

Coverage Of Science



تم تحميل هذا الملف من موقع المناهج الإماراتية

موقع المناهج ⇨ المناهج الإماراتية ⇨ الصف الثامن ⇨ علوم ⇨ الفصل الثالث ⇨ ملفات متنوعة ⇨ الملف

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المزيد من مادة
علوم:

إعداد: Elhddad Ahmed .Mr

التواصل الاجتماعي بحسب الصف الثامن



صفحة المناهج
الإماراتية على
فيسبوك

الرياضيات

اللغة الانجليزية

اللغة العربية

التربية الاسلامية

المواد على تلغرام

المزيد من الملفات بحسب الصف الثامن والمادة علوم في الفصل الثالث

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(يَرْفَعِ اللَّهُ الَّذِينَ آمَنُوا مِنْكُمْ وَالَّذِينَ أُوتُوا الْعِلْمَ دَرَجَاتٍ)

Coverage Of Science

054 455 7773



معهد رواد التعليمية

و

مركز النخبة المتميزة

Mr. Ahmed Elhddad

G8
ADV,ATS
T3

2025-2026

Mr. Ahmed Elhddad

"the first Bio – Sci teacher" 2025 – 2026

054 455 7773



معهد رواد التعليمية

و

مركز النخبة المتميزة

Mr. Ahmed Elhddad

Analyze and calculate displacement as a vector quantity, distinguishing it from distance, and applying direction in one-dimensional motion.

Section: Displacement; Section:
Adding Displacements

p. 39; 40

1a, 1b, 1c, 1d

Displacement

Suppose a runner jogs to the 50-m mark and then turns around and runs back to the 20-m mark, as shown in **Figure 3**. The runner travels 50 m in the original direction (east) plus 30 m in the opposite direction (west), so the total distance that she ran is 80 m. How far is she from the starting line? The answer is 20 m. Sometimes, you may want to know the change in an object's position relative to the starting point. An object's **displacement** is the distance and direction of the object's change in position. In **Figure 3**, the runner's displacement is 20 m east.

The length of the runner's displacement and the total distance traveled would be the same if the runner's motion were in a single direction. For example, if the runner ran east from the starting line to the finish line without changing direction, then the distance traveled would be 50 m, and the displacement would be 50 m east.

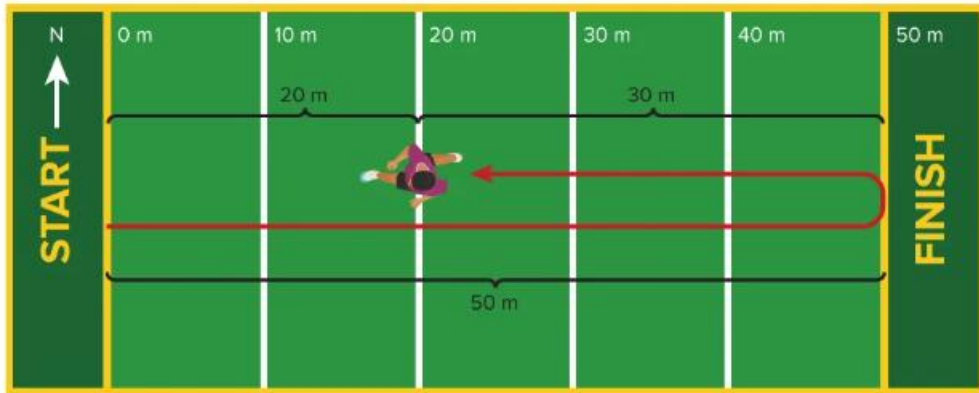


Figure 3 An object's displacement is not the same as the total distance that the object traveled. The runner's displacement is 20 m east of the starting line. However, the total distance the runner traveled is 80 m.

5 m east 5 m east

10 m east

Displacements in the same direction can be added.

10 m east

5 m east

Displacements in opposite directions can be subtracted.

5 m northeast
3 m north
4 m east

Displacements that are not in the same direction or opposite directions cannot be directly added or subtracted.

Figure 4 These arrows represent the students' walks. The green arrows show the first part of the walk, and the purple arrows show the second part. The orange arrows show the students' displacements.

Adding displacements

You know that you can add distances to get the total distance. For example, $2\text{ m} + 3\text{ m} = 5\text{ m}$. But how would you add the displacements 5 m east and 10 m east? Directions in math problems are much like units: you can add numbers with like directions. For example, suppose a student walks 5 m east, stops at a crosswalk, and then walks another 5 m east, as shown on the left in **Figure 4**. His displacement is

$$5\text{ m east} + 5\text{ m east} = 10\text{ m east}$$

But what if the directions are not the same? Then compare the two directions. If the directions are exactly opposite, the distances can be subtracted. Suppose a student walks 10 m east, turns around, and walks 5 m west, as shown in the center of **Figure 4**. The size of the displacement would be

$$10\text{ m} - 5\text{ m} = 5\text{ m}$$

The direction of the total displacement is always the direction of the larger displacement. In this case, the larger displacement is east, so the total displacement is 5 m east.

Table 1 Rules for Adding Displacements

1. Add displacements in the same direction.
2. Subtract displacements in opposite directions.
3. Displacements that are not in the same or in opposite directions cannot be directly added together.

Q1. Which definition accurately describes an object's displacement?

- A. The total length of the entire path traveled by an object regardless of direction.
- B. The distance and direction of an object's change in position relative to a starting point.
- C. The rate at which an object changes its physical location over a given timeframe.
- D. The total time taken for an object to move from an initial point to a terminal point.

Q2. Under what condition will the length of an object's displacement be exactly equal to the total distance it traveled?

- A. The object moves continuously in a single, unchanging direction.
- B. The object moves forward and then returns completely to its starting line.
- C. The object travels along a curved path at a fixed, uniform speed.
- D. The object moves in two opposite directions during its journey.

Q3. A student walks 12 meters east, stops at a crosswalk, and then continues walking another 8 meters east along the same straight path. What is the total displacement?

- A. 4 meters west
- B. 4 meters east
- C. 20 meters west
- D. 20 meters east

Q4. A delivery drone flies 15 kilometers north to drop off a package, turns around, and flies 10 kilometers south along the exact same flight path. What is the magnitude and direction of the drone's final displacement?

- A. 5 kilometers north
- B. 5 kilometers south
- C. 25 kilometers north
- D. 25 kilometers south

Q5. Why can displacements of 4 meters east and 3 meters north strictly NOT be added or subtracted directly through simple arithmetic?

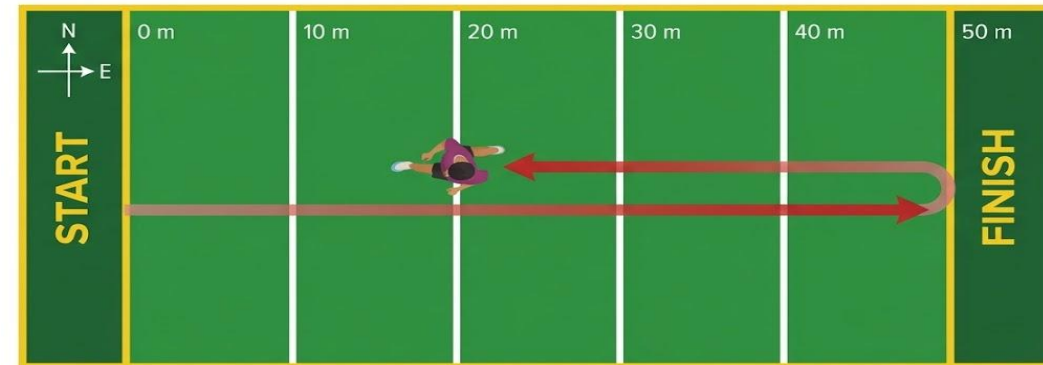
- A. They represent two scalar quantities rather than vector paths.
- B. They are not oriented in the same direction or in exactly opposite directions.
- C. The total distance traveled must always be smaller than the final displacement.
- D. Displacements in opposite directions can only be calculated using multiplication.

Q6. An athlete completes a continuous workout on a straight track by running 100 meters east, turning directly around, and running 100 meters west back to the starting line. What are the total distance and final displacement of this run?

- A. Distance = 0 meters; Displacement = 200 meters east
- B. Distance = 200 meters; Displacement = 0 meters
- C. Distance = 200 meters; Displacement = 200 meters west
- D. Distance = 0 meters; Displacement = 0 meters

Q7. A remote-controlled toy car is placed on a one-dimensional coordinate tracking track. A student drives the car 45 meters east to a checkpoint, stops, and drives it 60 meters west to park it near a charging station. Which statement correctly evaluates the resulting motion parameters of the toy car? A. The total distance traveled is 15 meters, and the net displacement is 105 meters west.

- B. The total distance traveled is 105 meters, and the net displacement is 15 meters west.
- C. The total distance traveled is 105 meters, and the net displacement is 15 meters east.
- D. The total distance traveled is 15 meters, and the net displacement is 15 meters west.



Question 8: Visual & Diagram-Based Question

A runner starts at the 0-meter mark, jogs east to the 50-meter finish line, turns around, and runs back west to the 20-meter mark. Which mathematical combination properly sets up the calculations for both the distance and the displacement of this runner?

- A. Distance = $50\text{ m} - 30\text{ m}$; Displacement = $50\text{ m} + 30\text{ m}$ east
- B. Distance = $50\text{ m} + 20\text{ m}$; Displacement = 30 m west
- C. Distance = $50\text{ m} + 30\text{ m}$; Displacement = $50\text{ m} - 30\text{ m}$ east
- D. Distance = $50\text{ m} + 50\text{ m}$; Displacement = 20 m west

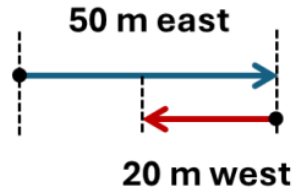
Question 1a

A cat walks 5 m east followed by another 2 m east. What is the displacement of the cat?



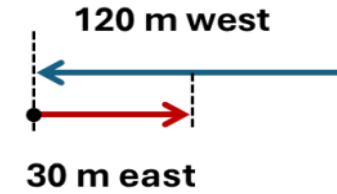
Question 1b

A cyclist rides 50 m east followed by 20 m west. What is the displacement of the cyclist?



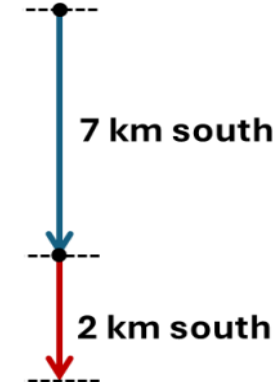
Question 1c

An athlete runs 120 m west followed by 30 m east. What is the displacement of the athlete?



Question 1d

A boat travels 7 km south followed by another 2 km south. What is the displacement of the boat?



Speed

Think back to the mail truck moving down the street. You could describe the movement by the distance traveled or by the displacement. You might also want to describe how fast the truck is moving. To do this, you need to know how far it travels in a given amount of time. To describe how fast an object moves, scientists use the object's speed. **Speed** is the distance an object travels per unit of time.

Calculating speed

Any change over time is called a rate. For example, you could describe how quickly water is leaking from a tank by stating how many liters are lost each hour. This would be the rate of water leakage. If you think of distance as the change in position, then speed is the rate of change in position. Speed can be calculated from the equation shown below.

Speed Equation

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

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

In SI units, distance is measured in meters, and time is measured in seconds. Therefore, the SI unit for speed is meters per second (m/s). Sometimes, it is more convenient to express speed in other units, such as kilometers per hour (km/h). **Table 2** shows the speeds of some common objects.

Table 2 Common Speeds

Motion	Speed (m/s)
Olympic 100-m dash	10 m/s
Car on city street (35 mph)	16 m/s
Car on interstate highway (65 mph)	29 m/s
Commercial airplane	250 m/s

EXAMPLE Problem 1



CALCULATE SPEED A car traveling at a constant speed covers a distance of 750 m in 25 s. What is the car's speed?

PRACTICE Problems

1. A passenger elevator travels from the first floor to the 60th floor, a distance of 210 m, in 35 s. What is the elevator's speed?
2. A motorcycle is moving at a constant speed of 40 km/h. How long does it take the motorcycle to travel a distance of 10 km?
3. How far does a car travel in 0.75 h if it is moving at a constant speed of 88 km/h?
4. **CHALLENGE** A long-distance runner is running at a constant speed of 5 m/s. How long does it take the runner to travel 1 km?

Q1. What is the scientific definition of speed?

- A. The total displacement of an object divided by the direction of travel.
- B. The distance an object travels per unit of time.
- C. The rate of change in an object's overall acceleration.
- D. The total time required to change a fixed physical position.

Q2. What is the standard SI unit used by scientists to express speed?

- A. Kilometers per hour (km/h)
- B. Miles per hour (mph)
- C. Meters per second (m/s)
- D. Liters per hour (L/h)

Q3. Which mathematical equation correctly expresses the relationship between speed (s), distance (d), and time (t)?

- A. $s = d \times t$
- B. $s = \frac{t}{d}$
- C. $s = \frac{d}{t}$
- D. $s = d + t$

Q4. A remote-controlled car travels a total distance of 80 meters along a straight hallway in exactly 5 seconds. What is the speed of the car?

- A. 0.0625 m/s
- B. 16 m/s
- C. 75 m/s
- D. 400 m/s

Q5. A commercial airplane cruises at a steady speed of 250 m/s. How far will the airplane travel in a time span of 10 seconds?

- A. 25 meters
- B. 240 meters
- C. 260 meters
- D. 2,500 meters

Q6. Any change calculated over a specific duration of time is fundamentally classified as which of the following?

- A. A constant variable
- B. A scalar quantity
- C. A rate
- D. A displacement vector

Q7.

Two local delivery robots, Robot X and Robot Y, are performing test runs down a straight avenue. Robot X travels a distance of 48 meters in 3 seconds. Robot Y covers a distance of 100 meters in 5 seconds. Which statement correctly evaluates and compares the motion rates of the two robots?

- A. Robot X is moving faster because its calculated speed is 16 m/s, while Robot Y is moving at 20 m/s.
- B. Robot Y is moving faster because its calculated speed is 20 m/s, while Robot X is moving at 16 m/s.
- C. Both robots are moving at the exact same speed because they are traveling on the same straight avenue.
- D. Robot X is moving faster because it took less time to complete its individual delivery run.

Question 2a

A motorcycle is moving at a constant speed of 30 km/h. How long does it take the motorcycle to cover a distance of 15 km?

Question 2b

A car travels at a constant speed of 60 km/h for 1.5 hours. What is the total distance travelled?

Question 2c

A lorry travels 150 km in 2 hours. What is the average speed of the lorry?

3	Recall the formula for momentum ($p = mv$).	Section: Momentum	p. 48	3
4	Apply the momentum equation to calculate velocity, including magnitude and direction, in one-dimensional motion.	Section: Example Problem 2; Practice Problems 12 to 15	p. 48	4a, 4b, 4c

Momentum

An object is moving at 2 m/s toward a glass vase. Will the vase be damaged in the collision? If the object has a small mass, like a bug, a collision will not damage the vase. But if the object has a larger mass, like a car, a collision will damage the vase.

A useful way of describing both the velocity and mass of an object is to state its momentum. The **momentum** of an object is the product of its mass and velocity. Momentum is usually represented by the symbol p and is defined for a particular frame of reference.

Momentum Equation

momentum (in kg·m/s) = **mass** (in kg) × **velocity** (in m/s)

$$p = mv$$

The unit for momentum is kg·m/s. Like velocity, momentum has a size and a direction. An object's momentum is always in the same direction as its velocity. **Table 3** shows the momenta of some common objects.

Table 3 Typical Momenta

Object	Momentum (kg·m/s)
Tossed baseball	0.15
Person walking	100
Car on interstate	45,000

Q1. What physical properties of an object are multiplied together to determine its momentum?

- A. Distance and speed
- B. Mass and velocity
- C. Weight and acceleration
- D. Volume and displacement

Q2. Which algebraic equation properly represents the formula for calculating momentum?

- A. $p = \frac{m}{v}$
- B. $p = m + v$
- C. $p = mv$
- D. $p = \frac{v}{m}$

Question 3

Write the formula for momentum.

Q3. What is the standard SI unit used to measure the momentum of a moving body?

- A. m/s^2
- B. $\text{kg} \cdot \text{m/s}$
- C. kg/m^3
- D. $\text{N} \cdot \text{m}$

Q4. Which operational statement describes the directional behavior of an object's momentum?

- A. Momentum acts in the opposite direction of the object's acceleration.
- B. Momentum is always oriented in the exact same direction as the object's velocity.
- C. Momentum has only magnitude and does not possess a specific direction.
- D. Momentum is directed perpendicular to the path of moving displacement.

Q5. A mechanical device has a mass of 15 kilograms and moves down a laboratory track with a constant velocity of 4 meters per second east. What is the calculated momentum of the device?

- A. $3.75 \text{ kg} \cdot \text{m/s}$ east
- B. $11 \text{ kg} \cdot \text{m/s}$ west
- C. $19 \text{ kg} \cdot \text{m/s}$ east
- D. $60 \text{ kg} \cdot \text{m/s}$ east

Q6. A small insect and a passenger car are both moving down a road at an identical velocity of 2 meters per second. Why will a collision with the passenger car cause significantly more damage to a roadside structure than a collision with the insect?

- A. The passenger car has a vastly larger mass, resulting in a much higher momentum.
- B. The insect undergoes a greater rate of acceleration during the structural impact.
- C. The passenger car has a smaller mass, which increases its impact velocity.
- D. The insect possesses a greater overall momentum due to its tiny cross-sectional area.

Q7.

An automated sorting system in a fulfillment center tracks two different packages moving down a straight conveyor belt. Package A has a mass of 4 kilograms and moves with a velocity of 6 meters per second north. Package B has a mass of 8 kilograms and moves with a velocity of 3 meters per second north. Which statement provides a correct evaluation of their momentum?

- A. Package A has a higher momentum than Package B because it is moving at a higher velocity.
- B. Package B has a higher momentum than Package A because it possesses a greater mass.
- C. Both packages have the exact same momentum because the product of their mass and velocity is identical.
- D. Package A has a lower momentum because its mass is half the mass of Package B.

Q8. A group of students is designing a physics simulation and references the data regarding standard motion values provided in the reference table.

An engineer measures a custom motorized cart moving down a test lane. The cart has a total mass of 50 kilograms and is traveling at a constant velocity of 2 meters per second. which object from the reference table shares the exact same momentum magnitude as this moving motorized cart?

- A. Tossed baseball
- B. Person walking
- C. Car on interstate
- D. None of the listed objects

	Object	Momentum (kg·m/s)
	Tossed baseball	0.15
	Person walking	100
	Car on interstate	45,000

EXAMPLE Problem 2

SOLVE FOR MOMENTUM At the end of a race, a sprinter with a mass of 80.0 kg has a velocity of 10.0 m/s east. What is the sprinter's momentum?

PRACTICE Problems

- 12.** What is the momentum of a car with a mass of 1300 kg traveling north at a speed of 28 m/s?
- 13.** A baseball has a momentum of 6.0 kg·m/s south and a mass of 0.15 kg. What is the baseball's velocity?
- 14.** Find the mass of a person walking west at a speed of 0.8 m/s with a momentum of 52.0 kg·m/s west.
- 15. CHALLENGE** The mass of a basketball is three times greater than the mass of a softball. Compare the momenta of a softball and a basketball if they are moving at the same velocity.

Question 4a

A baseball has a momentum of 8.0 kgm/s south and a mass of 0.2 kg. What is the velocity of the baseball?

Question 4b

A car of mass 2000 kg is travelling with a velocity of 40 m/s North. What is the momentum of the car?

Question 4c

A bullet has a speed of 250 m/s east. Calculate the mass of the bullet, Given that its momentum is 5 kgm/s east.

Interpret and analyze speed–time graphs to describe motion, including rest, constant speed, and acceleration.

Section: Velocity and Acceleration;
Section: Speed-time graphs and acceleration

p. 50; 51

5a, 5b, 5c

Velocity and Acceleration

You are in a stopped car when the light turns green. The driver steps on the gas pedal, and the car starts moving faster and faster. Just as speed is the rate of change of position, **acceleration** is the rate of change of velocity. When the velocity of an object changes, the object is accelerating. Remember that velocity includes the speed and direction of an object. Therefore, a change in velocity can be either a change in speed or a change in direction. Acceleration occurs when an object changes its speed, its direction, or both.

When you think of acceleration, you might think of speeding up. However, an object that is slowing down also is accelerating, as is an object that is changing direction. **Figure 15** shows the three ways an object can accelerate. Like velocity and momentum, acceleration has a direction. In **Figure 15**, you can see that when the car is speeding up, its acceleration and velocity are in the same direction. When the car is slowing down, its acceleration is in the opposite direction of its velocity. When the car changes direction, the acceleration is neither in the same direction nor opposite direction as the car's velocity.



