CHAPTER

13

Optics

MAIN TOPICS

CHAPTER 13

- Lens
- Types of Lenses
- Lens formula
- Refractive Index
- Association of lenses
- Aberration
- Human Eye
- Characteristics of human eye

LENS

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A lens is a piece of transparent medium that can focus a transmitted beam of light so an image is formed.

- The lenses in man-made optical instruments are usually manufactured from glass or plastic
- The lens in the human eye is formed by a transparent membrane filled with a clear fluid.

CONVEX LENS

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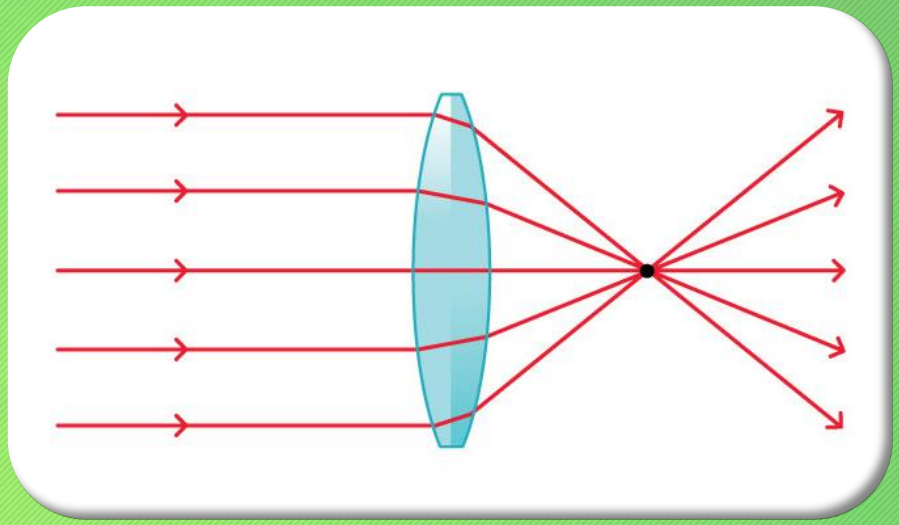
A convex lens is thicker in the center and thinner at edges.



A convex lens bends parallel rays of light to single point, hence it is also called converging lens.

CONCAVE LENS

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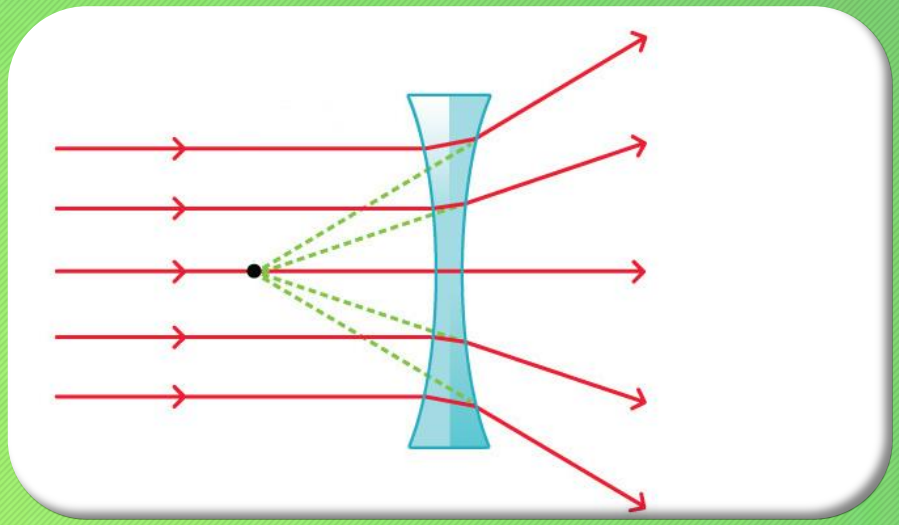
A concave lens is thinner in the center and thicker at edges.



A concave lens bends parallel rays of light outwards, so that they appear to be coming from a single point

TYPES OF LENS

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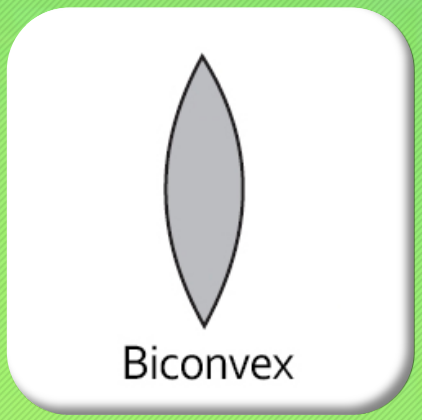

