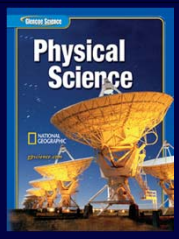
14



CHAPTER RESOURCES

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Unit 3: Energy On the Move

Chapter 14: Mirrors and Lenses

14.1: Mirrors

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CHAPTER RESOURCES

Mirrors

14.1

How do you use light to see?

- When light travels from an object to your eye, you see the object.
- Light can reflect more than once.
- When no light is available to reflect off of objects and into your eye, your eyes cannot see anything.

CHAPTER RESOURCES

Mirrors

14.1

Light Rays

- Light sources send out light waves that travel in all directions.
- These waves spread out from the light source just as ripples on the surface of water spread out from the point of impact of a pebble.

CHAPTER RESOURCES

Mirrors

14.1

Light Rays

- You also could think of the light coming from the source as being many narrow beams of light.
- Each narrow beam of light travels in a straight line and is called a light ray.

CHAPTER RESOURCES

Mirrors

14.1

Light Rays

- Even though light rays can change direction when they are reflected or refracted, your brain interprets images as if light rays travel in a single direction.

CHAPTER RESOURCES

Mirrors

14.1

Seeing Reflections with Plane Mirrors

- Like pools of water, mirrors are smooth surfaces that reflect light to form images.
- You can see yourself as you glance into a quiet pool of water or walk past a shop window.

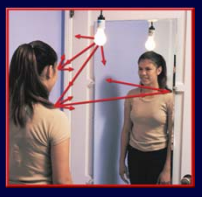
CHAPTER RESOURCES

Mirrors

14.1

Seeing Reflections with Plane Mirrors

- Most of the time, however, you probably look for your image in a flat, smooth mirror called a **plane mirror**.



CHAPTER RESOURCES

Mirrors

14.1

Reflection from Plane Mirrors

- What do you see when you look into a plane mirror? Your reflection appears upright.
- If you were one meter from the mirror, your image would appear to be 1 m behind the mirror, or 2 m from you.

CHAPTER RESOURCES

Mirrors

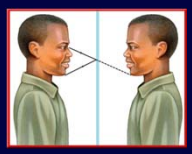
14.1 Reflection from Plane Mirrors

- Your image is what someone standing 2 m from you would see.
- Seeing an image of yourself in a mirror involves two sets of reflections.

Mirrors

14.1 Virtual Images

- Light waves that are reflected off of you travel in all directions.
- Light rays reflected from your chin strike the mirror at different places.
- Then, they reflect off of the mirror in different directions.



Mirrors

14.1 Virtual Images

- Recall that your brain always interprets light rays as if they have traveled in a straight line.
- It doesn't realize that the light rays have been reflected and that they changed direction.

Mirrors

14.1 Virtual Images

- An image like this, which your brain perceives even though no light rays pass through it, is called a **virtual image**.
- The virtual image formed by a plane mirror is always upright and appears to be as far behind the mirror as the object is in front of it.

Mirrors

14.1 Concave Mirrors

- If the surface of a mirror is curved inward, it is called a **concave mirror**.
- Concave mirrors, like plane mirrors, reflect light waves to form images.
- The difference is that the curved surface of a concave mirror reflects light in a unique way.

Mirrors

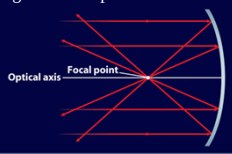
14.1 Features of Concave Mirrors

- A concave mirror has an optical axis.
- The **optical axis** is an imaginary straight line drawn perpendicular to the surface of the mirror at its center.
- Every light ray traveling parallel to the optical axis as it approaches the mirror is reflected through a point on the optical axis called the **focal point**.

Mirrors

14.1 Features of Concave Mirrors

- When light rays travel toward the mirror parallel to the optical axis, they reflect through the focal point.



