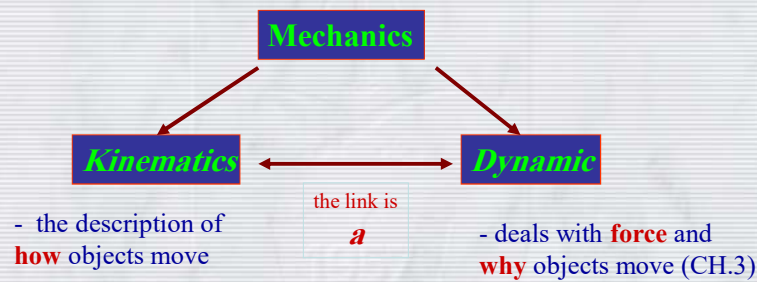


CH 1.Introduction to Mechanics

What is **Mechanics** ?

The study of the **motion of objects (through Equations)**, and the related concepts of **force** and **energy**, form the field called **mechanics**.



Kinematics

Kinematics : the description of how objects move.

- Kinematics in one dimension : describing an object that moves along a straight line path, which is **one dimensional motion**.
- Kinematics in two dimensions : the description of the motion of objects that **move in paths in two (or three) dimensions**.

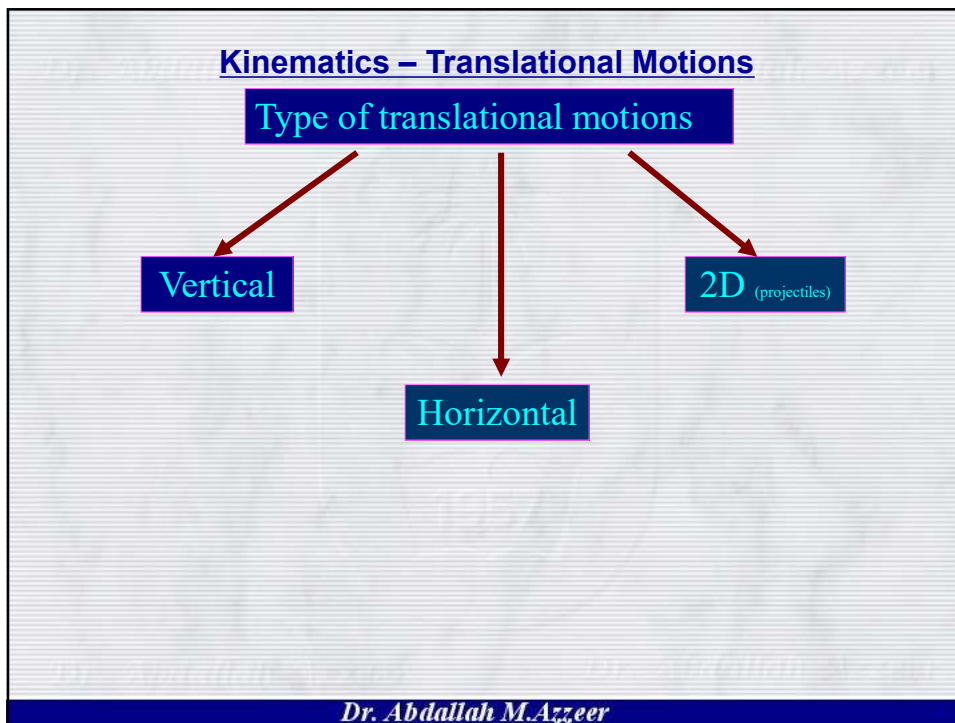
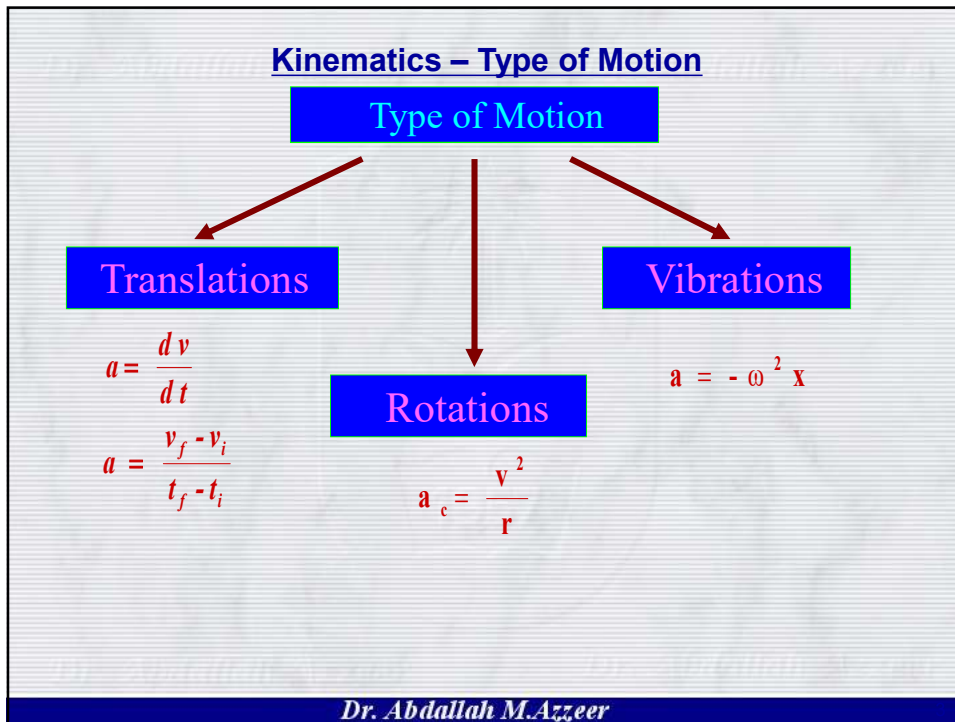
Dynamics

