KINEMATICS

CHAPTER 2
PPP 0101

CONTENTS

AT THE END OF THIS CHAPTER YOU SHOULD BE ABLE TO :

- **Define distance, displacement, velocity, acceleration.**
- **Know how to apply all the equation for linear motion with constant acceleration.**
- **Draw graph velocity versus time , distance versus time and explain them.**
- **Understand the concept of free fall and should be able to solve the problem.**

BEFORE WE START

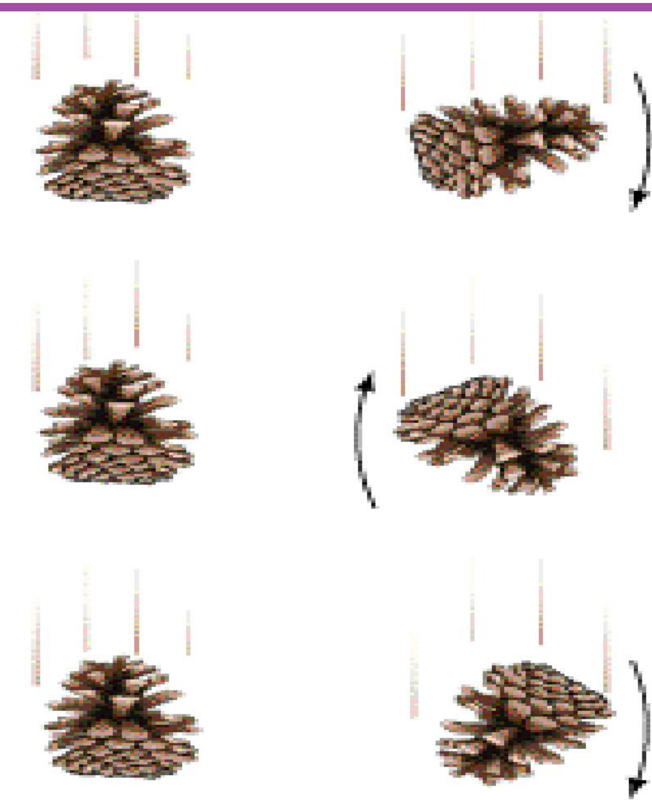
- **Mechanics**
  - **Study of the motion of objects and the related concepts of force, energy.**
  - **Divide into 2 area**
    - Kinematics (Constant Acceleration Kinematics)
      - how objects move?
      - *Not* concerned with the cause of the motion
    - Dynamics
      - why objects move as they do?
      - Deals with force

2.1 TYPE OF MOTION

- There are 3 types of motion
  - Translation
  - Rotational

a) **Pinecone undergoes pure translational as it falls**

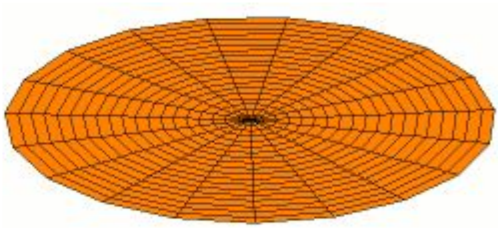
b) **it is rotating as well as translating**



(a) (b)

