Experiment No. 4

Object : *To determine the resolving power of a telescope.*

Apparatus Required : A telescope provided with a variable slit, a cardboard coated lamp-black with equispaced and of equal width white strips drawn on it (or a blackened glass plate with equispaced and of equal width slits on it and a monochromatic light source such as sodium lamp), vernier callipers, travelling microscope and a metre scale.

Description of the Apparatus : Fig. 14 shows the experimental arrangement. It consists of an astronomical telescope T provided with a rectangular slit on its objective lens. The width of the slit can be changed with the help of a micrometer screw. The reading of the micrometer screw can be read on a main scale and a circular scale. The telescope is mounted on a vertical stand and is kept horizontally opposite to the cardboard (or the glass plate). If glass plate is used, it is illuminated by keeping the sodium lamp at its back.

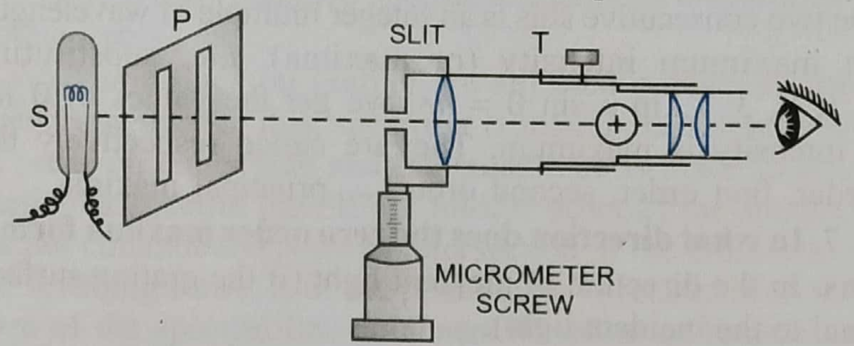

Fig. 14. Arrangement for resolving power of telescope

Theory : The resolving power of telescope is equal to the reciprocal of the angle subtended at the objective lens of the telescope by the two distant point objects when their images formed in the focal plane of telescope are just resolved.

In Fig. 15, A and B are the two distant objects. The light rays of wavelength λ from these objects are incident on the objective lens of telescope subtending an angle θ. After refraction, they form images A′ and B′ in its focal plane. From the diagram, it is clear that angular separation between principal maxima A′ and B′ is θ.

But from the theory of diffraction at a circular aperture, the angular spread of principal maxima $\alpha = \frac{1 \cdot 22\,\lambda}{d}$ where d is the diameter of circular aperture (or the objective of telescope).

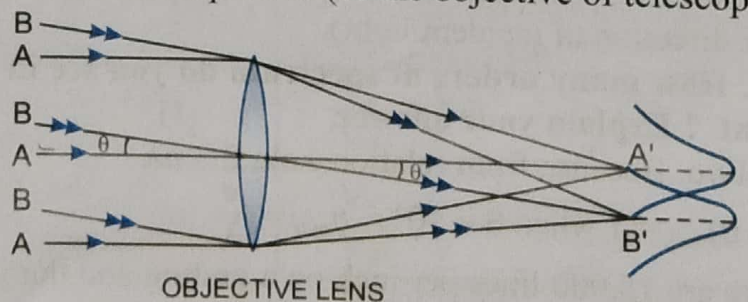

Fig. 15. Formation of images by telescope at just resolutions

According to Rayleigh criterion, for just resolution the principal maxima of image of one object must be at the minima of image of other object. *i.e.,*

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The angular separation between the two maxima

= Angular spread of principal maxima.

or $$\theta = \frac{1{\cdot}22\,\lambda}{d}$$

Hence resolving power of telescope $= \frac{1}{\theta} = \frac{d}{1{\cdot}22\,\lambda}$ ...(i)

Now if the width of slit mounted on the objective lens is a, when it just resolves the two strips at separation b on the cardboard (or on the glass plate) kept at a distance D, then

The angle subtended by the strips at the slit = b/D

Angular separation between the two principal maxima *i.e.*, the angular spread of principal maxima = λ/a

Hence, just at the limit of resolution,

$$\frac{\lambda}{a} = \frac{b}{D} \quad \text{or} \quad \lambda = \frac{ab}{D} \qquad ...(ii)$$

∴ From eqns. (i) and (ii), resolving power of telescope

$$\text{R.P.} = \frac{dD}{1{\cdot}22\,ab} \qquad ...(iii)$$

Knowing all the quantities in the above expression, the resolving power of telescope can be calculated.

Formula Used : Resolving power of telescope R.P.

$$= \frac{dD}{1{\cdot}22\,ab}\ \text{rad}^{-1}$$

where d = diameter of objective of telescope, D = distance of cardboard (or glass plate) from the objective of telescope, a = width of slit mounted on the objective of telescope in the position of just resolution, b = separation between the two strips drawn on the cardboard (or the glass plate).

Procedure : (1) The cardboard (or the glass plate) is clamped on a vertical stand such that the strips drawn on it are exactly vertical. If glass plate is used, it is illuminated by placing a sodium lamp at its back.