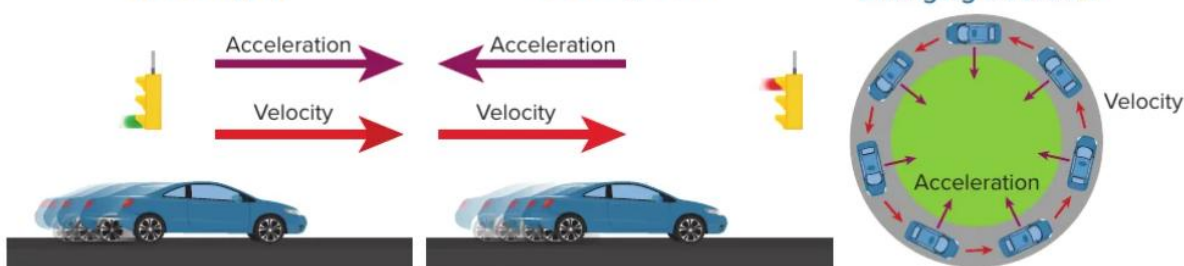
Get It?

Identify three ways that an object can accelerate.

Speeding Up

Slowing Down

Changing Direction



Speed of Tamara's Car

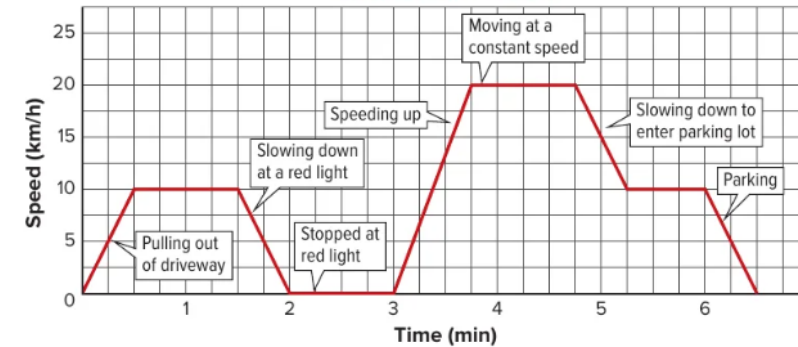


Figure 16 For objects that are speeding up and slowing down, the slope of the line on a speed-time graph is the acceleration.

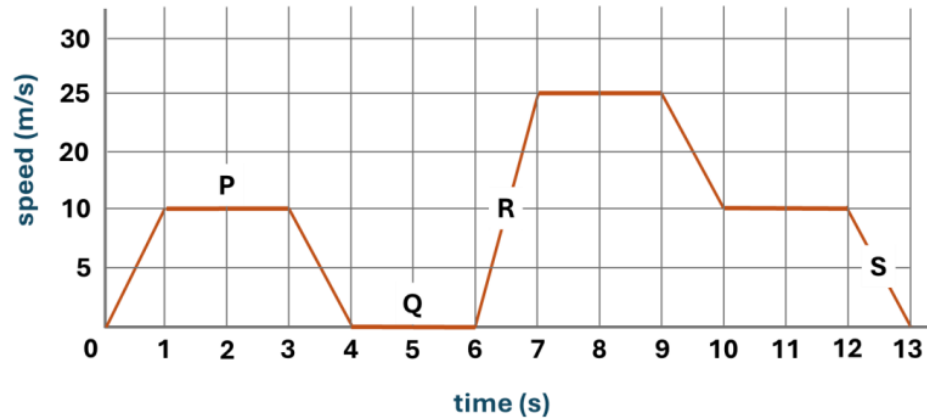
Identify the time intervals during which Tamara's car is not accelerating.

Speed-time graphs and acceleration

When an object travels in a straight line and does not change direction, a graph of speed versus time can provide information about the object's acceleration. **Figure 16** shows the speed-time graph of Tamara's car as she drives to the store. Just as the slope of a line on a distance-time graph is the object's speed, the slope of a line on a speed-time graph is the object's acceleration. For example, when Tamara pulls out of her driveway, the car's acceleration is 0.33 km/min^2 , which is equal to the slope of the line from $t = 0$ to $t = 0.5 \text{ min}$.

Question 5a

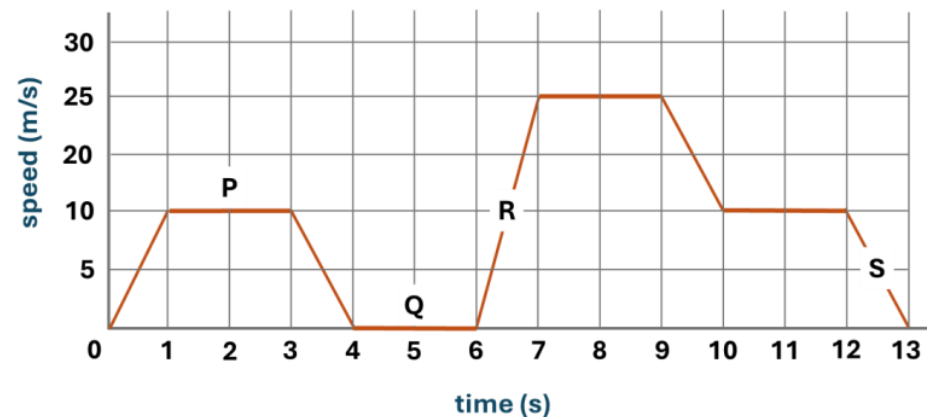
The speed-time graph given below of a cyclist is shown below.



In which section of the graph does the cyclist have a constant speed of 10 m/s?

Question 5b

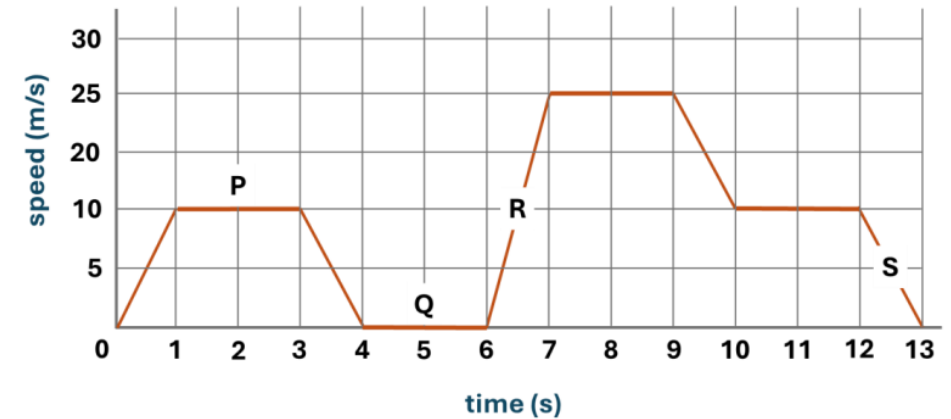
The speed-time graph given below of a cyclist is shown below.



During what time interval does the cyclist have a constant speed of 25 m/s?

Question 5c

The speed-time graph given below of a cyclist is shown below.



Which section of the graph shows the cyclist is at rest? For how long was the cyclist at rest?

Q1. What is scientifically defined as the rate of change of velocity?

- A. Speed
- B. Distance
- C. Momentum
- D. Acceleration

Q2. Which physical structural change will cause an object to undergo acceleration?

- A. A change in speed only
- B. A change in direction only
- C. A change in both speed and direction
- D. A change in speed, direction, or both

Q3. A car is moving forward along a straight road while slamming on its brakes to slow down. What is the directional relationship between the car's velocity and its acceleration?

- A. The acceleration and velocity are in the exact same direction.
- B. The acceleration is in the opposite direction of its velocity.
- C. The acceleration is perpendicular to the direction of its velocity.
- D. The acceleration is zero because the car is not speeding up.

Q4. What physical property of motion does the slope of a line on a speed-time graph represent?

- A. Total distance traveled
- B. Net displacement vector
- C. Acceleration
- D. Total time elapsed

Q5. A mechanical tracking device shows a flat, completely horizontal line above the zero mark on a speed-time graph for a duration of 3 minutes. What does this horizontal line indicate about the object's motion?

- A. The object is completely at rest.
- B. The object is moving at a constant speed.
- C. The object is experiencing a uniform positive acceleration.
- D. The object is slowing down at a steady rate.

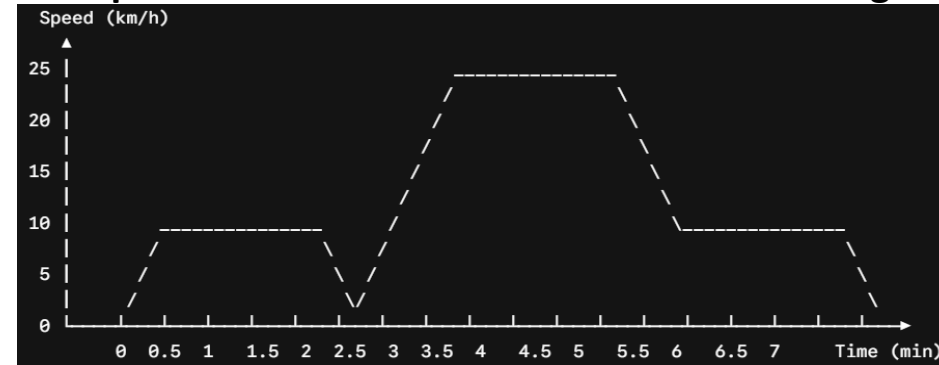
Q6. A vehicle moves at a constant speed of 40 km/h around a perfectly circular test track. Why is this vehicle considered to be accelerating?

- A. Its speed is continuously increasing as it moves around the track.
- B. Its direction of travel is continuously changing.
- C. The total distance covered is equal to its net displacement.
- D. Its velocity vector remains completely constant.

Q7. A continuous monitoring system logs the motion of an electric transit cart traveling along a straight delivery line. During the first segment, the cart's velocity and acceleration point in the same direction. During the second segment, the cart's acceleration points in the exact opposite direction of its velocity. Which statement accurately diagnoses the dynamic behavior of the transit cart?

- A. The cart is speeding up in the first segment and slowing down in the second segment.
- B. The cart is slowing down in the first segment and speeding up in the second segment.
- C. The cart is maintaining a constant speed in both segments because it is moving on a straight line.
- D. The cart is changing its physical direction in the first segment and coming to a complete rest in the second segment.

Analyze the speed-time graph below representing the motion profile of a vehicle over a 7-minute period. Use the visual data to select the single best answer.



QUESTION 8: Based on the geometric layout of the speed-time graph, during which explicit time intervals is the vehicle experiencing zero acceleration ($a = 0$)?

- A. From $t = 0$ to $t = 0.5$ min, and from $t = 3$ to $t = 3.8$ min
- B. From $t = 0.5$ to $t = 1.5$ min, from $t = 2$ to $t = 3$ min, and from $t = 5.3$ to $t = 6$ min
- C. From $t = 1.5$ to $t = 2$ min, and from $t = 4.8$ to $t = 5.3$ min
- D. From $t = 0.5$ to $t = 1.5$ min, from $t = 3.8$ to $t = 4.8$ min, and from $t = 5.3$ to $t = 6$ min

Apply kinematic equations to calculate acceleration from changes in velocity over time in linear motion.

Section: Velocity and Acceleration;
Section: Calculating acceleration;
Example Problem 3, Practice
Problems 22 to 24

p. 51; 52

6a, 6b, 6c

Calculating acceleration

Acceleration is the rate of change in velocity. To calculate the acceleration of an object, the change in velocity is divided by the length of the time interval over which the change occurs. The change in velocity is the final velocity minus the initial velocity. If the direction of motion does not change and the object moves in a straight line, the size of the change in velocity can be calculated from the change in speed. Then, the acceleration of an object can be calculated from the following equation.

Acceleration Equation

$$\begin{aligned} \text{acceleration} &= \frac{\text{change in velocity (in meters/second)}}{\text{time (in seconds)}} \\ a &= \frac{v_f - v_i}{t} \end{aligned}$$

In SI units, velocity has units of m/s and time has units of s, so the SI unit of acceleration is m/s². In some cases, your calculations will result in a negative acceleration. The negative sign means *in the opposite direction*. For example, an acceleration of -10 m/s^2 north is the same as 10 m/s^2 south.

EXAMPLE Problem 3

CALCULATE ACCELERATION A skateboarder has an initial velocity of 3 m/s west and comes to a stop in 2 s. What is the skateboarder's acceleration?

PRACTICE Problems



- 22.** An airplane starts at rest and accelerates down the runway for 20 s. At the end of the runway, its velocity is 80 m/s north. What is its acceleration?
- 23.** A cyclist starts at rest and accelerates at 0.5 m/s^2 south for 20 s. What is the cyclist's final velocity?
- 24. CHALLENGE** A ball is dropped and falls with an acceleration of 9.8 m/s^2 downward. It hits the ground with a velocity of 49 m/s downward. How long did it take the ball to fall to the ground?

Question 6a

A car accelerates from rest at a constant rate for 5 seconds. What is its acceleration given that it reaches a final velocity of 15 m/s?

time = 0 s
velocity = 0 m/s



time = 5 s
velocity = 15 m/s



Q1. What is the fundamental formula used to calculate the linear acceleration of an object?

A. $a = \frac{v_f + v_i}{t}$

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

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

D. $a = (v_f - v_i) \times t$

Question 6b

A car accelerates from rest at a constant rate of 2 m/s^2 for 5 seconds. What is the final velocity of the car?

time = 0 s
velocity = 0 m/s



time = 5 s
final velocity = ?



Q2. What is the standard SI unit used to express the acceleration of a moving body?

A. m/s

B. km/h

C. m/s^2

D. $\text{kg} \cdot \text{m/s}$

Question 6c

A car accelerates at a constant rate of 2 m/s^2 for 5 seconds and reaches a final velocity of 25 m/s. What is the initial velocity of the car?

time = 0 s
initial velocity = ?



time = 5 s
final velocity = 25 m/s



Q3. A skateboarder moving at 2 m/s speeds up to 8 m/s along a straight path in exactly 3 seconds. What is the skateboarder's acceleration?

A. 2 m/s^2

B. 3 m/s^2

C. 6 m/s^2

D. 10 m/s^2

Q4. An acceleration calculation results in a negative value, such as -5 m/s^2 north. What is the correct physical interpretation of this negative sign?

- A. The object is completely at rest.
- B. The acceleration acts in the opposite direction, which is equivalent to 5 m/s^2 south.
- C. The object is moving backwards with an increasing speed.
- D. The calculation is mathematically invalid for linear motion.

Q5. How is the net change in velocity (Δv) mathematically defined in the acceleration equation?

- A. Initial velocity plus final velocity
- B. Initial velocity divided by total time
- C. Final velocity minus initial velocity
- D. Final velocity multiplied by total time

Q6. A passenger car maintains a completely steady velocity of 25 m/s north along a straight highway for 10 seconds. What is the acceleration of the car during this time frame?

- A. 0 m/s^2
- B. 2.5 m/s^2
- C. 25 m/s^2
- D. 250 m/s^2

Q7.

An engineer tests an automated drone on a linear flight track. The drone starts from a standstill checkpoint ($v_i = 0 \text{ m/s}$) and fires its thrusters to accelerate at a constant rate of 4 m/s^2 north for a duration of 5 seconds. Which statement properly evaluates the terminal velocity of the drone at the end of this test scenario?

- A. The drone reaches a final velocity of 0.8 m/s north.
- B. The drone reaches a final velocity of 9 m/s north.
- C. The drone reaches a final velocity of 20 m/s north.
- D. The drone reaches a final velocity of 80 m/s north.

Explain motion in circular paths, including the role of velocity direction and centripetal acceleration.

Section: Motion in Two Dimensions;
Section: Circular Motion

p. 52; 53

7a, 7b

Motion in Two Dimensions

So far, we have discussed only motion in a straight line. But most objects are not restricted to moving in a straight line. Recall that we cannot add measurements that are not in the same or opposite directions. So, we will discuss motion in each direction separately. For example, suppose a student walked three blocks north and four blocks east. The trip could be described this way: the student walked north for three blocks at 1 m/s and then walked east for four blocks at 2 m/s.

Recall that objects that change direction are accelerating. For an object that is changing direction, its acceleration is not in the same or opposite direction as its velocity. This means that we cannot use the acceleration equation. Just as with displacement and velocity, accelerations that are not in the same or opposite directions cannot be directly combined.

Circular motion

Think about a horse's horizontal motion on a carousel, such as the one in **Figure 17**. The horse moves in a circular path. Its speed remains constant, but it is accelerating because its direction of motion changes. The change in the direction of the horse's velocity is toward the center of the carousel. The horse's velocity is perpendicular to the inward acceleration. Acceleration toward the center of a curved or circular path is called **centripetal acceleration**. In the same way, Earth experiences centripetal acceleration as it orbits the Sun in a nearly circular path.



Question 7a

An object is moving in a circle at constant speed. A student claims that the velocity of the object is continuously changing. Do you agree with this statement? Why?

Question 7b

An object is moving in a circle at constant speed. In what direction is the acceleration of the object?

Q1. Why can measurements of motion in different directions strictly NOT be combined or added directly through simple arithmetic?

- A. They represent non-vector scalar quantities.
- B. They are not oriented in the same direction or in exactly opposite directions.
- C. The distance traveled always equals the displacement in two dimensions.
- D. Acceleration equations only apply when speed decreases to zero.

Q2. What is the explicit scientific term for acceleration directed toward the center of a curved or circular path?

- A. Linear acceleration
- B. Centripetal acceleration.
- C. Momentum acceleration
- D. Negative displacement

Q3. An object moves in a perfectly circular path at a constant, unchanging speed. What happens to its velocity during this motion?

- A. Its velocity remains completely constant.
- B. Its velocity changes because its direction of motion is constantly changing.
- C. Its velocity drops to zero due to the circular path.
- D. Its velocity becomes independent of the time interval.

Q4. When an object travels in a circular path, what is the geometric relationship between its velocity vector and its inward centripetal acceleration?

- A. The velocity is parallel to the inward acceleration.
- B. The velocity is perpendicular to the inward acceleration.
- C. The velocity points in the exact opposite direction of the acceleration.
- D. There is no directional relationship between them.

Q5. Why is the standard linear acceleration equation strictly invalid for describing an object that is changing direction in two dimensions?

- A. The acceleration is neither in the same direction nor in the opposite direction as the velocity.
- B. The object is not undergoing any real physical acceleration.
- C. The speed of the object must remain perfectly vertical at all times.
- D. Displacements in two dimensions cannot possess a measurable magnitude.

Q6. Which celestial or real-world system demonstrates centripetal acceleration through an orbital path?

- A. A mail truck driving down a straight city street.
- B. Earth orbiting the Sun in a nearly circular path.
- C. A runner jogging along a straight line toward a finish mark.
- D. A package resting on a flat, stationary conveyor belt.

Q7.

A mechanical tracking capsule moves inside a multi-directional testing chamber. It initially travels 3 meters north at a rate of 1 m/s and immediately turns to travel 4 meters east at a rate of 2 m/s . Which statement provides the correct physical analysis of the capsule's multi-dimensional motion profile?

- A. The total distance and displacement can be summed directly as 7 meters because the paths are perpendicular.
- B. The capsule accelerates during the turn because its direction changes, meaning its perpendicular motion components must be analyzed separately.
- C. The linear acceleration equation can find the total acceleration since the speed changed from 1 m/s to 2 m/s .
- D. The net displacement vector points directly south with a total magnitude of exactly 1 meter.

Analyze two-dimensional motion by separating horizontal and vertical components, particularly in projectile motion.

Section: Projectile Motion

p.53

8a, 8b

Projectile motion

If you have tossed a ball to someone, you have probably noticed that thrown objects do not travel in straight lines. They curve downward. That is why quarterbacks, dart players, and archers aim above their targets. Anything that is thrown or shot through the air is called a projectile. Earth's gravity causes projectiles to follow a curved path.

Horizontal and vertical motion When you throw or shoot an object, such as the rubber band in **Figure 18**, the force exerted by your hand gives the object a horizontal velocity. For example, after the rubber band is released, its horizontal velocity is constant. The rubber band does not accelerate horizontally. If there were no gravity, the rubber band would move along the straight dotted line in **Figure 18**.

However, when you release a rubber band, gravity causes it to accelerate downward. The rubber band has an increasing vertical velocity. The result of these two motions is that the rubber band travels in a curve, even though its horizontal and vertical motions are completely independent of each other.

