THE NEOTIA UNIVERSITY

WORK INSTRUCTION

1.0 EXPERIMENT NO: BO/02
2.0 NAME OF EXPERIMENT: Laser Diffraction
3.0 OBJECTIVE: Determination of wavelength of monochromatic light by laser diffraction method
4.0 THEORITICAL BACKGROUND:

(A) **What is diffraction?**

When a light passes through a small aperture whose dimensions are comparable with the ‘λ’(wavelength) of light then light deviates from its rectilinear path and bends round the corner of the placed aperture of its geometrical shadow, this phenomenon is called ***diffraction***.

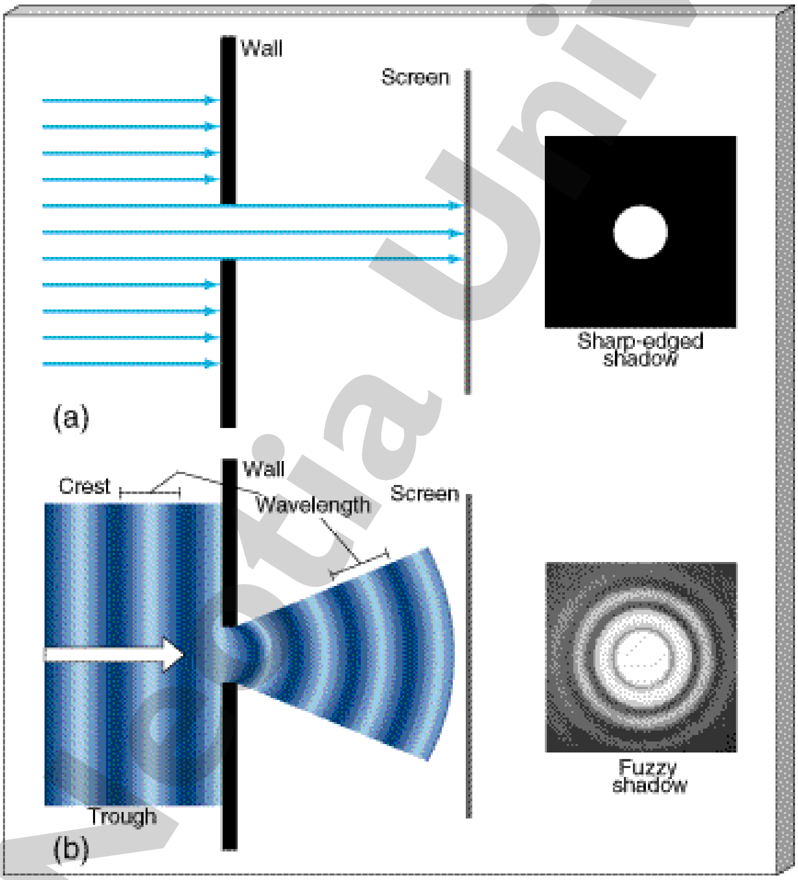


Figure 1.

If the source and the screen are placed effectively at infinite distance from the diffracting element it forms a class of **Fraunhoffer** diffraction and if the source and screen are placed at finite distance then **Fresnel**’s class observed.

(B) What is grating?

A diffraction grating consists of a number of closely spaced parallel lines ruled on a glass surface. A diffraction grating can be simply thought of as a set of identical and equally spaced slits separated by opaque strips. In reality gratings are made by ruling fine grooves by a diamond point either on a plane glass surface to produce a transmission grating or on a metal mirror to produce a reflection grating (see figure 2). In a transmission grating the grooves scatter light and so are opaque while the unruled surfaces transmit and act like slits. Typically a high quality grating (used for studying spectra in the visible range) has about 15000 grooves per inch, which gives a slit spacing of the order of a micron.