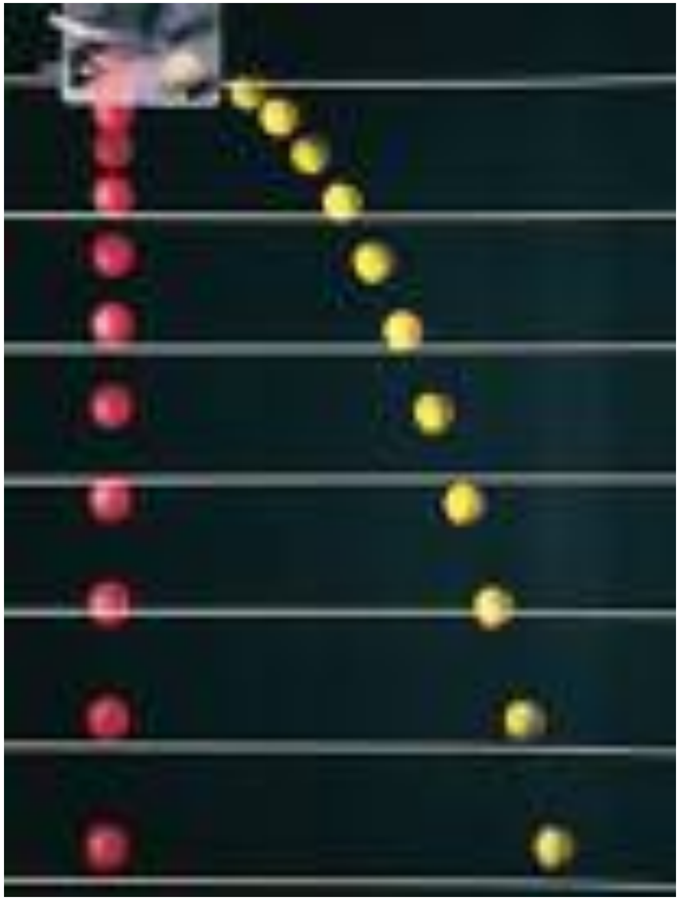
2.1 TYPE OF MOTION

- Vibration



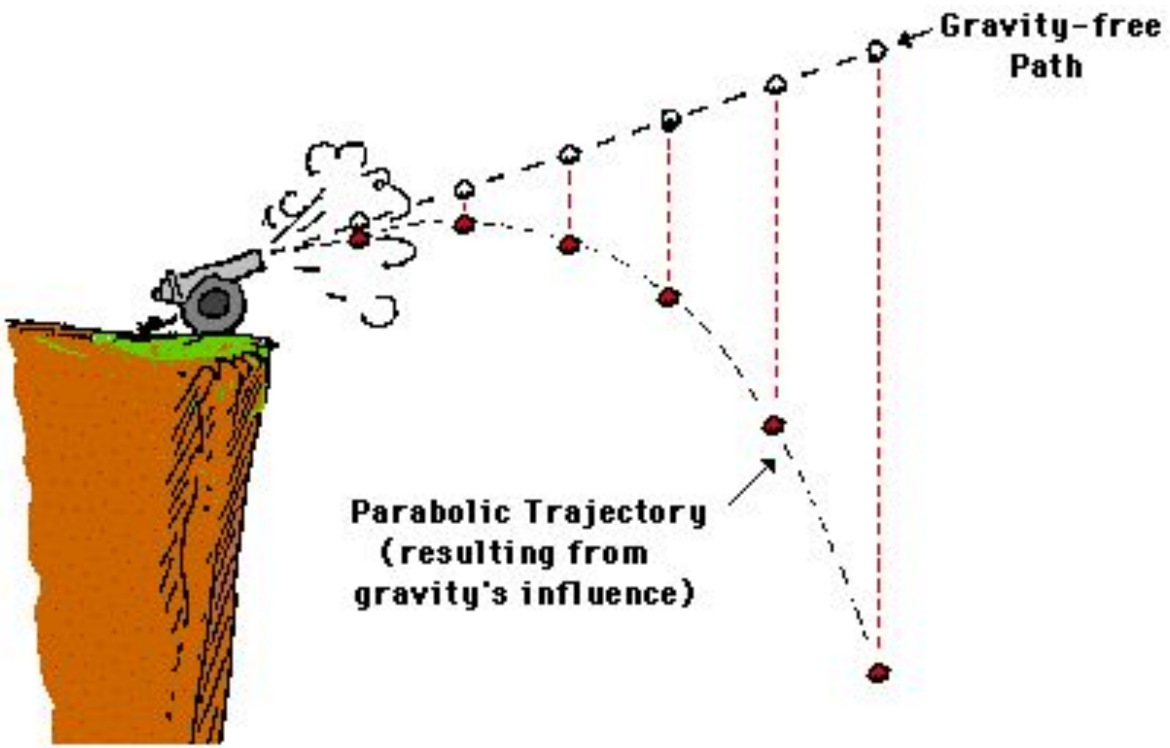
2.2 MOTION IN A STRAIGHT LINE

- Vertical



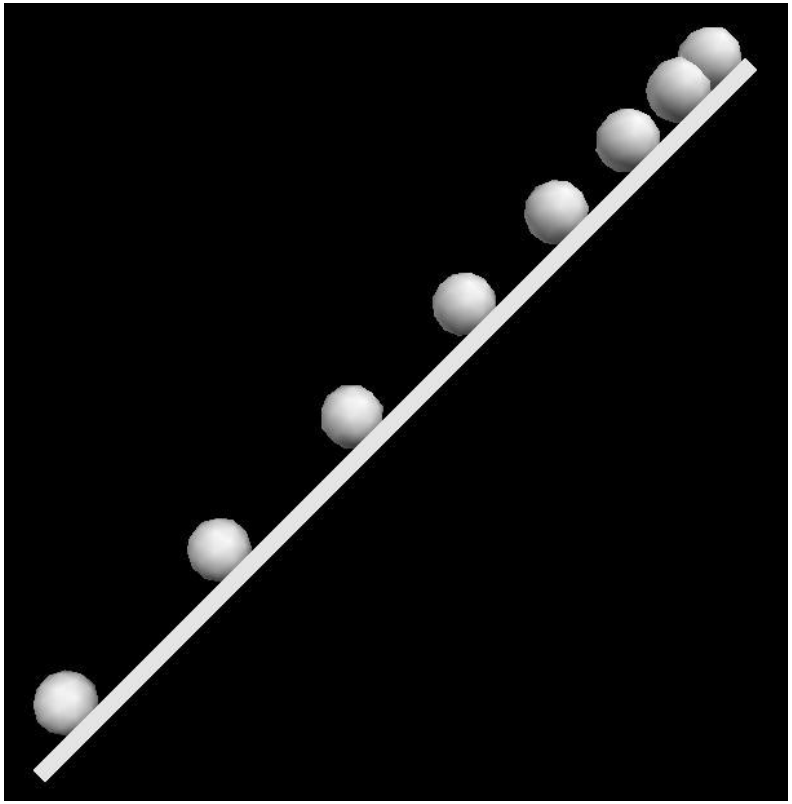
2.2 MOTION IN A STRAIGHT LINE

- Horizontal



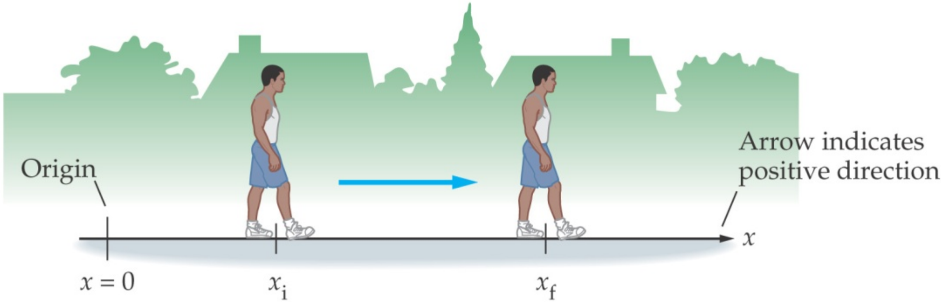
2.2 MOTION IN A STRAIGHT LINE

- Slanting



2.3 POSITION, DISTANCE AND DISPLACEMENT

- **Position**
  - An indicated for a place or location
  - We need to setup a coordinate system

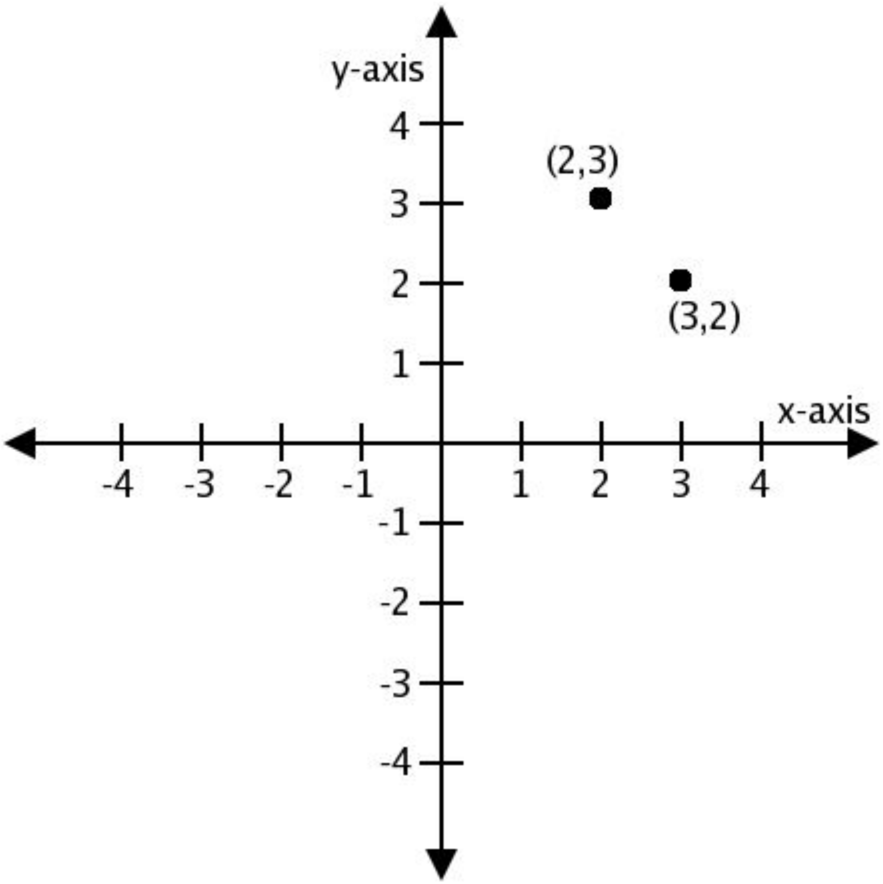


How to setup a coordinate ?

1. **Choose any place as origin.**
2. **Define the positive and negative direction as you like.**
3. **Please stick with your definition while you choose the positive and negative direction.**

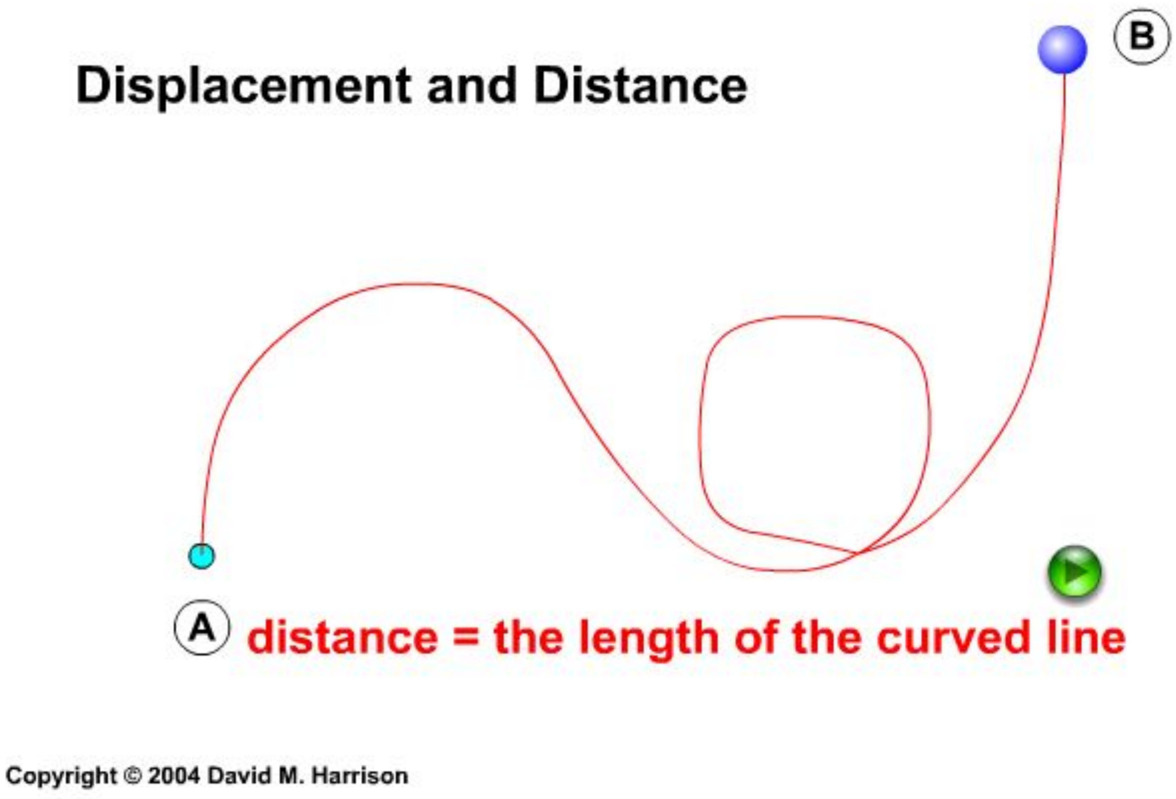
2.3 POSITION, DISTANCE AND DISPLACEMENT

- Position



2.3 POSITION, DISTANCE AND DISPLACEMENT

- Distance and Displacement



2.3 POSITION, DISTANCE AND DISPLACEMENT

- Distance
  - Euclidean distance
  - The length of the actual path or total path length or total length of travel.
  - SI unit: Meter, m

2.3 POSITION, DISTANCE AND DISPLACEMENT

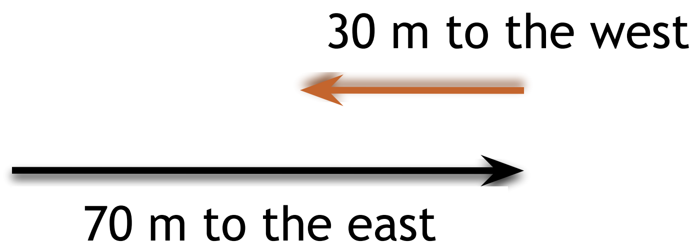
- Displacement
  - Change in position of the object.
  - How far the object is from its starting point.
  - Vector quantity
  - SI Unit: Meter, m
  - Symbol : s

$$\Delta x = x_f - x_i$$

Change of position from final position to its initial position which mean final position minus initial position.