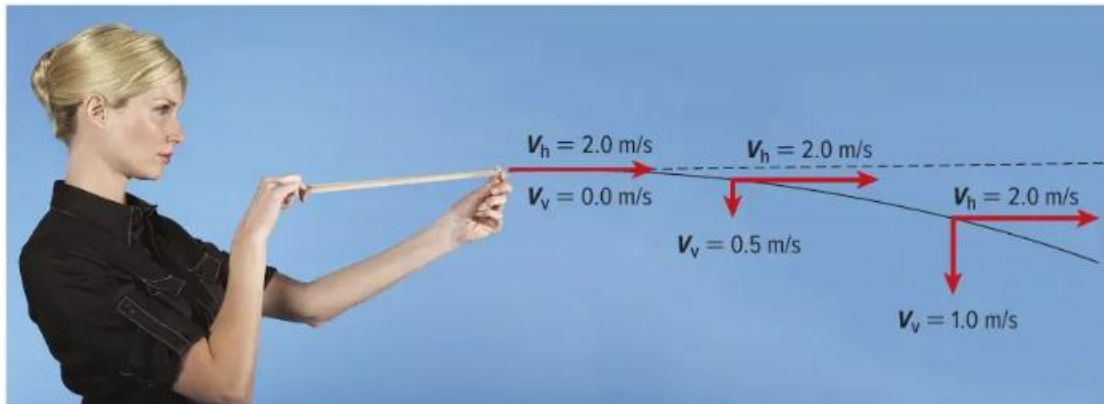
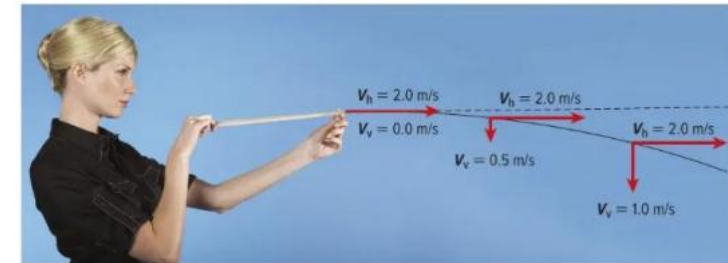


Figure 18 The woman gives the rubber band a horizontal velocity. The horizontal velocity of the rubber band remains constant, but gravity causes the rubber band to accelerate downward. The combination of these two motions causes the rubber band to move in a curved path.

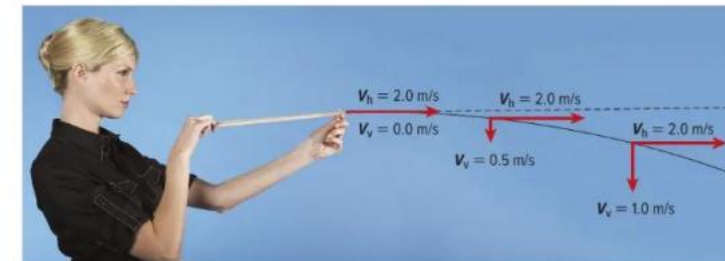
Question 8a

Describe the horizontal velocity of the rubber band? What is horizontal acceleration of the rubber band?



Question 8b

Describe the vertical velocity of the rubber band? What is vertical acceleration of the rubber band?



Q1. What is the scientific term used to describe any object that is thrown or shot through the air?

- A. Accelerator
- B. Projectile
- C. Vector base
- D. Constant frame

Q2. What fundamental force causes all thrown objects or projectiles on Earth to follow a downward curved path?

- A. Atmospheric pressure
- B. Friction from air resistance
- C. Earth's gravity
- D. Centripetal force

Q3. When a projectile is released horizontally, what happens to its horizontal velocity over time if we ignore air resistance?

- A. It decreases at a steady rate until it stops moving forward.
- B. It remains completely constant and does not accelerate horizontally.
- C. It increases rapidly due to the downward pull of gravity.
- D. It constantly changes its forward direction to point upward.

Q4. Which statement accurately describes the dynamic physical behavior of a projectile's vertical motion after release?

- A. It maintains a constant vertical velocity of zero throughout its flight.
- B. Gravity causes it to accelerate downward, resulting in an increasing vertical velocity.
- C. Its vertical acceleration decreases to zero halfway through the flight path.
- D. It moves upward in a perfectly straight diagonal line before dropping instantly.

Q5. What is the fundamental relationship between the horizontal and vertical motion components of a traveling projectile?

- A. They are completely independent of each other.
- B. The horizontal component is always exactly twice the vertical component.
- C. They depend directly on each other to keep the speed constant.
- D. The vertical motion stops completely whenever horizontal velocity is active.

Q6. Why do quarterbacks, dart players, and archers systematically aim above their targets when throwing or shooting?

- A. Because projectiles travel in perfectly straight lines that slope upward.
- B. Because thrown objects do not travel in straight lines; they curve downward due to gravity.
- C. To decrease the total horizontal distance the object has to travel.
- D. To eliminate the effect of the initial horizontal velocity given by the hand.

Q7. A mechanical launcher fires a small steel ball horizontally from the top of a high laboratory platform. At the exact same microsecond, an identical steel ball is dropped from rest straight down from the same height. If we entirely ignore air resistance, which statement provides a correct evaluation of their motion?

- A. The launched ball hits the floor first because its horizontal velocity pulls it down faster.
- B. The dropped ball hits the floor first because it has no horizontal distance to cover.
- C. Both balls hit the floor at the exact same time because their independent vertical motions are both accelerated downward by gravity at the exact same rate.
- D. The launched ball never experiences any vertical acceleration because its horizontal motion is constant.

Describe wave motion as the transfer of energy through a medium without the transfer of matter.

Sections: Waves Defined, Wave Energy; Section: Waves and Matter, Making waves.

p. 226; 227

Waves Defined

Figure 1 shows a disturbance from a pebble splashing into a pond. This disturbance travels outward from the spot where the pebble splashed. The pebble produced a small wave in the pond. A **wave** is a repeating disturbance that transfers energy through matter or space. Other examples of waves include ocean waves, sound waves, seismic waves, and light waves. Do these and other types of waves have anything in common with one another?



Waves and Energy

Because a falling pebble is moving, the falling pebble has kinetic energy. As the falling pebble splashes into the pond in **Figure 1**, the pebble transfers some of its energy to nearby water molecules, causing them to move. Those molecules then pass the energy along to neighboring water molecules, which, in turn, transfer it to their neighbors. The energy travels farther and farther from the source of the disturbance. However, the water itself does not move outward. What you see is energy traveling in the form of a wave on the surface of the water.



Q8. Examine the sequential stages shown in the illustration where a hand creates a mechanical disturbance along a horizontal surface. Which conclusion is supported by the progression from the top diagram to the bottom diagram?

- A) Energy moves horizontally away from the source while individual sections of the rope move vertically.
- B) The entire rope shifts forward to accumulate at the opposite end of the table.
- C) The energy of the pulse increases in magnitude as it moves further away from the hand.
- D) The rhythmic motion of the hand decreases the mechanical tension of the material.

Waves and matter

Imagine that you are in a boat on a lake. Approaching waves bump against your boat, but they do not carry it along with them as they pass. The boat does move up and down, and maybe even a short distance back and forth, because the waves transfer some of their energy to the boat.

But after the waves have passed, the boat is still in nearly the same place. The waves do not even carry the water along with them. The water that is around the boat after the wave passes is the same water as was there before the wave passed. Only the energy travels along with the waves.

All waves, whether they are water waves, sound waves, light waves or earthquake waves, have this property: they carry energy without transporting matter from place to place.

Making waves

A wave will travel only as long as it has energy to carry. When you drop a pebble into a pond, small waves form, as shown in **Figure 1**. These waves carry energy. However, this energy is gradually transferred to the surrounding water and air. At the same time, the remaining energy in the waves spreads out as the waves spread out. As the energy spreads out and is transferred away from the waves, those waves shrink and disappear.



Get It?

Describe what happens to the energy carried by a water wave.

Suppose you are holding a rope at one end, and you give it a shake. You would create a pulse that would travel along the rope to the other end, and then the rope would be still again, as shown in **Figure 2**.

Now suppose you shake your end of the rope up and down for a while. You would make waves that travel along the rope. When you stop shaking your hand up and down, the rope will be still again. It is the up-and-down motion of your hand that creates the wave.

Anything that moves up and down or back and forth in a rhythmic way is vibrating. The vibrating movement of your hand at the end of the rope created the wave. In fact, all waves are produced by something that vibrates.



Get It?

Identify what produces waves.

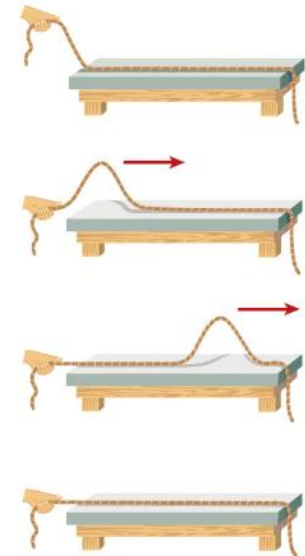


Figure 2 The hand's up and down motion produces a wave.

Explain what happened to the energy that was carried by the wave in this rope.

Q1. What is the primary quantity transferred by a wave as it moves through matter or space?

- A) Energy
- B) Matter
- C) Mass
- D) Particles

Q2. Which statement describes the motion of water molecules after a wave passes completely through a lake?

- A) The molecules return to nearly their original positions.
- B) The molecules move permanently to the edge of the lake.
- C) The molecules travel at the same speed as the wave pulse.
- D) The molecules completely stop vibrating permanently.

Q3. What standard physical phenomenon is responsible for generating all types of waves?

- A) A vibration
- B) Constant velocity
- C) Chemical reactions
- D) Thermal equilibrium

Q4. Why do small water ripples gradually shrink and completely disappear as they travel farther from the source splash?

- A) The wave energy gradually transfers to the surrounding water and air.
- B) The water molecules absorb the matter carried by the wave.
- C) The frequency of the disturbance increases rapidly.
- D) The wave changes from a mechanical wave into a light wave.

Q5. A student shakes a rope up and down once to create a single wave pulse. What will be the state of the rope after the pulse reaches the opposite fixed end?

- A) The rope will be still again.
- B) The rope will continuously vibrate forever.
- C) The rope will stretch and increase its total length.
- D) The rope will dissolve due to kinetic friction.

Q6. Which of these examples represents a wave that can transfer energy without requiring a physical substance or material medium to travel through?

- A) Light waves
- B) Sound waves
- C) Seismic waves
- D) Ocean waves

Q7. An oceanographer places a highly sensitive GPS buoy in the middle of the ocean to track sea level changes. During a major storm, massive waves with high energy pass directly under the buoy. How will the position of the buoy change after the storm waves pass completely?

- A) The buoy will oscillate up and down during the waves but remain at its original horizontal coordinates.
- B) The buoy will be pushed continuously forward in the direction of the wave until it reaches the distant shoreline.
- C) The buoy will sink straight down to the ocean floor due to the loss of surrounding matter.
- D) The buoy will move backward against the wave direction to fill the void left by the disturbance.

Correctly identify that mechanical waves include both transverse and longitudinal types.

Section: Mechanical Waves,
Transverse Waves; Section:
Longitudinal waves; Section: Check

p. 228; 229; 230

10a, 10b, 10c, 10d

Mechanical Waves

Sound waves travel through air to reach your ears. Ocean waves travel through water to reach the shore. A **medium** is matter through which a wave travels. The medium can be a solid, a liquid, a gas, or a combination of these. Not all waves need a medium. Some waves, such as light and radio waves, can travel through a vacuum. **Mechanical waves**, such as sound waves, are waves that can travel only through matter. Mechanical waves can be either transverse waves or longitudinal waves.



Get It?

Describe the connection between a medium and a mechanical wave.

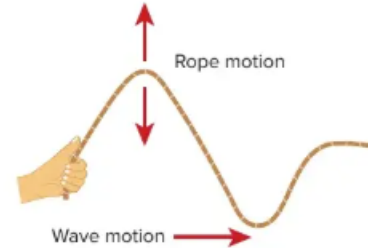
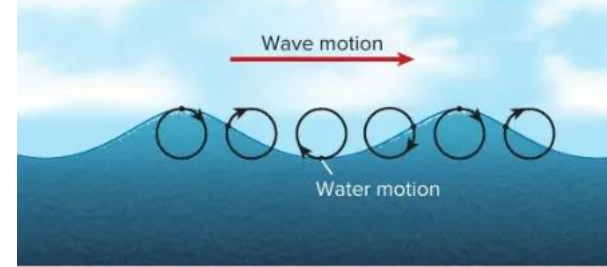
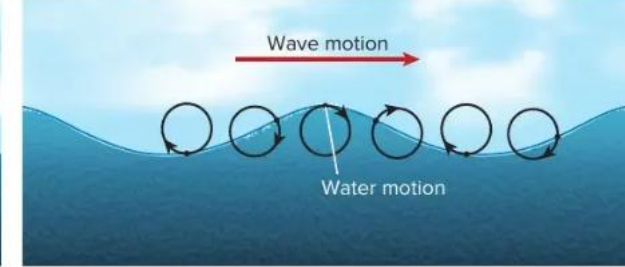


Figure 3 The wave along the rope travels horizontally, but the rope itself moves vertically, up and down.



The low point of a water wave is formed when water is pushed aside and up to the high point of the wave.



The water that is pushed aside returns to its initial position.

Transverse waves

In a **transverse wave**, particles in the medium move back and forth at right angles to the direction that the wave travels. For example, **Figure 3** shows how a wave along a rope travels horizontally, but the portions of the rope that the wave passes through move up and down. When you shake one end of a rope while your friend holds the other end, you are making transverse waves.



Get It?

Compare the direction that a transverse wave travels with the direction that matter in that wave vibrates.

Water waves When wind blows across the surface of the ocean, water waves form. Water waves are often thought of as transverse waves, but this is not entirely correct. The water in water waves does move up and down as the waves go by. But the water also moves short distances back and forth along the direction that the wave is traveling.

This movement happens because the low part of the wave can be formed only by pushing water forward or backward toward the high part of the wave, as shown on the left in **Figure 4**. This is much like a child pushing sand into a pile. Sand must be pushed in from the sides to make the pile. As the wave passes, the water that was pushed aside moves back to its initial position, as shown on the right in **Figure 4**.

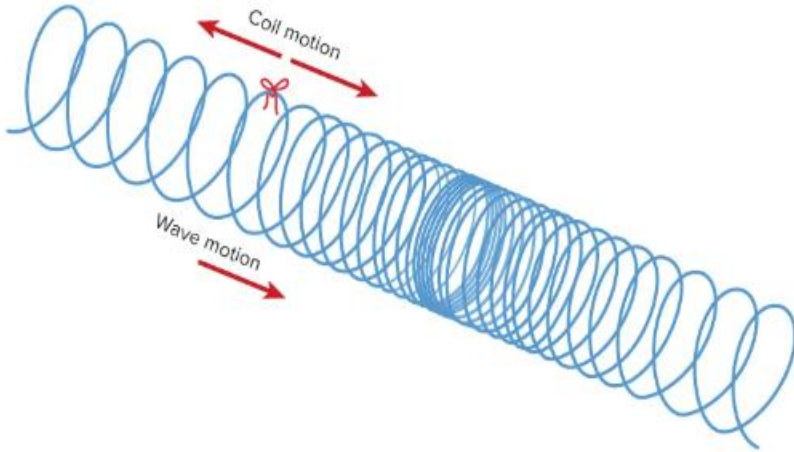


Figure 5 The longitudinal wave through this spring toy moves in only one direction, but the coils of this spring toy move back and forth.

Describe another example of a longitudinal wave.

Longitudinal waves

In a **longitudinal wave**, matter in the medium moves back and forth along the same direction that the wave travels. You can model longitudinal waves with a coiled spring toy, as shown in **Figure 5**. Squeeze several coils together at one end of the spring. Then let go of the coils, still holding onto coils at both ends of the spring. A wave will travel along the spring. As the wave moves, it looks as if the whole spring is moving toward one end.

Suppose you watched the coil with yarn tied to it, as in **Figure 5**. You would see that the yarn moves back and forth as the wave passes and then stops moving after the wave has passed. The wave carries energy, but not matter, forward along the spring. Longitudinal waves are sometimes called compressional waves.

Sound waves Sound waves are longitudinal waves. When a noise is made, such as when a locker door slams shut, nearby molecules in the air are pushed together by the vibrations caused by the slamming door. The molecules in the air are squeezed together, like the coils of the spring toy in **Figure 5**. These compressions travel through the air to make a sound wave. The sizes of a sound wave's compressions, as well as the distances between those compressions, determine the nature of that sound.

Sound waves in liquids and solids Sound waves can also travel through liquids and solids, such as water and wood. Particles in these mediums are pushed together and move apart as the sound waves travel through them.

Check Your Progress

Summary

- A wave is a repeating disturbance that transfers energy through matter or space.
- Waves carry energy without transporting matter.
- In a transverse wave, matter in the medium moves at right angles to the direction that the wave travels.
- In a longitudinal wave, matter in the medium moves back and forth along the direction that the wave travels.

Demonstrate Understanding

1. **Describe** the motion of an unanchored rowboat when a water wave passes. Does the wave move the boat forward?
2. **Contrast** how you would move a spring to make a transverse wave with how you would move a spring to make a longitudinal wave.
3. **Identify** evidence that seismic waves transfer energy without transferring matter.
4. **Identify** a mechanical wave that is also a longitudinal wave.

Explain Your Thinking

5. **Describe** how the world would be different if all waves were mechanical waves.
6. **MATH Connection** The average speed of sound in water is 1500 m/s. How long would it take a sound wave to travel 9000 m in water?

Q1. Which type of wave requires a physical substance or medium to travel through?

- A) Mechanical wave
- B) Radio wave
- C) Light wave
- D) Microwave

Q2. What is the defining characteristic of particles moving in a transverse wave?

- A) They move back and forth at right angles to the direction of wave travel.
- B) They move back and forth along the exact same direction as the wave travel.
- C) They move in a continuous straight line forward with the wave energy.
- D) They remain completely stationary without any vibration.

Q3. How do particles of matter move within a longitudinal mechanical wave?

- A) Back and forth along the same direction that the wave travels.
- B) Up and down at strict right angles to the wave motion.
- C) In perfect circles without returning to their starting position.
- D) Outward in all directions away from the line of propagation.

Q4. What happens to air molecules when a mechanical sound wave travels through them?

- A) They are pushed together and moved apart by vibrations.
- B) They travel continuously from the sound source into the listener's ear.
- C) They stop moving and form a permanent vacuum.
- D) They transform into electromagnetic particles.

Q5. Which wave can travel through both a physical material and the vacuum of empty space?

- A) Light wave
- B) Sound wave
- C) Seismic wave
- D) Coiled spring wave

Q6. What alternate term is commonly used to describe longitudinal waves due to the behavior of the medium's particles?

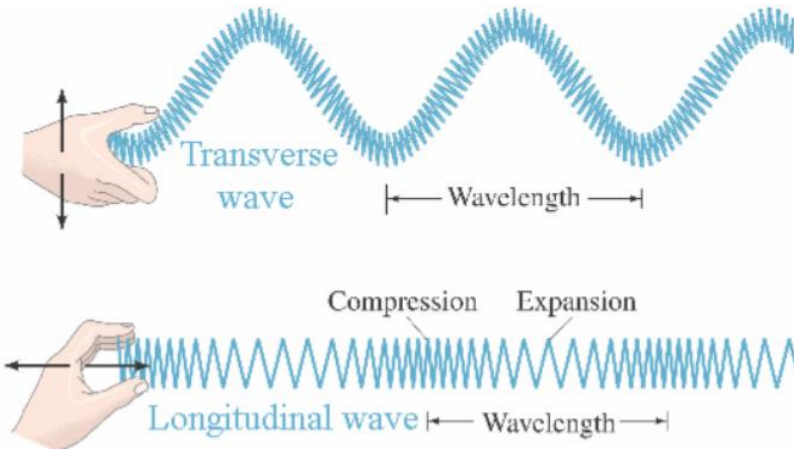
- A) Compressional waves
- B) Transverse waves
- C) Electromagnetic waves
- D) Surface water waves

Q7. An astronaut on a space walk outside the International Space Station slams a heavy metal cargo door shut. A nearby astronaut watching through a window cannot hear any sound from the impact. What physical property explains this occurrence?

- A) Sound waves are mechanical waves that require a material medium to propagate, which is absent in a vacuum.
- B) Sound waves automatically transform into transverse radio waves when exiting a solid material.
- C) The kinetic energy of the door is entirely converted into light energy rather than sound vibrations.
- D) Sound waves travel too fast in empty space to be captured by human hearing mechanisms.

Q8. Examine the illustrated circular paths showing water motion. What complex particle behavior distinguishes ocean water waves from a purely theoretical transverse wave?

