PHY 140Y – FOUNDATIONS OF PHYSICS
1999-2000
Term Test #2
Tuesday, December 7, 1999
6:30 PM - 8:30 PM

INSTRUCTIONS:

Please give your name, student number, and TA's name on ALL examination booklets used.
Answer ALL questions. Total marks = 100.
Marks, shown in brackets, will be given for workings and units as well as for final answers.
[Non-]programmable calculators may be used. No aid/crib sheets are allowed.

Constants: $g = 9.81\ m/s^2$, $c = 3.00 \times 10^8\ m/s$

Lorentz transformations:

$$x' = \gamma(x - vt) \qquad x = \gamma(x' + vt')$$

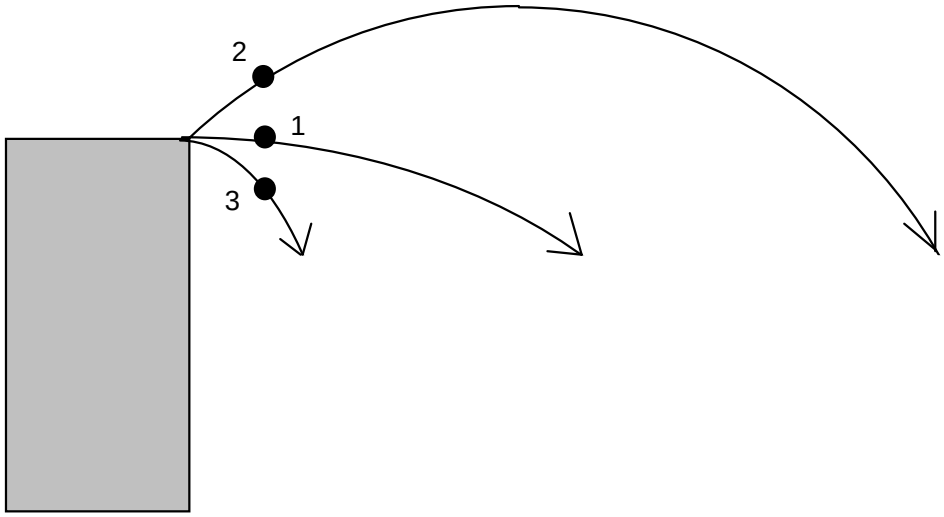
$$t' = \gamma\left(t - \frac{vx}{c^2}\right) \qquad t = \gamma\left(t' + \frac{vx'}{c^2}\right)$$

Inspiration can have many sources (especially during tests…)!

QUESTIONS:

1. Give BRIEF answers to each of the following. ***[5 marks each for 20 total]***

(a) Three identical balls are thrown from the top of a building, all with the same initial speed. The first is thrown horizontally, the second at some angle above the horizontal, and the third at some angle below the horizontal, as shown below. Neglecting air resistance, rank the speeds of the balls at the instant each hits the ground. Explain your reasoning from a consideration of energy.



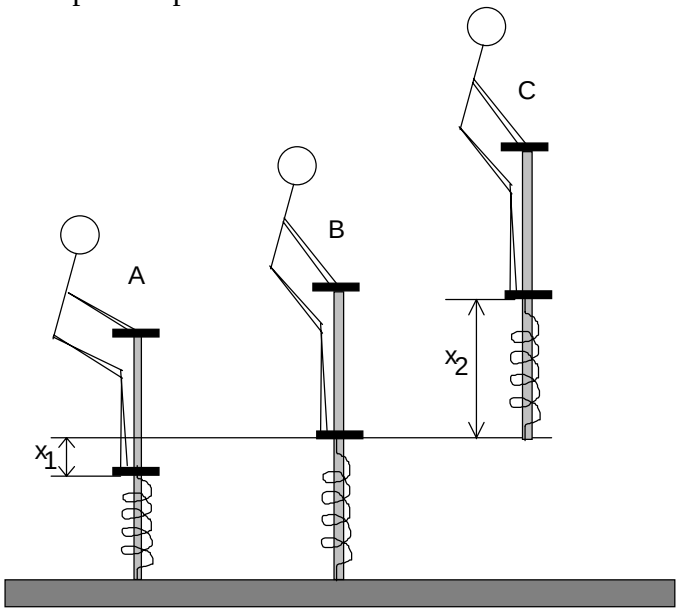
(b) Some parachutes have holes in them to allow air to move smoothly through the parachute. Without these holes, the air gathered under the parachute as the parachutist falls is sometimes released from under the edges of the parachute alternately and periodically from one side and then the other. Why might this periodic release of air cause a problem?

(c) If you go bungee jumping, you will bounce up and down at the end of the cord after your daring dive off a bridge. Suppose that you perform this dive and measure the frequency of your bouncing. You then move to another bridge. You discover that the bungee cord is too long for dives off this bridge, and you will hit the ground. Therefore, you fold the bungee cord in half and make the dive from the doubled bungee cord. How does the frequency of your bouncing at the end of this dive compare to the frequency after the dive from the first bridge?

