ESCI 340 – Physical Meteorology
Answers to Selected Exercises for Radiation Lesson 4

1. You shoot a laser beam of wavelength λ horizontally through a homogeneous atmosphere of density 1.23 kg/m³ at a target 10 km away. You find that the monochromatic radiance is half of what it started out as.

   a. What is the path optical thickness? **Answer:** 0.693
   b. What is the mass extinction cross section? **Answer:** 5.6×10^{-5} m²/kg
   c. What is the transmissivity? **Answer:** 0.5
   d. What is the absorptivity (assume there is no backscattering)? **Answer:** 0.5

2. The laser in problem 1 is now fired straight upward at an airplane. Density decreases with height according to the equation
$$\rho(z) = \rho_0 \exp(-z/H)$$
   where H is 8.1 km and $\rho_0 = 1.23$ kg/m³.

   a. What is the path optical thickness? **Answer:** 0.396
   b. What is the vertical optical thickness? **Answer:** 0.396
   c. What are the transmissivity and absorptivity (assume there is no backscattering)?
      Answer: 0.673 and 0.327 respectively

3. The airplane is still at an altitude of 10 km, but has moved 5 km away horizontally.
   a. Now what is the optical thickness? **Answer:** 0.442
   b. What is the vertical optical thickness? **Answer:** 0.396
   c. What are the transmissivity and absorptivity (assume there is no backscattering)?
      Answer: 0.643 and 0.357 respectively

5. A mixture of gas A and gas B is at a temperature of 20°C and a pressure of 1000 mb. The particulars of the mixture are

	Gas A	Gas B
% by volume	75	25
M (g/mol)	20.0	30.0
b_λ^a (cm²)	10^{-36}	10^{-22}
b_λ^s (cm²)	10^{-28}	10^{-28}

   a. What is the total extinction cross section of the mixture?
      Answer: 2.5×10^{-23} cm²

   b. What is the total mass extinction cross section of the mixture?
      Answer: 0.67 cm²/g

c. What physical distance within the gas corresponds to a path optical thickness of 1? (You may need to find the density of the mixture using the ideal gas law. The specific gas constant for the mixture is the universal gas constant [8.3145 J-mol^{-1}-K^{-1}] divided by the molecular weight of the mixture.
   Answer: 16.2 m