

LECTURE 2

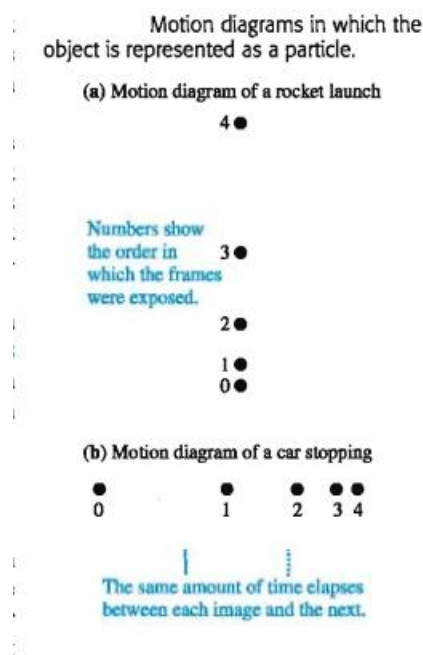
Concept of Motion

Motion Diagrams

Motion is defined as the change of an object's position with the time

The particle Model

For many objects, such as cars and rockets, the motion of the object *as a whole* is not influenced by the “details” of the object’s size and shape. To describe the object’s motion, all we really need to keep track of is the motion of a single point, such as a white dot painted on the side of the object.



STOP TO THINK 1.3

Three motion diagrams are shown. Which is a dust particle settling to the floor at constant speed, which is a ball dropped from the roof of a building, and which is a descending rocket slowing to make a soft landing on Mars?

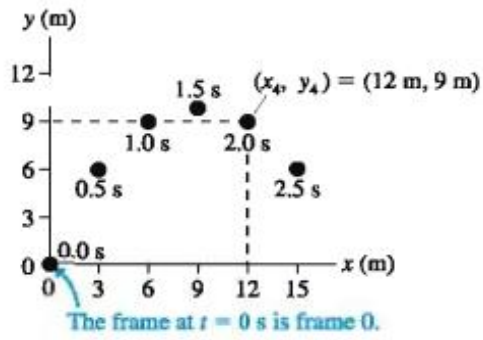
- (a) 0 ●
1 ●
2 ●
3 ●
4 ●
5 ●

- (b) 0 ●
1 ●
2 ●
3 ●
4 ●
5 ●

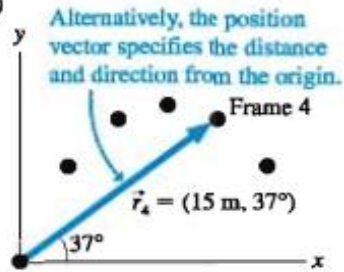
- (c) 0 ●
1 ●
2 ●
3 ●
4 ●
5 ●

FIGURE 1.5 Position and time measurements made on the motion diagram of a basketball.

(a)



(b)



Motion in One Dimension

As you've seen, an object's motion can be described in terms of three fundamental quantities: its position \vec{r} , velocity \vec{v} , and acceleration \vec{a} . These quantities are vectors, having a direction as well as a magnitude. But for motion in one dimension, the vectors are restricted to point only "forward" or "backward." Consequently, we can describe one-dimensional motion with the simpler quantities x , v_x , and a_x (or y , v_y , and a_y). However, we need to give each of these quantities an explicit *sign*, positive or negative, to indicate whether the position, velocity, or acceleration vector points forward or backward.

Determining the Signs of Position, Velocity, and Acceleration

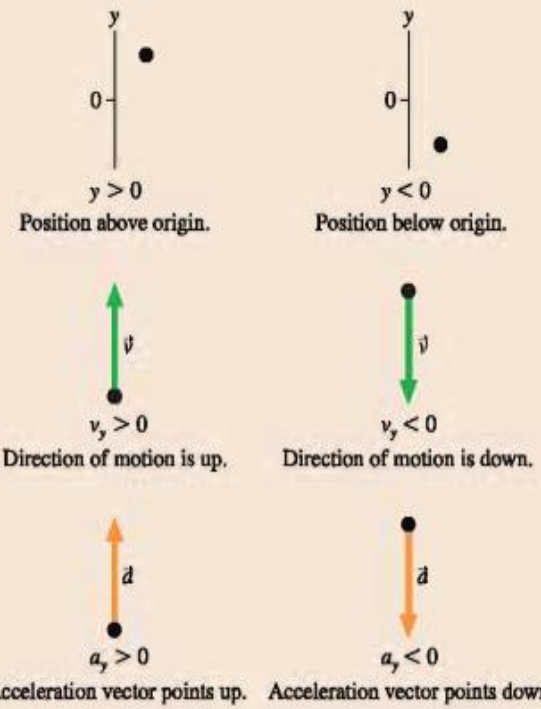
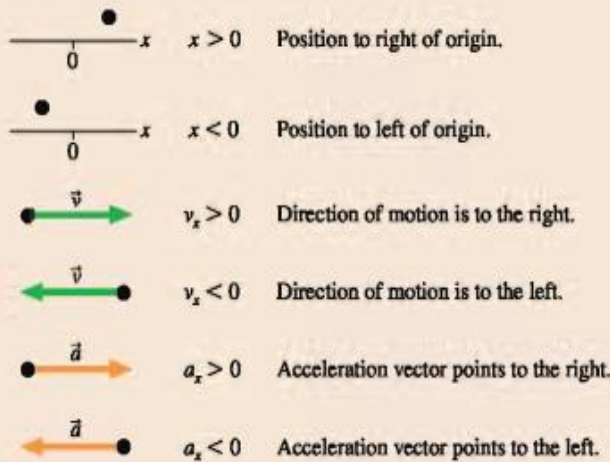
Position, velocity, and acceleration are measured with respect to a coordinate system, a grid or axis that *you* impose on a problem to analyze the motion. We will find it convenient to use an x -axis to describe both horizontal motion and motion along an inclined plane. A y -axis will be used for vertical motion. A coordinate axis has two essential features:

1. An origin to define zero; and
2. An x or y label to indicate the positive end of the axis.

We will adopt the convention that the **positive end of an x -axis is to the right and the positive end of a y -axis is up**. The signs of position, velocity, and acceleration are based on this convention.

