Chapter 11.1 Distance and Displacement

CHOOSING A FRAME OF REFERENCE

In this chapter, we will be studying and describing motion.

To describe motion, you need to state the following:

- The **direction** the object is moving
- How **fast** the object is moving
- The objects **location** at a certain time

***To describe motion **accurately**, a **frame of reference** is necessary!

**Frame of Reference**- a system of objects that are **NOT** moving with respect to one another.

***Use the example of the butterfly and girl:

- How **fast** the butterfly is moving depends on which **frame of reference** you are using.
- **Q:** What would be a good frame of reference to use when describing the butterfly’s motion?
  - **A:** The Ground

Since the description of the motion depends on the **frame of reference**, there can be **several** correct answers to describe the motion…depending on which frame of reference you use.

In other words, it’s all **relative**!

**Relative Motion**- movement in relation to a frame of reference

**Example:** people moving past each other **in** a train, or people moving past other people **outside** the train.

MEASURING DISTANCE AND DISPLACEMENT

To describe an object’s position, you need to know its **distance and direction** from a certain point.

**Distance**- the length of a path between **2 (two) points**

- What is the **SI unit** for distance?
Displacement: the direction from the starting point and the length of a straight line from start to end. (how far gone from the original position)

***If you travel in a circle, you will end up with a displacement of zero.

***Displacement is an example of a vector.

- Vector- a quantity that has magnitude and direction
  - Magnitude refers to size, length, or amount
  - Arrows on graphs represent vectors
    - The length of the arrow represents magnitude

***You can add up displacement using vector addition

- When two displacements are in the same direction, add the magnitude of their vector arrows.
- When they are in opposite directions, subtract their magnitudes from each other.
  - Example: Look at Figure 3 on page 330!

***If the path is not straight, all the vectors can be added together for a total.

- To get the total displacement (start to finish), use a resultant vector.
- This shows how far from the original position the object has moved.
- It can be different than the actual distance traveled.

11.2 Speed and Velocity

Speed

Speed: The ratio of the distance an object moves to the amount of time the object moves

- The SI unit for speed is m/s
  - meters for distance
  - seconds for time
However, be sure to choose the **BEST SI** unit to measure speed

Two ways to express speed are **average speed** and **instantaneous speed**

- **Average speed** is calculated for the entire **duration** of a trip
  - It lets us know **how long** a trip will take
  - The speed may **vary** during the trip, but the following equation will tell the **average speed** over the entire trip
    - **Average Speed =**
  - **Instantaneous speed** is measured at a particular **instant**
    - Measured on the **speedometer**

**Graphing Motion**

**In this chapter we will use graphs to help us analyze motion.**

**A distance-time graph** is a good way to describe motion

**Refer to page 334, figure 7!!!**

- Each is an example of a distance-time graph
- What does the **slope** of each line represent?

The slope of a line on a distance-time graph is **speed!!!**

- **Slope = change in y ÷ change in x = rise ÷ run =SPEED!!!**

**Q**: What does a **steeper slope** on a distance-time graph represent?

**A**: A **higher speed**

**In the space below, determine the slope of the line in Figure A and B. SHOW YOUR WORK!!**

**Velocity**

**Knowing just the speed of an object is not always enough information to accurately describe its motion**

**You need to know speed AND direction** of the object’s motion

**Velocity**: the **speed** and **direction** in which an object is moving
Velocity is a vector

- Longer vectors represent faster speeds
- Shorter vectors represent slower speeds
- The direction of the vector represents the object’s direction

Velocity can change as a result of a change in speed, direction, or both

Example: The sailboat in figure 9 can change its velocity, even if its speed remains the same. How is this possible???

How does the magnitude and direction change if the sailboat slows down at the same time it changes direction???

- Magnitude: WILL CHANGE – VECTOR (ARROW) WILL BECOME SHORTER
- Direction: WILL CHANGE – VECTOR (ARROW) WILL CHANGE DIRECTION IT’S POINTING

Q: When would an object’s motion involve more than one velocity?

A: For example, when a boat is traveling downstream

- It has its own velocity
- Plus the velocity of the current of the river

**When there are 2 or more velocities add by vector addition

- If the vectors are in the same direction, add them
- If the vectors are at right angles to each other, use a resultant vector
  - To determine the length of the resultant vector use the Pythagorean Theorem

\[ a^2 + b^2 = c^2 \]
WHAT IS ACCELERATION?

Review:

Q: What is velocity?
A: A combination of speed and direction

So to determine the rate at which velocity changes we use acceleration

**Acceleration** - the rate at which velocity changes (over time)

- What would the units for acceleration be?
- Velocity units are m/s then divide by time (s)
- Unit = m/s$^2$ or m/s/s

***Acceleration can be described as

- Changes in speed,
- Changes in direction,
- Or changes in both

Q: Is acceleration a vector?

