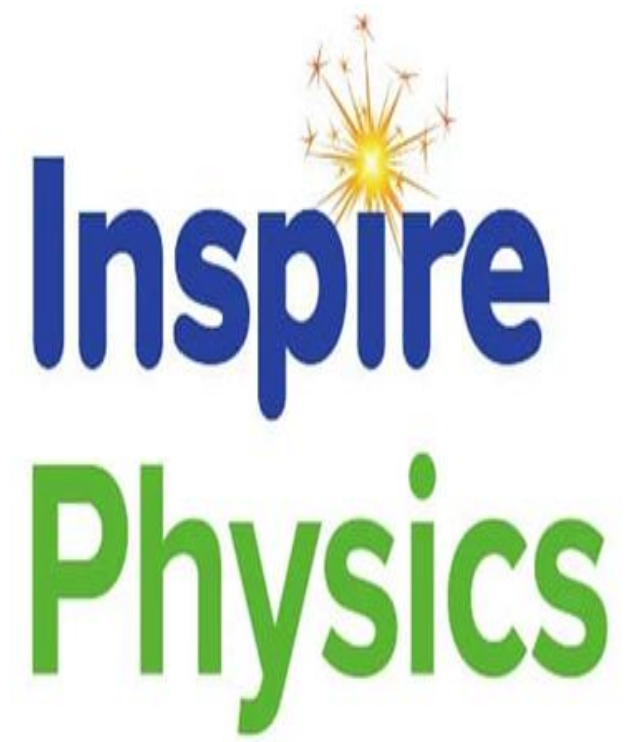


Academic Year العام الدراسي	2025-2026
Term/الفصل	T1
Subject الموضوع	Physics (Inspire)
Grade الصف	12
Stream. المسار	Advanced المتقدم



Grade 12 Advanced

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(Luminous Flux - P):

What is it? It is the rate of light energy emitted by a source per second. In other words, it is the total amount of light produced by the source in all directions

- **Unit:** It is measured in lumens (lm)

What is illumination?

- It is the amount of light (luminous flux) falling on a specific area of a surface at a given moment.
- Unit: It is measured in lux (lx) or lumens per square meter (lm/m^2). ($1 \text{ lx} = 1 \text{ lm}/\text{m}^2$)

$$E = \frac{P}{4\pi r^2}$$

○ E: Illuminance

o The amount of light falling on a surface.

o Unit: Lux (lx) .

○ P: Luminous Flux

o The total amount of light emitted by the source in all directions.

o Unit: Lumen (lm).

○ r: Distance

o: The distance between the light source and the illuminated surface.

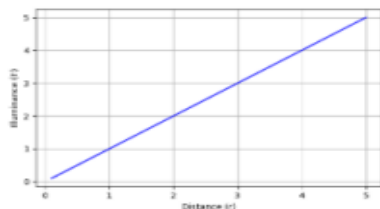
o Unit: Meter (m).

○ $4\pi r^2$: Surface Area of a Sphere

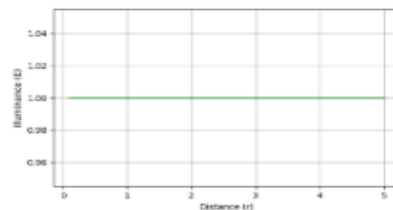
o: The total area over which light is scattered at a distance (r) from the source.

Which of the following graphs **correctly** shows the relationship between illuminance and the distance between the light source and the surface?

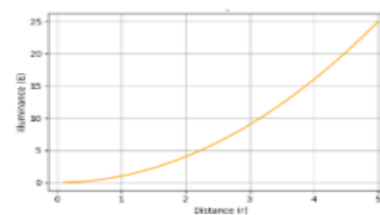
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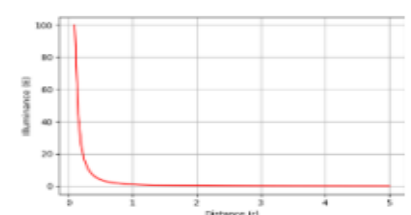
②



③



④



1. What is the definition of Luminous Flux?

- a) The amount of light falling on a surface.
- b) The rate of light energy emitted by a source per second.
- c) The brightness of a light source.
- d) The unit for measuring illumination.

Answer: b

2. What is the unit of measurement for Luminous Flux?

- a) Lux (lx)
- b) Watts (W)
- c) Lumens (lm)
- d) Candela (cd)

Answer: c

3. Illumination is defined as:

- a) The total light energy produced by a source.
- b) The color temperature of light.
- c) The amount of luminous flux falling on a specific surface area.
- d) The rate at which light is emitted.

Answer: c

4. Which unit is used to measure Illumination?

- a) Lumens (lm)
- b) Lumens per square meter (lm/m²)
- c) Meters (m)
- d) Joules per second (J/s)

Answer: b

5. According to the text, which of the following is TRUE?

- a) Luminous flux and illumination are the same concepts.
- b) Lux is the unit for luminous flux.
- c) One lux is equal to one lumen per square meter.
- d) Illumination measures light emitted in all directions.

Answer: c

6. The primary concept described as "the total amount of light produced by the source in all directions" is:

- a) Illuminance
- b) Luminous Intensity
- c) Luminous Flux
- d) Luminance

Answer: c

7. If you want to measure how much light is actually hitting your desk, you are measuring:

- a) Luminous Flux
- b) Illumination
- c) Luminous Efficacy
- d) Radiant Flux

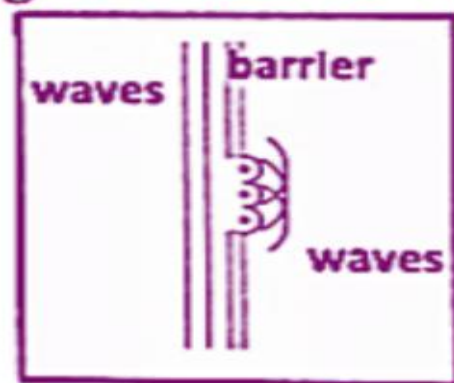
Answer: b

What is the diffraction of light?

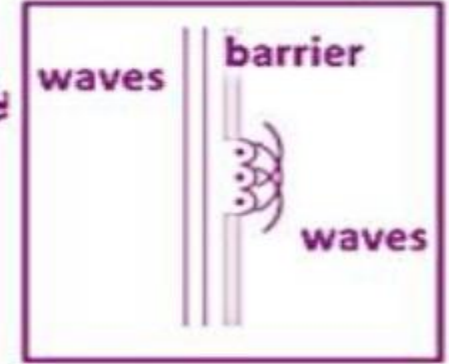
Diffraction is a physical phenomenon that occurs when a wave, such as a light wave, passes through a **narrow aperture** or **around the edge** of an obstacle. Instead of continuing in its straight path, the wave **bends and spreads** out. This can be imagined like water waves passing through a small gap in a barrier; you would notice that they spread out in a circular pattern after passing through the gap.

- What is the name of the phenomenon of the waves after passing the barrier in the figure?

- ☐ reflection
- ☐ refraction
- ☐ diffraction
- ☐ polarization



The figure shows a waves before and after passing the barrier. Which of the following is true for the waves after passing the barrier?



يظهر الشكل المجاور انتشار الموجات قبل وبعد اجتيازها الحاجز، أي الآتية صحيح للموجات بعد اجتيازها الحاجز؟

- | | |
|--|---------------------|
| ☐ the wavelength is increased | قل طولها الموجي |
| ☐ the wavelength is decreased | زاد طولها الموجي |
| ☐ the direction of its propagate is changed | تغير اتجاه انتشارها |
| ☐ the frequency is decreased | قل ترددها |

What is the term for the bending of light as it passes the edges of a barrier?

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

1) Diffraction is best described as:

- a) The change in wave speed in a new medium.
- b) The bending of a wave as it passes the edge of a barrier.
- c) The superposition of two waves meeting.
- d) The change in frequency due to motion.

2) Which phenomenon occurs when a water wave spreads out after passing through a narrow opening in a barrier?

- a) Refraction
- b) Reflection
- c) Diffraction
- d) Dispersion

3) The bending of light around the edge of an obstacle is an example of:

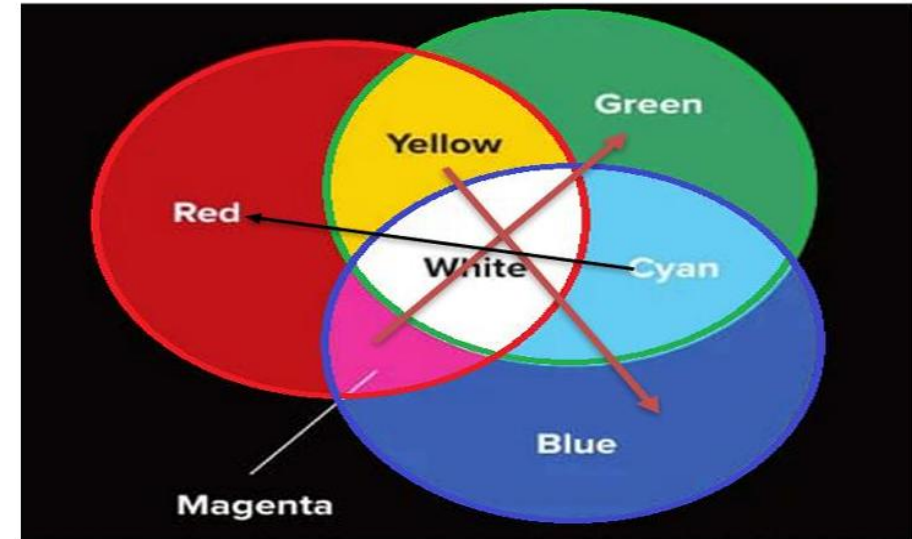
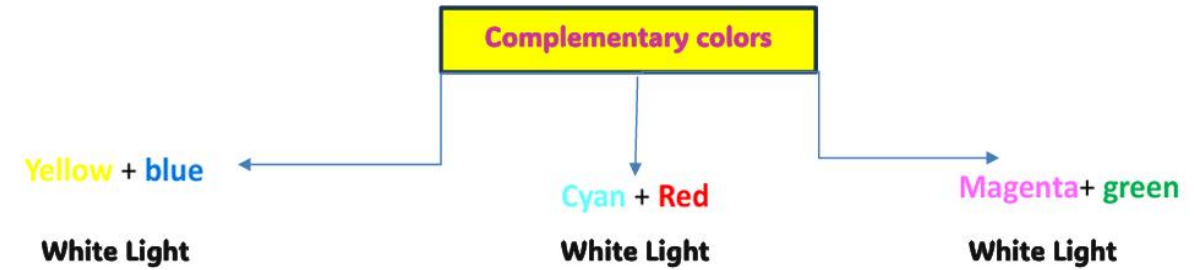
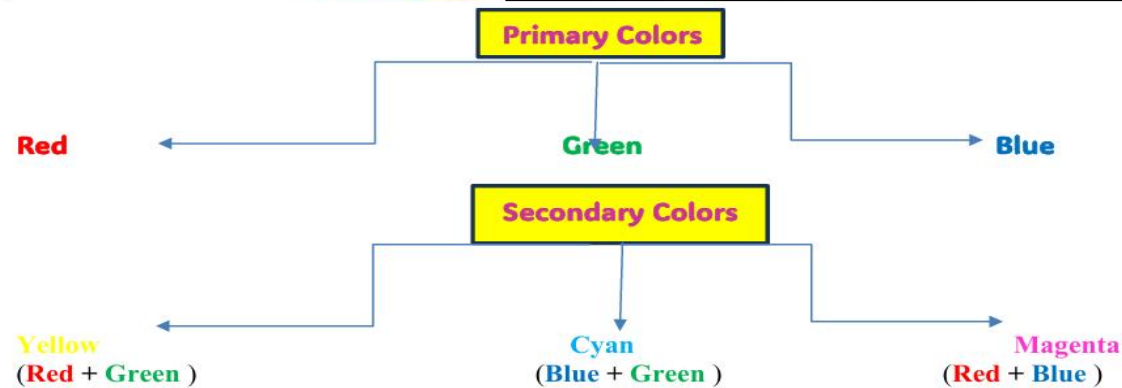
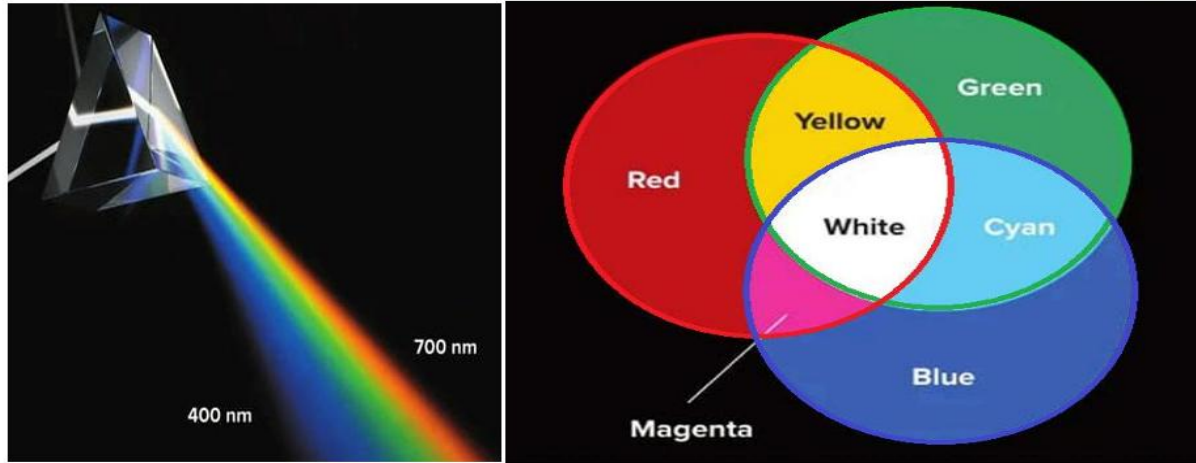
- a) Reflection
- b) Refraction
- c) Diffraction
- d) Polarization

Answers:

- 1. b) The bending of a wave as it passes the edge of a barrier.
- 2. c) Diffraction
- 3. c) Diffraction

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-Describe that the colour of light is related to its wavelength and frequency.
 -Describe primary and secondary pigments and the effects of mixing pigments or dyes.



- **The Nature of White Light:** Newton concluded that white light is not pure but is composed of different colors, and the prism separates these colors.
- **Different Wavelengths:** The wave model explains the colors of the spectrum by stating that each color has a different wavelength, ranging from 400 nm (violet) to 700 nm (red).

Primary Pigments

Yellow

Absorbs **blue** light.
Reflects **red** and **green**

Cyan

Absorbs **red** light.
Reflects **blue** and **green**

Magenta

Absorbs **green** light.
Reflects **red** and **blue**

- **Secondary Pigments:-** is a pigment that absorbs two primary colors of light and reflects one primary color.

Secondary Pigments

Red

Absorbs **green** and **blue** light.
Reflects **red** light

Green

Absorbs **red** and **blue** light.
Reflects **green** light

Blue

Absorbs **red** and **green** light.
Reflects **blue** light

Question : What are the primary colors of light that, when combined with correct intensity, produce white light?

- A) Red, Yellow, Blue
- B) Cyan, Magenta, Yellow
- C) Red, Green, Blue
- D) Orange, Purple, Green

Question : In which application is the process of forming white light by mixing colored lights used?

- A) Photography film
- B) Television screens
- C) Solar panels
- D) Microscopes

Question : Which of the following is a secondary color created by combining Red + Green light?

- A) Cyan
- B) Yellow
- C) Magenta
- D) Blue

Question : How is Cyan light created?

- A) Red + Green light
- B) Blue + Green light
- C) Red + Blue light
- D) Yellow + Blue light

Question : What is the definition of complementary colors in the context of light?

- A) Two colors that are opposite each other on the color wheel.
- B) Two colors of light that can be combined to produce white light.
- C) Two colors that absorb all light.
- D) Two colors that reflect all light.

Question : Which pair of colors combines to produce white light?

- A) Red + Green
- B) Yellow + Blue
- C) Cyan + Magenta
- D) Blue + Green

Question : What is the practical application mentioned for complementary colors?

- A) Mixing paints for art.
- B) Whitening yellowish laundry with a bluing agent.
- C) Creating special effects in movies.
- D) Designing traffic lights.

Question : What is a primary pigment defined as?

- A) A pigment that reflects only one primary color of light.
- B) A pigment that absorbs all primary colors of light.
- C) A pigment that absorbs only one primary color of light and reflects the other two.
- D) A pigment that produces white light when combined with another pigment.

Question : What colors does Magenta Pigment reflect?

- A) Green and blue light
- B) Red and green light
- C) Red and blue light
- D) Only blue light

Question : What is the color model associated with primary pigments?

- A) Additive Color Model نموذج اللون الجمعي
- B) Subtractive Color Model نموذج اللون الطرحي
- C) RGB Color Model
- D) CMYK Color Model

Question : What is a secondary pigment defined as?

- A) A pigment that absorbs one primary color of light and reflects the other two.
- B) A pigment that absorbs two primary colors of light and reflects one primary color.
- C) A pigment that reflects all primary colors of light.
- D) A pigment that produces white light when mixed with another pigment.

Question : What colors does a Red Pigment absorb?

- A) Red light only
- B) Green and blue light
- C) Red and blue light
- D) Yellow and cyan light

Question : What happens when a Yellow Pigment absorbs blue light?

- A) It reflects only red light.
- B) It reflects green and blue light.
- C) It reflects red and green light.
- D) It reflects all colors of light.

Question : Which primary color of light does Cyan Pigment absorb?

- A) Green light
- B) Blue light
- C) Red light
- D) Yellow light

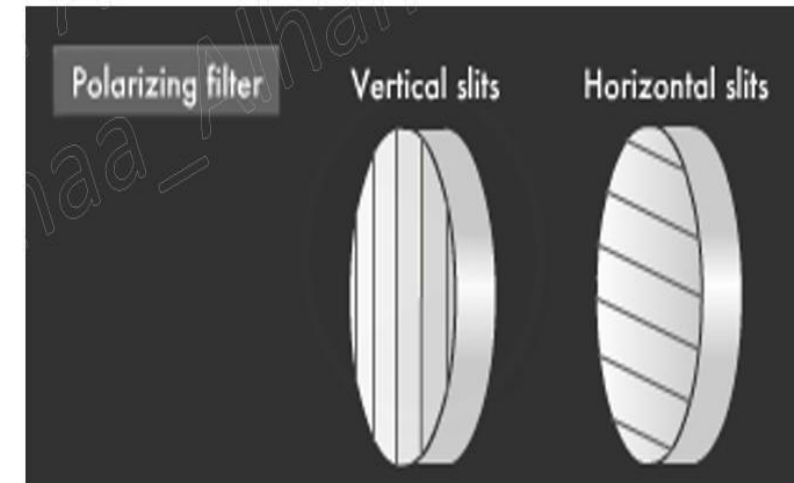
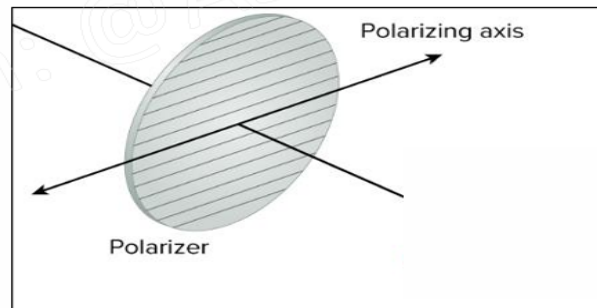
Question : Which primary colors of light does a Blue Pigment absorb?

