Name: ______________________________ October 16, 2003 9:20 - 10:35 p.m.

Physics/Astronomy/Planetary Sciences 589 Exam I

This is a closed book exam, but you are allowed a crib sheet. A calculator would be very useful. Do all of the problems. There are a total of 100 points to be awarded. Partial credit can be earned. The exam will last 75 minutes. The best of luck!

$1 \text{ parsec} \equiv 3.086 \times 10^{18} cm$	$G = 6.67259 \times 10^{-8}$
$1 \ AU \equiv 1.5 \times 10^{13} cm$	$\sigma = 5.67 \times 10^{-5} cgs$
$c = 2.9979245 \times 10^{10} cm \ s^{-1}$	$a = 7.56 \times 10^{-15} erg \, cm^{-3} \, K^{-4}$
$m_H \sim 1.6726 \times 10^{-24} gms$	$R = 8.31 \times 10^{7} ergs/gmK$

Kirchhoff's Law: $\dfrac{j}{\kappa_a^*} = \dfrac{cB}{4\pi} = I_B$

$$F_{diff.} = -\frac{c}{3\kappa_T \rho}\frac{\partial U}{\partial x}; = -D\frac{\partial n}{\partial x}$$

$$\frac{\partial n}{\partial t} + div\vec{F} = -\kappa_a \rho v n + S$$

$$\frac{1}{c}\frac{\partial I}{\partial t} + \vec{\Omega} \cdot \vec{\nabla} I = -(\kappa_a^* + \kappa_s)\rho I + j\rho + \frac{\kappa_s \rho}{4\pi}\int I(\Omega')\Phi(\Omega', \Omega) d\Omega'$$

1) (20 points) A spherical shell is illuminated at all points simultaneously by a central source of UV light that causes the shell to fluoresce. An observer 10 parsecs away sees not a delta function flash of fluorescence, but a constant flux that lasts for 1.5 years. What are the dimensions of the shell?

2) (20 points) At some initial time, a hot gas of temperature T in a box of volume V is devoid of radiation (photons). If the absorptive opacity is 1 cm^2 gm^{-1} and the mass density of the gas is 10^{-5} gm cm^{-3}, about how long will it take for a blackbody sea of radiation to build up in the box? Assume that the box is leak-proof and that the gas is kept at a constant temperature.

3) (20 points) a) In the Milne atmosphere problem in the Eddington approximation, assuming that the boundary condition at $\tau = 0$ is $F = cU/\sqrt{3}$, what is the temperature (T) in the atmosphere as a function of τ and the effective temperature T_e? b) What is the gas temperature at $\tau = 0$? c) For what τ is $T = T_e$?

4) (20 points) A point source of neutrons emitting q_0 neutrons per second isotropically is embedded in an infinite, constant density medium comprised of liquid molecular hydrogen (H_2). The density (n) of the H_2 is $\sim$0.08 g cm^{-3}. The scattering cross section (σ_s) for the neutrons off protons is 10 barns and the absorption cross section (σ_a) is 0.1 barns. The speed of the neutrons is 2×10^5 cm s^{-1}. a) Using the diffusion approximation, what is the general formula for the steady-state neutron density distribution as a function of radius around the point source? b) What is the approximate characteristic linear size of the region containing most of the neutrons (number!)?.

5) (20 points) A pinhole camera is a rectangle box of length L with a circular pupil opening of diameter d. a) Derive the distribution of the light flux ($F(\theta, \phi)$) at the back of the camera as a function of angle (θ) from the axis of the box, the f-ratio of the camera, and the incident specific intensity field $I(\theta, \phi)$. b) If the camera is taking a picture of a uniform sky, at what angle θ is the flux at the back of the box down by a factor of 10? Comment.