(Hint: does it have magnitude and direction?)

A: YES, if velocity is a vector and acceleration is a change in velocity, then acceleration is a vector, too!

The term *Acceleration* if often used incorrectly, or out of the scientific context.

Example: a newscaster describing a shuttle launch by saying “That shuttle is really accelerating!”

**Technically**, acceleration **only applies to a change in VELOCITY**.

What were some of those factors that change velocity, again?

***So, a change in speed, or direction, or BOTH can cause acceleration!

Q: Is there acceleration while traveling at a constant speed?
A: NO, not until the object speeds up or slows down.
Speeding up = **POSITIVE (+)** acceleration

Slowing down = (-) acceleration = **DECELERATION**

**Example:** of acceleration due to change in speed:

- **FREE FALL**- the movement of an object toward Earth solely because of **gravity**
  - The rate of acceleration downward toward the Earth during free fall is **9.8 m/s²**
  - Is this rate constant?
    - If it were **constant** could it be considered acceleration?
      - **NO**
    - As an object falls, or **free falls** toward the Earth, **each second its velocity increases downward by 9.8 m/s²**
      - What would be the velocity of an object in free fall after 2 seconds? (9.8 m/s² * 2 = 19.6 m/s²)

The above example described acceleration due to a **change in speed**.

However, when could you have acceleration **due to a change in direction**?

**Example:** The **carousel** on page 344 of your text shows acceleration, even though it travels at a constant speed.

- **HOW??** Explain in the space below:
  - While the speed is remaining constant, the horses on the carousel are constantly changing their direction
  - Can you think of another example of acceleration due to change in direction???

What about changes in **speed and direction at the same time**?!?!

When would you see acceleration due to both?

- **Roller Coaster**!!

**Constant acceleration**- a **steady** change in **velocity**.

- The **velocity** of the object is changing by the same amount each second.
- **Example:** an **airplane** takes off at a constant acceleration
CALCULATING ACCELERATION

***You can calculate acceleration for straight-line motion by dividing the change in velocity by the total time.

\[
a = \frac{\text{ACCELERATION}}{\text{FINAL VELOCITY}} \\
v_f = \text{FINAL VELOCITY} \\
v_i = \text{INITIAL VELOCITY} \\
t = \text{TOTAL TIME}
\]

\[
\text{Acceleration} = \frac{\text{Change in Velocity}}{\text{Total time}} = \frac{(v_f - v_i)}{t}
\]

Using the formula, you can see that an increase in velocity will result in a positive velocity (because \(v_f\) is larger than \(v_i\))

- a positive velocity = a positive acceleration.

If the velocity decreases, however, from start to finish, than the numerator in the equation will be negative and so will the acceleration

- negative acceleration = DECELERATION

***Since acceleration is a vector, you must include both units for velocity AND time when stating the acceleration of the object!

Example: Refer to Math Skills on page 346 of your text! Notice the units!

**GRAPHS OF ACCELERATED MOTION**

Review:

Q: What was the slope of a distance-time graph?

A: change in distance/change in time

***You can use a line graph to calculate an object’s acceleration.

***Review Figure 16 and 17 on page 347 for examples of graphs showing (+) and (-) acceleration!

Q: What would be the slope of a speed-time graph? (Hint: the slope is change in speed divided by change in time.)
A: **Acceleration!!!**

The **type of line** that is graphed on a speed-time graph tells if an object is traveling at a **constant acceleration** or **speed** or it can tell us how much an object is **accelerating** or **decelerating**.

**Q:** When looking at a speed-time graph, what does a **straight** line represent?

**A:** Constant **acceleration**.

**Q:** What does a negative slope usually tell us about the motion of the object?

**A:** It is **decelerating**, or slowing down.

**Acceleration** can also be seen on a **distance-time graph**!

- Data for **an object** plotted on a distance-time graph would create a **nonlinear graph**
  - Nonlinear graphs look like a **curve**

- If you were to compare the **slope of the line over the course of time**, it would **change!!!**
  - Because the slope represents **speed**, we can see that the object’s speed is **changing!!!**
  - Increasing speed = **acceleration**!

Last, but not least…

*****Instantaneous acceleration** is how fast a velocity is changing at a **specific instant**!

**Example:** a skateboarder has **instantaneous acceleration** as she changes **speed and direction**

- The acceleration **vector** for this girl could **point in any direction**

- The **length** of the acceleration vector **depends on how fast** she is changing her velocity

- At **every moment** the skateboarder has **instantaneous acceleration**, even if she is **standing still**!
  - Her acceleration vector would be **zero in that case**!