

13

Physical Science

NATIONAL GEOGRAPHIC

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CHAPTER RESOURCES

END

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CHAPTER RESOURCES

END

The Behavior of Light

13.1 Light and Matter

- What you see depends on the amount of light in the room and the color of the objects.
- For you to see an object, it must reflect some light back to your eyes.

CHAPTER RESOURCES

END

The Behavior of Light

13.1 Opaque, Transparent, and Translucent

- Objects can absorb light, reflect light, and transmit light—allow light to pass through them.
- The type of matter in an object determines the amount of light it absorbs, reflects, and transmits.

CHAPTER RESOURCES

END

The Behavior of Light

13.1 Opaque, Transparent, and Translucent

- **Opaque** (oh PAYK) material only absorbs and reflects light—no light passes through it. 🗣️

CHAPTER RESOURCES

END

The Behavior of Light

13.1 Opaque, Transparent, and Translucent

- Materials that allow some light to pass through them are described as **translucent** (trans LEW sunt). 🗣️
- You cannot see clearly through translucent materials.


CHAPTER RESOURCES

END

The Behavior of Light

13.1 **Opaque, Transparent, and Translucent**

- **Transparent** materials transmit almost all the light striking them, so you can see objects clearly through them.
- Only a small amount of light is absorbed and reflected.



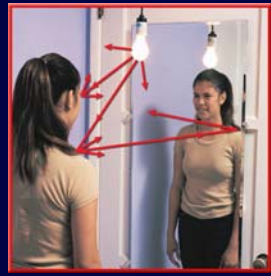
CHAPTER RESOURCES

END

The Behavior of Light

13.1 **Reflection of Light**

- For you to see your reflection in a mirror, light has to reflect off you, hit the mirror, and reflect off the mirror into your eye.
- Reflection occurs when a light wave strikes an object and bounces off.



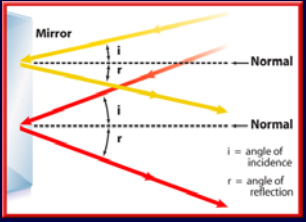
CHAPTER RESOURCES

END

The Behavior of Light

13.1 **The Law of Reflection**

- Because light behaves as a wave, it obeys the law of reflection.
- According to the law of reflection, light is reflected so that the angle of incidence always equals the angle of reflection.



CHAPTER RESOURCES

END

The Behavior of Light

13.1 **Regular and Diffuse Reflection**

- A smooth, even surface like that of a pane of glass produces a sharp image by reflecting parallel light waves in only one direction.
- Reflection of light waves from a smooth surface is regular reflection.

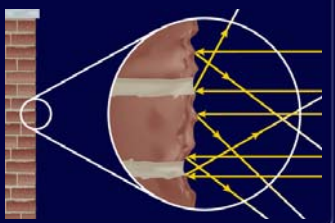
CHAPTER RESOURCES

END

The Behavior of Light

13.1 **Regular and Diffuse Reflection**

- A brick wall has an uneven surface that causes incoming parallel light waves to be reflected in many directions.
- Reflection of light from a rough surface is diffuse reflection.



CHAPTER RESOURCES

END

The Behavior of Light

13.1 **Regular and Diffuse Reflection**

- A metal pot might seem smooth, but at high magnification, the surface shows rough spots.
- To cause a regular reflection, the roughness of the surface must be less than the wavelengths it reflects.

CHAPTER RESOURCES

END

13.1

Refraction of Light

- Refraction is caused by a change in the speed of a wave when it passes from one material to another.
- If the light wave is traveling at an angle and the speed that light travels is different in the two materials, the wave will be bent, or refracted.



CHAPTER RESOURCES



13.1

The Index of Refraction

- The amount of bending that takes place depends on the speed of light in both materials.
- The greater the difference is, the more the light will be bent as it passes at an angle from one material to the other.



CHAPTER RESOURCES



13.1

The Index of Refraction

- Every material has an **index of refraction**—a property of the material that indicates how much the speed of light in the material is reduced.
- The larger the index of refraction, the more light is slowed down in the material.



CHAPTER RESOURCES



13.1

Prisms

- Wavelengths of visible light range from the longer red waves to the shorter violet waves.
- White light, such as sunlight, is made up of this whole range of wavelengths.



CHAPTER RESOURCES



13.1

Prisms

- When white light passes through a prism, the triangular prism refracts the light twice—once when it enters the prism and again when it leaves the prism and reenters the air.



