

Experiment No. -----

Aim: To determine the wavelength of sodium light with diffraction grating.

Practical significance:

The experiment has great practical importance because it demonstrates one of the most accurate methods of measuring the wavelength of light. It helps students understand the wave nature of light and develops practical skills in using a spectrometer, taking precise angular measurements, and applying the diffraction grating equation.

The principles learned in this experiment are widely used in spectroscopy, optical communication, laser technology, astronomy, material analysis, and chemical testing. Diffraction gratings are key components of spectrometers and optical spectrum analyzers used in research laboratories, industries, and scientific instruments.

By performing this experiment, students gain both theoretical knowledge and hands-on experience that form the foundation for advanced studies in optics, photonics, and modern engineering applications.

Relevant Program Outcomes (POs):

- PO1 -Engineering Knowledge: Apply the principles of wave optics, diffraction, and interference to determine the wavelength of sodium light.
- PO2 – Problem Analysis: Analyze experimental observations and use the diffraction grating equation to calculate the wavelength accurately.
- PO5 – Modern Tool Usage: Use a spectrometer and diffraction grating effectively for precise optical measurements.
- PO9 (Individual and Team Work): Perform the experiment individually or collaboratively while following standard laboratory practices.
- PO10 – Communication: Present observations, calculations, graphs (if required), and conclusions clearly in the laboratory record and viva examination.

Relevant Course Outcomes (COs):

These are the specific objectives tied to first-semester Engineering Physics:

- Apply the concepts of wave optics—specifically interference and diffraction—to analyse optical phenomena and comprehend how light interacts with microscopic structures.

Practical Learning Outcomes

- Understand the principle of diffraction and interference of light.
- Explain the working of a diffraction grating.
- Measure diffraction angles accurately using a spectrometer.
- Apply the grating equation $n\lambda = d \sin\theta$.
- Calculate the wavelength of sodium light experimentally.
- Compare experimental results with standard values and analyze errors.

Practical Skills Developed: -

1. Experimental Measurement Skills: Develop the ability to measure diffraction angles accurately and determine the wavelength of sodium light using a diffraction grating and spectrometer.

2. Observation and Data Recording Skills: Learn to carefully observe diffraction spectra, record vernier readings systematically, and maintain accurate experimental data in the observation table.

3. Analytical and Calculation Skills: Apply the diffraction grating equation to calculate the wavelength of sodium light, analyze the experimental results, and compare them with the standard value.

4. Laboratory Instrument Handling Skills: Gain hands-on experience in handling and aligning the spectrometer, diffraction grating, sodium vapour lamp, and other optical accessories with proper laboratory techniques.

5. Scientific Reporting Skills: Improve the ability to prepare a well-organized laboratory record by presenting observations, calculations, results, precautions, and conclusions in a clear scientific format.

6. Teamwork and Communication Skills: Develop teamwork by performing the experiment collaboratively, sharing responsibilities, discussing observations, and effectively communicating the experimental findings during viva and laboratory discussions.

Relevant Affective Domain Outcomes: -

- **Receiving:** - Demonstrate attentiveness to laboratory instructions, safety precautions, and the correct experimental procedure.
- **Responding:** - Actively participate in performing the experiment, recording observations, and discussing the experimental results.
- **Valuing:** - Appreciate the importance of accurate measurements, ethical data recording, and careful handling of laboratory equipment.
- **Organization (Partially Developed):** - Develop a positive attitude toward maintaining discipline, teamwork, and systematic laboratory practices during experimental work.

Theoretical Background: -

A diffraction grating is an optical device consisting of a large number of equally spaced parallel slits (or lines). When monochromatic light passes through these slits, each slit acts as a source of secondary wavelets according to Huygens' principle. These waves interfere with each other, producing a pattern of bright and dark fringes known as a diffraction pattern.

Constructive interference (bright fringes) occurs when the path difference between light waves from adjacent slits is an integral multiple of the wavelength.

