Homework #7: Exponential Curves, Radioactive Decay, and Half-Lives

1. The rubidium nuclide ${}_{37}Rb^{87}$ is used to determine the age of rocks and fossils. Consider a hypothetical rock. When this rock formed, there was Rb in the rock, but no strontium. A chemical analysis of the rock today finds it to have a number ratio of ${}_{38}Sr^{87}$ to ${}_{37}Rb^{87}$= .018.

a) Explain where the strontium came from.

b) Will this ratio remain constant? Why or why not?

c) Estimate the age of this rock.

2. The Shroud of Turin was long believed by some to be the burial cloth laid over the body of Jesus of Nazareth after his crucifiction. In 1989, scientists at three different institutions[1] took tiny samples of the cloth, cleaned it to remove impurities, and measured an average ratio of C^{14}/C^{12} to be 0.92 ± 0.04 of the ratio one would find in a living organism. To 95% confidence, when was the Shroud of Turin made?

3. Data show that when Uranium atoms are formed in the explosions of massive stars, the number ratio of U^{235} to U^{238} falls in the range of 1.16 and 1.34. (i.e. for every 100 U^{238} atoms there are 116 to 134 U^{235} atoms.) However, when we examine the uranium in the Earth today, we find that ratio to be 0.00723 (i.e. for every 100,000 U^{238} atoms there are 723 U^{235} atoms.). Use these numbers to estimate how long ago the star exploded, out of whose ashes the solar system formed.

4. An old-fashioned silver quarter was irradiated with slow neutrons. These neutrons are captured by the silver nuclei in the quarter. The quarter was then placed close to a Geiger counter and the following count rates (in counts/sec) were recorded as a function of time. The data points are shown in Table 1. This one you will need to plot the data and use Graphical Analysis or Excel to figure out what is going on. Most people get this wrong, so think carefully.

a) Using the table of nuclides that has a link on the class web page, determine the reactions that could happen if the silver nuclei in the quarter absorbed a neutron. Are the products of the neutron capture stable?

b) Determine the half-life of the decay of the silver nuclides produced when the silver in the quarter absorbed a neutron. Use the data to determine your answer. After you have your answers, look up the half-lives on the table of nuclides on the web and compare.

[1] See "Radiocarbon Dating of the Shroud of Turin", *Nature*, Vol. 337, No. 6208, pp. 611-615, 16th February, 1989.

Time (sec)	Activity (Cnts/sec)	Time (sec)	Activity (Cnts/sec)
0	2135	280	260
20	1476	300	220
40	1120	320	205
60	939	340	199
80	780	360	179
100	660	380	157
120	595	400	142
140	529	420	135
160	480	440	110
180	420	460	109
200	389	480	96
220	344	500	84
240	310	560	65
260	290	600	52

Table 1: Measured activity of a silver quarter as a function of elapsed time after it has been irradiated by slow neutrons. The table wraps around to the top of the third column after the bottom of the first column.

5. Listed in Table 2 are data Prof. Rex Adelberger and I collected on the population of the world throughout recorded history. The data come from a number of different sources. As you may guess, some of the early data are not from carefully measured and analyzed census figures, but are estimates made by folks who are interested in demography. The most recent points are from the U.S. Census Bureau.

a) Find an empirical formula that describes these data.

b) Does the formula make physical sense to you? Why?

6. Ford, P3.4 (p. 68). Note that Ford suggests plotting the data on semi-log paper. The modern equivalent is to make a calculated column in Graphical Analysis where the new column consists of the logrithm of the column you entered manually. You might also want to try a log-log plot if the semi-log curve doesn't look like a straight line. Also, use 2009 instead of 2000, and look up the "Large Hadron Collider" on the internet. How does it compare with your predictions? Remember to consider diameter, energy *and* cost.

Due: Friday, October 16, 2:30 pm

Year	World Population Billions of people	Year	World Population Billions of people	Year	World Population Billions of people
1650	0.507	1850	1.21	1980	4.432
1900	1.59	1750	0.74	1960	3.008
1800	0.943	1850	1.262	1950	2.52
1980	4.453	1985	4.826	1950	2.4
1985	4.85	1987	5.024	1970	3.632
1988	5.112	1989	5.202	1920	1.834
1990	5.292	1991	5.385	1960	3.037
1993	5.572	1992	5.48	1650	0.425
1949	2.378	1939	2.195	1900	1.61
1930	2.008	2003	6.314	2006	6.54
1950	2.486	1970	3.696	2009	6.79

Table 2: World population by year in billions of people. Note that the lines are not sorted.