2.3 POSITION, DISTANCE AND DISPLACEMENT

- A person walks 70 m east, then 30 m west.



displacement = 70 to east + 30 to west

= 40 to east

distance = 70 + 30

= 100 m

2.4 AVERAGE SPEED AND VELOCITY

- Average Speed
  - The distance traveled along its path divide by the time it takes to travel this distance

$$\text{Average Speed} = \frac{\text{Total distance traveled}}{\text{time elapsed}}$$

  - Example

What is the average speed to travel KL to JB in 4.25 hours ? (distance between KL to JB is 368 KM)

$$\text{Average Speed} = \frac{368\text{km}}{4.25\text{h}}$$

$$= 86.6 km / h$$

2.4 AVERAGE SPEED AND VELOCITY

- Average Velocity
  - The displacement (change of distance) divided by elapsed time (change of time)

$$\bar{v} = \frac{\Delta x}{\Delta t}$$

$$= \frac{x_f - x_i}{t_f - t_i}$$

  - Unit SI : Meter per Second (ms^{-1})
  - 0 ms^{-1} mean starting and ending points are the same.

2.4 AVERAGE SPEED AND VELOCITY

Example

A person jogs eight complete laps around 400 m track in a total 12.5 min. Calculate the average speed and average velocity in m/s

$$\text{average speed} = \frac{(400 \times 8)m}{(12.5 \times 60)s} = 4.26 m/s$$

$$\bar{v} = \frac{0\text{m}}{12.5 \times 60 s} = 0 m/s$$

This is because the ending and starting point are located at same position, there is no displacement

2.5 INSTANTANEOUS VELOCITY

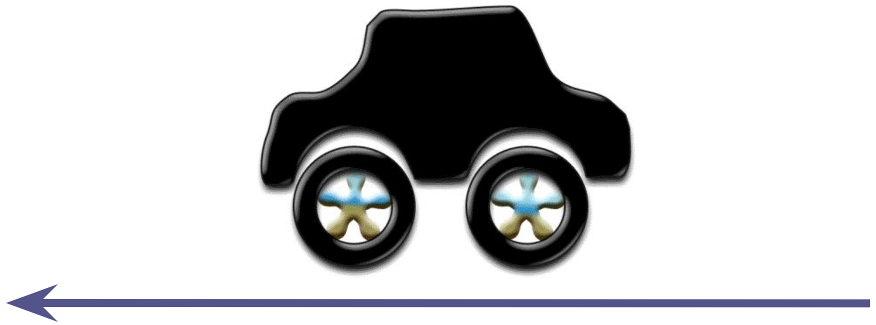
- Since a moving object often changes its speed during its motion, it is common to distinguish between the average speed and the instantaneous speed.

  - **Instantaneous Speed** - the speed at any given instant in time.
  - **Average Speed** - the average of all instantaneous speeds; found simply by a distance/time ratio.

2.5 *INSTANTANEOUS VELOCITY*

- You might think of the **instantaneous speed as the speed that the speedometer reads at any given instant in time** and the **average speed as the average of all the speedometer readings during the course of the trip.**

2.5 *INSTANTANEOUS VELOCITY*



- If this car travel for 150km in 2 hours time. The average velocity is 75km/h
- This average velocity value does not mean that this car will travel with 75 km/h in every instant.

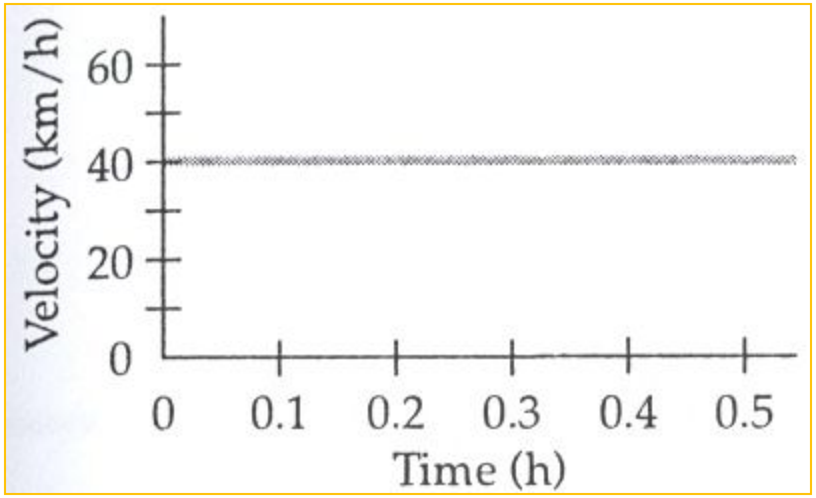
2.5 INSTANTANEOUS VELOCITY

- Instantaneous velocity at any moment
  - Average velocity over an infinitesimally short time interval.

$$v = \lim_{\Delta t \to 0} \frac{\Delta x}{\Delta t}$$

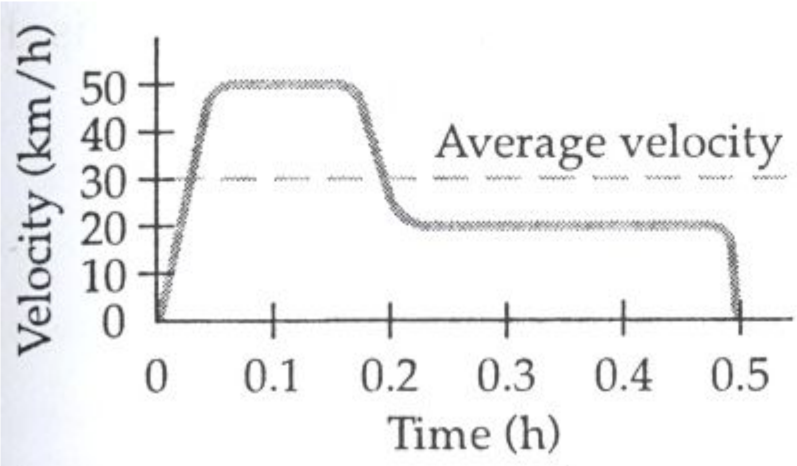
$$= \frac{dx}{dt}$$

2.5 INSTANTANEOUS VELOCITY



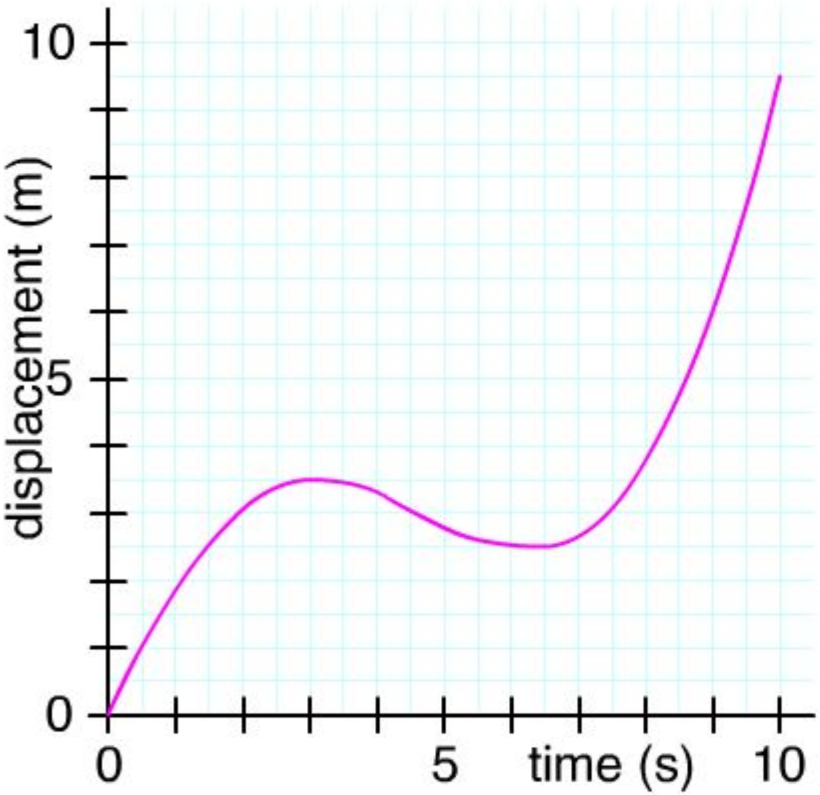
- What can you tell me about the move of the object from this graph ?
  - Velocity is constant.
  - Its instantaneous velocity at any instant is the same.

