Analyzing Motion

Position, Distance, & Displacement

- Position
  - The distance and direction an object is located from an origin
- Distance
  - How far an object travels
- Displacement
  - The difference between the final position and the initial position of the object

$$\Delta\vec{d} = d_{final} - d_{initial}$$

Example 1

- A car, starting at the origin, travels 5 km east and then 3 km west.
  - What is the final position of the car?
    - 2 km east
  - What is the displacement of the car?
    - 2 km east

Example 2

- John is standing 10 blocks east of his house. He walks 3 blocks east and 12 blocks west.
  - What is his final position in relation to the house?
    - 1 block east
  - What is his displacement?
    - 9 blocks west

Time

- Instant of time
  - Time at a particular moment
  - 10:32
- Interval of time
  - The difference between two times
  - 10 minutes

$$\Delta t = t_{final} - t_{initial}$$

Speed

- A measure of how fast an object is moving
- Does not take direction of travel into account
- The average speed is the total distance traveled divided by the total time for the trip

$$v_{av} = \frac{\Delta d}{\Delta t}$$

Example

- Jill skates a total distance of 4.5 km to school. She has to slow down twice to cross busy streets. The overall journey takes her 0.62 hours. What is Jill's average speed?

$$v_{av} = \frac{\Delta d}{\Delta t} = \frac{4.5\ \text{km}}{0.62\ \text{h}} = 7.3\ \text{kmh}^{-1}$$

Velocity

- Rate of change of displacement for an object
- Always includes a direction of travel
- The average velocity is the displacement divided by the total time for the trip

$$\vec{v}_{av} = \frac{\Delta \vec{d}}{\Delta t}$$

Example

- A car travels with a uniform velocity of 80 kmh^{-1} towards the north for 2.5 hours. What is the displacement of the car?

$$\vec{v}_{av} = \frac{\Delta \vec{d}}{\Delta t}$$

$$80\ \text{kmh}^{-1} = \frac{\Delta \vec{d}}{2.5\ \text{h}}$$

$$\Delta \vec{d} = 200\ \text{km north}$$

Uniform Motion

- If the velocity of an object remains the same for a period of time then we say it is moving with uniform (or constant) velocity.

Acceleration

- Change in velocity divided by the change in time

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

- So, we accelerate when we can…
  - Speed up
  - Slow down (sometimes called deceleration)
  - Change direction

Example

- A car starting from rest reaches a velocity of 100 kmh^{-1} in 5 s. What is the acceleration of the car?
  – First convert kmh^{-1} to ms^{-1}

$$100\,\text{kmh}^{-1}\left(\frac{1000}{3600}\right) = 27.78\,\text{ms}^{-1}$$

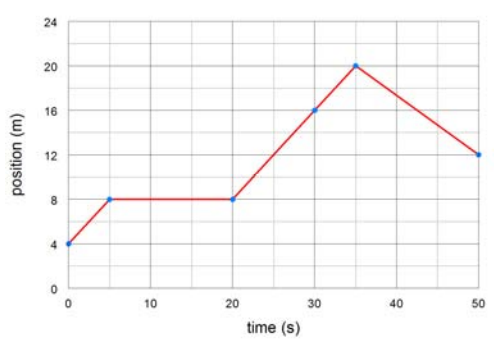
$$\vec{a}_{av} = \frac{\vec{v}_2 - \vec{v}_1}{\Delta t} = \frac{(27.78\,\text{ms}^{-1} - 0)}{5\,\text{s}} = 5.6\,\text{ms}^{-2}$$

Graphing

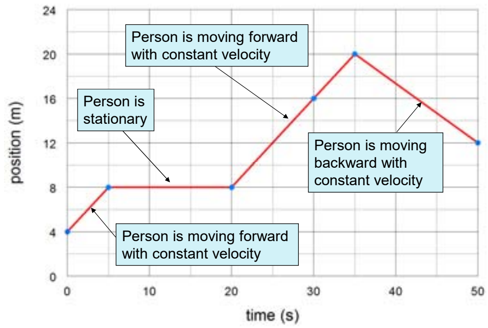
- The position of a person walking down the street is recorded in the following table.

Time (s)	Position (m)
0	4
5	8
20	8
30	16
35	20
50	12

- This gives us the following graph.



- We can use the graph to explain the person's motion



Calculating Velocity from a Position-Time Graph

- We can calculate the velocity (when it is uniform) by calculating the slope of the line on a position-time graph

$$slope = \frac{rise}{run}$$

Example

- Calculate the velocity from 0 to 4 s.

$$velocity = slope$$

$$velocity = \frac{rise}{run}$$

$$velocity = \frac{8-4}{4-0}$$

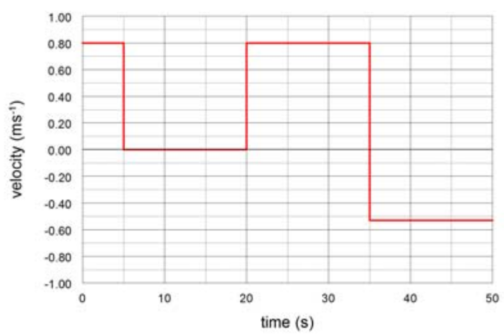
$$velocity = \frac{4}{4}$$

$$velocity = 1.0\ \text{ms}^{-1}$$

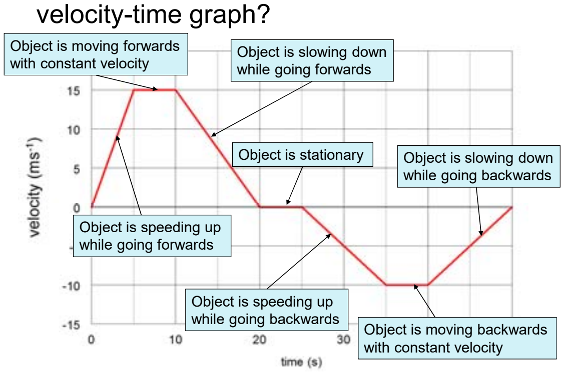
- Similarly, we can calculate the velocity for the other time intervals on the graph.

Time Interval (s)	Velocity (m/s)
0 – 5	0.8
5 – 20	0
20 – 30	0.8
30 – 35	0.8
35 – 50	-0.53

- This can be shown on the following velocity-time graph.

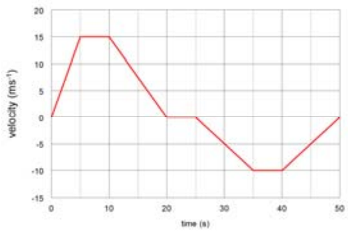


- What does acceleration look like on a velocity-time graph?



Example 1

- Calculate the acceleration from 10-20s given the following velocity-time graph.



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

$$\vec{a}_{av} = \frac{0 - 15}{20 - 10}$$

$$\vec{a}_{av} = -1.5 \text{ ms}^{-2}$$

- What does acceleration look like on a position-time graph?