Name: ____ Date: ______

PHYSICS
UNIT 1: LINEAR MOTION

POSITION: DISTANCE & DISPLACEMENT

Position	A unique location. A specific location.
Distance	The total path-length of travel. How far an object physically moved from one place to another. Scalar parameter.
Displacement	The absolute change in position. The straight-line change in position from the starting position to the current position or ending position. Vector parameter.

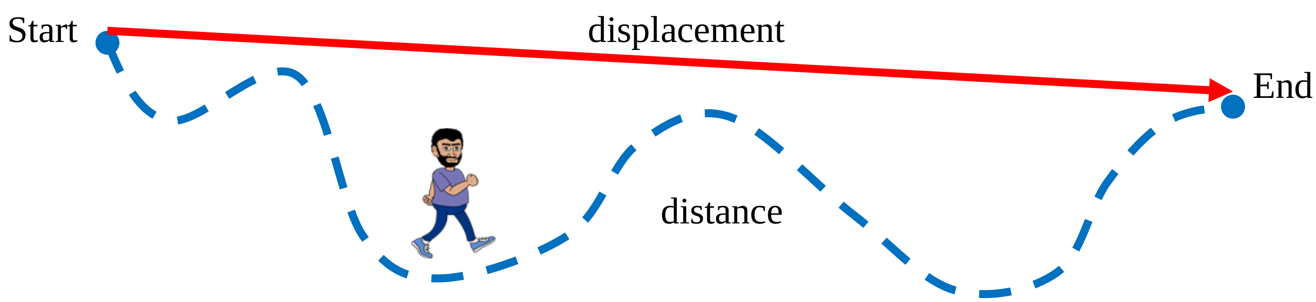
Distance and displacement are variables that describe **changes in location** or "how far" an object moved. They are not interchangeable. They mean different things.

Distance is defined as the **total path length of travel** from the starting position to the end position. The symbol **d** is used to note distance. In other words, distance describes how far an object moved regardless of direction. Distance may be in a straight line (if the object in motion is moving in a straight line) or it may be in an irregular path. Distance is a ***scalar*** and only describes the total path length of travel; no direction is reported, therefore distance is always a positive number.

Displacement is defined as the **straight-line, absolute change in position with direction** between the starting position and the end position. The symbol **Δx** is used to note displacement. Displacement is a vector and must have a direction (N, S, E, W, up, down, left, right). Displacement describes the absolute difference between where motion starts and where motion ends regardless of how the object gets from the start to the finish. Displacement may be positive or negative depending on the direction.

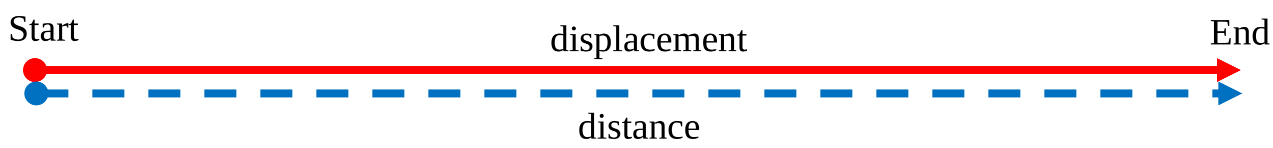
All paths of travel *have both distance and displacement* regardless if the motion is in a straight line or in a curved path. This is true because every path of travel has a starting position, and ending position, and an overall change of position.

Illustrative Example 1



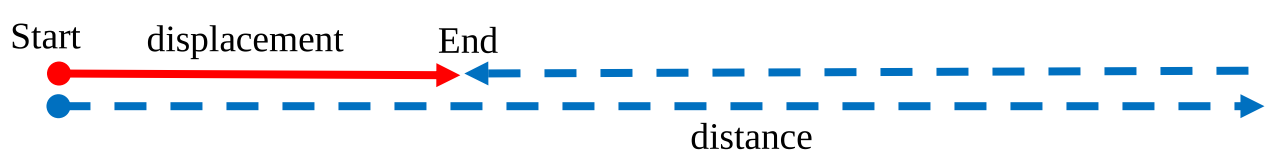
A man walks the blue dashed line to move from the starting position to the end position. The dashed blue line is his distance of travel. The straight red line represents his displacement, the absolute change in position from where he started his walk and where he ended his walk. Notice that the distance he walked is longer than the displacement. This makes sense because in real life, people and cars must follow roads over uneven surfaces that are not straight.

