Mechanics

Kinematics

Dynamics

The study of *how* objects move.

4.1 Motion

- Define motion.
- Explain how frame of reference is related to motion.

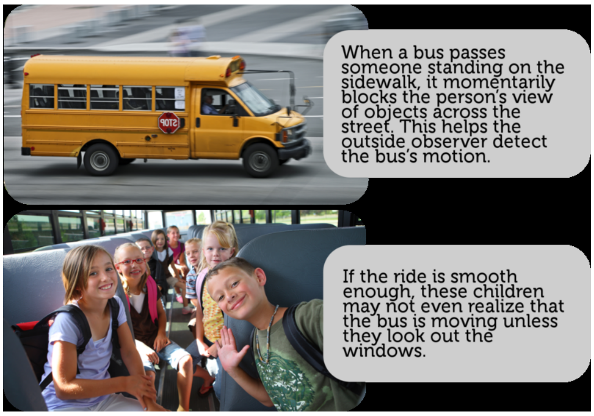
Defining Motion

In science, **motion** is defined as a change in position. An object's position is its location.

Frame of Reference

Example with object in room and hot wheels®

There's more to motion than objects simply changing position. You'll see why when you consider the following example. Assume that the school bus pictured in the **Figure** 4.2 passes by you as you stand on the sidewalk. It's obvious to you that the bus is moving, but what about to the children inside the bus? The bus isn't moving relative to them, and if they look at the other children sitting on the bus, they won't appear to be moving either. If the ride is really smooth, the children may only be able to tell that the bus is moving by looking out the window and seeing you and the trees whizzing by.



Summary

- Motion is defined as a change of position.
- How we perceive motion depends on our frame of reference. Frame of reference refers to something that is not moving with respect to an observer that can be used to detect motion.

Vocabulary

- **frame of reference**: Something that is not moving with respect to an observer that can be used to detect motion.
- **motion**: Change in position.

Frame of Reference Practice

Suppose you are in a car traveling 70 km/h East; the velocities list below are relative to an observer watching traffic from the road. Relative to you in the car, what is the velocity of the cars in the following situations:

1. A car in front of you traveling 70 km/h [E].
2. A car behind you is driving 40 km/h [E].
3. A car approaches driving 60 km/h [W].
4. A car driving away at 20 km/h [W].

*Work in Pairs *Use White Board

Frame of Reference Review (Smart Response)

Suppose you are in a car traveling 50 km/h East; relative to you, what is the velocity of the following cars (velocities given are relative to an observer on the side of the road):

1. A car in front of you traveling 75 km/h [E].
2. A car behind you driving 100 km/h [W].
3. Does the position of the car relative to you even matter?
4. For relative motion questions, what does matter?

Frame of Reference

Grade: 11
Subject: Physics 112
Date: Sept. 2014

1 Frame of Reference Review Question #1

A 125 km/h [E]

B 125 km/h [W]

C 25 km/h [E]

D 25 km/h [W]

2 Frame of Reference Review Question #2

A 150 km/h [W]

B 150 km/h [E]

C 50 km/h [W]

D 50 km/h [E]

3 Frame of Reference Review #4: Does position matter?

Yes

No

4 Frame of Reference Review #4: For relative motion, what does matter?

direction

Intro to Motion Review

Grade: 11

Subject: Physics 112

Date: Sept. 2014

1 Complete the statement: In physics, motion is best described _________

A as movement in a straight line.

B as the change in an object's position. ✓

C as what happens when kicking a ball.

D as a type of sickness.

2 How is motion perceived?

A Using our eyes.

B With data collection technology.

C Depends where you are.

