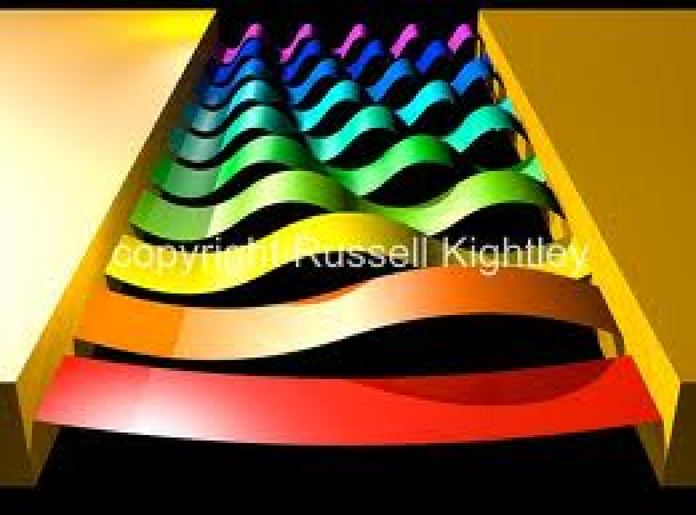
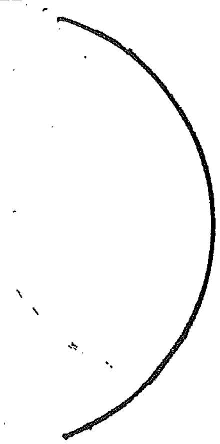

copyright Russell Kightley

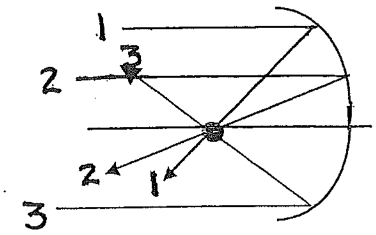
Lesson One (light)

DEFINITIONS

1. **Concave Mirror: reflects** light rays causing rays to **CONVERGE** or come together **at focal point**

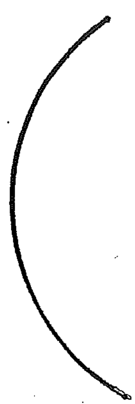
front →

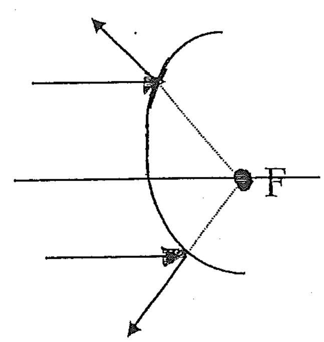




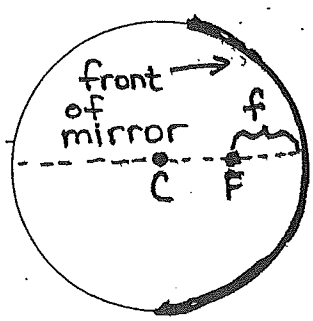
2. **Convex Mirror: reflects** light from surface causing rays to **DIVERGE** or **spread** apart **from focal point**

front →





3. **Center of Curvature** (C): the point that is the distance of the **RADIUS** from the **mirror.** (note the distance is represented by a lower case letter while an upper case letter represents the point itself)



C is always **2xf**

or $f = \frac{c}{2}$

4. **Principle Focus (F):** the point where **reflected** rays **converge to** or **diverge from.**

5. **Focal Length (f):** distance between mirror and F (half the radius)

and **$f = r/2 = c/2$**

6. **Spherical aberration**: when using a **spherical mirror**, light **rays** do **not converge** or diverge **exactly at F** causing spherical aberration. To **eliminate** this **problem** a **PARABOLIC mirror** is **used.**

7. **Real images are:**

- produced **in front** of a mirror when light **rays converge.**
- can be **projected** onto a screen
- usually it is **INVERTED** (when compared to the object).

8. **Virtual Images:**

- **appear** to be **BEHIND** the **mirror**
- light **rays** do **not converge**
- can **not** be **projected** on a screen
- usually **erect** (right side up)

MIRRORS & LENSES

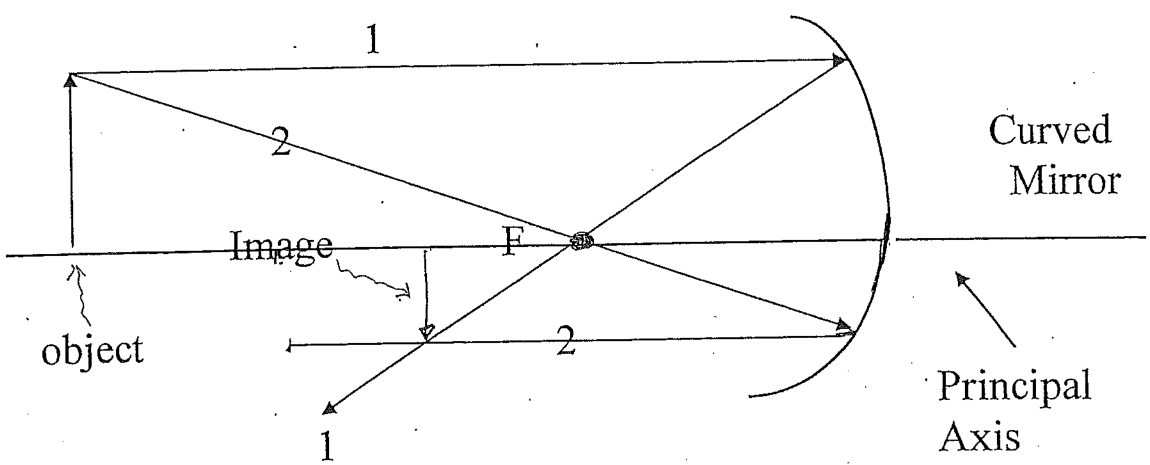
RAY DIAGRAMS

- Ray diagrams involve the drawing of **two rays from** the **object** to the mirror (or lens) and the two **reflected** (for mirrors) **or refracted rays** (after striking the mirror or lens) to **locate** the **image.**

- Almost always, the two easiest rays (from the object) to draw are:

    i. **to** the mirror (or lens) **parallel** to the principal axis and the reflected (mirror) or refracted (lens) ray **through** the **focal point.**
    ii. **to** the mirror (or lens) through the **focal point** and **returning parallel**

Sample Ray Diagram



Lesson 1 (Light)

REFLECTIONS FROM Curved MIRRORS

CONVEX - Convex mirrors are mirrors that are **curved outward.**

CONCAVE - Concave mirrors are mirrors that are **curved inward**.

Terms You Need to Know:

Centre of curvature (C) – *center of sphere*

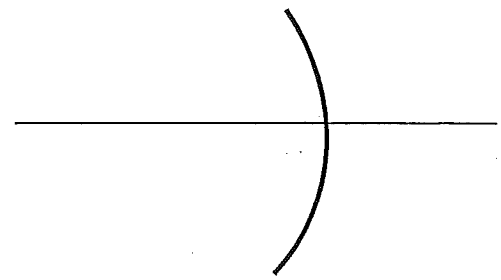
Principle axis – *center line*

Vertex – *where the mirror meets the principle axis (center of mirror)*

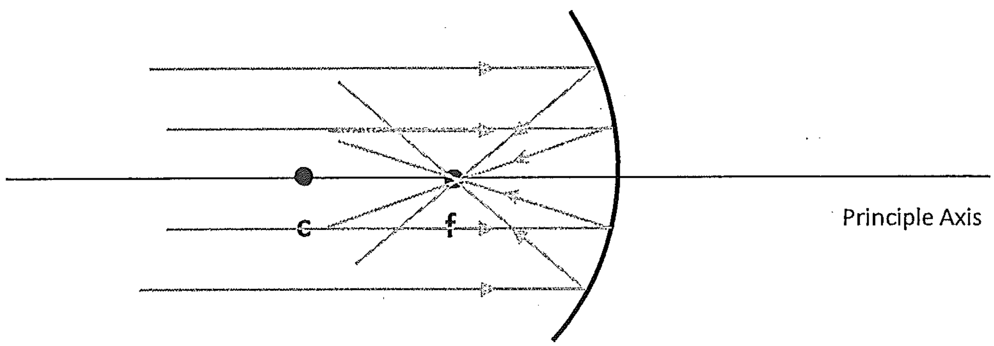
Radius of curvature – *distance from (C) to the vertex*

Focal point (f) - *half the distance between (C) and the vertex*

Focal length – *distance from the focal point (f) to the vertex*

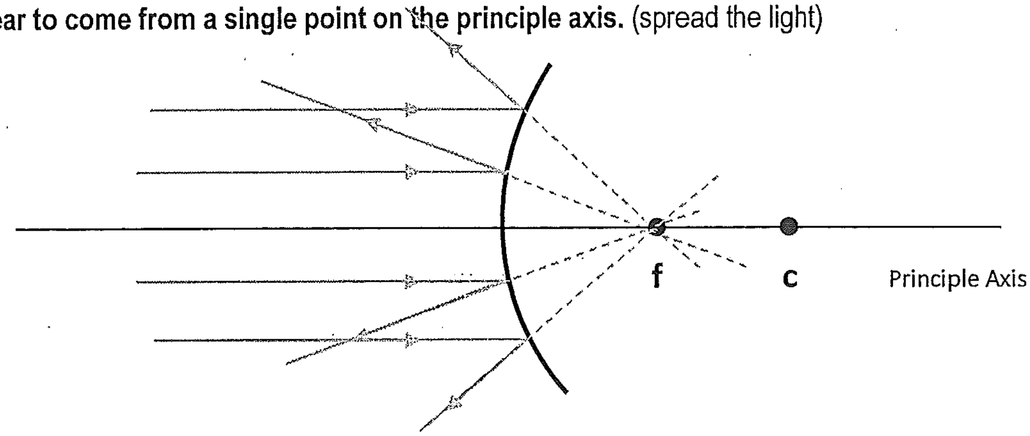


When rays of light that are parallel to the principle axis hit a **concave mirror**, they reflect in such a way that **they all move through a single point on the principle axis = the focal point** (focus the light)



When the focal point is on the same side as the source of the light rays, it is considered a ______________ focal point. **All concave mirrors use a real focal point.**

When rays of light that are parallel to the principle axis hit a **convex mirror**, they will reflect in such a way that **they all appear to come from a single point on the principle axis.** (spread the light)



This point is on the opposite side of the mirror from the light rays and is considered a ________________ focal point. **All convex mirrors use a virtual focal point.**

Because of the way light reflects from curved mirrors there are two names that can refer to each type of mirror:

A concave mirror can be called a __________________ mirror.

A convex mirror can be called a __________________ mirror.

RAY DIAGRAMS USING CURVED MIRRORS

When drawing a wave diagram for curved mirrors, we draw two incoming rays of light to determine where the image will form. The position, size and type (real or virtual) of an image produced by a curved mirror can then be found.

CONCAVE MIRRORS-

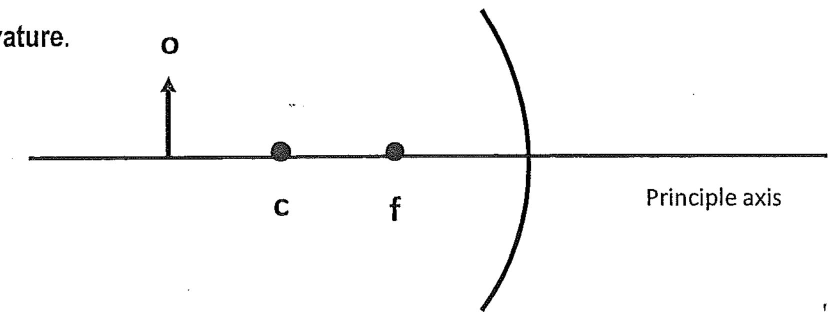
A. The object is beyond the centre of the curvature.
The image is -

Step One - Line in from top of object (O) to mirror

Step Two - Reflect through focal point (f)

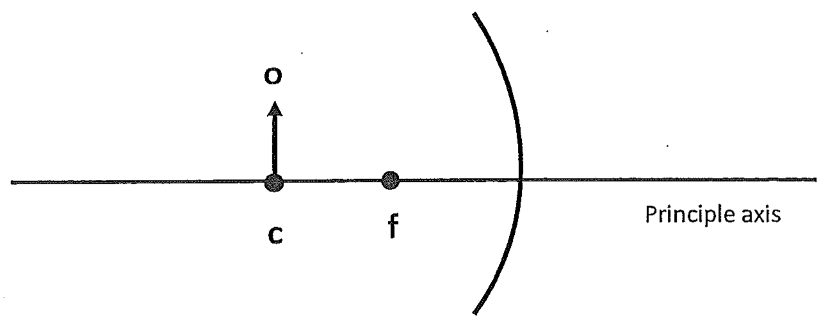
Step Three - Line from top of object through (f) to mirror

Step Four - Reflect straight out parallel to principle axis



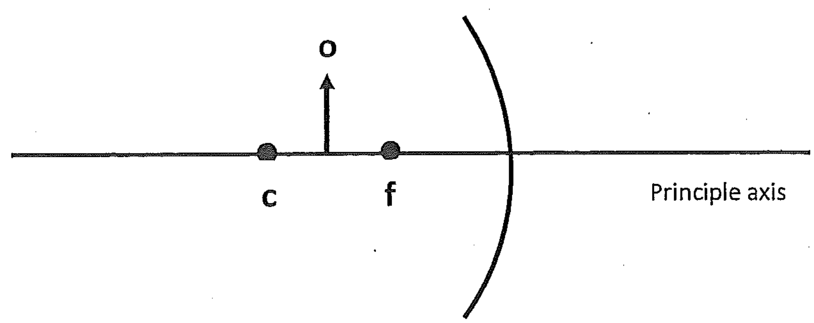
B. The object is at the centre of the curvature.
The image is -

Same as A.

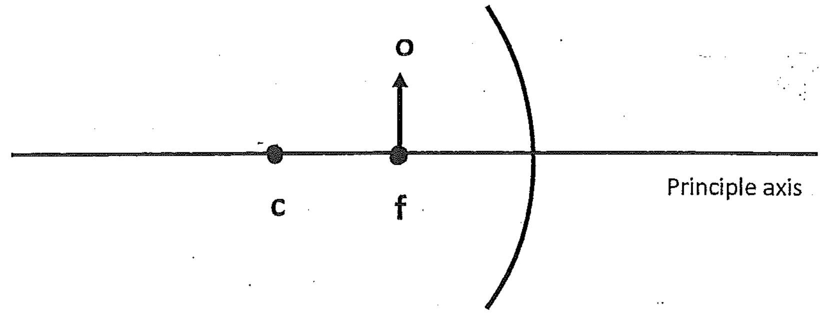


C. The object is between c and f.
The image is -

Same as A



D. The object is at the focal point.
There is ______ image.

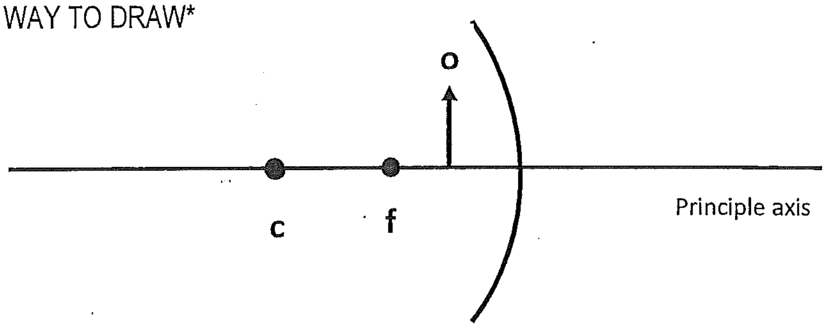


E. The object is **inside** the focal point. *SPECIAL WAY TO DRAW*
The image is -

Step One - Line in from object to mirror

Step Two - Reflect through focal point but now *extend to virtual side of mirror*

Step Three - Line from top of object through (C) and *extend to virtual side of mirror*



SAMPLE DIAGRAMS USING CONVEX MIRRORS

When using convex mirrors, the focal point used is always a **virtual focal point**. The images that form are always **the same**. *SPECIAL WAY TO DRAW*

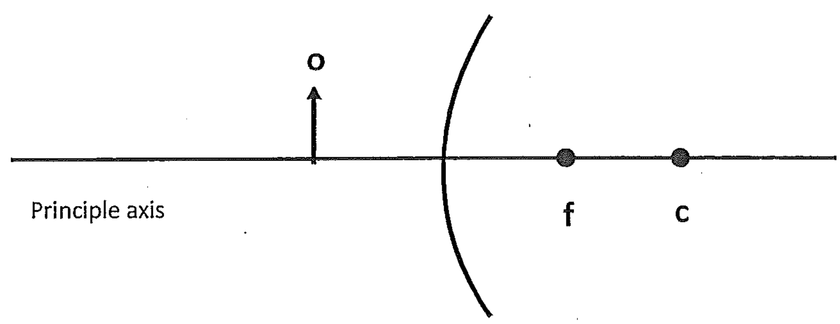
The image is -

Step One - Line in from object to mirror

Step Two - Reflect off virtual focal point

Step Three - Line up with focal point and draw line to mirror - extend into virtual side

Step Four - Reflect parallel to principle axis - extend into virtual side



IMPORTANT CONCEPTUAL UNDERSTANDING:

By looking at the diagrams, we observe that certain things are true about virtual and real images:

All real images are inverted **= $-h_i$** (results in a negative height of image (h_i))

All virtual images are erect **= $+h_i$** (results in a positive height of image (h_i))

All real images are formed in front of the mirror (where the light actually meets)

= $+d_i$ (positive distance to the image from mirror)

All virtual images are formed behind the mirror (the light cannot reach here)

= $-d_i$ (negative distance to the image from mirror)

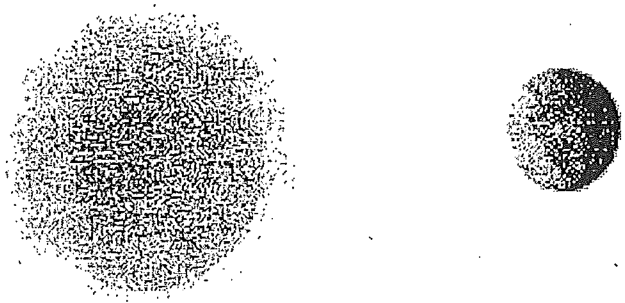
Physics 11 Light
Principles and Problems
Merrill Physics

lesson 1

PROBLEMS (p 344)