- A) Red and green light
- B) Blue and green light
- C) Red and blue light
- D) Only blue light

Question : According to the Color Model Comparison table, what are the primary colors for light?

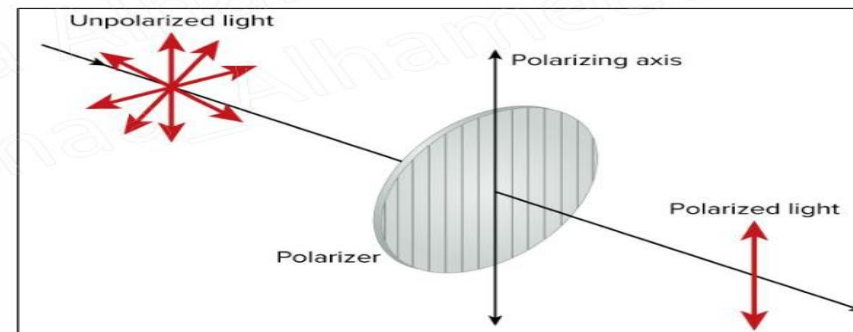
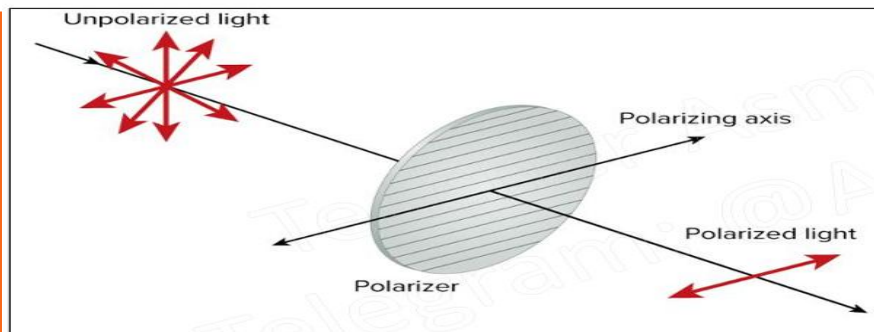
- A) Yellow, Cyan, Magenta
- B) Red, Green, Blue
- C) Red, Green, Yellow
- D) Blue, Cyan, Magenta

- **Polarization** is the production of light with a specific pattern of oscillation.
- When the electric field of a light wave oscillates in random directions, the light is nonpolarized.
- The lines in the polarizer represent a polarizing axis. The light with the portion of the electric field that oscillates parallel to the polarizing axis passes through, while the light with the portion of the electric field that oscillates perpendicular to the axis is absorbed.



If a polarizer is placed in a beam of nonpolarized light, only the components of the waves in the same direction as the polarizing axis can pass through.

As a result, half of the total light passes through, reducing the intensity of the light by half.

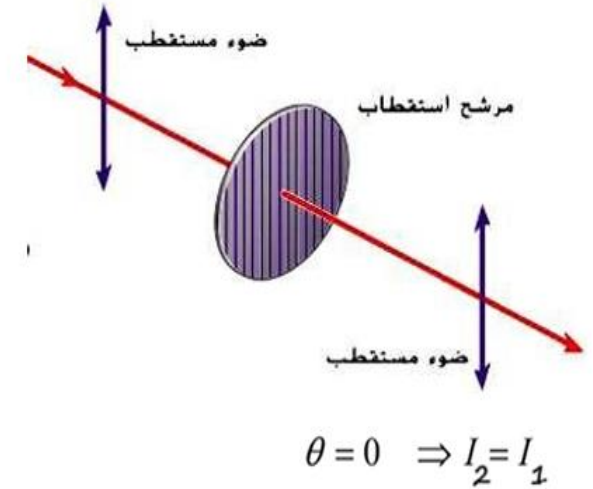
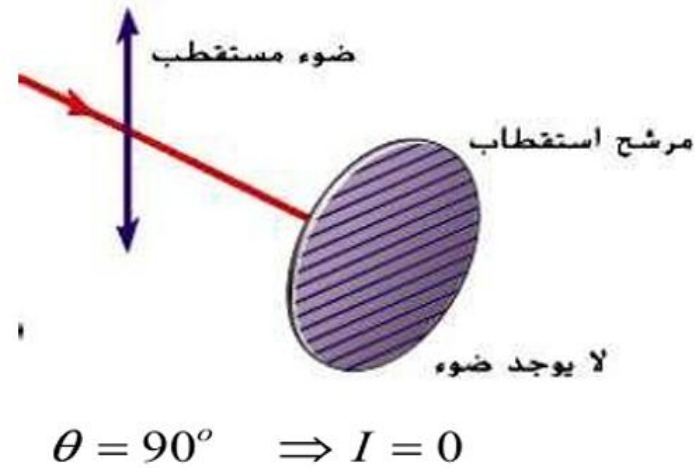
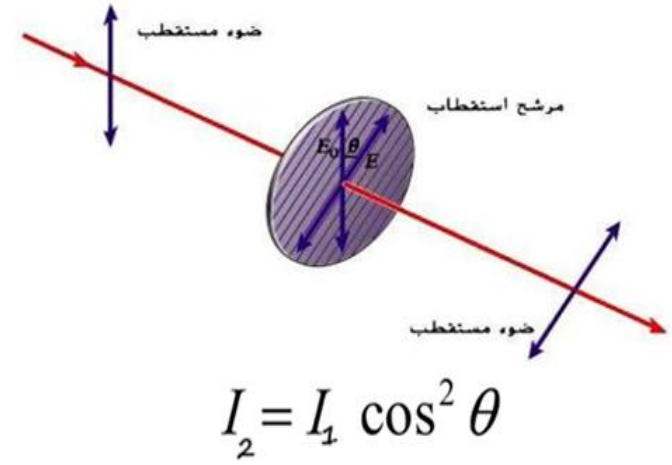
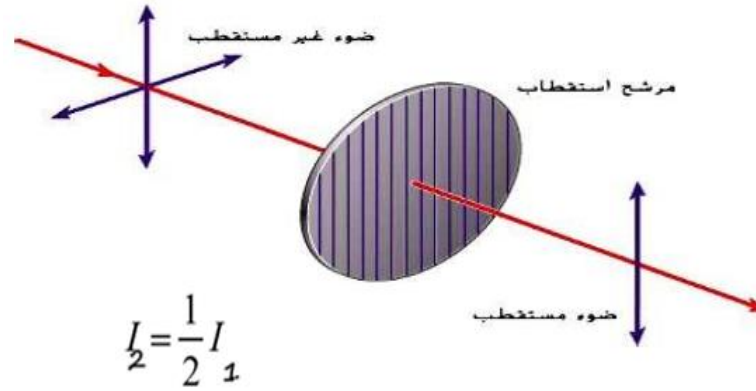


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Malus's Law

The intensity of light coming out of a second polarizing filter is equal to the intensity of polarized light coming out of a first polarizing filter multiplied by the cosine, squared, of the angle between the polarizing axes of the two filters.

$$I_2 = I_1 \cos^2 \theta$$



1) According to Malus's Law, if the angle between the transmission axes of a polarizer and an analyzer is 0° , the intensity of transmitted light is:

- a) Zero
- b) Minimum
- c) Maximum
- d) Half the original intensity

2) Unpolarized light of intensity I_0 passes through a single polarizer. The intensity of the transmitted light is:

- a) I_0
- b) $I_0/2$
- c) $I_0/4$
- d) Zero

3) Polarized light of intensity I passes through an analyzer rotated at 60° from the polarizer's axis. What is the final intensity? (Malus's Law: $I = I_0 \cos^2 \theta$)

- a) I
- b) $I/2$
- c) $I/4$
- d) $I/8$

Answers:

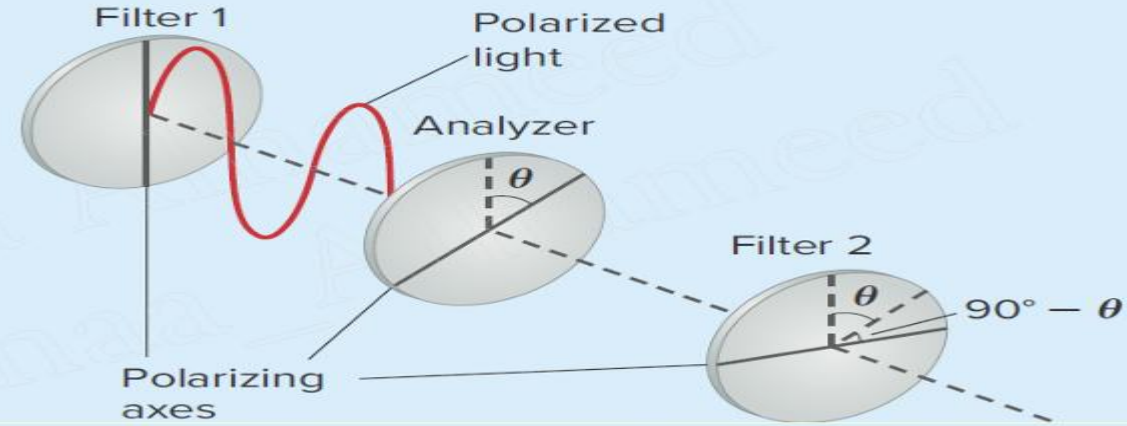
- 1. c) Maximum
- 2. b) $I_0/2$
- 3. c) $I/4$

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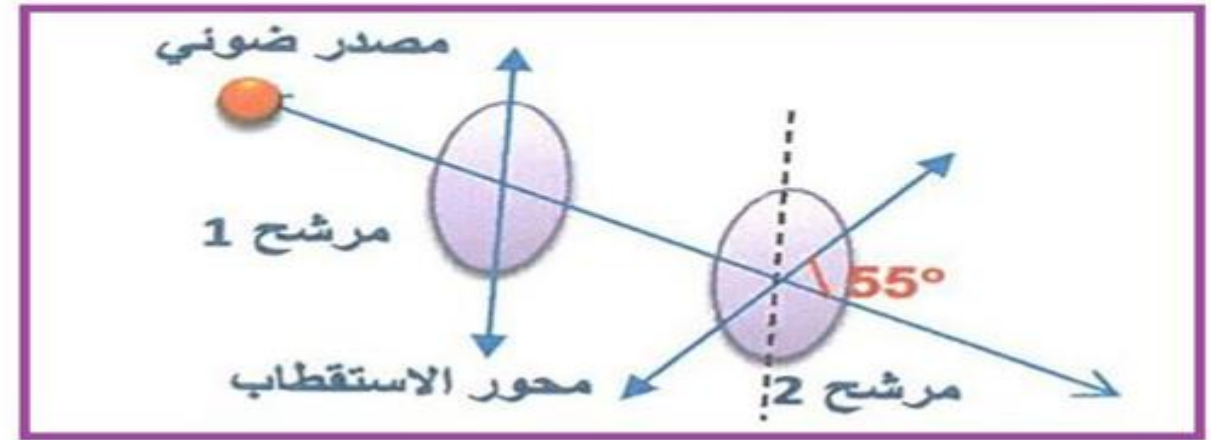
PHYSICS Challenge

You place an analyzer filter between the two cross-polarized filters, such that its polarizing axis is not parallel to either of the two filters, as shown in the figure to the right.

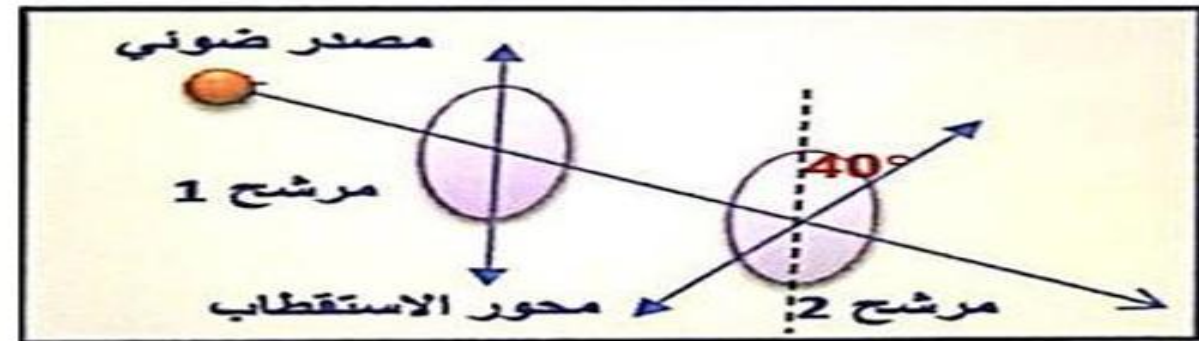
1. You observe that some light passes through filter 2, though no light passed through filter 2 before you inserted the analyzer filter. Why does this happen?
2. The analyzer filter is placed at an angle of θ relative to the polarizing axis of filter 1. Derive an equation for the intensity of light coming out of filter 2 compared to the intensity of light coming out of filter 1.



In the adjacent figure, light passes through filter 1 with an intensity of (75 W/m^2). Calculate the intensity of the light transmitted through filter 2.



In the adjacent figure, light passes through filter 2 with an intensity of (60.0 W/m^2). Calculate the intensity of the light transmitted through filter 1.



Speed, Wavelength, and Frequency of Light

The observed frequency

The observed frequency of light from a source is equal to the true frequency of the light generated by the source, multiplied by the sum of one plus (the relative speed along the axis between the source and the observer divided by the speed of light) if they are moving toward each other. Or multiplied by one minus (the relative speed divided by the speed of light) if they are moving away from each other.

$$f_{\text{obs}} = f \left(1 \pm \frac{v}{c} \right)$$

Doppler Shift

The difference between the observed wavelength of light and the true wavelength of the light generated by the source, multiplied by the relative speed of the source and the observer divided by the speed of light. This quantity is positive if they are moving away from each other, and negative if they are moving toward each other.

$$(\lambda_{\text{obs}} - \lambda) = \Delta\lambda = \pm \left(\frac{v}{c} \right) \lambda$$

16. Oxygen can be made to produce light with a wavelength of 513 nm. What is the frequency of this light?

17. A hydrogen atom in a galaxy moving with a speed of 6.55×10^6 m/s away from Earth emits light with a frequency of 6.16×10^{14} Hz. What frequency of light from that hydrogen atom would be observed by an astronomer on Earth?

18. A hydrogen atom in a galaxy moving with a speed of 6.55×10^6 m/s away from Earth emits light with a wavelength of 486 nm. What wavelength would be observed on Earth from that hydrogen atom?

19. CHALLENGE An astronomer is looking at the spectrum of a galaxy and finds that it has an oxygen spectral line of 525 nm, while the laboratory value is measured at 513 nm. Calculate how fast the galaxy would be moving toward or away from Earth and how you know.

1) A distant galaxy emits light with a rest wavelength of 500 nm. An observer on Earth measures this wavelength to be 505 nm. What can be concluded about the galaxy's motion relative to Earth?

- a) It is moving toward Earth at $0.01c$.
- b) It is moving away from Earth at $0.01c$.
- c) It is moving toward Earth at $0.02c$.
- d) It is moving away from Earth at $0.02c$.

2) A spaceship is moving toward a stationary star at $0.1c$. If the star emits light of frequency 6.0×10^{14} Hz, what frequency does the spaceship observe? (Use the Doppler formula for light)

- a) 5.4×10^{14} Hz
- b) 6.0×10^{14} Hz
- c) 6.6×10^{14} Hz
- d) 7.2×10^{14} Hz

3) A police radar gun uses the Doppler effect to measure the speed of a car. If the reflected microwave has a frequency shift of +1500 Hz from the transmitted frequency of 10.5 GHz, how fast is the car moving toward the radar gun? (Assume speed of light $c = 3 \times 10^8$ m/s)

- a) 15 m/s
- b) 21.4 m/s
- c) 30 m/s
- d) 42.8 m/s

Answers:

1. b) It is moving away from Earth at $0.01c$.

2. c) 6.6×10^{14} Hz

3. b) 21.4 m/s

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Law of Reflection

The angle that a reflected ray makes as measured from the normal to a reflective surface equals the angle that the incident ray makes as measured from the same normal.

$$\theta_r = \theta_i$$

3. Suppose the angle of incidence of a light ray is 42° .
- What is the angle of reflection?
 - What is the angle the incident ray makes with the mirror?
 - What is the angle between the incident ray and the reflected ray?

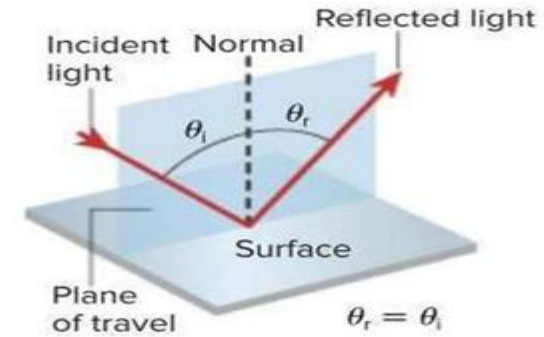


Figure 2 Reflecting light waves have an angle of reflection in the same plane as and equal to the angle of incidence.

5. You position two plane mirrors at right angles to each other. A light ray strikes one mirror at an angle of 60° to the normal and reflects toward the second mirror. What is its angle of reflection off the second mirror?

4. Light from a laser strikes a plane mirror at an angle of 38° to the normal. If the angle of incidence increases by 13° , what is the new angle of reflection?

2. What is the angle of incidence of a light ray reflected off a plane mirror at an angle of 35° to the normal?

- Draw a ray diagram to locate the position of an image formed by a plane mirror, showing its properties.
- Represent mathematically the relation between image position and object position, as well as the image height and object height for a plane mirror.

Properties of Plane-Mirror Images

Plane-Mirror Image Position

With a plane mirror, the image position is equal to the negative of the object position. The negative sign indicates that the image is behind the mirror (and therefore virtual).

$$x_i = -x_o$$

$$x_i = -x_o$$

Image position Object position

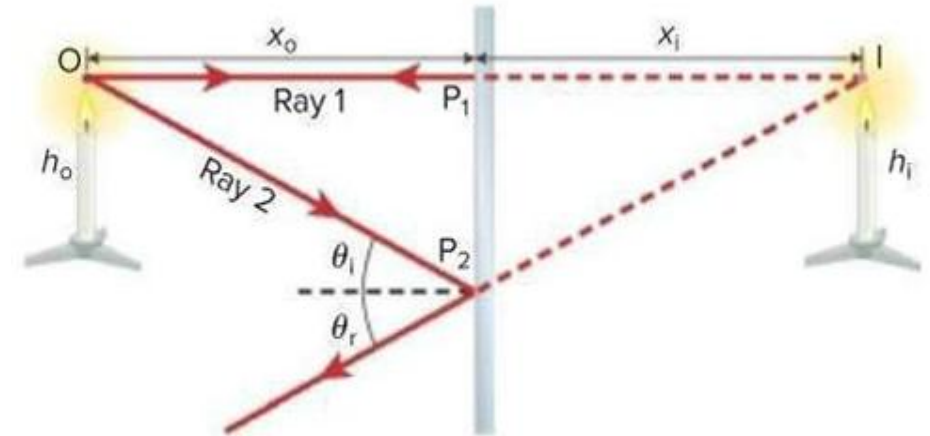
Plane-Mirror Image Height

With a plane mirror, image height is equal to object height.

$$h_i = h_o$$

$$h_i = h_o$$

Image height object height



- Virtual (خيالية)
- same orientation as the object (same altitude)
- gives a front-to-back reversal (laterally inverted) (معكوسة جانبياً)
- Object height = image height
- Object position = image position

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Image Properties A dog looks at its image, as shown in **Figure 9**. What are the position, height, and type of image?