- A) Water particles move both up and down and short distances back and forth, creating a circular motion.
- B) Water particles are transported permanently forward across the surface along with the wind.
- C) Water particles only move at right angles at the low point and stop moving at the high point.
- D) Water particles break apart into individual hydrogen and oxygen atoms as the wave energy passes.



Q9. Compare the two visual models showing a wave traveling through a rope and a wave traveling through a coiled spring toy. Which statement correctly identifies the distinction between the two behaviors?

- A) The rope models a transverse wave where motion is perpendicular to energy flow, while the spring models a longitudinal wave where motion is parallel to energy flow.
- B) The rope models a wave that transports matter forward, while the spring models a wave that only transfers energy.
- C) The rope models an electromagnetic pulse, while the spring models a mechanical disturbance that can pass through a vacuum.
- D) The rope models a compressional wave, while the spring models a wave where sections move only up and down.

Question 10a

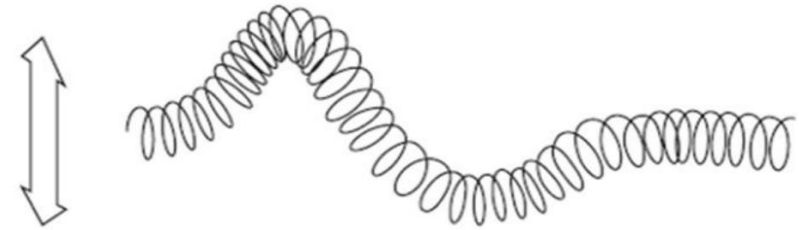
What is a transverse wave?

Question 10b

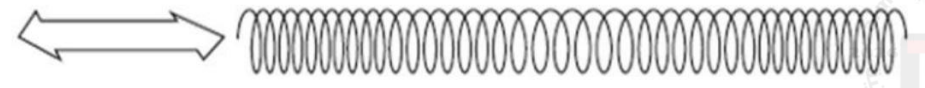
What is a longitudinal wave?

Question 10c

A teacher uses a slinky to show how energy is transferred from point to another. What type of wave is shown below?

**Question 10d**

A teacher uses a slinky to show how energy is transferred from point to another. What type of wave is shown below?



Q1. Describe the motion of an unanchored rowboat when a water wave passes. Does the wave move the boat forward?

- A) The boat moves up and down and maybe a short distance back and forth, but it is not carried forward by the wave.
- B) The boat is carried continuously forward along the water in the direction of the wave.
- C) The boat remains completely stationary with zero movement as the wave passes.
- D) The boat sinks immediately because the wave removes the water underneath it.

Q2. Contrast how you would move a spring to make a transverse wave with how you would move a spring to make a longitudinal wave.

- A) Move it up and down for a transverse wave, and push and pull it back and forth along its length for a longitudinal wave.
- B) Move it up and down for a longitudinal wave, and push and pull it back and forth along its length for a transverse wave.
- C) Spin it in continuous circles for both transverse and longitudinal waves.
- D) Keep the spring completely motionless and shake the table instead.

Q3. Identify evidence that seismic waves transfer energy without transferring matter.

- A) Ground shaking and destruction occur far from the focus, but the rocks and crust remain in their same general locations.
- B) Large rocks and soil are physically transported hundreds of kilometers away through the crust.
- C) Entire tectonic plates are converted into gas vacuums after the wave passes.
- D) The ground permanently stops all atomic vibrations after an earthquake.

Q4. Identify a mechanical wave that is also a longitudinal wave.

- A) A sound wave
- B) A light wave
- C) A radio wave
- D) A wave on a rope shaken up and down

Q5. Describe how the world would be different if all waves were mechanical waves.

- A) Sunlight could not travel through the vacuum of space, leaving Earth completely dark and cold.
- B) Sound waves would easily travel through the vacuum of space without any medium.
- C) Gravity would completely disappear from Earth, causing everything to float.
- D) Shaking a rope or a spring would no longer transfer any energy.

Q6. MATH Connection: The average speed of sound in water is 1500 m/s. How long would it take a sound wave to travel 9000 m in water?

- A) 6 s
- B) 135 s
- C) 0.16 s
- D) 60 s

11	Correctly identify wavelength as the distance between two crests (or troughs).	Section: The Parts of a Wave; Section: Wavelength	p. 231; 232	11a, 11b
18	Identify and distinguish between compressions and rarefactions in a longitudinal wave	Section: The parts of a wave	p. 231	18

The Parts of a Wave

What makes sound waves, water waves, and seismic waves different from each other? Waves can differ in how much energy they carry and in how fast they travel. Waves also have other characteristics that make them different from each other.

Suppose you shake the end of a rope and make a transverse wave. The transverse wave in **Figure 7** has alternating high points and low points. **Crests** are the high points of a transverse wave. **Troughs** are the low points of a transverse wave. The imaginary line that is half the vertical distance between a crest and a trough is called the rest position.

On the other hand, a longitudinal wave has no crests and troughs. When a longitudinal wave passes through a medium, it creates regions where the medium becomes crowded together and more dense, as shown in **Figure 7**. These regions are compressions. A **compression** is the more dense region of a longitudinal wave. **Figure 7** also shows that the coils in the region next to a compression are spread apart, or less dense. The less-dense region of a longitudinal wave is called a **rarefaction**.

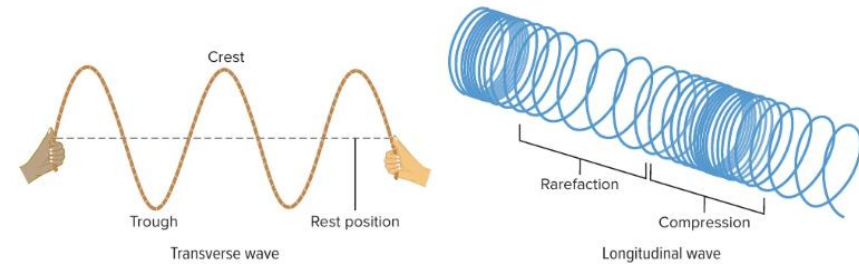
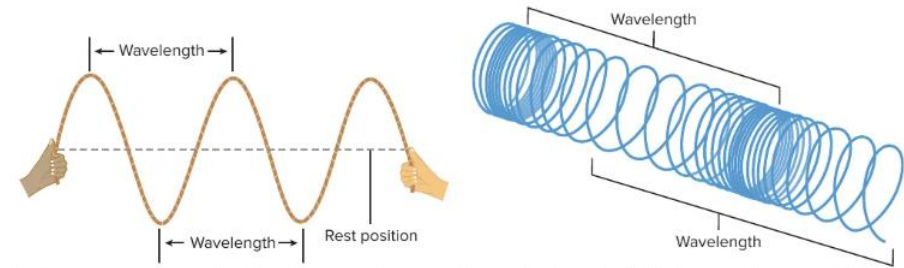


Figure 7 Different types of waves are described in different ways. Transverse waves have crests and troughs, but longitudinal waves have compressions and rarefactions.



For transverse waves, a wavelength can be measured from crest to crest or trough to trough.

The wavelength of a longitudinal wave can be measured from compression to compression or from rarefaction to rarefaction.

Figure 8 One wavelength is the distance from one point on a wave to the nearest point just like it.

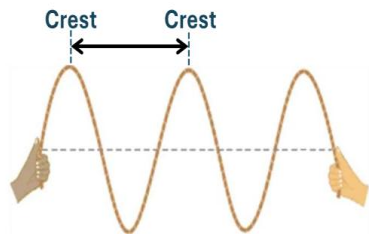
Wavelength

All waves have wavelength. **Wavelength** is the distance between one point on a wave and the nearest point just like it. **Figure 8** shows that for transverse waves, the wavelength is the distance from crest to crest or trough to trough. These two distances are equal on a transverse wave.

A wavelength of a longitudinal wave is the distance from the middle of one compression to the middle of the next compression, as shown in **Figure 8**. The wavelength of a longitudinal wave is also the distance from the middle of one rarefaction to the middle of the next rarefaction. These two distances are equal on a longitudinal wave.

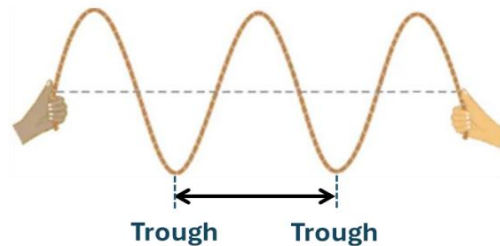
Question 11a

What is the distance between the two crests in image below called?



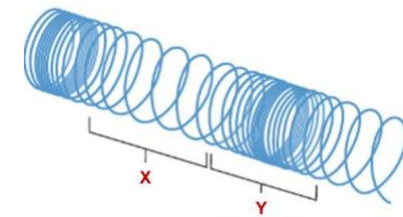
Question 11b

What is the distance between the two troughs in image below called?



Question 18

What are the two regions, labelled X and Y, in the longitudinal wave shown below called?



Q1. What are the specific names given to the alternating high points and low points of a transverse wave?

- A) Crests are the high points, and troughs are the low points.
- B) Compressions are the high points, and rarefactions are the low points.
- C) Troughs are the high points, and crests are the low points.
- D) Crests are the high points, and rarefactions are the low points.

Q2. Which term describes the more dense, crowded region of a longitudinal wave?

- A) Compression
- B) Rarefaction
- C) Crest
- D) Trough

Q3. How is the wavelength of a transverse wave measured?

- A) The distance from crest to crest or from trough to trough.
- B) The vertical distance from the rest position to a single crest.
- C) The distance from the first crest to the very end of the rope.
- D) The distance from a crest to the nearest trough.

Q4. What is the less-dense, spread-apart region of a longitudinal wave called?

- A) Rarefaction
- B) Compression
- C) Rest position
- D) Crest

Q5. A sound engineer uses a special software program to analyze a recording of a musical instrument. The software displays a structural map of the sound wave traveling through the air, showing a series of dense molecule clusters followed by spread-out spaces. If the distance from the center of the first dense molecule cluster to the center of the second dense molecule cluster is exactly 0.34 meters, what wave property has the engineer measured?

- A) Wavelength of a longitudinal wave
- B) Amplitude of a transverse wave
- C) Rest position of a mechanical wave
- D) Total displacement of a surface wave

Q6. Examine the two visual representations shown in the wave characteristics diagrams. Which conclusion accurately explains how one full wavelength is determined across different wave structures?

- A) It is the distance between any point on a wave to the nearest point just like it, such as from the middle of one compression to the middle of the next compression.
- B) It is measured by calculating the total vertical distance from a high crest to a low trough in both types of waves.
- C) It is the distance from a high crest in a transverse wave directly to a crowded compression in a longitudinal wave.
- D) It is measured only from the rest position to the maximum peak of a vibration.

Coverage Of SCIENCE		G8 ADV, ATS	T3	2025-2026	Mr. Ahmed Elhddad	0544557773
12	Solve for unknown variables in wave problems.	Section: Calculating wave speed, Example Problem 1, Practice Problems 7 to 9		p. 234	12a, 12b, 12c	

Wave Speed Equation

speed (in m/s) = frequency (in Hz) × wavelength (in m)

$v = f\lambda$

EXAMPLE Problem 1

SOLVE FOR WAVE SPEED What is the speed of a sound wave that has a wavelength of 2.00 m and a frequency of 170.5 Hz?

PRACTICE Problems  ADD

7. A wave traveling in water has a frequency of 250 Hz and a wavelength of 6.0 m. What is the speed of the wave?

8. The lowest-pitched sounds humans can generally hear have a frequency of roughly 20 Hz. What is the approximate wavelength of these sound waves if their wave speed is 340 m/s?

9. A particular radio station broadcasts radio waves at 100 MHz (100 million Hz). If radio waves travel at the speed of light (300 million m/s), then what is the wavelength of the radio waves that the station is broadcasting?

10. **CHALLENGE** A sound wave with a frequency of 100.0 Hz travels in water with a speed of 1500 m/s and then travels in air with a speed of 340 m/s. Approximately how many times larger is the wavelength in water than in air?

Question 12a

A wave has a wavelength of 1.5 m and speed of 1500 m/s. What is the frequency of the wave?

Question 12b

A sound wave has a frequency of 10,000 Hz and travels at 5000 m/s in a metal. What is the wavelength of the sound wave?

Question 12c

A sound wave has a frequency of 100 Hz and a wavelength of 3.3 m. Determine the speed of the wave.

Recall that the angle of incidence equals the angle of reflection.

Section: Reflection; Section: The law of reflection

p. 237; 238

13a, 13b, 13c, 13d, 13e

Reflection

If you are one of the last people to leave your school building at the end of the day, you will probably find that the hallways are quiet and empty. When you close your locker door, the sound echoes down the empty hall. Your footsteps also make a hollow sound. Thinking you are all alone, you might be startled by your own reflection in a classroom window. The echoes and your image looking back at you from the window are caused by wave reflection. Without wave reflection, you could not even see the lockers in your school's hallway.

Reflection occurs when a wave strikes an object and bounces off it. All types of waves—including sound, water, and light waves—can be reflected. How does the reflection of light allow the girl in **Figure 12** to see herself in the mirror? It happens in two steps. First, light strikes her face and bounces off her face. Then, the light reflected off her face strikes the mirror and is reflected into her eyes.



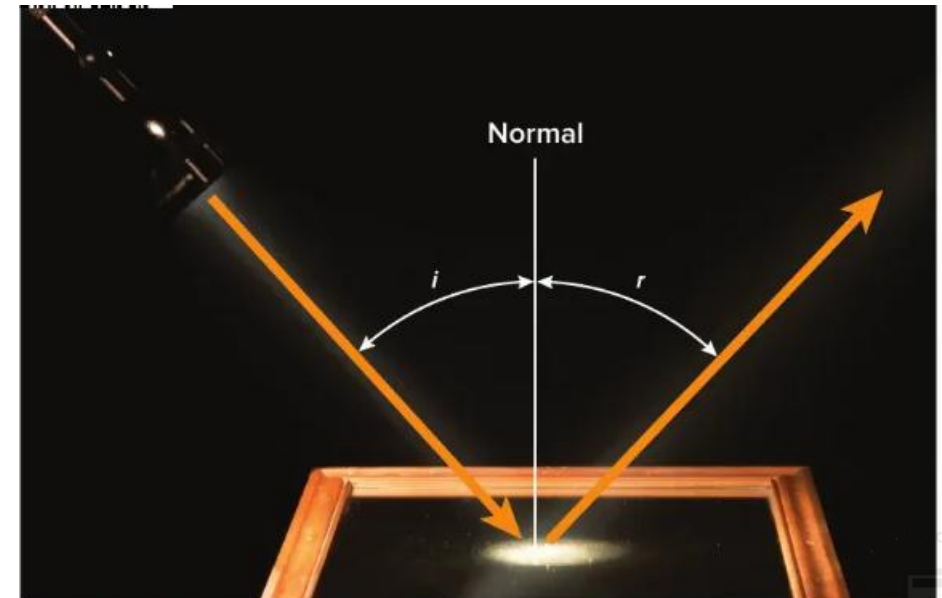
Figure 12 Some of the light that strikes this girl's face is reflected into the mirror. Some of that light then reflects off the mirror into her eyes.

Describe how the path of the light reflected from the girl's face would be different if the mirror were not present.

The law of reflection

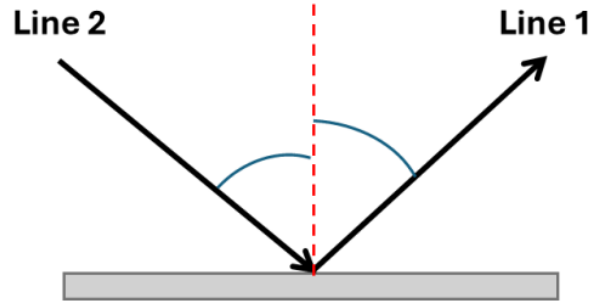
Look at the two light beams in **Figure 13**. The beam striking the mirror is called the incident beam. The beam that bounces off the mirror is called the reflected beam. The line drawn perpendicular to the surface of the mirror is called the normal. The angle formed by the incident beam and the normal is the angle of incidence, labeled i . The angle formed by the reflected beam and the normal is the angle of reflection, labeled r .

According to the law of reflection, the angle of incidence is always equal to the angle of reflection. All reflected waves, including light waves, sound waves, and water waves, obey this law. Objects that bounce from a surface sometimes behave like waves that are reflected from a surface. For example, suppose you throw a bounce pass while playing basketball. The angle between the ball's direction and the normal to the floor is the same before and after it bounces.



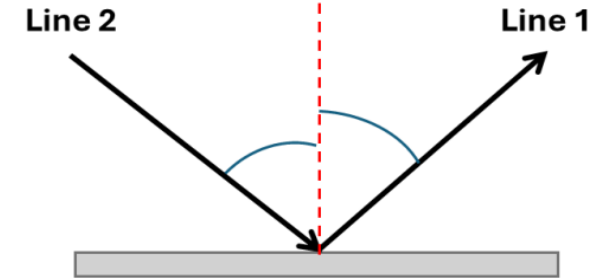
Question 13a

What does line 1 and line 2 represent?



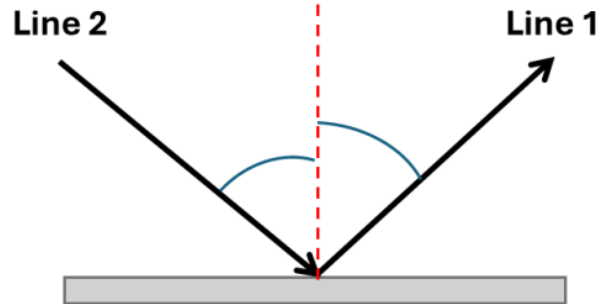
Question 13d

What is the name given to the angle between the red dotted line and line 1?



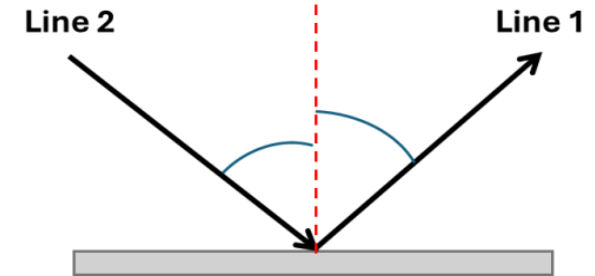
Question 13b

What is the red dotted line called?



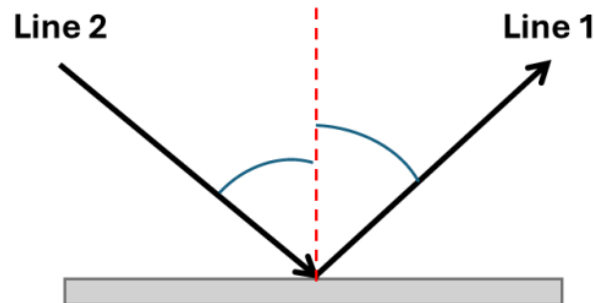
Question 13e

Name and state the law of Physics that is modeled below.



Question 13c

What is the name given to the angle between line 2 and the red dotted line?



1. What primary physical event occurs when a wave strikes an object and bounces off it?

A. Reflection

B. Diffraction

C. Refraction

D. Absorption

2. Which types of waves strictly follow the law of reflection when interacting with an appropriate boundary?

A. All types of waves, including light, sound, and water waves.

B. Only electromagnetic light waves.

C. Only mechanical sound and seismic waves.

D. Transverse waves only.

3. In the study of wave optics, what is the 'normal' defined as?

A. The path taken by the incoming incident beam.

B. The total distance between the incident and reflected beams.

C. A line drawn perpendicular to the reflecting surface.

D. The flat horizontal surface of the mirror itself.

4. According to the formal law of reflection, how does the angle of incidence (i) compare to the angle of reflection (r)?

A. The angle of incidence is always equal to the angle of reflection.

B. The angle of incidence is always double the angle of reflection.

C. The angle of incidence is always half the angle of reflection.

D. The relationship changes randomly depending on the wave speed.

5. An industrial laser strikes a polished titanium plate during a manufacturing process. A sensor records that the angle formed between the incoming laser beam and the perpendicular normal line is exactly 35° . What is the predicted angle of reflection for the exiting laser beam?

A. 55°

B. 0°

C. 35°

D. 70°

6. A sound wave hits a flat concrete wall at an angle. If the total measured angle between the incoming incident path and the outbound reflected path is exactly 80° , what is the value of the angle of incidence?

A. 40°

B. 50°

C. 20°

D. 80°

Explain how light behaves when it passes between different media, focusing on refraction and its real-life effects.