Mathematically, the condition for principal maxima is:

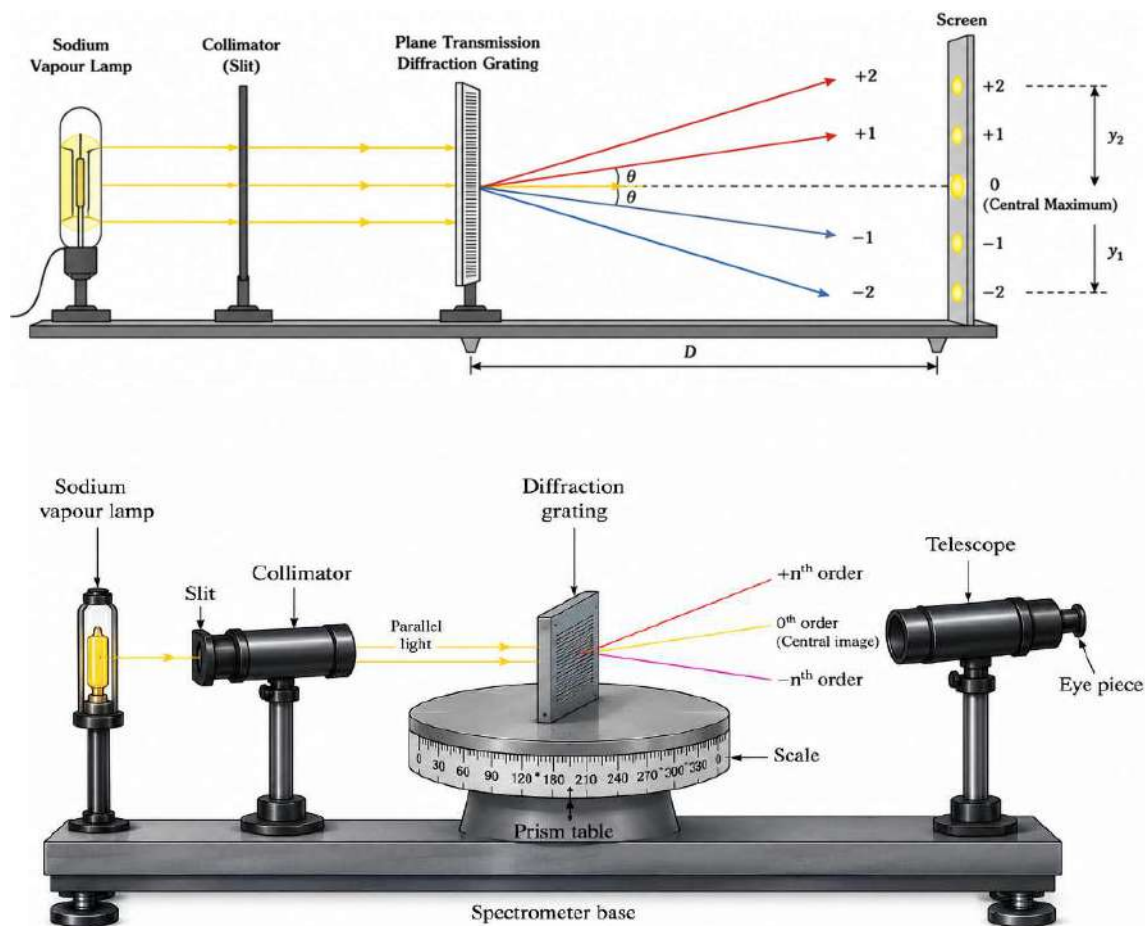
$$d \sin \theta = n \lambda$$

where,

- d = grating element (distance between the centres of two adjacent slits),
- θ = angle of diffraction,
- n = order of diffraction spectrum.
- λ = wavelength of light.

