In Class Test. Please complete all the questions showing your work for full credit.

1. The lifetime of a high speed elementary particle relative to a stationary observer appears to a stationary observer to be
   (a) Shorter than the particle's lifetime at rest;
   (b) The same as the particle's lifetime at rest;
   (c) Longer than the particle's lifetime at rest;
   (d) Any of the above depending on whether the particle is approaching or receding from the stationary observer.

2. Two spaceships leave a space station with identical speeds in opposite directions. After each captain records that one year has passed she turns the space ships around and comes back at the same speed to meet the other spaceship. When the captains discuss their journey they
   (a) agree that the other turned around at the same time as they did and that it was two years ago that they first passed each other;
   (b) each think that the journey took more than two years for the other captain;
   (c) each think that the journey took less than two years for the other captain.
   (d) disagree about who turned around first, but agree that it was two years ago that they first passed each other.

3. An observer in a closed laboratory wishes to determine if she is at rest or in motion with constant velocity. She can find out by
   (a) making a careful measurement of the speed of light in the lab.
   (b) by making a careful measurement of the length of meter sticks in the lab.
   (c) by making a careful measurement of the lifetime of known radioactive elements in the lab.
   (d) she cannot find out.

4. Cookie batter is rolled out on a conveyer belt moving at 0.8c. A square cookie cutter of length 5cm cuts out cookies at regular intervals. What shape are the cookies when the machine is turned off and the cookies come to a stop?
   (a) They are square with length smaller than 5 cm.
   (b) They are square with length 5 cm.
   (c) They are rectangular with width 5 cm and length longer than 5 cm.
   (d) The are rectangular with width 5 cm and length less than 5 cm.

5. Two identical space ships pass each other at high speed. The captains on both ships will always agree
   (a) that the other ship is the same length as theirs.
   (b) on the speed of a passing comet.
   (c) that they have the same speed relative to each other.
   (d) on none of the above.

6. A train of proper length L travels at $c/2$ relative to the ground. A person at the back of the train throws a ball at speed $c/3$ (relative to the train) toward the front. How far does the ball travel and how long does it take to hit the far end of the train in:

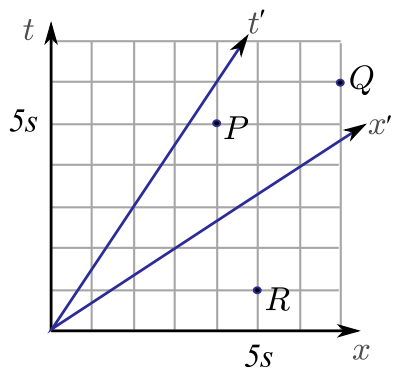
   (a) in the train's frame?

   (b) in the ground's frame?

   (c) in the ball's frame?

7. Two photons with equal frequency collide at an angle θ and combine to form a particle of mass M. Find M in terms of θ and f, the frequency of the photons. (Hint: Choose the x direction in the direction of one of the photons.)

8. Below is the space-time diagram showing two frames of reference.



(a) What is the velocity of S' relative to S?

(b) Find the coordinates of the point P in the S' frame.

(c) Find a frame (relative to S) in which the interval P and Q are simultaneous events.

(d) Find a frame (relative to S) in which P and R occur in the same place.

(e) Find the space time interval ds^2 between the two events Q and R

9. An unstable particle is created with energy 3.5 Gev and Momentum 3 Gev in a bubble chamber at CERN. It moves 3mm in the bubble chamber before decaying, leaving a track as evidence of its fleeting existence.

   (a) What is the rest mass of the particle in Gev?

   (b) How long did it exist, as measured in its rest frame?

10. If you travel fast enough to another galaxy the microwave background radiation will be blue shifted until you can see it as a disc of visible light ahead of you. How fast do you need to travel so the cosmic microwave background radiation (withwave length about 2 mm) directly in front of you is visible as yellow light with wavelength 570 nm (The speed will be pretty close to one, so specify γ instead). Traveling at this speed, what would be the angle subtended by the visible disc of light, assuming the longest wave length we can see is 650 nm. (Hint: find the angle measured from the forward direction corresponding to microwave background radiation sifted to 650 nm.)

Take Home Test. Please complete all the questions showing your work for full credit. You may consult your notes and textbooks but you must work independent of other people.

1. A π^0 meson decays spontaneously into two photons, with a half life of 8.4×10^{-17} seconds in the meson's rest frame. The mass of the π^0 meson is 135 Gev.

   (a) Suppose a π^0 meson travels at speed $0.99c$ and it decays in such a way that one photon travels in the direction of motion and the other photon travels in the opposite direction. Find the energy and momentum of each photon in the rest frame of the π^0 and in the lab frame.

   (b) Find the frequencies of the photons in both frames, and show that forwarding moving photon is blue shifted and the backward moving photon is red shifted by the amount predicted by the doppler shift.

2. A particle is free to move in the x-direction.

   (a) If a force acts on the particle show that the relativistic version of Newton's second law becomes $F = \gamma^3 m \dfrac{\mathrm{d}^2 x}{\mathrm{d}t^2}$.

   (b) If the particle feels a spring force $F = -kx$ and is given an initial displacement from equilibrium of $x = x_0$ then find the first integral of Newton's second law to show that the relation between speed and position is given by $\gamma = 1 + \frac{k}{2m}(x_0^2 - x^2)$.

   (c) Show that the particle oscillates with frequency.

   $$T = 4 \int_0^{x_0} \frac{\gamma}{\sqrt{\gamma^2 - 1}}\, dx\,.$$

   Don't try to evaluate this integral.

3. Your boss is traveling from Earth to Pluto at 0.6c on board the Pluto Express. Pluto is 5 light hours away from Earth.

   (a) Draw a spacetime diagram in the Earth frame of reference, showing the world line of Pluto and the world line of your boss. On the spacetime diagram show the time for the journey as measured by you and measured by your boss.

   (b) You decide to send her a welcome message at the speed of light that will arrive at Pluto the moment she arrives. Draw the worldline of this light and determine when you should send the message?

   (c) She decides to send you a message that arrives back at Earth the moment she arrives at Pluto, according to her. How much time does she say has passed on Earth when she arrives? When should she send it, in her frame, so that it arrives on time? Draw the world line of this message.

   (d) When you get the message you quit your job. Why?