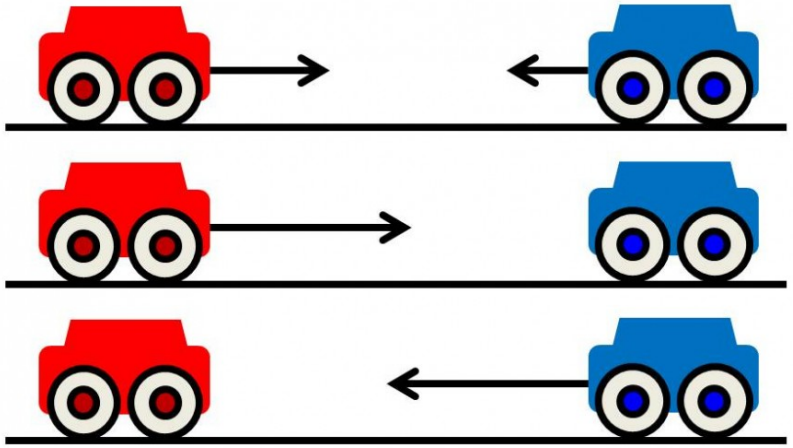
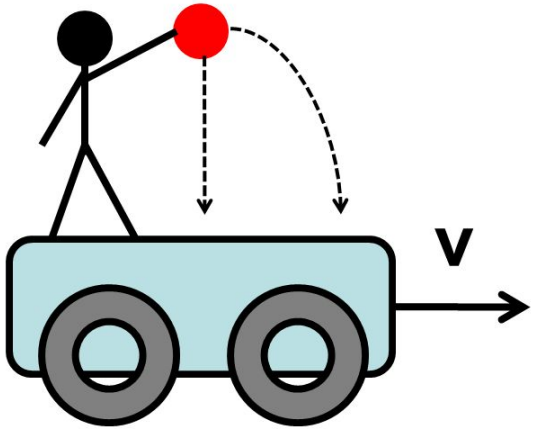
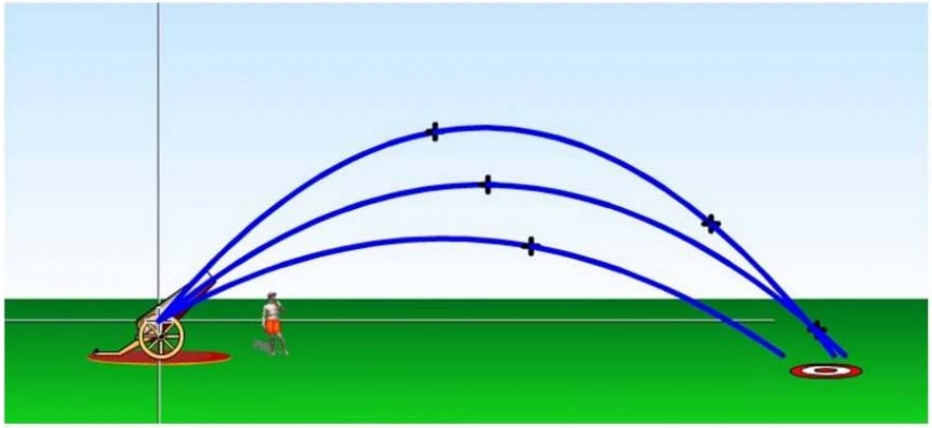
Kinematics

Relative Velocities

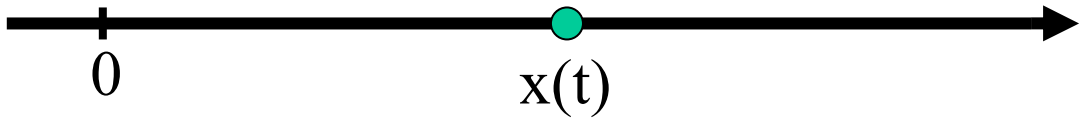


Ball on a Moving Cart





1. One dimensional motion



x(t) : position (distance) [m] t : time [s]

