Chapter 2
Describing Motion: Kinematics in One Dimension

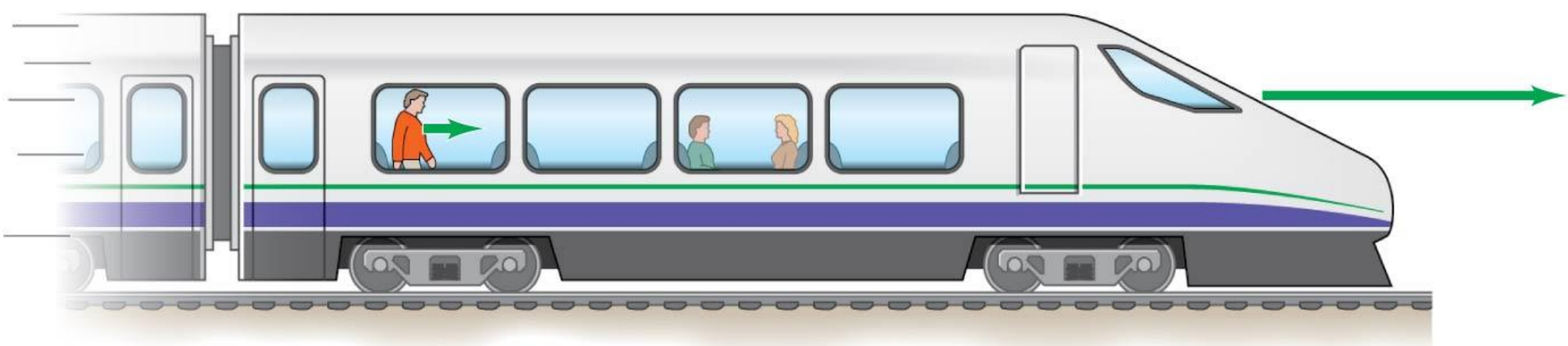
Contents of Chapter 2

- Reference Frames and Displacement
- Average Velocity
- Instantaneous Velocity
- Acceleration

2-1 Reference Frames and Displacement

Any measurement of position, distance, or speed must be made with respect to a reference frame.

For example, if you are sitting on a train and someone walks down the aisle, their speed with respect to the train is a few kilometers per hour, at most. Their speed with respect to the ground is much higher.

