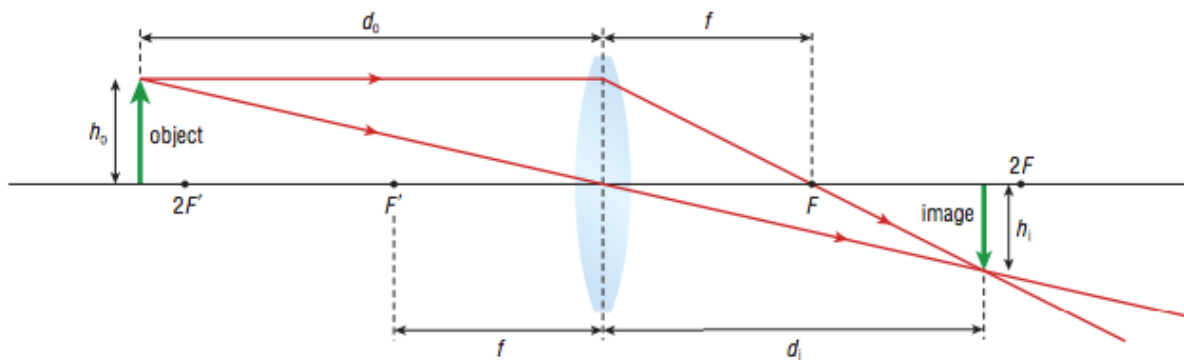


Grade 10 Science

Light and Geometric Optics
Class 11

The Lens Equation

- Besides a diagram, you can also use algebra to determine the characteristics of an image
- Variables:
 - d_o = distance from the object to the optical centre
 - d_i = distance from the image to the optical centre
 - h_o = height of the object
 - h_i = height of the image
 - f = focal length of the lens; distance from the optical centre to the principal focus



The Thin Lens Equation

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

- Object distances (d_o) are always positive
- Image distances (d_i) are positive for real images (opposite side) and negative for virtual (same side)
- The focal length is positive for converging lenses and negative for diverging lenses



Checkpoint



a) A converging lens has a focal length of 17cm. A candle is located 48cm from the lens. What type of image will be formed and where will it be located?

b) A diverging lens has a focal length of 29cm. A virtual image of a marble is located 13cm in front of the lens. Where is the marble located?

The Magnification Equation

$$M = \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

- Object (h_o) and image (h_i) heights are positive when measure upward from the principal axis and negative when measured downward
- Magnification is positive for an upright image and negative for an inverted image



Checkpoint



a) A toy of height 8.4cm is balanced in front of a converging lens. An inverted, real image of height 23cm is noticed on the other side of the lens. What is the magnification of the lens?

b) A coin of height 2.4cm is placed in front of a diverging lens. An upright, virtual image of height 1.7cm is noticed on the same side of the lens as the coin. What is the magnification of the lens?

Table 1 Sign Conventions for Lenses

Variable	Positive	Negative
(object distance) d_o	always	never
(image distance) d_i	real image (image is on opposite side of lens as object)	virtual image (image is on same side of lens as object)
(height of object) h_o	when measured upward	when measured downward
(height of image) h_i	when measured upward	when measured downward
(focal length) f	converging lens	diverging lens
(magnification) M	upright image	inverted image

Applications of Lenses

- Cameras use a converging lens to produce an inverted, smaller, real image on the film or digital sensor
- Object must be located more than $2F'$ and the image will be between F and $2F$; cannot change the film so the lens moves back and forth to focus

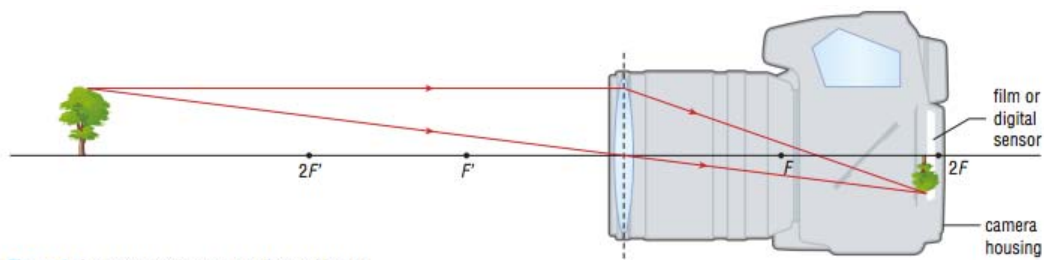


Figure 1 A camera produces a smaller, real image.

