EXPERIMENT

AIM

Determination of reverse saturation current I_0 and material constant η of pn junction.

APPARATUS REQUIRED

1. Study of P-N Junction, PN-01 : One
2. Oven : One
3. Sample Set : One
   (BC-109-Si ; IN-34-Ge ; IN5408-Diode : Mounted on Teflon Plugs)

FORMULA USED :

Material constant is given by:

$$\eta = \frac{q}{kT}\frac{\Delta V}{\Delta \ln I}$$

The reverse saturation current is given by

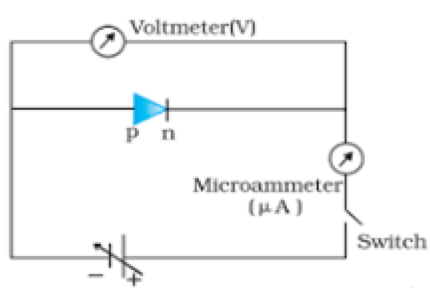
$$I_0 = kT^m e^{\frac{-V_{G0}}{\eta V_T}}$$

And Energy Band gap

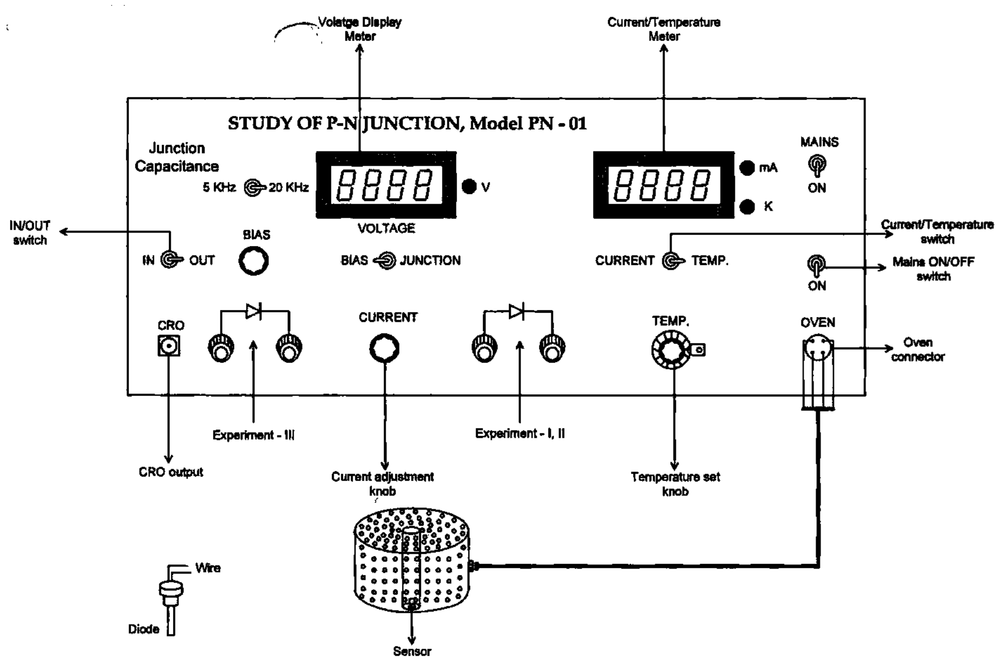
$$\boxed{V_{G0} = V - T\frac{dV}{dT} - \frac{m\eta kT}{q}}$$

For notations please see the theory of both the experiments.

DIAGRAM :



Circuit Diagram of pn junction diode in reverse bias



Panel diagram of Study of P-N Junction, Model PN-01

THEORY

The current I in a p-n junction is given by

$$I = I_0\left(e^{\frac{qV}{\eta kT}} - 1\right) \qquad (1)$$

Where,

q, electronic charge = 1.602 X 10^{-19} coulomb

η ,material constant = 1 for Ge

= 2 for Si

K, Boltzman constant=1.381 X 10^{-23} J/K

T, Temperature in Kelvin

V, Junction voltage n volts

The reverse saturation current is usually too small to be measured directly. An indirect graphical method may be obtained by taking logarithm of eqn. (1) for $e^{qV/\eta kT} \rangle\rangle 1$ as,

$$\ln I = \ln I_0 + \frac{qV}{\eta kT}$$

If, V and In I are plotted on a graph paper a straight line is obtained. This line intersects the current (In I) axis at In I_0 and its slope may be solved to compute η ,

