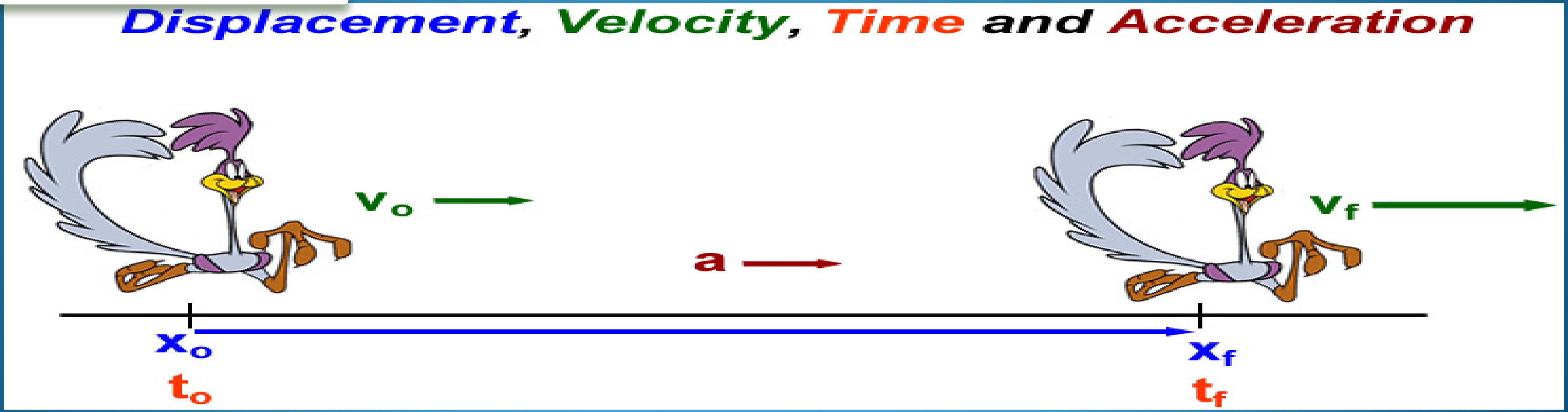
Chapter two
Motion kinematics

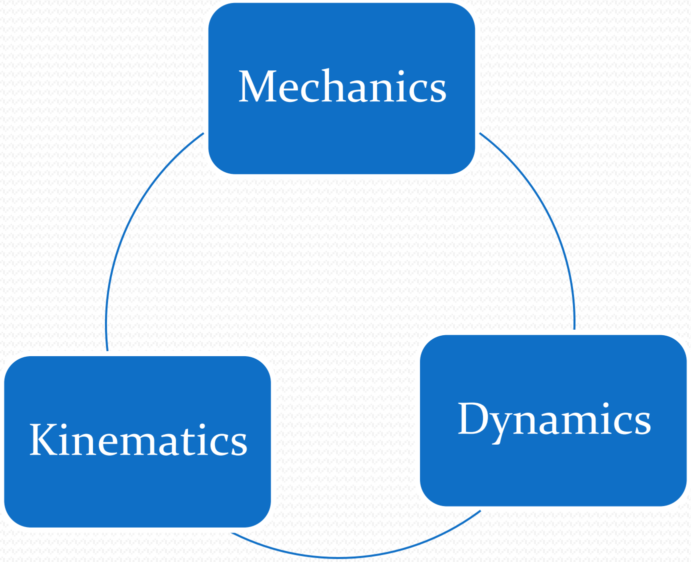
Lecture one



Motion kinematics

- Position vector and displacement vector
- Average velocity and Instantaneous velocity
- The Average and Instantaneous Acceleration
- One -dimensional
- Free fall
- Motion in two dimensions
- Projectile motion

- علم الميكانيك من العلوم الواسعة التي تهتم بدراسة حركة الاجسام ومسبباتها و يتفرع من هدا العلم فروع اخرى مثل Kinematicsو Dynamics.



