Speed and Velocity

by

Nada Saab-Ismail, PhD, MAT, MEd, IB

nhsaab.weebly.com

nhsaab2014@gmail.com

P2.1A Calculate the average speed of an object using the change of position and elapsed time.

P2.2A Distinguish between the variables of distance, displacement, speed, velocity, and acceleration.

Items:

1. Scalar and Vector quantities.

2. Distance and Displacement.

3. Speed Using Distance and Time.

4. Velocity Using Displacement and Time.

Introduction

In this universe, most things are in constant motion, whether it be planets orbiting suns, electrons in atoms, or birds in the sky. Describing these motions mathematically is the first step toward understanding them.

Kinematics deals with the concepts that are needed to describe motion.

Dynamics deals with the effect that forces have on motion.

Together, kinematics and dynamics form the branch of physics known as **Mechanics**.

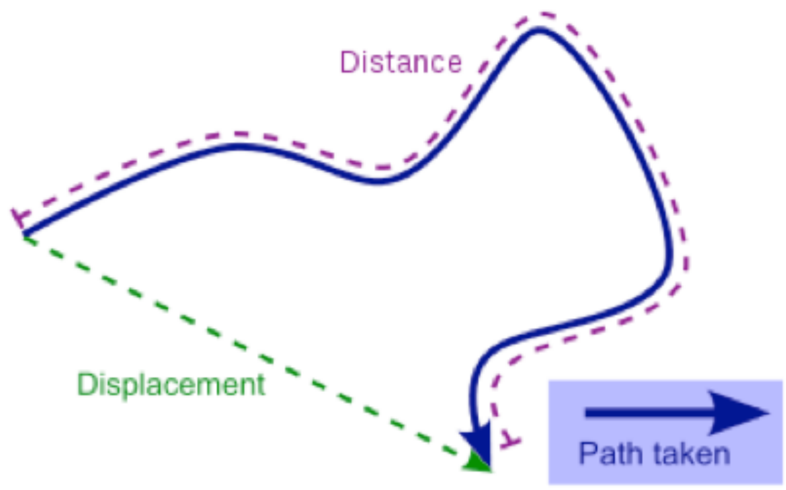
Translational motion refers to motion without rotation. Strictly linear motion can be viewed in one dimension.

Distance

Distance is the total measure of the path traveled from starting to finishing position. It is a scalar quantity. Scalar quantities have a magnitude and a unit.
A distance of 2.0 m (2.0 is the magnitude, m is the unit meter)

Displacement

Displacement is a vector that points from an object's initial position to its final position. It is strictly the shortest difference in the starting and finishing position.



Vector quantities have a magnitude, a unit and a direction. The direction is an important piece of information.

Example: A displacement 2 meters north from where you are standing is expressed as 2.0 m[N]. That means (2.0 is the magnitude, m is the unit meter and N is north direction)

Distance and **displacement** are different. When you traveled 50 km to the East and then 20 km to the West, the total distance you traveled is 70 km (50 + 20), but your displacement is 30 km (50 -20) East.

Note: N is for North. S is for South. E is for East. W is for West

Displacement Formula
$\vec{\Delta x} = \vec{X} - \vec{X}_0$
Displacement = Final position - Initial position

Δ is the Greek Letter **delta,** commonly used in mathematics and science. It means "**change in**". It is usually used to express difference. The SI unit for displacement is meter (m).

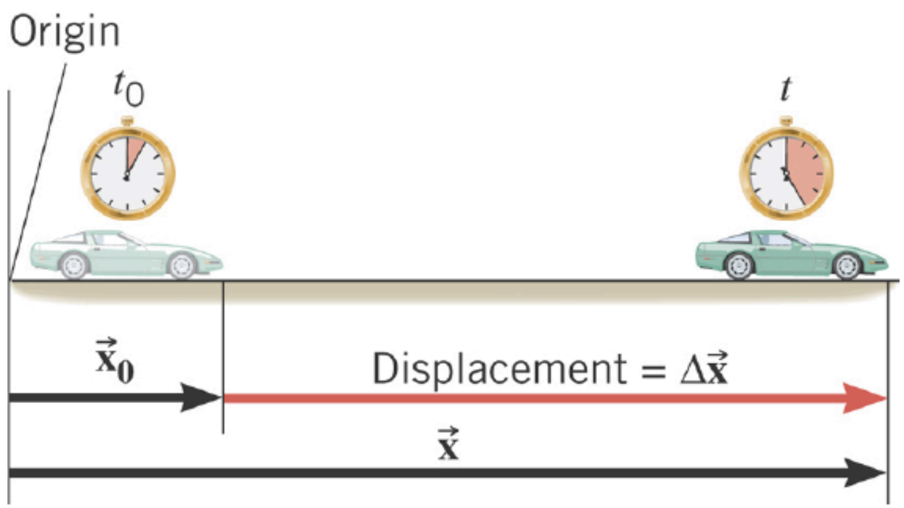
$\rightarrow$: means that this is a vector quantity with direction

X_0 is the initial position

X is the final position.

