Viva Voce for μ by Spectrometer

Q. 1. What is refraction, laws of refraction and refractive index? How refractive index vary with wavelengths?

Ans. A. The bending of the light-ray from its path in passing from one medium to the other medium is called 'refraction' of light. If the refracted ray bends towards the normal relative to the incident ray, then the second medium is said to be 'denser' than the first medium (Fig. 1a). But if the refracted ray bends away from the normal, then the second medium is said to be 'rarer' than the first medium (Fig.1b).

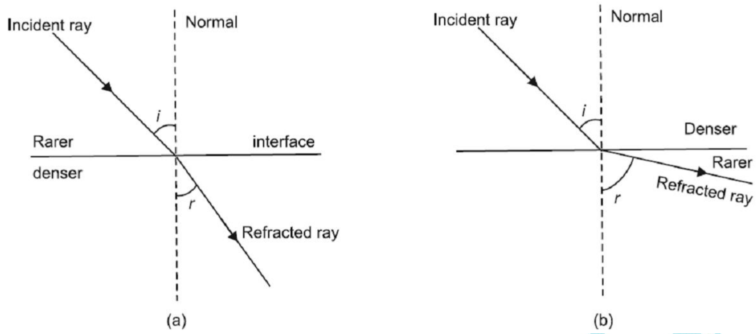

Fig.A1

B. The refraction of light takes place according to the following two laws known as the 'laws of refraction':

1. The incident ray, the refracted ray and the normal to the interface at the incident point all lie in the same plane.
2. For any two media and for light of a given colour (wavelength), the ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant.

If the angle of incidence is i and the angle of refraction is r, then $\frac{\sin i}{\sin r} = constant$

C. The ratio of the sine of the angle of incidence to the sine of angle of refraction is constant of any two media, i.e.,

$n = \mu = \frac{\sin i}{\sin r}$; where μ is a constant known as refractive index.

D. According to Cauchy's relation, we know that, $\mu = A + \frac{B}{\lambda^2}$, here A and B are constants. This relation indicates that Higher is the wavelength, smaller is the refractive index.

Q. 2. What is angle of minimum deviation?

Ans. The angle between incident and emergent ray (PQ and RS) for a prism is called as angle of deviation (FigA2). The angle of deviation is called as minimum angle of deviation when angle of emergence becomes equal to angle of incidence.

Note: For a given prism, the angle of deviation depends upon the angle of incidence of the light-ray falling on the prism. If a light-ray is allowed to fall on the prism at different angles of incidence (but not less than 30°) then for each angle of incidence the angle of deviation will be different. If we determine experimentally the angles of deviation corresponding to different angles of incidence and then plot i against δ, then we shall get a curve as shown in Fig. B2. It is seen from the curve that as the angle of incidence i increases, the angle of deviation first decreaes, becomes minimum for a particular angle of incidence and then again increases. Thus, for one, and only one particular angle of incidence the prism produces minimum deviation. The minimum angle of deviation is represented by δ_m. In the position of minimum deviation, the angle of incidence i and the angle of emergence i′ are equal and hence r=r′.

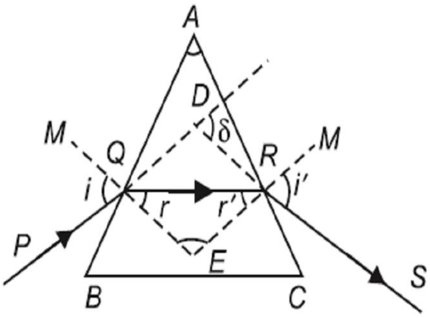

Fig.A2

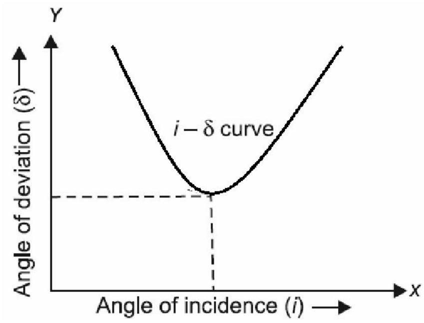

Fig.B2

Proof:

In Δ QDR, we have

$$\delta = \angle DQR + \angle DRQ$$
$$= (i - r) + (i' - r')$$
$$= (i + i') - (r + r') \qquad ...(1)$$

In the quadrilateral $AQER$, $\angle AQE$ and $\angle ARE$ are right angles. Hence the sum of the angles A and E is 180°.

$$A + E = 180^\circ$$

In Δ QER $\qquad r + r' + E = 180^\circ$

From these two equations, we have

$$\boxed{r + r' = A} \qquad ...(2)$$

Substituting this value of $r + r'$ in Eq (1), we have

$$\delta = i + i' - A \qquad ...(3)$$
$$i' = i, r' = r, \delta = \delta_m$$

Hence from the equations (2) and (3), we have

$$2r = A \text{ or } r = A/2$$

and $\qquad \delta_m = 2i - A$ or $i = (A + \delta_m)/2$

By Snell's law, $\qquad n = \dfrac{\sin i}{\sin r}$

Substituting the value of i and r, we get

$$n = \sin\left(\frac{A+\delta_m}{2}\right) \Big/ \sin\frac{A}{2}$$

Thus, knowing the angle of minimum deviation and the angle of prism, the refractive index of the material of the prism can be calculated.

If the prism is thin (i.e. its angle A is nearly 5° or less), δ_m will also be small and we can put.

$$\sin\frac{A+\delta_m}{2} = \frac{A+\delta_m}{2} \text{ and } \sin\frac{A}{2} = \frac{A}{2}$$

$\therefore$ $$n = \frac{(A+\delta_m)/2}{A/2}$$

or $$\boxed{\delta_m = (n-1)A}$$

It is clear from this expression that the deviation produced by a thin prism depends only upon the refractive index n of the material of the prism and the angle A of the prism. It does not depend upon the angle of incidence.

Q. 3. Is it essential in your experiment to place the prism in the minimum deviation position? If so, why?

Ans. Yes, it is essential because we obtain a bright and distinct spectrum and magnification is unity i.e. the distance of the object and image from the prism is same. The rays of different colours after refraction diverge from the same points for various colours.

Q. 4. Will the angle of minimum deviation change, if the prism is immersed in water?

Ans. Yes, the refractive index of glass in water is less than air hence angle of minimum deviation becomes less.

Q. 5. Does the angle of minimum deviation vary with the colour of light?

Ans. Yes, it is minimum for red and maximum for violet colour.

Q. 6. Does the deviation not depend upon the length of the base of the prism?

Ans. No, it is independent of the length of the base. By increasing the length of base, resolving power is increased.

Q. 7. What is dispersion and angular dispersion?

Ans. White light is a mixture of lights of different colours. When a beam of white light falls on a prism, it splits into the rays of its constituents colours. This phenomenon is called the 'dispersion' of light.

The reason for the dispersion is that in a material medium the light rays of different colours travel with different speeds although in vacuum (or air) rays of all colours travel with the same speed (3×10^8 m/sec). Hence the refractive index n of a material is different for different colour of light. In glass, the speed of violet light is minimum while that of red light is maximum. Therefore, the refractive index of glass is maximum for the violet light and minimum for the red light ($n_V > n_R$). Hence according to the formula $\delta_m = A(n-1)$, the angle of deviation for the violet light will be greater than the angle of deviation for the red light. When white light enters a prism, then rays of different colours emerge in different directions. The ray of violet colour bends maximum towards the base of the prism, while the ray of red colour bends least. Thus, white light splits into its constituent colours. This is 'dispersion'.