- وعلم الكينماتيكا kinematics يهتم بوصف حركة الاجسام دون النظر الى مسبباتها ،اما علم dynamicsفهو يدرس حركة الاجسام ومسبباتها مثل القوة والكتلة .
- سنقوم بدراسة حركة الاجسام وعلاقتها بكل من الاحداثيات المكانية والزمانية ثم بعد دلك سوف ندرس الفرع الثاني وهو علم الديناميكا

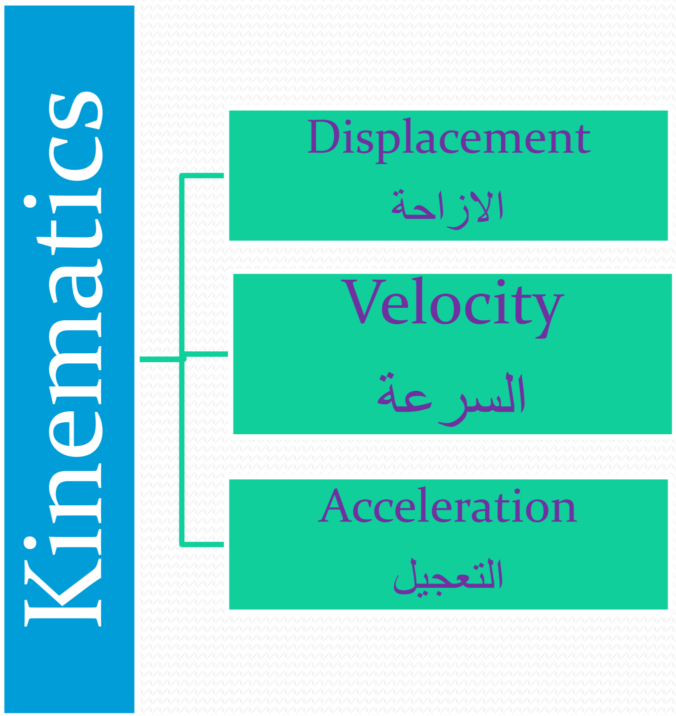
Kinematics

- Motion in 1D
- Motion in 2D
- Circular motion

Quantities in Motion

- اساسيات دراسة علم وصف الحركة kinematics للأجسام المادية
- Any motion involves three concepts
  - Displacement
  - Velocity
  - Acceleration
- These concepts can be used to study objects in motion

اساسيات دراسة علم وصف الحركة kinematics للأجسام المادية.



The position vector and the displacement vector

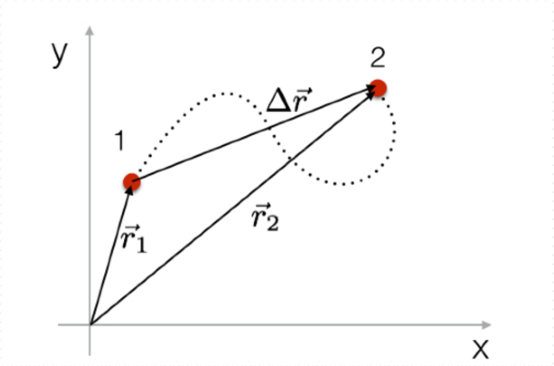
نحتاج هنا الى اعتماد محاور اسناد لتحديد موضع الجسم المتحرك عند ازمنة مختلفة ومن المناسب اعتماد محاور الاسناد الكارتيزية rectangular coordinate(x , y , z).

يمكن اعتبار متجه الموضع position vectorهو المتجه الواصل من مركز اسناد معين الى مكان الجسم المراد تحديده.

$\overrightarrow{r_1} = x_1 \text{ i} + y_1 \text{ j}$

$\overrightarrow{r_2} = x_2 \text{ i} + y_2 \text{ j}$

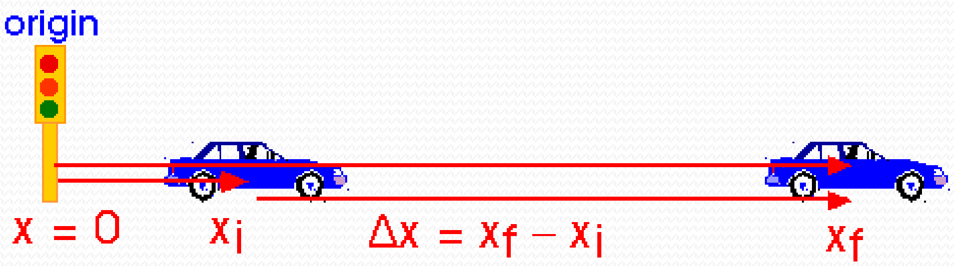
$\Delta\vec{r} = \overrightarrow{r_2} - \overrightarrow{r_1}$



Δr is the displacement vector which represent the change in the position vector.

