PHY 140Y – FOUNDATIONS OF PHYSICS
2001-2002
Term Test #2
Thursday, December 6, 2001
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:
$$x' = \gamma(x - vt) \qquad x = \gamma(x' + vt')$$
and
$$t' = \gamma\left(t - \frac{vx}{c^2}\right) \qquad t = \gamma\left(t' + \frac{vx'}{c^2}\right)$$
with
$$\gamma = \frac{1}{\sqrt{1 - v^2/c^2}}$$

Lorentz velocity addition:
$$u_x = \frac{u_x' + v}{1 + \frac{v}{c^2}u_x'} \qquad u_x' = \frac{u_x - v}{1 - \frac{v}{c^2}u_x}, \qquad u_y = \frac{u_y'}{\gamma\left(1 + \frac{v}{c^2}u_x'\right)}, \qquad u_z = \frac{u_z'}{\gamma\left(1 + \frac{v}{c^2}u_x'\right)}$$

QUESTIONS:

1. Describe the Michelson-Morley experiment. Include the following in your answer:
   [4 marks each for 20 total]

(a) a discussion of the historical context and motivation for the experiment,
(b) a sketch of the apparatus and discussion of the principle of operation of a Michelson interferometer,
(c) the derivation of the two-way travel time for each arm of the interferometer, and hence the path difference between the two arms,
(d) sketches of the expected signal for the original and rotated orientations, an explanation of why the rotation was required, and a discussion of how the phase shift is related to the path difference in (c),
(e) a summary of the results and their significance.

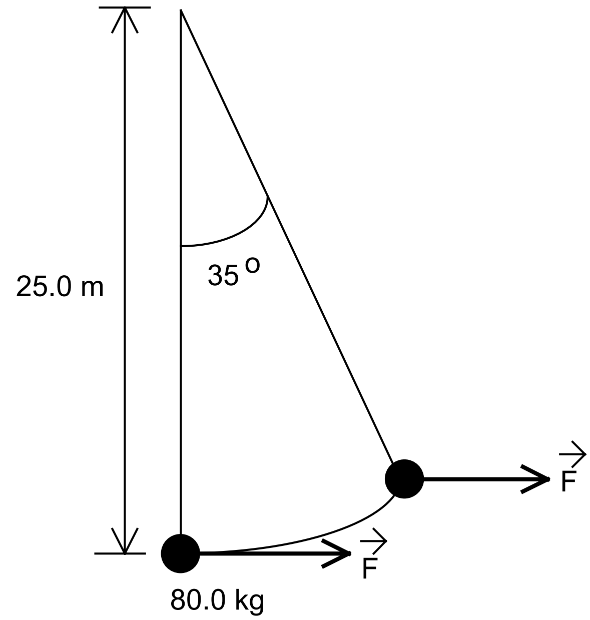
[Each of the following five questions is worth 16 marks.]

2. An 80.0 kg sphere is suspended by a wire of length 25.0 m from the ceiling of a science museum as indicated in the figure. A horizontal force of magnitude F is applied to the ball, moving it very slowly at constant speed until the wire makes an angle with the vertical direction equal to 35°.

(a) Sketch the force diagram for the sphere, indicating all forces acting on it at any point along the path.

(b) Is the force needed to accomplish the task constant in magnitude along the path followed by the ball? Clearly derive your answer.

(c) From a consideration of work and energy, find the work done by the force $\vec{F}$.



3. 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:

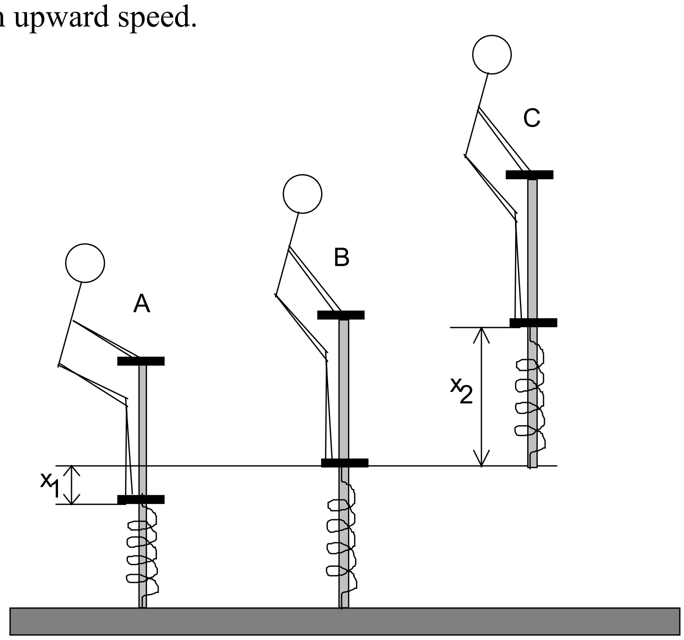
(a) the total energy of the system if both potential energies (child and pogo stick) are zero at $x = 0$,

