Physics 197 **Summer 2009** **Problem Set 7**

Show all calculations. Explain all assumptions. Answer in standard MKS units.
Explicitly substitute units into your symbolic equations to verify solution.
Express answers in 5 or fewer digits. Use scientific notation as appropriate.

Conceptual Questions: Answer in the space provided. Write legibly.

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1. When we charge an object, we either add or remove some charge from it to cause a net charge to appear. This requires that we do some amount of work. But, given enough energy, can charge be created out of the vacuum of empty space?

   ☐ a) Yes, this happens all the time
   b) No, this cannot happen without violating the principles of physics
   Explain:

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2. Consider the amount of charge contained in a single electron spread throughout infinite space. Work would be required to compress this charge to a tiny volume the size of an electron. The energy required to do this would be

   ☐ a) nearly zero
   b) equal to the energy equivalent of the electron mass
   c) nearly infinite
   Explain:

Due on or before 8/3

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3. If you were traveling through space with respect to the stars at a speed close to the speed of light, you could detect it because

[ ]
a) Your mass would increase
b) Your heart would slow down
c) You would shrink
d) All of the above
e) You could never detect speed changes by changes in your own body

Explain:

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4. Why does a group of ten fermions always have a higher total energy than a group of identical bosons?

[ ]
a) The asymmetric nature of the boson wavefunctions prevents them from occupying the same energy state.
b) The asymmetric nature of the fermion wavefunctions prevents them from occupying the same energy state.
c) There is no difference in total system energy.

Explain

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Calculation Questions: **Use** homework format. Make sure pages are in order.

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1. As mentioned in class, one of the primary pieces of evidence for the time and space distortions predicted by special relativity is the detection of cosmic ray muons on the earth's surface. Muons created at rest in the laboratory are found to have a mean lifetime of 2μs and the average height of the outer edge of earth's atmosphere is 10^3km. *Hint: Keep at least 6 decimal places in your calculations. More is better in this case.*

a) In order for a muon created in the upper atmosphere to reach the planetary surface, what relative velocity must it have? Express your answer as a fraction of *c*
b) How long does the trip take in the muon reference frame? Is this a proper time? Explain.
c) Determine the atmosphere thickness in the muon reference frame. Is this a proper length? Explain.

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2. One of the more interesting and infrequent fission decay chains involves an isotope of radium. Very rarely, radium decays into radioactive lead by the following reaction:

$$^{223}_{88}\text{Ra} \rightarrow {}^{14}_{6}\text{C} + \text{Pb}$$

a) Balance the nucleon numbers to describe lead in $^{A}_{Z}X_{N}$ notation.
b) Calculate the Quality Factor (Q) for this reaction.
c) Use conservation of energy and momentum to calculate the kinetic energy of each of the decay products.
d) If the half-life of Radium is 11.43 days, how long would it take for an initial number of 10^5 atoms to decay to 500 remaining atoms?

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3. Of great concern is the potential for a 'dirty bomb' to be detonated in a population center. These non-nuclear devices are intended to cause exposure to high levels of radiation in the form of plutonium dust that would be carried aloft by the conventional explosive blast. As this dust falls back to earth, creatures will inhale it and it will cover exposed surfaces. Plutonium is ultimately absorbed into the bones and there the ^{239}Pu decays by emitting an alpha particle according to the relation $^{239}\text{Pu} \rightarrow {}^{235}\text{U} + \alpha$. Absorbed alphas destroy the bone's ability to produce new red blood cells.

a) Use the masses of the particles and conservation of energy and momentum to estimate the energy of the alpha particles. Remmeber that the uranium nucleus and the alpha particle move in opposite directions after the decay. You may not ignore the effects of the recoiling nucleus. Plutonium has a half-life of 24,360 years. Mass of Plutonium is 239.0521565 u, Mass of Uranium is 235.043 9231 u, Mass of Alpha particle is 4.0015058 u, where u is in atomic mass units.
b) If a person standing in the fallout zone absorbed 5mg of Plutonium, how many atoms would that represent?
c) How many alpha particles would be produced each second inside their body?
d) If a total dose of 5 J/kg of body mass is sufficient to cause death, how long after ingestion will it take to reach a lethal dose level in an average (80 kg) individual?

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