Displacement

- Displacement is a change of position in time.
- Displacement: $\Delta x = x_f(t_f) - x_i(t_i)$
- It is a vector quantity.
- It has both magnitude and direction: + or – sign
- It "s units is: meters.
- Δx is +ve if is greater than x_i :and –ve if x_f is less than x_i

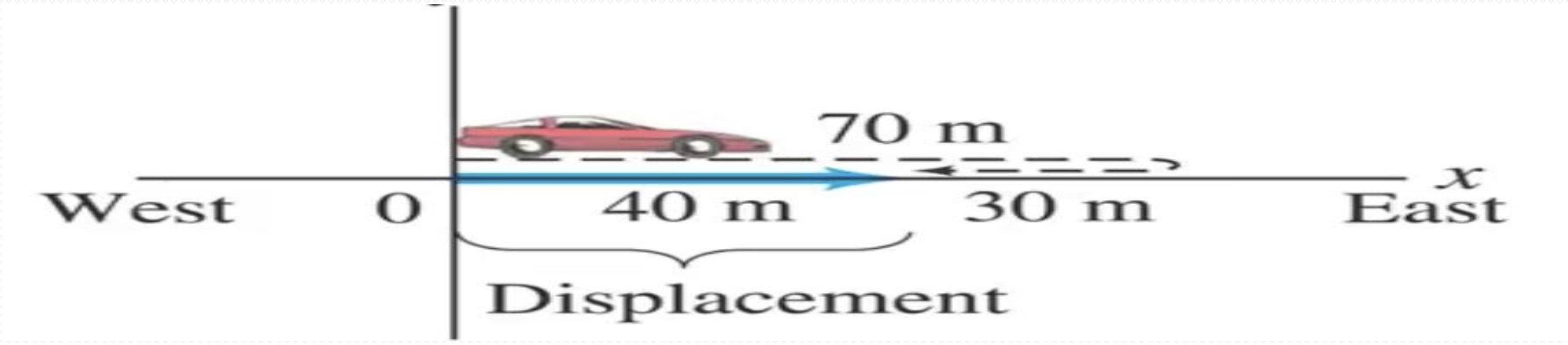


Distance and displacement

الازاحة displacementتعتمد على المسافة بين نقطتي البداية والنهاية فقط ولا تعتمد على المسار الدي يسلكه الجسم. الإزاحة تأخذ قيم سالبة وموجبة.

اما المسافة distanceتعتمد على المسار الدى يسلكه الجسم. المسافة دائما موجبة.

Displacement has both a magnitude and a direction , its vector quantity ,but Distance has a magnitude only ,it's a scalar quantity



Example (1)

- Write the position vector for a particle in the rectangular coordinate $(x\ , y, z)$ for the $points(5,-6,0), (5,-4)$,and$(-1,3,6)$
- Solution
- For the $point(5,-6,0)the$ position is: $\vec{r}$=5i-6j
- For the $point(5,-4)the$ position is: $\vec{r}$=5i-4j
- For the point$(-1,3,6)the$ position is: $\vec{r}$=-i+3j+6k

Example(2)

Calculate the displacement vector for a particle moved from the point (4, 3, 2) to a point (8, 3, 6).

Solution

The position vector for the first point is: $\overrightarrow{r_1}$ **=4i+3j+2k**

The position vector for the second point is: $\overrightarrow{r_2}$ **=8i+3j+6k**

$\Delta\vec{r} = \overrightarrow{r_2} - \overrightarrow{r_1}$

$\therefore \Delta\vec{r}$ **=4i+4k**

Example(3)

