* Experiment Name :- SONOMETER

* Objective:- sonometer with metallic wire, inbuilt AC supply, electromagnet, meter scale, slotted half kg weights, two knife edges.

* Theory and formula used:-

- Sonometer:- A sonometer is a device which consists of a thin wire stretched over two bridges that are usually mounted on a sound board and which is used to measure the vibration frequency, tension, density or diameter of the wire, or to verify relations between these quantities.

- Electromagnet:- An electromagnet is a type of magnet in which the magnetic field is produced by the flow of electric current. The magnetic field disappears when the current inceases.

- Frequency of AC mains:- The utility frequency or mains frequency is the frequency at which AC is transmitted from a power plant to the end user.

The natural frequency of the wire is given by,

$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

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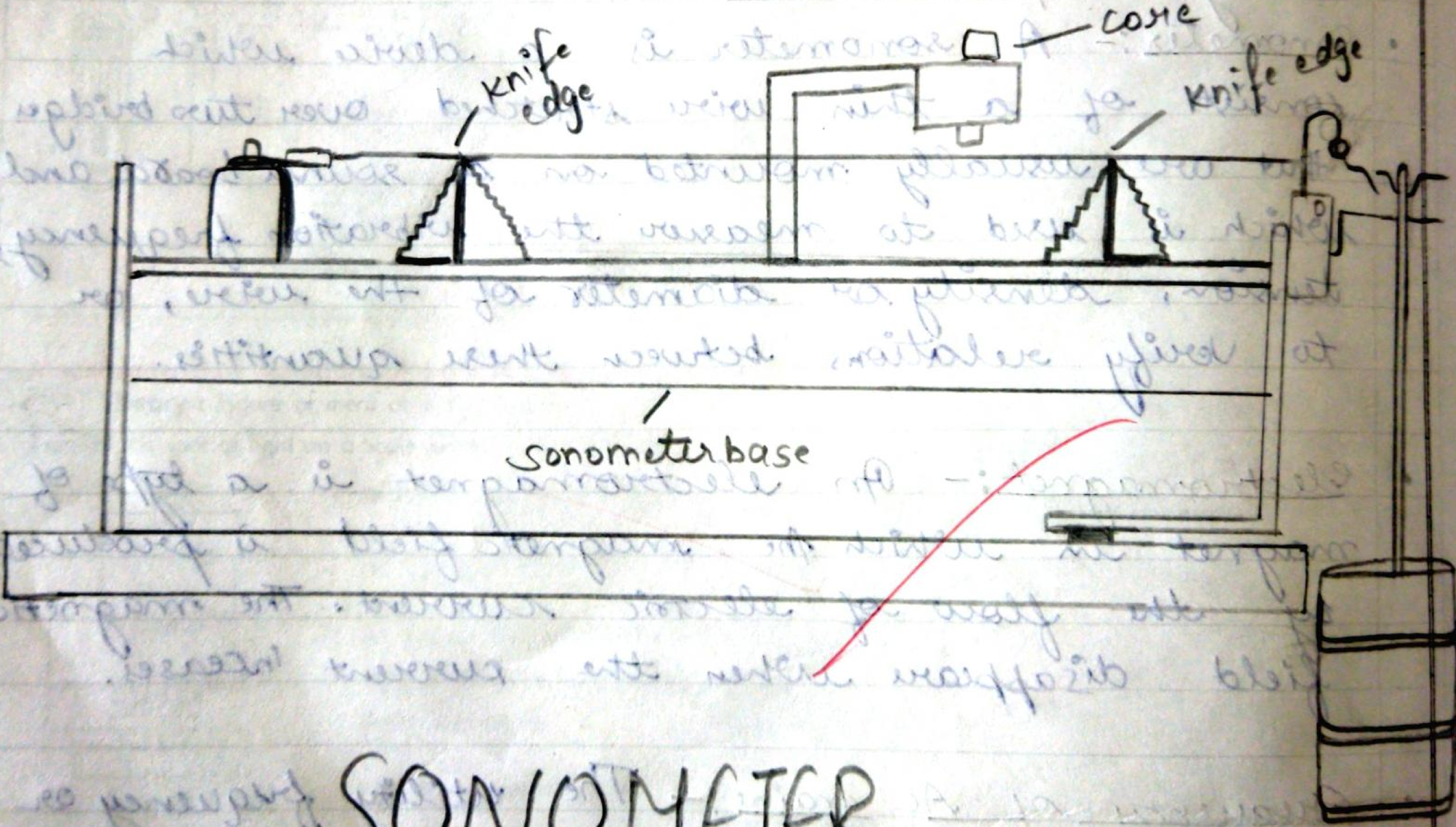

SONOMETER

where,

l = length of the sonometer wire between two knifes edges when it is thrown into resonant vibrations.

T= Tension in the wire.

m = mass per unit length of the wire.

The frequency of the AC mains is given by,

$$n = \frac{f}{2} = \frac{1}{4l}\sqrt{\frac{T}{m}}$$

* Observation :- Mass per unit length of the wire (m) = 0.0056 kg/m.

S.No	load in (kg) (W)	Tension in Newton $T = (W \times 9.8)$	Resonating length of the wire (cm) Position of bridges increasing (l_1)	Position of bridges decreasing (l_2)	Mean resonating length (l)	Frequency $f = \frac{1}{2l}\sqrt{\frac{T}{m}}$ (Hz)
	2.1 kg	20.58	28.1	26.5	27.5	112.25
	1.6 kg	15.68	27.5	25.5	26.5	99.83
	1.1 kg	10.78	27.1	27.05	27.05	81.16
	0.6 kg	5.88	13.2	13.66	12.6	123.1

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* Calculations :-

(1)
$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$
$$f = \frac{1}{2 \times 27.5}\sqrt{\frac{20.58}{0.0056}}$$
$$f \Rightarrow 112.25\ Hz$$

(2)
$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$
$$f = \frac{1}{2 \times 26.5}\sqrt{\frac{15.68}{0.0056}}$$
$$\Rightarrow 99.83\ Hz$$

(3)
$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$
$$f \Rightarrow \frac{1}{2 \times 27.05}\sqrt{\frac{10.78}{0.0056}}$$
$$f = 81.16\ Hz$$

(4)
$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$
$$f = \frac{1}{2 \times 12.6}\sqrt{\frac{5.88}{0.0056}}$$
$$f = 123.12\ Hz$$

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$$Mean = \frac{112.257 + 99.83 + 81.16 + 123.12}{4}$$

$$= 104.152\,Hz$$

Frequency of AC mains $\Rightarrow n = \frac{f}{2}$

$$\Rightarrow \frac{104.152}{2}$$

$$\Rightarrow 52.076$$

* Result: The frequency of AC mains = 52.076 Hz
Standard Result → The frequency of AC Mains = 50 Hz

* Percentage error :-

$$\Rightarrow \left| \frac{\text{standard value} - \text{calculated value}}{\text{standard value}} \right| \times 100$$

$$\Rightarrow \left| \frac{50 - 52.06}{50} \right| \times 100$$

$$\Rightarrow 0.04 \times 100$$

$$\Rightarrow 4\%$$

* Precaution and source of error :-

i). The wire should be of a uniform area of cross-section, free from kinks and should be light.

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ii) The observation should start with maximum distance between the two knife edges.

iii). The weight of hanger should always be included in the load.

iv) The pulley should be free from friction.

* SOLARCELL :-

- Objective :- To draw the characteristic of solar cell and to estimate fill factor (FF) of solar cell.

- Apparatus Required :- Solar cell, rheostat, ammeter, voltmeter, illumination source, Bulb and connecting wires.

- Circuit Diagram :-

⟸ next page.

- Theory and formula used :- solar cell is basically a two terminal p-n junction device designed to absorb photon absorption through the electrical signal or power in the external circuits. Therefore it is necessary to discuss the physics of semiconductor p-n junction diode, which converts the optical energy into electrical signals.

