Introduction to Mechanics
Kinematic Quantities

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Jan 13, 2020

Last time

- significant figures
- unit conversions (non-SI units)
- order of magnitude calculations

Overview

- introducing 1-D kinematics
- quantities of motion
  - position, displacement, and distance
  - speed and velocity

Order of magnitude exercise

What is the radius of the Earth?

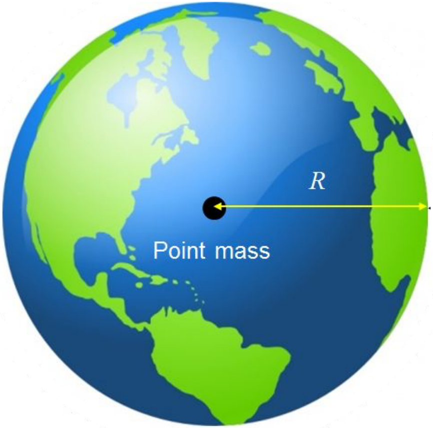

Figure from https://www.antonine-education.co.uk, edited.

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What is the average distance across the US? Answer: about 3000 miles.

On average, there are about **1000 miles** of distance traveled per time zone.

How many time zones are around the Earth?

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What is the average distance across the US? Answer: about 3000 miles.

On average, there are about **1000 miles** of distance traveled per time zone.

How many time zones are around the Earth?

There must be **24** time zones around the earth in all since there are 24 hours in the day.

Order of magnitude examples

What is the circumference of the Earth?

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[1] maa.org

Order of magnitude examples

What is the circumference of the Earth? Answer: about 24,000 miles.

The circumference of a circle is $c = 2\pi r$ where r is the radius. Take $2\pi \approx 6$. The radius of the Earth:

$$r = \frac{c}{2\pi} \approx \frac{24,000 \text{ mi}}{6} = 4,000 \text{ mi}$$

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1 mi $\approx$ 1.6 km
Radius of the Earth in meters:

$$4,000 \text{ mi} \times 1600 \text{ m/mi} = 6,400,000 \text{ m} = \underline{\mathbf{6.4 \times 10^6} \text{ m}}$$

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Actual answer: 6.37×10^6 m   Pretty close!

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Kinematics in 1-dimension

We begin by studying motion along a single line.

This will encompass situations like

- cars traveling along straight roads
- objects falling straight down under gravity

Vectors and Scalars

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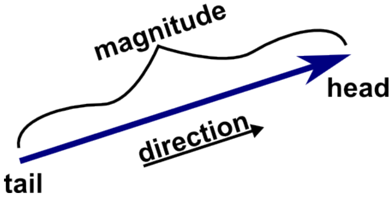
vector

A vector quantity indicates both an amount (magnitude) and a direction. It is represented by a real number for each possible direction, or a real number and (an) angle(s).



Notation for Vectors

In the lecture notes vector variables are represented using **bold** variables with over arrows. This is to match the textbook.

Example:

k is a scalar

$\vec{\mathbf{x}}$ (or $\mathbf{x}$) is a vector

In handwriting, just write an arrow or "harpoon" over the variable to indicate it is a vector.

The magnitude of a vector, $\vec{\mathbf{v}}$ is written:

$$|\vec{\mathbf{v}}| = v$$

Unit Vectors

Unit vectors are one-unit-long vectors that just give a direction.

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Unit vectors are one-unit-long vectors that just give a direction.

Since we are only considering 1-dimension right now, we only need one so far: $\hat{\mathbf{i}}$

It is written with a “carrot” over the letter to indicate it is a unit vector.

$\hat{\mathbf{i}}$ is a unit vector pointing in the $+x$ direction. In the textbook, $\hat{\mathbf{x}}$ is used for this.

Examples of Scalars and Vectors

Some physical quantities that are **scalars** are

- temperature
- mass
- pressure

Some physical quantities that are **vectors** are

- velocity
- force

Distance vs Displacement

How far are two points from one another?

Distance is the length of a path that connects the two points.

Displacement is the length together with the direction of a straight line that connects the starting position to the final position.

Displacement is a vector.

Position

Quantities

position	$\vec{\mathbf{x}}$ or $\vec{\mathbf{r}}$
displacement	$\overrightarrow{\Delta x} = \vec{\mathbf{x}}_f - \vec{\mathbf{x}}_i$ (or $\overrightarrow{\Delta r}$)
distance	d

Position and displacement are *vector* quantities.

