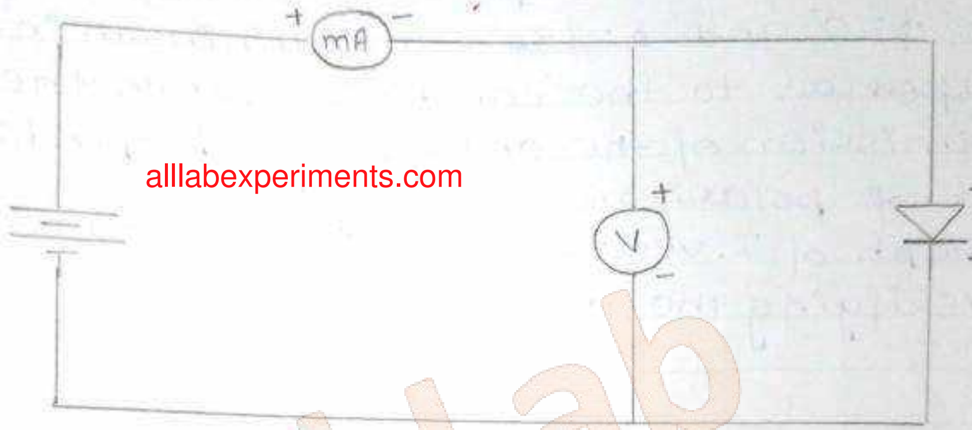
To determine the value of Boltzmann constant using semiconductor diode



Room Temp ? Room temperature = 25°C

Observations :

Least count of voltmeter = 0.1 V

Least count of milliammeter = 1 mA

Least count of microammeter = 1 μA

Forward bias

Voltage (V)	Current (mA)	I current (A)	$\log_{10} I$
0.20	0	0	
0.30	0	0	
0.40	0	0	
0.50	0	0	
0.60	2	0.002	-2.698
0.62	4	0.004	-2.397
0.64	7	0.007	-2.154
0.68	11	0.011	-1.958
0.70	18	0.018	-1.744
0.72	28	0.028	-1.552
0.74	41	0.041	-1.387

Aim: To determine the value of Boltzmann's constant using a semiconductor diode.

Apparatus: A p-n junction diode, a DC-power supply, a milliammeter, a voltmeter and connecting wires.

Theory: When a positive potential is applied to the p-side of a p-n junction diode with respect to its n-side, the diode is said to be forward biased. If V is the voltage across the junction, the current through diode I is given by

$$I = I_S\left[\exp\frac{qV}{nKT} - 1\right]$$

where I_S is reverse saturation current. For Si $n = 2$ and Ge $n = 1$.

For silicon diode at room temperature reduces to $I = I_S[\exp(19.3V) - 1]$

where V is voltage across diodes in volts.

$$I = I_S\left[\exp\left(\frac{qV}{nkT}\right)\right]$$

$$\log_{10} I = \log_{10} I_S + \frac{qV}{2.303nkT}$$

So a plot of $\log_{10} I$ versus V gives $\frac{q}{2.303nkT}$ as the slope from which Boltzmann constant k can be evaluated.

Reverse bias

Voltage (V)	Current (μA)
0.1	41
0.2	45
0.3	53
0.4	58
0.5	63
0.6	70
0.7	76
0.8	83
0.9	88
1.0	100

Calculation:

$$Slope = \frac{-1.5 - (-2.45)}{0.725 - 0.614} = 8.5585$$

$$k = \frac{11.59 \times 10^{-23}}{Slope} = \frac{11.59 \times 10^{-23}}{8.5585}$$