The angle between the emergent rays of any two colours is called 'angular dispersion' between those colours. If δ_R and δ_V be the angles of (minimum) deviation for the red and the violet rays respectively, then the angular dispersion between them is

$$\theta = \delta_R - \delta_V = A\,(n_V - n_R)$$

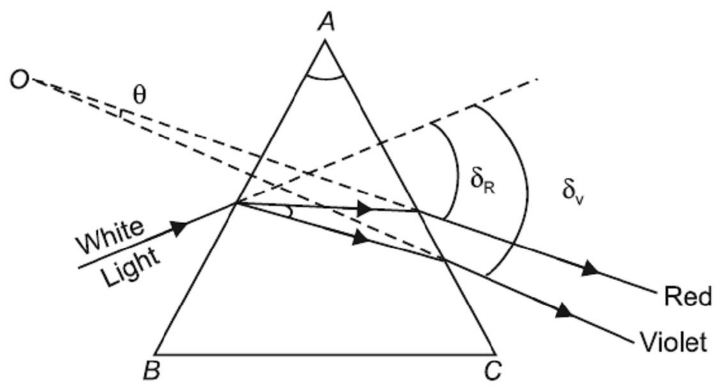

Fig.A7

Note: Higher is deviation, smaller is wavelength i.e. deviation for violet colour is most but wavelength is least.

Q. 8. What is dispersive power?

Ans. When white light passes through a thin prism, the ratio of the angular dispersion between the violet and red emergent rays and the deviation suffered by a mean ray (ray of yellow colour) is called the 'dispersive power' of the material of the prism. It is denoted by ω.

$$\omega = \frac{\delta_V - \delta_R}{\delta_Y} = \frac{n_V - n_R}{n_Y - 1}$$

The dispersive power depends only upon the material of the prism, not upon refracting angle of the prism. Greater is its value for a material, larger is the span of the spectrum formed by the prism made of that material. Dispersive power flint-glass is more than that of crown-glass.

Q. 9. What do you mean by spectrum, impure spectrum and pure spectrum?

Ans. An arrangement of radiation according to their wavelength or frequency is called as spectrum.

When a beam of white light coming from a slit S passes through a prism, it splits up into its constituent colours and form a colour band from red to violet on a screen. This colour band is called 'spectrum'. In this spectrum, the different colours are not distinctly separated, but mutually overlap. Such a spectrum is an 'impure spectrum'. The reason for the *impure spectrum is that the beam of light contains a large number of rays and each ray produces it own spectrum*.

Let the rays 1 and 2 form their spectra R_1V_1 and R_2V_2 respectively which overlap, as shown in FigA9. Clearly, the upper and lower edges of the composite spectrum are red and violet respectively, but in the middle part the colours are mixed.

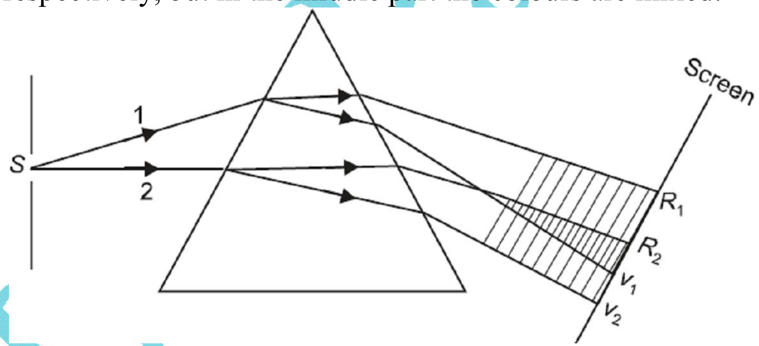

Fig.A9

A spectrum in which there is no overlapping of colours is known as pure spectrum. Each colour occupies a separate and distinct position. In practice, following conditions should be satisfied to obtain a pure spectrum.

(*i*) *The slit should be narrow:* Then only a few rays will fall on the prism and overlapping of colours will be reduced.

(*ii*) The rays falling on the prism should be parallel. Then all the rays will be incident on the prism at the same angle and rays of the same colour emerging from the prism will be parallel to one another which may be focussed at one point.

(*iii*) The rays emerging from the prism should be focussed on the screen by an achromatic convex lens. Then the rays of different colours will be focussed on the screen at different points.

(*iv*) The prism should be placed in minimum-deviation position with respect to the mean ray and the refracting edge of the prism should be parallel to the slit. Then the focusing of different colours at different points will be sharpest.