Dynamics : deals with **force** and **why** objects move as they do.

In this part we will solve the following questions :

- What makes an object at rest **begin to move** ?
- What causes a body to **accelerate** or **decelerate** ?
- What is involved when an object **moves in a circle** ?

We can answer in each case that a **FORCE** is required.





Kinematics – Terms and Concepts

Some important terms which you must know !

- Reference Frames
- Displacement
- Distance
- Speed
- Average Velocity
- Instantaneous Velocity
- Average Acceleration
- Instantaneous Acceleration

1. Reference Frames:
Any measurement of position, distance or speed must be made with respect to a frame of reference.

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أهمية وجهة النظر

إن ما يلاحظه كل منا يعتمد على وجهة نظره

فمثلاً : نفترض عربة قطار تسير بسرعة ثابتة مقدارها 30 m/s في إتجاه الشمال وبداخل هذه العربة رجل يقذف كرة بسرعة ثابتة مقدارها 1 m/s في إتجاه الشمال، ماهي سرعة الكرة ؟



الإجابة على هذا السؤال قد تكون سهلة ولكن ليس هناك إجابة واحدة كيف؟

الإجابة الصحيحة تعتمد على مرجع معين أو راصد..... فهناك إجابتين:

1- بالنسبة الى أرضية العربة (الرجل داخل العربة) تكون سرعة الكرة مساوية لـ 1 m/s شمالاً

2- بالنسبة الى راصد يقف على الأرض خارج العربة تكون سرعة الكرة مساوية 1 m/s شمالاً + 3 m/s شمالاً أو 4 m/s بإتجاه الشمال

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Dropping a Ball From the Top of the Mast of a Moving Sailboat



Frame of Reference Where the Boat is Stationary

Air resistance is negligible

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Frame of Reference Where the Boat is Moving to the Right at Constant Speed



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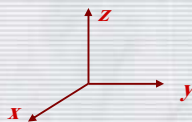
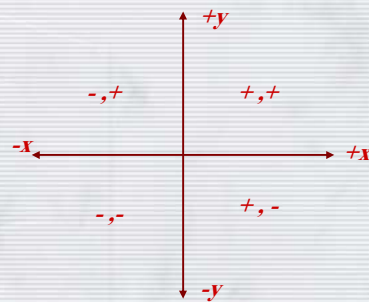
Reference Frames, Coordinate Systems

- Every measurement must be made with respect to a **reference frame**.
- Usually, speed is relative to the Earth.
- When specifying speed, always specify the frame of reference unless its obvious ("with respect to the Earth").
- Distances are also measured in a reference frame.
- When specifying speed or distance, we also need to specify **DIRECTION**.

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Coordinate Axes

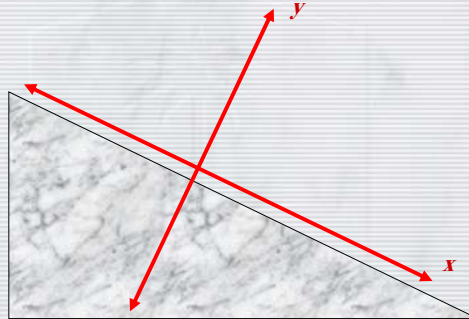
- Define reference frame using a standard coordinate axes.
- 2 Dimensions **(x,y)**
- Note, if its convenient, could reverse + & - !
- 3 Dimensions **(x,y,z)**



- Define direction using these.

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- For inclined plane problems (later), tilted axes will be used (for convenience!):



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Distance and Displacement:

Distance:

The length of the actual path or total path length

Example,

Jeddah is ~1000 km away from Arriyadh.

Displacement:

The change in position of the object.

