University of Wisconsin-Madison
Engineering Physics Department
Spring 2009 Qualifying Exams

Modern Physics

You must solve 4 out of the 6 problems.
Start each problem on a new page.

SHOW ALL YOUR WORK.
WRITE ONLY ON THE FRONT PAGES OF THE WORKSHEETS, NOT ON THE EXAM PAGES

Grading is based on both the final answer and work done in reaching your answer. All problems receive an equal number of points.

Clearly indicate which problems you want graded. If you do not indicate which problems are to be graded, the first four solutions you provide will be graded.

1. _____
2. _____
3. _____
4. _____
5. _____
6. _____

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Problem 1.

Using the (α, n) reaction on a target nucleus of ^{13}C it is desired to study the first excited state of ^{16}O, which is at an energy level of 6.049 MeV.

a) (5 points) What is the minimum energy of incident α's which will populate the excited state?

b) (5 points) If it is desired to detect the neutrons at 90° to the incident beam, what is the minimum α energy that can result in the excited state being populated?

Some data.

Masses in amu

^{13}C	13.003355
^{4}He	4.002603
^{16}O	15.994915
^{1}n	1.008665

931.502 MeV/amu

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Problem 2.

(10 points) It is desired to determine the age of a wood timber used to construct an ancient shelter. A sample of the wood is analyzed for its ^{14}C content and gives 2.1 decays per minute. Another sample of the same size from a recently cut tree of the same type of wood gives 5.3 decays per minute. What is the age of the sample? The half-life of ^{14}C is 5730 years. Assume the concentrations of radioisotopes in air were the same at the times the ancient wood timber and the current tree were formed.

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Problem 3.

a) (2 points) What is a formula for the binding energy of a nucleus?

b) (3 points) Sketch the binding energy per nucleon vs. number of nucleons. Explain the general features of the dependence of binding energy per nucleon on the nuclear mass. How are nuclear fission and fusion energetically enabled by these features?

c) (5 points) Describe as completely as you can each term in the semi-empirical mass formula.

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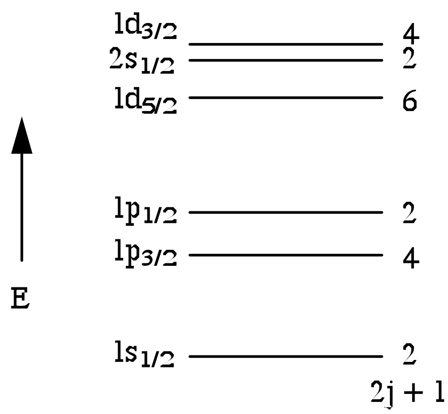
Problem 4.

a) (3 points) Using the nuclear shell model (shown below), give the total angular momentum and parity of the ground states of ^{15}O, ^{16}O, and ^{17}O. (note: $Z_O = 8$)



b) (4 points) Assume a neutron (spin = 1/2) with orbital angular momentum $l = 1$ is absorbed by each of the nuclei in (a). What are the possible values of the total angular momentum I* for each of the resulting compound nuclei?

c) (3 points) What is the parity of the compound nucleus for each case?

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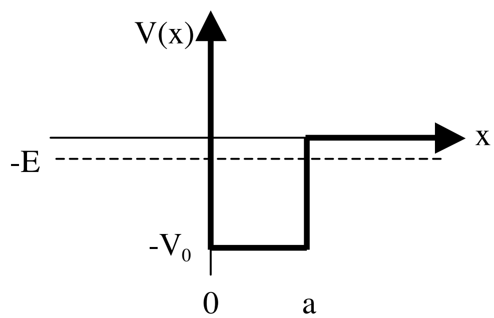
Problem 5.

A particle with total energy –E is bound in the one-dimensional potential well:

$$V(x) = \begin{cases} +\infty & x < 0 \\ -V_0 \quad \text{for:} & 0 < x \leq a \\ 0 & x > a \end{cases}$$



a) (5 points) Derive a relationship for the allowed values of the energy E.

b) (5 points) What is the minimal potential well depth required to have the particle be just barely bound?

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Problem 6.

Muons appear in the upper atmosphere as secondary radiation from cosmic rays. They decay with a mean lifetime $\approx 2 \times 10^{-6}$ sec.

a) (5 points) Assuming a muon is created with a speed of 0.998c, at what maximum height above the ground can the muon be created and still be detected at the earth's surface if we assume all of the muons decay in exactly a single mean lifetime? How does this compare to the distance the muon travels in its own timeframe? Explain any differences between the two.

b) (5 points) If the rest energy of the muon is 105.7 MeV, what will observers on earth measure for the total energy of the cosmic ray-produced muon?