The International System of Units

- **Three Basic Units (SI)**

Quantity	Unit Name	Symbol
Length	meter	m
Time	second	s
Mass	kilogram	kg

- **Many SI Derived Units:**

1 Newton = 1 N = 1 kg · m/s^2

1 Watt = 1 W = 1 N · m = 1 kg · m^2/s^2

- **Prefixes for SI Units:**

1 kg = 1 × 10^3 grams

1 ps = 1 × 10^{-12} seconds

Factor	Prefix	Symbol
10^{12}	tera-	T
10^{9}	giga-	G
10^{6}	mega-	M
10^{3}	kilo-	k
10^{-2}	centi-	c
10^{-3}	milli-	m
10^{-6}	micro-	μ
10^{-9}	nano-	n
10^{-12}	pico-	p

- **Changing Units:**

Conversion Factor

1 min = 60 s → $\frac{1\,\text{min}}{60s} = 1$ $\quad \frac{60s}{1\,\text{min}} = 1$

$$2\,\text{min} = (2\,\text{min})(1) = (2\,\cancel{\text{min}})\left(\frac{60s}{1\,\cancel{\text{min}}}\right) = 120s$$

distance: meter

1791: one ten-millionth of a quadrant of the Earth…

- - -

1889: platinum-iridium bar

- - -

1983: The meter is the length of the path traveled by light in vacuum during a time interval of 1 / (299,792,458) of a second

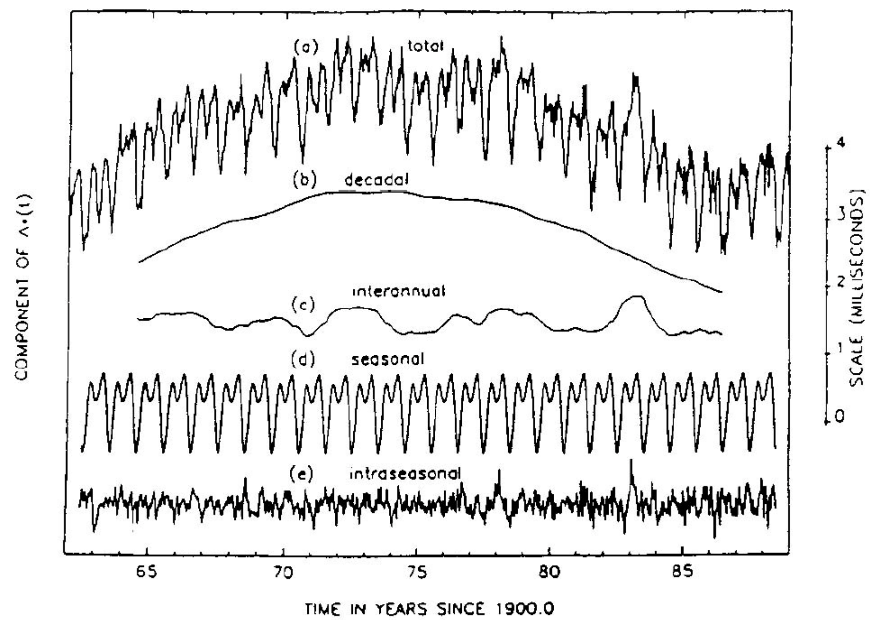
(*i.e.*, by definition, c = 299,792,458 m/s)

time: second

Since long ago (Egyptians and Greeks): 1 day = 24 hours

1 s = (1/24) x (1/60) x (1/60) of the full Earth turn

However, the Earth rotation period varies by a few ms…



1967: The second is the duration of 9,192,631,770 periods of the radiation emitted by caesium-133 atom

mass: kilogram

1799: 10x10x10 cm³ of water

- - -

1899: platinum-iridium cylinder (d=h=39 mm)

$1\ u = 1.66053886 \times 10^{-27}$ kg

atomic mass unit (u):
- 12 u = mass of ^{12}C atom
- universal, reproducible, nor requiring an artifact

Density: The density of a material, ρ, is the mass per unit volume:

