Physics 7C, Spring 2013 Instructor: Professor Adrian Lee
Second Midterm Examination, Tuesday, April 9, 2013

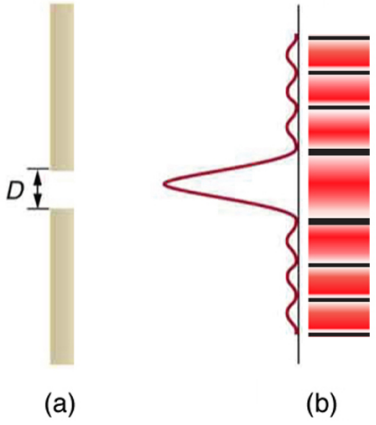
Please do work in your blue/greenbooks. Show your reasoning carefully so that we can be sure that you derived the answer rather than guessing it or relying on memory; in addition, this enables us to give partial credit. You may use one double-sided 3.5 x 5 index cards of notes. You can use a simple calculator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

1 Diffraction Pattern [30 pts. total]

Consider diffraction through a slit of width D.

a) Using a Huygens wavelet construction, identify the angular location of the central maximum. Next, identify the angular location of the first minimum, the second maximum, and the second minimum which occur symmetrically on both sides of the central maximum. For the second maximum, this line of argument is only approximate, but the approximation is fairly good. [20 pts.]

b) Again using the Huygens wavelet model, explain why the central maximum has a much higher amplitude than any of the other maxima. This argument only requires several sentences perhaps with reference to some figures. [10 pts.]



2 Simultaneity [30 pts. total]

A fast car of proper length $L = 10$ meters, moving at velocity $v = 0.6c$ relative to the lab frame, drops two objects on the ground, one from the front (bag A) and one from the back (bag B) of the car, simultaneously in the frame of the car. The bags immediately hit the ground and stop relative to the lab.

a) Find the separation between the two bags in the lab frame. Show in detail which Lorentz tranformation(s) you use and the assumptions that lead to the choice(s). [5 pts.]

b) In the lab frame, which bag hits the ground first? Show in detail which Lorentz tranformation(s) you use and the assumptions that lead to the choice(s). [10 pts.]

c) Find a frame in which the time order of hitting the ground is opposite from that in (b), or explain why such a frame does not exist. [5 pts.]

d) Make a space-time diagram for this situation and show roughly that it agrees with parts (a) and (b). [10 pts.]

3 Bevatron - Discovery of the anti-proton [30 pts. total]

An antiproton $\bar{p}$ has the same rest energy as a proton. It was first created at Berkeley using a reaction similar to $p + p \rightarrow p + p + p + \bar{p}$. The 1960 Nobel prize was awarded to Berkeley professors Chamberlain and Segre for discovering the antiproton. A photo of the circular Bevatron is shown. It was up on the hill at LBNL.

In the experiment, the target proton was at rest in the laboratory and the beam was incident with kinetic energy E_k, which was chosen to be large enough so that some of the kinetic energy could be converted into rest energy $2m_pc^2$, which is sufficient to produce another proton and one antiproton. In the center-of-mass frame, the two protons (beam and target) move toward each other with speed u' so that enough kinetic energy is available for the required additional rest energy.

a) Find the center-of-mass frame speed of each proton u', so that the total kinetic energy in the center-of-mass frame is $2mc^2$. [10 pts.]

b) Find the value of the kinetic energy E_k of the proton in the incident beam (lab frame) required to cause the reaction to proceed. Please express the answer in terms of multiples of the proton rest mass. [10 pts.]

c) Describe the motion in the lab frame of the proton and antiproton produced in the reaction. What is their speed and direction in the lab frame? [10 pts.]

4 Trip to a nearby planet [30 pts. total]

Suppose a very interesting planet has been discovered near a star 50 light years from the Earth. In the year 2050 NASA decides to send an expedition to explore this planet. The decision is made that the men and women on the expedition should reach the planet after 20 years of their own body time has elapsed.

a) What should be the speed at which the expeditions ship travels from Earth to the planet? (You may assume constant speed and ignore initial acceleration and deceleration). [10 pts.]

b) How long does the expedition appear to take according to the NASA observers on Earth? [5 pts.]

c) The ship carries radio transmitters tuned to the frequency 90 MHz (9×10^7 cycles per second) that they use to send messages back to earth. What frequency should the NASA base station tune to in order to receive these signals? [5 pts.]

d) When the ship reaches the half way point, the astronauts get impatient and send out an advanced party. The advanced party leaves the ship with a velocity of 0.99c relative to the ship. (Again ignore acceleration and deceleration.) How many years have passed since the original departure from Earth according to the astronauts in the advanced party when they reach the planet? [10 pts.]