Electrons and holes are modelled using Fermi-Dirac statistics since they are fermions with spin half.

The probability that a particular energy level, E, is occupied is given by the Fermi-Dirac distribution function

$$F(E) = \frac{1}{1 + e^{\frac{(E-E_F)}{kT}}}$$

where E_F is the Fermi level energy.

The equation for the current in a diode

$$I = I_0 \left(\exp\left(\frac{eV}{kT}\right) - 1 \right)$$

can be derived by an analysis of the flow of charge carriers across the pn junction based on the distribution of carriers as a function of energy (Fermi-Dirac statistics)

$$I = I_0 \left(\exp\left(\frac{eV}{kT}\right) - 1 \right)$$

If the voltage across the diode is zero, then

$$\exp(\frac{eV}{kT}) = 1$$

and the junction current is zero.

If the voltage across the diode is negative, corresponding to a reverse bias, then the term

$$\exp(\frac{eV}{kT}) << 1$$

and the junction current is $-I_0$ as expected.

When a forward bias is applied, the current increases exponentially.

For T = 293K

Voltage V	Current A
-10	-1.0^{-10}
0	0
0.1	5.5×10^{-9}
0.4	0.9×10^{-3}
0.5	4.8×10^{-2}
0.6	2.65
0.7	144
0.9	4.3×10^{5}

A very useful simplification is made if the numerical values

for Boltzman's constant, $1.38 \times 10^{-23} JK^{-1}$,

the electronic charge, $1.6 \times 10^{-19} C$ and

the assumed room temperature of $t = 20^oC = 293K$

are substituted to give:—

$$\frac{kT}{e} = \frac{1.38 \times 10^{-23} \times 293}{1.6 \times 10^{-19}} = 0.025V = 25mV$$

The junction diode forward current then becomes:—

$$I = I_0 \exp\left(\frac{V}{25mV}\right)$$

This is a result which we will use very frequently in our analysis of circuits.