$\Delta x = x_f - x_i$ Δx means the **change in x (position)** which is the displacement.

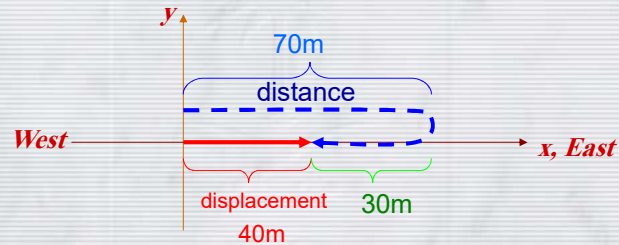
A vector quantity



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Distance Vs Displacement**Example:**

A person walking 70 m to the east and then turning around and walking back (west) a distance of 30 m.

**Total distance = 100 m****Displacement = $x_f - x_i = 70 \text{ m} - 30 \text{ m} = 40 \text{ m}$** *Dr. Abdallah M. Azzeer***Average Speed:**Average Speed is defined *as the distance travelled along its path divided by the time it takes to travel this distance,*

$$\text{average speed} = \frac{\text{distance travelled}}{\text{time elapsed}}$$

It is a scalar quantity, with unit (ms^{-1})**Average Velocity**Average velocity is defined *as the displacement divided by the elapsed time*

$$\text{average velocity } \bar{v} = \frac{\text{displacement}}{\text{time elapsed}} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

It is a vector quantity, with unit (ms^{-1})*Dr. Abdallah M. Azzeer*

Instantaneous Velocity:

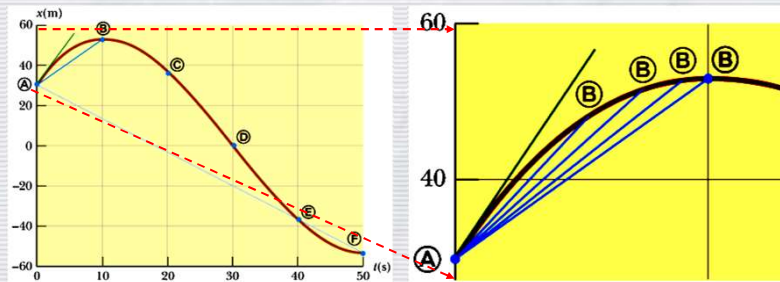
The instantaneous velocity is the velocity at any instant of time.

In general the *instantaneous velocity at any moment is defined as the average velocity over an infinitesimally short time interval.*

$$v_x = \lim_{\Delta t \rightarrow 0} \frac{\Delta x}{\Delta t} = \frac{dx}{dt}$$

Instantaneous velocity is the derivative of x with respect to t , dx/dt !

Velocity is the slope of a position-time graph!



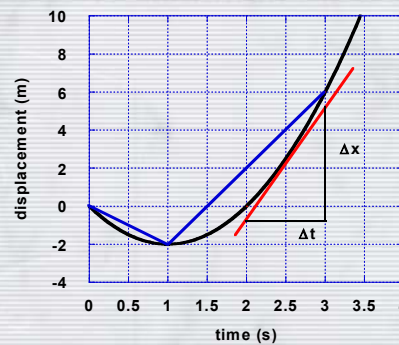
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Example 2.3

A particle moves along the x -axis. Its coordinate varies with time according to the expression

$$x = - (4 \text{ m / s}) \cdot t + (2 \text{ m/s}) \cdot t^2$$

- Determine the displacement of the particle in the time intervals $t=0$ to $t=1$ s and $t=1$ s to $t=3$ s.
- Calculate the average velocity during these two time interval.
- Find the instantaneous velocity of the particle at $t=2.5$ s.
- What is the instantaneous velocity at 1 s (graph).

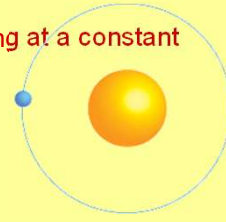


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Example: Velocity

Assume the earth is in circular orbit about the sun, moving at a constant speed. What are the earth's

- i) average velocity
- ii) average speed
- iii) instantaneous velocity ?



Given that the radius of the earth's orbit is $1.5 \times 10^{11} \text{m}$

Solution:

i) average velocity
$$\bar{v} = \frac{\text{displacement}}{\text{time elapsed}} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

$$= \frac{0}{T} = 0 \text{ ms}^{-1}$$

because, in one full cycle, the displacement of earth from original point is zero (earth reaches the initial point again)

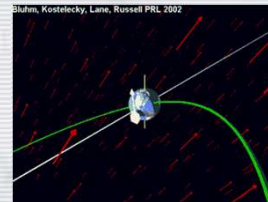
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- ii) Average speed

$$\bar{v}_s = \frac{\text{distance travelled}}{\text{time elapsed}}$$

but, $d = 2\pi r = 2\pi (1.5 \times 10^{11} \text{m}) = 9.4 \times 10^{11} \text{m}$

$$\bar{v}_s = \frac{9.4 \times 10^{11} \text{m}}{(365.25)(24)(60)(60)} = 2.98 \times 10^4 \text{ms}^{-1}$$

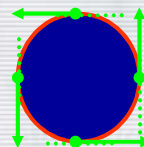


- iii) Instantaneous velocity

Because the earth are orbit around the sun at constant speed, and the average speed is given in (ii) above, thus,

magnitude of v : $2.98 \times 10^4 \text{ms}^{-1}$

direction : tangent to the path at each instant.



