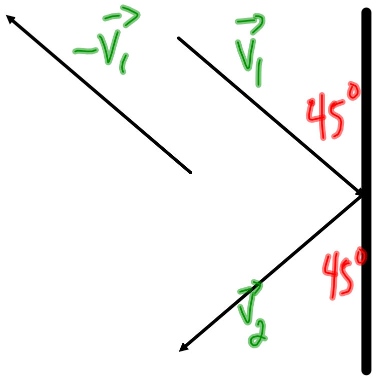
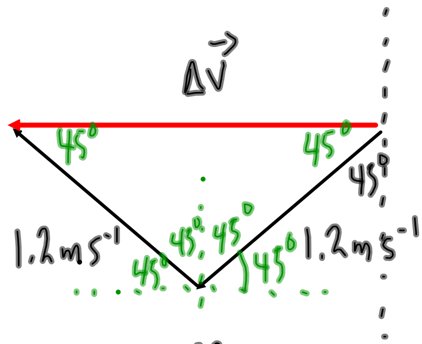
Example:
A billiard ball travelling at 1.2 m s^{-1} bounces off the edge of the table with no change in speed, with directions as shown below. The ball is in contact with the edge of the table for 5.0 x 10^{-3} s. What is the acceleration of the billiard ball?

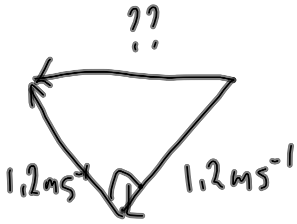


Recall: $\vec{a} = \dfrac{\Delta \vec{v}}{\Delta t}$

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

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





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

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

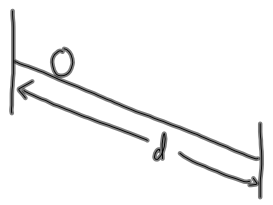
$$c = 1.7 \text{ m s}^{-1}$$

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

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

Average Speed

Consider a ball rolling down an incline.



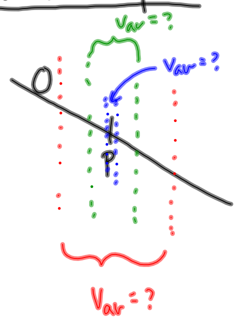
When you divide $d/\Delta t$ you get:

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

since the speed is not constant.

Average speed is the ratio of the distance travelled to the time interval over which the body moves that distance.

Instantaneous Speed



Think of the instantaneous speed as the average speed when the distance travelled is almost zero and the time interval to travel that distance is almost zero

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

$$V_{ave} = \frac{0}{0}$$

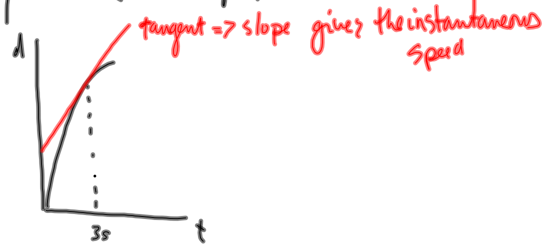
As the distance (and time interval) gets closer to zero, the average velocity will be closer to the instantaneous velocity.

The problem is that this is undefined.

Mathematically, we can express this:

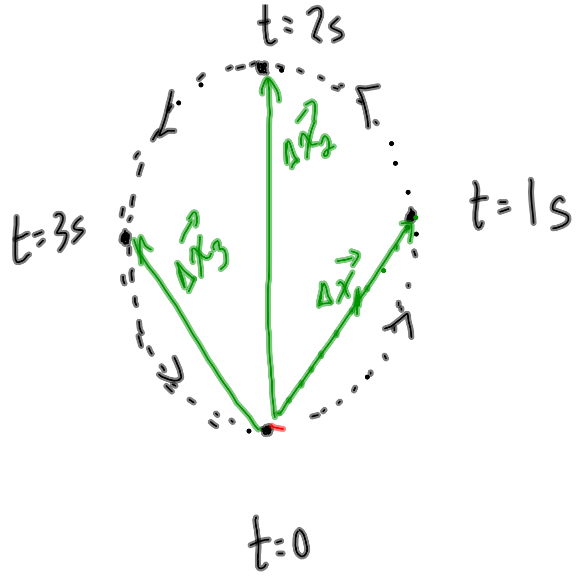
$$V_{inst} = \lim_{\Delta t \to 0} \frac{d}{\Delta t}$$

The instantaneous speed of an object at a point P is its speed at the instant that it passes P and it is the average speed of the object calculated over an infinitely small (but not zero) distance around P.



Average Velocity

Consider an object moving with a constant speed around a circle. It starts moving at time $t=0$



Average velocity: $\vec{v}_{av} = \dfrac{\Delta\vec{x}}{\Delta t}$

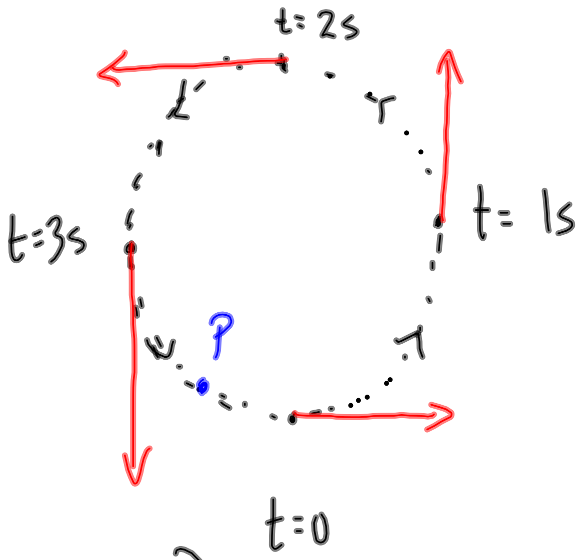
Average velocity is the ratio of the displacement to the time interval over which the object achieves that displacement

<u>Note</u>: The magnitude and direction of the average velocity will depend on the time interval selected.

<u>Note</u>: The direction of the average velocity is the same as the direction of the displacement.

Instantaneous Velocity

The instantaneous velocity of the object at a point P is determined by measuring the displacement $\Delta\vec{x}$ over a small time interval when it passes P.



$$\vec{V}_{inst} = \frac{\Delta\vec{x}}{\Delta t}$$ when Δt is very small (almost zero)

$$\boxed{\vec{V}_{inst} = \lim_{\Delta t \to 0} \frac{\Delta\vec{x}}{\Delta t}}$$

The instantaneous velocity of an object at a point P is its velocity at the instant that it passes P and it is the average velocity of the object calculated over an infinitely small (but not zero) displacement around P.

Acceleration

We have already defined acceleration:

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

A better way (more accurate) is to define acceleration as the rate of change of instantaneous velocity

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

Acceleration can be the average acceleration in a range or the instantaneous acceleration at a point

average acceleration: $\vec{a}_{av} = \frac{\Delta \vec{v}_{inst}}{\Delta t}$

instantaneous acceleration: $\vec{a}_{inst} = \lim_{\Delta t \to 0} \frac{\Delta \vec{v}_{inst}}{\Delta t}$

So instantaneous acceleration is like finding the average acceleration but over a very small (but not zero) time interval.

Instantaneous velocity can be found:
- use calculus (if an equation is known for the position with respect to time)
- use a graph (draw a tangent line at time t)

experimental:
- ticker tape
- multi-image photography / video analysis
- motion detector