

Reflection and Refraction

Reflection

- Light -
 - Moves in
 - Velocity is
- Law of Reflection -
-
- Regular Reflection
 - reflection from a
 - Parallel incident rays will reflect
- Diffuse Reflection
 - Surface is
 - Parallel incident rays will be reflected

Refraction of Light

- Light appears to bend because there is a
- Refraction only happens when the
 - When the incident angle is equal to zero
 - Then, incident ray =
 - The light changes speed, but
- Optically Dense - medium that slows down the light.
- ***Light entering an Optically dense medium***
 - Angle incidence $>$
 - Speed of light
 - Light bends
 - Draw a ray diagram!
- ***Light entering Optically less dense medium***
 - Angle of incidence $<$
 - Speed of light
 - Light bends
 - Draw a ray diagram!

- Snell's Law
 - A ray of light bends so that the ratio of the sine of the angle of incidence to the
 - $n =$ index of
 -
 - n is a
 - $n = 1.00$ for a
 - If the light is going from a vacuum into a medium:
 -

- You can calculate the speed of light in different medium.
 - $c = 3.00 \times 10^8$ m/s

- 1. A ray of light strikes a plane mirror at an angle of incidence of 28° . What is the angle of reflection?

- 2. A ray of light passes from an unknown substance into air. If the angle in the unknown substance is 35° and the angle in air is 52.0° , what is the index of refraction of the unknown substance?

- 3. A ray of light has an angle of incidence of 25.0° upon the surface of a piece of quartz. What is the angle of refraction?

Applications of Reflected and Refracted Light

Total Internal Reflection

- Light that goes from an optically dense to a less optically dense is
 - Light
 - If the incident angle is very large, the light is
- Critical Angle - angle of incidence that causes
- $n_i \sin$
- if $n_r =$
- \sin
- If the $n_i > 1.00$ then the light is internally
- Total internal reflection occurs when the angle of incidence is
 -
- If the incident angle is equal to the critical angle, the light is
- Sometimes when you are underwater and look up at an angle that is greater than the
- Used in
 - Laser light enters a long thin glass fiber and is kept in by
 - Used in

Effects of Reflection and Refraction

- Mirages
 - Caused by hot air rising and cooling and the
- Extended Daylight
 - Speed of light decreases in the Earth's dense atmosphere and is refracted. So we "see"
- Dispersion
 - separation of light into
 - $c =$
 - Speed of light is slower in
 - Speed of light changes, and is refracted differently, depending on the
 - Index of refraction, n , depends on the optically density of the
 - Gives gems the
- White light enters a prism, it is refracted and
 - Red Light -

- Violet Light -
 - Rainbows
 - Rainbow is caused by
 - White light enters the droplet, is
9. George finds that a plastic has a critical angle of 40.0° . What is the index of refraction of the plastic?
10. Kathy decides to find the critical angle of arsenic trioxide, $n = 2.01$, which is very toxic. What angle did Kathy find?
11. A light source is in a cylindrical container of carbon dichloride, $n = 1.500$. The light source sends a ray of light parallel to the bottom of the container at a 45.0° angle from the radius to the circumference. What will the path of the light ray be?
12. 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° .

Mirrors (Reflect!)

Mirror Terms

- **Real Image** - can be projected onto a screen. For mirrors, the
- **Virtual Image** - cannot be projected onto a screen, the
- **Focal Point** - F , a point where light rays
- **Focal Length** - f , distance from the focal point to the
- **Principal Axis** - imaginary line that runs through the
- **Center of Curvature** - C , the "center" of the sphere if a curved mirror would extend into a sphere. Often called

$$C = 2F \text{ or } F =$$

- d_o - distance of the
- d_i - distance of the
- h_o -
- h_i -
- m - magnification of the image, how

Plane Mirror

- Flat, smooth,
- Creates a **virtual image** -
- Image appears to be the **same**
- Image is the
- Image is
- Most common use -