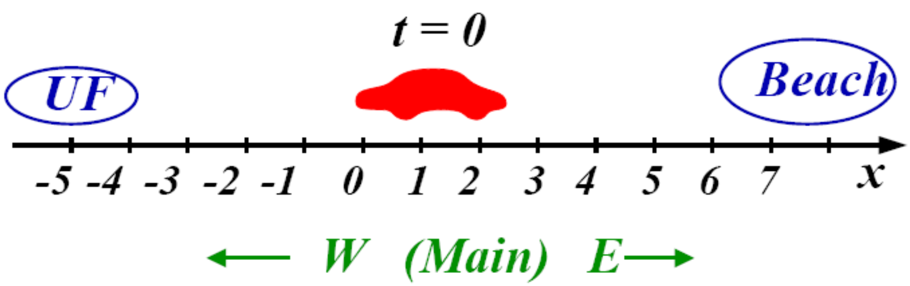
$$\rho = m/V$$

ρ(water) = 1.00 g/cm³

1-d Motion: Position & Displacement

- **The x-axis:**

We locate objects by specifying their position along an axis (in this case x-axis). The positive direction of an axis is in the direction of increasing numbers. The opposite is the negative direction.



- **Displacement:**

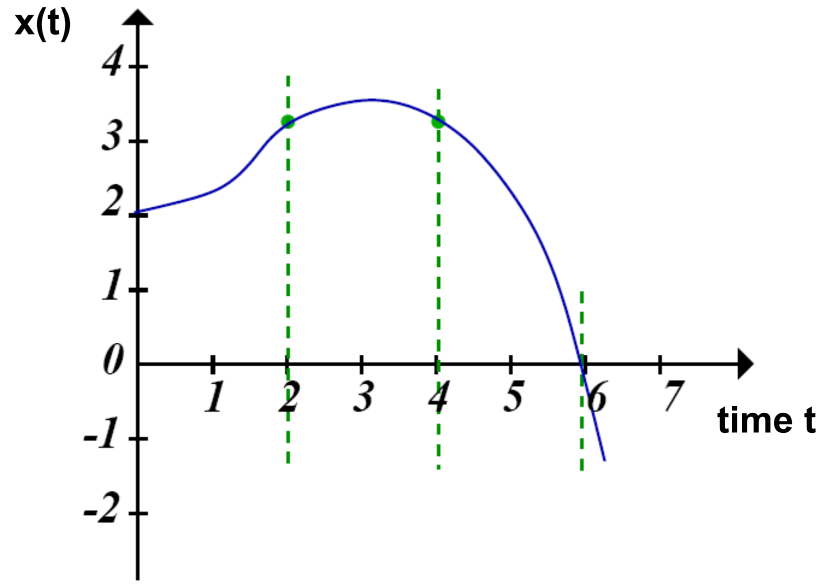
The change from position x_1 to position x_2 is called the displacement, Δx.

$$\Delta x = x_2 - x_1$$

The displacement has both a magnitude, $|\Delta x|$, and a direction (positive or negative).

- **Graphical Technique:**

A convenient way to describe the motion of an object is to plot the position x as a function of time t (*i.e.* x(t)).

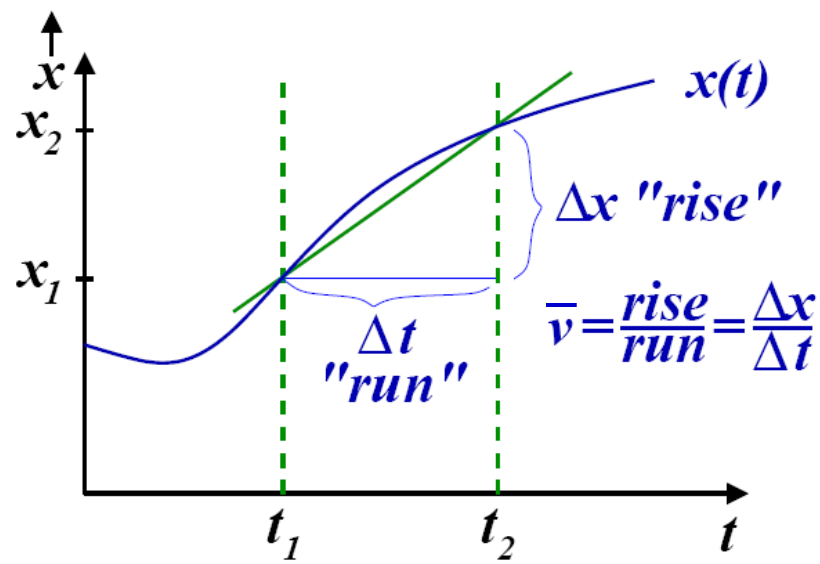


1-d Motion: Average Velocity

- **Average Velocity**

$$\bar{v} = v_{ave} = \frac{\Delta x}{\Delta t} = \frac{x(t_2) - x(t_1)}{t_2 - t_1} = \frac{x_2 - x_1}{t_2 - t_1}$$

