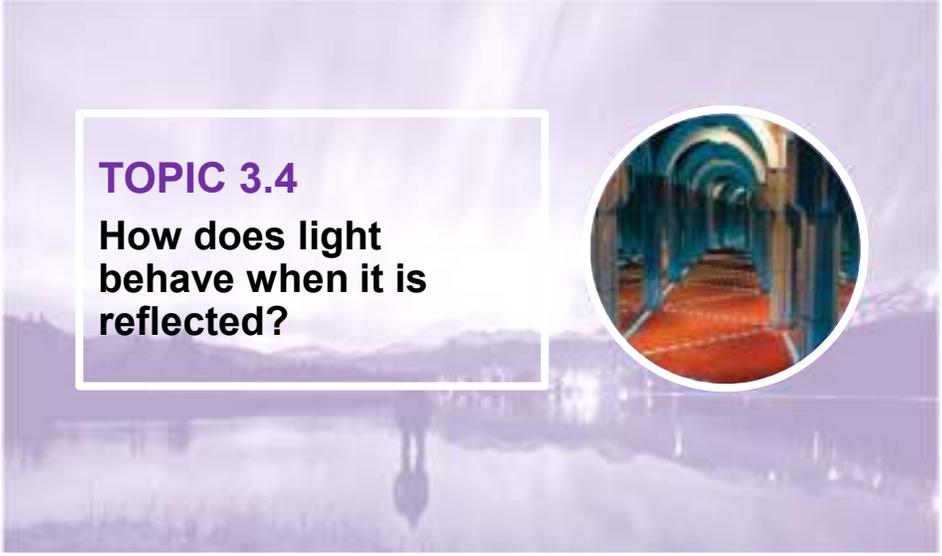




UNIT 3
Energy can be transferred as both a particle and a wave

TOPIC 3.4
**How does light
behave when it is
reflected?**



TOPIC 3.4 How does light behave when it is reflected?

Topic 3.4: How does light behave when it is reflected?

- Light is reflected in predictable patterns.
 - Light reflected by different types of mirrors behave in unique ways
 - Example: funhouse mirrors can form misshapen images



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TOPIC 3.4 How does light behave when it is reflected?

Concept 1: Light is reflected in predictable patterns.

- Light rays follow a predictable path, no matter what surface they reflect from.
- **Laws of reflection:** three laws that describe the predictable path light follows when it strikes a reflective surface

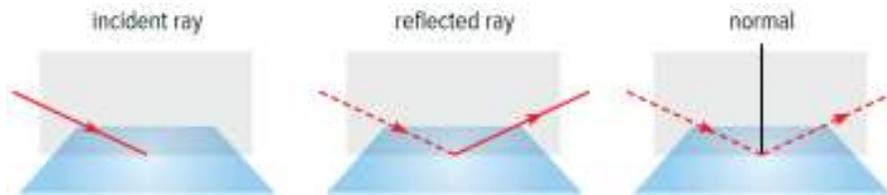
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TOPIC 3.4 How does light behave when it is reflected?

Laws of Reflection: Ray Diagram Components

Ray diagrams can help you understand the laws of reflection.

- **Incident ray:** the light ray travelling toward the reflecting surface
- **Reflected ray:** the light ray that has bounced off a reflecting surface
- **Normal:** the line perpendicular to a surface, such as a mirror

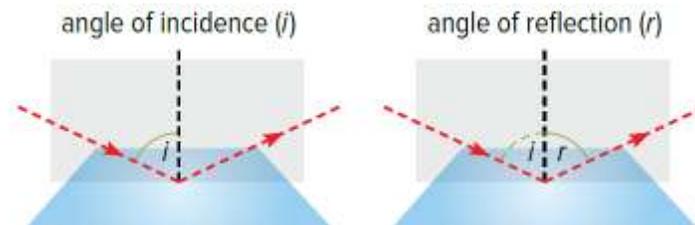


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TOPIC 3.4 How does light behave when it is reflected?

