Physics 214 - Problem Set 4

Due in Class on Wednesday, April 4, 2007 (Time allowed=two weeks)

Numbers like the mass of the Sun, distance of the Earth, number of meters in a light year, etc, can be found in the text or on the Internet.

To receive full credit you must show all working.

(1) In lecture 19 we discussed codons and how the four nucleotides are ordered in sets of three to encode the synthesis of the 20 amino acids used in proteins. Given the four nucleotides, sets of three encode $4^3 = 64$ possible amino acids (in fact only 20 are required, so there is some duplication, with different codons coding the same amino acids). Imagine on another planet life has developed a genetic code that differs from terrestrial life's in the following way: In order to guard against mutations, the codons used are in the form of *palindromes*. (Palindromes read the same way backwards and forwards. By way of example, the words *radar, mom* and *kook* are palindromes.) On this planet there are six bases rather than four, and 44 amino acids to be encoded for.
(a) Suppose the codon has a length of one or two, how many possible combinations are there?
(b) Suppose the codon has length three or four, how many possible combinations are there now?
(c) If we need to encode all of the amino acids on this planet what is the minimum length for codons on this planet?
(HINT: there is no simple formula for this problem, but there is a pattern that you should be able to see from looking at the combinations for the short codons, which can then be used to deduce the result for the longer ones.)

(2) Impact events have played a significant role in the evolution of life on Earth. The global catastrophes that result are due in part to the exceptionally large amount of energy present in colliding bollides (asteroids). The kinetic energy of the incoming bollide will be given by $\frac{1}{2}mv^2$ where m is the mass and v is the velocity. In this question we will assume that all the kinetic energy in the bollide on impact is used to heat up all the water on the surface of the Earth (which is quite inaccurate but we'll work on this basis).
(a) In lecture 19 we looked at possible alternatives to water as a solvent and compared the different heat capacities. The heat capacity, C, gives the number Joules, E_c, required to heat a mass of material, m kg, by ΔT Kelvins. Write down the formula giving E_c as a function of $C, m, \Delta T$. If we need to increase the temperature of the liquid from a temperature, T, to boiling point then $\Delta T = T_b - T$ where T_b is the boiling point.
(b) Once a liquid reaches boiling point large amounts of energy are still required to produce vapourization (this is the heat of vapourization, L_v, values of which, along with values for C, are given on slide 13 of lecture 19). Since the latent heat of vapourization describes the amount of energy, E_v, required to vapourize a mass m of liquid at boiling point, write down the corresponding equation for E_v in terms of L_v and m.
(c) Write down and simplify the formula for the total energy required to heat a mass of liquid from a temperature T to complete vapourization.
(d) You can now equate this formula to that for the kinetic energy of an incoming bollide. Note that you should be careful not to confuse the mass of the bollide and the mass of the water. Rearrange the formula to give the mass of the bollide as a function of all the other variables.
(e) Calculate the mass of the bollide travelling at 40 km s^{-1} that vapourizes the Earth's surface water, assuming the mass of this water is 10^{21} kg and that the starting temperature is 4 C.
(f) If the average density of asteroids is approximately 3000 kg m^{-3} what would be the approximate diameter of the bollide? (Research) How does this compare to the size of the bollide that caused the Cretaceous extinction event?