ASTRONOMY 294Z
The History of the Universe
Professor Barbara Ryden

Problem Set # 4
Due Tuesday, February 5
at class time

NAME (please print clearly): _____

SCORE (instructor use only): _____

Reminder: The midterm exam will be on Thursday, February 7, at class time.

1) [20 points] Today, the average density of matter in the universe is $\rho = 3 \times 10^{-27}\,\mathrm{kg/m^3}$. If the matter consisted entirely of hydrogen atoms, how many hydrogen atoms (on average) would be contained in a cubic meter of the universe? If the matter consisted entirely of regulation baseballs (of mass $M = 0.145\,\mathrm{kg}$ apiece), how many baseballs (on average) would be contained in a cubic astronomical unit of the universe?

2) [20 points] The temperature of the cosmic background light today is $T \approx 3\,\mathrm{K}$. At the time the universe became transparent, the temperature of the cosmic background light was $T \approx 3000\,\mathrm{K}$. This means that the universe has expanded by a factor of 1000 since it became transparent. If the density of matter today is $\rho = 3 \times 10^{-27}\,\mathrm{kg/m^3}$, what was the density of matter when the universe became transparent? [Hint: you may assume that matter is neither created nor destroyed.]

3) [20 points] At the time of primordial nucleosynthesis, the temperature of the cosmic background light was $T \approx 4.8 \times 10^8\,\mathrm{K}$. By what factor has the universe expanded since the time of primordial nucleosynthesis? If the density of matter today is $\rho = 3 \times 10^{-27}\,\mathrm{kg/m^3}$, what was the density of matter at the time of primordial nucleosynthesis?

4) [20 points] Look up the density of the Earth's air at sea level. (Using an online search engine is probably the simplest way of doing this, but you can also harass a reference librarian or use an old-fashioned dead-tree encyclopedia.) Is the density of matter at the time of primordial nucleosynthesis greater than or less than the density of the Earth's air at sea level?

5) [20 points] Suppose that you have used a Cepheid variable star as a "standard candle" to compute the distance to a particular galaxy. The distance you computed is $d = 35\,\mathrm{Mpc}$. Much to your embarrassment, you find that the Cepheid variable star has a luminosity L that is actually *twice* the luminosity you assumed when making your calculation. Is the galaxy *closer* or *farther* than you originally calculated? What is the true distance to the galaxy?