You position two plane mirrors at right angles to each other. A light ray strikes one mirror at an angle of 60° to the normal and reflects toward the second mirror. What is its angle of reflection off the second mirror?

1) When drawing a standard ray diagram for a plane mirror, where is the image of an object located?

- a) In front of the mirror
- b) Behind the mirror
- c) At the surface of the mirror
- d) At the center of curvature

2) Which of the following is a property of an image formed by a plane mirror?

- a) It is always magnified.
- b) It is always inverted relative to the object.
- c) It is always virtual and erect.
- d) It can be projected onto a screen.

3) In a ray diagram for a plane mirror, two rays from the top of an object are drawn. One ray strikes the mirror perpendicularly. What is the path of the second ray typically used?

- a) A ray striking the mirror at the focal point.
- b) A ray striking the mirror at an arbitrary angle, then reflecting according to the law of reflection.
- c) A ray passing through the center of curvature.
- d) A ray parallel to the principal axis.

Answers:

- 1. b) Behind the mirror
- 2. c) It is always virtual and erect.
- 3. b) A ray striking the mirror at an arbitrary angle, then reflecting according to the law of reflection.

4) If an object is placed 4 meters in front of a plane mirror, where is the image located relative to the mirror?

- a) 2 meters behind the mirror
- b) 4 meters in front of the mirror
- c) 4 meters behind the mirror
- d) 8 meters behind the mirror

5) What is the mathematical relationship between the image height (h_i) and the object height (h_o) for a plane mirror?

- a) $h_i > h_o$
- b) $h_i < h_o$
- c) $h_i = h_o$
- d) $h_i = 2h_o$

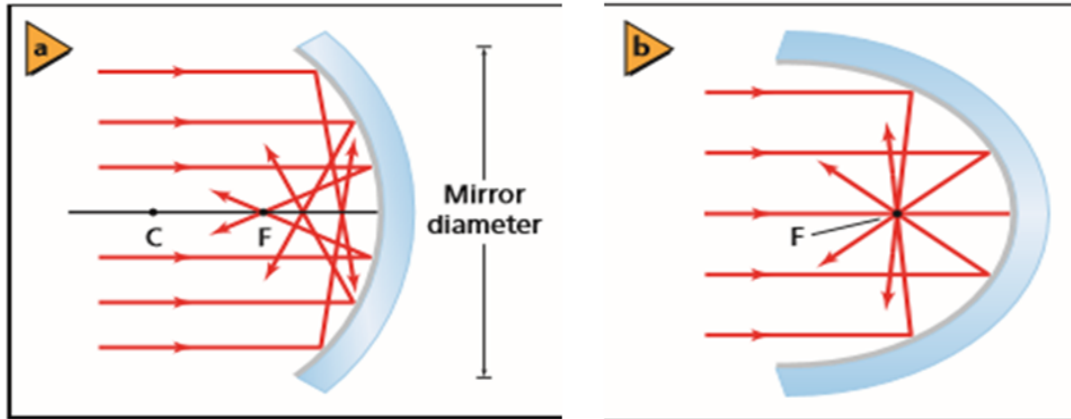
6) An object is 1.8 meters tall and stands 3 meters from a plane mirror. What is the distance between the object and its image?

- a) 3 meters
- b) 4.8 meters
- c) 6 meters
- d) 7.8 meters

Answers:

- 4. c) 4 meters behind the mirror
- 5. c) $h_i = h_o$
- 6. c) 6 meters

spherical aberration



spherical aberration occurs because the light rays do not converge at a focal point, which makes an image look fuzzy.

Use Case

Shaving/Makeup Mirror

Vehicle Headlight

Reflecting Telescope

Solar Furnace

A spherical mirror suffers from spherical aberration because its shape does not focus all parallel rays into a single point, while a parabolic mirror does not suffer from this defect because it is geometrically designed to perfectly focus parallel rays into a single focal point.

المرآة الكروية تعاني من الانزياح الكروي لأن شكلها لا يجمع كل الأشعة المتوازية في نقطة واحدة، بينما المرآة القطعية لا تعاني من هذا العيب لأنها مصممة هندسيًا لجمع الأشعة المتوازية تمامًا في بؤرة واحدة.

The most effective and common way to eliminate spherical aberration is to use a parabolic mirror instead of a spherical one.

أكثر طريقة فعالة وشائعة للتخلص من الزيغ الكروي هي استخدام مرآة على شكل قطع مكافئ بدلاً من المرآة الكروية.

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1) What is the primary cause of spherical aberration in a concave spherical mirror?

- a) Different colors of light focus at different points
- b) Marginal rays focus at a different point than paraxial rays
- c) The mirror absorbs too much light
- d) The image becomes magnified unevenly

2) How can spherical aberration in concave mirrors be corrected?

- a) By using a parabolic mirror instead of a spherical one
- b) By placing a convex lens in front of the mirror
- c) By silvering the mirror surface
- d) By increasing the mirror's focal length

3) Which statement best describes spherical aberration?

- a) Light rays parallel to the principal axis converge at a single point
- b) The mirror produces multiple images of a single object
- c) The mirror focuses parallel rays to different points, creating a blurred image
- d) The mirror changes the color of the reflected light

Answers:

- 1. b) Marginal rays focus at a different point than paraxial rays
- 2. a) By using a parabolic mirror instead of a spherical one
- 3. c) The mirror focuses parallel rays to different points, creating a blurred image

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4) Which application typically uses a concave mirror?

- a) Car side-view mirrors
- b) Security mirrors in stores
- c) Shaving/makeup mirrors
- d) Rear-view mirrors in vehicles

5) Where would you most commonly find a convex mirror being used?

- a) In astronomical telescopes
- b) In dental examination tools
- c) In vehicle side-view mirrors
- d) In flashlight reflectors

6) What makes concave mirrors suitable for use in solar cookers?

- a) They create virtual, erect images
- b) They provide a wide field of view
- c) They diverge light rays
- d) They converge sunlight to a focal point

Answers:

4. c) Shaving/makeup mirrors

5. c) In vehicle side-view mirrors

6. d) They converge sunlight to a focal point

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Ray Diagrams for Concave Mirrors

- image is formed where the outgoing rays cross
- two principle rays are sufficient to find image, use third and fourth to check your diagram

1. object outside center ($x_o > 2f$)

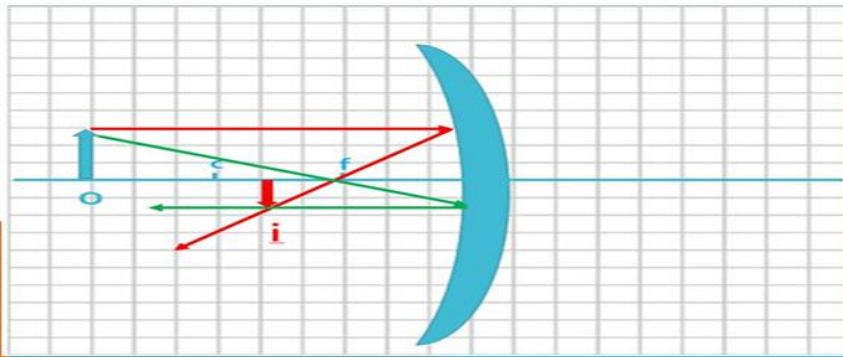


image is:

- 1. Inverted** (upside down)
- 2. smaller** than object
- 3. real**

2. object at center ($x_o = 2f$)

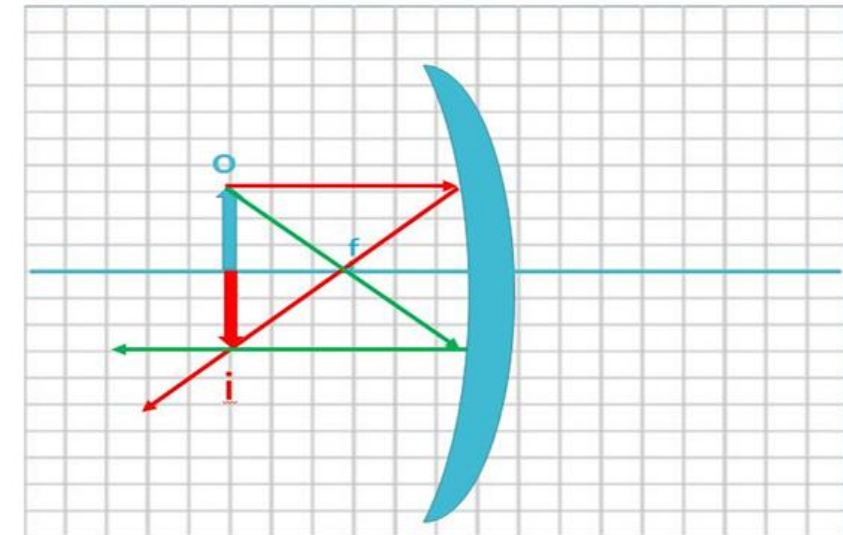


image is:

- 1. inverted**
- 2. Same size** of the object
- 3. real**

Exactly at distance from the mirror $2f$

3. object between f and $2f$ ($2f > x_o > f$)

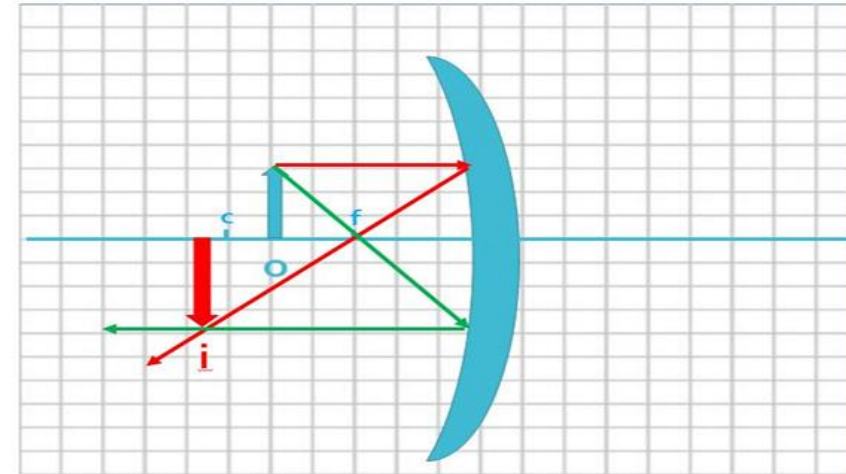
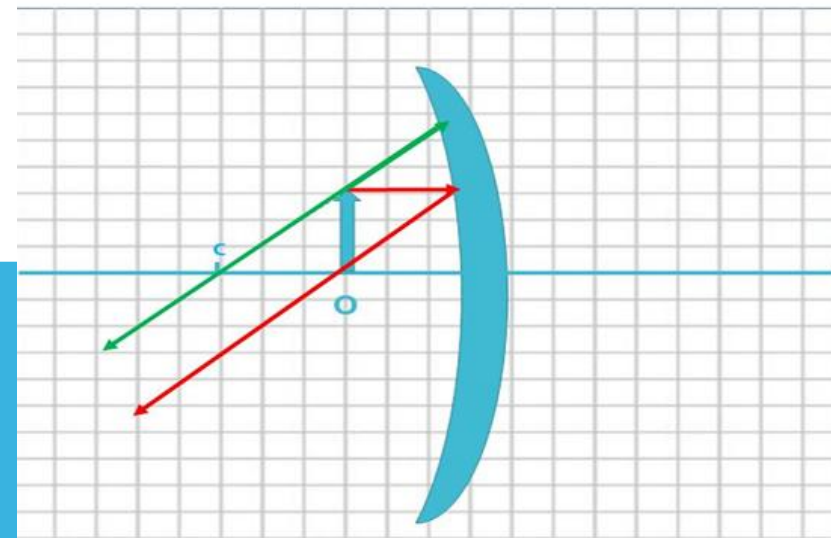


image is:

- 1. inverted**
- 2. larger** than object
- 3. real**

4. object at focal point ($x_o = f$)



the image:

is said to be **at infinity**, so **the image could never be seen.**

5. object between mirror and focal point ($x_o < f$)

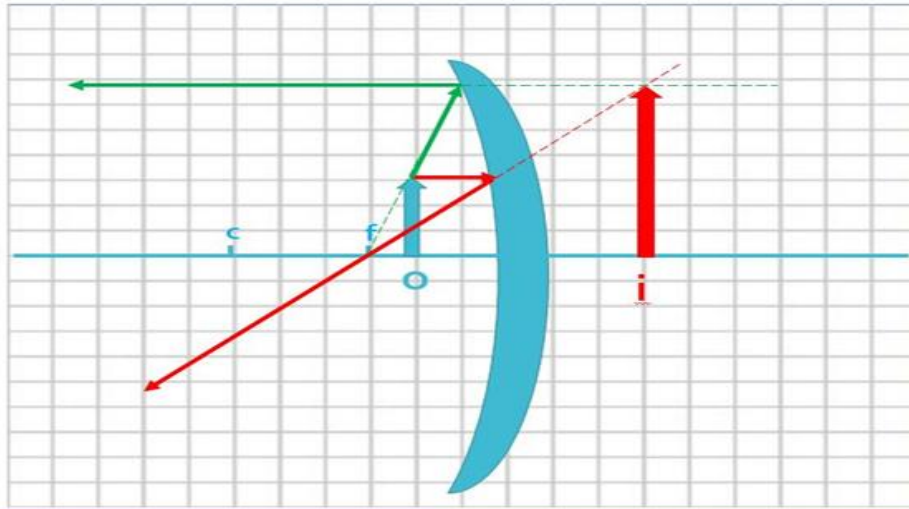


image is:

1. **upright**
2. **larger** than object
3. **virtual**

Virtual Images with Convex Mirrors

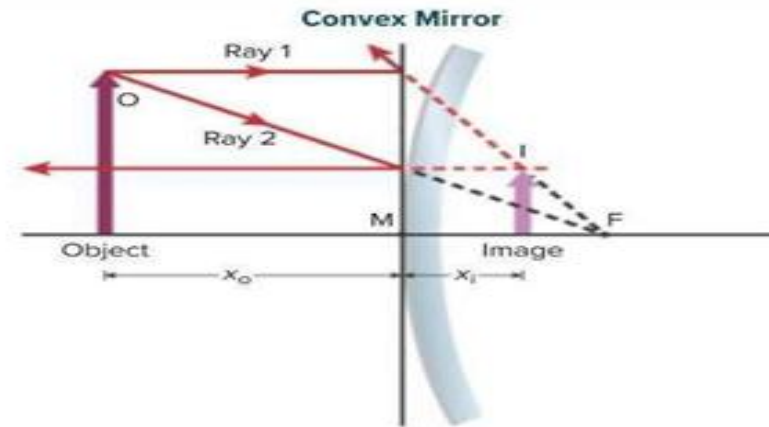
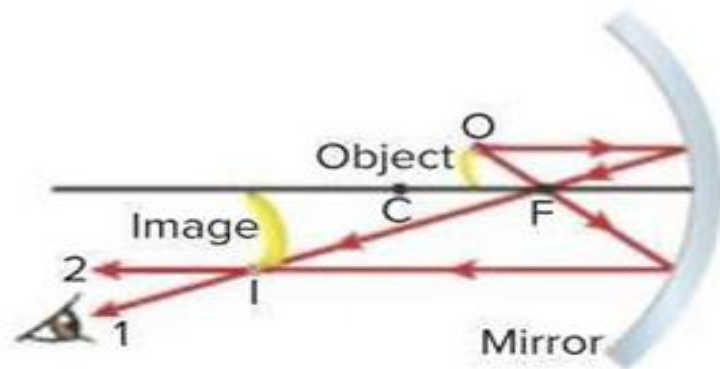
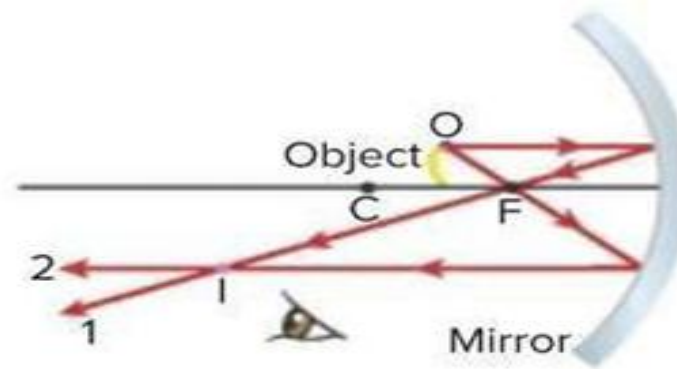


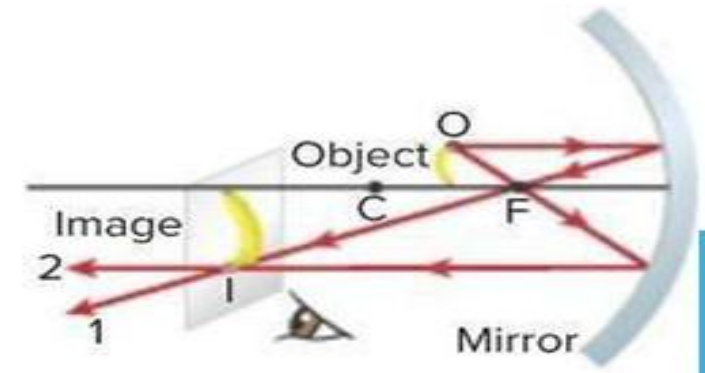
Figure 15 Convex mirrors form images that are virtual, upright, and smaller than the object.



The eye is positioned so that the rays that form the real image strike the eye, allowing the image to be seen.



Rays from the object do not reach the eye, so the image cannot be seen from this position.



The image can be seen when projected on a white opaque screen.

1) For a concave mirror, an object is placed between the focal point (F) and the center of curvature (C). In a ray diagram, which describes the image formed?

- a) Virtual, erect, and magnified
- b) Real, inverted, and diminished
- c) Real, inverted, and magnified
- d) Virtual, erect, and diminished

2) When drawing a ray diagram for a convex mirror, where is the image always located?