16.1 Light Fundamentals

1. Convert 700 nm, the wavelength of red light, to metres. (7.00×10^{-7} m)
2. Light takes 1.28 s to travel from the moon to Earth. What is the distance between them? (3.84×10^{8} m)
3. The sun is 1.5×10^8 km from Earth. How long does it take for its light to reach us? (5.0×10^{2} s)



4. Ole Roemer found that the maximum increased delay in the appearance of Io from one orbit to the next was 14 s.
   a. How far does light travel in 14 s? (a) 4.2×10^{9} m
   b. Each orbit of Io is 42.5 h. Earth traveled the distance calculated above in 42.5 h. Find the speed of Earth in km/s. b. 28 km/s
   c. See if your answer for part **b** is reasonable. Calculate Earth's speed in orbit using the orbital radius, 1.5×10^8 km, and the period, one year. c. 30 km/s

PROBLEMS (p 364)

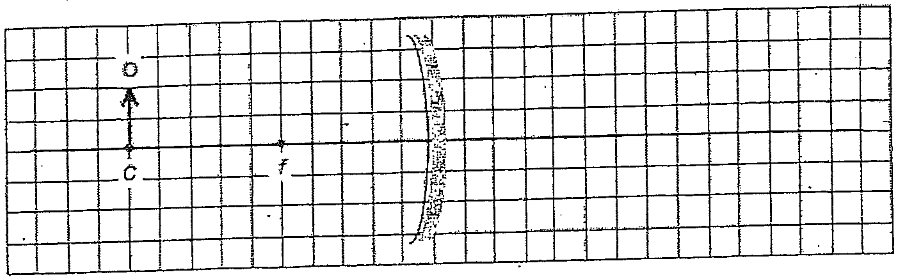
17.1 How Light Behaves at a Boundary

1. A ray of light strikes a mirror at an angle of 53° to the normal. (a. 53° b. 106°)
   a. What is the angle of reflection?
   b. What is the angle between the incident ray and the reflected ray?
2. A ray of light incident upon a mirror makes an angle of 36.0° with the mirror. What is the angle between the incident ray and the reflected ray? (108°)
3. A ray of light has an angle of incidence of 30.0° on a block of quartz and an angle of refraction of 20.0°. What is the index of refraction for this block of quartz? (1.46)

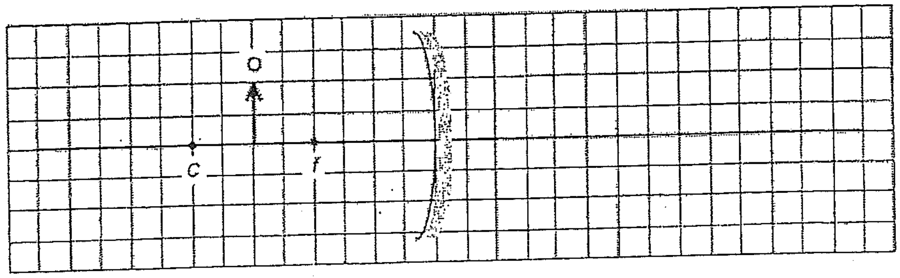
6. A light ray strikes the surface of a pond at an angle of incidence of 36.0°. At what angle is the ray refracted? (26.2°)
7. Light is incident at an angle of 60.0° on the surface of a diamond. Find the angle of refraction.
8. A ray of light has an angle of incidence of 33.0° in crown glass. What is the angle of refraction?
9. A ray of light passes from water into crown glass at an angle of 23.2°. Find the angle of refraction. (20.2)
10. Light goes from flint glass into ethanol. The angle of refraction in the ethanol is 25°. What is the angle of incidence in the glass?
11. A beam of light strikes the flat, glass side of a water-filled aquarium at an angle of 40° to the normal. For glass, $n = 1.50$. At what angle does the beam (a) 25° b) 28.4°)
    a. enter the glass?
    b. enter the water?

Practice Problems: Lesson 2 (light)

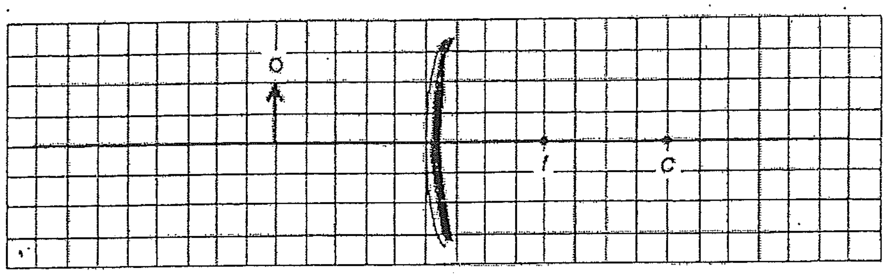
1. Complete the following ray diagrams and state the characteristics of the images (real/virtual, erect/inverted, larger/smaller/same size).

a) 

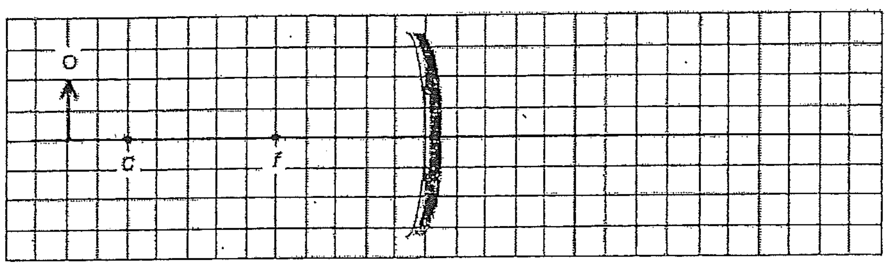
Characteristics:

b) 

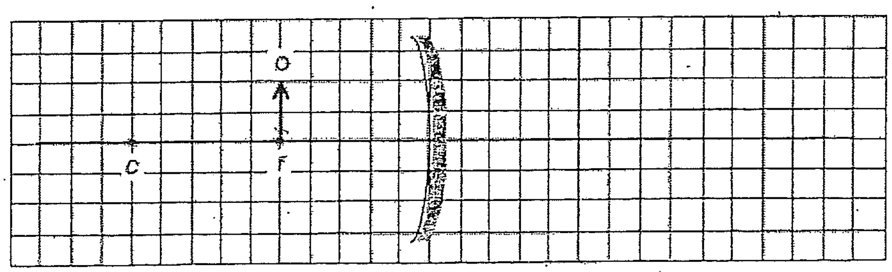
Characteristics:

c) 

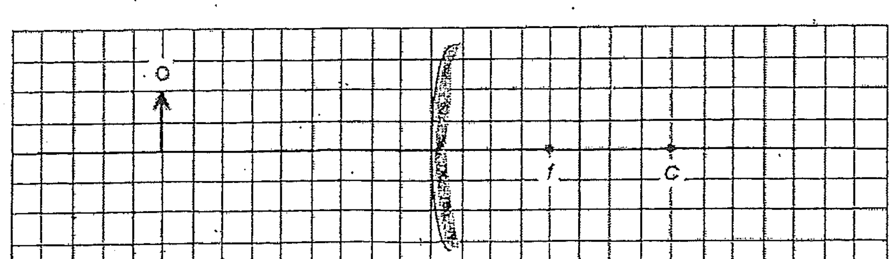
Characteristics:

d) 

Characteristics:

e) 

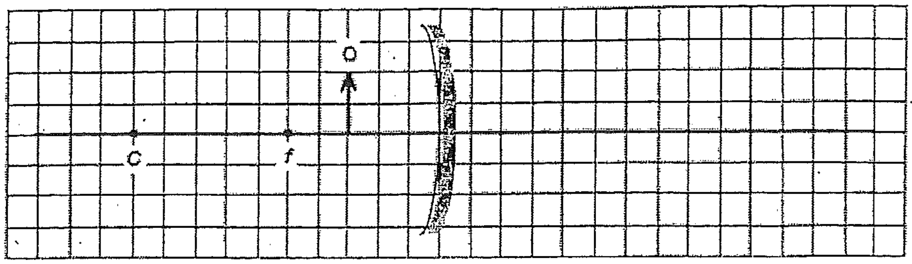
Characteristics:

f) 

one more diagram on next page →

Characteristics:

g)



Characteristics:

Reflections from **Curved** Mirrors – Equations

The position, size and nature of the image produced by curved mirrors can also be described mathematically.

MAGNIFICATION

$\frac{h_i}{h_o}$ OR $\frac{d_i}{d_o}$ →

MIRROR EQUATION

$$\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$$

Example 1

An object 3.00 cm tall is placed 10.0 cm in front of concave mirror that has a focal length of 3.0 cm. Find the characteristics of the image produced by using the mathematical formulae.

Example 2

An object 2.5 cm tall is placed 9.0 cm in front of a convex mirror that has a focal length of 4.0 cm. Find the characteristics by using the mathematical formulae.

Example 3

An object 3.5 cm tall is placed 4.5 cm in front of a concave mirror that has a radius of curvature of 6.0cm. Find the characteristics of the image produced by using the mathematical formulae.

Lesson 2 (light)

Curved Mirror Problems:

1. An object 5.0cm tall is placed 7.0cm in front of a concave mirror. If a real image is produced that is also 5.0cm tall, what is the focal length of the mirror? (3.5 cm)

2. An object 3.0cm tall is placed 6.0cm in front of a mirror. If a virtual image is produced that is 1.0 cm tall, what is the focal length of the mirror? What kind of mirror is used? (-3.0cm, convex)

3. An object is 9.0 cm tall is placed at the focal point of a concave mirror. If the focal length is 5.0cm, what is the size of the image? (*no image produced*)

4. A convex mirror produced an image that is 3.0cm behind the mirror. If the focal length of this mirror is 5.0cm, at what distance from the mirror is the object placed? (7.5cm)

5. An object is placed 8.0cm in front of a convex mirror that has a radius of curvature of 8.0 cm. What is the magnification of this object? (0.33)

6. An object is placed 5.0cm in front of a concave mirror. The magnification of the object is 2.5. If a real image is produced, what is the radius of curvature of the mirror? (7.1cm)

7. An object 4.0cm tall is placed 8.0cm in front of a concave mirror. If the real image produced is 6.0cm tall, what is the focal length of the mirror? (4.8cm)

8. An object 3.0cm tall produces a virtual image that is 2.0cm tall. If the image is 2.5cm behind the mirror, what is the focal length of the mirror? What kind of mirror is used? (-7.5cm, convex)

9. An object 5.0 cm tall produces an image that is 7.0cm behind the mirror. If the radius of curvature of this mirror is 10.0cm, what is the magnification of the object? What kind of mirror is used? (2.4, concave)

10. When an object 4.0 cm tall is placed 7.0 cm in front of a mirror, the image is 6.0 cm tall and virtual.

a) What type of mirror is used? How do you know?(concave)

b) Find the focal length and radius of curvature of the mirror. (21 cm, 42 cm)

11. A convex mirror is used to monitor the aisles in a store. The mirror has a radius of curvature of 4.0 m, and a 1.5 m tall customer is standing 12 m in front of the mirror.

a) Locate the image of the customer. (-1.7m)

b) How tall is the image? (+0.21 m)

c) Is the image real or virtual? Explain. (virtual)

d) Is the image erect or inverted? Explain. (erect)

12. A man is using a mirror to shave his chin. When he stands 1.48 m in front of the mirror, the inverted image of his chin is produced 32 cm in front of the mirror. Determine the radius of curvature of the mirror. (0.526 m)

13. An object 5.0 cm tall produces an image that is 2.5 cm behind the mirror. If the radius of curvature of this mirror is 12.0 cm, what is the magnification of the object? What kind of mirror is used? (0.58 times, convex mirror)

Reflection from a plane mirror lab

Lesson 3: (Lesson 2 review)
light

FORMULAE:

$$\frac{1}{d_i} + \frac{1}{d_o} = \frac{1}{f} \qquad \text{AND}$$

$$\frac{h_i}{h_o} = \frac{-d_i}{d_o} = m \leftarrow \textbf{magnification}$$

where :

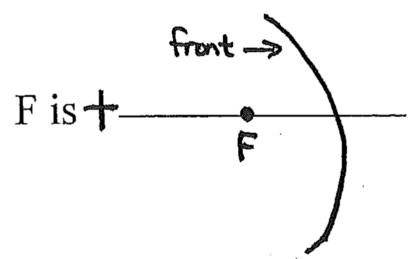
distance to the object is d_o
distance to the image is d_i
height of the object is h_o
height of the image is h_i

MIRROR EQUATION RULES (+ in front of mirror
− behind mirror)

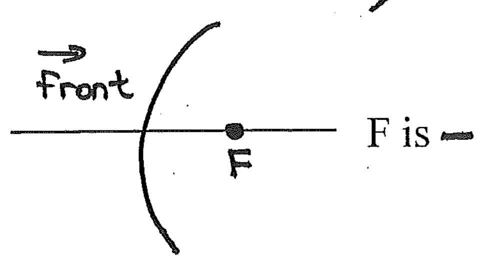
1. d_o + (positive)

2. d_i + for real images
− for virtual images

3. f + for CONCAVE mirrors
(F is in **front** of the mirror)



− for CONVEX mirrors
(f is behind the mirror)



Sample Problems

1. A 5.00 cm object is placed 10.0 cm in front of a concave mirror that has a focal length of 4.00 cm. Describe the image. Use the formulae to find:
a. the distance of the image b. the magnification.

a. $\frac{1}{f} = \frac{1}{d_o} + \frac{1}{d_i}$ $\frac{1}{4.00\text{cm}} = \frac{1}{10.0\text{cm}} + \frac{1}{d_i}$

Therefore: $\frac{1}{d_i} = \frac{1}{4} - \frac{1}{10} = \frac{1}{d_i} = 0.25/\text{cm} - 0.10/\text{cm} = 0.15/\text{cm}$

and $d_i = 6.66666$ cm Therefore $d_i = 6.67$ cm
And since the sign of $\mathbf{d_i}$ is **positive**, the image is **real.**

b. $\frac{-d_i}{d_o} = m$ $\frac{-6.67\text{ cm}}{10.0\text{ cm}} = m$ $m = -0.667$

- if **magnificataion** is **negative, image** is **INVERTED**
- if **m < 1, image** is **smaller**

Therefore: image is: 1. inverted 2. smaller 3. real

2. A 3.7 cm high object is placed 8.0 cm in front of a convex mirror that has a focal length of 5.0 cm (remember the **focal length** is **negative** as it is a **convex** mirror. Describe the image. Use the formulae to find:
a. the distance of the image b. the magnification c. size of image
(**Note** - find size of image means to find "h_i")

a. $\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$ so $\frac{-1}{5.0\text{cm}} = \frac{1}{8.0\text{cm}} + \frac{1}{d_i}$

$\frac{1}{d_i} = \frac{-1}{5.0} - \frac{1}{8.0} = -0.20/\text{cm} - 0.125/\text{cm} = -0.325/\text{cm}$ so $d_i = -3.1$ cm

And since the sign of $\mathbf{d_i}$ is **negative**, the image is **virtual.**

b. $\frac{-d_i}{d_o} = m$ $\frac{-(-3.1\text{cm})}{8.0\text{cm}} = m$ $m = 0.38$

- magnification is **positive** therefore the **image** is **ERECT**
- **m< 1** Therefore **image** is **smaller**

Therefore image is: 1. ERECT 2. SMALLER 3. VIRTUAL

c. $\frac{h_i}{h_o} = m$ $h_i = mh_o = 0.36(3.7\text{ cm}) = 1.4$ cm

Lesson 3

REVIEWING CONCEPTS (p 387)

1. Describe the physical properties of the image of a person seen in a plane mirror.
2. Where is the image of an object in a plane mirror?
3. What causes the defect that all concave spherical mirrors have?
4. Describe the physical properties of a virtual image.
5. How does a virtual image differ from a real image?

APPLYING CONCEPTS (p 388)

1. If you use a shaving or makeup mirror underwater in a swimming pool, will its focal length change? Explain.
2. You have to order a large concave mirror for a piece of high quality equipment. Should you order a spherical mirror or a parabolic mirror? Explain.
3. Locate and describe the physical properties of the image produced by a concave mirror when the object is located at the centre of curvature.
4. An object is located beyond the centre of curvature of a spherical concave mirror. Locate and describe the physical properties of the image of the object. (20 cm)
5. An object is located between the centre of curvature and the focus of a concave mirror. Locate and describe the physical properties of the image of the object.

(p 389)

(7.) An object is 30.0 cm from a concave mirror of 15-cm focal length. The object is 1.8 cm high.
a. Find the image with the mirror equation.
b. How high is the image?

(a. 30cm b. -1.8cm)

(8.) A jeweller inspects a watch with a diameter of 3.0 cm by placing it 8.0 cm in front of a concave mirror of 12.0 cm focal length.
a. Where will the image of the watch appear?
b. What will be the diameter of the image?

(a. 24 cm b. 9.0cm)

(9.) A dentist uses a small mirror of radius 40 mm to locate a cavity in a patient's tooth. If the mirror is concave and is held 16 mm from the tooth, what is the magnification of the resulting image?

(5.0cm)

(10.) A production line inspector wants a mirror that produces an upright image with magnification of 7.5 when it is located 14.0 mm from a machine part.
a. What kind of mirror would do this job?
b. What is its radius of curvature?

(concave 32.4mm)

CONCEPT REVIEW (p 336)

(1.1) How far does light travel in the time it takes sound to go 1 cm (at 20°C)?

(1.2) The speed of light is slower in air or water than in a vacuum. The frequency does not change when light enters water. Does the wavelength change? in which direction?