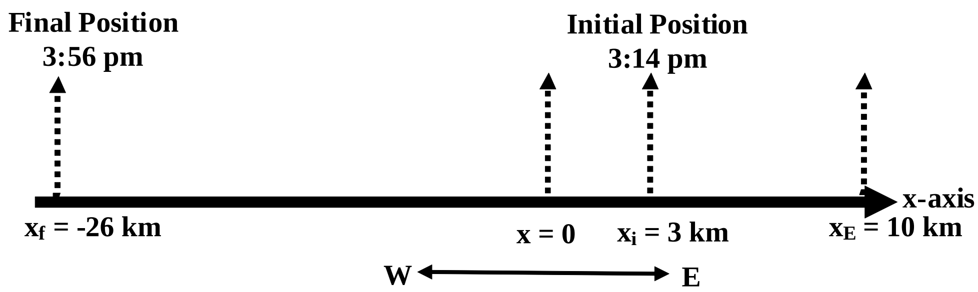
The average velocity is defined to be the displacement, Δx, that occurred during a particular interval of time, Δt (*i.e.* $v_{ave} = \Delta x/\Delta t$).



- **Average Speed**

The average speed is defined to be the magnitude of total distance covered during a particular interval of time, Δt (*i.e.* s_{ave} = (total distance)/Δt).

Average Velocity: Example Problem



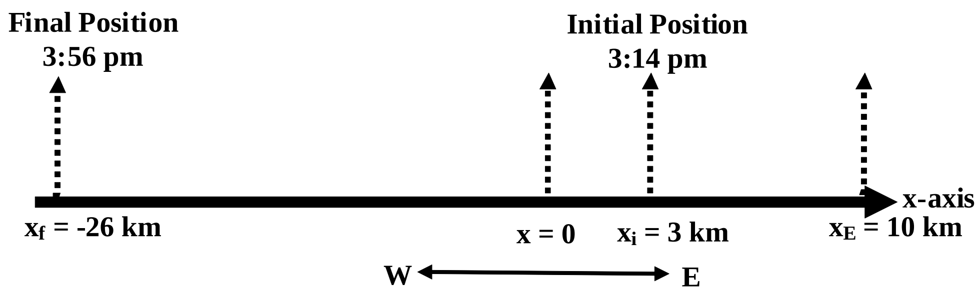
A train that is initially at the point x_i = 3 km at 3:14 pm travels 7 km to the East to the point x_E = 10 km. It then reverses direction and travels 36 km to the West to the final point x_f = -26 km arriving at 3:56 pm. What is the train's average velocity (in km/h) for this trip?

$$\bar{v} = v_{ave} = \frac{\Delta x}{\Delta t} = \frac{x(t_f) - x(t_i)}{t_f - t_i} = \frac{x_f - x_i}{t_f - t_i} = \frac{-26km - (3km)}{42\min \times (1h/60\min)} = \frac{-29km}{0.7h} \approx \boxed{-41.43km/h}$$

Note that the displacement Δx is equal to the average velocity times Δt.

$$\Delta x = v_{ave}\Delta t = (-41.43km/h)(0.7h) \approx -29km$$

Average Speed: Example Problem



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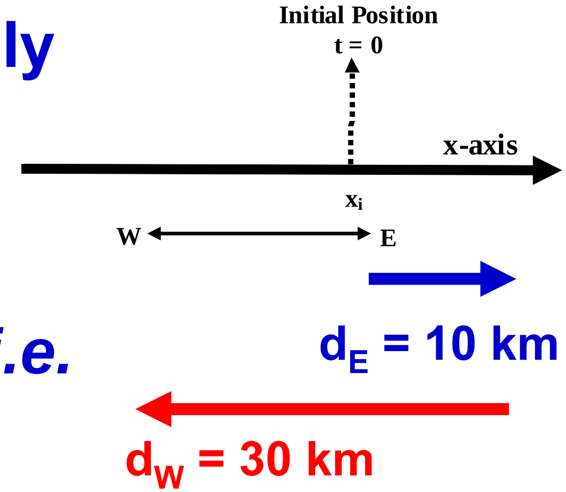
$$s_{ave} = \frac{d_{tot}}{\Delta t} = \frac{7km + 36km}{42\,\text{min} \times (1h/60\,\text{min})} = \frac{43km}{0.7h} \approx \boxed{61.43km/h}$$

