Physics IV [2704] Practice Midterm I

Directions: This exam is closed book. You are allowed one 8.5"x11" sheet with equations etc., which should be turned in with your test. Read all the questions carefully and answer every part of each question. Please show your work on all problems – partial credit may be granted for correct logic or intermediate steps, even if your final answer is incorrect. Please use a calculator only to check arithmetic – all steps of calculations should be explicitly shown. Unless otherwise instructed, you can express your answers in terms of fundamental constants like *k, h, c* rather than calculating numerical values. If your answer includes a $\sqrt{N}$ you can leave it that way unless the number N is a perfect square. If the question asks for an explanation, please write at least a full sentence explaining your reasoning. Please ask if you have any questions, including clarification about any of the instructions, during the exam.

Good luck!

A few useful numbers:

$v/c = 0.5$	$\gamma = 1.15$	|	$v/c = 0.8$	$\gamma = 5/3$
$v/c = 0.6$	$\gamma = 1.25$	|	$v/c = (\sqrt{3})/2 = 0.866$	$\gamma = 2$
$v/c = 1/\sqrt{2}$	$\gamma = \sqrt{2}$	|	$v/c = 0.98$	$\gamma = 5$
$v/c = 0.75$	$\gamma = 1.51$	|	$v/c = 0.999$	$\gamma = 22$

Speed of light $c = 3\text{x}10^{8}$ m/s
Planck's constant $h = 6.6\text{x}10^{-34}$ J s = $4\text{x}10^{-15}$ eV s $\hbar = h/(2\pi)$
Compton wavelength $h/(m_e c) = 2.4\text{x}10^{-12}$ m
Photon energy = $h\nu = hc/\lambda \sim 1240$ eV-nm /(λ in nm)

Honor Pledge: I understand that sharing information with anyone during this exam by talking, looking at someone else's test, or any other form of communication, will be interpreted as evidence of cheating. I also understand that if I am caught cheating, the result will be no credit (0 points) for this test, and disciplinary action may result.

Sign Your Name_______________________________________

Print Your Name_______________________________________

Question 1 (10 points): A particle of mass *m* is moving at a speed of v=0.80*c*. It collides with and merges with another particle of the same mass *m* that is initially at rest. Is the mass of the resulting combined particle *greater than, less than, or equal to* 2*m*? EXPLAIN YOUR ANSWER.

Question 2 (20 points): A ship is launched from a space station at velocity $v_{ship\_station}$ = 0.4c. After traveling some distance, the ship launches a shuttle in the same direction that it is traveling, with a velocity relative to the ship of $v_{shuttle\_ship}$. The velocity of the shuttle as observed from the space station is $v_{shuttle\_station}$ = 0.75 c. What is $v_{shuttle\_ship}$ as observed by the ship?

Question 3 (20 points): A particle of mass M is moving in the positive x direction with speed v. It spontaneously decays into 2 photons, with the original particle disappearing in the process. One photon has energy 450 MeV and moves in the positive x direction, and the other photon has energy 50 MeV and moves in the negative x direction.

A (5 points). What is the total relativistic energy of the particle before its decay?

B (5 points). What is the momentum of the particle before its decay, in units of MeV/c?

C (5 points). Find the mass M of the particle, in units of MeV/c^2.

D (5 points). Find the original speed of the particle, expressed as a fraction of the speed of light (okay to leave as an unreduced √).

Question 4 (10 points): A beam of photons of energy E is incident on a metal target. The photons scatter from the nearly free electrons in the target, and the scattered photons are observed at an angle θ relative to the direction of the original beam of photons. When the photons emerge at that angle, the scattered electrons have a certain kinetic energy. As the angle θ is made smaller, does the corresponding kinetic energy of the scattered electrons *increase, decrease, or remain the same*? EXPLAIN YOUR ANSWER.

Question 5 (20 points): In an electron diffraction experiment, the distance between the target and a screen is ~10 cm, and the spacing between the interference fringes seen on the screen is ~1 cm. The (non-relativistic) electron kinetic energy is ~300 eV or 5×10^{-17} J. To make the calculation easy, approximate the electron mass as 10^{-30} kg, and approximate h as 10^{-33} J s.

A (5 points). Find the momentum of the electrons, in kg m/s.

B (5 points). Find the de Broglie wavelength of the electrons, in nm.

C (10 points). Estimate the approximate inter-atomic spacing of the atoms in the target material, in nm.

Question 6 (20 points): In a Compton scattering experiment, a photon with a wavelength of 4.8×10^{-12} m (0.0048 nm) is observed to scatter at 180° from its incident direction.

A (5 points). What is the wavelength of the scattered photon?

B (5 points). What are the energies of the incoming and scattered photons, in eV? As an approximation to make the calculation easy, use $hc/\lambda \sim 1200$ eV-nm /(λ in nm).

C (5 points). What are the momenta of the incoming and scattered photons, in eV/c?

D (5 points). What is the kinetic energy of the scattered electron (in eV), and which direction does it travel in comparison to the incoming photon?