ASTR-3415, *Astrophysics* — Exam 1

Spring 2003

6 February 2003

Name: ______________________________

Useful Constants and Identities

G	=	6.673×10^{-8} dyne cm^2/gm^2	g	=	980 cm/s^2
c	=	2.997925×10^{10} cm/s	σ	=	5.6696×10^{-5} erg/cm^2/s/K^4
h	=	6.6262×10^{-27} erg s	e	=	4.803×10^{-10} esu
$M_{\rm Moon}$	=	7.35×10^{25} gm	$M_\odot$	=	1.99×10^{33} gm
$M_\oplus$	=	5.98×10^{27} gm	$R_\oplus$	=	6.38×10^{8} cm
$R_\odot$	=	6.96×10^{10} cm	$T_\odot$	=	5770 K
1 AU	=	1.496×10^{13} cm	$L_\odot$	=	3.827×10^{33} erg/s
1 ly	=	9.4605×10^{17} cm	1 pc	=	3.0856×10^{18} cm
1 eV	=	1.602×10^{-12} erg	1 eV/hc	=	8065.46 cm^{-1}
1 eV/k_B	=	1.16048×10^{4} K	1 amu	=	1.66×10^{-24} gm
m_e	=	9.109×10^{-28} gm	m_p	=	1.67×10^{-24} gm
R_∞	=	109,737.31 cm^{-1}	$k_B = k$	=	1.3806×10^{-16} erg/K
1 Å	=	10^{-8} cm	1 nm	=	10^{-7} cm

Answer the questions on the space provided below the question and on the additional blank pages supplied after each question. Feel free to use the back of all pages as well. Remember to **show <u>all</u> work!** The answer is of secondary importance, the technique used to determine the answer is of fundamental importance. Answer your problems as I have done in the solutions to Problem Set 1 that I have supplied to you. Logic and deductive reasoning are being tested here in addition to number crunching! Also remember to pay attention to units and significant digits.

1. (40 pts) Assume a gas has an opacity that is constant at all wavelengths and has the functional form

$$\kappa = A\left(\frac{z}{z_\circ}\right)^{3/2} ,$$

where $A = 3.45 \times 10^{11}$ cm^{-1} is the opacity at the reference depth $z_\circ = 5.26 \times 10^3$ km and z increases into the gas as viewed from outside. (Note that z increases as τ increases.)

(a) What is the optical depth of the gas at $z_\circ$?

(b) At what depth (both in cm and in terms of $z_\circ$) does $\tau = 1$?

(c) Assume the gas is in thermal equilibrium at a temperature of 10,000 K, what is the emissivity (a number is requested here) for the gas at $z = z_\circ$ and $\lambda = 5000$ Å?

(d) What is the value of the source function (again a number is requested) at this temperature and wavelength? Define *source function* in words.

Problem 1 continued:

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2. (60 pts) Three terms (see Table I-2 on page I-21 in your notes) exist in an atomic model. Each term is in a subshell that is less than half filled. Term 1 has the following characteristics: $S = 0$, $L = 0$ and even parity; Term 2 has $S = 0$, $L = 1$, and odd parity; finally, Term 3 has $S = 1$, $L = 2$, and odd parity. The partition function for the ion of this atom is equal to 1 and the partition function of the atom itself is equal to 4 for a gas at the Sun's effective temperature. The ionization energy of the atom is 8.67 eV.

(a) Write out the spectroscopic notation for all 5 levels (including J values) arising from these terms.

(b) Draw an energy level diagram similar to the one in Figure I-6 on page I-20 of your course notes and locate each level with respect to the other levels using Hund's Rule.

(c) Determine which of the 7 transitions from these levels are allowed, semi-forbidden, and forbidden. List the reasons for why they are considered as such. (Note that in addition to what is given in your notes, forbidden transitions also occur if either ΔS and ΔJ or ΔL and ΔJ are violated.)

(d) If the ratio of the ion number density to the neutral atom number density is 4.56×10^{-2} at the continuum formation depth in the Sun's atmosphere, what is the electron density at this depth?

Problem 2 continued:

Problem 2 continued: