Physics 202H - Introductory Quantum Physics I **Homework #01**

Fall 2004 Due 5:01 PM, Monday 2004/09/20

[70 points total]

"Journal" questions. Briefly share your thoughts on the following questions:
– What are your goals for the course? What are your expectations for the course?
– Any comments about this week's activities? Course content? Assignment? Lab?

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1. Electronic communications:
   (a) Send me (jbeda@trentu.ca) an e-mail message from your trentu.ca account, with a subject of "202H–HW–01" [5]
   (b) Sign onto WebCT and post a message in the discussion forum "General social 'discussions". [5]
   (c) Put your name and email address and phone number inside your texts and on your calculator and anything else you might misplace - it will not prevent theft, but it will allow anyone who finds your stuff to have a chance of returning it. [0]

2. A relativistic car:
   (a) How fast must a car of length L be traveling in order to fit into a garage of length $L/2$, ie. in the garage rest frame at what speed is the car's length equal to the proper length of the garage? [5]
   (b) If a car of length L is traveling at speed $c/2$, how long does it take for the car to travel past an observer, in the observer's rest frame? How long does it take for the car to travel past an observer in the car's rest frame? [5]

3. (From problem "Simple Nature", Crowell, 1-9, pg 39) A free neutron (as opposed to a neutron bound into an atomic nucleus) is unstable, and decays radioactively into a proton, an electron, and a particle called a neutrino. (This process can also occur for a neutron in a nucleus, but then other forms of mass-energy are involved as well.) The masses are as follows:

neutron	$m_n = 1.67495 \times 10^{-27}$ kg
proton	$m_p = 1.67265 \times 10^{-27}$ kg
electron	$m_e = 0.00091 \times 10^{-27}$ kg
neutrino	$m_\nu \approx 0$ kg, negligible mass

   (a) Find the energy released in the decay of a free neutron. [5]
   (b) We might imagine that a proton could decay into a neutron, a positron, and a neutrino. Although such a process can occur within a nucleus, explain why it cannot happen to a free proton. (If it could, hydrogen would be radioactive!) [5]

4. (From problem 1-17, "Simple Nature", Crowell, pg 40) Our sun lies at a distance of 26,000 light years from the center of the galaxy, where there are some spectactular sights to see, including a supermassive black hole that is rapidly eating up the surrounding interstellar gas and dust. Rich tourist Bill Gates IV buys a spaceship, and heads for the galactic core at a speed of 99.99999% of the speed of light.
   (a) According to observers on Earth, how long does it take before he gets back? (Ignore the short time he actually spends sightseeing at the core.) [5]
   (b) In Bill's frame of reference, how much time passes? [5]
   (c) When you compare your answer to part b with the round-trip distance, do you conclude that Bill considers himself to be moving faster than the speed of light? If so, how do you reconcile this with relativity? If not, then resolve the apparent paradox. [5]

5. (From problem A-13, Eisberg & Resnick, pg A-19)
   (a) Show that when $v/c < 1/10$, then [15]
      i. K/m_0c^2 is less than about 1/200, and
      ii. the classical expressions for kinetic energy, $K_c = m_0v^2/2$, may be used with an error of less than 1%, and
      iii. the classical expressions for momentum, $p_c = m_0v$, may be used with an error of less than 1%.
   (b) Show that when $v/c > 99/100$, then [10]
      i. $K/m_0c^2 > 6$, and
      ii. the relativistic relation $p_0 = E/c$ for the momentum of a zero rest-mass particle may be used for a particle of rest mass m_0 with an error of less than 1%.

Headstart for next week, Week 02, starting Monday 2004/09/20:
– Read Chapter 1 “Relativity” in “Simple Nature” by Crowell
– Read Appendix A “The Special Theory of Relativity” in Eisberg & Resnick
– Read Chapter 1 “Thermal Radiation and Planck’s Postulate” in Eisberg & Resnick