Determination of refractive index of a dispersing triangular prim for spectroscopic applications

Aim: Given the angle of the prism, aim of the experiment is to determine the angle of minimum deviation of the prism and hence calculate its refractive index.

Apparatus Required:

Spectrometer, Given Prism, Mercury Vapour lamp, etc.

Formula Used:

Refractive index (μ) of the prism is given by

$$\mu = \frac{\sin\frac{\alpha + \delta}{2}}{\sin\left(\frac{\alpha}{2}\right)}$$

where α is the angle of prism

δ is the angle of minimum deviation

Theory:

Refraction by a prism:

In a prism, the two surfaces are inclined at some angle α so that the deviation produced by the first surface is not annulled by the second but is further increased. The chromatic dispersion is also increased, which is the main function of the prism. Let us consider first the geometrical optics of the prism for a monochromatic light source.

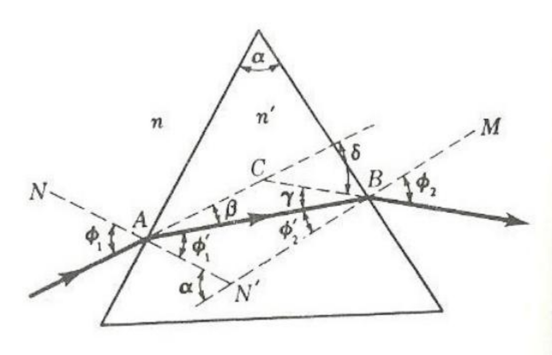


Fig. 1

The solid ray in fig. 1 shows the path of a ray incident on the first surface at the angle φ_1. Its refraction at the second surface, as well as at the first surface, obeys Snell's law, so that in terms of the angles shown

$$\frac{\sin \varphi 1}{\sin \varphi 1'} = \frac{n'}{n} = \frac{\sin \varphi 2}{\sin \varphi 2'}$$

The angle of deviation produced by the first surface is $\beta = \varphi 1 - \varphi 1'$, and that produced by the second surface is $\gamma = \varphi 2 - \varphi 2'$. The total angle of deviation δ between the incident and emergent rays is given by $\delta = \beta + \gamma$.

Since NN' and MN' are perpendicular to the two prism faces, α is also the angle at N'. From triangle ABN' and the exterior angle α, we obtain $\alpha = \varphi 1' + \varphi 2'$.

Combining the above equations, we obtain

$$\delta = \beta + \gamma = \varphi 1 - \varphi 1' + \varphi 2 - \varphi 2'$$

$$= \varphi 1 + \varphi 2 - (\varphi 1' + \varphi 2')$$

$$\delta = \varphi 1 + \varphi 2 - \alpha$$

Minimum Deviation:

When the total angle of deviation δ for any given prism is calculated by the use of the above equations, it is found to vary considerably with the angle of incidence. The angles thus calculated are in exact agreement with the experimental measurements. If during the time a ray of light is refracted by a prism, the prism is rotated continuously in one direction about an axis (A in fig.1) parallel to the refracting edge, the angle of deviation δ will be observed to decrease, reach a minimum, and then increase again as shown in fig. 2.

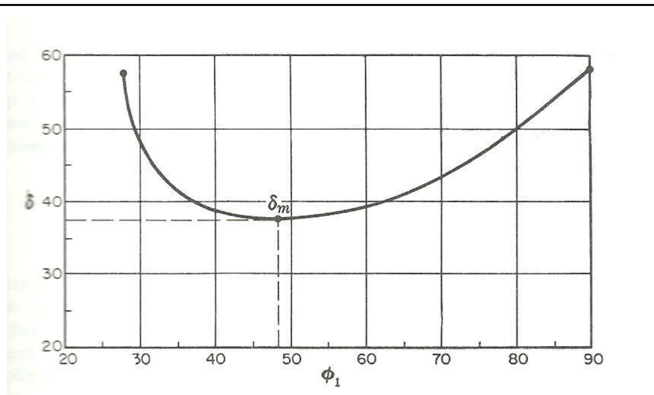


Fig. 2

The smallest deviation angle, called the angle of minimum deviation δ_m, occurs at that particular angle of incidence where the refracted ray inside the prism makes equal angles with the two prism faces (Fig. 3). In this special case,

$$\varphi 1 = \varphi 2; \qquad \varphi 1' = \varphi 2'; \qquad \beta = \gamma$$

To prove these angles equal, assume $\varphi 1$ does not equal to $\varphi 2$ when minimum deviation occurs. By the principle of the reversibility of light rays, there would be two different angles of incidence capable of giving minimum deviation. Since experimentally we find only one, there must be symmetry and the above equalities must hold.

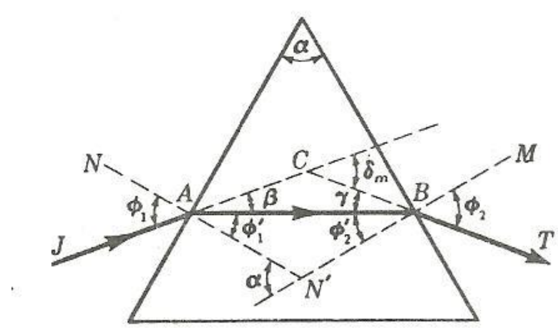


Fig. 3

In triangle ABC in fig. 3, the exterior angle δ_m equals the sum of the opposite interior angles $\beta + \gamma$. Similarly for the triangle ABN', the exterior angle α equals the sum of $\varphi 1' + \varphi 2'$. Consequently, $\alpha = 2\varphi 1'$; $\delta_m = 2\beta$; $\varphi 1 = \varphi 1' + \beta$

Solving these three equations for $\varphi 1$ & $\varphi 1'$ gives $\varphi 1' = (½)\alpha$ and $\varphi 1 = (½)(\alpha + \delta_m)$

Since by Snells's law $n'/n = (\sin\varphi 1)/(\sin\varphi 1')$, we have

$$n'/n = \sin[1/2\,(\alpha + \delta)]\,/\sin[1/2\,\alpha] = \mu$$

Here, for mathematical representation, δ is equated to δ_m

Procedure:

(a) Following **preliminary adjustments** should be made before starting any experiments with the spectrometer.

(i) ***Focusing the eyepiece on the cross-wires:*** The telescope is turned towards the wall and by looking through the eye-piece, its positions are adjusted till the vertical and horizontal cross-wires are seen most distinctly.

(ii) ***Adjusting the telescope for parallel rays:*** The telescope is then turned towards a distant object and by means of the rack and pinion arrangement, the length of the telescope is carefully adjusted till the image of the distant object coincides, without parallax, with the cross-wires.

(iii) ***Adjusting the collimator for parallel-rays:*** The telescope is then brought in line with the collimator. The slit is opened sufficiently wide and illuminated by any source of light. The image of the slit is viewed through the telescope, and the length of the collimator is adjusted till the clear, well-defined image of the slit coincides without parallax with the cross-wires. Since the telescope is already adjusted for parallel-rays, the well-defined image of the slit can be formed at the cross-wire, only if the rays of light from the slit falling on the telescope are parallel. The width of the slit is adjusted to make the image sharp.

(iv) ***Levelling the prism table:*** Spirit level is used to level the prism table. Spirit level is placed between the adjacent screws on any one side and then the screws are adjusted such that the liquid level stays in the centre of the spirit level. Same procedure is repeated by placing the spirit-level on the sides corresponding to other two adjacent screws. Finally, the liquid level should be in the centre of the spirit-level in all the sides.