FOCAL POINT

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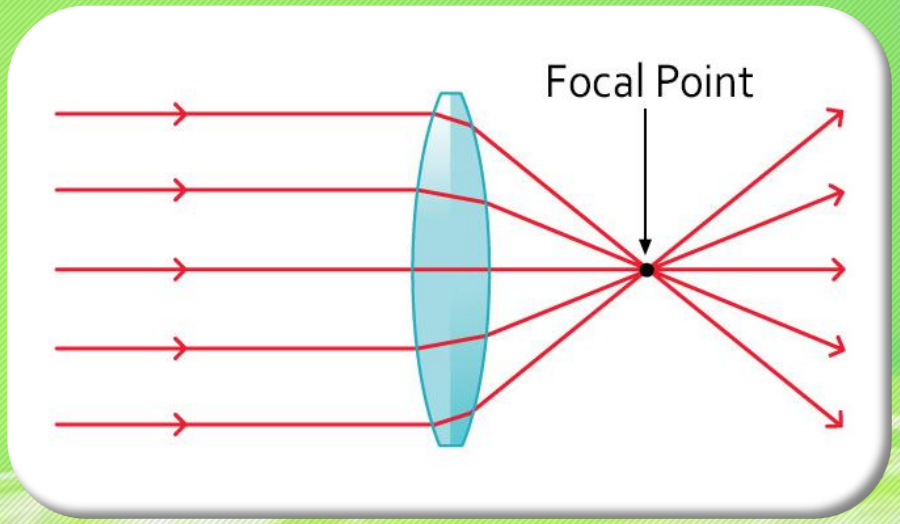
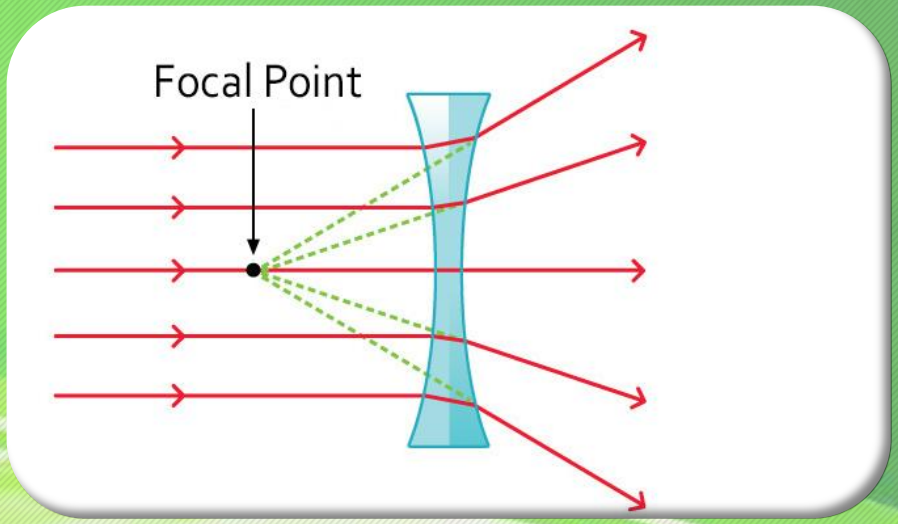
- A convex lens bends parallel rays of light to single point, which is called focal point.
- In concave lens, parallel rays appear to be coming from a single point, which is called focal point.