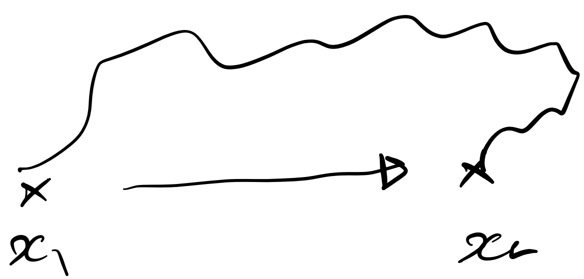


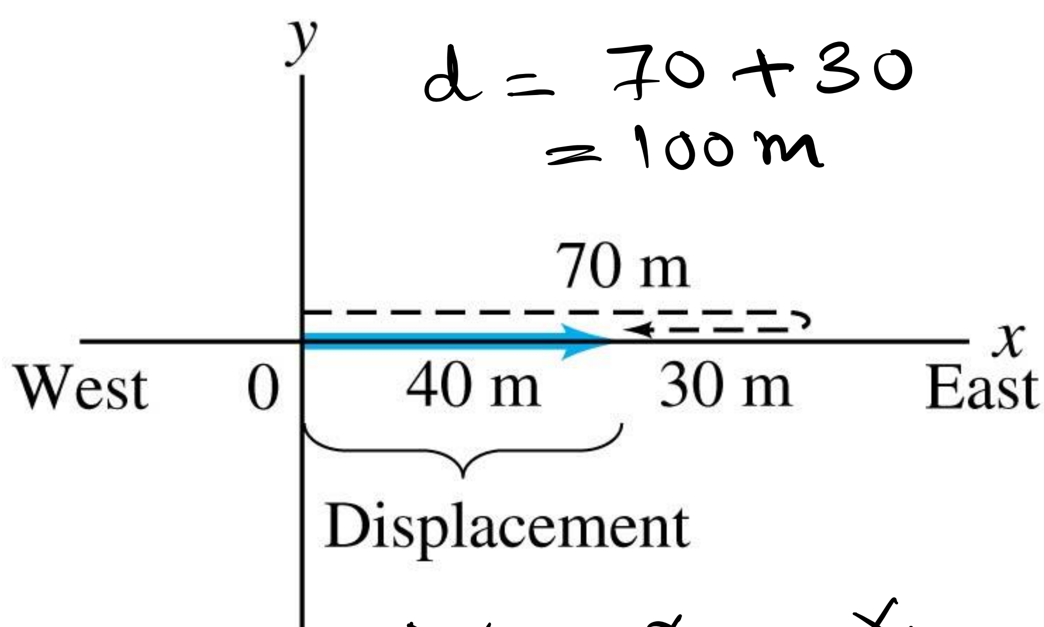
2-1 Reference Frames and Displacement

We make a distinction between distance and displacement.

Displacement (blue line) is how far the object is from its starting point, regardless of how it got there.

Distance traveled (dashed line) is measured along the actual path.





