SUBJECT	PHYSICS
PAPER NO & TITLE	Paper – II Optics
MODULE TITLE	Eye-pieces
MODULE TAG	DAYA_B.Sc.I_PHY_P-II_EP

Dr. S. G. Pawar

Assistant Professor,

Department of Physics

D.B.F. Dayanand College of Arts and Science, Solapur

Email: shaileshgpawar@gmail.com

D.B.F. Dayanand College of Arts and Science, Solapur

Department of Physics

Presented by: Dr. S. G. Pawar

CONTENT

Dr. S. G. Pawar, Department of Physics

1. Learning Outcomes

- **In this module,**
- You shall learn need of eye-piece.
- You shall learn about construction, working, spherical and chromatic aberration conditions, equivalent focal length and position of cross wires of:
  - Huygen's eye-piece
  - Ramsden's eye-piece
  - Gauss eye-piece

Dr. S. G. Pawar, Department of Physics

1.1 Introduction

- The eye-piece is one of the important parts of optical instruments.
- An optical instrument is required to produce a magnified image free from aberrations and a bright image covering a wide field of view.
- The single eye lens cannot produce such an image, so the extra lens called as field lens alongwith the eye lens is used in the eyepiece. The field lens and the eye lens together constitute an ocular or eyepiece. The two lenses are made and kept in such a way that their combination is achromatic and free from spherical aberrations.

Dr. S. G. Pawar, Department of Physics

1.2 Types of Eye-pieces

Depending on the purpose of use, the eye-pieces are designed in different ways.

There are mainly two types of eye-pieces:

(a) Positive eye-piece and (b) Negative eye-piece.

Positive eye-piece

Positive eye-pieces are provided with cross wires.

They are used for quantitative measurements like distance, angle etc.

The cross-wires are placed outside and infront of field lens.

e.g. Ramsden eyepiece, Gauss eye-piece.

Negative eye-piece

Cross wires are not used in negative eye-pieces.

They are used for structural studies like tissue structure, etc.

The cross wires are not used since they are not required in structural studies.

Huygen's eye-piece.

Dr. S.G. Pawar, Department of Physics

1.3 HUYGEN'S EYE-PIECE

Huygen's eye-piece consists of two plano-convex lenses having focal length in the ratio 3 : 1. The distance between them is equal to the difference between the focal lengths. If f is the focal length of the eye-lens then 3f will be the focal length of the field lens.

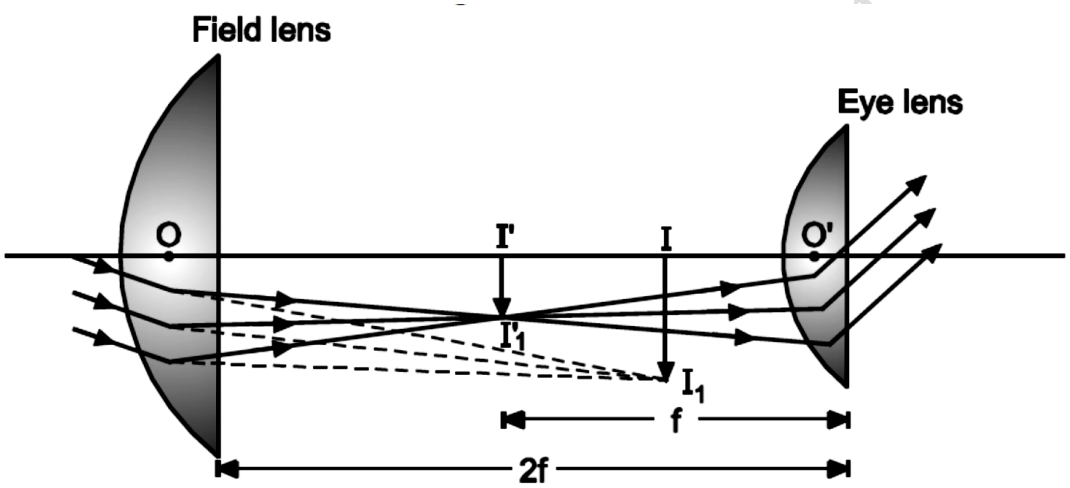

Fig. 2.1 : Huygen's eye-piece

II1 – Image of distant object formed by the objective in the absence of field lens.

I'I'1 – Image formed by field lens.

The image formed is at the focus of the eye-lens, hence image is seen at infinity.

It is a negative type of eye-piece in which both chromatic and spherical aberrations are minimised.

Now, check the conditions for achromatic combination and for minimum spherical aberration.