FOCAL LENGTH

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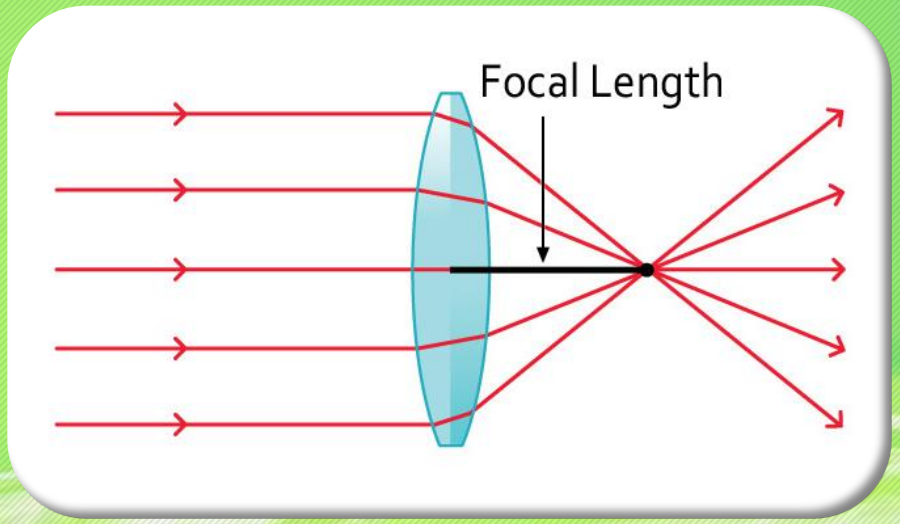
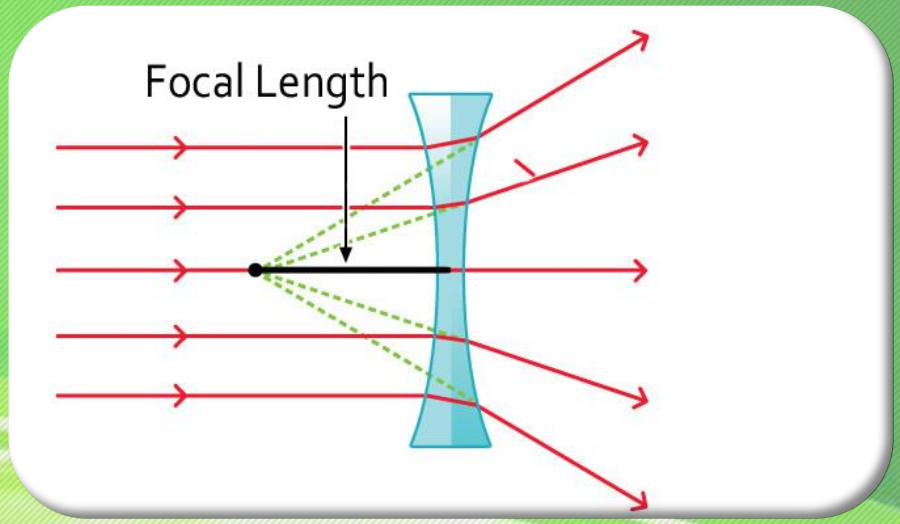
Focal length is the distance between focal point and the center of the lens.

- Focal length is positive for convex lens while it is negative for concave lens.





LENS FORMULA

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$$\frac{1}{f} = \frac{1}{p} + \frac{1}{q}$$

Where

- f = Focal length
- P = Distance of object from the lens
- q = Distance of image from the lens

ANSWER CHECK

CHAPTER 13

If an object is 3m from lens and its images is formed at 4m from the lens. What is focal length of the lens

A. 1.5m
B. 1.7m
C. 2.0m
D. 2.5m

ANSWER CHECK

CHAPTER 13

If an object is 3m from lens and its images is formed at 4m from the lens. What is focal length of the lens

A. 1.5m

B. 1.7m

C. 2.0m

D. 2.5m

Explanation:

p = 3

q = 4

$$\frac{1}{f} = \frac{1}{3} + \frac{1}{4}$$

$$= 0.33 + 0.25$$

$$= 0.58$$

$$\frac{1}{f} = 0.58$$

$$\frac{1}{0.58} = f$$

$$1.7 = f$$

ANSWER CHECK

CHAPTER 13

Where image will be formed from a lens of 2 m if object is 5 m from lens.

A. 1.4m

B. 3.3m

C. 7.0m

D. 2.5m

ANSWER CHECK

CHAPTER 13

Where image will be formed from a lens of 2 m focal length, if object is 5 m from lens.

A. 1.4m

B. 3.3m

C. 7.0m

D. 2.5m

Explanation:

f = 2 & p = 5

$$\frac{1}{2} = \frac{1}{5} + \frac{1}{q}$$

$$0.5 = 0.2 + \frac{1}{q}$$

$$0.5 - 0.2 =$$

$$0.3 =$$

$$0.3 = \frac{1}{q}$$

$$q = \frac{1}{0.3}$$

$$q = 3.33$$

POWER OF LENS

CHAPTER 13

Power of lens is defined as the reciprocal of the focal length of the lens.

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

unit:

Power of the lens is measured in diopter. A diopter is equal to m^{-1} .

ANSWER CHECK

CHAPTER 13

Which lens has more power

A. Lens with short focal length
B. Lens with long focal length
C. Lens with very long focal length
D. Focal length can not define the power

ANSWER CHECK

CHAPTER 13

Which lens has more power

A. Lens with short focal length
B. Lens with long focal length
C. Lens with very long focal length
D. Focal length can not define the power

REFRACTIVE INDEX

CHAPTER 13

Refractive index of any medium is the ratio of speed of light in vacuum to the speed of light in that medium

$$n = \frac{c}{v}$$

Where n = refractive index

c = speed of light in vacuum (3×10^8 m/s)

v = speed of light in that medium

REFRACTIVE INDEX

CHAPTER 13

Refractive index of few common things

Air	1.00
Water	1.33
Glass	1.5-1.6
Diamond	2.41
Ethanol	1.36

ASSOCIATION OF LENSES

CHAPTER 13

Two lenses will work in combination if we place them next to each other.

