# Kinematics

## Position, Distance & Displacement

- Position
  - Where the object is
- Distance
  - The total amount that the object has moved
- Displacement
  - The difference between the final position and the initial position of the object

## Velocity

- Speed and direction
- Defined as the displacement divided by time

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

## Acceleration

- How velocity changes with time
- Defined as the change in velocity divided by time

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$$

## A Note about Acceleration

- Acceleration can occur three ways:
  - Speeding up
  - Slowing down (sometimes called decelleration)
  - Changing direction

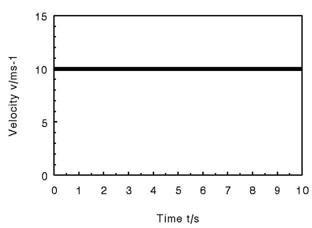
## A Note about Signs

- Velocity
  - Sign indicates direction
    - Positive = moving “forward”
    - Negative = moving “backward”

- Acceleration
  - Sign could indicate direction or whether the object is speeding up or slowing down
    - Positive - object speeding up while going forwards (++)
    - Negative - object speeding up while going backwards (+-)
    - Negative - object slowing down while going forwards (-+)
    - Positive - object slowing down while going backwards (--)

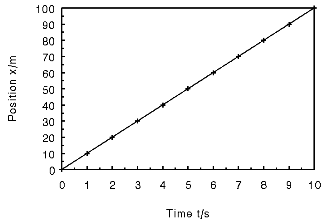
## Graphical Representation of Motion

- Consider a car traveling at a constant velocity of 10 m/s. If we were to draw a graph of velocity versus time, it would look like this:




- It is also useful to graph position versus time.
- We will make the decision that when t=0, our position, x, will be 0.
- Since the car is moving with constant velocity, we can easily calculate how far the car will have traveled in 1s, 2s, 3s, etc.

- Plotting this gives us the following graph:

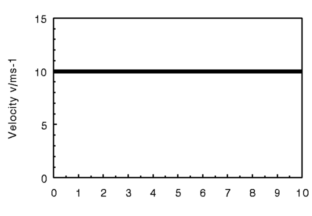



- What is the slope of this line?

$$\frac{\Delta x}{\Delta t} = \frac{90-10}{9-1} = \frac{80}{8} = 10\ m/s$$

- Notice that the slope calculation is exactly the same as our definition of velocity
- We can therefore conclude that the **slope of a position – time graph is velocity**

- Let's go back to our original velocity – time graph

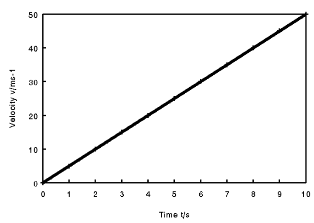



- Calculating the area under the curve gives:

$$v \times t = 10 \times 10 = 100\, m$$

- Notice that this gives us the total displacement of the car
- Therefore, the **area under a velocity – time graph is displacement**

- Now consider a car that constantly accelerates at a rate of 5 $m/s^2$ from a velocity of zero
- Graphing the velocity versus time gives us:

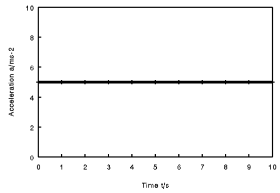



- Calculating the slope of this line gives us:

$$\frac{\Delta v}{\Delta t} = \frac{45-5}{9-1} = \frac{40}{8} = 5\, m/s^2$$

- Notice that this is exactly the same as acceleration
- We can therefore say that the **slope of a velocity – time graph is acceleration**

- Let's graph this car's acceleration versus time

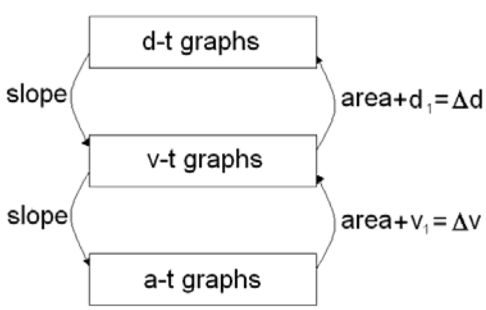



- Calculating the area under the curve gives us:

$$a \times t = 5 \times 10 = 50\ m/s$$

- Notice that the area gives us the final velocity of the car
- This means that the **area of an acceleration – time graph is velocity**

- We can summarize all of this as follows:



## Kinematic Equations

$$v_f = v_i + at$$

$$d = \left(\frac{v_i + v_f}{2}\right)t$$

$$d = v_i t + \tfrac{1}{2}at^2$$

$$v_f^2 = v_i^2 + 2ad$$