(i) *The condition for achromatic combination is that, the distance (d) between the lenses should be equal to the mean of their focal lengths.*

Here, the distance between the lenses is

$$3f - f = 2f \qquad \ldots (2.1)$$

and the mean of focal lengths is,

$$\frac{3f + f}{2} = \frac{4f}{2} = 2f \qquad \ldots (2.2)$$

Hence from equations (2.1) and (2.2), the condition for achromatic combination is satisfied.

(ii) *The condition for minimum spherical aberration is that two plano convex lenses facing towards the incident light must be kept apart with a distance equal to the difference in their focal lengths.*

Here, two plano convex lenses facing towards the incident light and the distance between the lenses is 3f – f = 2f.

Hence, the condition for minimum spherical aberration is also satisfied.

Dr. S. G. Pawar, Dept. of Physics

Equivalent focal length (F):

The focal length of the combination for the eye-piece is,

$$\frac{1}{F} = \frac{1}{f} + \frac{1}{3f} - \frac{d}{f \times 3f}$$

$$= \frac{1}{f} + \frac{1}{3f} - \frac{2f}{3f^2} \qquad \ldots (\square\ d = 2f)$$

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

$$F = \frac{3}{2} f \qquad \ldots (2.3)$$

Position of cross wires:

Cross wires cannot be used in the eye-piece. Because if the cross wires are to be used, they must be placed at $I'I'_1$ between the field lens and eye lens. Then cross wire will be viewed through eye-lens only and the distant object will be viewed through both the lenses. Therefore, magnification of the cross wire and object will not be in the same proportion. Hence, the relative lengths of the images will also be not in the same proportion.

Huygen's eye-piece is known as negative eye-piece, because the real inverted image (II_1) formed by the objective is behind the field lens and it acts as a virtual object for the eye lens. Therefore, this eye-piece cannot be used to examine directly an object or real image formed by the objective.

1.4 RAMSDEN'S EYE-PIECE

Ramsden's eye-piece consists of two plano-convex lenses each of focal length f separated by a distance equal to (2/3) f. The lenses are kept with their curved surfaces facing each other as shown in Fig. 2.2, thereby reducing spherical aberration.

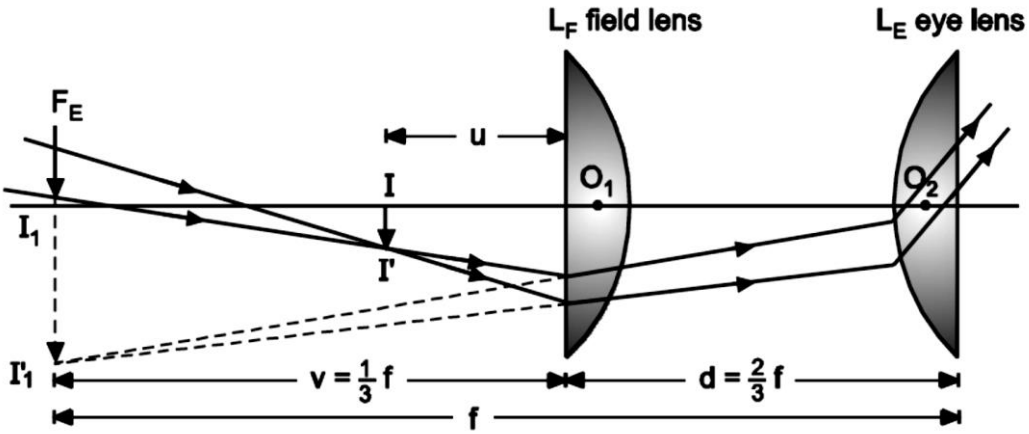

Fig. 2.2 : Ramsden's eye-piece

The objective forms the image II' of the object at I. This serves as an object for the field lens. It forms its virtual image I1I'1 at the focus FE of the eye-lens. Hence, distance between the eye lens and I1I'1 = f. The virtual image I1I'1 formed by the field lens acts as a virtual object for the eye lens. Hence,

eye lens forms the final image of the object at infinity. Therefore, the rays emergent from the eye lens are mutually parallel.

Equivalent focal length (F):

If F is the equivalent focal length of the combination of field lens and eye-lens then,

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

$$= \frac{1}{f} + \frac{1}{f} - \frac{(2/3)\,f}{f^2} = \frac{2}{f} - \frac{2}{3f} = \frac{4}{3f}$$

$$F = \frac{3}{4} f \qquad \ldots (2.4)$$

Position of cross wires:

Since $I_1O_2 = f$ and $O_1O_2 = \frac{2}{3} f$.