Two lenses with focal length f_1 and f_2 will act as a single lens with focal length f, which can be found by the formula

$$\frac{1}{f} = \frac{1}{f_1} + \frac{1}{f_2}$$

But $$P = \frac{1}{f}$$

So $$P = P_1 + P_2$$

ANSWER CHECK

CHAPTER 13

An Ophthalmologist places lenses with 3 diopter and 0.5 diopter. This combination is equal to lens with power

A. 2.5 diopter

B. 3.5 diopter

C. 0.4 diopter

D. 0.6 diopter

ANSWER CHECK

CHAPTER 13

An Ophthalmologist places lenses with 3 diopter and 0.5 diopter. This combination is equal to lens with power

A. 2.5 diopter

B. 3.5 diopter

C. 0.4 diopter

D. 0.6 diopter

ABERRATION

CHAPTER 13

Aberration is the deviation from perfection.

- It is the property of the lenses which limits sharpness.
- Image formed by the lens may be blurred.
- Image formed by the lens may be distorted

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SPHERICAL ABERRATION

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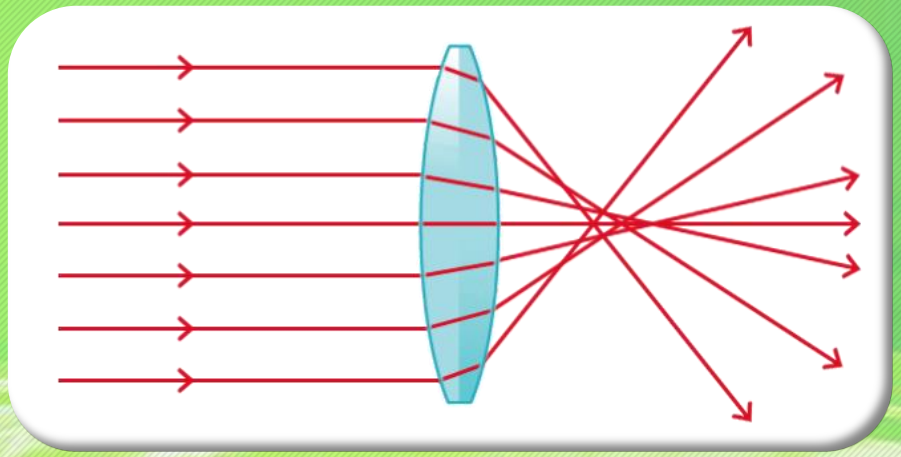
Light rays near the axis of the lens are focused farther than the rays near the edge and cause the image to have a small diameter. It occur for light of single wavelength.



CHROMATIC ABERRATION

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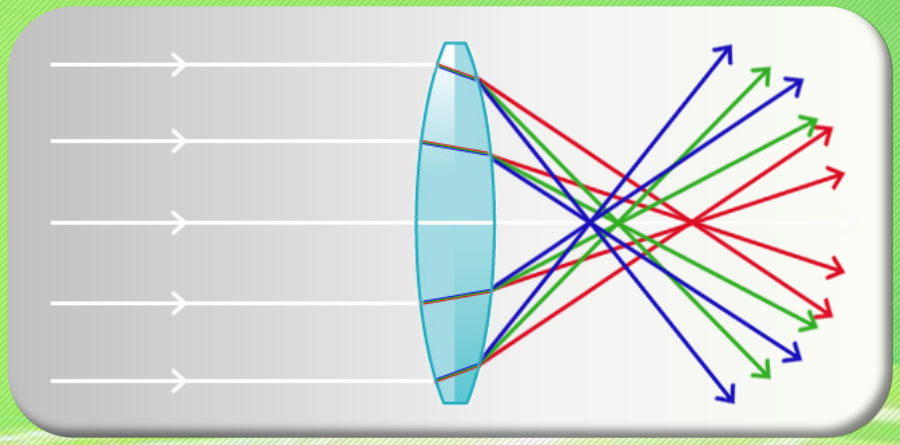
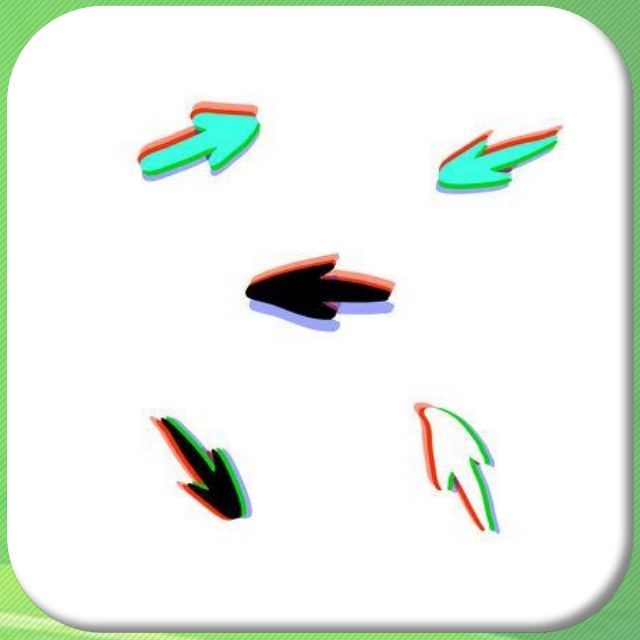
When an object is illuminated with white light, if its image on a screen is in focus for one color component, it will be slightly out of focus for the others.



