Your name: ____________________

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AST 10: Homework 10b

1. I presented a table in class listing different values for the Hubble constant at present, H_0, and the age of the Universe in billions of years. But, I engaged in a little standard astronomical hanky-panky with the units. In the numbers presented there, the age of the Universe, T, is not simply $1/H_0$. For example, the first line had Hubble's measured value $H_0 = 500$ corresponding to an age of $T = 2$ billion years. But $2 \neq 1/500$. You need to divide H_0 by something to get the units to match up so that $T = 1/H_0$. What division factor do you need?

2. Using the "correct" (i.e., consistent) units, here's a table of recent measurements of H_0. What are the biggest and smallest ages of the Universe that you get from these values?

H_0 and T (billions of years)

Year	Mission/Instrument	H_0	$T = 1/H_0$
2013	ESA Planck satellite	0.0678	
2012	NASA Explorer 80	0.0693	
2008	Chandra	0.0776	
2005	Hubble	0.0720	

3. One of the lines in the Hydrogen spectrum has a wavelength of 4.861×10^{-7} m. The line is observed in the spectrum of a distant galaxy at 4.923×10^{-7} m.
   a) What is the change in wavelength, $\Delta\lambda$?
   b) What is $\Delta\lambda/\lambda$?
   c) Using $\Delta\lambda/\lambda = v/c$ (and the value $c = 3 \times 10^5$ km/sec) what is the velocity, v, of the galaxy?
   d) Is the galaxy moving away from us or toward us?

4. Let's use Hubble's Law, $V = H_0 R$, as a distance-measuring tool to estimate how far away the galaxy in the previous question is.
   a) Using a value of $H = .075$ (in appropriate units – see below), and V from the answer to the previous question, what is R?
   b) The answer in (a) is in kpc (kilo parsecs), where the pc is a unit astronomers like to use. 1 pc$=3.26$ ly. Convert your answer to ly and express it in millions of light years.

5. The left-hand side of the red-shift equation, $\Delta\lambda/\lambda = v/c$, is often denoted by astronomers by the letter z.
   a) Objects with $z > 1$ are known. What does that say about the velocity of their recession?
   b) It is a basic pillar of the theory of relativity that no physical object can travel faster than c, the speed of light. Is that consistent with part (a)? If not, how do you think this inconsistency might be resolved? (Hint: remember the picture with people riding motorcycles through space as opposed to merely sitting in chairs.)

6. We've seen that if the "acceleration" of the scale factor, $a(t)$, is negative everywhere, then the graph of $a(t)$ must be concave down and, therefore, $a(t) = 0$ at some point in the past. If you don't require the acceleration to be negative, sketch a possible graph for $a(t)$ that does not have $a(t) = 0$ anywhere.