2.5 INSTANTANEOUS VELOCITY



- What can you tell me about the move of the object from this graph ?
  - The objects moves in a varying velocity.
  - The instantaneous velocity is not equivalent to the average velocity.

2.5 INSTANTANEOUS VELOCITY



t (s)	s (m)	v(m/s)
0.0	0.0	+2.0
2.0	3.2	–0.7
3.0	3.5	0.0
4.5	3.0	–0.6
6.5	2.5	0.0
7.8	3.8	+1.5
8.8	5.4	+2.5

2.5 INSTANTANEOUS VELOCITY

- Exercise

A jet engine moves along an experimental track (which we call the x-axis). Its position as a function of time is given by the equation:

$$x = At^2 + B$$

where $A = 2.10 m/s^2$ and B = 2.80 m .

a.) determine the displacement of the engine during the time interval from t_1=3.00 s and t_2=4.00s

b.) determine the magnitude of the instantaneous velocity at t = 5.0 s.

2.6 ACCELERATION

- An object whose velocity is changing is said to be accelerating

- Which car or cars (red, green, and/or blue) are undergoing an acceleration?
- Which car (red, green, or blue) experiences the greatest acceleration?

2.6 ACCELERATION

- The rate of change of velocity.

$$\bar{a} = \frac{\Delta v}{\Delta t}$$

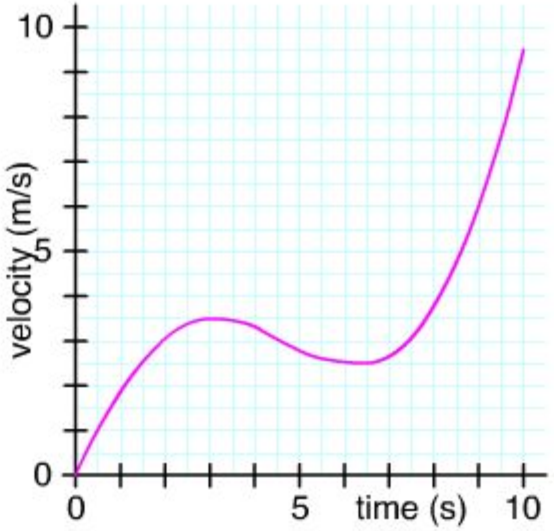
$$= \frac{v_f - v_i}{t_f - t_i}$$

- SI Unit: ms^{-2}

2.6 ACCELERATION

- The instantaneous acceleration

$$a = \lim_{\Delta t \to 0} \frac{\Delta v}{\Delta t} = \frac{dv}{dt} = \frac{d}{dt}\left(\frac{dx}{dt}\right) = \frac{d^2x}{dt^2}$$

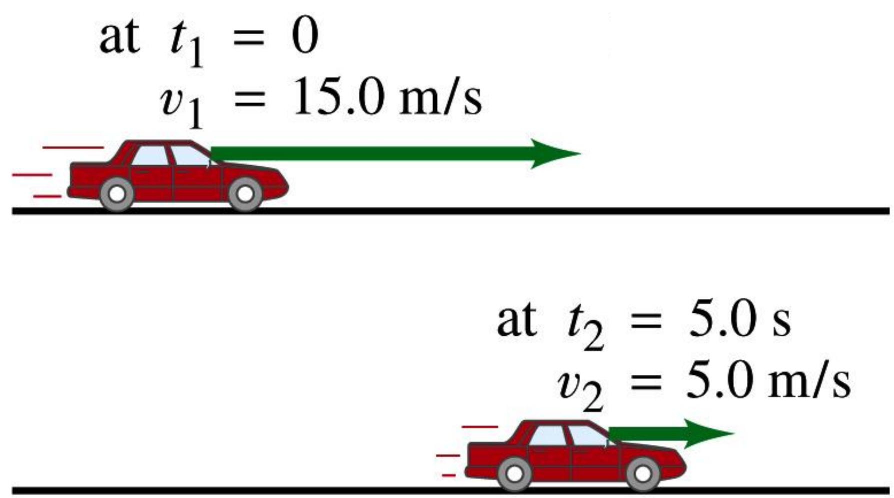


t (s)	v (m/s)	a (m/s^2)
0.0	0.0	+2.0
2.0	3.2	–0.7
3.0	3.5	0.0
4.5	3.0	–0.6
6.5	2.5	0.0
7.8	3.8	+1.5
8.8	5.4	+2.5

2.6 ACCELERATION

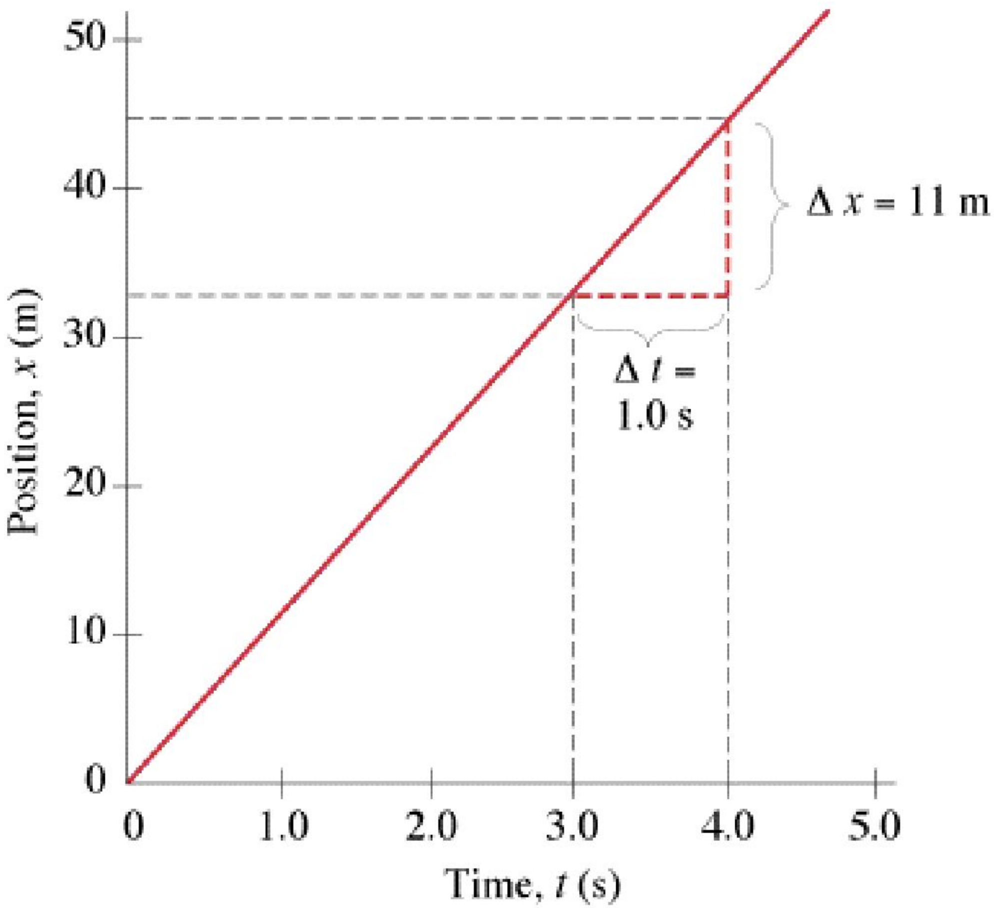
- Example

An automobile is moving to the right along a straight highway. If the initial velocity is 15.0 ms^{-1} and it takes 5.0 s to slow down to, what was the car's average acceleration?



2.7 MOTION GRAPH

- Now we are looking on graph analysis
  - Type 1 Position VS. Time



- ❖ The slope
  - ❖Change of the position divided by change of the time.