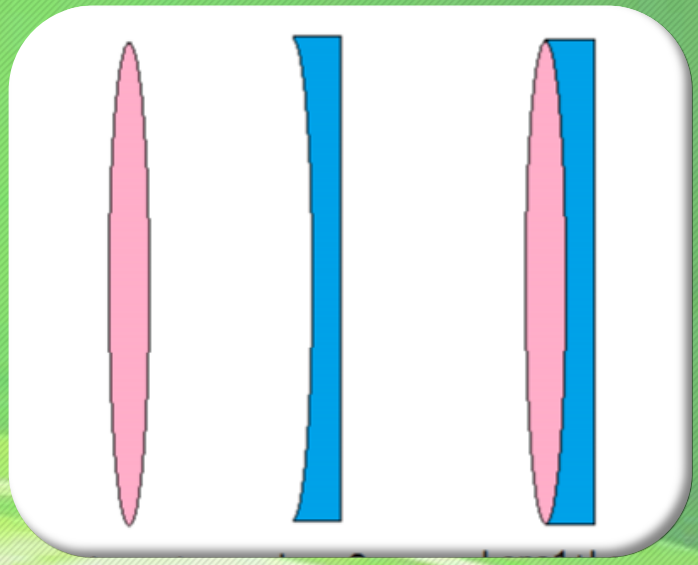


ELIMINATING ABERRATION

CHAPTER 13

Aberration can be cancelled by using two lenses in combination

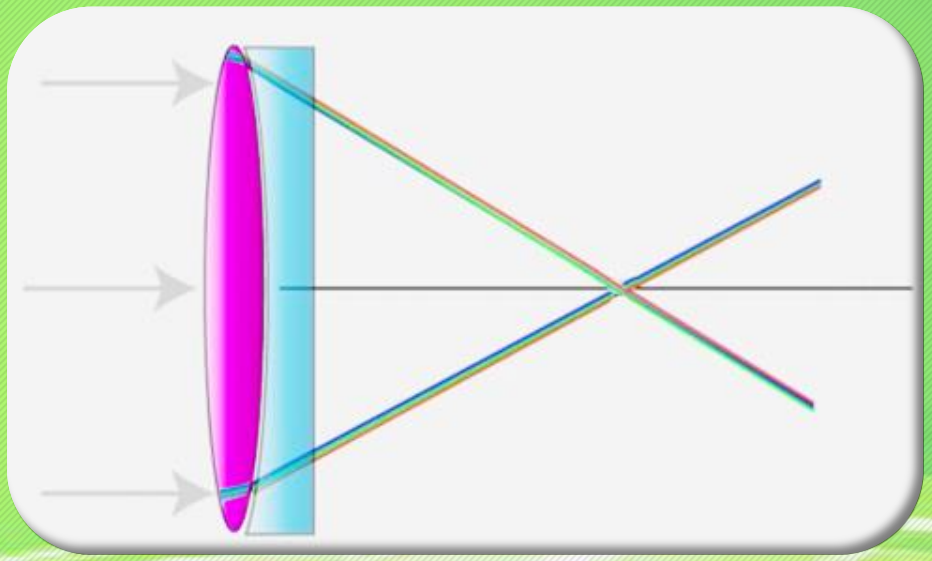
- One lens has two convex sides
- Other lens has a plan side and a concave side
- Both lenses are made up of different material
- The radius of curvature is 10cm for all curved surfaces



ELIMINATING ABERRATION

CHAPTER 13

Same can be used to remove chromic aberration.



