In the diode equation the voltage equivalent of temperature

Description This mock test of Test: The Volt Ampere Characteristics for Electrical Engineering (EE) helps you for every Electrical Engineering (EE) entrance exam. This contains 10 Multiple Choice Questions for Electrical Engineering (EE) Test: The Volt Ampere Characteristics (mcq) to study with solutions a complete question bank. The solved questions answers in this Test: The Volt Ampere Characteristics quiz give you a good mix of easy questions and tough questions. Electrical Engineering (EE) students definitely take this Test: The Volt Ampere Characteristics exercise for a better result in the exam. You can find other Test: The Volt Ampere Characteristics extra questions, long questions & short questions for Electrical Engineering (EE) on EduRev as well by searching above. A diode is a non-linear component of an electrical circuit. That allows current in forward biasing and block current in reverse biasing. The behavior of a diode can be identified using VI characteristics. The diode current depends upon the voltage across the diode. The diode current can be expressed in the form of a diode current equation. We will learn in this article what is the equation for diode current?Derivation of Diode EquationThe diode current equation relates the current with the voltage across the diode. Suppose the voltage V across and current I flowing through the diode. The current I can be expressed as$I=I_{o}\lbrack e^{\frac{V}{\eta V_{T}}}-1\rbrack \ldots (1)$Where$I$ – Diode CurrentI_{o}- Diode reverse saturation current at room temperature$V $- External Voltage applied to the diode$\eta $ – A constant, two for Silicon and one for GermaniumV_{T} = $\frac{kT}{q}=\frac{T}{11600}$ Volts-equivalent of temperature, thermal voltageBy putting the value of V_{T}, we may get the following equation$I=I_{o}\lbrack e^{\frac{qV}{\eta kT}}-1\rbrack $Where$k$ – Boltzmann's constant, $1.38066\times 10^{-23} J/K $$q $- charge of an electron, $1.60219\times 10^{-19}C$$T $- temperature of the diode junction $K=C+273\deg$At the room temperature K=300, the thermal voltage $V_{T}=26mV$. Put these values in the current equation (1), we get$I=I_{o}\lbrack e^{40\frac{V}{\eta }}-1\rbrack $As the constant $\eta $, is one for germanium and two for silicon, so the above equations will becomeFor Germanium$I=I_{o}\lbrack e^{40V}-1\rbrack $For Silicon$I=I_{o}\lbrack e^{20V}-1\rbrack $For reverse bias current, the sign of the voltage applied V is changed and the equation for reverse bias will be$I=I_{o}\lbrack e^{\frac{-V}{\eta V_{T}}}-1\rbrack $As $V\gg V_{T}$, so the term $e^{-\frac{V}{\eta V_{T}}}\ll 1$. So, $I\approx I_{o}$, is valid up till external voltage is below the breakdown voltage. The diode reverse saturation current is also called dark saturation current. It depends upon the rate of recombination and quality of the material. It is also notable that the dark current increases as the temperature increases. And it decreases as the material quality increases.Diode Current Equation Example:A reverse bias is applied to the germanium PN junction diode. And noted the reverse saturation current of $0.3\mu A$ at room temperature. What will be the current at room temperature when the forward bias is $0.15v$.Example Solution:How to calculate diode current with the given data in the example$I_{0}=0.3\times 10^{-6}A$$V=0.15v$So, the diode current will be$I=I_{o}\lbrack e^{40V}-1\rbrack $$I=0.3\times 10^{-6}(e^{40\times 0.15}-1)$$I=120.73\mu A$The above will be the forward bias current of the diode for the given situation.Can I use Shockley's ideal diode equation for the reverse current?For the reverse current, the diode exhibits a constant reverse current that is very small and negligible. The reverse current of the diode is not represented by Shockley's ideal diode equation.Diode Equation Calculator:Diode Equation Calculator calculates the current in the diode. Put external voltage, saturation current temperature, and material type to calculate diode current. When we talk about semiconductors, there exists thermal voltage which ranges from 25 to 26 mV as you mentioned. I'm no chemist but it comes from the Boltzmann Constant that is arbitrarily noted as \$k\$. We use \$k\$ for a lot of things including the Ideal Gas Law in chemistry or thermodynamics, etc. It relates to the kinetic energy of the particles in gas state of matter. Consider this equation: \$k=R/N_A\$ where \$R\$ is a gas constant that is related to the molar with ideal gases and \$N_A\$ is simply Avogardro's Number. In Shockley Diode Equation, thermal voltage is equal to \$ \displaystyle V_T=\frac{kT}{q}\$ where \$T\$ is an ambient temperature and \$q\$ is the charge of an electron. At 300 Kelvin, thermal voltage is \$\approx\$25.85 mV... and that's pretty much it... It's a relationship between electrostatic potential and electric current across a P-N junction. You can utilize the calculation of the thermal voltage when you model a diode. Diode Law Graph, shows relationship of voltage and current of an ideal diode The Shockley diode equation or the diode law, named after transistor co-inventor William Shockley of Bell Telephone Laboratories, gives the I–V (current-voltage) characteristic of an idealized diode in either forward or reverse bias (applied voltage): I = I S (e V D n V T − 1) {\displaystyle I=I_{\mathrm {S} }\left(e^{\frac {V_{\text{D}}}{nV_{\text{T}}}}-1\right)} where I is the diode current, IS is the reverse bias saturation current (or scale current), VD is the voltage across the diode, VT is the thermal voltage kT/q (Boltzmann constant times temperature divided by electron charge), and n is the ideality factor, also known as the quality factor or sometimes emission coefficient. The equation is called the Shockley ideal diode equation when n, the ideality factor, is set equal to 1. The ideality factor n typically varies from 1 to 2 (though can in some cases be higher), depending on the fabrication process and semiconductor material and is set equal to 1 for the case of an "ideal" diode (thus the n is sometimes omitted). The ideality factor was added to account for imperfect junctions as observed in real transistors. The factor mainly accounts for carrier recombination as the charge carriers cross the depletion region. The thermal voltage VT is approximately 25.8563 mV at 300 K (27 °C; 80 °F). At an arbitrary temperature, it is a known constant defined by: V T = k T q , {\displaystyle V_{\text{T}}={\frac {kT}{q}}\,,} where k is the Boltzmann constant, T is the absolute temperature of the p–n junction, and q is the magnitude of charge of an electron (the elementary charge). The reverse saturation current, IS, is not constant for a given device, but varies with temperature; usually more significantly than VT, so that VD typically decreases as T increases. The Shockley diode equation doesn't describe the "leveling off" of the I–V curve at high forward bias due to internal resistance. This can be taken into account by adding a resistance in series. Under reverse bias (when the n side is put at a more positive voltage than the p side) the exponential term in the diode equation is near zero and the current is near a constant (negative) reverse current value of −IS. The reverse breakdown region is not modeled by the Shockley diode equation. For even rather small forward bias voltages the exponential is very large, since the thermal voltage is very small in comparison. The subtracted '1' in the diode equation is then negligible and the forward diode current can be approximated by I = I S e V D n V T {\displaystyle I=I_{\text{S}}e^{\frac {V_{\text{D}}}{nV_{\text{T}}}}} The use of the diode equation in circuit problems is illustrated in the article on diode modeling. Derivation Shockley derives an equation for the voltage across a p-n junction in a long article published in 1949.[1] Later he gives a corresponding equation for current as a function of voltage under additional assumptions, which is the equation we call the Shockley ideal diode equation.[2] He calls it "a theoretical rectification formula giving the maximum rectification", with a footnote referencing a paper by Carl Wagner, Physikalische Zeitschrift 32, pp. 641–645 (1931). To derive his equation for the voltage, Shockley argues that the total voltage drop can be divided into three parts: the drop of the quasi-Fermi level of holes from the level of the applied voltage at the p terminal to its value at the point where doping is neutral (which we may call the junction) the difference between the quasi-Fermi level of the holes at the junction and that of the electrons at the junction the drop of the quasi-Fermi level of the electrons from the junction to the n terminal. He shows that the first and the third of these can be expressed as a resistance times the current, R1I. As for the second, the difference between the quasi-Fermi levels at the junction, he says that we can estimate the current flowing through the diode from this difference. He points out that the current at the p terminal is all holes, whereas at the n terminal it is all electrons, and the sum of these two is the constant total current. So the total current is equal to the decrease in hole current from