Laws of Reflection: Ray Diagram Components

- **Angle of incidence (i):** the angle between the incident ray and the normal
- **Angle of reflection (r):** the angle between the reflected ray and the normal

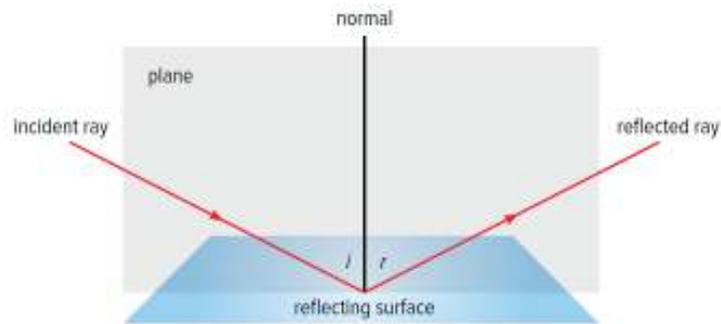


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TOPIC 3.4 How does light behave when it is reflected?

Laws of Reflection

- The angle of reflection (r) is equal to the angle of incidence (i).
- The reflected ray and the incident ray are on opposite sides of the normal.
- The incident ray, the normal, and the reflected ray lie on the same plane (flat surface).

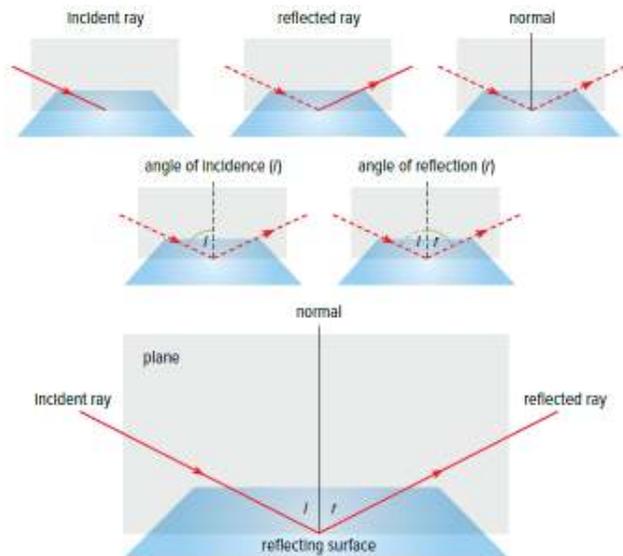


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TOPIC 3.4 How does light behave when it is reflected?

Laws of Reflection: Summary Diagram

Figure 3.24: All light rays obey the laws of reflection, as shown here.



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TOPIC 3.4 How does light behave when it is reflected?

Visualizing the Laws of Reflection

A game of pool can help you visualize the laws of reflection.

- (A) If a shot is made head-on, the ball will bounce straight back in the opposite direction
- (B) If a shot is made at an angle, the ball will also bounce off at the same angle, but in the opposite direction



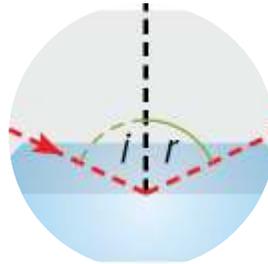
Figure 3.25

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TOPIC 3.4 How does light behave when it is reflected?

Discussion Questions

- What do the angle of reflection and the angle of incidence have in common? Consider how they are measured and how they compare to one another.
- Why does an expert billiards (pool) player need to understand the laws of reflection to make an accurate shot?



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TOPIC 3.4 How does light behave when it is reflected?

Concept 2: Light reflected by a plane mirror produces an image that is nearly identical to the object.

- **Plane mirror:** an extremely smooth, flat reflective surface
 - Some sources are artificial (cell phones, light bulbs)
 - Some sources are living organisms (humans)



Figure 3.26: Reflection in a plane mirror.

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TOPIC 3.4 How does light behave when it is reflected?

How an image forms in a plane mirror

- When light shines on an object (the tomato), it reflects on all points of the object in all directions.