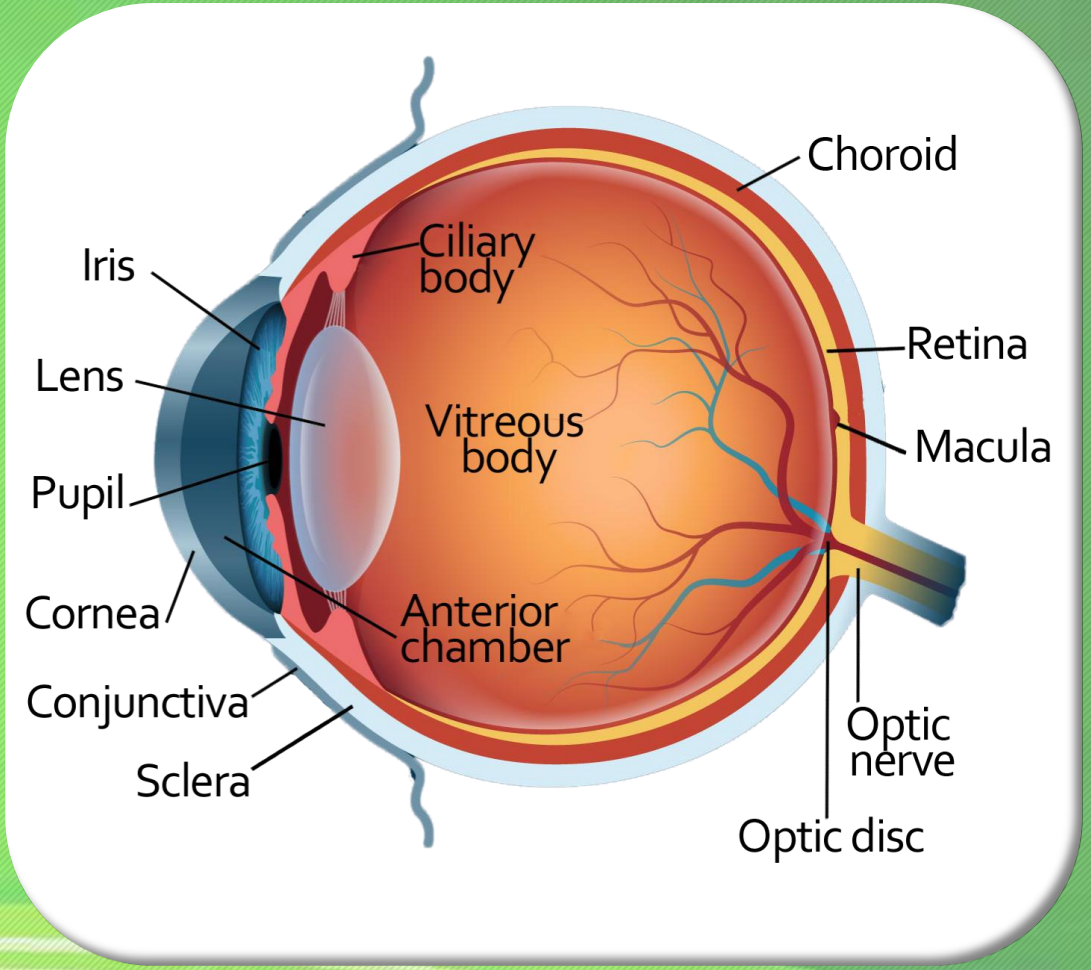
HUMAN EYE

CHAPTER 13

The eye ball is approximately spherical with diameter of 2.3cm.

Cornea:

Transparent covering in front of the eye which protects internal parts.



HUMAN EYE

CHAPTER 13

Iris:

Colored part of the eye behind the Cornea. It regulate the amount of light which should enter the eye

Pupil:

The adjustable hole at the center of the iris through which light enters the eye.

Lens:

The transparent structure inside the eye that focuses light rays onto the retina.

HUMAN EYE

CHAPTER 13

Ciliary body:

Part of the eye, above the lens, that control the shape and focal length of the lens

Retina:

The light-sensitive nerve layer that lines the back of the eye. The retina senses light and creates impulses

Optical nerve:

A bundle of nerve fibers that connect the retina to the brain. It carries signals of light, dark, and colors to brain