Illustrative Example 2



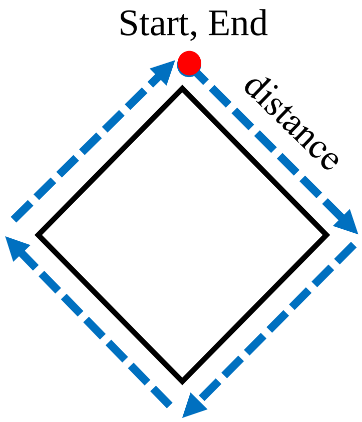
In the diagram above, distance and displacement are equal in magnitude. In this case, they are equal in magnitude because motion is in a straight line in one direction, the absolute difference in position from where motion started and where motion ended was the same. The red line for displacement is equal in length to the dashed blue line for distance.

Illustrative Example 3



In the diagram above, distance and displacement are unequal in magnitude. Distance is greater than displacement. The dashed blue line is the total path of travel, the distance moved from start to the final resting place. The red line is the displacement, the straight-line vector arrow that connects the starting position to the final resting place.

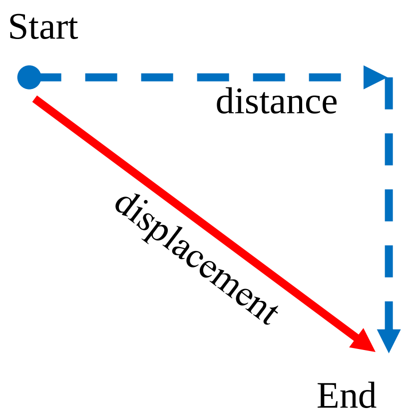
Illustrative Example 4



In the diagram to the left, the path of travel is the blue dashed lines. The motion was in a complete circuit. The object moved around the diamond and ended its motion at its starting place. The start and end are at the same location.

Distance is very large—the physical path taken around the diamond (blue dashed lines). Displacement is zero because the object returned to its starting position. It is like the object never moved at all—there was no overall change.

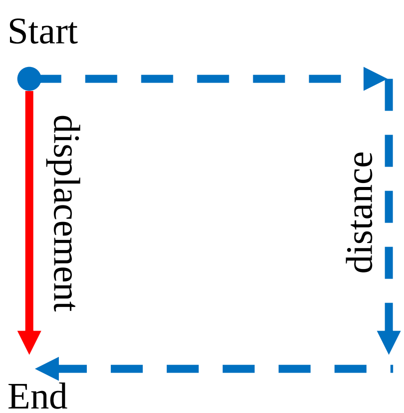
Illustrative Example 5



In the diagram to the left, the path of travel is the blue dashed lines. The motion was to the east, turned, then to the south. The distance traveled is the sum of the east and south segments of motion. The displacement is the straight red arrow that connects the starting position to the end position.

The path of travel was at perpendicular directions (east and south). These make the sides of the right triangle. The displacement is represented by a vector arrow as the hypotenuse of the right triangle.

Illustrative Example 6



In the diagram to the left, the path of travel is the blue dashed lines. The displacement is the straight red line connecting the start to the end. In this case, displacement is to the south of the start, the segments of travel east and west are equal magnitudes and cancel each other out.

