Chapter 2

1

Motion in one dimension

Kinematics

2

- Describes motion while ignoring the external agents that might have caused or modified the motion.
- Describes motion in terms of: time, position, velocity and acceleration.
- Motion represents a continual change in an object's position.
- For now, will consider motion in one dimension. (Along a straight line)

Types of Motion

3

Translational	Rotational	Vibrational
An example is a car traveling on a highway.	An example is the Earth's spin on its axis.	An example is the back-and-forth movement of a pendulum.

Position, Distance and Displacement

4

Position: the location of an object with respect to a reference point.

Data Table

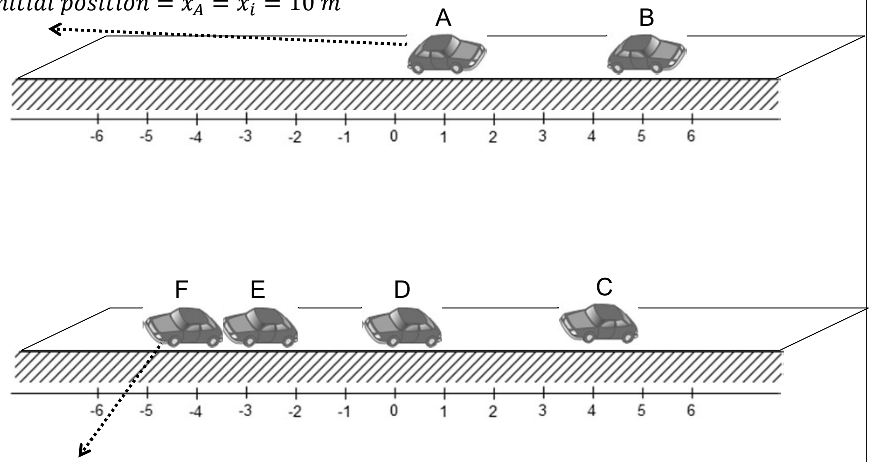
- The table gives the actual data collected during the motion of a car.
- Once every 1 s we note the car's position.

Position	t (s)	x (m)
A	0	1.0
B	1.0	5.0
C	2.0	4.0
D	3.0	0.0
E	4.0	-3.0
F	5.0	-4.5

Position

5

$initial\ position = x_A = x_i = 10\ m$



$final\ position = x_F = x_f = -45\ m$

Position

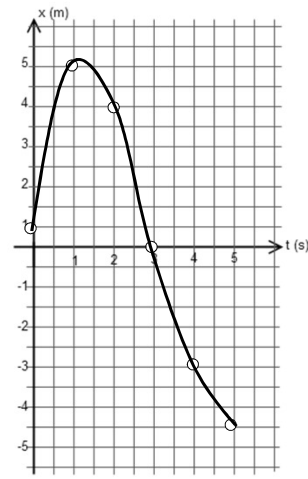
6

- Consider the reference point to be the origin of a coordinate system.
- Positive is defined as being to the right.
- Negative is defined as being to the left.
- Vector quantity
- SI units are meters (m)

Position-Time Graph

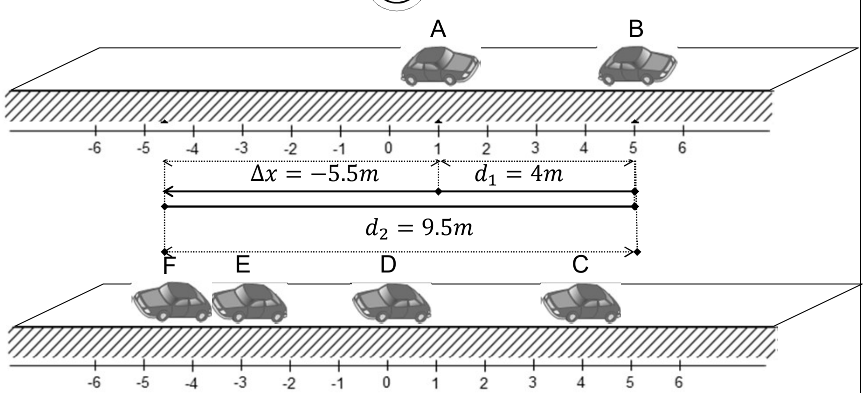
7

- The position-time graph shows the motion of the particle (car).



Displacement and distance

8



$$Distance = d_1 + d_2 = 4 + 9.5 = 13.5\ m$$
$$Displacement = \Delta x = -5.5\ m$$

Displacement and distance

9

Displacement is defined as the change in position during some time interval.