Mirrors

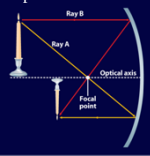
14.1 Features of Concave Mirrors

- On the other hand, if a light ray passes through the focal point before it hits the mirror, it is reflected parallel to the optical axis.
- The distance from the center of the mirror to the focal point is called the **focal length**.

Mirrors

14.1 How a Concave Mirror Works

- The image that is formed by a concave mirror changes depending on where the object is located relative to the focal point of the mirror.
- Rays A and B start from the same place on the candle, travel in different directions, and meet again on the reflected image.



Mirrors

14.1 How a Concave Mirror Works

- The place where Ray A and Ray B meet after they are reflected forms a point on the flame of the reflected image.
- More points on the reflected image can be located in this way.
- From each point on the candle, one ray can be drawn that passes through the focal point and is reflected parallel to the optical axis.

CHAPTER RESOURCES END

Mirrors

14.1 How a Concave Mirror Works

- Another ray can be drawn that travels parallel to the optical axis and passes through the focal point after it is reflected.
- The point where the two rays meet is on the reflected image.

CHAPTER RESOURCES END

Mirrors

14.1 Real Images

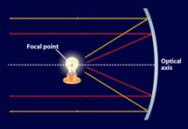
- The image that is formed by the concave mirror is not virtual.
- Rays of light pass through the location of the image.
- A **real image** is formed when light rays converge to form the image.
- When an object is farther from a concave mirror than twice the focal length, the image that is formed is real, smaller, and upside down, or inverted.

CHAPTER RESOURCES END

Mirrors

14.1 Creating Light Beams

- What happens if you place an object exactly at the focal point of the concave mirror?
- If the object is at the focal point, the mirror reflects all light rays parallel to the optical axis.
- No image forms because the rays never meet.



CHAPTER RESOURCES END

Mirrors

14.1 Creating Light Beams

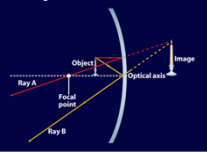
- A light placed at the focal point is reflected in a beam.
- Car headlights, flashlights, lighthouses, spotlights, and other devices use concave mirrors in this way to create concentrated light beams of nearly parallel rays.

CHAPTER RESOURCES END

Mirrors

14.1 Mirrors That Magnify

- The image formed by a concave mirror changes again when you place an object between it and its focal point.
- The location of the reflected image again can be found by drawing two rays from each point.



CHAPTER RESOURCES END

Mirrors

14.1 Mirrors That Magnify

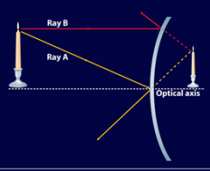
- Just as it does with a plane mirror, your brain interprets the diverging rays as if they came from one point behind the mirror.
- Because no light rays are behind the mirror where the image seems to be, the image formed is virtual. The image also is upright and enlarged.

CHAPTER RESOURCES END

Mirrors

14.1 Convex Mirrors

- A mirror that curves outward like the back of a spoon is called a **convex mirror**.
- Light rays that hit a convex mirror diverge, or spread apart, after they are reflected.

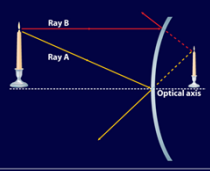


CHAPTER RESOURCES END

Mirrors

14.1 Convex Mirrors

- The reflected rays diverge and never meet, so the image formed by a convex mirror is a virtual image.
- The image also is always upright and smaller than the actual object is.



CHAPTER RESOURCES END

Mirrors

14.1

Uses of Convex Mirrors

- Because convex mirrors cause light rays to diverge, they allow large areas to be viewed.
- As a result, a convex mirror is said to have a wide field of view.

Mirrors

14.1

Mirror Images

- The different shapes of plane, concave, and convex mirrors cause them to reflect light in distinct ways. Each type of mirror has different uses.