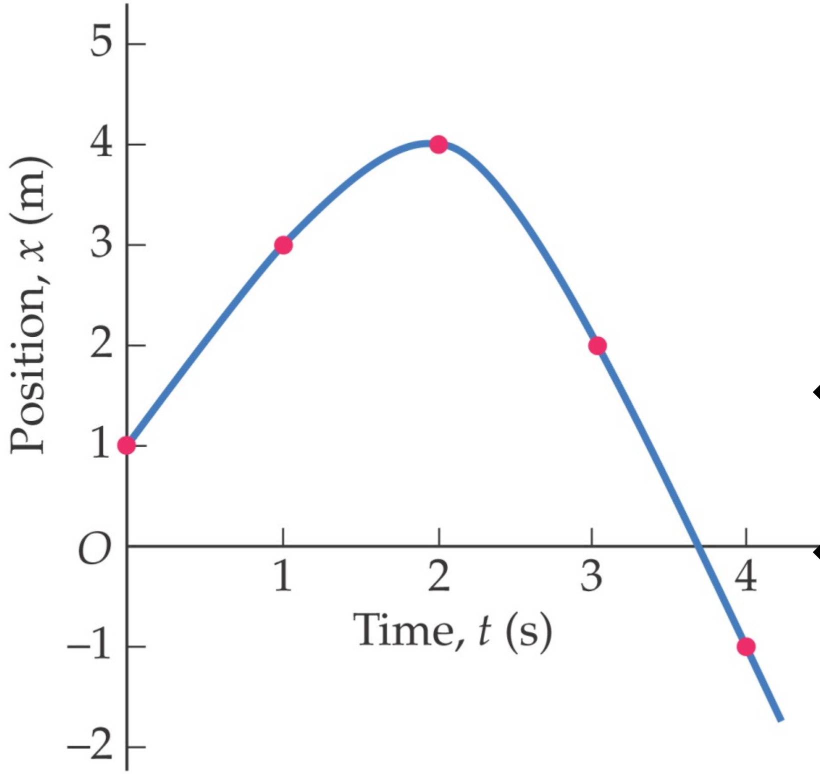
$$\frac{\Delta x}{\Delta t}$$

  - ❖ Slope of this graph is Velocity.

- ❖What is the characteristic of this velocity ?
  - ❖Constant Velocity
  - ❖ Why ?

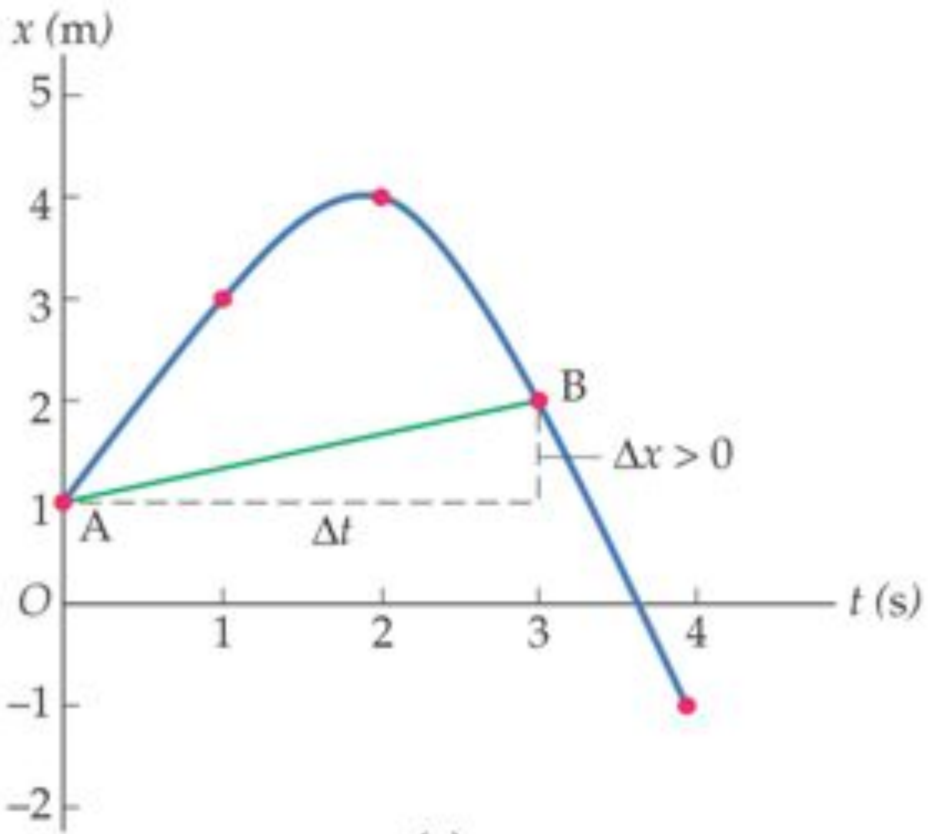
2.7 MOTION GRAPH

- What can you tell me on this graph ?



- ❖The velocity is changing corresponding to the time.
- ❖The instantaneous acceleration are difference.

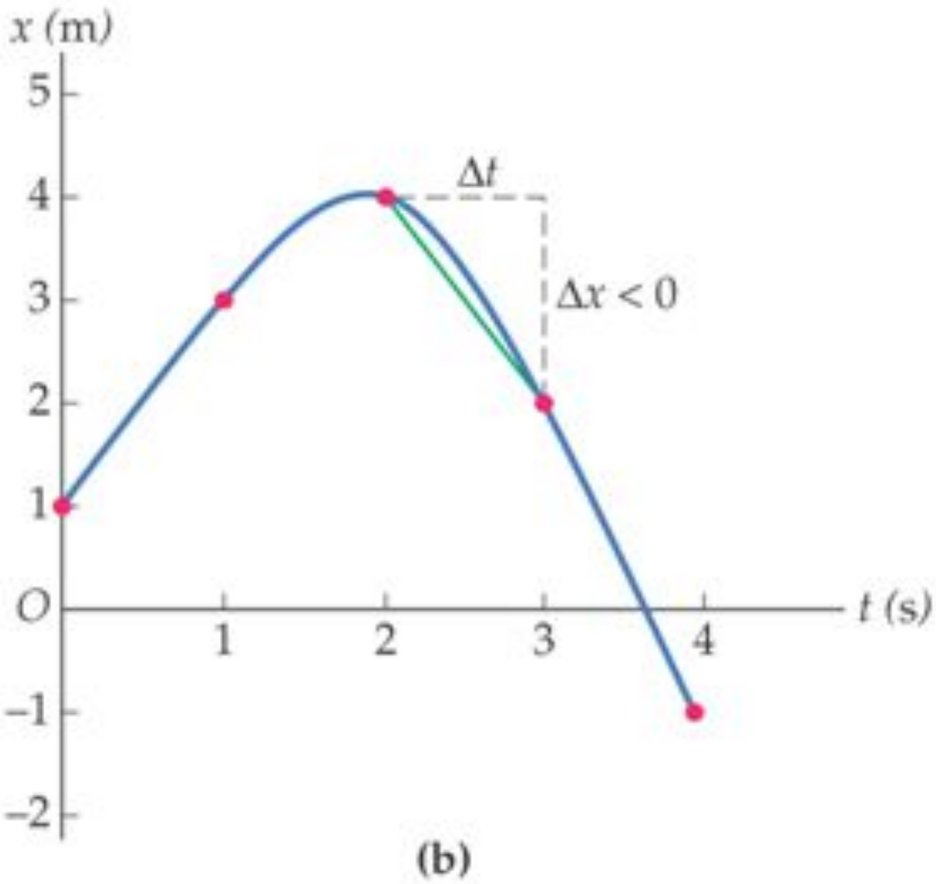
2.7 MOTION GRAPH



(a)