An arrangement for obtaining a pure spectrum is shown in Fig. B9

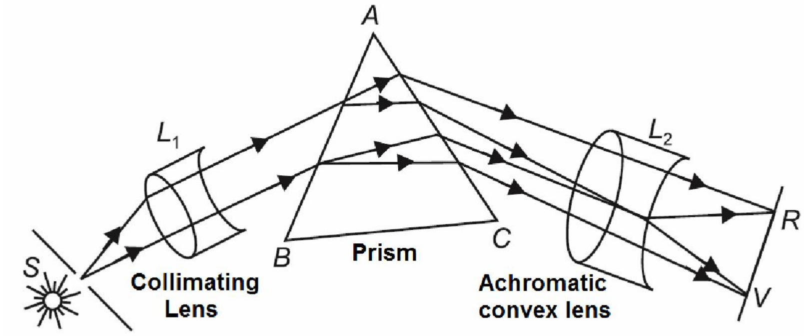

Fig.B9

All requirements for obtaining a pure spectrum are fulfilled in spectrometer (Fig.C9).

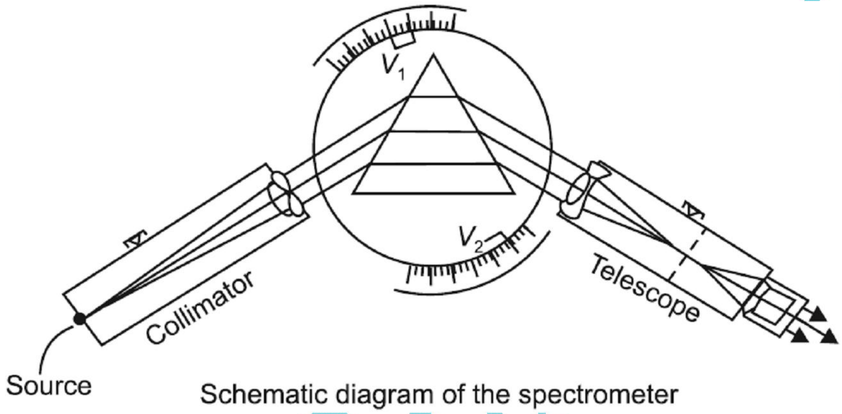

Fig.C9

Q.10 . Can you determine the refractive index of a liquid by this method?
Ans. Yes, the experimental liquid is filled in a hollow glass prism.
Q. 11. Which source of light are you using? Is it a monochromatic source of light?
Ans. Neon lamp or mercury lamp. It is not a monochromatic source of light. The monochromatic source contains only one wavelength.
Q. 12. Can you not use a monochromatic source (sodium lamp)?
Ans. Yes, we can use a sodium lamp but it will give only yellow lines and not the full specturm.
Q. 13. What is an eyepiece?
Ans. Eyepiece is a magnifier designed to give more perfect image than obtained by a single lens.
Q. 14. Which eyepiece is used in the telescope of a spectrometer?
Ans. Ramsden's eyepiece.
Q. 15. What is the construction of Ramsden's eyepiece?
Ans. It consists of two plano-convex lenses each of focal length f separated by a distance equal to $2f/3$.
Q. 16. What is the construction of Huygen's eyepiece?
Ans. It consists of two plano-convex lenses one having focal length $3f$ and other with focal length f and separated at distance $2f$.

Q. 17. What are chromatic and spherical abberration?
Ans. The image of white object formed by a lens is coloured and blurred. This defect is known as chromatic abberration. The failure or inability of the lens to form a point image of a axial point object is called spherical abberration.
Q. 18. How these two defects can be minimised?
Ans. The chromatic aberration can be minimised by taking the separation between two lenses [$d=(f_1+f_2)/2$] . The spherical aberration can be minimised by taking the separation as the difference of two focal lengths $d = (f_1 - f_2)/2$.
Q. 19. What is the main reason for which Ramsden's eyepiece is used with a spectrometer?
Ans. In this eyepiece, the cross wire is outside the eyepiece and hence mechanical adjustment and measurements are possible.
Q. 20. What is a telescope? What is its construction?
Ans. It is an instrument designed to produce a magnified and distinct image of very distinct object. It consists of a convex lens and eyepiece placed coaxially in a brass tube. The lens towards the object is called objective. This is of wide aperture and long focal length. Observations are made by eyepiece. This is fitted in a separate tube which can slide in main tube.
Q. 21. What do you mean by dispersive power? Define it.
Ans. The dispersive power of a material is its ability to disperse the various components of the incident light. For any two colours, it is defined as the ratio of angular dispersion to the mean deviation, i.e.