Note that the total distance d is equal to the average speed times Δt.

$$d_{tot} = s_{ave}\Delta t = (61.43km/h)(0.7h) \approx 43km$$

Exam 1 Fall 2013: Problem 5



- A train traveling along the x-axis is initially at the point x_i at t = 0. The train then travels 10 km to the East (*i.e.* right) as shown in the figure. It then reverses direction and travels 30 km to the West (*i.e.* left) to the final point x_f. If the train's average speed for this trip was 20 km/h what was its average velocity for the trip (in km/h)?

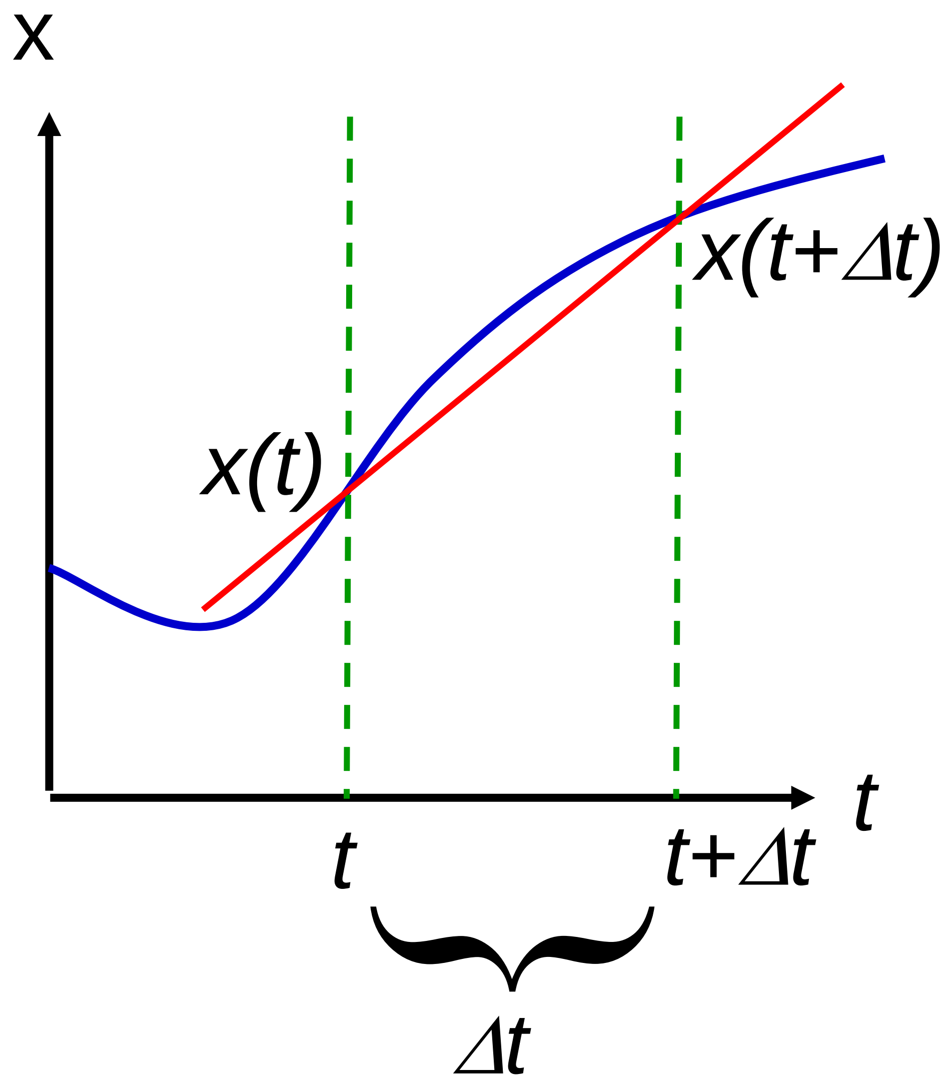
$$x_f = x_i + d_E - d_W$$

Answer: -10
% Right: 64%

$$s_{ave} = \frac{d_{tot}}{\Delta t} = \frac{d_E + d_W}{\Delta t} \qquad \Delta t = \frac{d_E + d_W}{s_{ave}}$$