CHAPTER RESOURCES



13.1

Prisms

- Because the longer wavelengths of light are refracted less than the shorter wavelengths are, red light is bent the least.
- As a result of these different amounts of bending, the different colors are separated when they emerge from the prism.

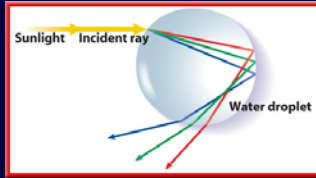


CHAPTER RESOURCES



13.1 Rainbows

- Like prisms, rain droplets also refract light.
- The refraction of the different wavelengths can cause white light from the Sun to separate into the individual colors of visible light.



CHAPTER RESOURCES



END

13.1 Rainbows

- In a rainbow, the human eye usually can distinguish only about seven colors clearly.
- In order of decreasing wavelength, these colors are red, orange, yellow, green, blue, indigo, and violet.



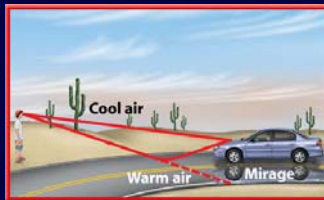
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END

13.1 Mirage

- A **mirage** is an image of a distant object produced by the refraction of light through air layers of different densities.
- Mirages result when the air at ground level is much warmer or cooler than the air above it.



CHAPTER RESOURCES



END

13.1 Mirage

- The density of air increases as air cools.
- Light waves travel slower as the density of air increases, so that light travels slower in cooler air.
- As a result, light waves refract as they pass through air layers with different temperatures.



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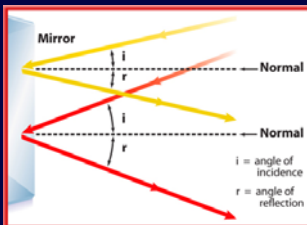


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13.1

Question 1

What is the law of reflection?



CHAPTER RESOURCES



END

13.1

Answer

According to the law of reflection, the angle at which a light wave strikes a surface is the same as the angle at which it is reflected.



CHAPTER RESOURCES



END

Section Check

13.1

Question 2

What happens to light waves that strike an object?

Answer

Light waves that strike objects can be absorbed, reflected, or transmitted.

END

Section Check

13.1

Question 3

What is the difference between refraction and reflection?

END

Section Check

13.1

Answer


Refraction occurs if a light wave changes speed in moving from one material to another. Reflection occurs when light waves are returned or thrown back from a surface.

END

Light and Color

13.2 **Colors**

- An object's color depends on the wavelengths of light it reflects.
- You know that white light is a blend of all colors of visible light.
- This image shows white light striking a green leaf. Only the green light is reflected to your eyes.



END

Light and Color

13.2 **Colors**

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

END

Light and Color

13.2 **Colored Filters**


- Wearing tinted glasses changes the color of almost everything you look at.
- Something similar would occur if you placed a colored, clear plastic sheet over this white page.
- The paper would appear to be the same color as the plastic.

END

Light and Color

13.2 Colored Filters

- The plastic sheet and the tinted lenses are filters.
- A filter is a transparent material that transmits one or more colors of light but absorbs all others.



Color Filters


CHAPTER RESOURCES

END

Light and Color

13.2 Seeing Color

- At a busy intersection, traffic safety depends on your ability to detect immediate color changes.
- How do you see colors?



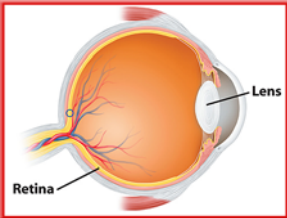
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END

Light and Color

13.2 Light and the Eye

- In a healthy eye, light enters and is focused on the retina, an area on the inside of your eyeball.
- The retina is made up of two types of cells that absorb light.



CHAPTER RESOURCES

END

Light and Color

13.2 Light and the Eye

- When these cells absorb light energy, chemical reactions convert light energy into nerve impulses that are transmitted to the brain.
- One type of cell in the retina, called a cone, allows you to distinguish colors and detailed shapes of objects.
- Cones are most effective in daytime vision.

CHAPTER RESOURCES

END

Light and Color

13.2 Cones and Rods

- Your eyes have three types of cones, each of which responds to a different range of wavelengths.
- Red cones respond to mostly red and yellow, green cones respond to mostly yellow and green, and blue cones respond to mostly blue and violet.
- The second type of cell, called a rod, is sensitive to dim light and is useful for night vision.