Photo voltaic system converts sunlight directly into electrical energy. The backbone of this technology is semi-conducting materials such as silicon. A typical solar cell consist of two

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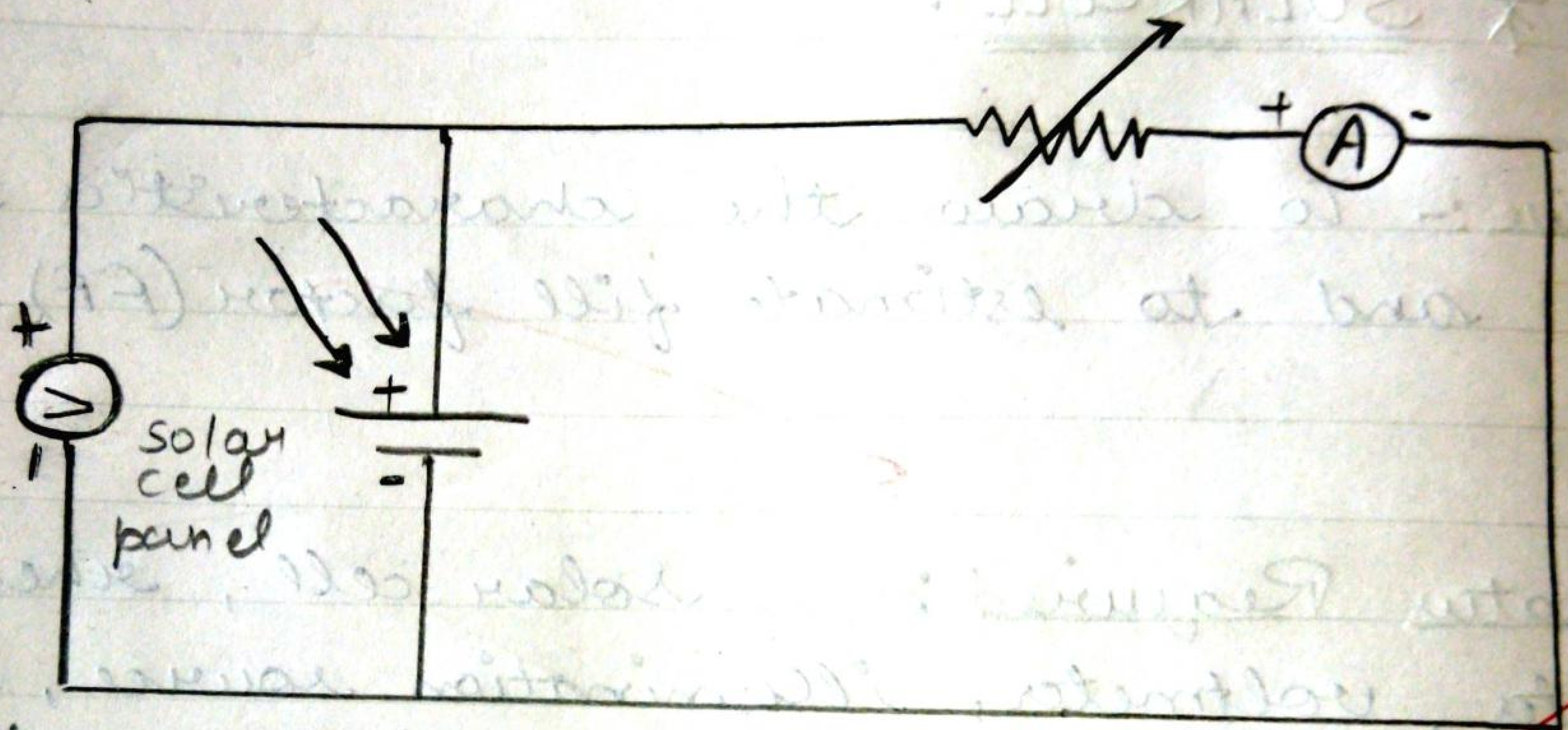

Set up for determining characteristics of a Solar cell differently doped semiconductor p-n junction diode, which converts the optical energy into the host material. starting out with a pure semi-conductor crystal. this is achieved by substituting some of the atoms in the crystal lattice with elements that have on more or less valence electron than the host material. Semiconductor elements have four valence electrons all of which are used for bonding in the crystal lattice. If dopping is controlled introduction of impurities into the host material. If doping material has five electrons all of which are used for bonding in the crystal lattice. These 'free' atoms can move about easily in lattice and are responsible for an increase in conductivity. Since they have a negative charge the doping material doped in this way is called n-type semiconductor. Since in case of free charge carriers are positive this kind of semiconductor is said to be of p-type. When a p-type semiconductor is joined to an n-type semiconductor, a p-n junction is created.

* **Characteristics of a solar cell :-**

The usual voltage from solar cells depends on the semiconductor material. In silicon it amounts to approximately 0.5 V. Terminal.

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voltage is only weakly dependent on light radiation, while the current intensity increases with higher luminosity.

* Fill factor (FF):-

FF percentage measures the "squareness" of the I-V curve. It states the degree to which the voltage at the maximum power point (V_{mp}) matches the open-circuit voltage (V_{oc}) and that the current at the maximum power point (I_{mp}). This relation is given by:-

$$FF = \frac{V_m I_m}{V_{sc} I_{sc}}$$

* Efficiency of solar cell:-

The efficiency of the solar cell is the ratio of produced electrical power (P_{out}) and the incident radiant power (P_{in}).

Efficiency of solar cell,

$$\eta = \frac{P_{out}}{P_{in}}$$

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Observation Table :-

S.No.	Voltage, V (Volts)	Current, I (mA)	Power calculated $P = VI$ (watt)	$P = V.I$ (watt) $P = VI/100$
1.	1	119.6	119.6	1.196
2.	2	117.6	235.2	2.352
3.	3	114.8	344.4	3.444
4.	4	112.1	448.4	4.484
5.	5	110.2	551.0	5.510
6.	6	110.1	684.6	6.846
7.	7	109.4	779.8	7.798
8.	8	108.9	871.2 ⟹	8.712
9.	9	94.8	853.3	8.533
10.	9.90	14.1	139.59	1.395
12.	0.12	121.6	14.592	0.145

* Procedure :-

1). Take the solar Energy trainer along with solar panel.

2). Place the solar panel in the stand and adjust the panel at an angle of about 45° with the ground. Direct the sunlight straight at the solar panel (angle of 90°)

3). With the DB 15 - connector connect the solar energy trainer with solar panel. Then wait for 1 minute to avoid errors due to temperature fluctuations.

4). Set the potentiometer to maximum resistance, i.e., at fully clockwise position and measure and record its resistance into the observation table.

5). Connect solar cell.

6). Connect positive terminal of solar cell to P_1 terminal of potentiometer.

7). Connect other end of potentiometer i.e., P2 to positive terminal of ammeter.

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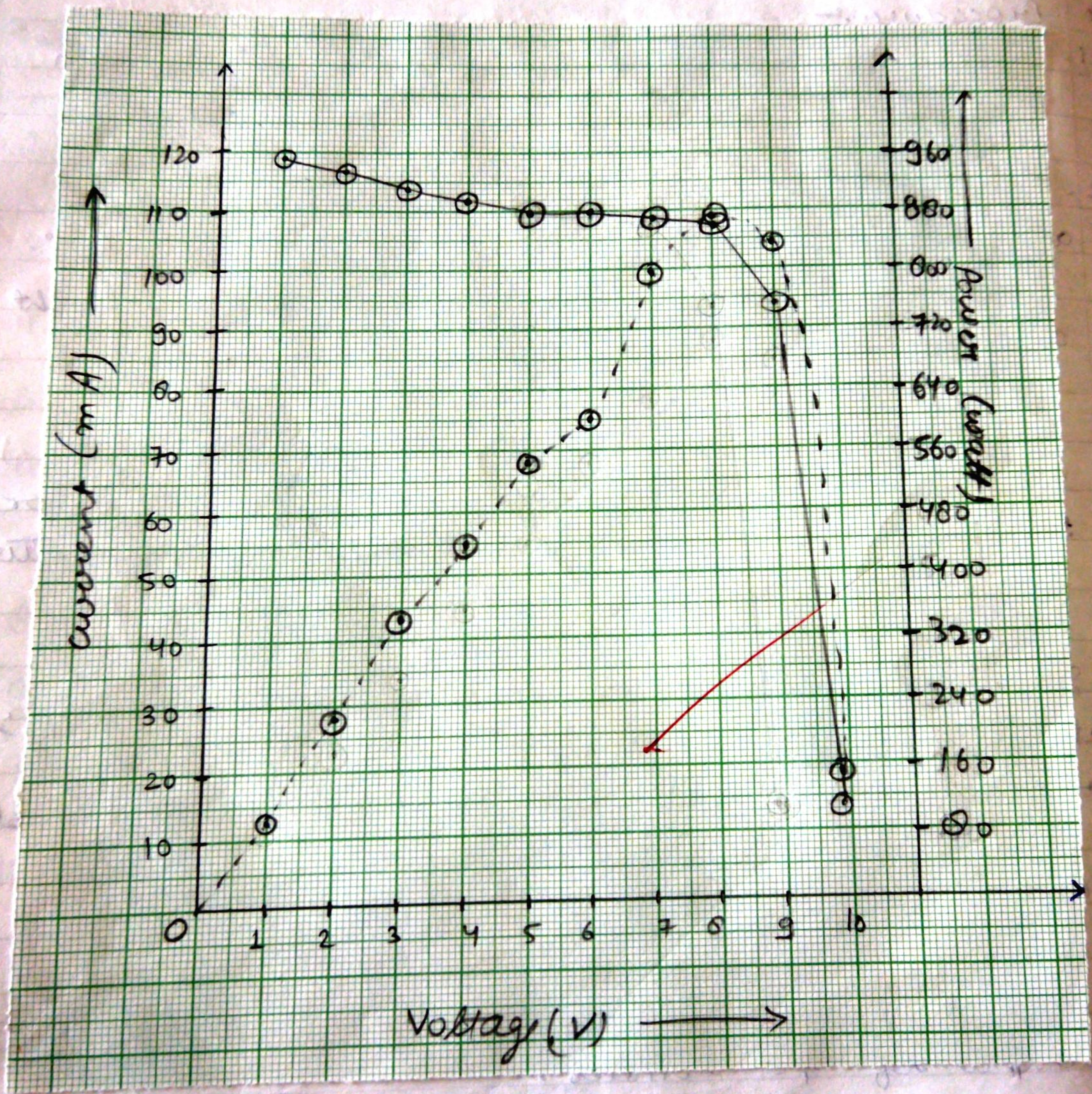

