Name: _____ Date: _____

PHYSICS
UNIT 1: LINEAR MOTION

AVERAGE SPEED & AVERAGE VELOCITY

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.
Speed	How fast an object moves from one place to another. Distance traveled per unit time.
Velocity	How fast an object changes position. How fast an object moves in a straight-line with direction. Displacement per unit time.
Average speed	The average "how fast" an object physically moves when moving over a longer distance at variable speeds and direction. Total distance traveled divided by total time of travel.
Average velocity	The average "how fast" an object changes position. Displacement divided by total time of travel.
Total time	The time from start to finish as an object moves over a longer or complicated path of travel.

Average speed and **average velocity** are useful to characterize the average rates of motion when objects travel long distances and do not maintain the same speed or velocity throughout the trip. Consider a school bus carrying children to school. The school bus travels a long distance, but must stop at corners and traffic signals, speed up and slow down, and travel on different roads with different speed limits and different directions as it collects children and carries the children to school. Because of those factors, the school bus's motion is best described with average speed and with average velocity.

Average speed is calculated as the *total traveled distance* divided by the *total time traveled*.

$$v_{avg} = \frac{\text{Total Distance}}{\text{Total Time}}$$

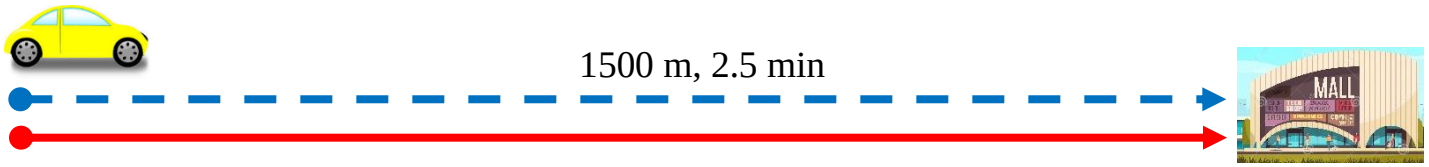
Average velocity is calculated as the *displacement* divided by the *total time traveled*. Remember, displacement is the absolute straight-line difference in position from where motion started to where motion ended.

$$\vec{v}_{avg} = \frac{\text{Displacement}}{\text{Total Time}}$$

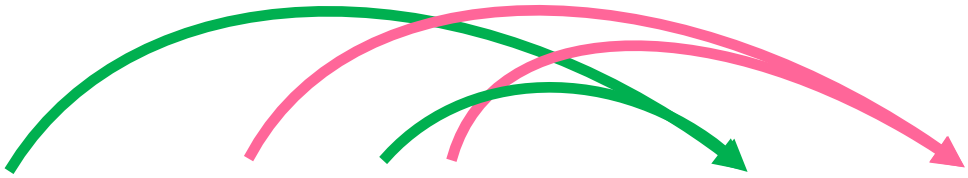
The **total time** of travel includes all time between the start of motion and the end of motion. If the object stops or pauses within its travel, that stop or pause time must be included in the total travel time because it is part of the total trip.

Example Calculation 1

The car moved 1500 m E in 2.5 minutes to the mall.



1. Calculate total distance (in meters)
2. Calculate displacement (in meters)
3. Calculate total time (in seconds)
4. Calculate average speed (total distance divided by total time)
5. Calculate average velocity (displacement divided by total time)



Total Distance TOT d (m)	Displacement ΔX	Total Time TOT t (s)	Avg. Speed v = avg	Avg. Velocity $\vec{v}$
1500 m	1500 m E	(2.5 min) 150 s	10.0 m/s	10.0 m/s E

The car moved 1500 m E. The car moved in a straight line. The total distance and displacement of the car will have equal magnitudes. The displacement will have the addition of direction, E.

