Astro 519A; Final Exam

Book, notes and calculator are allowed for all the calculations. The exam is two hours.

1.) An upright cylinder of height h and diameter D is emitting with surface brightness B at distance d. Does the received flux in the limit $d \gg (h, D)$ depend on the cylinder's orientation? In the same limit, what flux is expected when viewed from "above" so it looks like a circle or "the side" so it looks like a rectangle?

2.) A relativistic shell is expanding spherically around a source and radiating in all wavebands. The Lorentz factor of each point on the shell is $\gamma = 100$ relative to the point at the center of the shell (the shell's center of mass). Approximately what fraction of the surface area of the shell contributes most to the flux at a point that lies outside of the shell? [You can assume the point is in the shell's center of mass frame for the calculation.]

3.) Consider the average intensity incident on the earth, excluding radiation from the sun. Link entries in the following two lists {radio, microwave, far infrared, gamma ray}, {dust, inverse Compton, thermal, synchrotron}.

4.) The naked eye is sensitive to surface brightnesses with $B > B_{\rm eye}$. An unobscured nebula at a distance 100pc with surface brightness $B_{\rm neb}$ is unobservable with the naked eye (i.e. $B_{\rm neb} < B_{\rm eye}$). How close to the nebula does one need to travel to see it with the naked eye?

5.) Imagine some two level electronic system (perhaps two electronic states of a molecule) where neither level is degenerate and the levels have an energy difference of ΔE_{01}. The collisional excitation coefficient into the excited state of the system from collisions with passing particles is C_{01} such that the system is taken to the excited state is $C_{01}n_0$, where n_0 is the fraction of electrons in the ground state. Similarly the deexcitation rate is $C_{10}n_1$. In thermal equilibrium with temperature T, write an expression for C_{01} in terms of C_{10} and T? You can assume that there are no other processes exciting or deexciting the system (although the result does not depend on this assumption).

6.) An electron is oscillating in one dimension with trajectory $x(t) = fc/\omega \cos[\omega t]$, where c is the speed of light and f is some number that is just slightly less than one. Write an expression for the power radiated as a function of time.

7.) The flux of some unknown source at a distance of d is shown above in diagram A.

a) Name the emission process and give the values of the parameters that characterize the emission (such as, where relevant, T, N_e, $n_e^2 V$, $\gamma_{\rm min}$, $\gamma_{\rm max}$, B, etc). Also state whether the emission is optically thin or thick.

b) In orbit, the flux of this source can in principle be observed down to $\sim 10^5$Hz, but on earth only to $\sim 10^7$Hz is possible. Why?

8.) The source in question 7 is also observed in scattered light off of two nearby clouds, shown in diagrams B and C on the top of the page. Name the type of particle that is doing the scattering in both cases.

9.) The following plot shows the electric field received by a radiometer as a function of time. How does the specific intensity of this radiation scale with frequency? [Assume that each of the spikes in the electric field are uncorrelated and, at the frequencies of concern, their shape can be approximated as a Dirac delta function.]

10.) Estimate the timescale that ionized gas with temperature $T = 10^4$ K loses its energy via inverse Compton scattering with the cosmic microwave background, which has $T = 2.7$ K.

Extra credit: Future NASA exoplanet missions targeting planetary transits require star shades that are placed in front of the telescope to block out the light from the host star. In particular, at the position of a planet on the CCD, the star shade is optimized to minimize the amount of light from the host star. Star shade designs typically look like a flower (as drawn below) rather than a disk. Why is this the case?

Have a great winter break! The graded final and problems sets will be put in your box later this week.