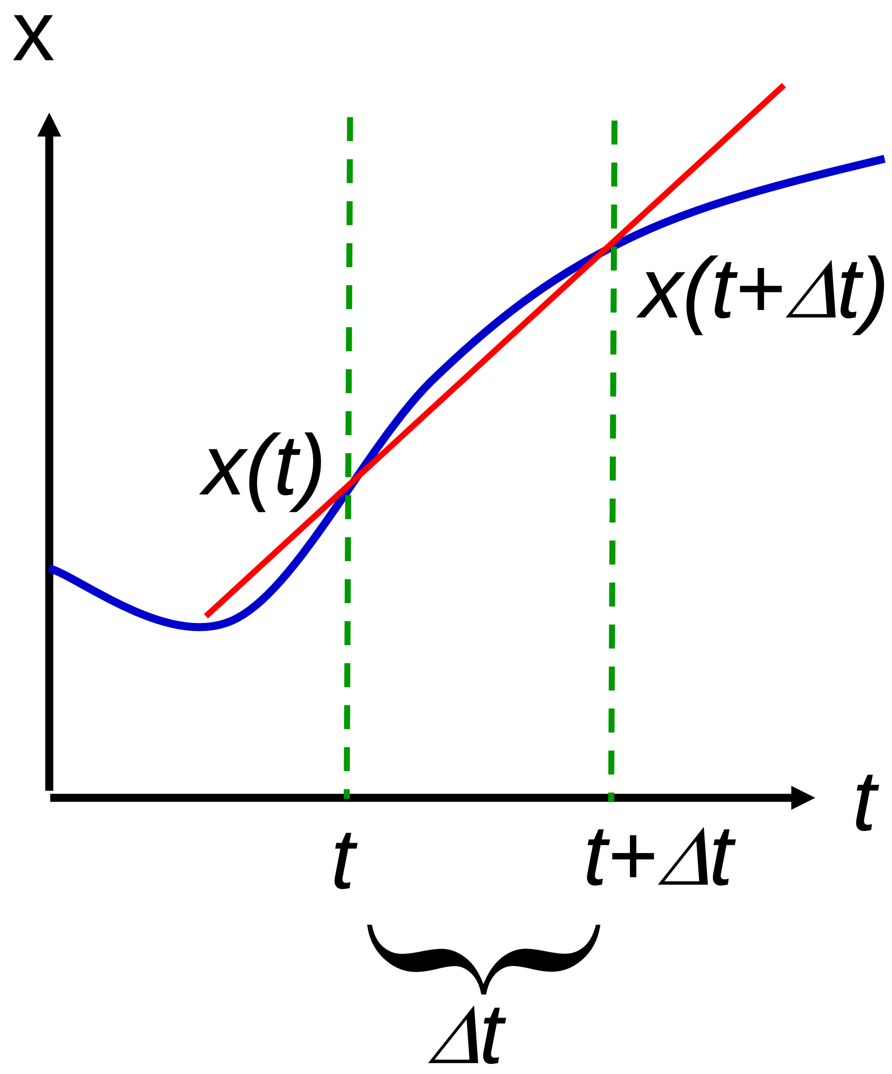
$$v_{ave} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{\Delta t} = \frac{d_E - d_W}{\Delta t} = \frac{d_E - d_W}{d_E + d_W} s_{ave} = \frac{-20km}{40km}(20km/h) = -10km/h$$