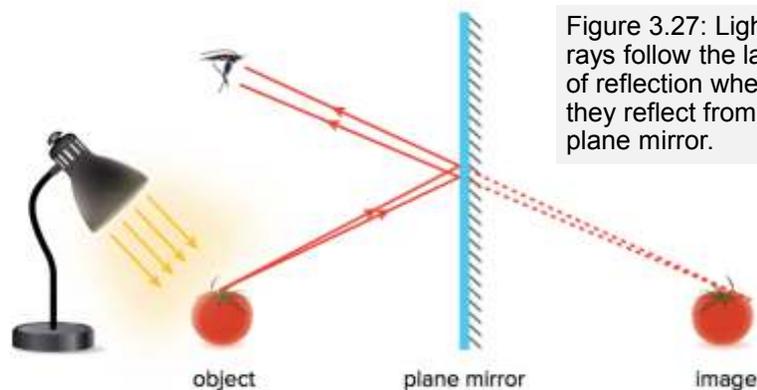


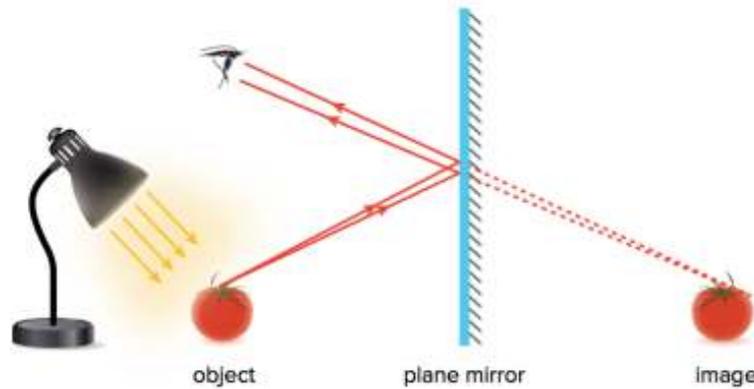
Figure 3.27: Light rays follow the laws of reflection when they reflect from a plane mirror.

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TOPIC 3.4 How does light behave when it is reflected?

How an image forms in a plane mirror

- When these reflected rays reach the plane mirror, they follow the laws of reflection and reflect backwards.

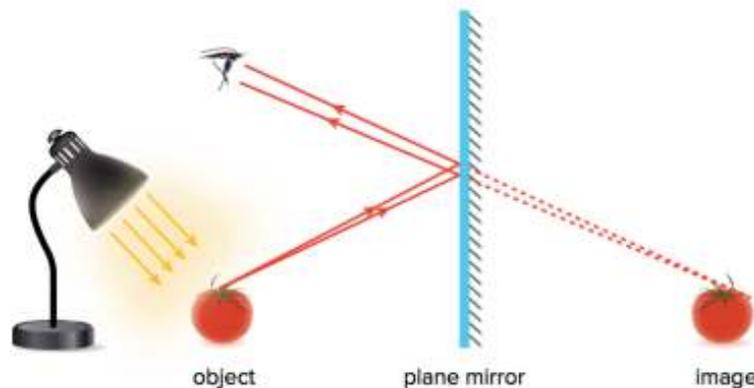


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TOPIC 3.4 How does light behave when it is reflected?

How an image forms in a plane mirror

- Some rays reach your eyes if you are looking at the mirror.
 - They carry the same pattern of light to the eye that was reflected off the object.

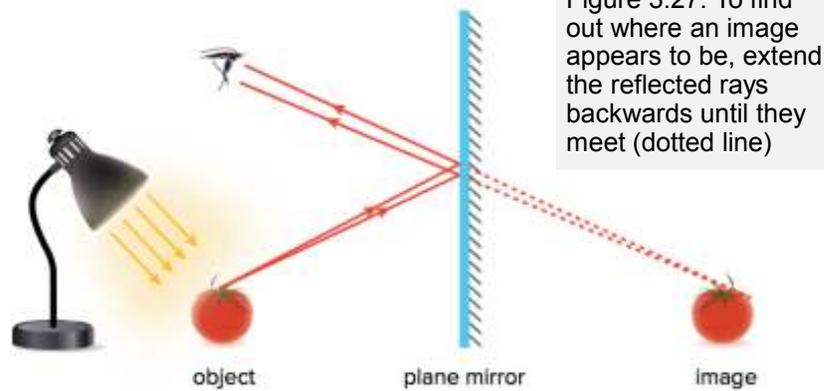


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TOPIC 3.4 How does light behave when it is reflected?

How an image forms in a plane mirror

- Your brain assumes light travels in a straight line and thinks the image is behind the mirror.



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TOPIC 3.4 How does light behave when it is reflected?

Characteristics of Images

- **Location:**
 - Image may be closer to or farther from the mirror than the object.
 - Object may also be the same distance from the mirror as the object.
- **Orientation:**
 - Image be up upright or inverted (upside-down)
- **Size:**
 - Image may be the same size as, larger than, or smaller than the object
- **Type:**
 - Image may be real or virtual

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TOPIC 3.4 How does light behave when it is reflected?

