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2 Unit 1: Energy and Motion

Chapter 2: Motion

Describing Motion

2.1 Motion

- Are distance and time important in describing running events at the track-and-field meets in the Olympics?

Describing Motion

2.1 Motion

- Distance and time are important. In order to win a race, you must cover the distance in the shortest amount of time.
- How would you describe the motion of the runners in the race?

Describing Motion

2.1 Motion and Position

- You don't always need to see something move to know that motion has taken place.
- A reference point is needed to determine the position of an object.
- Motion occurs when an object changes its position relative to a reference point.
- The motion of an object depends on the reference point that is chosen.

Describing Motion

2.1 Relative Motion

- If you are sitting in a chair reading this sentence, you are moving.
- You are not moving relative to your desk or your school building, but you are moving relative to the other planets in the solar system and the Sun.

Describing Motion

2.1 Distance

- An important part of describing the motion of an object is to describe how far it has moved, which is **distance**.
- The SI unit of length or distance is the meter (m). Longer distances are measured in kilometers (km).

2.1

Distance

- Shorter distances are measured in centimeters (cm).

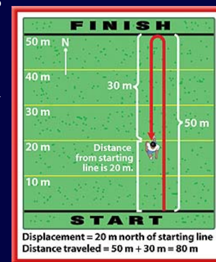
SI Metric/English, English/Metric Conversions

When you want to convert:	To:	Multiply By:
inches	centimeters	2.54
centimeters	inches	0.39
yards	meters	0.91
meters	yards	1.09
miles	kilometers	1.61
kilometers	miles	0.62

2.1

Displacement

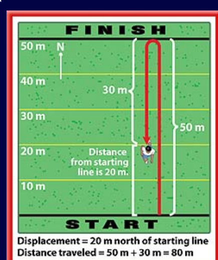
- Suppose a runner jogs to the 50-m mark and then turns around and runs back to the 20-m mark.
- The runner travels 50 m in the original direction (north) plus 30 m in the opposite direction (south), so the total distance she ran is 80 m.



2.1

Displacement

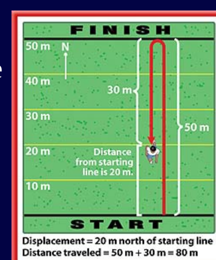
- Sometimes you may want to know not only your distance but also your direction from a reference point, such as from the starting point.
- **Displacement** is the distance and direction of an object's change in position from the starting point.



2.1

Displacement

- The length of the runner's displacement and the distance traveled would be the same if the runner's motion was in a single direction.



2.1

Speed

- You could describe movement by the distance traveled and by the displacement from the starting point.
- You also might want to describe how fast it is moving.
- **Speed** is the distance an object travels per unit of time.

2.1

Calculating Speed

- Any change over time is called a rate.
- If you think of distance as the change in position, then speed is the rate at which distance is traveled or the rate of change in position.

Speed Equation

$$\text{speed (in meters/second)} = \frac{\text{distance (in meters)}}{\text{time (in seconds)}}$$

$$s = \frac{d}{t}$$

2.1

Calculating Speed

- The SI unit for distance is the meter and the SI unit of time is the second (s), so in SI, units of speed are measured in meters per second (m/s).

Examples of Units of Speed

Unit of Speed	Examples of Uses	Approximate Speed
km/s	rocket escaping Earth's atmosphere	11.2 km/s
km/h	car traveling at highway speed	100 km/h
cm/yr	geological plate movements	2cm/yr–17 cm/yr

2.1

Calculating Speed

- Sometimes it is more convenient to express speed in other units, such as kilometers per hour (km/h).