1-d Motion: Instantaneous Velocity



shrink Δt

1-d Motion: Instantaneous Velocity



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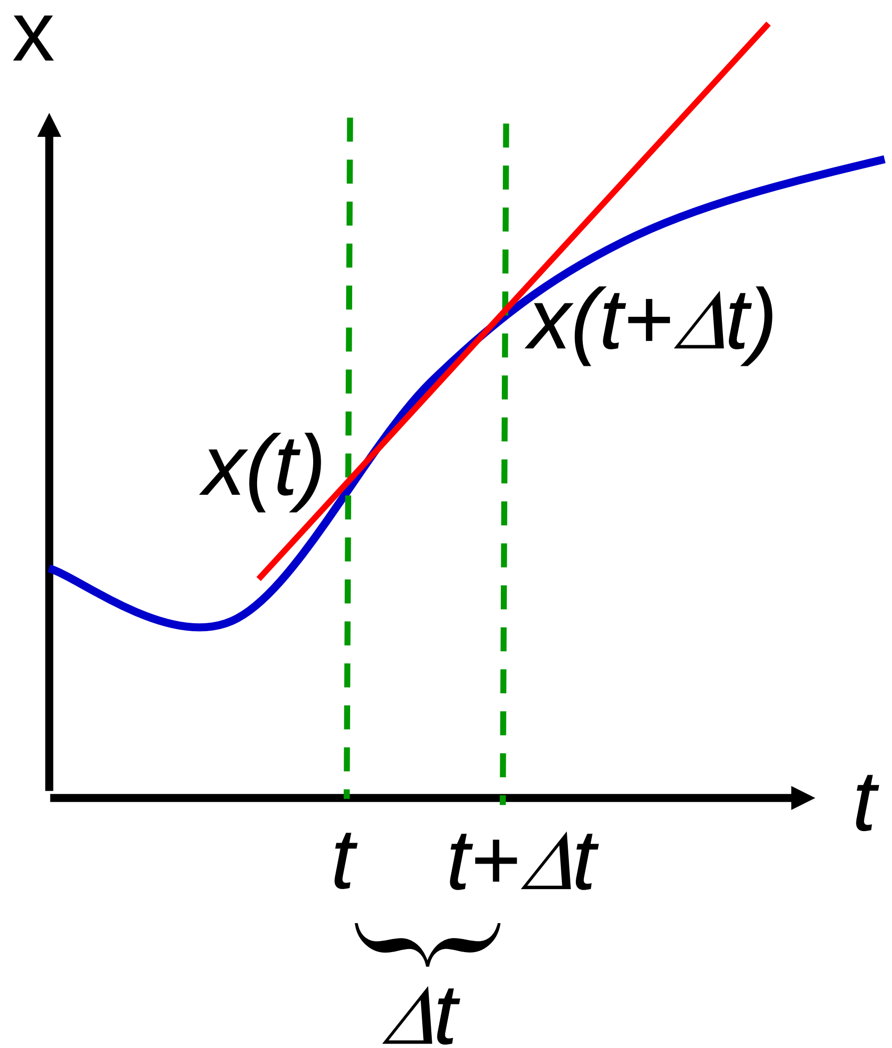