one side of the diode to the other. This decrease is due to an excess of recombination of electron-hole pairs over generation of electron-hole pairs. The rate of recombination is equal to the rate of generation when at equilibrium, that is, when the two quasi-Fermi levels are equal. But when the quasi-Fermi levels are not equal, then the recombination rate is exp ((ϕ p − ϕ n) / V T) {\displaystyle \exp((\phi _{p}-\phi _{n})/V_{\text{T}})} times the rate of generation. We then assume that most of the excess recombination (or decrease in hole current) takes place in a layer going by one hole diffusion length (Lp) into the n material and one electron diffusion length (Ln) into the p material, and that the difference between the quasi-Fermi levels is constant in this layer at VJ. Then we find that the total current, or the drop in hole current, is I = I s [e V J V T − 1] {\displaystyle I=I_{s}\left[e^{\frac {V_{J}}{V_{\text{T}}}}-1\right]} where I s = g q (L p + L n) {\displaystyle I_{s}=gq\left(L_{p}+L_{n}\right)} and g is the generation rate. We can solve for V J {\displaystyle V_{J}} in terms of I {\displaystyle I} : V J = V T ln (1 + I I s) {\displaystyle V_{J}=V_{\text{T}}\ln \left(1+{\frac {I}{I_{s}}}\right)} and the total voltage drop is then V = I R 1 + V T ln (1 + I I s) . {\displaystyle V=IR_{1}+V_{\text{T}}\ln \left(1+{\frac {I}{I_{s}}}\right).} When we assume that R 1 {\displaystyle R_{1}} is small, we obtain V = V J {\displaystyle V=V_{J}} and the Shockley ideal diode equation. The small current that flows under high reverse bias is then the result of thermal generation of electron-hole pairs in the layer. The electrons then flow to the n terminal and the holes to the p terminal. The concentrations of electrons and holes in the layer is so small that recombination there is negligible. In 1950, Shockley and coworkers published a short article describing a germanium diode that closely followed the ideal equation.[3] In 1954, Bill Pfann and W. van Roosbroek (who were also of Bell Telephone Laboratories) reported that while Shockley's equation was applicable to certain germanium junctions, for many silicon junctions the current (under appreciable forward bias) was proportional to e V J / A V T , {\displaystyle e^{V_{J}/AV_{\text{T}}},} with A having a value as high as 2 or 3.[4] This is the "ideality factor" called n above. In 1981, Alexis de Vos and Herman Pauwels showed that a more careful analysis of the quantum mechanics of a junction, under certain assumptions, gives a current versus voltage characteristic of the form I (V) = − q A [F i − 2 F o (V)] {\displaystyle I(V)=-qA\left[F_{i}-2F_{o}(V)\right]} in which A is the cross-sectional area of the junction and Fi is the number of in-coming photons per unit area, per unit time, with energy over the band-gap energy, and Fo(V) is out-going photons, given by[5] F o (V) = ∫ ν g ∞ 1 exp (h ν − q V k T c) − 1 2 π ν 2 c 2 d ν . {\displaystyle F_{o}(V)=\int _{u _{g}}^{\infty }{\frac {1}{\exp \left({\frac {hu -qV}{kT_{c}}}\right)-1}}{\frac {2\pi u ^{2}}{c^{2}}}du .} Where the lower limit is described later. Although this analysis was done for photovoltaic cells under illumination, it applies also when the illumination is simply background thermal radiation. It gives a more rigorous form of expression for ideal diodes in general, except that it assumes that the cell is thick enough that it can produce this flux of photons. When the illumination is just background thermal radiation, the characteristic is I (V) = 2 q [F o (V) − F o (0)] {\displaystyle I(V)=2q\left[F_{o}(V)-F_{o}(0)\right]} Note that, in contrast to the Shockley law, the current goes to infinity as the voltage goes to the gap voltage hνg/q. This of course would require an infinite thickness to provide an infinite amount of recombination. References ^ William Shockley (Jul 1949). "The Theory of p-n Junctions in Semiconductors and p-n Junction Transistors". The Bell System Technical Journal. 28 (3): 435–489. doi:10.1002/j.1538-7305.1949.tb03645.x.. Equation 3.13 on page 454. ^ Ibid. p. 456. ^ F.S. Goucher; et al. (Dec 1950). "Theory and Experiment for a Germanium p-n Junction". Physical Review. doi:10.1103/PhysRev.81.637.2. ^ W. G. Pfann; W. van Roosbroek (Nov 1954). "Radioactive and Photoelectric p-n Junction Power Sources". Journal of Applied Physics. 25 (11): 1422–1434. Bibcode:1954JAP....25.1422P. doi:10.1063/1.1721579. ^ A. De Vos and H. Pauwels (1981). "On the Thermodynamic Limit of Photovoltaic Energy Conversion". Appl. Phys. 25 (2): 119–125. Bibcode:1981ApPhy..25..119D. doi:10.1007/BF00901283. S2CID 119693148.. Appendix. Retrieved from "