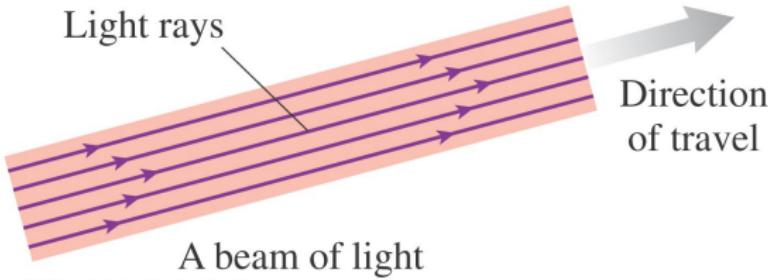


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The Ray Model of Light - Chapter 23

When apertures are big ($> 1\text{ mm}$), light travels in a straight line. A light ray is a line in a direction along which light energy is flowing. It is an idea, not a thing.

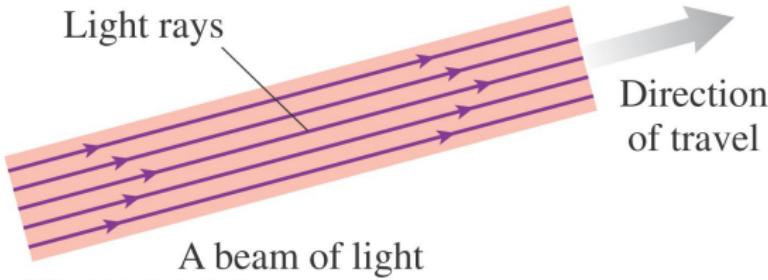


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The Ray Model of Light - Chapter 23

When apertures are big ($> 1\text{ mm}$), light travels in a straight line. A light ray is a line in a direction along which light energy is flowing. It is an idea, not a thing. Some properties:

- Light rays travel in straight lines

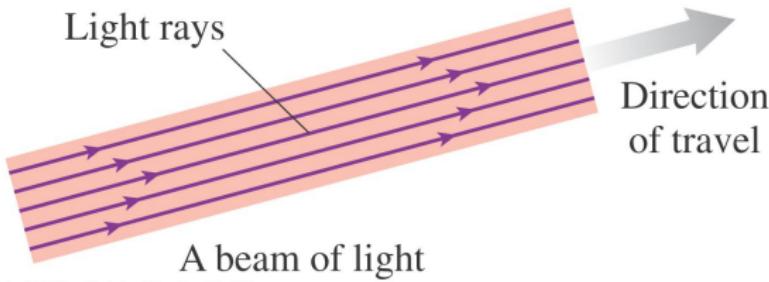


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The Ray Model of Light - Chapter 23

When apertures are big ($> 1\text{ mm}$), light travels in a straight line. A light ray is a line in a direction along which light energy is flowing. It is an idea, not a thing. Some properties:

- Light rays travel in straight lines
- Light rays can cross

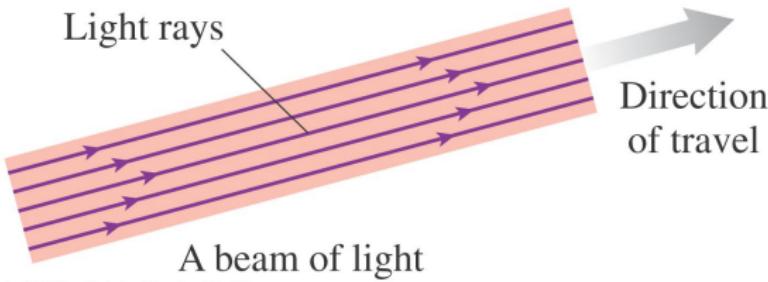


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The Ray Model of Light - Chapter 23

When apertures are big ($> 1\text{ mm}$), light travels in a straight line. A light ray is a line in a direction along which light energy is flowing. It is an idea, not a thing. Some properties:

- Light rays travel in straight lines
- Light rays can cross
- Light rays travel forever unless they interact with matter



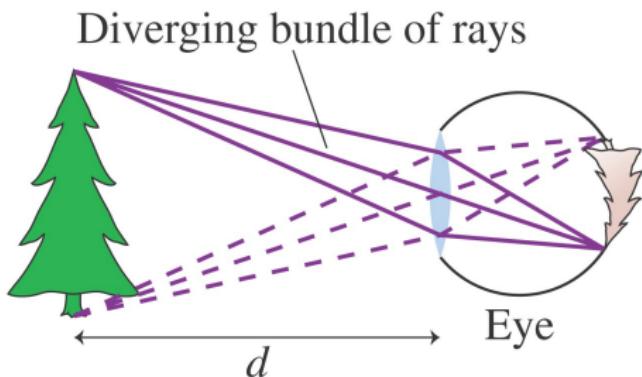
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The Ray Model of Light - Chapter 23

When apertures are big ($> 1\text{ mm}$), light travels in a straight line. A light ray is a line in a direction along which light energy is flowing. It is an idea, not a thing. Some properties:

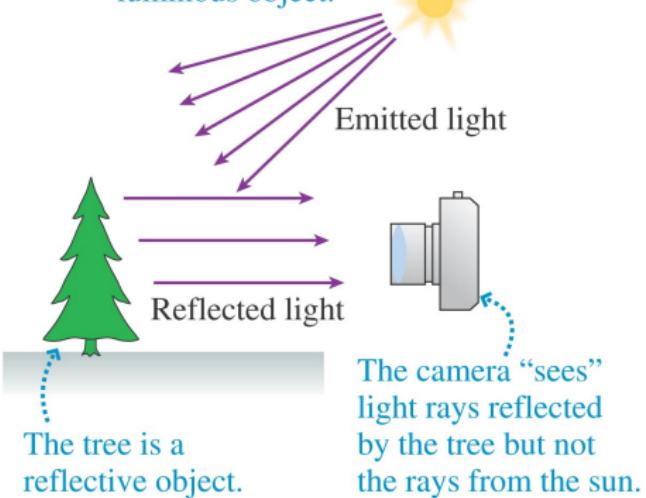
- Light rays travel in straight lines
- Light rays can cross
- Light rays travel forever unless they interact with matter
- An object is a source of light rays

Seeing Objects



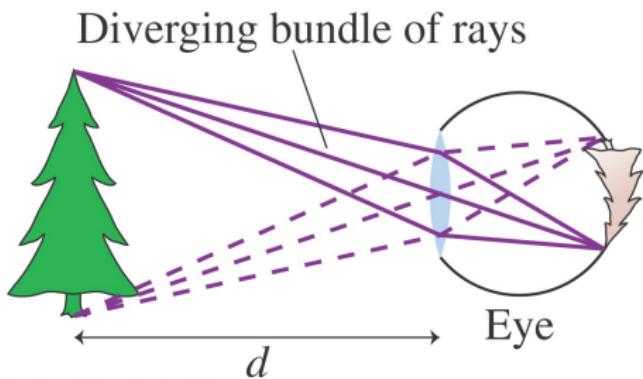
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The sun is a self-luminous object.



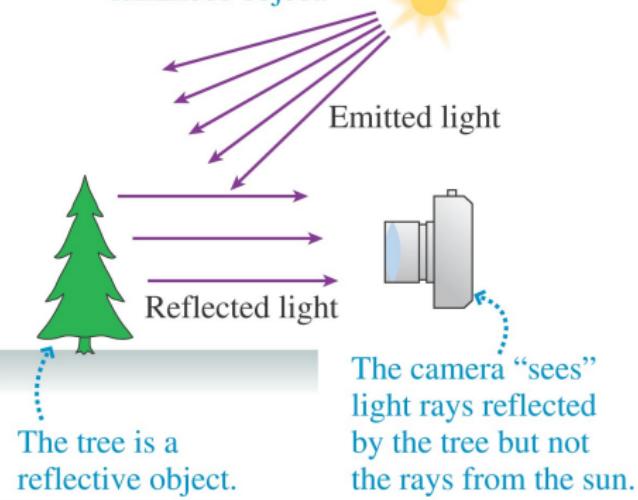
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Seeing Objects



Copyright © 2008 Pearson Education, Inc., publishing as Pearson Addison-Wesley.

The sun is a self-luminous object.



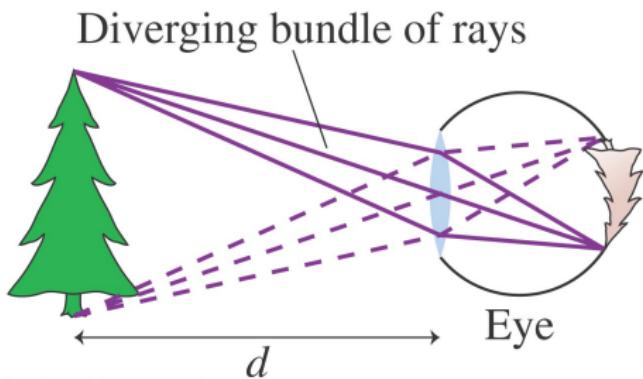
The tree is a reflective object.

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The camera “sees” light rays reflected by the tree but not the rays from the sun.

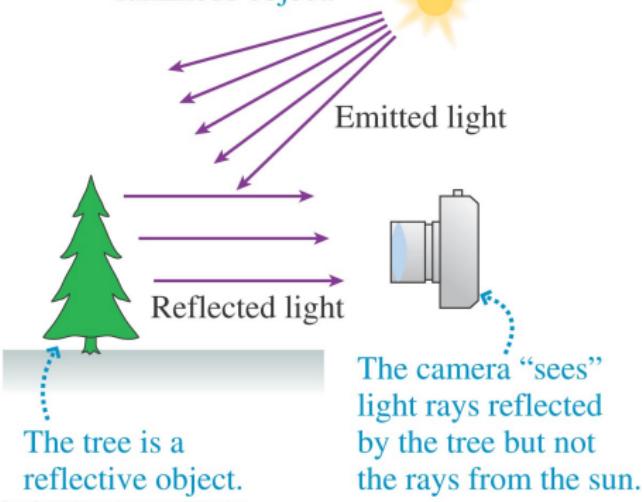
You can see an object because it either produces its own light (eg. the sun) or reflects light.