Section: Refraction; Section
Refraction of light in water

p. 239; 240

14

Refraction

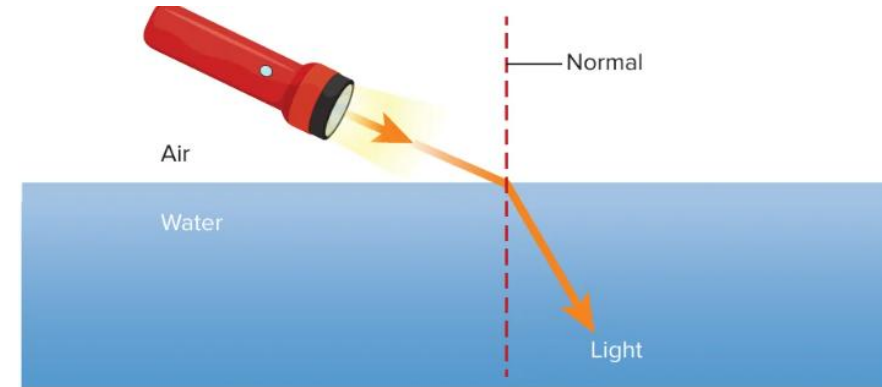
Do you notice anything unusual in **Figure 14**? The straw looks as if it is broken into two pieces. But if you pulled the straw out of the water, you would see that it is unbroken. This illusion is caused by refraction. How does refraction work?

Remember that a wave's speed depends on the medium through which it is traveling. When a wave passes from one medium to another, such as when a light wave passes from air to water, it changes speed. If the wave is traveling at an angle when it passes from one medium to another, it changes direction, or bends, as it changes speed.

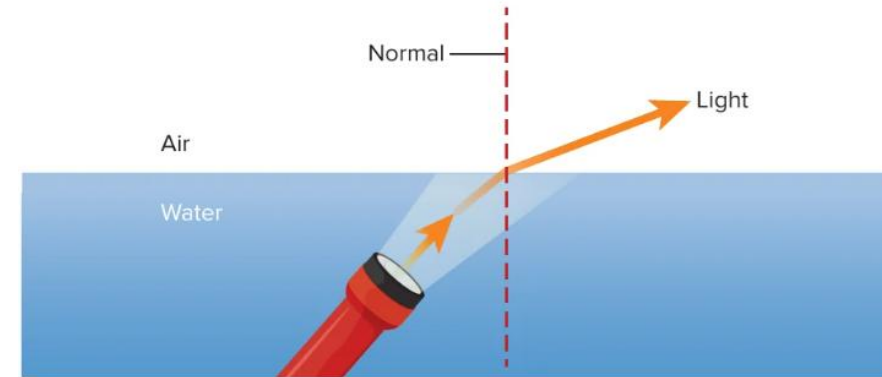
Refraction is the bending of a wave caused by a change in its speed as it travels from one medium to another. The greater the change in speed, the more the wave bends. The top panel in **Figure 15** shows how a wave refracts when it passes into a material in which that wave slows down. The wave is refracted (bent) toward the normal. The bottom panel in **Figure 15** shows how a wave refracts when it passes into a medium in which it speeds up. Then, the wave is refracted away from the normal.



Figure 14 Light waves refract as they enter and leave the water. This results in the illusion of the broken straw.



When light waves travel from air to water, they slow down and bend toward the normal.



When light waves travel from water to air, they speed up and bend away from the normal.

Figure 15 Light waves travel more slowly in water than in air. This causes light waves to refract when they move from water to air or air to water.

Predict how the beam would bend if the speed of light were the same in both air and water.



Figure 16 The fish in this photo are farther from the surface of the water than they appear. Refraction causes this pond to appear to be much shallower than it actually is.

Q9: A person standing on the deck of a swimming pool looks down at a friend standing upright inside the pool water. The friend in the water appears shorter than their actual height. What explains this visual phenomenon?

- A) Light rays from the friend's feet speed up and refract toward the normal at the surface.
- B) Light rays from the friend's feet refract downward at the water's surface, misaligning the actual position.
- C) Light rays from the friend's feet bend away from the normal at the surface, causing the brain to trace them back to a higher position.
- D) Light waves traveling through air bend when hitting the dry skin of the observer.

Refraction of light in water

Have you ever gazed at fish in a pond, such as those in **Figure 16**? You may have noticed that objects that are underwater seem closer to the surface than they really are. **Figure 17** shows how refraction causes this illusion.

In **Figure 17**, the light waves reflected from the swimmer's foot are refracted away from the normal and enter the girl's eyes. However, the brain assumes that all light waves have traveled in a straight line. The light waves that enter the girl's eyes seem to have come from a foot that was higher in the water.

This is also why the straw in **Figure 14** seems to be broken. The light waves coming from the part of the straw that is underwater are refracted, but your brain interprets them as if they have traveled in a straight line. However, the light waves coming from the part of the straw above the water are not refracted. So, the part of the straw that is underwater looks as if it has shifted.

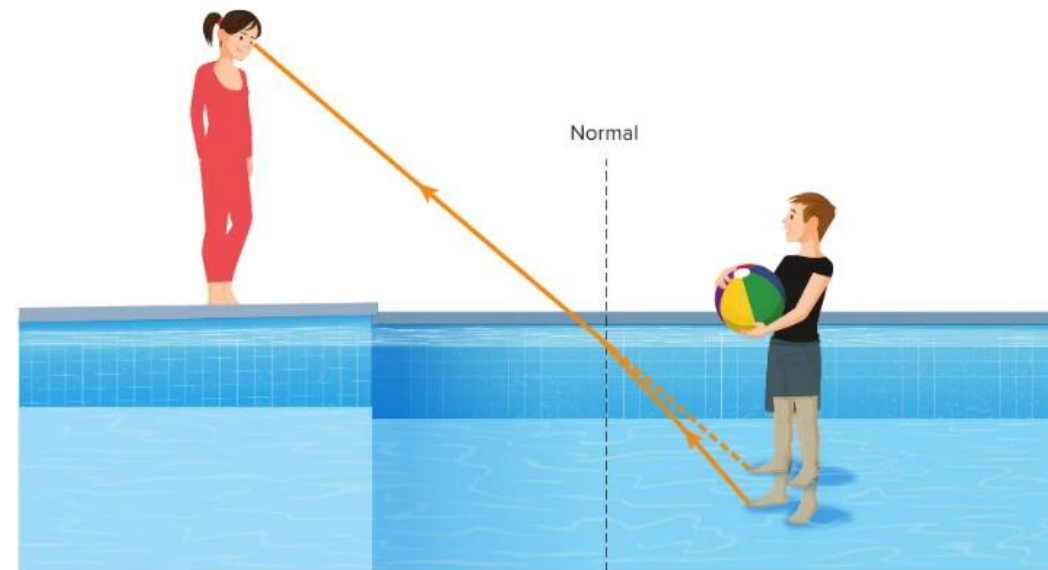


Figure 17 From the girl's perspective, refraction causes the boy to appear shorter than he actually is. Light rays from the boy's foot refract downward at the water's surface.

Q 1: What causes a light wave to bend when it travels from air into water?

- A) A change in the frequency of the wave
- B) A change in the speed of the wave
- C) An increase in the wave's amplitude
- D) Complete absorption of the wave by water

Q2 How does a light ray behave when it transitions from air into water at an angle?

- A) It continues in a straight line without changing direction.
- B) It slows down and bends toward the normal line.
- C) It speeds up and bends away from the normal line.
- D) It reflects completely back into the air.

Q3: What happens to the direction of a light beam traveling from water out into the air at an angle?

- A) It speeds up and bends away from the normal.
- B) It slows down and bends toward the normal.
- C) It stops completely at the boundary.
- D) It reflects downward into the bottom of the pool.

Q4: Which factor determines the magnitude or amount of bending that occurs during refraction?

- A) The total distance the light wave travels before hitting the boundary
- B) The color intensity of the flashlight or light source
- C) The degree of change in the wave's speed between the two media
- D) The surface area of the boundary between the two media

Q5: Why does a straight straw placed in a glass of water appear broken or shifted at the water's surface?

- A) Water chemically reacts with the straw material, altering its shape.
- B) Light waves reflected from the submerged part of the straw bend as they exit the water.
- C) The glass surface acts as a concave mirror, reversing the image.
- D) Light waves traveling through air are completely scattered before reaching the glass.

Q6: How does the human brain interpret light rays that enter the eyes from an underwater object?

- A) The brain calculates the exact angle of refraction automatically.
- B) The brain assumes all light waves travel in a straight line.
- C) The brain perceives the light as coming from a deeper location.
- D) The brain ignores the light rays coming from underwater.

Q7: A marine biologist looks directly at a colorful coral reef formation at the bottom of a clear, shallow coastal lagoon. If the biologist wants to take a precise laser measurement of the coral's actual physical position, how does the true depth of the coral compare to its apparent depth?

- A) The true depth is deeper than the apparent depth because light bends away from the normal as it leaves the water.
- B) The true depth is shallower than the apparent depth because light speeds up when entering the water.
- C) The true depth is exactly the same as the apparent depth because clear water does not cause refraction.
- D) The true depth is deeper than the apparent depth because light bends toward the normal as it leaves the water.

Q8: An observer is looking down at a school of fish swimming in a garden pond. Due to the behavior of light passing from water to air, how do the fish appear to the observer, and what is the reason?

- A) They appear deeper because the pond seems much deeper than it actually is.
- B) They appear closer to the surface, making the pond look shallower than its actual depth.
- C) They appear larger and upside down because the water acts like a magnifying lens.
- D) They appear in their exact physical positions because looking from above eliminates refraction.

Diffraction

When waves strike an object, several things can happen. The waves can be reflected. If the object is transparent, light waves can be refracted as they pass through it. Often, some waves are reflected and some waves are refracted. If you look into a glass window, sometimes you can see your reflection in the window as well as objects behind it. Light is passing through the window and is also being reflected at its surface.

Waves can also behave another way when they strike an object. The waves can bend around the object. **Figure 18** shows ocean waves changing direction and bending after they strike an island.



Get It?

Compare how light would respond differently when striking an object that is not transparent than when striking an object that is transparent, such as a glass window.

Diffraction is the bending of a wave around an object. Diffraction and refraction both cause waves to bend. The difference is that refraction occurs when waves pass through an object, while diffraction occurs when waves pass around an object. All waves, including water waves, sound waves, and light waves, can be diffracted.



Get It?

Contrast refraction with diffraction.

Waves also can be diffracted when they pass through a narrow opening, as shown in **Figure 19**. After they pass through the opening, the waves spread out. In this case, the waves are bending around the corners of the opening.



Get It?

Describe What are two situations in which a wave will diffract?



Figure 18 Diffraction can cause ocean waves to change direction as they pass around an island.

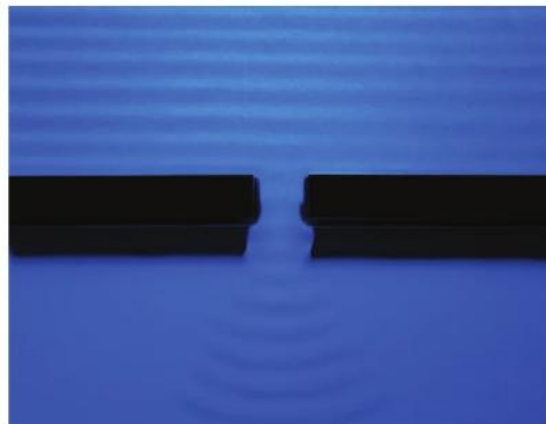


Figure 19 Waves diffract and spread out when they pass through a small opening or around a small obstacle.

21. **Infer** Sound waves often bend around columns in large concert halls. Is this a result of refraction or diffraction?

Q1: What is the scientific term for a wave bending around an object or spreading out after passing through a narrow opening?

- A) Reflection
- B) Refraction
- C) Diffraction
- D) Absorption

Q2: Which type of waves can undergo diffraction?

- A) Only water waves in the ocean
- B) Only sound waves and light waves
- C) All waves, including water, sound, and light waves
- D) Only electromagnetic waves in a vacuum

Q3: What is the fundamental difference between refraction and diffraction?

- A) Refraction involves waves bouncing off an object, while diffraction involves waves changing speed.
- B) Refraction occurs when waves pass through an object, while diffraction occurs when waves pass around an object.
- C) Refraction only happens to light waves, while diffraction only happens to water waves.
- D) Refraction causes waves to straighten, while diffraction causes them to stop completely.

Q4: What happens to straight, parallel waves immediately after they pass through a narrow opening?

- A) They stop moving forward and reflect completely backward.
- B) They turn into a single, highly concentrated straight line.
- C) They bend around the corners of the opening and spread out.
- D) They change their frequency and wavelength instantly.

Q5: When light strikes a transparent glass window, which behaviors can happen simultaneously?

- A) The light waves can be both reflected at the surface and refracted as they pass through.
- B) The light waves are always completely destroyed and converted to sound.
- C) The light waves only diffract around the edges without entering the glass.
- D) The light waves turn into water waves upon impact.

Q6: What primary wave behavior occurs when ocean waves strike an island and change direction to curve around its shores?

- A) Total internal reflection
- B) Digital refraction
- C) Wave diffraction
- D) Medium absorption

Q7: A person sitting inside a room can easily hear the conversation of people talking out in the hallway around a sharp corner, even though the speaker is completely out of the direct line of sight. However, the person inside the room cannot see the people in the hallway. Which statement explains this phenomenon?

- A) Sound waves travel through solid walls much faster than light waves can pass through glass windows.
- B) Sound waves have wavelengths that allow them to diffract around the edges of the doorway, while light waves do not bend noticeably around such large obstacles.
- C) Sound waves undergo refraction when hitting the floor, whereas light waves are completely absorbed by the hallway air.
- D) Sound waves bounce off the ceiling using refraction, while light waves only use diffraction to travel straight.

Define amplitude as a measure of the size of the disturbance from a wave.

Section: Amplitude

p.235

16

Amplitude

Why do some earthquakes cause terrible damage, while others are hardly felt? This is because the disturbance from a wave can vary. **Amplitude** is a measure of the size of the disturbance from a wave. If the wave's amplitude is greater, then the disturbance from that wave is also greater. Amplitude is measured differently for longitudinal waves and transverse waves.

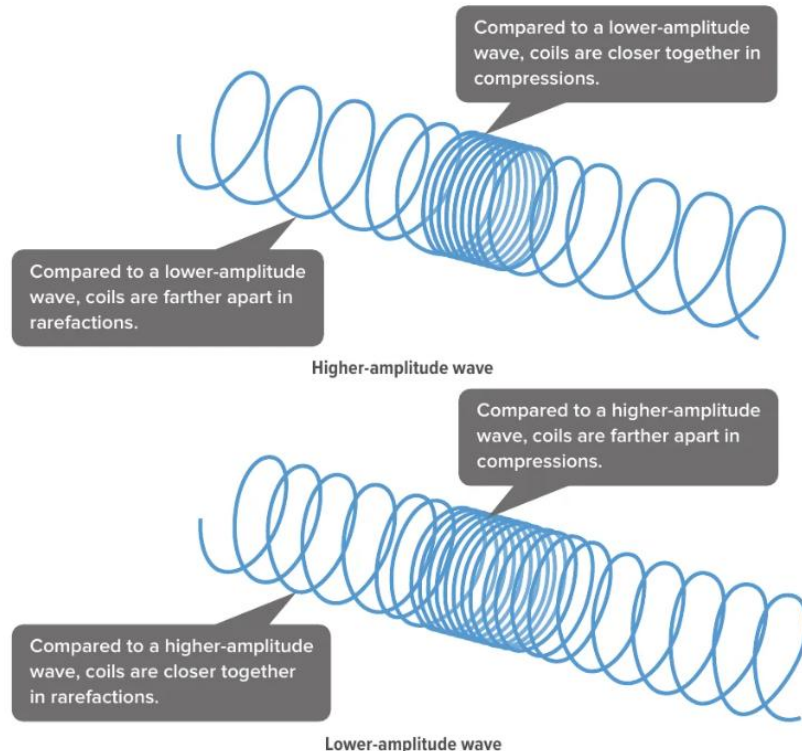


Figure 10 The coils in the high-amplitude wave's compression are closer together than the coils in the low-amplitude wave's compression.

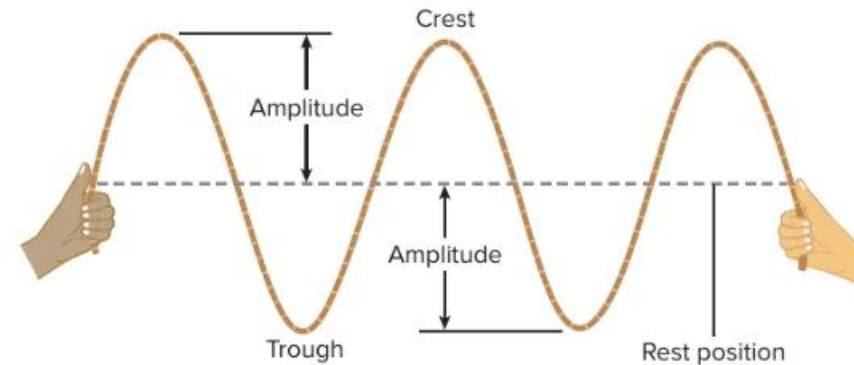


Figure 11 The amplitude of a transverse wave is half the vertical distance between the crests and the troughs. Describe how you could create waves with different amplitudes in a piece of rope.

Q1: Which property describes the measure of the size of the disturbance caused by a wave?

- A) Wavelength
- B) Frequency
- C) Amplitude
- D) Wave speed

Q2: What happens to the disturbance from a wave as its amplitude increases?

- A) The disturbance becomes greater.
- B) The disturbance completely disappears.
- C) The disturbance decreases in size.
- D) The disturbance changes from physical to chemical.

Q3: How is the amplitude of a transverse wave determined from a visual diagram?

- A) It is the total horizontal distance from one crest to the next crest.
- B) It is half the vertical distance between the crests and the troughs.
- C) It is the full distance from the highest crest to the lowest trough.
- D) It is the length of the rope from one hand to the other.

Q4: Which structural feature characterizes a longitudinal wave with a higher amplitude?

- A) Coils are farther apart in compressions compared to a lower-amplitude wave.
- B) Coils are closer together in rarefactions compared to a lower-amplitude wave.
- C) Coils are closer together in compressions and farther apart in rarefactions.
- D) Coils maintain an equal and uniform distance throughout the entire wave.

Q5: In a transverse wave diagram, what is the reference line from which amplitude is measured vertically upward to a crest or downward to a trough?

- A) Trough position
- B) Crest position
- C) Rest position
- D) Advanced track line

Q6: When comparing two different longitudinal waves moving through identical spring coils, how can a lower-amplitude wave be identified?

- A) The coils in the compressions are less tightly packed and farther apart.
- B) The wave has noticeably higher crests and deeper troughs.
- C) The coils in the rarefactions are completely spread to the ends of the room.
- D) The wave does not cause any areas of compression at all.

Q7: Two distinct earthquakes strike different areas of a coastal region. The first earthquake causes severe structural destruction to buildings, while the second earthquake is barely noticed by the local residents. Based on wave physics properties, what explains this difference in damage?

- A) The first earthquake produced longitudinal waves with much larger wavelengths.
- B) The first earthquake generated seismic waves with a significantly higher amplitude, carrying a larger physical disturbance.
- C) The second earthquake transformed its transverse waves into quiet sound waves.
- D) The second earthquake possessed a higher rest position that absorbed the ground energy.

Q8: A student performs a classroom demonstration using a heavy rope secured at both ends, shaking it to form the wave pattern.

If the student wants to modify the rope wave to double its current amplitude without changing the frequency, what physical action must be taken?

- A) Move the hand up and down over a greater distance from the rest position, using more energy.
- B) Shake the hand back and forth much faster while keeping the vertical movement very small.
- C) Pull the rope tighter in a straight horizontal line to completely eliminate the troughs.
- D) Let go of one end of the rope so the wave can travel freely through the air.

Q9: If an engineer needs to design a high-amplitude shock-absorbing system utilizing longitudinal waves, which design requirement must the compressed phases satisfy?

- A) The active coils must remain perfectly uniform and parallel with zero rarefaction zones.
- B) The system must force the medium particles to move perpendicular to the wave direction.
- C) The structural medium must allow the coils to pack much closer together during the compression phase compared to a standard system.
- D) The mechanical system must decrease the size of the wave disturbance during high impacts.

Explain how sound speed varies in different media based on particle arrangement and elasticity.

Section: The speed of sound,
Temperature and sound speed;
Section: Density and sound speed,
Elasticity and sound speed

The speed of sound

The speed of a sound wave through a medium depends on that medium's composition and whether that medium is solid, liquid, or gas.