(b) x_2, the position at C,

(c) the speed of the child at $x = 0$,

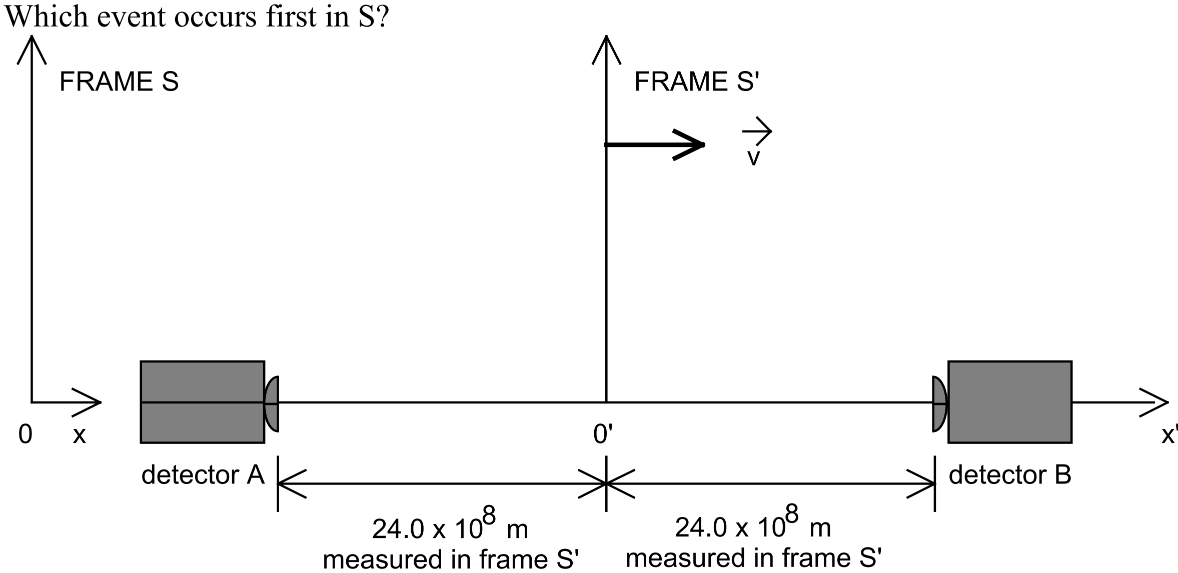
(d) the value of x for which the kinetic energy of the system is a maximum, and

(e) the child's maximum upward speed.



4. A 0.250 kg sugar plum fairy is attached to a vertically suspended spring whose spring constant is 2.00 N/m. The sugar plum fairy is pulled down 10.0 cm and released from rest.
(a) Find x(t).
(b) At what position is the fairy when t = 3.5 s?
(c) What is the velocity of the fairy when t = 3.5 s?
(d) What is the acceleration of the fairy when t = 3.5 s?

5. In reference frame S', a flashbulb goes off at the origin and the light propagates towards positive x' and negative x' to two detectors, each located 24.0×10^8 m from the S' origin as measured in S' (see the figure below).
(a) Define two events in S' corresponding to the detectors' reception of the light.
(b) Reference frame S' is moving at speed v = 0.995c relative to reference frame S in the standard geometry. Find the relativistic factor γ.
(c) Find the spatial separation Δx between the two events in S.
(d) Fin the time interval Δt between the two events in S.
(e) Which event occurs first in S?



6. A particle in the S' reference frame has a velocity $\vec{u}' = 0.779c\hat{i}' + 0.450c\hat{j}'$. The S' frame is moving in the standard geometry with speed 0.950c with respect to reference frame S.
(a) Sketch the situation.
(b) What is the angle θ' that $\vec{u}'$ makes with the x'-axis in S'?
(c) What is the speed u' of the particle in the S' frame when measured with clocks and rulers at rest in reference frame S'?
(d) Find the velocity components u_x and u_y of the particle in the S reference frame.
(e) What is the speed u of the particle in S, measured using rulers and clocks in that frame?
(f) What angle θ does the velocity vector $\vec{u}$ make with the x-axis in reference frame S?

END