Seeing Objects



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The sun is a self-luminous object.

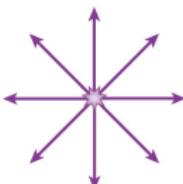


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You can see an object because it either produces its own light (eg. the sun) or reflects light. The diverging bundles of rays are then focused by a lens onto your retina and your brain turns the pattern into an image.

Ray Diagrams

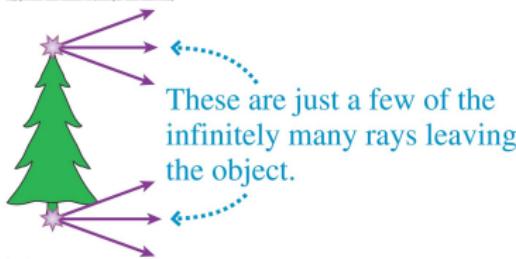
- Divergent rays from a point source are emitted in all directions.



Point source

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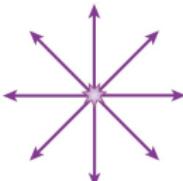
Parallel bundle



These are just a few of the infinitely many rays leaving the object.

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Ray Diagrams

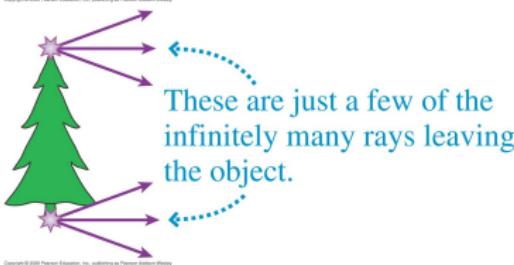


Point source

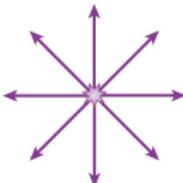


Parallel bundle

- Divergent rays from a point source are emitted in all directions.
- A parallel bundle of rays could be from a laser beam or just a very distant object (eg. star).



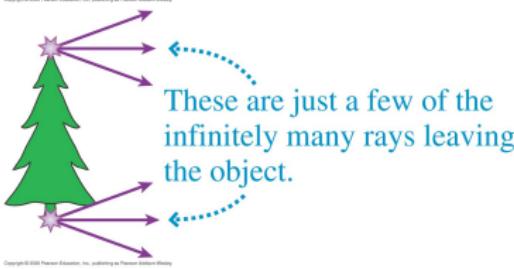
Ray Diagrams



Point source

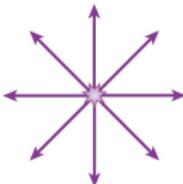


Parallel bundle



- Divergent rays from a point source are emitted in all directions.
- A parallel bundle of rays could be from a laser beam or just a very distant object (eg. star).
- A **ray diagram** is a simplification in which we draw just a few representative rays.

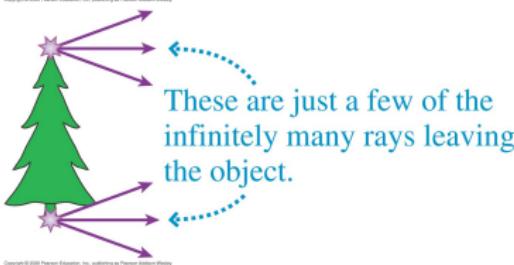
Ray Diagrams



Point source



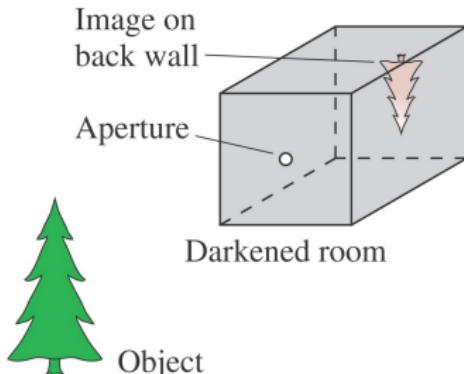
Parallel bundle



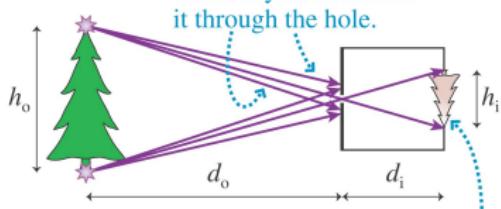
- Divergent rays from a point source are emitted in all directions.
- A parallel bundle of rays could be from a laser beam or just a very distant object (eg. star).
- A **ray diagram** is a simplification in which we draw just a few representative rays.
- We use a ray diagram to figure out the size, orientation, etc. of an image. Please remember that it is just a simplification, not the whole picture....