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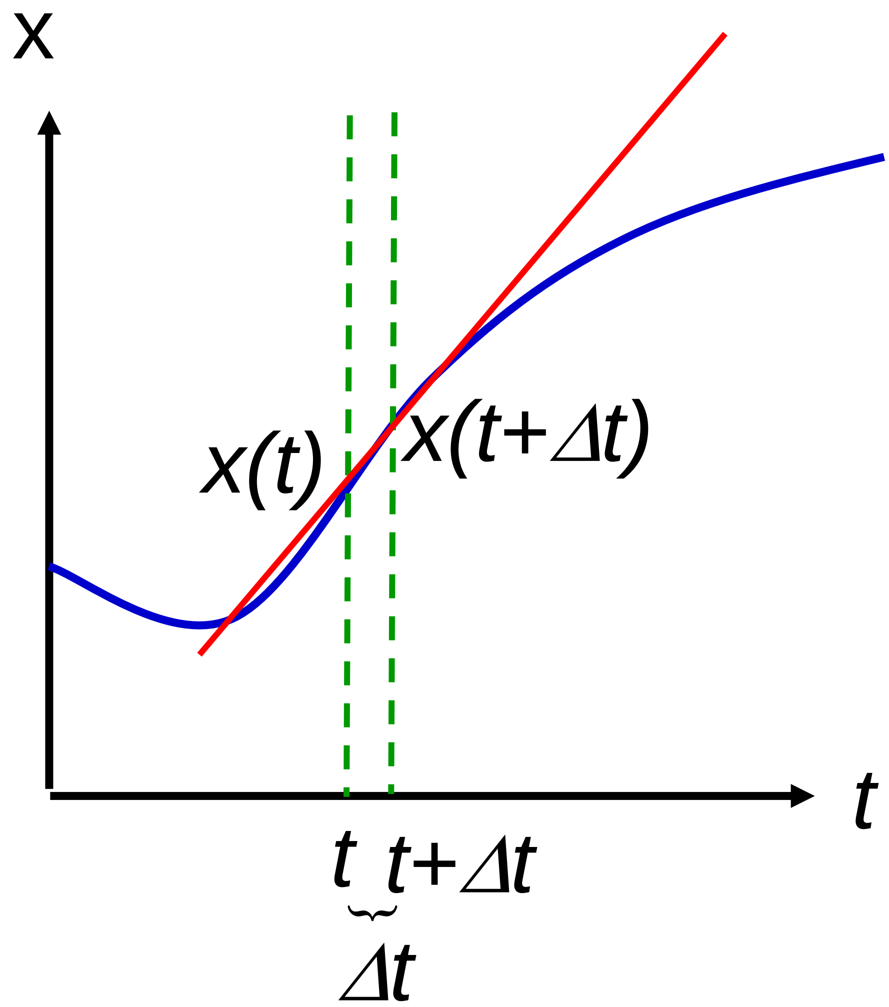

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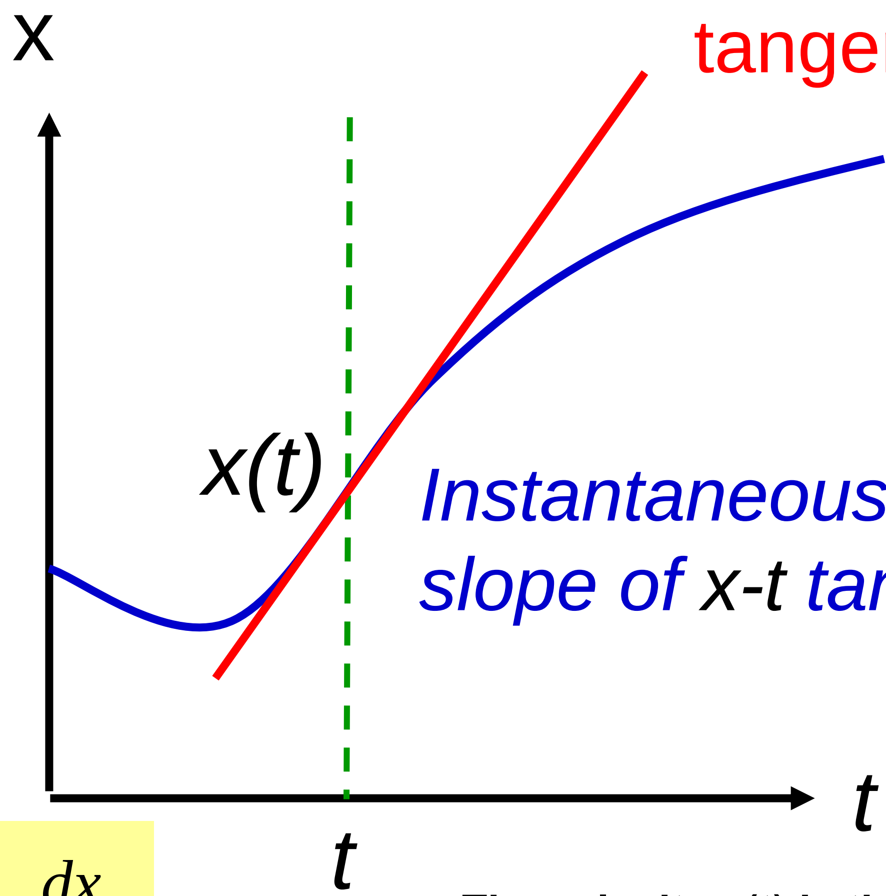
1-d Motion: Instantaneous Velocity