$\therefore$ For field lens,

$$I_1O_1 = v = f - \frac{2}{3} f = \frac{1}{3} f$$

and $$IO_1 = u$$

Here $v = -\frac{f}{3}$ on sign convention.

$\therefore$ From equation

$$\frac{1}{v} - \frac{1}{u} = \frac{1}{f} \text{ we get,}$$

$$-\frac{3}{f} - \frac{1}{u} = \frac{1}{f}$$

$$\therefore \quad -\frac{1}{u} = \frac{1}{f} + \frac{3}{f} = \frac{4}{f}$$

$$\therefore \quad u = -\frac{f}{4} \qquad \ldots (2.5)$$

Hence, the cross-wires must be arranged at the distance of f/4 from the field lens outside the eye-piece. Since the cross-wires are arranged outside the eye-piece on the field lens side, Ramsden's eye-piece is called a positive eye-piece.

The Ramsden's eye-piece has some chromatic aberration since the condition for achromatic combination is not satisfied. However, the spherical aberration is reduced because two plano convex lenses facing each other are used, but the condition for minimum spherical aberration is not satisfied.

Dr. S. G. Pawar, Department

1.5 COMPARISON BETWEEN HUYGEN'S EYE-PIECE AND RAMSDEN'S EYE-PIECE

Huygen's eye-piece	Ramsden's eye-piece
1. It is a negative eye-piece.	1. It is a positive eye-piece.
2. The image formed by the objective lies between the field lens and the eye lens.	2. The image formed by the objective lies infront of the field lens.
3. Cross wires cannot be used.	3. Cross wires can be used.
4. It cannot be used for quantitative measurements in microscopes and telescopes.	4. It is used for quantitative measurements in microscopes and telescopes.
5. The condition for minimum spherical aberration is satisfied.	5. The condition for minimum spherical aberration is not satisfied.
6. The condition for achromatic combination is satisfied.	6. The condition for achromatic combination is not satisfied.

Dr. S. G. Pawar, Department of Physics

1.6 GAUSS EYE-PIECE

Gauss eye-piece is the modification of Ramsden's eye-piece. The field lens and the eye-lens are two plano convex lenses of equal focal lengths and separated by the distance equal to two third (2/3) of focal length.

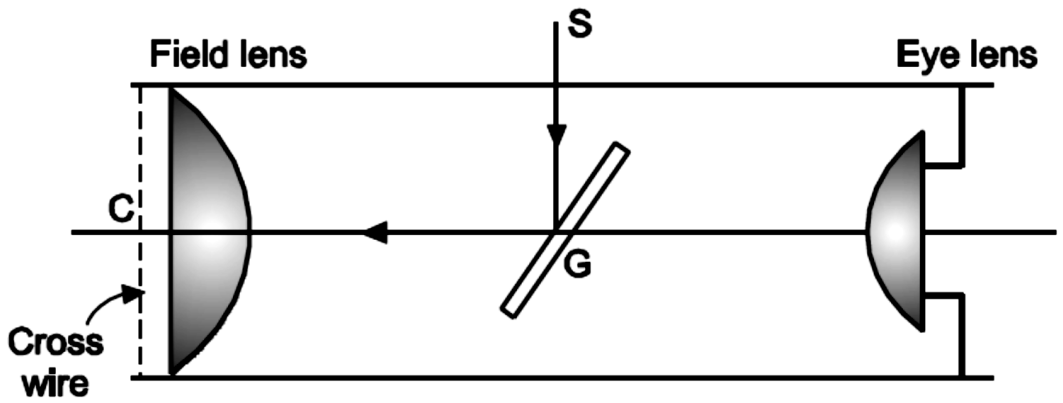

Fig. 2.3 : Gauss eye-piece

To illuminate the field of view, a glass plate G is held at an angle of 45° to the axis of the lens system. S is the source of light. Light reflected from G illuminates the field of view. The cross wires C are kept at a distance f/4 infront of the field lens. This eye-piece is used in the telescope of the spectrometer.

Dr. S. G. Pawar, Physics

1.7 SUMMARY

- The eye-piece is one of the important parts of optical instruments
- The eye-piece has two lenses: eye lens and field lens
- **Huygen's eye-piece:**
  - Negative type of eye-piece
  - The conditions for chromatic and spherical aberrations are satisfied
  - The equivalent focal length of is F = 3f/2
  - The cross wires cannot be used
- **Ramsden's eye-piece**
  - Positive type of eye-piece
  - The conditions for chromatic and spherical aberrations are not satisfied
  - The equivalent focal length of is F = 3f/4
  - The cross-wires must be arranged at the distance of f/4 from the field lens outside the eye-piece
- **Gauss eye-piece**
  - Gauss eye-piece is the modification of Ramsden's eye-piece
  - To illuminate the field of view with source of light, a glass plate is held at an angle of 45° to the axis of the lens system.