Virtual Image

Virtual image:

- Not a real image
- Formed when extended rays (not reflected rays) meet
- Located behind the mirror

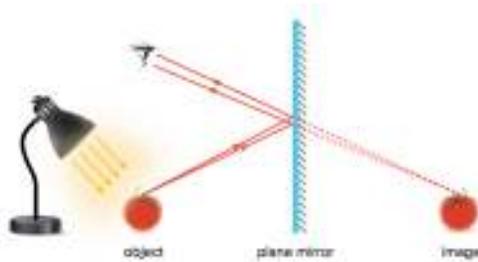


Figure 3.27: No light rays are going to or coming from the image behind the mirror. Light rays only appear to be coming from the image.

- Only extended rays meet
- Brain imagines that an image forms behind the mirror

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TOPIC 3.4 How does light behave when it is reflected?

Real Image

Real image:

- Formed when reflected rays (not extended rays) meet
- Located in front of the mirror
- If you place a screen at the position of a real image, the rays will meet at the screen and form an image
 - Example: an image on a movie screen is a real image

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TOPIC 3.4 How does light behave when it is reflected?

Characteristics of Images in Plane Mirrors

- Same size as the object
- Same distance from the mirror as the object
- Upright
- Virtual image
- Image is nearly identical to the object but is reversed
- Direction of reversal depends on the position of the object and the mirror



Figure 3.28: This image in a plane mirror appears reversed.

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TOPIC 3.4 How does light behave when it is reflected?

Discussion Questions

- What is meant when the image is said to be behind the mirror? What do you call this type of image?



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TOPIC 3.4 How does light behave when it is reflected?

Concept 3: Light reflected by curved mirrors behaves in unique ways.

- Curved mirrors:
 - Do not produce images that are identical to the object
 - What properties of the image in Sky Mirror are different from those in plane mirrors?



Figure 3.29: Sky Mirror by Anish Kapoor (Nottingham, UK)

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TOPIC 3.4 How does light behave when it is reflected?

Curved Mirrors

- How is the image in Cloud Gate similar to the one in Sky Mirror? How is it different?



Figure 3.30: Cloud Gate by Anish Kapoor (Chicago, USA)

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TOPIC 3.4 How does light behave when it is reflected?

Concave and Convex: Two Types of Curved Mirrors

- **Concave mirror:** A mirror with a reflective surface that curves inward (Sky Mirror)
- **Convex mirror:** A mirror with a reflecting surface that curves outward (Cloud Gate)



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TOPIC 3.4 How does light behave when it is reflected?

Images in Concave Mirrors

- Incoming parallel light rays come together (converge) at a single point (focal point)
- Images formed by concave mirror have different characteristics
 - Depend on where it is located compared to surface of mirror and the focal point
 - Images are misshapen around the edges of the mirror

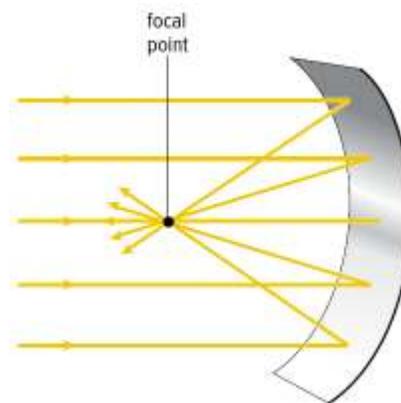


Figure 3.31: Incoming parallel light rays converge when they reflect off a concave mirror.

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TOPIC 3.4 How does light behave when it is reflected?

**Characteristics of Images in Concave Mirrors:
Object located far from focal point**

- Object located far from the focal point
 - Object is reflected to produce a smaller, inverted image
 - Reflected rays meet: image is real
 - Image is closer to the mirror than the object

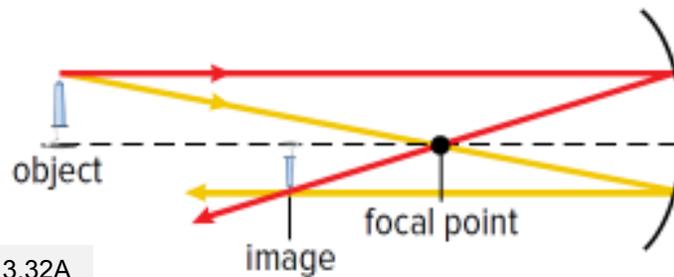


Figure 3.32A

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TOPIC 3.4 How does light behave when it is reflected?