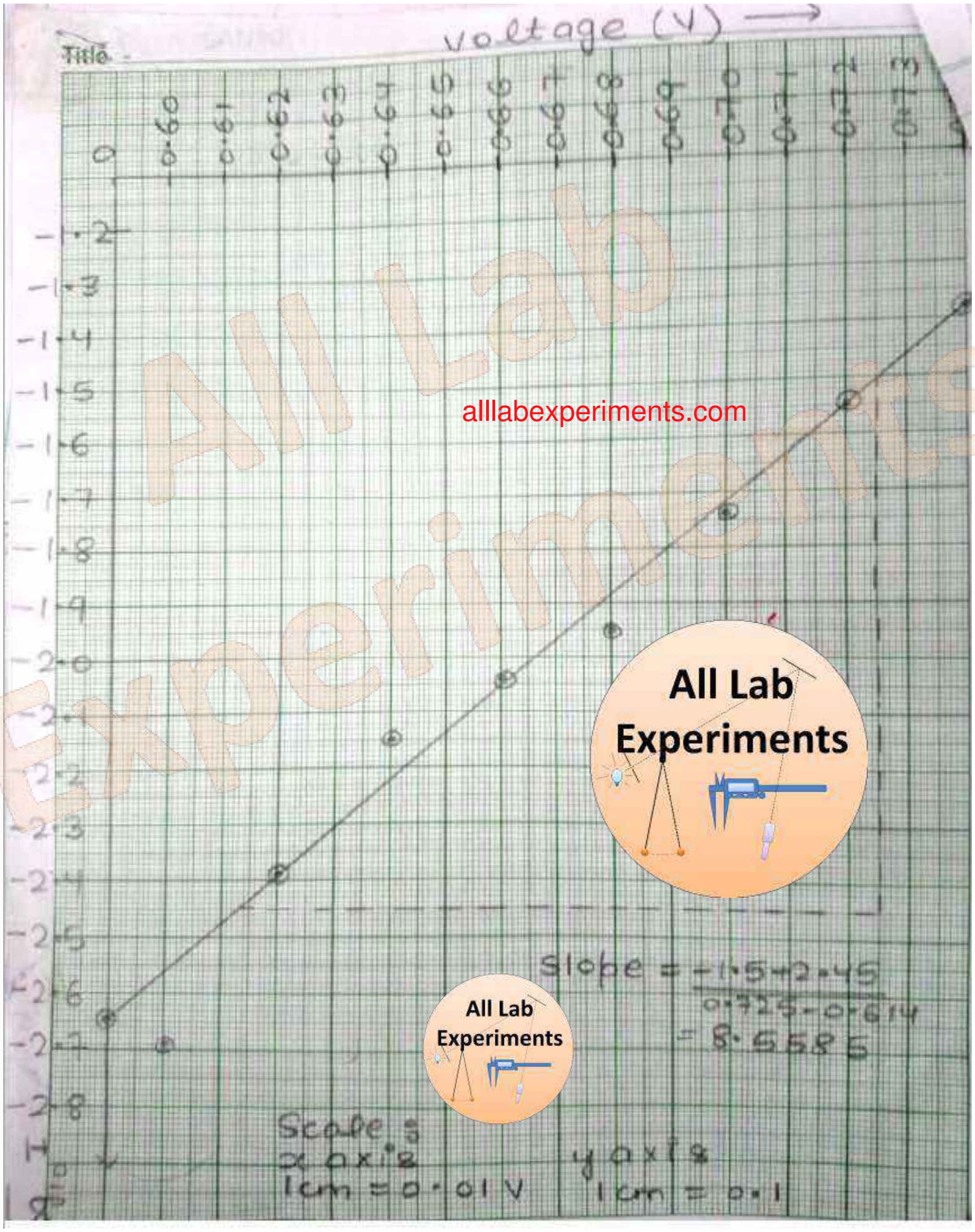
$$k = 1.3542 \times 10^{-23}$$

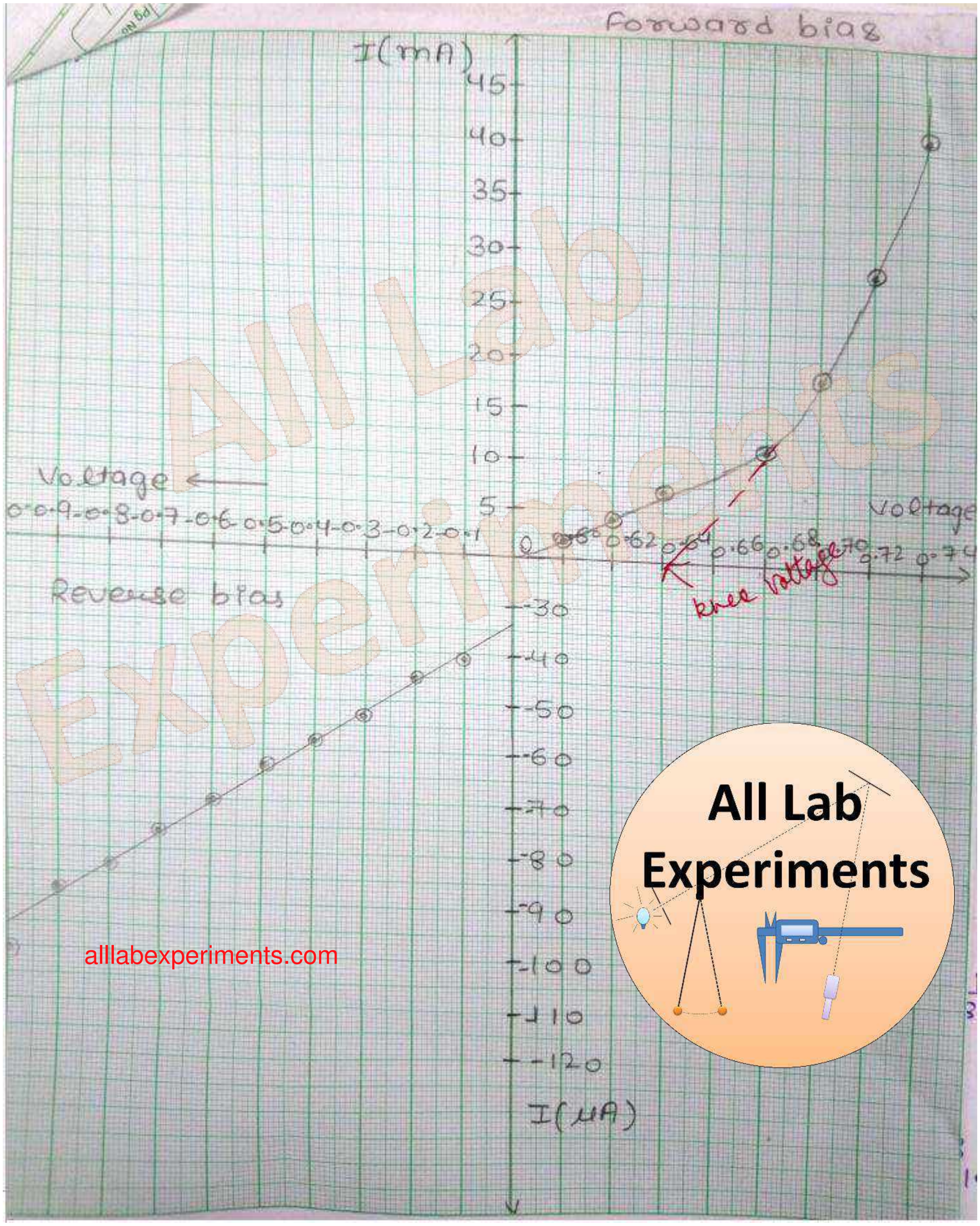
$$k = \frac{q}{2.303 nT} \times \frac{1}{Slope} = \frac{1.6 \times 10^{-19}}{2.303 \times 2 \times 298} \times \frac{1}{8.55}$$

$$k = 1.362 \times 10^{-23} \ J/K$$

$$\text{Percentage error} = \frac{(1.362 - 1.38) \times 10^{-23}}{1.38 \times 10^{-23}} \times 100$$

$$= 1.3\%$$


Title
voltage (V) →
alllabexperiments.com
slope = -1.5+2.45 / 0.725-0.614
= 8.5585
Scale:
x axis
1cm = 0.01 V
y axis
1cm = 0.1


Forward bias
I(mA)
45
40
35
30
25
20
15
10
5
Voltage
Voltage
0.62
0.64
0.66
0.68
0.70
0.72
0.74
-0.9
-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
Reverse bias
knee voltage
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
I(μA)
All Lab Experiments
alllabexperiments.com

1. connect the circuit.
2. Slowly increase input voltage in steps and note the voltage across diode and current I through it. Take readings till the current is about 20 mA.
3. Plot a graph between V along x-axis and $\log_{10} I$ along y-axis.

Result: Experimentally determined value of Boltzmann's constant = $1.3622 \times 10^{-23}\ JK^{-1}$

Standard value = $1.38 \times 10^{-23}\ JK^{-1}$

% Error = 1.3 %

Precautions and Sources of Error:

1. Ensure that p-side is made positive w.r.t n side.
2. Increase supply voltage slowly from zero.
3. It should be remembered that $\eta = 1$ for germanium diode and $\eta = 2$ for silicon diode