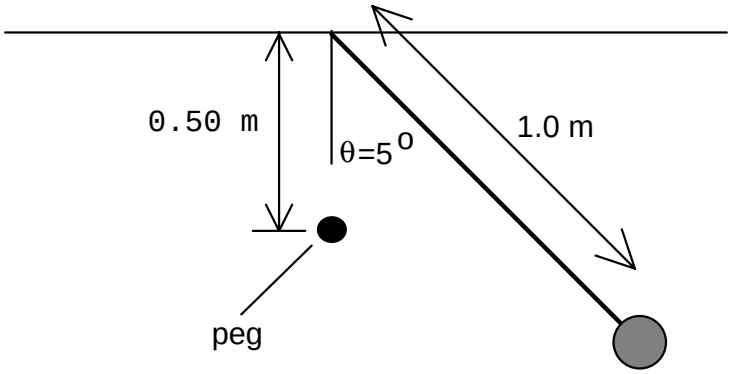
(d) You are packing for a trip to a distant star, to which you will be travelling at 0.99c. Should you buy smaller sizes of clothing, since you will be skinnier on your trip? Can you sleep in smaller cabin than usual, since you will be shorter when you lie down (assuming that the cabin bed is aligned with the direction of motion)? Explain your answer.

[Each of the following five questions is worth 16 marks.]

2. A child's pogo stick stores energy in a spring having spring constant $k = 2.5 \times 10^4$ N/m. At position A ($x = x_1 = -0.10$ m) in the figure below), the spring compression is a maximum and the child is momentarily at rest. At position B ($x = 0$), the spring is relaxed and the child is moving upwards. At position C, the child is again momentarily at rest at the top of the jump. Assuming that the combined mass of the child and pogo stick is 25 kg, determine the following:
   (a) the total energy of the system if both potential energies (child and pogo stick) are zero at $x = 0$,
   (b) x_2, the position at C,
   (c) the speed of the child at $x = 0$,
   (d) the value of x for which the kinetic energy of the system is a maximum, and
   (e) the child's maximum upward speed.



3. A small ball of mass 2.0 kg is suspended at the end of a string 1.0 m in length. A small peg, located 0.50 m below the suspension point, as shown in the figure below, catches the string in its swing. The ball is released at an angle $\theta = 5.0°$.
   (a) What is the period of the simple pendulum?
   (b) How high will the ball rise in its motion to the left of the peg?



4. An RCMP officer is riding along a straight trail into town at a speed of 0.867c. Two gunslingers are glaring at each other with only 50.0 m of dirt between them (oriented parallel to the line along which the officer is riding), according to witnesses cowering behind hitching posts along the street. The two desperadoes draw and fire simultaneously according to them.
   (a) Determine the value of the relativistic factor γ.
   (b) How far apart are the desperadoes according to the RCMP officer?
   (c) Carefully sketch and define two appropriate reference frames. Then define two events corresponding to the shots fired by the two desperadoes. Transform the events into the other reference frame.
   (d) Which gunslinger fired first according to the reference frame of the RCMP officer?
   (e) How does your answer to part (d) change if one gunslinger fires 0.5 μs after the other?

5. Given an object moving at speed u'_x (in the x' direction) in reference frame A', which is in turn moving at speed v (in the x direction) relative to reference frame A, we have shown that the object has speed u_x (in the x direction) in A:

$$u_x = \frac{u'_x + v}{1 + \frac{v}{c^2} u'_x}.$$

   (a) Using a similar approach to that used to obtain the above expression, derive an equation for u_y (the y component of the object's speed as measured in reference frame A), given u'_y (the y' component of the object's speed as measured in reference frame A'), with A' still moving at speed v <u>in the x direction</u> relative to A.
   (b) A particle in the A' reference frame has a velocity $\vec{u}' = 0.779c\hat{i}' + 0.450c\hat{j}'$. The A' frame is moving in the standard geometry at speed 0.950c with respect to reference frame A. Sketch the geometry.
   (c) What is the angle θ' that velocity vector $\vec{u}'$ makes with the x'-axis in A'? What is the speed u' of the particle in A' when measured with clocks and rulers at rest in A'?
   (d) What are the velocity components u_x and u_y of the particle in the A reference frame?
   (e) What is the angle θ that velocity vector $\vec{u}$ makes with the x-axis in A? What is the speed u of the particle in A when measured with clocks and rulers at rest in A?

6. A proton (mass = 1.67×10^{-27} kg) is moving at speed v = 0.900c.
   (a) What is the proton's total relativistic energy?
   (b) What is the proton's kinetic energy?
   (c) What is the proton's rest energy?
   (d) What is the magnitude of the proton's relativistic momentum?

END