D Within a frame of reference. ✓

Types of Measurement Quantities: Scalar and Vector

You are already familiar with them from your everyday lives, you are just missing the terminology. In pairs, which of the following would you say in a conversation:

1. It will take you 3 hours to drive to Fredericton. ✓
2. My speed is 65 km/h. ✓
3. The mass of the car is 125 kg north. ?!
4. The movie starts at 2:30 pm west. ?!
5. The velocity of the plane is 200 m/s east. ✓
6. Gravity pulls me down with 195 lbs of force. ✓
7. The flight lasts 7 hours [E25°S]. ?!
8. Today I drove 50 km. ✓
9. Today I drove 50 km south. ✓

- **Scalars** are measurements that are independent of direction.
  - Time
  - Mass
  - Distance
  - Speed
- **Vectors** are measurements that require a direction (it is relative to a coordinate system within a frame of reference)
  - Position
  - Displacement
  - Velocity
  - Acceleration
  - Force

Important Examples of the Differences Between Scalars and Vectors (measurements or calculations).

Scalar

1. Walked 25 m. distance
2. Drove 62 km. distance
3. Flew 150 m/s. speed
4. Ran 15 km/h. speed

Vectors

1. Walked 25 m [E]. displacement
2. Drove 62 km [N]. displacement
3. Flew 150 m/s [W]. velocity
4. Ran 15 km/h [S]. velocity

4.2 Distance

Information taken from the Physical Science Concepts electronic document.

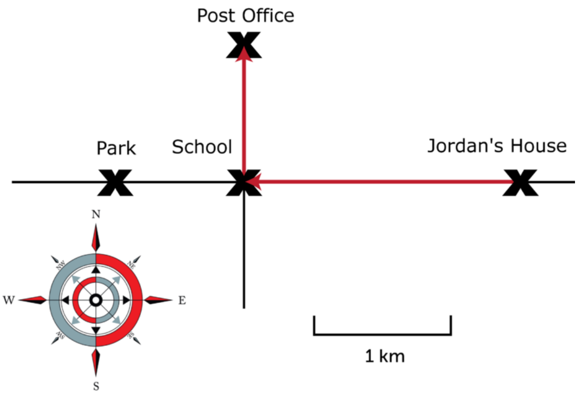
What Is Distance?

Distance is the length of the route between two points. The distance of a race, for example, is the length of the track between the starting and finishing lines. In a 100-meter sprint, that distance is 100 meters.

4.3 Direction

Introducing Direction

Direction can be described in relative terms, such as up, down, in, out, left, right, forward, backward, or sideways. Direction can also be described with the cardinal directions: north, south, east, or west. On maps, cardinal directions are indicated with a compass rose. You can see one in the bottom left corner of the map in the **Figure** 4.4. You can use the compass rose to find directions on the map. For example, to go to the school from Jordan's house, you would travel from east to west. If you wanted to go on to the post office, you would change direction at the school and then travel from south to north.



Position and Displacement

displacement final position Initial position

$$\vec{d} = \vec{d}_f - \vec{d}_o$$

The Big Idea

Speed represents how quickly an object is moving through space. Velocity is speed with a direction, making it a *vector* quantity. If an object's velocity changes with time, the object is said to be accelerating. As we'll see in the next chapters, understanding the acceleration of an object is the key to understanding its motion. We will assume constant acceleration throughout this chapter.

When beginning a one dimensional problem, define a positive direction. The other direction is then taken to be negative. Traditionally, "positive" is taken to mean "to the right"; however, any definition of direction used consistently throughout the problem will yield the right answer.

Key Concepts

***Very important* We cannot do the math unless each variable is measured relative to the same direction.**

- When you begin a problem, define a coordinate system. For positions, this is like a number line; for example, positive $(+x)$ positions can be to the right of the origin and negative $(-x)$ positions to the left of the origin.
- For velocity v you might define positive as *moving to the right* and negative as *moving to the left*. What would it mean to have a **positive position** and a **negative velocity?**