- a) Behind the mirror
- b) Between F and C in front of the mirror
- c) Beyond C in front of the mirror
- d) At the focal point in front of the mirror

3) In a ray diagram for a concave mirror with the object placed beyond the center of curvature (C), one standard ray is drawn parallel to the principal axis. After reflection, this ray:

- a) Passes through the focal point (F)
- b) Appears to come from the focal point (F)
- c) Reflects back parallel to the principal axis
- d) Passes through the center of curvature (C)

Answers:

- 1. c) Real, inverted, and magnified
- 2. a) Behind the mirror
- 3. a) Passes through the focal point (F)

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-Apply the mirror equation to calculate the image distance, the object distance, or the focal length of a spherical mirror using appropriate algebraic signs for focal length and corresponding distances

MIRROR EQUATION

The reciprocal of the focal length of a spherical mirror is equal to the sum of the reciprocals of the image position and the object position.

$$\frac{1}{f} = \frac{1}{x_i} + \frac{1}{x_o}$$

$$x_i = \frac{fx_o}{x_o - f}$$

$$x_o = \frac{fx_i}{x_i - f}$$

$$f = \frac{x_i x_o}{x_i - x_o}$$

MAGNIFICATION

The magnification of an object by a spherical mirror, defined as the image height divided by the object height, is equal to the negative of the image position, divided by the object position.

$$m \equiv \frac{h_i}{h_o} = -\frac{x_i}{x_o}$$

$$h_i = \frac{-x_i h_o}{x_o}$$

Curved mirrors

Convex mirror

f

Focal point for convex mirror is
virtual (negative)

Concave mirror

f

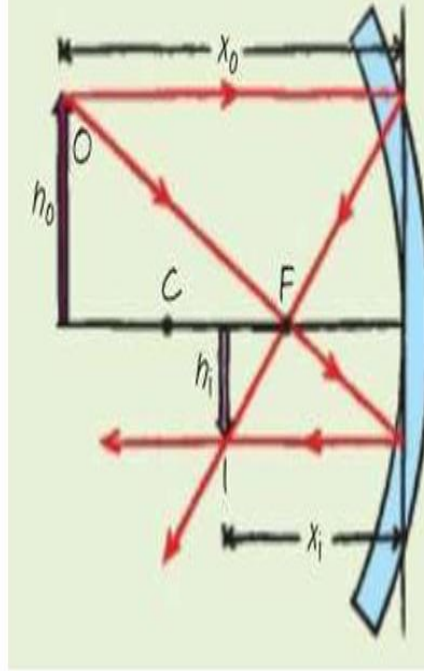
Focal point for concave
mirror is real (Positive)

$$f = \frac{r}{2}$$

x_i → positive Real image
 x_i → negative Virtual image

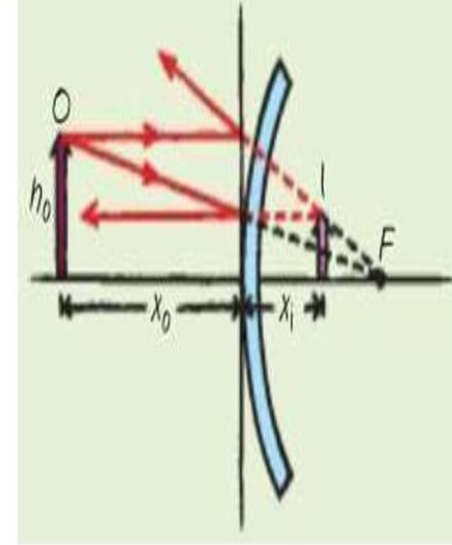
EXAMPLE Problem 2

REAL IMAGE FORMATION BY A CONCAVE MIRROR A concave mirror has a radius of curvature of 20.0 cm. You place a 2.0-cm-tall object 30.0 cm from the mirror. What are the image position and image height?



EXAMPLE Problem 3

IMAGE IN A SECURITY MIRROR A convex security mirror in a warehouse has a -0.50-m focal length. A 2.0-m-tall forklift is 5.0 m from the mirror. What are the forklift's image position and image height?



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13. You place an object 36.0 cm in front of a concave mirror with a 16.0-cm focal length. Determine the image position.

16. CHALLENGE You place an object near a concave mirror with a 10.0-cm focal length. The image is 3.0 cm tall, inverted, and 16.0 cm from the mirror. What are the object position and object height?

17. You place an object 20.0 cm in front of a convex mirror with a -15.0 -cm focal length. Find the image position using both a scale diagram and the mirror equation.

19. A 7.6-cm-diameter ball is located 22.0 cm from a convex mirror with a radius of curvature of 60.0 cm. What are the ball's image position and diameter?

- 21. CHALLENGE** A convex mirror is needed to produce an image that is three-fourths the size of an object and located 24 cm behind the mirror.
- a. What is the object's distance?
 - b. What focal length should be specified?

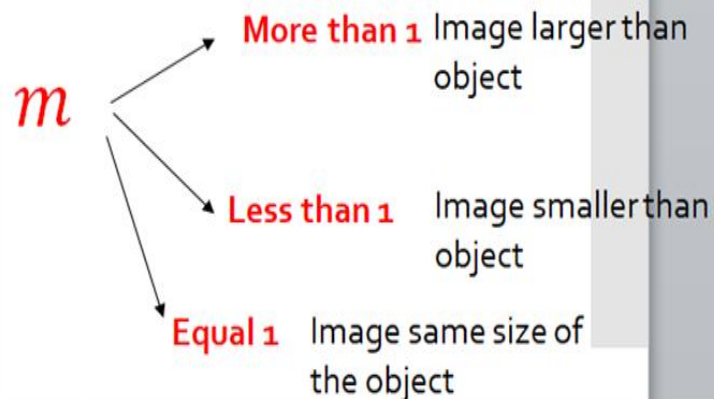
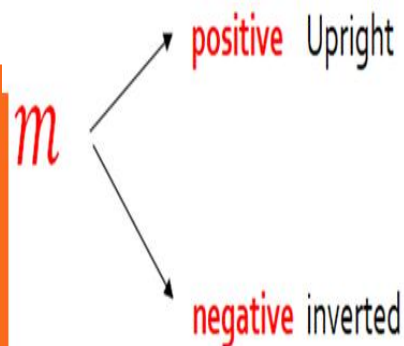
Magnification Another property of a spherical mirror is **magnification** (m), which is the ratio of the image height to the object height.

The sign of the magnification tells you whether the image is upright or inverted. For virtual images such as those formed by convex mirrors, x_i is negative. This means m is positive. Note that virtual images are always upright, so the height is always positive.

Magnification

The magnification of an object by a spherical mirror, defined as the image height divided by the object height, is equal to the negative of the image position, divided by the object position.

$$m \equiv \frac{h_i}{h_o} = -\frac{x_i}{x_o}$$



If the magnification (m) is greater than 1, what does this indicate about the image?

- A) The image is inverted.
- B) The image is smaller than the object.
- C) The image is larger than the object.
- D) The image is virtual.

. For a virtual image formed by a convex mirror, the magnification (m) is:

- A) Negative
- B) Zero
- C) Positive
- D) Undefined

. What does a negative magnification (m) value signify about the image orientation?

- A) The image is upright.
- B) The image is virtual.
- C) The image is inverted.
- D) The image is smaller than the object.

1) A spherical mirror produces an image with a magnification of -2.0 . What can be concluded about the image?

- a) Virtual, upright, and diminished
- b) Virtual, upright, and magnified
- c) Real, inverted, and diminished
- d) Real, inverted, and magnified

2) What does a magnification value of $+0.5$ indicate about the image?

- a) Real, inverted, and twice the size of the object
- b) Virtual, upright, and half the size of the object
- c) Real, upright, and half the size of the object
- d) Virtual, inverted, and twice the size of the object

3) An optical system forms an image with a magnification of -0.8 . Which statement correctly describes the image?

- a) The image is virtual and larger than the object
- b) The image is real and smaller than the object
- c) The image is virtual and inverted
- d) The image is real and upright

Answers:

- 1. d) Real, inverted, and magnified
- 2. b) Virtual, upright, and half the size of the object
- 3. b) The image is real and smaller than the object

Table 1 Single-Mirror System Properties

Mirror Type	f	x_o	x_i	m	Image
Plane	∞	$x_o > 0$	$ x_i = x_o$ (negative)	same size	virtual
Concave	+	$x_o > r$	$r > x_i > f$	reduced, inverted	real
		$r > x_o > f$	$x_i > r$	enlarged, inverted	real
		$f > x_o > 0$	$ x_i > x_o$ (negative)	enlarged	virtual
Convex	—	$x_o > 0$	$ f > x_i > 0$ (negative)	reduced	virtual

1) Which type of mirror can form a real, inverted image that is larger than the object?

- a) Plane mirror
- b) Concave mirror
- c) Convex mirror
- d) Both b and c

2) For which mirror type is the image always virtual, upright, and the same size as the object?

- a) Plane mirror
- b) Concave mirror
- c) Convex mirror
- d) Both a and c

3) Which statement about algebraic signs for image distance (v) is correct?

- a) For convex mirrors, v is always positive
- b) For concave mirrors forming real images, v is negative
- c) For virtual images (all mirrors), v is positive
- d) For virtual images (all mirrors), v is negative

Answers:

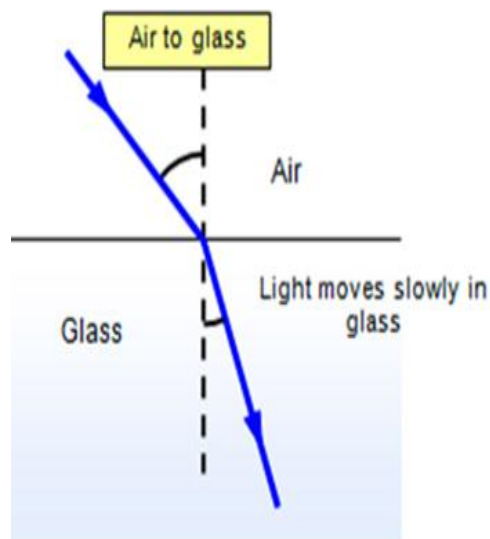
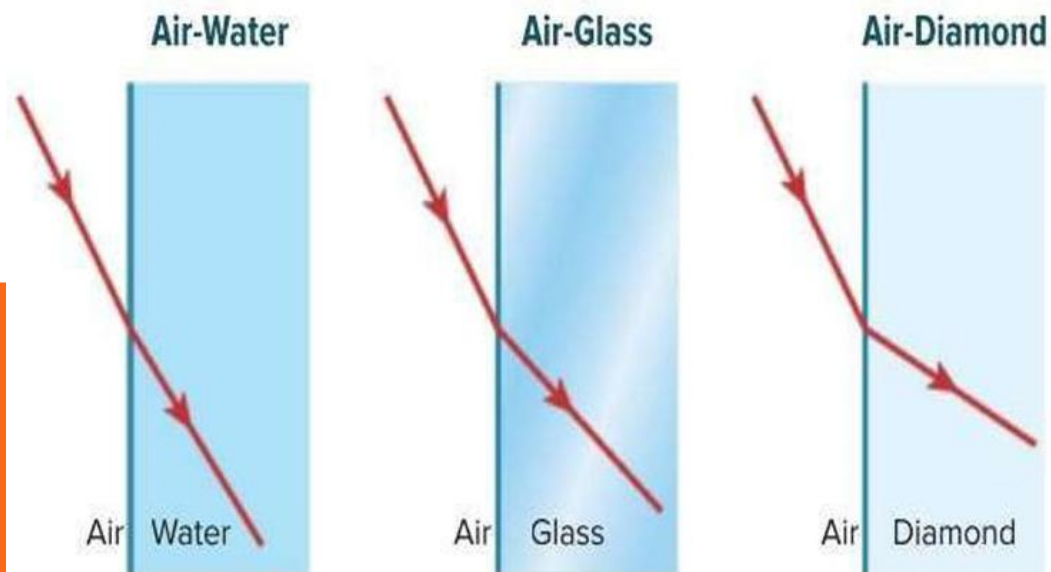
- 1. b) Concave mirror
- 2. a) Plane mirror
- 3. d) For virtual images (all mirrors), v is negative

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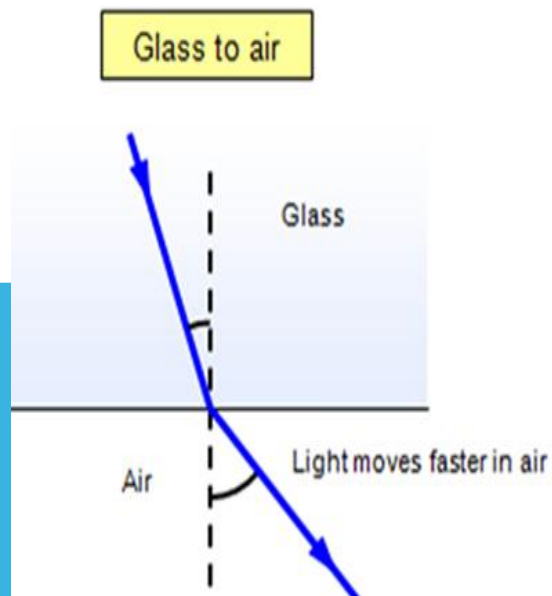
Refraction Observe the light rays in **Figure 18**.

Identical rays of light start in air and pass into three different mediums: water, glass, and diamond. The light rays hit the surface of each medium at the same angle and bend, or refract, as they cross the boundaries.

What difference do you notice between the three mediums shown? The light rays bend more when traveling from air to diamond than from air to water or air to glass. The amount of refraction depends on properties of the mediums that the light rays are traveling from and into.



When light goes from air to glass it moves from material with a lower index of refraction to one with a higher index of refraction ($n_1 < n_2$). The light beam is bent toward the normal to the surface.



When light travels from glass to air it moves from material having a higher index of refraction to one with a lower index ($n_1 > n_2$), the light is bent away from the normal.

1) What is the best description of refraction?

- a) The bouncing of light off a surface
- b) The bending of light as it passes from one medium to another
- c) The spreading of light around obstacles
- d) The change in light's speed in a vacuum

2) In a ray diagram showing light passing from air into glass, how does the ray behave at the boundary?

- a) It bends away from the normal
- b) It bends toward the normal
- c) It continues straight without bending
- d) It reflects back into the air

3) When drawing a refraction ray diagram, what must be included at the point where the ray crosses the boundary between two media?

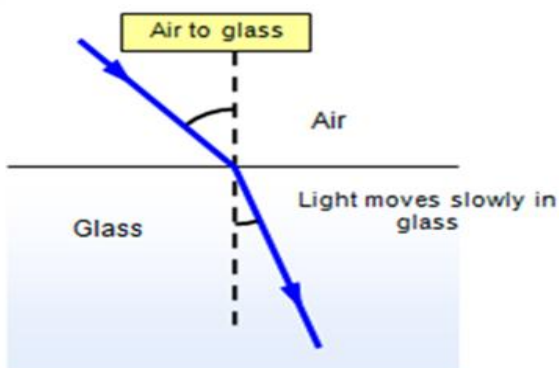
- a) A dotted line showing the original path
- b) A label showing the wavelength change
- c) A normal line perpendicular to the boundary
- d) An arrow showing the speed increase

Answers:

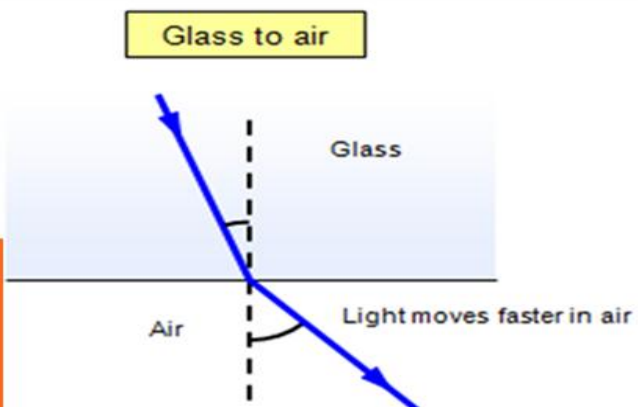
- 1. b) The bending of light as it passes from one medium to another
- 2. b) It bends toward the normal
- 3. c) A normal line perpendicular to the boundary

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Index of refraction Snell found that when light passes from air into a transparent medium, the sines of the angles are related. This **index of refraction** (n) determines the angle of refraction of light as it crosses the boundary between two mediums. Properties of the mediums light is traveling through determine indices of refraction. Values of n for several mediums are listed in **Table 2**.



When light goes from air to glass it moves from material with a **lower index of refraction to one with a higher index of refraction** ($n_1 < n_2$), The light beam is **bent toward the normal to the surface**.



When light travels from glass to air it moves from material having a **higher index of refraction to one with a lower index** ($n_1 > n_2$), the light is bent **away from the normal**.

Table 2 Indices of Refraction for Yellow Light ($\lambda = 589 \text{ nm}$ in a vacuum)

Medium	n
Vacuum	1.00
Air	1.0003*
Water	1.33
Ethanol	1.36
Float glass	1.52
Quartz	1.54
Flint glass	1.62
Diamond	2.42

*The value given for air contains additional significant figures to distinguish it from that for a vacuum. Use a value of $n = 1.00$ for air in problems in this text.

1) How is the index of refraction (n) of a medium defined?

- a) The speed of light in the medium multiplied by the speed of light in a vacuum
- b) The speed of light in a vacuum divided by the speed of light in the medium
- c) The wavelength of light in the medium divided by its wavelength in a vacuum
- d) The frequency of light in the medium divided by its frequency in a vacuum

2) A medium with a higher index of refraction will cause light to:

- a) Travel faster and bend less
- b) Travel slower and bend more
- c) Travel faster and bend more
- d) Travel slower and bend less

3) Which material typically has the highest index of refraction?

- a) Air
- b) Water
- c) Glass
- d) Diamond

Answers:

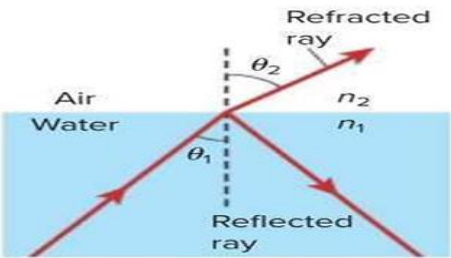
- 1. b) The speed of light in a vacuum divided by the speed of light in the medium
- 2. b) Travel slower and bend more
- 3. d) Diamond

-Describe some applications of total internal reflection
 -Explain some natural phenomena, such as the formation of mirage or rainbows or others, which involve optical phenomena like reflection, refraction, total internal reflection, or dispersion of light.

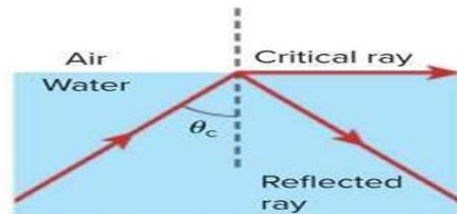
Total Internal Reflection

Recall that when light strikes a transparent boundary, some of the light is transmitted and some is reflected. As light travels from a medium of higher index of refraction to a medium of lower index of refraction, the angle of refraction is larger than the angle of incidence, as shown in **Figure 21**.

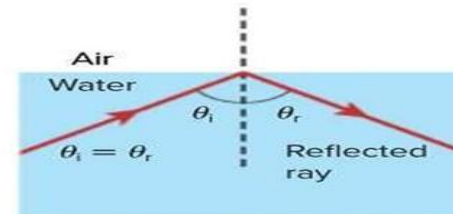
This leads to an interesting phenomenon. As the angle of incidence increases, the angle of refraction increases. At a certain angle of incidence known as the **critical angle** (θ_c), the refracted light ray lies along the boundary of the two mediums.