$d = 70 + 30$
$= 100\text{ m}$

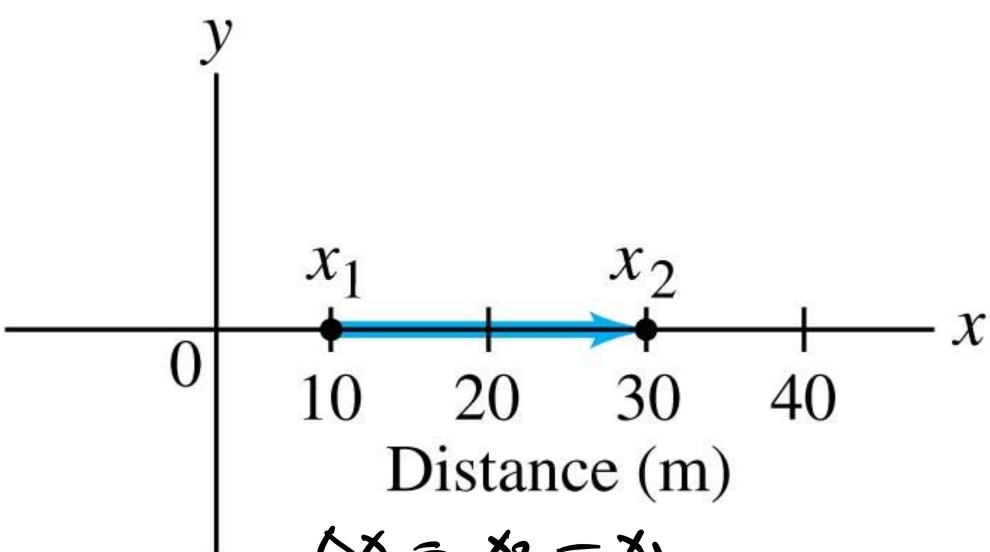
$\Delta x = x_2 - x_1$

= 40 − 0 = 40m

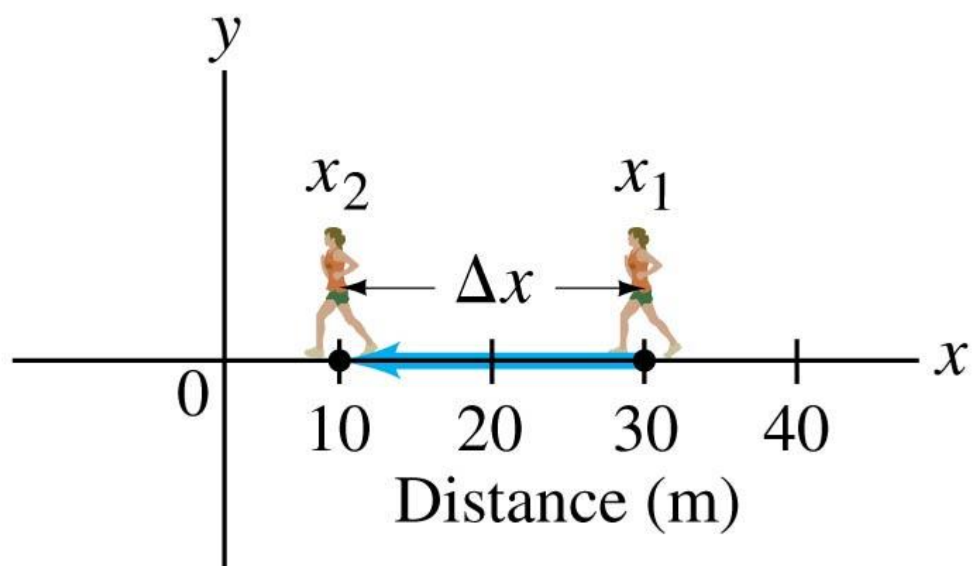
2-1 Reference Frames and Displacement

The displacement is written: $\Delta x = x_2 - x_1$

Left: Displacement is positive. Right: Displacement is negative.



$\Delta x = x_2 - x_1$
$= 30 - 10$
$= 20$ m



$\Delta x = x_2 - x_1$
$= 10 - 30$
$= -20$ m

2-2 Average Velocity

Speed: how far an object travels in a given time interval

v_{avg} = average speed $= \dfrac{\text{distance traveled}}{\text{time elapsed}}$ (2-1)

scalar

unit km/h m/s etc

Velocity includes directional information:

$\vec{v}_{avg}$

$$\text{average velocity} = \frac{\text{displacement}}{\text{time elapsed}} = \frac{\text{final position} - \text{initial position}}{\text{time elapsed}}.$$

vector quantity

unit km/h m/s

5. (I) A bird can fly 25 km/h. How long does it take to fly 3.5 km?

average speed

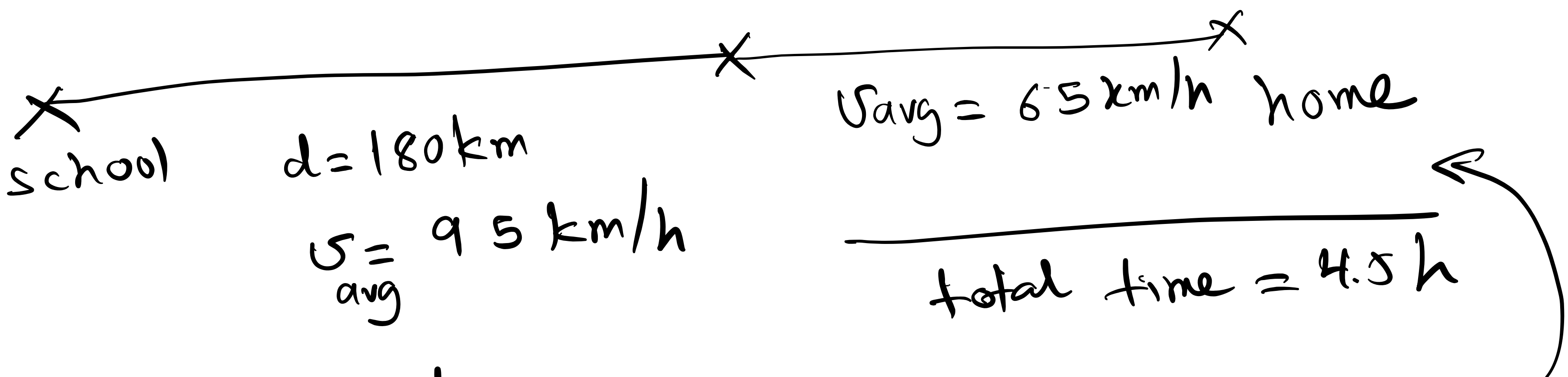
$$v_{avg} = 25\ km/h$$

$$d = 3.5\ km$$

$$v_{avg} = \frac{d}{t}$$

$$25 = \frac{3.5}{t} \Rightarrow t = \frac{3.5}{25} = 0.14\ h$$

7. (II) You are driving home from school steadily at 95 km/h for 180 km. It then begins to rain and you slow to 65 km/h. You arrive home after driving 4.5 h. (*a*) How far is your hometown from school? (*b*) What was your average speed?



