Modern Physics

Introduction to Modern Physics 15-030-241
Modern Physics for Engineers 15-030-276

Final Examination

December 7, 1992

Exam No. ______________________________

Name: ______________________________

S.S. No. ______________________________

Do all work in this exam booklet. Use the backs of the sheets if necessary. Two 8.5" x 11" sheet of notes are permissible. Please use your calculator. If integrals are needed, there is a CRC handbook available at the front of the class for your use. If you cannot find the integral in that, leave it. On some questions, there are multiple parts. If you need the answer from the previous part to do a calculation, but were unable to obtain it, assume some reasonable value (informing me what you are doing) and continue.

Useful Constants: $c = 3 \times 10^{8}$ m/sec
$h = 4.14 \times 10^{-15}$ eV sec
$= 6.63 \times 10^{-34}$ joule sec

Mass Table for problem II:

$^{1}n_{0}$	1.008665
$^{1}H_{1}$	1.007825
$^{2}H_{1}$	2.014102
$^{3}H_{1}$	3.016049
$^{3}He_{2}$	3.016029
$^{4}He_{2}$	4.002603
$^{5}Li_{3}$	5.012539

Section I.

True/False Questions -- 2 points for correct answers, -1 point for wrong answers, 0 for unanswered questions. 30 points total.

1. The fact that the electron has spin of 1/2 plays an important role in atomic physics. T F

2. Electrons are "elementary" particles. That is, we have seen no evidence of smaller particles inside them. T F

3. Protons are "elementary" particles. That is, we have seen no evidence of smaller particles inside them. T F

4. The best nuclear reactor could be made by the using iron nuclei as the fuel because iron is the most stable of the nuclei. T F

5. Invoking only general relativity and what we know from atomic, nuclear, and high energy physics, we can get a complete model of the universe (the "Big Bang Model") that requires no additional input. T F

6. The twin paradox is just a construct to simplify the equations of special relativity. There are no testable consequences of "time slowing down for moving objects". T F

7. For all spherically symmetric potentials (three dimensional potentials where the potential energy depends only on the distance between the two particles and not upon the angle), the energy of the levels depends only on constants and "n", the principle quantum number, and are independent of the angular momentum quantum number. T F

8. Black body radiation can be explained completely by classical physics which treats light as waves. T F

9. X-Ray defraction is a good example of the wave like nature of light. T F

10. The uncertainty principle illustrates only that we have not been able to develop good enough experiments to measure position and momentum accurately. T F

Section I Continued.

11. Since free neutrons decay to protons and electrons, all weak interaction decays of nuclei will increase the proton number of the nuclei. T F

12. The sun is a young star and is in the midst of its hydrogen burning. T F

13. The Fermi level in insulators is at the band gap. T F

14. There is one and only one type of neutrino. T F

15. Gamma rays are really just energetic photons. T F

Short Answer Problems: Each are worth 5 points

Problems 1 through 3 refer to the following potential:

1. Draw, approximately, the ground state for such a potential.

2. Draw, approximately, the first excited state for such a potential.

3. What system is similar to the above potential and leads to a bound state similar to the one drawn in 1 and an antibound state similar to the one drawn in 2.

4. A neutral carbon atom has six electrons. What are the quantum numbers of each of these electrons.

5. What is the force which holds the protons and neutrons together in the nucleus? In quantum mechanics, forces are represented by particle exchange. What particle(s) is exchanged in the strong force.

6. When you first approximate a solid, you use the model that the conduction electrons are free particles in a box the size of the solid. This results in such a model are that the available energy levels are very closely spaced and very dense at all energies. However, experimentally, we see that there are some energies where there are no energy levels. What causes these "gaps" in energy levels? At what energy do they occur?

7. What are "beta particles"?

8. How much energy is released (in joules) when one mole of $^{232}U_{92}$ nuclei (mass = 232.037130 amu) decays to $^{228}Th_{90}$ (mass = 228.028715 amu) + $^{4}He_{2}$ (mass = 4.002603 amu)?

9. Describe a test of general relativity.

10. Deformed nuclei can have rotational levels superimposed on vibrational levels just like HBr molecules. If the analogy with HBr is correct, would you expect that the size of the steps in the rotational levels to be greater, less than or about the same as the steps in the vibrational levels?

11. There are three major direct consequences of the Big Bang theory of the evolution of the universe. Describe one of them.

12. A meson called the K^+ decays to a $\pi^o + e^+ + \nu$. The K^+ consists of a u and s quarks and the π^o consists of a u and u quark. Draw this decay as a decay of quarks. Show that charge is conserved on the quark level.

Problem I. (20 points)

The wave function for the first excited state of a harmonic oscillator potential is:

$$\psi_1 = A_1 \; x \; \exp\,(-\alpha^2 \; x^2/2).$$

A. (10 points) Find the values of E and α that allow this function to satisfy Schrodinger's equation

B. (5 points) What equation would you use to determine A_1? Write the equation <u>but do not solve it</u>.

C. (5 points) Write the equation that you would use to determine the average of the square of the momentum of the particle in the harmonic potential well. <u>Again do not solve the equation; no credit will be given for working the solution.</u>

Problem II. (20 points)

A. (5 points) In a fusion reactor, one possible combination of fuels is equal amounts of deutrium and tritium. the primary reaction would be

$$^{2}H_{1} + {}^{3}H_{1} \rightarrow {}^{4}He_{2} + ???$$

What must the unknown particle be?

B. (5 points) How much energy is release per mole of reactants fused? (See mass tables at front of exam.)

C. (10 points) If both the tritium and the deutrium nuclei are essentially at rest when the reaction occurs, what is the energy and momentum of the helium nucleus?