Chapter Goal: To introduce the fundamental concepts of motion.

Making a Motion Diagram

- Consider an old-style movie of a moving object.
- Each separate photo is called a frame.
- The car is in a different position in each frame.

Making a Motion Diagram

- Imagine cutting individual frames of the filmstrip apart, and stacking them on top of each other.
- This composite photo shows an object’s position at several equally spaced instants of time.
- This is called a motion diagram.

The Particle Model

- Often we can treat the object as if all its mass were concentrated into a single point.
- A mass at a single point in space is called a particle.
- Below is a motion diagram of a car stopping, using the particle model.
Position as a Vector

- Shown is the motion diagram of a basketball, with 0.5 s intervals between frames.
- One way to locate the ball is to draw an arrow from the origin to the point representing the ball.
- You can then specify the length and direction of the arrow.
- This arrow is called the position vector $\mathbf{r}$ of the object.
- The position vector $\mathbf{r}$ is an alternative form of specifying position.
- Another way of specifying position is to use coordinates $(x, y)$.

Definition of Displacement

- The displacement $\Delta \mathbf{r}$ of an object as it moves from an initial position $\mathbf{r}_i$ to a final position $\mathbf{r}_f$ is
  \[ \Delta \mathbf{r} = \mathbf{r}_f - \mathbf{r}_i \]
- The definition of $\Delta \mathbf{r}$ involves vector subtraction.
- With numbers, subtraction is the same as the addition of a negative number.
- Similarly, with vectors $\mathbf{A} - \mathbf{B} = \mathbf{A} + (-\mathbf{B})$

Average Speed, Average Velocity

To quantify an object’s fastness or slowness, we define a ratio:

\[ \text{average speed} = \frac{\text{distance traveled}}{\text{time interval spent traveling}} = \frac{d}{\Delta t} \]

- Average speed is a scalar quantity (no direction information)
- The average velocity of an object during a time interval $\Delta t$, in which the object undergoes a displacement $\Delta \mathbf{r}$, is the vector:
  \[ \mathbf{v}_{\text{avg}} = \frac{\Delta \mathbf{r}}{\Delta t} \]
Sometimes an object’s velocity changes as it moves. Acceleration describes a change in velocity.

Consider an object whose velocity changes from \( \vec{v}_1 \) to \( \vec{v}_2 \) during the time interval \( \Delta t \).

The quantity \( \Delta \vec{v} = \vec{v}_2 - \vec{v}_1 \) is the change in velocity. The rate of change of velocity is called the average acceleration:

\[
a_{\text{avg}} = \frac{\Delta \vec{v}}{\Delta t}
\]

The Audi TT accelerates from 0 to 60 mph in 6 s.

When an object is speeding up, the acceleration and velocity vectors point in the same direction.

When an object is slowing down, the acceleration and velocity vectors point in opposite directions.

An object’s velocity is constant if and only if its acceleration is zero.

In the motion diagrams to the right, one object is speeding up and the other is slowing down, but they both have acceleration vectors toward the right.

Science is based on experimental measurements, and measurements require units.

The system of units in science is called le Système International d'unités or SI units.

The SI unit of time is the second, abbreviated s.

The SI unit of length is the meter, abbreviated m.

The SI unit of mass is the kilogram, abbreviated kg.

Many lengths, times, and masses are either much less or much greater than the standards of 1 m, 1 s, and 1 kg.

We use prefixes to denote various powers of 10, which make it easier to talk about quantities.
If you report a length as 6.2 m, you imply that the actual value is between 6.15 m and 6.25 m and has been rounded to 6.2.

The number 6.2 has two significant figures.

More precise measurement could give more significant figures.

The appropriate number of significant figures is determined by the data provided.

Calculations follow the “weakest link” rule: The input value with the smallest number of significant figures determines the number of significant figures to use in reporting the output value.

Problem: You travel 163.1 m in 120 s. What was your average speed?

\[
\frac{d}{t} = \frac{163.1 \text{ m}}{120 \text{ s}} = 1.359166667 \approx 1.4 \text{ m/s}
\]