Quadrant II – Transcript and Related Materials

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Name of the Presenter: Ms. Alysia Fernandes, Assistant Professor of Physics.
DCT's Dhempe College of Art's & Science, Miramar, Goa.

Notes

Objectives and Eyepiece:

The magnifying power of a simple microscope can be increased by decreasing the focal length of the lens. The focal length of the lens cannot be decreased beyond a certain limit. The lens of small length has a smaller diameter because the curvature of the surface is large and the field of view is small. Therefore, to increase the magnifying power two separate lenses are used. The lens near the object is called the objective which forms the rear image of an object under examination. The lens used to enlarge the image further to form a final image and which then viewed by the eye is called an eyepiece or ocular.

An optical instrument is required to produce a magnified image free from aberrations and a bright image covering a wide field of view. If a single lens is used as an eyepiece the final image will suffer from spherical and chromatic aberration. Another drawback is the small field of view which becomes lesser and lesser as the magnification of the instrument is increased. The rays passing through the outer portions of the image are refracted through the peripheral portions of the eye lens and they cannot simultaneously enter the small aperture of the pupil of the eye placed close to the eye lens.

Hence, only that part of the image, which is nearer to the axis will be seen. Therefore, the final image will cover a small field of view. The field of view will progressively decrease as the distance between the objective and ocular is increased. The distance is varied in order to increase the magnification. So, the greater the magnifying power of the instrument, the smaller the field of view. Therefore, we need an additional lens in the eyepiece to cause all the rays from the image to enter the eye lens. This extra lens is called a field lens. The function of the field lens is to gather in more of the rays from the objective towards the axis of the eyepiece. The field lens and the eye lens together constitute an ocular or eyepiece.

Kellner's Eyepiece:

It consists of two Plano-convex lenses of equal focal lengths. The distance between the two lenses is equal to the focal length of either lens. The convex surface of both the lenses faces the incident ray of light.

Let us look if the eyepiece is obeying the following conditions:

1. Condition for Achromatism: The distance between the two lenses for achromatism is $d = (f_1 + f_2)/2$
   Here if we say $f_1 = f_2 = f$ and substitute in the above formula we get, $d = f$.
   Thus, Kellner's eyepiece satisfies the condition for achromatism.
2. Condition for minimum spherical aberration: the distance between the two lenses for minimum spherical aberration is $d = f_1 – f_2$
   Where we get $d = 0$ if we follow the same as for achromatism. But the distance between the two lenses in Kellner's eyepiece is f. Thus, the eyepiece does not satisfy the condition for minimum spherical aberration.
3. Equivalent focal length: if we use the equivalent focal length formula and solve, we get the equivalent focal length of the eyepiece equal to the focal length of either lens.
4. Principal points: the first principal point lies at a distance f to the right of the field lens and the second principal point lies at a distance f to the left of the eye lens.
5. Focal points: the first focal point coincides with the pole of the field lens and the second focal point coincides with the pole of the eye lens.
6. Nodal points: as the lenses are in the air medium, the nodal points coincide with the principal points respectively. (N_1 with P_1 and N_2 with P_2)

Merits and demerits:

1. The field of view of the eyepiece is very large. Therefore, it may be used in the microscope and high-power telescopes.
2. As the eyepiece does not satisfy the condition of minimum spherical aberration, the defect is present.
3. The defect of distortion is produced.

Huygens Eyepiece:

In the Huygens eyepiece a converging beam enters the field lens and forms a virtual image before the eye lens. The need for a converging beam implies that this eyepiece does not act like a simple magnifier.

Construction:

Huygens eyepiece consists of two lenses having focal lengths in the ratio of 3:1 and the distance between them is equal to the difference in their focal lengths.

The eyepiece is free from chromatic as well as the spherical aberrations as it satisfies the two conditions simultaneously.

1. The distance between the two lenses for achromatism is $d = (f_1 + f_2)/2$
2. Condition for minimum spherical aberration: the distance between the two lenses for minimum spherical aberration is $d = f_1 – f_2$

Conclusion:

To satisfy the conditions for minimum chromatic and spherical aberrations, the focal length of the field lens should be three times the focal length of the eye lens and the distance between them should be equal to twice the focal length of the eye lens.

Equivalent focal length: if we use the equivalent focal length formula and solve, we get the equivalent focal length of the eyepiece at a distance of $3f – 2f = f$ behind the eye lens.

Principal points: The first principal point P_1 lies at a distance 3f from the field lens. The second principal point P_2 lies at a distance -f from the eye lens towards the field lens.

Focal points: The first focal point F_1 lies at a distance 3f/2 from the first principal point P_1, at a distance f/2 from the eye lens on the side of the field lens. The second focal point lies at a distance 3f/2 from the second principal point P_2 at a distance of f/2 from the eye lens away from the field lens.

Merits and Demerits:

1. The Huygens' eyepiece is fully free from chromatic aberration because the distance between the lenses is equal to half the sum of their focal lengths.
2. Spherical aberration is also minimum because the distance between the two lenses is equal to the difference of their focal lengths.
3. The field of view of this eyepiece is smaller than that of Ramsden's eyepiece.

Ramsden eyepiece:

Ramsden's eyepiece consists of two Plano-convex lenses each of focal length f separated by a distance equal to 2f/3. The lenses are kept with their curved surfaces facing each other as shown in the figure thereby reducing the spherical aberration. The field lens is a little larger than the intermediate image and is placed close to this image to allow as much light as possible to pass through it. The eye lens has a smaller diameter but carries out the actual magnification.

It does not satisfy the condition for achromatism but can be made achromatic by using an achromatic doublet as the eye lens.

Theory:

The objective forms the real inverted image I of a distant object. This serves as an object for the field lens, which gives rise to a virtual image I_1. I_1 in turn serves as an object for the eye lens which gives the final image at infinity, because I_1 is made to lie at its principal focus.

The equivalent focal length of the eyepiece can be found by using the equivalent focal length formula which is equal to 3f/4 and must be placed behind the field lens.

The principal points: the first principal point of the equivalent lens lies behind the field lens at a distance f/2. The second principal point lies behind the eye lens at a distance of f/2.

The Nodal points: As the lens system is situated in air, the nodal points coincide with the principal points. Thus, P_1 and P_2 are the nodal points, N_1 and N_2 respectively.

The focal points: The first focal point F_1 lies at a distance of 1f/4 to the lens of the field lens. The second focal point F_2 lies at a distance of f/4 behind the eye lens away from the field lens.