(b) To determine the angle of minimum deviation:

Having made the preliminary adjustments, the given prism is mounted vertically on the prism table with the edge of the prism turned away from the collimator, as shown in the fig. 4. On looking through the prism in the proper direction, the refracted image of the slit is seen. The telescope is adjusted to obtain this image in its field of view. The prism table (and therefore also the prism) is then slightly rotated in either directions, with the view to finding out the direction in which the prism should be rotated in order to decrease the angle of deviation. The prism table is then slowly rotated in this direction, following the image with the telescope. In a particular position, the image is found to remain stationary for the same direction as before, to turn back and move in the opposite direction. The position where it just turns back is the minimum deviation position and the telescope is fixed in this position, and finer adjustments are made with the tangential screw for the exact position. The readings of the scale and vernier are taken. The prism is then removed. The telescope alone is then released, brought in a line with the collimator and the direct reading is taken. The difference between these two readings gives D, the angle of minimum deviation.

Having determined α & δ, the refractive index of the prism is calculated from the formula,

$$\mu = \frac{\sin\frac{\alpha+\delta}{2}}{\sin\left(\frac{\alpha}{2}\right)}$$

Experiment is repeated for **atleast three different wavelengths** and the refractive index of the prism is calculated corresponding to all these three wavelengths.

Result:

The Refractive index (μ) of the given prism is calculated to be …………

Tabulations:

Angle of prism =

(i) Wavelength of light =

Least count of spectrometer = 0.5°

	Vernier I			Vernier II		
	MSR	**VSC**	**TR**	**MSR**	**VSC**	**TR**
Reading of Refracted Image (i)						
Reading of Direct Ray (ii)						
Difference between (i) & (ii) (D)						
Mean Value of D						

Figure 4 - Schematic Representation for angle of minimum deviation

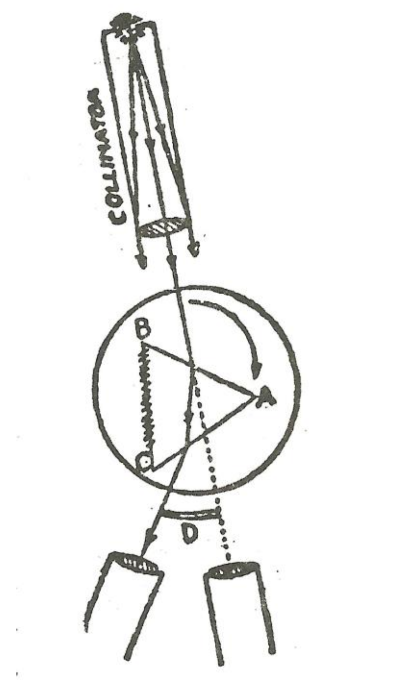
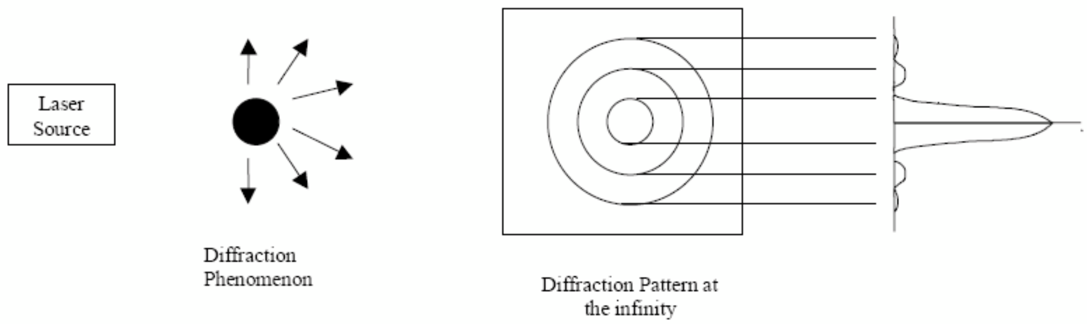


Fig. 4

DETERMINATION OF SIZE OF FINE PARTICLE USING LASER DIFFRACTION

Aim: To find particle size from laser diffraction pattern

Principle: This method is based on diffraction phenomenon and is based on Fraunhofer theory. When a particle is lightened by a monochromatic source (laser source), a diffraction pattern, called Airy`s pattern is obtained at the infinity.



This diffraction pattern gives the light scattering intensity (I), in the function of diffraction angle. It is composed of concentric rings. The distance between the different rings depends on the particle size. The size (***D***) of the particle is

$D=1.22\lambda d/r$, $D=2.23\lambda d/r$ and $D=3.23\lambda d/r$ respectively for first, second and third order of dark ring,

where λ is wavelength of source, ***d*** is distance between particle and the screen, r is the radius of the dark ring. The factor 1.22(resp. 2.23 and 3.23) is derived from a calculation (Bessel function) of the position of the first dark ring surrounding the central Airy disc of the pattern.

Assumptions:

1. Particles are spherical in nature and they do not absorb light
2. Particle diameter must be at least 3-5 times bigger than the λ –value (normally µm size)
3. The distance between 2 particles must be 3-5 times bigger than their diameter

Procedure:

1. Place the imprinted diameter screen at the edge of the measuring bench.
2. Keep the glass plate (having particle of uniform diameter dispersed on it) in between the laser source and screen.
3. Adjust the relative positions of laser and glass plate to get clear concentric circular rings of bright and dark fringes on the screen
4. For three different position of glass plate with respect to screen estimate the diameters of first and second order fringes

Data Table: To find the size of particle

Sl. No.	Order of diffraction	d (cm)	Diameter of dark ring (cm)	Radius of dark ring, r (cm)	Size of particle, D (μm)
1	1				
	2				
2	1				
	2				
3	1				
	2				

Mean D value =

Suggestion: It is better to adjust distance (d) to make one of the two dark rings match with imprinted diameter and make approximation in the size of diameter of other ring.

Result:

Interpretations:

Error estimation: Analysis should be done for diameter estimation by standard deviation process for one position of ***d*** and measuring diameter of first dark ring for at least for 10 times.

Electron Diffraction- deBroglie Wavelength

AIM:

To observe the diffraction of electrons on polycrystalline graphite and to confirm the wave nature of electrons.

To calculate and compare both the deBroglie's and Bragg's wavelength of

To calculate the kinetic energy of the electrons.

Apparatus Required:

- electron diffraction tube
- Tube holder
- High voltage power supply
- Analogue multimeter

Formula Used:

1. Bragg's wavelength

$$d\,\frac{D}{2L} = \lambda$$

d- the separation between two adjacent planes
D- diameter of the rings
L- distance between graphite target and fluorescent screen= 135mm

2. deBroglie's wavelength

$$\lambda =$$

Where m- mass of electron,
e - Charge of electron,
h- Planck's constant,
V- Applied voltage, kV.

3. Kinetic energy of the electron,

$$K = \frac{p^2}{2m} = eV$$

Where p, m and e are, respectively, the momentum, mass and charge of the electron

Theory:

In 1923, in his doctoral dissertation, Louis de Broglie proposed that all forms of matter have wave as well as particle properties, just like light. The wavelength, λ, of a particle, such as an electron, is related to its momentum, p, by the same relationship as for a photon:

$$\lambda = h/p \quad \text{----(1)}$$

where h is Planck's constant. The first experimental evidence of the existence of matter waves was obtained by Davisson and Germer in 1927. The wave properties of electrons are illustrated in this experiment by the interference when they are scattered from successive planes of atoms in a target composed of graphite microcrystals. The spacing between successive planes can be deduced from the interference pattern. When the beam of electrons strikes a family of parallel crystal atomic planes, each plane will reflect part of the waves. If the reflected waves from O and Q, as indicated in Figure 1, are to be in phase (interfere constructively), the path difference

