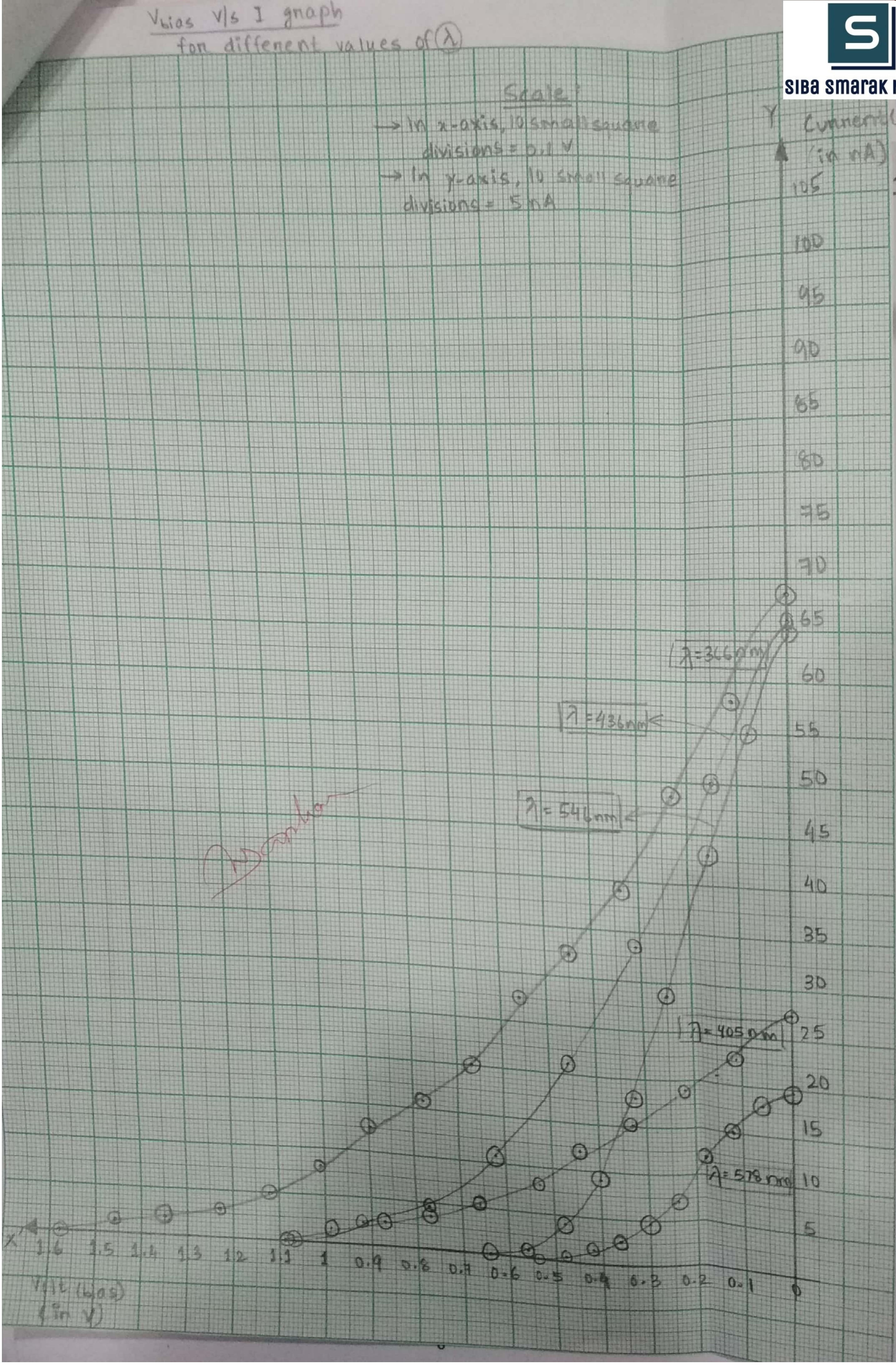


Vbias V/s I graph
for different values of (λ)
Scale:
→ In x-axis, 10 small square divisions = 0.1 V
→ In y-axis, 10 small square divisions = 5 nA
Y
Current (I)
(in nA)
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
λ=366 nm
λ=436 nm
λ=546 nm
λ=405 nm
λ=578 nm
X
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Volt (bias)
(in V)

