ECE 6390: Satellite Communications and Navigation Systems
Solutions to TEST 1 (Fall 2008)

1. **Short Answer Section**

   (a) spinner, momentum wheels

   (b) Explorer

   (c) batteries

2. **Radar Detector:** If every radar gun, detector, detector detector, detector detector detector, etc. uses the same standard 9.825 GHz local oscillator, then all of the detector detectors will be looking for this frequency for LO leakage. If the device *also* uses 9.825 GHz (LO) to mix down the 9.825 GHz received signal (RF). Thus, the intermediate frequency (IF) is 0 GHz with an image (before filtering) at 19.650 GHz. [Note: I omitted this question from scoring since there was some confusion in the class about mixer operation due to light treatment in the lecture and the book.]

3. **Antenna Gains:** Gain and directivity both describe the radiation pattern of an antenna, but gain includes an additional efficiency factor to account for Ohmic losses, mismatches, etc.

   Although I had to go back and check for some tests, I did *not* ask the following questions:

   > Write a verbose definition of *gain* and *directivity* that illuminates nothing about the difference between these two quantities. (**6 points**)
   >
   > Explain the difference **concisely** between *gain* and *directivity*, but make sure your explanation does not contain words. (**6 points**)
   >
   > Write down everything you know about antennas, including the relationship between size and beamwidth, different types of antennas you've studied in the course so far, what you had for breakfast, what sports you played in high school, etc. (**6 points**)

4. **Look Angles:** For geosynchronous orbit, the semi-major axis must be

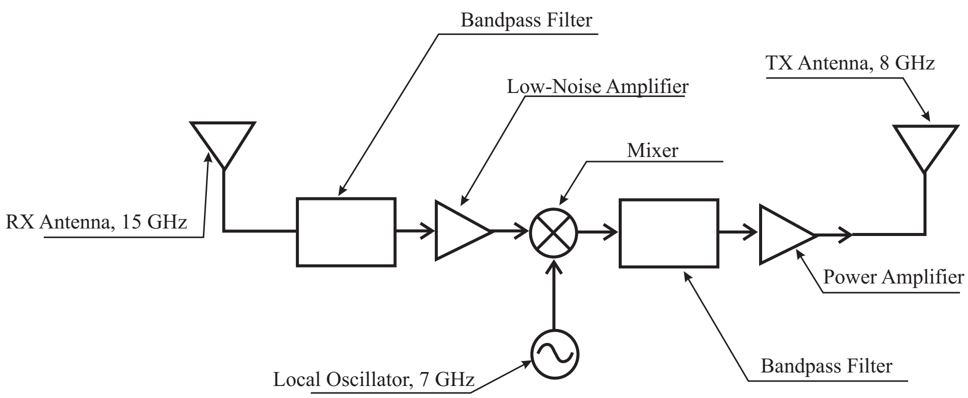
$$a = \left(\frac{M_e G T_s^2}{4\pi^2} \right)^{\frac{1}{3}} = 42,164 \text{ km}$$

   where T_s is a sidereal day. The perigee of this orbit is the 1,000 km altitude of the satellite at its closest point to the earth *plus* the earth radius. Eccentricity for this orbit would be

$$e = 1 - \frac{\rho_{\min}}{a} = 1 - \frac{7,378 \text{ km}}{42,164 \text{ km}}$$

The most common error on this problem was to mistake the 1,000 km altitude for the *perigee* of the orbit without adding in the radius of the earth. One wonders if a satellite that had to plow through magma once a day should have made more students suspicious than it appears to have done on the test.

5. **Transponder RF Chain:** There is no single right answer for this, but a bare minimum diagram should include the following components:



6. **Link Budget for MEO Satellites:** The dB link budget for this problem is

$$P_R - P_T = -20\log_{10}\left(\frac{4\pi r}{\lambda}\right)$$

since the transmit and receive antenna gains are 0 dBi. Keeping in mind that $\lambda f = c$, where c is the speed of light:

$$f = \frac{c}{4\pi r}10^{\frac{P_T - P_R}{20}} = 169 \text{ MHz}$$

7. **Antenna Coverage:** The peak gain of this antenna occurs at $\theta = 90°$ and is 1.5. Half of this linear power gain results in a beamwidth of

$$\theta_{\text{HPBW}} = 90° \pm 45°$$

Thus, the square geometry sketched below dictates the minimum satellite radius:

$$r = \sqrt{2}R_e = 9,020 \text{ km}$$