Current (mA)
Voltage (V)
Power (watt)

8. Connect negative terminal of ammeter to negative terminal of solar cell.

9. Now connect the positive terminal to P1 and negative terminal to P2.

10. Record the values of corresponding voltage and current into observation table.

11. The Fill Factor (FF) is defined by the ratio

$$FF = \frac{V_m I_m}{V_{sc} I_{sc}}$$

$$\Rightarrow \frac{8 \times 108.9}{10.49 \times 121}$$

$$\Rightarrow \frac{871.2}{1269.29}$$

$$\Rightarrow 0.6863$$

* Calculation:-

1. Plot the IV characteristic of solar cell.

2. Plot the power (=VI) vs V and determine the maximum power.

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3- Determine the Fill factor(FF).

$$FF = \frac{V_m \; I_m}{V_{sc} \; I_{sc}}$$

* **Results :-**

1)- The I-V characteristic was drawn for given solar cell.

2)- Fill factor(FF) = 0.6863

* **Precautions:-**

1) Make sure that all the connections are tight.

2)- Wait for few minutes to avoid errors due to temperature fluctuations.

3)- To measure the resistance of potentiometer at any position.

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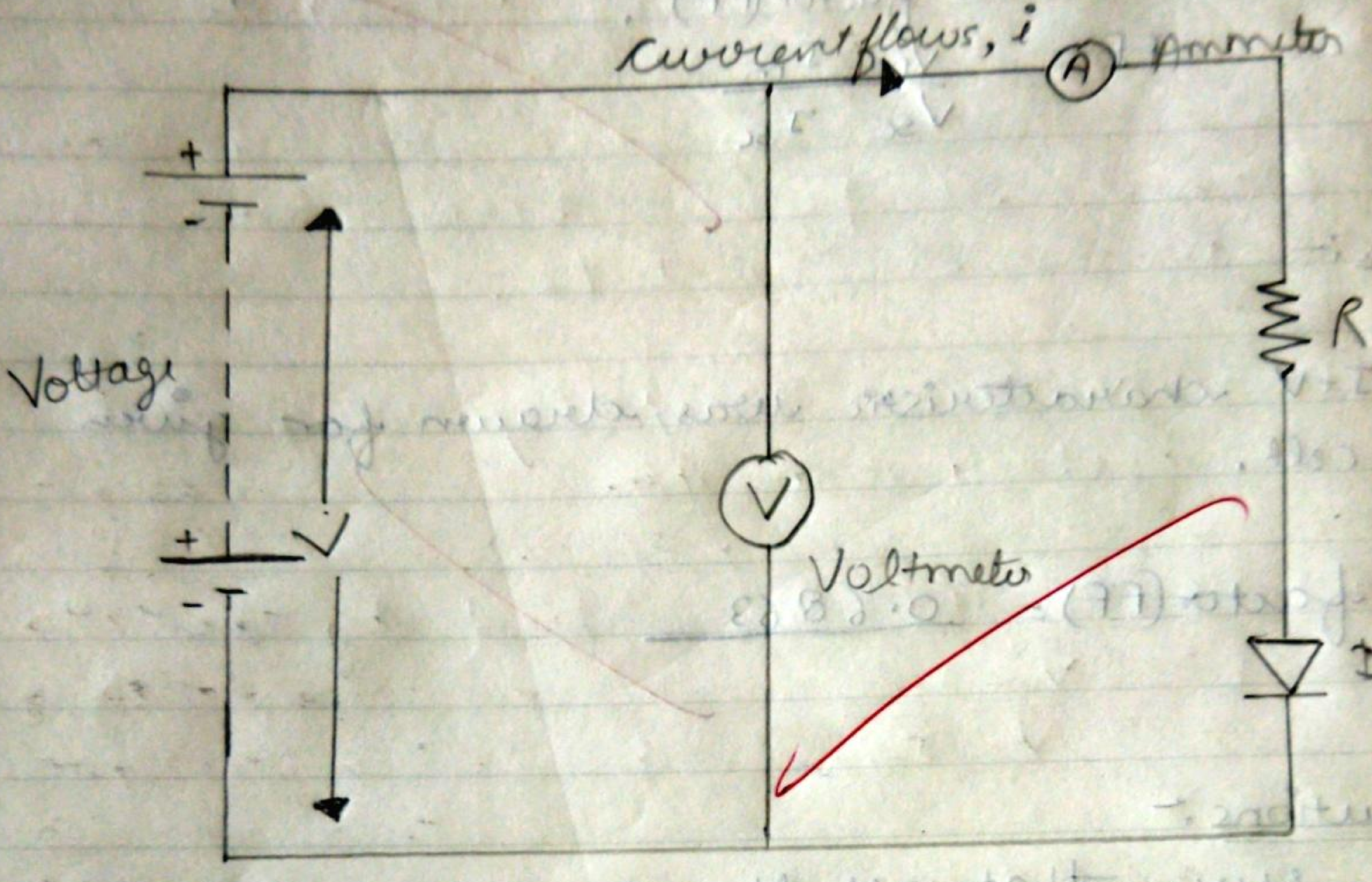
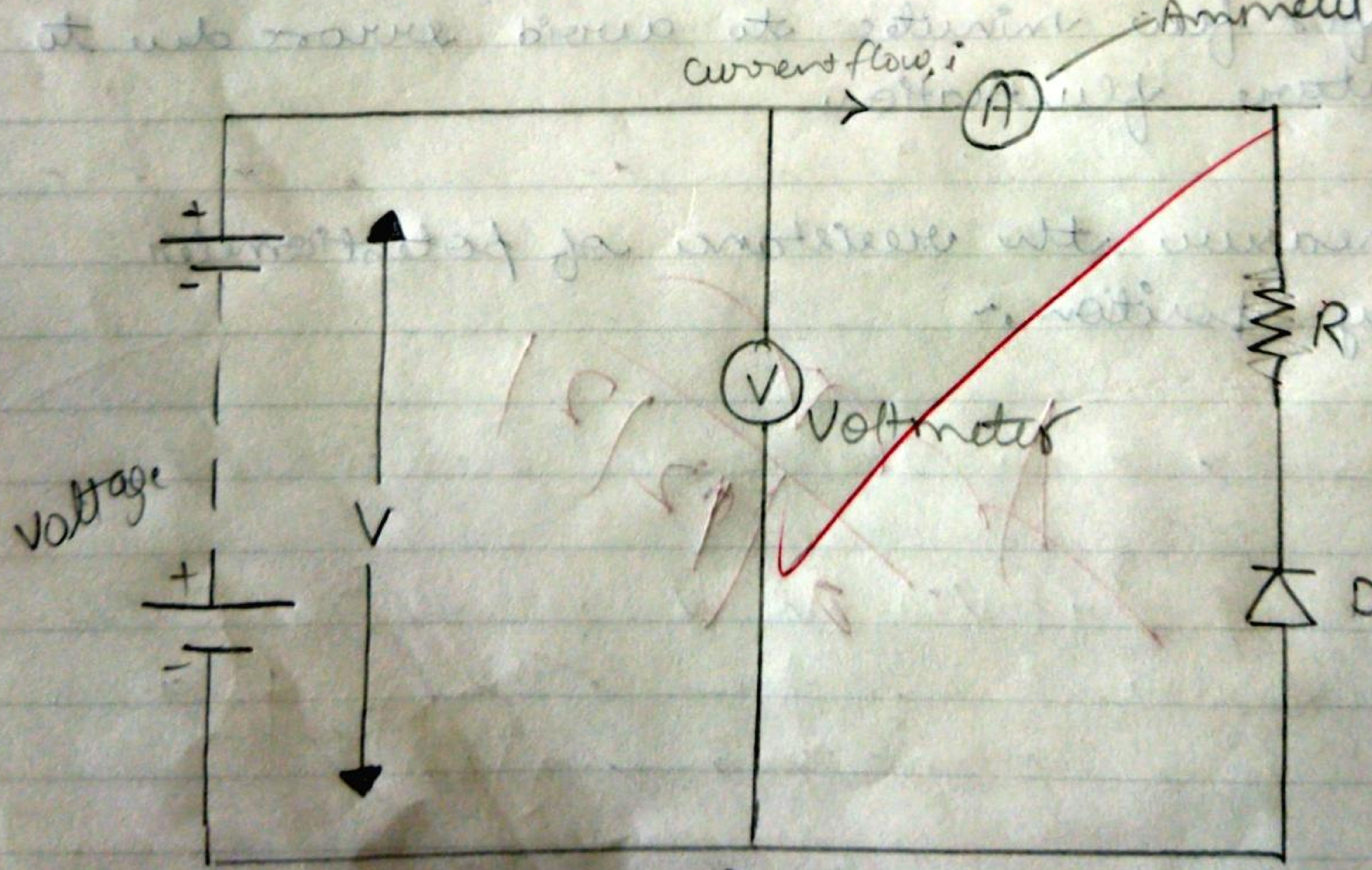


(a)- Forward-bia



(b) Reverse - bia

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P-n Junction :-

- **Objective :-** To draw the (V-I) characteristics of P-n junction diode and to estimate the dynamic resistance.