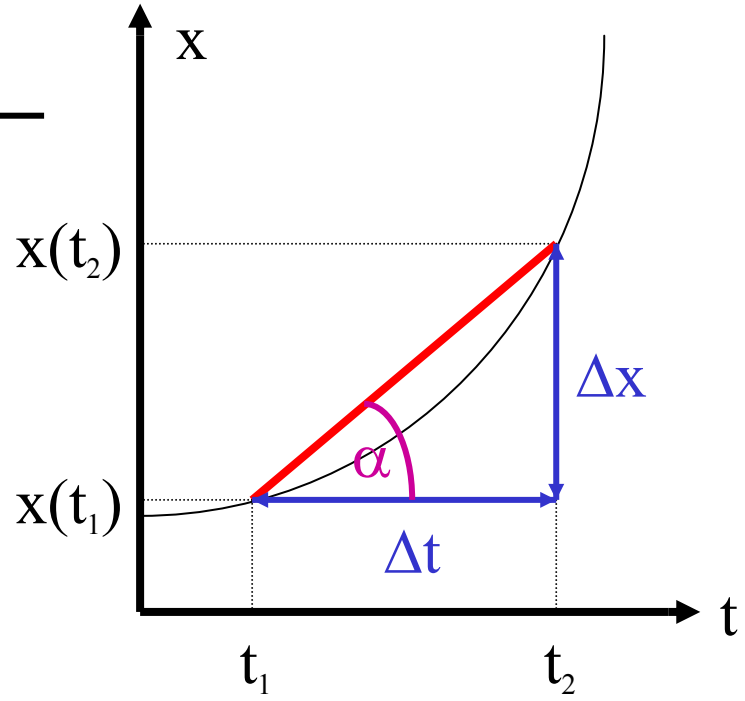
Def. : average velocity $v_{ave} = \frac{\Delta x}{\Delta t} = \frac{x(t_2) - x(t_1)}{t_2 - t_1}$ $\left[\frac{m}{s}\right]$

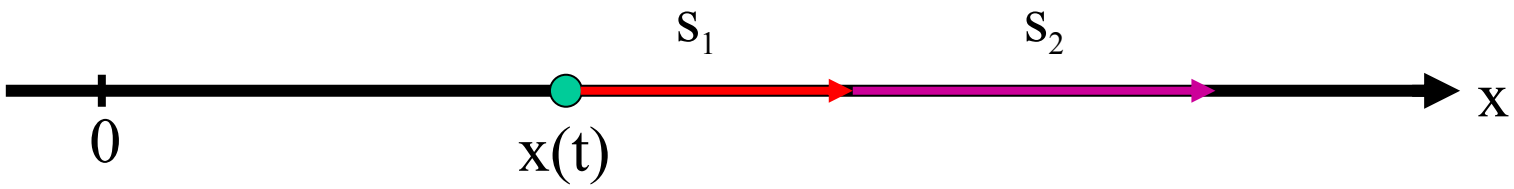
average velocity = $\frac{\text{displacement}}{\text{time elapsed}}$

v > 0

v < 0

$tg(\alpha) = v_{ave}$





x(t) : position (distance) [m] t : time [s]

$$\text{Def.: average speed} = \frac{\text{total distance}}{\text{total time}}$$

$$\text{average speed:} \qquad \langle v \rangle = \frac{s_1 + s_2 + \ldots}{t_1 + t_2 + \ldots} \qquad \left[\frac{m}{s}\right]$$

1.a. Uniform motion

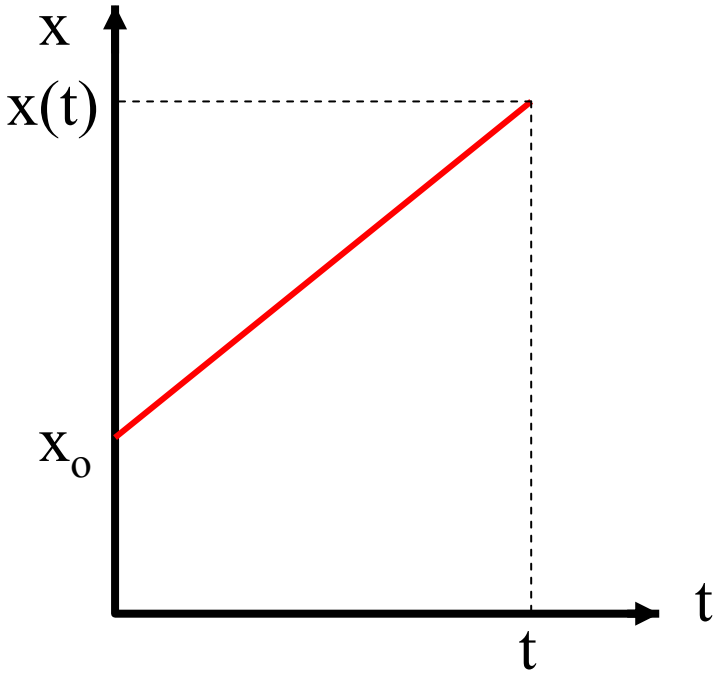
v = const.