Calculations of Distance (d) and Displacement (Δx)

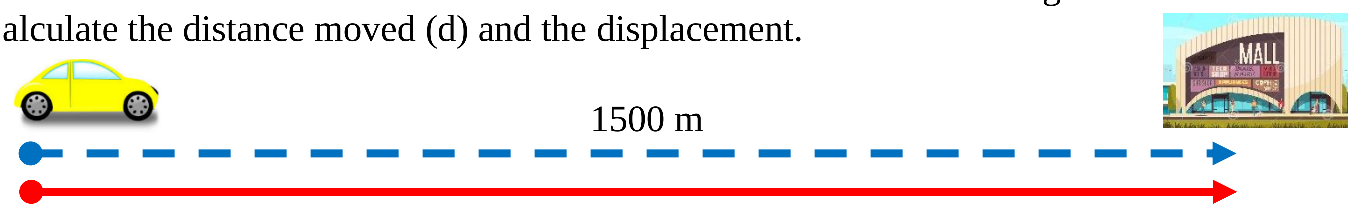
Linear motion in 1-Dimension

If motion is in a straight line (north-south, OR east-west)
Distance = the total length traveled. Add together all segments of travel. Distance is a scalar and all values of distance are positive.

Displacement = the straight line change in position from the start position to the current position or to the end position. Add the segments of travel as vectors, using + and – conventions for directions.

Example Calculation 1

The car moved 1500 m to the east to the mall. The car moved in a straight line. Calculate the distance moved (d) and the displacement.

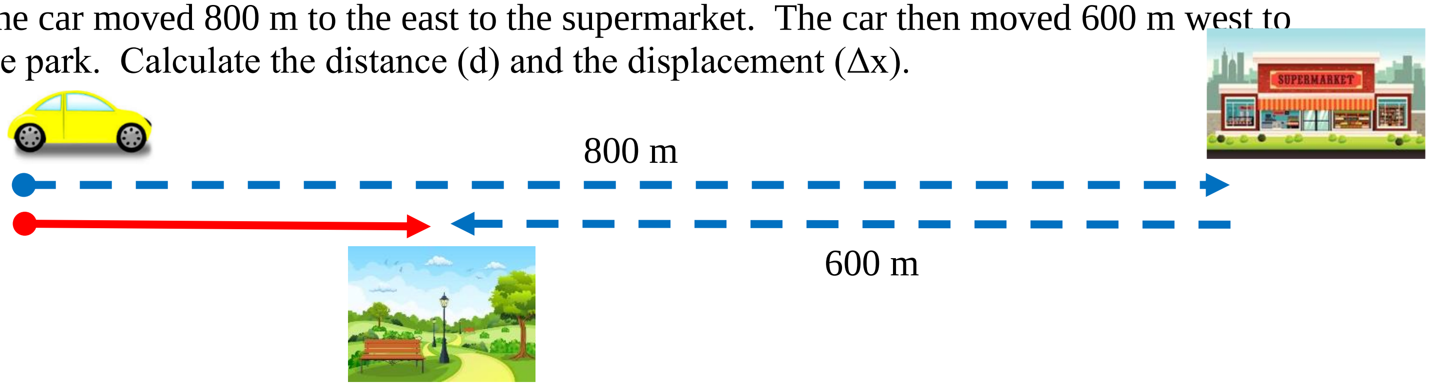


- Distance (d) = 1500 m
- Displacement Δx = 1500 m E

Distance is 1500 m, the total length traveled. The displacement is 1500 m E, the straight-line change of position between the starting place and the end. The magnitudes of distance and displacement are equal because the motion was in a straight line in one direction.

Example Calculation 2

The car moved 800 m to the east to the supermarket. The car then moved 600 m west to the park. Calculate the distance (d) and the displacement (Δx).

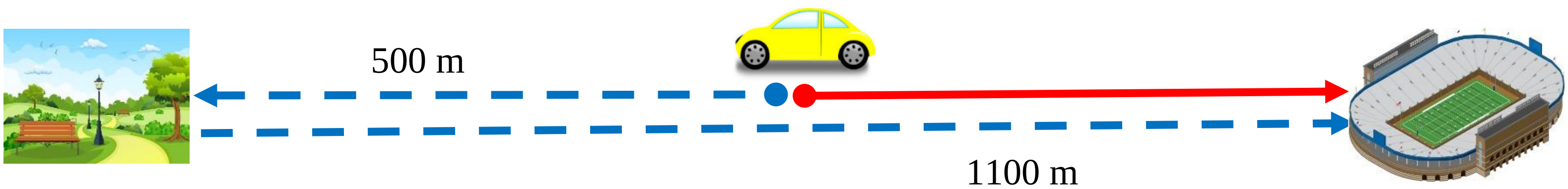


- Distance (d) = 800 m + 600 m = 1400 m
- Displacement Δx = +800 m + -600 m = +200 m = 200 m E

Distance is 1400 m, the total length traveled. The displacement is 200 m E, the straight-line change of position between the starting place and the end. The displacement is calculated as the vector sum of the segments of travel because east and west are linear to each other. 800 m E = +800 m. 600 m W = -600 m.