$$\eta = \frac{q}{kT}\frac{\Delta V}{\Delta \ln I}$$

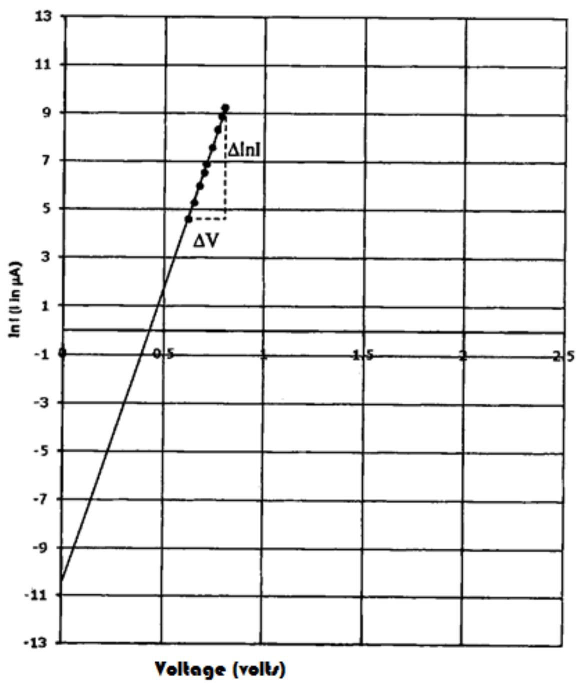
PROCEDURE

The diode to be tested is connected to the terminals with the polarity as indicated (already connected). Readings are now recorded from the two display set to JUNCTION and CURRENT respectively with the current source adjusted in steps from 100 µA to 10 mA.

OBSERVATIONS

Sample: BC 109 (Base – Emitter Junction)

S.NO.	Forward Current I in µA	ln I	Junction Voltage V in Volts
1	100	4.61	
2	200	5.30	
3	400	5.99	
4	700	6.55	
5	1000	6.91	
6	2000	7.60	
7	4000	8.29	
8	7000	8.85	
9	10000	9.21	



Graph 1 Reverse Saturation current

CALCULATIONS:

<u>*Note: Values written here are just for your understanding. Actual readings may differ.</u>

From graph no. 1, we get

$\ln I_0 = -11.5$

Slope of the curve $\frac{\Delta V}{\Delta \ln I} = \frac{0.18}{4.7}$

Therefore,

$I_0 = 0.10 \text{ X } 10^{-10}$ A

And,

$$\eta = \frac{q}{kT}\frac{\Delta V}{\Delta \ln I} = \frac{1.602\times10^{-19}\times0.18}{1.381\times10^{-23}\times305\times4.7}$$

$\eta = 1.46$

EXPERIMENT-II

AIM

Determination of Temperature Coefficient of Junction Voltage and Energy band - gap.

THEORY

The reverse saturation current is given by

$I_0 = kT^m e^{\frac{-V_{G0}}{\eta V_T}}$, and the diode forward current by

$$I = I_0\left(e^{\frac{V}{\eta V_T}} - 1\right) \approx I_0 e^{\frac{V}{\eta V_T}}$$

$= kT^m e^{\frac{V-V_{G0}}{\eta V_T}}$, where for Si: m = 1.5, η = 2 and for Ge: m=2.0, η =1

Also $V_T = \dfrac{kT}{q}$, taking logarithm,

$$\ln I = \ln k + m \ln T + \frac{V - V_{G0}}{\eta V_T}$$

At I=Constant, differentiating w.r.t. T

$$0 = 0 + \frac{m}{T} + \frac{d}{dT}\left[\frac{(V - V_{G0})q}{\eta kT}\right]$$

$$0 = \frac{m}{T} + \frac{q}{\eta kT}.\frac{dV}{dT} - \frac{(V - V_{G0})q}{\eta k}.\frac{1}{T^2}$$

$$0 = \frac{m}{T} + \frac{q}{\eta kT}.\frac{dV}{dT} - \frac{q}{\eta kT^2}(V - V_{G0})$$

$$0 = \frac{\eta kT^2}{q}.\frac{m}{T} + T\frac{dV}{dT} - (V - V_{G0})$$

$$\boxed{V_{G0} = V - T\frac{dV}{dT} - \frac{m\eta kT}{q}}$$

At 300 K for Si,

$$\frac{m\eta kT}{q} = (1.5 \text{ X } 2 \text{ X } 1.381 \text{ X } 10^{-23} \text{ X } 300) / 1.602 \text{ X } 10^{-19}$$

$$= 0.078 \text{ V}$$

Where slope of the V-T curve is the temperature coefficient of the junction voltage and V_{G0} is the energy band-gap.

PROCEDURE

With the connections as in Experiment-I, the OVEN and SENSOR leads are inserted in the respective sockets. The diode is put in the oven and its forward current is set to low value (say 1 mA) to avoid heating. The display-1 is now switched to TEMP, to read the oven temperature.