To calculate the car's average speed

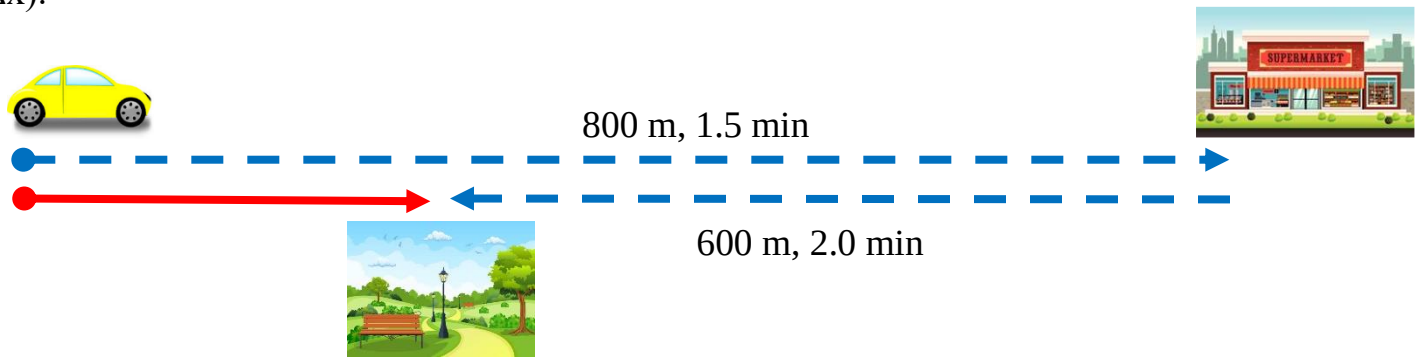
$$\bar{v} = \frac{\text{Total Distance}}{\text{Total Time}} = \frac{1500\ \text{m}}{150\ \text{s}} = 10.0\ {}^{\text{m}}/_{\text{s}}$$

To calculate the car's average velocity

$$\bar{v} = \frac{\text{Displacement}}{\text{Total Time}} = \frac{1500\ \text{m E}}{150\ \text{s}} = 10.0\ {}^{\text{m}}/_{\text{s}}\ \text{E}$$

Example Calculation 2

The car moved 800 m to the east in 1.5 minutes to the supermarket. The car then moved 600 m west in 2.0 minutes to the park. Calculate the distance (d) and the displacement (Δx).



1. Calculate total distance (in meters)
2. Calculate displacement (in meters)
3. Calculate total time (in seconds)
4. Calculate average speed (total distance divided by total time)
5. Calculate average velocity (displacement divided by total time)

Total Distance TOT d (m)	Displacement ΔX	Total Time TOT t (s)	Avg. Speed v = avg	Avg. Velocity $\overleftarrow{v}$
1400 m	200 m E	(3.5 min) 210 s	6.67 m/s	0.95 m/s E

The car moved 1400 m E. The displacement of the car when it arrived at the park was 200 m E of its starting position.

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

To calculate the car's average speed

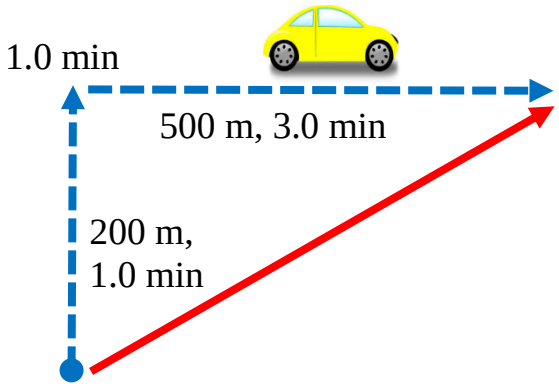
$$\bar{v} = \frac{\text{Total Distance}}{\text{Total Time}} = \frac{1400\ \text{m}}{210\ \text{s}} = 6.67\ {}^{\text{m}}/_{\text{s}}$$

To calculate the car's average velocity

$$\bar{v} = \frac{\text{Displacement}}{\text{Total Time}} = \frac{200\ \text{m E}}{210\ \text{s}} = 0.95\ {}^{\text{m}}/_{\text{s}}\ \text{E}$$

Example Calculation 3

The car moved 200 m N for 1.0 min to the street corner. The car paused at the corner for traffic for 1.0 min. The car moved another 500 m E in 3.0 min to the park.



The trip includes a 1.0 minute stop time in the middle of the trip. That 1.0 minute stop time must be part of the total time.

