Astronomy 142 — Practice Midterm Exam #1

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Name: ______________________________

You may consult *only* one page of formulas and constants and a calculator while taking this test. You may *not* consult any books, digital resources, or each other. All of your work must be written on the attached pages, using the reverse sides if necessary. The final answers, and any formulas you use or derive, must be indicated clearly (answers must be circled or boxed). You will have one hour and fifteen minutes to complete the exam. Good luck!

- First, work on the problems you find the easiest. Come back later to the more difficult or less familiar material. Do not get stuck.
- The amount of space left for each problem is not necessarily an indication of the amount of writing it takes to solve it.
- Numerical answers are incomplete without units and should not be written with more significant figures than they deserve.
- Remember, you can earn partial credit for being on the right track. Be sure to show enough of your reasoning that we can figure out what you are thinking.

$R_\odot = 6.96 \times 10^{10}$ cm	$M_{\rm bol} = 4.74$
$M_\odot = 1.989 \times 10^{33}$ g	$m_V = -26.71$
$L_\odot = 3.827 \times 10^{33}$ erg/s	$M_V = 4.86$
$T_e = 5772$ K	$BC_V = -0.12$
1 AU $= 149,597,870$ km	1 pc $= 206,265$ AU
$k = 1.38 \times 10^{-16}$ erg/K	$\sigma = 5.6704 \times 10^{-5}$ erg s^{-1} cm^{-2} K^{-4}
$G = 6.674 \times 10^{-8}$ dyn cm^2 g^{-2}	$c = 3 \times 10^{10}$ cm/s
$h = 6.6261 \times 10^{-27}$ erg s	$m_p = 1.6726 \times 10^{-24}$ g
$m_n = 1.6749 \times 10^{-24}$ g	$m_e = 9.1094 \times 10^{-28}$ g
$q_e = 4.803 \times 10^{-10}$ esu	

1. **Short answers**: Please write in complete sentences, and feel free to use equations and/or sketches to help explain your thoughts.
   (a) (5 points) A celestial object is above the horizon for exactly 12 hours. What is its declination?
   (b) (5 points) Explain why there is a maximum degeneracy pressure that electrons are capable of exerting, and therefore a maximum mass for white dwarf stars.

(c) (5 points) Describe the difference in nature between the pulsations exhibited by the Sun — the "five minute oscillations" — and those found in Mira, Cepheid, and RR Lyrae variables.

(d) (5 points) Most of the double-line spectroscopic binaries that we see involve two stars of similar mass. Why?

2. Consider two fusion mechanisms: the main proton-proton chain and deuterium fusion. The masses of deuterium and helium are

$$m({}^2_1\mathrm{H}) = 3.3426 \times 10^{-24}\ \mathrm{g} \qquad\qquad m({}^4_2\mathrm{He}) = 6.6447 \times 10^{-24}\ \mathrm{g}$$

(a) (10 points) Fill in the blanks in the nuclear reaction chains for these two processes:

p-p chain I

$$2\,{}^1_1\mathrm{H} \rightarrow {}^2_1\mathrm{H} + \underline{\qquad} + \underline{\qquad} \qquad (2\times)$$

$${}^2_1\mathrm{H} + \underline{\qquad} \rightarrow {}^3_2\mathrm{He} + \underline{\qquad} \qquad (2\times)$$

$$2\,{}^3_2\mathrm{He} \rightarrow \underline{\qquad} + 2\,{}^1_1\mathrm{H}$$

$$\text{Total: } \underline{\qquad} \rightarrow \underline{\qquad} + \underline{\qquad} + \underline{\qquad} + \underline{\qquad}$$

d-d fusion :

$$2\,{}^2_1\mathrm{H} \rightarrow {}^4_2\mathrm{He} + \underline{\qquad}$$

(b) (5 points) Calculate the energy $\Delta E_{\text{p-p}}$ and $\Delta E_{\text{d-d}}$ released by fusion and available for the lightweight products (electrons, photons, etc.) in each of the "total" reactions. Express your answer in ergs.

(c) (5 points) Compare the neutrino production in these two mechanisms. Which is a better explanation of the detected quantity of solar neutrinos: neutrino oscillation or the Sun being made of pure deuterium? In other words, if the core of the Sun were made of pure deuterium, would the original solar neutrino problem be solved or does neutrino oscillation still look like a better explanation?

3. **A deuterium star**. A $1M_\odot$ main-sequence star like the Sun has a central temperature of 1.57×10^7 K and the subatomic particles in its center (electrons, protons, and other ions) have an average mass of $0.62m_p$. Consider a $1M_\odot$ star made completely of deuterium ${}^2_1$H, which produces energy by d-d fusion into helium. Assume its internal structure is like that of the Sun, apart from its different internal composition.

   (a) (5 points) Calculate the average particle mass μ in the deuterium star's interior assuming that the material is fully ionized. Express your answer in terms of m_p.

   (b) (10 points) Suppose the deuterium star has the same radius as the Sun. Calculate its central temperature.

(c) (10 points) Show that at this temperature, d-d fusion reactions in the core of the deuterium star occur a bit less than half as often as p-p reactions in the Sun's core.

4. You have observed an eclipsing double-line spectroscopic binary in which the two sets of lines are identical, but for which the Doppler shifts are sinusoidal and opposite. The velocity amplitudes are both $v = 43$ km/s and the period $P = 31$ days. The visual magnitude of the binary is $V = 10$.

   (a) (10 points) Make some reasonable assumptions and deductions about the shape and orientation of the orbits and the relative masses of the stars in the binary system. Then calculate the separation of the stars. Express your answer in terms of $R_\odot$.

   (b) (5 points) Calculate the masses of the stars in the binary system, expressing your answer in terms of $M_\odot$.

(c) (10 points) Calculate the visual magnitude of each star.

5. A $1 M_\odot$ star is observed to oscillate in brightness with a period of 48 hr and an amplitude of 1 visual magnitude.
   (a) (10 points) Assume the star is uniform in density. What is its radius in terms of $R_\odot$?

   (b) (5 points) In what phase of its evolution is the star likely to be?