

Subject: Optics and Acoustics

Topic: Optical Instruments

4. Optics and Acoustics

Cardinal points, Huygens and Ramsden eyepiece, Defect of visions, Human eye and camera, Telescope and microscope, Theories of light, concept and condition of interference, Young's double slits, Biprism, Colour in thin films, Newton's ring, Michelson interferometer, Fabry-Perot interferometer, Fresnel and Fraunhofer's Diffraction, Zone Plate, Single slit and multiple slits diffraction, plane Grating, Resolving Power of Grating and optical instruments, Limit and criteria of resolution.

Unpolarised and polarised light, Plane of vibration and plane polarization, Polarization by Reflection, Refraction, Double refraction, Dichroism, Law of Malus, Nicol Prism, Retardation Plates (Half and Quarter), Babinet compensator, Optical rotation, Polarimeters, Coherence (Temporal and Spatial), Induced emission, Spontaneous emission, Induced absorption, Einstein's A & B co-efficients, components of Laser, Types of pumping, Ruby lasers, He-Ne lasers, Semi-conductor lasers, Holography and Photography, Medical application of lasers, Undamped, Damped, Forced and Resonance Vibrations, Lissajous figures, Velocity of Sound, Plane progressive and stationary waves, Vibration of Stretched strings and organ Pipes, Reflectivity and Transmittivity at boundary, Phase velocity and Group velocity.

1. Two types of Instruments →

Forms Real Image	Forms Virtual Image
• Real image is formed on the screen / photographic plate • Image can be seen by many people at once. • eg. Projectors.	• Some instruments form virtual image. Virtual image is transformed into real image by our eyes. • Can be seen by only one person. • Such instruments are called optical aids. • eg. microscope, telescope, Spectacles etc

2. Human Eye →

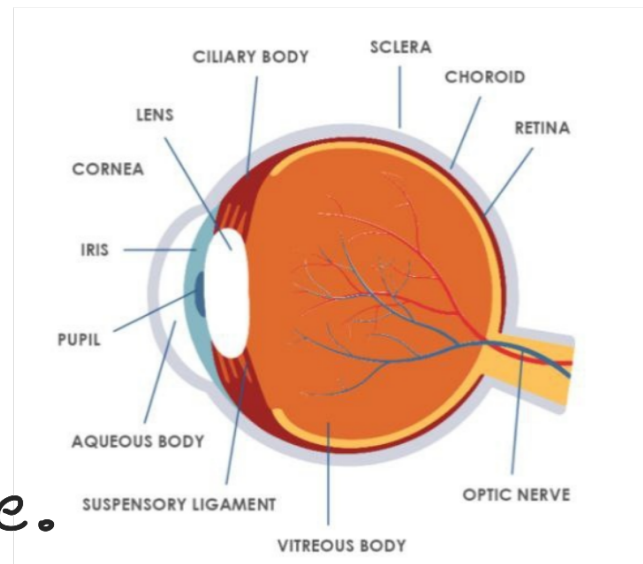
a) Sclera : Tough outer skin. Protect eye and give necessary stiffness. White part of eye.

b) Cornea : Entrance lens of eye. Convex lens. Transparent layer above colored/black part of eye.

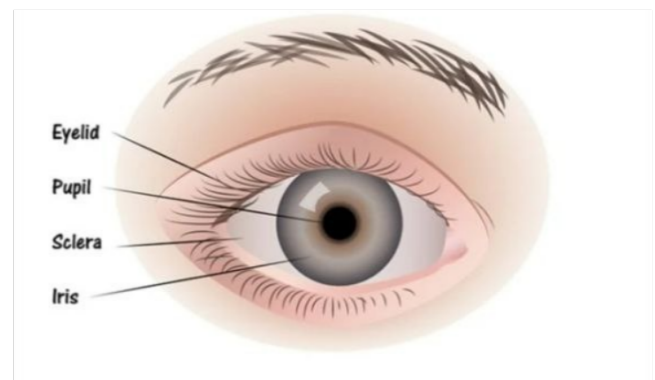
c) Iris : Back of cornea. It is colored part of eye. Some have blue, brown etc. Cornea is transparent layer above it.

d) Pupil : Iris contains an aperture called pupil. Centre most black part. Its diameter changes with light intensity.

e) Lens : Behind the iris contains crystalline lens. Biconvex lens - natural made. Made of fibrous Jelly. Hard at centre and progressively softer at outer portions.



