$$\text{average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{d}{\Delta t}$$

(scalar quantity)

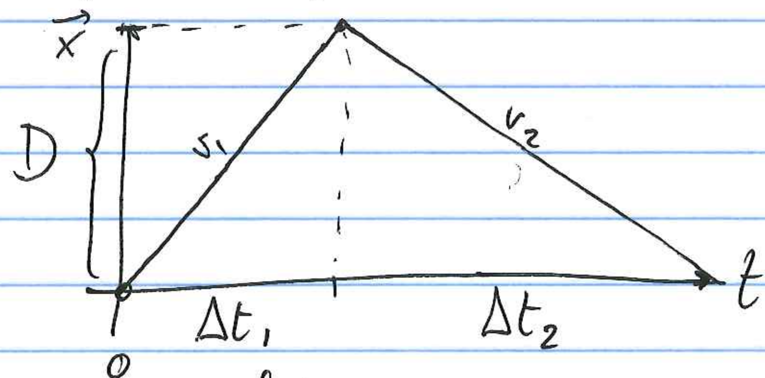
$$\text{average velocity} = \frac{\text{displacement}}{\text{total time}} = \frac{\Delta \vec{x}}{\Delta t}$$

(vector quantity)

Example: my weekend trip to VA Beach

$v_1 = 100 \text{ km/h}$

$v_2 = 80 \text{ km/h}$



what was my average speed for this entire trip?

$$\text{average speed} = \frac{\text{total distance}}{\text{total time}} = \frac{2D}{\Delta t_1 + \Delta t_2}$$

$$\Delta t_1 = \frac{D}{100 \text{ km/h}} \qquad \Delta t_2 = \frac{D}{80 \text{ km/h}}$$

$$\text{average speed} = \frac{2D}{\frac{D}{100 \text{ km/h}} + \frac{D}{80 \text{ km/h}}} = \frac{2}{\frac{1}{100 \text{ km/h}} + \frac{1}{80 \text{ km/h}}}$$

$$= 85 \text{ km/h}$$

velocity = rate of change of the position = $\frac{\Delta \vec{x}}{\Delta t}$
= slope of the position vs. time in a position vs. time graph

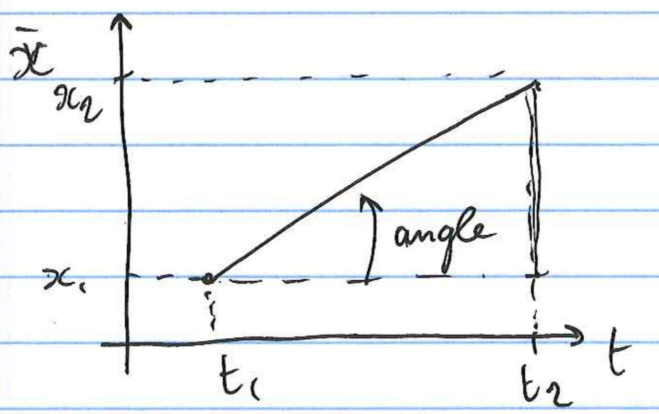
+ Acceleration = rate of change of the velocity = $\frac{\Delta \vec{v}}{\Delta t}$
= slope of the velocity in a velocity vs. time graph

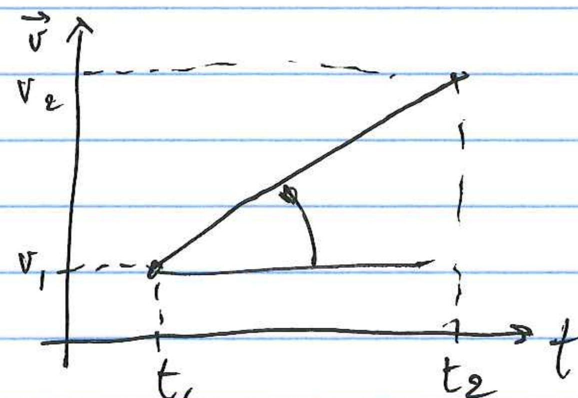
Example: accelarating car

t [s]	$\vec{v}$ [m/s]
0	0
10	+30
20	+60
30	+90

$$\vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{+30\ m/s}{10\ s}$$
$$= 3\ m/s^2$$