$$PQ + QR = 2d \sin \theta \quad \text{----- (2)}$$

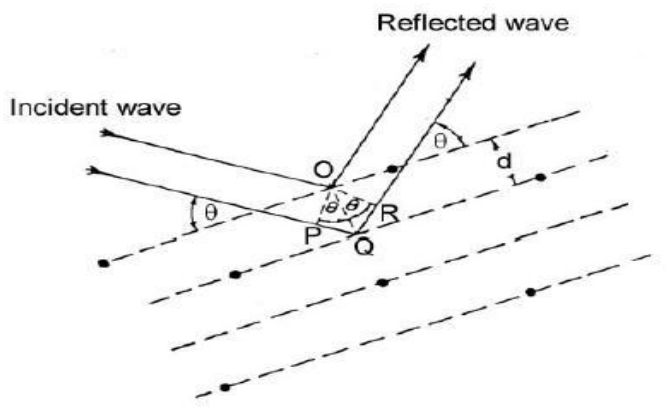


Figure 1: Diffraction from a single crystal.

must equal an integral number of wavelengths, or

$$2d \sin \theta = n\lambda \ (n = 1, 2, 3\ldots..) \quad \text{----------- (3)}$$

where d is the separation between two adjacent planes. Equation (3) is known as Bragg's law for constructive interference. For any incident angle other than those satisfying equation (3), there is no reflected beam because of destructive interference.

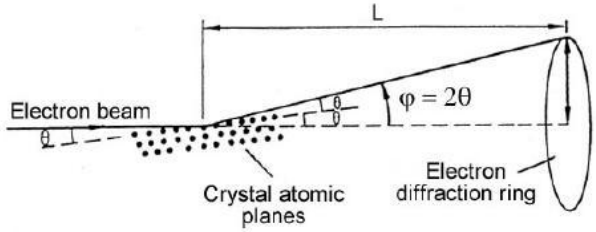


Figure 2: Diffraction from a large number of microcrystals.

In the graphite target, there are very many perfect microcrystals randomly oriented to one another. Therefore the strongly emerging beam will be of a conical shape of half angle 2θ as shown in Figure 2. If this beam falls on a phosphor-coated screen, rings of light will then be formed. Now, the condition for constructive interference becomes

$$2d\,\sin\left(\frac{\psi}{2}\right) = n\lambda \qquad \text{------------(4)}$$

which for small angles and first order diffraction (n = 1) becomes

$$d\,\frac{D}{2L} = \lambda \qquad \text{--------------(5)}$$

where D is the diameter of the diffraction ring and L is the distance from the graphite target to the luminescent screen.

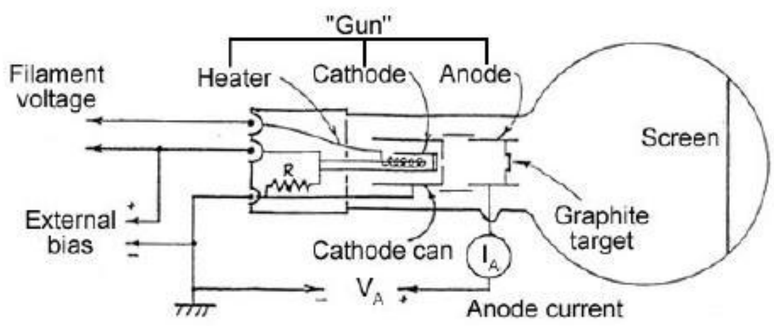


Figure 3: Schematic diagram of the electron diffraction tube.

This experiment uses Thomson's method for sending electrons through a thin film of graphite target to investigate the resulting ring diffraction pattern with the aid of Bragg's law. A schematic diagram for the apparatus is shown in Figure 3. Electrons emitted by thermionic emission from a heated filament (the cathode) are accelerated towards the graphite target (the anode) by a potential difference, V. Their kinetic energy, K, on reaching the target is equal to their loss of potential energy:

$$K = \frac{p^2}{2m} = eV \qquad \text{----------- (6)}$$

where p, m and e are, respectively, the momentum, mass and charge of the electron. Com- bining equations (1) and (6), the wavelength of the electrons is given by

$$\lambda = \frac{h}{\sqrt{2meV}} \qquad \text{---------- (7)}$$

With equation (7), equation (5) becomes

$$D\,\frac{d}{2L} = \frac{h}{\sqrt{2me}}\,\frac{1}{\sqrt{V}} \qquad \text{---------- (8)}$$