Guidance

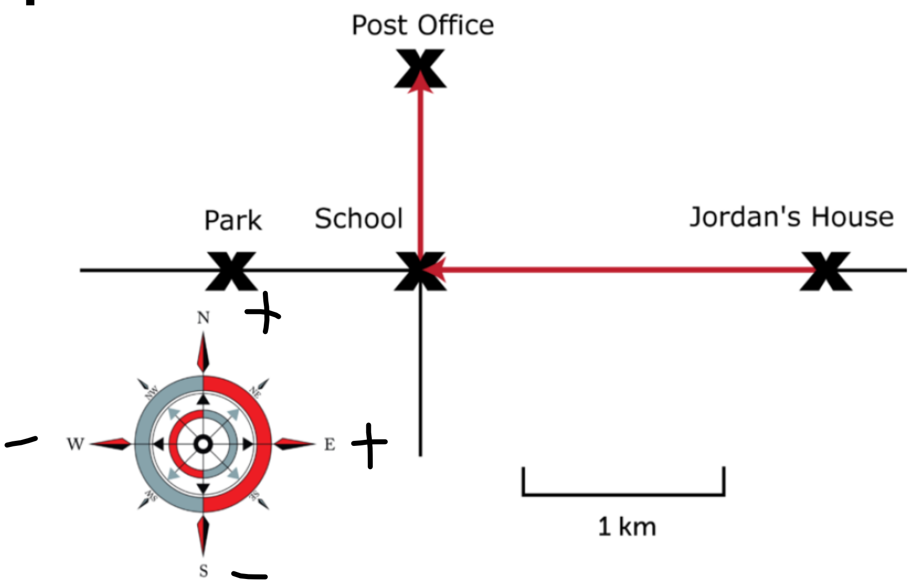
Position is the location of the object (whether it's a person, a ball or a particle) at a given moment in time. Displacement is the difference in the object's position from one time to another. Distance is the total amount the object has traveled in a certain period of time. Displacement is a vector quantity (direction matters), where as distance is a scalor (only the amount matters). Distance and displacement are the same in the case where the object travels in a straight line and always moving in the same direction.

Motion and Vectors

When both distance and direction are considered, motion can be represented by a vector. A **vector** is a measurement that has both size and direction. It may be represented by an arrow. If you are representing motion with an arrow, the length of the arrow represents distance, and the way the arrow points represents direction. The red arrows on the map above are vectors for Jordan's route from his house to the school and from the school to the post office. If you want to learn more about vectors, watch the video at this URL:

http://www.youtube.com/watch?v=B-iBbcFwFOk

Concept Practice:



In, pairs, carefully answer the questions below:

1. Calculate the distance from Jordan's house to the post office.
2. T or F, the park is North-East from the post office.
3. Calculate the position of the school from Jordan's house.
4. Calculate Jordan's final position from school if he walks to the park and then home.
5. How would you calculate the displacement from Jordan's house to the post office?
6. T or F, the school is -1 km North from the post office.
7. T or F, the park is -3 km from the Jordan's house
8. T or F, Jordan's house is -3 km East from the park.
9. Calculate the distance traveled if Jordan walked from home, to the park, to the post office, and finally to school.
10. Calculate Jordan's displacement from home for question 9.
11. T or F, Jordan lives South-East of the post office.
12. T or F, the post office is located North-West of Jordan's house.
13. How does the choice of frame of reference effect the calculations for displacement?
14. Describe the importance of a coordinate system in physics.

Distance and Displacement Practice

A person walked the following path:

- 20 m [W]
- 10 m [E]
- 50 m [E]
- 25 m [W]
- 60 m [W]

Calculate this person's distance and displacement. Do the calculations relative to east (east is positive).

W (−) ⟵⟶ E (+)

$d = 20 + 10 + 50 + 25 + 60$

$d = 165\,m$

$\vec{d} = (-20[E]) + 10[E] + 50[E] + (-25[E]) + (-60[E])$

$\vec{d} = -45\,m\,[E]$

or

$\vec{d} = 45\,m\,[W]$

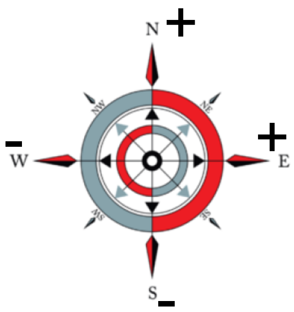
Brains On!

