Homework 4
Physics 1000
Preparatory Physics
Due: Friday February 7, 1997

Reading Assignment

Basic Technical Physics, by Tippens. Chapter 6, *Uniformly Accelerated Motion.*

Written Assignment

Displacement, Velocity, and Acceleration in 1D

Velocity

1. Which of the following statements indicate the difference(s) between speed and velocity in one dimension:

   (a) Speed is always greater than velocity.

   (b) Speed is always less than velocity.

   (c) Speed and velocity are always equal.

   (d) Speed is always equal to velocity or the negative of velocity.

   (e) Speed and velocity may be equal or may be unequal.

   Answer: Unfortunately, this question would be answered differently if you use the book's definition of speed or the one I introduced in class. You will get credit for this problem if you answer using either defition, but not both. Mine is that speed is the absolute value of velocity, where velocity is displacement divided by time of travel. With this definition, (d) and (e) are the right answers. The book's definition of speed is that speed is the total distance traveled divided by time of travel. In this case, (d) would not be true and the only true answer would be (e). With the book's definition of speed, in a round trip, for example, average velocity is 0 since total displacement is 0. However, speed would be the based on the total distance traveled, which is non-zero, and speed would be non-zero. Thus, in this example speed is neither equal to velocity or the negative of velocity. (Sorry if this confused you.)

2. A car is moving east at a constant velocity. Assume that we choose a coordinate system such that east is the positive direction and west is the negative.

   (a) Is the car's velocity positive or negative?

   Answer: Positive. Remember an object's velocity is positive if it is moving in the positive direction. In this case, the positive direction is east and that 's the direction the car is moving.

   (b) If we chose a coordinate system such that west is the positive direction and east is the negative direction, is the car's velocity positive or negative?

   Answer: Negative, since the car in moving in the negative direction.

3. Yes or No.

   (a) Can the result of adding two velocities be zero?

   Answer: Yes it can. Imagine a car travels with a velocity of 40 km/h in the east (positive) direction and then 40 km/h in the west (negative) direction. If you add these two velocities: $v_{\text{total}} = v_{\text{east}} + v_{\text{west}} = 40km/h - 40km/h = 0$.

   (a) Can the result of adding two speeds be zero?

   Answer: Yes it can, but only if both of the individual speeds are themselves 0.

4. A jet airliner flies from one airport to another 1,200 miles away in 2.5 h. What is its average speed in miles/hour?

   Answer: We don't specify direction of travel here, so we must assume here that speed is just total distance divided by time of travel: s = speed = 1,200 miles/2.5 h = 480 miles/h.

5. Communication satellites are stationed in geostationary orbits about 22,000 miles above the earth's surface. How long does it take a radio signal traveling at the speed of light (186,000 miles/s) to travel from the earth to the satellite and back in seconds? State your result in scientific notation.

   Answer: Again, no direction is specified, so we use the formula that s = speed = distance traveled/ time of travel = x/t. Thus, $t = x/s$ = 2(22,000 miles)/(186,000 miles/s) = 44,000 miles/(186,000 miles/s) = 0.24 s. Note that the distance traveled is not 22,000 miles but 2 × 22,000 miles, since the signal must travel up to the satellite and then back down again.

Acceleration

6. A car approaches a red light and brakes, slowing down. Displacement is positive in the direction of motion of the car. Is its acceleration positive or negative?

   Answer: The car is decelerating in the positive direction, thus this is a negative acceleration.

7. A baseball is thrown horizontally, it goes from 0 m/s to 40 m/s in 0.15 s. (Ignore the vertical motion of the baseball.)

   (a) What is the horizontal acceleration of the baseball?

   Answer: First, we need to define our coordinate system. Let the positive direction be in the direction of motion of the ball. The the initial velocity is $v_0 = 0$ m/s, the final velocity is $v = 40$ m/s, time elapsed during flight of the ball is $t - t_0 = 0.15$ s. Thus, acceleration, which is just the change in velocity divided by the elapsed time is:

$$a = \frac{\Delta v}{\Delta t} = \frac{v - v_0}{t - t_0} = \frac{(40 - 0)\text{m/s}}{0.15\text{s}} \sim 267\text{m/s}^2. \quad (1)$$

   Note the unit of acceleration: m/s^2.

(b) What is its acceleration in g's? (The g is the acceleration of gravity which is approximately equal to 9.8 m/s^2. So the question is, how many g's are there in the acceleration of the baseball.)

Answer: The g is a unit of acceleration like the radian or the degree is a unit of angular measure. Don't be confused, the g here does not mean grams. The g is a common unit when measuring the acceleration applied to pilots by an airplane. In steep turns, a pilot may be subjected to several g's. If subjected to about 8-10 g's (I think) the pilot would black out due to the draining of blood from the brain. The conversion factor is that there are 9.8 m/s^2/1 g. Thus, a = 267 m/s^2 (1 / 9.8 m/s^2) = 27.2 g.

8. A ball is dropped out of a window.

(a) Assume that we choose a coordinate system such that displacement downward is positive. Is the ball's acceleration positive or negative?

Answer: The ball is accelerating in the positive direction, thus acceleration is positive.

(b) Assume that we choose a coordinate system such that displacement downward is negative. Is the ball's acceleration positive or negative?

Answer: The ball is accelerating in the negative direction, thus acceleration is negative.

9. A ball is thrown upward with an initial speed of 20 m/s. It will continue to rise for about how long? (Hint: Think of it this way. How long before its speed will become zero? For the sake of this problem, assume that the acceleration of gravity is 10 m/s^2 in the downward direction.)

a. 1s

b. 2s

c. 3s

d. 4s

e. 8s

Answer: The answer is (b). Note that the definition of acceleration can be rewritten as follows:

$$a = \frac{v - v_0}{\Delta t} \rightarrow \Delta t = \frac{v - v_0}{a}. \tag{2}$$

where a is the ball's accleration which is constant in this problem, v is the velocity of the ball at the top of its trajectory, v_0 is the ball's initial velocity just as it leaves the thrower's hand, and Δt is the elapsed time. It is frequently convenient to define $t_0 = 0$ s, and then $\Delta t = t - t_0 = t$, so we get:

$$t = \frac{v - v_0}{a}. \tag{3}$$

Let the positive direction be up. In this case, initial velocity $v_0 = 20$ m/s. At the top of its trajectory, the ball is instantaneously stationary, thus $v = 0$ m/s. The acceleration of gravity points down with magnitude of 10 m/s^2, thus $a = -10\text{m/s}^2$. Substituting in equation (3) yields:

$$t = \frac{v - v}{a} = \frac{(0 - 20)\text{m/s}}{-10\text{m/s}^2} = 2\text{s}. \tag{4}$$

10. A ball is thrown upward from ground level with a speed of 20 m/s. About how long after it was thrown will the ball reach the ground? (Hint: The ball must go up and then down before it reaches the ground. For the sake of this problem, assume that the acceleration of gravity is 10 m/s^2 in the downward direction.)

    a. 1s

    b. 2s

    c. 4s

    d. 8s

    e. 16s

Answer: The answer is (c). The ball has to go up and then come down. We found in problem 9 that it takes 2 s to go up. Since it takes the same time to come down: $t_{total} = t_{up} + t_{down} = 2\text{ s} + 2\text{ s} = 4\text{s}$.