- Represented as: $\Delta x = x_f - x_i$
- SI units are meters (m)
- can be positive, negative or zero
- vector quantity

Distance is the length of a path followed by a particle.

- SI units are meters (m)
- always positive
- scalar quantity

Average Speed

10

Defined as:

$$average\ speed = \frac{total\ distance}{total\ time}$$

- The SI units are m/s
- Speed is a scalar quantity.
- always a positive number.

Average Velocity

11

The average velocity is rate at which the displacement occurs.

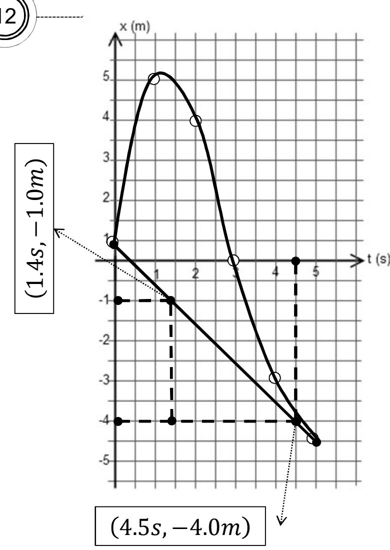
$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{x_f - x_i}{t_f - t_i}$$

- The x indicates motion along the $x - axis.$
- vector quantity
- The SI units are m/s
- Is also the slope of the line in the $position - time$ graph

Average Velocity

12

Position – time graph



$slope\ of\ the\ straight\ line = v_{avg}$

$$= \frac{\Delta x}{\Delta t} = \frac{-4.0 - -1.0}{4.5 - 1.4}$$

$$= \frac{-3.0}{3.1} = -0.97\ m/s$$

Average Speed and Average Velocity

13

The average speed is not the magnitude of the average velocity.

- For example, a runner ends at her starting point.
- Her displacement is zero.
- Therefore, her velocity is zero.
- However, the distance traveled is not zero, so the speed is not zero.

The average speed equals the average velocity when the object is moving along a straight line and don't change direction.

Mustafa Al-Zyout - Philadelphia University 04-Nov-20

Instantaneous Velocity

14

It is the velocity at a certain time.

It is the slope of the line tangent to the position – time curve.

The first derivative of the position with respect to time.

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

The instantaneous velocity can be positive, negative, or zero.

Mustafa Al-Zyout - Philadelphia University 04-Nov-20

Instantaneous Velocity

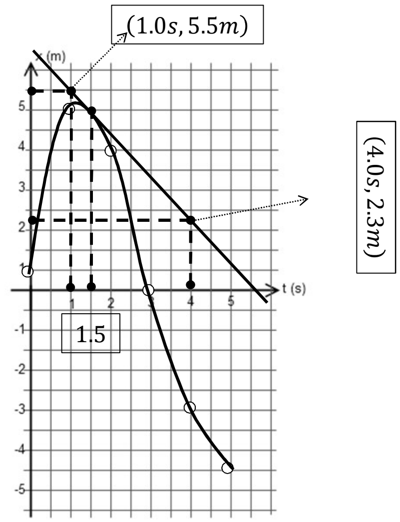
15

Position – time graph

$$slope\ of\ the\ tangent = v\Big|_{t=1.5\ s}$$

$$= \frac{\Delta x}{\Delta t} = \frac{2.3 - 5.5}{4 - 1}$$

$$= \frac{-3.2}{3} = -1.1\ m/s$$



Instantaneous Speed

16

The instantaneous speed is the magnitude of the instantaneous velocity.

The instantaneous speed has no direction associated with it.

A Particle Under Constant Velocity

17

Constant velocity indicates that at any instant during a time interval the instantaneous velocity is the same as the average velocity.

$$v = v_{avg}$$

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

Common practice is to let $ti\ =\ 0$, $tf = t$ and the equation becomes:

$$x_f = x_i + vt$$

Particle Under Constant Velocity, Graph

18

Position – time graph

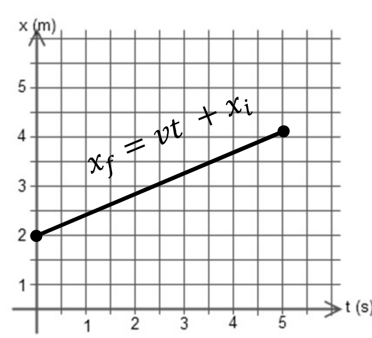
The graph represents the motion of a particle under constant velocity.
The slope of the graph is the value of the constant velocity;

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

$$v = \frac{4-2}{5-0} = 0.4\ m/s$$

The y-intercept is $x_{i.}$

$$x_i = 2\ m$$



Average Acceleration

19

SI units are m/s^2

Acceleration is the rate of change of the velocity.

$$a_{avg} = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}$$

Vector quantity

In one dimension, positive and negative can be used to indicate direction.