$x_1 (t_1) = - 3.0$ m

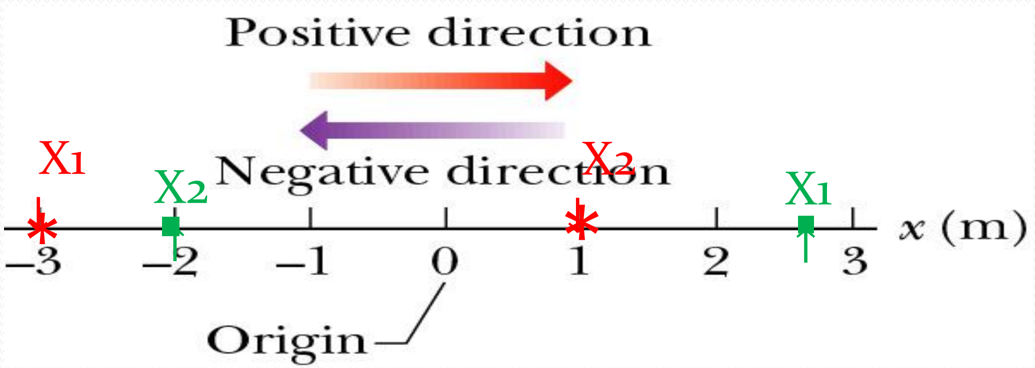
$x_2 (t_2) = + 1.0$ m

$\Delta x = +1.0$ m $+ 3.0$ m $= +4.0$ m

$x_1 (t_1) = + 2.5$ m

$x_2 (t_2) = - 2.0$ m

$\Delta x = -2.0$ m $- 2.5$ m $= -4.5$ m



Example(4)

If the position of a particle is given as a function of time according to the equation

$\vec{r}\,(t)=3t^2 i+(3t-2)j$

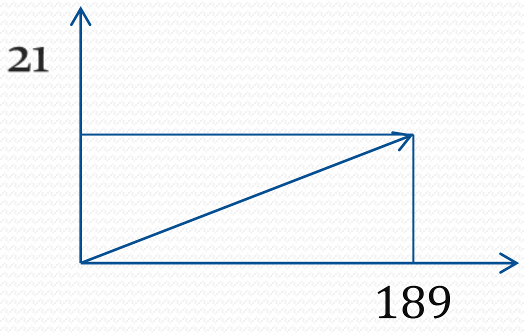
Where t in second .Find the displacement vector for $t_1=1$ and $t_2=8$