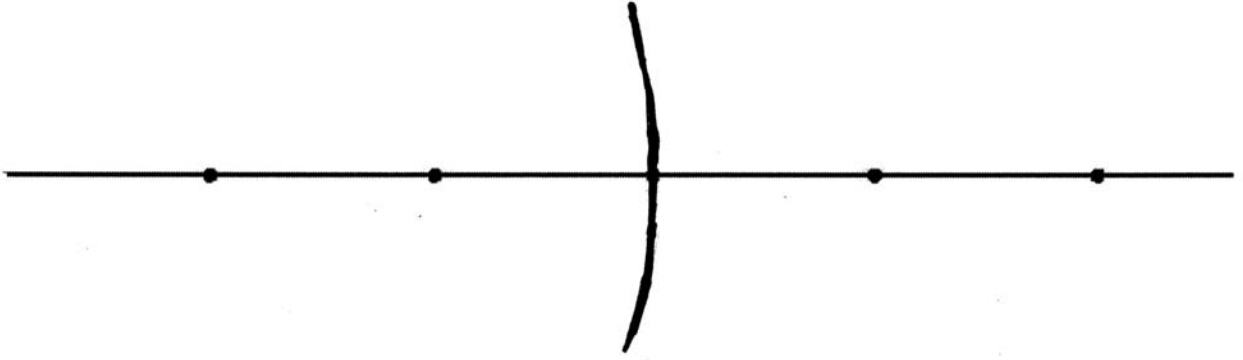
Drawing Ray Diagrams for Mirrors

- Draw a ray, from the **top** of the object, **parallel** to the principal axis to the mirror then
- Draw a ray, from the **top** of the object, through the **focal point** to the mirror, then
- If the reflected rays do not meet (they diverge), extend the
- The **top of the image** is located where the rays