Table 1 shows the speed of sound through some common mediums. The temperature, density, and elasticity of the medium also affect the speed of sound.

Temperature and sound speed The speed of sound through a fluid depends on the temperature of that fluid. This relationship is particularly pronounced for gases but also exists for liquids, such as water. As the temperature of a fluid increases, the particles that make up that fluid move faster. This makes them more likely to collide with each other. If the particles that make up a medium collide more often, more energy can be transferred in a shorter amount of time. As a result, the sound waves travel faster.

Density and sound speed Sound usually travels fastest in solids and slowest in gases. One reason for this is that the individual particles that make up liquids and solids are usually closer together than the particles that make up gases. **Figure 3** helps to illustrate why sound travels quickly in solids and liquids. Imagine that you are going door to door to raise money for a charity. In a city, it doesn't take very long to walk from house to house. In a rural area, it takes longer to walk from house to house. Similarly, when the particles that make up a medium are farther apart, sound travels more slowly through that medium.

Elasticity and sound speed Elasticity is the tendency of an object to rebound to its original state when it is deformed. A rubber ball is elastic. It tends to spring back to its original shape after someone squeezes it. A ball of clay is much less elastic.

Elastic objects also rebound more quickly when sound waves travel through them. Therefore, sound waves travel more quickly through elastic objects. Usually, solids are more elastic than liquids, and liquids are more elastic than gases. This is another reason why sound waves typically travel fastest through solids, slower through liquids, and slowest through gases.

Table 1 Speed of Sound in Different Mediums

Medium	Speed of Sound (m/s)
Air (0°C)	330
Air (20°C)	340
Cork	500
Water (0°C)	1400
Water (20°C)	1500
Copper	3600
Bone	4000
Steel	5800

Q7: Examine the two structural models shown in Figure 3 representing a closely packed city neighborhood and a widely separated rural countryside. If a student uses this visual presentation to explain sound energy transfer, which molecular condition does the rural countryside illustration accurately model?

- A) A solid material like steel where energy transfers instantly.
- B) A dense liquid like water at room temperature.
- C) A gaseous medium where particles are far apart, causing energy to take a longer time to transfer from particle to particle.
- D) A highly elastic rubber substance that rebounds immediately.



When houses are close together, you can walk quickly from house to house. When particles are close together, such as in a solid or a liquid, energy can be transferred quickly from particle to particle.



When houses are far apart, it takes longer to walk from house to house. When particles are far apart, such as in a gas, it takes longer to transfer energy from particle to particle.

Figure 3 Walking between houses is a model for particles transferring the energy of a sound wave.

Q1: What happens to the speed of a sound wave through a fluid as the temperature of that fluid increases?

- A) Sound travels slower because the fluid becomes denser.
- B) Sound travels faster because the particles move quicker and collide more often.
- C) Sound stops completely due to heat absorption.
- D) Sound speed remains completely unchanged.

Q2: Why does sound usually travel fastest in solids and slowest in gases?

- A) Solid particles are much farther apart than gas particles.
- B) Gas particles have more negative electrical charges.
- C) Individual particles in solids are much closer together, transferring energy more quickly.
- D) Solids completely block out any heat variations.

Q3: What is the scientific definition of elasticity?

- A) The total weight of an object when measured in a vacuum.
- B) The tendency of an object to rebound to its original state when it is deformed.
- C) The distance between the individual particles inside a gaseous medium.
- D) The maximum temperature a fluid can reach before evaporating.

Q4: How does the elasticity of a medium affect the travel of sound waves?

- A) Sound waves travel more quickly through highly elastic objects because they rebound faster.
- B) Sound waves slow down in elastic objects because energy is lost during bouncing.
- C) Elasticity completely prevents sound waves from entering a solid material.
- D) Elasticity changes longitudinal sound waves into visible light waves.

Q5: Reviewing the relative mechanical properties of matter, which state of matter is typically the most elastic?

- A) Gases are more elastic than liquids.
- B) Liquids are more elastic than solids.
- C) Solids are more elastic than liquids, and liquids are more elastic than gases.
- D) All states of matter possess the exact same level of physical elasticity.

Q6: According to the properties of sound in different media, what value represents the speed of sound in air at a temperature of 20°C ?

- A) 330 m/s
- B) 340 m/s
- C) 500 m/s
- D) 1500 m/s

A deep-sea exploration team sends a sound pulse downward through a pocket of cold ocean water measured at 0°C . As the sound wave travels deeper, it enters a thermal vent region where the water temperature rises sharply to 20°C . What change occurs to the sound wave upon entering the warm water zone, and what is the physical reason?

- A) The sound wave slows down from 1500 m/s to 1400 m/s because hot water particles freeze.
- B) The sound wave speeds up from 1400 m/s to 1500 m/s because the warmer particles collide more frequently to transfer energy in a shorter amount of time.
- C) The sound wave maintains a constant speed of 340 m/s because temperature only affects sound speed inside atmospheric gases.
- D) The sound wave drops its speed to 330 m/s because the vent adds dense volcanic ash to the fluid medium.

A structural engineer conducts an acoustic test by striking three different rods made of cork, copper, and steel with a mechanical hammer. Based on particle arrangement and the elastic tendencies of these solids, which sequence correctly ranks the speed of the sound waves through these materials from slowest to fastest?

- A) Steel → Copper → Cork
- B) Copper → Steel → Cork
- C) Cork → Steel → Copper
- D) Cork → Copper → Steel

Intensity and Loudness

Recall that the degree of disturbance from a wave corresponds to its amplitude. For a longitudinal wave, amplitude is related to how close together the particles of the medium are in the compressions.

Figure 6 compares longitudinal waves of low amplitude and high amplitude. Increasing the amplitude of a longitudinal wave pushes the particles in that wave's compressions closer together.

To produce a sound wave with greater amplitude, more energy must be transferred from the vibrating object to the medium. This greater energy is then transferred through the medium as the sound wave is transmitted.

What happens to the sound waves from a speaker when you turn up the volume? The notes sound the same, but the amplitude of the sound waves increases. This, in turn, causes your eardrums to vibrate with a higher amplitude when the sound waves reach your ears.

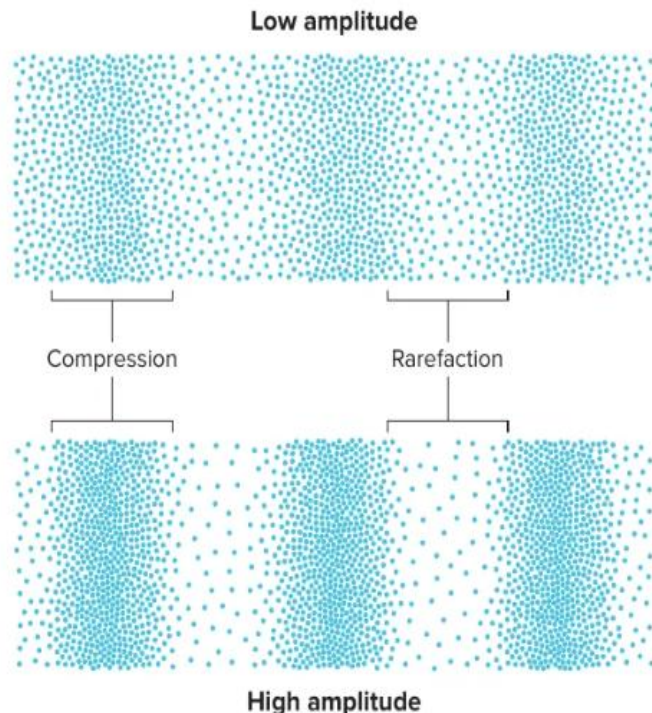


Figure 6 The amplitude of a sound wave depends on the density of the medium in the compressions and rarefactions.

Identify the areas of highest and lowest density for each wave.

Intensity

For sound waves, the amplitude of the waves is related to intensity. **Intensity** is the amount of energy that passes through a certain area in a specific amount of time. Picture sound waves traveling from a computer speaker, through an imaginary rectangle, and to your ears, as shown in **Figure 7**. If you could measure how much energy passed through such a rectangle in one second, you would measure intensity.

When you turn up the volume on your computer, the speaker cone moves in and out through a greater distance. In turn, greater energy is transferred through the medium, resulting in greater intensity. When you turn down the volume, you reduce the energy carried by the sound waves, so you also reduce the intensity.

Distance and intensity Intensity influences how far away a sound can be heard. If you and a friend whisper a conversation, the sound waves you produce have low intensity and are not heard at a far distance. However, when you shout, the sound waves have high intensity and can be heard farther away.

Sound intensity decreases with distance for two reasons. First, the energy that a sound wave carries spreads out as the sound wave spreads out. Second, some of a sound wave's energy converts to other forms of energy, usually thermal energy, as the sound travels through matter. As the sound wave travels farther, more of its energy converts into other forms. Some materials, such as soft, thick curtains, are very effective at converting sound energy to other forms of energy.

Loudness

Some sounds are so loud that they can be painful to hear. **Loudness** is the human perception of sound volume and primarily depends on sound intensity. When sound waves of high intensity reach your ear, they cause your eardrum to move back and forth a greater distance than when sound waves of low intensity reach your ear. As a result, you hear a loud sound.

Q1: What is the scientific term for the amount of energy that passes through a certain area in a specific amount of time?

- A) Loudness
- B) Frequency
- C) Intensity
- D) Wavelength

Q2: What physical change occurs to the particles in a longitudinal wave's compressions when the amplitude increases?

- A) The particles are pushed closer together.
- B) The particles stop vibrating completely.
- C) The particles move much farther apart.
- D) The particles decrease their individual mass.

Q3: What is required from a vibrating object to produce a sound wave with a greater amplitude?

- A) Less energy must be transferred to the medium.
- B) More energy must be transferred to the medium.
- C) The object must stop shifting its position.
- D) The medium must be changed from liquid to gas.

Q4: Which human sensory experience is defined as the human perception of sound volume and primarily depends on sound intensity?

- A) Pitch
- B) Loudness
- C) Frequency
- D) Elasticity

Q5: What happens to your eardrums when sound waves of high intensity reach your ears?

- A) They vibrate with a lower amplitude.
- B) They move back and forth a greater distance.
- C) They stop moving and absorb thermal fluids.
- D) They alter the frequency of the incoming note.

Q6: What are the two physical reasons why sound intensity decreases as distance from the source increases?

- A) The wave's frequency increases and the wavelength shortens over time.
- B) The sound energy vanishes completely and converts back into magnetic fields.
- C) The energy spreads out over a larger area, and some energy converts to other forms like thermal energy.
- D) The particles of the medium become completely solid and block the sound.

Q7: An audio engineer is testing a new computer speaker system. When the engineer turns up the volume control, the musical notes produced by the speaker sound exactly the same in terms of pitch, but the sound becomes much louder. What is happening mechanically at the speaker cone and at the listener's ear to cause this effect?

- A) The speaker cone decreases its horizontal movement, causing the listener's eardrum to vibrate over a shorter distance.
- B) The speaker cone moves in and out through a greater distance, transferring more energy to increase the wave amplitude and making the eardrum vibrate with higher amplitude.
- C) The speaker cone alters its frequency to pack the rarefactions much tighter, destroying the thermal energy.
- D) The speaker cone stops moving completely, allowing the sound intensity to spread out without any resistance.

Q8: Analyze the mechanical dot diagrams illustrating longitudinal waves. If a student wants to identify the wave with the higher intensity and louder sound, what visual features should they look for in the diagram?

- A) A wave where the dots are uniformly and equally spaced throughout the compression and rarefaction zones.
- B) A wave where the compression zones have a much higher density of dots packed closely together, and the rarefaction zones are highly cleared out.
- C) A wave that shows the dots shifting vertically up and down to form high crests and deep troughs.
- D) A wave where the total number of dots decreases sharply from left to right.

Q9: A school wants to build a quiet study room right next to a busy, noisy gymnasium. To prevent the high-intensity sound waves from the gymnasium from traveling far into the study room, the builders decide to line the shared wall with soft, thick curtains. Why is this structural material effective based on wave energy properties?

- A) Soft, thick materials increase the amplitude of the longitudinal waves to push them backward.
- B) Soft, thick materials are highly effective at converting the sound wave's mechanical energy into other forms of energy, such as thermal energy.
- C) Soft, thick materials force the sound waves to travel faster so they bypass the study room.
- D) Soft, thick materials keep the individual particles of the air completely frozen in place.

The decibel scale It is hard to say how loud is too loud. Two people are unlikely to agree on what is too loud because people vary in their perceptions of loudness. A sound that seems fine to you may seem earsplitting to your teacher. Even so, the intensity of sound can be described using a measurement scale.

A **decibel** (DE suh bel), abbreviated dB, is a unit of sound intensity. The loudest sounds that you hear are probably more than 10 billion times more intense than the softest sounds that you can hear. In order to handle this wide range of intensities, the decibel measurement scale is set up in a special way.

Every increase in 10 dB on the decibel scale represents a tenfold increase in intensity. This means that a 50-dB sound is 10 times more intense than a 40-dB sound. You might think that this means a 60-dB sound is 20 times more intense than a 40-dB sound. However, a 60-dB sound is 10×10 , or 100, times more intense than a 40-dB sound. A 100-dB sound is 10^7 , or 10 million, times more intense than a 30-dB sound. A sound can also have an intensity of less than 0 dB. However, people generally cannot hear these sounds.

Sustained sounds above about 90 dB can cause permanent hearing loss. Even short, sudden sounds with intensity levels above 120 dB may cause pain and permanent hearing loss. During some rock concerts, sounds reach this damaging intensity level. Wearing ear protection, such as earplugs, around loud sounds can help protect against hearing loss. **Figure 8** shows some sounds and their intensity levels in decibels.

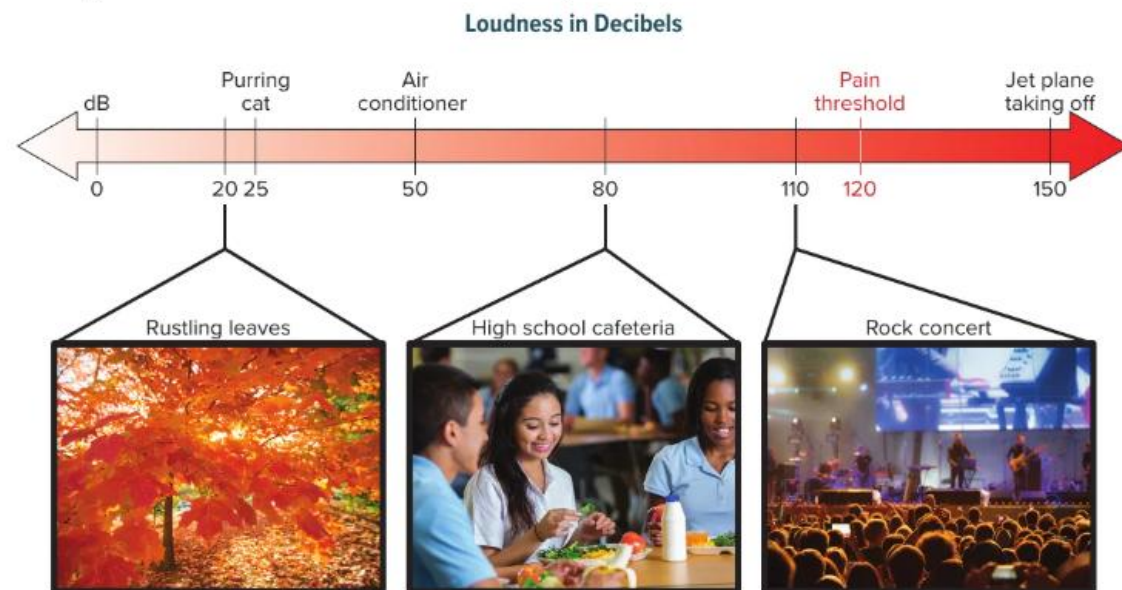


Figure 8 The volumes of different sounds are often measured in decibels.

Question 20a

The loudness in a library is 20 dB. The street outside is 40 dB loud. How many times louder is the street compared to the library?

Question 20b

The loudness of rain on a rainy day was found to be 40 dB. A dishwasher is 70 dB loud. How many times louder is the dishwasher compared to the rain?

Q1: What is the standard unit of measurement used to describe and handle the wide range of sound intensities?

- A) Hertz (Hz)
- B) Decibel (dB)
- C) Meter per second (m/s)
- D) Newton (N)

Q2: What mathematical change in sound intensity does every increase of 10 dB on the decibel scale represent?

- A) A twofold increase in intensity
- B) A tenfold increase in intensity
- C) A decrease in intensity by half
- D) A completely linear increase of 10 units

Q3: If a sound measurement changes from 40 dB to 50 dB, how many times more intense has the sound become?

- A) 2 times more intense
- B) 5 times more intense
- C) 10 times more intense
- D) 100 times more intense

Q4: Based on the physical limits of human hearing, what occurs when a sound has an intensity level below 0 dB?

- A) The sound causes immediate permanent hearing loss.
- B) Human ears generally cannot hear these sounds.
- C) The sound converts into visible red light.
- D) The sound vibrates the eardrum at maximum amplitude.

Q5: What risk is associated with exposure to sustained, continuous sounds that are above the level of about 90 dB?

- A) They cause an increase in the frequency of human speech.
- B) They can cause permanent hearing loss.
- C) They improve the overall elasticity of the eardrum.
- D) They temporarily cool down the surrounding air medium.

Q6: At what specific decibel level does sound reach the threshold of pain where even short, sudden exposures can cause physical pain and permanent injury?

- A) 25 dB
- B) 50 dB
- C) 80 dB
- D) 120 Db

Q7: An environmental safety officer measures the sound level inside an empty warehouse and records a value of 40 dB. Later, when heavy machinery is turned on, the noise level jumps sharply to 60 dB. How many times more intense is the sound pollution from the machinery compared to the empty warehouse?

- A) 20 times more intense
- B) 40 times more intense
- C) 100 times more intense
- D) 1,000 times more intense

Q8: If a student compares the sound of rustling leaves 20 dB to the sound inside a busy high school cafeteria 80 dB, what is the exact mathematical relationship between their intensities?

- A) The cafeteria sound is 60 times more intense than the rustling leaves.
- B) The cafeteria sound is 10^6 (or 1 million) times more intense than the rustling leaves.
- C) The cafeteria sound is 4 times less intense than the rustling leaves.
- D) The cafeteria sound has exactly the same intensity but a different color background.

Q9: A sound technician is setting up audio equipment for a live rock concert where sound intensity levels are expected to reach up to 110 dB or 120 dB, Which personal safety recommendation should the technician enforce for the crew working near the stage speakers?

- A) They must wear specialized ear protection, such as earplugs, to prevent permanent hearing damage from the high-intensity environment.
- B) They must drink cold fluids to prevent the sound waves from traveling faster through their bodies.
- C) They must stand closer to the speakers to reduce the distance over which the sound spreads out.
- D) They must switch the microphone settings to less elastic gaseous elements.

Pitch

If you have ever studied music, you are probably familiar with the musical scale *do, re, mi, fa, so, la, ti, do*. If you were to sing this scale, your voice would start low and become higher with each note. As you sang, you would hear a change in pitch. **Pitch** is how high or low a sound seems to be. The notes on the right side of a piano have high pitches. The pitch of a sound is primarily related to the frequency of the sound waves.

Frequency and pitch

Frequency is a measure of how many wavelengths pass a particular point each second. For a longitudinal wave, such as sound, the frequency is the number of compressions or the number of rarefactions that pass by each second. Frequency is measured in hertz (Hz). One Hz means that one wavelength passes by in one second.

When sound waves with high frequency reach your ears, many compressions reach your eardrums each second. The waves cause your eardrums and all the other parts of your ears to vibrate more quickly than a sound wave with a low frequency. Your brain interprets these fast vibrations caused by high-frequency waves as a sound with a high pitch.

As the frequency of sound waves decreases, the pitch becomes lower. **Figure 9** shows different notes and their frequencies. Notice that when you sing *do, re, mi, fa, so, la, ti, do*, the second *do* has twice the frequency of the first *do*.

Animals differ in their sensitivities to different ranges of sound frequencies. A human teenager with typical hearing can hear sounds with frequencies from about 20 Hz to 20,000 Hz. However, the highest frequency that a typical human can hear decreases with age. The human ear is most sensitive to sounds in the range of 440 Hz to about 7000 Hz. This roughly corresponds to the notes on the upper half of a piano. Dogs can hear sounds with frequencies up to about 35,000 Hz, and bats can detect frequencies higher than 100,000 Hz.