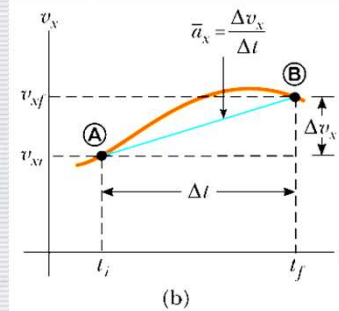
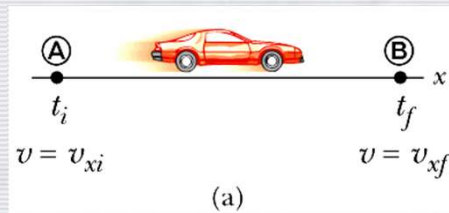
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ACCELERATION

Average Acceleration:

Acceleration specifies **how rapidly the velocity of an object is changing**. Average acceleration is defined as the change in velocity divided by the time taken to make this change

$$\text{average acceleration } \bar{a}_x = \frac{\text{change of velocity}}{\text{time elapsed}} = \frac{\Delta v_x}{\Delta t} = \frac{v_{xf} - v_{xi}}{t_f - t_i}$$

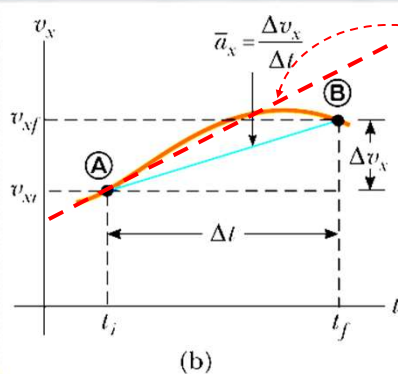


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Instantaneous Acceleration:

The instantaneous acceleration is **the acceleration at any instant of time**. In general the *instantaneous acceleration at any moment is defined as the average acceleration over an infinitesimally short time interval*

$$\text{instantaneous acceleration } a_x = \lim_{\Delta t \rightarrow 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt}$$



$$a_x \equiv \lim_{\Delta t \rightarrow 0} \frac{\Delta v_x}{\Delta t} = \frac{dv_x}{dt} \quad \text{Units: m/sec}^2$$

Because $v_x = dx/dt$, the acceleration can also be written as:

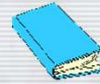
$$a_x \equiv \frac{dv_x}{dt} = \frac{d}{dt} \left(\frac{dx}{dt} \right) = \frac{d^2x}{dt^2}$$

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Conceptual Question #1

- Velocity and acceleration are both vectors (they have magnitude & direction).
- Are the *velocity* and the *acceleration* always in the same direction?

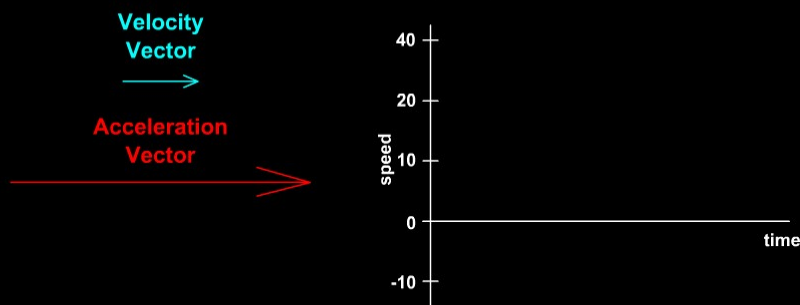
NO!!•



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Motion Animation

Based on Serway & Jewett Figure 2.11



$v_0 = 12$

Set Acceleration:



Units are arbitrary



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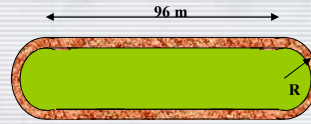
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Pervious Final question

A runner runs around a track consisting of two parallel lines 96 m long connected at the ends by two semicircles with a radius of 49 m. If he completes one lap in two minutes, then his average speed is:

- A. 1.6 m/s
- B. 4.2 m/s
- C. 2.9 m/s
- D. 0 m/s



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