PS113 Chapter 2

Kinematics in one dimension

1 Displacement

- Displacement is defined as the vector drawn from an object's initial position toward its final position and has a magnitude that equals the shortest distance between the two positions. **SI unit of displacement:** meter (m)
- Displacement is: $\mathbf{\Delta x}$ where $\mathbf{\Delta x} = \mathbf{x} - \mathbf{x_o}$
- Examples of the displacement vector: $\mathbf{\Delta x}$

2 Speed and velocity

$$\text{Average speed} = \frac{\text{Distance}}{\text{Elapsed time}} \qquad \text{(a scalar quantity)}$$

$$\overline{v} = \frac{\text{distance}}{\Delta t}$$

$$\text{Average velocity} = \frac{\text{Displacement}}{\text{Elapsed time}} \qquad \text{(a vector quantity)}$$

$$\overline{\mathbf{v}} = \frac{\mathbf{x} - \mathbf{x_o}}{t - t_o} = \frac{\mathbf{\Delta x}}{\Delta t}$$

- **SI Units for velocity:** m/s
- Instantaneous velocity

$$\vec{\mathbf{v}} = \lim_{\Delta t \to 0} \frac{\mathbf{\Delta x}}{\Delta t}$$

- For brevity, we will use the word *velocity* to mean "instantaneous velocity" and *speed* to mean "instantaneous speed."

Problem 1. The Space Shuttle travels at a speed of about 7.6×10^3 m/s. The blink of an astronaut's eye lasts about 110 ms. How many football fields (length = 91.4 m) does the Shuttle cover in the blink of an eye? **Answer:** 9.15 football fields

3 Acceleration

- The velocity of a moving object may change during the course of its motion. To describe this change, we introduce the concept of *acceleration* as the change in velocity during a given time interval.

$$\text{Average acceleration} = \frac{\text{Change in velocity}}{\text{Elapsed time}} \qquad \text{(a vector quantity)}$$

$$\overline{\mathbf{a}} = \frac{\mathbf{v} - \mathbf{v_o}}{t - t_o} = \frac{\mathbf{\Delta v}}{\Delta t}$$

- **Note:** The change in velocity can be calculated from

$$\mathbf{\Delta v} = \overline{\mathbf{a}}\, \Delta t$$

- **Note:** Whenever the acceleration and velocity vectors have opposite directions, the object slows down and is said to be "decelerating."

Problem 17. A motorcycle has a constant acceleration of 2.5 m/s^2. Both the velocity and acceleration of the motorcycle point in the same direction. How much time is required for the motorcycle to change its speed from (a) 21 to 31 m/s, and (b) 51 to 61 m/s?

4 Equations of kinematics for constant acceleration

- It is now possible to describe the motion of an object traveling with a constant acceleration along a straight line.
- There are 5 kinematical quantities to identify:

  1. x the final position,
  2. v_o the initial velocity,
  3. v the final velocity,
  4. a the constant acceleration, and
  5. t the final time

- There are 4 kinematical equations to remember:

  1. $v = v_o + at$
  2. $x = \frac{1}{2}(v_o + v)t$
  3. $x = v_o t + \frac{1}{2}at^2$
  4. $v^2 = v_o^2 + 2ax$

- Each of these four equations contains four of the five kinematical quantities.
- Once you've identified three kinematical quantities, you can solve for the fourth by using the equation that contains those four kinematical quantities.
- **In order to master these equations,** you must solve many problems.

Problem 26. The 1999 VW Beetle goes from 0 to 60.0 mi/h with an acceleration of +2.35 m/s^2. (a) How much time does it take for the Beetle to reach this speed? (b) A top-fuel dragster can go froom 0 to 60.0 mi/h in 0.600 s. What is the acceleration (in m/s^2) of the dragster? **Answers:** 11.4 sec and 44.7 m/s^2

Problem 29. A jetliner, traveling northward, is landing with a speed of 69 m/s. Once the jet touches down, it has 750 m of runway in which to reduce its speed to 6.1 m/s. Compute the average acceleration (magnitude and direction) of the plane during landing.
Answer: -3.15 m/s^2 The negative sign means it's decelerating.

5 Applications of the equations of kinematics

- This section doesn't introduce any new equations but has many applications worked out in the form of examples. I encourage you to "work out" the examples to make sure you become familiar with the techniques.
- I also encourage you to read the section on *reasoning strategies* described on page 39. These techniques will help you set up and solve problems in kinematics.
- In the x direction, set up the kinematical quantities such that $x_o = 0$ when $t_o = 0$. Likewise, in the y direction, set up the kinematical quantities such that $y_o = 0$ when $t_o = 0$.