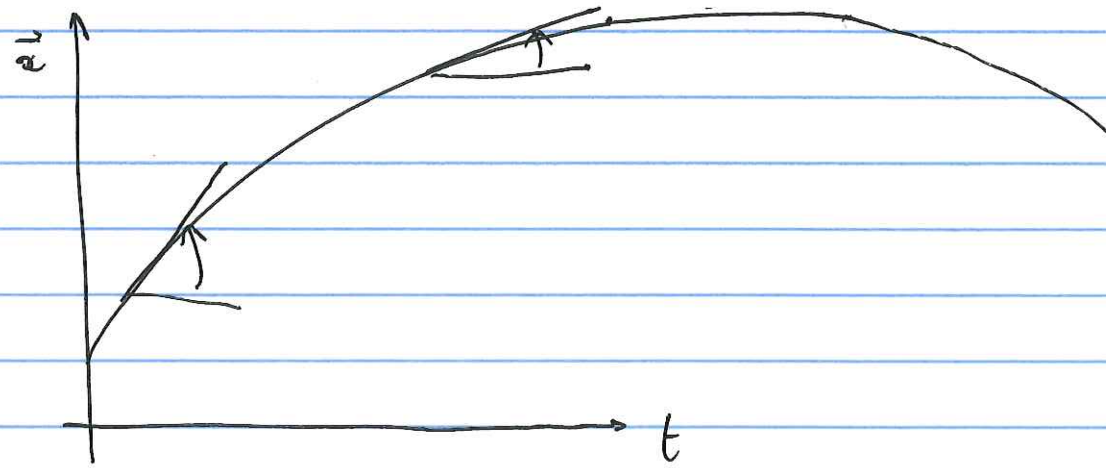
$$\Delta \vec{v} = \vec{v}_{later} - \vec{v}_{earlier}$$

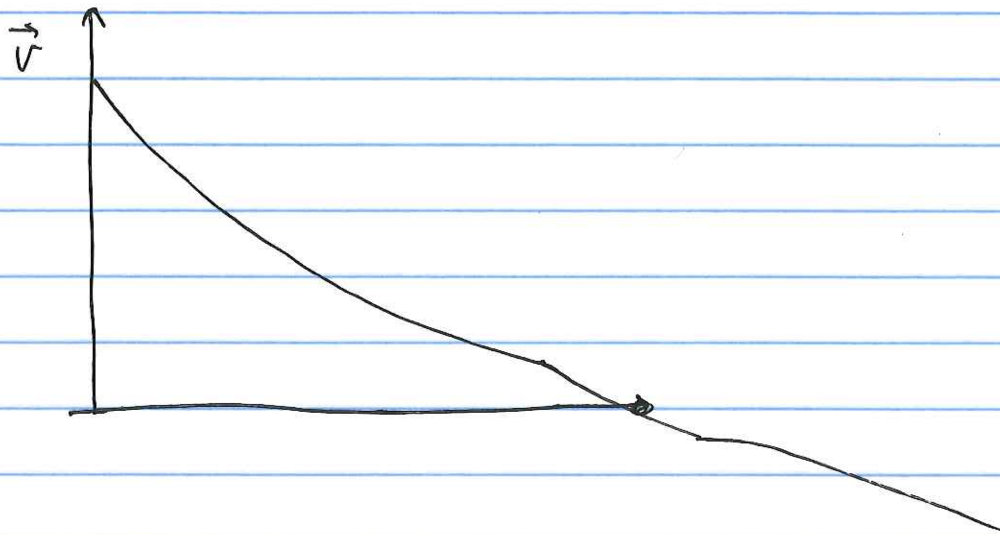


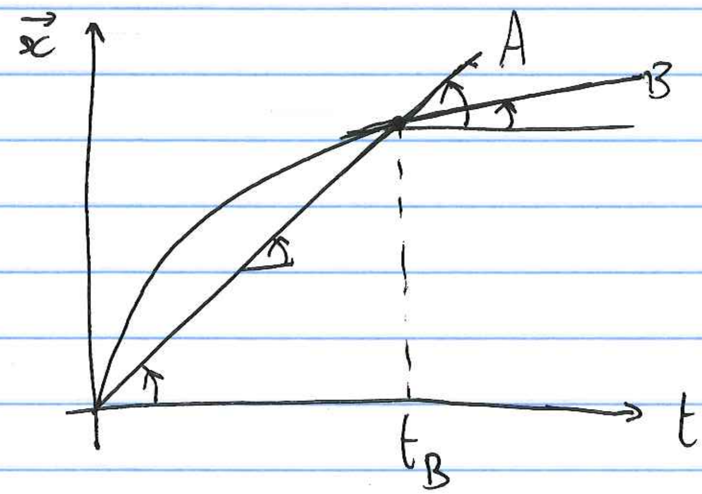


$$\vec{v} = \frac{\Delta \vec{x}}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} \qquad \vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1}$$

slope = tan (angle) = $\frac{\text{opposite}}{\text{adjacent}}$


$\vec{x}$
t


$\vec{v}$


$\vec{x}$
A
B
t
t_B

Formulas for 1D kinematics

start

$$\begin{cases} t_1 = 0 \\ x_1 = x_0 \\ v_1 = v_0 \end{cases}$$

finish

$$\begin{cases} t_2 = t \\ x_2 = x \\ v_2 = v \end{cases}$$

$$\vec{a}_{avg} = \vec{a} = \frac{\Delta \vec{v}}{\Delta t} = \frac{v_2 - v_1}{t_2 - t_1} = \frac{v - v_0}{t}$$

$$\vec{v}_{avg} = \frac{\Delta \vec{x}}{\Delta t} = \frac{x_2 - x_1}{t_2 - t_1} = \frac{x - x_0}{t}$$

$$\boxed{x = x_0 + \underbrace{\vec{v}_{avg}}_{\text{average velocity}} t}$$

$$\boxed{\vec{v} = \vec{v}_0 + \vec{a}_{avg} t = \vec{v}_0 + \vec{a} t} \rightarrow t = \frac{v - v_0}{a}$$