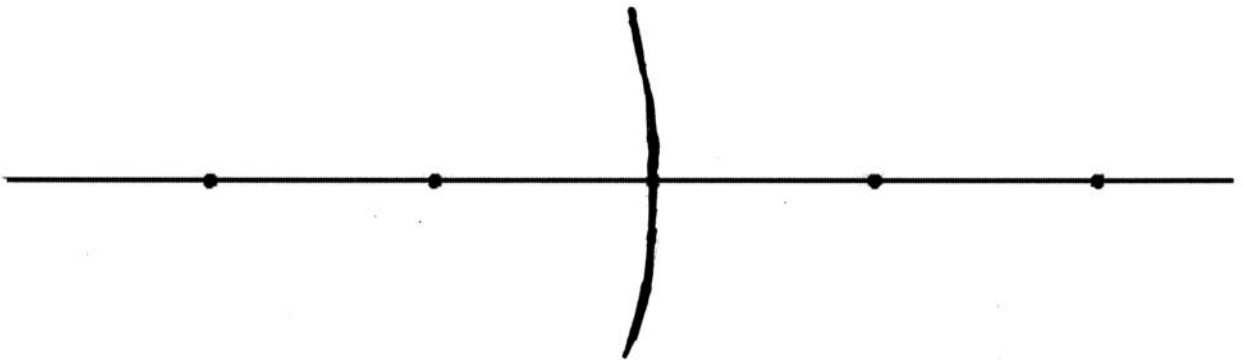
Concave Mirror

- Curved-inward, the
- Called a converging mirror, the light usually

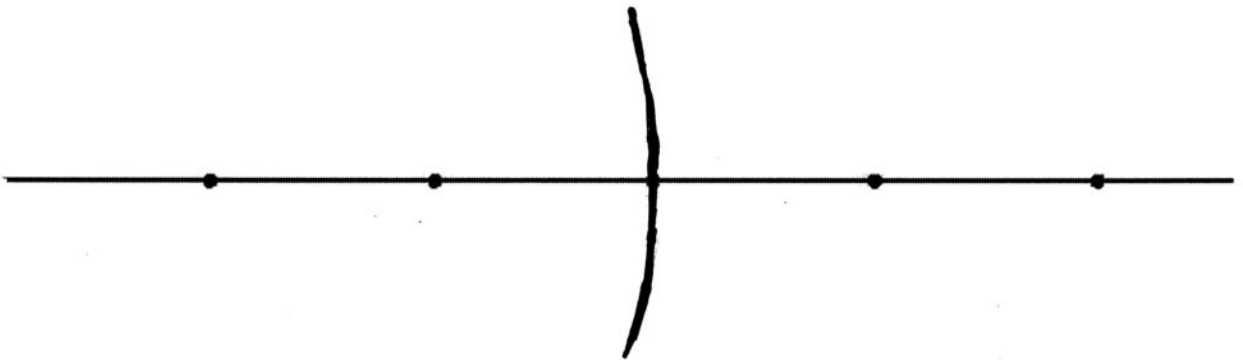
- The type of image formed depends on the



- Object is farther than C (or $2F$)

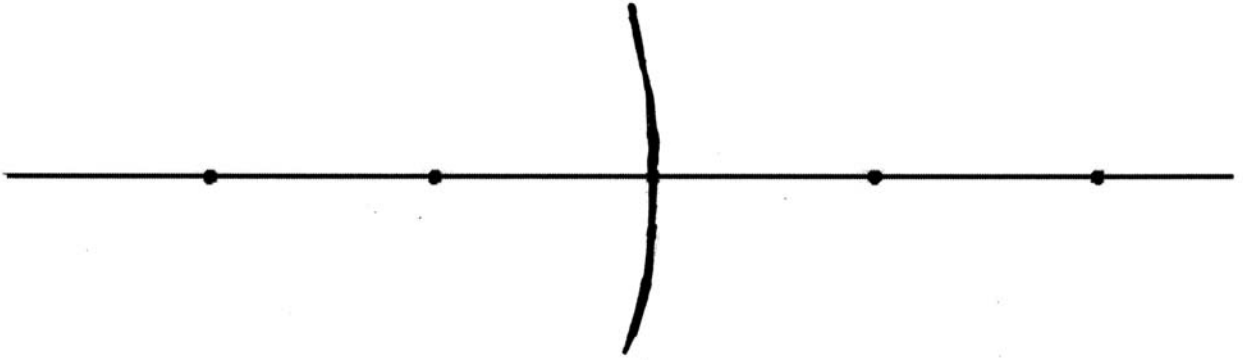


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-
- Object is between C and F