$$v_{avg} = \frac{d}{t}$$

$$t = \frac{d}{v_{avg}} = \frac{180}{95} = 1.89\ h$$

$$t = 4.5\ h - 1.89\ h = 2.60\ h$$

$$d = 65 \times 2.60 = 169\ km$$

(a) $d_{tot} = 180 + 169 = 349\ km$

(b) $v_{avg} = \frac{349}{4.} = 77.5\ km/h$

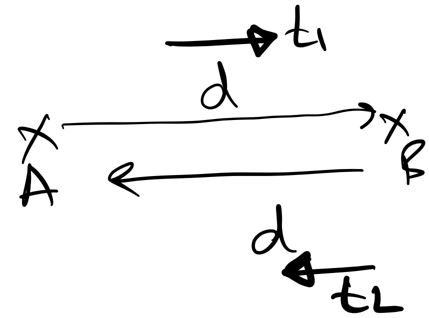
a particle moves from point A → B with average speed of 20 m/s and back to point A with average speed of 30 m/s.

(a) average velocity

(b) 〃 speed

(a) $\vec{v}_{avg} = \frac{\Delta x}{t} = \frac{0}{t} = 0$

(b) $v_{avg} = \frac{\text{distance}}{\text{time}}$



$$v_{avg} = \frac{d+d}{t_1+t_2}$$

$t_1 = \frac{d}{v_{avg1}}$ $\quad t_2 = \frac{d}{v_{avg2}}$

$$v_{avg} = \frac{2d}{\frac{d}{v_{avg1}} + \frac{d}{v_{avg2}}} = \frac{2}{\frac{1}{20} + \frac{1}{30}}$$

$\cong$ 24 m/s

9. (II) A person jogs eight complete laps around a 400-m track in a total time of 14.5 min. Calculate (*a*) the average speed and (*b*) the average velocity, in m/s.