How to calculate displacement or change in position?

To describe the motion of an object, we must be able to specify the location of the object at all times as shown in the figure below. The figure shows the initial position of a car and the final position of a car after 20 minutes.



$\vec{\mathbf{x}}_o$ = initial position $\quad\quad$ $\vec{\mathbf{x}}$ = final position

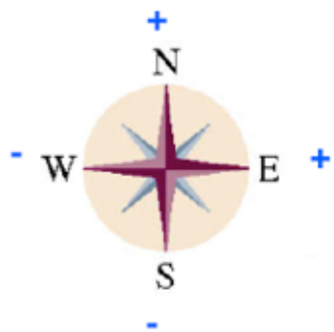
$$\Delta\vec{\mathbf{x}} = \vec{\mathbf{x}} - \vec{\mathbf{x}}_o = \text{displacement}$$

Displacement Along a Straight Line:

Often we deal with motion along a straight line. We assign a positive value for a displacement in one direction along the line. A displacement in the opposite direction is assigned a negative value.

We normally assume that the east direction has the positive values. So, the west direction has a negative value.

We also can assume that the north direction has the positive values. So, the south direction has a negative value.

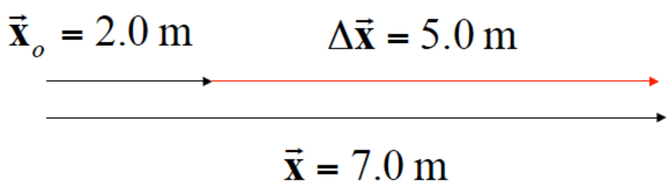


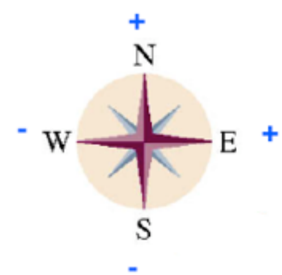
Examples are shown below.

Example 1:

Assuming that the east direction has the positive values. So, the west direction has a negative value.

Assuming that Suppose that the original position of the car was + 2.0 m in the east direction. The driver drove the car in the east direction to a final position of + 7.0 m. The car displacement is 5.0 m toward the east direction as shown below.



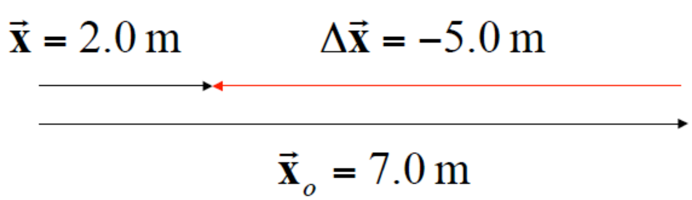


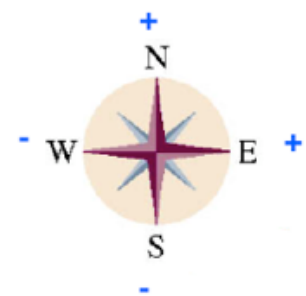
$$\Delta\vec{\mathbf{x}} = \vec{\mathbf{x}} - \vec{\mathbf{x}}_o = 7.0\text{ m} - 2.0\text{ m} = 5.0\text{ m}$$

Example 2:

Assuming that the east direction has the positive values. So, the west direction has a negative value.

Suppose that the original position of the car was + 7.0 m in the east direction. The driver drove the car in the west direction to a final position of + 2.0 m. The car displacement is - 5.0 m, or 5.0 m in the west direction.