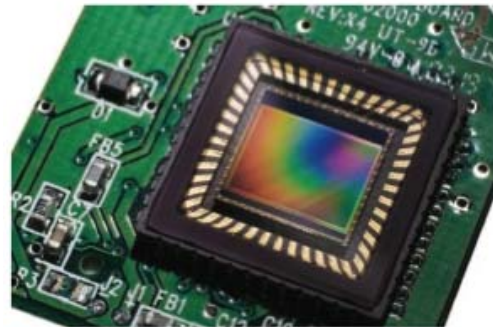
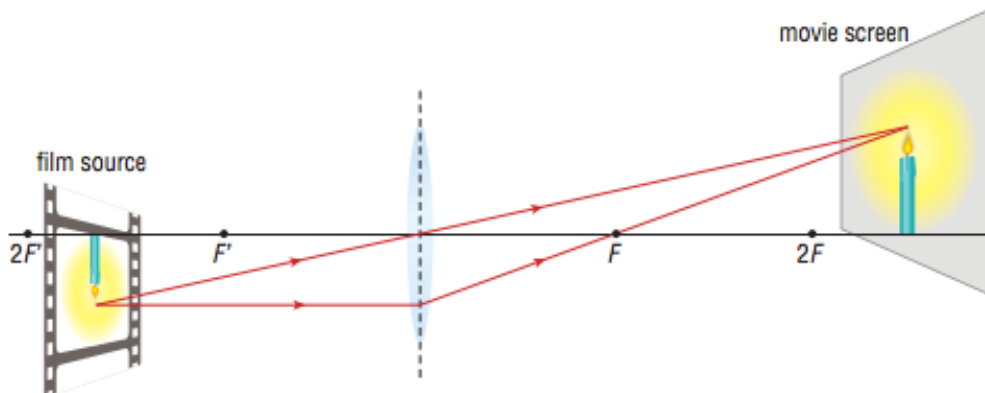


Figure 2 In a digital camera, a charge-coupled device (CCD) replaces the film found in a traditional camera.

- Traditional film was developed by George Eastman in 1884
- Digital cameras use a charge-coupled device (CCD) to capture the light

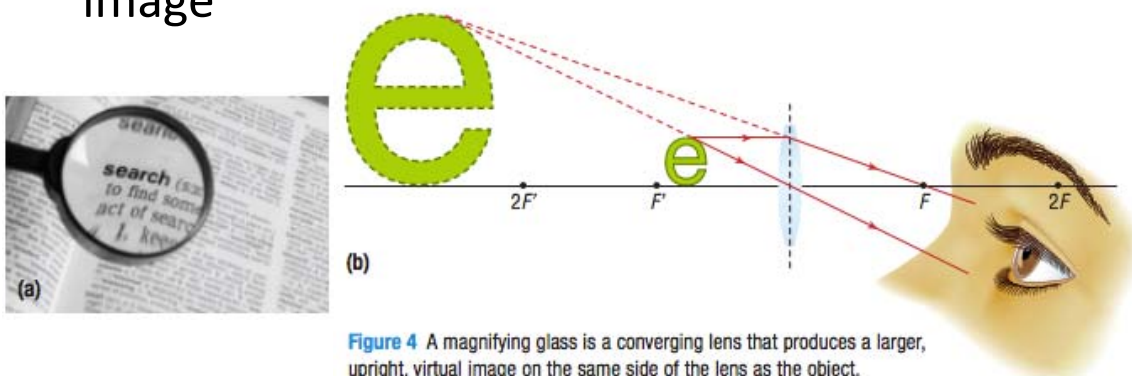
Movie Projector

- Takes a small object and projects a large, inverted, real image on a screen
- Film must be located F' and $2F'$ and loaded upside down for image to be upright