total distance = $400 \times 8 = 3200\ m$

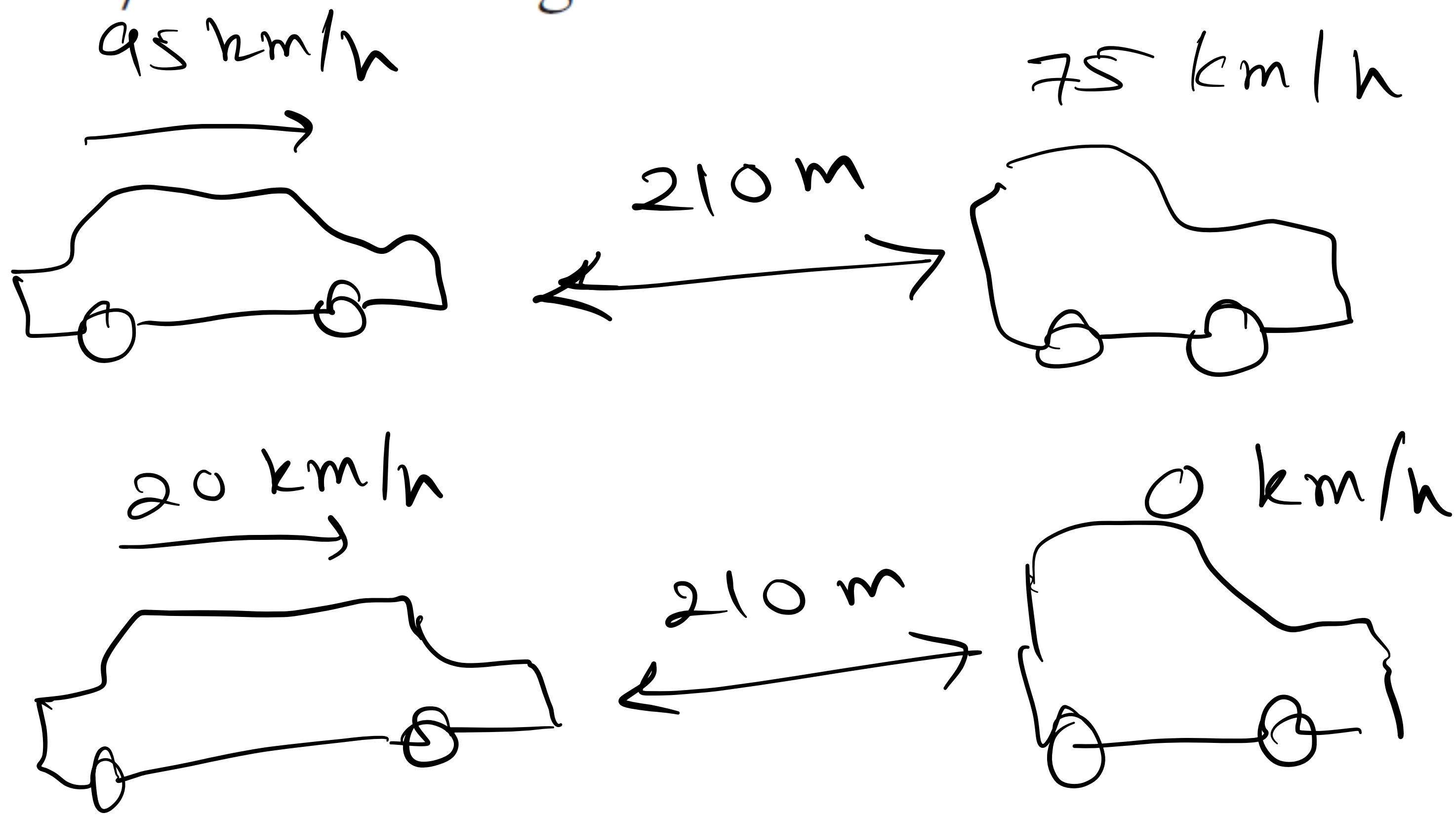
total time in seconds = 14.5×60

$= 870\ s$

(a) $v_{avg} = \frac{d}{t} = \frac{3200}{870} = 3.67\ m/s$

(b) $\vec{v}_{avg} = \frac{\Delta x}{t} = 0$

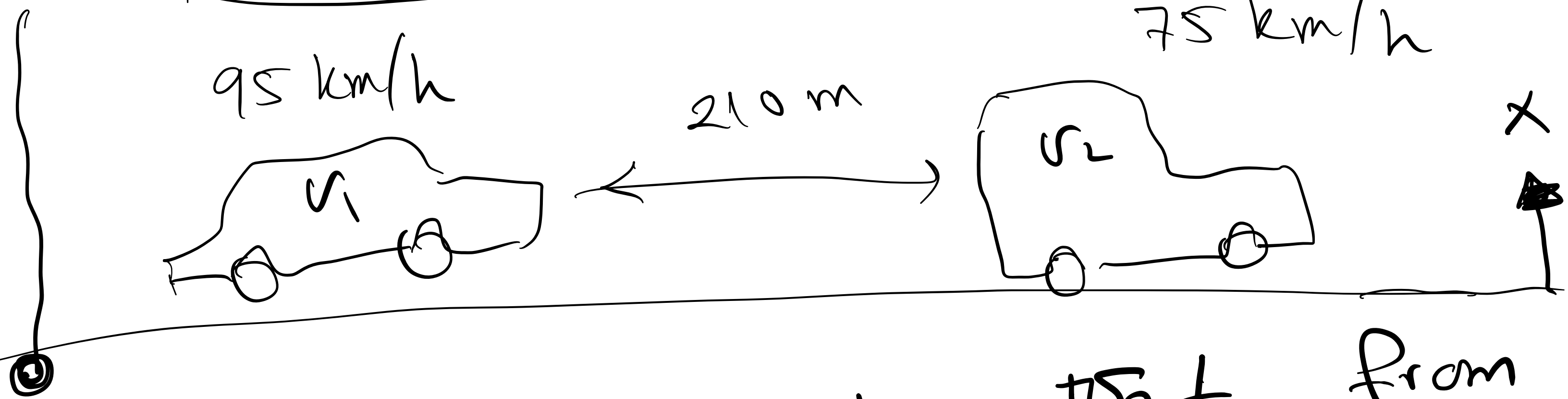
11. (II) A car traveling 95 km/h is 210 m behind a truck traveling 75 km/h. How long will it take the car to reach the truck?