Calculations

$N = 5$

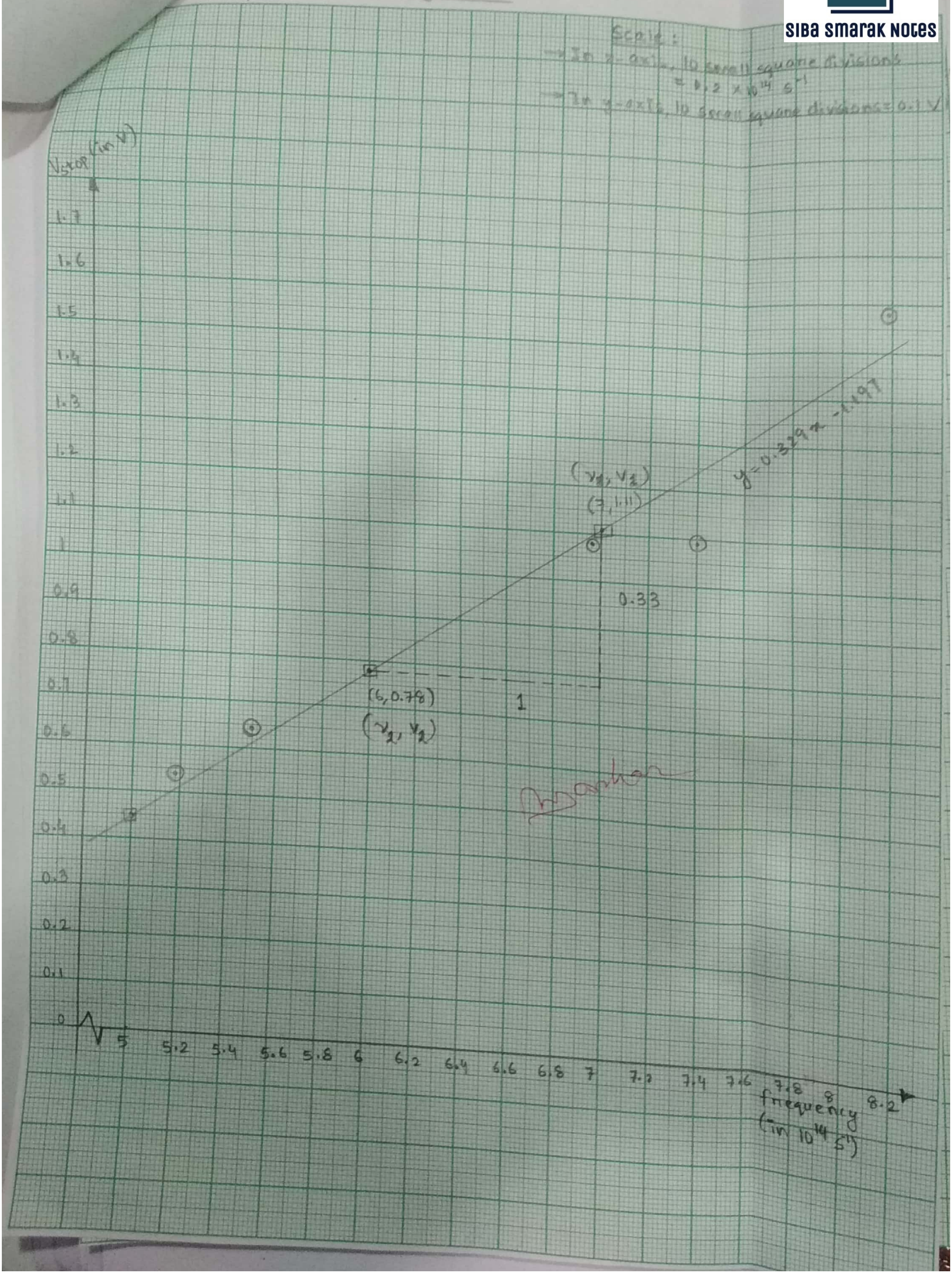
y (V)	x (Hz) $\times 10^{14}$	$x_n y_n$	x_n^2
1.584	8.19	12.973	67.076
1.089	7.40	8.059	54.760
1.077	6.88	7.410	47.334
0.641	5.49	3.519	30.140
0.543	5.19	2.818	26.936
$\bar{y} = 0.985$	$\bar{x} = 6.630$	$\Sigma x_n y_n = 34.779$	$\Sigma x_n^2 = 226.246$
		$N \bar{x}_n \bar{y}_n = 32.653$	$N \bar{x}^2 = 219.785$