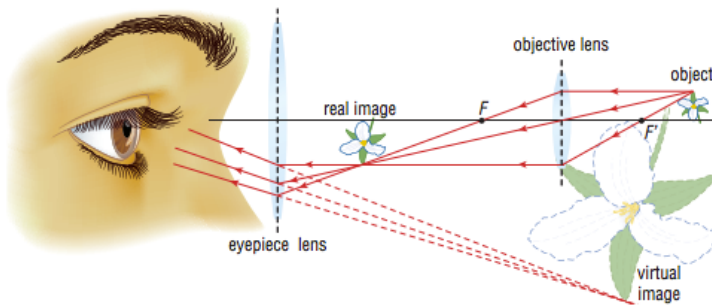
Magnifying Glass

- Converging lens in which object is between F' and the lens
- Human brain extends the refracted rays backwards to produce an enlarged, virtual image



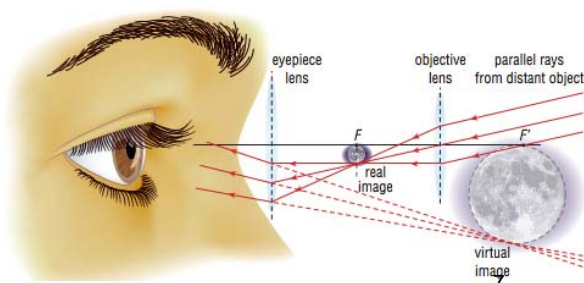
Compound Microscope

- Arrangement of two converging lenses to produce two enlarged, inverted images: one real and one virtual
 - Real image is in the body tube of the microscope
 - Virtual image is the one you see through the eyepiece



Telescope

- The object you are looking at is so far beyond $2F'$ that incident rays passing through the lens are considered to be parallel
- Produces two enlarged, inverted images, one real image that is inside the telescope and one larger virtual image that you see



The Human Eye

- Iris – opens and closes to let in more or less light
- Pupil – where light enters the eye
- Cornea – causes light to converge
- Lens - causes light to converge
- Retina – where the image is focused; sends electrical signals to the brain through the optic nerve