- Nearly Spherical
- About 2.5cm diam.



f.) Aqueous Humor : Between transparent cornea layer and iris : liquid called aqueous humor is present.

g.) Vitreous Humor : Behind lens of eye : thin water jelly exists called vitreous humor.

* Refractive index of Aqueous and Vitreous humor ≈ 1.336

* Refractive index of lens ≈ 1.437

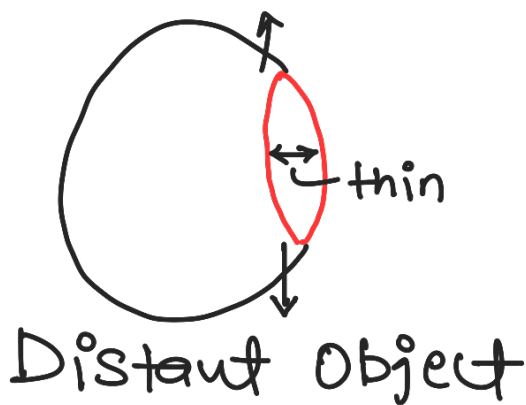
h.) Retina : Sensory layer on the inner surface of chamber of eye. It contains light receptors called rods and cones. 125 million rods and 6.5 million cones. They sense image and transmit via optic nerves to brain.

How eye form image?

- Refraction at cornea and surface of lens produces real and inverted image of object on retina.
- Eye adjust to different object distance by changing the focal length of lens. Focal length is changed by varying radii of lens (using ciliary muscles of eyes).
- Process of change in focal length of lens is called Accommodation.
- lens to retina distance does not change.

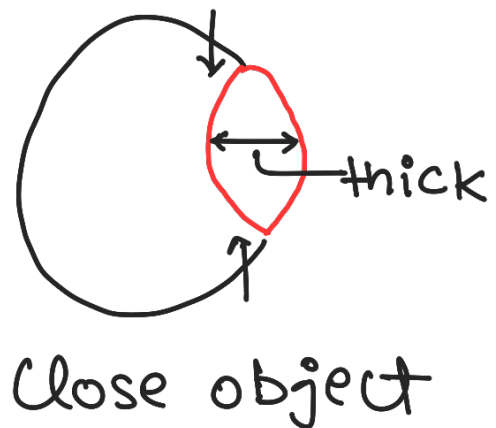
Muscles relaxed

- lens become thin
- Focal length increases
- We see distant objects

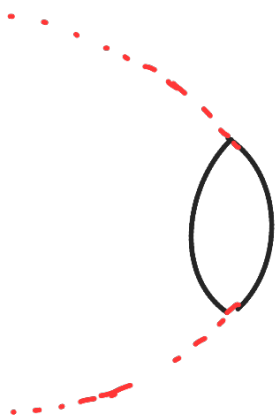


Muscle contracts

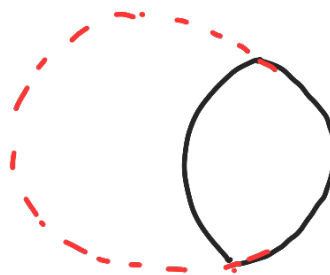
- lens become thick
- Focal length decreases
- we see close objects



* Physics : More curvature = Less radius
= Less focal length



less curvature
Bigger radius
more focal length



More curvature
less radius
less focal length

• Focal length of lens can not decrease below a certain limit. Try reading this page from very close. You will feel strain on eyes.

* To read Comfortably : distance $\geq 25\text{cm}$. It is called least distance of distinct vision.

- Farthest our eyes can see : Far point . It is infinity for normal eye .
- Range decreases with age .

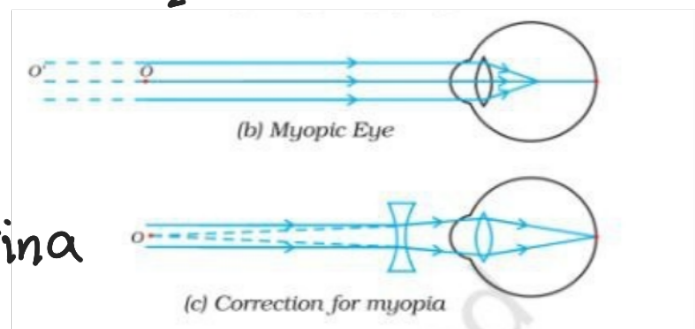
Cataract : Lens become milky and cloudy.