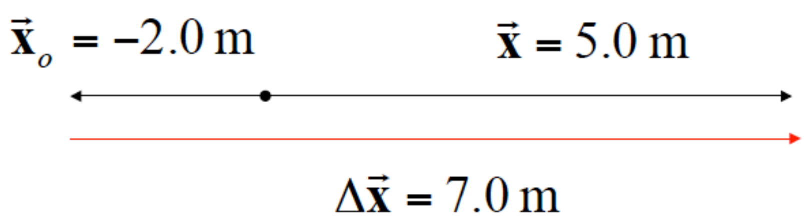


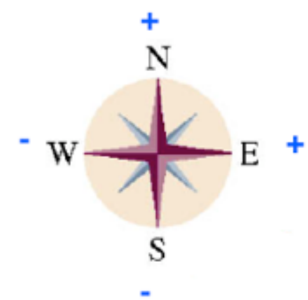
$$\Delta\vec{\mathbf{x}} = \vec{\mathbf{x}} - \vec{\mathbf{x}}_o = 2.0\,\mathrm{m} - 7.0\,\mathrm{m} = -5.0\,\mathrm{m}$$

Example 3:

Assuming that the east direction has the positive values. So, the west direction has a negative value.

Suppose that the original position of the car was 2.0 m in the west direction, or - 2.0 m. The driver drove the car in the east direction to a final position of + 5.0 m. The car displacement is 7.0 m in the east direction.



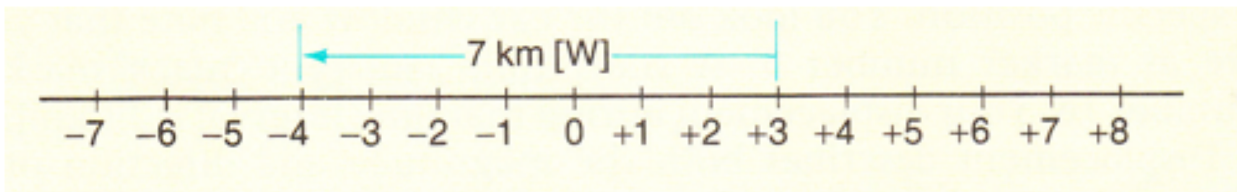


$$\Delta\vec{\mathbf{x}} = \vec{\mathbf{x}} - \vec{\mathbf{x}}_o = 5.0\ \mathrm{m} - (-2.0)\,\mathrm{m} = 7.0\ \mathrm{m}$$

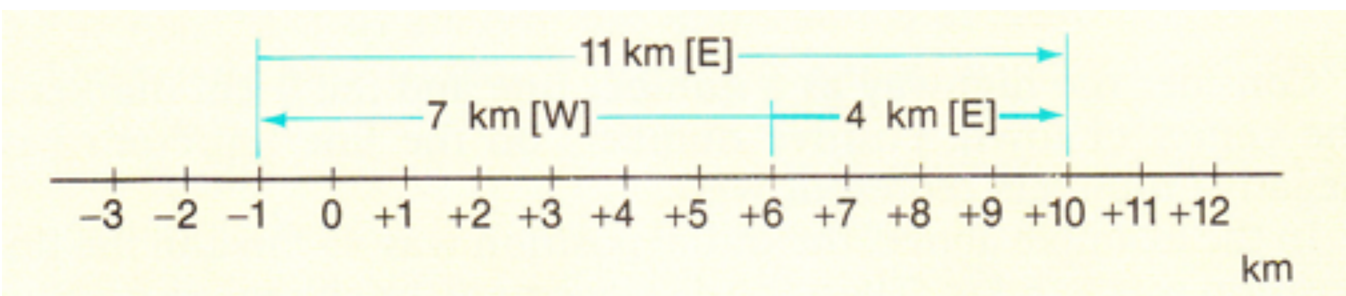
Notes:

Remember that displacement for an interval is simply the difference between the final position and the initial position.

1. The displacement for a driver who started at marker +3 km (in the east direction) and ended at marker -4 km (in the west direction) is 7 km [W]



2. The displacement of a cyclist who starts at maker + 6 km moves to -1 km and then proceeds to marker +10 km is 11 km [E]



Average Speed and Distance

Average speed is the distance traveled divided by the time required to cover the distance. The formula of average speed in shown in the table below as well as two derivatives (a, b) of the formula. The symbol for speed is v.

Formula of Average Speed	**Derivatives of the Formula**
$\text{Average speed} = \dfrac{\text{Distance}}{\text{Elapsed time}}$	**a**) Distance = (Average Speed) x (Time) **or** b) Time = (Distance) / (Average Speed)

Speed is a scalar quantity. A speed of 80 km/h means the the object moves 80 km every one hour (80 is the magnitude, km/h is the unit kilometer/hour). SI units for speed: meters per second (m/s) or km/h

Example 4:

What is the speed of a train that travels a distance of 480 km in 8.0h?

