Physics 309
Alpha Decay

1. Identify the unknown isotope in the following decays.
   (a) $^{230}\mathrm{Th} \to \mathrm{X} + \alpha$
   (b) $^{35}\mathrm{S} \to \mathrm{X} + \mathrm{e}^- + \overline{\nu}$
   (c) $\mathrm{X} \to {}^{40}\mathrm{K} + \mathrm{e}^+ + \nu$
   (d) $^{24}\mathrm{Na} \to {}^{24}\mathrm{Mg} + \mathrm{e}^- + \overline{\nu} \to \mathrm{X} + \gamma$
   (e) $\mathrm{X} \to {}^{224}\mathrm{Ra} + \alpha$

2. We are given the atomic masses below. What is the energy released during the alpha decay of ^{238}U? Can ^{238}U decay by emitting a proton?

^{238}U	238.05079 u	^{4}He	4.00260 u
^{234}Th	234.04363 u	^{1}H	1.00783 u
^{237}Pa	237.05121 u		

3. Pick apart an alpha particle (^{4}He) by removing in sequence a proton, a neutron, and another proton. Calculate the work required for each step, the total binding energy of the alpha particle and the binding energy per nucleon. Some needed masses are listed below.

^{4}He	4.00260 u	^{1}H	1.00783 u
^{2}H	2.01410 u	^{3}H	3.01605 u
n	1.00867 u		

4. The final state of many stars after they burn up their nuclear fuel is to collapse under the force of their own gravity into a neutron star. The force of gravity is large enough to fuse electrons and protons into neutrons and the collapsed star becomes a ball of neutrons with the density of the nucleus.
   (a) What would be the radius of the Sun if it collapsed into a neutron star?
   (b) The Sun's rotational period is 27 days. What will be its rotation period after it becomes a neutron star?

5. A method to calculate the transmission coefficient for quantum tunneling for a potential energy function of arbitrary shape is called the WKB approximation. It is

$$T_{WKB} = \exp\left[-2\int_{x_1}^{x_2} \sqrt{\frac{2m(V(x) - E}{\hbar^2}}dx\right]$$

where x_1 and x_2 are the points where the total energy E is equal to the potential energy $V(x)$. Consider the decay $^{238}\mathrm{U} \to {}^{4}\mathrm{He} + {}^{234}\mathrm{Th}$ ($E_\alpha = 4.2$ MeV). For the potential shown in the figure below let $x_1 = 1.2A^{1/3}$ fm where A is the mass number of the residual ^{234}Th nucleus. The value of x_2 is the point where the Coulomb potential between the ^{4}He and ^{234}Th equals the ^{4}He energy of 4.2 MeV. What is the transmission coefficient for ^{4}He nuclei of energy $E_\alpha = 4.2$ MeV to tunnel through the barrier for a potential energy shown in the figure?