3. Defects of Vision →

- Sometimes eye gradually loses its power of accommodation
- 3 Common Refractive defects of vision :
 - (a) Myopia or near sightedness
 - (b) Hypermetropia or far sightedness
 - (c) Presbyopia

A) Myopia

- Person can't see far objects distinctly.
- Far point $< \infty$.
- Clear vision in meters
- Image forming in front of retina and not on retina.



- Causes → excessive curvature of lens
→ elongation of eye ball

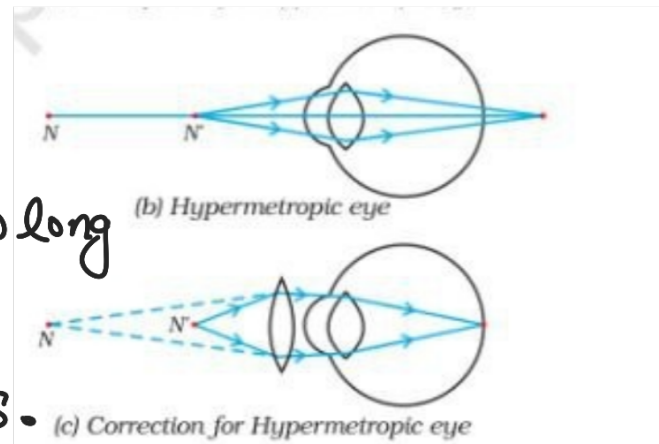
- Concave lens can fix this issue.

B. Hypermetropia

- Cannot see near sighted objects distinctly.
- Near point is farther than normal ($\approx 25\text{cm}$).
- Light is focused beyond retina and not on retina.

Causes → focal length of lens too long
→ eye ball too small

- Can be fixed with Convex lens.



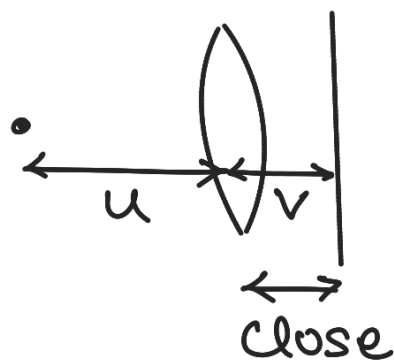
C. Presbyopia

- Age related defect: losing ability to see close by objects. Ciliary muscles weaken and fails to contract eye properly.

4. Camera →

- Camera contains: Convex lens, photographic film and shutter.
- Lens form real image on photographic film.
- For proper image: Intensity of light reaching the film must be in particular range. We use shutter for this purpose. Shutter allows light to enter for a particular amount of time only.

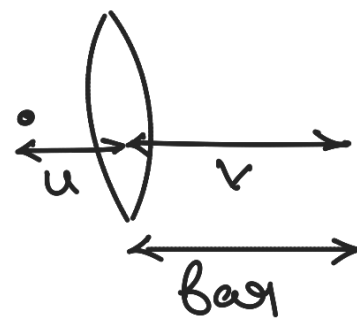
- When you press 'click' on phone. Shutter opens and light enters for fixed duration and shutter closes.
- In Camera : Focal length of lens does not change but distance between lens and photographic plate changes. lens moves to and fro.



Object is close
lens needs to move
close to plate.

$u = \text{more}$ $v = \text{less}$ $f = \text{fix}$

according to $\boxed{\frac{1}{v} - \frac{1}{u} = \frac{1}{f}}$



Object is far
lens needs to move
far from plate.