Instantaneous velocity v(t) is slope of x-t tangent line at t

$$v(t) = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

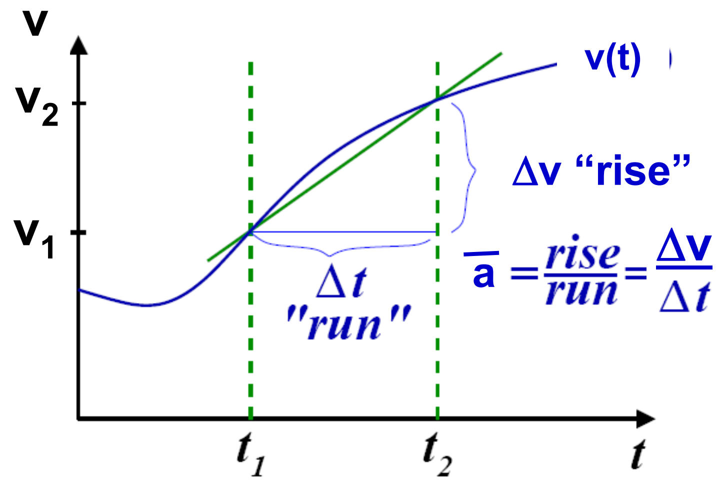
The velocity v(t) is the rate of change of x(t) with respect to t at time t.

1-d Motion: Acceleration

- **Acceleration**

When a particles velocity changes, the particle is said to undergo acceleration (*i.e.* accelerate).

$$\bar{a} = a_{ave} = \frac{\Delta v}{\Delta t} = \frac{v(t_2) - v(t_1)}{t_2 - t_1} = \frac{v_2 - v_1}{t_2 - t_1}$$



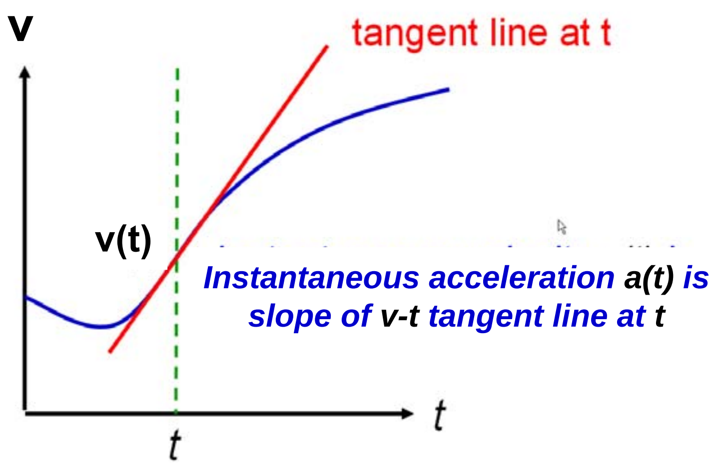
- **Average Acceleration**

The average acceleration is defined to be the change in velocity, Δv, that occurred during a particular interval of time, Δt (*i.e.* $a_{ave} = \Delta v/\Delta t$).

- **Instantaneous Acceleration**

The acceleration a(t) is the rate of change of v(t) with respect to t at time t.

$$a(t) = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt}$$



1-d Motion: Summary

- **Instantaneous Velocity**

The velocity v(t) is the rate of change of x(t) with respect to t at time t.

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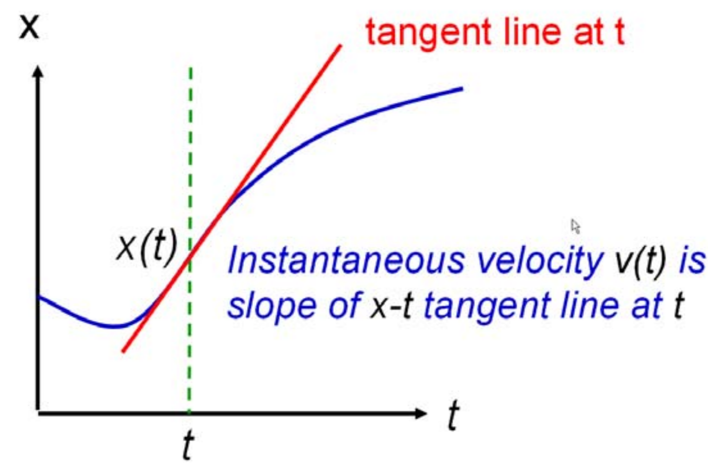

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