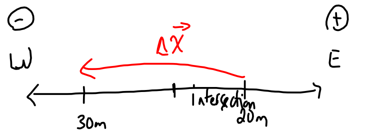
Displacement.

Example

A car starts from a position 20m east of an intersection and stops 30m west of the intersection.

a) what distance does it travel?

b) what is its displacement?



a) $d = 50m$

b) $\Delta\vec{x} = \vec{x}_2 - \vec{x}_1$

$\Delta\vec{x} = -30m - 20m$

$\Delta\vec{x} = -50m$

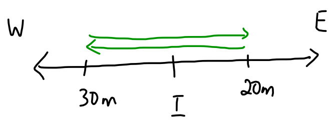
$\Delta\vec{x} = 50m\,[W]$

Example

A car starts from a position 20m east of an intersection, travels to a position 30m west of the intersection, and then returns to its original position 20 m east of the intersection.

a) what distance did the car travel?

b) what is the displacement?



a) $d = 100m$

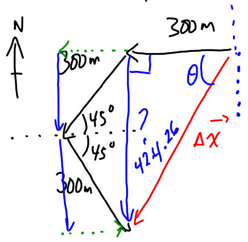
b) $\Delta\vec{x} = 0$

Example

A car travels 300m west, then 300m southwest, then 300m south east.

a) what distance does it travel? 900m

b) what is its displacement?



$c^2 = a^2 + b^2$

$c^2 = (300m)^2 + (300m)^2$

$c = 424.26\,m$

$c^2 = a^2 + b^2$

$c^2 = (300m)^2 + (424.26m)^2$

$c = 519.615\,m$

$\tan\theta = \frac{424.26}{300}$

$\theta = 54.7°$

The displacement is: $5.20 \times 10^2\,m$ [W 54.7° S]

215° T

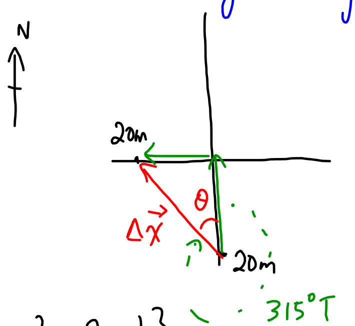
Speed and Velocity

Example

A car starts from a position 20 m south of an intersection, travels north until it reaches the intersection, and then travels west to a position 20 m west of the intersection, in a time of 10 s.

a) What is its average speed?

b) What is its average velocity?



$c^2 = a^2 + b^2$

$c^2 = (20\,m)^2 + (20\,m)^2$

$c = 28\,m$

a) $V_{ave} = \dfrac{d}{\Delta t}$

$V_{ave} = \dfrac{40\,m}{10\,s}$

$V_{ave} = 4\,ms^{-1}$

b) $\vec{V}_{ave} = \dfrac{\Delta \vec{x}}{\Delta t}$

$\vec{V}_{ave} = \dfrac{28\,m\ [N45°W]}{10\,s}$

$\vec{V}_{ave} = 2.8\,ms^{-1}\ [N45°W]$

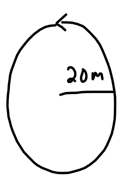
315°T

Example

A girl on a bicycle rides once around a circle of radius 20 m, arriving at her starting position after 15.0 s.

a) What is her average speed?

b) What is her average velocity?



$\Delta t = 15.0\,s$

a) $V_{ave} = \dfrac{d}{\Delta t}$

$V_{ave} = \dfrac{2\pi r}{\Delta t}$

$V_{ave} = \dfrac{2\pi (20\,m)}{15.0\,s}$

$V_{ave} = 8.4\,ms^{-1}$

b) $\vec{V}_{ave} = 0$

Acceleration

Acceleration occurs if the speed and/or direction changes during a given time interval.

Examples

- a car moves off in a straight line from the traffic lights.
- a car slows down + stops at the lights
- a car travels at a constant speed around a circle.
- a car moves faster + faster around a circle
- a car slows down, stops, reverses and gets faster + faster going backwards.

Example

A car increases its velocity from 30 ms^{-1} east ($\vec{v}_1$) to 40 ms^{-1} east ($\vec{v}_2$) in 5.0 s (Δt). What is its acceleration?

$\vec{v}_1 = 30 ms^{-1}$ east

$\vec{v}_2 = 40 ms^{-1}$ east

$\Delta t = 5.0 s$

$a = ?$

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

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

$$\vec{a} = \frac{40 ms^{-1} \text{ east} - 30 ms^{-1} \text{ east}}{5.0 s}$$

these must be the same to subtract numerically.

$$\vec{a} = \frac{10 ms^{-1} \text{ east}}{5.0 s}$$

$$\vec{a} = 2.0 ms^{-2} \text{ east}$$

Example

A car decreases it velocity from 40 ms^{-1} east ($\vec{v}_i$) to 30 ms^{-1} east ($\vec{v}_2$) in 5.0 s (Δt). What is its acceleration?