Solution

First we must find the position vector for time t_1 and t_2

For $t_1=1s$ $\quad \overrightarrow{r_1}(t_1)=3\,i+j$

For $t_2=8s$ $\quad \overrightarrow{r_2}(t_2)=192\,i+22\,j$



The displacement vector

$\Delta\vec{r}=\overrightarrow{r_2}-\overrightarrow{r_1}$

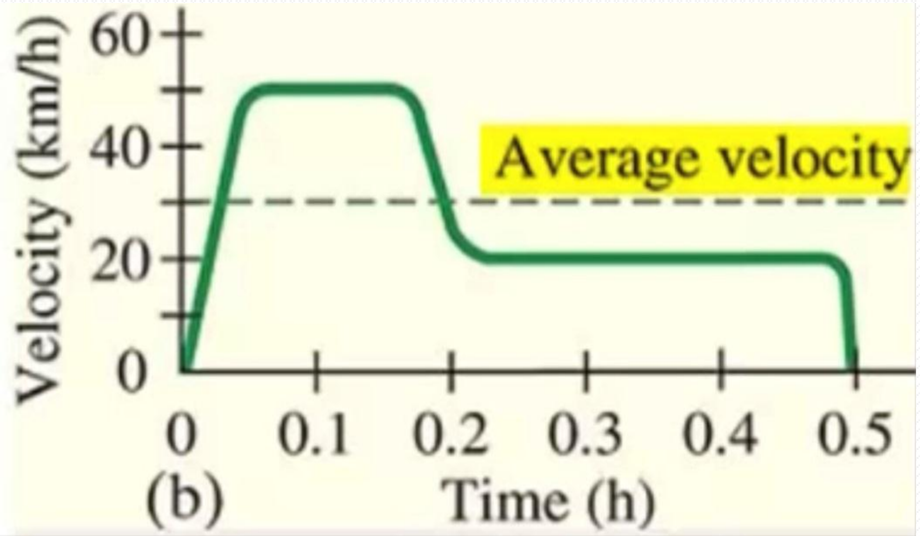
$=192\,i+22j-3\,i-j$

$=189\,i+21\,j$

The Average velocity and Instantaneous velocity

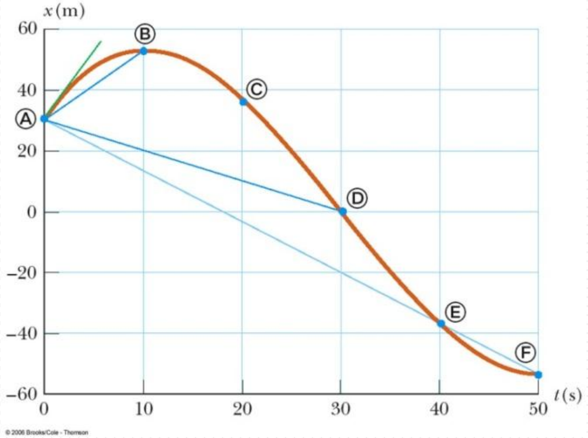
عند انتقال الجسم من موضع البداية عند الزمن $t1$ الى موضع النهاية عند الزمن t2 فان حاصل قسمة الإزاحة Δx على فرق الزمن t2-t1يعرف بالسرعة velocity وحيث ان الجسم يقطع المسافة بسرعات مختلفة فان السرعة المحسوبة تسمى بمتوسط السرعة Average velocity ويمكن تعريف السرعة عند اية لحظة بالسرعة اللحظية Instantaneous velocity

$$\overrightarrow{v_{ave}} = \frac{\Delta \vec{x}}{\Delta t}$$



Instantaneous Velocity

- **Instantaneous velocity:**
- Instantaneous means "at some given instant". The instantaneous velocity indicates what is happening at every point of time.
- Limiting process: as $\Delta t \Rightarrow 0$
- It is a vector quantity.
- $\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$



- Dimension: length/time (L/T), [m/s].
- It is the slope of the tangent line to x(t).
- Instantaneous velocity v(t) is a function of time.

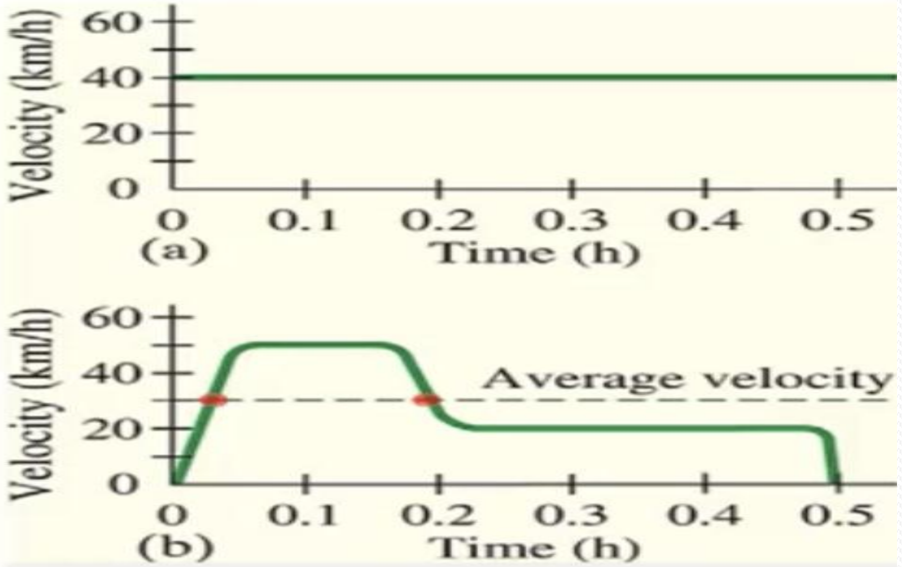
The average velocity of a particle is defined as the ratio displacement to the time interval.

