PHYS 3614

Modern Physics

Test 1

Monday, September 26th, 2022

This is a 50 minute open book test, followed by a take home test. You may use a calculator. There are four questions worth 10 points each. You should answer two questions of your choice in the 50 minute in-class time period. The other two questions (of your choice) can be answered at home and turned in during the class period on Wednesday, September 28th. The test will be scored out of 40 points.

Q. 1. In your laboratory, you observe particle A of rest mass 498 MeV/c^2 to be moving in the positive x direction with a speed of 0.462c. It decays into 2 particles B and C, each of rest mass 140 MeV/c^2. Particle B moves in the negative x direction with a speed of 0.591c.

(a) Find the relativistic total energy of each of the three particles.

(b) Find the velocity (magnitude and direction) of particle C.

(c) Your laboratory supervisor is watching this experiment from a spaceship that is moving in the positive x direction with a speed of 0.635c. What values would your supervisor measure for the velocities of particles B and C?

Q. 2. X-ray photons of wavelength 0.01575 nm are incident on free electrons at rest. After the interaction, photons of wavelength 0.01772 nm are observed.

(a) Relative to the direction of the original X-rays, at what angle would we observe these photons?

(b) What is the kinetic energy given to the electrons by this interaction?

Q. 3. An electron moving at a speed of 0.0202c is trapped in an atomic-sized region of width 0.12 nm.

(a) What range of values would likely result from a measurement of the speed of the electron?

(b) Find the de Broglie wavelength of the electron and sketch its wave packet.

Q. 4. (a) A neutron ($mc^2 = 939.6$ MeV) is confined in a nucleus of diameter 11 fm. Inside the nucleus, the neutron moves freely (no forces act on it), but at the edges of the nucleus a very strong force (which we can take to be infinitely strong) prevents the neutron from leaving the nucleus. Treating this as a one-dimensional problem, find the energy difference between the ground state and the first excited state of the neutron.

(b) In the ground state, what is the probability to find the neutron in a narrow region of width 0.10 fm located at the center of the nucleus? Note that you may take the region to be narrow enough that the wave function does not change appreciably over it.