MIRRORS AND LENSES

Lenses refract (bend) light rays.
Mirrors reflect (bounce back) light rays.

- An arrow called a ray can represent the path and direction of the light wave.
- These rays are used to show the light after it is reflected or refracted; it shows the change of direction.

OBJECTS AND IMAGES

The image seen depends on the light rays entering the eye. What the brain thinks it sees compared to the actual object can change in the following way:

**SIZE:** same, bigger or smaller

**ORIENTATION:** upright, upside down (inverted), or flipped horizontally (left to right)

**IMAGE:** real (light goes through image) or virtual (light does not go through image)

VIRTUAL IMAGE

Virtual images are images that are formed in locations where light does not actually reach.
Real images are images that are formed in locations where light does reach.

**How an Image Is Developed**

- Images that our brains perceive depend on how the light enters our eyes.
- We develop diagrams to show what happens to light rays that are reflected or refracted.
- We need at least two rays bouncing off the object, one at the top and one at the bottom, to visually define the object.

**Mirrors**

- **Mirror** - an opaque surface that forms an image by reflecting light. The image formed is reversed from left to right.
- Classified by shape
  - **Plane** – a flat surface
  - **Concave** – curves inward
  - **Convex** – curves outward
Reflection Off a Plane Mirror

Light rays bounce off the boy and hit the mirror.

Rays are reflected off the mirror into his eyes.

Image is SAME SIZE UPRIGHT REVERSED LEFT TO RIGHT VIRTUAL IMAGE

The brain sees the object as though it is behind the mirror.

PLANE MIRRORS

Concave Mirrors

- Mirrors that are **curved inward**
- Able to form **virtual or real images** depending where the object is in relation to the focal point.
- If the object is placed at the focal point, **NO IMAGE IS FORMED**
**Concave Mirror**  
(mirror ‘caves in’)

Optical axis goes through the center of mirror.
Light rays travel parallel to the optical axis.
Light rays reflect off the mirror back through the focal point (●).

**Concave Mirror – Ray Diagrams**

**OBJECT BEYOND FOCAL POINT**

1. Draw a ray from the top of the object parallel to the optical axis.
2. Reflect this ray through the focal point.
3. Draw a ray from the top of the object through the focal point.
4. Reflect this ray parallel to the optical axis.
5. The position of the top of the inverted image is located where the rays intersect.
6. The position of the bottom of the inverted image is on the optical axis.

Image is **ENLARGED**, **INVERTED**, **REAL**

When the focal point is between the object and the mirror, the image that forms:
- will always be inverted (upside down)
- will always be real
- will be magnified less the farther the object is from the focal point
Concave Mirror – Ray Diagrams

OBJECT IN FRONT OF FOCAL POINT

1. Draw a ray from the top of the object parallel to the optical axis.
2. Reflect this ray through the focal point.
3. Draw the virtual light ray (dashed line behind the mirror) of the reflected ray.
4. Draw a ray from the focal point past the top of the object.
5. Reflect this ray parallel to the optical axis.
6. Draw the virtual light ray (dashed line behind the mirror) of the reflected ray.
7. The position of the top of the image is located where the rays intersect.
8. The position of the bottom of the image is on the optical axis.

Image is: UPRIGHT, ENLARGED, VIRTUAL

Concave Mirrors

When the object is between the focal point and the mirror, the image formed:

- will always be upright
- will always be magnified
- will always be virtual

Uses of Concave Mirrors

JVC developed a new optical projection system that uses a concave lens. Using this lens enabled them to create a larger screen in a slimmer unit. Both the old and new design use a reflective mirror to form the final image.