$\overrightarrow{v_{ave}} = \frac{\Delta\vec{r}}{\Delta t}$ **average velocity**

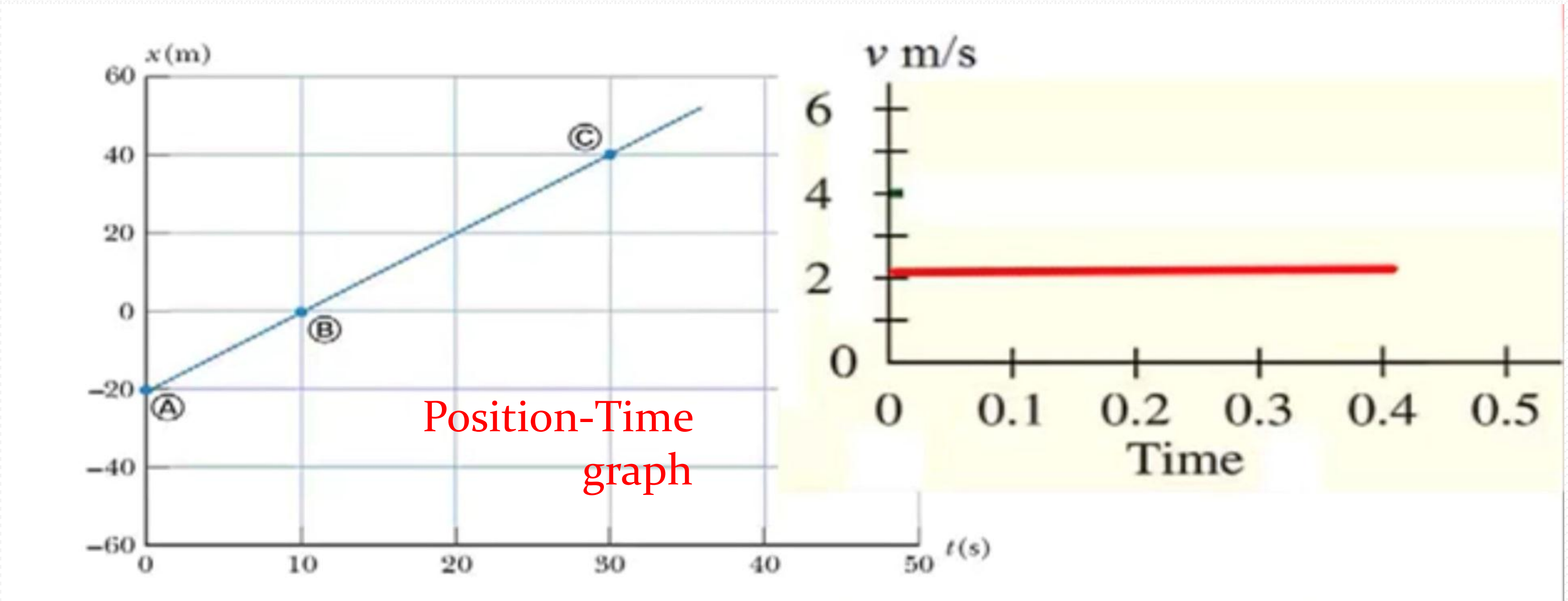
The instantaneous velocity of a particle is defined as the limit of the average velocity as the time interval approaches zero.

$$\vec{v} = \lim_{\Delta t \to 0} \frac{\Delta r}{\Delta t} = \frac{dr}{dt}$$

$\therefore \vec{v} = \frac{d\vec{r}}{dt}$ **instantaneous velocity**



These graphs show (a) constant velocity and (b) varying velocity.



- Average velocity equals the slope of the line joining the initial and final positions . It is a vector quantity.
- An object moving with a constant velocity will have a graph that is a straight line.

