Physics 7C, Spring 2014 Instructor: Professor Adrian Lee
Midterm Examination, Tuesday, April 8, 2014

Please do work in your blue/greenbooks. Show your reasoning carefully so that we can be sure that you derived the answer rather than guessing it or relying on memory; in addition, this enables us to give partial credit. You may use one double-sided 3.5 x 5 index cards of notes. You can use a simple calculator (no smart phones or devices that can store notes). Test duration is 110 minutes.

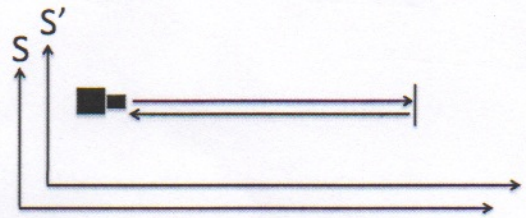
1 Qualitative Questions [20 pts. total]

Only a few lines of explanation is needed for these. You don't have to use cartoons or equations, unless specified, but you can. No derivations are needed.

a) In the twin paradox, one twin travels to another planet and returns to find the twin who was left at home to be much older. But isn't time dilation symmetric? What is the asymmetry between the two twins? You don't have to write any equations, just a few sentences are required. [5 pts.]

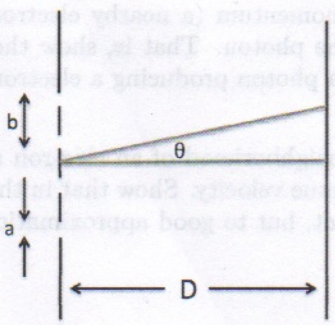
b) Consider Newton's rings where there is a convex curved piece of glass on top of a flat piece and interference occurs in the gap between the two. In transmission (light source and observer are on opposite sides of apparatus) and in reflection (light source and observer are on the same side of apparatus) is the center of the pattern light or dark? A drawing is helpful here. [5 pts.]

c) Consider a laser clock in S' where S' is moving in the $+x$ direction with respect to S. This laser clock shoots a laser forward in the $+x$ direction and back over a proper length L. Draw a space-time diagram showing the two laser shots and show how you'd measure the time interval in S. You don't need to calibrate the axes of the diagram. It can be a very simple diagram. [5pts.]



d) In a simple microscope, there are two possible reasons why taking the limit of focal length going to zero does not result in a practical high-performance microscope. Name the effects and briefly explain them. [5 pts]

2 Four-Slit grating [30 pts. total]



Light of wavelength $\lambda = 600$ nm falls as a plane wave on four slits (the wavefront is parallel to the slit plane). Each slit is a = 2 μm wide and center-to-center separated from the next by b = 6 μm. In all sections, make arguments based on path length differences rather than simply quoting known formulas.

a) Find the angle from the center to the first point of zero intensity of the single-slit *diffraction* pattern on a distant screen. [10 pts.]

b) Find the angles of any bright *interference* maxima that lie inside the central *diffraction* maximum (that is, between two first diffraction minima). [10 pts.]

c) Find the angular spread between the central *interference* maximum and the first interference minimum on either side of it. [10 pts.]

3 The Tortoise and the Hare [40 pts. total]

The totoise and the hare agree to have a rematch, but this time the hare gets a head start. They run a footrace where the tortoise starts at $x = 0$, the hare starts at $x = L/2$, and the finish line is at $x = L$ (the unprimed frames is the stationary reference frame, relative to the ground). At $t = 0$ in the stationary reference frame, both runners start running and instantly reach their top speed. In all sections, if you use Lorentz contraction or time dilation you have to justify why those are the correct formulas for the situation.

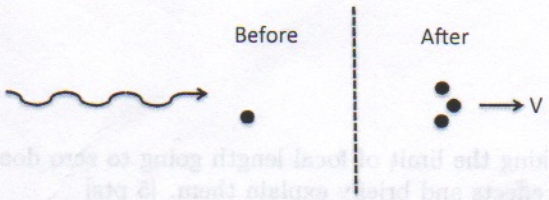
a) Once she has started running, the hare looks back to the tortoise. In her new reference frame, does it appear that the tortoise jumped the gun and started before she did, or had a slow start and started after she had already started running? [10 pts.]

b) Hypothetically, if the hare runs at speed $c/3$, and ends up in a tie with the tortoise, how fast much the tortoise have run, *relative to the hare?* [10 pts.]

c) At what minimum speed can the hare run and be guaranteed to win the race, regardless of how fast the tortoise runs? At this speed, how far away is the finsih line (in her frame) when she starts the race? [10 pts.]

d) In actuality, the totoise did not catch up. On his own stopwatch, he measures that the race took him time T' in his frame. How long did the race take him according to a stationary fan on the sidelines? [10 pts.]

4 Pair Production [30 pts. total]



A γ-ray photon can create an electron-positron ($e^-$and e^+) pair. The rest mass of the electron is m_0.

a) Neglecting momentum conservation, what is the absolute minimum photon energy needed to create the $e^-$and e^+ pair? This part is simple and meant to be compared to the derivation in part (c). [5 pts.]

b) Show that, without the presence of another body to take up some of the momentum (a nearby electron, for example), pair production can not happen no matter how high the energy of the photon. That is, show that it's impossible to simultaneously satisfy conservation of energy and momentum for a photon producing a electron-positron pair by itself. [10 pts.]

c) It is possible for a γ-ray photon to produce an electron-positron pair in the neighborhood of an electron at rest initially. The threshold case is when all three particles move off together at the same velocity. Show that in this case the threshold energy for the photon is 4 m_0c^2. (Note, the nucleus is also present, but to good approximation does not play a role in this process). [15 pts.]