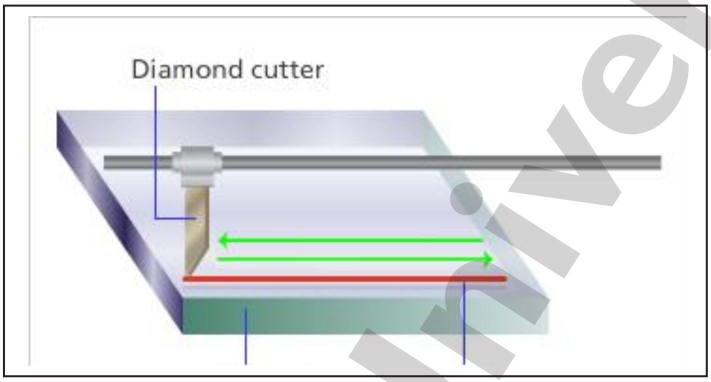


Figure 2: Construction of grating

It is a useful device for separating out the various wavelengths in a spectrum. It has the same effect as a prism but with greater resolving power (see fig. 3).

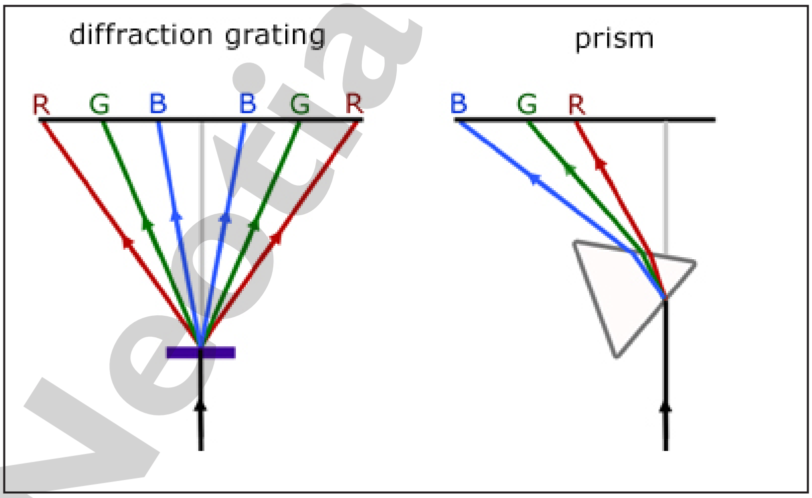


Figure 2.

(C) LASER :

(D) A **laser** (from the acronym ***L****ight* ***A****mplification by* ***S****timulated* ***E****mission of* ***R****adiation*) is an optical source that emits photons in a coherent beam. Laser light is typically near-monochromatic, i.e., consisting of a single wavelength or color, and emitted in a narrow beam. This is in contrast to common light sources, such as the incandescent light bulb, which emit incoherent photons in almost all directions, usually over a wide spectrum of wavelengths (see fig 3.).

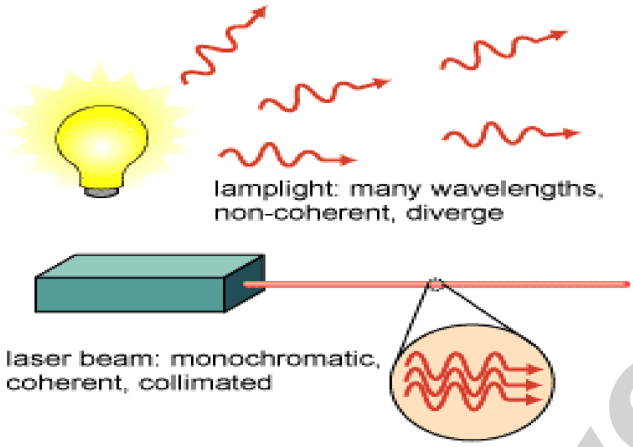


Figure 3

Lasers are finding ever increasing military applications -- principally for target acquisition, fire control, and training. These lasers are termed rangefinders, target designators, and direct-fire simulators. Lasers are also being used in communications, laser radars (LIDAR), landing systems, laser pointers, guidance systems, scanners, metal working, photography, holography, and medicine.