Examples of Units of Speed

Unit of Speed	Examples of Uses	Approximate Speed
km/s	rocket escaping Earth's atmosphere	11.2 km/s
km/h	car traveling at highway speed	100 km/h
cm/yr	geological plate movements	2cm/yr–17 cm/yr

2.1

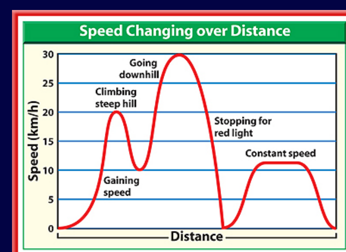
Motion with Constant Speed

- Suppose you are in a car traveling on a nearly empty freeway. You look at the speedometer and see that the car's speed hardly changes.
- If you are traveling at a constant speed, you can measure your speed over any distance interval.

2.1

Changing Speed

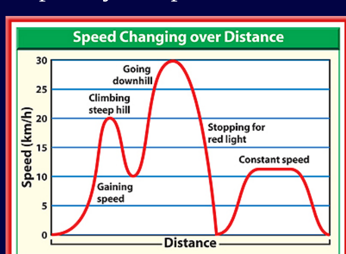
- Usually speed is not constant.
- Think about riding a bicycle for a distance of 5 km, as shown.



2.1

Changing Speed

- How would you express your speed on such a trip? Would you use your fastest speed, your slowest speed, or some speed between the two?



2.1

Average Speed

- Average speed describes speed of motion when speed is changing.
- **Average speed** is the total distance traveled divided by the total time of travel.
- If the total distance traveled was 5 km and the total time was 1/4 h, or 0.25 h. The average speed was:

$$s = \frac{d}{t} = \frac{5\text{ km}}{0.25\text{ h}} = 20\text{ km/h}$$

2.1 Instantaneous Speed

- A speedometer shows how fast a car is going at one point in time or at one instant.
- The speed shown on a speedometer is the instantaneous speed. **Instantaneous speed** is the speed at a given point in time.

2.1 Changing Instantaneous Speed

- When something is speeding up or slowing down, its instantaneous speed is changing.
- If an object is moving with constant speed, the instantaneous speed doesn't change.

2.1 Graphing Motion

- The motion of an object over a period of time can be shown on a distance-time graph.

Click image to play movie

- Time is plotted along the horizontal axis of the graph and the distance traveled is plotted along the vertical axis of the graph.

2.1 Plotting a Distance-Time Graph

- On a distance-time graph, the distance is plotted on the vertical axis and the time on the horizontal axis.
- Each axis must have a scale that covers the range of number to be plotted.

2.1 Plotting a Distance-Time Graph

- Once the scales for each axis are in place, the data points can be plotted.
- After plotting the data points, draw a line connecting the points.

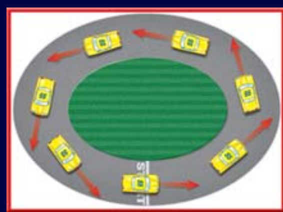
2.1 Velocity

- Speed describes only how fast something is moving.
- To determine direction you need to know the velocity.
- **Velocity** includes the speed of an object and the direction of its motion.

Describing Motion

2.1 Velocity

- Because velocity depends on direction as well as speed, the velocity of an object can change even if the speed of the object remains constant.
- The speed of this car might be constant, but its velocity is not constant because the direction of motion is always changing.



CHAPTER RESOURCES | END

Describing Motion

2.1 Motion of Earth's Crust

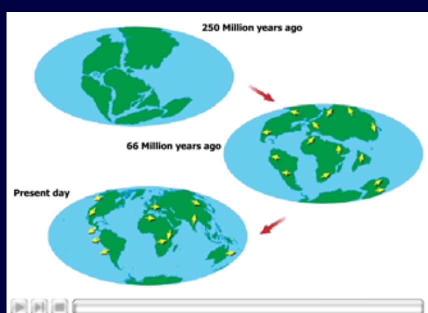
- As you look around the surface of the Earth from year to year, the basic structure of the planet seems the same.
- Yet if you examined geological evidence of what Earth's surface looked like over the past 250 million years, you would see that large changes have occurred.

CHAPTER RESOURCES | END

Describing Motion

2.1 Motion of Earth's Crust

Click the play button to see how the continents have moved over time.