Images Formed by Mirrors

Mirror Shape	Position of Object	Virtual/Real	Image Created Upright/Upside Down	Size
Plane		virtual	upright	same as object
Concave	Object more than two focal lengths from mirror	real	upside down	smaller than object
	Object between one and two focal lengths	real	upside down	larger than object
	Object at focal point	none	none	none
	Object within focal length	virtual	upright	larger than object
Convex		virtual	upright	smaller than object

Section Check

14.1

Question 1

A _____ mirror curves inward.

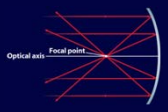
A. concave
B. convex
C. obtuse
D. plane

Section Check

14.1

Answer

The answer is A. A concave mirror curves inward and forms a real image. A convex mirror curves outward and forms a virtual image.



Section Check

14.1

Question 2

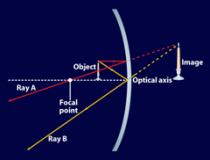
What is the difference between a real image and a virtual image?

Section Check

14.1

Answer

Light rays converge and pass through a real image; light rays do not converge at a virtual image.



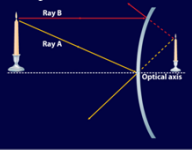
Section Check

14.1

Question 3

What type of mirror is pictured here?

A. plane
B. convex
C. concave
D. focal



Section Check

14.1

Answer

The answer is B. A convex mirror produces images that are virtual, upright and smaller than the object.

Lenses

14.2

What is a lens?

- A lens is a transparent material with at least one curved surface that causes light rays to bend, or refract, as they pass through.
- The image that a lens forms depends on the shape of the lens.
- Like curved mirrors, a lens can be convex or concave.

Lenses

14.2 Convex Lenses

- A **convex lens** 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.

CHAPTER RESOURCES END

Lenses

14.2 Convex Lenses

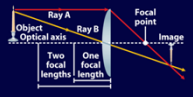
- All light rays traveling parallel to the optical axis are refracted so they pass through a single point, which is the focal point of the lens.
- If the sides of a convex lens are less curved, light rays are bent less.
- As a result, lenses with flatter sides have longer focal lengths.

CHAPTER RESOURCES END

Lenses

14.2 Forming Images with a Convex Lens

- The type of image a convex lens forms depends on where the object is relative to the focal point of the lens.
- When the candle is more than two focal lengths away from the lens, its image is real, reduced, and upside down.

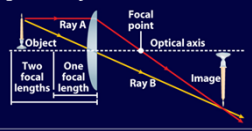


CHAPTER RESOURCES END

Lenses

14.2 Forming Images with a Convex Lens

- When the candle is between one and two focal lengths from the lens, its image is real, enlarged, and upside down.

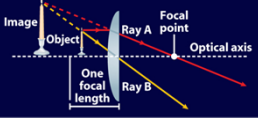


CHAPTER RESOURCES END

Lenses

14.2 Forming Images with a Convex Lens

- When the candle is less than one focal length from the lens, its image is virtual, enlarged, and upright.

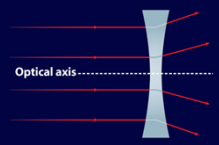


CHAPTER RESOURCES END

Lenses

14.2 Concave Lenses

- A **concave lens** is thinner in the middle and thicker at the edges.
- Light rays that pass through a concave lens bend outward away from the optical axis.



CHAPTER RESOURCES END

Lenses

14.2 Concave Lenses

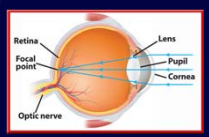
- The rays spread out and never meet at a focal point, so they never form a real image.
- The image is always virtual, upright, and smaller than the actual object is.

CHAPTER RESOURCES END

Lenses

14.2 Lenses and Eyesight

- Light enters your eye through a transparent covering on your eyeball called the **cornea** (KOH nee uh).
- The cornea causes light rays to bend so that they converge.