1. Calculate total distance (in meters)
2. Calculate displacement (in meters)
3. Calculate total time (in seconds)
4. Calculate average speed (total distance divided by total time)
5. Calculate average velocity (displacement divided by total time)

Total Distance TOT d (m)	Displacement ΔX	Total Time TOT t (s)	Avg. Speed v = avg	Avg. Velocity $\vec{v}$
700 m	538 m E	(5.0 min) 300 s	2.33 m/s	0.95 m/s E

Distance (d) = 200 m + 500 m = 700 m
Displacement = 538 m NE

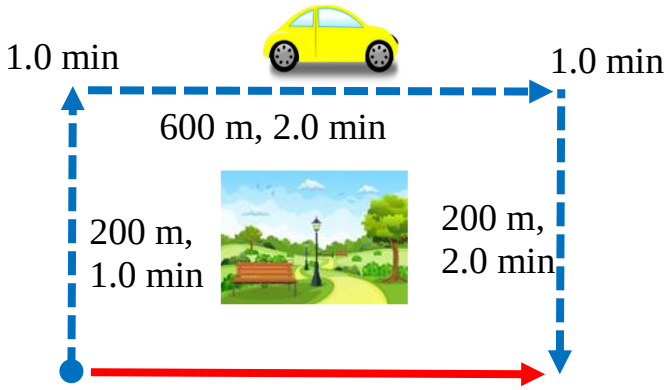
$\Delta x = \sqrt{200^2 + 500^2} = \sqrt{290{,}000} = 583$
$\Delta x = 583$ m NE

To calculate the car's average speed $\quad \bar{v} = \frac{\text{Total Distance}}{\text{Total Time}} = \frac{700 \text{ m}}{300 \text{ s}} = 2.33 \, {}^{\text{m}}/_{\text{s}}$

To calculate the car's average velocity $\quad \bar{v} = \frac{\text{Displacement}}{\text{Total Time}} = \frac{583 \text{ m E}}{300 \text{ s}} = 1.79 \, {}^{\text{m}}/_{\text{s}} \text{ E}$

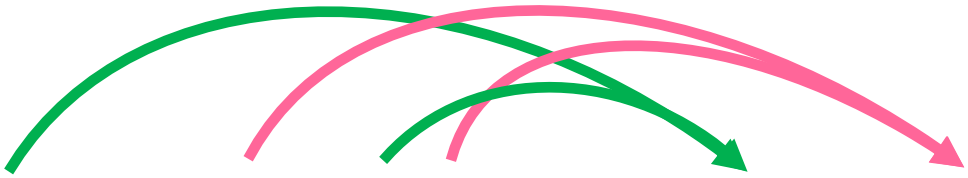
Example Calculation 4

The car moved 200 m N in 1.0 minute, then paused for 1.0 minute at the street corner.
The car moved another 600 m E in 2.0 minutes, turned, and moved 200 m S in 2.0 min.



The trip includes a 1.0 minute stop time in the middle of the trip. That 1.0 minute stop time must be part of the total time.

1. Calculate total distance (in meters)
2. Calculate displacement (in meters)
3. Calculate total time (in seconds)
4. Calculate average speed (total distance divided by total time)
5. Calculate average velocity (displacement divided by total time)



Total Distance TOT d (m)	Displacement ΔX	Total Time TOT t (s)	Avg. Speed v = avg	Avg. Velocity $\vec{v}$
1000 m	600 m E	(6.0 min) 360 s	2.78 m/s	1.67 m/s E

Distance (d) = 200 m + 600 m + 200 m = 1000 m

Displacement = 600 m E

200 m N cancels out 200 m S. The remaining vector is the 600 m E.

To calculate the car's average speed

$$\bar{v} = \frac{\text{Total Distance}}{\text{Total Time}} = \frac{1000\ \text{m}}{360\ \text{s}} = 2.78\ {}^{\text{m}}/_{\text{s}}$$

To calculate the car's average velocity

$$\bar{v} = \frac{\text{Displacement}}{\text{Total Time}} = \frac{600\ \text{m E}}{360\ \text{s}} = 1.67\ {}^{\text{m}}/_{\text{s}}\ \text{E}$$