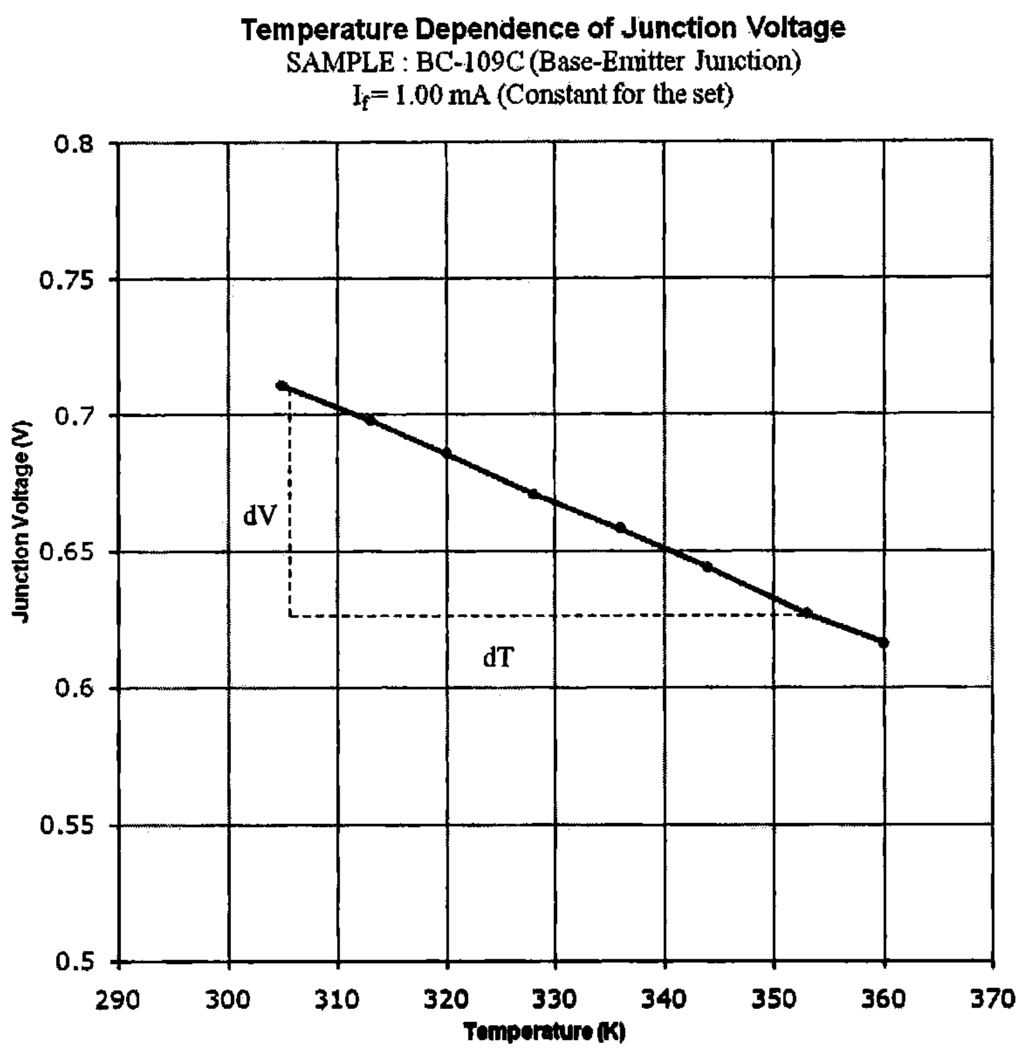
The Oven temperature can now be varied from room temperature to about 360 K in suitable steps and the junction voltage may be recorded. The temperature controlled oven requires about 5 minutes to stabilize at every new setting. Before noting any readings, one must ensure that a few ON/OFF cycles of the oven have been completed as shown by the indicator.

OBSERVATIONS

Sample : BC 109 (Base – Emitter Junction)

$\mathbf{I_f}$ = 1.00 mA (Constant for the set)

S.No.	Temperature	Junction Voltage
1	305	
2	313	
3	320	
4	328	
5	336	
6	344	
7	353	
8	360	



Graph 2

CALCULATIONS

We know,

$$\text{Energy Band gap } V_{G0} = V(T) - T\frac{dV}{dT} - \frac{m\eta kT}{q}$$

From graph no. 2

At T = 300 K, V(T) = 0.720 V, $\frac{dV}{dT} = -1.79 \times 10^{-3} V/K$

& for Si at 300 K, $\frac{m\eta kT}{q} = 0.078V$

V_{G0} = 0.720 – [300(-1.79X10^{-3})]-0.078

= 0.720 – [-0.357]-0.078

= 0.720 + 0.537 – 0.078

= 1.18 eV