Chapter 3

1

Motion in one dimension

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Lecture 01

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Position, Speed and Velocity

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Kinematics

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- 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)

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Types of Motion

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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.

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Position, Distance and Displacement

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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

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Position

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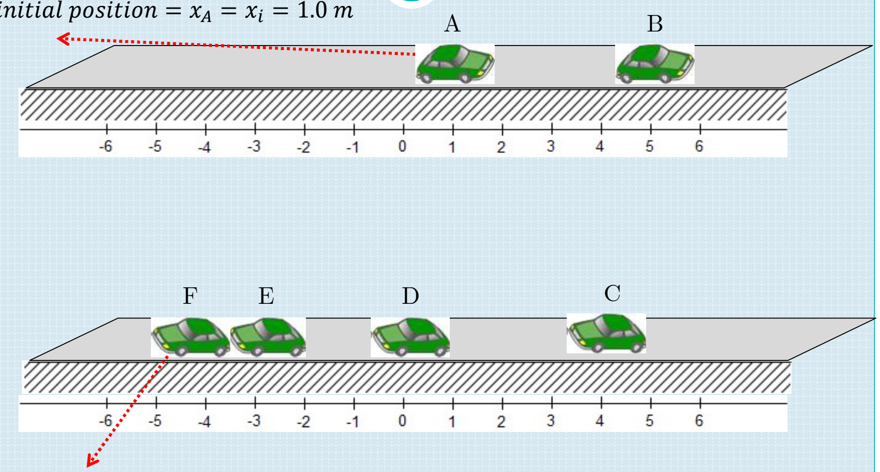
$initial\ position = x_A = x_i = 1.0\ m$



$final\ position = x_F = x_f = -4.5\ m$

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Position

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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)

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Position-Time Graph

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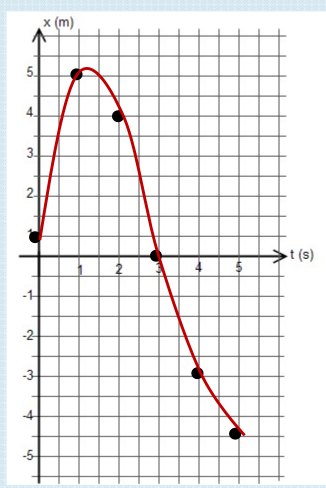
- The position-time graph shows the motion of the particle (car).



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Displacement and distance

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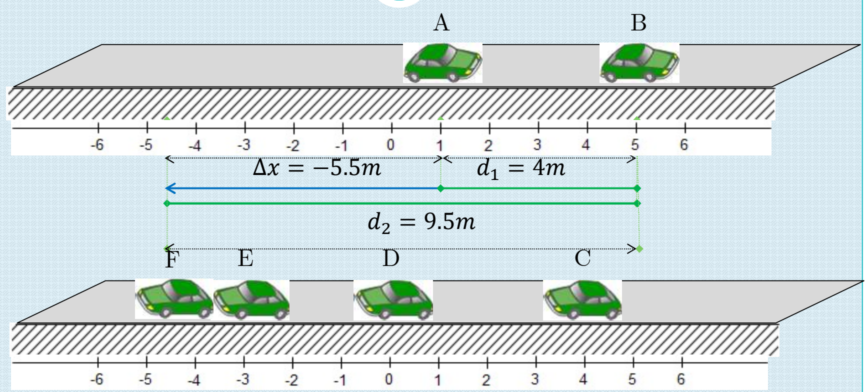

$Distance = d_1 + d_2 = 4 + 9.5 = 13.5\ m$

$Displacement = \Delta x = -5.5\ m$

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Displacement and distance

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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

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Average Speed

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Defined as:

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

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

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Average Velocity

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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

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Average Velocity

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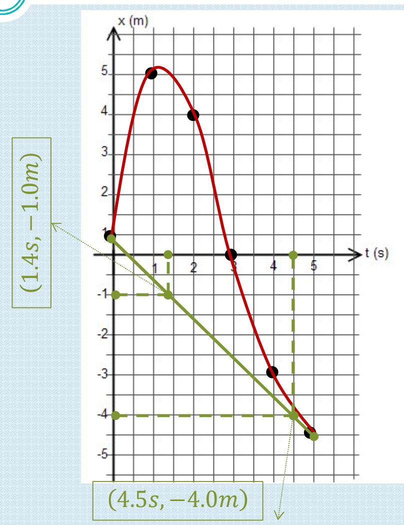
Position – time graph



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

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

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

Average Speed and Average Velocity

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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.

Instantaneous Velocity

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- 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.

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Instantaneous Velocity

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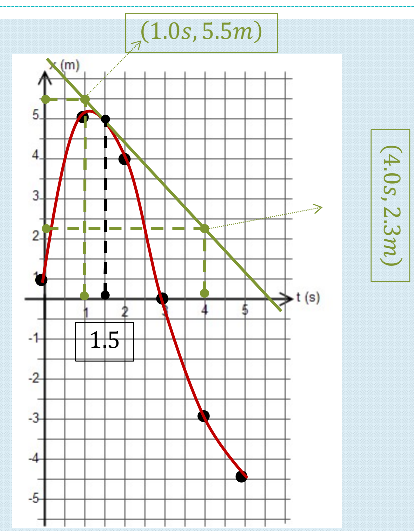
Position – time graph

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

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

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



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Instantaneous Speed

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The instantaneous speed is the magnitude of the instantaneous velocity.