Apertures

(a)



(b)

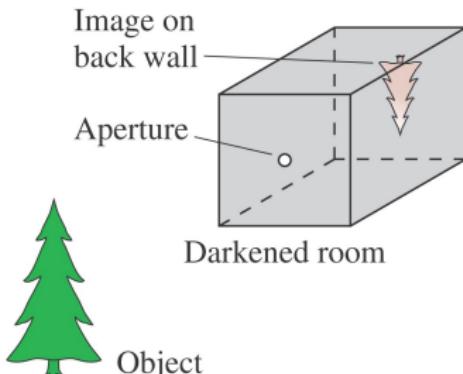


These rays don't make it through the hole.
The image is upside down. If the hole is sufficiently small, each point on the image corresponds to one point on the object.

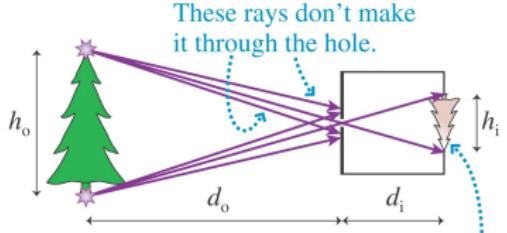
- A **camera obscura** is an example of what happens when light passes through a circular aperture.

Apertures

(a)



(b)

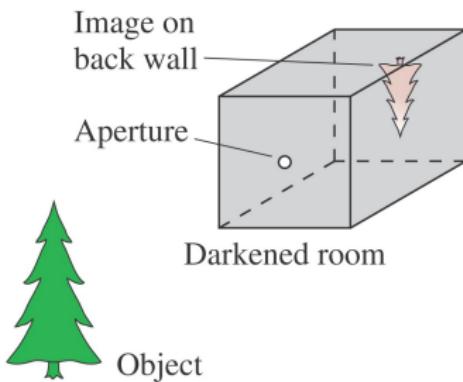


The image is upside down. If the hole is sufficiently small, each point on the image corresponds to one point on the object.

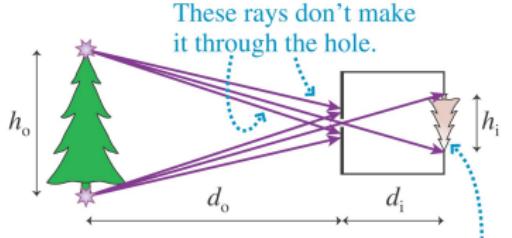
- A **camera obscura** is an example of what happens when light passes through a circular aperture.
- We can understand what is going on with a simple ray diagram.

Apertures

(a)



(b)

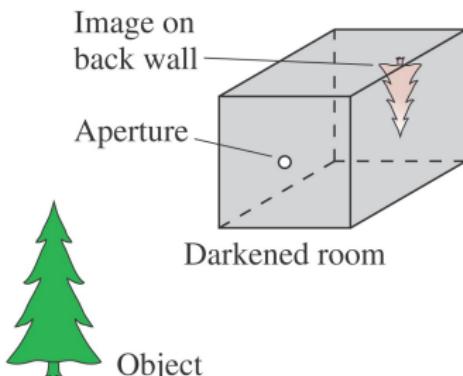


The image is upside down. If the hole is sufficiently small, each point on the image corresponds to one point on the object.

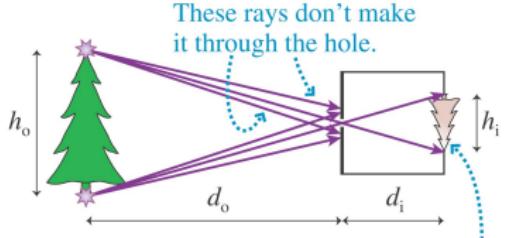
- A **camera obscura** is an example of what happens when light passes through a circular aperture.
- We can understand what is going on with a simple ray diagram.
- Each point on the object is reflecting light rays, but most are blocked.

Apertures

(a)



(b)

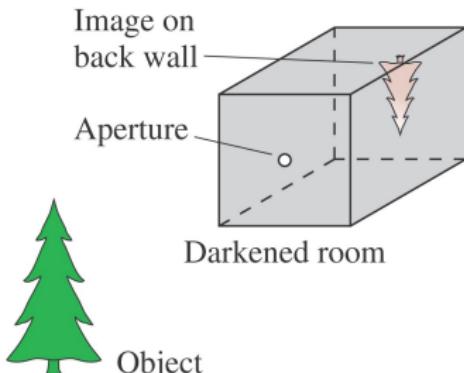


The image is upside down. If the hole is sufficiently small, each point on the image corresponds to one point on the object.

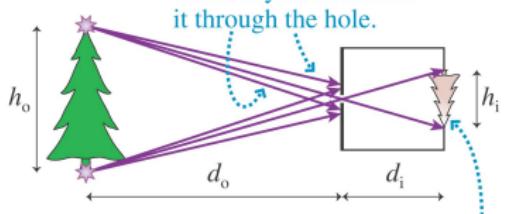
- A **camera obscura** is an example of what happens when light passes through a circular aperture.
- We can understand what is going on with a simple ray diagram.
- Each point on the object is reflecting light rays, but most are blocked.
- The geometry shows us that the image will be upside-down.

