

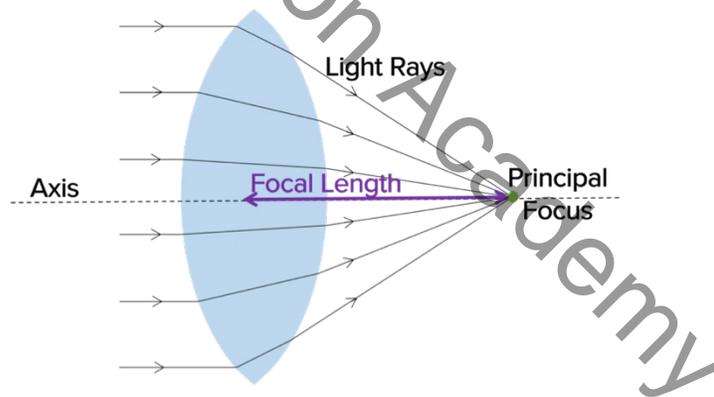
Lenses

- A lens is a shaped piece of transparent glass or plastic that refracts light. When light is refracted it changes direction due to the change in density as it moves from air into glass or plastic.
- Lenses are used in cameras, telescopes, binoculars, microscopes and corrective glasses.
- There are 2 types of lenses

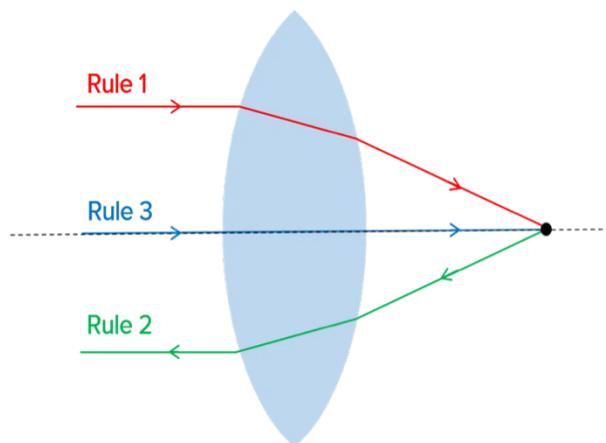
1. Concave lenses
2. Convex lenses

1. Convex Lenses

- **Convex lenses** are thicker in the middle than at the edges.
- Light entering the convex lens is **refracted** inwards towards a point called the **principal focus**. There is a principal focus on either side of the lens, for rays entering the lens from each direction.
- The distance between the centre of the lens to the principal focus is called the **focal length**. The ray diagram below shows the effect of a convex lens on the path of light rays.

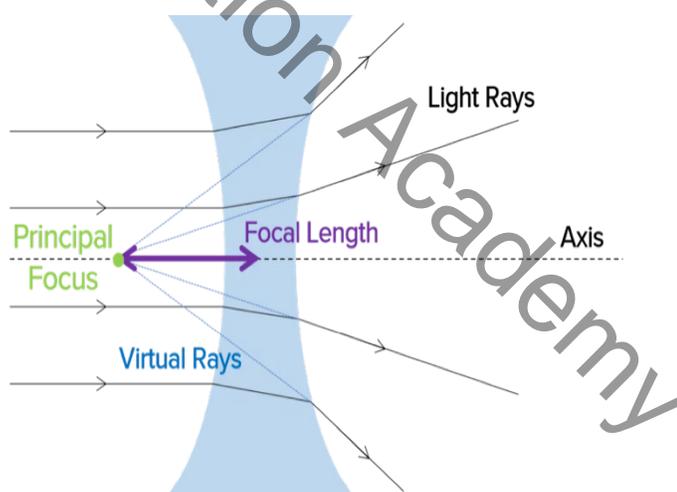


- Rules about convex lenses:
 - **Rule 1:** Any ray that enters the lens **parallel to the axis** will refract through the lens and pass through the **principal focus**.
 - **Rule 2:** Any ray that enters the lens from the **principal focus** will refract through the lens and leave the lens **parallel to the axis**.
 - **Rule 3:** Any ray that enters the lens along the **axis** will continue in the same direction.