- **Apparatus required :-** Diode trainer kit, Power supply voltmeter, ammeter and connecting wires.

- **Theory used :-** An equation describes the exact current through a diode, given the voltage dropped across the junction the temperature of the junction and several physical constants. It is commonly known as the diode equation.

$$I_D = I_S \{exp. (eV_D / K_B T) - 1\}$$

where I_D is diode current in amperes and I_S is total saturation current in amperes.

V_D = Voltage applied across diode in volts. It is positive for forward bias and negative for reverse biase.

K_B = Boltz man's constant $(1.38 \times 10^{-23} J/Kelvin)$
T = Junction temperature in Kelvin.
Such that, $exp. (eV_D / K_B T) >>> 1$ then
$$D_D = I_S \; exp (eV_D / K_B T)$$

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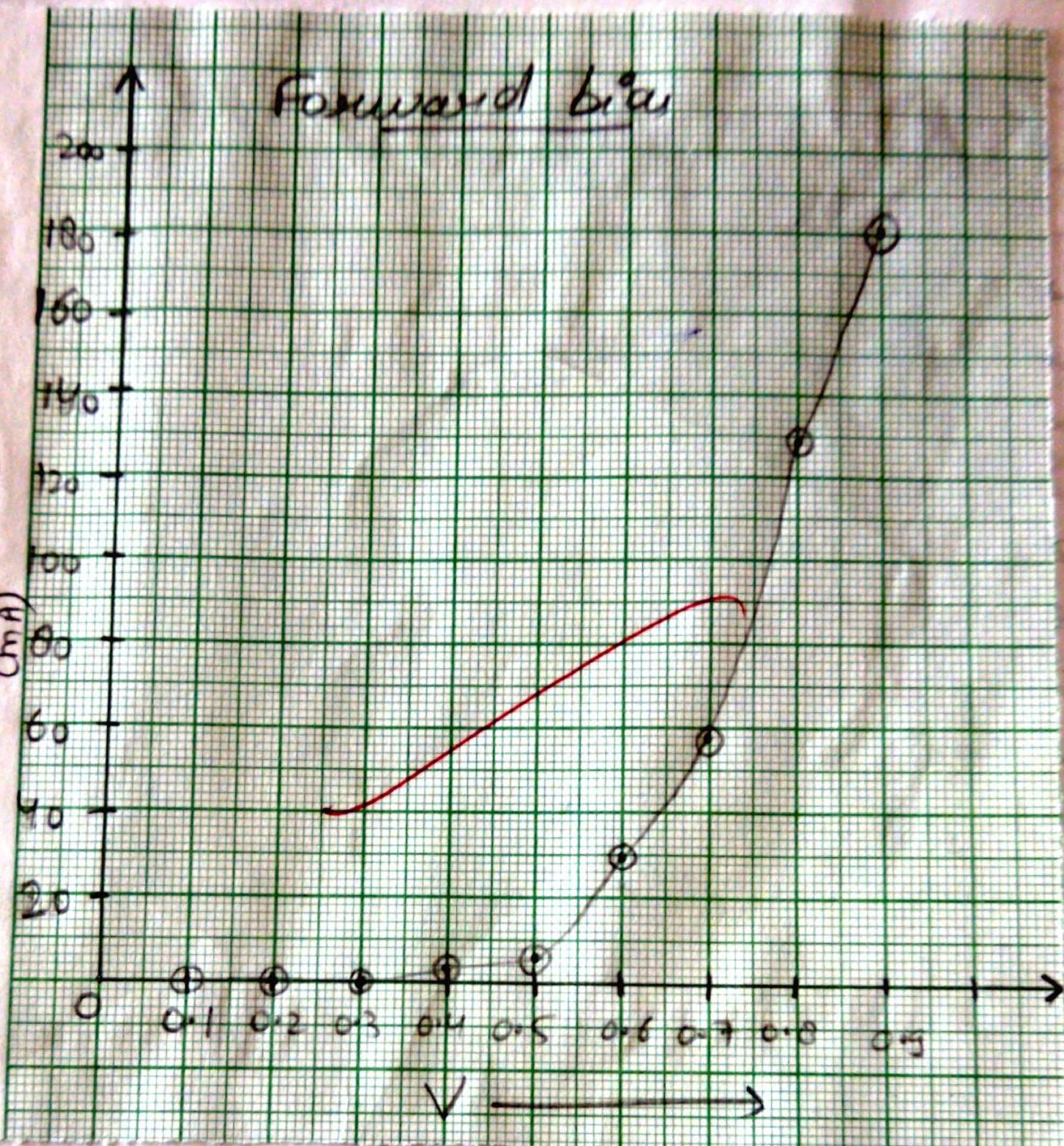

Forward bias
200
180
160
140
120
100
80
60
40
20
0
I (mA)
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
V

This shows that in forward bias, current increase exponentially as shown, (V-I) graph in figure.

• **Observation :-**

S.No.	Forward bias (1) Diode voltage V_D	Diode current (mA)	Reverse bias (2) Diode voltage	Diode current (uA)
1.	0.1	0	1	2.03
2.	0.2	0	2	3.49
3.	0.3	0	3	4.83
4.	0.4	0.1	4	6.18
5.	0.5	2.1	5	7.49
6.	0.6	30.4	6	8.83
7.	0.7	58.6	7	10.28
8.	0.8	128.4	8	11.68
9.	0.9	181.2	9	13.18

• **Calculation :-** Plot a graph between V and I.