$u = \text{less}$ $v = \text{more}$ $f = \text{fixed}$

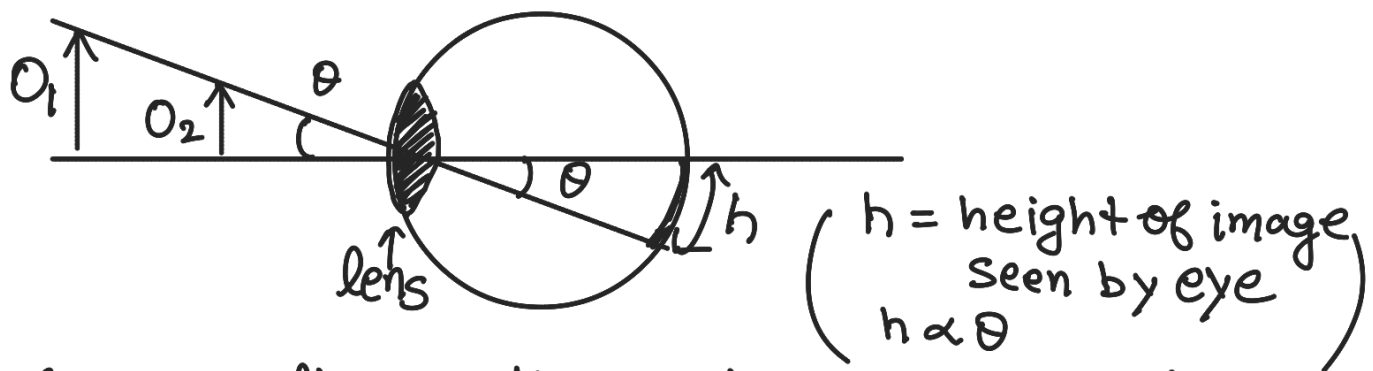
* Intensity of light entering lens $\propto \frac{1}{(f)^2}$

5. Simple Magnifier →

- Converging lens (convex lens) is used as magnifier.
- It forms virtual image much larger than original size.

Concept 1 : Size of an object

- We think Size of object is height of an object.
i.e. linear dimension.
- But our feeling of size is from image casted on our retina. It depends upon visual angle i.e. angle subtended by object on our retina.
That's why aeroplane at far distance away looks smaller.



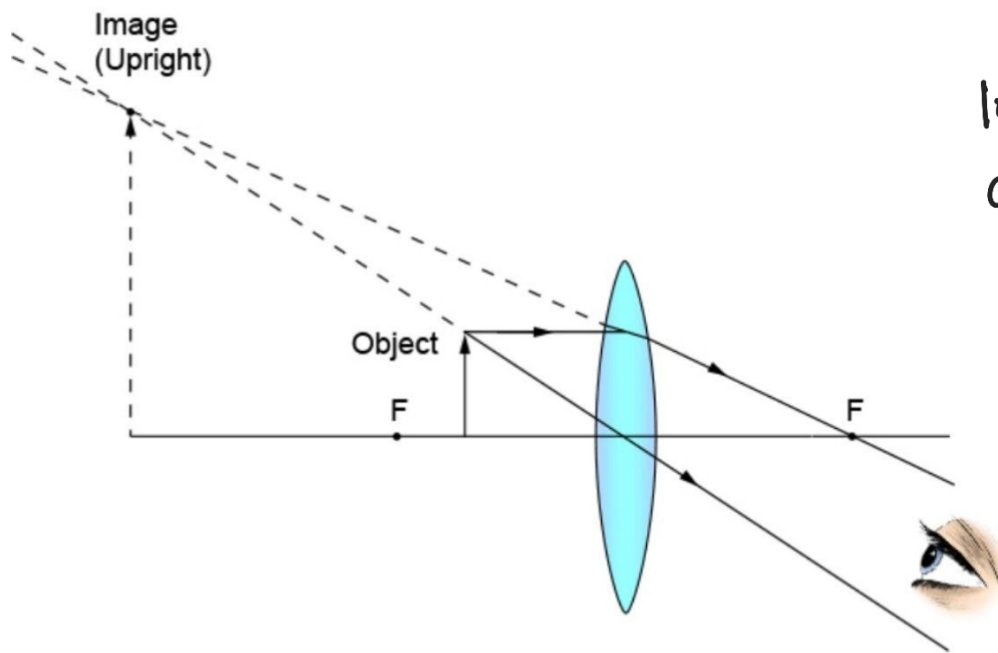
O_1 has more linear dimension than O_2 but both subtend same angles. Hence, to our eye both will appear of same size.

* Size of image on retina $\propto \theta$

* Closer Object = more θ

Farther object = less θ

Concept 2 : Image diagram of Convex lens



For Convex lens

Image is virtual and large.

if object is b/w lens and Focus.