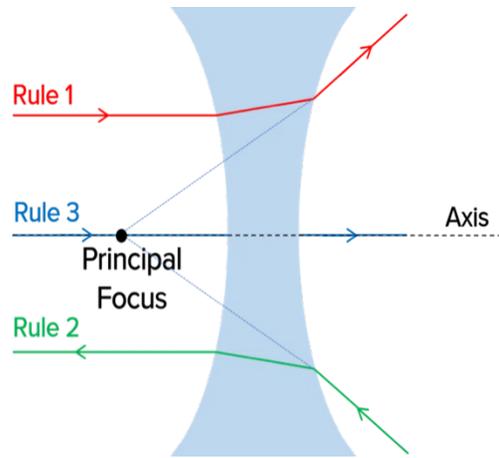
2. Concave Lenses

- **Concave lenses** are thicker at the edges and thinner in the centre. They cause light to **diverge**, meaning spread out.
- The **principal focus** of a concave lens is the point where rays hitting the lens **parallel** to the axis appear to have come from. We represent this on a **ray diagram** by tracing **virtual rays** backwards from the ray leaving the lens. Like a convex lens, there is a **principal focus** on both sides of the lens.



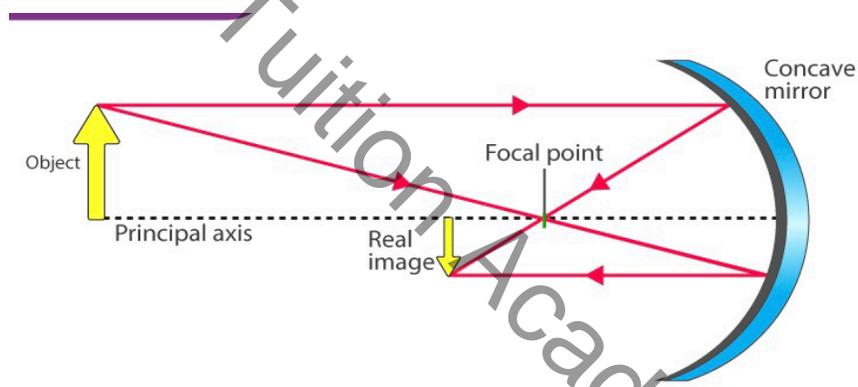
- Rules to remember for **concave lenses**:

- **Rule 1:** Any ray that enters the lens **parallel to the axis** will refract through the lens and travel in line with the **principal focus** so that it appears to have come from the principal focus.
- **Rule 2:** Any ray that enters the lens, travelling towards the **principal focus** refracts through the lens and leaves it **parallel to the axis**.
- **Rule 3:** Any ray that enters the lens along the **axis** continues in the same direction.

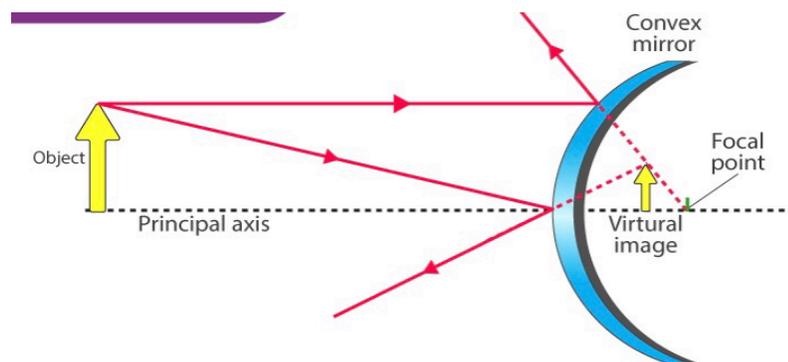


Real and Virtual Images

- When light comes together to form an image, such as on a **screen** or on the **retina** (the back of the eye), a **real image** is formed. **Only convex lenses produce real images.**



- A **virtual image** is formed when light rays are **diverging**, and so the object appears to be in a different place. For example, when you look into a **mirror**, you see a virtual image. This is because the reflection appears to be behind the mirror.
- **Concave lenses always produce virtual images.** Convex lenses may also produce virtual images.