Take 5 minutes:

1. What is the difference between distance and displacement?
2. At a certain point in time can a moving object have the same numerical value for distance and displacement?
3. From home I drive around the city going to Walmart, Canadian Tire, and Sobeys. When I return home what is my displacement? How could I determine my distance traveled?

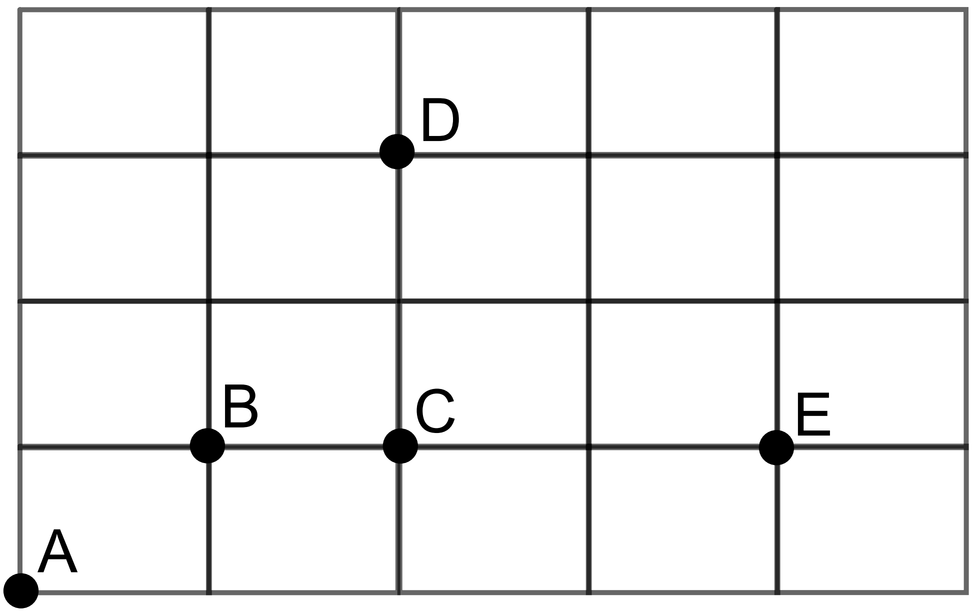
Position & Displacement

Grade: 11
Subject: Physics 112
Date: Sept. 2014



Each grid is 1km x 1km.

Cannot move digonally.



1 Calculate the shortest distance from A to E

A 5 km [E]

B 5 km

C 1 km [N] then 4 km [E]

2 Position C is -2 km North from D.

True

False

3 A person ran from C, to D, back to C, and finally to E. What was their resulting displacement from C?

A 2 km [E]

B 2 km

C 6 km [E]

D 6 km

4 Position E is South-West relative to D.

True

False

5 Calculate the shortest distance from B to D and finally to A.

A 2 km

B 5 km

C 8 km

6 Position B is -3km [W] of point E.

True

False

7 Point C is the same distance from D and E.

True

False

8 Point C is the same position from D and E.

True

False

4.4 Speed

- Define speed, and give the SI unit for speed.
- Show how to calculate average speed from distance and time.
- Describe instantaneous speed.
- Show how to calculate distance or time from speed when the other variable is known.

Introducing Speed

How fast or slow something moves is its **speed**. Speed determines how far something travels in a given amount of time. The SI unit for speed is meters per second (m/s). Speed may be constant, but often it varies from moment to moment.

Average Speed

Even if speed varies during the course of a trip, it's easy to calculate the average speed by using this formula:

$$speed = \frac{distance}{time}$$ ← Scalar

Instantaneous Speed

When you travel by car, you usually don't move at a constant speed. Instead you go faster or slower depending on speed limits, traffic lights, the number of vehicles on the road, and other factors. For example, you might travel 65 miles per hour on a highway but only 20 miles per hour on a city street (see the pictures in the **Figure** 4.6.) You might come to a complete stop at traffic lights, slow down as you turn corners, and speed up to pass other cars. Therefore, your speed at any given instant, or your instantaneous speed, may be very different than your speed at other times. Instantaneous speed is much more difficult to calculate than average speed. If you want to learn more about calculating speed, watch the video at this URL:

http://www.youtube.com/watch?v=a8tIBrj84II

FIGURE 4.6
Cars race by in a blur of motion on an open highway but crawl at a snail's pace when they hit city traffic.