Position and displacement can be positive or negative numbers.

Distance is a *scalar*. It is always a positive number.

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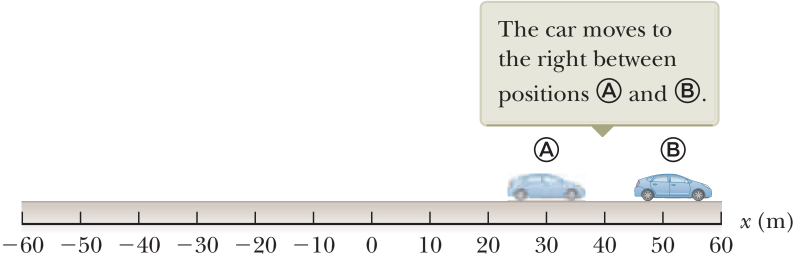
Units: meters, m

Position, Displacement, Distance Example

The starting position of the car is $\vec{\mathbf{x}}_i = 30 \text{ m } \hat{\mathbf{i}}$, the final position is $\vec{\mathbf{x}}_f = 50 \text{ m } \hat{\mathbf{i}}$.

The distance the car travels is



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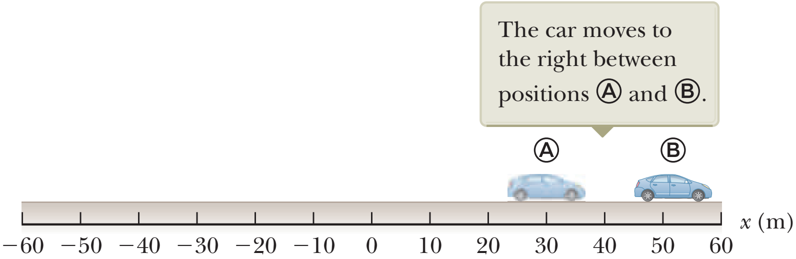

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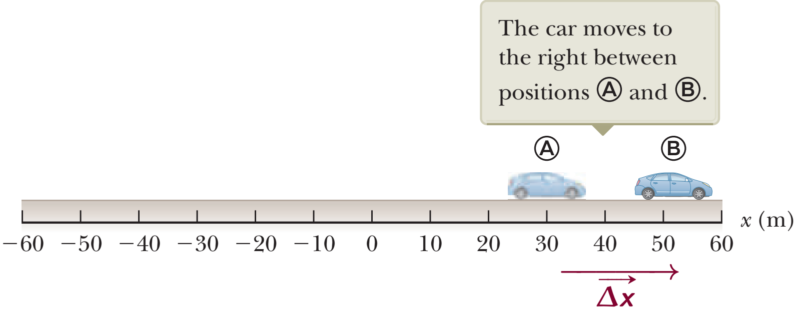

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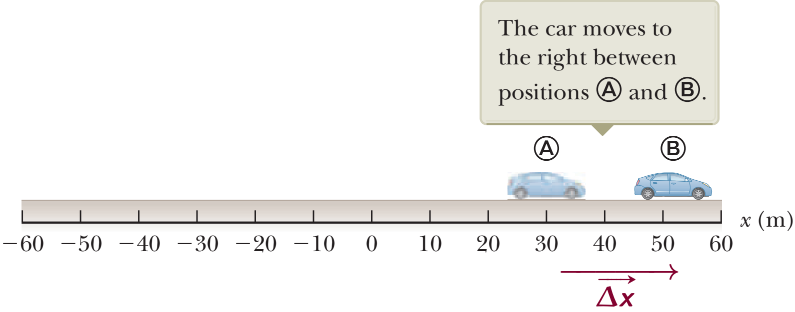
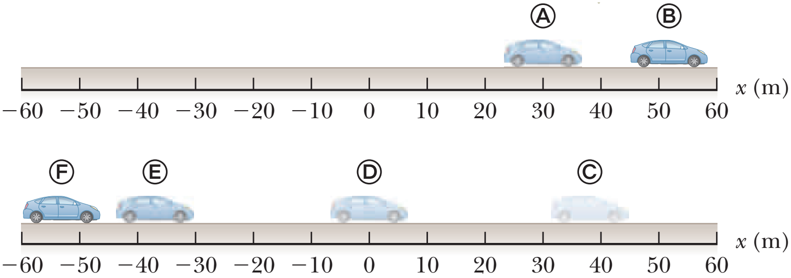


The displacement of the car is $\overrightarrow{\Delta x} = \vec{\mathbf{x}}_f - \vec{\mathbf{x}}_i = \boxed{20 \text{ m } \hat{\mathbf{i}}}$.

