ASTRONOMY 143
The History of the Universe
Professor Barbara Ryden

Problem Set # 6
Due Wednesday, November 18
at class time

NAME (please print clearly): _____

SCORE (instructor use only): _____

1) [20 points] Potassium-40 is an unstable atomic nucleus; it decays to argon-40 with a half-life of 1.3 billion years. Suppose that a rock contains 1,000 potassium-40 atoms at the time it forms. How many potassium-40 atoms will be left after 1.3 billion years? How many will be left after 2.6 billion years? How many will be left after 3.9 billion years?

2) [20 points] The "life span" of the Sun is 10 billion years; that is, at the time it formed, it contained enough hydrogen to power nuclear fusion for 10 billion years. In general, the amount of hydrogen fuel that a star contains is proportional to its mass M; the rate at which it consumes that fuel is proportional to its luminosity L. This implies that the life span t of the star is proportional to M/L.

The star Altair, like the Sun, is powered by the fusion of hydrogen to helium. The mass of Altair is $M_{\text{altair}} = 1.7 M_{\text{sun}}$. The luminosity of Altair is $L_{\text{altair}} = 10.7 L_{\text{sun}}$. Is the life span of Altair *shorter* or *longer* than that of the Sun? What is the approximate life span of Altair, in billions of years?

3) [20 points] There are 411,000,000 cosmic microwave photons per cubic meter of the universe. The average energy of a cosmic microwave photon is very small: only $E = 1.02 \times 10^{-22}$ joules. What is the energy density of the Cosmic Microwave Background, in joules per cubic meter? Using Einstein's relation, $E = mc^2$, what is the equivalent *mass* density, in kilograms per cubic meter? What fraction of the critical density, $\rho_{\rm crit} = 10^{-26}\,{\rm kg/m^3}$, does this density represent?

4) [40 points] The star Phi Orionis, like the Sun, is powered by the fusion of hydrogen to helium. The mass of Phi Orionis is $M_{\rm phi} = 18 M_{\rm sun}$. The luminosity of Phi Orionis is $L_{\rm phi} = 20{,}000 L_{\rm sun}$. Discuss the likelihood of intelligent life existing on a planet orbiting the star Phi Orionis. [Questions you might want to consider: What is the "life span" of Phi Orionis? How long did it take intelligent life to develop on Earth? How far would you have to be from Phi Orionis to receive the same flux of light that we receive here on Earth from the Sun?]