Acceleration

Acceleration (a vector quantity) is the rate at which an object changes its velocity.

Anytime an object's velocity is changing, it is accelerating whether or not it is speeding up, slowing down, and/or changing directions.

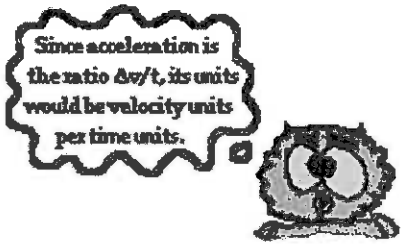
Average Acceleration

The average acceleration ($\overrightarrow{a_{av}}$) of any object over a given interval of time (t) can be calculated using the equation

$$Ave.\ acceleration, \overrightarrow{a_{av}} = \frac{\Delta velocity}{\Delta time} = \frac{\overrightarrow{v_f} - \overrightarrow{v_i}}{t_f - t_i}$$

Acceleration is expressed in units of velocity/time.
Typical acceleration units include:

- m/s/s
- mi/hr/s
- km/hr/s
- m/s^2



Ex: 1. The velocity of a train increases from 3.0 m/s at 2.0 s to 18 m/s at 6.8 s. What is the train's average acceleration?

Given: $v_i = 3.0\ m/s\ [str]$ need: $\vec{a}_{av}$
$v_f = 18\ m/s\ [str]$
$t_i = 2.0\ s$
$t_f = 6.8\ s$

$$\vec{a}_{av} = \frac{\vec{v}_f - \vec{v}_i}{t_f - t_i} = \frac{18 - 3\ m/s}{6.8 - 2\ s}$$

$\vec{a}_{av} = 3.1\ m/s^2\ [straight]$

Ex: 2. A car slams on its brakes and reduces its velocity from 30.0 m/s to 0.0 m/s in 4.0 s. What is the average acceleration?

Given: $v_i = 30.0\ m/s\ [str]$ need: $\vec{a}_{av}$
$v_f = 0\ m/s$
$\Delta t = 4.0\ s$

$$\vec{a}_{ave} = \frac{\vec{v}_f - \vec{v}_i}{\Delta t} = \frac{0 - 30\ m/s}{4\ s}$$

$\vec{a}_{av} = -7.5\ m/s^2\ [straight]$

Ex: 3. If a snowboarder is travelling at 8.0 m/s, how long will it take her to reach 36.0 m/s if she can accelerate at a rate of 3.5 m/s^2?

Given: $v_i = 8.0\,m/s\ [stn]$
$v_f = 36\,m/s\ [stn]$
$\vec{a} = 3.5\,m/s^2\ [stn]$

Need: Δt

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

$$\Delta t = \frac{\Delta \vec{v}}{\vec{a}} = \frac{\vec{v}_f - \vec{v}_i}{\vec{a}}$$

$$= \frac{36 - 8\,m/s}{3.5\,m/s^2}$$

$$t = 8.0\,s$$

Direction of the Acceleration Vector

Since acceleration is a vector quantity, it has a direction associated with it. The direction of the acceleration vector depends on:

1. whether the object is speeding up or slowing down

2. whether the object is moving in the +ve or -ve direction
   - Remember that: North, south, east, west, right, left, up and down are all directions
     - up or to the right are often positive
     - down or to the left are negative.

The general principle for determining the acceleration is:

- If an object is slowing down, then its acceleration is in the opposite direction of its motion.

Example A

Time (s)	Velocity (m/s)
0	0
1	2
2	4
3	6
4	8

Example B

Time (s)	Velocity (m/s)
0	-8
1	-6
2	-4
3	-2
4	0

These are both examples of positive acceleration.

Example C

Time (s)	Velocity (m/s)
0	8
1	6
2	4
3	2
4	0

Example D

Time (s)	Velocity (m/s)
0	0
1	-2
2	-4
3	-6
4	-8

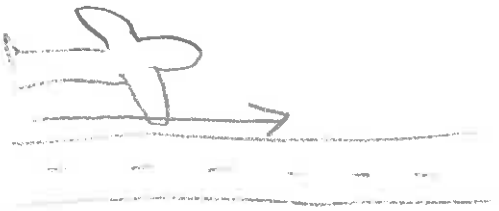
These are both examples of negative acceleration.

Ex: 4. Determine the direction of each vector.

	Velocity	Acceleration
A car sitting at a stop light hits the gas	+	+
From rest you back out of your driveway	−	−
A plane lands and comes to a stop	+	−
You drop a rock off a cliff	−	−
You throw a rock straight up	+	−

* Important to understand: Negative accelerations do not refer to acceleration values that are less than 0. An acceleration of -2 m/s/s is an acceleration with a magnitude of 2 m/s/s that is directed in the negative direction. *

eg.



let → be +ve

so v_i is +

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

$$= \frac{0\,km/h - 50\,km/h}{7s}$$

$$= -7.14\,km/h/s$$