Position, Displacement, Distance Example

Now, the starting position of the car is $\vec{\mathbf{x}}_i = 30 \text{ m } \hat{\mathbf{i}}$, the final position is $\vec{\mathbf{x}}_f = -60 \text{ m } \hat{\mathbf{i}}$.



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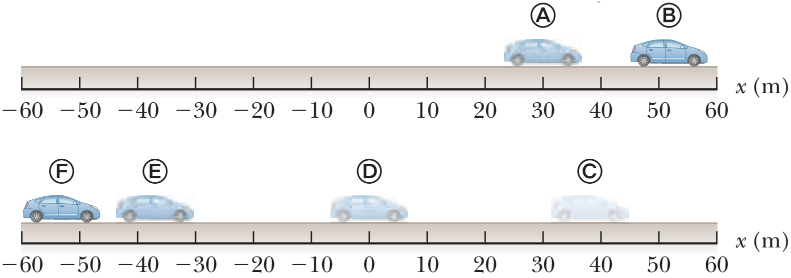
The distance the car travels is $d = \boxed{130\text{ m}}$.



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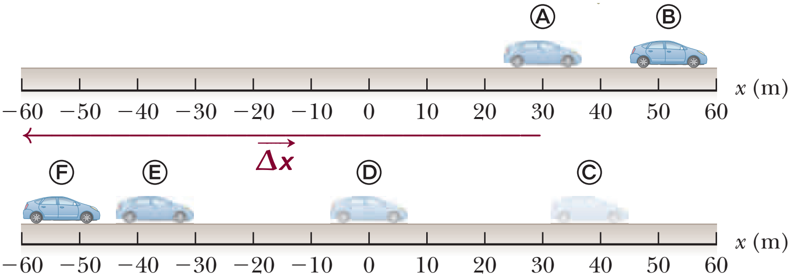

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$$\begin{aligned} \overrightarrow{\Delta x} &= \vec{\mathbf{x}}_f - \vec{\mathbf{x}}_i \\ &= (-60\,\hat{\mathbf{i}}) - 30\,\hat{\mathbf{i}} \text{ m} \\ &= \boxed{-90 \text{ m } \hat{\mathbf{i}}} \end{aligned}$$

Speed

We need a measure how fast objects move.

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

If an object goes 100 m in 1 second, its speed is 100 m/s.

Speed

Speed can change with time.

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$$\text{average speed} = \frac{\text{total distance traveled}}{\text{time interval}}$$

Velocity

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Is its velocity constant?

Velocity

How position changes with time.

Quantities

velocity	$\vec{\mathbf{v}} \ \left(= \frac{\mathrm{d}\,\vec{\mathbf{x}}}{\mathrm{dt}} \right)$
average velocity	$\overrightarrow{\mathbf{v_{avg}}} = \frac{\overrightarrow{\boldsymbol{\Delta x}}}{\Delta t}$
instantaneous speed	v or $\lvert\vec{\mathbf{v}}\rvert$
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Units: meters per second, m/s

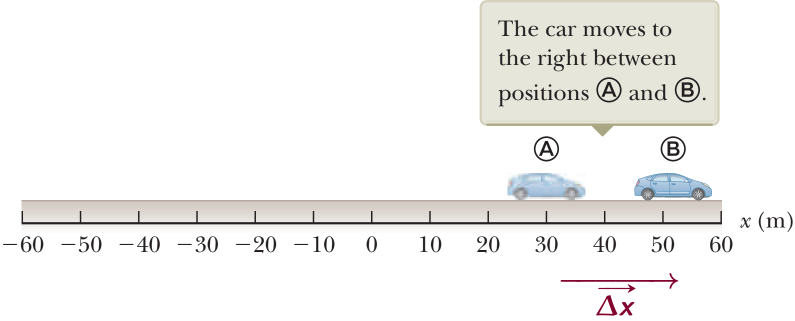
Average Velocity vs Average Speed Example

The displacement of the car is $\overrightarrow{\Delta x} = 20 \text{ m } \hat{\mathbf{i}}$.

The distance the car travels is $d = 20$ m.