**Characteristics of Images in Concave Mirrors:
Object located closer to focal point**

- Object located closer to the focal point, but is not between the focal point and concave mirror
 - Object is reflected to produce a larger, inverted image
 - Reflected rays meet: image is real
 - Image is farther from the mirror than the object

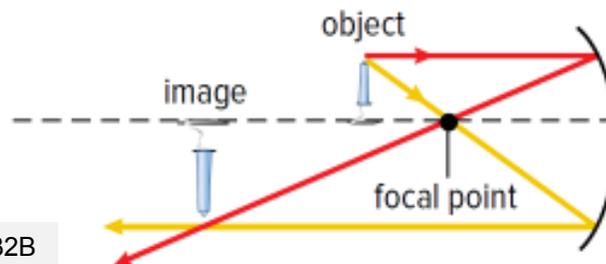


Figure 3.32B

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TOPIC 3.4 How does light behave when it is reflected?

Characteristics of Images in Concave Mirrors: Object located between focal point and concave mirror

- Object located between focal point and concave mirror
 - Object is reflected to produce a larger, upright image
 - Reflected rays do not meet (need to extend them in the opposite direction): image is virtual
 - Image is farther from the mirror than the object

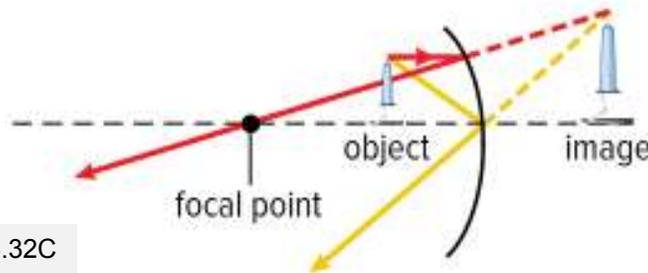


Figure 3.32C

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TOPIC 3.4 How does light behave when it is reflected?

Images in Convex Mirrors

- Incoming parallel light rays spread apart in different directions (diverge) after they are reflected off the mirror
- Extending the diverging rays behind the mirror shows that they meet at a focal point
 - The actual rays do not meet
- Image produced is always a virtual image (like plane mirror images)

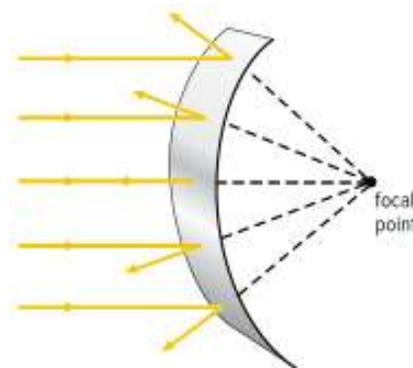


Figure 3.33: Incoming parallel light rays diverge when they reflect off a convex mirror.

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TOPIC 3.4 How does light behave when it is reflected?

Characteristics of Images in Convex Mirrors

- Image is smaller than the object
- Image is closer to the mirror than the object
- Image is virtual
- Image is upright

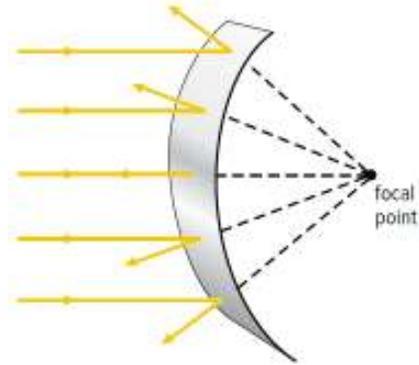


Figure 3.33: Incoming parallel light rays diverge when they reflect off a convex mirror.

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TOPIC 3.4 How does light behave when it is reflected?