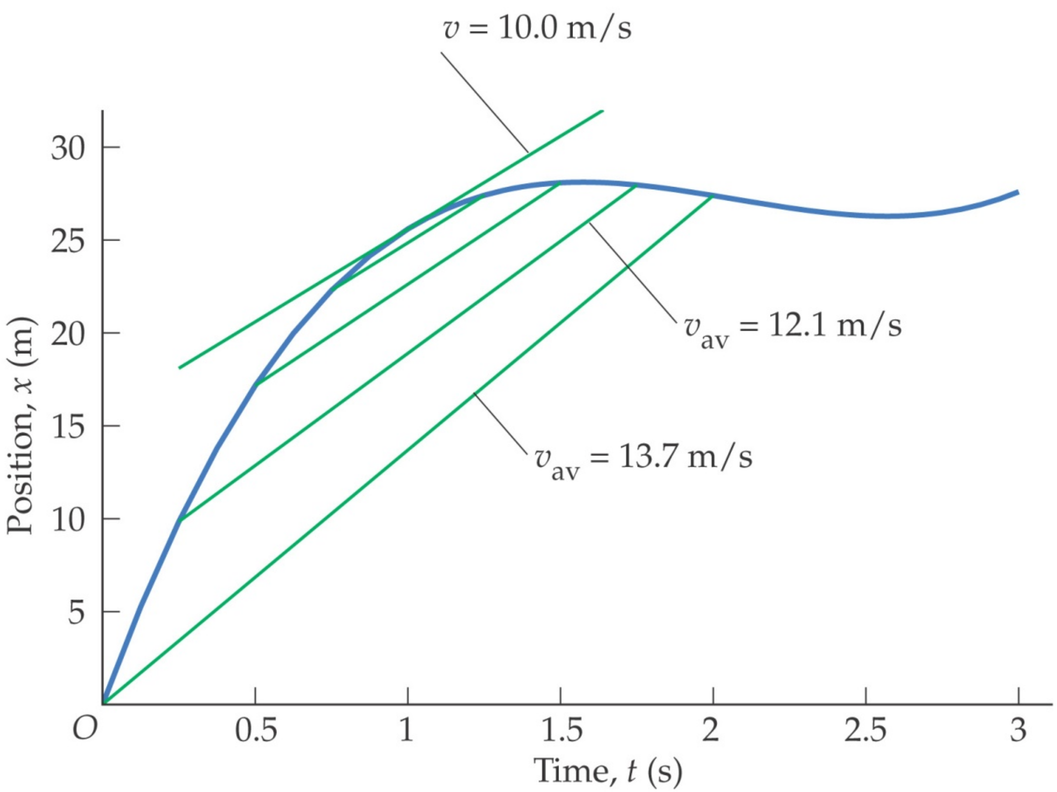
- To calculate the average velocity for the first 3 seconds, just draw a straight line as in diagram. Then use the formula of velocity to calculate the velocity.

2.7 MOTION GRAPH



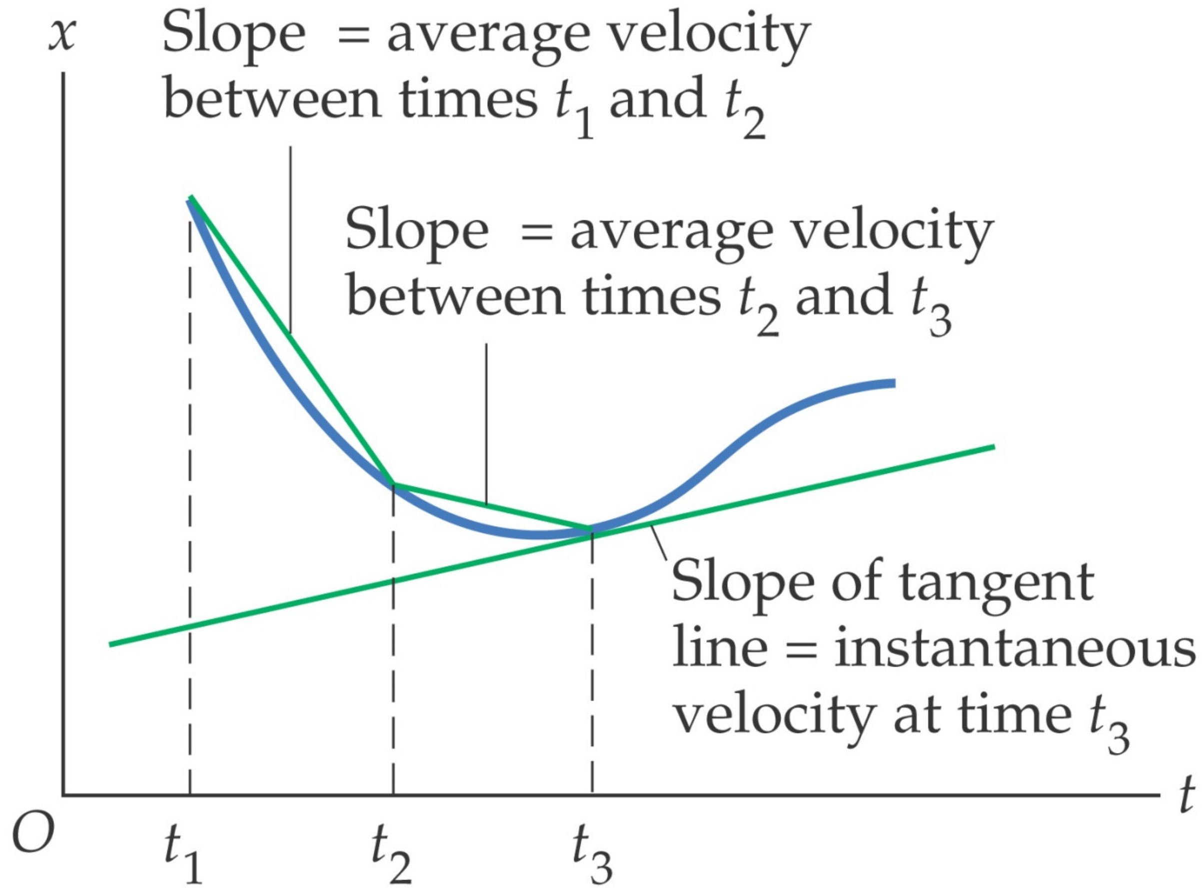
- The slope of this straight line is the average velocity between t = 2 s and t = 3 s. Note that the average velocity is negative, indicating motion to the left.

2.7 MOTION GRAPH



- The instantaneous velocity at t = 1 s is equal to the slope of the tangent line at that time.
- The average velocity for a small time interval centered on t = 1 s approaches the instantaneous velocity at t = 1 s as the time interval goes to zero.

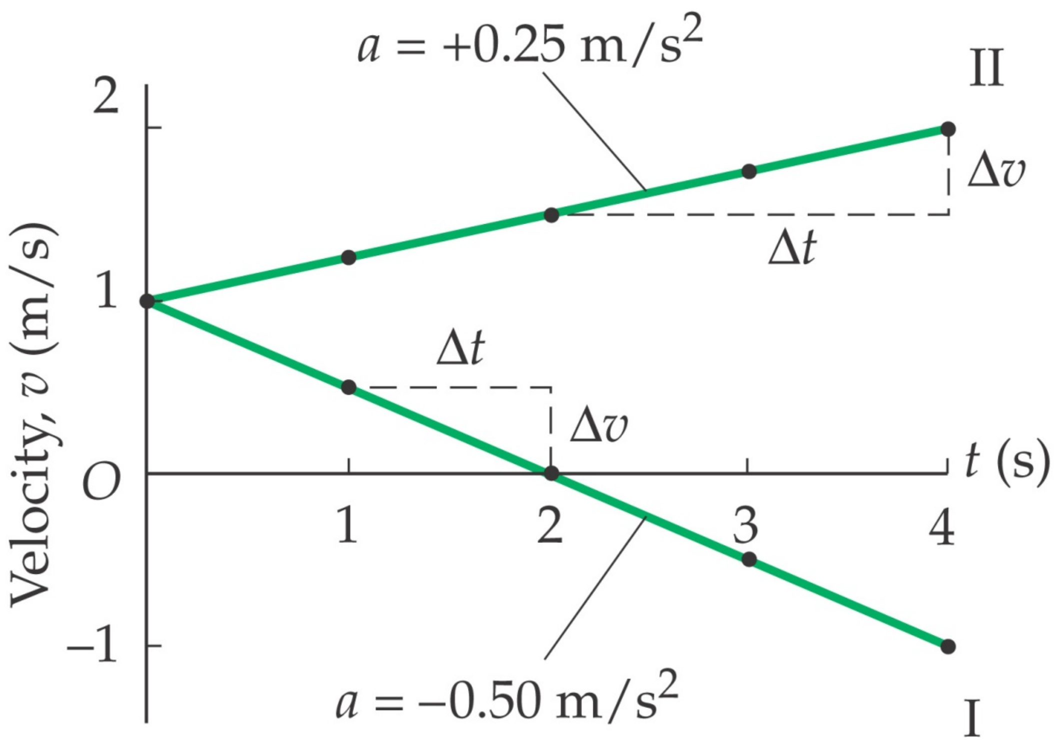
2.7 MOTION GRAPH



Graphical interpretation of average and instantaneous velocity.