Apertures

(a)



(b)

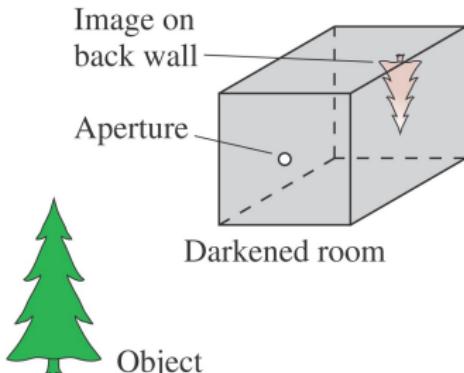


The image is upside down. If the hole is sufficiently small, each point on the image corresponds to one point on the object.

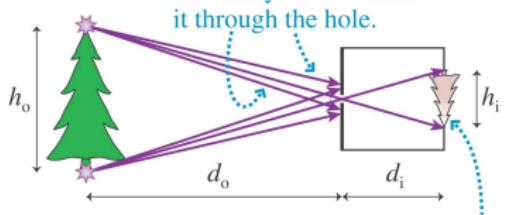
- A **camera obscura** is an example of what happens when light passes through a circular aperture.
- We can understand what is going on with a simple ray diagram.
- Each point on the object is reflecting light rays, but most are blocked.
- The geometry shows us that the image will be upside-down.
- The aperture allows rays from the same point to enter at slightly different angles (fuzzy image).

Apertures

(a)



(b)



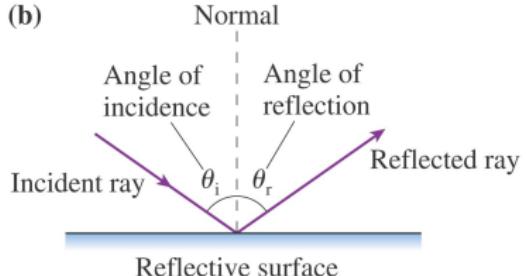
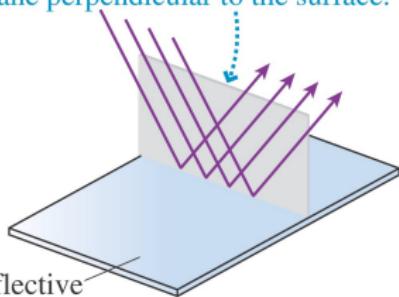
The image is upside down. If the hole is sufficiently small, each point on the image corresponds to one point on the object.

- A **camera obscura** is an example of what happens when light passes through a circular aperture.
- We can understand what is going on with a simple ray diagram.
- Each point on the object is reflecting light rays, but most are blocked.
- The geometry shows us that the image will be upside-down.
- The aperture allows rays from the same point to enter at slightly different angles (fuzzy image).
- The image heights go like:

$$\frac{h_i}{h_o} = \frac{d_i}{d_o}$$

Reflection

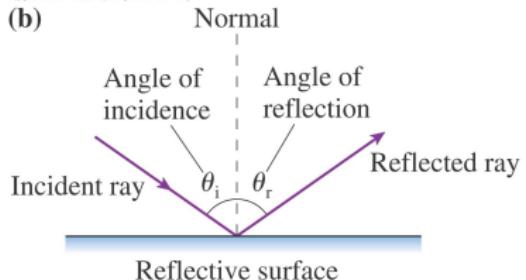
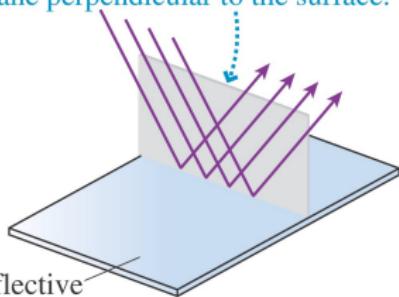
(a) The incident and reflected rays lie in a plane perpendicular to the surface.



- Reflection from a mirror is called **specular reflection**

Reflection

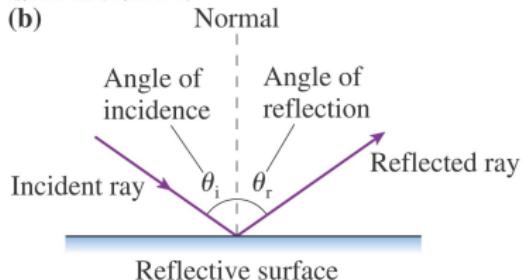
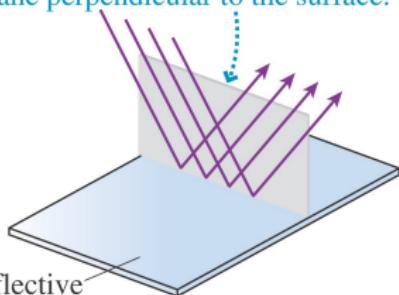
(a) The incident and reflected rays lie in a plane perpendicular to the surface.



- Reflection from a mirror is called **specular reflection**
- Incident and reflected rays lie in a plane perpendicular to the surface.