At an angle of incidence less than the critical angle, light is partially refracted and partially reflected.



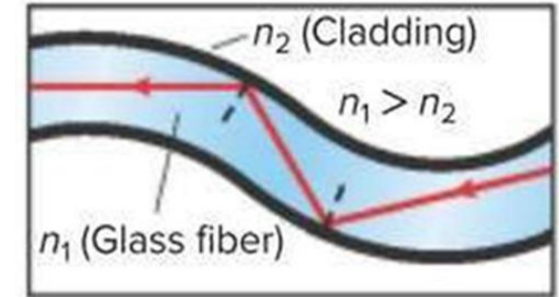
A ray refracted along the boundary of the medium forms the critical angle.



An angle of incidence greater than the critical angle results in total internal reflection, which follows the law of reflection.

Using Snell's law and substituting $\theta_1 = \theta_c$, and $\sin \theta_2 = \sin 90.0^\circ = 1$:

$$\sin \theta_c = \frac{n_2}{n_1}$$

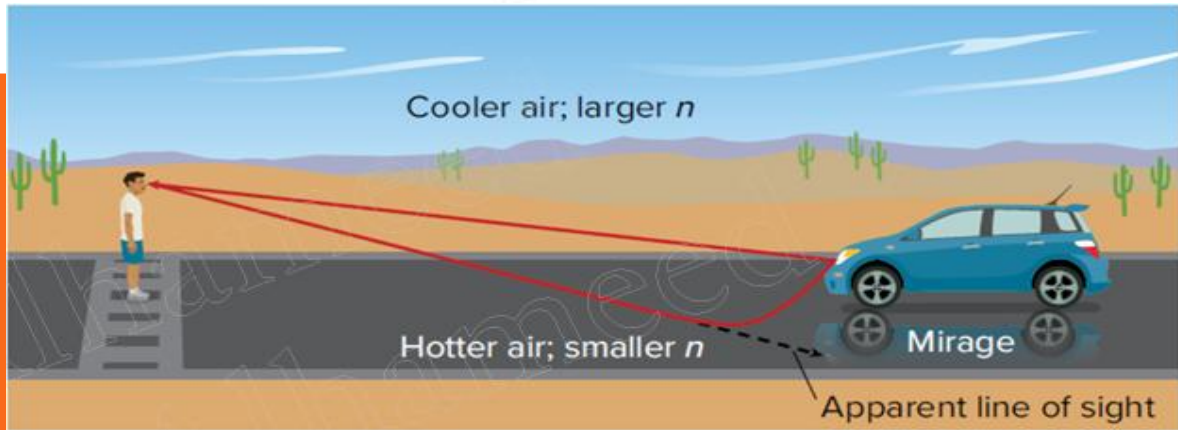


TOTAL INTERNAL REFLECTION is used in communication via optical fibers. The light traveling through the transparent fiber always hits the internal boundary of the optical fiber at an angle greater than the critical angle. All the light is reflected, and

Mirages

mirage is the result of the Sun heating the road. The speed of light and, therefore, the index of refraction, for a gaseous medium can change slightly with temperature. The hot road heats the air above it and produces a thermal layering of air, causing light traveling toward the road from the car to gradually bend upward. This makes the light appear to be coming from a reflection in a pool.

The diagram in Figure 22 shows how this occurs. As light from a distant object travels downward toward the road, the index of refraction of the air decreases as the air gets hotter, but the temperature change is gradual. Recall that light wavefronts are comprised of Huygens' wavelets. In the case of a mirage, the Huygens' wavelets closer to the ground travel faster than those higher up, causing the wavefronts to gradually turn upward.



Rainbows A rainbow is a spectrum formed when sunlight is dispersed by water droplets in the atmosphere. Sunlight that falls on a water droplet is refracted. Since each color has a different wavelength, it is refracted at a slightly different angle, as shown in Figure 24 on the next page, resulting in dispersion. At the back surface of the droplet, some of the light undergoes internal reflection. On the way out of the droplet, the light once again is refracted and dispersed.

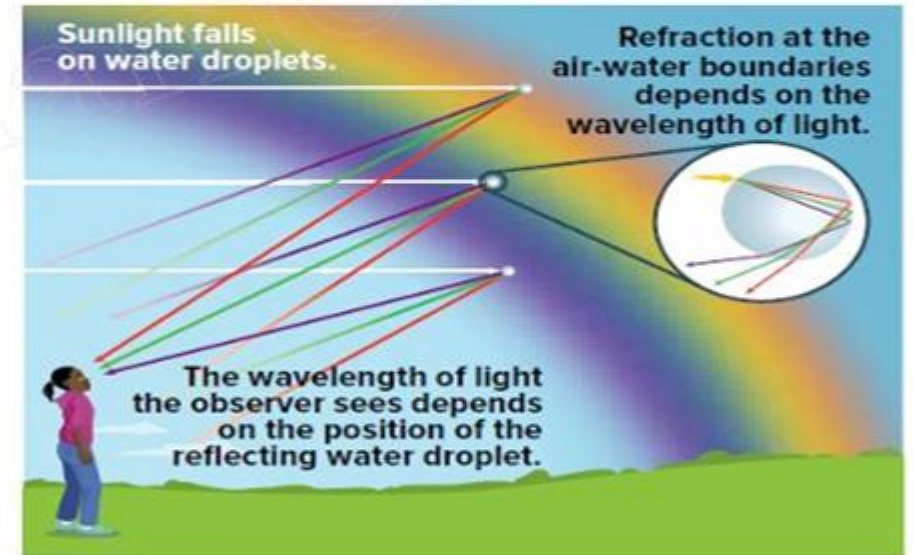


Figure 24 Light from the Sun is dispersed by water droplets to form rainbows. Because there are many droplets at various positions in the sky, a complete spectrum is visible.

Consider whether it is possible for a rainbow to be close enough to touch.

1) Which of the following devices operates primarily based on total internal reflection?

- a) Convex lens
- b) Plane mirror
- c) Optical fiber
- d) Concave mirror

2) In binoculars and single-lens reflex (SLR) cameras, what optical component is used to redirect light through 90 degrees using total internal reflection?

- a) Concave lens
- b) Prism
- c) Diffraction grating
- d) Convex mirror

3) Why are diamonds often cut to have many facets?

- a) To decrease their refractive index
- b) To maximize the light that undergoes total internal reflection, increasing brilliance
- c) To minimize reflection and increase transparency
- d) To spread light out and reduce its intensity

Answers:

1. c) Optical fiber
2. b) Prism
3. b) To maximize the light that undergoes total internal reflection, increasing brilliance

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4) The formation of a rainbow primarily involves:

- a) Reflection and diffraction only
- b) Refraction and total internal reflection only
- c) Refraction, dispersion, and internal reflection within water droplets
- d) Polarization and interference of sunlight

5) A mirage, such as the appearance of water on a hot road, is caused by:

- a) Reflection from a hot surface
- b) Total internal reflection in cool air layers
- c) The refraction of light in layers of air with different densities and temperatures
- d) The dispersion of light into its component colors

6) The "green flash" sometimes seen just as the sun sets over the ocean is an atmospheric phenomenon caused primarily by:

- a) Diffraction of sunlight
- b) Refraction and dispersion of sunlight in the atmosphere
- c) Total internal reflection in clouds
- d) Polarization of light by water molecules

Answers:

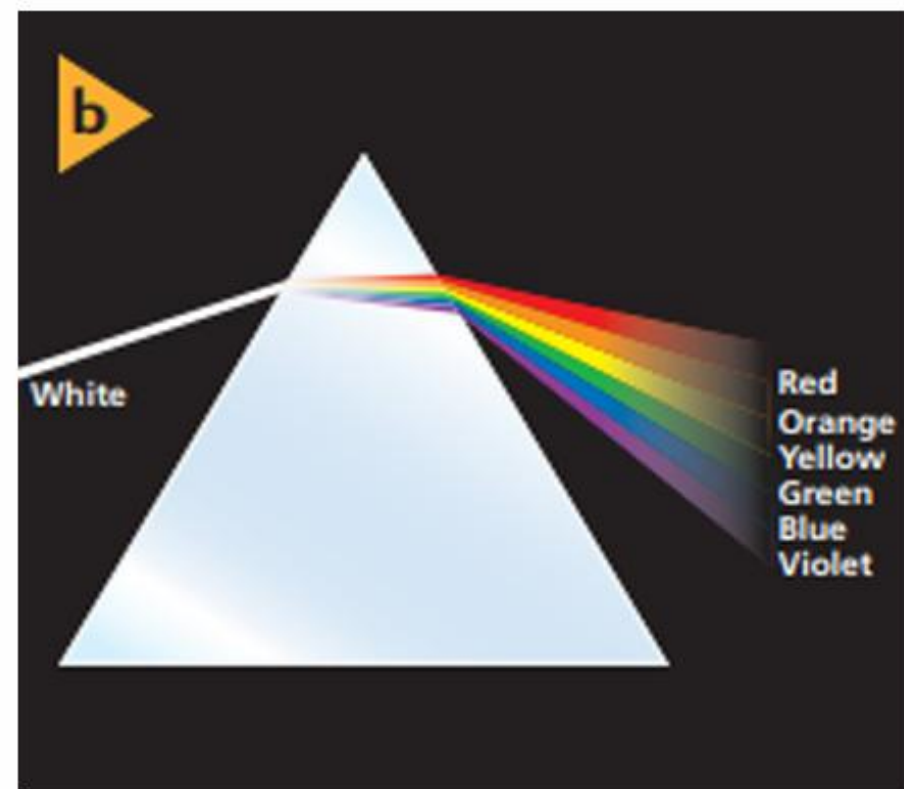
- 4. c) Refraction, dispersion, and internal reflection within water droplets
- 5. c) The refraction of light in layers of air with different densities and temperatures
- 6. b) Refraction and dispersion of sunlight in the atmosphere

Dispersion of light

Dispersion: is the refraction of white light into separate wavelengths (colors)

If you look carefully at the spectrum formed by light passing through the prism in **Figure 23**, you will notice that violet light is refracted more than red light. This occurs because the speed of violet light through glass is less than the speed of red light through glass. Violet light has a higher frequency than red light, which causes it to interact differently with the atoms of the

glass. This results in glass having a slightly higher index of refraction for violet light than it has for red light. This separation of white light into a spectrum of colors is called **dispersion**.



1. What is dispersion?

- A) The reflection of white light off a surface.
- B) The refraction of white light into separate wavelengths (colors).
- C) The absorption of specific colors by a material.
- D) The combination of different colors to form white light.

Answer: B

2. According to the text, which color of light is refracted the MOST by a prism?

- A) Red
- B) Green
- C) Yellow
- D) Violet

Answer: D

3. Why is violet light refracted more than red light when passing through glass?

- A) Violet light has a longer wavelength.
- B) The speed of violet light through glass is less than the speed of red light.
- C) Red light interacts more strongly with the atoms of the glass.
- D) Violet light has a lower frequency.

Answer: B

4. What causes the different indices of refraction for different colors of light in glass?

- A) Different wavelengths of light travel at the same speed in glass.
- B) The temperature of the glass affects different colors uniquely.
- C) Higher frequency light, like violet, interacts differently with the glass atoms.
- D) Red light is absorbed more easily than violet light.

Answer: C

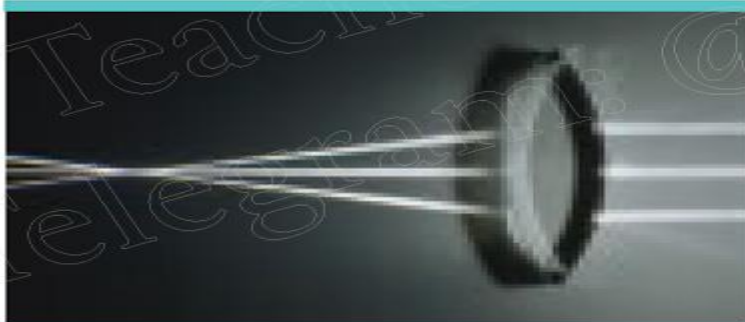
-Distinguish between a convex (converging) lens and a concave (diverging) lens.
 --Compare and contrast convex and concave lenses regarding the properties of images formed and the algebraic signs for different quantities involved.

Student Textbook
 Check your progress
 50

51,
 54
 60

Table 3 Properties of a Single Spherical Lens System

Lens Type	f	x_o	x_i	m	Image
Convex	+	$x_o > 2f$	$2f > x_i > f$	reduced, inverted	real
		$2f > x_o > f$	$x_i > 2f$	enlarged, inverted	real
		$f > x_o > 0$	$ x_i > x_o$ (negative)	enlarged	virtual
Concave	-	$x_o > 0$	$ f > x_i > 0$ (negative)	reduced	virtual



Convex Lens



Concave Lens

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50. **Types of Lenses** The cross sections of four different thin lenses are shown in **Figure 38**.

- Which of these lenses, if any, are convex, or converging, lenses?
- Which of these lenses, if any, are concave, or diverging, lenses?



Figure 38

1. The primary distinction between a convex (converging) lens and a concave (diverging) lens is their ability to:

- a) Reflect light.
- b) Disperse light into its constituent colors.
- c) Converge or diverge parallel rays of light.
- d) Change the speed of light.

2. A student looks through a concave lens. What type of image will she always see?

- a) A real, inverted, and magnified image.
- b) A virtual, upright, and magnified image.
- c) A real, inverted, and diminished image.
- d) A virtual, upright, and diminished image.

3. In the lens formula ($1/f = 1/v + 1/u$), which of the following sign conventions is correct for a concave lens?

- a) The focal length (f) is positive, and the image distance (v) is negative.
- b) The focal length (f) is negative, and the image distance (v) is positive.
- c) The focal length (f) is negative, and the image distance (v) is negative.
- d) The focal length (f) is positive, and the image distance (v) is positive.

4. An object is placed at a distance greater than the focal length in front of a convex lens. The image formed will be:

- a) Virtual and located on the same side of the lens as the object.
- b) Real and located on the opposite side of the lens from the object.
- c) Virtual and upright.
- d) Real but smaller than the object regardless of the object's position.

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5. When comparing the properties of images formed by convex and concave lenses, a key difference is that a convex lens can form a real image, while a concave lens:

- a) Can also form a real image under certain conditions.
 - b) Can form a real image only if the object is placed at infinity.
 - c) Can never form a real image, only virtual ones.
 - d) Forms a real image that is always inverted.
-

Answer Key

- 1. c) Converge or diverge parallel rays of light.
- 2. d) A virtual, upright, and diminished image.
- 3. c) The focal length (f) is negative, and the image distance (v) is negative.
- 4. b) Real and located on the opposite side of the lens from the object.
- 5. c) Can never form a real image, only virtual ones.

Defects of Spherical Lenses

The defect of lenses due to inaccurate focusing is called **spherical aberration** while that due to the focusing of different colours at different places is known as **chromatic aberration**.

Spherical aberration

This inability of a spherical lens to focus all parallel rays to a single point is called spherical aberration.

How to reduce Spherical aberration:

Making lens surfaces aspherical, such as in cameras, eliminates spherical aberration. In high-precision instruments, many lenses, often five or more, are used to form sharp, well-defined images

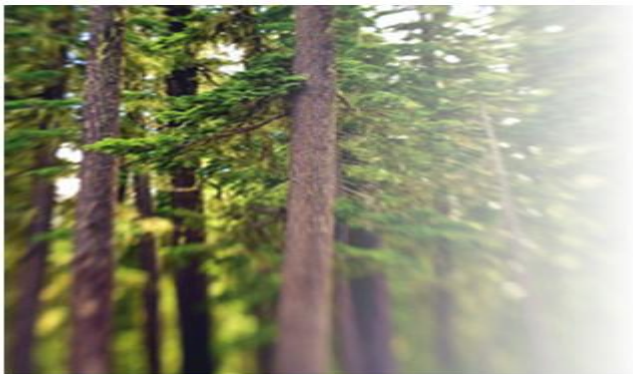


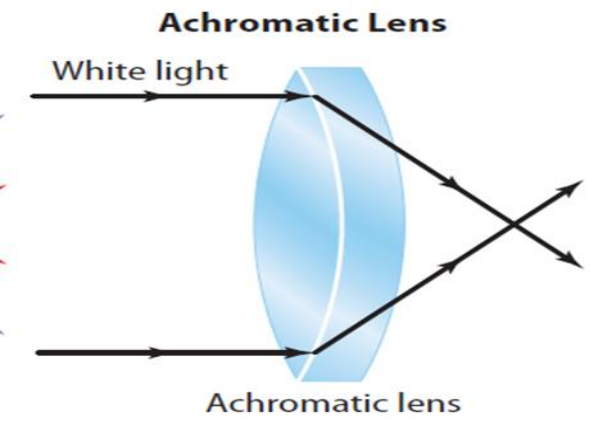
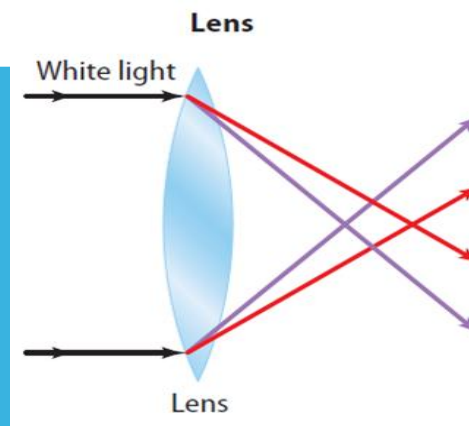
Figure 16 Spherical aberration from the camera lens blurs the edges of this image.

2. Chromatic aberration

Chromatic aberration, also known as “color fringing” or “purple fringing”, is a common optical problem that occurs when a lens is either unable to bring all wavelengths of color to the same focal plane, and/or when wavelengths of color are focused at different positions in the focal plane.

How to reduce Chromatic aberration:

this defect can be greatly reduced by an **achromatic lens**, which is a system of two or more lenses, such as a convex lens with a concave lens, that have different indices of refraction



1) What is the primary cause of spherical aberration in a simple spherical lens?

- a) Different colors of light focus at different points.
- b) Marginal rays and paraxial rays focus at different points along the principal axis.
- c) The lens material absorbs too much light.
- d) The image becomes distorted due to lens curvature.

2) Chromatic aberration in lenses occurs because:

- a) Light rays strike the edges of the lens at different angles.
- b) The lens has an irregular surface.
- c) The refractive index of the lens material varies with the wavelength of light.
- d) The lens fails to reflect certain colors properly.

3) How can chromatic aberration in optical instruments be effectively corrected?

- a) By using a lens with a shorter focal length.
- b) By combining lenses made of different types of glass (an achromatic doublet).
- c) By using a diaphragm to block marginal rays.
- d) By silvering the surface of the lens.

Answers:

- 1. b) Marginal rays and paraxial rays focus at different points along the principal axis.
- 2. c) The refractive index of the lens material varies with the wavelength of light.
- 3. b) By combining lenses made of different types of glass (an achromatic doublet).