2.7 MOTION GRAPH

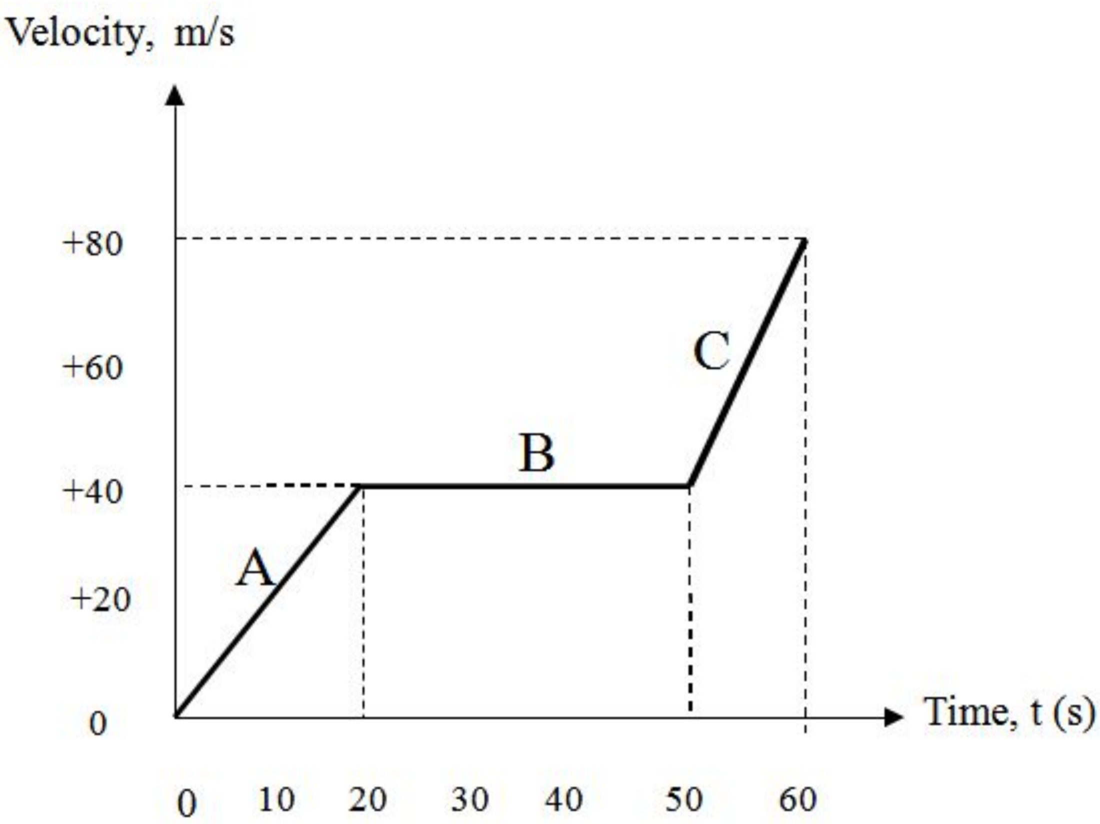
- Type 2 Velocity VS. Time



- The slope of the tangent to the velocity-time graph at a point is it acceleration

- The area under the velocity-time curve between two time intervals is equivalent to the displacement during that time

2.7 MOTION GRAPH



- Average acceleration of Segment A is

$$\bar{a} = \frac{40ms^{-1}}{20s}$$
$$= 2.0ms^{-2}$$

- Average acceleration of Segment B is

$$\bar{a} = \frac{0ms^{-1}}{30s}$$
$$= 0.0ms^{-2}$$

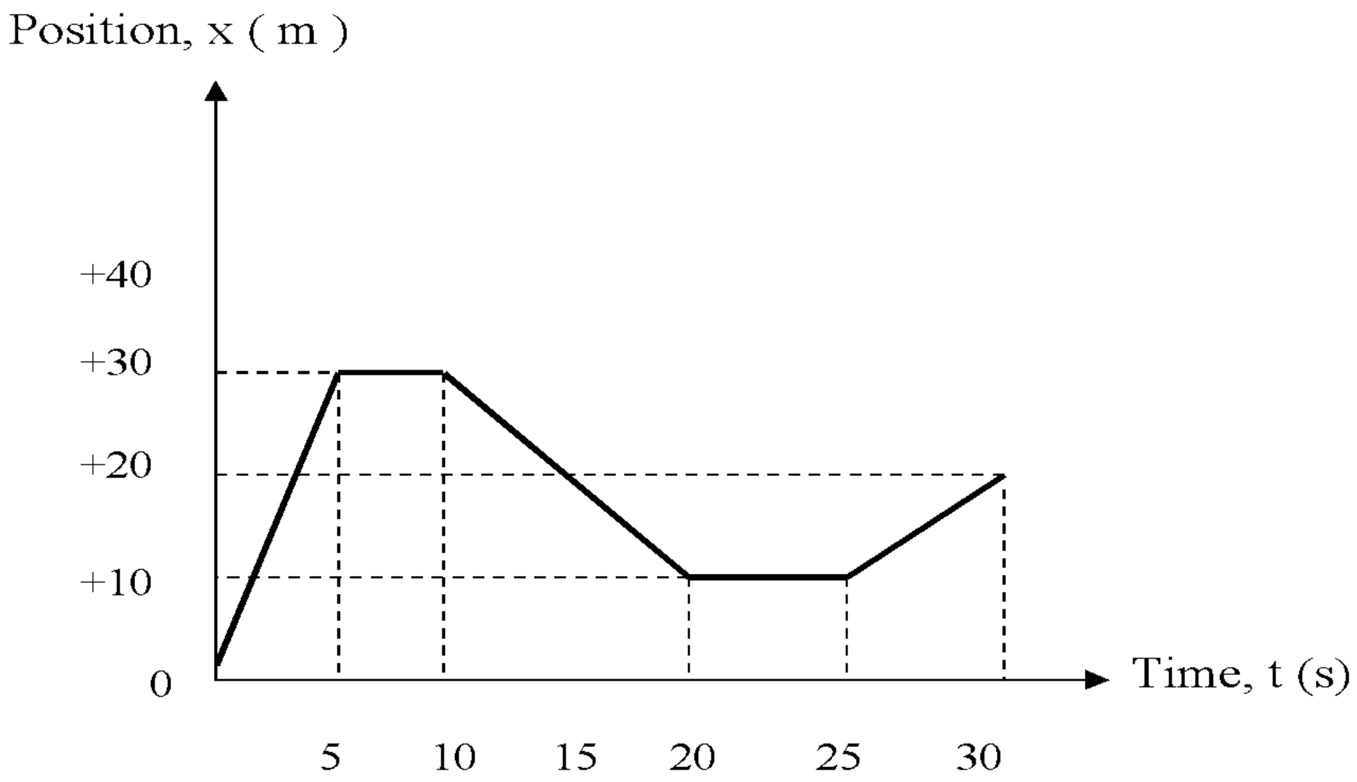
- Average acceleration of Segment C is

$$\bar{a} = \frac{40ms^{-1}}{10s}$$
$$= 4.0ms^{-2}$$

2.7 MOTION GRAPH

- Example

Using the position-time graph shown below, draw the corresponding velocity-time graph.



2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- There are 4 golden equation in motion:
  - Before it is applied, it must fulfill some of the criteria:
    - Acceleration must be constant

$$v = v_0 + at$$

$$s = \frac{1}{2}(v + v_0)t$$

$$s = v_0 t + \frac{1}{2}at^2$$

$$v^2 = v_0^2 + 2as$$

$v_0 =$ initial velocity

$v =$ final velocity

$s =$ displacement

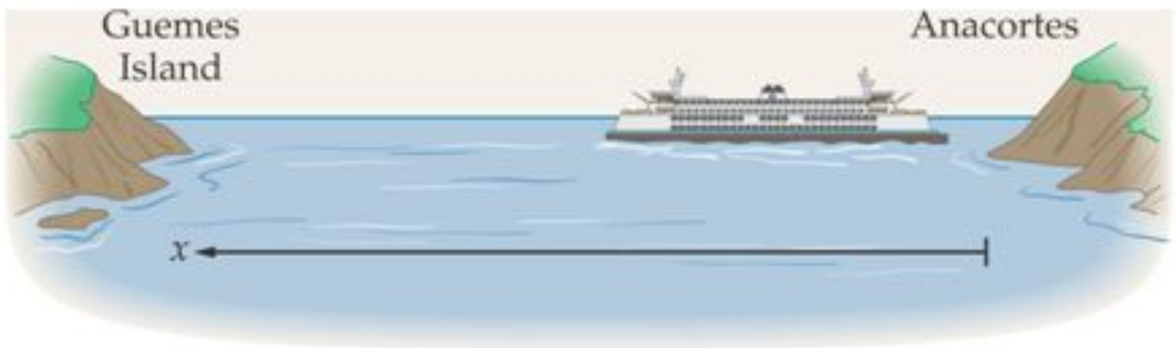
$a =$ acceleration

$t =$ time

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- Hints to solve the problem
- Be sure all the units are consistent
  - Convert if necessary
- Choose a coordinate system
- Sketch the situation, labeling initial and final points, indicating a positive direction
- Choose the appropriate kinematic equation
- Check your results

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION



- Example

A ferry makes a short run between two docks; one in Anacortes, the other on Guemes Island. As the ferry approaches Guemes Island, its speed is 7.4 m/s

a) If the ferry slows to a stop in 12.3 s, what is its average acceleration?

b) As the ferry returns to the Anacortes dock its speed is 7.3 m/s. What is its average acceleration when the time is 13.1s?