Find the static and dynamic resistances

Static resistance :-

$$R_D = V_D / I_D$$

$$= \frac{0.6}{30.4} \Rightarrow 0.019\ \Omega$$

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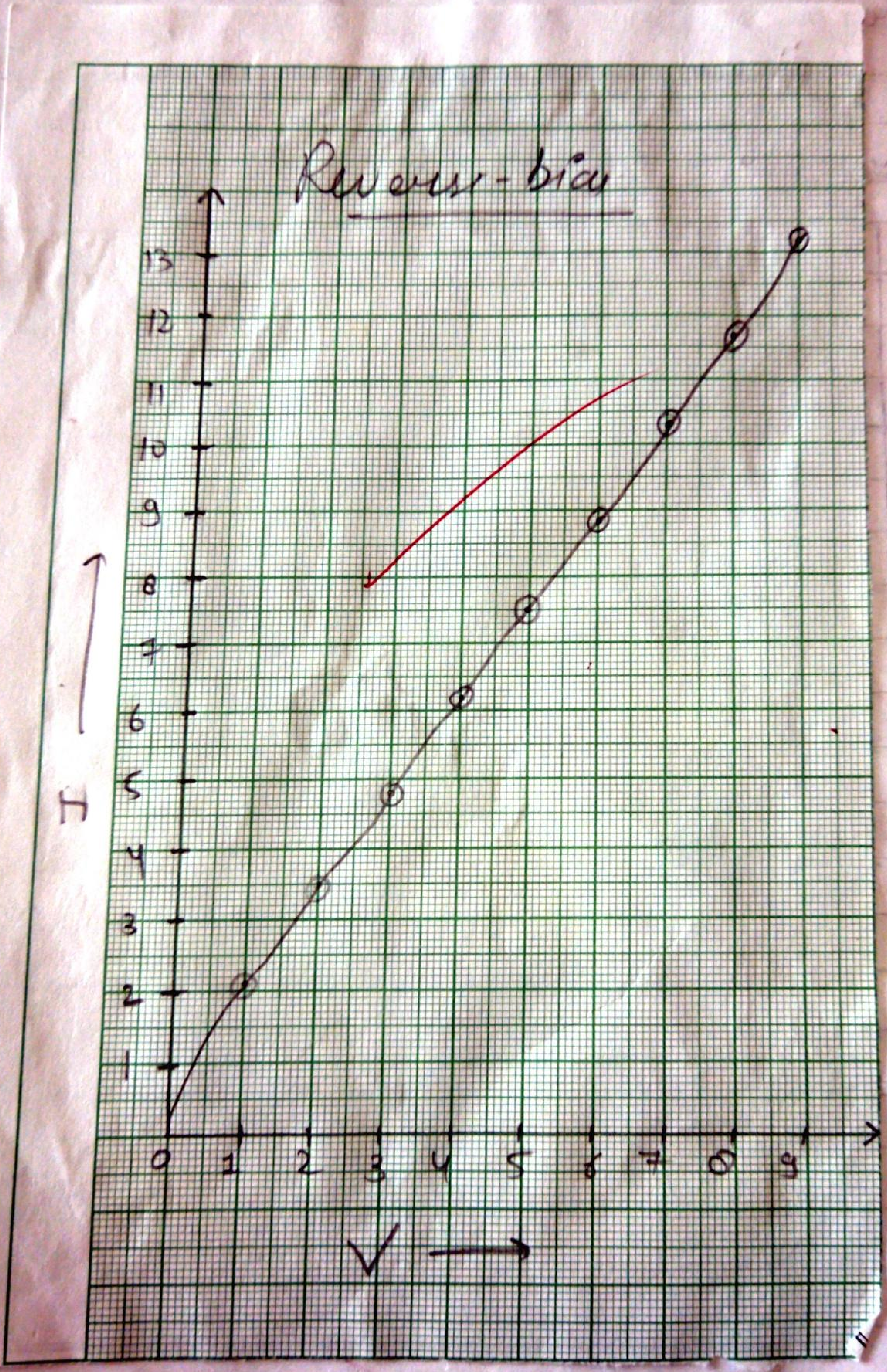

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• **Result :–** The I-V characteristics of the diode are shown in the forward and reverse bias. The static and dynamic resistance are :- 0.019 Ω

• **Precautions :–**

1. Make sure that all the connections are tight.
2. The voltage should not exceed the specified breakdown voltage in reverse bias.

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Hall Effect

- **Objective:-** To study the hall effect and to determine the hall co-efficient, charge carrier concentration and carrier mobility of given semiconductor material using hall set up.

- **Apparatus Required:-**
Gauss and Tesla meter, measurement unit, constant current power supply, electromagnet, Hall probe, In-As probe, etc.

- **Theory and formula used:-** If an electric current flow through a conductor in a magnetic field, the magnetic field, the magnetic exerts transverse force on the moving charge carriers which trends to push them to one side of the conductor. A build up of charge at the sides of the conductor will balance this magnetic influence, producing a measureable voltage between the two sides of the conductor. The presence of this measurement transverse voltage is called the Hall effect after 1879.

The Hall coefficient is given by,

$$R_H = \frac{V_H d}{IB} \quad \text{------} (1)$$

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where,

V_H → Hall voltage

I → Probe current

d → Thickness of sample

B → applied magnetic field.

• **Observations:-**

S.No.	I_B (A)	Magnetic field (B^+) from one side of probe)	Magnetic (B^-) field (from another side of probe)	mean ⇒ $(B^+ - B^-)/2$ B (Tesla)
1.	1.0	1.62	-1.62	1.62
2.	1.5	1.91	-1.91	1.91
3.	2.0	2.36	-2.36	2.36
4.	2.5	2.63	-2.63	2.63
5.	3.0	3.02	-3.20	3.11
6.	3.5	3.01	-3.21	3.11
7.	4.0	3.24	-3.40	3.32
8.	4.5	3.40	-3.56	3.48

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S.No.	Probe current (m a)	Zero field potential out set voltage V_0, (mV)	Observed Voltage for one side (V^+_H)	Observed voltage for another side (V^-_H)	Actual hall Voltage $(V_H = V^+_H - V_0)$	Actual hall voltage $(V = V^-_H - V_0)$	Measured voltage, mean voltage $\frac{V_H \cdot V}{2}$
1.	1.0	17.6	30.0	5.3	12.4	-12.3	12.35
2.	1.5	26.9	43.8	8.7	16.9	-18.2	17.55
3.	2.0	36.4	56.4	14.1	20.0	-22.3	21.15
4.	2.5	43.1	70.3	14.7	27.2	-28.4	20.95
5.	3.0	50.1	82.4	19.0	32.3	-31.1	31.70
6.	3.5	58.1	94.3	10.1	36.2	-40.0	38.10
7.	4.0	65.	104.4	22.6	31.4	-42.6	37.00
8.	4.5	73.0	122.5	24.4	49.5	-48.6	49.05
9.	5.0	78.5	130.0	26.0	51.5	-52.5	52.00

- <u>Formulas</u> :-

$$R_H = \frac{V_H * t}{I * B}$$

where, $V_H \Rightarrow$ Hall voltage

$B =$ applied magnetic.

$t \Rightarrow$ Thickness

$R_H =$ Hall co-efficient

$I \Rightarrow$ current

$$\boxed{R_H = \frac{1}{ne}}$$

where, $e \Rightarrow$ electronic charge

$n \Rightarrow$ number density as electrons in conductor.

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The charge 'e' carrier density 'n' can be calculated,

$$n = \frac{1}{|R_H| e}$$

we know that carrier mobility is the velocity of current carrying particles per unit electric field and it is related with hall effecient as :-

$$\mu = \sigma R_H$$

where, $\sigma = \frac{1}{\rho}$ or conductivity

$\rho \rightarrow$ resistivity.

$$\mu = \frac{1}{\rho} R_H$$

$$\Rightarrow \frac{1}{0.47} \times 1000$$

$$\Rightarrow 3.33 \times 10^{-4} \ cm^2/volt\,sec.$$

- Results → The hall co-efficient $(R_H) = \underline{1.569 \times 10^{-1}}$ cm^3 coulomb.

The value of charge carrier density = $\underline{3.98 \times 10^{19}}$ cm^{-3}

The value of charge mobility $(\mu) = \underline{3.33 \times 10^{-4}}$ cm^2/volt sec.

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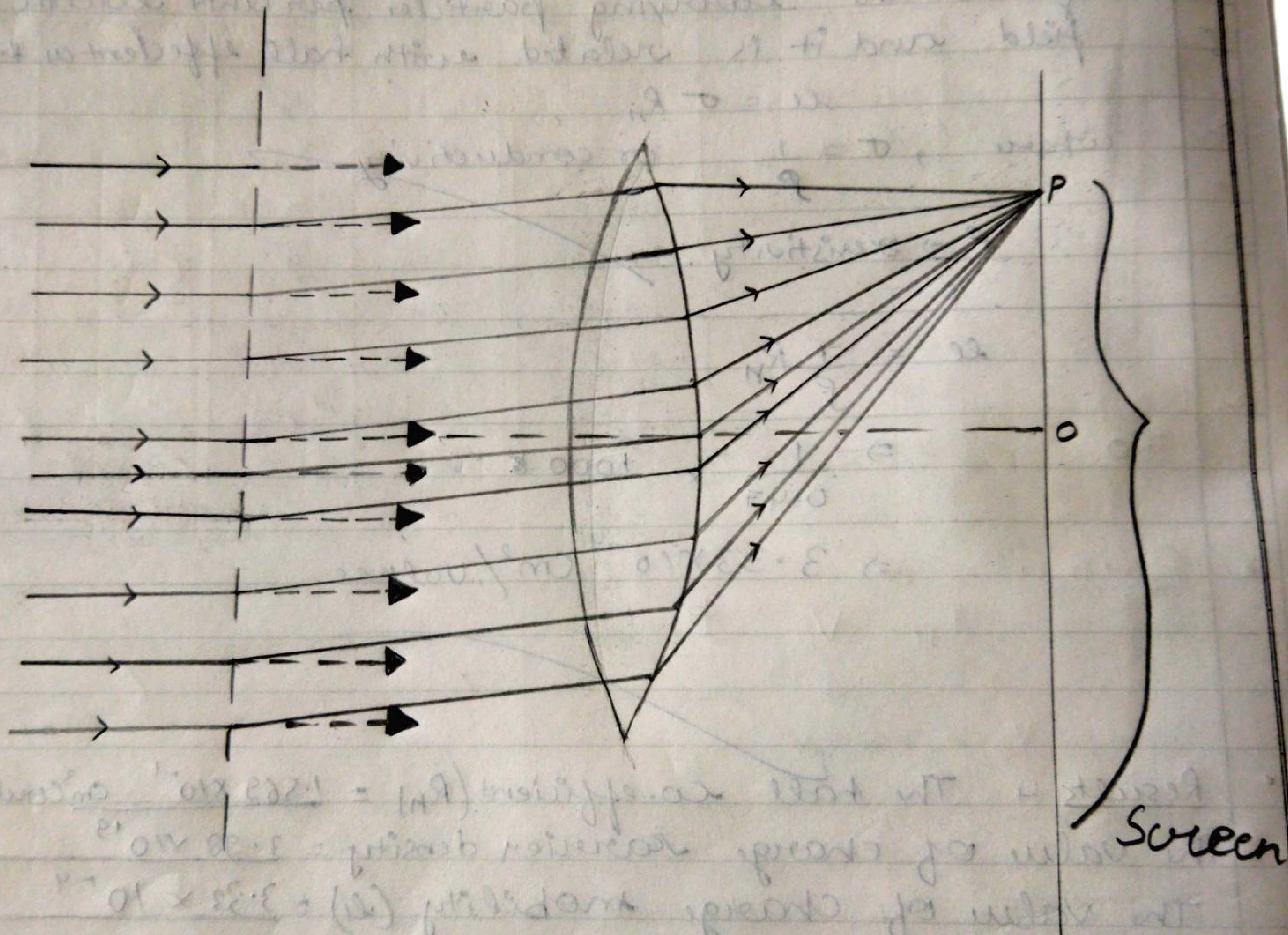

