Name: ______________________

GTID: ______________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 1 (Fall 2010)

- 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 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. **Short Answer Section** (**20 points**)

(a) ________________

A $\boxed{\textit{Answer}}$ is the only feasible power source for long-lasting, deep space missions.

(b) ________________

One drawback of using $\boxed{\textit{Answer}}$ in space is that they typically require small, radioactive warming devices to keep active.

(c) ________________ (1) ________________ (2) ________________ (3)

For a satellite to be geostationary, it must have an $\boxed{\textit{Answer 1}}$ orbit with $\boxed{\textit{Answer 2}}$ eccentricity and a $\boxed{\textit{Answer 3}}$ of 1 sidereal day.

(d) ________________

The $\boxed{\textit{Answer}}$ is the largest single source of orbital distortion for geostationary satellites.

(e) ________________

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

(f) ________________

The type of space propulsion system that has the best thrust-to-weight ratio is an $\boxed{\textit{Answer}}$ drive.

(g) ________________

Earth $\boxed{\textit{Answer}}$ cause gravitational irregularities in an otherwise ideal orbit.

(h) ________________

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

2. **Look Angles:** Your earth station is at $-84°$ longitude and $+30°$ latitude. At a given moment, your dish antenna is pointed to azimuth $180°$ (due South) and $30°$ of elevation to receive a signal from a satellite in an equatorial orbit. Answer the following questions based on this scenario. (**30 points**)

   (a) What is the latitude and longitude of the satellite subpoint at this moment? (**5 points**)

   (b) What is the orbital radius (measured from the center of the earth) for this satellite at this moment? (**10 points**)

   (c) If you are told that the radius in part (a) is the perigee of an elliptical geosynchronous orbit, what is this orbit's eccentricity? (**15 points**)

3. **Moon-based Bent Pipe Transponders:**

   One alternative for deploying a stand-alone bent-pipe transponder satellite would be to install the transponder hardware at a moon station somewhere in the center of the side that always faces the earth's surface. (The moon has a phase-locked rotation such that the same face of the moon always points towards the surface of the earth.) Although such a transponder would not be geostationary (the moon's orbit is much slower than the rotation of the earth), it would not require any station keeping fuel to maintain its very predictable sky track. Answer the following questions based on this scenario. (**25 points**)

   (a) Using first principles in orbital mechanics, estimate the moon's distance from the center of the earth based only from the mass of the earth and knowledge that the moon takes

28.25 solar days to complete an orbit. (**15 points**)

(b) Based on your knowledge of spacecraft subsystem requirements that you have learned in this class, what are two engineering reasons that might prohibit practical bent-pipe transponders from being placed on the moon. (**10 points**)

4. **Satellite-to-Satellite Relay:**

   Two relay satellites at different locations of the same circular earth orbit communicate using *identical*, circular transmit/receive dish antennas at a separation distance of 10,000 km. The satellite link operates on a 20 GHz carrier. The antenna for the receive satellite in the link must output at least -86 dBm of received power at its antennas in order for proper digital decoding of the signal by the receiver. Answer the following questions based on this scenario. (**30 points**)

   (a) If the transmitter at the transmit satellite is capable of sending up to 100 Watts into the transmit antenna feed element, estimate the minimum diameter of the transmit/receive dishes in meters required to receive the minimum amount of signal power with an extra 6 dB of margin. You may assume ideal dishes with 100% aperture efficiency. (**15 points**)

(b) Based on your answer in part (b) with the 6 dB margin, approximate the pointing error for each dish antenna in this link in order to maintain communications. Hint: think half-power (3-dB) beamwidth – how badly would each dish need to be tilted off boresight to wipe out the 6 dB of extra link margin (3 dB on both transmitter and receiver antennas). Your answer should be in the form $\pm X.X^{\circ}$. (**15 points**)

Cheat Sheet

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

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

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

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

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

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

Earth radius: $R_E = 6380$ km

$$\lambda f = v_p \qquad \omega = 2\pi f \qquad k = \frac{2\pi}{\lambda}$$

Law of Sines for Triangles: $\dfrac{L_1}{\sin\theta_1} = \dfrac{L_2}{\sin\theta_2} = \dfrac{L_3}{\sin\theta_3}$