Example Calculation 3

The car moved 500 m to the west to the park. The car then moved 1100 m east to the stadium. Calculate the distance (d) and the displacement (Δx).



- Distance (d) = 500 m + 1100 m = 1600 m
- Displacement Δx = -500 m + +1100 m = +600 m = 600 m E

Distance is 1600 m, the total length traveled. The displacement is 600 m E, the straight-line change of position between the starting place and the end. The displacement is calculated as the vector sum of the segments of travel because east and west are linear to each other. 500 m W = -500 m. 1100 m E = +1100 m.

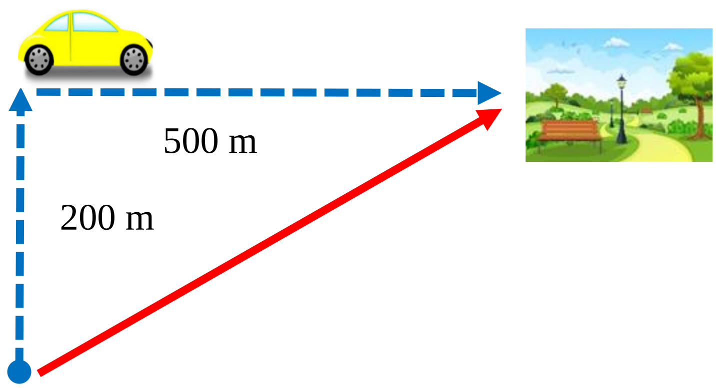
Motion in 2-Dimensions

If motion at perpendicular direction (north-east, south-east, north-west, south-west).
Distance = the total length traveled. Add together all segments of travel. Distance is a scalar and all values of distance are positive.

Displacement = the use the Pythagorean theorem to determine the displacement. The displacement is the hypotenuse of the right triangle. The sides of the right triangle are created by the segments of travel for distance.

Example Calculation 4

The car moved 200 m N to the street corner, turned, and moved another 500 m E to the park. Calculate the distance and the displacement.



Distance (d) = 200 m + 500 m = 700 m

Displacement Δx = 538 m NE

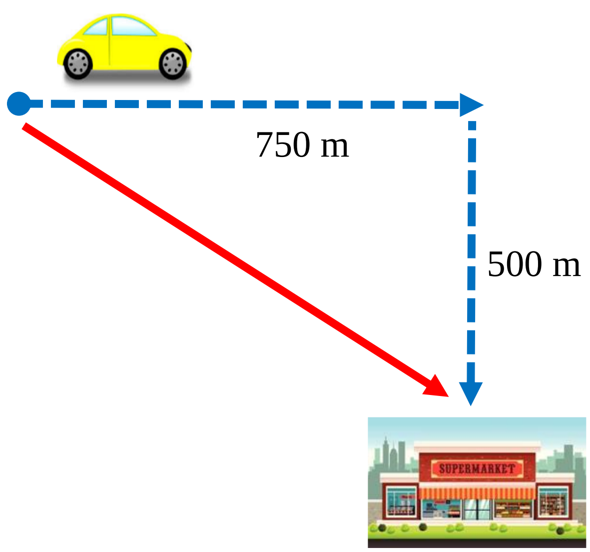
The distance moved is 700 m, the sum of the two segments of travel. The displacement of 538 m NE is the length of the hypotenuse of the right triangle formed by the 200 m and 500 m length segments. The direction NE is the hybrid of the two directions N and E.

$$\Delta x = \sqrt{200^2 + 500^2} = \sqrt{290{,}000} = 583$$

Δx = 583 m NE

Example Calculation 5

The car moved 750 m E to the street corner, turned, and moved another 500 m S to the supermarket. Calculate the distance and the displacement.



