20 May 2009 **Ph 101** E.S. Phinney & D.J. Stevenson

Order of Magnitude Physics

Problem Set 8

Due **in class** Wednesday 27 May 2009

Homework Problems:

1. **Human Eyes and TV**

   The angular resolution of the human eye at the center of its field of view (fovea) is about 5×10^{-4} radians. Compare this to the following:

   a) The diffraction limit set by the pupil size, $0.2 < p < 0.4$ cm, and the distance, 2.4 cm, between the cornea and retina.

   b) The maximum density 1.5×10^7 cm^{-2} of light sensitive cells(cones) at the fovea.

   c) The angular size of a picture element in a 50 cm wide TV viewed from a distance of 3 m. Consider both the soon-to-be obsolete NTSC analog standard definition and HDTV[1]

2. **Rocks, Asteroids, Satellites, and Planets**

   a) Rocks, small asteroids, and small satellites come in all shapes. Large asteroids, satellites, and planets are approximately spherical. Estimate the size of the largest asteroid that could maintain a distinctly nonspherical shape.

   b) How large could the radius of a rocky planet be before pressure significantly modifies molecular structure in its central region?

3. **Visiting a Neutron Star**

   a) How close could you comfortably orbit a cold neutron star?

   b) Has the human race generated enough energy to lift a teaspoon of material out of the interior of a neutron star?

4. **Construction in Siberia** The ground in much of Siberia is saturated with water. In winter, the soil is frozen hard. During the short warm summers, the upper layers of soil turn to mud. Buildings built on shallow foundations then sink into the mud. Longer-lasting buildings are built on piers sunk into the ground to a depth where the water is permanently frozen. Estimate the required length of pier, and the safety factor you would recommend to avoid sinking during an unseasonably warm summer. Explain why the piers extend above ground, leaving an open airspace beneath the building.

5. **Interplanetary Communication at Radio Frequencies**

   a) Calculate the power p received by an earth based radio telescope of diameter D from a spacecraft at distance s that transmits power P at wavelength λ using an onboard antenna of diameter d. Provide an analytical formula and a numerical evaluation in watts for $D = 70$m, $d = 3$m, $s = 10$AU, $\lambda = 4$cm, and $P = 10$watts.

[1] NTSC analog consisted of 486 visible vertical scan lines and effectively about 640 horizontal pixels. HDTV has 1920x1080 pixels. The image is redrawn at 30Hz (alternate horizontal lines are actually drawn at 60Hz, known as interlacing).

b) Denoting the system temperature[2] of the earth based radio telescope by T, what is the maximum bandwidth $\Delta\nu$ at which the signal exceeds the noise? As for a), provide both an analytical formula and a numerical evaluation in Hz for $T = 20$K.

c) Relate $\Delta\nu$ to the bit rate at which information can be transmitted from the spacecraft to earth.

[2]System temperature is the effective noise temperature. Fourier transforming the position $x(t)$ of a spring with a damping time τ gives a signal spread over a bandwidth $\Delta\nu = 1/\tau$. If the spring is in thermal equilibrium, it has kT of energy. Thus the noise power in bandwidth $\Delta\nu$ is $P_{\text{noise}} \sim kT/\tau \sim kT\Delta\nu$.