Basic operation of a HE-Neon LASER:

Any LASER have three components

- Lasing material (crystal, gas, semiconductor, dye, etc...)
- Pump source (adds energy to the lasing material , e.g. flash lamp, electrical current to cause electron collisions, radiation from a laser, etc.)
- Optical cavity consisting of reflectors to act as the feedback mechanism for light amplification

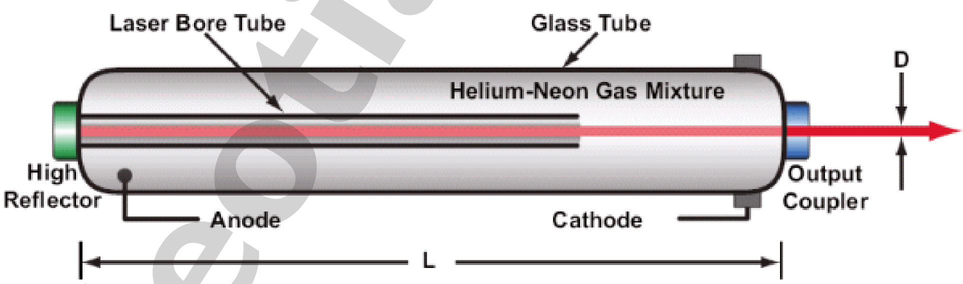
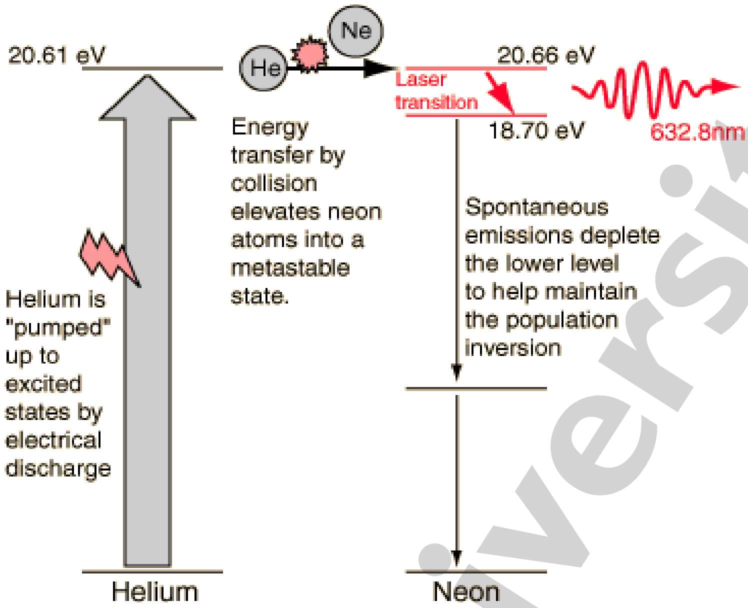


Figure 3: Typical construction of a He-Neon Laser

Basic operation of a helium Neon Laser has been shown in the figure below



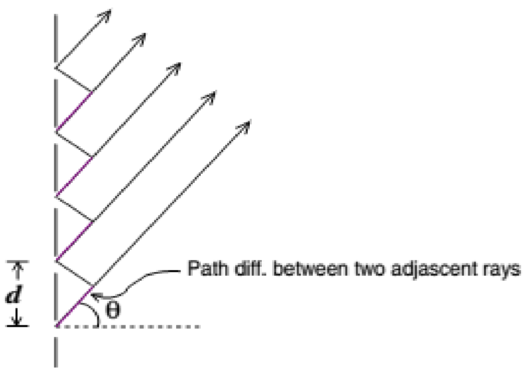
Types of Lasers

There are many different types of lasers. The laser medium can be a solid, gas, liquid or semiconductor. Lasers are commonly designated by the type of lasing material employed:

- **Solid-state lasers-** have lasing material distributed in a solid matrix such as the ruby or neodymium:yttrium-aluminum garnet "Yag" lasers.
- **Gas lasers-** have lasing material as gas such as Helium and helium-neon, CO_2 lasers.
- **Excimer lasers** use reactive gases, such as chlorine and fluorine, mixed with inert gases such as argon, krypton or xenon. When electrically stimulated, a pseudo molecule (dimer) is produced.
- **Dye lasers** use complex organic dyes, such as rhodamine 6G, in liquid solution or suspension as lasing media.
- **Semiconductor lasers**, sometimes called diode lasers, are not solid-state lasers. These electronic devices are generally very small and use low power. They may be built into larger arrays, such as the writing source in some laser printers or CD players.

(E) Determination of wavelength of monochromatic light by Laser diffraction method

Consider a plane wavefront incident on a grating surface. Portions of the wavefront falling on the slits will be transmitted through the grating. Now each point on a wavefront falling on a slit will act as a source of secondary wavefront.