FUNCTIONIG OF EYE

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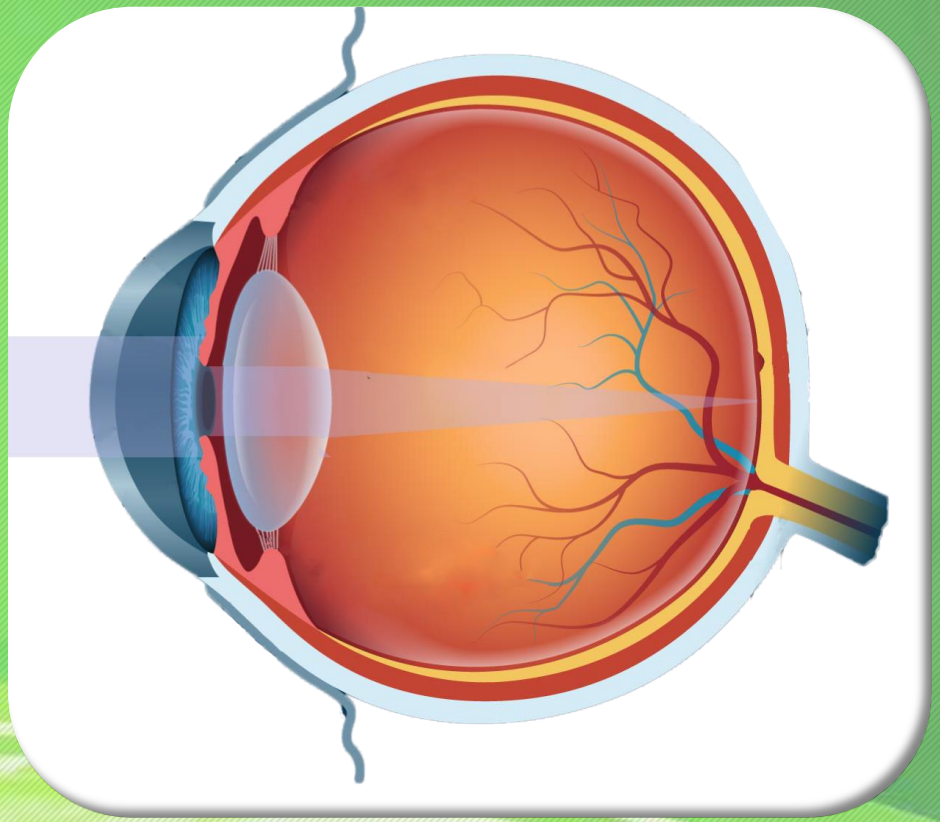
- Light can pass through cornea.
- Light enter the eyes through Pupil.
- Lens focus light on Retina.
- Retina is light sensitive tissue which detects light.
- Retina convert light into electrical impulse.
- Optic nerves carries that impulse to the brain.



ACCOMODATION

CHAPTER 13

The ability of the lens to adjust its focal length is called accommodation.

- If the ciliary muscles are relaxed, then front surface of the lens is relatively flat and light from distant objects is focused on the retina.
- When the ciliary muscles contract, the lens assume more rounded shape and its focal length decreases binging the nearby into focus on the retina.

POWER OF ACCOMODATON

CHAPTER 13

The power of accommodation of the eye is the maximum difference between its power for focusing on near objects and power for focusing on far objects

$$A = P_n - P_f$$

Where

P_n = power for focusing on near objects

P_f = power for focusing on far objects

POWER OF ACCOMODATON

CHAPTER 13

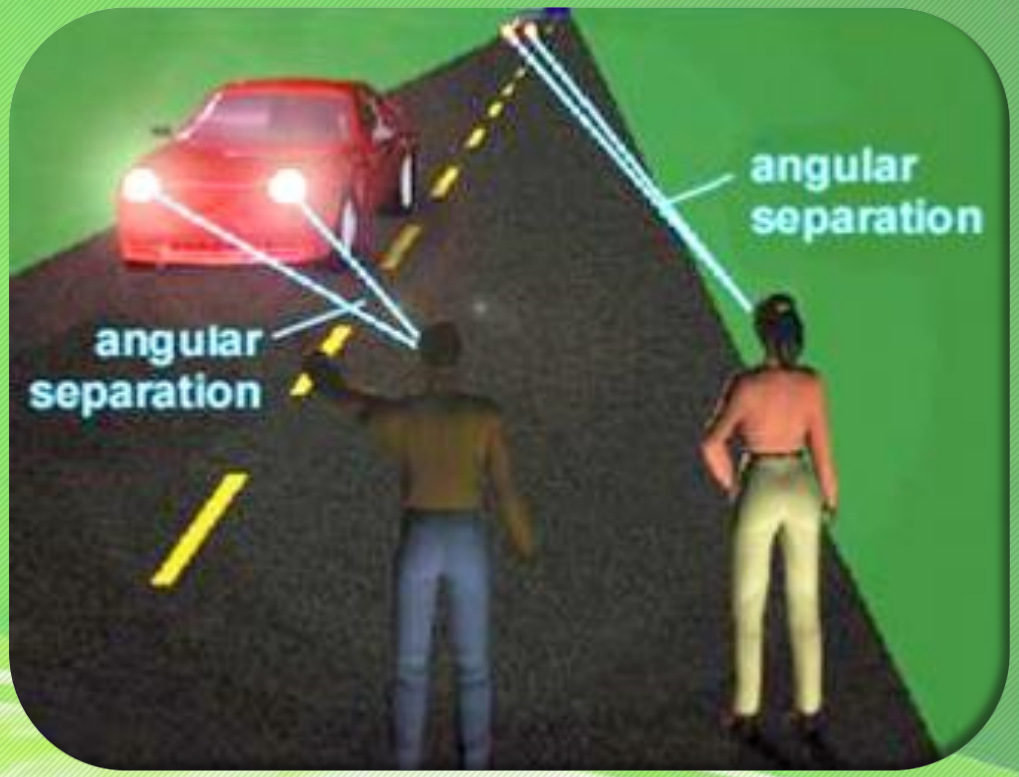
- Young children have a much greater power of accommodation, and often can read books held quite close to their eyes.
- The accommodation decreases with aging, and most people find their near point gradually recedes until they cannot read comfortably without glasses.
- The power of accommodation for a normal vision is 4 diopter.