$$a = \frac{(\Sigma x_n y_n) - N \bar{x}_n \bar{y}_n}{\Sigma x_n^2 - N \bar{x}^2} = \frac{34.779 - 32.653}{226.246 - 219.785} = 0.329$$

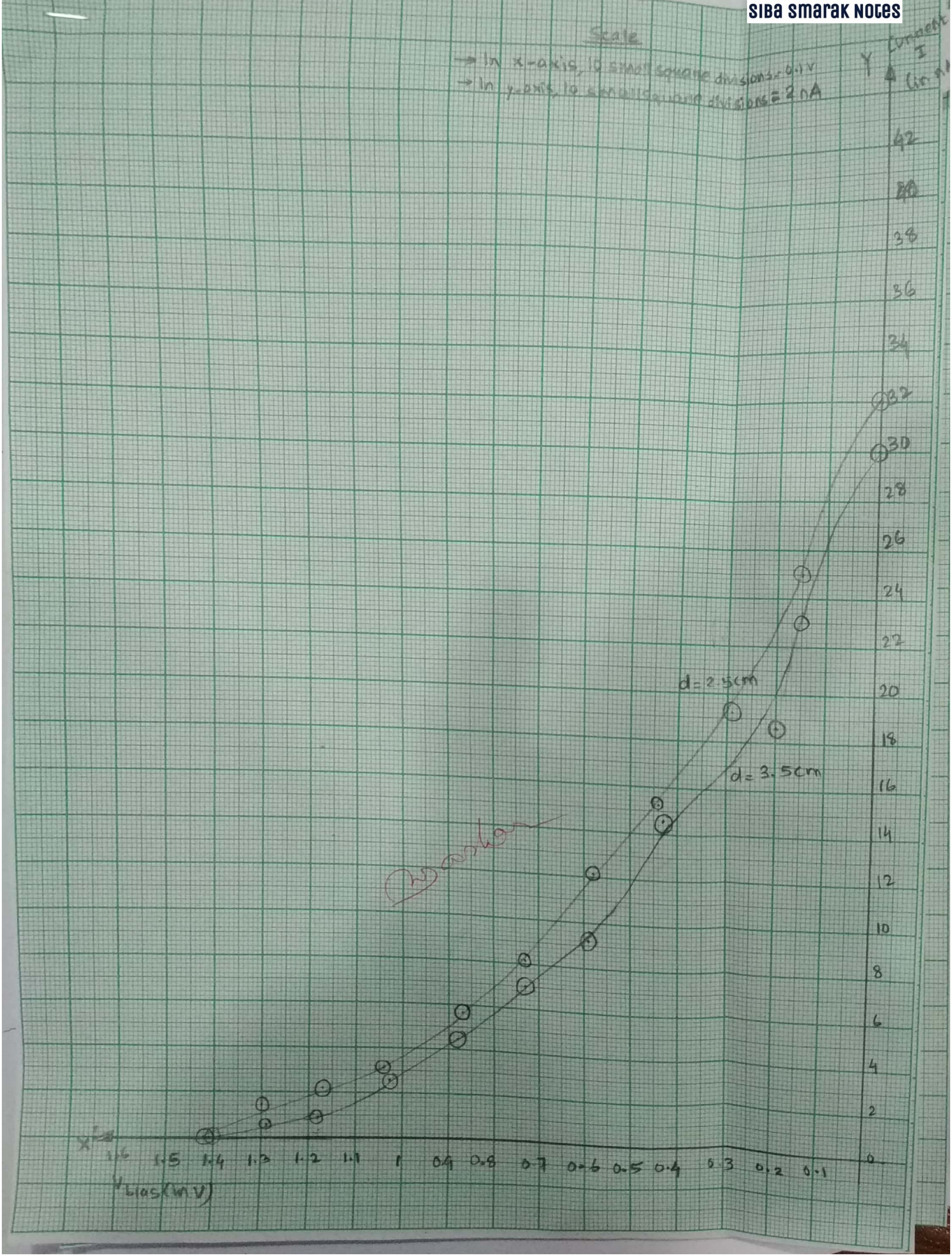
$$b = \frac{\bar{y}(\Sigma x_n^2) - \bar{x}(N \bar{x}\bar{y})}{\Sigma x_n^2 - N \bar{x}^2} = \frac{0.985 \times 226.246 - 6.630 \times 34.779}{226.246 - 219.785} = -1.1\text{[illegible]}$$