The instantaneous speed has no direction associated with it.

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A Particle Under Constant Velocity

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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 $t_i = 0$, $t_f = t$ and the equation becomes:

$$\boxed{x_f = x_i + vt}$$

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Particle Under Constant Velocity, Graph

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Position – time graph

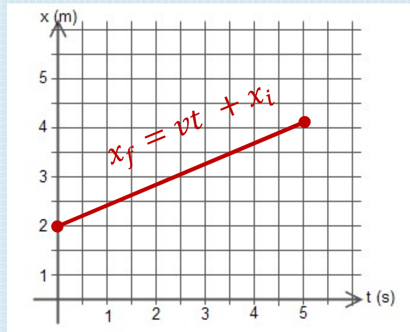
The graph represents the motion of a particle under constant velocity.
The slope of the graph is the value of the constant velocity;

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

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

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

$$x_i = 2\ m$$



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Average velocity and average speed

Friday, 10 September, 2021 09:04

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.

J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.

H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.

H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

A car moving along the x-axis starts from the position $x_i = 2\ m$ when $t_i = 0$ and stops at $x_f = -3\ m$ when $t_f = 2\ s$.

- (a) Find the displacement, the average velocity, and the average speed during this interval of time.
- (b) If the car goes backward and takes $3\ s$ to reach the starting point, then repeat part (a) for the whole time interval.

Solution:

$$\Delta x = x_f - x_i = -3 - 2 = -5m$$

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{-5}{2} = -2.5\ m/s$$

$$\text{average speed} = \frac{dis\tan ce}{time} = \frac{5}{2} = 2.5\ m/s$$

Solution:

$$\Delta x = x_f - x_i = 2 - 2 = 0m$$

$$v_{avg} = \frac{\Delta x}{\Delta t} = \frac{0}{2} = 0\ m/s$$

$$\text{average speed} = \frac{dis\tan ce}{time} = \frac{10}{5} = 2\ m/s$$

Average and Instantaneous Velocity

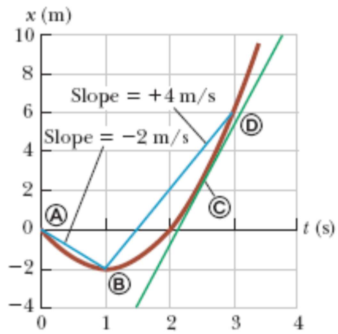
Thursday, 28 January, 2021 16:01

Lecturer: Mustafa Al-Zyout, Philadelphia University, Jordan.

- R. A. Serway and J. W. Jewett, Jr., *Physics for Scientists and Engineers*, 9th Ed., CENGAGE Learning, 2014.
- J. Walker, D. Halliday and R. Resnick, *Fundamentals of Physics*, 10th ed., WILEY,2014.
- H. D. Young and R. A. Freedman, *University Physics with Modern Physics*, 14th ed., PEARSON, 2016.
- H. A. Radi and J. O. Rasmussen, *Principles of Physics For Scientists and Engineers*, 1st ed., SPRINGER, 2013.

A particle moves along the x axis. Its position varies with time according to the expression $x = -4t + 2t^2$, where (x) is in meters and (t) is in seconds.

- 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 intervals.
- Find the instantaneous velocity of the particle at (t = 2.5 s).



(A) Solution

In the first time interval, let $t_i = t_A = 0$ and $t_f = t_B = 1$ s, the displacement:

$$\Delta x_{A\to B} = x_f - x_i = x_B - x_A$$

$$\Delta x_{A\to B} = [-4(1) + 2(1)^2] - [-4(0) + 2(0)^2] = -2m$$

In the second time interval, let $t_i = t_B = 1$ s and $t_f = t_D = 3$ s, the displacement:

$$\Delta x_{B\to D} = x_f - x_i = x_D - x_B$$

$$\Delta x_{B\to D} = [-4(3) + 2(3)^2] - [-4(1) + 2(1)^2] = +8m$$

(B) Solution

In the first time interval, $\Delta t = t_f - t_i = t_B - t_A = 1\ s$:

$$\Rightarrow\ \vec{v}_{(A\to B)} = \frac{\Delta \vec{x}_{A\to B}}{\Delta t} = \frac{-2\ m}{1\ s} = -2\ m/s$$

In the second time interval, $\Delta t = t_f - t_i = t_D - t_B = 2\ s$

$$\Rightarrow\ \vec{v}_{(B\to D)} = \frac{\Delta \vec{x}_{B\to D}}{\Delta t} = \frac{8\ m}{2\ s} = +4\ m/s$$

(C) Solution

Measure the slope of the tangent at (t = 2.5 s) (point C):

$$v_x = \frac{10-(-4m)}{3.8s-1.5s} = +6m/s$$

OR:

$$v_x = \frac{dx}{dt} = \frac{d}{dt}(-4t + 2t^2) = -4 + 4t$$

$$v_{t=2.5s} = -4 + (4)(2.5) = +6m/s$$