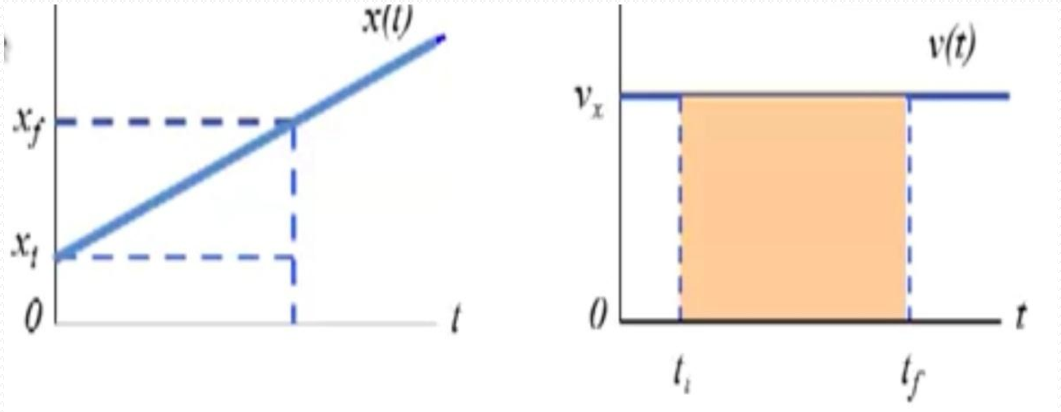
Uniform Velocity

Uniform velocity is constant velocity

In this case, instantaneous velocities are always the same, all the instantaneous velocities will also equal the average velocity

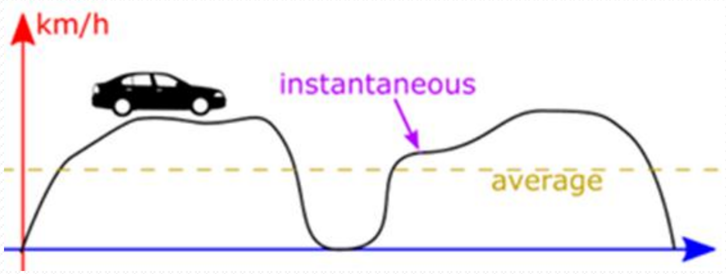
Begin with: $v_x = \frac{\Delta x}{\Delta t} \quad = \frac{x_{f-x_i}}{\Delta t}$ then

$\Delta x = x_f - x_i = v_x \Delta t$



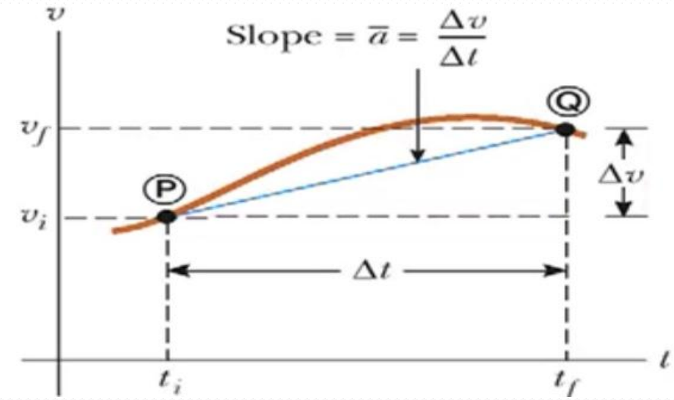
The Average acceleration and Instantaneous acceleration

- Acceleration is the rate of change of velocity.
- Acceleration is a vector quantity.
- Acceleration has both magnitude and direction.
- Acceleration has a dimensions of length/time^2: [m/s^2].
- Definition:
- The average acceleration of particle is defined as the ratio of the change in instantaneous velocity to the time interval.
- $\vec{a}=\frac{\Delta\vec{v}}{\Delta t}$ Average acceleration
- The Instantaneous acceleration is defined as the limiting value of the average velocity to the time interval as the time approaches zero.
- $\vec{a} = \lim_{\Delta t\to 0} \Delta\vec{v}/\Delta t = \frac{dv}{dt}$
- $\therefore \vec{a} = \frac{d\vec{v}}{dt}$ Instantaneous acceleration
- $\vec{a} = \frac{d}{dt}(\frac{dx}{dt}) = \frac{d2x}{dt^2}$



Relationship between Acceleration and Velocity

- Velocity and acceleration are in the same direction.
- Positive velocity and positive acceleration.