Rays coming out from these points interfere with each other producing a diffraction pattern on a viewing screen placed behind the grating. Moreover, beams coming from different slits also interfere with each other producing a net intensity distribution of light which is resultant of both the diffraction effect due each single slit and interference effect due to all the N slits. Now consider a setting in which the viewing screen is placed at 'large distance' from the grating (Fraunhoffer diffraction class) so that the interfering rays can be considered almost parallel (Fig. 1). Consider parallel rays emerging at an angle θ with the horizontal line from identical points in each slit as shown in Fig. 1. The path difference between two such adjacent rays will be 'd sinθ', where 'd' is the distance between two slits. It can shown that the intensity of the resultant wave obtained as a result of superposition of all such rays (emerging from all points from all slit wavefronts) is given by,

$$I = I_0 \frac{\sin^2 \beta}{\beta^2} \frac{\sin^2 N\gamma}{\sin^2 \gamma}$$

Where I_0 is a constant and β

$$\beta = \frac{\pi b \sin\theta}{\lambda}, \quad \gamma = \frac{\pi d \sin\theta}{\lambda}$$

where 'b' is the slit width and 'λ'is the wavelength of light used. Thus the intensity, *I* will vary as a function of angle θ. For very large N , points of highest intensity, called principal maxima will be obtained when $\gamma = n\pi$ that is when, $d\sin\theta_m = m\lambda$, m = 0; ±1; ±2;::: (principal maxima)………………..(1)

The maxima for m = 0; ±1; ±2 are called zeroth order, first order, second order maxima and so on, respectively. If 'y_m' is the distance of the m^{th} principal maxima from the central maximum, and 'D' is the distance between the grating and the screen, then the corresponding diffraction angle can be estimated using

$$\theta_m = \tan^{-1}\left(\frac{y_m}{D}\right)$$ (see figure 4.)

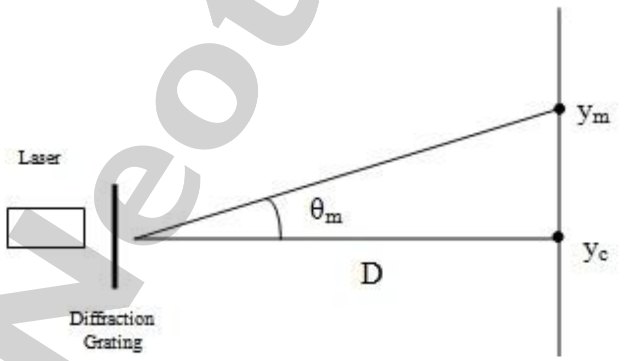


Figure 4.

Using (1) and (2) wavelength of the monochromatic light can be determined from the following formula

$$\lambda = \frac{\sin\theta_m}{nN}$$

Where *N=1/d* is the number of lines per unit length of the grating.

5.0 PRINCIPLE: Let a parallel beam of light of wavelength λ coming from laser source fall normally on a plane transmission grating. Diffraction maxima of different orders would be formed on the other side of the grating at different angles with the incident beam. The angle of diffraction (θ) for any order can be measured from the central maximum and *n*-th order secondary maximum of the diffraction pattern.
If *d* is the distance of *n*-th order secondary maximum from central maximum and D is the distance of the screen from the grating, then the angle of diffraction for *n*-th order is