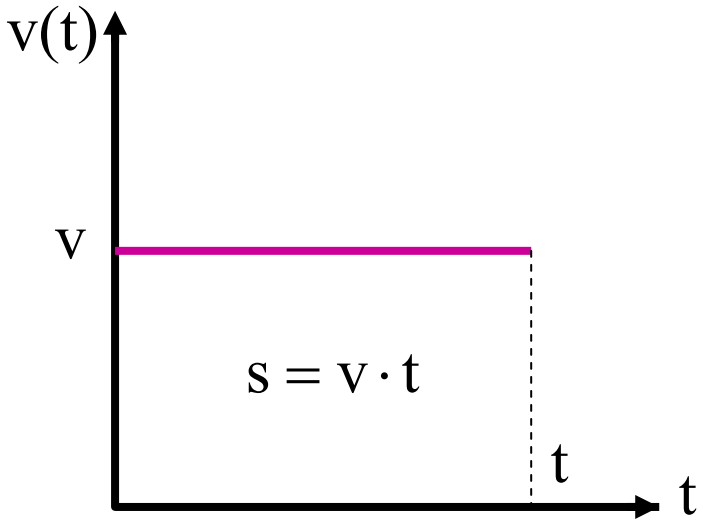
$$v_{ave} = \frac{\Delta x}{\Delta t} = \frac{x(t_2) - x(t_1)}{t_2 - t_1}$$

$$v = \frac{x(t) - x_o}{t}$$

$$x(t) = x_o + v \cdot t$$

$$v = \frac{s}{t} \quad \Rightarrow \quad s = v \cdot t$$





Example:

Average speed (seen before): $v_{ave} = \frac{s_{total.}}{t_{total}}$

A B

s

Average velocity:

$$\frac{\text{displacement}}{\text{time}} = \frac{x(t_2) - x(t_1)}{t_2 - t_1}$$

Average speed:

$$v_{ave} = \frac{s_{total.}}{t_{total}}$$

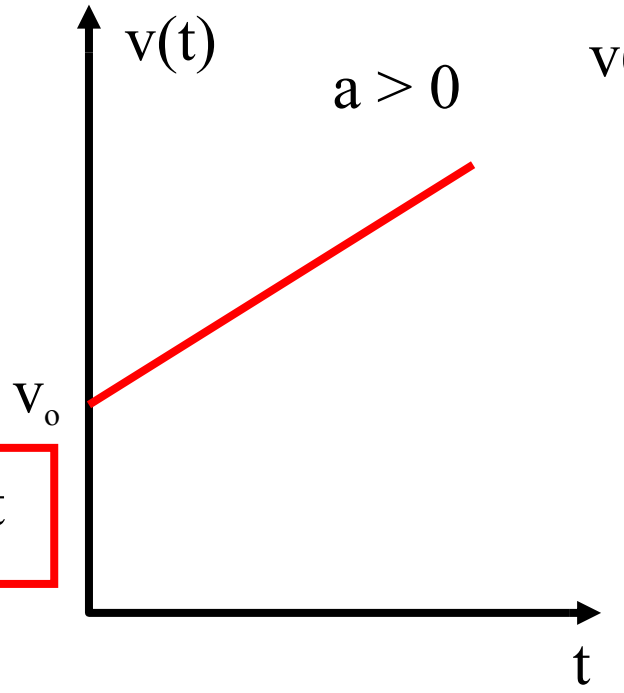
1. b. Nonuniform motion - acceleration

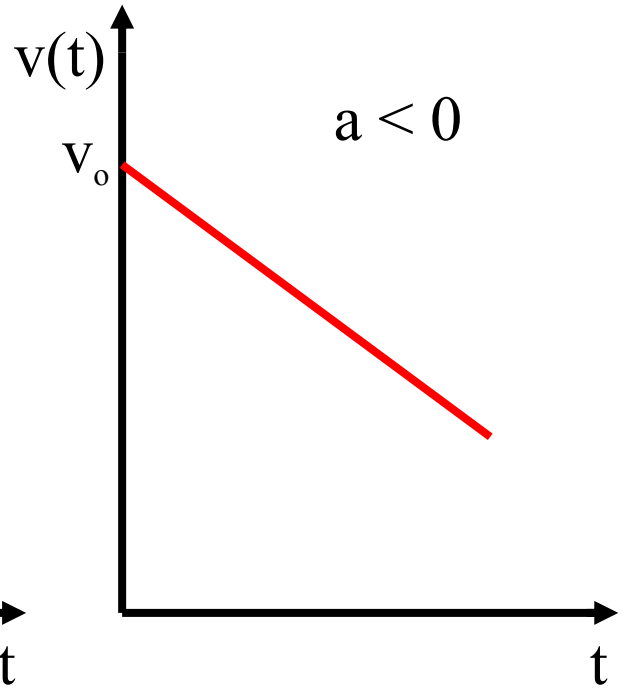
Def.: average acceleration $$a_{ave} = \frac{\Delta v}{\Delta t} = \frac{v(t_2) - v(t_1)}{t_2 - t_1} \left[\frac{m}{s^2}\right]$$

Motion with uniform acceleration: $a = \text{const.}$

$$a = \frac{v(t) - v_o}{t}$$

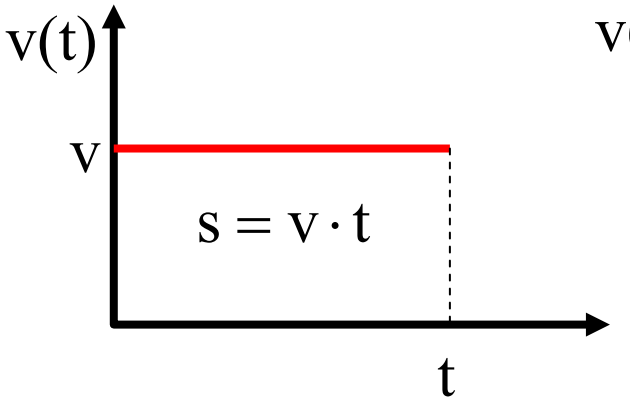
$$v(t) = v_o + a \cdot t$$



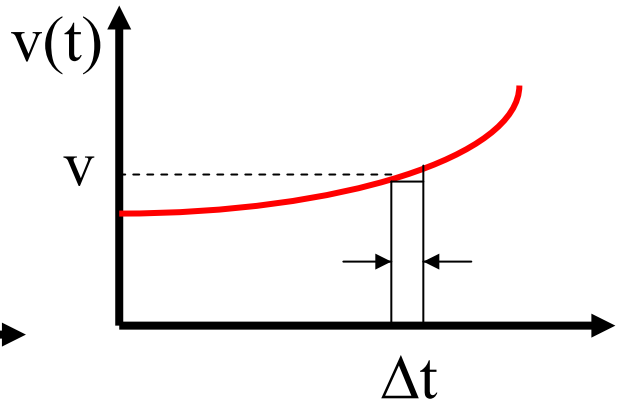


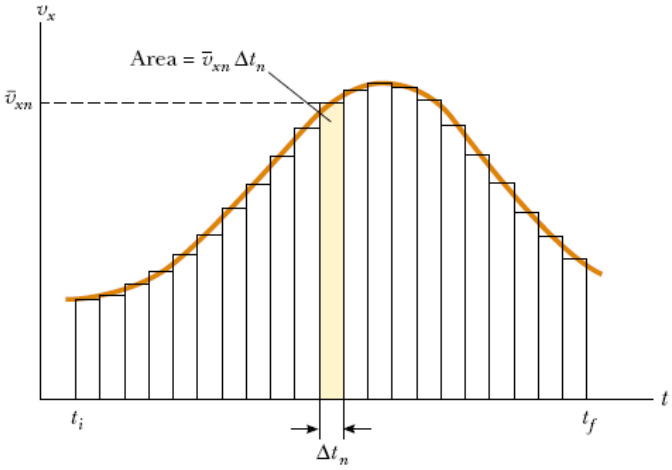
Distance (displacement) covered by the object moving with uniform acceleration