Mustafa Al-Zyout - Philadelphia University 04-Nov-20

Average Acceleration

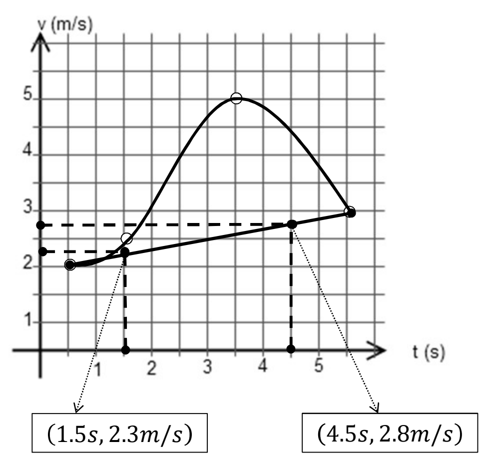
20

Velocity – time graph

$$slope\ of\ the\ straight\ line = a_{avg}$$

$$= \frac{\Delta v}{\Delta t} = \frac{2.8 - 2.3}{4.5 - 1.5}$$

$$= 0.17\ m/s^2$$



Mustafa Al-Zyout - Philadelphia University 04-Nov-20

Instantaneous Acceleration

21

- It is the acceleration at a certain time.
- It is the slope of the line tangent to the *velocity – time* curve.
- The first derivative of the velocity with respect to time: $\boldsymbol{a} = \frac{dv}{dt}$
- The second derivative of the position with respect to time: $\boldsymbol{a} = \frac{d^2\boldsymbol{x}}{dt^2}$
- The instantaneous acceleration can be positive, negative, or zero.