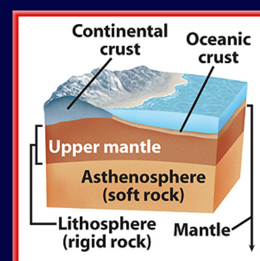
MAC OSX users click here to view.

CHAPTER RESOURCES | END

Describing Motion

2.1 Moving Continents

- How can continents move around on the surface of the Earth? Earth is made of layers.
- Together the crust and the top part of the upper mantle are called the lithosphere.

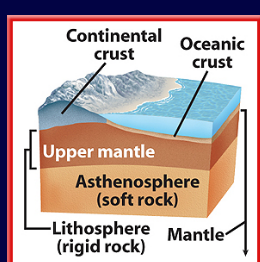


CHAPTER RESOURCES | END

Describing Motion

2.1 Moving Continents

- The lithosphere is broken into huge sections called plates that slide slowly on the puttylike layers just below.



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Describing Motion

2.1 Moving Continents

- These moving plates cause geological changes such as the formation of mountain ranges, earthquakes and volcanic eruptions.
- The movement of the plates also is changing the size of the oceans and the shapes of the continents.

CHAPTER RESOURCES | END

2.1

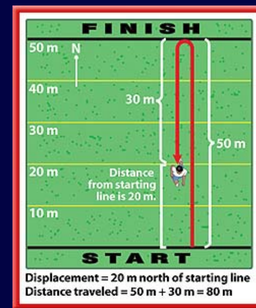
Question 1

What is the difference between distance and displacement?

2.1

Answer

Distance describes how far an object moves; displacement is the distance and the direction of an object's change in position.



2.1

Question 2

__________ is the distance an object travels per unit of time.

A. acceleration

B. displacement

C. speed

D. velocity

2.1

Answer

The answer is C. Speed is the distance an object travels per unit of time.

2.1

Question 3

What is instantaneous speed?

Answer

Instantaneous speed is the speed at a given point in time.

2.2

Acceleration, Speed and Velocity

- **Acceleration** is the rate of change of velocity. When the velocity of an object changes, the object is accelerating.
- A change in velocity can be either a change in how fast something is moving, or a change in the direction it is moving.
- Acceleration occurs when an object changes its speed, it's direction, or both.

2.2

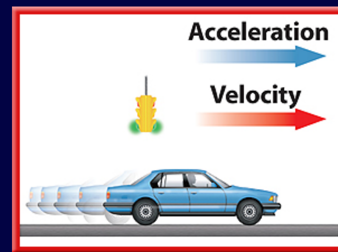
Speeding Up and Slowing Down

- When you think of acceleration, you probably think of something speeding up. However, an object that is slowing down also is accelerating.
- Acceleration also has direction, just as velocity does.

2.2

Speeding Up and Slowing Down

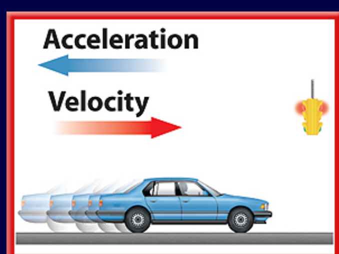
- If the acceleration is in the same direction as the velocity, the speed increases and the acceleration is positive.



2.2

Speeding Up and Slowing Down

- If the speed decreases, the acceleration is in the opposite direction from the velocity, and the acceleration is negative.



2.2

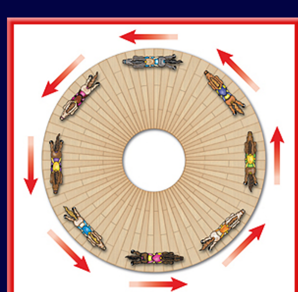
Changing Direction

- A change in velocity can be either a change in how fast something is moving or a change in the direction of movement.
- Any time a moving object changes direction, its velocity changes and it is accelerating.

2.2

Changing Direction

- The speed of the horses in this carousel is constant, but the horses are accelerating because their direction is changing constantly.