CHAPTER RESOURCES

END

Light and Color

13.2 Interpreting Color

- Why does a banana look yellow?
- The light reflected by the banana causes the cone cells that are sensitive to red and green light to send signals to your brain.



CHAPTER RESOURCES

END

13.2

Color Blindness

- If one or more of your sets of cones did not function properly, you would not be able to distinguish between certain colors.
- Most people who are said to be color-blind are not truly blind to color, but they have difficulty distinguishing between a few colors, most commonly red and green.




CHAPTER RESOURCES



END

13.2

Mixing Colors

- A **pigment** is a colored material that is used to change the color of other substances. 
- The color of a pigment results from the different wavelengths of light that the pigment reflects.



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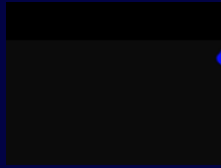


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13.2

Mixing Colored Lights

- All the colors you see can be made by mixing three colors of light.
- These three colors—red, green, and blue—are the primary colors of light.



Click image to play movie



CHAPTER RESOURCES



END

13.2

Mixing Colored Lights

- When mixed together in equal amounts, they produce white light.
- Mixing the primary colors in different proportions can produce the colors you see.



CHAPTER RESOURCES



END

13.2

Paint Pigments

- Paints are made with pigments.
- Paint pigments usually are made of chemical compounds such as titanium oxide, a bright white pigment, and lead chromate, which is used for painting yellow lines on highways.



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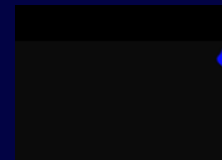


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13.2

Mixing Pigments

- You can make any pigment color by mixing different amounts of the three primary pigments—magenta (bluish red), cyan (greenish blue), and yellow.
- A primary pigment's color depends on the color of light it reflects.



Click image to play movie



CHAPTER RESOURCES



END

13.2

Mixing Pigments

- Pigments both absorb and reflect a range of colors in sending a single color message to your eye.
- The color of a mixture of two primary pigments is determined by the primary colors of light that both pigments reflect.



CHAPTER RESOURCES



END

13.2

Mixing Pigments

- Primary pigment colors combine to produce black.
- Because black results from the absence of reflected light, the primary pigments are called subtractive colors.



CHAPTER RESOURCES



END

13.2

Question 1

An object's color depends on the _____ it reflects.



CHAPTER RESOURCES



END

13.2

Answer

An object's color depends on the wavelengths of light it reflects. If an object absorbs all wavelengths of visible light except green, the object appears green.



CHAPTER RESOURCES



END

13.2

Question 2

What are the two types of light-detecting cells in the eye?

Answer

The two types of light-detecting cells that make up the retina are the rods and cones.



CHAPTER RESOURCES



END

13.2

Question 3

What is the appearance of the three primary colors of pigment when they are mixed?

- black
- brown
- grey
- white



CHAPTER RESOURCES




END

Section Check

13.2

Answer

The answer is A. The three primary colors of pigment are magenta, cyan and yellow, and appear black when they are mixed.



END

Producing Light

13.3 **Incandescent Lights**

- Most of the lightbulbs in your house probably produce **incandescent light**, which is generated by heating a piece of metal until it glows.




END

Producing Light

13.3 **Incandescent Lights**

- Inside an incandescent lightbulb is a small wire coil, called a filament, which usually is made of tungsten metal.



END

Producing Light

13.3 **Incandescent Lights**

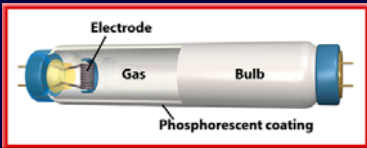
- When an electric current flows in the filament, the electric resistance of the metal causes the filament to become hot enough to give off light.

END

Producing Light

13.3 **Fluorescent Lights**

- A fluorescent bulb, like the one shown is filled with a gas at low pressure.
- The inside of the bulb is coated with phosphors that emit visible light when they absorb ultraviolet radiation.
- The tube also contains electrodes at each end.

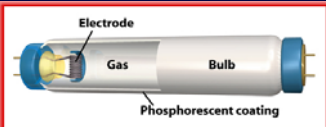


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Producing Light

13.3 **Fluorescent Lights**

- Electrons are given off when the electrodes are connected in a circuit.
- When these electrons collide with the gas atoms, ultraviolet radiation is emitted.
- The phosphors on the inside of the bulb absorb this radiation and give off visible light.