Average Speed = Distance / Time

= 480 / 8

= 60 km/h

Example 5:

How far does a jogger run in 1.5 hours (5400 s) if his average speed is 2.22 m/s?

Average Speed = Distance / Time

or

Distance = (Average Speed) x (Time)

= (2.22) x (4500)

= 12000m

Average Velocity and Displacement

Average Velocity is the displacement divided by the elapsed time.

The symbol for velocity is ($\vec{v}$)

The formula of average speed in shown in the table below as well as two derivatives (a, b) of the formula.

Uniform motion is motion at a constant velocity.

Formula of Average Velocity	Derivatives (a, b) of the Formula
$\text{Average velocity} = \dfrac{\text{Displacement}}{\text{Elapsed time}}$	**a**) Displacement = (Average Velocity) x (Time) **or** b) Time = (Displacement) / (Average Velocity)

Velocity is a vector quantity and has a direction. It shows how fast an object is moving to which direction. A velocity of 80 km/h[E] , means that the object is moving with a speed of 80 km/h in the east direction (80 is the magnitude, km/h is the unit kilometer/hour and E is East direction).

Average velocity can be calculated mathematically as shown below:

$$\overline{\vec{\mathbf{v}}} = \frac{\vec{\mathbf{x}} - \vec{\mathbf{x}}_o}{t - t_o} = \frac{\Delta \vec{\mathbf{x}}}{\Delta t}$$

In this formula:

$\vec{\mathbf{x}}_o$ = initial position $\qquad$ $\vec{\mathbf{x}}$ = final position

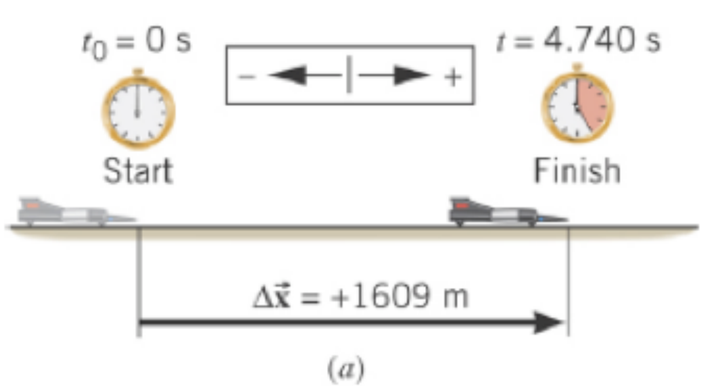
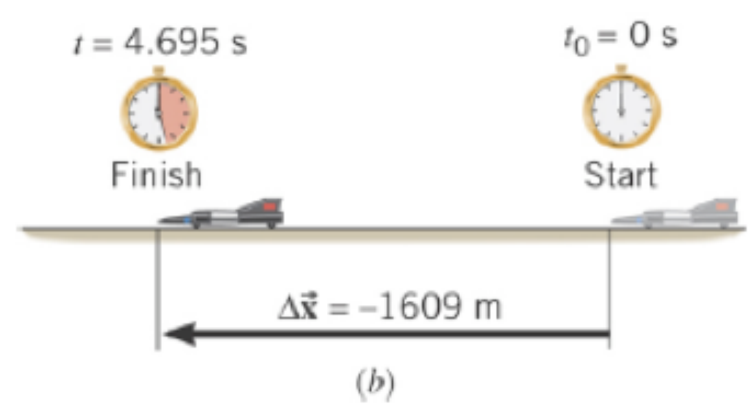
$\Delta \vec{\mathbf{x}} = \vec{\mathbf{x}} - \vec{\mathbf{x}}_o$ = displacement

t = final time $\qquad$ t_o = initial time

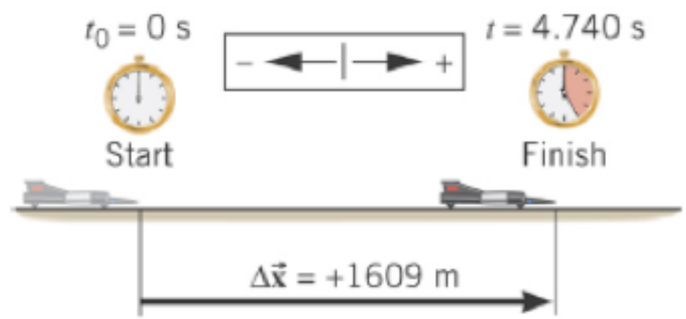
Δt = elapsed time = $t - t_o$

Example 6: The World’s Fastest Jet-Engine

in 1997, Car Andy Green in the car Thrust SSC set a world record of 341.1 m/s. To establish such a record and nullify wind effects, the driver makes two runs through the course, one in each direction. From the data given in the figure below, determine the average velocity for each run a (east) and b (west).

