Lab 5: Carbon and Uranium Dating

In this lab you will do several problems that will give you more practice dealing with exponential equations and using logarithms to solve them. Do the problems neatly in pencil. Clearly lay out your work using proper notation.

If you need more space, attach additional paper (if you do so, make sure you number your problems). If a problem involves algebraic work, circle/highlight/box your final answer. **I have bolded all sub-questions that you need to answer so you don't miss anything.** This lab is worth 40 points.

If a quantity decreases by the same percentage each year, it is said to be decaying exponentially. The function $\boldsymbol{A(t) = A_0 e^{kt}}$ models such a process, where:
$\boldsymbol{A_0}$ is the initial value of the quantity (note that the subscript is simply part of this variable's name)
$\boldsymbol{t}$ is the time in years
$\boldsymbol{k}$ is a **negative** constant that describes the rate of decay

A radioactive element decays (transforms) into its stable (nonradioactive) counterpart exponentially. All living organisms contain 2 types of carbon, the radioactive carbon-14 and the stable carbon-12. While the organism is alive, it maintains a consistent ratio between the two types. Once it dies, though, the amount of carbon-12 remains the same, but the amount of carbon-14 starts decreasing through radioactive decay. Since the rate of decay of carbon-14 is known, an examination of the ratio between the two types of carbon can tell a scientist how old a once-living object is (like a fossil or a piece of cloth or paper).

Exponential decay is often described in terms of **half-life**, the amount of time it takes for the quantity to lose 50% of its value. The half-life of carbon-14 is about 5600 years. Thus, after 5600 years, a piece of cotton cloth will contain half the carbon-14 that was in the original cotton plant. After another 5600 years (11,200 total), the cloth will contain half of that amount, or a quarter of the original quantity, and so on.

Task 1 (5 pts): Use the half-life of carbon-14 given on the previous page to **find an exponential equation of the form $A(t) = A_0 e^{kt}$** that describes the amount of carbon-14 remaining after t years, if the sample originally contained 100 grams. **You should find an exact value for k** (it will involve the natural log) **as well as a decimal approximation** (write it in scientific notation, with as many digits as your calculator provides).

Since you'll be using this value in future problems, I suggest that you store it in your calculator with STO, ALPHA, and then the "(" key if you want to store it under the letter K.

Task 2 (10 pts): Use your equation from Task 1 (with either exact or approximate k) to **determine the ages** of the following objects, to the nearest year:

a) A fossilized leaf that contains 75% of its original amount of carbon-14.

b) The bones of a prehistoric man, which contain about 10% of their original amount of carbon-14.

Task 3 (5 pts): Use the equation from Task 1 again to answer the following question. If a scientist today is trying to date something to the time of Tutankhamen (King Tut) in ancient Egypt, about 1330 BC, **what percentage of its original amount of carbon-14 should he expect the object to have**, to the nearest percent?

Uranium-238 is another naturally occurring radioactive isotope. It can be used to date objects over a much longer time period than carbon, and they don't have to have once been living (however, it's not as accurate as carbon over "short" time periods like those you examined above—you'll determine why below). It decays into lead-206 very slowly, with a half-life of 4.468 billion years.

Task 4 (10 pts): Small pieces of zircon from the Jack Hills of Western Australia have been found to contain 53.45% of their original amount of uranium-238. **Approximately how old are they, to the nearest million years? What does that imply about the Earth's age (answer with a sentence)?**

Note: You'll need to start by computing *k* for uranium-238.

Task 5 (10 pts): Suppose that scientists can determine the percentage the original amount of uranium-238 remaining in an object to an accuracy of one thousandth of a percent. **Why would this imply that uranium dating is not useful for an object that is "only" 20,000 years old (answer with a sentence)?**

Note: You'll need to **start by determining how much of the original uranium-238 remains in an object after 20,000 years.**