TACTICS
BOX 1.4

Determining the sign of the position, velocity, and acceleration



- The sign of position (x or y) tells us *where* an object is.
- The sign of velocity (v_x or v_y) tells us *which direction* the object is moving.
- The sign of acceleration (a_x or a_y) tells us which way the acceleration vector points, *not* whether the object is speeding up or slowing down.

Acceleration was defined as $\vec{a}_{\text{avg}} = \Delta\vec{v}/\Delta t$. The direction of \vec{a} can be determined by using a motion diagram to find the direction of $\Delta\vec{v}$. The one-dimensional acceleration a_x (or a_y) is then positive if the vector \vec{a} points to the right (or up), negative if \vec{a} points to the left (or down).

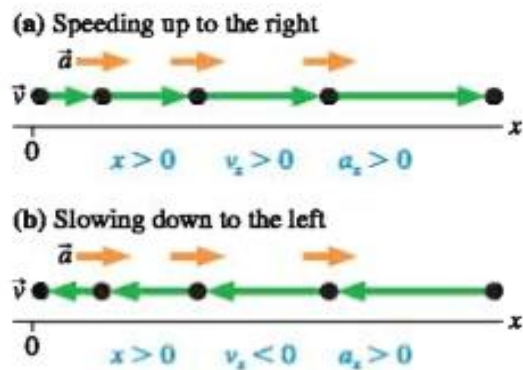
FIGURE 1.19 shows that this method for determining the sign of a does not conform to the simple idea of speeding up and slowing down. The object in Figure 1.19a has a positive acceleration ($a_x > 0$) not because it is speeding up but because the vector \vec{a} points to the right. Compare this with the motion diagram of Figure 1.19b. Here the object is slowing down, but it still has a positive acceleration ($a_x > 0$) because \vec{a} points to the right.

We found that an object is speeding up if \vec{v} and \vec{a} point in the same direction, slowing down if they point in opposite directions. For one-dimensional motion this rule becomes:

- An object is speeding up if and only if v_x and a_x have the same sign.
- An object is slowing down if and only if v_x and a_x have opposite signs.
- An object's velocity is constant if and only if $a_x = 0$.

Notice how the first two of these rules are at work in Figure 1.19.

FIGURE 1.19 One of these objects is speeding up, the other slowing down, but they both have a positive acceleration a_x .



Notice how the first two of these rules are at work in Figure 1.19.

Position-versus-Time Graphs

FIGURE 1.20 is a motion diagram, made at 1 frame per minute, of a student walking to school. You can see that she leaves home at a time we choose to call $t = 0$ min and makes steady progress for a while. Beginning at $t = 3$ min there is a period where the distance traveled during each time interval becomes less—perhaps she slowed down to speak with a friend. Then she picks up the pace, and the distances within each interval are longer.

FIGURE 1.20 The motion diagram of a student walking to school and a coordinate axis for making measurements.

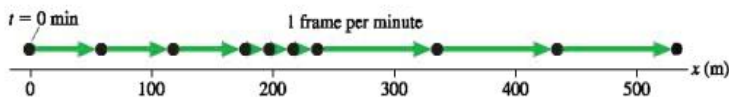


TABLE 1.1 Measured positions of a student walking to school

Time t (min)	Position x (m)
0	0
1	60
2	120
3	180
4	200
5	220
6	240
7	340
8	440
9	540

Figure 1.20 includes a coordinate axis, and you can see that every dot in a motion diagram occurs at a specific position. Table 1.1 shows the student's positions at different times as measured along this axis. For example, she is at position $x = 120$ m at $t = 2$ min.

The motion diagram is one way to represent the student's motion. Another is to make a graph of the measurements in Table 1.1. FIGURE 1.21a is a graph of x versus t for the student. The motion diagram tells us only where the student is at a few discrete points of time, so this graph of the data shows only points, no lines.

NOTE ▶ A graph of “ a versus b ” means that a is graphed on the vertical axis and b on the horizontal axis. Saying “graph a versus b ” is really a shorthand way of saying “graph a as a function of b .” ◀

However, common sense tells us the following. First, the student was *somewhere specific* at all times. That is, there was never a time when she failed to have a well-defined position, nor could she occupy two positions at one time. (As reasonable as this belief appears to be, it will be severely questioned and found not entirely accurate when we get to quantum physics!) Second, the student moved *continuously* through all intervening points of space. She could not go from $x = 100$ m to $x = 200$ m without passing through every point in between. It is thus quite reasonable to believe that her motion can be shown as a continuous line passing through the measured points, as shown in FIGURE 1.21b. A continuous line or curve showing an object's position as a function of time is called a **position-versus-time graph** or, sometimes, just a *position graph*.

FIGURE 1.21 Position graphs of the student's motion.

