PHY 140Y - FOUNDATIONS OF PHYSICS
2000-2001
Problem Set #1

HANDED OUT: Friday, September 22, 1999 (in class).

DUE: **1:00 PM, Thursday, October 5, 1999 (in class).**
Late penalty = 5 marks/day (which also applies to weekend days!) until 1:00 PM, Monday, October 9, after which it will not be accepted (as solutions will then be available in tutorials and on the WWW).

NOTES: Answer all questions.
50% will be awarded for making a reasonable attempt at all questions.
50% will be awarded for the answers to a selected subset of the questions.
Marks will be given for workings and units, as well as for final answers.

QUESTIONS:

1. A ladybug is observed crawling along a metre stick. The position of the ladybug at various times is recorded by a clever entomologist who obtains the following data:

TIME (s)	POSITION (cm)
0.0	5.4
2.0	7.6
4.0	9.2
5.0	10.0
7.0	9.2
10.0	8.6
12.0	8.2
14.0	7.8

(a) Graph the position vs. time of the ladybug.

Take the x-axis to be the metre stick with its origin at 0 m and with $\hat{\imath}$ in the direction that the scale increases. Use the data or the graph to answer the following questions. Give your results in appropriate SI units.

(b) What is the average velocity of the ladybug during the interval between 10.0 s and 14.0 s?

(c) What is the velocity of the ladybug when t = 12.0 s? f

(d) At about what time(s) is the velocity of the ladybug approximately 0 m/s?

(e) What is the average acceleration of the ladybug during the interval from 2.0 to 12.0 s?

2. A lawyer notices an ambulance go by at a constant speed of 50.0 m/s along a level straight road, apparently headed towards an accident. As the ambulance passes, the lawyer sets out in pursuit of a potential new client, with zero initial speed and a stopwatch initially set to zero, maintaining a constant acceleration of magnitude 1.0 m/s^2.
   (a) Set up an appropriate coordinate system to analyze the situation.
   (b) Set up an equation that describes the position of the ambulance as a function of time on the stopwatch.
   (c) Set up an equation that describes the lawyer's position as a function of time on the stopwatch.
   (d) How much time elapses before the lawyer catches the ambulance?
   (e) What distance did the ambulance and lawyer travel during this time?
   (f) Draw a graph showing the x-component of the position vectors of the ambulance and lawyer as a function of time. Indicate on this graph the event that represents the lawyer catching the ambulance.

3. It is always fun to drop rocks down into a well. An enterprising physics student realizes that it is possible to determine the distance to the surface of the water in the well using a stopwatch. From the top of the well, the student drops a rock (with zero initial speed) into a deep wishing well and discovers that the total time from the release to the reception of the sound from the resulting splash is 3.00 s. Allowing for the finite speed of sound in air, 343 m/s at 20°C, calculate the distance to the water surface.

4. You throw a ball vertically upward in a room with a high ceiling. The ball leaves your hand 1.2 m above the floor and reaches a maximum height of 3.0 m before falling to the floor.
   (a) Over how long a time interval did the ball rise?
   (b) What was the speed of the ball when it left your hand?
   (c) What is the duration of the entire time of flight?
   (d) What is the speed of the ball at the instant before it hits the floor?

5. The Stanford Linear Accelerator (SLAC) at Stanford University in California is 3.0 km long. Electrons are accelerated along the length of the straight beam tube. Assume that the acceleration of the electrons is constant along the length of the accelerator. If the electrons begin at rest and emerge with a speed of 6.0×10^6 m/s, find:
   (a) the time it takes each electron to traverse the tube, and
   (b) the magnitude of the acceleration.
   (c) The local acceleration due to gravity may be ignored. Why is this a reasonable assumption?