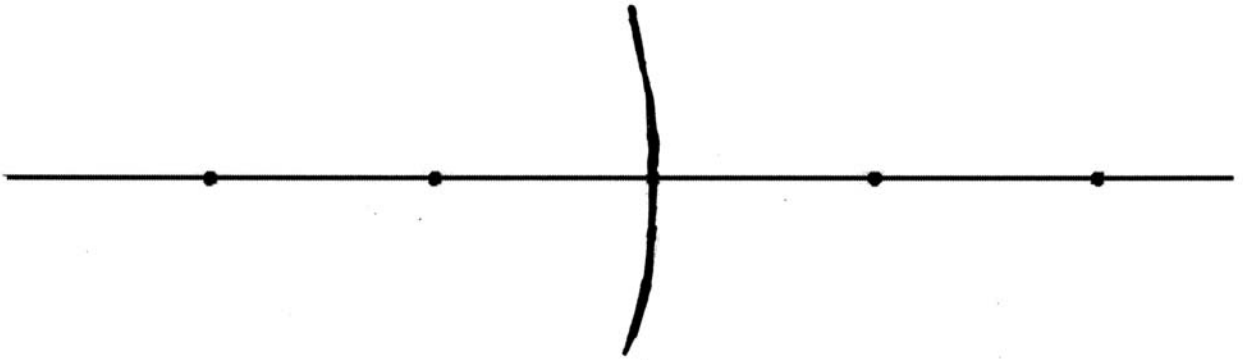


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-
-
-
- Light source at F



- All light
- No
- Creates a
- Used in
- Object if between F and the mirror

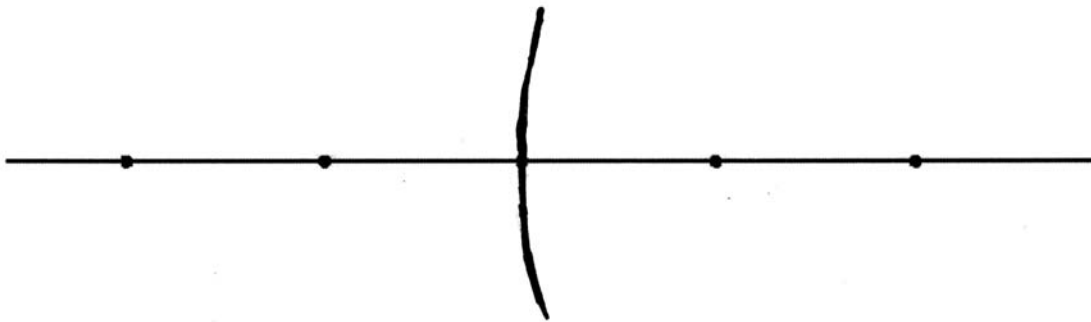


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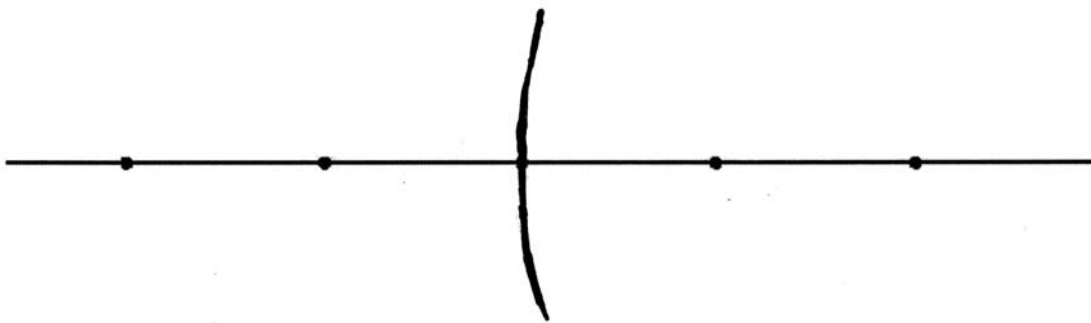
- **Summary for Concave Mirrors**
- Objects that are far away have
- As the object comes closer to the mirror, the image
- When the object passes the focal point, the image

Convex Mirror

- Curved-
- Called a ***diverging mirror***, the light
- The image formed does
- Focal Point is



- **Object is located anywhere**



-
- Used for
- Used in
- Side mirrors on cars - "objects are closer than they appear" They

Spherical Aberration

- Large mirrors have
- The outer edges reflect and the
- Use a

- Parabolic mirrors are

Mirror Equations

- f = focal length
- d_o =
- d_i = image distance
- h_o =
- h_i = image height
- m = magnification
-

13. Kermit's face is 75 cm in front of a plane mirror. Where is the image of Kermit's face?

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

15. 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?

16. 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?

17. 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?

18. Just after you dry a spoon, you look into the convex part of the spoon. If the spoon has a focal length of 8.2 cm and you are 18 cm in front of the spoon, where does your image appear? What is your magnification?

