Name: ______________________

GTID: ______________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 1 (Fall 2004)

- 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** (**30 points**)

(a) ________ (1) ________ (2) ________ (3) ________ (4)
The Helmholtz (scalar) wave equation holds for a medium that has the following four properties: *Answer 1*, *Answer 2*, *Answer 3*, and *Answer 4*.

(b) ________ (1) ________ (2) ________ (3)
For a satellite to be geostationary, it must have an *Answer 1* orbit with *Answer 2* eccentricity and a *Answer 3* of 1 sidereal day.

(c) ________
A satellite with *Answer* transponders simply relays a signal back to earth at a different carrier frequency without any signal regeneration.

(d) ________
Thermal noise received by an antenna is due to *Answer* radiation in the environment from objects that are not at absolute zero temperature.

(e) ________
A transmitter sends 200 mW into an antenna with peak *linear* gain of 500 with respect to an isotropic radiator; the EIRP of this system is *Answer* dBW.

(f) ________
A navigation satellite passes overhead, such that you can only receive the signal for 12 minutes. This satellite must be in *Answer* orbit.

(g) ________ (1) ________ (2)
A cylindrical satellite that performs attitude control with its own rotation is called a *Answer 1*; if the satellite is not cylindrical, it is likely using *Answer 2* for attitude control.

(h) ________
The *Answer* is the largest single source of orbital distortion for geostationary satellites.

(i) ________
(**True or False:**) The trajectory of a moving, motorless body in the presence of another, larger body is always an ellipse.

2. **Descriptive Answer Section (20 points)**

Write a **concise** answer to each question in the spaces provided beneath each problem statement. **Note:** Correct answers that are extremely verbose will be penalized.

(a) **Dish Antennas (10 points):** Your DirectTV owner's manuals states that, in order for the system to work properly, a user must brush snow off the dish reflector shortly after a snow fall. Give two fundamental electromagnetic reasons why this is necessary.

(b) **Orbital Mechanics (10 points):** At any given moment, a body with mass m in orbit around a planet has both kinetic and potential energies of

$$\text{Potential Energy: } -\frac{m\mu}{r} \qquad \text{Kinetic Energy: } \frac{1}{2}mV^2$$

where V is the instantaneous velocity of the object, r is its distance from the center of the planet, and μ is Kepler's constant. The sum of potential energy and kinetic energy is the same for any point in the orbit. Prove that the velocities of the satellite at perigee and apogee (V_p and V_a, respectively) satisfy the following equation, which depends only on orbit eccentricity e and semi-major axis a:

$$V_p^2 - V_a^2 = \frac{4\mu e}{a(1-e^2)}$$

3. **Link Budget for LEO Mobile Communications:** Below are the specifications for the digital downlink of a GEO Ku-band satellite system. Stations across the US use this digital video feed to link TV channels into their cable networks. Calculate the carrier-to-noise ratio, assuming clear-sky conditions. You may assume that the low-noise amplifier at the receiver contributes the dominant amount of device noise to the received signal. (**25 points**)

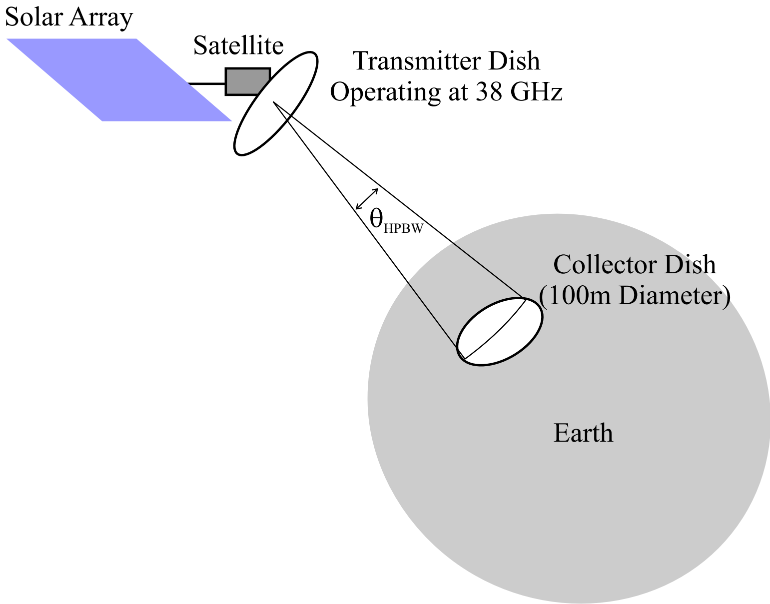
Communications Link		
Ku-band Downlink Frequency	11.45	GHz
Digital Video Bandwidth	43.2	MHz
Transmitter-Receiver Separation Distance	36,000	km

Satellite Transmitter Hardware		
Satellite Transmit Power (Amplifier Output)	2.24	kW
Satellite Transmit Antenna Gain	31	dBi

Earth Station Receiver Hardware		
Earth Station Receiver Antenna	36	dBi
Receiving Antenna Noise Temperature	30	K
Low-Noise Amplifier Device Noise Temperature	110	K

4. **Solar Power from Space:** One of the big drawbacks of using solar energy on earth is the unreliability of the power supply due to overcast weather. In space, this drawback does not exist; in fact, solar radiation is much more intense and broad in spectrum outside the earth's atmosphere. Some technologists have imagined that in the future a geostationary satellite with a gigantic, lightweight solar cell array could collect solar power and beam it back on a 38 GHz link to a large earth station (ES) dish collector. If the ground dish were 100m in diameter, how big would the satellite's transmitter dish have to be in order to have the bulk of its power fall within the ES collector dish (i.e. the 100m dish must contain the half-power beamwidth)? How feasible do you think this is? (**25 points**)

   Assume an aperture efficiency of 100% and an equatorial ES with coordinates identical to the subsatellite point. (Radius of earth is 6000 km and geosynchronous orbit is 42,000 km.)



Cheat Sheet

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

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

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

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

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

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

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