Final - Modern Physics for Engineers

December 8, 1997

Name:______________________________

S.S. No.:____________________________

Do all work in this exam booklet. Use the backs of the sheets if necessary. You may use the equation sheet that has been given to you. No calculators or other aids are allowed. Leave all answers in a form that can be easily computed with a calculator if you had one. If the problem requires an integration, leave the answer as an integral. It is not necessary to evaluate the integral.

Good luck.

Short Answers - 5 points each

1. State the Pauli exclusion principle. If you can use it to predict how many nucleons (protons and neutrons) will fill the 1s shell of the nucleus, then do so. If you cannot, explain why it is not applicable.

2. What assumption did Bohr make to get the correct energy levels for the hydrogen atom? Is this assumption correct?

3. I measure the distance from earth to the closest star to be 3 light years. What is the distance that astronaut flying from earth to that star at a velocity of .99 c measures? Who is right?

Short Answers (continued) - 5 points each

4. Which type of semi-conductor, an n-doped type or a p-doped type has more electrons in the conduction band? Both have about the same resistivity. In the material that has the fewest electrons in the conduction band, what conducts the electricity?

5. Sodium has 11 electrons. Give the the structure of this atom either in spectroscopic notation or as a list of quatum numbers for the electrons.

6. For a particle in a 3-dimensional box, what is the degeneracy of the second level? (Hint: one of the states in the second level has the quantum numbers $(n_x,\ n_y,\ n_z) = (2,\ 1,\ 1)$.)

Short Answers (continued) - 5 points each

7. How do astronomers measure the velocity of a star that is hundreds of light years away?

8. Why doesn't helium form a He_2 molecule?

9. $^{227}Ac_{89}$ decays via either alpha decay or beta decay. Write down the complete reaction including all products for both of these processes. Including the correct Z and A numbers for all of the products. (The following names may be helpful: At_{85}, Rn_{86}, Fr_{87}, Ra_{88}, Ac_{89}, Th_{90}, Pa_{91}, U_{92}, Np_{93}.) My notation is $^{A}X_{Z}$.

Short Answers (continued) - 5 points each

10. A Ξ^- is produced by the following reaction: $p + K^- \rightarrow \Xi^0 + \overline{K^0}$. The quark content of the particles is as follows: $p = uud$, $\Xi^0 = uss$, $K^- = \bar{u}s$, $\overline{K^0} = \bar{s}d$. Draw the quark line representation of this reaction.

11. If the Ξ^0 has a lifetime of 1.6×10^{-10} seconds, but is moving in the laboratory at a velocity of .9999 c, how far would you expect it to travel before it decayed?

12. Cheseaux argued in 1744 that if the density of galaxies is uniform throughout space and that if the average star gave off an average intensity that was invariant throughout the universe, then the night sky should be very bright. Explain why either or both of his assumptions are wrong or if they are not, then what another effect makes the night sky black.

Problem 1

The ground state wave function for the potential

$$V(x) = \begin{cases} \infty & \text{if } |x| \geq a; \text{ and} \\ 0 & \text{if } |x| < a. \end{cases}$$

is

$$\psi(x) = A \cos \frac{\pi}{2a} x.$$

In the questions that follow, leave any answer that requires an integration as an integral, but pug all the necessary functions into that integral and give the proper limits of that integral.

Part 1 - (**5 points**) How would you determine A?

Part 2 - (**5 points**) What is the probability of finding the particle between $a/2$ and a?

Problem 1 - Continued

Part 3 - (**5 points**) What is the average kinetic energy of the particle?

Part 4 - (**5 points**) Sketch approximately the wave function for the third excited state for this potential.

Problem 2

The following decay can occur: $D^- \to \tau^- + \bar{\nu}_\tau$. The the quark content of the D^- meson is $\bar{c}d$ and it has a mass of 1869 MeV/c^2. The τ^- is a lepton and has a mass of 1777 MeV/c^2. Assume that the neutrino has zero mass.

Part 1 - (**4 points**) In terms of quarks, draw the diagram that corresponds to this decay.

Part 2 - (**8 points**) Write the equations that you would need to solve to determine the energy of the neutrino in the D^-'s rest frame.

Part 3 - (**8 points**) If the original D^- was moving with a velocity of .9999 c in the lab before the decay, write the equations necessary to determine the maximum energy the neutrino could have in the lab after the decay.

Problem 3

Part 1 - (**10 points**) Red giants are stars that have a cool surface temperature but a very large radius (compared to main sequence stars). These stars are much too far away to measure their radius directly. How do we know that they are so large? (Or, in other words, what measurements can we make to infer their radius assuming that we know how far away they are?)

Part 2 - (**10 points**) Helium burning occurs during the red giant phase. One of the reactions during helium burning is

$$^{12}C_6 +^4 He_2 \rightarrow^{16} O_8 + \text{energy}.$$

Given the following masses and that 1 amu = 931.5 MeV/c^2, how much energy is released per reaction?

Mass of $^{12}C_6$ = 12.000000 amu

Mass of $^{16}O_8$ = 15.994915 amu

Mass of $^{4}He_2$ = 4.002603 amu