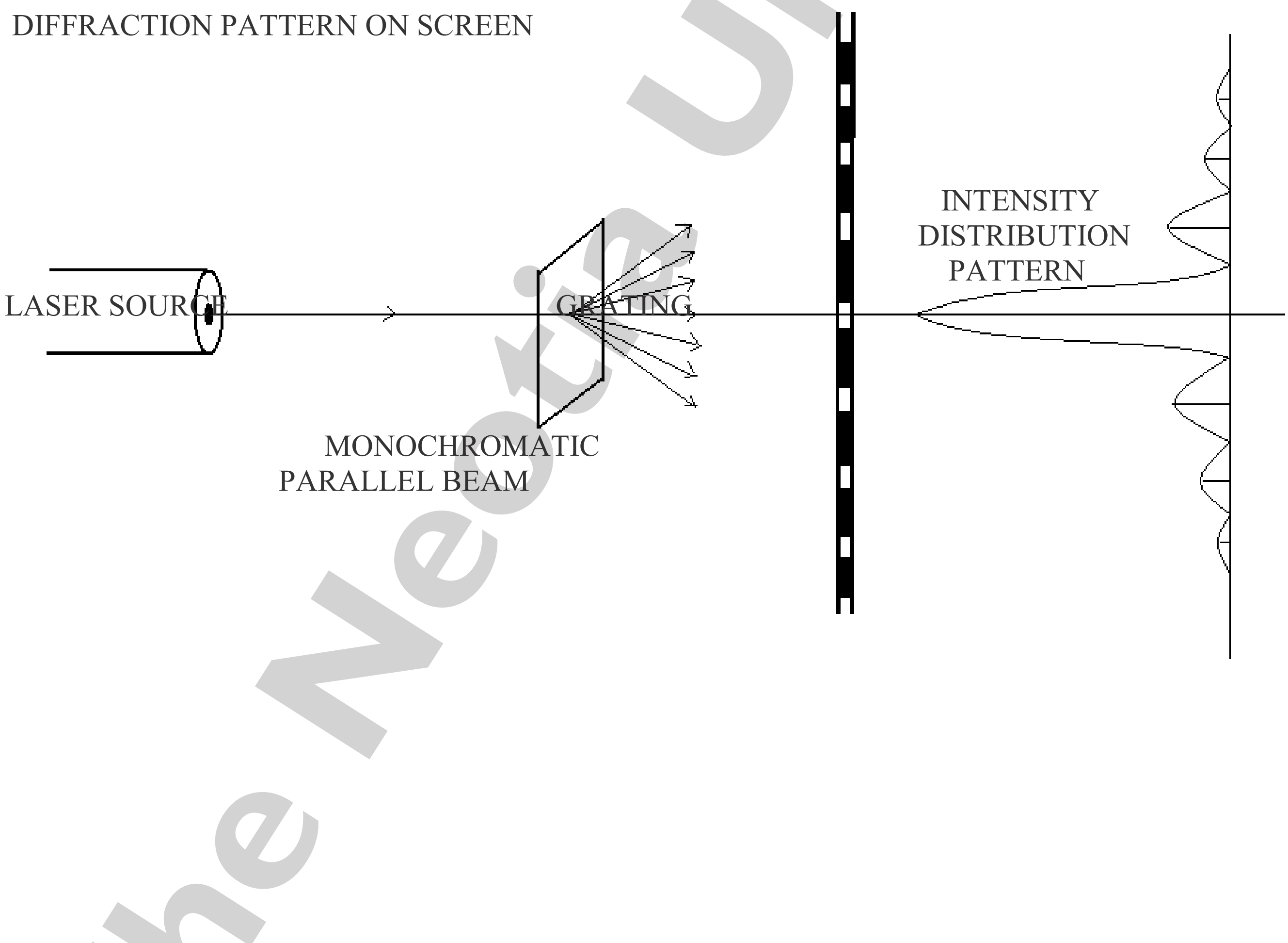
$$\theta = \tan^{-1}\left(\frac{d}{D}\right) \qquad (1)$$

Knowing θ the wavelength of the monochromatic light can be determined from the following formula

$$\lambda = \frac{\sin\theta}{nN}, \qquad (2)$$

where *N* is the number of lines per unit length of the grating.

6.0 TOOLS/APPARATUS REQUIRED:
- Laser Source
- Screen
- Plane Transmission Grating
- Scale



7.0 PROCEDURE: (don't write the procedure in your Lab. Copy)

- Switch on the Laser Source

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- Place the transmission grating on the grating stand keeping it perpendicular to the source

↓

- Diffraction spots are seen on the screen

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- Measure the distance (*D*) of the screen from the grating.

↓

- Measure the distance (*d*) of different secondary maxima from the central maximum by a meter scale.

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- Repeat the above step for two more different values of *D*.

8.0 TABULATION:

TABLE-1

Determination the angle of diffraction

Distance of the screen from the grating (D)=……….. cm.

