Homework #2
due Feb. 10

Remember: Show your work to get full credit, and whenever possible do problems symbolically before plugging in numbers.

1. Make an order of magnitude estimate of the following:
   (a) The thickness of a page in your book.
   (b) The number of pennies you can fit into a jar that is 6 inches in diameter and 8 inches high.
   (c) The number of copies of a 200 page paperback novel that can be stored on an 80 GB hard drive. (In case you didn’t know, a GB = 10^9 bytes, and each byte can represent a number from 0 to 255.)

2. An astronaut in zero gravity swings a ball on the end of a string in a circle over her head with constant speed. This problem concerns the tension in the string, which is the force exerted by the string on the ball. Do this problem using only dimensional analysis.
   (a) What quantities do you need to know in order to determine the tension of the string? Make sure that these quantities are independent, i.e. you cannot determine any one from all the others.
   (b) What are the dimensions of tension in terms of $M, L,$ and $T$?
   (c) Write a formula for the tension in terms of the quantities in part (a) that has the right units. Is your formula the only possible answer?
   (d) If the astronaut doubles the rate at which the ball is going around, what happens to the tension?

3. Sketch a graph of position as a function of time, velocity as a function of time, and acceleration as a function of time for each of the following situations. For each situation, draw the three graphs above each other, so that equal times correspond to the same position on the horizontal axis.
   (a) A car is initially going at a constant speed on a highway. It then speeds up to pass a truck, and then slows down to its original speed.
   (b) A raindrop falls from a cloud. It initially experiences only the force of gravity, but air resistance eventually causes it to approach a constant final velocity (‘terminal velocity’).
(c) A rubber ball is dropped from rest. It hits the floor and bounces several times. Each time it bounces, it’s maximum height is less than on the previous bounce.

4. A ball is dropped from rest from a tower that is 26 m high. One second later, a ball is thrown downward. With what speed must the second ball be thrown so that it hits the ground at the same time as the first ball?

5. A typical car has a maximum deceleration of 5 m/s², and the typical reaction time of a driver is 0.5 s. It is desired to set the speed limit so that a driver who sees a pedestrian 3 m away can stop in time to avoid hitting the pedestrian. What is the maximum safe speed under these assumptions?

6. A flower pot is observed to take 0.2 s to fall past a window that is 1.5 m high. From how far above the window did the flower pot drop?

7. Captain Kirk and Spock land on a mysterious planet whose gravitational pull is increasing steadily. In the space of 1 hour, Spock determines that the acceleration due to gravity at the planet’s surface has increased from 8.95 m/s² to 10.6 m/s². (Spock always gives numbers to 3 significant digits, and he always uses the metric system.) Spock makes the reasonable assumption that the increase of the gravitational acceleration is linear in time.

(a) According to Spock’s measurements and assumptions, find the the kinematic equations that replace the constant acceleration kinematic equations

\[ \Delta v = a_0 \Delta t, \quad \Delta x = v_i \Delta t + \frac{1}{2} a_0 \Delta t^2. \]  

Introduce symbols for all the quantities you need, and explain the meaning of these symbols.

(b) A rock is thrown upward with an initial speed of 20 m/s at an instant when the acceleration due to gravity is 8.95 m/s². What is its maximum height? How much higher or lower is this compared to the case where the acceleration due to gravity stays constant at 8.95 m/s²?

Study Problems

Chapter 1, Problems 21, 42
Chapter 2, Problems 39, 41, 96, 108, 111