Instantaneous Acceleration

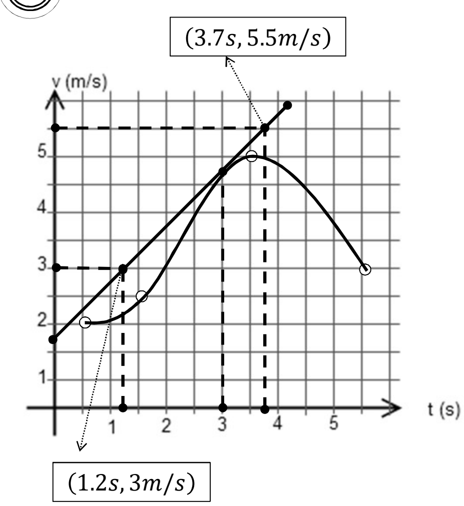
22

Velocity – time graph

$$slope\ of\ the\ tangent = a\Big|_{t=3s}$$

$$= \frac{\Delta v}{\Delta t} = \frac{5.5-3}{3.7-1.2}$$

$$\frac{2.5}{2} = 1.25\ m/s^2$$



Integrating velocity ≡ Displacement

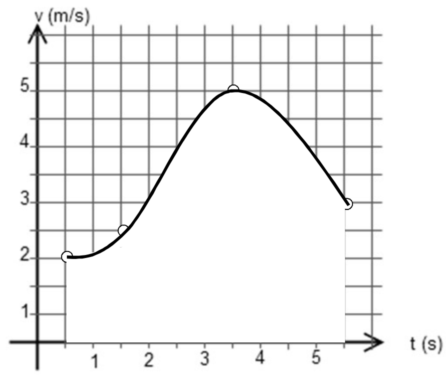
23

Velocity – time graph

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

$$\Delta x = \int_{t_f}^{t_i} v\, dt$$

$$\Delta x = Area\ under\ v - t\ graph$$



Integrating acceleration ≡ Change in velocity

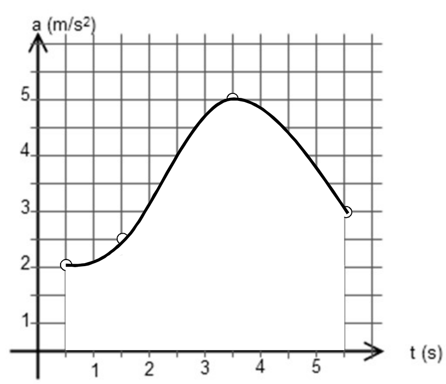
24

acceleration – time graph

$$a = \frac{dv}{dt}$$

$$\Delta v = \int_{t_f}^{t_i} a\, dt$$

$$\Delta v = Area\ under\ a - t\ graph$$



Acceleration and Velocity, Directions

25

- When an object's velocity and acceleration are in the same direction, the object is speeding up.
- When an object's velocity and acceleration are in opposite directions, the object is slowing down.
- When the object's velocity is constant, the acceleration is zero.
- When the object's acceleration is constant, NOTHING to conclude.
- Force and acceleration are both vectors and directed in the same direction.
- The word deceleration has the connotation of slowing down.

Notes About Acceleration

26

- Negative acceleration does not necessarily mean the object is slowing down.
  - If the acceleration and velocity are both positive, the object is speeding up.
  - If the acceleration and velocity are both negative, the object is speeding up.
  - If the acceleration and velocity are of opposite signs, the object is slowing down.
- The word deceleration has the connotation of slowing down.
  - This word will not be used in the text.

Producing An Acceleration

27

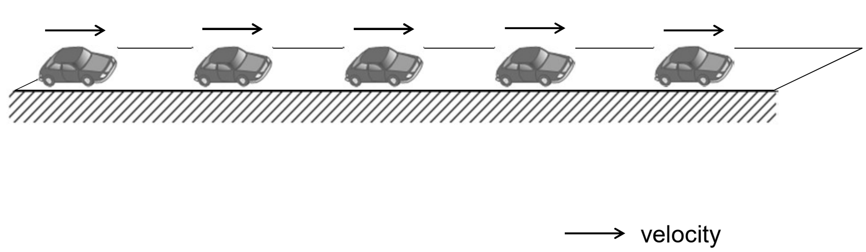
Various changes in a particle's motion may produce an acceleration.

- The magnitude of the velocity vector may change.
- The direction of the velocity vector may change.
- Both may change simultaneously

Constant Velocity

28

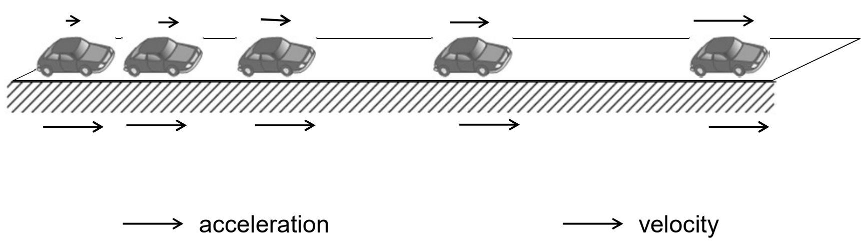
- Images are equally spaced.
- The car is moving with constant positive velocity (shown by red arrows maintaining the same size).
- Acceleration equals zero.



Acceleration and Velocity

29

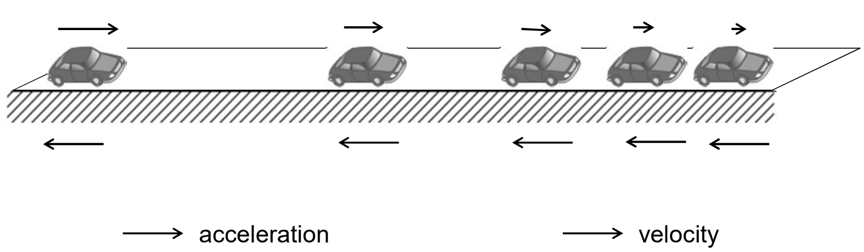
- Images become farther apart as time increases.
- Velocity and acceleration are in the same direction.
- Acceleration is uniform (violet arrows maintain the same length).
- Velocity is increasing (red arrows are getting longer).
- This shows positive acceleration and positive velocity.



Acceleration and Velocity

30

- Images become closer together as time increases.
- Acceleration and velocity are in opposite directions.
- Acceleration is uniform (violet arrows maintain the same length).
- Velocity is decreasing (red arrows are getting shorter).
- Positive velocity and negative acceleration.