a) Run in the forward east direction (+) **Displacement = +1609 m** **Elapsed time = 4.740 s**	**b) Run in backward west direction (-)** **Displacement = -1609 m** **Elapsed time = 4.695 s**
	

a) In forward east direction (+): the driver moves 1609 m forward during 4.695 seconds. So, the displacement is +1609 m. The velocity is +339.5 m/s or 342.7 m/s [west] as calculated below;

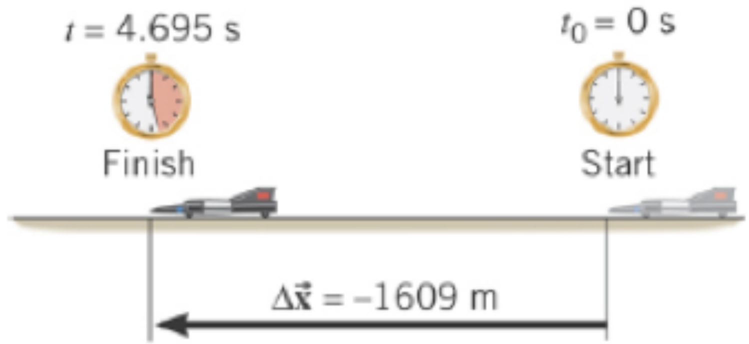


(a)

Velocity ($\vec{v}$) = displacement / elapsed time

$$\bar{\vec{v}} = \frac{\Delta \vec{x}}{\Delta t} = \frac{+1609\,\text{m}}{4.740\,\text{s}} = +339.5\,\text{m/s}$$

b) Backward west direction (-): the driver moves 1609 m backward during 4.695 seconds. So, the displacement is -1609 m. The velocity is -342.7 m/s or 342.7 m/s [west] as calculated below;



(b)

Velocity ($\vec{v}$) = displacement / elapsed time

$$\bar{\vec{v}} = \frac{\Delta\vec{x}}{\Delta t} = \frac{-1609\,\text{m}}{4.695\,\text{s}} = -342.7\,\text{m/s}$$

Example 7: Speed and Velocity

Suppose a car travels with uniform motion from a position of 2.0 km[N] to a position of 20 km[S] in 0.5h. Find the car's a) displacement, b) velocity, c) distance travelled and d) speed. In this case (+) will be used for north and (-) will be used for south.

a) Displacement = Final position - Initial position = -20 - 2.0 = - 22 km or 22 km [S],

b) Average velocity= Displacement / Time = -22 / 0.5 = - 44 km/h or 44 km/h [S]

c) Distance = 20 + 2 = 22 km

d) Speed = Distance / Time = 22 / 0.5 = 44 km/h

Note that since the car does not change direction, the distance is the same as the magnitude of the displacement, and the speed is the same as the magnitude of the velocity.

References:

1) Humanic. (2013). www.physics.ohio-state.edu/~humanic/. In Thomas Humanic Brochure Page.

Physics 1200 Lecture Slides: Dr. Thomas Humanic, Professor of Physics, Ohio State University, *2013-2014 and Current.* *www.physics.ohio-state.edu/~humanic/*

2) Cutnell, J. D. & Johnson, K. W. (1998). *Cutnell & Johnson Physics, Fourth Edition*. New York: John Wiley & Sons, Inc.

The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

3) Martindale, D. G. & Heath, R. W. & Konrad, W. W. & Macnaughton, R. R. & Carle, M. A. (1992). *Heath Physics.* Lexington: D.C. Heath and Company

4) Zitzewitz, P. W. (1999). *Glencoe Physics Principles and Problems*. New York: McGraw-Hill Companies, Inc.

5) Nada H. Saab (Saab-Ismail), (2010-2013) Westwood Cyber High School, Physics.

6) Nada H. Saab (Saab-Ismail), (2009- 2014) Wayne RESA, Bilingual Department.