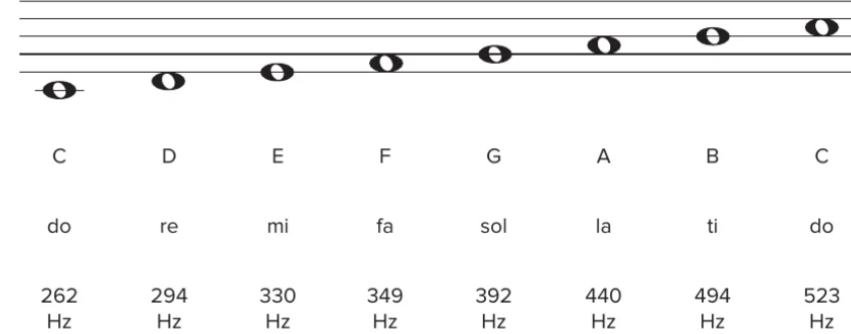


Figure 9 Every musical note has a distinct frequency, which gives that note a distinct pitch.

Describe how pitch changes when frequency increases.

Question 21a

What is the highest frequency that can be heard by the human ear?

Question 21b

What is the lowest frequency that could be heard by the human ear?

Q1: What property of a sound wave determines how high or low a sound seems to be to a listener?

- A) Amplitude
- B) Intensity
- C) Frequency
- D) Speed

Q2: How does the human brain interpret the fast vibrations of the eardrum caused by high-frequency sound waves?

- A) As a sound with a low pitch
- B) As a sound with a high pitch
- C) As a sound with low intensity
- D) As a sound with zero amplitude

Q3: What is the standard unit of measurement for frequency, representing one wavelength passing by a point each second?

- A) Decibel {Db}
- B) Meter per second m/s
- C) Hertz Hz
- D) Newton N

Q4: What is the typical range of sound frequencies that a human teenager with typical hearing can detect?

- A) 0 Hz to 100 Hz
- B) 20 Hz to 20,000 Hz
- C) 440 Hz to 7,000 Hz
- D) 20,000 Hz to 100,000 Hz

Q5: What biological change typically occurs regarding human hearing sensitivity as a person ages?

- A) The lowest frequency a person can hear drops below 0 Hz.
- B) The highest frequency a typical human can hear decreases with age.
- C) The human ear becomes more sensitive to frequencies above 100,000 Hz.
- D) Aging causes all sound waves to travel slower inside the ear.

Q6: Within what specific frequency range is the human ear known to be most sensitive?

- A) 20 Hz to 200 Hz
- B) 440 Hz to about 7,000 Hz
- C) 20,000 Hz to 35,000 Hz
- D) Higher than 100,000 Hz

Q7: During a biology field trip, a student uses an adjustable acoustic whistle. At the initial setting, the whistle emits a sound at 15,000 Hz. The student then turns the dial to increase the frequency to 25,000 Hz. How will this adjustment affect what the student and nearby animals perceive?

- A) The student will hear a higher-pitched sound, while local dogs will hear nothing at all.
- B) The student will no longer hear the sound because it exceeds the 20,000 Hz human limit, but a dog can still detect it since dogs can hear up to 35,000 Hz.
- C) Both the human student and local bats will lose track of the sound entirely.
- D) The pitch of the whistle drops so low that it converts to a mechanical vibration felt only through the ground.

Q8: Examine the musical scale mapped out in Figure 9. If a vocalist sings the musical note "do" at the beginning of the scale 262 Hz and then finishes by singing the higher "do" at the end of the scale 523 Hz, what exact mathematical relationship exists between the sound waves of these two notes?

- A) The second note has half the frequency of the first note.
- B) The second note has exactly twice the frequency of the first note, creating a higher pitch.
- C) The second note produces fewer compressions per second than the first note.
- D) The frequencies of both notes are identical, but their wave amplitudes differ by ten billion units.

Q9: A laboratory technician designs an ultrasonic sensor designed to detect bats flying near an orchard. The sensor needs to capture high-frequency sounds that human ears cannot perceive and that even household dogs cannot detect. Which frequency threshold should the sensor be programmed to monitor?

- A) A range between 100 Hz and 500 Hz
- B) A range between 2,000 Hz and 5,000 Hz
- C) A range between 10,000 Hz and 15,000 Hz
- D) Frequencies higher than $100,000 \text{ Hz}$

Describe how sound changes when a source approaches or moves away (Doppler Effect).

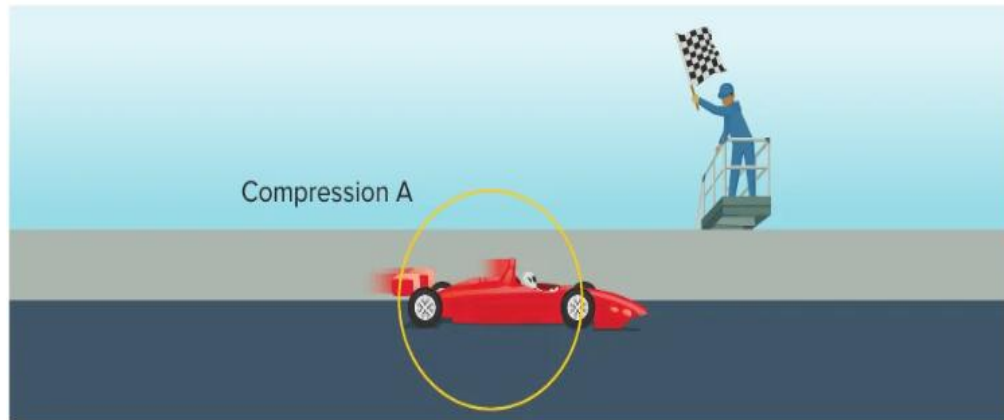
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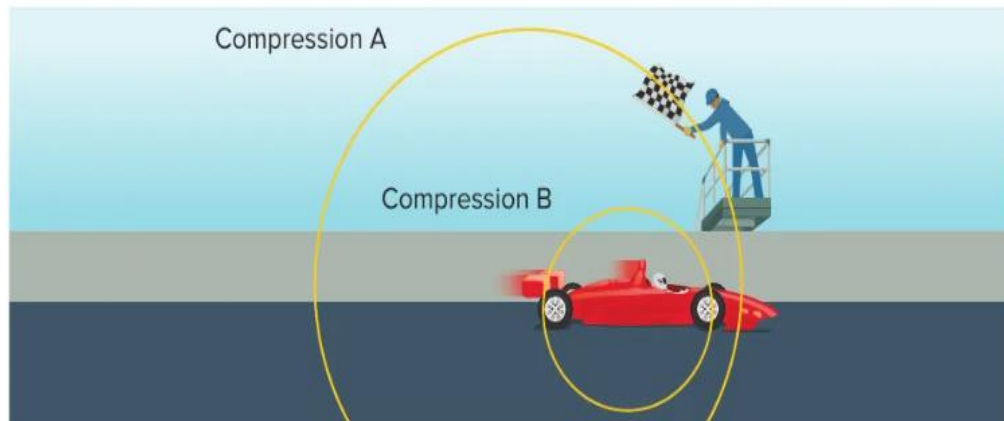
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The Doppler Effect

Imagine that you are standing at the side of a racetrack with race cars zooming past. When the cars are moving toward you, the pitches of their engines are higher. When the cars are moving away from you, the pitches are lower. The **Doppler effect** is the change in wave frequency due to a wave source moving relative to an observer or an observer moving relative to a wave source. **Figure 10** shows how the Doppler effect occurs.



The race car sends out a sound wave as it moves, producing compression A. Compression A continues to move outward, and the car continues to move forward.



The car is closer to the flagger when it creates compression B. Compressions A and B are closer together in front of the car, so the flagger hears a higher-pitched sound.

Figure 10 The Doppler effect occurs when the source of a sound wave is moving relative to a listener.

Demonstrate Understanding

8. **Determine** which will change if you turn up a radio's volume: *wave velocity, intensity, pitch, frequency, wavelength, loudness*. Explain.
9. **Identify** the range of human hearing in decibels and the level at which sound can damage human ears.
10. **Compare and contrast** frequency and pitch.
11. **Draw and label** a diagram that explains the Doppler effect.

Explain Your Thinking

12. **Explain** why a passing car would exhibit a greater sound frequency change when it moves at 30 m/s than when it moves at 12 m/s.
13. **MATH Connection** Using the musical scale in **Figure 9**, make a table showing how many wavelengths will pass you in one minute for each note. What is the relationship between frequency and the number of wavelengths per minute?

Q1: What is the scientific definition of the Doppler effect?

- A) The change in wave speed when sound travels from a solid to a gas.
- B) The change in wave frequency due to a wave source moving relative to an observer.
- C) The total absorption of sound energy by soft and thick materials.
- D) The amplification of sound intensity inside a vacuum.

Q2: When a moving sound source approaches an observer, how does the pitch change?

- A) The pitch becomes lower.
- B) The pitch becomes higher.
- C) The pitch drops instantly to zero.
- D) The pitch fluctuates randomly between high and low.

Q3: What happens to the perceived pitch of a sound engine as the source moves away from you?

- A) The pitch stays exactly the same.
- B) The pitch increases exponentially.
- C) The pitch becomes lower.
- D) The pitch turns into an electromagnetic wave.

Q4: The Doppler effect occurs when there is relative motion between which two components?

- A) The wave amplitude and the wave speed.
- B) The source of a sound wave and a listener.
- C) The density of a solid and the temperature of a gas.
- D) The compression phase and the thermal energy.

Q5: Why does an observer standing in front of an approaching car hear a higher-pitched sound?

- A) The car blocks the rarefactions from spreading backward.
- B) The individual sound waves change their physical velocity through the fluid air.
- C) The sound compressions are closer together in front of the car.
- D) The sound intensity decreases linearly with distance.

Q7: If a sound source moves toward a stationary listener, what physical property of the sound waves actually changes for the observer?

- A) The original frequency emitted by the source itself.
- B) The wave frequency detected by the observer due to relative motion.
- C) The fundamental elasticity of the medium.
- D) The maximum speed of sound inside the air.

Q8: Refer to Figure 10 ,When the moving car creates a new compression (Compression B) closer to a forward observer, what happens to the previously emitted compression (Compression A)?

- A) Compression A completely vanishes to make room for Compression B.
- B) Compression A stops moving and remains attached to the vehicle.
- C) Compression A continues to move outward while the car continues to move forward.
- D) Compression A reverses its direction and travels backward.

Q8: Which of the following conditions will NOT produce a Doppler effect for sound waves?

- A) A sound source moves toward a stationary observer.
- B) An observer moves toward a stationary sound source.
- C) Both the sound source and the observer are moving relative to each other.
- D) Both the sound source and the observer are completely stationary relative to each other.

23

Explain how objects appear coloured based on selective reflection and absorption of light.

Sections: Colors, Seeing Colors

p. 307

23a, 23b, 23c

Colors

Why do some apples appear to be red, and others look green or yellow? An object's color depends on the wavelengths of light that it reflects and that our eyes detect. You know that white light is a blend of all colors of visible light. When a red apple is struck by white light, it reflects more red light than green or blue light. **Figure 8** shows white light striking a green leaf. The leaf reflects more green light than other colors and appears green.

Although some objects appear to be black, black is not a color that is present in visible light. Objects that are black absorb all colors of light and reflect little or no light back to your eye. White objects are white because they reflect all colors of visible light.



Get It?

Explain why a white object is white.

Seeing Color

As you approach a busy intersection, the color of the traffic light changes from green to yellow to red. On the cross street, the color changes from red to green. How do your eyes detect the differences between red, yellow, and green light?



Figure 8 When white light hits this green leaf, more green light is reflected than red or blue light. The leaf absorbs more red and blue light than green light, so the leaf appears green.

Question 23a

What color of light does the ball reflect so that it appears red?



Question 23b

What color of light does the ball reflect so that it appears blue?



Question 23c

What color of light does the ball reflect so that it appears green?



Q1: A student shines white light on a blue school bag. Which of the following best explains why the bag appears blue to the student's eyes?

- A) The bag absorbs blue light and reflects all other colors of visible light.
- B) The bag reflects more blue light than red or green light, while absorbing most other colors.
- C) The bag creates its own blue light when struck by white light.
- D) The bag filters out the white light and turns it completely into green light.

Q2: Why does a piece of white printer paper appear white when placed under sunlight?

- A) It absorbs all colors of visible light equally.
- B) It reflects only the yellow wavelengths from the sun.
- C) It reflects all colors of visible light that make up white light.
- D) It refracts the light into a rainbow spectrum.

Q3: An asphalt road looks completely black on a hot, sunny day. What is happening to the white light hitting the road?

- A) The road reflects all colors of visible light back to your eyes.
- B) The road absorbs all colors of light and reflects little or no light.
- C) The road only reflects green and blue light while absorbing red.
- D) Black light is being reflected from the road into space.

Q4: When white light strikes a green leaf, which statement correctly describes the behavior of light?

- A) The leaf absorbs green light and reflects red and blue light.
- B) The leaf reflects all white light without absorbing any wavelengths.
- C) The leaf reflects more green light than other colors, and absorbs more red and blue light.
- D) The leaf transforms white light into heat energy without reflecting any light.

Q5: Which of the following statements is true regarding black objects?

- A) Black is a specific color wavelength present in the visible light spectrum.
- B) Black objects appear black because they reflect all colors of light equally.
- C) Black is not a color present in visible light; it is the absence of reflected light.
- D) Black objects reflect only green and blue wavelengths.

Q6: If you place a perfectly red apple in a dark room and shine only pure blue light on it, what color will the apple most likely appear to your eyes?

- A) Red, because apples are always red.
- B) Blue, because it reflects the blue light hitting it.
- C) Black, because the red apple absorbs the blue light and has no red light to reflect.
- D) Green, because blue and red light mix to form green.

Q7: An object's color depends primarily on two main factors. What are they?

- A) The weight of the object and the temperature of the room.
- B) The wavelengths of light that it reflects and that our eyes detect.
- C) The size of the object and the speed of sound.
- D) The amount of heat the object releases into the air.

Q8: A traffic light changes from green to yellow to red. How do human eyes detect these different changes in the color of the traffic light?

- A) By detecting the different wavelengths of light reflected or emitted by the light source.
- B) By measuring the temperature changes of the light bulbs.
- C) The eyes change their internal color to match the intersection lights.
- D) By sensing the sound frequencies produced when the lights switch.

Explain how coloured filters interact with white light by absorbing and transmitting specific wavelengths.

Filtering Colors

Wearing tinted glasses changes the color of almost everything that you see. If the lenses are yellow, the world takes on a golden glow. If they are rose-colored, everything looks pinkish. Something similar would occur if you placed a colored, transparent plastic sheet over this white page. The paper would appear to be the same color as the plastic. The plastic sheet and the tinted lenses are filters. A **filter** is a transparent material that selectively transmits light. For example, color filters transmit one or more colors of light but absorb all others. The color of a filter is the color of the light that it transmits.

Figure 11 shows what happens when you look at a colored object through various colored filters. On the left in **Figure 11**, a blue bowl looks blue because it primarily reflects blue light and absorbs more of the other colors of light. If you look at the bowl through a blue filter, as in the center of **Figure 11**, the bowl still looks blue because the filter transmits the reflected blue light. The right image in **Figure 11** shows how the bowl looks when you examine it through a red filter.

Figure 11 The color of the bowl seems to change when it is viewed through different colored filters.

Explain Why does the blue bowl appear to be black when viewed through a red filter?



The bowl appears to be blue in white light.

The bowl appears to be blue when viewed through a blue filter.

The bowl appears to be black when viewed through a red filter.

Question 24a

When white light shines through red glass, the glass _____.

- ☐ A) absorbs all red light
- ☐ B) absorbs all light except red light
- ☐ C) absorbs all green light
- ☐ D) reflects all light except red light

Question 24b

In blue light, a red object would look _____.

- ☐ A) blue
- ☐ B) red
- ☐ C) black
- ☐ D) white

Q1: What is the primary function of a transparent color filter when white light shines on it?

- A) It changes the wavelength of all light passing through it to create a new color.
- B) It selectively transmits certain colors of light while absorbing all other colors.
- C) It reflects all visible light back to the source and transmits nothing.
- D) It magnifies the intensity of the light to make the colors brighter.

Q2: A student looks at a white page through a yellow, transparent plastic sheet. Which of the following correctly describes what the student will observe?

- A) The paper will appear black because the plastic sheet blocks all light.
- B) The paper will appear to be the same color as the plastic sheet (yellow).
- C) The paper will show a rainbow spectrum due to total refraction.
- D) The paper will remain pure white because paper cannot change its color.

Q3: How is the specific color of a transparent filter determined?

- A) By the color of the light that it absorbs.
- B) By the thickness and mass of the plastic material.
- C) By the color of the light that it transmits through it.
- D) By the temperature of the light source hitting it.

Q4: A blue bowl appears completely black when viewed through a red filter. Which statement best explains this phenomenon?

- A) The blue bowl reflects blue light, but the red filter absorbs that blue light and transmits no light to your eyes.
- B) The red filter changes the blue light coming from the bowl into red light.
- C) The blue bowl absorbs the red light coming from the filter and turns black.
- D) Red and blue wavelengths cancel each other out to create a bright green light.

Q5: If you are wearing rose-colored tinted glasses, everything around you looks pinkish. Why does this happen?

- A) The lenses absorb pink light and transmit all other colors.
- B) The lenses transmit pink/rose light to your eyes while absorbing other colors.
- C) The lenses reflect pink light into the environment around you.
- D) The lenses create new wavelengths of light that do not exist in white light.

Q6: Imagine you shine pure green light onto a pure red transparent filter. What will be observed on the other side of the filter?

- A) Bright red light will pass through.
- B) Bright green light will pass through.
- C) A mixture of yellow light will pass through.
- D) No light will pass through, and the filter will appear dark/black.

Q7: A green spotlight is needed for a school theater play, but the school only has a white light lamp. How can the students get a green spotlight using what they learned about filters?

- A) By placing a red filter in front of the white lamp to absorb the green light.
- B) By placing a green filter in front of the white lamp to transmit only green light.
- C) By painting the light bulb black so it reflects green light.
- D) By placing an opaque green block in front of the lamp to block all white light.

Describe image formation in a convex lens and relate ray behavior to image characteristics.

Section: What is a lens?, Convex Lens; Section: Forming images with convex lenses

p. 335; 336

What is a lens?

What do your eyes have in common with cameras and eyeglasses? Each of these things contains at least one lens. A lens is a transparent material with at least one curved surface that causes light rays to bend, or refract, as those rays pass through the lens. The image that a lens forms depends on the shape of the lens. Like curved mirrors, a lens can be convex or concave.

Convex Lenses

A **convex lens** is a lens that is thicker in the middle than at the edges. Its optical axis is an imaginary straight line that is perpendicular to the surface of the lens at its thickest point. When light rays approach a convex lens traveling parallel to its optical axis, the rays are refracted toward the center of the lens, as shown in **Figure 9**.

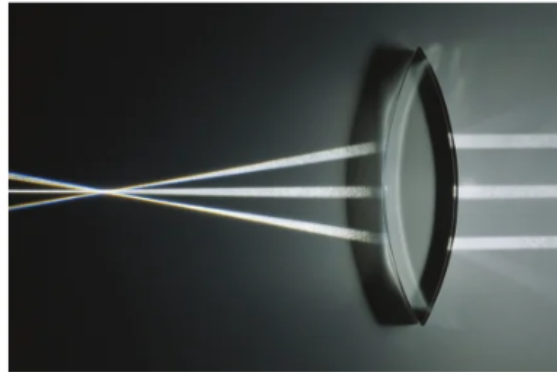


Figure 9 A convex lens bends light inward, toward the optical axis. A light ray that passes straight through the center of the lens does not refract.

Identify the focal point of the lens.

All light rays traveling parallel to the optical axis in **Figure 9** are refracted so they pass through a single point, which is the focal point of the lens. The focal length of the lens depends on the shape of the lens. If the sides of a convex lens are less curved, light rays are bent less. As a result, lenses with flatter sides have longer focal lengths. **Figure 9** also shows that light rays traveling along the optical axis are not bent at all.

Forming images with convex lenses

The type of image that a convex lens forms depends on where the object is relative to the focal point of the lens. If an object is more than two focal lengths from the lens, as in the top panel of **Figure 10**, the image is real, reduced, upside-down (inverted), and on the opposite side of the lens from the object.

As the object moves closer to the lens, the image gets larger. The middle panel of **Figure 10** shows the image formed when the object is between one and two focal lengths from the lens. Now the image is larger than the object but is still upside-down.

When an object is less than one focal length from the lens, as shown in the bottom panel of **Figure 10**, the image becomes an enlarged, virtual image. The image is virtual because the light rays from the object are not converging after they have passed through the lens. When you use a magnifying glass, you move a convex lens so that it is less than one focal length from an object. This causes the image of the object to be magnified.

