

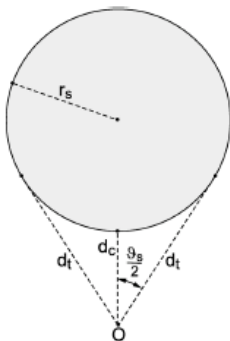
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attempt all questions, if you are having trouble with one, move on and come back to it.

1. write down the radiative transfer equation and explain the terms. explain how it reduces for terrestrial and solar radiative transfer.
2. explain the significance of the 2 components to the index of refraction
3. define the 3 main radiative parameters describing a cloud or aerosol layer.
4. the transmission through a liquid layer of depth 10 cm is measured to be 70% for an overhead Sun. what is the volume extinction coefficient?
5. a slab of optical depth tau is illuminated both by a direct beam, and by an isotropic diffuse beam of light, both of the same intensity. how much is transmitted in both cases? at what angle of illumination do the 2 become equal?
6. estimate the temperature of the filament of a 100 W electric light bulb. State all assumptions.
7. At a beach in Miami, the net flux of solar energy absorbed by the sand is 500 W m^{-2} over a period of 12 hours. Assuming a sand heat capacity of $2 \cdot 10^6 \text{ J m}^{-3} \text{ K}^{-1}$ how much does the temperature of the sand increase? If all the heat is transferred to a boundary layer of depth 300 m (air density = 1 kg m^{-3} , $c_p = 1004 \text{ J/(kg} \cdot \text{K)}$) how much does the air temperature rise? what would you expect to see happen to the depth of the boundary layer?
8. suppose the sun were hotter, with maximum emission occurring at 0.4 rather than 0.475 micron. what would that imply for the earth's equilibrium temperature?
9. derive Planck's law for the limit of large wavelengths. This is known as the Rayleigh-Jeans Approximation, and is used for microwave-based retrievals. Recall

$$B_\lambda(T) = \frac{2hc^2}{\lambda^5 (e^{hc/k_B\lambda T} - 1)}; \text{ your answer can be left in terms of the constants}$$

10. what is the solid angle at point O of the sphere in the following diagram as a function of the distances dc and rs?

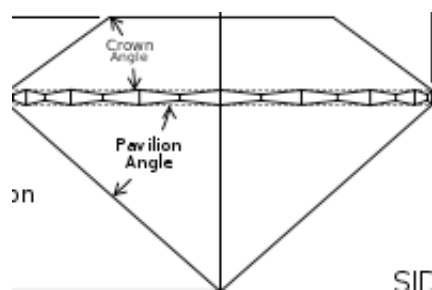


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11. the net (longwave+shortwave) radiative forcing of a cloud - whether or not a cloud warms or cools the climate relative to clear-sky conditions - depends strongly on the properties of the cloud. comment on differences in the radiative forcing of low and high clouds, include some rough estimates of the clouds' (3 main) optical properties.

12. an approximation for the cloud-top albedo of a non-absorbing cloud is $(1-g)*\tau / (1+(1-g)*\tau)$ (Petty eqn 13.63). As a cloud ages, the collision-coalescence process creates larger drops, increasing the width of its droplet size distribution. Assuming the larger drops remain within the cloud (i.e. liquid water path remains the same), how would you expect the cloud albedo to evolve? consider changes in both the optical depth and g .

13. a diamond's cut is meant to maximize light return. The shape of a classic diamond cut is shown below. given a real index of refraction of 2.42, trace the path of light entering the diamond directly from above. include one sample calculation - how does the "pavilion angle" figure into the light's trajectory? where does the light go if the cone is cut too deep (ie the pavilion angle is too large)? *