$\vec{v}_1 = 40\ ms^{-1}$ east

$\vec{v}_2 = 30\ ms^{-1}$ east

$\Delta t = 5.0 s$

$\vec{a} = ?$

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

$$\vec{a} = \frac{30\ ms^{-1}\ east - 40\ ms^{-1}\ east}{5.0 s}$$

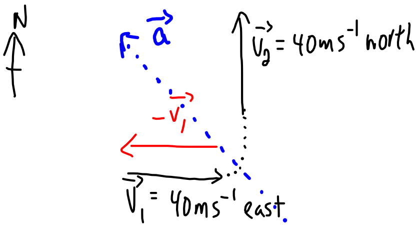
$$\vec{a} = \frac{-10\ ms^{-1}\ east}{5.0 s}$$

$$\vec{a} = -2.0\ ms^{-2}\ east$$

or 2.0 ms^{-2} west.

Example

A car changes its velocity from 40 ms^{-1} east ($\vec{v}_1$) to 40 ms^{-1} north ($\vec{v}_2$) in 5.0 s. What is its acceleration?



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

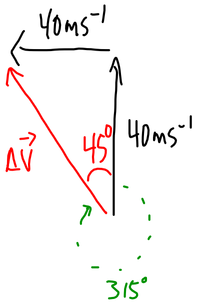
$$\vec{a} = \frac{40\ ms^{-1}\ north - 40\ ms^{-1}\ east}{5.0 s}$$

(vector subtraction)

$\Delta \vec{v} = \vec{v}_2 - \vec{v}_1$

$\Delta \vec{v} = \vec{v}_2 + (-\vec{v}_1)$

$\Delta \vec{v} = 40\ ms^{-1}$ north + 40 ms^{-1} west



$c^2 = a^2 + b^2$

$c^2 = (40 ms^{-1})^2 + (40 ms^{-1})^2$

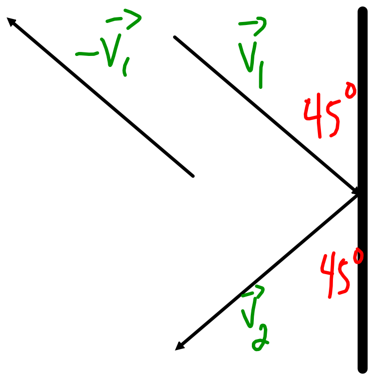
$c \doteq 57\ ms^{-1}$

$\therefore \Delta \vec{v} = 57\ ms^{-1}$ [NW] ← or 315°T

$$\vec{a} = \frac{57\ ms^{-1}\ [NW]}{5.0 s}$$

$\vec{a} \doteq 11\ ms^{-2}$ [NW]

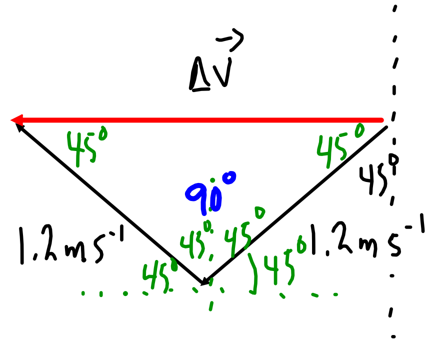
Example:
A billiard ball travelling at 1.2 m s^{-1} bounces off the edge of the table with no change in speed, with directions as shown below. The ball is in contact with the edge of the table for 5.0 x 10^{-3} s. What is the acceleration of the billiard ball?



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

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

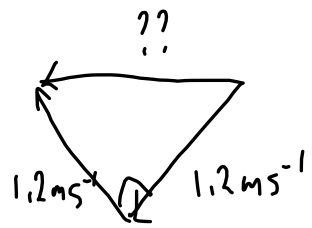
$\vec{a} = \frac{\vec{v}_2 + (-\vec{v}_1)}{\Delta t}$



$c^2 = a^2 + b^2$

$c^2 = (1.2)^2 + (1.2)^2$

$c = 1.7 \text{ m s}^{-1}$



$\vec{a} = \frac{1.7 \text{ m s}^{-1}}{5.0 \times 10^{-3} \text{ s}}$ [directly away from table edge]

$\vec{a} \doteq 3.4 \times 10^{2} \text{ m s}^{-2}$ [directly away from the table edge]