University of Wisconsin-Madison
Engineering Physics Department
Spring 2007 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. ______

Student No._________________

Engineering Physics Department
Spring 2007 Qualifying Exams

Modern Physics

Problem 1. Pair production in the Coulomb field of an electron is called triplet production. The minimum photon energy required for the reaction can be determined from the following simple model. A photon of energy E_γ strikes an electron at rest and undergoes pair production:

$$\gamma + e^- \longrightarrow e^- + e^+ + e^- .$$

The original electron and the created electron and positron move off with identical momenta in the direction of the initial photon.

a). (8pts) What is the kinetic energy of each of the final state particles?

b). (2pts) What is the minimum initial energy of the photon?

Student No.________________

Engineering Physics Department
Spring 2007 Qualifying Exams

Modern Physics

Problem 2.

a).(4pts) Sketch the Zeeman Effect using an energy level diagram that shows the expected splitting of a 2p and 1s state in the presence of an external magnetic field. **<u>Ignore spin.</u>**

b). (2pts) What are the selection rules for transitions governing the l and m_l quantum numbers?

c). (2pts) Indicate all allowed transitions from each of the m_l states to the 2p level to the 1s level.

d). (2pts) What energies are emitted?

Student No.________________

Engineering Physics Department
Spring 2007 Qualifying Exams

Modern Physics

Problem 3.

Suppose the vacuum vessel of a fusion device is made of pure ${}^{56}_{26}Fe$ and the vessel is exposed to a high-energy neutron flux of $\phi_0 = 1.0 \times 10^{12}$ neutrons/cm^2-s. The following high-energy reaction occurs as the neutrons interact with the iron: ${}^{56}_{26}Fe(n,p){}^{??}_{??}Mn$. The manganese in turn decays by β^- emission with a half-life of $t_{1/2} = 2.6$ hours.

(a). (1pts) Determine the specific resultant product nuclides from the (n,p) and β^- decay reactions.

(b). (2pts) Determine the rate equations for the nuclides involved.

(c). (5pts) Solve for the time-dependence of the iron and manganese isotopes.

(d). (2pts) Find the limit of the nuclide concentrations as $t \to \infty$.

Student No.________________

Engineering Physics Department
Spring 2007 Qualifying Exams

Modern Physics

Problem 4.

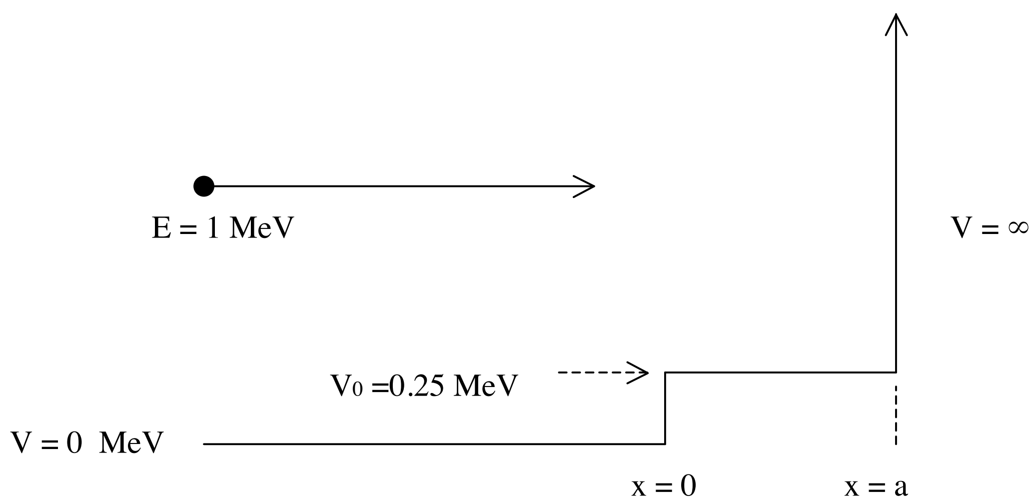
A beam of nucleons coming from minus infinity with kinetic energy 1 MeV is incident on an infinite barrier that is preceded by a potential step of 0.25 MeV and width a as depicted in the figure below. By treating the nucleon as a plane wave:

a). (2pt) determine the appropriate boundary and interface conditions for the problem.

b). (3pt) determine the general solution for each region and indicate the incident and reflected waves.

c). (3pt) determine the ratio of the transmitted to incident wave amplitudes at $x = 0$.

d). (1pt) determine the total reflection coefficient .



Student No.________________

Engineering Physics Department
Spring 2007 Qualifying Exams

Modern Physics

Problem 5.

a). (5pts) Discuss the fission of ${}^{235}_{92}U$ and ${}^{238}_{92}U$ in terms of the liquid drop model and the fission barrier. Include in your discussion the concepts of compound nucleus formation and activation energy. Why does ${}^{235}_{92}U$ fission by bombardment with thermal neutrons, whereas ${}^{238}_{92}U$ does not?

b). (5pts) A 1.2 MeV neutron is captured by ${}^{240}_{94}Pu$. Will a fission event take place? Justify your answer by providing a supporting calculation. The activation energy for ${}^{240}_{94}Pu$ is 6.1 MeV. (Note: 1 amu = 931.48 MeV.)

Mass	Mass
M(${}^{1}_{0}n$) = 1.00866501 amu	M(${}^{240}_{94}Pu$) = 240.053808 amu
M(${}^{239}_{94}Pu$) = 239.052158 amu	M(${}^{241}_{94}Pu$) = 241.056846 amu

Student No._________________

Engineering Physics Department
Spring 2007 Qualifying Exams

Modern Physics

Problem 6.

${}^{20}_{11}Na({}^{+}2)$ decays to an excited state of ${}^{20}_{10}Ne$ through the emission of positrons of maximum kinetic energy 5.55 MeV. The excited state of ${}^{20}_{10}Ne$ decays by α emission to the ground state of ${}^{16}_{8}O$.

(a). (2pt) Sketch the energy level diagram (scheme) for this series of decays.

(b). (6pt) Compute the energy of the emitted α.

(c). (2pt) What is the degree of forbiddenness if the positrons decay to the ${}^{+}2$ excited state of ${}^{20}_{10}Ne$?

Mass	Mass
M(${}^{4}_{2}He$) = 4.002603 amu	M(${}^{20}_{11}Na$) = 20.007344 amu
M(${}^{20}_{10}Ne$) = 19.992436 amu	M(${}^{16}_{8}O$) = 15.004915 amu