

Lenses, the eye and dispersion of light

Typed version of the handwritten O Level Physics class notes (10 August to 19 October 2020). The original handwritten pages, with their ray diagrams, are on the same page of megalecture.com.

Lenses

- A piece of glass or clear plastic with curved surfaces is called a lens.
- A lens is used to refract light: light refracts when it passes through a lens.
- When light passes through the centre of the lens it does not refract at all.
- When parallel light rays pass through the lens (other than at the centre) they refract.
- The angle of refraction is greatest for the light which passes through the edges of the lens.

Converging lens (convex)	Diverging lens (concave)
A lens which is thick at the middle and thin at the edges.	A lens which is thin at the middle and thick at the edges.
Used to bring parallel rays of light to a point: it converges parallel rays of light at a single point.	Used to spread out parallel rays of light: it diverges parallel rays of light.

Properties of a converging lens

- **Principal axis:** the horizontal line passing through the centre of a lens perpendicularly.
- **Optical centre (C):** the centre of the lens, which lies on the principal axis. Light will not refract when it passes through the optical centre, regardless of the angle of incidence.
- When a light ray parallel to the principal axis passes through the lens, it refracts.
- **Focal point (F):** a point at which parallel rays of light meet after passing through the lens.
- **Principal focus:** the point on the principal axis through which light passes after refraction.
- **Focal length (f):** the distance between the focal point and the optical centre.
- u is the object distance from the centre of the lens; v is the image distance from the centre of the lens.

Image formed by a thin converging lens

O: object. I: image. u = distance of the object from the lens. v = distance of the image from the lens. f = focal length.

A light ray parallel to the principal axis must pass through the focal point (F) after refraction. The opposite also holds: a light ray passing through the focus will refract parallel to the principal axis.

Steps for the ray diagram

1. Draw a horizontal line to represent the principal axis.
2. Draw a converging lens at the middle of the principal axis. It must be perpendicular to the principal axis.
3. Label the optical centre of the lens as point C.



4. Label the focal point on both sides of the lens.
5. Draw a vertical arrow on the left side of the lens to represent the object O.
6. Label the distance between point O and C as u .
7. Pass two rays of light from the head of the object such that one of the rays passes through the optical centre and the other ray passes parallel to the principal axis.
8. Join the axis with the intersection of the rays with an arrow and label it I. (A real image is where the light rays actually come to a focus.)

Case	Object distance	Image distance	Image	Use
1	$u = \text{infinity}$	$v = f$	inverted, real, diminished	objective lens of a telescope
2	$u > 2f$	$f < v < 2f$	inverted, real, diminished	camera, the eye
3	$u = 2f$	$v = 2f$	inverted, real, same size	photocopier
4	$f < u < 2f$	$v > 2f$	inverted, real, magnified	projector
5	$u = f$	$v = \text{infinity}$	real, inverted, highly magnified (the rays leave parallel)	
6	$u < f$	$v > u$ (same side as the object)	upright, virtual, magnified	magnifying glass

Conclusion. (i) $u > f$: the image is inverted, real, and on the opposite side of the lens. (ii) $u < f$: the image is upright, virtual, and on the same side of the lens as the object.

Magnification = height of image / height of object = image size / object size = image distance / object distance = v / u . Linear magnification is the ratio of image size to object size for a converging lens, or the ratio of image distance to object distance.

Uses of a thin converging lens

1. **Camera** (parts: shutter, shutter button, film, spool, wind-on spool, thin converging lens). The camera uses a convex lens to produce a real, inverted and diminished image on the film. Focusing is done by varying the distance of the lens from the film. The object distance varies from infinity to slightly larger than f .
2. **Projector** (parts: curved mirror, lamp, condenser lens, slide O, converging lens, image I on the screen). The image produced by a projector is real, inverted and magnified. Focusing of the image is done by moving the convex lens so that the object falls between f and $2f$. Since the image is inverted both vertically and laterally, the slide is placed upside down and flipped 180° , so that the image is projected the right way.
3. **Photographic enlarger**. The working principle of a photographic enlarger is basically the same as that of a projector. The film in a photographic enlarger is placed between f and $2f$ of the focusing lens. The image produced is real, magnified and inverted.

The eye

Parts: cornea, converging lens, retina. The image on the retina is real, inverted and diminished.

- For a distant object the lens is thinner in the middle and less curved; for a near object the lens is thicker at the middle and more curved. This is to have the rays converge at the retina instead of before or after the retina.

Defects of the eye

1. **Short sightedness:** the eye is able to see closer objects clearly but is unable to see distant objects clearly (the rays meet before the retina). This defect is corrected by placing a diverging lens in front of the eye.
2. **Long sightedness:** the eye is able to see distant objects clearly but is unable to see closer objects clearly (the rays would meet behind the retina). This defect is corrected by placing a converging lens in front of the eye.

Dispersion of light

- When white light passes through a prism (at an angle other than 90° to the face), it splits into 7 colours called the spectrum, bent towards the base of the prism: red, orange, yellow, green, blue, indigo, violet (ROYGBIV). This process is called dispersion of light.
- **Why does it split?** Because white light is a combination of 7 wavelengths. When it passes through a prism, every wavelength refracts by a different amount, so every wavelength comes out at a different position (or angle), displaying its own colour. In air, all the colours travel at the same speed.
- Red: least refraction, longest wavelength, minimum frequency (the fastest in glass). Violet: most refraction, shortest wavelength, maximum frequency, the greatest refractive index.
- Since the refraction of the red wavelength is minimum, red comes first in the spectrum of white light, and the refraction of the violet wavelength is maximum, so it comes at the end of the spectrum. Each colour travels with the speed of light.
- **Monochromatic light:** light of a single wavelength; it does not split into any colours, e.g. red laser light, blue laser light.
- **Ultraviolet radiation:** beyond the violet end of the spectrum is invisible UV radiation. It can be detected by the blackening of photographic film or by fluorescence, e.g. currency notes usually have certain marks which glow under UV lamps.
- **Infra-red radiation:** beyond the red end of the visible spectrum is invisible IR radiation. It can be detected by a thermopile (its galvanometer deflects when it senses IR radiation) or by placing a thermometer, since IR radiation causes heating effects.

Concave (diverging) lens

Rules for the rays: a ray through the optical centre passes straight on; a ray parallel to the principal axis refracts so that it appears to be coming from the focal point on the same side; a ray heading towards the focal point on the far side refracts parallel to the principal axis.

Case 1 (object beyond $2F$) and case 2 (object between F and $2F$): in both cases the image is virtual, upright and diminished, on the same side as the object. A concave lens always gives an image with these properties.

Checked by Mega Lecture

This typed version follows the handwritten notes. Corrections: case 1's use is written as the objective lens of a telescope (the notes say "contact lens"); the conclusion's second rule is written as $u < f$ (the notes say $u \leq f$, but at $u = f$ the image is at infinity, case 5); "unable to see closer objects unclearly" is written as "unable to see closer objects clearly". The Urdu side notes are given in English and the ray diagrams are described in words or in the table. Spotted a mistake? Tell us on WhatsApp: +92 336 780 1123.