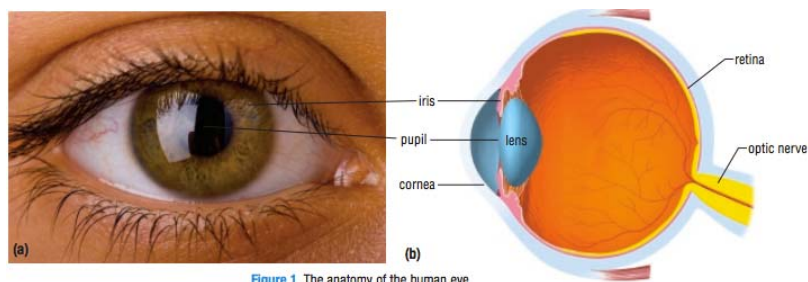
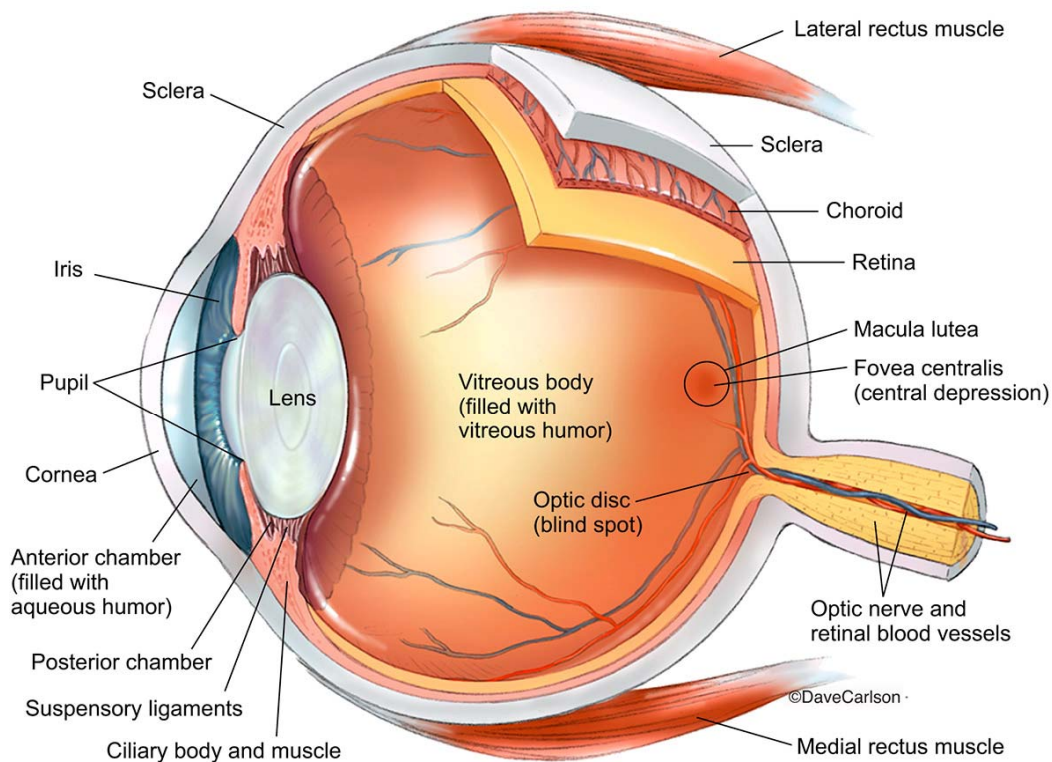


Figure 1 The anatomy of the human eye



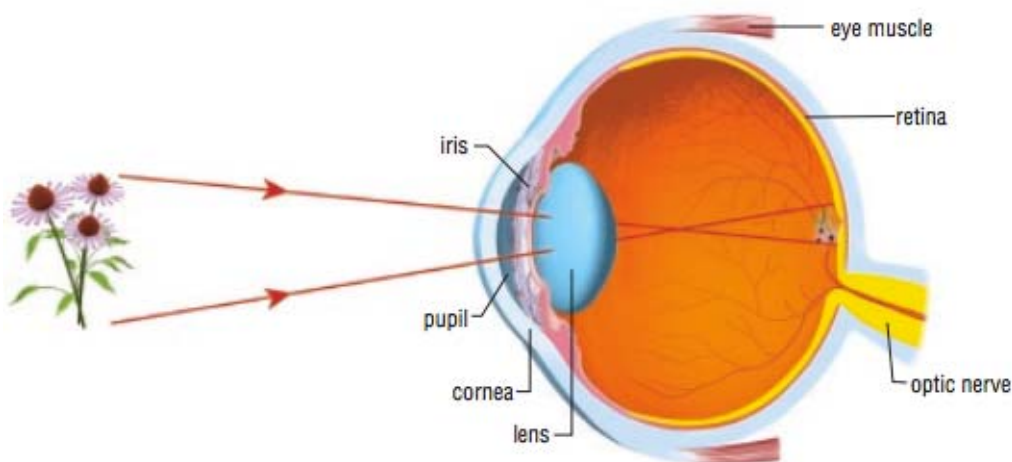
Right Eye (viewed from above)