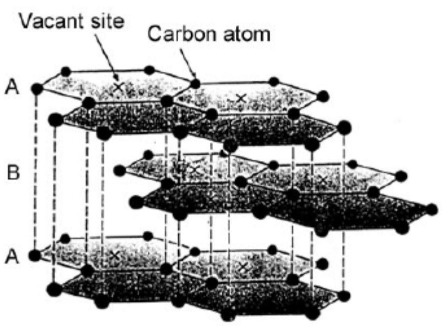


Figure 4: Atomic structure of graphite.

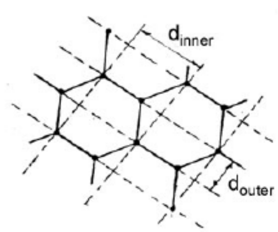


Figure 5: Parallel atomic planes responsible for the observations.

Graphite possesses a hexagonal sheet structure as shown in Figure 4. Each layer has strong internal bonds but weak bonds between layers which stack into crystals. The properties parallel and perpendicular to the sheets are markedly different. The two sets of parallel atomic planes responsible for our observation are all perpendicular to the sheets as shown in Figure 5. The interatomic distance is 0:142nm and all bond angles are 120°.

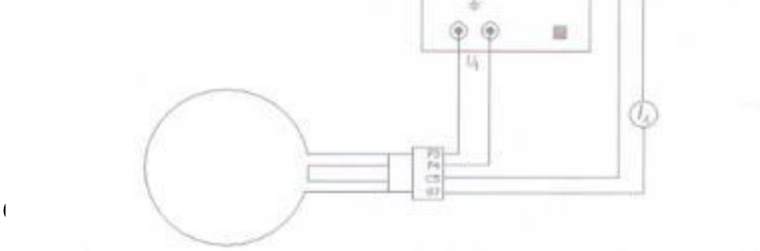


Fig:6 Circuit Diagram of the Electron Diffraction tube

Procedure:

1. Do the experimental set up as shown in figure 6.
2. Apply the heater voltage and wait about one minute for the heater temperature to achieve thermal stability.
3. Apply an anode voltage of 4kV
4. Two diffraction rings will be observed on the fluorescent screen centered on the undeflected beam in the middle.
5. Determine the outer diameter D of the two diffraction rings using a vernier caliper.What
6. Now repeat the same by changing the voltage by a difference of 0.5V.
7. Reducing the voltage will make the ring wider.Why?
8. The deBroglie wavelength is calculated by the formula

$$\lambda = \frac{\quad}{\quad}$$

Where m= mass of electron, e= charge of electron, h= Plancks constant, V- applied voltage.

Using the Braggs formula, wavelength can be calculated by the formula **nλ=2dsin**θ

If θ is small,and n=1 the Bragg's wavelength becomes,

$$\lambda = 2 \cdot d_{1/2} \cdot \sin\left(\frac{1}{2} \cdot \arctan\left(\frac{D_{1/2}}{2 \cdot L}\right)\right)$$

Outer diameter: d=0.213nm.

L= distance between graphite target and fluorescent screen= 135mm

To calculate deBroglie and Bragg’s wavelength of electrons.

S.No	Voltage(kV)		Diameter of the ring			Tan2θ=—	θ=– —	Braggs (λ),m	deBroglie (λ),m
			MSR mm	VSC	TR mm				
1.		Ring1 Ring2							
2.		Ring1 Ring2							
3.		Ring1 Ring2							

Result:

1. deBroglie wavength of electron =
2. Bragg’s wavelength of electron =
3. Kinetic energy of the electron =