6. A zoologist notices a monkey located at a position (20.0 m)$\hat{j}$ which is intent on finding a banana. The monkey wanders to a tree situated at (30.0 m)$\hat{i}$ + (40.0 m)$\hat{j}$, and then proceeds to a nearby vertical vine whose lower end is located at (40.0 m)$\hat{i}$ + (30.0 m)$\hat{j}$. The x-y plane is the horizontal plane.
   (a) Sketch the situation on an x-y coordinate system.
   (b) What is the change in the position vector of the monkey in moving from the tree to the vine?
   (c) The monkey climbs the vine to a height of 10.0 m and finally spies a banana at the origin. What is the distance between the monkey on the vine and the banana?
   (d) The monkey leaps from the vine and lands in a swampy pool at (25.0 m)$\hat{i}$ + (25.0 m)$\hat{j}$. What is the distance between the tree and where the monkey landed in the pool?

7. A baseball is hurled at a speed of 30 m/s at an angle of 60.0° to the horizontal as indicated in the figure below. The ball leaves the thrower's hand at a point 2.50 m above the ground and 20.0 m from the base of a barrier 30.0 m high.

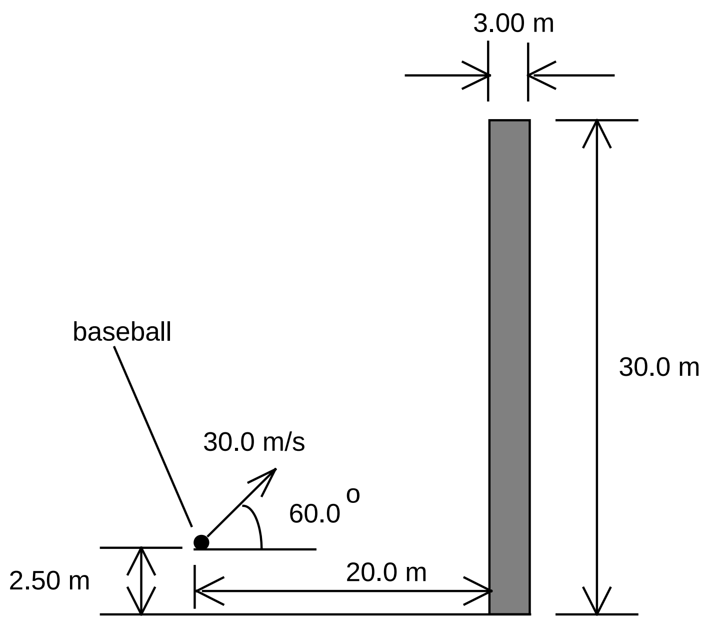
(a) Sketch an appropriate coordinate system for analyzing this problem.

(b) Using the given information, find expressions for x(t), y(t), $v_x(t)$, and $v_y(t)$.

(c) Does the ball hit or clear the vertical barrier?

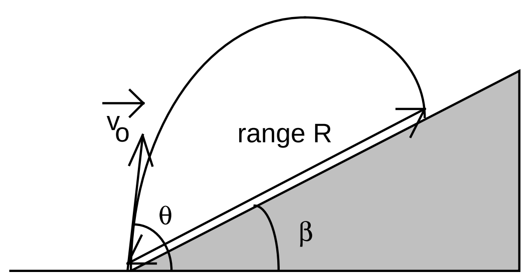
(d) Where does the ball first strike?

(e) How long is the ball in the air before its final impact?



8. A projectile is launched at speed v_o at an angle θ (with the horizontal) from the bottom of a hill of constant slope β as shown in the figure below. Show that the range of the projectile up the slope is

$$R = \frac{2v_o^2 \cos\theta \sin(\theta - \beta)}{g\cos^2\beta}.$$



9. The orbit of the Earth around the Sun is approximately circular and of radius 1.496×10^8 km. It takes the Earth one year (about 365.25 days) to revolve around the Sun.
(a) Determine the speed of the Earth in its orbit in km/s.
(b) Calculate the angular speed of the Earth in rad/s.
(c) What is the magnitude of the centripetal acceleration (in m/s^2) of the Earth in its orbit about the Sun?

10. A physics student is located at latitude 38° North.
(a) Calculate the centripetal acceleration of the student due to the rotation of the Earth.
(b) At what places on the surface of the Earth is the centripetal acceleration due to the rotation of the Earth a maximum? Why?
(c) At what places is it a minimum? Why?