$$\boxed{y = 0.329\,x - 1.197}$$

V_{stop} v/s frequency Graph



V_{bias} v/s I graph (λ=366 nm)
(at different distances from source)



Questions

1. What is the value of Planck's constant?
2. What are the sources of error in this experiment?
3. What is photoelectric effect?
4. Define "work-function".
5. What is the time lag between the arrival of light at a metal surface and the emission of photoelectron?
6. What do you mean by stopping potential/extinction voltage/cut off voltage?
7. What type of material should be chosen for photoelectron emission?
8. What is photoelectric cell?
9. What do you know about the structure of photovoltaic cell?
10. Can you name a recent method of a very accurate determination of Planck's constant?
11. Interpret thermionic emission in light of photoelectric effect.
12. In which phenomenon do you see the inverse photoelectric effect?

References

1. PHYWE, TEP 5.1.05-02 "External photoelectric effect and Planck's constant – wavelength selection with grating spectrometer."
2. Prospective of Modern Physics by A. Beiser 539 BEI/P N69
3. The Feynman Lectures on Physics (Vol III) by R.P. Feynman 530 FEY/L

→ Photoelectric effect is the emission of photo electrons. Photo electrons are those electrons which, when absorb photons of light energy incident on them, have enough energy to overcome the binding forces which hold them in a metal kernel.

→ This experiment is of great historical significance as it is the result of this experiment which led to the Quantum Theory of Electromagnetic Radiation.

→ This was one of experiment which showed that light can have particle nature (as well as wave nature).

Results and Calculations

Value of h from the plot ......5.29 × 10^{-34}..........J. sec.

Slope of the graph (from ν_1 and ν_2) $= \left(\frac{h}{e}\right) = \frac{1.11 - 0.78}{7 - 6} = \frac{0.33}{1} = 0.33 \times 10^{-14}$

$\Rightarrow h = 0.33 \times 10^{-14} \times 1.602 \times 10^{-19} = 5.287 \times 10^{-34}$
$= 5.29 \times 10^{-34}$

Error Calculation: If the slope is calculated using voltages $V1$ and $V2$ from the graph, then

$$\frac{\delta h}{h} = \frac{\delta V_1 + \delta V_2}{V_1 - V_2}$$

We know that $\delta V_1 = \delta V_2 = 0.01$ V

$\nu_2 = 7 \times 10^{14}$ Hz; $\nu_1 = 6 \times 10^{14}$ Hz ;

$V_2 = 0.78$ V ; $V_1 = 1.11$ Hz

$\left(\frac{\delta h}{h}\right) = \frac{0.01 + 0.01}{1.11 - 0.78} = \frac{0.02}{0.33} = \frac{2}{33} = 0.061$

$\left(\frac{\delta h}{h}\right)\% = 6.1\%$

$(\delta h) = (0.061)\, h = 0.323 \times 10^{-34}$ J.s.