4.6 Velocity

- Distinguish between velocity and speed.
- Represent velocity with vector arrows.
- Describe objects that have different velocities.
- Show how to calculate average velocity when direction is constant.

Speed and Direction

Speed tells you only how fast or slow an object is moving. It doesn't tell you the direction the object is moving. The measure of both speed and direction is called **velocity**. Velocity is a vector. A **vector** is measurement that includes both size and direction. Vectors are often represented by arrows. When using an arrow to represent velocity, the length of the arrow stands for speed, and the way the arrow points indicates the direction. If you're still not sure of the difference between speed and velocity, watch the cartoon at this URL:

http://www.youtube.com/watch?v=mDcaeO0WxBI&feature=related

Using Vector Arrows to Represent Velocity

The arrows in the **Figure** 4.10 represent the velocity of three different objects. Arrows A and B are the same length but point in different directions. They represent objects moving at the same speed but in different directions. Arrow C is shorter than arrow A or B but points in the same direction as arrow A. It represents an object moving at a slower speed than A or B but in the same direction as A.

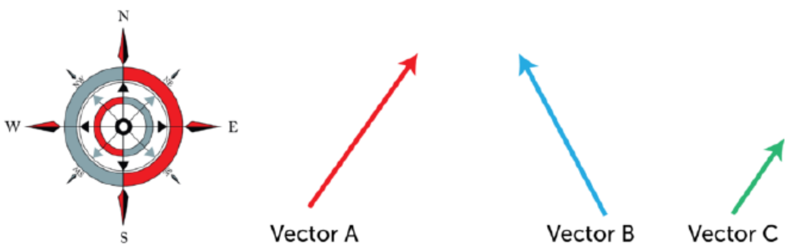


FIGURE 4.10

Differences in Velocity

Objects have the same velocity only if they are moving at the same speed and in the same direction. Objects moving at different speeds, in different directions, or both have different velocities. Look again at arrows A and B from the **Figure** 4.10. They represent objects that have different velocities only because they are moving in different directions. A and C represent objects that have different velocities only because they are moving at different speeds. Objects represented by B and C have different velocities because they are moving in different directions and at different speeds.

Calculating Average Velocity

← displacement

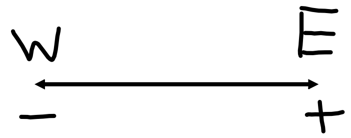
$$\vec{v}_{avg} = \frac{\vec{d}}{t} \quad \text{where} \quad \vec{d} = \vec{d}_f - \vec{d}_o$$

If the object does not change direction the displacement will be the same value as the distance.

Guided Practice

A person drives the following in 3.5 hours:

- 25 km [E]
- 40 km [W]
- 30 km [W]
- 60 km [E]



1. Calculate the total distance traveled. (Does direction matter?)

$$d = 25 + 40 + 30 + 60 = \boxed{155\ km}$$

2. Calculate the displacement. (How do we adjust for different directions in the same dimension?)

25 km [E] , 60 km [E]

−40 km [E]

−30 km [E]

$$\vec{d} = 25 - 40 - 30 + 60$$

$$\boxed{= 15\ km\ [E]}$$

3. Calculate the average speed. (check handbook/notes for formula)

$$v_{sp} = \frac{d}{t} \qquad v_{sp} = \frac{155\ km}{3.5\ h} = \boxed{44.3\ km/h}$$

$t = 3.5\ h$

4. Calculate the average velocity. (check handbook/notes for formula)

$$\vec{v}_{avg} = \frac{\vec{d}}{t} = \frac{15\ km\ [E]}{3.5\ h}$$

$$\boxed{= 4.3\ \frac{km}{h}\ [E]}$$

Attachments

moving-man_en.jnlp