W4260: Problem Set #1
Due: Monday, September 20

Problem 1

The first problem is to install python and numpy (a numerical python library) on your computer. See [www.python.org](http://www.python.org) for instructions on how to install python for your operating system. For many numerical projects we will also need some additional python modules, collected in a package called numpy. See [numpy.scipy.org](http://numpy.scipy.org) for documentation and installation instructions.

If you do not have access to a computer that you can install these packages on, then you will have to use python either on the astronomy lab computers in Pupin 1402, or connect remotely to cunix, Columbia University’s UNIX system. See [www.wikicu.com/CUNIX](http://www.wikicu.com/CUNIX) for instructions on how to access it. No submission is required for this problem.

Problem 2

Write a program to print out the value of $x$ and log $x$ where $x$ ranges from 1 to 10 in steps of 0.5.

Problem 3

The cosmological lookback time $t_L$ is the time difference between the current age of the universe and the age when a photon from a distance object was emitted. The lookback time is given by equation (30) (along with the definitions in equations 3 and 14) of the paper at [arxiv.org/pdf/astro-ph/9905116v4](http://arxiv.org/pdf/astro-ph/9905116v4). For the current best-fit parameters for our universe of $\Omega_M = 0.27, \Omega_k = 0, \Omega_\Lambda = 0.73$ and $h = 0.70$, compute the lookback time for the most distant (confirmed) galaxy at redshift $z = 8.5$. To compute the integral in equation (30), approximate it as a sum with a small step in $z$. For example, you can write an integral of the form:

$$\int_{x_0}^{x_1} f(x)dx \approx \sum_{i=0}^{N} f(x_i)\Delta x$$

where $\Delta x = (x_1 - x_0)/N$ and $x_i = x_0 + i\Delta x$. How many steps $N$ do you need to get an accurate solution?

Note: When submitting solutions, please include (1) the program listing, (2) any input to the program, and (3) all program output. The output alone is not a valid solution. You may consult other students, but please write and run your program yourself. Also, if you do work with others, please indicate who you worked with. Solutions may be emailed to gb2141@columbia.edu (preferably as one email with attachments clearly marked); please be sure to include the course number [W4260] and problem set number in the subject. Thanks.