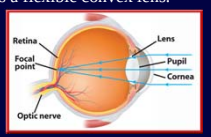


CHAPTER RESOURCES END

Lenses

14.2 Lenses and Eyesight

- The light then passes through an opening called the pupil.
- Behind the pupil is a flexible convex lens.
- The lens helps focus light rays so that a sharp image is formed on your retina.



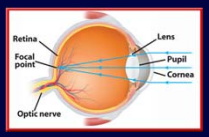
CHAPTER RESOURCES END

Lenses

14.2

Lenses and Eyesight

- The **retina** is the inner lining of your eye.
- It has cells that convert the light image into electrical signals, which are then carried along the optic nerve to your brain to be interpreted.



CHAPTER RESOURCES

Lenses

14.2

Focusing on Near and Far

- For an image to be formed on the retina, the focal length of the lens needs to be able to change as the distance of the object changes.
- The lens in your eye is flexible, and muscles attached to it change its shape and its focal length.
- This is why you can see objects that are near and far away.

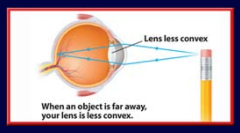
CHAPTER RESOURCES

Lenses

14.2

Focusing on Near and Far

- As an object gets farther from your eye, the focal length of the lens has to increase.
- The muscles around the lens stretch it so it has a less convex shape.



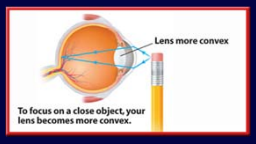
CHAPTER RESOURCES

Lenses

14.2

Focusing on Near and Far

- But when you focus on a nearby object, these muscles make the lens more curved, causing the focal length to decrease.



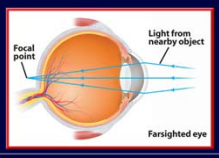
CHAPTER RESOURCES

Lenses

14.2

Vision Problems—Farsightedness

- If you can see distant objects clearly but can't bring nearby objects into focus, then you are farsighted.



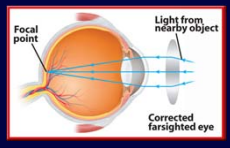
CHAPTER RESOURCES

Lenses

14.2

Farsightedness

- To correct the problem, convex lenses cause incoming light rays to converge before they enter the eye.



CHAPTER RESOURCES

Lenses

14.2

Astigmatism

- Another vision problem, called astigmatism occurs when the surface of the cornea is curved unevenly.
- When people have astigmatism, their corneas are more oval than round in shape.
- Astigmatism causes blurry vision at all distances.

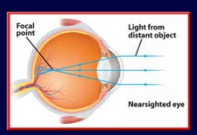
CHAPTER RESOURCES

Lenses

14.2

Nearsightedness

- If you have nearsighted friends, you know that they can see clearly only when objects are nearby.
- When a nearsighted person looks at distant objects, the light rays from the objects are focused in front of the retina.



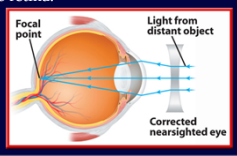
CHAPTER RESOURCES

Lenses

14.2

Nearsightedness

- A concave lens in front of a nearsighted eye will diverge the light rays so they are focused on the retina.



CHAPTER RESOURCES

Section Check

14.2

Question 1

A _____ lens focuses light rays at a focal point.

A. concave
B. convex
C. flat
D. plane

Section Check

14.2

Answer

The answer is B. Convex lenses focus light rays at a focal point.

Section Check

14.2

Question 2

What type of lens refracts light rays away from the optical axis?

Section Check

14.2

Answer

Concave lenses are thicker at the edges and refract light rays away from the optical axis.

Section Check

14.2

Question 3

In nearsightedness, the image forms _____ the retina and a _____ lens can be used to correct it.

A. behind, concave
B. behind, convex
C. in front of, concave
D. in front of, convex

Section Check

14.2

Answer

The answer is C. The image forms in front of the retina and a concave lens corrects it.

