INSTRUCTION MANNUAL

EXPERIMENTAL MANUAL

Determination of Boltzmann Constant

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

Apparatus: A p-n-junction diode, a 0-10 volt DC variable power supply, a milliammeter (2000μ & 20mA), a voltmeter (2V/20V) and connecting wires.

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

$$I = I_s\left[exp\frac{qV}{nkT} - 1\right] \quad \ldots\ldots\ldots \qquad (01)$$

Where I_S is the reverse saturation current, ***q*** is the electronic charge, ***k*** is the Boltzmann constant, ***T*** is the absolute temperature, and ***n*** is a numerical constant depending on the material of the diode. For Germanium ***n*** **= 1**, and for Silicon ***n*** **= 2.**

For Silicon diode at room temperature **(*T=300°K)*** Equation (01) reduce to

$$I = I_S\,[\,exp(19.3V)\,-1] \quad \ldots\ldots\ldots \qquad (02)$$

Where ***V*** is the voltage across the diode in volts.
For a positive voltage of value 0.5 – 1V, the exponential term varies from 1.55×10^4 to 2.14×10^8.
Hence in this voltage range or above it, we can easily neglect **'1'** in equation (01) as compared to the exponential term and can write

$$I = I_s exp\left(\frac{qV}{nkT}\right)$$

Or

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

So a plot of ***log₁₀I*** versus ***V*** gives $\frac{q}{2.303nkT}$ as the slope from which Boltzmann constant ***k*** can be evaluated easily.

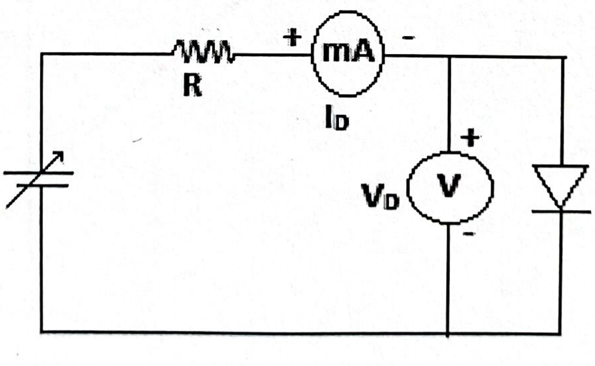

Fig. 1.1

Procedure

1. Make the connections as shown in fig. (1.1) with p-n diode in the forward bias mode.
2. Slowly increase the input voltage from zero in convenient steps, and no the voltage V across the diode and the current ***I*** through it. Take reading till the current is about 20mA. To get a large number of readings digital voltmeter and digital milliammeter should be of low least counts.
3. Plot a graph between ***V*** along ***x***-axis and $log_{10}I$ along ***y***-axis.

Observations

Temperature T = 300°K (Approx room temperature)

Sl. No.	Voltage, V (in Volts)	Current (mA)	Current, I (in Amp.)	$Log_{10}I$
01.				
02.				
03.				
..				
..				

Calculations:

The graph between ***V*** and $log_{10}I$ is a straight line as shown in fig. (1.2). Calculate its slope.

[**Note:** The $log_{10}I$ are negative values. So the graph is actually in the fourth quadrant but the slope remains positive. (Fig. 1.2)]

Boltzmann's constant ***k*** is calculated from the formula

$$k = \frac{q}{2.303nT} \times \frac{1}{slope}$$

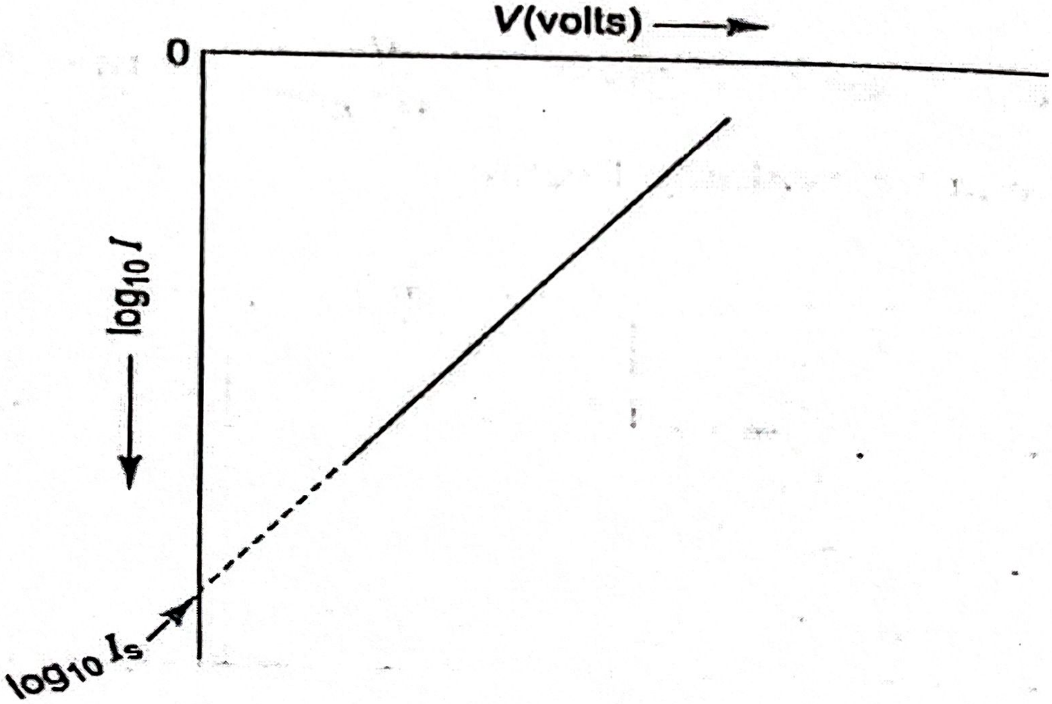

Fig: 1.2

Thus for a Silicon diode at 300°K

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

$= ...JK^{-1}$

Result: The experimentally obtained value of Boltzmann's constant

$= ...JK^{-1}$

Standard value = ... $1.38\times10^{-23}JK^{-1}$

% Error = ...%

Precautions and Sources of Error

1. Ensure that ***p***-side is made positive w.r.t the ***n***-side
2. Increase the supply voltage slowly from zero. Take care that he input voltage does not increase excessively; the safe value for 1N4007 is about 2V. For this reasons our trainer kit have with current limiting resistance of three values. Did not connect or complete the circuit without this resistance.
3. The temperature T should be noted down in Kelvin.
4. It should be remembered that in Eqn. (01) $n = 1$ for Germanium diode and 2 for Silicon diode.

Note: We can determine the reverse saturation current I_s at room temperature as the ***y***- intercept in fig. 2 gives $\log_{10} I_s$ from which I_s can be found.