$$v_{avg} = \frac{d}{t}$$

$$t = \frac{d}{v_{avg}} = \frac{210\text{ m}}{5.5} = 38.9\text{ s}$$

Another solution



x is at distance $210 + v_2 t$ from origin

$$d = v_1 t = 210 + v_2 t$$

$$v_1 = 95 \text{ km/h} \div 3.6 = 26.3$$

$$v_2 = 75 \text{ km/h} \div 3.6 = 20.8$$

$$26.3t = 210 + 20.8t$$

$$26.3t - 20.8t = 210$$

$$5.5t = 210$$

$$t = \frac{210}{5.5} = 38.9 \text{ s}$$

istantenous velocity ≡

~~is~~ instantenous velocity = velocity

= $\vec{v}$ = velocity at a certain moment

---

instantenous speed = speed

= v

= speed at certain moment

---

magnitude of velocity = speed

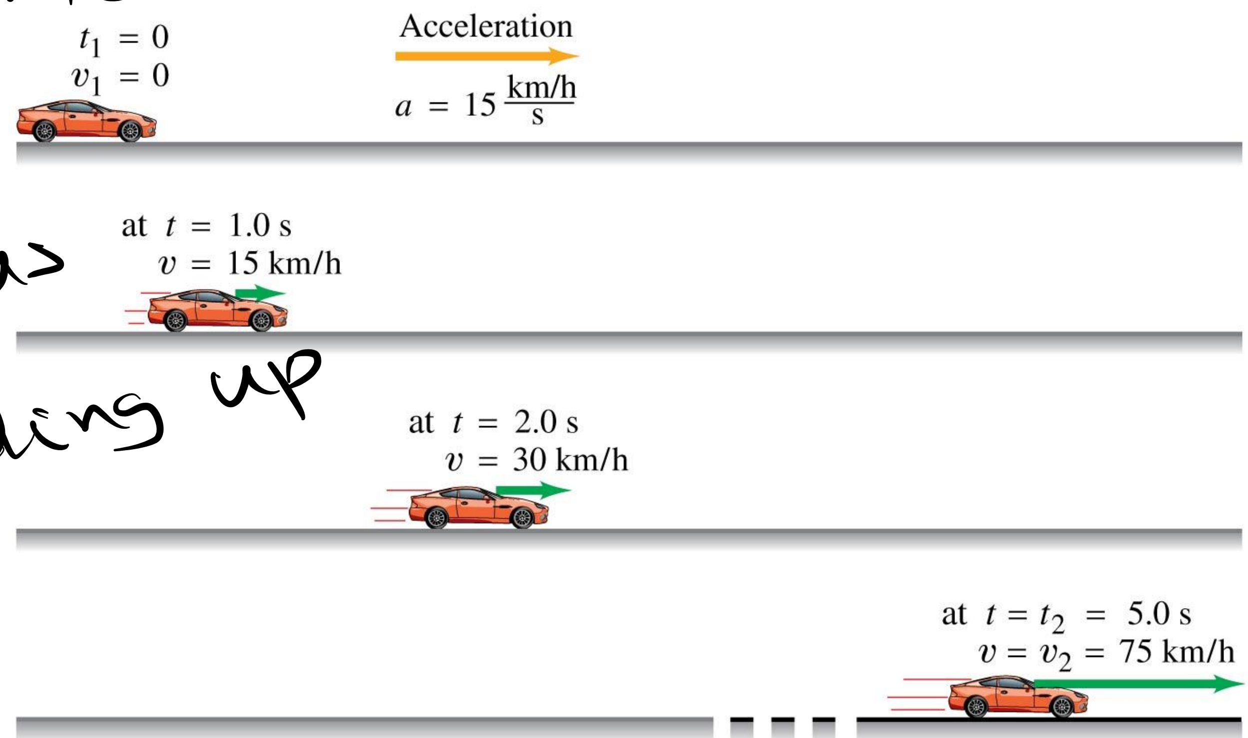
75 ÷ 3.6
= 20.8

2-4 Acceleration

Acceleration is the rate of change of velocity.

$$\text{average acceleration} = \frac{\text{change of velocity}}{\text{time elapsed}} = \frac{\vec{v}_2 - \vec{v}_1}{t}$$

unit m/s^2



direction of $\vec{a}$ is same as $\vec{v}$ ⇒ speeding up

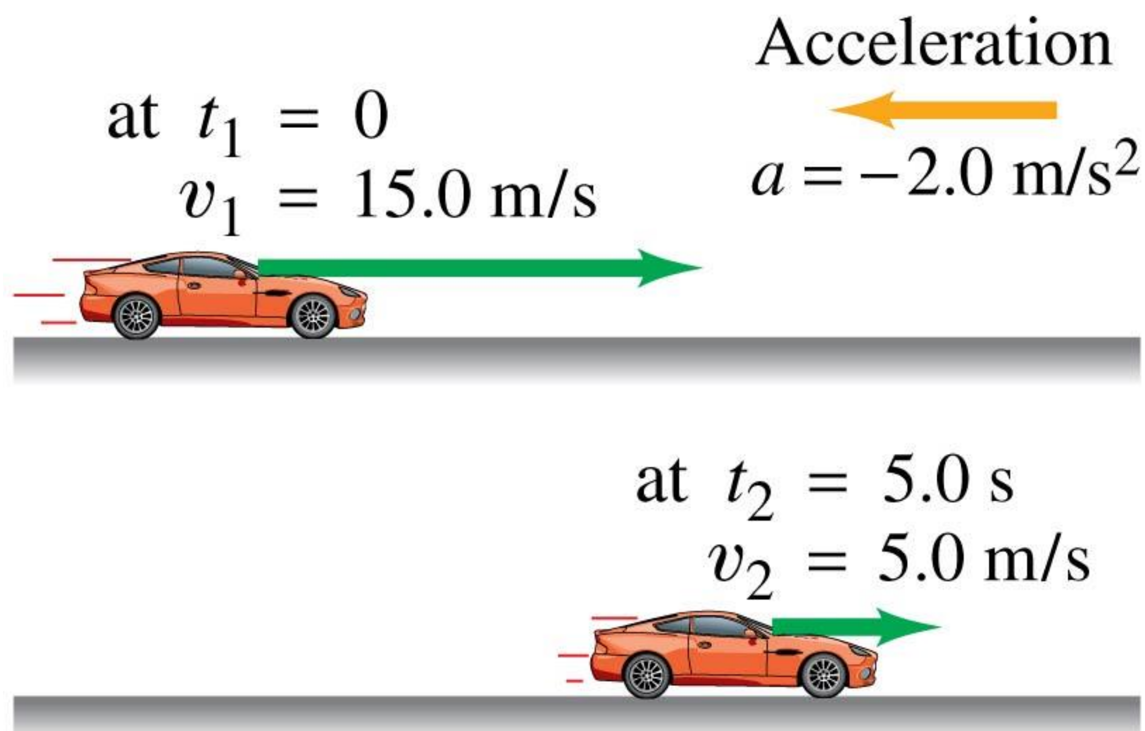
2-4 Acceleration

Acceleration is a vector, although in one-dimensional motion we only need the sign.