Distance (d) = 750 m + 500 m = 1250 m

Displacement Δx = 901 m SE

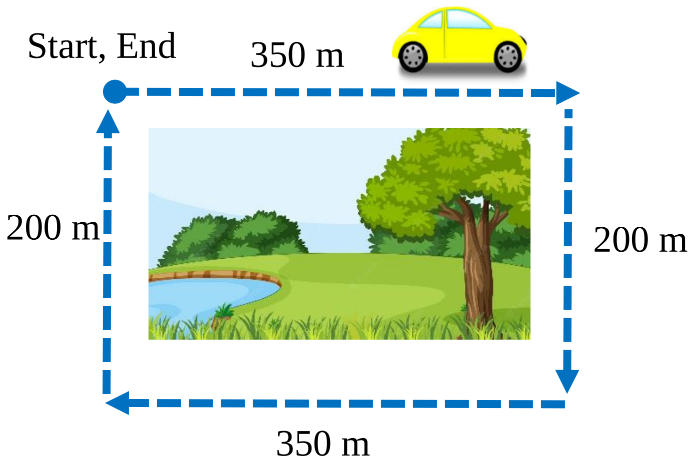
The distance moved is 1250 m, the sum of the two segments of travel. The displacement of 901 m SE is the length of the hypotenuse of the right triangle formed by the 750 m and 500 m length segments. The direction SE is the hybrid of the two directions Sand E.

$$\Delta x = \sqrt{750^2 + 500^2} = \sqrt{812{,}500} = 901$$

Δx = 901 m NE

Example Calculation 6

The car moved around the perimeter of a park, starting from the northwest corner and completing one full circuit returning to its starting place. The park's perimeter was a rectangle. Calculate the distance and displacement moved.



Distance (d) = 350 m + 200 m + 350 m + 200 m =1100 m

Displacement $\Delta x = 0$ m

The distance moved is 1100 m, the sum of the sides of the park's perimeter. Displacement is zero because the car returned to his starting place—there was no overall change in position.

From a mathematical perspective, 350 m E cancels out 350 m W, and 200 m S cancels out 200 m N.

+350 + -350 = 0

-200 + +200 = 0

Comparing Distance and Displacement

Distance is a scalar parameter. Distance describes how far an object physically moved from one place to another, but is independent of direction. Displacement is a vector parameter. Displacement describes how far an object changed position, the overall change between start and its current location, and requires direction to be correct.

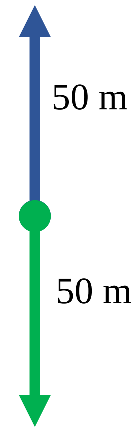
For two objects to move the equal distance, the overall pathlength of travel must be the same. The directions can be different.

For two objects to move equal displacement, the two objects must start and end their travels in equivalent places. In other words, for two displacements to be equal, the two objects must have moved overall the same change in position in the same direction.

Illustrated Example #7

Joey walked 50 m N.
Sam walked 50 m S.

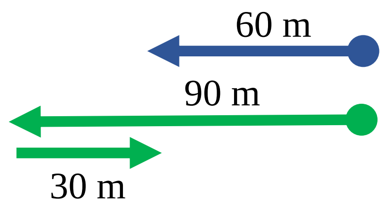
Distances are equal; displacements are unequal. Joey and Sam walked the same pathlength, 50 m. Displacements are unequal because they moved in different directions and finished their journey at different places relative to their starting position.



Illustrated Example #8

Joey walked 60 m W.
Sam walked 90 m W, turned, walked 30 m E.

Distances are unequal; displacements are equal. Distances are unequal because both walked different path lengths, 60 m and 120 m, respectively. Displacements are equal because their ending points relative to their starting points are equal, 60 m W of their starting points.



Illustrated Example #9

Joey walked 50 m W, turned, walked 30 m E
Sam walked 30 m E, turned, walked 50 m W

Distances are equal; displacements are equal. Distances are equal, both walked 80 m total. Displacements are equal because both ended their trip at 20 m W of their starting positions.