VISUAL ACUITY

CHAPTER 13

The visual acuity (clearness of images) depend upon the angular separation.

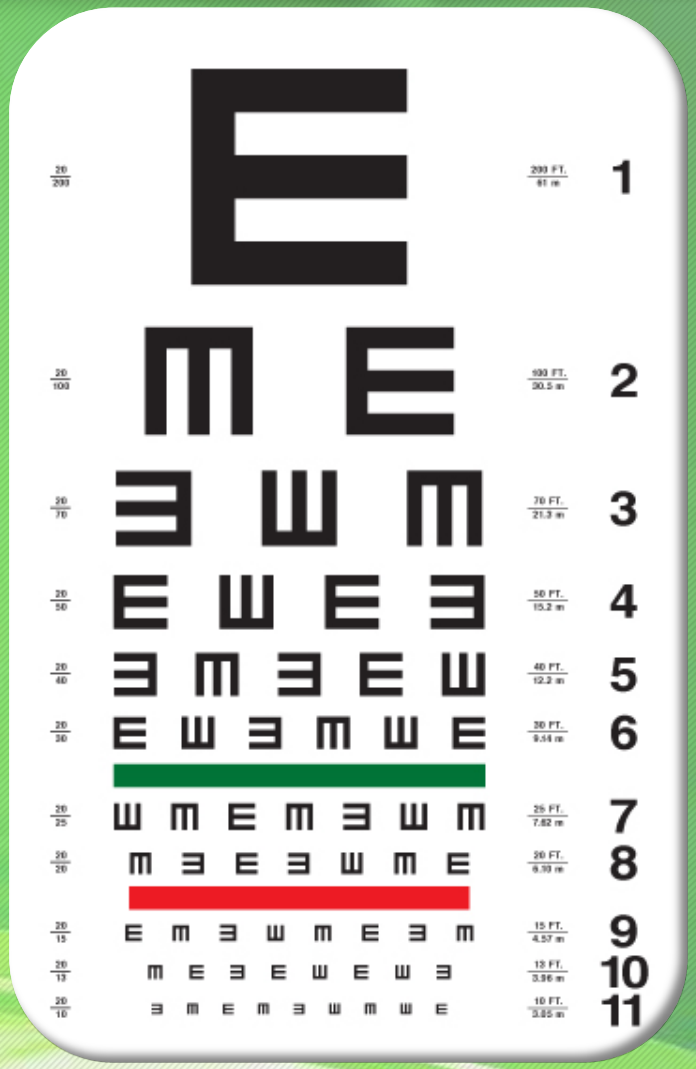
- The acuity of a typical person is about $5x10^{-4}$ rad.
- Objects with smaller angular (less than $5x10^{-4}$ rad separation cannot be distinguished



VISUAL ACUITY

CHAPTER 13

Visual acuity test is often measured according to the size of letters viewed on a Snellen chart or the size of other symbols, such as Tumbling E



EYE INTENSITY

CHAPTER 13

The minimum intensity needed to see light depends on the wavelength of light.

- Eye is sensitive to light which has wavelength between 380 and 750 nm.
- Maximum eye sensitivity is at 500 nm in dark, and 550 nm in light. Both wavelengths correspond to green light.

Violet	Blue	Cyan	Green	Yellow	Orange	Red
380-450	450-470	470-495	495-570	570-590	590-620	620-750

EYE INTENSITY

CHAPTER 13

- The cornea is opaque to wavelengths shorter than 300 nm, and the lens to wavelengths below 380 nm, so ultraviolet light does not contribute to vision.
- The sensitivity of the eye goes to zero rapidly above 700 nm

Violet	Blue	Cyan	Green	Yellow	Orange	Red
380-450	450-470	470-495	495-570	570-590	590-620	620-750