Lenses (Refract)

Lens Terms

- Lenses are
- $n_{\text{lens}} > n_{\text{air}}$ (refractive index is
- Refract the light (bend) towards the
- We are using thin lenses, refraction happens at the
- A lens can be
- **Real image** - can be projected on a screen. For lenses, the
- **Virtual image** - cannot be projected onto a screen. For lenses, the image
- **Focal Point** is on the opposite side of the object for a convex lens and is on the
- Light that passes through the

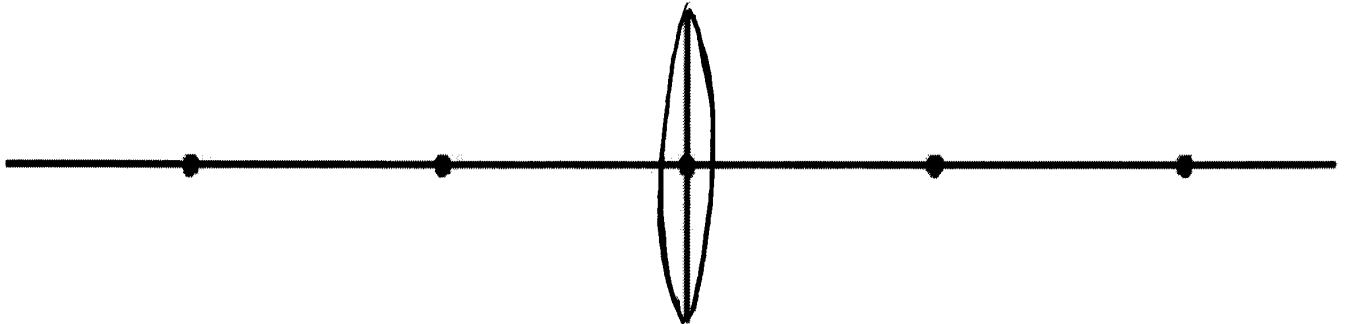
Ray diagrams for Lenses

- Draw a ray, from the **top** of the object, **parallel** to the principal axis to the lens, then refracting at the principal plane and

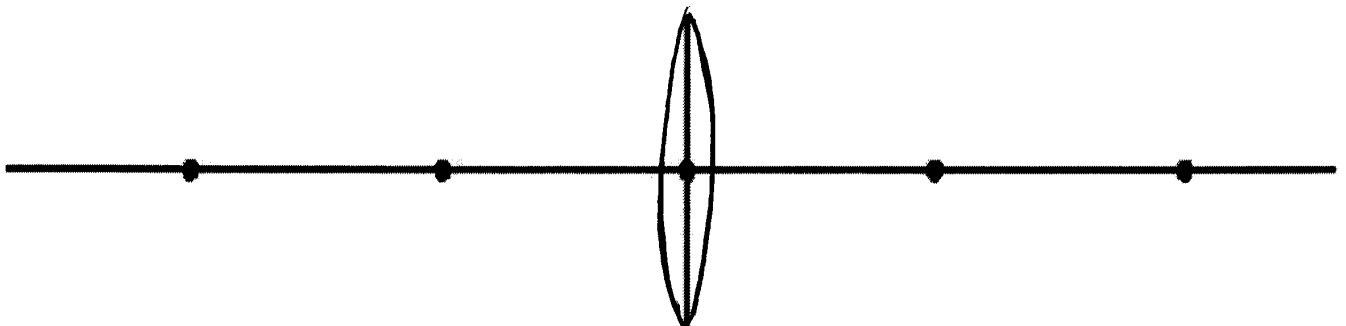
- Draw a ray, from the **top** of the object to the **center** of the lens (where the principal axis and principal plane meet). The light is not
- Draw a ray, from the **top** of the object, through the **focal point** on the **same side as the object** to the lens. Then it is refracted at the lens and is
- If the refracted rays do not meet (they **diverge**), **extend** the refracted rays
- The top of the image is located where the rays converge (intercept). Extend the image

Convex Lens

- Thicker at the
- One side
- Converging lenses, light that is parallel is refracted and
- Image depends on the
- **Object is more than 2F away**