(2) The telescope is clamped horizontally on another vertical stand and is placed at a distance 4-5 metre from the cardboard (or the glass plate). Take care that the axis of telescope is horizontal and the height of telescope is in line with the strips drawn on the cardboard.

(3) Mount the rectangular variable slit on the objective of telescope such that the slit is vertical and parallel to the strips of the cardboard.

(4) Note the least count of the micrometer screw provided with the rectangular slit.

(5) Then open the rectangular slit completely and focus the telescope on the strips drawn on the cardboard so that the distinct image of strips is seen in the field of view. Now gradually decrease the width of the slit by the micrometer screw till the separate visibility of the two strips just disappears (*i.e.*, the two strips just appear as a single strip). Note the reading of micrometer screw in this position.

(6) The micrometer screw is rotated in the same direction till there is complete darkness in the field of view. The reading of micrometer screw is again noted. The difference in the two readings of the micrometer screw gives the width a of the rectangular slit in the position of just resolution of the two strips.

(7) Now the slit is completely closed and then opened gradually. As we get light in the field of view, the reading of micrometer screw is noted. Then the micrometer screw is turned in the same direction till the two strips just appear to be separated from each other (*i.e.*, the two strips just appear separately). Again the reading of micrometer screw

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is noted. The difference in the two readings of micrometer screw gives the width a of the rectangular slit in the position of just resolution of two strips.

(8) The experiment is repeated for the strips of different separation.

(9) The least count of travelling microscope is noted and then with its help, the distance b between the two consecutive strips on the cardboard (or on the glass plate) is measured. Note that this distance can also be measured with the help of metre scale if travelling microscope is not given.

(10) Note the least count and zero error of the vernier callipers and then with its help, find the diameter d of the objective lens of the telescope after removing the slit from it.

(11) Measure the distance D of the cardboard (or the glass plate) from the objective of telescope, using a metre scale (or a measuring tape).

Observations : (1) For the width a of the slit at just resolution :

Pitch of the micrometer screw = ... cm,

Total number of divisions on the circular scale = ...

Least count of micrometer screw

$$= \frac{\text{Pitch}}{\text{Total number of divisions on the circular scale}}$$

S. No.	Reading of micrometer screw while closing the slit gradually			Reading of micrometer screw while opening the slit gradually			Mean width of slit $a = \frac{a_1 + a_2}{2}$ (cm)
	When resolution just ceases x_1 (cm)	When field of view becomes dark x_2 (cm)	Width of slit $a_1 = x_1 \sim x_2$ (cm)	When light just enters the field of view x_1' (cm)	When resolution just starts x_2' (cm)	Width of slit $a_2 = x_1' \sim x_2'$ (cm)	
1.							
2.							
3.							

(2) For the separation b between the strips on the cardboard :

Value of one main scale division of travelling microscope x = ...cm

Total number of divisions on the vernier scale n = ...

Least count of travelling microscope = $\frac{\text{Value of one main scale division } x}{\text{Total number of divisions on vernier scale } n}$ = ... cm

S. No.	Reading of microscope						Separation between the two strips $b = y_1 \sim y_2$ (in cm)	ab (cm^2)
	Position of first strip			Position of second strip				
	M.S. reading (in cm)	V.S. reading (in cm)	Total reading y_1 (in cm)	M.S. reading (in cm)	V.S. reading (in cm)	Total reading y_2 (in cm)		
1.								
2.								
3.								

Mean value of ab = ... cm^2

(3) For the diameter d of objective of telescope :

Value of 1 main scale division on vernier callipers x = ...cm.

Total number of divisions on vernier scale n = ...

Least count of vernier callipers

$$= \frac{\text{Value of one main scale division } x}{\text{Total number of divisions on vernier scale } n} = \text{.....cm}$$

Zero error = ±.....cm

S.No.	M.S. reading (in cm)	V.S. reading (in cm)	Total reading = diameter d (in cm)
1. In one direction Along ⊥ direction			
2. In one direction Along ⊥ direction			
3. In one direction Along ⊥ direction			

Mean observed diameter d = ...cm

True diameter = Observed diameter – zero error (with sign)

= .....cm.

(4) Distance of cardboard from the objective of telescope

D = ...cm

(5) Wavelength of light used λ = ...Å = ...cm. (From standard tables).

(Remember that 10^{-8} cm = 1 Å).

Calculations : Substituting the mean value of ab and the values of d, D in the following expression, the resolving power can be calculated.

$$\text{Resolving power} = \frac{dD}{1 \cdot 22ab} = \text{.....rad}^{-1}$$

Result : Experimental value of resolving power of the given telescope

= .....rad^{-1}

$$\text{Theoretical value of resolving power} = \frac{d}{1 \cdot 22\lambda} = \text{.....rad}^{-1}$$

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Percentage error :

Percentage error

$$= \frac{\text{Experimental value} \sim \text{Theoretical value}}{\text{Theoretical value}} \times 100\%$$

$= .....\%$

Precautions : (1) The axis of telescope must be horizontal.

(2) The strips on the cardboard should be vertical.

(3) To avoid the backlash error, the micrometer screw must always be turned in one direction.

(4) The plane of the slit must be parallel to the cardboard.

(5) The width of slit at the position of just resolution must be adjusted carefully.

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