END

13.3

Efficient Lighting

- A **fluorescent light** uses phosphors to convert ultraviolet radiation to visible light.
- Fluorescent lights use as little as one fifth the electrical energy to produce the same amount of light as incandescent bulbs.



CHAPTER RESOURCES



END

13.3

Efficient Lighting

- Fluorescent bulbs also last much longer than incandescent bulbs.
- This higher efficiency can mean lower energy costs over the life of the bulb.



CHAPTER RESOURCES



END

13.3

Neon Lights

- The vivid, glowing colors of neon lights make them a popular choice for signs and eye-catching decorations on buildings.
- These lighting devices are glass tubes filled with gas, typically neon, and work similarly to fluorescent lights.



CHAPTER RESOURCES



END

13.3

Neon Lights

- When an electric current flows through the tube, electrons collide with the gas molecules.
- In this case, however, the collisions produce visible light.
- If the tube contains only neon, the light is bright red. Different colors can be produced by adding other gases to the tube.



CHAPTER RESOURCES



END

13.3

Sodium-Vapor Lights

- Inside a sodium-vapor lamp is a tube that contains a mixture of neon gas, a small amount of argon gas, and a small amount of sodium metal.
- When the lamp is turned on, the gas mixture becomes hot.
- The hot gases cause the sodium metal to turn to vapor, and the hot sodium vapor emits a yellow-orange glow.



CHAPTER RESOURCES



END

13.3

Tungsten-Halogen Lights

- These lights have a tungsten filament inside a quartz bulb or tube.
- The tube is filled with a gas that contains one of the halogen elements, such as fluorine or chlorine.



CHAPTER RESOURCES



END

13.3

Tungsten-Halogen Lights

- The presence of this gas enables the filament to become much hotter than the filament in an ordinary incandescent bulb.
- As a result, the light is much brighter and also lasts longer.



CHAPTER RESOURCES



END

13.3

Lasers

- A laser's light begins when a number of light waves are emitted at the same time.
- To achieve this, a number of identical atoms each must be given the same amount of energy.
- When they release their energy, each atom sends off an identical light wave.



CHAPTER RESOURCES



END

13.3

Lasers

- This light wave is reflected between two facing mirrors at opposite ends of the laser.
- One of the mirrors is coated only partially with reflective material, so it reflects most light but allows some to get through.
- Some emitted light waves travel back and forth between the mirrors many times, stimulating other atoms to emit identical light waves also.



CHAPTER RESOURCES



END

13.3

Lasers

- Lasers can be made with many different materials, including gases, liquids, and solids.
- One of the most common is the helium-neon laser, which produces a beam of red light.




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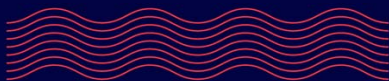


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13.3

Coherent Light

- **Coherent light** is light of only one wavelength that travels with its crests and troughs aligned. 



- The beam does not spread out because all the waves travel in the same direction.




CHAPTER RESOURCES



END

13.3

Incoherent Light

- **Incoherent light** can contain more than one wavelength, and its electromagnetic waves are not aligned. 



- The waves don't travel in the same direction, so the beam spreads out.
- The intensity of the light is much less than that of the laser beam.



CHAPTER RESOURCES



END

13.3

Using Lasers

- A laser beam is narrow and does not spread out as it travels over long distances. So lasers can apply large amounts of energy to small areas.



CHAPTER RESOURCES



END

13.3

Using Lasers

- In industry, powerful lasers are used for cutting and welding materials.
- Surveyors and builders use lasers for measuring and leveling.



CHAPTER RESOURCES



END

13.3

Lasers in Medicine

- Lasers are routinely used to remove cataracts, reshape the cornea, and repair the retina.
- In the eye and other parts of the body, surgeons can use lasers in place of scalpels to cut through body tissues.
- The energy from the laser seals off blood vessels in the incision and reduces bleeding.



CHAPTER RESOURCES



END

13.3

Compact Discs

- When a CD is produced, the information is burned into the surface of the disc with a laser.
- The laser creates millions of tiny pits in a spiral pattern that starts at the center of the disc and moves out to the edge.



CHAPTER RESOURCES

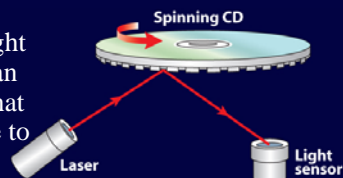


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13.3

Compact Discs

- A CD player also uses a laser to read the disc.
- As the laser beam strikes a pit or flat spot, different amounts of light are reflected to a light sensor.
- The reflected light is converted to an electric signal that the speakers use to create sound.