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Experiment →

Diffraction Grating

- **Objective** :- To find the wavelength of monochromatic light with the help of a plane transmission diffraction grating and spectrometer.

- **Apparatus** :- A spectrometer, a spirit level, a ~~sq~~ source of monochromatic light (sodium lamp), diffraction grating with clamping arrangement.

- **Formula ~~used~~** :- The wavelength 'λ' of any spectral line can be calculated by the formula.

$$(a+b)\sin\theta = n\lambda$$

$$\lambda = \frac{(a+b)\sin\theta}{n}$$

where $(a+b)$ = grating element
θ = Angle of diffraction
n = order of spectrum

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• <u>Theory</u> :- A plan diffraction grating consists of an optically plan glass plan on which large no. of equidistant parallel lines are ruled. These lines divide the glass plate into opacities and transparencies, the thickness of which are of the order of wavelength of the visible light. The region where a line is drawn becomes opaque and the space between the two lines is transparent.

When a parallel beam of monochromatic light is incident normally on the grating. It suffers diffraction. The transmitted light gives rise to primary maxima in certain directions given by the relation,

$$(a+b)\sin\theta = n\lambda$$

where $a \rightarrow$ width of transparency

$b \rightarrow$ is that of opacity. θ is the angle of diffraction for n^{th} order maxima and λ is the wave length of light.

For the first order spectrum, $n = 1$

Therefore, $(a+b)\sin\theta_1 = \lambda$

for the second order spectrum, $n = 2$

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Order of spectrum	No. of vernier scale	Reading of Telescope from left side spectrum			Reading of Telescope from right side spectrum			Angle $2\theta = (a-b)$	Mean 2θ	Angle θ
		M.S reading	V.S reading	Total reading	M.S. reading	V.S reading	Total reading			
first	V_1	59.5	9	59.65	94	10	94.16	34.51	34.4	17.24
	V_2	240	4	240.06	274.5	1	274.5	34.44		
Second	V_1	64	5	64.083	89	20	89.33	25.27	25.16	12.58
	V_2	244.5	0	244.5	269.5	3	269.55	25.05		

and $(a+b)\sin\theta_2 = 2\lambda$

The number of lines N per inch are marked on the grating element (a+b) is given by:-

$$(a+b) = \frac{2.54}{N} \text{ cm.}$$

- **Spectrometer:-** An spectrometer is basically an instrument for measuring the angular deviation of light ray. A prism produces this angular deviation of light ray or grating, which is wavelength dependend. The emergent light from these component is dispersed into a spectrum in which wavelength is a function of angle. Spectrometer consists of mainly three parts: collimator, Prism table and ~~tele~~ telescope.

- **Observations:-**

(A). **Determination of least count of spectrometer→**

Reading of one smallest division of M.S. 'a' = 0.5 degree

Total no. of division on vernier scale 'b' = 30

Least count of spectrometer = $a/b \Rightarrow \frac{0.5}{30}$ degree

$\Rightarrow$ 1 minute

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(B) Determination of grating element of diffraction grating →

No. of lines per inch on the grating 'N' = 300.

∴ Grating element $(a+b) = \frac{2.54}{N}$ cm

$= 1.693 \times 10^{-4}$ cm

(C) Determination of angle of diffraction →

Calculation :—

First order spectrum:—

wavelength of spectral lines of first order (n=1)

$\lambda_1 = \frac{(a+b)\sin\theta}{1}$

$\lambda_1 = 4668$ A°

Second order spectrum:—

wavelength of special lines of second order (n=2)

$\lambda_2 = \frac{(a+b)\sin\theta_2}{2}$

$\lambda_2 = 7036$ Å

Mean of $\lambda = \frac{(\lambda_1 + \lambda_2)}{2} \Rightarrow 5852$ A°

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- Result :-

The wavelength of given monochromatic light is → 3673 Å

- Percentage error:-

$$\% \text{ Error} = \frac{(\text{Standard value} - \text{Experimental value})}{\text{Standard value}} \times 100$$

- Precaution:-

- The slit should be narrow
- The diffraction grating should be parallel to the slit.

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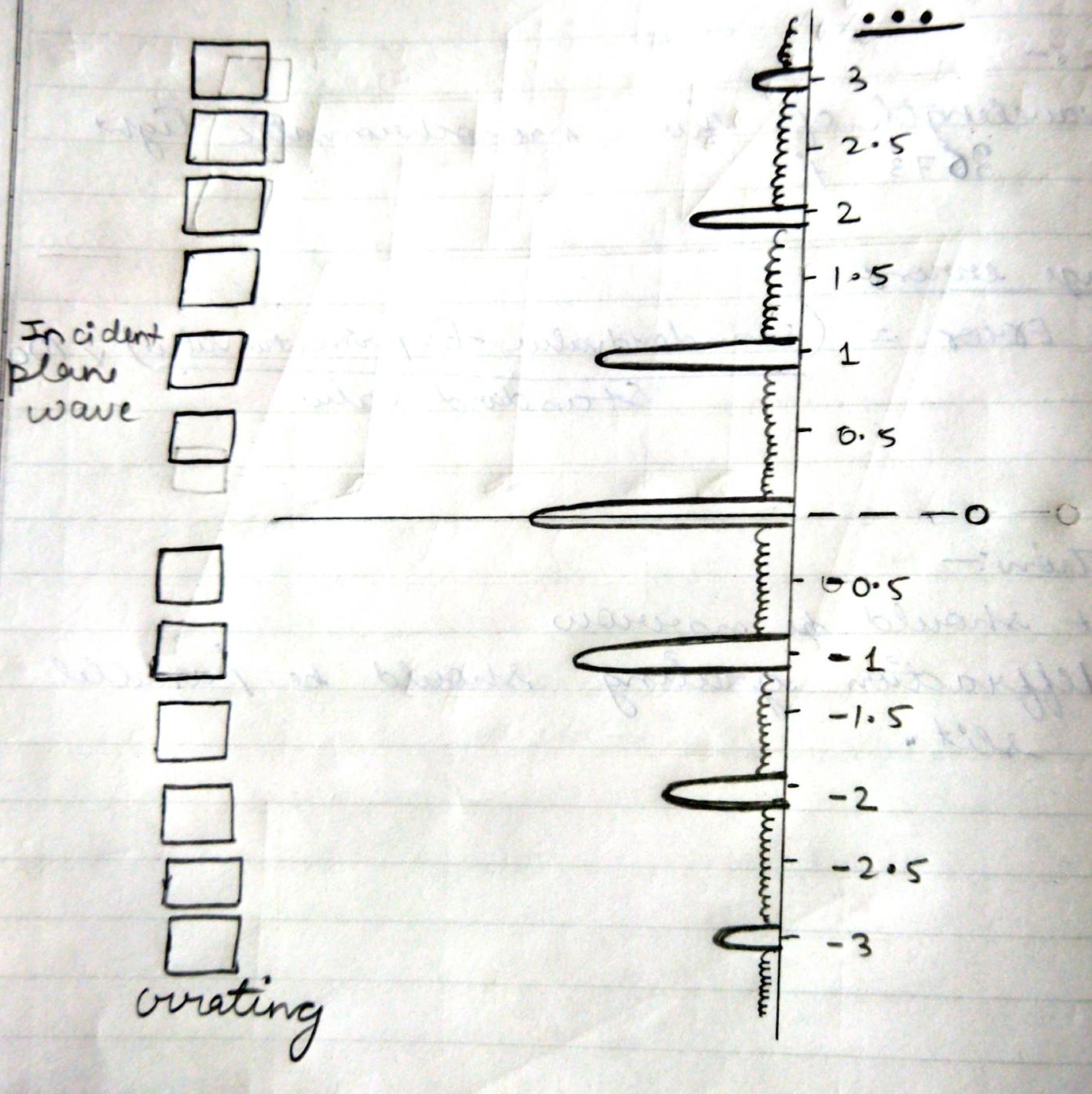

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Experiment - 6

He - Ne Laser

- **Objective :-** To determine the wavelength of He-Ne laser source using diffraction grating.