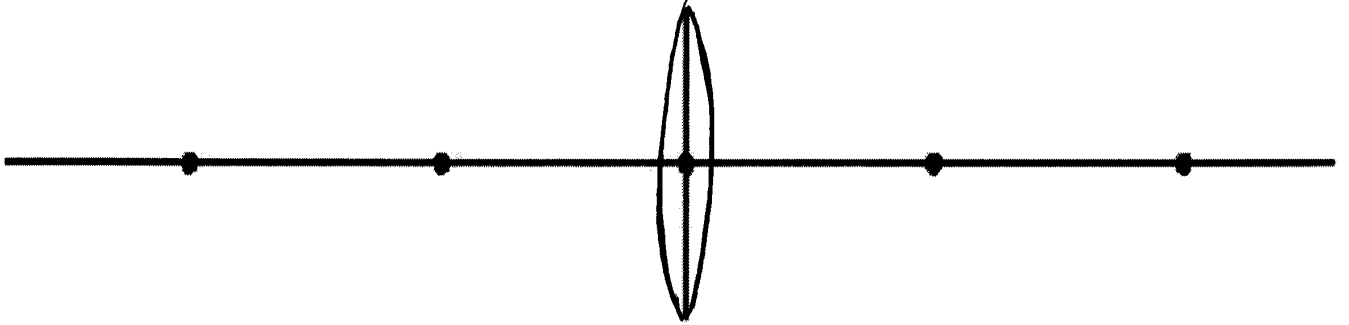


- Image is
- Image is
- Used for camera lens, eyeball, objective lens of a
- **Object is at 2F**

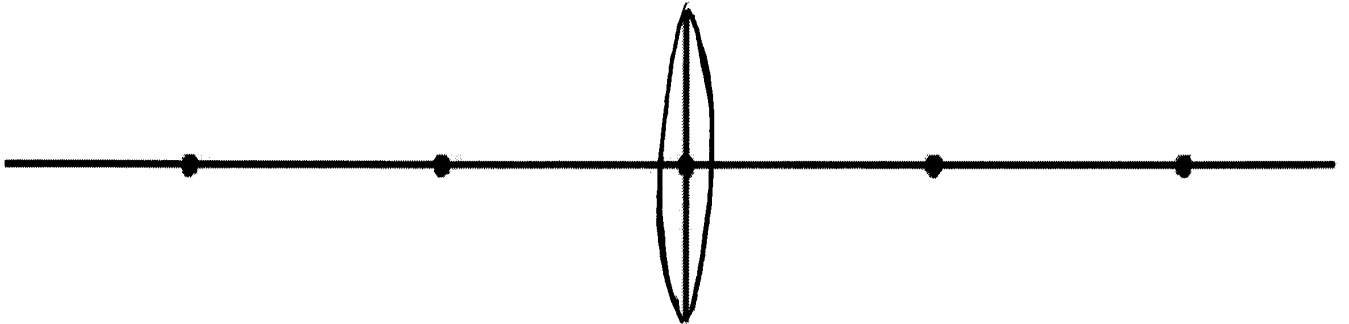


- Image is real, inverted, same size, at 2F
- Used as an inverting lens of a field telescope.

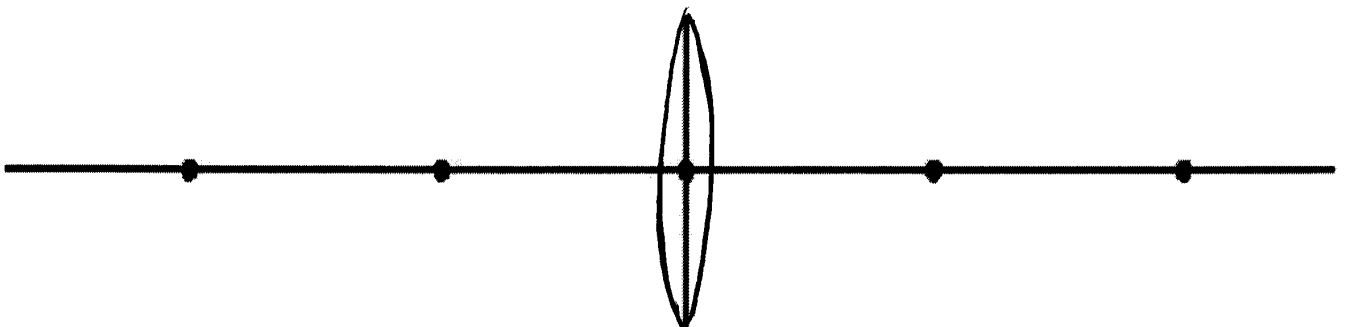
- Object is between F and 2F



- Image is real,
- Used for slide projector, motion picture projector,
- Object is at F