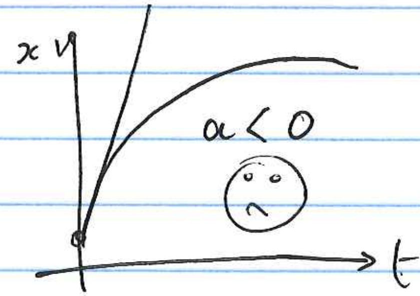
$$\vec{v}_{avg} = \frac{\vec{v}_0 + \vec{v}}{2} = \frac{\vec{v}_1 + \vec{v}_2}{2}$$

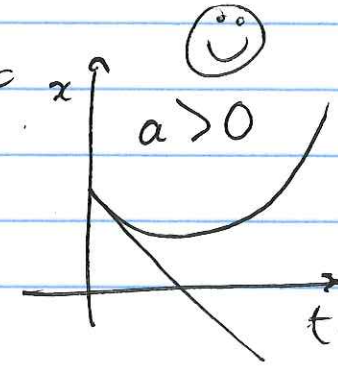
$$x = x_0 + \vec{v}_{avg} t = x_0 + \left(\frac{v_0 + v}{2}\right) t$$

$$x = x_0 + \left(\frac{v_0 + v_0 + a t}{2}\right) t$$

$$\boxed{x = x_0 + v_0 t + \frac{1}{2} a t^2}$$

parabolic





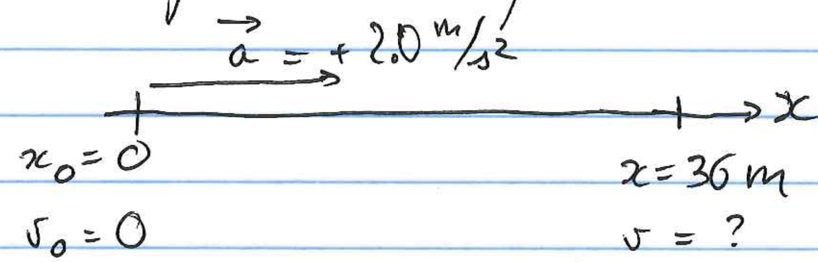
$$x = x_0 + \left(\frac{v_0 + v}{2}\right) t$$

$$x = x_0 + \left(\frac{v_0 + v}{2}\right)\left(\frac{v - v_0}{a}\right)$$

$$x = x_0 + \frac{v^2 - v_0^2}{2a}$$

$$\boxed{v^2 = v_0^2 + 2a(x - x_0)}$$

Example: how long does it take a car to travel 36m if it accelerates from rest with $\vec{a} = +2.0\,m/s^2$



$$a = +2.0\,m/s^2$$

$$\boxed{x = x_0 + v_0 t + \frac{1}{2} a t^2}$$

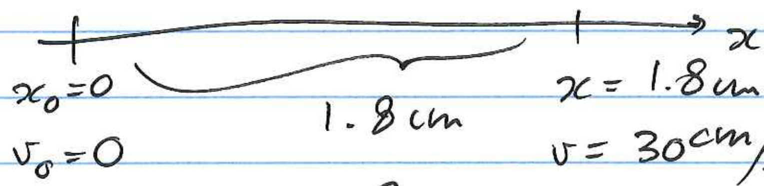
$$36\,m = 0\,m + 0\,m/s\, t + \frac{1}{2}(2.0\,m/s^2)\, t^2$$

$$36\,m = \frac{1}{2}(2.0\,m/s^2)\, t^2 \rightarrow t^2 = \frac{2(36\,m)}{2.0\,m/s^2}$$

$$t = 6\,s$$

v? $\quad v^2 = \underbrace{v_0^2}_{0\,m/s} + 2\underbrace{a}_{+2.0\,m/s^2}\underbrace{(x - x_0)}_{36\,m} \Rightarrow v = 12\,m/s$

Example: left ventricle accelerates blood from rest to $30\,\text{cm/s}$ in a distance of $1.8\,\text{cm}$. What is the acceleration? What is the time required?



$a = ?$

$$v^2 = v_0^2 + 2a(x - x_0)$$

$$\hookrightarrow a = \frac{v^2 - v_0^2}{2(x - x_0)} = \frac{(30\,\text{cm/s})^2}{2(1.8\,\text{cm})} = 2.5\,\text{m/s}^2$$

$$\boxed{v = v_0 + at} \rightarrow t = \frac{v - v_0}{a} = \frac{30\,\text{cm/s}}{2.5\,\text{m/s}^2}$$

$$= 0.12\,\text{s}$$