$$\omega = \frac{\delta_V - \delta_R}{\delta_Y} = \frac{n_V - n_R}{n_Y - 1}$$

Q. 22. On what factors, the dispersive power depends?
Ans. It depends upon (*i*) material and (*ii*) wavelengths of colours.
Q. 23. Out of the prism of flint and crown glasses, which one will you prefer to use?
Ans. We shall prefer a prism of flint glass because it gives greater dispersion.
Q. 24. What is a normal spectrum?
Ans. A spectrum in which angular separation between two wavelengths is directly proportional to difference of the wavelengths is called a normal spectrum.
Q. 25. Do you think that a prismatic spectrum a normal one?
Ans. No.
Q. 26. Can you find out the dispersive power of a prism with sodium light?
Ans. No, this is a monochromatic source of light.
Q. 27. How many types of spectra you know?
Ans. There are two main types of spectra: (*i*) emission spectra and (*ii*) absorption spectra.
Q. 28. What type of spectra do you expect to get from (*i*) an incandescent filament lamp (*ii*) sun light (*iii*) mecury lamp?
Ans. (*i*) continuous spectrum, (*ii*) band spectrum and (*iii*) Line spectrum.
Q. 29. What is difference between a telescope and microscope?
Ans. Telescope is used to see the magnified image of a distinct object. Its objective has large aperture and large focal-length. The microscope is used to see the magnified image of very near object. Its objective has small focal-length and aperture.

Q. 30. Without touching can you differentiate between microscope and telescope?
Ans. The objective of microscope has small aperture while the telescope has a large aperture.
Q. 31. What is that which you are adjusting in focussing the collimator and telescope for
parallel rays?
Ans. In case of collimator, we adjust the distance between collimating lens and slit while in case of telescope the distance between cross wires from the objective lens is adjusted.
Q. 32. What are these distances equal to when both the adjustments are complete.
Ans. The slit becomes at the focus of collimating lens in collimator and cross wires become at the focus of objective lens in telescope.
Q. 33. How can telescope and collimator be adjusted together?
Ans. (*i*) the prism is set in minimum deviation for yellow colour.
(*ii*) Prism is rotated towards telescope and telescope is adjusted to get a well defined spectrum.
(*iii*) Now the prism is rotated towards collimator and the collimator is adjusted to get well defined spectrum.
(*iv*) The process is repeated till the spectrum is well focussed. This is known as Schuster's method.
Q. 34. Why do you, often, use sodium lamp in the laboratory?
Ans. Sodium lamp is a convenient source of monochromatic light.
Q. 35. Do you know any other monochromatic source of light?
Ans. Red line of cadmium is also monochromatic source.
Q. 36. Why are two verniers provided with it?
Ans. Because one vernier will not give the correct value of the angle of rotation due to eccentricity of the divided circles with respect to the axis of the instruments. Two verniers eliminates this error.
Q. 37. Why are the lines drawn on the prism table?
Ans. With the help of these lines we can place the prism on the table in any particular manner. For example, when we measure the angle of the prism, we keep the prism such that it is at the centre of the table and one of its faces perpendicular to the line joining two of the levelling screws.
Q. 38. Why are the concentric circles drawn on the prism table?
Ans. These help us in placing the prism on the table such that axis of rotation of the table passes through the centre of the circumscribing circle of the prism.
Q. 39. Why is it necessary to place the prism on the table with the help of lines or circles?
Ans. Because, this minimises the error due to lack of parallism of the incident light.
Q. 40. What conclusion will you draw if the spectrum becomes rapidly worse in this process?
Ans. This means that the adjustments of the collimator and the telescope are being done in the wrong order.