A fellow in Michigan (Michael Lockwood) built his own telescope using his knowledge of optics with mirrors. Pretty cool!
CONVEX MIRRORS

• A mirror that curves outward
• All images formed are VIRTUAL and UPRIGHT and SMALLER than the original

CONVEX MIRRORS (bows out)
Focal point is behind mirror
Virtual rays extend back through the focal point
Focal distance depends on curvature of mirror

Convex Mirrors – Ray Diagrams

1. Draw two rays traveling towards the mirror from the top of the object. One should be parallel to the optic axis and the other should be headed towards the focal point.
2. Draw a virtual light ray from the first ray to the focal point.
3. Now extend the virtual ray past the mirror (solid line) to show the reflected ray.
4. Draw a virtual light ray from the 2nd ray parallel to the optic axis.
5. Now extend this virtual ray past the mirror (solid line) to show the reflected ray.
6. The position of the top of the object will be where the two virtual light rays intersect.
7. The position of the bottom of the image is on the optic axis.
Uses for Convex Mirrors

Convex mirrors are often used to maximize the vision or view. Both side view and security mirrors use convex lenses.

Lenses

**Lens** - a curved, transparent object that forms an image by refracting, or bending light

**Classified by shape**

- **Convex** - thicker in the middle than at the edges
- **Concave** - thinner in the middle than at the edges

Convex Lenses

- Light is refracted towards the center (converges)
- Light rays enter parallel to axis and are refracted so that they go through the focal point
  - Amount of refraction and focal length depends on the thickness of the lens
  - Light rays passing through the center of a lens are not refracted
- Can form **REAL AND VIRTUAL** images depending on the focal length and placement of the object
More Than Two Focal Lengths

Two rays reflected from the top of the object determine where the top of the image will be located.

1. Draw a ray from the top of the object to the middle of the lens.
2. Now draw a ray from the middle of the lens to the focal point on opposite side.
3. Draw a ray from the top of the object through the optical axis.
4. The optical axis serves as the ray that reflects off the bottom of the object and the intersection of ray 2 & 3 are where the top of the image is located.

Image is INVERTED SMALLER REAL

A camera focuses the smaller, real image on the film.

A convex lens in your eye focuses light on the back surface of your eye called the retina.

Between One and Two Focal Lengths

Two rays reflected from the top of the object determine where the top of the image will be located.

1. Draw a ray from the top of the object to the middle of the lens.
2. Now draw a ray from the middle of the lens to the focal point on opposite side.
3. Draw a ray from the top of the object through the optical axis.
4. The optical axis serves as the ray that reflects off the bottom of the object and the intersection of ray 2 & 3 are where the top of the image is located.

Image is INVERTED LARGER REAL
Use for this convex lens?

A movie projector focuses the enlarged image on a movie screen.

Less Than One Focal Length

Two rays reflected from the top of the object determine where the top of the image will be located.

1. Draw a ray from the top of the object to the middle of the lens.
2. Now draw a ray from the middle of the lens to the focal point.
3. Draw a ray from the top of the object through the optical axis.
4. Draw a dotted line from ray 2 and ray 3.
5. The optical axis serves as the ray that reflects off the bottom of the object.

Image is UPRIGHT ENLARGED VIRTUAL

Use for this convex lens??

A magnifying glass shows an enlarged, or magnified, virtual image.
Concave Lenses

- Light is refracted outward (diverges)
- Light rays enter parallel to axis and are refracted so that they bend towards the edges. They will NEVER meet.
  - Light rays passing through the center of a lens are not refracted
- Can only form VIRTUAL, SMALLER, ERECT (Upright) images

Concave Lens – Ray Diagram

1. Draw a ray from the top of the object parallel to the optical axis.
2. Refract this ray so that its virtual ray will go through the focal point.
3. Draw the virtual light ray.
4. Draw a ray from the top of the object through the center of the lens.
5. Where the virtual ray and the 2nd incident ray intersect is the top of the image.
6. The bottom of the image is on the optic axis.

Uses for Concave Lenses

The Galilean telescope uses a combination of convex and concave lenses. The concave lens is used to diverge the light rays coming from the convex lens so they may be focused by the next convex lens. It is used to see very small objects.

Concave lenses are used in the glasses for a person who is nearsighted or cannot see distant objects.