Lesson 4 Concave Mirror lab

Lesson 4

Practice Problems (p 376)

5. An object is 4.0 cm in front of a concave mirror having a 12.0-cm radius. Locate the image using the mirror equation and a ray diagram. (-12cm)

6. A concave mirror has a focal length of 9.0 cm. A 15-mm high object is placed 6.0 cm from the mirror.
   a. Find the image using the mirror equation.
   b. How large is the image?
   (a. -18cm b. 45mm)

7. A 4.0-cm high candle is placed 10.0 cm from a concave mirror having a focal length of 16.0 cm.
   a. Where is the image located?
   b. What is the height of the candle's image?
   (a. -27cm b. 11cm)

8. What should be the radius of curvature of a concave mirror that magnifies an object placed 25 cm from the mirror by a factor of +3.0? (f=37.5 r=75cm)

CONCEPT REVIEW (p 378)

1.1 Draw a ray diagram showing your eye placed 12 cm from a plane mirror. Two rays leave a point on an eyelash and enter opposite sides of the pupil of your eye, 1 cm apart. Locate the image of the eyelash.

1.2 If a beam of parallel light rays is sent into a spherical concave mirror, do all the rays converge at the focal point?

1.3 If a mirror produces an erect, virtual image, can you immediately say it is a plane mirror? Explain.

Lesson 5 (light)

REFRACTION OF LIGHT THROUGH A LENS

Refraction of light through lenses is very similar to what we learned about curved mirrors (convex and concave)

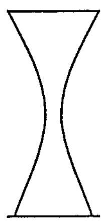
There are two types of lenses: **CONVEX** and **CONCAVE.**

A **concave lens** can be called a **diverging lens** – when light passes through it –

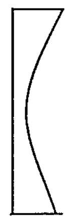
A **convex lens** can be called a **converging lens** – when light passes through it –

Concave Lenses

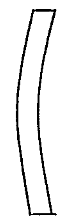
Any lens that is thinner at the centre than at the edges is a concave (diverging) lens.



double concave



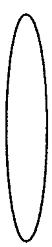
plano-concave



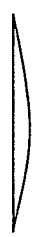
convex-concave

Convex Lenses

Any lens that is thicker at the centre than at the edges is a convex (converging) lens.



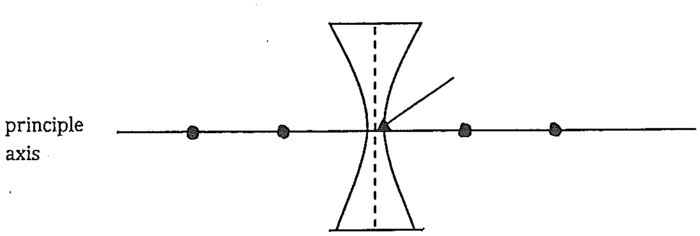
double convex

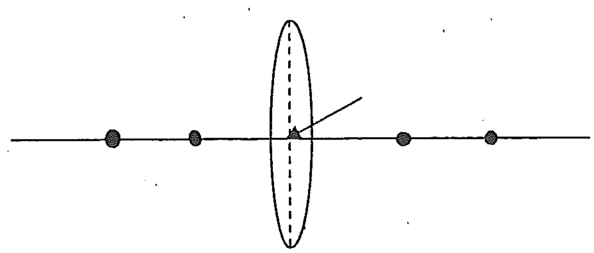


plano-convex

concave-convex

Terms:





The centre of the lens is called the **optical center (O)**

RAY DIAGRAMS – **CONVEX LENS**

Step One - draw beam of light from the top of the object parallel to principal axis to center of lens, refract the beam through f.

Step Two - draw beam of light from the top of the object straight through the optical center

Step Three - draw image where the beams meet

A. When an object is placed at a point greater than 2f.

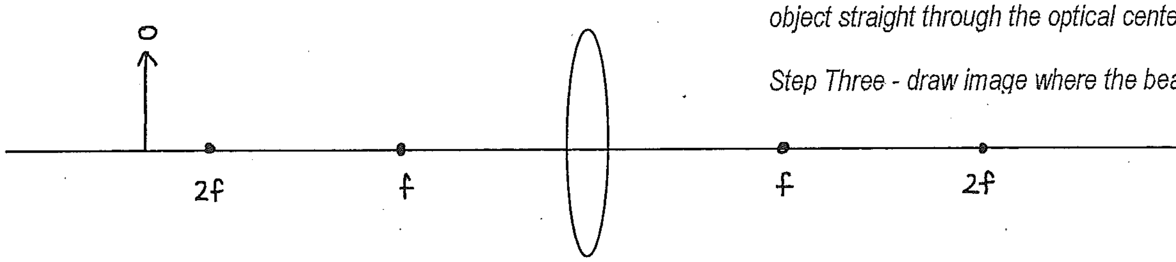


Image characteristics:

B. When an object is placed at 2f.

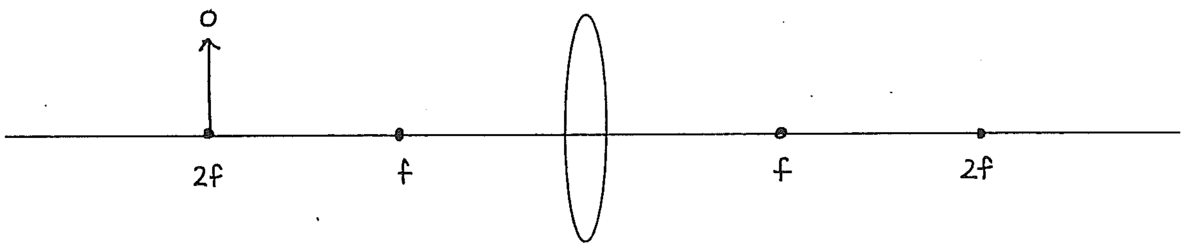


Image characteristics:

C. When an object is placed between 2f and f.

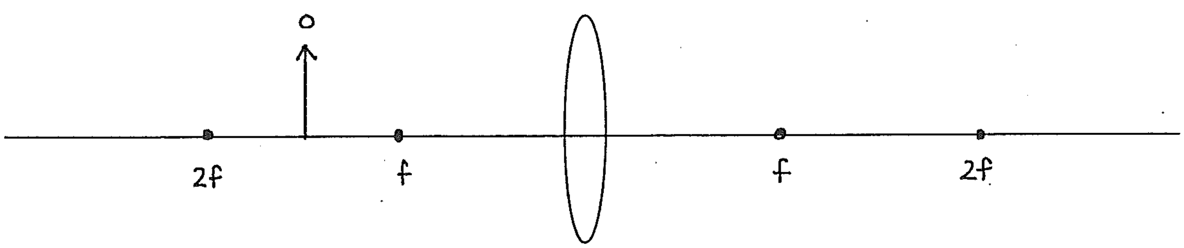


Image characteristics:

D. When an object is placed at f

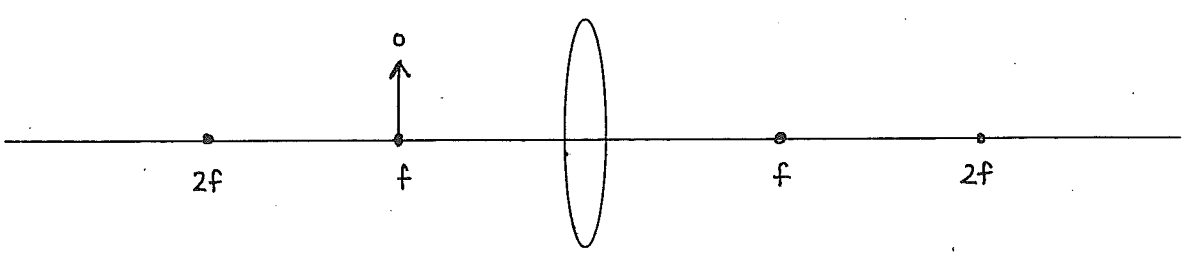


Image characteristics:

E. When an object is placed inside f.

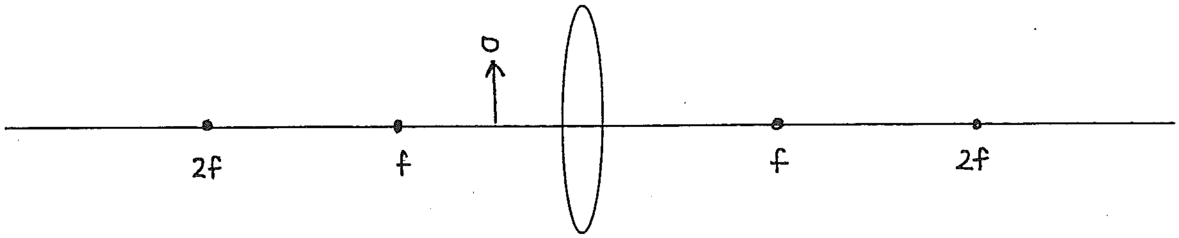


Image characteristics:

Step One - draw a beam of light from the top of the object parallel to the principle axis to the center of the lens, refract the beam lined up with the ***virtual f.***

Step Two - draw beam of light from the top of the object straight through the optical center

Step Three - draw image where the beams meet

<u>RAY DIAGRAMS</u> – **CONCAVE LENS**

The images are always the same in concave lens.

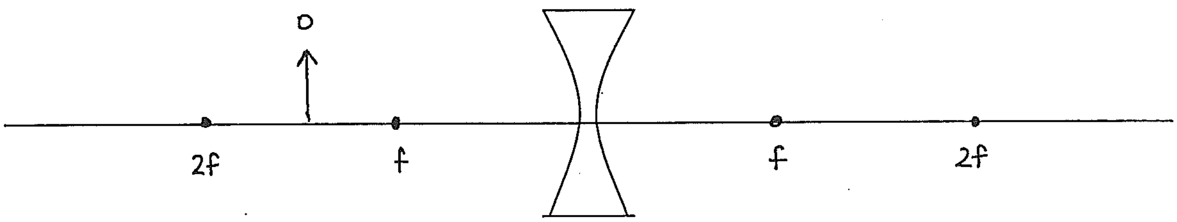


Image characteristics:

Lens Equations:

We will be using the same equations and methods as curved mirrors.

Magnification = $\frac{\text{height of image}}{\text{height of object}}$ OR Magnification = $\frac{\text{distance of image from lens}}{\text{distance of object from lens}}$

FORMULAS: [ ] and [ ]

Remember the signs!;

- convex lens focal point:
- concave lens focal point:
- real images:
- virtual images:

Examples:

1. A glowing object 2.5 cm tall is placed 15 cm from a convex lens. If the lens has a focal length of 7.5 cm, what is (are)

a) the distance of the image from the lens?

b) the size of the image?

c) the characteristics of the image?

2. A glowing object 4.0 cm tall is placed 9.0 cm from a concave lens. If the lens has a focal length of 5.0 cm, what is (are)

a) the distance of the image from the lens?

b) the size of the image?

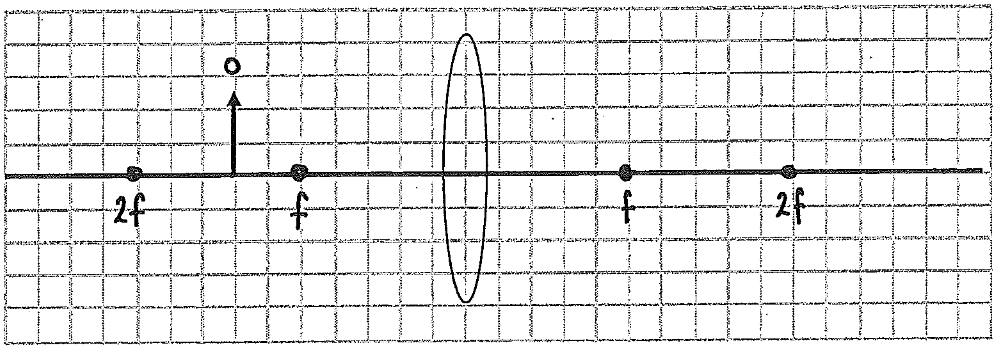
c) the characteristics of the image?

Lesson 5 (light)

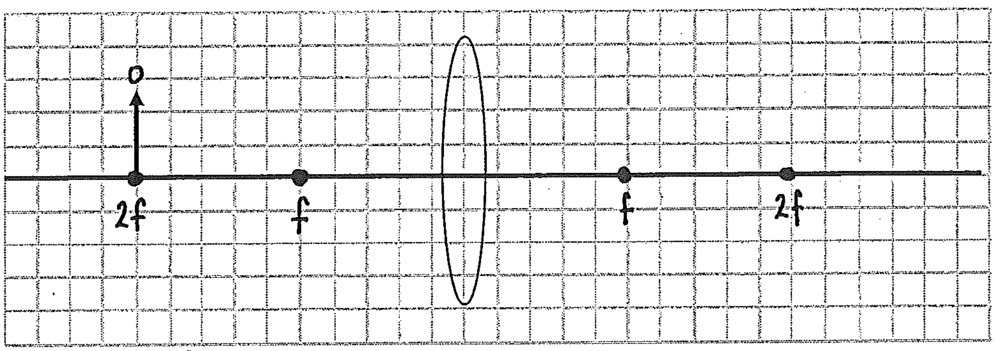
Refraction through Lenses Problems:

Complete the following ray diagrams and state the characteristics of the images.

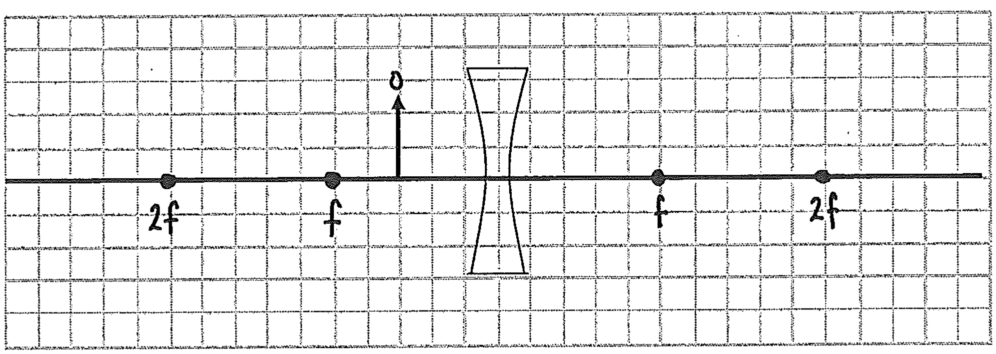
1.



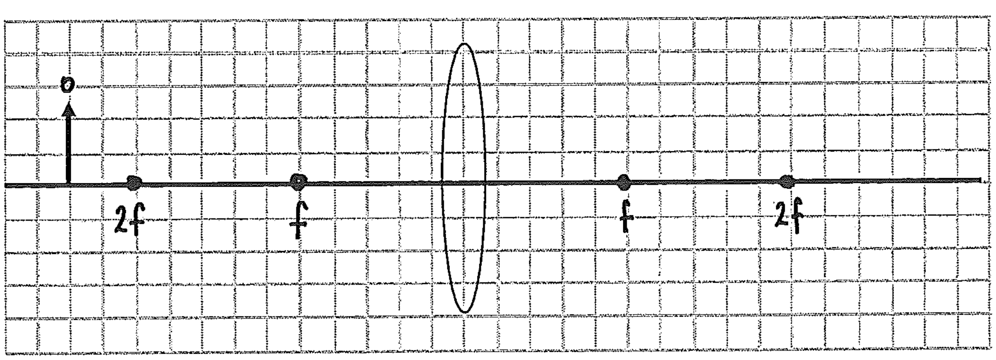
Characteristics:



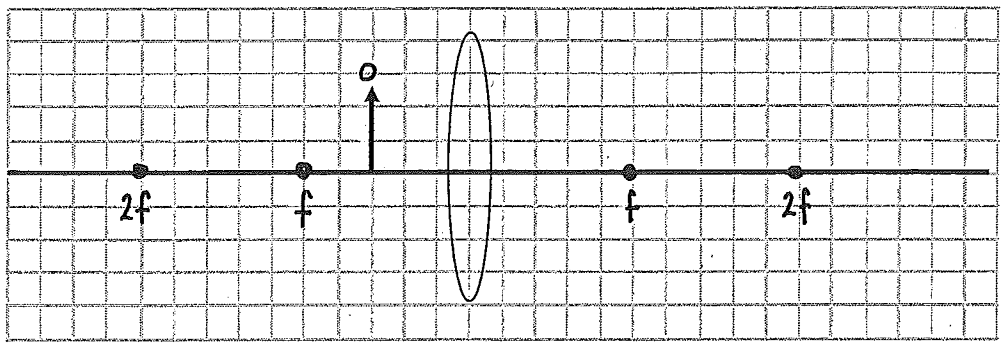
Characteristics:



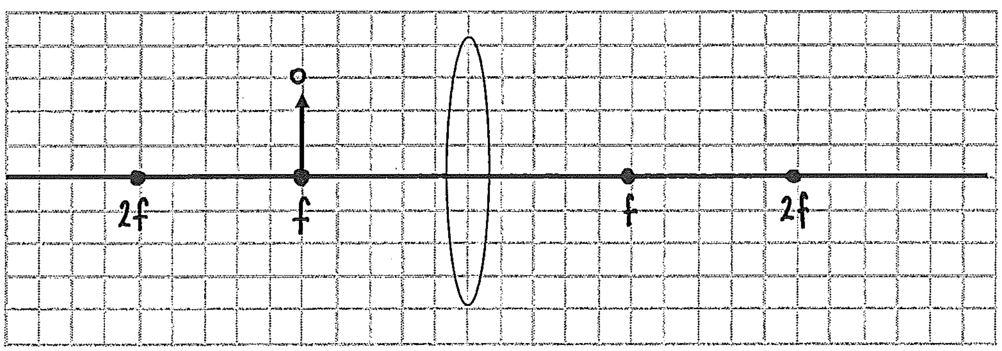
Characteristics:



Characteristics:



Characteristics:



Characteristics:

2. A glowing object 6.0 cm tall is placed 9.0 cm from a convex lens. If the lens has a focal length of 8.0 cm, what is:

a) the distance of the image from the lens? (+72 cm)

b) the height of the image? (-48 cm)

c) the characteristics of the image?

3. A glowing object 5.0 cm tall is placed 4.5 cm from a concave lens. If the lens has a focal length of 4.5 cm, what is:

a) the distance of the image from the lens? (-2.3 cm)

b) the size of the image? (+2.5 cm)

c) the characteristics of the image?