Dr. S. G. Pawar, Department of Physics

Exercise

1. The focal length of the eye lens in Huygen's eye-piece is 5 cm. Calculate (i) focal length of field lens, (ii) distance between the lenses, (iii) focal length of eye-piece.

Solution: Given: f = focal length of eye-lens = 5 cm.

(i) The focal length of field lens = 3f = 3 x 5 = **15cm**.

(ii) The distance between the lenses = d = 2f = 2 x 5 =**10 cm.**

(iii) The focal length of the eye-piece is,

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

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

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

$$\frac{1}{F} = \frac{2}{3 \times 5} = \frac{2}{15}$$

$$\therefore \boldsymbol{F = 7.5\ cm}$$

Dr. S. G. Pawar, Department of Physics

2. In Ramsden's eye-piece, two thin plano convex lenses are separated from each other by 8 cm. Calculate (i) the focal length of each lens, (ii) the position of the cross wires, (iii) the equivalent focal length.

Solution: Given: d = 8 cm.

If f = then

(i)Focal length of field lens and eyelens

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

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

$$f = \frac{3}{2} \times 8$$

$$\boldsymbol{f = 12\ cm}$$

(ii) The cross wires are kept at a distance of f/4 from the field lens.

$$x = \frac{f}{4}$$

$$x = \frac{12}{4}$$

$$\boldsymbol{x = 3\ cm}$$

(iii) Equivalent focal length F is given by

$$F = \frac{3}{4}f$$

$$= \frac{3}{4} \times 12$$

$$\boldsymbol{F = 9\ cm}$$

Homework

Multiple Choice Questions:

1. In Huygen's eye-piece the distance between two plano-convex lenses is ……

(a) f (b) 2f

(c) 2/3f (d) 1/3f

2. The equivalent focal length for Huygen's eye-piece is ……

(a) $\frac{3}{4}$ f (b) $\frac{3}{2}$ f

(c) $\frac{4}{3}$ f (d) $\frac{2}{3}$ f

3. Cross-wires cannot be used with …… eye-piece.

(a)Huygen's (b) Ramsden's

(c) Gauss (d) none of these

4. Ramsden's eyepiece is …… type of eyepiece.

(a)positive (b) negative

(c) single lens (d) zero

Dr. S. G. Pawar, Department of Physics

5. In Ramsden's eye-piece the two plano-convex lenses used have focal lengths in the ratio ……

(a) 3 : 1 (b) 1 : 1

(c) 2 : 3 (d) 3 : 2

6. Gauss eyepiece is a modification of …… eyepiece.

(a) Huygen's (b) Ramsden's

(c) Kellner's (d) Newton's

7. In …… eyepiece, a glass plate (G) is held at an angle of 45° to the axis of the lens system to illuminate the field of view.

(a) Huygen's (b) Ramsden's

(c) Gauss (d) Newton

Dr. S. G. Pawar, Department of Physics

Answer Key			
1. b	**2.** b	**3.** a	**4.** a
5. b	**6.** b	**7.** c	

D.B.F. Dayanand College of Arts and Science, Solapur

Department of Physics

Presented by: Dr. S. G. Pawar

References and Know More

1. Ray Optics by R. K. Verma

2. Text Book of Optics (new edition) – Brijlal and Subramanyam

3. Optics (second edition) – Ajay Ghatak

4. A Textbook for Optics (Nirali Prakashan) by R. N. Mulik 2017

Ctrl + Click Following links to Know More

https://www.youtube.com/watch?v=uWh_OicffO4

https://www.youtube.com/watch?v=C6xPN0VTr-w

Dr. S. G. Pawar, Department of Physics

Feedback

1) How was the learning experience?

Outstanding/ Excellent / Nice /Good/Fair

2) Which aspect do you like most?

Introduction/Concept/Diagrams/Exercise

3) Anything else to be added?

Applications/Problems/Illustrations/Notes/Videos

4) Which point was not up to the mark and need revision?

Introduction/Concept/Diagrams/Exercise

5) Suggestions if any:

……

Name of the student and class: ……

……..

Dr. S. G. Pawar, Department of Physics