- **Apparatus :-** HeNe laser source, Diffraction grating with its mount, optical bench, a screen with millimeter scale.

- **Theory :-** Diffraction is the bending of wave around an obstacle or small aperture whose size is comparable to the wavelength of light if source and screen are far away from each other than fresnel diffraction occurs.

A plane diffraction grating consists of an optically plane glass plate on which a number of equidistant lines are ruled. These lines divide the glass plate into opaque and transparent places, the width of which is of the order of wavelength of visible light. The region where a line is drawn become opaque whereas the space between two lines is transparent and acts as

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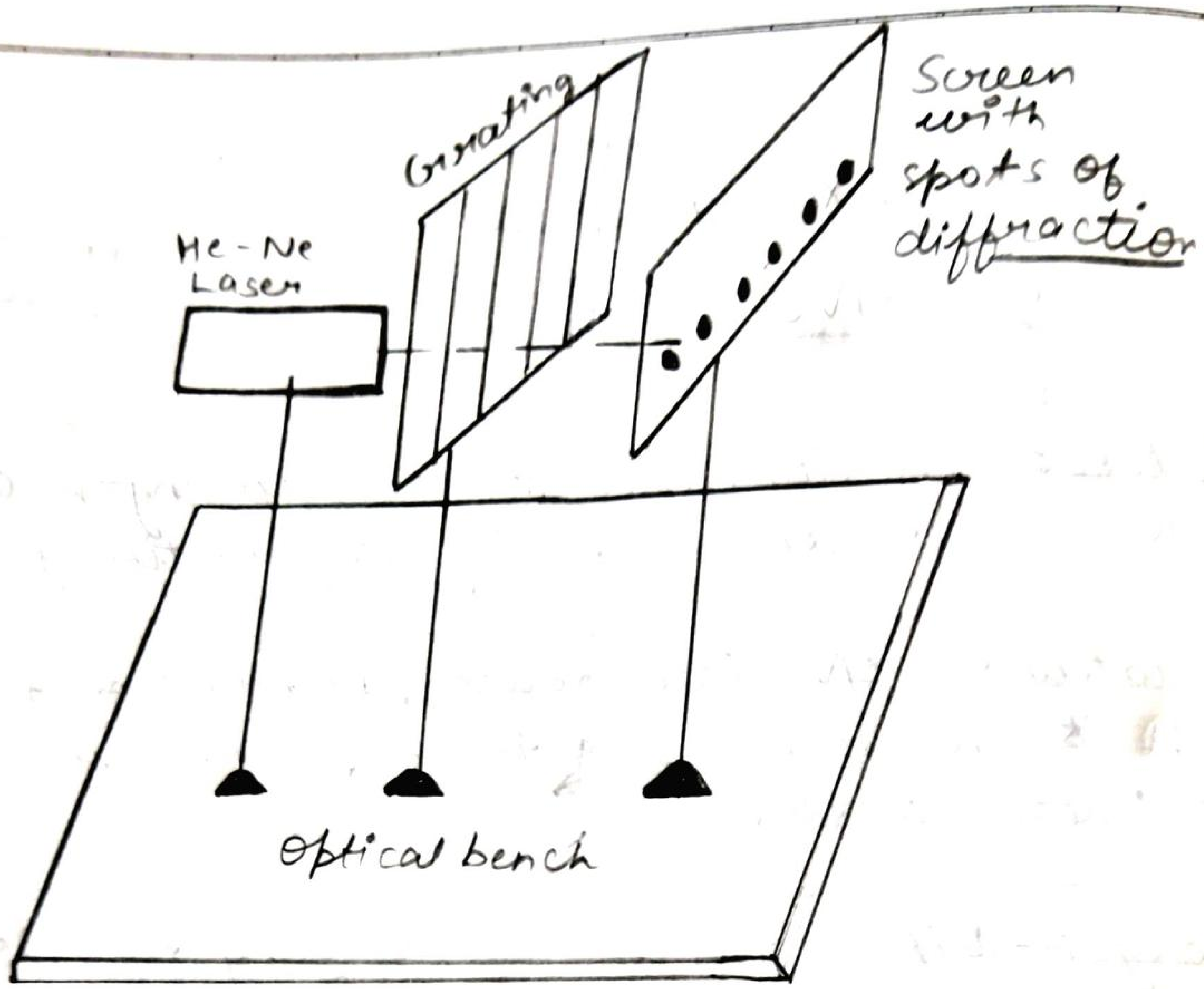
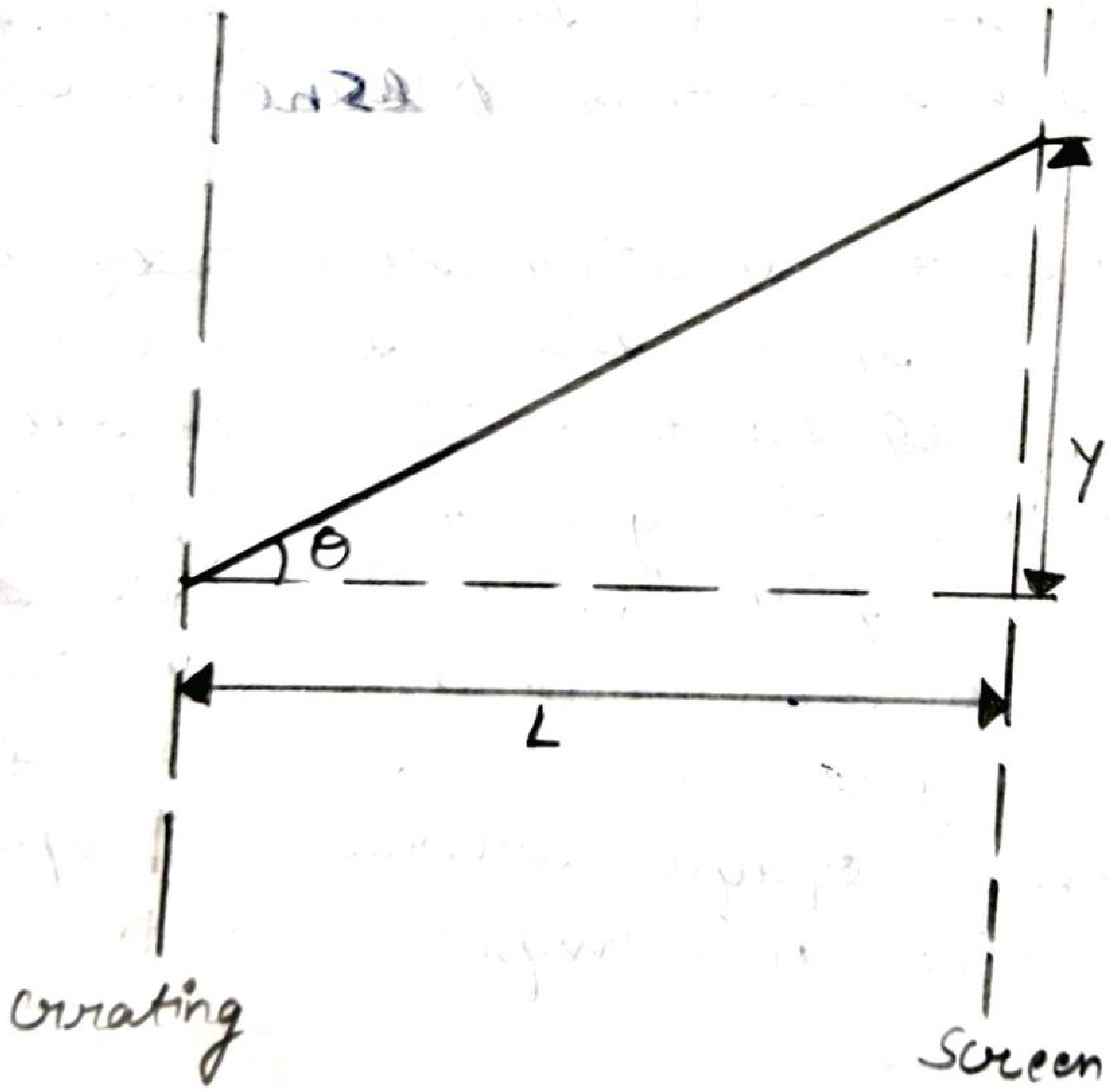


Experimental setup for
diffraction



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slit. The diffraction maxima satisfying the grating condition

$(a+b) \sin\theta_n = n\lambda$

where $(a+b) \rightarrow$ grating element

'a' $\rightarrow$ seperation between two sets.