4. A glowing object 3.0 cm tall is placed 6.0 cm from the concave lens. If a virtual image is produced that is 1.0 cm tall, what is the focal length of the lens? (-3.0 cm)

5. A glowing object 2.0 cm tall is placed 5.0 cm from a lens. If a virtual image is produced that is 4.0 cm tall, what is the focal length of the lens? What kind of lens is used? (10 cm)

6. A glowing object 8.0 cm tall is placed 11.0 cm in front of a convex lens. If the focal length is 5.5 cm, what is the magnification of the object? (1.0X)

7. A concave lens produces an image that is 2.5 cm from the lens. If the focal length of this lens is 6.0 cm, at what distance from the lens is the object? (4.3 cm)

8. A glowing object is 8.0 cm from a concave lens that has a focal length of 4.0 cm. What is the magnification of this object? (0.33X)

9. A glowing object is 7.0 cm from a convex lens. If a real image is produced that is 2.0 X larger than the object, what is the focal length of the lens? (+4.7 cm)

10. A glowing object 4.0 cm tall is 9.0 cm from a convex lens. If the real image produced is 6.0 cm tall, what is the focal length of the lens? (+5.4 cm)

11. A glowing object 3.0 cm tall is 7.0 cm from a convex lens. If the virtual image produced is 6.0 cm tall, what is the focal length of the lens? (14 cm)

12. A glowing object 3.0 cm tall produces a virtual image 2.0 cm tall. If the image is 3.0 cm from the lens, what is the focal length of the lens? What kind of lens is used? (-9.0 cm)

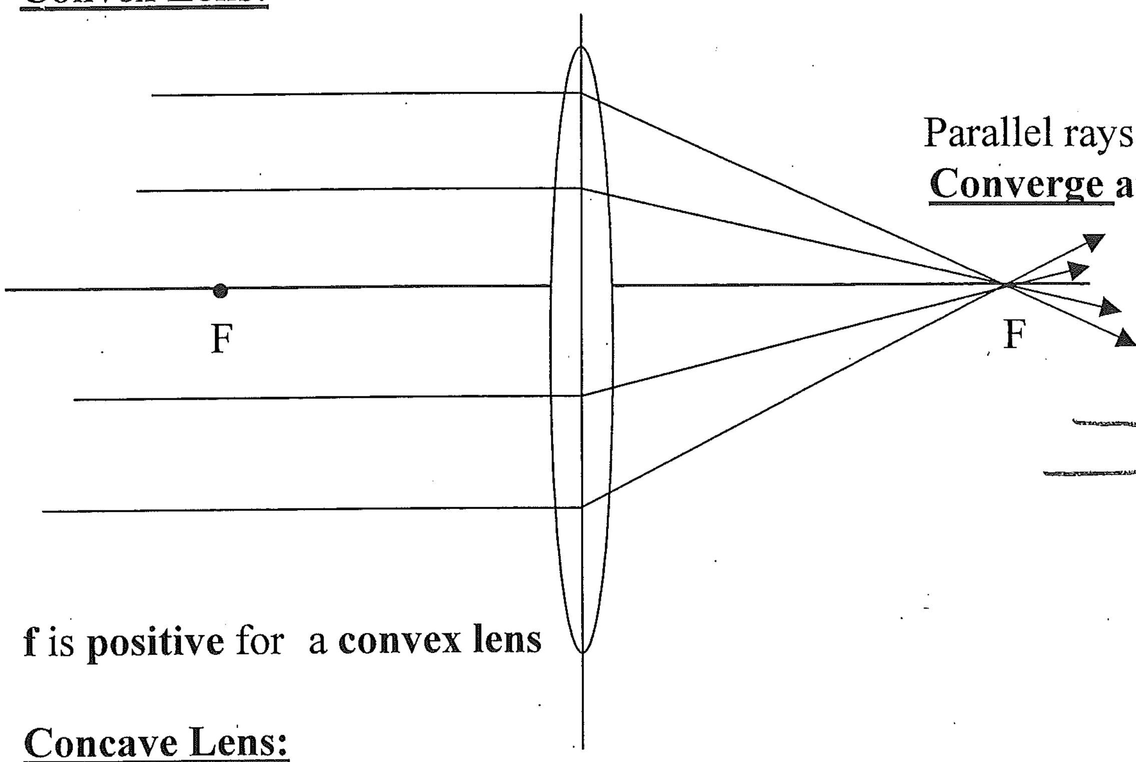
Lesson 6: light

Lesson 5 (light) review

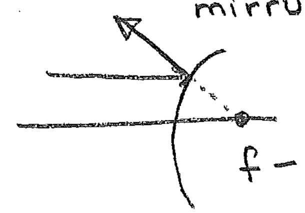
LENSES

- **lenses** are used to **change** the **direction** of light by **refraction**:
- the **two types** of lenses: **Convex**
  Concave

Convex Lens:

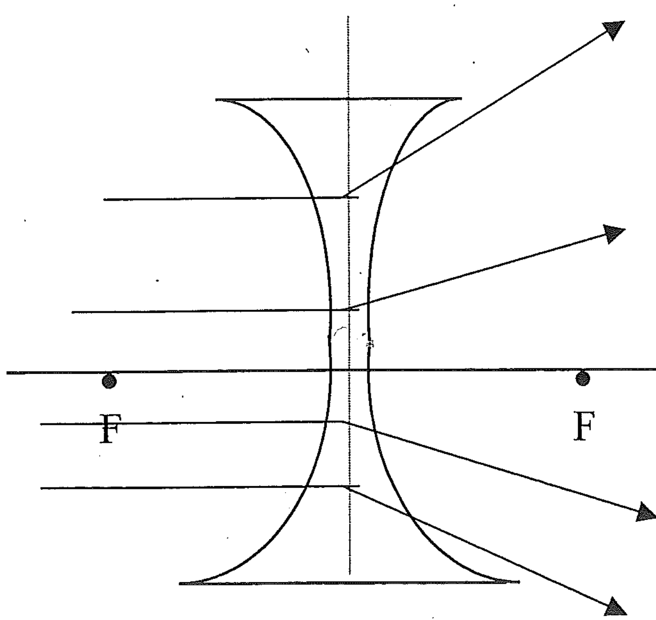


Parallel rays **Converge at "F".**

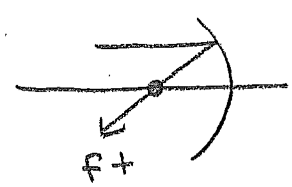


f is **positive** for a **convex lens**

Concave Lens:



Parallel rays **diverge from "F".**



f is **negative** for **concave lens**

	concave	convex
mirror	f +	−
lens	−	+

Lens Formulae

•the **lens equations** are the **same** as the **mirror equations**:

1. $$\frac{1}{f} = \frac{1}{d_i} + \frac{1}{d_o}$$

2. $$\frac{h_i}{h_o} = \frac{-d_i}{d_o} = m$$

Lens Conventions

d_o is + (as it is real)

"d_o & d_i" are the **same as mirrors!**

d_i + for **real** images
- for **virtual** images

f - for **concave** lens
+ for **convex** lens

"f" **is opposite to mirrors!**

Lenses

•for lenses the **focal point** can occur on **either side of lens** and "C" does **NOT** exist for a lens. (so we use F and 2F)

•both the **curvature** of the lens and the **index of refraction (n) determine** where the focal point **(F)** is.

•for **MIRRORS and LENSES:**

VIRTUAL IMAGES → always **ERECT**
REAL IMAGES → always **INVERTED**

Chromatic Aberration

•Different **colored components** of light passing through a **lens** are **refracted differently**, causing the **object** to "**APPEAR**" to be "**RINGED**" in a given color . This is called chromatic aberration.

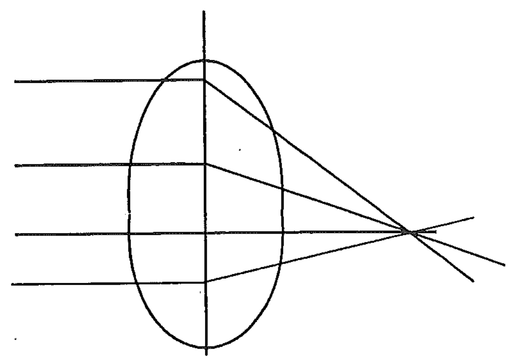
•An **achromatic lens** (a **converging lens** joined to a **diverging lens**) is used to **eliminate this problem.**

- See fig. 18.19 p. [illegible]

Lens Diagrams

I. Convex Lens Scale Diagrams

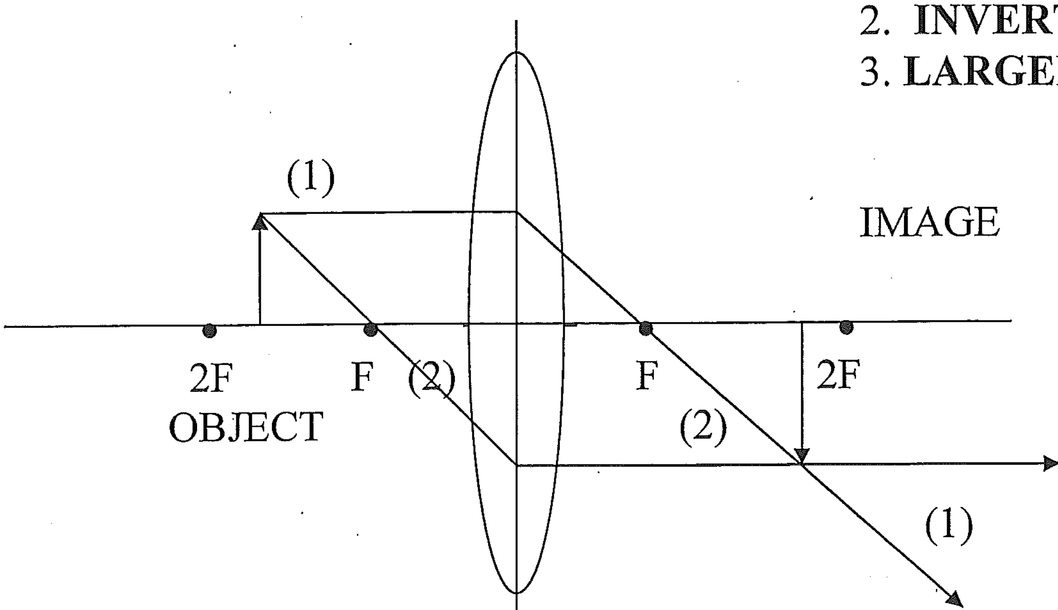
•**converging** lenses



•used in microscopes, telescopes, magnifying glasses and lenses in glasses (or contacts) to correct **far-sightedness.**

1. Object is at or **BEYOND F**:

A. Object is **between F and 2F, image** is
1. **REAL**
2. **INVERTED**
3. **LARGER**



B. Object **beyond 2F, image** is

1. **Real** 2. **Inverted** 3. **SMALLER**

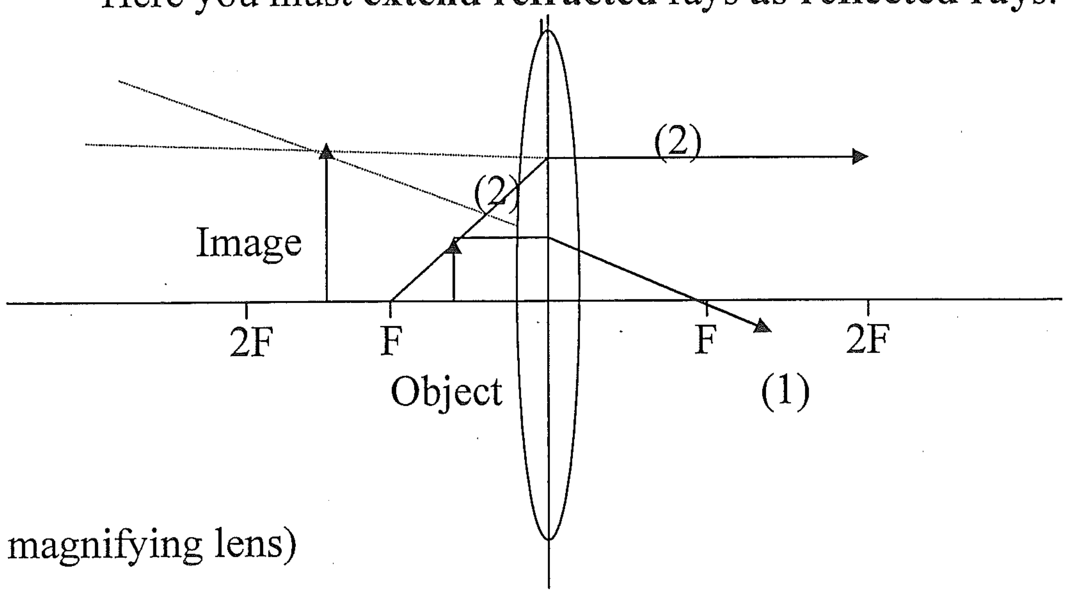
C. Object is **at 2F, image** is

1. **Real** 2. **Inverted** 3. **SAME SIZE**

2. Object is **INSIDE F, image** is always:

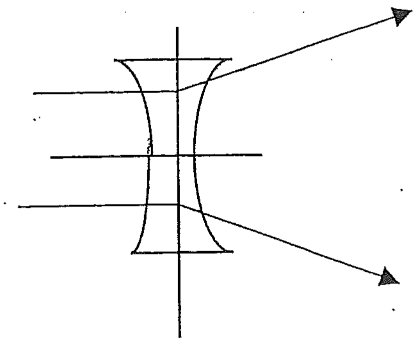
1. **VIRTUAL** 2. **ERECT** 3. **LARGER**

*Here you must **extend refracted** rays **as reflected rays.**



(like a magnifying lens)

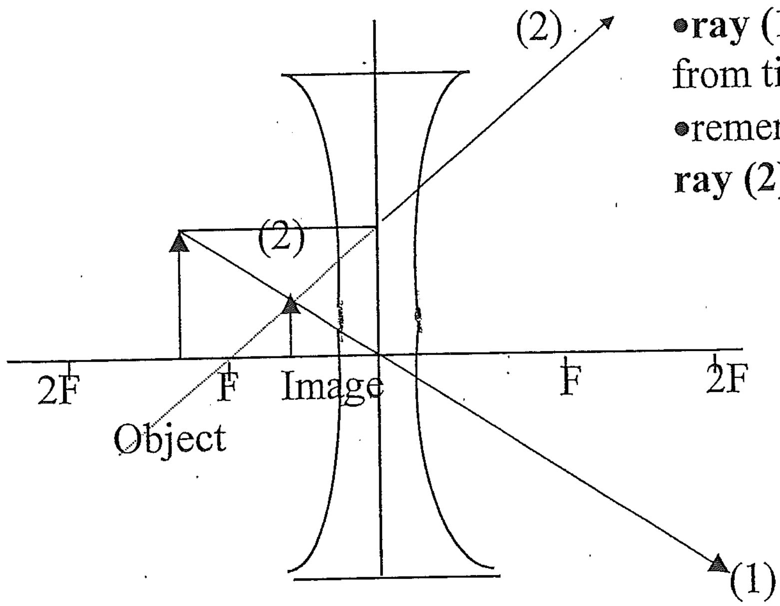
II. Scale Diagrams for Concave Lenses



- **diverging** lens
- used to correct **near sightedness**
- **ALWAYS** produce:

1. **VIRTUAL**
2. **ERECT**
3. **SMALLER images**

- Here **ray 1** is **different** than the **other diagrams**:



- **ray (1) through center** from tip of object
- remember to **extend refracted ray (2)** as a reflected ray

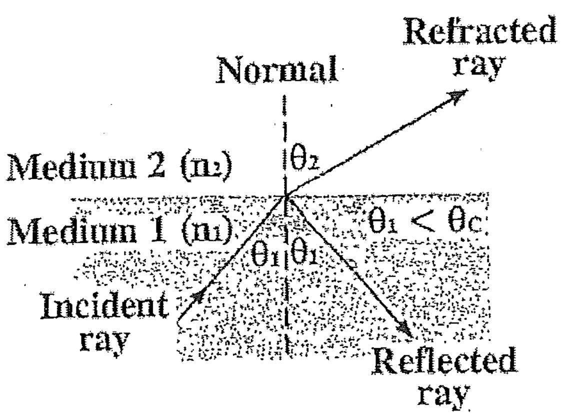
Lesson 6 (continued) (light)

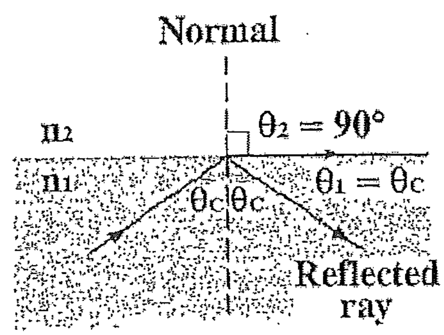
Refraction – Snell's Law – Critical Angles

When a ray of light passes from a medium into a less dense medium (with a smaller index of refraction), the refracted ray bends away from the normal. At a particular angle of incidence, the angle of refraction is 90°, and the refracted ray points along the surface of the medium.

A critical angle is the angle of incidence that causes the refracted ray to point along the surface of the interface ($\angle R = 90°$).

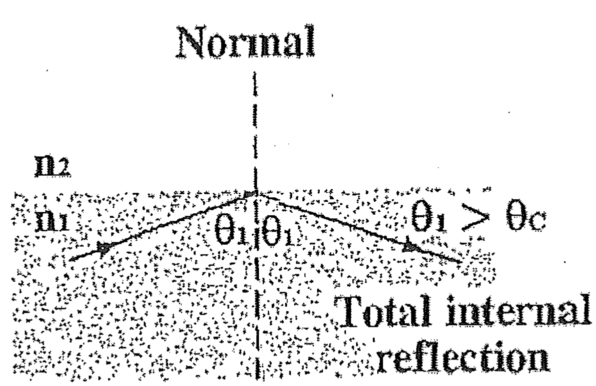
Critical Angle →



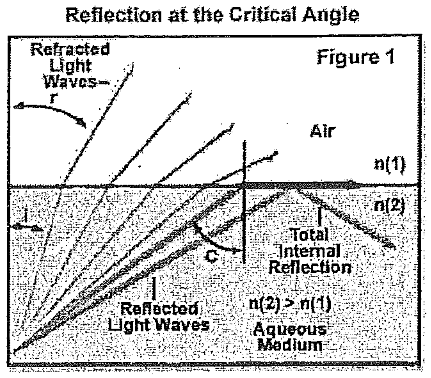


Total Internal Reflection →

Total internal reflection is the effect that occurs when an angle of incidence exceeds the critical angle. When this happens, there is no refracted ray, and all of the incident light is reflected back into the medium it came from following the law of reflection.



