September 11, 2006 Name:________________________

Astronomy 102: Examination 1

Do not open the test until instructed to begin.

You must do this test on your own without consulting any outside notes. You may not discuss this test with anybody else either before or during your taking of the test. You are allowed a calculator for purposes of arithmetic, but you may not use any device that connects you to a network or allows you to communicate with any other people.

I confirm that I did not receive any help, nor did I reference any disallowed materials in doing this test.

Signature:____________________________

Instructions: Write your answers in the space provided. If you need additional space, continue on the back of each page, but indicate **clearly** that you have done so. No books, notes, or assistance from anyone is allowed. You are allowed to use, and will need, a calculator. Please **write legibly and be brief and to the point!** The exam has four questions; each question has equal weight.

Possibly Useful Constants and Formulae

$$R_\odot = 6.96 \times 10^5 \text{ km}$$
$$M_\odot = 1.99 \times 10^{30} \text{ kg}$$
$$c = 3.00 \times 10^8 \text{ m s}^{-1}$$

$$1\,\text{pc} = 3.26 \text{ lyr}$$
$$1\,\text{pc} = 206,265 \text{ AU}$$
$$1\,\text{AU} = 1.496 \times 10^{11}\,\text{m}$$
$$1\,\text{km} = 1,000\,\text{m}$$

$$E = m\,c^2$$
$$eff = \frac{E_{\text{produced}}}{m\;c^2}$$

K-40 half-life : 1.26 billion years

Process	**Efficiency**
Chemical Reactions	$\sim 10^{-10}$
Nuclear Reactions	$\sim 10^{-2}$
Total Conversion	1

Age of Solar System: 4.6×10^9 years

Age of Universe: 13.7×10^9 years

1. Consider two stars. One is the Sun. The other is a bright, hot blue star. The blue star is 10 times as massive as the Sun. Its luminosity (the amount of energy it puts out every second) is 10,000 times as high as the luminosity of the Sun. Both stars will, during the main part of their lifetime, use 10% of their mass as fuel. Both stars are powering themselves through nuclear fusion of Hydrogen.

(a) Qualitatively, how does the efficiency eff of the energy generation process in the hot blue star compare to the eff of the energy generation process in the Sun? (That is, which, if any, is more efficient, and very roughly how do the efficiencies compare?)

(b) Which star will live longer? Explain.

(c) Given that the Sun will live about 10 billion years, about how long will the hot blue star live?

(d) At the end of its life, will the hot blue star have converted the same fraction, a greater fraction, or a smaller fraction of its mass to energy as the Sun will have by the end of its life? Roughly what fraction of the hot blue star's mass will have been converted to energy?

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2. We have measured the age of the Solar System by knowing that Potassium-40 (K-40) decays to Argon-40 (Ar-40), and by measuring the ratio of K-40 to Ar-40 in rocks formed at the beginning of the Solar System. Potassium-40 will combine with other elements into rocks, but Argon-40 is a noble gas and won't form into rocks. However, Argon-40 produced from decay of Potassium-40 inside solid rocks will be trapped in those rocks.

A hypothetical future space expedition goes to a nearby star system, and measures the K-40/Ar-40 ratio of meteors and small asteroids it finds in that star system. It finds that the oldest rocks in that star system have a *lower* K-40/Ar-40 ratio than do the oldest rocks in our Solar System.

Is that other star system older than, of similar age to, or younger than our Solar System? Explain.

3. A certain type of radioactive isotope has a half-life of 1 hour. You start with a single one of these radioactive isotopes. You watch it carefully, hoping to see when it decays. (**NOTE:** For this problem, you do not need to explain your answers.)

(a) Staring from the beginning, would you say it is impossible, unlikely, somewhat likely (50/50 chance), very likely, or certain that the particle will have completely decayed 10 hours from now?

(b) After 1 hour, can you say with certainty how much of this single particle remains? If not, what are the possibilities, and how likely is each possibility?

(c) Suppose that, by chance, you have watched this particle for *nine hours*, and have not seen it decay. Is it impossible, unlikely, somewhat likely (50/50 chance), very likely, or certain that it will decay in the next hour?

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4. A rock forms at the beginning of the Solar System. The rock drifts through the Solar System for 1.26 billion years. Then, it is involved in a collision that completely liquifies it and stirs it up. During the next few years, the rock comes back together and re-solidifies. The rock then continues to drift through the solar system for another 1.26 billion years.

(a) What is the ratio of Ar-40 to K-40 in the rock 1.26 billion years after the beginning of the Solar System, but before the rock is liquified?

(b) What is the ratio of the amount of K-40 in the rock following its re-solidification to the amount of K-40 in the rock at the beginning of the Solar System?

(c) What is the ratio of Ar-40 to K-40 in this rock 2.52 billion years after the beginning of the Solar System?

(d) What is the ratio of the amount of K-40 in the rock 2.52 billion years after the beginning of the Solar System to the amount of K-40 in the rock right at the beginning of the Solar System?

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