Physics IV [2704] Practice Midterm 2

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 $c = 3x10^8$ m/s
Planck's constant $h = 6.6x10^{-34}$ J s = $4x10^{-15}$ eV s $\hbar = h/(2\pi)$
Compton wavelength $h/(m_e c) = 2.4x10^{-12}$ 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): Two spaceships A and B are approaching a space station from opposite directions. An observer on the station reports that both ships are approaching the station at the same speed v. According to classical physics, each ship would see the other moving at a speed of $2v$. According to special relativity, does each ship sees the other moving at a speed that is *greater than 2v, less than 2v, or equal to 2v?* EXPLAIN YOUR ANSWER.

Question 2 (20 points): An alarm clock emits a pulse of light when it ticks, once per minute. The alarm clock is on a spacecraft that passes the origin as it ticks 12:00am, with a velocity of $u = 0.865c$. If I remain at the origin with another clock that also read 12:00am when the spacecraft passed, at what time (on my clock) do I receive the pulse of light sent when the moving alarm clock ticks 12:01am? Express your answer as a decimal number of minutes past 12:00.

Question 3 (20 points): A particle of mass m and relativistic velocity v collides with another particle of mass m at rest, forming a single particle of mass M that moves away at a velocity v'. You will prove that M > 2m for any v > 0.

A (5 points). Write down an expression for conservation of momentum that holds for this collision for any initial velocity v, in terms of the initial and final variables m, v, M, and v' (you can also use γ and γ' if you wish).

B (5 points). Write down an expression for conservation of total energy that holds for this collision for any initial velocity v, in terms of the initial and final variables.

C (5 points). Write down an expression for the mass of the final particle M in terms of its energy and momentum, and express it in terms of the initial variables m and v (and γ if you wish).

D (5 points). Reduce this expression to show that M > 2m for v > 0.

Question 4 (10 points): Consider two monochromatic (single-wavelength) light sources emitting light of respective wavelengths λ_1 and λ_2, with $\lambda_2 > \lambda_1$. The two bulbs are otherwise identical and emit light with exactly the same intensity (in J/[m^2 s]). A detector placed a distance *d* from bulb 1 (emitting at wavelength λ_1) records *N* photons per second. When the same detector is placed at the same distance *d* from bulb 2 (emitting at wavelength λ_2), is the number of photons per second recorded by the detector *greater than N, smaller than N, or equal to N?* EXPLAIN YOUR ANSWER.

Question 5 (20 points): In a photoelectric effect experiment, when light with a wavelength of 620 nm shines on a surface a stopping potential of 0.5 V is needed to stop all electrons emitted from the surface, and when light with a wavelength of 310 nm shines on the same surface a stopping potential of 2.5 V is needed to stop all electrons emitted from the surface.

A (10 points). What is the work function φ of the surface, in eV?

B (10 points). For light with a wavelength of 310 nm, if the arrival of each electron is recorded with a precision of 1 picosecond (10^{-12} s), what is the minimum fractional uncertainty in the electron energy $\Delta E/E$? Your answer only needs to be accurate to within an order of magnitude.

Question 6 (20 points): In a Compton scattering experiment, a photon with a wavelength of $2.4x10^{-12}$ m (0.0024 nm) interacts with an electron. After the interaction, the electron gains 250 keV (250,000 eV) of kinetic energy.

A (5 points). What are the kinetic energy and momentum of the incoming photon, in units of eV and eV/c respectively? As an approximation to make the calculation easy, use $hc/\lambda \sim 1200$ eV-nm /(λ in nm).

B (5 points). What were the kinetic energy and momentum of the scattered photon, in units of eV and eV/c?

D (10 points). At what angle (relative to the direction of the incoming photon) did the photon scatter?