Example: Light travels from water to air. The angle of incidence which results in a refracted angle of 90° is called the **critical angle.**



<u>Any angle greater than the critical angle will result in *total internal reflection.*</u>

Formulas to remember: $$\frac{\sin\theta_1}{\sin\theta_2} = \frac{v_1}{v_2} = \frac{\gamma_1}{\gamma_2} = \frac{n_2}{n_1}$$

Examples:

1. What is the critical angle for an air-Lucite interface if the index of refraction of Lucite is 1.51?

2. What is the critical angle for a water-Lucite interface if the index of refraction for water is 1.33 and of Lucite is 1.51?

3. The critical angle for a certain liquid-air interface is 51.2°. What is the index of refraction of the liquid?

Critical Angle Problems: Lesson 6

1. What is the critical angle for an air-glass interface if the index of refraction of glass is 1.50? (41.8^o)

2. What is the critical angle for a water-Lucite interface if the index of refraction of water is 1.33 and of Lucite is 1.51? (61.8^0)

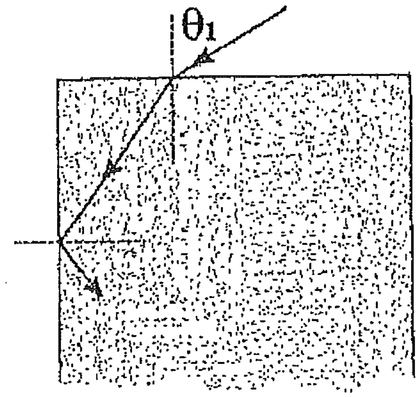
3. The critical angle for a certain liquid-air interface is 48.8^0. What is the index of refraction of the liquid? (1.33)

4. What is the critical angle of a substance whose index of refraction is 1.81? (33.5^0)

5. What is the index of refraction of a substance whose critical angle is 42.0^o? (1.49)

6. The speed of light in a clear liquid is 0.75c. What is the critical angle of the liquid? (49^0)

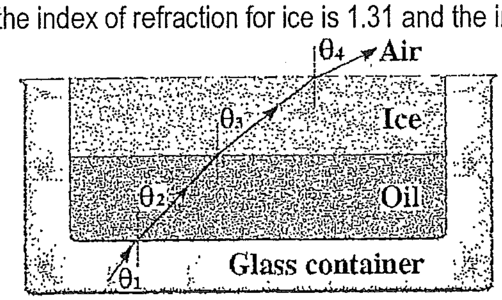
7. A laser beam strikes the top surface of a block of glass at an angle θ_1 and the refracted beam undergoes total internal reflection at the left vertical surface of the block as shown in the diagram. The index of refraction of the glass is 1.52.



a) If the block is surrounded by air, find the maximum value of θ_1.

b) If the block is surrounded by water (n=1.33), find the maximum value of θ_1.

8. In the following diagram, the index of refraction for ice is 1.31 and the index of refraction for oil is 1.45.



a) If the angle θ_1 of the incident ray is 36°, find the angle θ_4 of the emergent ray.

b) If total internal reflection occurs at the interface between the ice and air, find the critical angle of the incident ray.

Lesson 7 Index of Refraction Lab

Lesson 8 (light)

C. Polarization

When dealing with light, here is what scientists know:

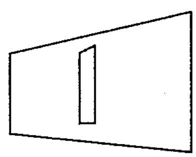
- Longitudinal waves **cannot** be polarized.
- Transverse waves **can** be polarized.
- Light **can** be polarized.
- CONCLUSION: **Light,** if it is wavelike, **behaves like a transverse wave.**

Transverse waves can vibrate in any plane (direction).

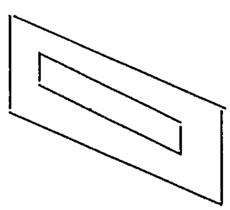
If a transverse wave encounters a **filter** that allows the transverse wave to vibrate in only one plane, then we have polarized the light wave.

unpolarized waves

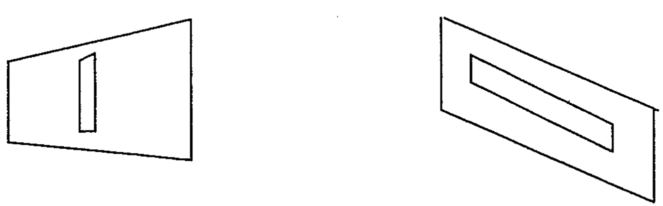
vertically polarized waves



horizontally polarized waves



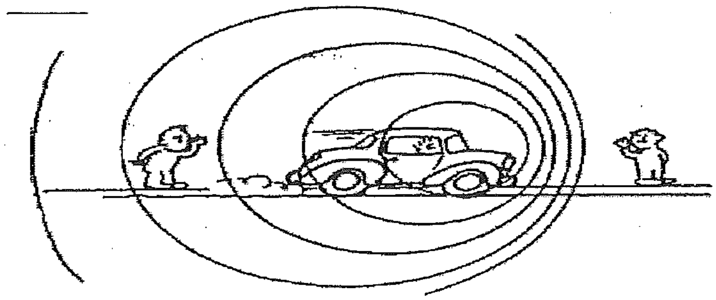
Polarizing filters at *right angles* to each other results in no waves.



Common Uses - Polarized Sunglasses – Used to reduce glare off horizontal surfaces (great for water glare).

The reflection **off horizontal surfaces is usually polarized horizontally**, therefore, **vertically** polarized lenses greatly reduce glare.

Wave Effects Review



1. When an automobile moves towards a listener, the sound of its horn seems relatively
   a. Low pitched b. High Pitched c. Normal

2. When the automobile moves away from the listener, its horn seems
   a. Low pitched b. High Pitched c. Normal

3. The changed pitch of the Doppler effect is due to changes in
   a. Wave speed b. wave frequency

4. What color of visible light does the atmosphere scatter the most?

5. What color of visible light does the atmosphere scatter the least?

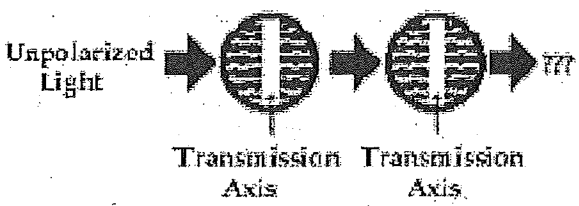
6. Using Rayleigh scattering, explain why the sky is blue..

7. Using Rayleigh scattering, explain why the sun at sunset is reddish. Include a diagram.

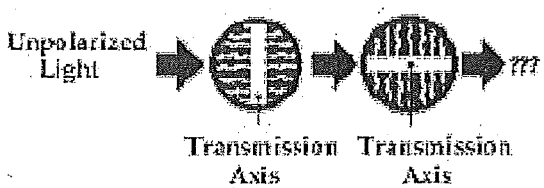
8. When a light wave vibrates in a variety of directions, the light is said to be ____.
   a. transverse b. polarized c. unpolarized

9. When a light wave's are isolated to a single plane, the light is said to be ____.
   a. transverse b. polarized c. unpolarized

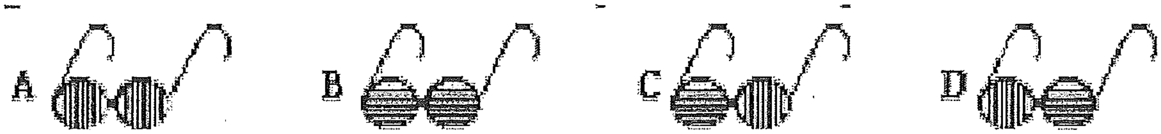
10. Describe the result of shining light through two polarizing filters whose transmission axes are parallel to each other.



11. Describe the result of shining light through two polarizing filters whose transmission axes are perpendicular to each other.



12. Carson Busses is driving down the road on a sunny day. Reflection of light off the road surface results in a large amount of polarization and a subsequent glare. Annoyed by the glare, Carson pulls out his Polaroid sunglasses. How must the axes of polarization be oriented in order to block the glare? (Note: the lines on the filters below represent the axis of polarization.)



Physics II Light and Waves Review lesson8

11. A wave has an angle of incidence of 24°. What is the angle of reflection? (24°)

Chapter 15

1. The echo of a ship's fog horn, reflected from an iceberg, is heard 5.0 s after the horn is sounded. How far away is the iceberg?

2. What is the speed of sound that has a frequency of 250 Hz and a wavelength of 0.600 m? (150 m/s)

3. A sound wave has a frequency of 2000 Hz and travels along a steel rod. If the distance between successive compressions is 0.400 m, what is the speed of the wave?

4. What is the wavelength of a sound wave that has a frequency of 250 Hz and a speed of 400 m/s? (1.60m)

5. What is the wavelength of sound that has a frequency of 539.8 Hz?

6. What is the wavelength of sound that has a frequency of 320.0 Hz?

▶ 7. A stone is dropped into a mine shaft 250.0 m deep. How many seconds pass before the stone is heard to strike the bottom of the shaft?

▶ 8. A rifle is shot in a valley formed between two parallel mountains. The echo from one mountain is heard after 2.00 s and from the other mountain 2.00 s later. What is the width of the valley?

▶ 9. Sam, a train engineer, blows a whistle that has a frequency of 4.0×10^2 Hz as the train approaches a station. If the speed of the train is 25 m/s, what frequency will be heard by a person at the station?

▶ 10. Jane is on a train that is travelling at 95 km/h. The train passes a factory whose whistle is blowing at 288 Hz. What frequency does Jane hear as the train approaches the factory?

11. What is the sound level of a sound that has a sound pressure one tenth of 90 dB?

12. What is the sound level of a sound that has a sound pressure ten times 90 dB?

13. A tuning fork produces a resonance with a closed tube 19.0 cm long. What is the lowest possible frequency of the tuning fork?

14. How do the frequencies of notes that are an octave apart compare?

15. Two tuning forks of 320 Hz and 324 Hz are sounded simultaneously. What frequency of sound will the listener hear?

16. How many beats will be heard each second when a string with a frequency of 288 Hz is plucked simultaneously with another string that has a frequency of 296 Hz?

17. A tuning fork has a frequency of 440 Hz. If another tuning fork of slightly lower pitch is sounded at the same time, 5.0 beats per second are produced. What is the frequency of the second tuning fork?

Chapter 16

1. The wavelength of blue light is about 4.5×10^{-7} m. Convert this to nm.

2. As a spacecraft passes directly over Cape Kennedy, radar pulses are transmitted toward the craft and are then reflected back toward the ground. If the total time interval was 3.00×10^{-3} s, how far above the ground was the spacecraft when it passed over Cape Kennedy?

3. It takes 4.0 years for light from a star to reach Earth. How far away is this star from Earth? (3.8×10^{16} m)

4. The planet Venus is sometimes a very bright object in the night sky. Venus is 4.1×10^{10} m away from Earth when it is closest to Earth. How long would we have to wait for a radar signal to return from Venus and be detected?

5. The distance from Earth to the moon is about 3.8×10^8 m. A beam of light is sent to the moon and, after it reflects, returns to Earth. How long did it take to make the round trip? (2.5 s)

6. A baseball fan in a ball park is 101 m away from the batter's box when the batter hits the ball. How long after the batter hits the ball does the fan see it occur?

7. A radio station on the AM band has an assigned frequency of 825 kHz (kilohertz). What is the wavelength of the station? (364 m)

8. A short-wave, HAM, radio operator uses the 5-m band. On what frequency does the HAM operate?

glass. It appears to be a mirror. Use your knowledge of geometry and critical angles to show that this is true.

17. The index of refraction for red light in arsenic trioxide is 2.010, while the index of refraction for blue light is 2.023. Find the difference between the angles of refraction if white light is incident at an angle of 65.0°.

18. The index of refraction for red light in a diamond is 2.410, while the index of refraction for blue light is 2.450. Find the difference in the speed of light in diamond.

Chapter 18

1. Sally's face is 75 cm in front of a plane mirror. Where is the image of Sally's face? (75 cm behind mirror)

2. A concave mirror has a focal length of 10.0 cm. What is its radius of curvature?

3. Light from a distant star is collected by a concave mirror that has a radius of curvature of 150 cm. How far from the mirror is the image of the star?

4. An object is placed 25.0 cm away from a concave mirror that has a focal length of 5.00 cm. Where is the image located? (6.25 cm in front of mirror)

5. An object and its image as seen in a concave mirror are the same height when the object is 48.4 cm from the mirror. What is the focal length of the mirror?

6. An object placed 50.0 cm from a concave mirror gives a real image 33.3 cm from the mirror. If the image is 28.4 cm high, what is the height of the object? (42.6 cm)

7. An object, 15.8 cm high, is located 87.6 cm from a concave mirror that has a focal length of 17.0 cm.

a. Where is the image located? (21.1 cm)

b. How high is the image? (-3.81 cm)

▶ **8.** The image of the moon is formed by a concave mirror whose radius of curvature is 4.20 m at a time when the moon's distance is 3.80×10^5 km. What is the diameter of the image of the moon if the diameter of the moon is 3480 km?

9. A shaving mirror has a radius of curvature of 30.0 cm. When a face is 10.0 cm away from the mirror, what is the magnification of the mirror? (m = 3.0)

10. A convex mirror has a focal length of −16 cm. How far behind the mirror does the image of a person 3.0 m away appear? (-0.15 m)

11. How far behind the surface of a convex mirror, focal length of −6.0 cm, does a car 10.0 m from the mirror appear? (-0.060 m)

12. A converging lens has a focal length of 25.5 cm. If it is placed 72.5 cm from an object, at what distance from the lens will the image be?

13. If an object is 10.0 cm from a converging lens that has a focal length of 5.00 cm, how far from the lens will the image be?

14. The focal length of a lens in a box camera is 10.0 cm. The fixed distance between the lens and the film is 11.0 cm. If an object is clearly focused on the film, how far must the object be from the lens?

15. An object 3.0 cm tall is placed 22 cm in front of a converging lens. A real image is formed 11 cm from the lens. What is the size of the image?

▶ **16.** An object 3.0 cm tall is placed 20 cm in front of a converging lens. A real image is formed 10 cm from the lens. What is the focal length of the lens?

▶ **17.** What is the focal length of the lens in your eye when you read a book that is 35.0 cm from your eye? The distance from the lens to the retina is 0.19 mm.

▶ **18.** When an object 5.0 cm tall is placed 12 cm from a converging lens, an image is formed on the same side of the lens as the object but the image is 61 cm away from the lens. What is the focal length of the lens?

▶ **19.** When an object 5.0 cm tall is placed 12 cm from a converging lens, an image is formed on the same side of the lens as the object but the image is 61 cm away from the lens. What is the size of the image?

Chapter 19

1. Monochromatic light passes through two slits that are 0.0300 cm apart and it falls on a screen 120 cm away. The first-order image is 0.160 cm from the middle of the center band. What is the wavelength of the light used?

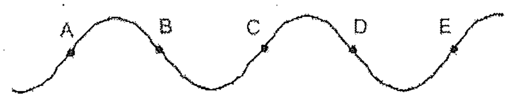
Concave lens lab

SELF-TEST
WAVE MOTION AND GEOMETRICAL OPTICS

1. Which of the following are fundamental properties of waves (i.e. properties that are characteristic of waves but not characteristic of particles)?

   i) refraction
   ii) interference
   iii) diffraction

   A. i) and ii) only
   B. i), ii), and iii)
   C. ii) and iii) only
   D. i) and iii) only

2. 

   Which of the following points on a vibrating string are in phase with point A?

   A. All points – B, C, D and E
   B. B and C only
   C. C and E only
   D. B and D only

3. When waves pass through a small opening, they may diffract. A student is telling his friend that the extent of this diffraction depends on:

   i) the speed of the wave
   ii) the wavelength
   iii) the size of the opening

   Which of the above are correct:

   A. All of them – i), ii), and iii)
   B. i) and ii) only
   C. ii and iii) only
   D. i) and iii) only

4. If you know the wavelength of a wave and its period, which of the following information about the wave can you calculate?

   i) the speed of the wave.
   ii) the frequency of the wave
   iii) the amplitude of the wave

   A. All of the above – i), ii) and iii)
   B. i) and ii) only
   C. ii) and iii) only
   D. i) and iii) only

5. When a train that is travelling at a speed of 80 km/h goes by you with its whistle blowing as you stand near the railroad track, the frequency of the whistle sound appears to fall (decrease). This phenomenon is most closely related to or referred to as

   A. refraction
   B. diffraction
   C. the superposition principle
   D. the doppler effect

6. A transverse wave is travelling through a medium at a speed of 10.0 cm/s. If this wave has an amplitude of 5.0 cm and a wavelength of 2.0 cm/s, what is the frequency of the wave?

   A. 2.0 Hz
   B. 5.0 Hz
   C. 20 Hz
   D. 50 Hz

7. The particles in the medium that are vibrating as to produce a longitudinal wave in the medium are vibrating

   A. parallel to the directions that the energy is transmitted through the medium
   B. perpendicular to the direction that the energy is transmitted through the medium
   C. in a circular path relative to the direction that the energy is transmitted through the medium
   D. in an elliptical path relative to the direction that the energy is transmitted through the medium

8. When light travels from air into water, which of the following properties of the wave change?

   i) direction
   ii) speed
   iii) wavelength
   iv) frequency

   A. All of the above – direction, speed, wavelength and frequency
   B. Direction, speed and wavelength only
   C. Speed, wavelength and frequency only
   D. Wavelength, frequency and direction only

Longitudinal waves can not be

A. refracted
B. diffracted
C. polarized
D. transmitted through a solid

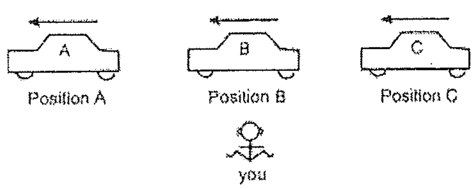
10. Electromagnetic waves like radio waves are different from mechanical waves in that electromagnetic waves can

A. travel through a vacuum
B. be polarized
C. demonstrate constructive and destructive interference
D. demonstrate the doppler effect

11. In an interference pattern, there are maxima and minima. the maxima result when waves meet

A. out of phase
B. in phase
C. with the same frequencies
D. with the same amplitudes

12.