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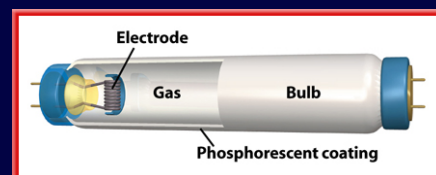


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13.3

Question 1

What is the difference between incandescent and fluorescent light?



CHAPTER RESOURCES



END

Section Check

13.3

Answer

Incandescent light is generated by heating a piece of metal until it glows. Fluorescent light bulbs are coated inside with phosphors. Ultraviolet radiation is emitted inside the bulb and causes the phosphors to give off visible light.

END

Section Check

13.3

Question 2

What is one advantage of using fluorescent light bulbs instead of incandescent bulbs?

Answer

The fluorescent bulbs are more efficient, which could reduce the amount of fossil fuels burned to generate electricity.

END

Section Check

13.3

Question 3

_____ is light of only one wavelength that travels with its crests and troughs aligned.

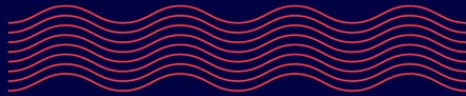
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Section Check

13.3

Answer

Coherent light is light of only one wavelength that travels with its crests and troughs aligned. Laser light is one example of coherent light.




The diagram shows several parallel, in-phase red wavy lines representing light waves that are coherent.

END

Using Light

13.4 **Polarized Light**

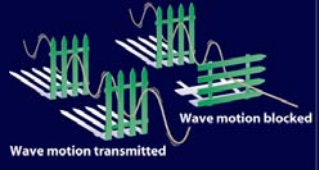
- You can make transverse waves in a rope vibrate in any direction—horizontal, vertical, or anywhere in between.
- Light also is a transverse wave and can vibrate in any direction.
- In **polarized light**, however, the waves vibrate in only one direction. 

END

Using Light

13.4 **Polarizing Filters**

- A polarizing filter acts like a group of parallel slits. Only light waves vibrating in the same direction as the slits can pass through.
- If a second polarizing filter is lined up with its slits at right angles to those of the first filter, no light can pass through.



The diagram shows two sets of parallel slits. The first set allows green waves vibrating vertically to pass through, labeled "Wave motion transmitted". The second set of slits is oriented horizontally, blocking the green waves, labeled "Wave motion blocked".

END

13.4

Polarizing Filters

- Polarized lenses are useful for reducing glare without interfering with your ability to see clearly.
- When light is reflected from a horizontal surface, such as a lake or a shiny car hood, it becomes partially horizontally polarized.



CHAPTER RESOURCES



END

13.4

Polarizing Filters

- The lenses of polarizing sunglasses have vertical polarizing filters that block out the reflected light that has been polarized horizontally.



CHAPTER RESOURCES



END

13.4

Holography

- Science museums often have exhibits where a three-dimensional image seems to float in space.

- **Holography** is a technique that produces a hologram—a complete three-dimensional photographic image of an object.



CHAPTER RESOURCES



END

13.4

Making Holograms

- Illuminating objects with laser light produces holograms.
- Laser light reflects from the object onto photographic film.
- At the same time, a second beam split from the laser also is directed at the film.



CHAPTER RESOURCES



END

13.4

Making Holograms

- The light from the two beams creates an interference pattern on the film.
- The pattern looks nothing like the original object, but when laser light shines on the pattern on the film, a holographic image is produced.



CHAPTER RESOURCES



END

13.4

Information in Light

- A hologram records the intensity as well as the direction.
- As a result, it conveys more information to your eye than a conventional two-dimensional photograph does, but it also is more difficult to copy.



CHAPTER RESOURCES




END

Using Light

13.4 Information in Light

- Holographic images are used on credit cards, identification cards, and on the labels of some products to help prevent counterfeiting.



CHAPTER RESOURCES

Using Light

13.4 Optical Fibers

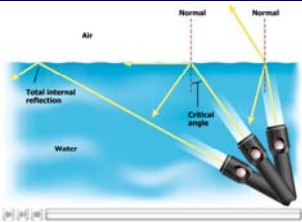
- When laser light must travel long distances or be sent into hard-to-reach places, optical fibers often are used.
- These transparent glass fibers can transmit light from one place to another.
- A process called total internal reflection makes this possible.