Reflection

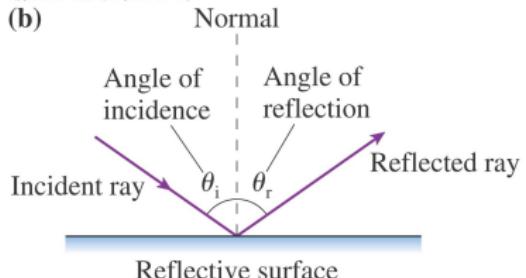
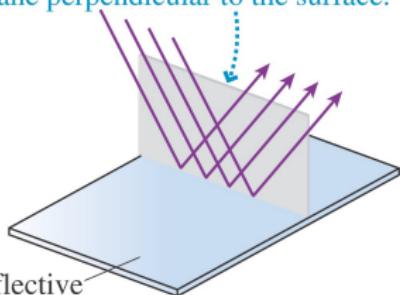
(a) The incident and reflected rays lie in a plane perpendicular to the surface.



- Reflection from a mirror is called **specular reflection**
- Incident and reflected rays lie in a plane perpendicular to the surface.
- Lower-left: a single ray represents a bundle of parallel rays “stacked” behind one another.

Reflection

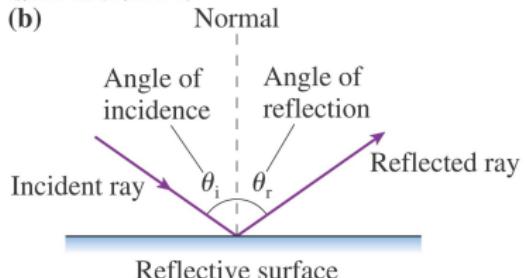
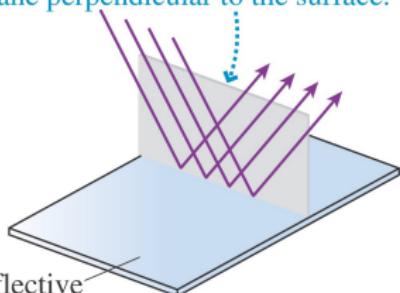
(a) The incident and reflected rays lie in a plane perpendicular to the surface.



- Reflection from a mirror is called **specular reflection**
- Incident and reflected rays lie in a plane perpendicular to the surface.
- Lower-left: a single ray represents a bundle of parallel rays “stacked” behind one another.
- The **angle of incidence** (θ_i) is the angle between the incoming ray and a line perpendicular to the surface.

Reflection

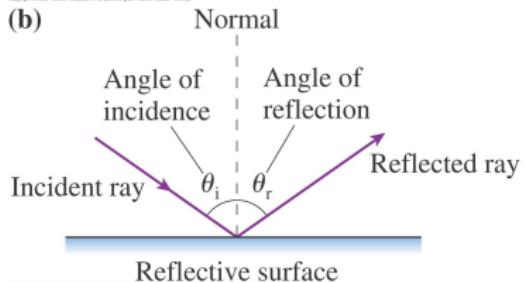
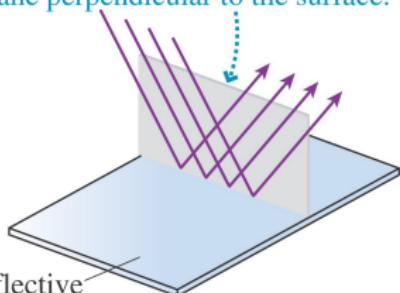
(a) The incident and reflected rays lie in a plane perpendicular to the surface.



- Reflection from a mirror is called **specular reflection**
- Incident and reflected rays lie in a plane perpendicular to the surface.
- Lower-left: a single ray represents a bundle of parallel rays “stacked” behind one another.
- The **angle of incidence** (θ_i) is the angle between the incoming ray and a line perpendicular to the surface.
- The **angle of reflection** (θ_r) is the angle between the reflected ray and a line perpendicular to the surface.

Reflection

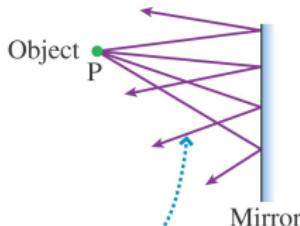
(a) The incident and reflected rays lie in a plane perpendicular to the surface.



- Reflection from a mirror is called **specular reflection**
- Incident and reflected rays lie in a plane perpendicular to the surface.
- Lower-left: a single ray represents a bundle of parallel rays “stacked” behind one another.
- The **angle of incidence** (θ_i) is the angle between the incoming ray and a line perpendicular to the surface.
- The **angle of reflection** (θ_r) is the angle between the reflected ray and a line perpendicular to the surface.
- The incident and reflected rays are in the same plane and $\theta_i = \theta_r$

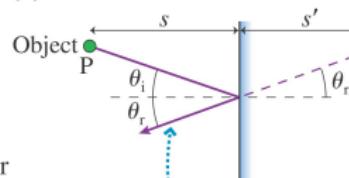
The Plane Mirror

(a)



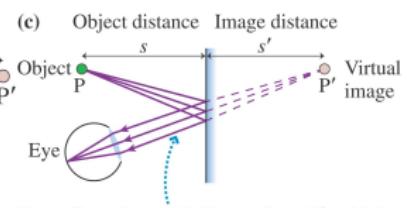
Rays from P reflect from the mirror. Each ray obeys the law of reflection.