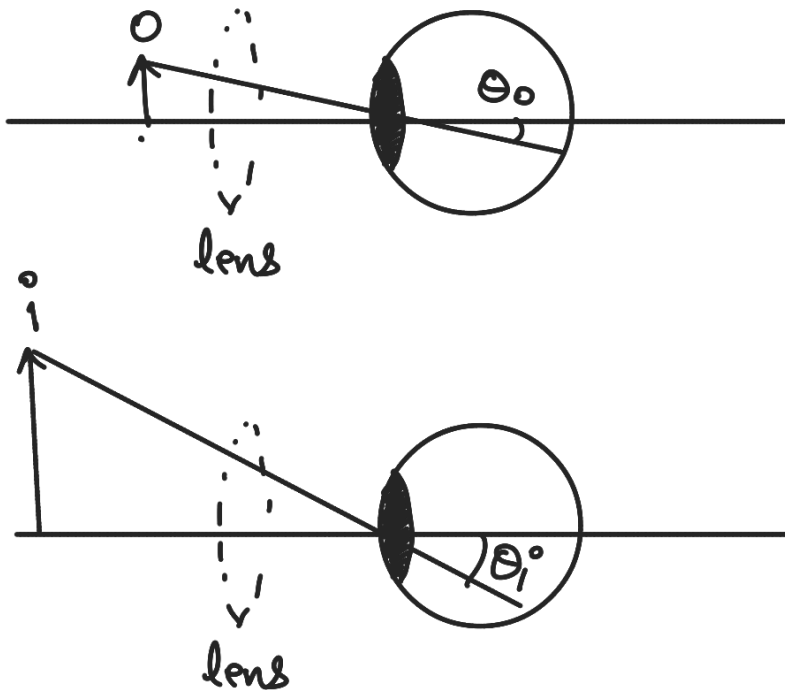
(magnifying glass)

- Light ray passes undeflected from O.
- Light ray which comes parallel to axis pass or appear to pass from Focus.
- Rays actually meet = real image

Rays appears to meet = virtual image

• $M = \text{Magnification} = \frac{\theta_{\text{image}}}{\theta_{\text{object}}}$ (angular magnification)

θ_{image} = angle image is making on retina



• $M = 1 + \frac{D}{f}$

D = least distance of distinct vision $\approx 25\text{cm}$.

f = focal length of magnifier (i.e. convex lens)

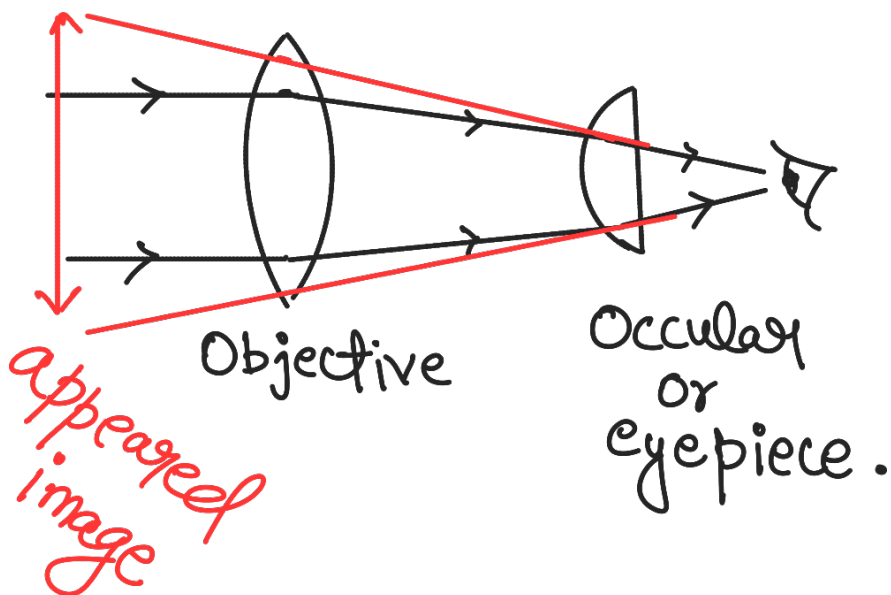
* Less focal length means more magnification

6. Objective and eyepiece →

- Magnifying power increase if focal length decrease.
- We can not reduce the focal length below a certain limit. Hence, to further increase magnifying power, two separate lenses are used.