Therefore, $\lambda = \frac{d \sin \theta}{n}$

Experimental Setup: -



Experimental setup for determination of wavelength of sodium light using a diffraction grating and spectrometer

Resources Required: -

S.No.	Name of Apparatus	Specifications	Quantity
1.	Spectrometer	Standard	1
2.	Diffraction Grating	15,000 LPI	1
3.	Sodium Lamp	Monochromatic	1
4.	Magnifying Glass	-	1
5.	Spirit Level	-	1

Precautions: -

Careful experimentation greatly improves the accuracy of the result. Follow these precautions:

1. Keep the spectrometer properly leveled.
2. Focus the telescope and collimator accurately.
3. Use a narrow slit for a sharp spectrum.
4. Avoid touching the ruled surface of the diffraction grating.
5. Keep the grating perfectly vertical.
6. Remove parallax before taking readings.
7. Record both left and right readings carefully.
8. Read the vernier scale without estimation errors.
9. Repeat observations for better accuracy.
10. Perform the experiment in a dimly lit laboratory.

Procedure

1. Arrange the sodium vapour lamp, diffraction grating, and optical bench as shown in the experimental setup.
2. Switch on the sodium vapour lamp and allow it to warm up for a few minutes to obtain a stable yellow monochromatic light.
3. Mount the diffraction grating vertically on the optical bench and ensure that light from the sodium lamp falls normally on it.
4. Use the spirit level and the levelling screws to make the grating table horizontal.
5. Observe the central maximum and the diffraction maxima formed on both sides of it.
6. Rotate the telescope from the central (zero-order) maximum towards the left. You will see the first bright yellow image of the slit — this is the **1st order maximum ($n = 1$)** on the left side.
7. Bring the cross-wire exactly on this image and note the angle reading on both verniers (V_1 and V_2).
8. Rotate the telescope to the right and similarly find the 1st order maximum on the right side. Record its angle.
9. Continue rotating further right (and left) to find the **2nd order maximum ($n = 2$)** on both sides. Record all readings.

10. Calculate the diffraction angle (θ) using the measured angular positions.

11. Determine the wavelength of sodium light using the grating equation.

Observation Table:

Least count of vernier scale -

Order of Spectrum	Vernier	Spectrum Left of Direct Image			Spectrum Right of Direct Image			$2\theta = \theta_2 - \theta_1$	θ
		MSR	VSR	Total θ_1	MSR	VSR	Total θ_2		
1	V_1								
	V_2								
2	V_1								
	V_2								

Calculation: -

1. Determination of the grating element (d):

$$N * d = 1 \text{ inch} = 2.54 \text{ cm}$$

$$d = 2.54 / N \text{ cm} \quad (N=15000)$$

$$d = 1.69 \times 10^{-4} \text{ cm}$$

2. Determination of Wavelength (λ)

$$\text{Since, } \lambda = d \sin \theta / n$$

• For First Order (n = 1):

$$\lambda_1 = \dots\dots\dots \text{ cm}$$

$$\lambda_1 = \dots\dots\dots \text{ \AA}$$

• For Second Spectrum (n = 2):

$$\lambda_2 = \dots\dots\dots \text{ cm}$$

$$\lambda_2 = \dots\dots\dots \text{ \AA}$$

• Mean wavelength:

$$\text{Mean } \lambda = (\lambda_1 + \lambda_2) / 2 = \dots\dots\dots \text{ \AA}$$

Result: -

The mean wavelength of sodium light = Å

Interpretation of Result:

$$\% \text{ Error} = \frac{\text{Calculated Value} - \text{Standard Value}}{\text{Standard Value}}$$
$$= \dots\dots\dots$$

Conclusion:

The wavelength of sodium light was successfully determined using a diffraction grating and spectrometer. The experiment verified the principles of diffraction and interference of light and demonstrated the practical application of the grating equation for wavelength measurement.

The observations obtained were consistent and satisfactory, showing that a diffraction grating is an accurate and reliable optical instrument for determining the wavelength of monochromatic light. This experiment also enhanced understanding of wave optics and improved skills in handling precision optical instruments.

Recommendations:

- Proper alignment of the spectrometer and diffraction grating should be ensured before taking observations.
- The sodium vapour lamp should be allowed to warm up adequately to obtain a stable monochromatic light source.
- Readings should be taken on both sides of the central maximum and their mean value should be used for calculations.
- Care should be taken to avoid parallax errors while observing and recording vernier readings.
- The diffraction grating should be handled carefully and kept free from dust, fingerprints, and scratches.

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