 = 1000$ km

$r_2 = 20{,}200$ km
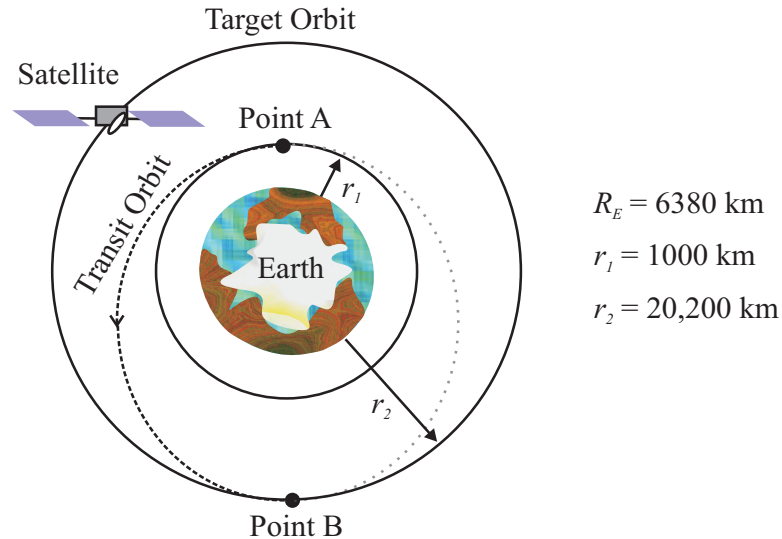
(a) Draw an arrow at point A that points in the direction of thrust for the second-stage rocket (keeping in mind that thrust is a force *opposite* the direction of rocket discharge). (**5 points**)

(b) Draw an arrow at point B that points in the direction of thrust for the second-stage rocket. (**5 points**)

(c) What is the eccentricity of the transit ellipse? (**10 points**)

(d) Estimate the transit time for the satellite between points A and B. (**10 points**)

(e) How fast is the satellite travelling in its final orbit? (**5 points**)

4

Cheat Sheet

$$\lambda f = c \qquad c = 3 \times 10^8 \text{ m/s}$$

$$P_R = P_T + G_T + G_R - 20 \log_{10}\left(\frac{4\pi}{\lambda}\right) - 20 \log_{10}(r) - \text{Additional Loss in dB}$$

$$\ddot{r} = r\dot{\theta}^2 - \frac{GM_P}{r^2} \qquad \ddot{\theta} = -\frac{2\dot{r}\dot{\theta}}{r}$$

$$T^2 = \frac{4\pi^2 a^3}{\mu} \qquad \mu = GM_p \qquad G = 6.672 \times 10^{-11} \text{ Nm}^2/\text{kg}^2 \qquad M_E = 5.974 \times 10^{24} \text{ kg}$$

$$V = \sqrt{\frac{\mu}{R}} \qquad b = a\sqrt{1-e^2} \qquad \text{perigee} = (1-e)a \qquad \text{apogee} = (1+e)a$$

$$G = \eta_A \frac{4\pi}{\lambda^2} A_e \qquad G \approx \frac{30,000}{\theta_{\text{HPBW}}\phi_{\text{HPBW}}} \text{ (angles in degrees)}$$

$$P_N = kTB \qquad k = 1.3807 \times 10^{-23} \text{ J K}^{-1}$$