Find Your Blind Spot



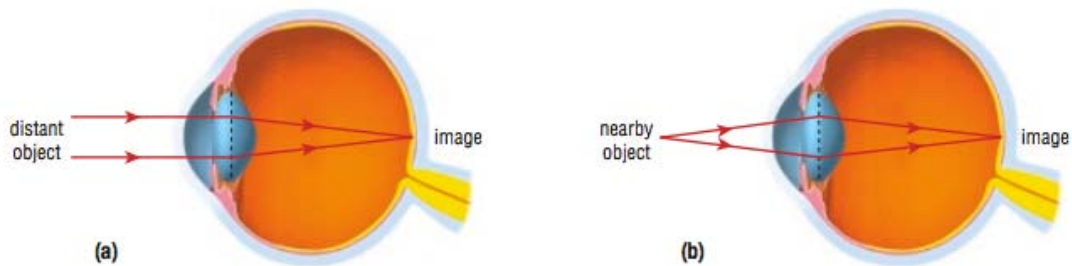
- Find your blind spot, close your left eye and focus on the small ball until the larger ball disappears

- The eye is a light gathering instrument, we see with our brain
- Brain flips the real, inverted image on the retina so that we see an upright image



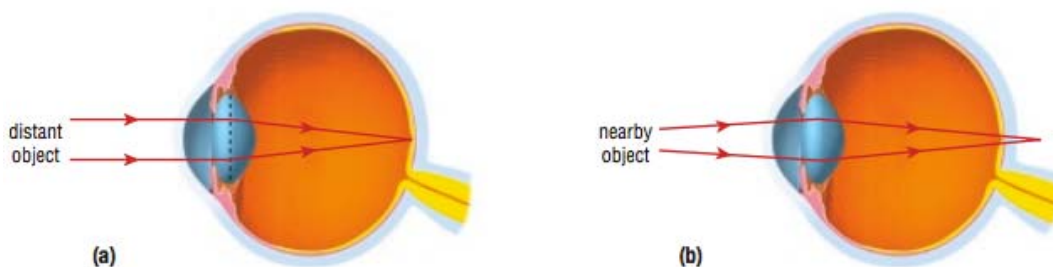
Accommodation in Healthy Eyes

- Ciliary muscles help the eye focus by changing the shape of the lens which changes the focal length to allow focusing on the retina
- Lens gets fatter when focused on nearby objects



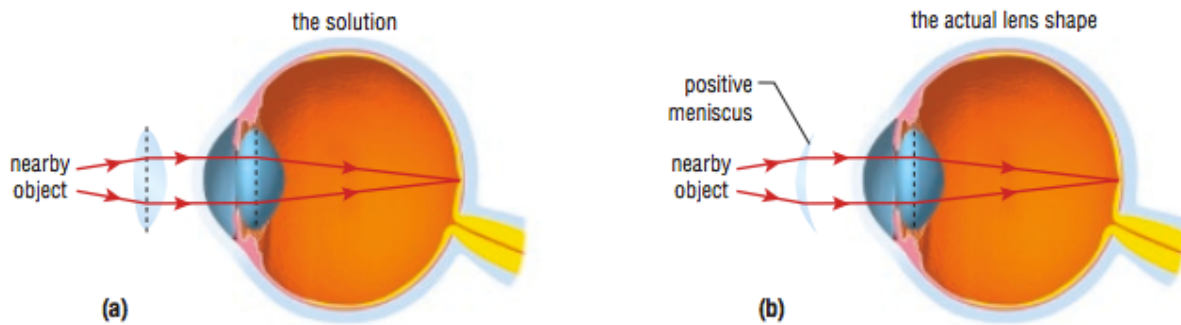
Hyperopia (Far-sightedness)

- Inability to see near
- Occurs because distance between the lens and retina is too small or cornea-lens combination is too weak
- Light focuses behind the retina