A Particle Under Constant Acceleration

31

Constant acceleration indicates that at any instant during a time interval the instantaneous acceleration is the same as the average acceleration.

$$a = a_{avg}$$

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

Common practice is to let $t_i = 0$, $t_f = t$ and the equation becomes:

$$v_f = v_i + at$$

Kinematic Equations

32

- The kinematic equations can be used with any particle under uniform acceleration.
- The kinematic equations may be used to solve any problem involving one-dimensional motion with a constant acceleration.
- You may need to use two of the equations to solve one problem.
- Many times there is more than one way to solve a problem.

Kinematic Equations

33

Equations	Missing
$v_f = v_i + at$	Δx : displacement (m)
$v_f^2 = v_i^2 + 2a\Delta x$	t : time (s)
$\Delta x = v_i t + \frac{1}{2}at^2$	v_f : final velocity (m/s)
$\Delta x = v_f t - \frac{1}{2}at^2$	v_i : initial velocity (m/s)
$\Delta x = \frac{1}{2}(v_i + v_f)t$	a : acceleration (m/s²)

When a = 0

34

When the acceleration is zero,

$$v_f = v_i = v$$

$$x_f = x_i + vt$$

The constant acceleration model reduces to the constant velocity model.

Freely Falling Objects

35

- A freely falling object is any object moving vertically under the influence of gravity alone.
- We will neglect air resistance
- It is a motion in one dimension
- It is a motion with constant acceleration
- It does not depend upon the initial velocity of the object. Including:
  - Dropped (released from rest)
  - Thrown vertically (straight) down
  - Thrown vertically (straight) up

Acceleration of Freely Falling Object

36

- The acceleration of an object in free fall is directed downward, regardless of the initial motion.
- The magnitude of free fall acceleration is

$$g = 9.8\ m/s^2$$

- Let upward be positive
- Use the kinematic equations and:
  - replace the acceleration (a) with (−g).
  - replace the displacement (Δx) with (Δy)

Equations – Freely Falling

37

$$g = 9.8\ m/s^2$$

Equations	Missing
$v_f = v_i - gt$	Δy : displacement (m)
$v_f^2 = v_i^2 - 2g\Delta y$	t : time (s)
$\Delta y = v_i t - \frac{1}{2} g t^2$	v_f : final velocity (m/s)
$\Delta y = v_f t + \frac{1}{2} g t^2$	v_i : initial velocity (m/s)

Equations – Freely Falling

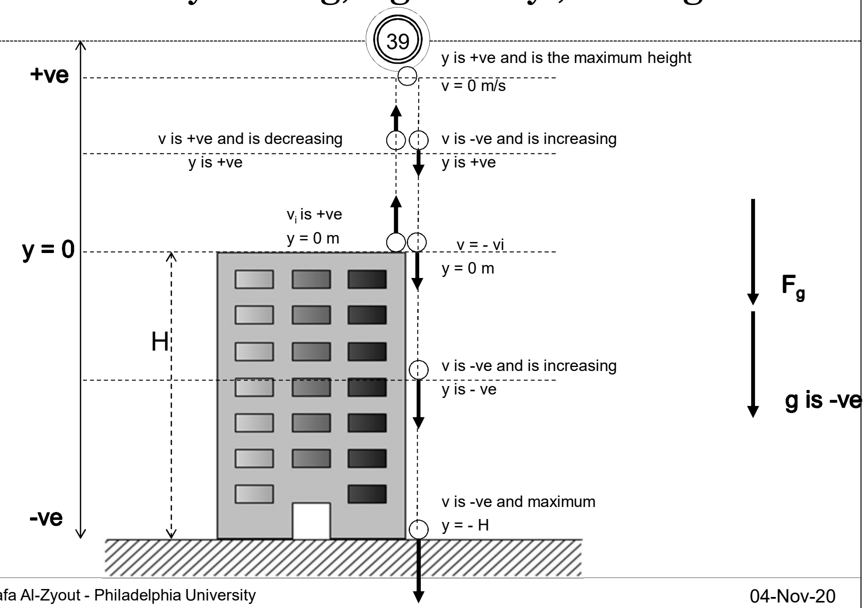
38

NOTE : when applying kinematic equations:

- Consider the launching point as our reference point ($y_i = 0$). Therefore; the final position will be:
  - positive when the object above (y_i),
  - and negative when it is below (y_i).

- The velocity is:
  - positive while the object is moving upward,
  - negative while it is moving downward
  - and Zero at its maximum height.

Freely Falling, signs of : y , v and g



Mustafa Al-Zyout - Philadelphia University 04-Nov-20