Optical Instruments

14.3

Telescopes

- When you look at an object, only some of the light reflected from its surface enters your eye.
- As the object moves farther away, the amount of light entering your eye decreases, as shown.

Optical Instruments

14.3

Telescopes

- A telescope uses a lens or a concave mirror that is much larger than your eye to gather more of the light from distant objects.
- As a result, objects such as distant galaxies appear much brighter, more detail can be seen when the image is magnified.

Optical Instruments

14.3

Refracting Telescopes

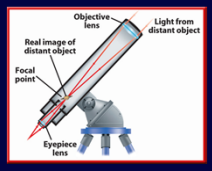
- One common type of telescope is the refracting telescope.
- A simple **refracting telescope** uses two convex lenses to gather and focus light from distant objects.

Optical Instruments

14.3

Refracting Telescopes

- Light from a distant object passes through an objective lens and an eyepiece lens in a refracting telescope.
- The two lenses produce a large virtual image.



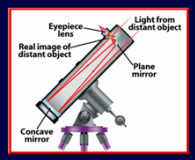
CHAPTER RESOURCES

Optical Instruments

14.3

Reflecting Telescopes

- Most large telescopes today are reflecting telescopes.
- A **reflecting telescope** uses a concave mirror, a plane mirror, and a convex lens to collect and focus light from distant objects.



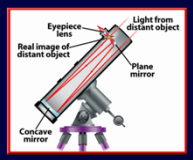
CHAPTER RESOURCES

Optical Instruments

14.3

Reflecting Telescopes

- Light from a distant object enters one end of the telescope and strikes a concave mirror at the opposite end.
- The light reflects off of this mirror and converges.



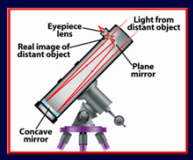
CHAPTER RESOURCES

Optical Instruments

14.3

Reflecting Telescopes

- Before it converges at a focal point, the light hits a plane mirror that is placed at an angle within the telescope tube.



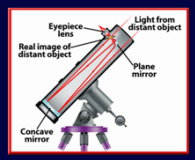
CHAPTER RESOURCES

Optical Instruments

14.3

Reflecting Telescopes

- The light is reflected from the plane mirror toward the telescope's eyepiece.
- The light rays converge at the focal point, creating a real image of the distant object.



CHAPTER RESOURCES

Optical Instruments

14.3

Telescopes in Space

- Earth's atmosphere blurs the view of objects in space.
- To overcome the blurriness of humans' view into space, the National Aeronautics and Space Administration (NASA) built a telescope called the *Hubble Space Telescope* to be placed into space high above Earth's atmosphere.

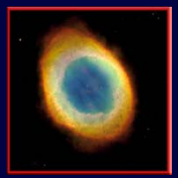
CHAPTER RESOURCES

Optical Instruments

14.3

Telescopes in Space

- The *Hubble Space Telescope* has produced images much sharper and more detailed than the largest telescopes on Earth can.



CHAPTER RESOURCES

Optical Instruments

14.3

Telescopes in Space

- The *Hubble* telescope is a type of reflecting telescope that uses two mirrors to collect and focus light to form an image.
- The primary mirror in the telescope is 2.4 m across.

CHAPTER RESOURCES

Optical Instruments

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Microscopes

- A **microscope** uses two convex lenses with relatively short focal lengths to magnify small, close objects.
- A microscope, like a telescope, has an objective lens and an eyepiece lens. However, it is designed differently because the objects viewed are close to the lens.

CHAPTER RESOURCES

Optical Instruments

14.3

Microscopes

- Play this animation to see how a microscope works.

MAC OSX users click here to view.

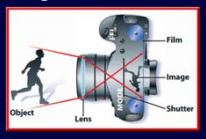
CHAPTER RESOURCES

Optical Instruments

14.3

Cameras

- When you take a picture with a camera, a shutter opens to allow light to enter the camera for a specific length of time.
- The light reflected off your subject enters the camera through an opening called the aperture.