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- Solution

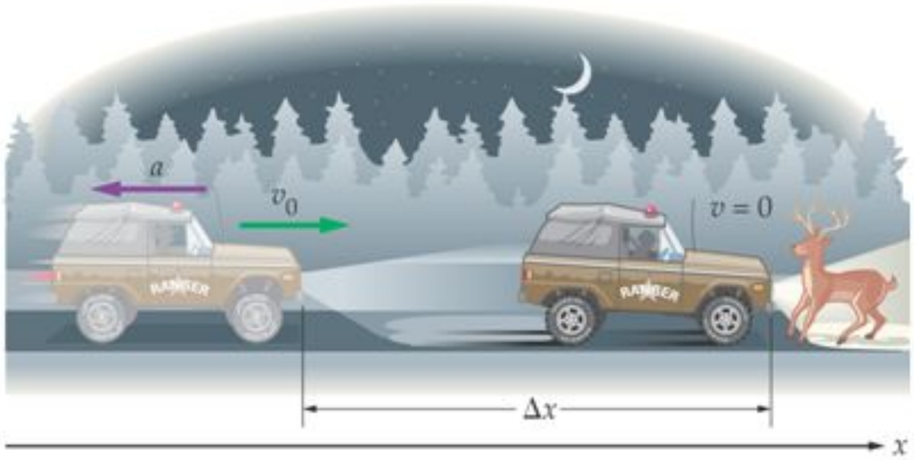
a.) $v_0 = 7.4 \text{ ms}^{-1}, v = 0 \text{ ms}^{-1}, t = 12.3 \text{ s}$

$$v = v_0 + at$$
$$0 = 7.4 + (12.3)(a)$$
$$a = -0.6ms^{-2}$$

b.) $v_0 = 0 \text{ ms}^{-1}, v = 7.3 \text{ ms}^{-1}, t = 13.1 \text{ s}$

$$v = v_0 + at$$
$$7.3 = 0 + (13.1)(t)$$
$$t = 0.6s$$

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION



- Example

A park ranger driving on a back country road suddenly sees a deer "frozen" in hid headlights. The ranger, who is driving at 11.4 m/s , immediately applies the breaks and slows with an acceleration of $3.8ms^{-2}$

a) If the deer is 20.0 m from the ranger's vehicle when the brakes are applied, how close the ranges come to hitting the deer?
b) How much time is needed for the ranger's vehicle to stop?

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- Solution

a.) $v_0 = 11.4\ \text{ms}^{-1}, v = 0\ \text{ms}^{-1}, a = 3.8\ \text{t}$

$$v^2 = v_0^2 + 2as$$

$$0^2 = 11.4^2 + (2)(3.8)s$$

$$s = \frac{-(11.4)^2}{(2)(3.80)}$$

$$= -17.1m$$

$$= 17.1m$$

the distance where the car stop

$$\text{gap between car and deer} = 20m - 17.1m$$

$$= 2.9m$$

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- Solution

b.) $v_0 = 11.4 \text{ ms}^{-1}, v = 0 \text{ ms}^{-1}, a = 3.8 \text{ ms}^{-2}$

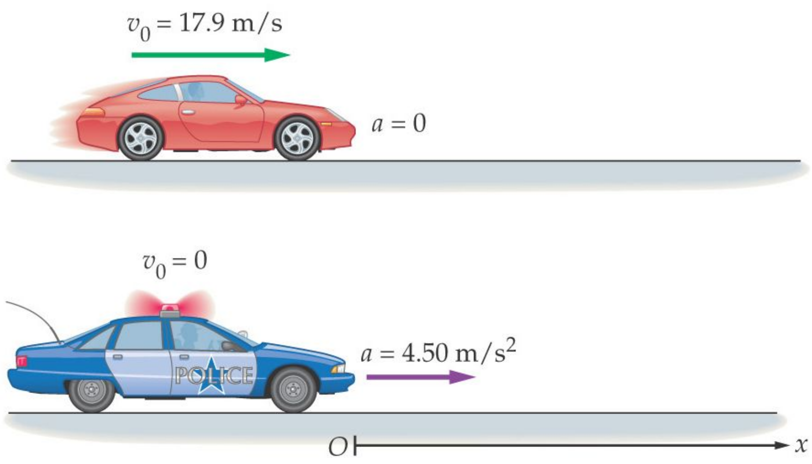
$$v = v_0 + at$$

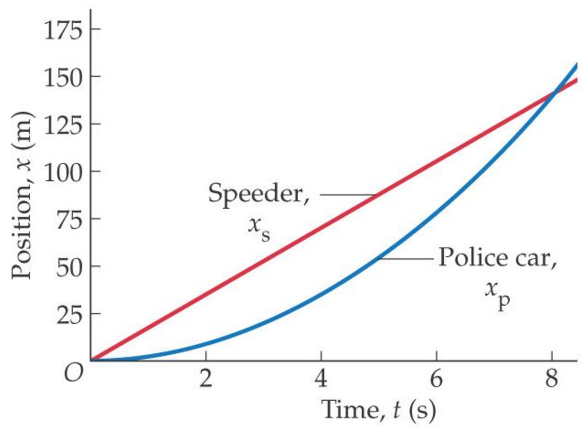
$$0 = 11.4 + (3.8)t$$

$$t = -3$$

$$= 3s$$

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION





A speeder doing 40.0 mi/h (about 17.9 m/s) in a 25 mi/h zone approaches a parked police car. The instant the speeder passes the police car, the police begin their pursuit. If the speeder maintain a constant velocity, and the police car accelerates with a constant acceleration of 4.5 m/s/s ,

- a) how long does it take for the police car to catch the speeder
- b) how far have the two cars traveled in this time, and
- c) what is the velocity of the police car when it catches the speeder?

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- Solution

a.) speeder's car

$$v_0 = 17.9 \text{ ms}^{-1}, v = 17.9 \text{ ms}^{-1}, a = 0 \text{ ms}^{-2}$$

police's car

$$v_0 = 0 \text{ ms}^{-1}, v = 17.9 \text{ ms}^{-1}, a = 4.5 \text{ ms}^{-2}$$

$$s = v_0 t + \frac{1}{2}at^2$$

$$s = (17.9)t + \frac{1}{2}(0)t^2$$

$$s = 17.9t$$

$$s = v_0 t + \frac{1}{2}at^2$$

$$s = (0)t + \frac{1}{2}(4.5)t^2$$

$$s = 2.25t^2$$

$$s = 17.9t \quad \text{.........(1)}$$

$$s = 2.25t^2 \quad \text{.........(2)}$$

$$2.25\text{t}^2 = 17.9t$$

$$2.25t^2 - 17.9t = 0$$

$$t(2.25t - 17.9) = 0$$

$$t = 0s, 7.96s$$

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- Solution

b.)

$$t = 0s, 7.96s$$

$$s = 17.9t \qquad ....(1)$$

$$s = 2.25t^2 \qquad ....(2)$$

if t =0s,

s=0

if t=7.96s

s=142.48m

2.8 EQUATION FOR MOTION WITH CONSTANT ACCELERATION

- Solution

c.)

$$v_0 = 0, a = 4.5ms^{-2}, t = 7.96s$$

$$v = v_0 + at$$

$$= 0 + (4.5)7.96$$

$$= 35.82ms^{-1}$$

2.9 FREE FALL ACCELERATION

- Let watch this video Clip

- The Gravity acceleration = 9.8 ms^{-2}

2.9 FREE FALL ACCELERATION

- When we solve the problem, we are relies on 4 equation in motion

$$v = v_0 + gt$$

$$s = v_0 t + \frac{1}{2} g t^2$$

$$v^2 = v_0^2 + 2gs$$

Tips: Just replace the acceleration to gravitational acceleration.

2.9 FREE FALL ACCELERATION

- Example

A boy on a bridge throws a stone vertically downward toward the river below with an initial velocity of 14.7 m/s . If the stone hits the water 2.00 s later, what is the height of the bridge above the water?

Solution :

$$v_0 = 14.7ms^{-1}, t = 2.0s, g = 9.8ms^{-2}$$

Take y as positive downward :

$$s = v_0 t + \frac{1}{2} g t^2$$

$$= (14.7)(2) + \frac{1}{2}(9.8)(2)^2$$

$$= 49.0m$$

2.9 FREE FALL ACCELERATION

- More Question will be given in tutorial session !!!


Thank you