A police car with its siren sounding is travelling at 100 km/h as it goes by you as you sit along side the road as shown above. At which position would the frequency of the siren appear to be the lowest?

A. Position A
B. Position B
C. Position C
D. It would appear to be the same at all positions.

13. The characteristics of an image formed by a pinhole camera are usually

A. erect, smaller, virtual
B. inverted, smaller, virtual
C. erect, smaller, real
D. inverted, smaller, real

14. Which of the following characteristics are used to describe an image produced by a plane mirror?

i) erect
ii) virtual
iii) laterally inverted

A. All of the above – i), ii), and iii)
B. i) and ii) only
C. ii) and iii) only
D. i) and iii) only

15. Which of the following characteristics are used to describe an image produced by a convex mirror? (Draw a diagram to be sure.)

i) erect
ii) virtual
iii) enlarged

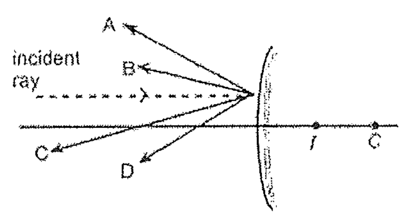
A. All of the above – i), ii), and iii)
B. i) and ii) only
C. ii and iii) only
D. i) and iii) only

16. Which of the following characteristics describe an image produced by a concave mirror when the object is placed between the focal point and the centre of curvature. (Draw a diagram to be sure.)

i) inverted
ii) virtual
iii) enlarged

A. All of the above – i), ii), and iii)
B. i) and ii) only
C. ii) and iii) only
D. i) and iii) only

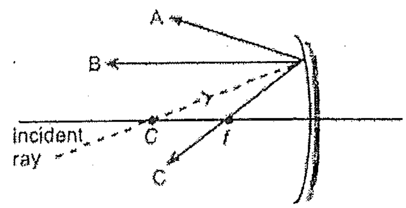
17.



If the incident ray is parallel to the principal axis as shown above, the light will reflect from the convex mirror along

A. A
B. B
C. C
D. D

18.



If the incident ray passes through the centre of curvature as shown above, the light will reflect from the concave mirror

A. straight back through the centre of curvature
B. along path A
C. along path B
D. along path C

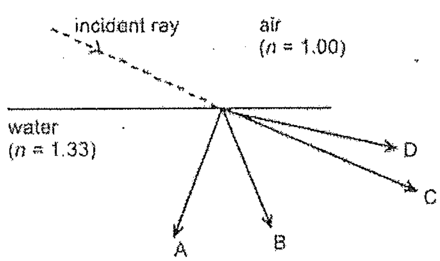
19. The magnification $\left(\frac{h_i}{h_o}\right)$ of an image produced by a plane mirror is always

A. greater than 1
B. less than 1
C. equal to 1

20. The magnification $\left(\frac{h_i}{h_o}\right)$ of an image produced by a diverging mirror is always

A. greater than 1
B. less than 1
C. equal to 1

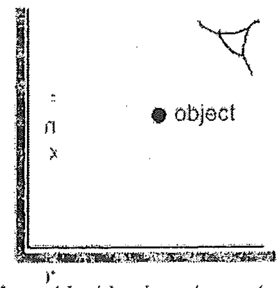
21.



When light passes from air into water as shown in the diagram, which ray can be the refracted ray?

A. A　　B. B
C. C　　D. D

22.



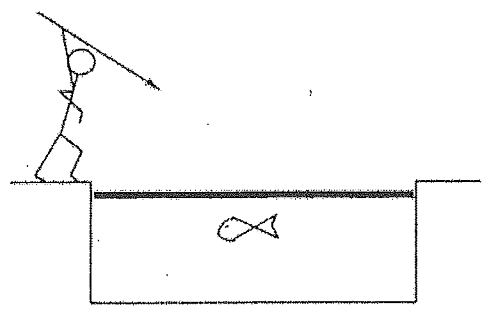
If an object is placed near to perpendicular mirrors as shown, how many images can be seen?

A. 1　　B. 2
C. 3　　D. 4

23. Light (frequency in air = 5.0×10^{14} Hz) passes from air (n = 1.00) into glass (n = 1.50). If the speed of the light in glass is 2.0×10^8 m/s, what is the frequency of the light in glass?

A. greater than 5.0×10^{14} Hz
B. less than 5.0×10^{14} Hz
C. equal to 5.0×10^{14}Hz

24.



You are attempting to spear a fish as shown above. Where should you aim?

A. Directly at the fish as you see it.
B. Below the fish as you see it.
C. Above the fish as you see it.
D. Behind the fish as you see it.

25. A student is explaining total internal reflection to her friend. She says that in order to observe total internal reflection

    i) the light must pass from a substance that has a higher index of refraction into a substance that has a lower index of refraction
    ii) the angle of incidence of the light must be greater than the critical angle

    Which of the above, if any, is (are) correct?

    A. Both i) and ii) are correct.
    B. Neither i) nor ii) are correct.
    C. Only i) is correct.
    D. Only ii) is correct.

26. Which of the following characteristics describe an image produced by a convex lens when the object is placed inside the focal point? (Draw a diagram to be sure.)

    i) inverted
    ii) virtual
    iii) enlarged

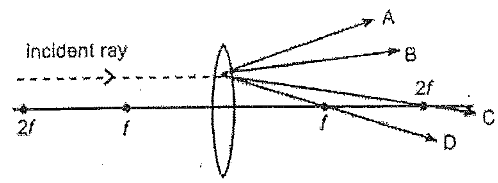
    A. All of the above – i), ii), and iii)
    B. i) and ii) only
    C. ii) and iii) only
    D. i) and iii) only

27. Which of the following characteristics describe an image produced by a concave lens? (Draw a diagram to be sure.)

    i) inverted
    ii) virtual
    iii) smaller

    A. All of the above – i), ii), and iii)
    B. i) and ii) only
    C. ii) and iii) only
    D. i) and iii) only

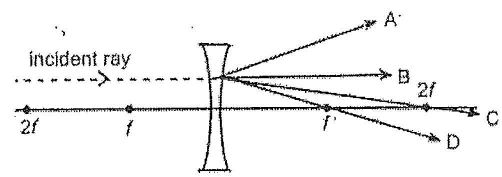
28.



If the incident ray is parallel to the principal axis as shown above, the light will be refracted by the convex lens along path

A. A
B. B
C. C
D. D

29.



If the incident ray passes through the focal point as shown in the diagram, the light will be refracted by the concave lens along path

A. A
B. B
C. C
D. D

30. The magnification $\left(\frac{h_i}{h_o}\right)$ of an image produced by a convex lens when the object is placed at $2f$ is

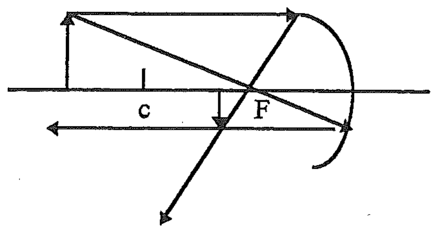
A. greater than 1
B. less than 1
C. equal to 1

* * * * * * * * * *

MIRRORS REVIEW

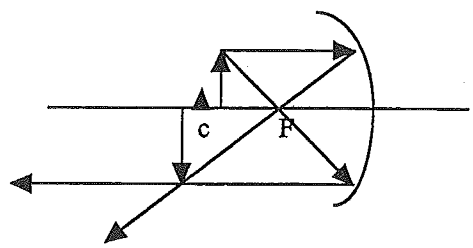
Concave Mirrors

1.



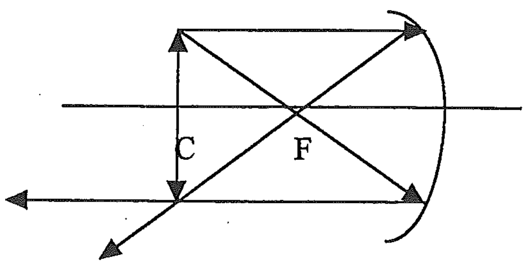
Object outside"C"
image 1. inverted
2. smaller
3. real

2.



Object between "F&C"
image 1. inverted
2. larger
3. real

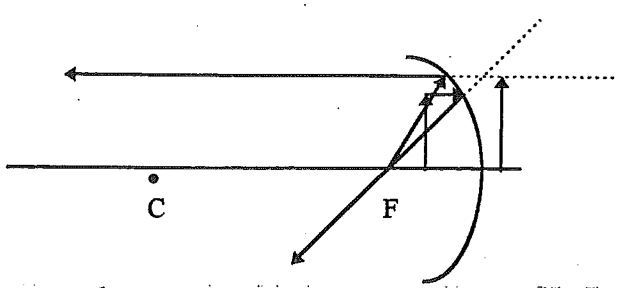
3.



Object at C
image 1. inverted (at C)
2. same size
3. real

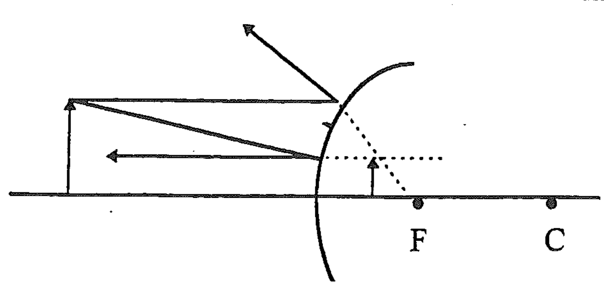
4. **Object at F** produces **NO IMAGE**

5.



Object between F and mirror
image **1. erect**
2. larger
3. virtual

1.



Object in front of mirror
image 1. erect
2. smaller
3. virtual

PHYSICS II - LIGHT Review (Extra Practice)

Problems

1. 27.7°

1. Light is incident upon a piece of crown glass at an angle of 45.0°. What is the angle of refraction?

2. 22.1°

2. A ray of light passes from air into water at an angle of 30.0°. Find the angle of refraction to the nearest degree.

3. 27.3°

3. Light is incident upon a piece of quartz at an angle of 45.0°. What is the angle of refraction to the nearest degree?

4. a. 17.0°
   b. diamond

4. A ray of light is incident upon a diamond at 45.0°.
   a. What is the angle of refraction?
   b. Compare your answer to that for Problem 1. Does glass or diamond bend light more?

5. a. 1.33
   b. water

5. A ray of light travels from air into a liquid. The ray is incident upon the liquid at an angle of 30.0°. The angle of refraction is 22.0°.
   a. What is the index of refraction of the liquid?
   b. Look at Table 18-1. What might the liquid be?

6. a. 19.2°
   b. 30.0°
   c. away from

6. In the Example on Snell's law, a ray of light is incident upon crown glass at 30.0°. The angle of refraction is 19.2°. Assume the glass is rectangular in shape. Construct a diagram to show the incident ray, the refracted ray, and the normal. Continue the ray through the glass until it reaches the opposite edge.
   a. Construct a normal at this point. What is the angle at which the refracted ray is incident upon the opposite edge of the glass?
   b. Assume the material outside the opposite edge is air. What is the angle at which the ray leaves the glass?
   c. As the ray leaves the glass, is it refracted away from the normal or toward the normal?

7. a. 2.20×10^8 m s
   b. 2.05×10^8 m s
   c. 1.86×10^8 m s

7. Use Table 18-1 to find the speed of light in
   a. ethanol b. quartz c. flint glass

8. 1.50

8. The speed of light in a plastic is 2.00×10^8 m/s. What is the index of refraction of the plastic?

9. 1.52

9. The speed of light in a glass plate is 196 890 km/s. Find the index of refraction of this material.

TABLE 18-1

Indices of Refraction

Medium	n	Medium	n
vacuum	1.00	crown glass	1.52
air	1.00*	quartz	1.54
water	1.33	flint glass	1.61
ethanol	1.36	diamond	2.42

Summary

1. Light rays follow the law of reflection. This law states that the angle of reflection is equal to the angle of incidence.
2. Refraction is the bending of light rays at the boundary between two media. Refraction occurs only when the incident ray strikes the boundary of a new medium at an angle.
3. Snell's law states that when a light ray passes from air into a more optically dense medium at an angle, the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant. This ratio is given the symbol n and called the index of refraction.
4. Light waves of different frequencies are refracted by slightly different amounts. Thus, when light falls on a prism, waves of each color bend by different amounts. A spectrum of colored light is produced.

Questions

1. How does regular reflection differ from diffuse reflection?
2. If a light ray does not undergo refraction at a boundary between two media, what is its angle of incidence?
3. How does the angle of incidence compare with the angle of refraction when a light ray passes from air into glass at an angle?
4. How does the angle of incidence compare with the angle of refraction when a light ray leaves glass and enters air?
5. State Snell's law.
6. Write two equations for finding the index of refraction of a medium.
7. What is the "critical angle" of incidence?
8. Explain mirages.
9. Which travels fastest in glass: red, green, or blue light?
10. What type of spectrum is provided by sunlight?

Problems–A

1. a. 53°
b. 106°

1. A ray of light strikes a mirror at an angle of 53° to the normal.
   a. What is the angle of reflection?
   b. What is the angle between the incident ray and the reflected ray?

2. 108°

2. A ray of light incident upon a mirror makes an angle of 36.0° with the mirror. What is the angle between the incident ray and the reflected ray?

3. A ray of light is incident at an angle of 60.0° upon the surface of a piece of glass ($n = 1.5$). What is the angle of refraction? 3. 35°
4. A light ray strikes the surface of a pond at an angle of incidence of 36.0°. At what angle, to the nearest degree, is the ray refracted? 4. 26.2°
5. Light is incident at an angle of 60.0° on the surface of a diamond. Find the angle of refraction. 5. 21.0°
6. The speed of light in a clear plastic is 1.90×10^8 m/s. A ray of light enters the plastic at an angle of 22°. At what angle is the ray refracted? 6. 14°

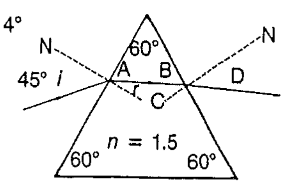


FIGURE 18-19. Use with Problem B-1.

Problems–B

1. A ray of light is incident upon a 60-60-60-degree glass prism ($n = 1.5$) as shown in Figure 18-19.
   a. Using Snell's law determine the angle r to the nearest degree.
   b. Using elementary geometry determine the value of angles A, B, and C.
   c. Angle C is actually the angle of incidence on the other side of the prism. However, the reversability of light rays tells us that if angle D were the incident angle, angle C would be the angle of refraction. Assume this statement is true and determine angle D.
2. A light source, S, is located 2.0 m below the surface of a swimming pool and 1.5 m from one edge of the pool. The pool is filled with water ($n = 1.33$) to its top.
   a. At what angle does the light reaching the edge of the pool leave the water?
   b. Does this cause the pool to appear to be deeper or less deep than it actually is? (Note: This problem illustrates the reversability of light rays. If angle r were the angle of incidence, then angle i would be the angle of refraction. Solve the problem by reversing the identity of the two angles.)

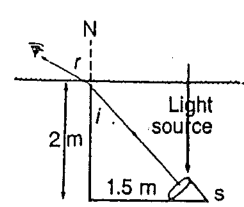


FIGURE 18-20. Use with Problem B-2.

1. a. 28°
b. 62°, 58°, 32°
c. 53°

2. a. 53°
b. It appears more shallow than it really is.

Problems C:

Needed: a compass, a metric ruler, a sharp pencil.

1. An object is 15 cm from a spherical concave mirror having a 20.0-cm radius. Locate the image by means of
   a. a ray diagram.
   b. the mirror equation.

1. a. ray diagram
b. 3.0×10^1 cm

2. Solve the Example in Section 19:5 by constructing a ray diagram. The problem states that the focal length of the mirror is 10.0 cm. Focal length is always half the radius of curvature, so the radius of the mirror is 20.0 cm. Draw to scale if necessary.

2. See Teacher's Guide.

3. An object 3.0 cm high is 10.0 cm in front of a spherical concave mirror having a 12.0-cm radius. Locate the image by means of
   a. a ray diagram.
   b. the mirror equation.
   c. What is the height of the image?

3. a. ray diagram
b. 15 cm
c. 4.5 cm

4.
b. 12 cm
c. 1.5 cm

4. An object 1.5 cm in height is 12 cm from a spherical concave mirror having a 12-cm radius. Locate the image by means of
   a. a ray diagram.
   b. the mirror equation.
   c. What is the height of the image?

5. a. ray diagram
b. 4.0 cm
c. 1.0 cm

5. An object 3.0 cm high is 12 cm from a concave mirror having a 6.0-cm radius. Locate the image by means of
   a. a ray diagram.
   b. the mirror equation.
   c. What is the height of the image?

6. 15.0 cm

6. An image of an object is 30.0 cm from a spherical concave mirror having a 20.0-cm radius. Locate the object.

7. 60.0 cm

7. An image of an object is 30.0 cm from a concave mirror having a 20.0-cm focal length. Locate the object.

8. An object is 4.0 cm in front of a spherical concave mirror of 12-cm radius. Locate the image.

8. −12 cm

9. An object is 6.0 cm in front of a concave mirror having a focal length of 10.0 cm. Where is the image?

9. −15 cm

10. A 4.0 cm high candle is 10.0 cm from a concave mirror having a focal length of 16 cm.
    a. What is the object distance?
    b. What is the height of the image of the candle?

10. a. −27 cm
b. 11 cm

11. −8.6 cm

11. An object is 20.0 cm in front of a convex mirror with a −15-cm focal length. Locate the image.

12. a. -1.0×10^1 cm
b. −1.0 cm

12. A convex mirror has a focal length of −12 cm. A light bulb with a diameter of 6.0 cm is placed 60.0 cm in front of the mirror.
    a. Locate the image of the light bulb.
    b. What is the diameter of the image?

13. −38 cm

13. In a department store a mirror used to watch for shoplifters has a focal length of −40.0 cm. A person stands in an aisle 6.0 m from the mirror. Locate the person's image.