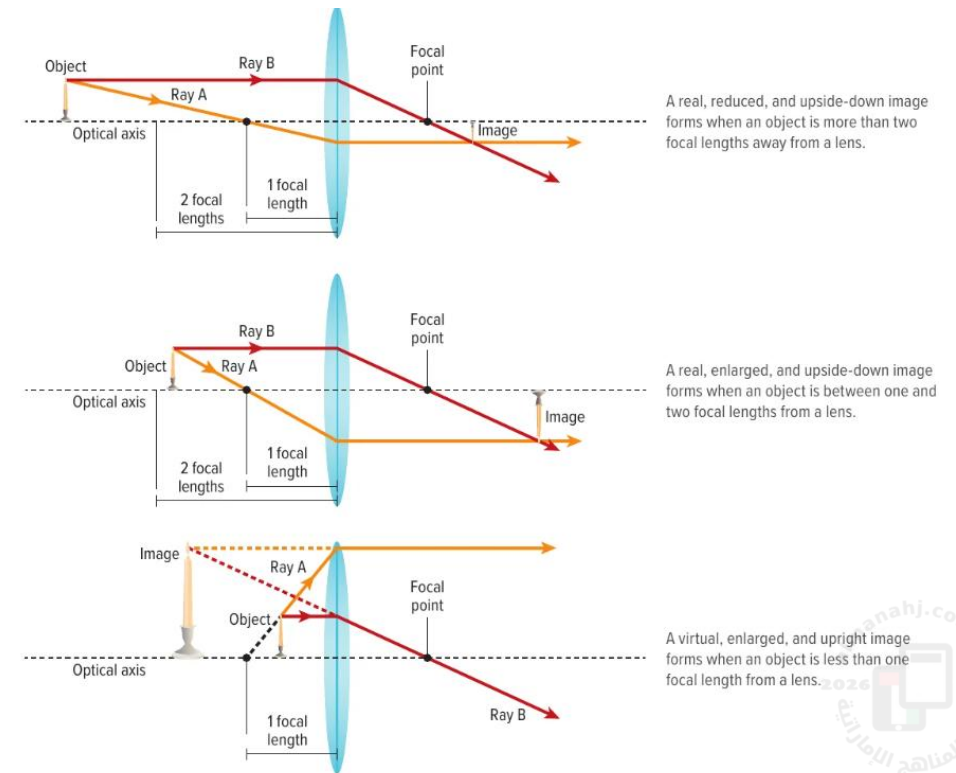
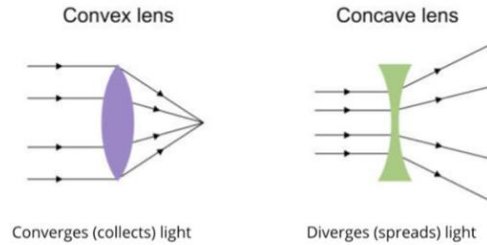


Figure 10 The image that a convex lens forms depends on the relative positions of the lens and the object.

LENSES



Concave lens (diverging)

- **Shape:** thinner in the middle than at the edges.
- **Behaviour:** parallel rays **diverge (spread apart)** after passing through the lens, as if coming from a focal point on the same side as the object.

MIRRORS – IMAGE FORMATION

A mirror is a surface that reflects light to form an image. The shape of the mirror decides what kind of image you see.

Plane mirrors (flat mirrors)

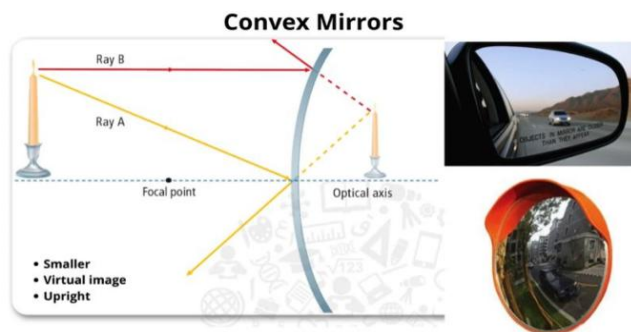
This is the ordinary mirror in your bathroom. The image formed is:

- **Virtual** (cannot be projected onto a screen — it only appears to be *behind* the mirror)
- **Upright** (the right way up)
- **Same size** as the object
- Same distance behind the mirror as the object is in front of it

Convex mirrors (curved outward, like the back of a spoon)

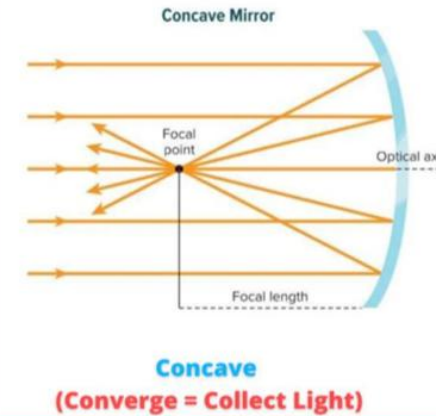
Convex mirrors are **diverging** — they spread parallel rays outward, so the focal point appears *behind* the mirror. A convex mirror **always** produces an image that is:

- **Virtual** (appears behind the mirror)
- **Upright**
- **Smaller (diminished)** than the object



A convex mirror always gives a virtual, upright, smaller image.

Ray Diagrams



- **Pole (P):**
Midpoint of the mirror surface.
- **Principal (Optical) axis:**
Straight line through P and C.
- **Focus / Focal point (F):**
Midpoint between P and C.
- **Focal length (f):**
Distance from P to F.

Concave mirrors (curved inward, like the inside of a spoon)

Concave mirrors are **converging** — they bring parallel rays of light together at the **focal point (F)** in front of the mirror. The image depends on *where the object is placed*:

Object position	Image type	Orientation	Size
Beyond C (beyond 2F)	Real	Inverted	Smaller
Between C and F	Real	Inverted	Larger
At F	No image — reflected rays are parallel	—	—
Between F and the mirror	Virtual	Upright	Larger (magnified)

Q1: Which of the following correctly describes the characteristics of an image formed by an ordinary plane mirror (flat mirror)?

- A) Real, inverted (upside-down), and larger than the object.
- B) Virtual, upright, same size, and the same distance behind the mirror as the object is in front of it.
- C) Real, upright, and smaller (diminished) than the object.
- D) Virtual, inverted, and located exactly at the focal point.

Q2: Concave mirrors are described as "converging". What does this mean for parallel rays of light hitting the mirror?

- A) They spread the parallel rays outward away from the center.
- B) They bring parallel rays of light together at a single point called the focal point (F) in front of the mirror.
- C) They absorb all the light rays and convert them into acoustic waves.
- D) They change the frequency of the light rays to make them invisible.

Q3: Based on the data table for concave mirrors, what type of image is formed when an object is placed between the focal point (F) and the mirror?

- A) Real, inverted, and smaller.
- B) No image is formed because the reflected rays are parallel.
- C) Virtual, upright, and larger (magnified).
- D) Real, inverted, and larger.

Q4: A science student places an object exactly at the focal point (F) of a concave mirror. What will be observed on a screen placed in front of the mirror?

- A) A very sharp, magnified real image.
- B) No image will form because the reflected light rays are completely parallel and never cross.
- C) A small, upright virtual image behind the mirror.
- D) The image will change color to a rainbow spectrum.

Q5: What type of mirror is curved outward (like the back of a spoon), acts as a diverging surface, and always produces a virtual, upright, and smaller (diminished) image?

- A) Plane mirror
- B) Concave mirror
- C) Convex mirror
- D) Flat mirror

Q6: A car manufacturer installs side-view passenger mirrors with a label that reads: "Objects in mirror are closer than they appear". What type of mirror is used here, and why does the object appear further away?

- A) A concave mirror is used because it always creates an enlarged image.
- B) A plane mirror is used because it flips the image upside-down.
- C) A convex mirror is used because it always produces a smaller (diminished) image, making the object look further away than it actually is.
- D) A concave lens is used because it stops light from reflecting.

Q7: What is the physical shape of a concave lens, and how does it affect parallel light rays?

- A) It is thicker in the middle than at the edges and converges light.
- B) It is thinner in the middle than at the edges and diverges (spreads apart) light rays.
- C) It is completely flat on both sides and reflects light backward.
- D) It is curved outward like a ball and absorbs light rays.

Q8: When parallel rays pass through a concave lens, they diverge (spread apart). From where do these spreading rays appear to be coming?

- A) They appear to be coming from a focal point on the opposite side of the lens.
- B) They appear to be coming from the center of the light source itself.
- C) They appear to be coming from a focal point on the same side of the lens as the object.
- D) They do not appear to come from any point because they travel in circles.

Q1: What is a convex lens, and how does it interact with light rays parallel to its optical axis?

- A) It is thinner in the middle than at the edges and bends light outward.
- B) It is thicker in the middle than at the edges and bends light inward toward the optical axis.
- C) It is completely flat on both sides and lets light pass through without refracting.
- D) It is a reflective mirror surface that bounces light backward.

Q2: When light rays traveling parallel to the optical axis pass through a convex lens, they are refracted and meet at a single point. What is this point called?

- A) The optical center
- B) The virtual image point
- C) The focal point
- D) The lens axis

Q3: How does the curvature of a convex lens affect its focal length?

- A) Lenses with more curved sides have longer focal lengths.
- B) Lenses with flatter sides have longer focal lengths because light rays are bent less.
- C) The shape of the lens has no effect on the focal length.
- D) Flat sides cause the focal length to become zero.

Q4: Based on the top panel of Figure 10, if an object is placed more than two focal lengths away from a convex lens, what are the characteristics of the image formed?

- A) Real, reduced, upside-down (inverted), and on the opposite side of the lens.
- B) Virtual, enlarged, upright, and on the same side as the object.
- C) Real, enlarged, upside-down (inverted), and on the same side.
- D) Virtual, reduced, upright, and at the focal point.

Q5: As an object is moved closer to a convex lens (from being far away down to a point between one and two focal lengths), how do the characteristics of the image change?

- A) The image gets smaller and turns upright.
- B) The image gets larger but stays upside-down (inverted).
- C) The image disappears completely.
- D) The image becomes virtual and reduced.

Q6: A student is using a magnifying glass to look at a small insect. Where must the insect (object) be located relative to the convex lens to create an enlarged, virtual, and upright image?

- A) More than two focal lengths away from the lens.
- B) Exactly at two focal lengths from the lens.
- C) Between one and two focal lengths from the lens.
- D) Less than one focal length from the lens.

Q7: Looking at the bottom panel of Figure 10, why is the image considered a virtual image when the object is less than one focal length away?

- A) Because the light rays actually cross each other on the opposite side.
- B) Because the light rays from the object are not converging (spreading apart) after they pass through the lens.
- C) Because the lens blocks all light rays from passing through it.
- D) Because the image is formed upside-down on a screen.

Q8: A student layout two different convex lenses, Lens X and Lens Y. Lens X has very curved, bulging sides, while Lens Y has much flatter sides. If parallel light rays pass through both lenses, which of the following is true?

- A) Lens X will bend the light rays less and have a longer focal length than Lens Y.
- B) Lens Y will bend the light rays less and have a longer focal length than Lens X.
- C) Both lenses will bend the light rays at the exact same angle and have identical focal lengths.
- D) Lens Y will reflect the light rays backward, while Lens X will transmit them without refraction.

A9: Imagine an object is initially placed very far away (more than two focal lengths) from a convex lens. If the object is moved continuously closer to the lens until it sits exactly between one and two focal lengths, what happens to the properties of the formed image?

- A) The image changes from being inverted (upside-down) to being upright.
- B) The image changes from being real to being virtual.
- C) The image remains inverted and real, but its size increases significantly.
- D) The image remains reduced in size but moves to the same side as the object.

Q10: According to the ray diagrams in Figure 10, when an object is placed less than one focal length from a convex lens, why can a real image NOT be formed on a screen on the opposite side?

- A) Because the light rays passing through the lens travel parallel to each other and never meet.
- B) Because the light rays from the object do not converge (they spread apart) after passing through the lens.
- C) Because a convex lens blocks and absorbs all light rays when the object is too close.
- D) Because the light rays reflect off the front surface of the lens and go backward.

Q11: If a light ray passes directly and straight through the exact geometric center of a convex lens along the optical axis, what happens to its direction?

- A) It refracts at a sharp 90-degree angle toward the focal point.
- B) It bends outward away from the center of the lens.
- C) It passes straight through the lens without bending or refracting at all.
- D) It is completely absorbed by the lens and transformed into heat.

Q12: Ahmed is performing a science lab experiment. He sets up a candle (the object) more than two focal lengths away from a convex lens. He places a white paper card on the opposite side of the lens and moves it until a sharp, clear image of the candle flame appears on the card. What will Ahmed observe about the image on the paper card?

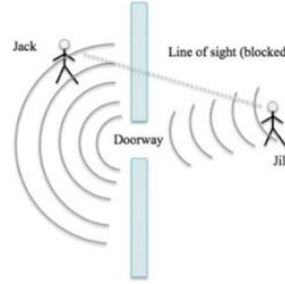
- A) The flame will look larger than the actual candle and will be upright.
- B) The flame will look smaller than the actual candle and will be upside-down (inverted).
- C) The flame will appear as a blurry, upright virtual image that cannot be focused.
- D) No image will appear on the card because the light rays are spreading apart.

Q13: Sarah is using a standard magnifying glass (which contains a convex lens) to read the tiny serial number printed on a smartphone component. To see the numbers clearly, magnified, and upright, she adjusts the distance of the magnifying glass so it is very close to the component. What did Sarah's adjustment achieve?

- A) She positioned the lens so the component is exactly at two focal lengths from the lens.
- B) She positioned the lens so the component is more than two focal lengths away.
- C) She positioned the lens so the component is located at less than one focal length from the lens.
- D) She positioned the lens so it blocks the light rays and reflects them into her eyes.

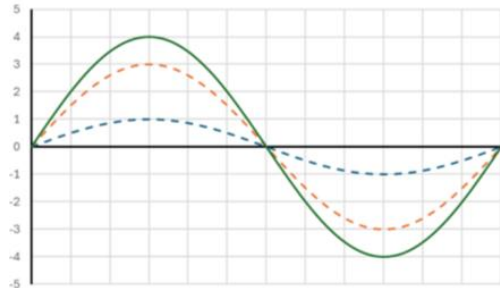
Diffraction

- **Diffraction** is the **bending or spreading of a wave** as it passes around an object or through a narrow opening.
- All waves can diffract.

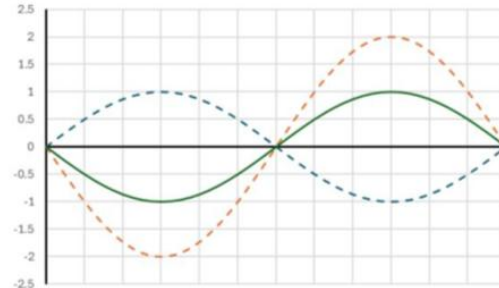


Interference

- **Interference** happens when two waves overlap and combine.
- **Constructive interference**: waves are in step — crests meet crests. The amplitudes **add** together to make a larger wave.
- **Destructive interference**: waves are out of step — a crest meets a trough. The amplitudes partly or fully **cancel**, making a smaller wave.



Constructive Interference



Destructive Interference

Q1: What is the best definition of diffraction?

- The bouncing back of a wave when it hits a smooth, solid surface.
- The bending or spreading of a wave as it passes around an object or through a narrow opening.
- The chemical reaction that occurs when light waves hit a transparent filter.
- The complete absorption of wave energy when passing through open spaces.

Q2: Look at the doorway diagram under the "Diffraction" section. Jack can talk to Jill even though his direct line of sight is completely blocked by the wall. Which property of waves allows Jill to hear his voice?

- Sound waves travel only in perfectly straight lines through solid objects.
- Sound waves completely stop and transform into light energy at the doorway.
- Sound waves diffract, bending and spreading out as they pass through the narrow doorway opening.
- Sound waves cannot diffract; only light waves are capable of this behavior.

Q3: When two waves overlap and combine in such a way that their crests meet crests (in step), their amplitudes add together to make a larger wave.

What is this phenomenon called?

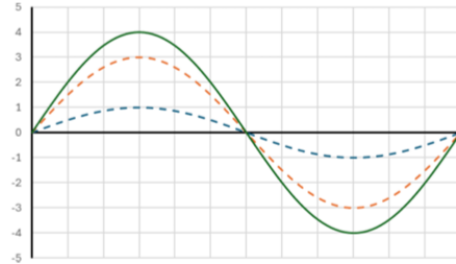
- Destructive interference
- Selective reflection
- Wave refraction
- Constructive interference

Q4: Based on the graphs provided for "Interference", what happens to the resulting wave during destructive interference when waves are out of step (a crest meets a trough)?

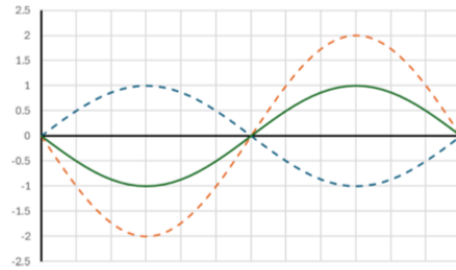
- The amplitudes add together to create a wave that is twice as large.
- The amplitudes partly or fully cancel each other out, making a smaller wave.
- The two waves turn into a solid matter and stop moving entirely.
- The frequency of the wave changes into a different color of light.

Question 16

In each graph, the blue (dashed) wave and the orange (dashed) wave pass through each other and produce the green (full) wave.



- (a) What type of interference is shown in the graph above? Explain your answer.
- (b) For the graph above, what is the amplitude of: (i) the blue wave, (ii) the orange wave, (iii) the green wave? (Give answers in units, e.g. 1 unit, 2 units.)



- (c) What type of interference is shown in the graph above? Explain your answer.
- (d) For the graph above, what is the amplitude of: (i) the blue wave, (ii) the orange wave, (iii) the green wave? (Give answers in units.)

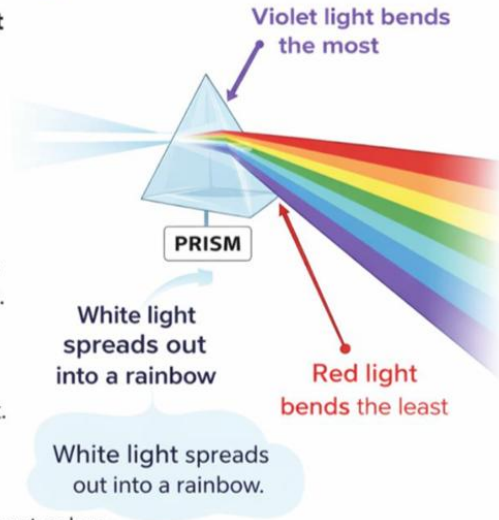
Question 22

Describe how the pitch of a sound changes when the source moves toward a listener and when it moves away from a listener (the Doppler effect).

Dispersion – Splitting White Light

Separating Colors of Light

- ✓ White light is made of many different colors.
- ✓ Each color of light has a different wavelength and frequency.
- ✓ When white light goes through a prism, the colors bend by different amounts.
- ✓ This makes the white light spread out into a rainbow.
- ✓ Violet light bends the most.
- ✓ Red light bends the least.
- ✓ That is why a prism can separate white light into different colors.



- White light is a mixture of **all the colours** of the spectrum.
- A **prism** (or a raindrop) **disperses** white light into the spectrum because each colour (frequency) refracts by a different amount.

Q1: What is the primary reason a triangular prism is able to separate white light into different colors?

- A) The prism absorbs all colors except red and violet light.
- B) White light is made of many colors, and each color refracts (bends) by a different amount when passing through the prism.
- C) The prism heats up the white light and changes its chemical properties.
- D) The prism reflects white light backward without letting it pass through.

Q2: Based on the prism, which color of the visible light spectrum bends the most when it is refracted, and which bends the least?

- A) Red bends the most; Violet bends the least.
- B) Green bends the most; Yellow bends the least.
- C) Violet bends the most; Red bends the least.
- D) All colors bend by the exact same amount.

Q3: Which of the following statements correctly describes the properties of the colors that make up white light?

- A) Every color of light has the exact same wavelength and frequency.
- B) White light is a single, pure color wavelength that cannot be split.
- C) Each color of light has a different wavelength and frequency.
- D) Only red and violet light have frequencies; other colors do not.

Q4: In nature, raindrops can act just like a glass prism to disperse white light into a beautiful rainbow. Why does this happen?

- A) Because raindrops are made of solid glass material.
- B) Because each color (frequency) within the white sunlight refracts by a different amount as it passes through the raindrop.
- C) Because raindrops block all sunlight from reaching the ground.
- D) Because raindrops change the frequency of sound into light.

“With my sincere wishes for success and excellence.”