1. (10 points) Why do we believe that the Milky Way galaxy and many other galaxies are each embedded in a large halo of Dark Matter? What do we guess that the Dark Matter is made of?

2. (40 points) Describe at least 5 pieces of evidence that give us confidence that the Big Bang theory is correct.

3. (25 points) Determine the number of seconds after the Big Bang when the temperature of the universe was just right to create electron/positron pairs.

You will need to use the rest mass of an electron to calculate the rest energy of an electron, $E = h\nu = hc/\lambda$, Wien’s Law, and this expression derived in class:

$$T = \frac{1.5186 \times 10^{10} K}{\sqrt{t_{sec}}}.$$

4. (25 points) The angular size of a large spiral galaxy in arc seconds is given by:

$$\theta_{arcsec} = 206265 \left(\frac{L}{D}\right) \times (1 + z).$$

$L$, the diameter of a galaxy, might be 25 kiloparsecs. $D$ is the “effective distance” (also known as the proper motion distance), and is usually given in Megaparsecs. You can calculate $D$ using the equation at the very end of the cosmology notes found here:

http://people.physics.tamu.edu/krisciunas/cosmology_notes.pdf

a. Let us assume that the universe can be described by the Einstein-de Sitter model ($\Omega_M = 1, \Omega_{\Lambda} = 0$). This is a critical density universe with no cosmological constant. Give the expression for the effective distance for $\Omega = \Omega_M = 1$.

b. If all galaxies have the same linear size, determine at what redshift the angular size reaches a minimum, beyond which the galaxies actually start getting larger in angular size.