Arts & Science 2D06

Assignment Due: Apr 7 2020, by 5pm Name:

NB: This assignment has 6 questions. Mark values are given in brackets [ ] beside each question. *Complete solutions must be shown to obtain full marks for any of the questions.*

Assignment submission as a PDF file by email (McMaster account) is preferred; camera images by email (McMaster account) are also acceptable. For the latter, please ensure that your writing is legible in the images.

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1. [3] An atomic nucleus (containing protons and neutrons) has a size of roughly 10 fm, where 1 fm = 10^{-15} m. Find the kinetic energy in MeV of a proton with a de Broglie wavelength of 10 fm.

2. [3] Consider a hydrogen atom initially in its ground state. It then absorbs a 12.75 eV photon, and right afterward undergoes a quantum transition with $\Delta n = 2$. Calculate the wavelength of the photon emitted in this quantum jump.

3. [10] Suppose that a particle constrained to live in a one-dimensional box of length 10 fm has an energy level $E_n = 32.9$ MeV and a neighboring energy level $E_{n+1} = 51.4$ MeV.

(a) What are the values of n and n+1?

(b) Sketch an energy level diagram with levels from the ground state up to n+1, and label each level with its energy.

(c) Draw the wavefunction corresponding to E_n. When the particle is in this state, where is it most likely to be found, and where (in the box) is it never found? Explain your answer.

(d) What is the wavelength of a photon emitted in a quantum transition from the n+1 state to the n state?

(e) Figure out what kind of particle this is, from calculating its mass.

(additional page for Question 3, if needed)

4. [4] (a) An ARTSSCI 2D06 student whose mass is 60 kg, is working on her assignment at a desk in a room that is 6 meters long. Can this student be certain that she is not moving, even if to all appearances she's sitting perfectly still? If not, then estimate within what range her velocity is likely to be (you may assume that her *average* speed is zero).

(b) Find the size of the smallest one-dimensional box in which you can confine an electron, in order to be sure that the speed of the electron is always less than 5 m/s (assuming its *average* speed is zero).

5. [4] Consider a helium balloon, attached by a string to the floor inside a car. If the car is speeding up, will the balloon be leaning forward or backward – or not be leaning at all? Explain your answer with *two* different arguments.

6. [4] In our universe, black holes can be found in the endpoint state of the evolution of some stars (Stellar Black Holes), and also in the centres of galaxies (Supermassive Black Holes). Calculate the acceleration due to gravity at the Event Horizon of (a) a black hole with a mass equal to that of the sun; and (b) a 100 billion solar-mass black hole. How do your results compare with the acceleration due to gravity at the surface of the earth?

[28] total marks