(a) Objective lens (b) eyepiece or ocular

- Objective is placed near object. It forms real image of object. Eye piece is then used to further enlarge this image and form final Virtual image on eye.



* We will study different eyepieces.

7. Huygen Eyepiece →

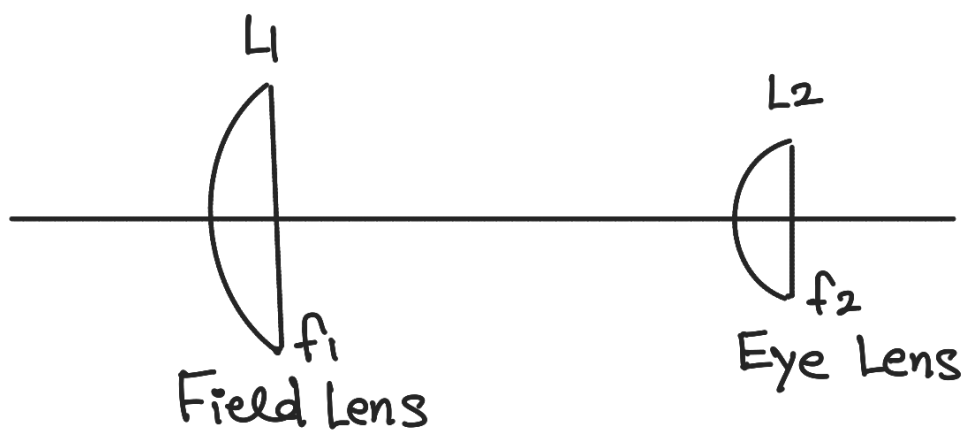
• Any eyepiece is made up of 2 lenses

a) Field lens

b) Eye lens

Why 2 lenses? → Avoid aberrations
→ Increase field of view
(field of view $\propto \frac{1}{\text{magnification}}$)

Important Facts about Huygen's eyepiece :



- 1) Focal lengths are in ratio 3:1 ($f_1 : f_2$)
- 2) Distance between them is equal to difference of their focal length.
- 3) Eye piece is free from spherical and Chromatic aberration. (Watch some reels to understand both).

4) D = distance b/w lenses

f_1 = focal length of lens 1

f_2 = " " " " 2

$$D = \frac{f_1 + f_2}{2} \quad \text{Condition to avoid Chromatic aberration}$$

$$= f_1 - f_2 \quad \text{" " " Spherical "}$$

both conditions are met in eye piece.

ex: $f_1 = 3f$ $f_2 = f$ $D = 2f$

* Both lenses produce equal deviation to rays.

5.) Equivalent Focal length :

$$\frac{1}{F} = \frac{1}{f_1} + \frac{1}{f_2} - \frac{D}{f_1 f_2}$$

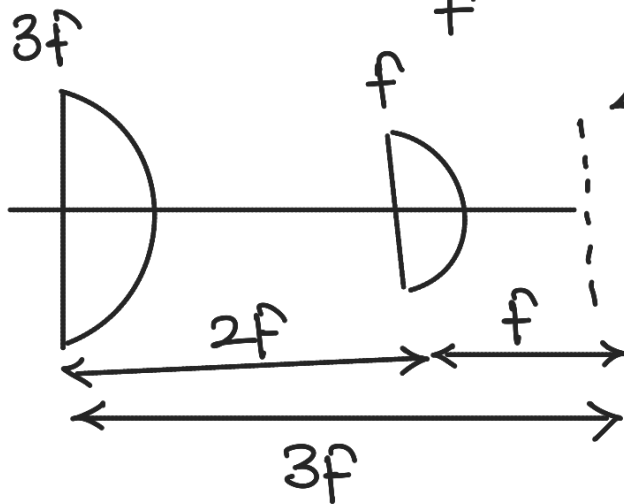
$$f_1 = 3f \quad f_2 = f \quad D = 2f$$

$$\frac{1}{F} = \frac{1}{3f} + \frac{1}{f} - \frac{2f}{3f^2} = \frac{2}{3f}$$

$$F = \frac{3f}{2}$$

6.) Equivalent lens position :

$$x = \frac{D \times F}{f} = \frac{2f \times \frac{3f}{2}}{f} = 3f$$



Place an equivalent lens here with focal length $3f/2$ (equivalent lens means it do the same thing which 2 combined lenses are doing)