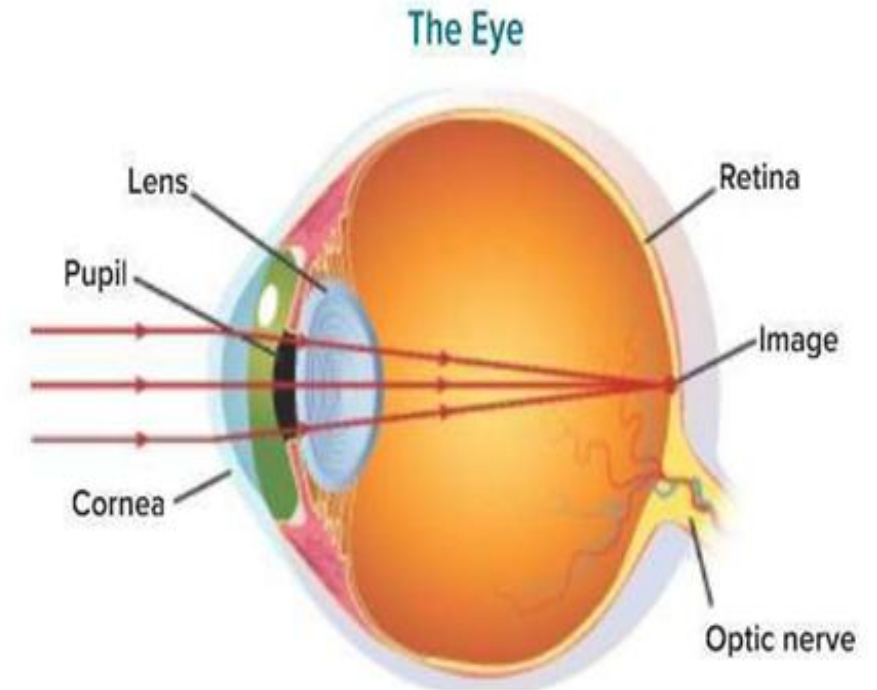
-Define nearsightedness (Myopia) and farsightedness (Hyperopia).
-Describe the formation of image in case of nearsightedness and farsightedness and how defects in vision are corrected using concave and convex lenses.

Student Textbook
Check your progress
57

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60

Lenses in Eyes

- Light enters the eye through the **cornea**. Light entering the eye is primarily focused by the cornea because the air-cornea surface has the greatest difference in indices of refraction.
- The light then passes through the **lens** and focuses onto the **retina** that is at the back of the eye.
- Specialized cells on the retina absorb this light and send information about the image along the **optic nerve** to the **brain**.
- The lens is responsible for the fine focus that allows you to clearly see both distant and nearby objects. Using a process called **accommodation**, muscles surrounding the lens can contract or relax, thereby changing the shape and focal length of the lens.

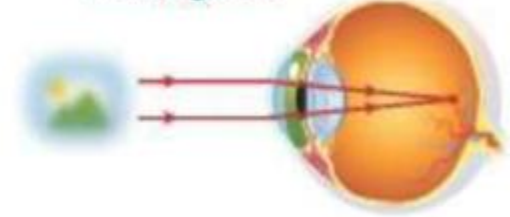


The eyes of many people do not focus sharp images on the retina. Instead, images are focused either in front of the retina or behind it.

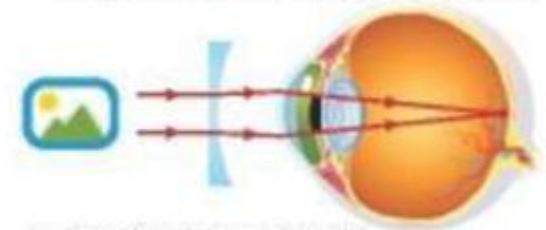
Nearsightedness The eyes of many people focus images either in front of the retina or behind it. External lenses, such as eyeglasses and contact lenses, adjust the focal length and move images to the retina.

With myopia, the focal length of the eye is too short to focus light on the retina. Images are formed in front of the retina. concave lenses correct this by diverging light, thereby increasing images' distances from the lens, and forming images on the retina.

Nearsighted



A nearsighted eye focuses images at a point in front of the retina, making distant images blurry.



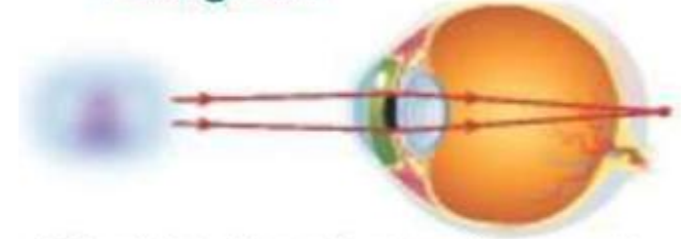
A concave lens corrects nearsightedness by increasing the focal length.

Farsightedness

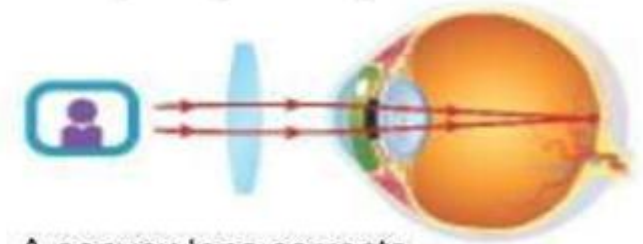
also called hyperopia, is the condition in which the focal length of the eye is too long. Images are therefore not formed on the retina.

, convex lenses produce virtual images farther from the eye than the associated objects, as shown in **Figure 35**. The images then become the objects for the eye lens and can be focused on the retina, thereby correcting the condition.

Farsighted



A farsighted eye focuses images at a point behind the retina, making nearby images blurry.



A convex lens corrects farsightedness by reducing the focal length.

57. **Eyeglass Lenses** Which type of lens, convex or concave, should a nearsighted person use? Which type should a farsighted person use? See **Figure 40**. Explain.



Figure 40

1) What is the primary cause of nearsightedness (Myopia)?

- a) The eyeball is too short, causing the image to focus behind the retina.
- b) The eyeball is too long, causing the image to focus in front of the retina.
- c) The lens of the eye becomes too weak with age.
- d) The cornea becomes irregularly shaped.

2) A person with farsightedness (Hyperopia) has difficulty seeing:

- a) Distant objects clearly
- b) Both near and far objects
- c) Near objects clearly
- d) Objects in low light conditions

3) Which statement correctly describes hyperopia?

- a) The focal point is in front of the retina
- b) It is corrected using a diverging lens
- c) The eyeball is typically shorter than normal
- d) It improves naturally with age

Answers:

- 1. b) The eyeball is too long, causing the image to focus in front of the retina.
- 2. c) Near objects clearly
- 3. c) The eyeball is typically shorter than normal

4) In a myopic eye, where does the image of a distant object form?

- a) On the retina
- b) Behind the retina
- c) In front of the retina
- d) Not formed at all

5) What type of lens is used to correct hyperopia and why?

- a) Concave lens to diverge light rays before they enter the eye
- b) Convex lens to converge light rays before they enter the eye
- c) Cylindrical lens to correct asymmetric curvature
- d) Plane glass to reduce light intensity

6) How does a concave lens help correct myopia?

- a) It converges light rays to move the focal point forward
- b) It diverges light rays to move the focal point backward onto the retina
- c) It magnifies the image to make it clearer
- d) It reduces chromatic aberration in the eye

Answers:

4. c) In front of the retina

5. b) Convex lens to converge light rays before they enter the eye

6. b) It diverges light rays to move the focal point backward onto the retina

Refracting Telescopes

- An astronomical refracting telescope uses lenses to magnify distant objects.
- Parallel light rays from distant stars enter the objective convex lens and are focused as a real, inverted image at the focal point of the objective lens.
- This image then becomes the object for the convex lens of the eyepiece and is located between the eyepiece lens and its focal point.
- This means that a virtual image is produced that is upright and larger than the first image.
- However, because the first image was already inverted, the final image is still inverted.

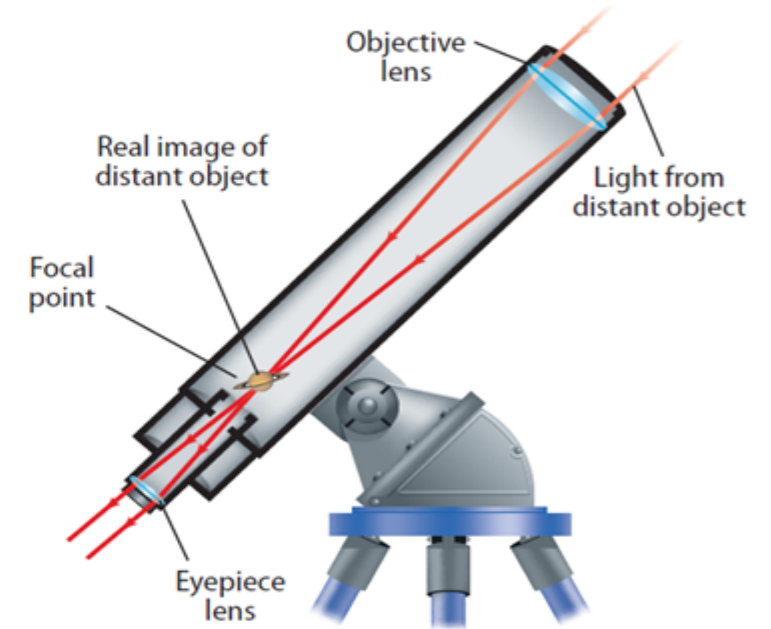
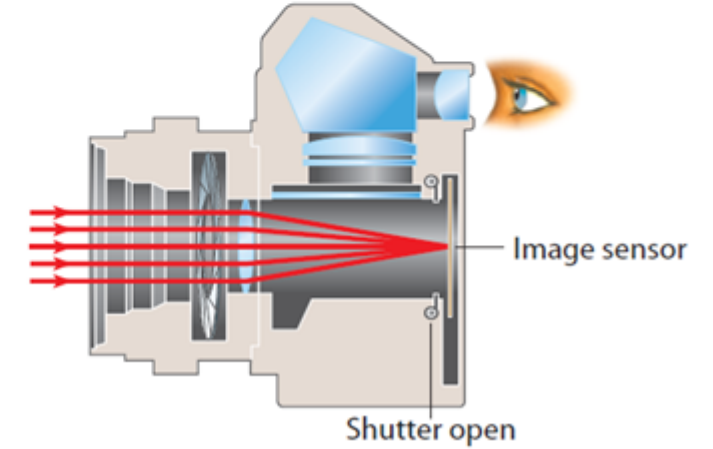
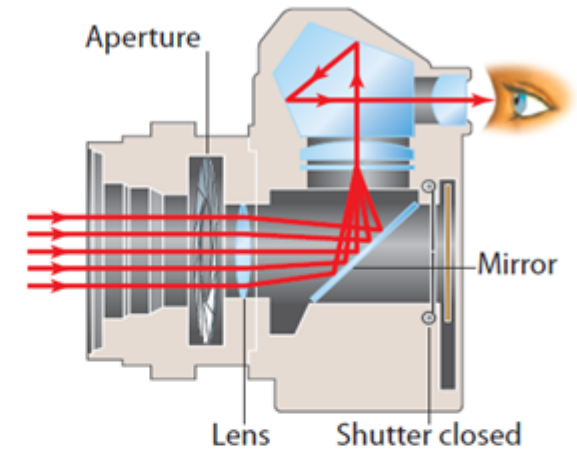


Figure 36 Light from distant objects is gathered by the objective lens and the eyepiece of a refracting telescope.

Cameras

- As light enters the camera, it passes through an achromatic lens.
- This lens system refracts the light much like a single convex lens would, forming an image that is inverted on the reflex mirror.
- The image is reflected upward to a prism that redirects the light to the viewfinder.
- When the person holding the camera takes a photograph, he or she presses the shutter-release button, which briefly raises the mirror.
- The light, instead of being diverted upward to the prism, then travels along a straight path to focus on the film.



1) In a simple camera, what type of image is formed on the film or sensor?

- a) Virtual, upright, and magnified
- b) Real, inverted, and diminished
- c) Virtual, inverted, and diminished
- d) Real, upright, and magnified

2) What is the primary function of the eyepiece lens in a compound microscope?

- a) To form a real, inverted image of the object
- b) To magnify the real image formed by the objective lens
- c) To reduce chromatic aberration in the system
- d) To illuminate the specimen being viewed

3) In an astronomical refracting telescope, the final image seen by the eye is:

- a) Real and inverted
- b) Virtual and inverted
- c) Real and upright
- d) Virtual and upright

Answers:

1. b) Real, inverted, and diminished
2. b) To magnify the real image formed by the objective lens
3. b) Virtual and inverted

- Apply the equation for illuminance of a point source to numerical problems.
- Relate luminous intensity to illuminance.

Student Textbook
Example problem1
Practice problems
Check your progress

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Point-Source Illuminance

If an object is illuminated by a point source of light, then the illuminance at the object is equal to the luminous flux of the light source divided by the surface area of the sphere whose radius is equal to the distance the object is from the light source.

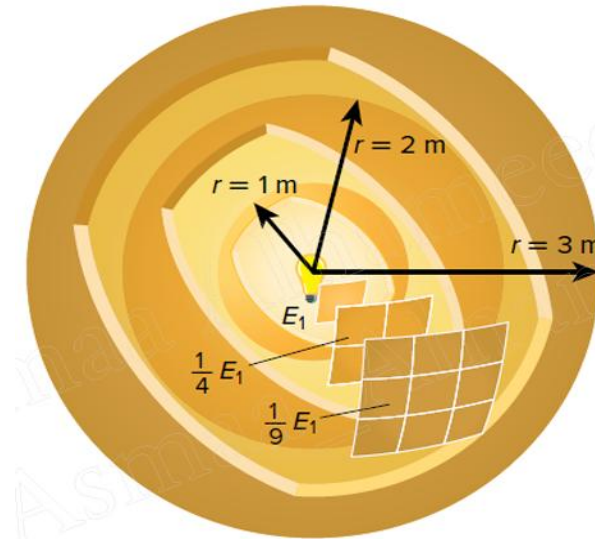
$$E = \frac{P}{4\pi r^2}$$

What is luminous intensity? (I)

- **It is the ability of a light source** to illuminate a specific area in a specific direction. It is a measure of the "**power**" or "concentration" of light emitted by the source.

•Unit: Measured in **candela (cd)**.

$$I_v = \frac{P}{4\pi}$$



Illuminance

$$E_1 = \frac{1750}{4\pi} \text{ lx}$$

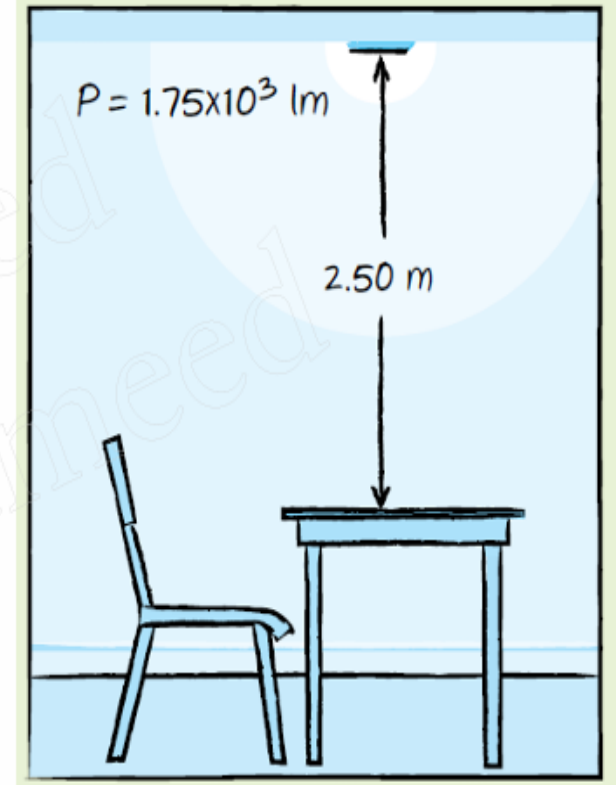
$$E_2 = \frac{1750}{4\pi 2^2} \text{ lx}$$

$$E_3 = \frac{1750}{4\pi 3^2} \text{ lx}$$

Quantity	Symbol	Definition	law	Unit	Symbol
Luminous flux التدفق الضوئي	P	The rate at which a luminous source produces light energy. معدل إنتاج المصدر الضوئي للطاقة الضوئية		Lumen	lm
Illuminance الاستضاءة	E	The luminous flux falling on a given surface area at any instant. التدفق الضوئي الساقط على مساحة سطح معينة في أي لحظة	$E = \frac{P}{4\pi r^2}$	lux	lx = lm/m²
Luminous intensity الشدة الضوئية	I _v	The luminous flux that falls on 1 m² of the inside of a 1-m radius sphere. التدفق الضوئي الساقط على 1 م² من السطح الداخلي لكرة نصف قطرها 1 م	$I_v = \frac{P}{4\pi}$	candela	cd

EXAMPLE Problem 1

ILLUMINATION OF A SURFACE What is the illuminance on your desktop if it is lit by a 1750-lm lamp that is 2.50 m above your desk?



1. A lamp is moved from 30 cm to 90 cm above the pages of a book. Compare the illumination on the book before and after the lamp is moved.

2. Draw a graph of the illuminance produced by a lamp with a luminous flux of 2275 lm at distances from 0.50 m and 5.0 m.

3. A 64-cd point source of light is 3.0 m away from a painting. What is the illumination on the painting in lux?

4. A screen is placed between two lamps so that they illuminate the screen equally, as shown in **Figure 9**. The first lamp emits a luminous flux of 1445 lm and is 2.5 m from the screen. What is the distance of the second lamp from the screen if the luminous flux is 2375 lm?

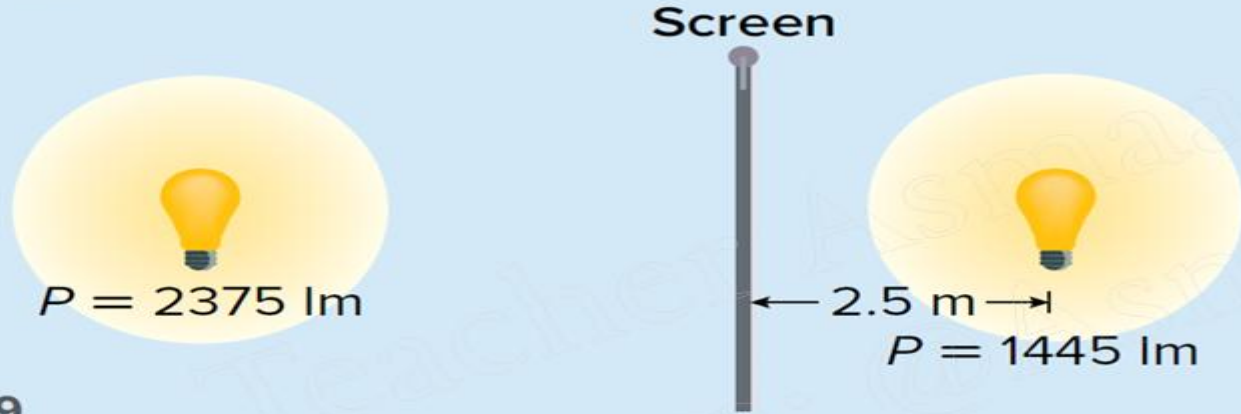


Figure 9

5. What is the illumination on a surface that is 3.0 m below a 150-W incandescent lamp that emits a luminous flux of 2275 lm?

