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

1. **Short Answer Section (30 points)**

   (a) (1-4): linear, homogeneous, isotropic, source-free

   (b) oblations

   (c) apogee   perigee

   (d) 26 dBm

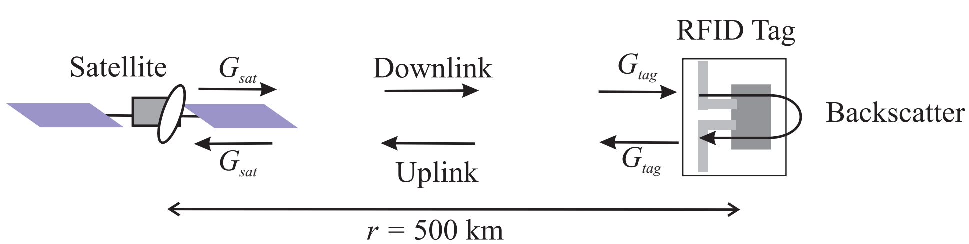
   (e) equator

   (f) (1-4): solar cells, batteries, RTGs, fuel cells

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

g	1630	a) First satellite *Sputnik* launched by USSR
c	1945	b) I started taking ECE 6390
a	1957	c) Arthur C. Clarke publishes "Extra-Terrestrial Relays"
e	1958	d) Telestar I and II launched by Bell Labs
d	1962	e) *Explorer I*, first US satellite is launched
h	1969	f) First mobile satellite telephone networks launched
i	1980s	g) Johannes Kepler born
f	2000	h) Moon landing
b	2005	i) Global Positioning System launched

2. **Conspiracy Theory:**



   (a) The one-way link budget is given below.

$$\underbrace{P_R}_{\text{-30 dBm}} = P_T + \overbrace{G_T}^{\text{10.0 dBi}} + \underbrace{G_R}_{\text{0.0 dBi}} - \overbrace{20\log_{10}\left(\frac{4\pi}{\lambda}\right)}^{\text{31.7 dB}} - \underbrace{20\log_{10} r}_{\text{114.0 dB}}$$

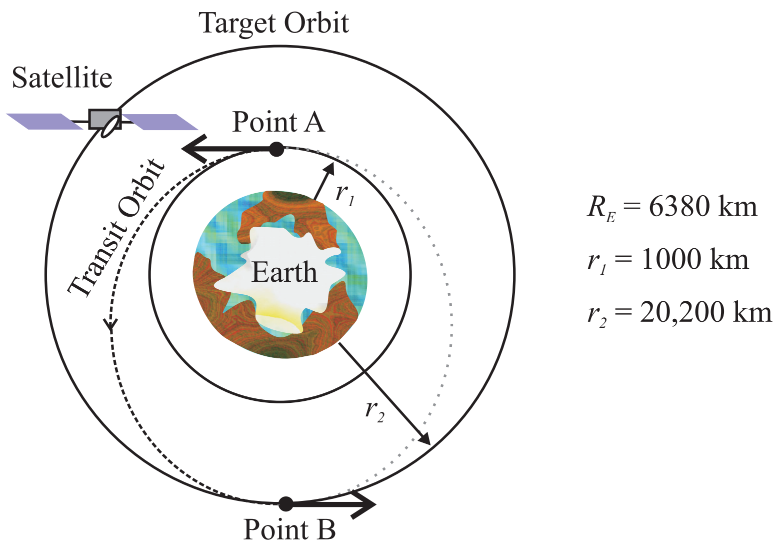
Solving for P_T, we find that at least 105.2 dBm of power is required to power up the RFID chip. That's at least 33 *MegaWatts* of transmit power. Clearly this is not reasonable for a satellite.

(b) The backscatter (double) link budget is given below.

$$\underbrace{P_R}_{\text{-110 dBm}} = P_T + \overbrace{2G_T}^{\text{20.0 dBi}} + \underbrace{2G_R}_{\text{0.0 dBi}} - \overbrace{40\log_{10}\left(\frac{4\pi}{\lambda}\right)}^{\text{63.4 dB}} - \underbrace{40\log_{10} r}_{\text{228.0 dB}}$$

Solving for P_T, we find that at least 161.4 dBm of transmit power is required to read an RFID backscatter signal. That's at least 13.8 *TeraWatts*! Impossible.

3. **Launch a GPS Satellite!:**



(a) See picture above. For a satelliate in circular orbit or at perigee/apogee, the radial component of velocity is zero ($V_r = 0$). Since this is true at point A for both types of orbit – the original and the elliptical transit – the rocket must provide thrust in the θ-direction to transition to the elliptical orbit. The speed at point A would be larger for the transit orbit than the circular orbit, so the direction of the arrow should be leftward.

(b) See picture above.

(c) We use our geometrical formulas relating apogee and perigee to eccentricity:

$$\frac{\text{Perigee, } r_p}{\text{Apogee, } r_a} = \frac{a(1-e)}{a(1+e)} \longrightarrow$$

$$e = \frac{r_a - r_p}{r_a + r_p} = \frac{(6380 \text{ km} + 20{,}200 \text{ km}) - (6380 \text{ km} + 1000 \text{ km})}{(6380 \text{ km} + 20{,}200 \text{ km}) + (6380 \text{ km} + 1000 \text{ km})} = 0.56$$

(d) We use the Kepler's law equation for semi-major axis:

$$T^2 = \frac{4\pi^2 a^3}{\mu} \quad \text{where } a = \frac{r_a + r_p}{2}$$

Since we are using exactly half the orbit, we only need to use half the period. The result is a transit time of approximately 11,000 seconds (3 hours and 3 minutes) long.

(e) The final orbit speed is approximately 3.8 km/s.