2.2

Calculating Acceleration

- To calculate the acceleration of an object, the change in velocity is divided by the length of time interval over which the change occurred.
- To calculate the change in velocity, subtract the initial velocity—the velocity at the beginning of the time interval—from the final velocity—the velocity at the end of the time interval.

Acceleration

2.2

Calculating Acceleration

- Then the change in velocity is:

change in velocity = final velocity – initial velocity

$= v_f - v_i$

Acceleration

2.2

Calculating Acceleration

- Using this expression for the change in velocity, the acceleration can be calculated from the following equation:

Acceleration Equation

$$\text{acceleration (in meters/second}^2\text{)} = \frac{\text{change in velocity (in meters/second)}}{\text{time (in seconds)}}$$

$$a = \frac{v_f - v_i}{t}$$

Acceleration

2.2

Calculating Acceleration

- If the direction of motion doesn't change and the object moves in a straight line, the change in velocity is the same as the change in speed.
- The change in velocity then is the final speed minus the initial speed.

Acceleration

2.2

Calculating Positive Acceleration

- How is the acceleration for an object that is speeding up different from that of an object that is slowing down?
- Suppose a jet airliner starts at rest at the end of a runway and reaches a speed of 80 m/s in 20 s.

Acceleration

2.2

Calculating Positive Acceleration

- The airliner is traveling in a straight line down the runway, so its speed and velocity are the same.
- Because it started from rest, its initial speed was zero.

Acceleration

2.2

Calculating Positive Acceleration

- Its acceleration can be calculated as follows:

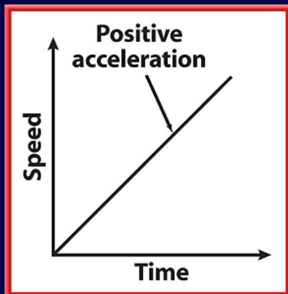
$$a = \frac{(v_f - v_i)}{t} = \frac{(80\text{ m/s} - 0\text{ m/s})}{20\text{ s}} = 4\text{ m/s}^2$$

Acceleration

2.2

Calculating Positive Acceleration

- The airliner is speeding up, so the final speed is greater than the initial speed and the acceleration is positive.



Acceleration

2.2

Calculating Negative Acceleration

- Now imagine that a skateboarder is moving in a straight line at a constant speed of 3 m/s and comes to a stop in 2 s.
- The final speed is zero and the initial speed was 3 m/s.

Acceleration

2.2

Calculating Negative Acceleration

- The skateboarder's acceleration is calculated as follows:

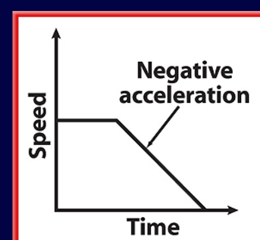
$$a = \frac{(v_f - v_i)}{t} = \frac{(0\ \text{m/s} - 3\ \text{m/s})}{20\ \text{s}} = 1.5\ \text{m/s}^2$$

Acceleration

2.2

Calculating Negative Acceleration

- The skateboarder is slowing down, so the final speed is less than the initial speed and the acceleration is negative.
- The acceleration always will be positive if an object is speeding up and negative if the object is slowing down.



Acceleration

2.2

Amusement Park Acceleration

- Engineers use the laws of physics to design amusement park rides that are thrilling, but harmless.
- The highest speeds and accelerations usually are produced on steel roller coasters.

Acceleration

2.2

Amusement Park Acceleration

- Steel roller coasters can offer multiple steep drops and inversion loops, which give the rider large accelerations.
- As the rider moves down a steep hill or an inversion loop, he or she will accelerate toward the ground due to gravity.

2.2

Amusement Park Acceleration

- When riders go around a sharp turn, they also are accelerated.
- This acceleration makes them feel as if a force is pushing them toward the side of the car.

2.2

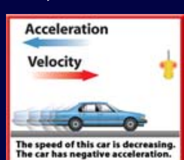
Question 1

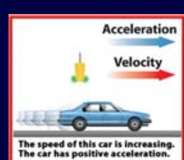
Acceleration is the rate of change of __________.