(b)



This reflected ray appears to have come from point P' .

(c)

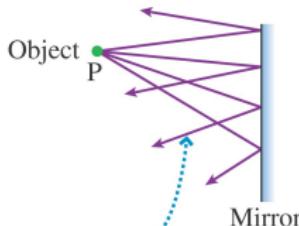


The reflected rays *all* diverge from P' , which appears to be the source of the reflected rays. Your eye collects the bundle of diverging rays and "sees" the light coming from P' .

- Every ray from point P gets reflected such that $\theta_r = \theta_i$

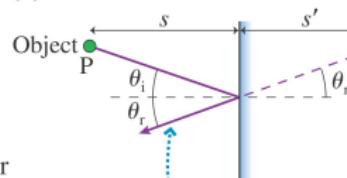
The Plane Mirror

(a)



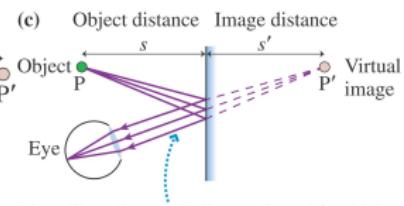
Rays from P reflect from the mirror. Each ray obeys the law of reflection.

(b)



This reflected ray appears to have come from point P' .

(c)

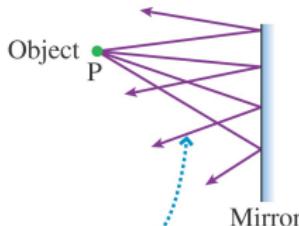


The reflected rays all diverge from P' , which appears to be the source of the reflected rays. Your eye collects the bundle of diverging rays and "sees" the light coming from P' .

- Every ray from point P gets reflected such that $\theta_r = \theta_i$
- All of the rays from point P that reach your eye appear to come from point P'

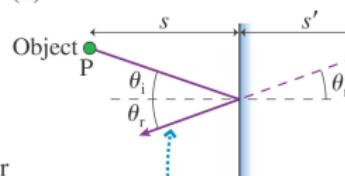
The Plane Mirror

(a)



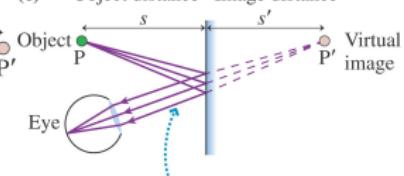
Rays from P reflect from the mirror. Each ray obeys the law of reflection.

(b)



This reflected ray appears to have come from point P' .

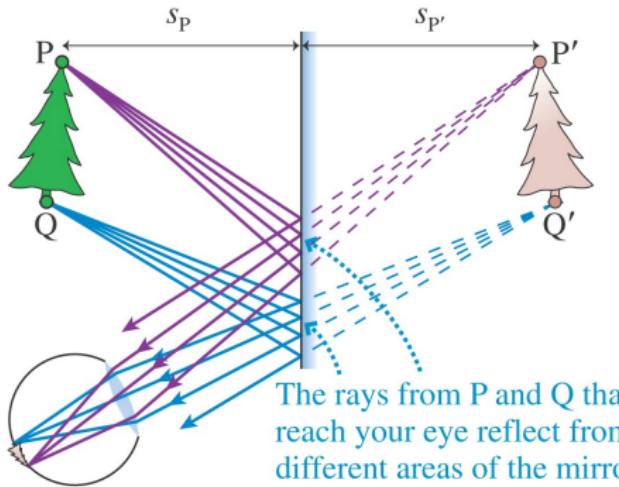
(c)



The reflected rays *all* diverge from P' , which appears to be the source of the reflected rays. Your eye collects the bundle of diverging rays and "sees" the light coming from P' .

- Every ray from point P gets reflected such that $\theta_r = \theta_i$
- All of the rays from point P that reach your eye appear to come from point P'
- The mirror forms a **virtual image** of point P at P'

An Extended Object in a Plane Mirror

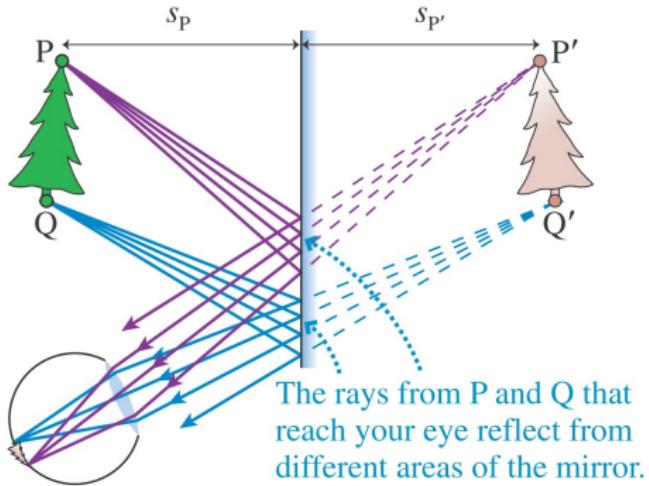


Your eye intercepts only
a very small fraction of
all the reflected rays.

