Name: ________________________

GTID: ________________________

ECE 6390: Satellite Communications and Navigation Systems
TEST 1 (Fall 2006)

- 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** (**19 points**)

(a) ________________ (1) ________________ (2)
List two methods for attitude control on board a satellite.

(b) ________________
All electronics must be space-[*Answer*] before launch to test their ability to withstand the harsh temperatures and radiation of outer space.

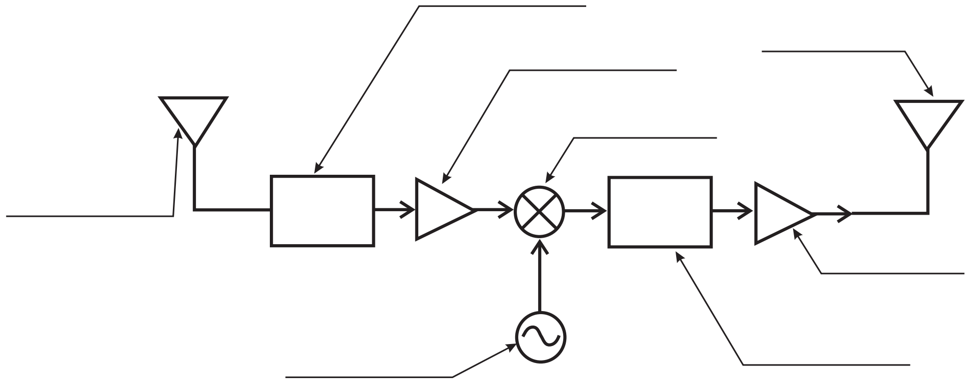
(c) ________________
The type of space propulsion system that has the best thrust-to-weight ratio is an [*Answer*] drive.

(d) ________________
In a simple medium, Maxwell's equations can be simplified and combined into the scalar or [*Answer*] wave equation, which describes radio wave propagation.

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

______	1630	a) First satellite *Sputnik* launched by USSR
______	1945	b) Georgia Tech last won the college football championship
______	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
______	1990	i) Global Positioning System launched

2. **Satellite Transponder:** Label the components in the bent-pipe transponder diagram below. Be as specific as possible. (**16 points**)

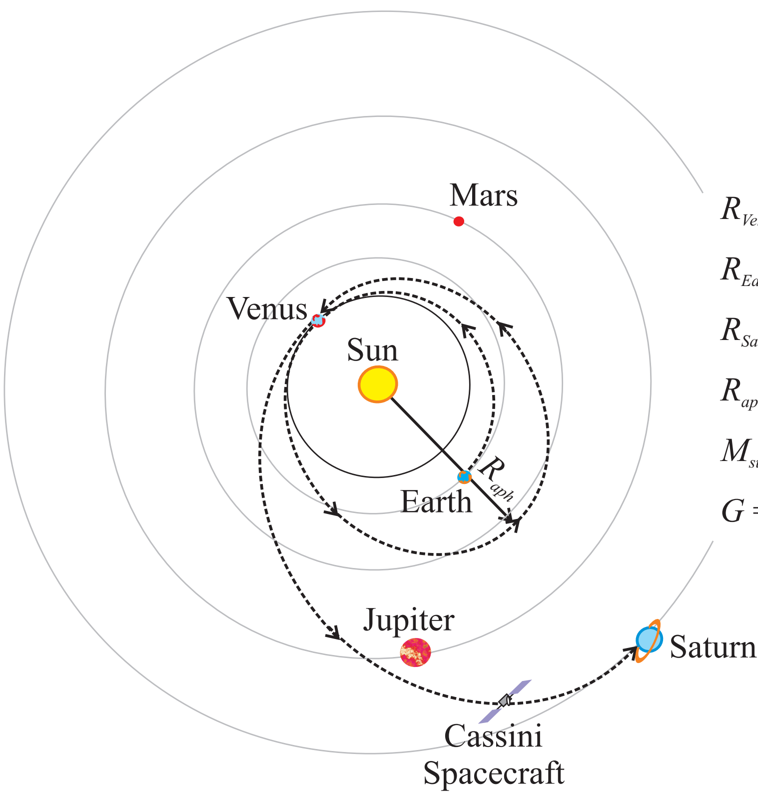


3. **LO Leakage:** Standard X-band radar guns in the US operate at 10.525 GHz. If all consumer electronics working in this portion of the spectrum use a similar superheterodyne RF front end with low-side local oscillators (LOs) to mix down the carrier to a common 10 MHz intermediate frequency, what would be the LO frequency used in a radar detector detector detector detector. (**5 points**)

4. **Deep Space Orbits:** A "gravitational slingshot" is a method for propelling a spacecraft to outer planets without using extraordinary amounts of fuel, cost, and propulsion complexity. Under most circumstances, the orbit of a satellite around the solar system is an ellipse with the massive sun at one of the focii. The sun provides the principle gravitational forces to maintain the orbit, unless the spacecraft approaches very close to a planet. For a brief time period, the spacecraft can get a "free" boost in its relative velocity with respect to the sun by getting "slung forward" by the nearby gravity well of a planet in motion. This will transfer the satellite to a higher orbit without firing thrusters. Conservation of energy still holds – the spacecraft is simply borrowing some of the momentum of the massive, moving planet.

Below is a series of slingshots and orbits approximately used by the NASA to send the Cassini spacecraft to Saturn, originally launched on 15 October 1998. The spacecraft was first sent to Venus in a half-orbit to receive its first slingshot. After the first boost, the spacecraft completed an entire elliptical orbit whose aphelion (furthest point from the sun) was slightly past Mars (the distance R_{aph} in the diagram below). Venus had made several revolutions and was nearly back at the same point in space when Cassini completed a full orbit and returned for its second slingshot boost. It was this final boost that placed the spacecraft in a half-orbit that would set a rendezvous with Saturn. Clearly, this is a very effective albeit time-consuming method for traveling to distant planets.

Below is a diagram of Cassini's approximate path through the solar system, as well as all the pertinent planetary data. Estimate the year and month that the spacecraft first arrived at Saturn. Show *all* the steps in your calculation, using the back of this page if necessary. (**30 points**)



$R_{Venus} = 1.08 \times 10^{11}$ m

$R_{Earth} = 1.52 \times 10^{11}$ m

$R_{Saturn} = 1.43 \times 10^{12}$ m

$R_{aph} = 2.40 \times 10^{11}$ m

$M_{sun} = 1.98 \times 10^{30}$ kg

$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2}

5. **Link Budget for a Deep Space Communications:** Below are the specifications for the digital downlink of a deep space probe. Assuming an ideal (Shannon limit) communication system, calculate the maximum distance from earth that this satellite is capable of maintaining communications. (**30 points**)

Communications Link		
Ku-band Downlink Frequency	14.0	GHz
RF Signal Bandwidth	200.0	kHz
Target Data Rate	100.0	kbps

Satellite Transmitter Hardware		
Satellite Transmit Power (Amplifier Output)	800	W
Satellite Transmit Antenna Gain	40	dBi

Earth Station Receiver Hardware		
Earth Station Receiver Antenna	55	dBi
Receiving Antenna Noise Temperature	30	K
Low-Noise Amplifier Device Noise Temperature	70	K

Cheat Sheet

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

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

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

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

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

Circular Orbit: $V = \sqrt{\frac{\mu}{R}}$

Shannon Limit: $C = B\log_2(1 + \text{SNR})$ (bits/sec)

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

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