The time for the car to move this far is **10 seconds**.

What is the average velocity of the car? What is the average speed of the car?



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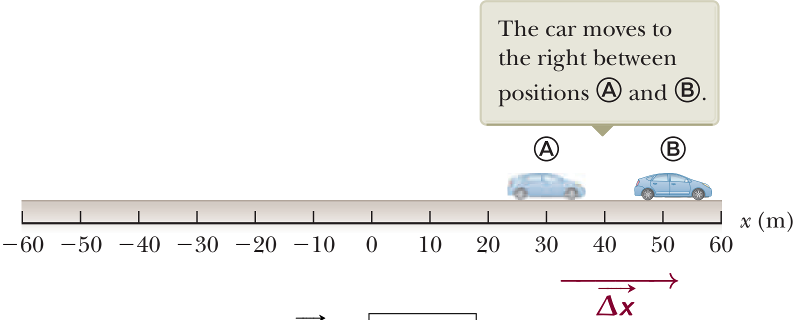


average velocity $\vec{\mathbf{v}}_{avg} = \frac{\overrightarrow{\Delta x}}{\Delta t} = \boxed{2 \text{ m/s } \hat{\mathbf{i}}}$

average speed $= \frac{d}{\Delta t} = \boxed{2 \text{ m/s}}$ (same magnitude in this case)

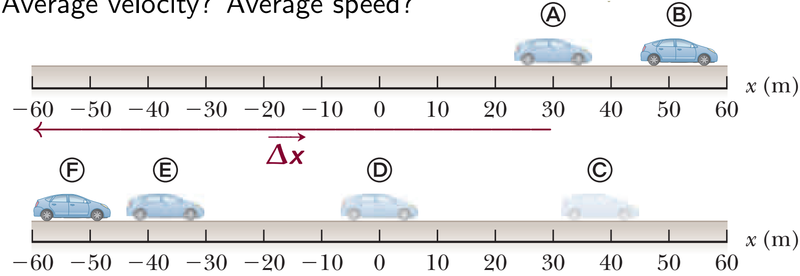
Average Velocity vs Average Speed Example

The displacement of the car is -90 m $\hat{\mathbf{i}}$.

The distance the car travels is $d = 130$ m.

The time for the car to move A→F is **50 seconds**.

Average velocity? Average speed?



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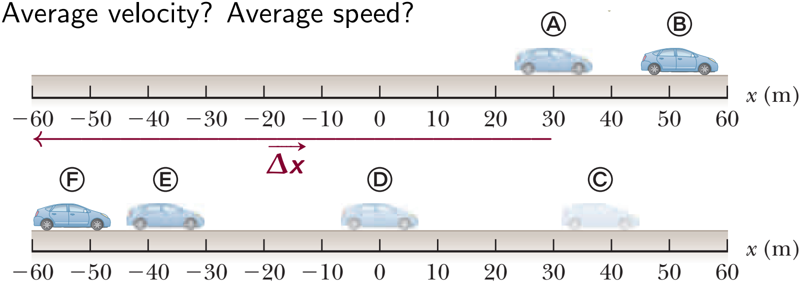

average velocity $\vec{\mathbf{v}}_{\text{avg}} = \frac{\overrightarrow{\Delta x}}{\Delta t} = \boxed{-1.8\text{ m/s}\,\hat{\mathbf{i}}}$

average speed $= \frac{d}{\Delta t} = \boxed{2.6\text{ m/s}}$ **Not the same!**

Question

Quick Quiz 2.1[1] Under which of the following conditions is the magnitude of the average velocity of a particle moving in one dimension smaller than the average speed over some time interval?

A A particle moves in the $+x$ direction without reversing.

B A particle moves in the $-x$ direction without reversing.

C A particle moves in the $+x$ direction and then reverses the direction of its motion.

D There are no conditions for which this is true.

[1] Serway & Jewett, page 24.

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Conceptual Question

1. If the average velocity of an object is zero in some time interval, what can you say about the displacement of the object for that interval?

[1] Serway & Jewett, page 50.

Summary

- introducing kinematics
- position, displacement, and distance
- speed and velocity

Quiz tomorrow, in class.

Homework

- unit conversion worksheet, due tomorrow.

Walker Physics:

- Ch 2, onward from page 47. Conc. Ques: 1, 3, 9; Probs: 1, 3, 5, 7, 9, 13 (can wait until tomorrow to do these)