2.2

Answer

The correct answer is velocity. Acceleration occurs when an object changes its speed, direction, or both.





2.2

Question 2

Which is NOT a form of acceleration?

A. maintaining a constant speed and direction
B. speeding up
C. slowing down
D. turning

2.2

Answer

The answer is A. Any change of speed or direction results in acceleration.

2.2

Question 3

What is the acceleration of a hockey player who is skating at 10 m/s and comes to a complete stop in 2 s?

A. 5 m/s^2
B. -5 m/s^2
C. 20 m/s^2
D. -20 m/s^2

Answer

The answer is B. Calculate acceleration by subtracting initial velocity (10 m/s) from final velocity (0), then dividing by the time interval (2s).

$$\frac{(0\text{ m/s} - 10\text{ m/s})}{2\text{s}} = -5\text{ m/s}$$

What is force?

- A **force** is a push or pull.
- Sometimes it is obvious that a force has been applied.
- But other forces aren't as noticeable.

Changing Motion

- A force can cause the motion of an object to change.
- If you have played billiards, you know that you can force a ball at rest to roll into a pocket by striking it with another ball.

Changing Motion

- The force of the moving ball causes the ball at rest to move in the direction of the force.

Balanced Forces

- Force does not always change velocity.
- When two or more forces act on an object at the same time, the forces combine to form the **net force**.

Balanced Forces

- The net force on the box is zero because the two forces cancel each other.
- Forces on an object that are equal in size and opposite in direction are called **balanced forces**.

Motion and Forces

2.3

Unbalanced Forces

- When two students are pushing with unequal forces in opposite directions, a net force occurs in the direction of the larger force.

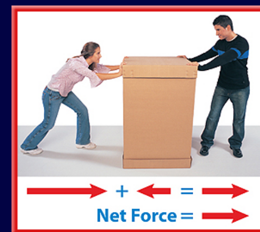
CHAPTER RESOURCES END

Motion and Forces

2.3

Unbalanced Forces

- The net force that moves the box will be the difference between the two forces because they are in opposite directions.
- They are considered to be unbalanced forces.



CHAPTER RESOURCES END

Motion and Forces

2.3

Unbalanced Forces

- The students are pushing on the box in the same direction.
- These forces are combined, or added together, because they are exerted on the box in the same direction.

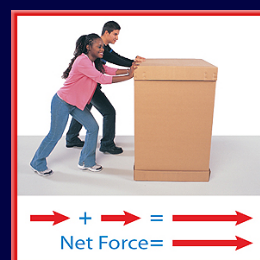
CHAPTER RESOURCES END

Motion and Forces

2.3

Unbalanced Forces

- The net force that acts on this box is found by adding the two forces together.



CHAPTER RESOURCES END

Motion and Forces

2.3

Inertia and Mass

- **Inertia** (ih NUR shuh) is the tendency of an object to resist any change in its motion.
- If an object is moving, it will have uniform motion.
- It will keep moving at the same speed and in the same direction unless an unbalanced force acts on it.

CHAPTER RESOURCES END

Motion and Forces

2.3

Inertia and Mass

- The velocity of the object remains constant unless a force changes it.
- If an object is at rest, it tends to remain at rest. Its velocity is zero unless a force makes it move.
- The inertia of an object is related to its mass. The greater the mass of an object is, the greater its inertia.

CHAPTER RESOURCES END

Motion and Forces

2.3

Newton's Laws of Motion

- The British scientist Sir Isaac Newton (1642–1727) was able to state rules that describe the effects of forces on the motion of objects.
- These rules are known as Newton's law's of motion.

CHAPTER RESOURCES END

Motion and Forces

2.3

Newton's First Law of Motion

- Newton's first law of motion states that an object moving at a constant velocity keeps moving at that velocity unless an unbalanced net force acts on it.
- If an object is at rest, it stays at rest unless an unbalanced net force acts on it.
- This law is sometimes called the law of inertia.

CHAPTER RESOURCES END

Motion and Forces

2.3

What happens in a crash?