The previous image shows positive acceleration; here is negative acceleration:

direction of a is opposite to v

$\Rightarrow$ slowing down

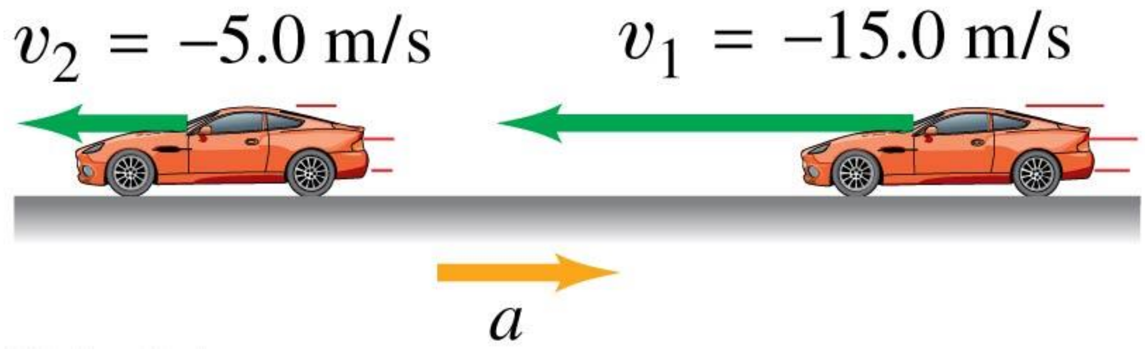


2-4 Acceleration

There is a difference between negative acceleration and deceleration:

Negative acceleration is acceleration in the negative direction as defined by the coordinate system.

Deceleration occurs when the acceleration is opposite in direction to the velocity.



17. (I) A sports car accelerates from rest to 95 km/h in 4.3 s. What is its average acceleration in m/s^2?

$\vec{v}_1$

$$\vec{a}_{avg} = \frac{\vec{v}_2 - \vec{v}_1}{t}$$

$\vec{v}_1 = 0$ (from rest)

$\vec{v}_2 = 95$ km/h

$= 26.3$

$$= \frac{26.3 - 0}{4.3}$$

$$= 6.11 \ m/s^2$$

20. (II) At highway speeds, a particular automobile is capable of an acceleration of about $1.8\ \mathrm{m/s^2}$. At this rate, how long does it take to accelerate from 65 km/h to 120 km/h?

$$\vec{v}_1 = 65\ \mathrm{km/h} = 18.1\ \mathrm{m/s}$$

$$\vec{v}_2 = 120\ \mathrm{km/h} = 33.3\ \mathrm{m/s}$$

$$\vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{t} =$$

$$1.8 = \frac{33.3 - 18.1}{t} = \frac{15.2}{t}$$

$$t = 8.5\ \mathrm{s}$$

21. (II) A car moving in a straight line starts at $x = 0$ at $t = 0$. It passes the point $x = 25.0\text{ m}$ with a speed of 11.0 m/s at $t = 3.00\text{ s}$. It passes the point $x = 385\text{ m}$ with a speed of 45.0 m/s at $t = 20.0\text{ s}$. Find (*a*) the average velocity, and (*b*) the average acceleration, between $t = 3.00\text{ s}$ and $t = 20.0\text{ s}$.

(a) $\vec{v}_{avg} = \frac{\Delta x}{t} = \frac{385 - 25}{17}$

$= 21.17\text{ m/s}$

(b) $\vec{a}_{avg} = \frac{\vec{v}_2 - \vec{v}_1}{t}$

$= \frac{45 - 11}{17} = 2\text{ m/s}^2$

Summary of Chapter 2

- Kinematics is the description of how objects move with respect to a defined reference frame.
- Displacement is the change in position of an object.
- Average speed is the distance traveled divided by the time it took; average velocity is the displacement divided by the time.
- Average acceleration is the change in velocity divided by time