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- For an extended object, each point on the object has a reflected image in the mirror.

An Extended Object in a Plane Mirror



Your eye intercepts only a very small fraction of all the reflected rays.

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- For an extended object, each point on the object has a reflected image in the mirror.
- Rays diverge from the object and strike every point on the mirror, only a few of the rays enter your eye

How High is the Mirror?

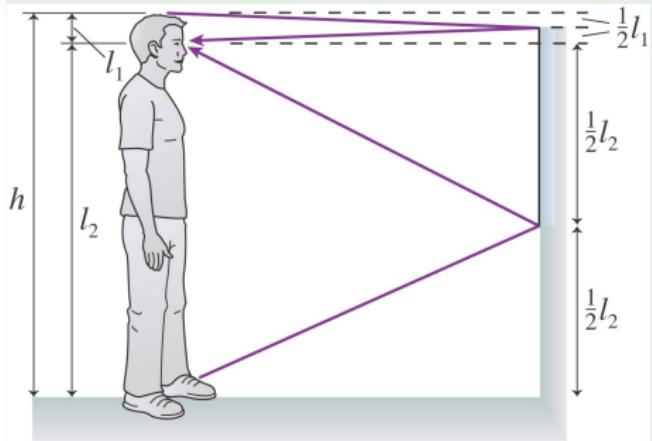
Example 23.2: How High is the Mirror?

If your height is h , what is the shortest mirror on the wall in which you can see your full image? Where must the top of the mirror be hung?

How High is the Mirror?

Example 23.2: How High is the Mirror?

If your height is h , what is the shortest mirror on the wall in which you can see your full image? Where must the top of the mirror be hung?

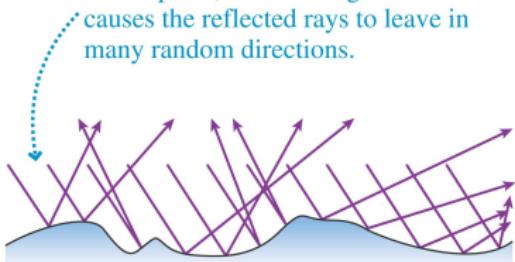


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- The minimum size is $h/2$, which only works if the top of the mirror is midway between your eyes and the top of your head.
- Your distance from the mirror does not matter in answering this question!!
- Left and right is not reversed in a mirror, rather it reverses front and back!

Diffuse Reflection

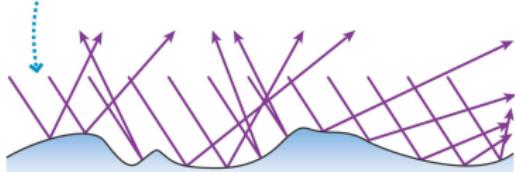
Each ray obeys the law of reflection at that point, but the irregular surface causes the reflected rays to leave in many random directions.



- Mirrors and **specular reflection** are interesting. However, you see most objects around you via **diffuse reflection**.

Diffuse Reflection

Each ray obeys the law of reflection at that point, but the irregular surface causes the reflected rays to leave in many random directions.



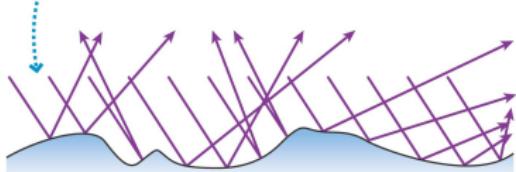
Magnified view of surface

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- Mirrors and **specular reflection** are interesting. However, you see most objects around you via **diffuse reflection**.
- Reflection from any rough surface will be diffuse.

Diffuse Reflection

Each ray obeys the law of reflection at that point, but the irregular surface causes the reflected rays to leave in many random directions.



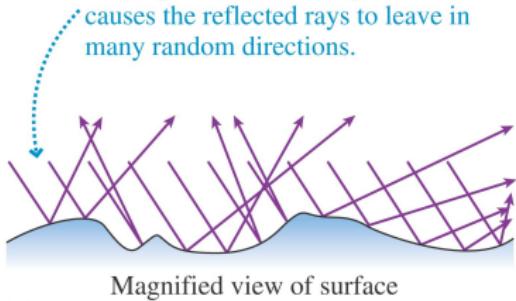
Magnified view of surface

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- Mirrors and **specular reflection** are interesting. However, you see most objects around you via **diffuse reflection**.
- Reflection from any rough surface will be diffuse.
- The law of reflection is the same, but the surface is rough and the scattering is randomized by the surface roughness.

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- The law of reflection is the same, but the surface is rough and the scattering is randomized by the surface roughness.
- Mirrors are special in that they are exceptionally smooth.