

Ph 444 Problem Set 4

Due: Friday, October 8, 2010

1. Ryden problem 4.2. Assume that the value of Λ is held fixed as some non-relativistic matter is turned into radiation.
2. Ryden problem 5.2. Note that in this problem, the source of light remains at a fixed comoving distance from us. Thus, the time of emission of the light must change when the time of observation changes.
3. Ryden problem 5.3.
4. The temperature at which the Universe becomes transparent is the temperature when hydrogen becomes stable against photo-dissociation. (This is called “recombination” although it had never “combined” before!) Calculations using the Saha equation put this temperature at 2970 K.
 - a) What is the scale factor at this point in time?
 - b) What is the redshift?
 - c) If the Universe is flat, what time after the Big Bang does this event occur?
 - d) What is the lookback time of this event?

This event is crucial to our understanding of the history of the Universe, since it represents the earliest direct observational evidence of evolution, and is the source of the surface of last scattering (and all the CMB photons) that are observed with the COBE and WMAP satellites.