- No image
- Used for search lights, lenses for light houses.
- Object is inside F



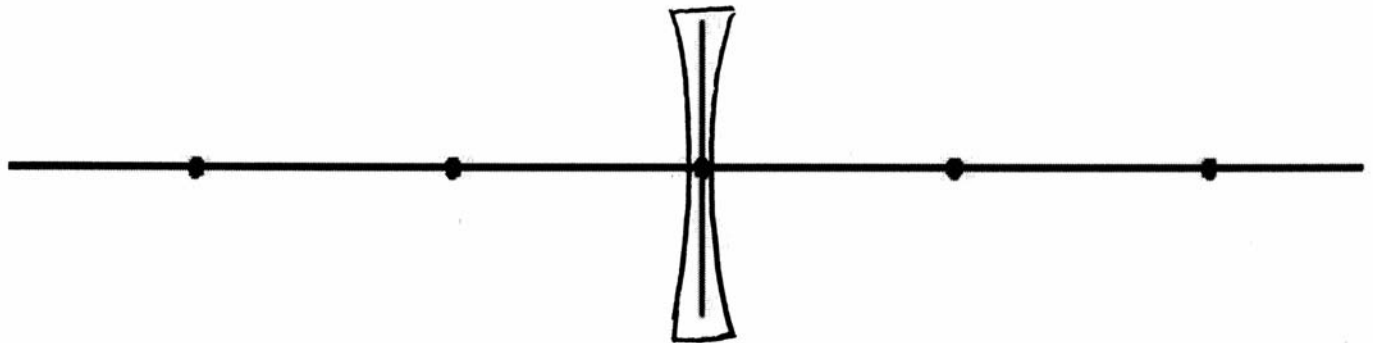
- Image is
- Magnifying glass
- Used as eye piece of

Summary for Convex Lenses

- As an object comes closer to the convex lens, the image gets

Concave Lens

- Thinner in the
- One
- Diverging
- Light is refracted
- Focal point is on the same
- Image will always be
- **Object is anywhere**



- Image is
- Used for eyeglasses to correct

Optical Instruments

- Eye Lenses
 - Most refraction occurs at the
 - Lens is flexible and muscles can change the
 - Myopic - nearsighted
- Focal length is too
- Distant objects form in
- Use Concave lens to
 - Hyperopia - farsightedness
- Focal length is
- Close objects focus
- Use a convex lens to

- Microscope -
 - **Objective lens** - object is placed very close to a lens with a **short focal length**.
Creates a
 - **Eyepiece** - creates a large virtual image from the real image produced by
 - Viewer sees a
- **Refracting Telescope** -
 - **Objective lens** with a **long focal length**. Image formed
 - **Eyepiece** with a short focal length. Refracts light into a
 - Viewer sees a

Lens Equations

- f = focal length
- d_o = distance of object
- d_i = image distance
- h_o = height of object
- h_i = image height
- m = magnification
-
-

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

20. 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? What is the focal length of the lens?

21. A 15 cm tall object is placed 44 cm in front of a diverging lens. A virtual image appears 14 cm in front of the lens. What is the lens's focal length? What is the image height and magnification?
22. Two converging lenses, each of focal length 15.0 cm, are placed 40.0 cm apart, and an object is placed 30.0 cm in front of the first lens. Where is the final image formed, and what is the magnification of the system. Describe the final image.