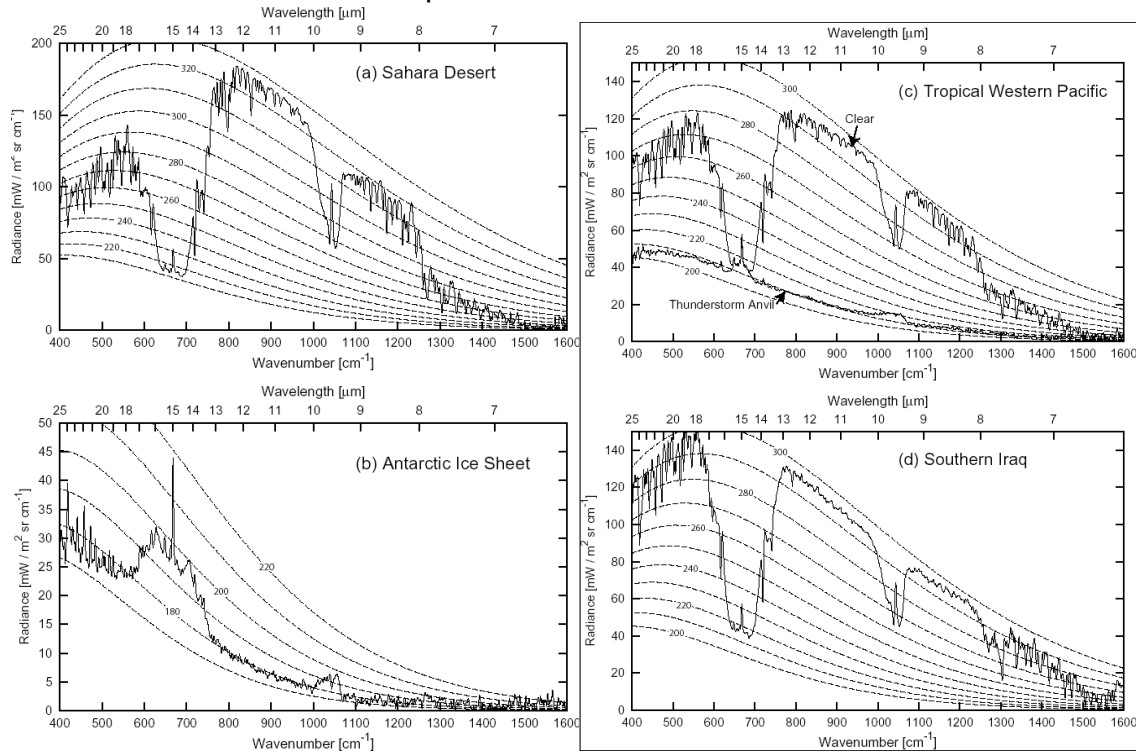
*early diamonds, lacking such cuts, often appeared black to the eye

14. Consider solar radiation with a zenith angle of 0 degrees, incident on a layer of aerosols with a single-scattering albedo of 0.9, an asymmetry factor of 0.6, and an optical depth of 0.15 averaged over the shortwave part of the spectrum. what fraction of the incident radiation is backscattered by the aerosol layer? how much is absorbed? Of the amount transmitted to the surface, how much is scattered back to space? (work this out as a geometrical series). what does the solution imply for the net impact of direct aerosol radiative forcing over a desert with a surface albedo of 0.4, compared to an ocean surface with an albedo of 0.05? (this is basically WH problem 4.42 slightly modified).

15. AERONET sites measure 5 or more transmitted direct solar spectral radiances (wavelengths between 0.34-10 micron), as well as the diffuse solar radiation. How is this used to estimate aerosol radiative properties? How does the principle underlying the "reddening" of aerosol also impact the AERONET aerosol optical depth retrievals?

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16. The 4 plots below show the top-of-atmosphere infrared spectra for 4 locations on earth: Sahara Desert, Antarctica, tropical western Pacific, southern Iraq. For each of the 4 scenes, provide an estimate of the surface temperature. For which scene does the surface appear to be significantly colder than any other level in the atmosphere? Identify the location of each scene. How does the drier atmosphere above southern Iraq distinguish its IR spectra from that of the TWP? Which molecules do the regions at 15 micron and 9.6 micron correspond to?



17. The Atmospheric Infrared Sounder (AIRS) measures infrared radiances at hyperspectral resolution (2378 channels). Write down the radiative transfer equation governing the radiances. What portion of this corresponds to the weighting functions? Assuming an atmosphere with an exponentially decaying water vapor atmospheric profile, how does the weighting function correspond to the water vapor density profile and transmittance? Both a pictorial depiction, and a simple equation relating the weighting function to the transmittance and volume extinction coefficient profile is desired.