'b' $\rightarrow$ slit width.

$d = (a+b)$

$d \sin\theta_n = n\lambda$

- Working formula:— If a parallel beam of monochromatic light is incident normally on the plane diffraction grating, maxima & minima occurs due to diffraction. The condition for diffraction maxima is $\rightarrow$

$d \sin\theta_n = n\lambda$ —— (1)

where d is known as grating element, θ_n is the angle of diffraction of n^{th} maximum. n is order of spectrum.

λ is the wavelength of incident light, again

$\tan\theta = \frac{Y}{L}$

Hence $\sin\theta = \frac{Y}{\sqrt{Y^2+L^2}}$ —— (2)

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✿ Observations →

No. of lines per centimeter on grating, $N = 3000/cm$

Grating element, $d = \frac{1}{N} = \frac{1}{3000}$ cm

S. No	Distance b/w grating screen and L (cm)	order of maxima (n)	Distance of maxima from centre			$\lambda = \frac{d\,y}{n\sqrt{y^2+L^2}}$ (in Å)	λ mean (Å)
			Left side (Y_1)	Right side (Y_2)	Mean, $Y = \frac{(Y_1+Y_2)}{2}$		
1.	10	1	2	2	$\frac{2+2}{2} = 2$	6542.36	
2.	15	1	3	3	$\frac{3+3}{2} = 3$	6540.22	6441.14 Å
3.	20	1	3.8	4.0	$\frac{3.8+4.0}{2} = 3.9$	6381.93	
4.	25	1	4.9	4.9	$\frac{4.9+4.9}{2} = 4.9$	6412.77	
5.	30	1	5.8	5.8	$\frac{5.8+5.8}{2} = 5.8$	6328.42	

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using equation (2)

$$d = \frac{y}{\sqrt{y^2+L^2}} = n\lambda$$

Hence, $$\lambda = \frac{dy}{n\sqrt{y^2+L^2}}$$

$d = \frac{1}{N}$; N is number of slits/cm.

- **Calculations :-**

$$\lambda = \frac{dy}{n\sqrt{y^2+L^2}}$$

$$\lambda_{mean} = \frac{\lambda_1 + \lambda_2 + \lambda_3 + \cdots + \lambda_n}{n}$$

$\Rightarrow$ 6.44114×10^{-5} cm

$\Rightarrow$ 6441.14 Å

- **Result :-**
- The wavelength of given laser source,
  $\lambda = 6441.14$ Å
- The standard value of HeNe laser source is 6328 Å

- **Percentage error :-**

$$\text{percentage error} = \frac{6441.14 - 6328}{6328} \times 100$$

$$\Rightarrow \frac{113.14}{6328} \times 100$$

$$\Rightarrow 1.78\%$$

Teacher's Signature : ....

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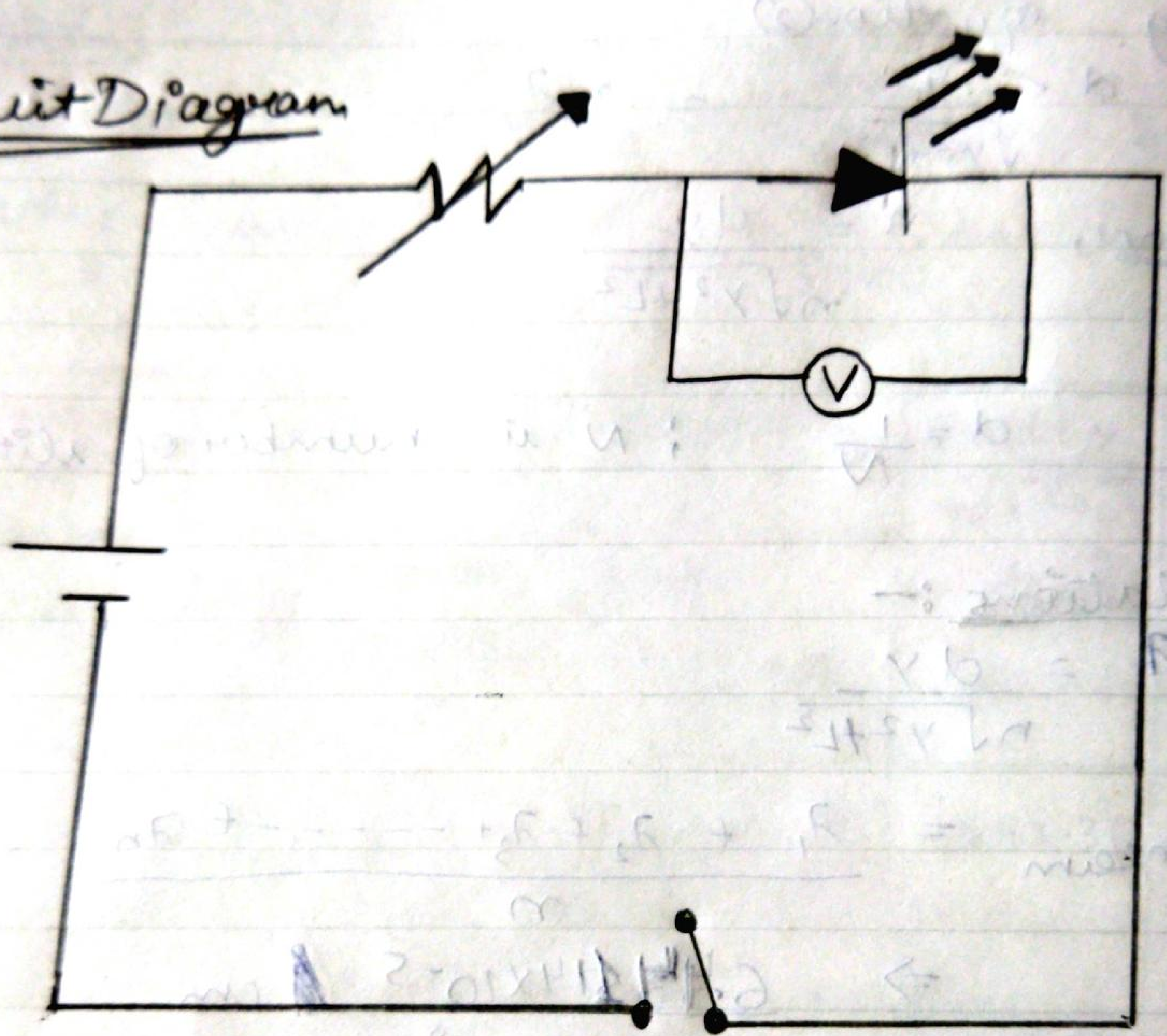
Circuit Diagram



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Experiment → 07

Planck's Constant

- **Objective :-** To determine planck's constant using light emitting diode.

- **Apparatus used :-** Trainer kit, super bright LEDs and variable power supply (0-5) Volts.

- **Objective :-**

Theory & formula used →

In this experiment, we are using LED to measure planck's constant. LED's are semiconductor diode that emits electromagnetic radiation in optical and near optical frequencies, when operated in forward bias, above a minimum threshold voltage. In this condition, an electron hole pair is created in diode & then current starts flowing. Above the threshold value, the current increases exponentially with voltage. A quantum of energy is required to create an electron hole pair and this energy is released when an electron & a hole recombine.

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★. Observation Table →

S.No.	Colour	Wavelength (A)	$1/\lambda$ $(m^{-1}) \times 10^{-6}$	V_0 (Volts)
1-	Blue	4.70nm	2.127	2.23
2.	Green	510nm	1.961	2.20
3-	Yellow	570nM	1.754	1.72
4-	Orange	600nm	1.666	1.56
5.	Red.	700nm	1.428	1.43

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The energy of photon is related to its wavelength. as :-

$$E = \frac{hc}{\lambda} = h\nu$$

$$\frac{hc}{\lambda} = eV_0 \quad \text{or} \quad h = \frac{eV_0\lambda}{c}$$

- **Results :-** Planck's constant is 7.066×10^{-34} Js
Standard value is 6.625×10^{-34} Js

$$\% \text{ error} = \left| \frac{(6.625 - 7.066) \times \cancel{10^{-34}}}{6.625 \times \cancel{10^{-34}}} \times 100 \right|$$

$$\Rightarrow \left| - \frac{0.441 \times 100}{6.625} \right|$$

$$\Rightarrow 6.65\%$$

- Sources of error →
- Make sure that all connections are tight
- Note the threshold voltage carefully, when the LEDs just start flow.
- Handle the equipment carefully.
- Make sure that LED is in the forward bias