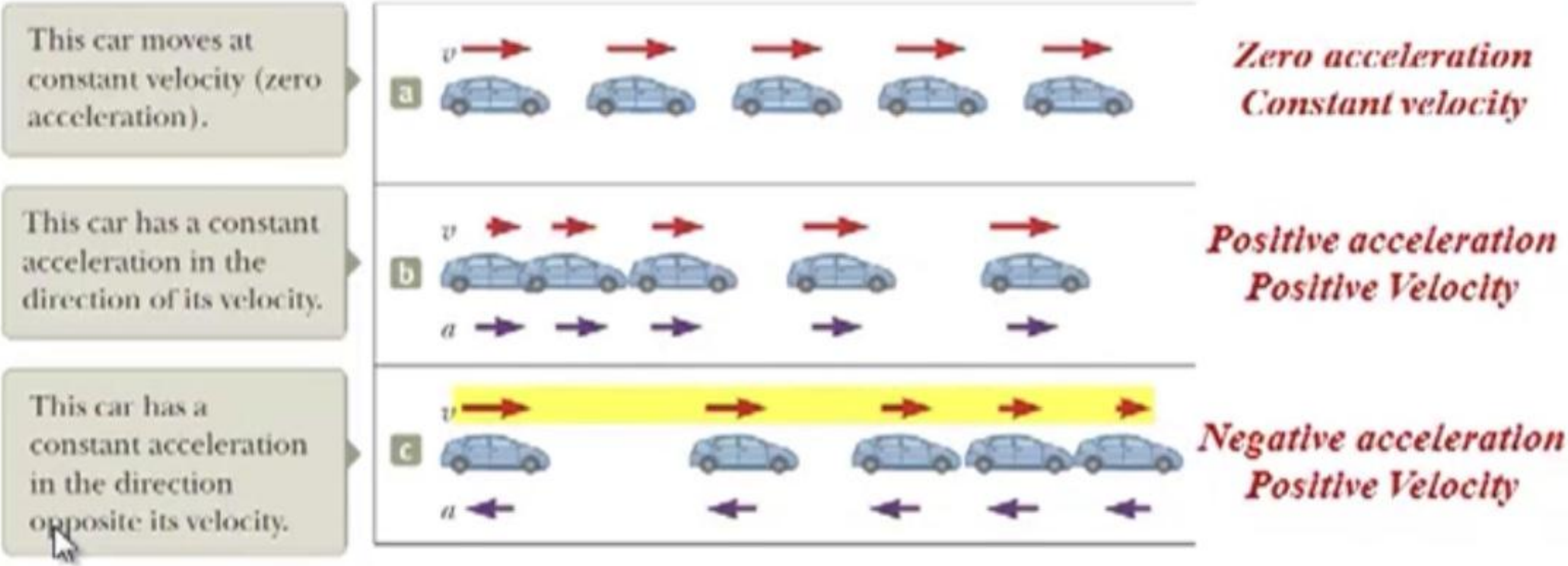
منحني يمثل تغير السرعة بالنسبة للزمن

Velocity-Time Graph

- Average acceleration is the slope of the line connecting the initial and final
- velocities on a velocity- time graph.

- Velocity as a function of time.
- $v_f(\text{t}) = v_i + a_{avg}\Delta t$ $\Delta v_{avg} = v_f - v_i = a_{avg}\Delta t$
-

Relation between velocity and acceleration



Three sets of strobe photographs of cars moving along a straight roadway in a single direction, from left to right. The time intervals between flashes of the stroboscope are equal in each part of the diagram.

Example(5)

The coordinate of a particle moving along the x-axis depends on time according the expression

$$X = 5t^2 - 2t^3$$

Where x is in meters and t is in seconds.

1-Find the velocity and acceleration of the particle as a function of time.

2-Find the displacement during first 2 seconds.

3-Find the velocity and acceleration of the particle after 2 seconds.

Solution

1- The velocity and acceleration can be obtained as follow

V=$\frac{dx}{dt}$ =$\frac{d(5t^2-2t^3)}{dt}$ =$10t - 6t^2$

a=$\frac{dv}{dt}$ =$10 - 12t$

2- using the equation X=5t^2- 2t^3 substitute for $t = 2s$

X=4m

3-using the result in part (1)

V= $-4\ \ m/s$

a= $-14\ \ m\ /\ s$^2

Example(6)

A car makes a 200 km trip at an average speed of 40 km/h .A second car $starting$ $1h$ later arrives at their mutual destination at the same time .What was the average speed of the second car.

Solution

- $t_1 = \frac{d}{v_1} = \frac{200}{40} = 5h$ for car1
- $t_2 = t_1 - 1 = 4h$ for car2
- $v_2 = \frac{d}{t_2} = \frac{200}{4} = 50 km/h$