6 Freely falling bodies

- When discussing freely falling bodies, the motion of the object is confined to the y direction.
- The four equations (for constant acceleration) that were used in the x direction can now be applied to motion in the y direction. As a matter of convention, we will choose $+y$ to be in the upward direction.
- That means that the acceleration a will be written as $a = -g$, where $g = 9.8$ m/s^2. So, in the four kinematical equations up above (see section 4), you can replace all the *a's* with -*g's*. For example, the first equation becomes $v = v_o - gt$ in the y direction, and so on for the other equations.
- There are many examples in this section, and I encourage you to work them out. Everything you learned about using the 4 kinematical equations in the x direction is equally applicable in the y direction. The only difference is that for freely falling bodies near the surface of the earth, you can set the acceleration in the y direction to $a = -g$.

Problem 45. The drawing shows a device that you can make with a piece of cardboard, which can be used to measure a person's reaction time. Hold the card at the top and suddenly drop it. Ask a friend to try to catch the card between his or her thumb and index finger. Initially, your friend's fingers must be level with the asterisks at the bottom. By noting where your friend catches the card, you can determine his or her reaction time in milliseconds (ms). Calculate the distances d_1, d_2, and d_3.
$t_1 = 60.0$ ms $t_2 = 120$ ms and $t_3 = 180$ ms.
Answers: 1.76 cm 7.06 cm and 15.9 cm

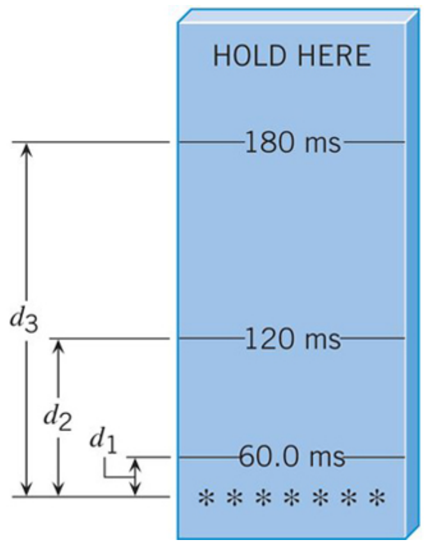

Figure 1: Figure for problem 45

Problem 49. A hot-air balloon is rising upward with a constant speed of 2.50 m/s. When the balloon is 3.00 m above the ground, the balloonist accidentally drops a compass over the side of the balloon. How much time elapses before the compass hits the ground?
Answer: 1.08 seconds.

Problem 68. A bus makes a trip according to the position-time graph shown in the drawing. What is the average velocity (magnitude and direction) of the bus during each of the segments labeled A, B, and C? Express your answer in km/h.

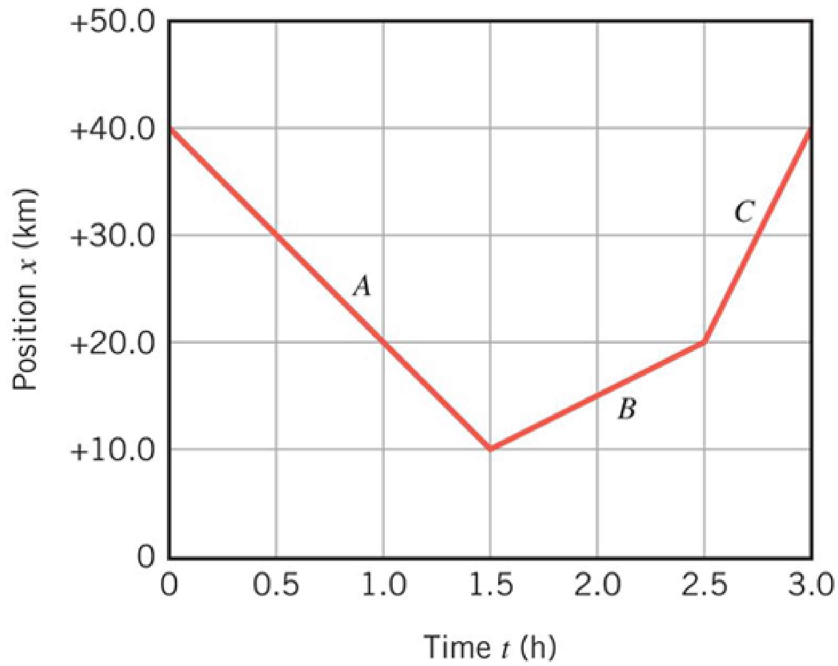

Figure 2: Figure for problem 68