14. −20.4 cm

14. Shiny lawn spheres placed on pedestals are convex mirrors. One such sphere has a focal length of −20.0 cm. A robin sits in a tree 10.0 m from the sphere. Locate the robin's image.

15. Use a ray diagram to find the image position of an object 30.0 cm from a convex lens with 10.0-cm focal length. (Let 1.0 cm represent 2.0 cm.)

15. ray diagram

16. An object 1.0 cm high is 15 cm from a convex lens of 10.0-cm focal length. Find the distance and size of the image
   a. using a ray diagram.
   b. mathematically.

16. b. 3.0×10^{1}, 2.0 cm

17. An object 3.0 cm high is 10.0 cm in front of a convex lens of 6.0-cm focal length. Find the image distance and height.

17. 15 cm, 4.5 cm

18. An object 1.5 cm high is 12 cm from a convex lens of 6.0-cm focal length. Find the height and position of the image
   a. using a ray diagram.
   b. mathematically.

18. b. 12 cm, 1.5 cm

19. An object 3.0 cm high is 12 cm from a convex lens of 3.0-cm focal length.
   a. Locate the image.
   b. Determine its size.

19. a. 4.0 cm
   b. 1.0 cm

20. An image is 12 cm from a convex lens of 4.0-cm focal length. Locate the object.

20. 6.0 cm

21. A camera lens having a focal length of 8.0 cm is 10.0 cm from the film. What distance from the lens should a flower be placed to obtain a sharp photograph?

21. 4.0×10^{1} cm

22. The focal length of a convex lens is 20.0 cm. A newspaper is 6.0 cm from the lens. Find the image distance.

22. −8.6 cm

23. A magnifying glass has a focal length of 12 cm. A coin, 2.0 cm in diameter, is placed 4.0 cm from the lens.
   a. Locate the image of the coin.
   b. What is the diameter of the image?

23. a. −6.0 cm
   b. 3.0 cm

24. An object is 8.0 cm from a lens. What focal length must the lens have to form a virtual, erect image 16 cm from the lens?

24. 16 cm

Summary

1. The image in a plane mirror is the same size as the object. It is as far behind the mirror as the object is in front of the mirror. The image is virtual and erect.
2. The focal point of a spherical mirror is halfway between the center of curvature of the mirror and the center of the mirror.
3. The distance from the focal point to the center of the mirror is the focal length of the mirror.
4. An imaginary radius that passes from the center of the mirror through the center of curvature and beyond is called the principal axis of the mirror.
5. All spherical mirrors have an inherent defect known as spherical aberration. Light rays that fall on the outer edges of the mirror do not pass through the focal point of the mirror.
6. Light rays do not converge to form a virtual image. A virtual image cannot be cast upon a screen. A real image is located where light rays converge and can be cast upon a screen.
7. Concave mirrors produce real, inverted images if the object is farther from the mirror than the focal point. If the object is between the focal point and the mirror, an enlarged, virtual image is formed behind the mirror.

Waves + Optics
Part 2
Key

Lesson 2 light

Curved Mirrors Assignment:

1. An object 5.0cm tall is placed 7.0cm in front of a concave mirror. If a real image is produced that is also 5.0cm tall, what is the focal length of the mirror? (3.5 cm)

$h_i = -5.0$
$h_o = 5.0$
$d_i = +7.0$
$d_o = 7.0$
$f =$

$\frac{-5.0}{5.0} = \frac{-d_i}{7.0}$ $\quad d_i = +7.0$ cm

$f^{-1} = d_i^{-1} + d_o^{-1}$
$= 7.0^{-1} + 7.0^{-1} = f = +3.5$ cm

2. An object 3.0cm tall is placed 6.0cm in front of a mirror. If a virtual image is produced that is 1.0 cm tall, what is the focal length of the mirror? What kind of mirror is used? (-3.0cm, convex)

virtual & smaller image = can only be convex mirror

$h_i = +1.0$
$h_o = 3.0$
$d_i = $ —
$d_o = 6.0$

$\frac{1.0}{3.0} = \frac{-d_i}{6.0}$

$d_i = -2.0$ cm

$f^{-1} = -2.0^{-1} + 6.0^{-1}$ $\quad f = -3.0$ cm

3. An object is 9.0 cm tall is placed at the focal point of a concave mirror. If the focal length is 5.0cm, what is the size of the image? (*no image produced*)

on focal point = no image

4. A convex mirror produced an image that is 3.0cm behind the mirror. If the focal length of this mirror is 5.0cm, at what distance from the mirror is the object placed? (7.5cm)

$d_o^{-1} = f^{-1} - d_i^{-1}$
$= -5.0^{-1} - (3.0^{-1})$ $\quad d_o = +7.5$ cm

5. An object is placed 8.0cm in front of a convex mirror that has a radius of curvature of 8.0 cm. What is the magnification of this object? (0.33)

$M = \frac{d_i}{d_o} = \frac{2.67}{8.0}$

$M = 0.33$

$d_i^{-1} = f^{-1} - d_o^{-1}$
$= -4.0 - (8.0^{-1})$
$d_i = -2.67$ cm

6. An object is placed 5.0cm in front of a concave mirror. The magnification of the object is 2.5. If a real image is produced, what is the radius of curvature of the mirror? (7.1cm)

$M = \frac{d_i}{d_o}$ $\quad 2.5 = \frac{d_i}{5.0}$ $\quad d_i = 12.5$ cm

$f^{-1} = 12.5^{-1} + 5.0^{-1}$
$f = 3.57$ cm
$C = 2f = 2(3.57) = 7.1$ cm

7. An object 4.0cm tall is placed 8.0cm in front of a concave mirror. If the real image produced is 6.0cm tall, what is the focal length of the mirror? (4.8cm)

real = $-h_i$

$h_i = -6.0$ cm

$h_o = 4.0$ cm

$d_i =$

$d_o = 8.0$ cm

$f = ?$

$\frac{-6.0}{4.0} = \frac{-d_i}{8.0}$

$d_i = 12.0$ cm

$f^{-1} = 12.0^{-1} + 8.0^{-1}$

$= 4.8$ cm

8. An object 3.0cm tall produces a virtual image that is 2.0cm tall. If the image is 2.5cm behind the mirror, what is the focal length of the mirror? What kind of mirror is used? (-7.5cm, convex)

$-d_i$

virtual & smaller = convex

$h_i = 2.0$ cm

$h_o = 3.0$ cm

$d_i = -2.5$ cm

$d_o =$ —

$f = ?$

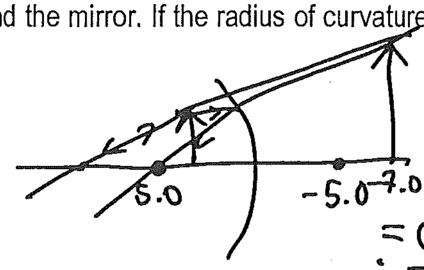
$\frac{2.0}{3.0} = \frac{-(-2.5)}{d_o}$

$d_o = 3.75$ cm

$f^{-1} = 3.75^{-1} + (-2.5^{-1})$

$f = -7.5$ cm

9. An object 5.0 cm tall produces an image that is 7.0cm behind the mirror. If the radius of curvature of this mirror is 10.0cm, what is the magnification



only option

= concave inside f.

$d_o^{-1} = f^{-1} - d_i^{-1}$

$= 5.0^{-1} - (-7.0^{-1})$

$d_o = 2.92$ cm

$M = \frac{d_i}{d_o} = \frac{7.0}{2.92}$

$M = 2.4$

10. When an object 4.0 cm tall is placed 7.0 cm in front of a mirror, the image is 6.0 cm tall and virtual.

a) What type of mirror is used? How do you know?(concave) virtual & larger = concave inside f

b) Find the focal length and radius of curvature of the mirror. (21 cm, 42 cm)

$\frac{h_i}{h_o} = \frac{-d_i}{d_o}$ $\frac{+6.0}{4.0} = \frac{-d_i}{7.0}$

$d_i = -10.5$ cm

$f^{-1} = -10.5^{-1} + 7.0^{-1}$

$f = 21$ cm

$C = 2(21) = 42$ cm

11. A convex mirror is used to monitor the aisles in a store. The mirror has a radius of curvature of 4.0 m, and a 1.5 m tall customer is standing 12 m in front of the mirror.

a) Locate the image of the customer. (-1.7m)

b) How tall is the image? (+0.21 m)

c) Is the image real or virtual? Explain. (virtual)

d) Is the image erect or inverted? Explain. (erect)

a) $d_i^{-1} = f^{-1} - d_o^{-1}$

$= -2.0^{-1} - 12^{-1}$

$d_i = -1.7\ m$

b) $\frac{h_i}{1.5} = -\frac{(-1.7)}{12}$

$h_i = +0.21\ m$

c) virtual → $+h_i$, $-d_i$

d) erect → $+h_i$

12. A man is using a mirror to shave his chin. When he stands 1.48 m in front of the mirror, the inverted image of his chin is produced 32 cm in front of the mirror. Determine the radius of curvature of the mirror. (0.526 m)

$f^{-1} = 1.48^{-1} + 0.32^{-1}$

$f = 0.263\ m$

$C = 0.526\ m$

13. An object 5.0 cm tall produces an image that is 2.5 cm behind the mirror. If the radius of curvature of this mirror is 12.0 cm, what is the magnification of the object? What kind of mirror is used? (0.58 times, convex mirror)

$d_o^{-1} = -6.0^{-1} - (-2.5^{-1})$

$d_o = 4.29\ cm$

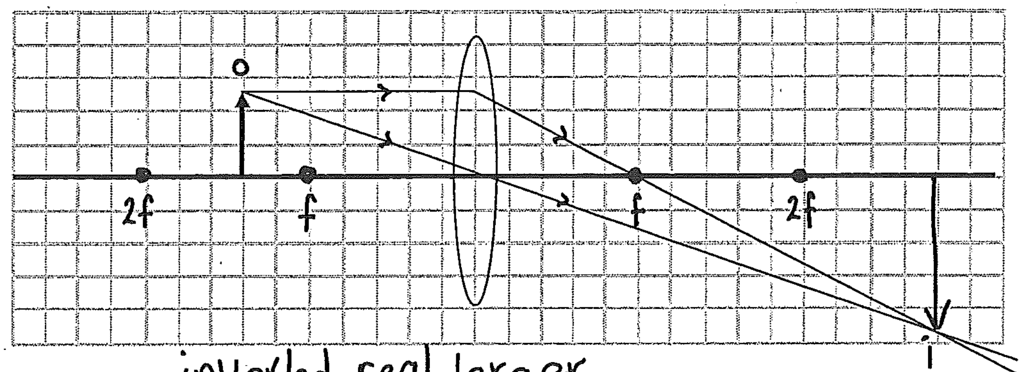
$M = \frac{d_i}{d_o} = \frac{2.5}{4.29} = 0.58$ times

must be convex → virtual image produced inside virtual f.

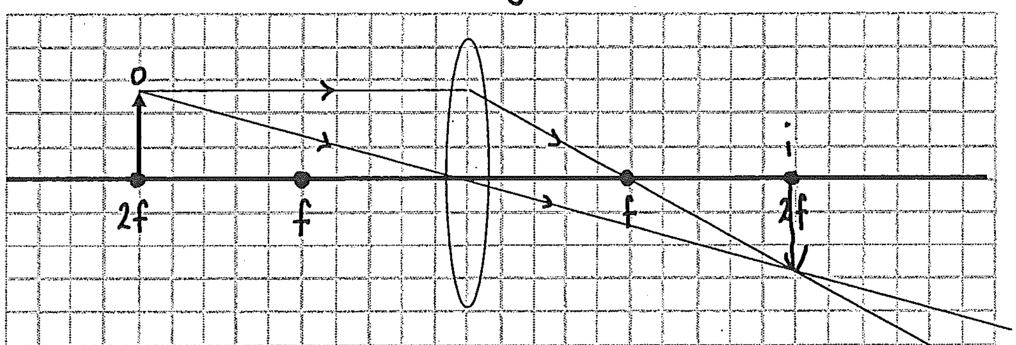
Refraction through Lenses Problems: Lesson 5 (answers) light.

Complete the following ray diagrams and state the characteristics of the images.

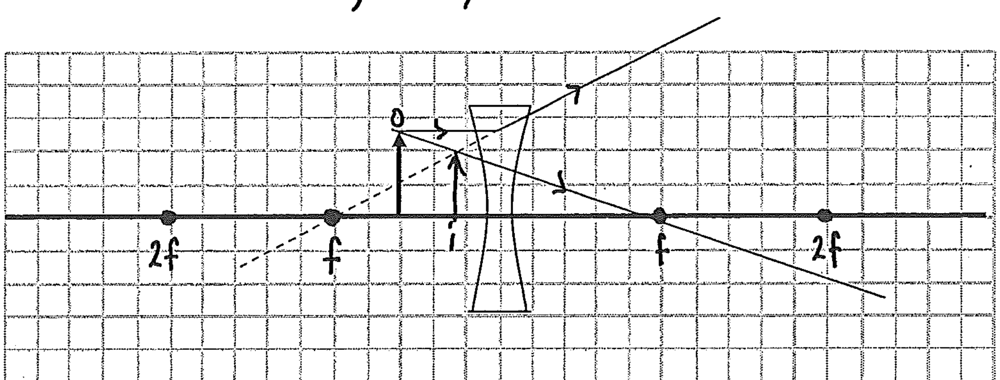
1.



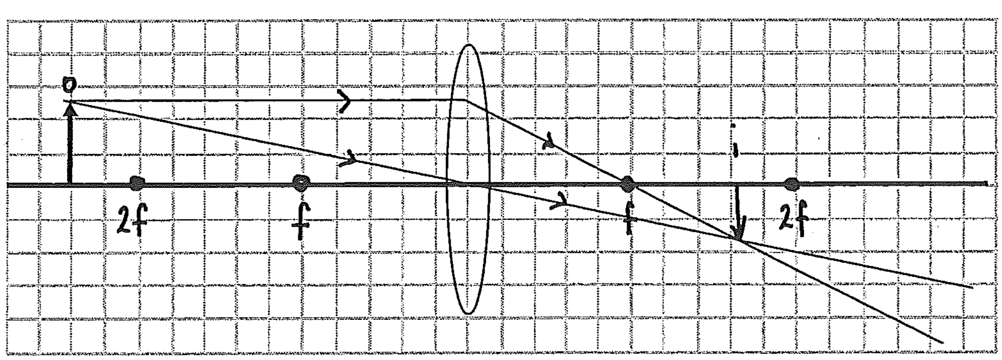
Characteristics: inverted, real, larger



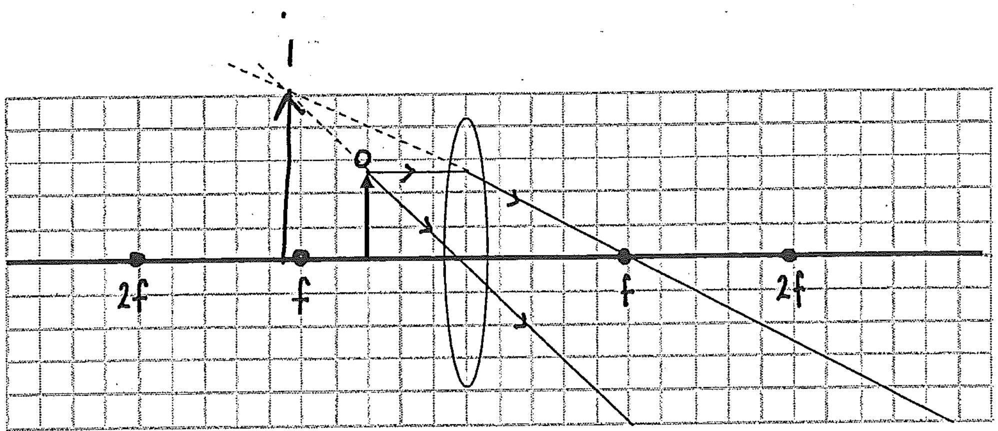
Characteristics: inverted, real, same size



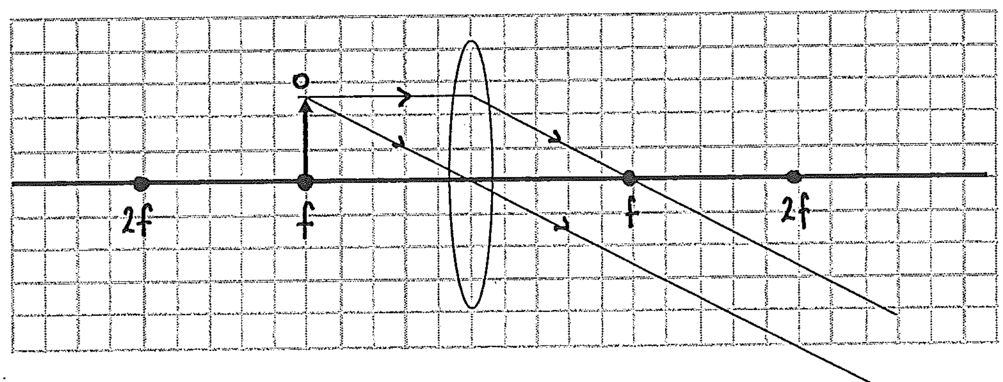
Characteristics: erect, virtual, smaller



Characteristics: inverted, real, smaller



Characteristics: erect, virtual, larger



Characteristics: no image

2. A glowing object 6.0 cm tall is placed 9.0 cm from a convex lens. If the lens has a focal length of 8.0 cm, what is:

+f

a) the distance of the image from the lens? (+72 cm)

b) the height of the image? (-48 cm)

c) the characteristics of the image?

$h_i =$
$h_o = 6.0$
$d_i =$
$d_o = 9.0$
$f = +8.0$

$d_i^{-1} = f^{-1} - d_o^{-1}$
$= 8.0^{-1} - 9.0^{-1}$

$d_i = +72\ cm$ ← real

$\frac{h_i}{6.0} = \frac{-(72)}{9.0}$

$h_i = -48 cm$ ← inverted

$h_i > h_o$ ← larger

3. A glowing object 5.0 cm tall is placed 4.5 cm from a concave lens. If the lens has a focal length of 4.5 cm, what is:

−f

a) the distance of the image from the lens? (-2.3 cm)

b) the size of the image? (+2.5 cm)

c) the characteristics of the image?