Order no.	Distance from the central spot (in cm)			Angle of diffraction $\theta = \tan^{-1}(d/D)$ (deg)
	Left d_1	Right d_2	Mean (d) $=(d_1+d_2)/2$	
1				
2				
3				
4				
5				
6				
7				
8				

Draw Table – 2 and Table – 3 by repeating the Table-1 for two other distances (D) of screen from the grating.

TABLE-4

Table for drawing order no. vs. angle of diffraction data

Order no.	Angle of diffraction θ From Table-1 (deg)	Angle of diffraction θ From Table-2 (deg)	Angle of diffraction θ From Table-3 (deg)	Mean Angle of diffraction(θ) (deg)
1				
2				
3				
4				
5				
6				
7				
8				

Graph and Result

Draw graph of order number (n) vs. angle of diffraction by plotting order number (n) along abscissa (x-axis) and angle of diffraction (θ) along vertices (y-axis). Then determine the wavelength of laser as per instruction given in the Table – 5.

TABLE-5

Determination of wavelength of laser beam:

Order of diffraction (n) (From graph)	Angle of diffraction of corresponding order no. (θ) (deg) (From graph)	Number of lines/cm (N) (Supplied)	Wave length of laser $\lambda = \sin\theta / nN$ (Å)
		1000	

8.0 COMPUTATION OF PERCENTAGE ERROR:

We have the formula for the Determination of wavelength of monochromatic light by diffraction with a laser as $\lambda = \sin\theta / nN \approx \tan\theta / nN$, if θ is small.

$$\text{So, } \lambda = \frac{d/D}{nN} = \frac{d}{DnN}$$

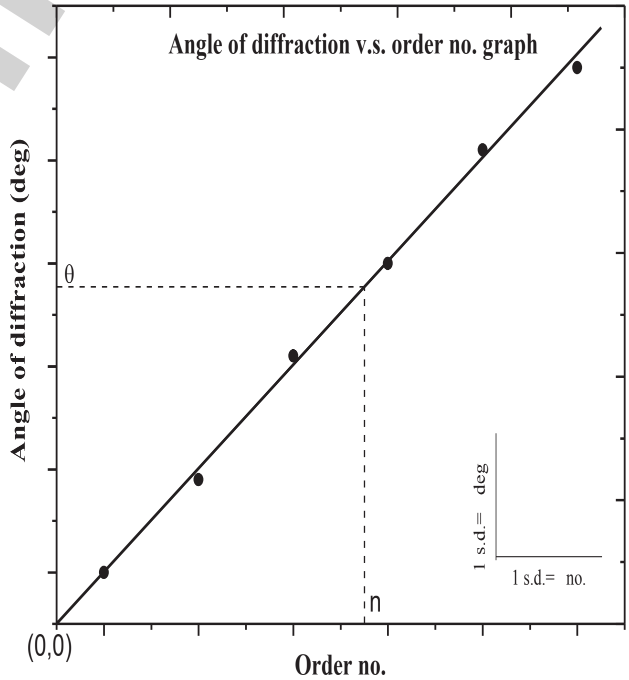
Where, θ is the angle of diffraction,
n is order no. and N is number of lines/cm.
Taking ln in both sides we get,

$$\ln\lambda = \ln d - \ln D - \ln n - \ln N$$

Differentiating we get for maximum proportional error,

$$\frac{\partial\lambda}{\lambda} = \frac{\partial d}{d} + \frac{\partial D}{D} + \frac{\partial n}{n}$$

(Rest of the term will be zero as N is constant and differentiation of this term will vanish)



$\delta d = \delta D$=error in measuring d or D
= 2 x minimum division of the scale used
(because probability of making error is in both sides)

δn = error in measuring n
= 1 (because probability of making error is in one side)

Putting suitable values calculate the value of proportional error.

Hence, the percentage error is $\left(\frac{\partial\lambda}{\lambda} \text{ x } 100\right)\%$

9.0 DISCUSSION :

You have to write all the difficulties you faced during the experiment and their remedies. Also you have to mention some way out that one should adopt during the practical to have a better result.

References

1) OPTICS - Ghatak
2) OPTICS – K. G. Majumdar
3) ADVANCED PRACTICAL PHYSICS- Ghosh & Majumdar
4) PRACTICAL PHYSICS- Rakshit, Chatterjee & Saha