Uniform motion

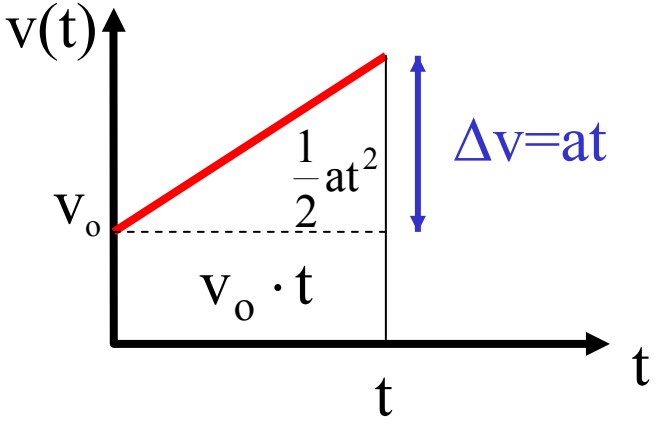


Nonuniform motion



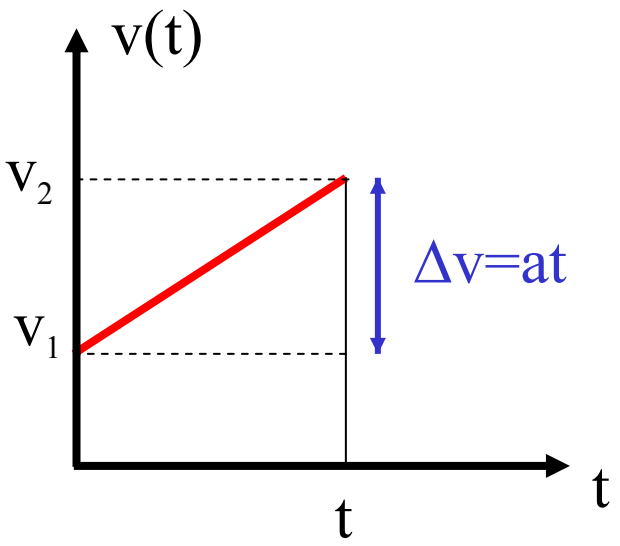


Motion with uniform acceleration:

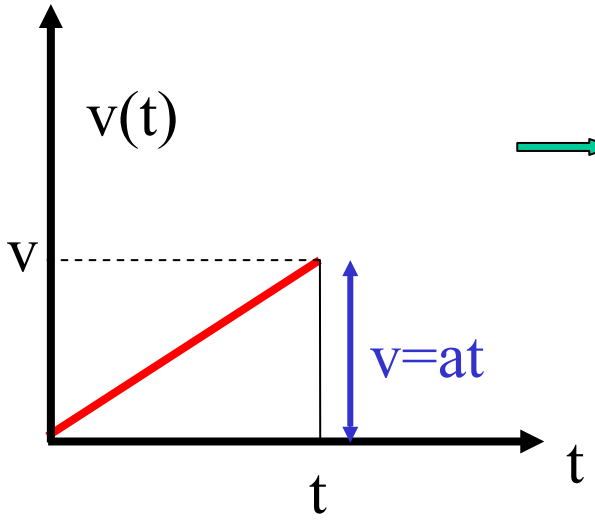


Distance: $s = v_o \cdot t + \frac{1}{2}at^2$

Position: $x(t) = x_o + v_o \cdot t + \frac{1}{2}at^2$



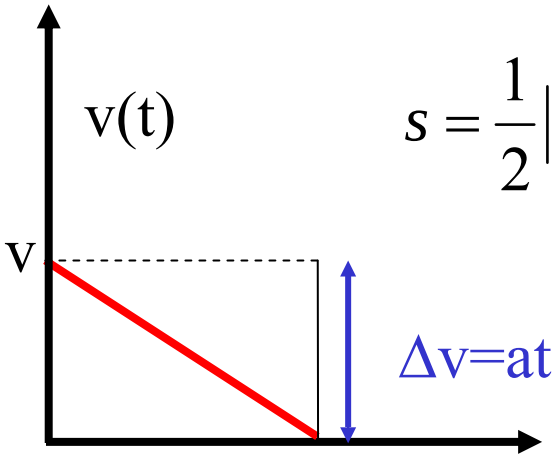
$$\text{Distance: } s = \frac{v_1 + v_2}{2} t = \frac{v_2^2 - v_1^2}{2a}$$