CHAPTER RESOURCES

Using Light

13.4 Total Internal Reflection

- When light travels from water to air the direction of the light ray is bent away from the normal.
- If the underwater light ray makes a larger angle with the normal, the light ray in the air bends closer to the surface of the water.

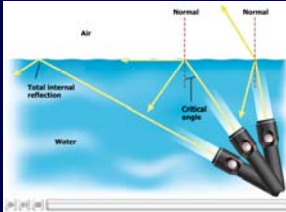


CHAPTER RESOURCES

Using Light

13.4 Total Internal Reflection

- At a certain angle, called the critical angle, the refracted ray has been bent so that it is traveling along the surface of the water.
- For a light ray traveling from water into air, the critical angle is about 49° .



CHAPTER RESOURCES

Using Light

13.4 Total Internal Reflection

- If the underwater light ray strikes the boundary between the air and water at an angle larger than the critical angle there is no longer any refraction, and the light ray does not travel in the air.
- Instead, the light ray is reflected at the boundary, just as if a mirror were there.

CHAPTER RESOURCES

Using Light

13.4 Total Internal Reflection

- Total internal reflection** occurs when light traveling from one medium to another is completely reflected at the boundary between the two materials.
- Then the light ray obeys the law of reflection.

CHAPTER RESOURCES

13.4

Total Internal Reflection

- For total internal reflection to occur, light must travel slower in the first medium, and must strike the boundary at an angle greater than the critical angle.
- Total internal reflection makes light transmission in optical fibers possible.



CHAPTER RESOURCES

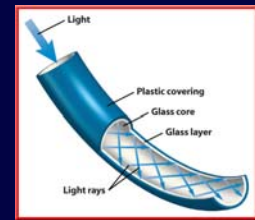


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13.4

Using Optical Fibers

- Light entering one end of the fiber is reflected continuously from the sides of the fiber until it emerges from the other end.



- Almost no light is lost or absorbed in optical fibers.



CHAPTER RESOURCES



END

13.4

Using Optical Fibers

- Optical fibers are most often used in communications.
- Telephone conversations, television programs, and computer data can be coded in light beams.
- Signals can't leak from one fiber to another and interfere with other messages, so the signal is transmitted clearly.



CHAPTER RESOURCES



END

13.4

Using Optical Fibers

- To send telephone conversations through an optical fiber, sound is converted into digital signals consisting of pulses of light by a light-emitting diode or a laser.



CHAPTER RESOURCES



END

13.4

Using Optical Fibers

- Optical fibers also are used to explore the inside of the human body.
- One bundle of fibers transmits light, while another carries the reflected light back to the doctor.



CHAPTER RESOURCES



END

13.4

Optical Scanners

- An optical scanner is a device that reads intensities of reflected light and converts the information to digital signals.
- You may have noticed that somewhere on each item the cashier scans is a pattern of thick and thin stripes called a bar code.



CHAPTER RESOURCES



END

13.4

Optical Scanners

- An optical scanner detects the pattern and translates it into a digital signal, which goes to a computer.
- The computer searches its database for a matching item, finds its price, and sends the information to the cash register.



CHAPTER RESOURCES



END

13.4

Optical Scanners

- With a flatbed scanner you lay a document or picture facedown on a sheet of glass and close the cover.
- An optical scanner passes underneath the glass and reads the pattern of colors.



CHAPTER RESOURCES



END

13.4

Optical Scanners

- The scanner converts the pattern to an electronic file that can be stored on a computer.



CHAPTER RESOURCES



END

13.4

Question 1

Polarized light has light waves that vibrate _____.

Answer

Polarized light waves vibrate in only one direction.



CHAPTER RESOURCES



END

13.4

Question 2

What occurs when light is completely reflected at the boundary between two materials?

Answer

When light is completely reflected at the boundary between two materials, total internal reflection occurs.



CHAPTER RESOURCES



END

13.4

Question 3

Optical fibers use _____ to transmit light waves over long distances.

- complete refraction
- isolated internal reflection
- total diffuse refraction
- total internal reflection



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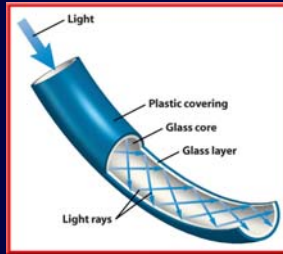
END

Section Check

13.4

Answer

The answer is D. An optical fiber reflects light so that it is piped through the fiber without leaving it, except at the ends.



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Help

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