- The law of inertia can explain what happens in a car crash.
- When a car traveling about 50 km/h collides head-on with something solid, the car crumples, slows down, and stops within approximately 0.1 s.

CHAPTER RESOURCES END

Motion and Forces

2.3

What happens in a crash?

- Any passenger not wearing a safety belt continues to move forward at the same speed the car was traveling.
- Within about 0.02 s (1/50 of a second) after the car stops, unbelted passengers slam into the dashboard, steering wheel, windshield, or the backs of the front seats.

CHAPTER RESOURCES END

Motion and Forces

2.3

Safety Belts

- The force needed to slow a person from 50 km/h to zero in 0.1 s is equal to 14 times the force that gravity exerts on the person.
- The belt loosens a little as it restrains the person, increasing the time it takes to slow the person down.

CHAPTER RESOURCES END

Motion and Forces

2.3

Safety Belts

- This reduces the force exerted on the person.
- The safety belt also prevents the person from being thrown out of the car.

CHAPTER RESOURCES END

2.3

Safety Belts

- Air bags also reduce injuries in car crashes by providing a cushion that reduces the force on the car's occupants.
- When impact occurs, a chemical reaction occurs in the air bag that produces nitrogen gas.
- The air bag expands rapidly and then deflates just as quickly as the nitrogen gas escapes out of tiny holes in the bag.

2.3

Question 1

A force is a __________.

Answer

A force is a push or pull. Forces, such as the force of the atmosphere against a person's body, are not always noticeable.

2.3

Question 2

When are forces on an object balanced?

Answer

When forces are equal in size and opposite in direction, they are balanced forces, and the net force is zero.

2.3

Question 3

Inertia is __________.

A. the tendency of an object to resist any change in its motion
B. the tendency of an object to have a positive acceleration

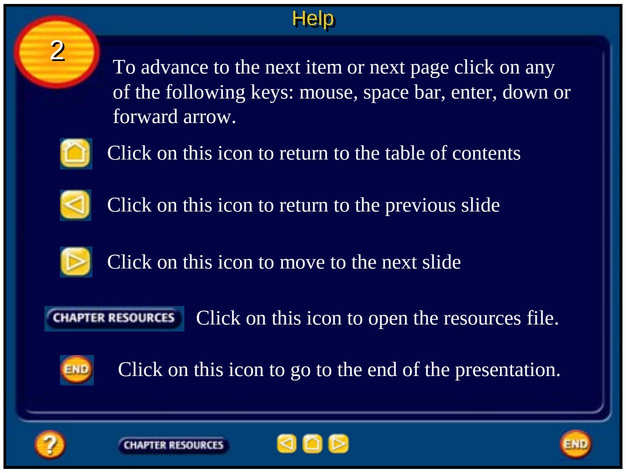
2.3

C. The tendency of an object to have a net force of zero.
D. The tendency of an object to change in speed or direction.

2.3

Answer

Inertia is the tendency of an object to resist any change in its motion. An unbalanced force must act upon the object in order for its motion to change.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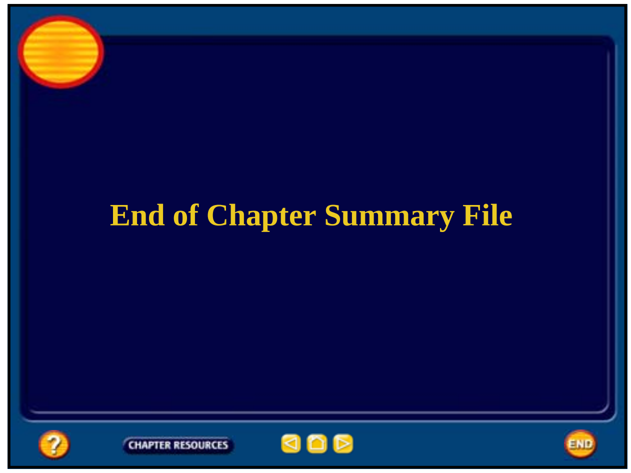
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