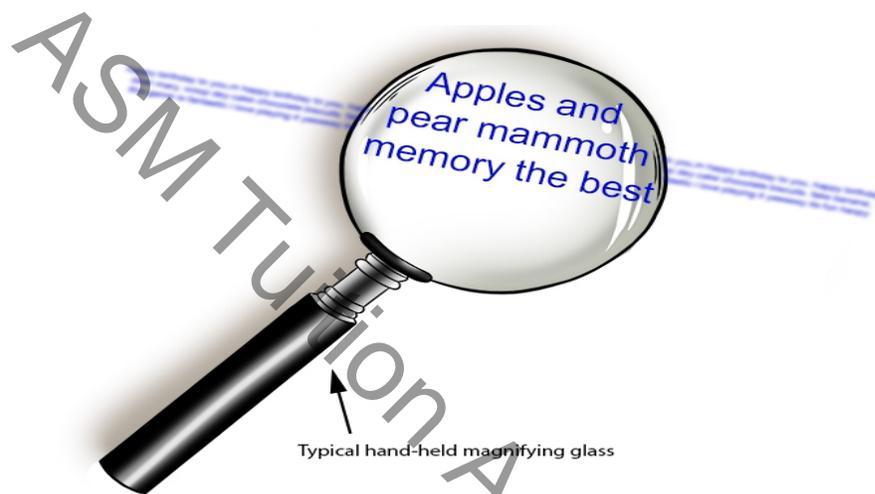


Magnification

- When an object is **magnified**, a **virtual image** of the object is created that is larger than the object itself. The image is called a **magnified virtual image**.
- For magnification to occur, the object must be closer to the lens than the **principal focus**.
- Formula of calculating Magnification

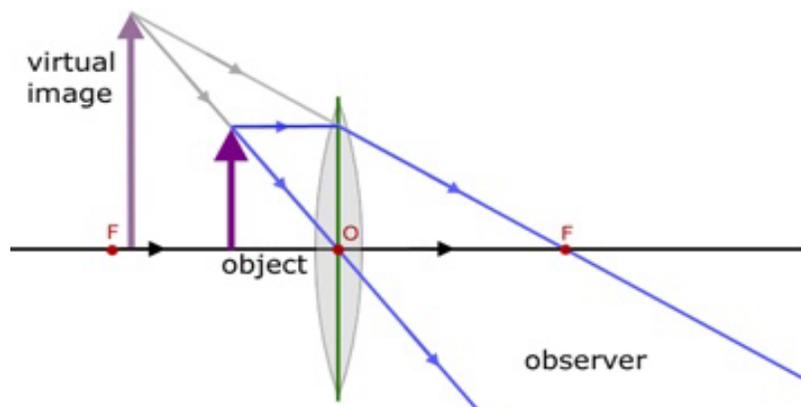
$$\text{Magnification} = \text{image size} / \text{Object size}$$

- Magnification is a **ratio** and so it has **no units**.
- If a virtual image has a **negative magnification**, this means the image is smaller than the object.



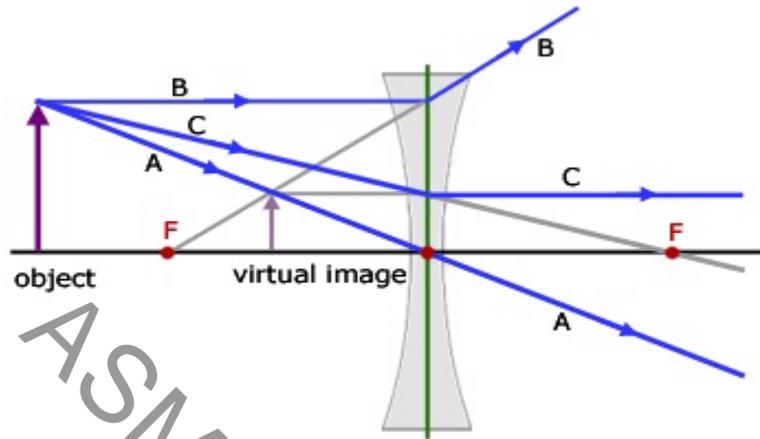
➤ Virtual image through convex lenses

If the object is **within the focal length** of the lens a virtual image is formed. Light rays on the observer side are diverging but appear to come from a point corresponding to a larger upright (virtual) object. This is the case for the **magnifying glass** when used to magnify things. Magnifier uses convex lens to magnify things



► Virtual image through concave lenses

Independent on whether the object is inside or outside the focal length, these lenses always produce a virtual image that is smaller than the original.



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