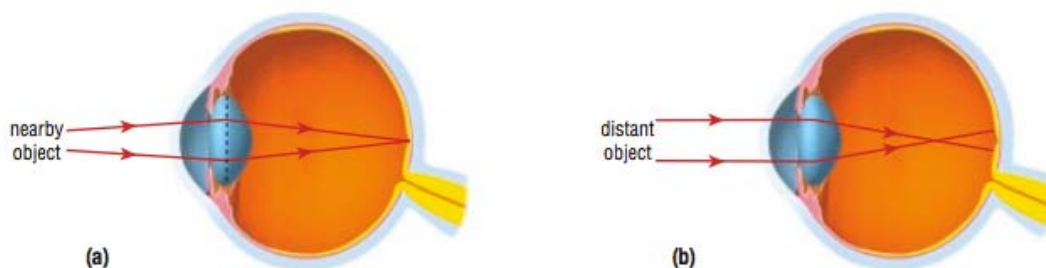
Correcting Hyperopia

- Needs help in refracting light – uses a converging lens
- **Presbyopia** – caused by age; eye lens loses elasticity



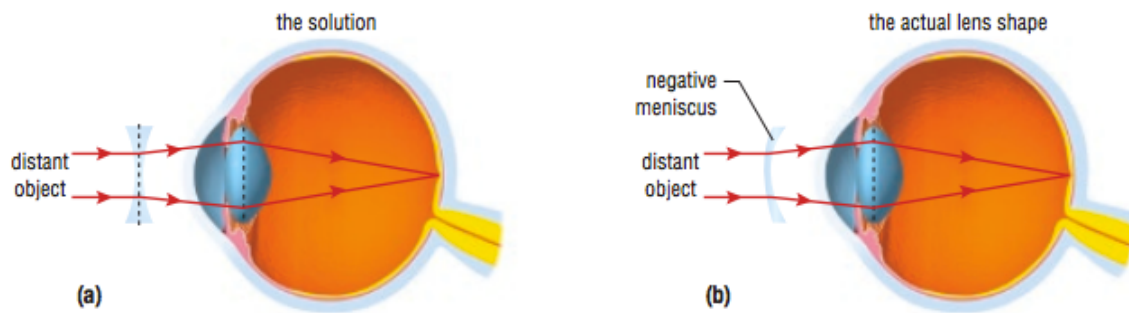
Myopia (Near-Sightedness)

- Inability to see far
- Distance between lens and the retina is too large or cornea-lens combination converges too strongly
- Light focuses in front of the retina



Correcting Myopia

- Corrected with a diverging lens
- Positive meniscus and Negative meniscus are lenses with a modified shape to make glasses more cosmetically appealing than a regular lens



Contact Lenses

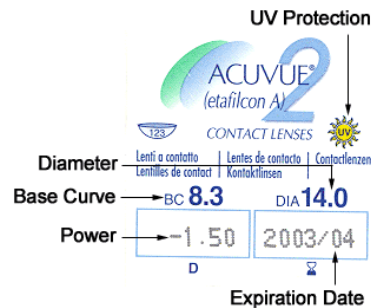
- Lens placed in front of the cornea
- Shaped to correct hyperopia and myopia
- Proximity to the eyeball allows the optic zone (central part of the lenses that contains the corrective power) to be smaller than glasses



Diometers (D)

- Contact lens and eyeglass lens powers are expressed in diometers (D)
- Lens powers that correct nearsightedness start with a (-) and farsightedness start with a (+) sign

$$D = \frac{1}{f}$$



Common Eye Problems

- **Astigmatism** - light fails to focus on a single point on the retina; instead multiple focus points occur
 - Symptoms: Causes vision to be blurred, lights seem to come from all directions
- **Glaucoma** – pressure buildup due to fluid in the aqueous humor damaging the optic nerve; can lead to blindness
 - Symptoms: Tends to be inherited; loss of peripheral or side vision, appearance of halos around lights

- **Cataract** – Clumping of proteins in the lens due to old age, UV light, diabetes, etc.
 - Symptoms: Blurred vision, glaring lights, dull colours; can lead to blindness
 - Can be helped with cataract surgery in which the clouded lens is replaced with a clear plastic intraocular lens
 - Patients regain clear vision



Cataract Patient