6. A public school law requires a minimum illuminance of 160 lx at the surface of each student's desk. An architect's specifications call for classroom lights to be located 2.0 m above the desks. What is the minimum luminous flux that the lights must produce?

10. **Illuminance** Does one lightbulb provide more or less illuminance than two identical lightbulbs at twice the distance? Explain.

11. **Luminous Intensity** Two lamps illuminate a screen equally from distances shown in **Figure 11**. If Lamp A is rated 75 cd, what is Lamp B rated?

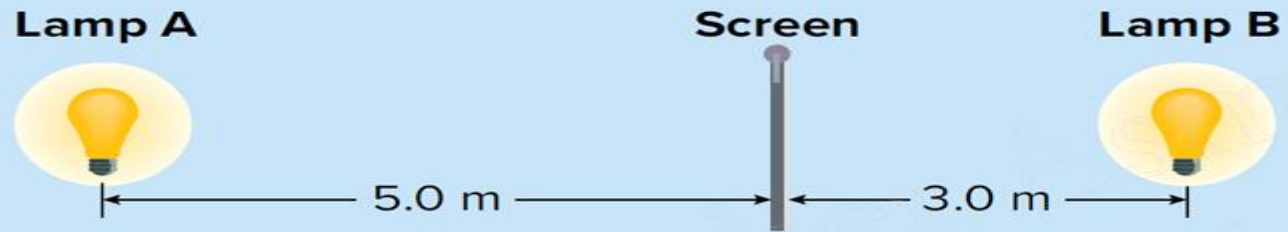


Figure 11

12. **Distance of a Light Source** A lightbulb illuminating your computer keyboard provides only half the illuminance that it should. If it is currently 1.0 m away, how far should it be to provide the correct illuminance?

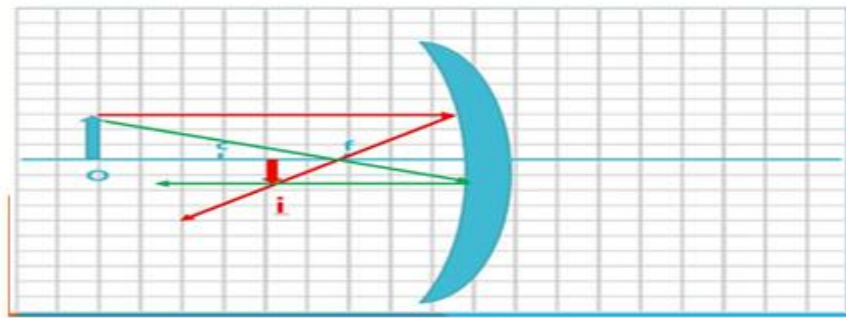
- Draw a ray diagram to find the image of an object formed by a curved mirror and determine the properties of the formed image.
- Apply the mirror equation to calculate the image distance, the object distance, or the focal length of a spherical mirror using appropriate algebraic signs for focal length and corresponding distances.
- Calculate the magnification produced by a spherical mirror.

Student Textbook Example problem 2,3 Practice problems	36-38 41,42
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Ray Diagrams for Concave Mirrors

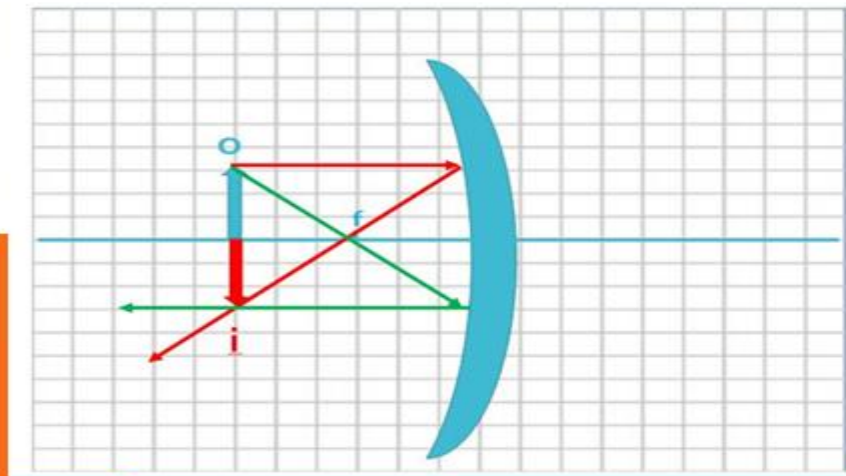
- image is formed where the outgoing rays cross
- two principle rays are sufficient to find image, use third and fourth to check your diagram

1. object outside center ($x_o > 2f$)



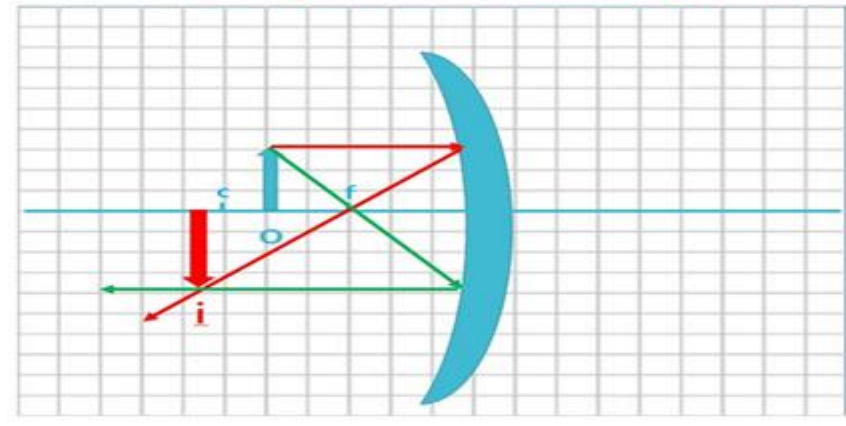
- image is:
1. **Inverted** (upside down)
 2. **smaller** than object
 3. **real**

2. object at center ($x_o = 2f$)



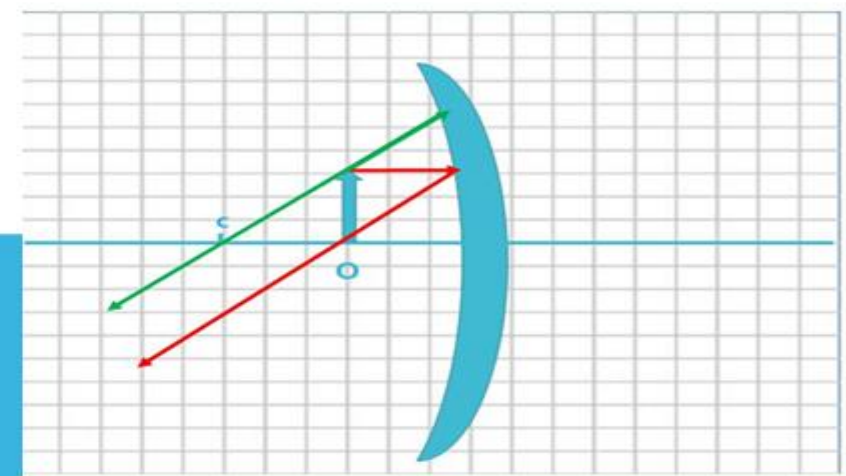
- image is:
1. **inverted**
 2. **Same size** of the object
 3. **real**
- Exactly at distance from the mirror $2f$

3. object between f and $2f$ ($2f > x_o > f$)



- image is:
1. **inverted**
 2. **larger** than object
 3. **real**

4. object at focal point ($x_o = f$)



the image:
is said to be at infinity, so the image could never be seen.

5. object between mirror and focal point($x_o < f$)

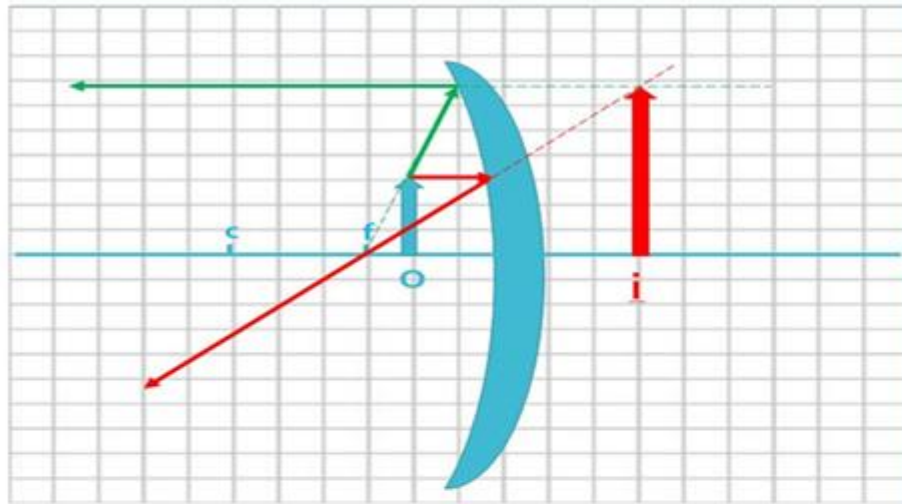


image is:

1. **upright**
2. **larger** than object
3. **virtual**

Virtual Images with Convex Mirrors

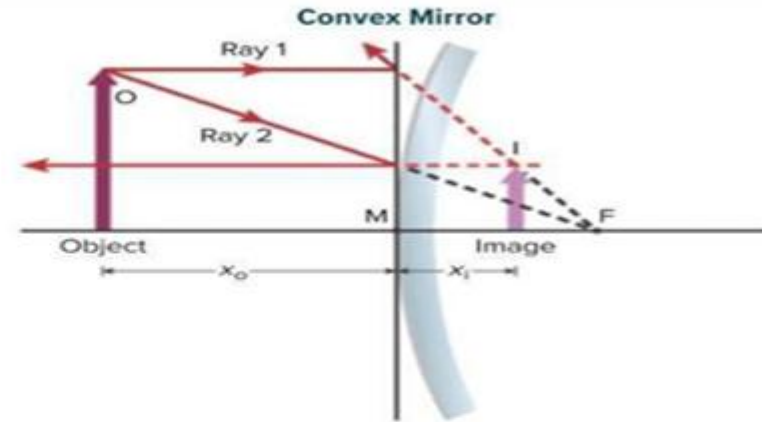
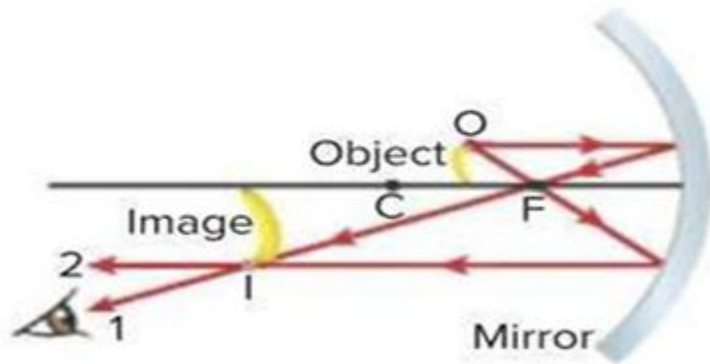
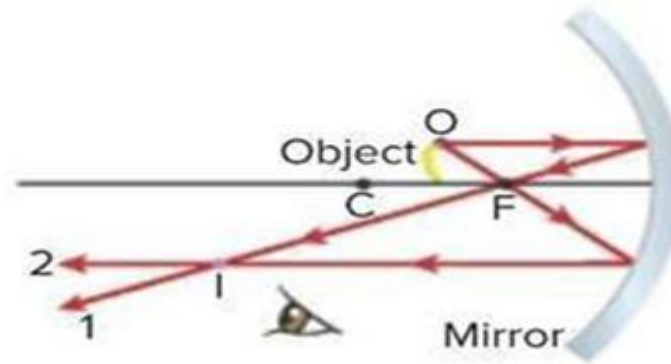


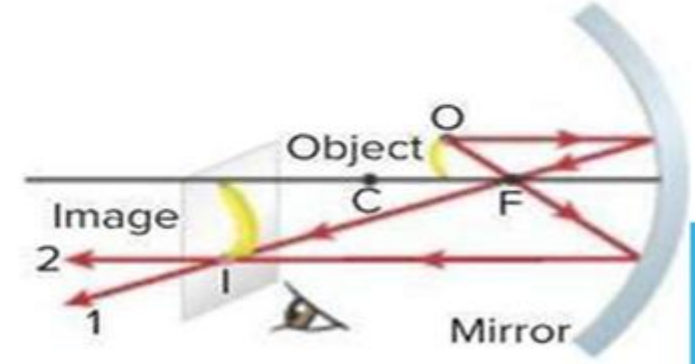
Figure 15 Convex mirrors form images that are virtual, upright, and smaller than the object.



The eye is positioned so that the rays that form the real image strike the eye, allowing the image to be seen.



Rays from the object do not reach the eye, so the image cannot be seen from this position.



The image can be seen when projected on a white opaque screen.

MIRROR EQUATION

The reciprocal of the focal length of a spherical mirror is equal to the sum of the reciprocals of the image position and the object position.

$$\frac{1}{f} = \frac{1}{x_i} + \frac{1}{x_o}$$

$$x_i = \frac{fx_o}{x_o - f}$$

$$x_o = \frac{fx_i}{x_i - f}$$

$$f = \frac{x_i x_o}{x_i - x_o}$$

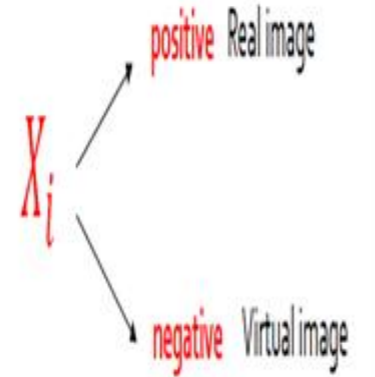
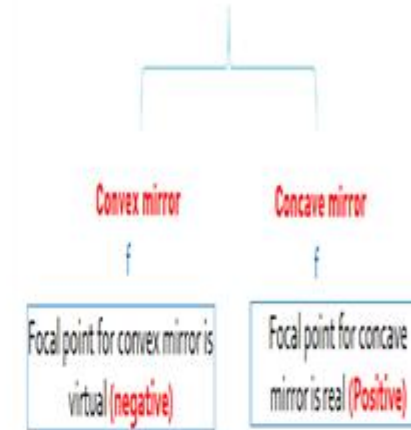
MAGNIFICATION

The magnification of an object by a spherical mirror, defined as the image height divided by the object height, is equal to the negative of the image position, divided by the object position.

$$m \equiv \frac{h_i}{h_o} = -\frac{x_i}{x_o}$$

$$h_i = \frac{-x_i h_o}{x_o}$$

Curved mirrors

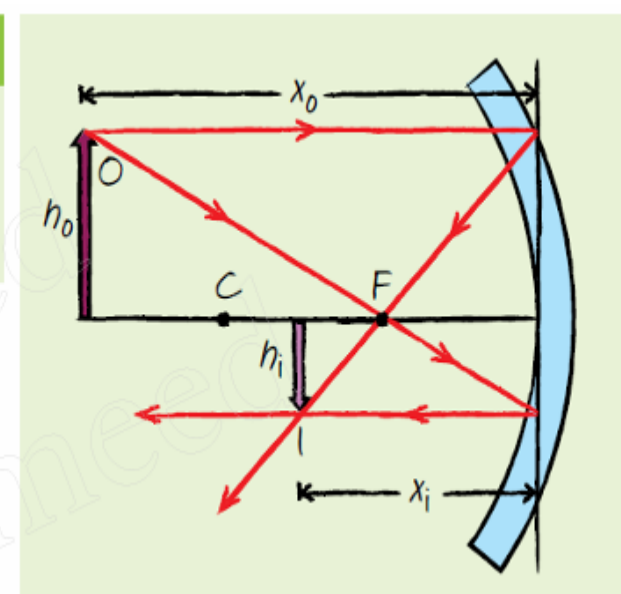


$$f = -\frac{r}{2}$$

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EXAMPLE Problem 2

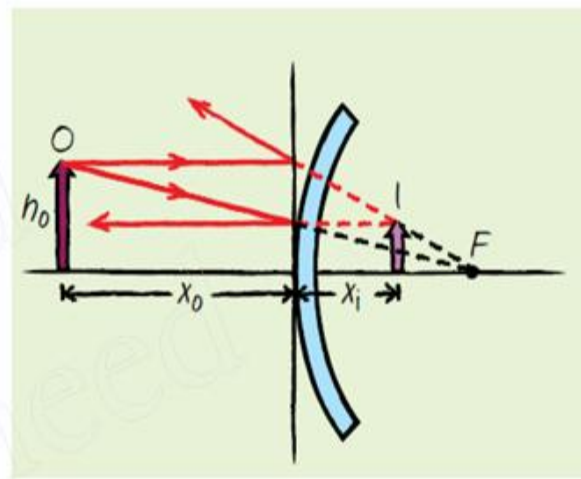
REAL IMAGE FORMATION BY A CONCAVE MIRROR A concave mirror has a radius of curvature of 20.0 cm. You place a 2.0-cm-tall object 30.0 cm from the mirror. What are the image position and image height?



- 12.** Use a ray diagram drawn to scale to solve Example Problem 2.

EXAMPLE Problem 3

IMAGE IN A SECURITY MIRROR A convex security mirror in a warehouse has a -0.50-m focal length. A 2.0-m -tall forklift is 5.0 m from the mirror. What are the forklift's image position and image height?



13. You place an object 36.0 cm in front of a concave mirror with a 16.0-cm focal length. Determine the image position.

14. You place a 3.0-cm-tall object 20.0 cm from a 16.0-cm-radius concave mirror. Determine the image position and image height.

15. A concave mirror has a 7.0-cm focal length. You place a 2.4-cm-tall object 16.0 cm from the mirror. Determine the image height.

16. CHALLENGE You place an object near a concave mirror with a 10.0-cm focal length. The image is 3.0 cm tall, inverted, and 16.0 cm from the mirror. What are the object position and object height?

17. You place an object 20.0 cm in front of a convex mirror with a -15.0 -cm focal length. Find the image position using both a scale diagram and the mirror equation.

18. A convex mirror has a focal length of -13.0 cm. You place a 6.0-cm diameter lightbulb 60.0 cm from that mirror. What are the lightbulb's image position and diameter?

20. A 1.8-m-tall girl stands 2.4 m from a store's security mirror. Her image appears to be 0.36 m tall.

- a. What is the image's distance?
- b. What is the focal length of the mirror?

21. CHALLENGE A convex mirror is needed to produce an image that is three-fourths the size of an object and located 24 cm behind the mirror.

- a. What is the object's distance?
- b. What focal length should be specified?

- Calculate the refractive index of a medium using a suitable mathematical representation ($n = c/v$).
- State and apply Snell's law of refraction.
- Calculate the critical angle using Snell's law.

Index of Refraction

The index of refraction of a medium is equal to the speed of light in a vacuum divided by the speed of light in the medium.

$$n = \frac{c}{v}$$

Snell's Law of Refraction

The product of the index of refraction of the first medium and the sine of the angle of incidence is equal to the product of the index of refraction of the second medium and the sine of the angle of refraction.