Characteristics of Images in Convex Mirrors

- More objects can be seen in a convex mirror than in a plane mirror
 - Convex mirrors reflect light from a large incoming area
- Images are distorted, especially at the edges

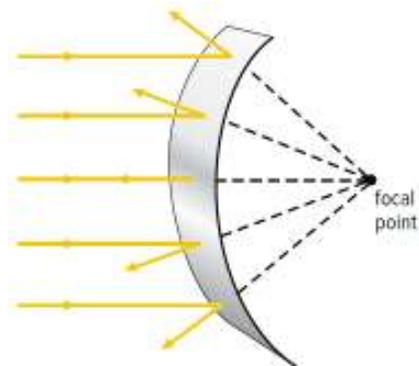


Figure 3.33: Incoming parallel light rays diverge when they reflect off a convex mirror.

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TOPIC 3.4 How does light behave when it is reflected?

Discussion Questions

- Use a T-chart to compare a convex mirror with a concave mirror.
- Convex mirrors are often used as security mirrors in convenience stores. Explain why.



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TOPIC 3.4 How does light behave when it is reflected?

Concept 4: Many technologies take advantage of light's behaviour when it strikes a reflective surface.

Curved Reflective Surfaces

- Concave mirrors: used to concentrate light
 - Light source is located exactly at focal point, the rays that strike the mirror are parallel to each other
 - Produces intense beam of light
 - Used in car headlights, flashlights



Car headlights are composed of concave mirrors.

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TOPIC 3.4 How does light behave when it is reflected?

Curved Reflective Surfaces: Radar

Radar: radio detection and ranging (used to detect aircraft)

- Radar antenna uses a concave reflective surface
 - Radio waves are generated and sent out to the sky
 - Rounded surfaces on airplane are convex reflective surfaces



Figure 3.34

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TOPIC 3.4 How does light behave when it is reflected?

Curved Reflective Surfaces: Radar

- Some of the surface is perpendicular to the radio waves; will reflect the waves back to antenna
- Antenna's concave surface directs the reflected rays to the detector at the focal point to locate the airplane



Figure 3.34

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TOPIC 3.4 How does light behave when it is reflected?

Plane Reflecting Surfaces

Plane reflecting surfaces help military aircraft avoid radar detection.



Figure 3.35:
Lockheed
F-117
Nighthawk

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TOPIC 3.4 How does light behave when it is reflected?

Plane Reflecting Surfaces

- Angular surfaces on the aircraft are rarely perpendicular to incoming radio waves
 - Very few waves reflect back to the radar antenna

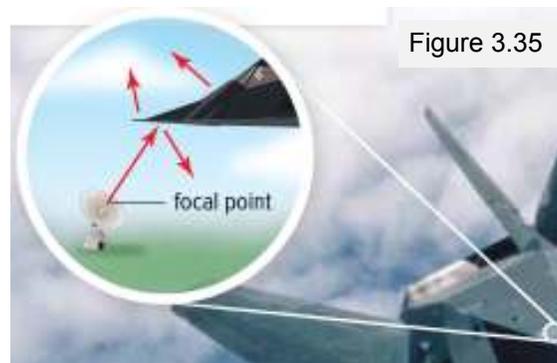


Figure 3.35

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TOPIC 3.4 How does light behave when it is reflected?

Plane Reflecting Surfaces

- Paint has tiny iron reflecting particles
 - Radio waves reflect back and forth among the iron particles
 - Energy is absorbed by the paint and converted to heat
 - Decreases the number of waves that bounce back to the radar antenna

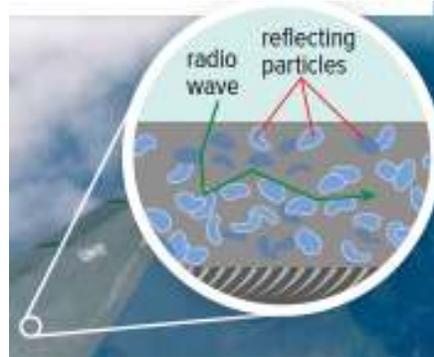


Figure 3.35

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TOPIC 3.4 How does light behave when it is reflected?

Discussion Questions

- Explain how car headlights create an intense beam of light.
- Radio telescopes can detect radio waves from outer space. What shape would a radio telescope most likely be and why?



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TOPIC 3.4 How does light behave when it is reflected?**Summary: How does light behave when it is reflected?**

- Light is reflected in predictable patterns.
- Light reflected by a plane mirror produces an image that is nearly identical to the object.
- Light reflected by curved mirrors behaves in unique ways.
- Many technologies take advantage of light's behaviour when it strikes a reflective surface