$d_i^{-1} = f^{-1} - d_o^{-1}$
$= -4.5^{-1} - 4.5^{-1}$

$d_i = -2.25\ cm$ ← virtual

$\frac{h_i}{5.0} = \frac{-(-2.25)}{4.5}$

$h_i = +2.5\ cm$ ← erect

$h_i < h_o$ ← smaller

4. A glowing object 3.0 cm tall is placed 6.0 cm from the concave (−f) lens. If a virtual image is produced that is 1.0 cm tall, what is the focal length of the lens? (-3.0 cm)

$h_i = 1.0$
$h_o = 3.0$
$d_i =$
$d_o = 6.0$
$f =$

$\frac{1.0}{3.0} = -\frac{d_i}{6.0}$ $d_i = -2.0$ cm

$f^{-1} = d_i^{-1} + d_o^{-1} = -2.0^{-1} + 6.0^{-1}$ $f = -3.0$ cm

5. A glowing object 2.0 cm tall is placed 5.0 cm from a lens. If a virtual image is produced that is 4.0 cm tall, what is the focal length of the lens? What kind of lens is used? (10 cm) virtual + $h_i > h_o$ = convex

$h_i = 4.0$
$h_o = 2.0$
$d_i =$
$d_o = 5.0$
$f =$

$\frac{4.0}{2.0} = -\frac{d_i}{5.0}$ $d_i = -10.0$ cm

$f^{-1} = -10.0^{-1} + 5.0^{-1}$
$= -3.0$ cm ; convex lens

6. A glowing object 8.0 cm tall is placed 11.0 cm in front of a convex lens. If the focal length is 5.5 cm, what is the magnification of the object? (1.0X)

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

$h_i =$
$h_o = 8.0$
$d_i =$
$d_o = 11.0$
$f = +5.5$

$d_i^{-1} = 5.5^{-1} - 11.0^{-1}$ $d_i = +11.0$ cm

$M = \frac{d_i}{d_o} = \frac{11.0}{11.0} = 1.0$x

7. A concave lens produces an image that is 2.5 cm from the lens. If the focal length of this lens is 6.0 cm, at what distance from the lens is the object? (4.3 cm) ↖ −2.5 cm ↖ −6.0 cm

$d_i = -2.5$ cm
$d_o = ?$
$f = -6.0$ cm

$d_o^{-1} = -6.0^{-1} - 2.5^{-1}$

$d_o = 4.3$ cm

8. A glowing object is 8.0 cm from a concave lens that has a focal length of 4.0 cm. What is the magnification of this object? (0.33X) ↖ −4.0 cm

$M = \frac{d_i}{d_o}$

$d_i = ?$
$d_o = 8.0$
$f = -4.0$

$d_i^{-1} = -4.0^{-1} - 8.0^{-1}$ $d_i = -2.67$

$M = \frac{d_i}{d_o} = \frac{2.67}{8.0} = 0.33$X

9. A glowing object is 7.0 cm from a convex lens. If a real image is produced that is 2.0 X larger than the object, what is the focal length of the lens? (+4.7 cm)

$M = \frac{h_i}{h_o}$ or $M = \frac{d_i}{d_o}$ $2.0 = \frac{d_i}{7.0}$ $d_i = 14.0$ cm

$f^{-1} = 14.0^{-1} + 7.0^{-1}$ $f = +4.7$ cm

10. A glowing object 4.0 cm tall is 9.0 cm from a convex lens. If the real image produced is 6.0 cm tall, what is the focal length of the lens? (+5.4 cm)

↖ always inverted = −6.0

$h_i = -6.0$
$h_o = 4.0$
$d_i =$
$d_o = 9.0$
$f =$

$\frac{-6.0}{4.0} = \frac{-d_i}{9.0}$ $d_i = 13.5\text{ cm}$

$f^{-1} = 13.5^{-1} + 9.0^{-1}$ $f = +5.4\text{ cm}$

11. A glowing object 3.0 cm tall is 7.0 cm from a convex lens. If the virtual image produced is 6.0 cm tall, what is the focal length of the lens? (14 cm)

→ +6.0 cm

$h_i = +6.0$
$h_o = 3.0$
$d_i =$
$d_o = 7.0$
$f =$

$\frac{6.0}{3.0} = \frac{-d_i}{7.0}$ $d_i = -14\text{ cm}$

$f = -14^{-1} + 7.0^{-1}$

$f = +14\text{ cm}$

12. A glowing object 3.0 cm tall produces a virtual image 2.0 cm tall. If the image is 3.0 cm from the lens, what is the focal length of the lens? What kind of lens is used? (-9.0 cm)

$h_i < h_o$ & virtual = concave only

$h_i = +2.0$
$h_o = 3.0$
$d_i = -3.0$
$d_o =$
$f = ?$

$\frac{2.0}{3.0} = \frac{-(-3.0)}{d_o}$ $d_o = 4.5\text{ cm}$

$f^{-1} = 4.5^{-1} + -3.0^{-1}$ $f = -9.0\text{ cm}$

Critical Angle Problems: Lesson 6 (light)

1. What is the critical angle for an air-glass interface if the index of refraction of glass is 1.50? (41.8°)

glass (high) ↓ air (low)

$$\frac{\sin\angle i}{\sin\angle R} = \frac{n_a}{n_g} \qquad \frac{\sin\angle i}{\sin 90} = \frac{1.00}{1.50}$$

$$\sin^{-1}(0.667) = 41.8°$$

2. What is the critical angle for a water-Lucite interface if the index of refraction of water is 1.33 and of Lucite is 1.51? (61.8°)

Lucite ↓ water

$$\frac{\sin\angle i}{\sin 90} = \frac{1.33}{1.51} \qquad \sin^{-1}(0.881) = 61.8°$$

3. The critical angle for a certain liquid-air interface is 48.8°. What is the index of refraction of the liquid? (1.33)

liquid ↓ air

$$\frac{\sin 48.8}{\sin 90} = \frac{1.00}{n_L} \qquad n_L = 1.33$$

4. What is the critical angle of a substance whose index of refraction is 1.81? (33.5°)

substance ↓ air

$$\frac{\sin\angle i}{\sin 90} = \frac{1.00}{1.81} \qquad \sin^{-1}(0.552) = 33.5°$$

5. What is the index of refraction of a substance whose critical angle is 42.0°? (1.49)

substance ↓ air

$$\frac{\sin 42.0}{\sin 90} = \frac{1.00}{n_s} \qquad n_s = 1.49$$

6. The speed of light in a clear liquid is 0.75c. What is the critical angle of the liquid? (49°)

liquid ↓ air

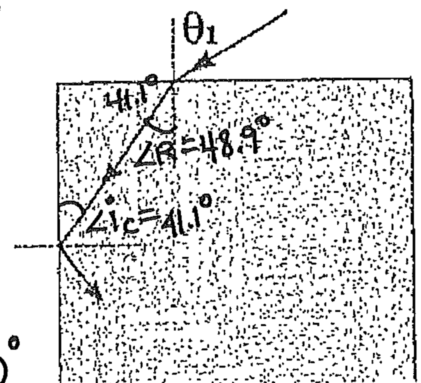
$$\frac{\sin\angle i}{\sin\angle R} = \frac{V_L}{V_a} \qquad \frac{\sin\angle i}{\sin 90} = \frac{0.75(3.0\times10^8)}{3.0\times10^8}$$

$$\sin^{-1}(0.75) = 49°$$

7. A laser beam strikes the top surface of a block of glass at an angle θ_1 and the refracted beam undergoes total internal reflection at the left vertical surface of the block as shown in the diagram. The index of refraction of the glass is 1.52.

a) glass (1.52) ↓ air (1.00) $\sin\theta_c = \frac{1.00}{1.52}$ $\angle i_c = 41.1°$

air ↓ glass $\frac{\sin\theta_1}{\sin 48.9} = \frac{1.52}{1.00}$ $\theta_1 = \sin^{-1}(1.15)$ ← not possible so $\theta_1 \leq 90°$ and there is no refraction



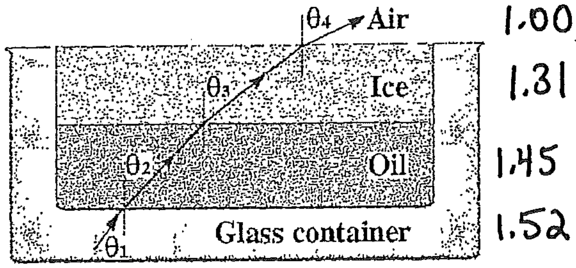
a) If the block is surrounded by air, find the maximum value of θ_1.

b) If the block is surrounded by water (n=1.33), find the maximum value of θ_1.

b) glass (1.52) ↓ water (1.33) $\sin\theta_c = \frac{1.33}{1.52}$ $\theta_c = 61°$ $\angle R = 29°$

water (1.33) ↓ glass (1.52) $\frac{\sin\theta_1}{\sin 29} = \frac{1.52}{1.33}$ $\theta_1 \leq 34°$

8. In the following diagram, the index of refraction for ice is 1.31 and the index of refraction for oil is 1.45.



a) If the angle θ_1 of the incident ray is 36°, find the angle θ_4 of the emergent ray.

b) If total internal reflection occurs at the interface between the ice and air, find the critical angle of the incident ray.

a) glass (1.52) ↓ oil (1.45) $\frac{\sin 36}{\sin \angle R} = \frac{1.45}{1.52}$ $\theta_2 = 38°$

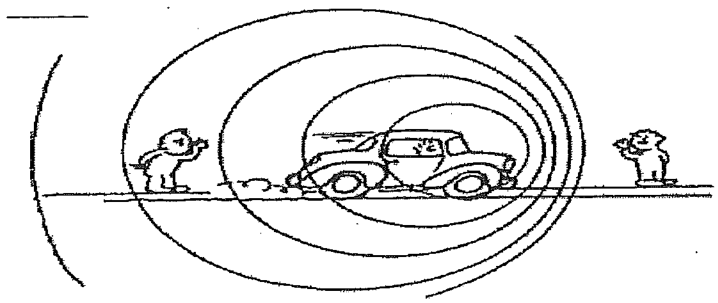
oil (1.45) ↓ ice (1.31) $\frac{\sin 38}{\sin \angle R} = \frac{1.31}{1.45}$ $\theta_3 = 43°$

ice (1.31) ↓ air (1.00) $\frac{\sin 43}{\sin \angle R} = \frac{1.00}{1.31}$ $\theta_4 = 63°$

b) $\sin\theta_c = \frac{1.00}{1.31}$ $\theta_c = 50°$

Lesson 8 light

Physics 11 - Wave Effects Assignment NAME:



1. When an automobile moves towards a listener, the sound of its horn seems relatively
   a. Low pitched b. High Pitched c. Normal

2. When the automobile moves away from the listener, its horn seems
   a. Low pitched b. High Pitched c. Normal

3. The changed pitch of the Doppler effect is due to changes in
   a. Wave speed b. wave frequency

4. What color of visible light does the atmosphere scatter the most?

   violet

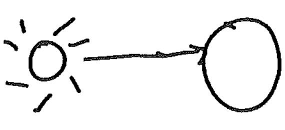
5. What color of visible light does the atmosphere scatter the least?

   red

6. Using Rayleigh scattering, explain why the sky is blue..

   light at the blue end of the spectrum is scattered in all directions by small particles in the atmosphere = our eyes see this blue scattered light

7. Using Rayleigh scattering, explain why the sun at sunset is reddish. Include a diagram.

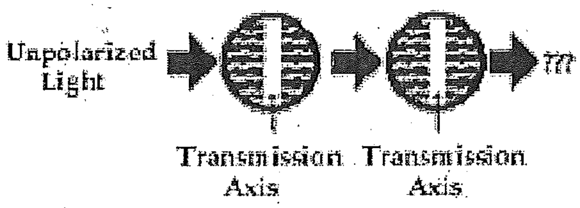


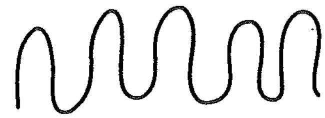
   blue light has already been scattered out due to longer distance that light has to travel = leaves red end of light spectrum.

8. When a light wave vibrates in a variety of directions, the light is said to be ____.
   a. transverse b. polarized c. unpolarized

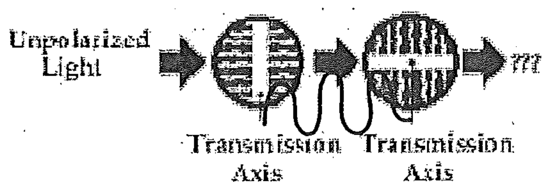
9. When a light wave's are isolated to a single plane, the light is said to be ____.
   a. transverse b. polarized c. unpolarized

10. Describe the result of shining light through two polarizing filters whose transmission axes are parallel to each other.





11. Describe the result of shining light through two polarizing filters whose transmission axes are perpendicular to each other.



blocked = no light

12. Carson Busses is driving down the road on a sunny day. Reflection of light off the road surface results in a large amount of polarization and a subsequent glare. Annoyed by the glare, Carson pulls out his Polaroid sunglasses. How must the axes of polarization be oriented in order to block the glare? (Note: the lines on the filters below represent the axis of polarization.)

20. When light passes from air to water, the light slows down. This means that it bends toward the normal, ruling out D and C. A cannot be the answer because the ray must cross the normal.

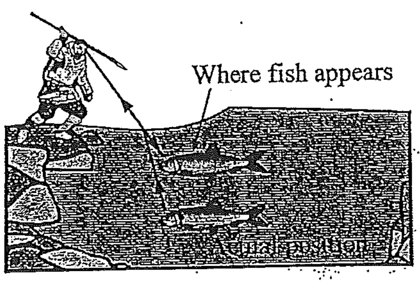
B is the answer.

21. Three images are produced.

C is the answer.

22. The frequency does not change during refraction. Therefore, the frequency in the glass is the same as it is in air.

23.



Due to refraction, the fish will appear to be higher than it actually is. Therefore, you must aim below.

A is the answer.

24. Total reflection only occurs when the light passes from a substance that has a high index to a substance that has a lower index at an angle greater than the critical angle.

C is the answer.

25. When the object is between the focal point and the convex lens, the image is virtual, larger and erect.

26. A concave lens always produces an image that is virtual, erect and smaller.

27. When the incident ray is parallel to the principal axis of a convex lens, the ray refracts through the focal point.

D is the answer.

28. When the incident ray is parallel to the principal axis of a concave lens, the ray refracts as if it came from the focal point.

A is the answer.

29. When the object is placed at $2f$ of a convex lens, the image produced is real, inverted and the same size. Therefore the magnification $\left(\frac{h_i}{h_o}\right)$ is 1.

B is the answer.

Practice Test

ANSWERS AND SOLUTIONS

1. Interference and diffraction are fundamental properties of waves.

D is the answer.

2. When points are in phase, they move up and down together. When A is moving up, B and D are moving down. B and D are not in phase with A.

C is the answer.

3. Diffraction depends on the wavelength and the size of the opening.

4. $v = \lambda f$ and $f = \frac{1}{T}$

$\therefore v = \frac{\lambda}{T}$

B is the answer.

5. The apparent change in frequency due to the motion of the source and/or observer is called the Doppler Effect.

C is the answer.

6. $v = \lambda f$

$$f = \frac{v}{\lambda} = \frac{10.0 \text{ cm/s}}{2.0 \text{ cm}} = 5.0 \text{ Hz}$$

B is the answer.

7. Longitudinal waves are waves in which the medium is vibrating parallel to the energy flow.

Transverse waves are waves in which the medium is vibrating perpendicular to the energy flow.

8. When light travels from one medium to another, the light refracts. This means that the light changes direction. It changes direction because the speed changes, and when the speed changes, the wavelength also changes.

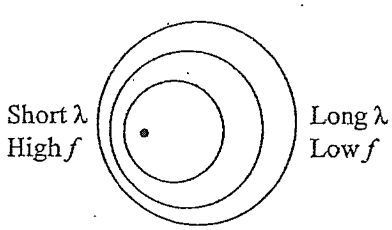
9. Only transverse waves can be polarized.

B is the answer.

10. Mechanical waves cannot travel through a vacuum, but electromagnetic waves can.

11. The superposition principle states that when waves overlap a new wave is formed that is the result of the algebraic sum of the amplitudes of the two overlapping waves. When waves meet in phase (crest to crest or trough to trough), a maxima will result due to constructive interference. When waves meet 180 degrees out of phase (crest to trough or trough to crest), destructive interference occurs resulting in a minima.

12.



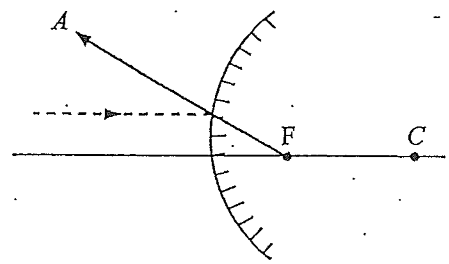
The frequency will be lowest when the police car is at position A. When the sound source is approaching you, you are in the region of high frequency. In the same way, if the sound source is moving away from you, you are in the region of low frequency. Position A is the answer.

13. Plane mirrors always produce images that are erect, virtual and laterally inverted.

14. Convex mirrors always produce images that are erect, smaller, and virtual.

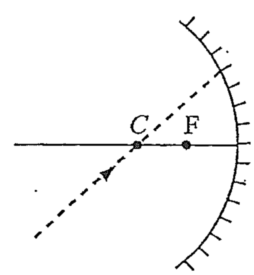
15. When the object is between the centre of curvature and the focal point of a concave mirror, the image is inverted, larger, and real.

16. If the incident ray is parallel to the principal axis of a convex mirror, the ray will reflect as if it came from the focal point.



A is the answer.

17. If the incident ray passes through the centre of curvature of a concave mirror, it will reflect straight back along the same path.



D is the answer.

18. The image produced by a plane mirror is virtual, erect and the same size.

B is the answer.

19. A diverging mirror is a convex mirror, and the image produced by a convex mirror is always erect, smaller and virtual. Therefore the magnification $\left(\frac{h_i}{h_o}\right)$ is less than 1.

C is the answer.