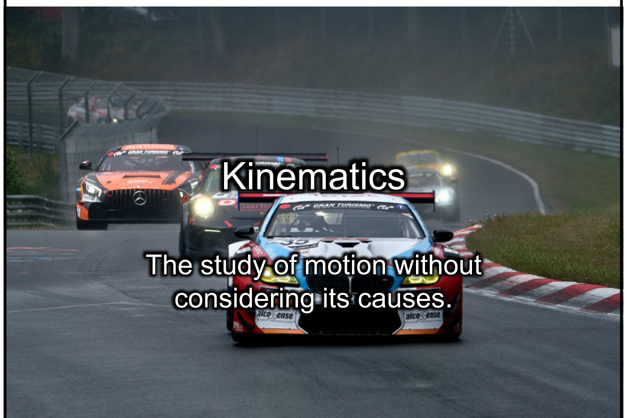


Displacement

- The change in position of an object.

$$\Delta d = d_f - d_i$$

where:
Δx is the displacement
d_f is the final position
d_0 is the initial position

Velocity

- **Average velocity** is displacement (change in position) divided by the time of travel.

$$\bar{v} = \frac{\Delta d}{\Delta t} = \frac{d_f - d_i}{t_f - t_i}$$

Where:
$\bar{v}$ is the average velocity
x is the displacement
t is the time

- The average velocity of an object does not tell us anything about what happens to it between the start and end points.
- The motion needs to be divided into smaller intervals to get more detailed information.
- **Instantaneous velocity**, v, is the average velocity at a specific instant in time (or over an infinitesimally small time interval).

Speed

- **Average speed** is the distance traveled divided by elapsed time.
- **Instantaneous speed** is the magnitude of instantaneous velocity.

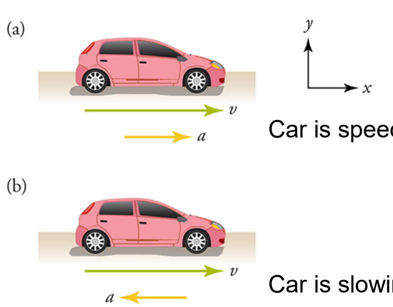
Acceleration

- **Average acceleration** is the rate at which velocity changes.

$$\bar{a} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_0}{t_f - t_0}$$

Where:
$\bar{a}$ is the average acceleration
v is the velocity
t is the time

- Acceleration is a vector in the same direction as the change in velocity.
- Since velocity is a vector, it can change either in magnitude or in direction.
- Acceleration is therefore a change in either speed or direction, or both.
- When an object's acceleration is in the same direction of its motion, the object will speed up.
- When an object's acceleration is opposite to the direction of its motion, the object will slow down.

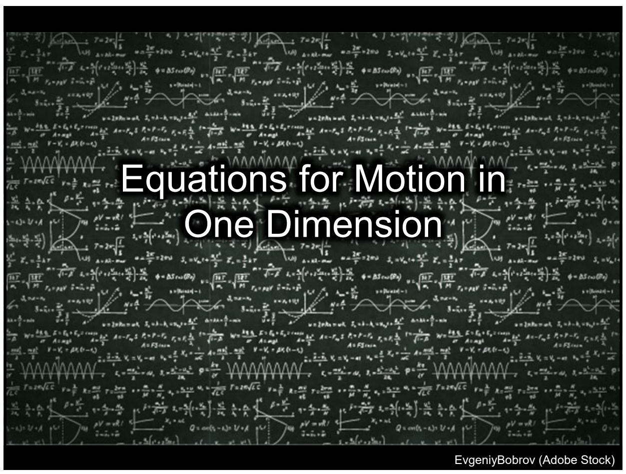


Car is speeding up

Car is slowing down

Image credit: Urone, Paul Peter, and Roger Hinrichs . "Defining Acceleration." In *Physics*. Houston, TX: OpenStax, 2020. https://openstax.org/books/physics/pages/3-1-acceleration (Creative Commons Attribution License 4.0)

One Dimensional Motion



- The motion of an object can be described mathematically by using equations showing the displacement, velocity, and acceleration of an object at a given time.
  - Notation and assumptions:
    - $t_i = 0$, so t will represent the final time.
    - $d_i = 0$, so d will represent the final position
    - Motion will be in one dimension
    - Velocity will be represented as follows:
      - v_i, v_f – initial and final velocity
    - Acceleration is constant
      - $\bar{a} = a = \text{constant}$

- Rearranging the equations defining velocity.

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

For constant acceleration

$$\bar{v} = \frac{v_i + v_f}{2}$$

$$\frac{v_i + v_f}{2} = \frac{d}{t}$$

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

- Rearranging the equations defining acceleration.

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

$$a = \frac{v_f - v_i}{t}$$

$$\boxed{v_f = v_i + at}$$

- Solve the first equation for position, make the two equations equal to each other and solve for d.

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

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

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

- Solve the second equation for time and substitute it into the first equation.

$$v_f = v_i + at$$

$$t = \frac{v_f - v_i}{a}$$

$$v_f = 2a\left(\frac{d}{v_f - v_i}\right) - v_i$$

- Rearrange the equation

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

$$(v_f + v_i)(v_f - v_i) = 2ad$$

$$v_f^2 - v_i^2 = 2ad$$

$$\boxed{v_f^2 = v_i^2 + 2ad}$$

The Kinematic Equations

$$v_f = v_i + at$$

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

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

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

Vertical Motion

OpenClipart - Vectors

- When air resistance is not a factor, **all** objects near Earth's surface fall with an acceleration of about 9.8 m/s^2.
- The value of 9.8 m/s^2 is labeled **g** and is referred to as the **acceleration due to gravity**.
- Since gravity pulls objects towards the earth's surface, this acceleration is **always** down (negative).