- Relative error = 0.061
- Percentage error = 6.1%
- Absolute error = 0.323×10^{-34} Js.

Discussion

i. The view that the light propagates as a series of little packets of energy (photons) is directly opposed to the wave theory of light. According to the wave theory, which provides the sole mean of explaining the optical effects like interference and diffraction, the energy carried out by the light is distributed continuously through out the wave pattern. According to the quantum theory, which is strikingly successful in explaining photoelectric effect, light spreads out from the source as a series of localized concentration of energy.

ii. In a specific event light exhibits either a wave or a particle nature, never both simultaneously. *The wave theory of light and the quantum theory of light are complement to each other.*

Wavelength, Frequency	V (V)	I (nA)	Wavelength, Frequency	V (V)	I (nA)
$\lambda = 578$ nm Frequency ($\nu = c/\lambda$) = 5.19 × 10^14 (sec^{-1})	0	19.6			
	0.063	17.9			
	0.123	14.8			
	0.181	11.9			
	0.243	7.3			
	0.303	4.6			
	0.363	2.6			
	0.421	1.6			
	0.482	0.7			
	0.543	0			

Values of the stopping potentials from the plot of V_{bias} vs I for different wavelengths:

V (for $\lambda = 366$ nm) = 1.584 V

V (for $\lambda = 405$ nm) = 1.089 V

V (for $\lambda = 436$ nm) = 1.077 V

V (for $\lambda = 546$ nm) = 0.641 V

V (for $\lambda = 576$ nm) = 0.543 V

Table 2

Dependence of the photocurrent on the intensity of light

$\lambda = 366$ nm; Frequency ($\nu = c/\lambda$) = 8.19 × 10^14 (sec^{-1})

Separation between lamp and filter (cm)	V (V)	I (nA)	Separation between lamp and filter (cm)	V (V)	I (nA)
2.5 cm	0	32	3.5 cm	0	30
	0.146	24.9		0.151	23.1
	0.294	19.2		0.291	18.7
	0.436	15.3		0.428	14.6
	0.584	12.1		0.590	9.2
	0.732	8.1		0.731	7.0
	0.874	5.7		0.879	4.5
	1.035	3.1		1.032	2.6
	1.168	2.2		1.170	0.9
	1.300	1.5		1.290	0.6
	1.419	0		1.404	0

Observations

Least count of the voltmeter: ...0.001 V...; Least count of the ammeter: ...1 nA...

Separation between lamp and filter compartments: ...3 mm...

Table 1

Determination of Stopping Potential

Wavelength, Frequency	V (V)	I (nA)	Wavelength, Frequency	V (V)	I (nA)
$\lambda = 366$ nm Frequency $(\nu = c/\lambda) =$ 8.19×10^{14} (sec^{-1})	0	68.6	$\lambda = 405$ nm Frequency $(\nu = c/\lambda) =$ 7.40×10^{14} (sec^{-1})	0	27.4
	0.112	58.1		0.109	22.6
	0.225	48.5		0.216	18.8
	0.337	39		0.328	15.1
	0.446	32.3		0.438	11.9
	0.559	25.5		0.532	7.8
	0.670	20		0.656	5.4
	0.783	15.8		0.765	3.6
	0.895	12.5		0.873	2.5
	1.008	7.9		0.986	1.6
	1.122	4.9		1.089	0
	1.232	3.1			
	1.346	2.0			
	1.464	1.5			
	1.584	0			
$\lambda = 436$ nm Frequency $(\nu = c/\lambda) =$ 6.88×10^{14} (sec^{-1})	0	66.0	$\lambda = 546$ nm Frequency $(\nu = c/\lambda) =$ 5.49×10^{14} (sec^{-1})	0	65.4
	0.154	49.8		0.084	54.9
	0.308	33.4		0.162	43.1
	0.457	21.2		0.246	28.6
	0.624	10.7		0.324	17.9
	0.771	4.5		0.400	9.2
	0.923	2.1		0.485	4.2
	1.077	0		0.561	0.9
				0.641	0