- 1. Carroll & Ostlie, Problem 9.7: Calculate how far you could see through Earth's atmosphere if it had the opacity of the solar photosphere. Use the value for the Sun's opacity from Example 9.2.2 (0.3 cm² gm⁻¹, from page 242) and 1.2×10^{-3} gm cm⁻³ for the density of the Earth's atmosphere. (3 pts)
- 2. Carroll & Ostlie, Problem 9.11: According to a "standard model" of the Sun, the central density is 153 gm cm⁻³ and the Rosseland mean opacity at the center is 2.17 cm² gm⁻¹.
 - (a) Calculate the mean free path of a photon at the center of the Sun. (2 pts)
 - (b) If this mean free path remained constant for the photon's journey to the surface, calculate the average time it would take for the photon to escape the Sun. (5 pts)
- 3. (a) Consider an optically thick ($\tau \gg 1$) cloud at a geocentric distance d. The cloud emits thermal radiation. Express the observed intensity, I_{ν} , from the center of this cloud, as a brightness, $B_{\nu}(T)$. (5 pts)
 - (b) The brightness temperature, T_b , is the temperature of a blackbody which has the same brightness at this frequency. Derive the relationship between T_b , τ , and T using the Rayleigh-Jeans approximation. Under what conditions does this condition hold? (5 pts)
 - (c) Approximate the cloud as a sphere. Define θ as the angle between the line of sight and the normal to the surface. Determine the center-to-limb variation in the observed intensity. (5 pts)

Use the following diagram to set up problems 3(c) and 4(c). Think qualitatively about what you would expect to happen for optically thick and thin clouds, and then perform appropriate calculations.



- 4. (a) Consider an optically thin ($\tau \ll 1$) cloud at a geocentric distance *d*. The cloud emits thermal radiation. Express the observed intensity, I_{ν} , from the center of this cloud, as a brightness, $B_{\nu}(T)$. (5 pts)
 - (b) The brightness temperature, T_b , is the temperature of a blackbody which has the same brightness at this frequency. Derive the relationship between T_b , τ , and T using the Rayleigh-Jeans approximation. Under what conditions does this condition hold? (5 pts)
 - (c) Approximate the cloud as a sphere. Define θ as the angle between the line of sight and the normal to the surface. Determine the center-to-limb variation in the observed intensity. (5 pts)
- 5. If you were to observe Jupiter's thermal emission at radio wavelengths, where one probes down to well below the planet's tropopause, would you expect limb brightening, darkening or no change in intensity when you scan the planet from the center to the limb? Explain your reasoning. (8 pts)

Note that for a line of sight which makes an angle θ to the normal to the surface (extending to the right in the figure), the radial distance z along a path length s is