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

Table 2 Indices of Refraction for
Yellow Light ($\lambda = 589 \text{ nm}$
in a vacuum)

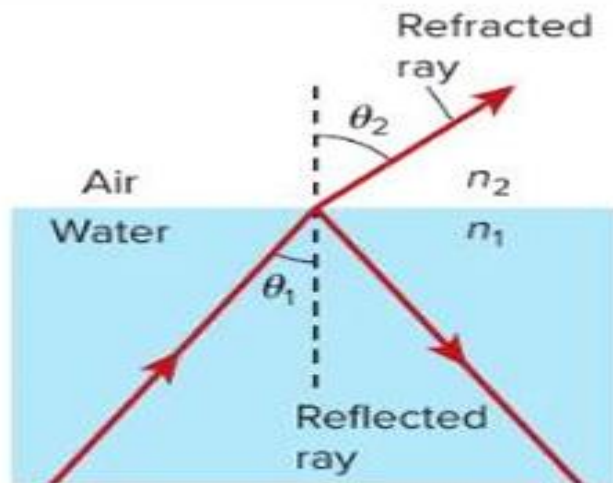
Medium	n
Vacuum	1.00
Air	1.0003*
Water	1.33
Ethanol	1.36
Float glass	1.52
Quartz	1.54
Flint glass	1.62
Diamond	2.42

*The value given for air contains additional significant figures to distinguish it from that for a vacuum. Use a value of $n = 1.00$ for air in problems in this text.

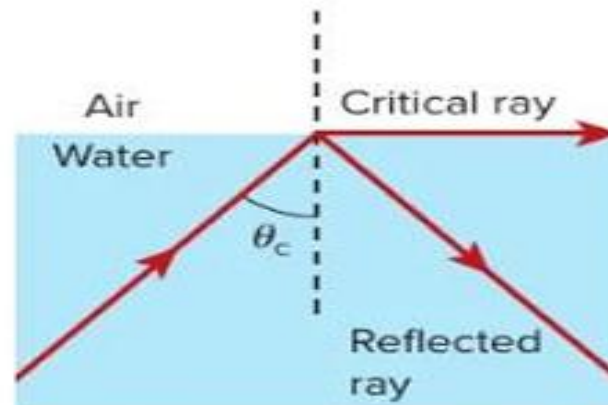
This leads to an interesting phenomenon. As the angle of incidence increases, the angle of refraction increases. At a certain angle of incidence known as the **critical angle** (θ_c), the refracted light ray lies along the boundary of the two mediums.

Total internal reflection occurs when light traveling from a region of a higher index of refraction to a region of a lower index of refraction strikes the boundary at an angle greater than θ_c such that all the light reflects back into the region of the higher index of refraction. This is shown in the third diagram of **Figure 21**. Using Snell's law and substituting $\theta_1 = \theta_c$, and $\sin \theta_2 = \sin 90.0^\circ = 1$:

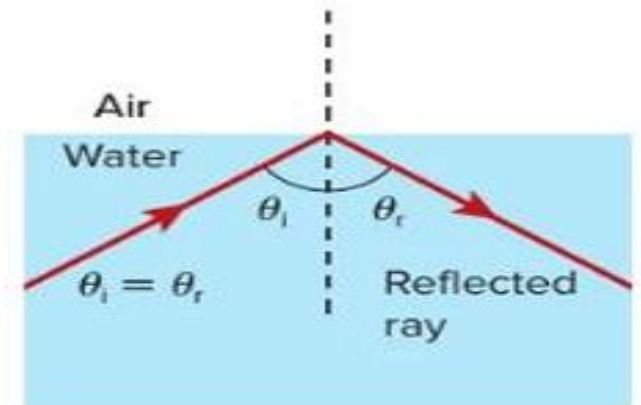
$$\sin \theta_c = \frac{n_2}{n_1}$$



At an angle of incidence less than the critical angle, light is partially refracted and partially reflected.



A ray refracted along the boundary of the medium forms the critical angle.



An angle of incidence greater than the critical angle results in total internal reflection, which follows the law of reflection.

30. A laser beam in air enters ethanol at an angle of incidence of 37.0° . What is the angle of refraction?

31. As light travels from air into water, the angle of refraction is 25.0° to the normal. Find the angle of incidence.

32. Light in air enters a diamond facet at 45.0° . What is the angle of refraction?

33. A block of unknown material is submerged in water. Light in the water enters the block at an angle of incidence of 31° . The angle of refraction of the light in the block is 27° . What is the index of refraction of the material of the block?

34. CHALLENGE Light travels from air into another medium. The angle of incidence is 45.0° and the angle of refraction is 27.7° . What is the other medium?

A ray of light travels from air (refractive index $n_1 = 1.00$) into a transparent medium. The angle of incidence is 30° , and the angle of refraction is measured to be 19.5° .

- **a)** Calculate the refractive index n_2 of the transparent medium using Snell's law.
- **b)** If the speed of light in vacuum is $c = 3.00 \times 10^8 \text{ m/s}$, calculate the speed of light in this medium.

A glass block with a refractive index of 1.52 is immersed in water (refractive index 1.33).

- **a)** Calculate the critical angle for light traveling from the glass into the water.
- **b)** Will total internal reflection occur if the angle of incidence in the glass is 50° ? Justify your answer.

- Draw a ray to find the image of an object located at different distances from a lens and determine the location and properties of the formed image.
- Apply the thin lens equation to calculate the image distance, the object distance, or the focal length of a convex or a concave lens using appropriate algebraic signs for focal length and corresponding distances
- Calculate the magnification produced by a thin convex or concave lens.

Student Textbook
Example problem5
Practice problems
Check your progress
45,55,51,55,56

52,53
55
60

Ray Diagrams for convex lenses

1. object outside $2f(x_o > 2f)$

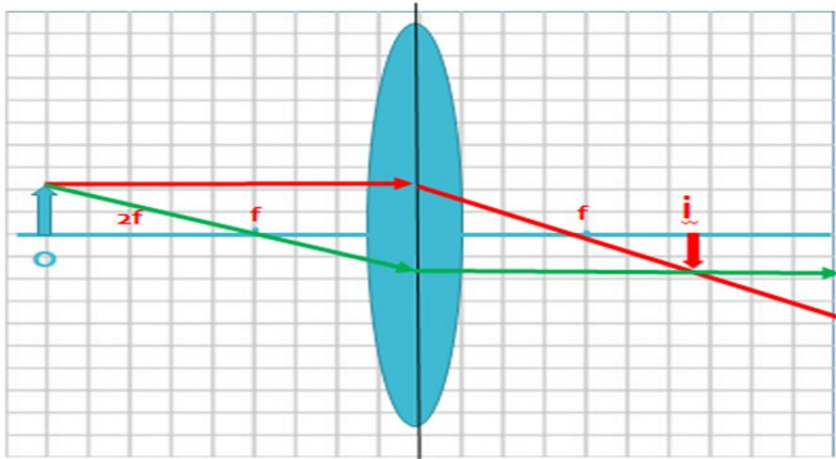


image is:

1. **Inverted** (upside down)
2. **smaller** than object (reduced)
3. **real**

2. object between f and $2f(2f > x_o > f)$

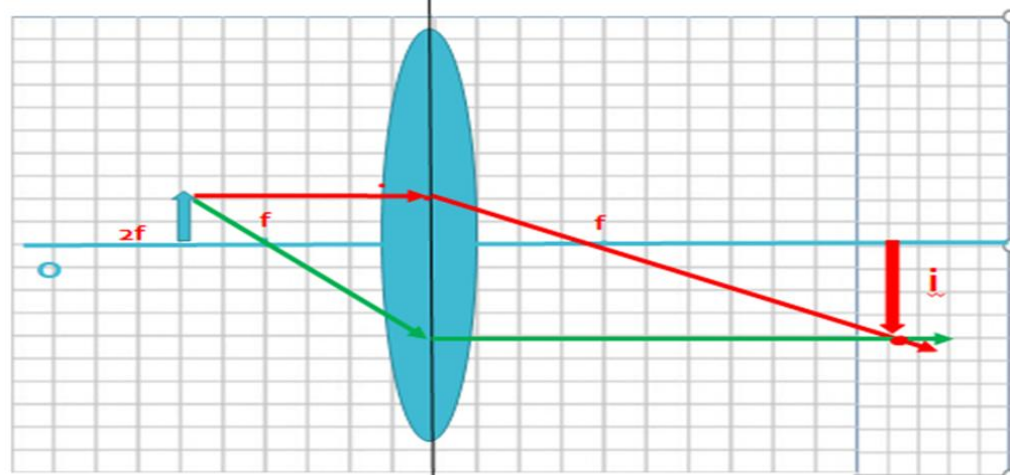


image is:

1. **inverted**
2. **larger** than object
3. **real**

3. object at center ($x_o = 2f$)

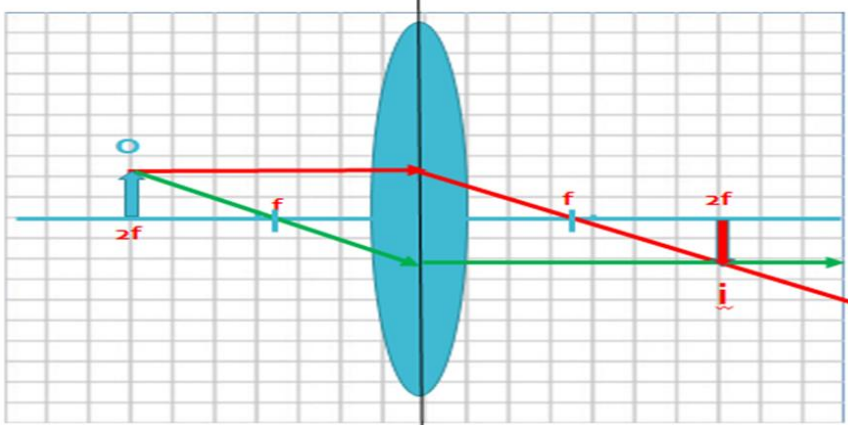


image is:

1. **inverted**
2. **Same size** of the object
3. **real**

Exactly at distance from the mirror $2f$

Convex Lens ($f > x_o > 0$)

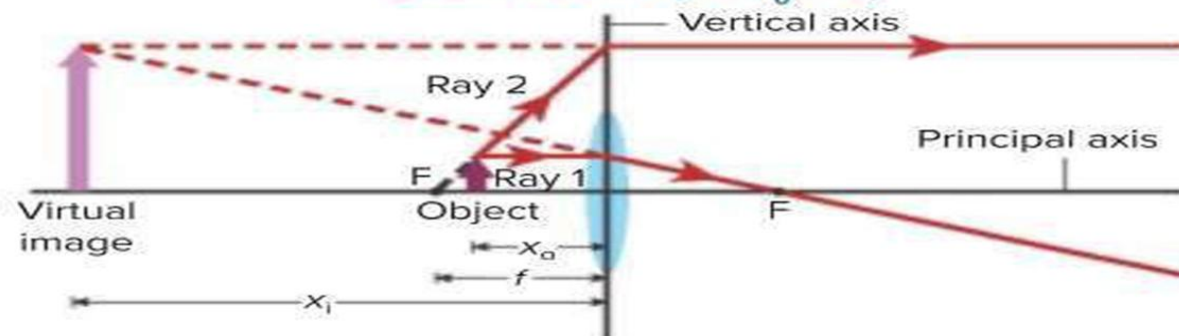
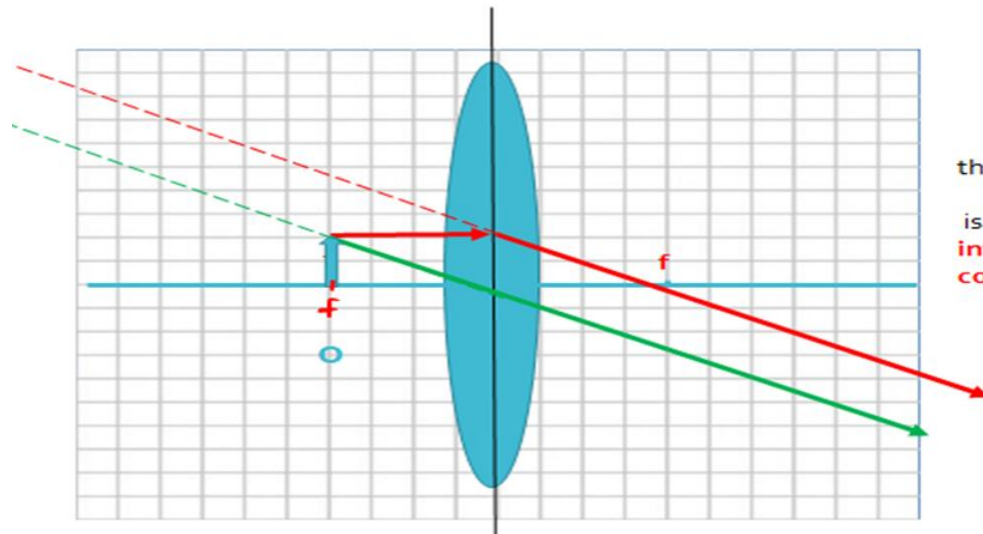


Figure 30 An object placed at a distance less than the focal length from the lens will produce an image that is virtual and enlarged.

5. object at focal point ($x_o=f$)



the image:
is said to be **at infinity**, so the image could never be seen.

Concave Lens

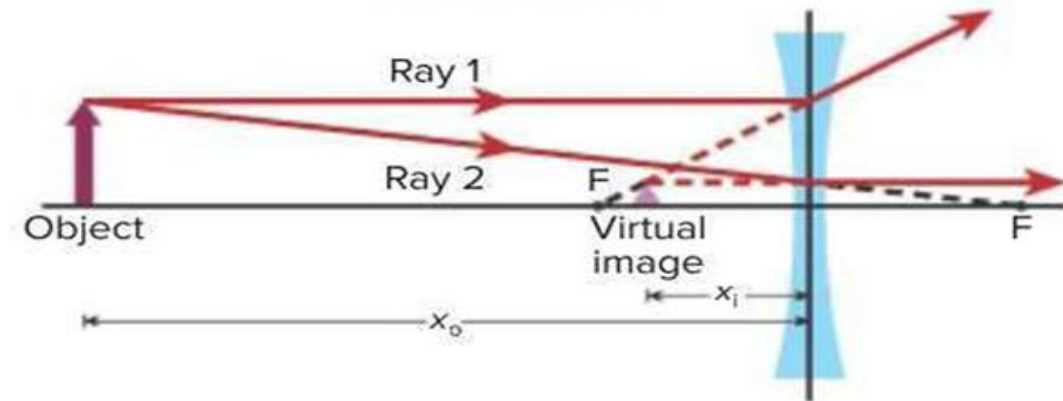


Figure 31 An object placed any distance from a concave lens will always produce an image that is virtual and reduced.

Table 3 Properties of a Single Spherical Lens System

Lens Type	f	x_o	x_i	m	Image
Convex	+	$x_o > 2f$	$2f > x_i > f$	reduced, inverted	real
		$2f > x_o > f$	$x_i > 2f$	enlarged, inverted	real
		$f > x_o > 0$	$ x_i > x_o$ (negative)	enlarged	virtual
Concave	-	$x_o > 0$	$ f > x_i > 0$ (negative)	reduced	virtual

Lens Equations

Thin Lens Equation

The inverse of the focal length of a spherical lens is equal to the sum of the inverses of the image position and the object position.

$$\frac{1}{f} = \frac{1}{x_i} + \frac{1}{x_o}$$

$$x_i = \frac{fx_o}{x_o - f}$$

$$x_o = \frac{fx_i}{x_i - f}$$

$$f = \frac{x_i x_o}{x_i - x_o}$$

Spherical Lenses

Convex Lenses

f

Focal point for convex lenses is real (**positive**)

Concave Lenses

f

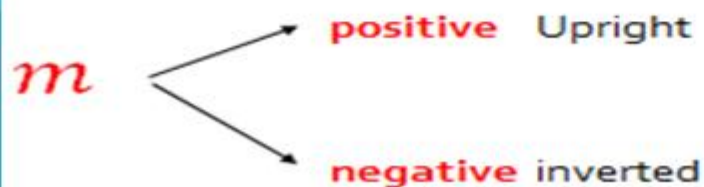
Focal point for concave lenses is virtual (**negative**)

Magnification

The magnification of an object by a spherical lens, defined as the image height divided by the object height, is equal to the negative of the image position divided by the object position.

$$m \equiv \frac{h_i}{h_o} = -\frac{x_i}{x_o}$$

$$h_i = \frac{-x_i h_o}{x_o}$$



EXAMPLE Problem 5

AN IMAGE FORMED BY A CONVEX LENS An object is placed 32.0 cm from a convex lens that has a focal length of 8.0 cm.

- Where is the image?
- If the object is 3.0 cm high, how tall is the image?
- What is the orientation of the image?

1 ANALYZE AND SKETCH THE PROBLEM

- Sketch the situation, locating the object and the lens.
- Draw the two principal rays.

Known

$$x_o = 32.0 \text{ cm}$$

$$h_o = 3.0 \text{ cm}$$

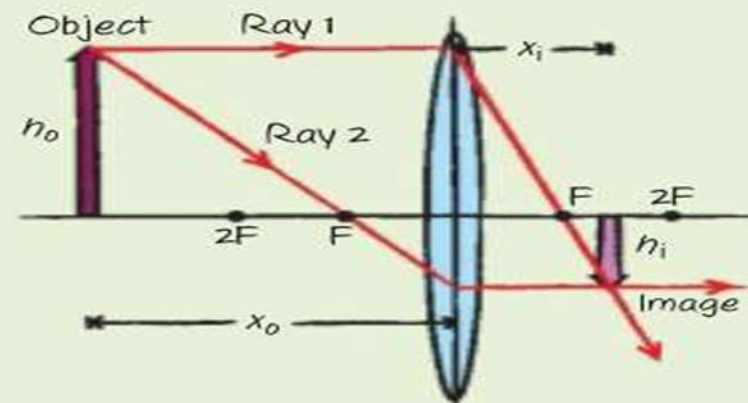
$$f = 8.0 \text{ cm}$$

Unknown

$$x_i = ?$$

$$h_i = ?$$

2 SOLVE FOR THE IMAGE POSITION AND HEIGHT



45. An object is placed to the left of a convex lens with a 25-mm focal length so that its image is the same size as the object. What are the image and object positions?

51. **Image Position and Height** An object is placed 1.5 m from a convex lens with a focal length of 1.0 m. Use the thin lens equation to determine the distance of the image from the lens. If the object height is 2.0 m, what is the image height? Is the image real or virtual? Is the image inverted or upright?

55. Image Position and Height A 6.0-cm-tall object is placed 5.0 cm from a convex lens with a focal length of 4.0 cm. Draw a ray diagram to determine the image location and size. Confirm your results using the thin lens equation and the magnification equation.

56. **Diverging Lens** A 6.5-cm-tall salt shaker is viewed through a diverging lens with a focal length of 5.0 cm.
- a. If the shaker is 6.0 cm from the lens, what is the image distance from the lens? Is the image virtual or real?
 - b. What is the magnification? Is the image smaller or larger than the object?
 - c. The salt shaker is now 4 cm from the lens. What is the distance of the image from the lens? The magnification? Is the image now smaller or larger than the object?