$$\text{Distance: } s = \frac{1}{2} a t^2 = \frac{vt}{2} = \frac{v^2}{2a}$$

$v_o = 0$

The object started from rest.

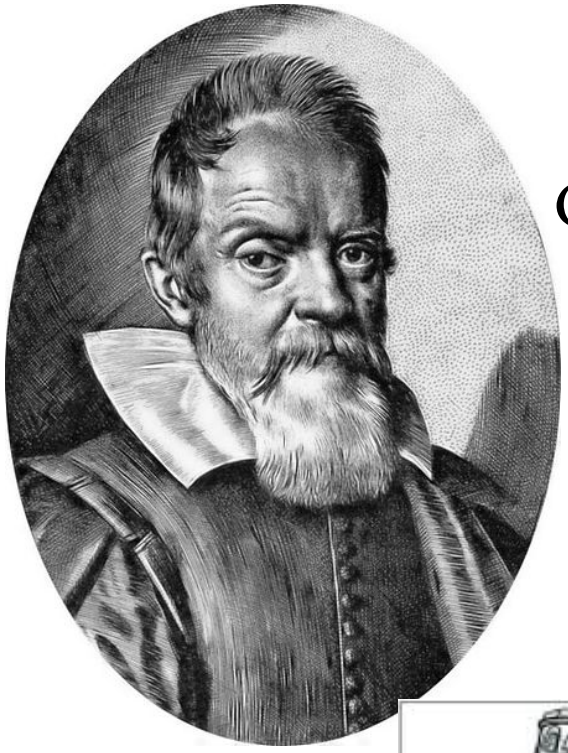


$$s = \frac{1}{2} |a| t^2 = \frac{v_o t}{2} = \frac{v^2}{2|a|}$$

$v_o \neq 0$

$v_f = 0$

Freely falling objects



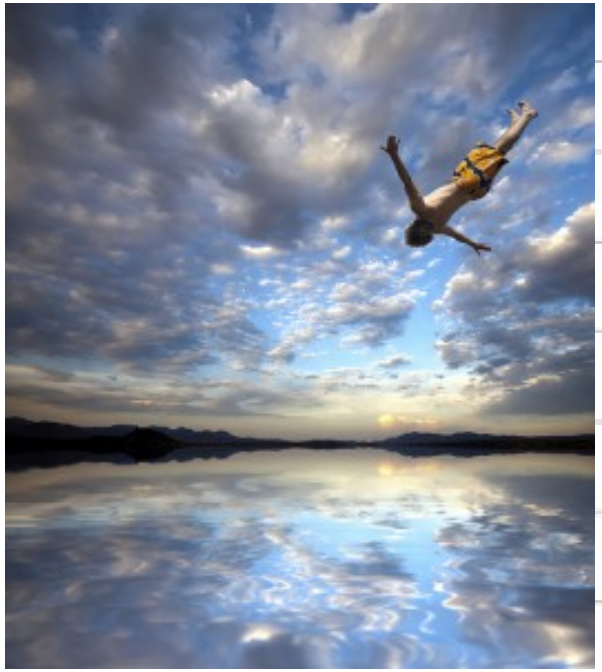
Galilei Galileo

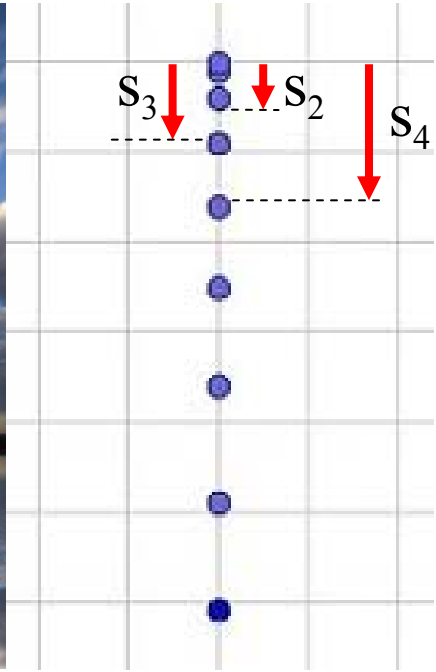
1564-1642

Gravitational acceleration:

$$a = g = 9.81\frac{m}{s^2} \approx 10\frac{m}{s^2}$$

Pisa tower

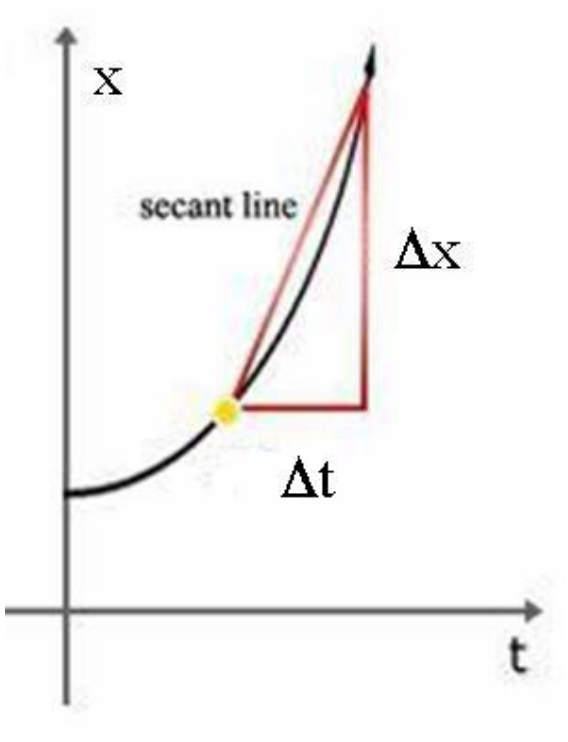


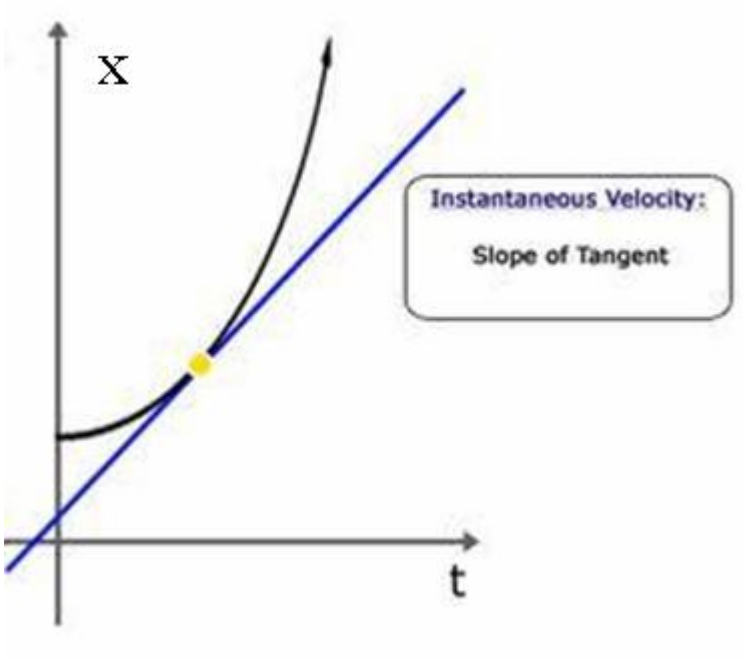


$$s_1 : s_2 : s_3 : s_4 : \ldots = 1 : 3 : 5 : 7 : \ldots$$

Instantaneous velocity, instantaneous acceleration

Instantaneous velocity: $$v(t) = \lim_{\Delta t \to 0} \frac{x(t+\Delta t) - x(t)}{\Delta t}$$





Instantaneous acceleration: $$a(t) = \lim_{\Delta t \to 0} \frac{v(t+\Delta t) - v(t)}{\Delta t}$$