CHAPTER RESOURCES

Optical Instruments

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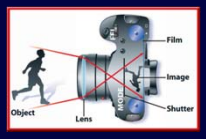
Cameras

- It passes through the camera lens, which focuses the image on the film.
- The image is real, inverted, and smaller than the actual object.



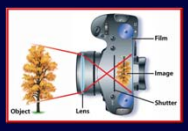
CHAPTER RESOURCES

Optical Instruments

14.3

Wide-Angle Lenses

- Some lenses have short focal lengths that produce a relatively small image of the object but have a wide field of view.
- These lenses are called wide-angle lenses, and they must be placed close to the film to form a sharp image with their short focal length.



CHAPTER RESOURCES

Optical Instruments

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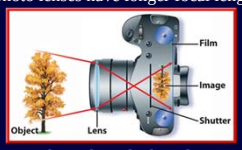
Telephoto Lenses

- Telephoto lenses have longer focal lengths.



- The image through a telephoto lens seems enlarged and closer than it actually is.

CHAPTER RESOURCES

Section Check

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Question 1

A(n) _____ telescope uses two convex lenses to gather and focus light from distant objects.

A. electron
B. refracting
C. reflecting
D. space

CHAPTER RESOURCES

Section Check

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Answer

The answer is B. A refracting telescope uses two convex lenses to gather and focus light.

CHAPTER RESOURCES

Section Check

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Question 2

How is a microscope similar to a refracting telescope?

CHAPTER RESOURCES

Section Check

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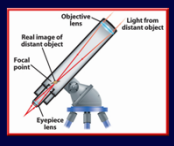
Answer

They both use two convex lenses. The objective lenses form real images within the instrument and the eyepiece lenses create virtual, enlarged images.



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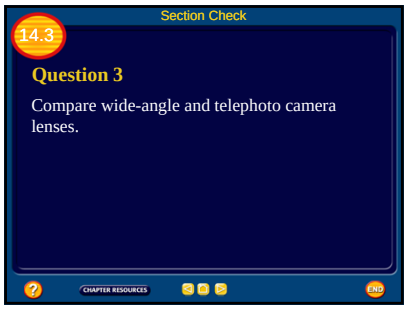
Section Check
14.3
Question 3
Compare wide-angle and telephoto camera lenses.
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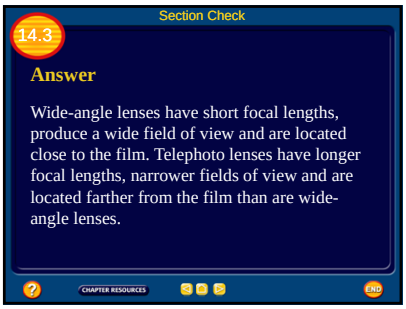
END


Section Check
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Answer
Wide-angle lenses have short focal lengths, produce a wide field of view and are located close to the film. Telephoto lenses have longer focal lengths, narrower fields of view and are located farther from the film than are wide-angle lenses.
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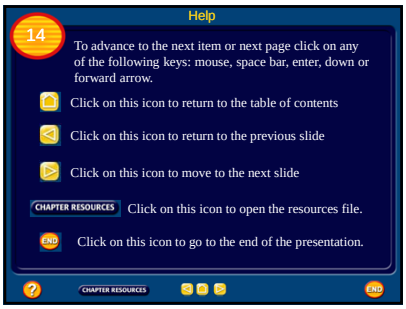
END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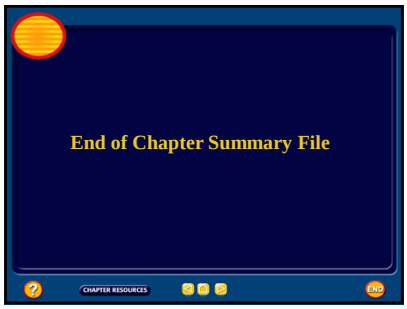
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