A. Stolp
2/23/03

Stuff

Lecture notes will be discontinued due to lack of attendance in class. I go through the trouble of making these notes so that you can get more from the lectures. Unfortunately, because of the lecture notes, many people don't bother to come to lectures at all, so they get absolutely nothing from the lectures. That makes the net effect of these notes negative rather than positive. I'm not interested in writing these notes for a net negative effect.

HW #12, due: M, 2/24 handout

SPICE #S1, due: W, 3/5 hw 12 handout

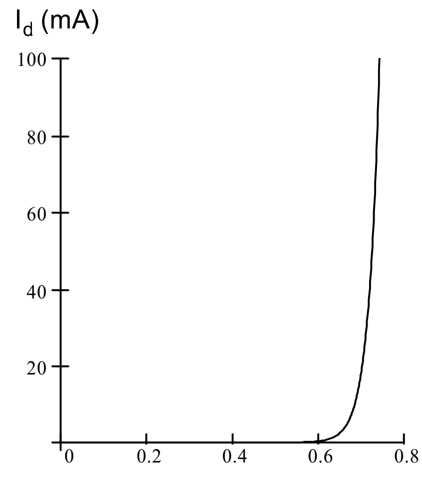
HW #13, due: F, 2/28 Ex3.10-12, prob. 3.32, 34, 35

Answers: 3.32 J_p=8.64x10^{-8} A/cm^3 3.35: N_D = 9.3x10^{17}/cm^3

HW #14, due: M, 3/3 Ex3.13-15 (Note: units of D_n & D_p are wrong in Ex3.15)

Diode Equation section 3.2 in book

Actually diode characteristic is a curve



Diode Equation

diode voltage

Diode current: $I_d = I_s \cdot \left(e^{\frac{V_d}{n \cdot V_T}} - 1 \right)$ Usually drop this 1 in forward bias

Saturation current (AKA scale current)

Thermal voltage $= \frac{k \cdot T}{q} \cong 25 \cdot mV$

Fudge factor, assume n = 1 in ICs and n = 2 for discrete parts

Other permutations of the diode equation:

$$V_d = n \cdot V_T \cdot \ln\left(\frac{I_d}{I_s}\right) \qquad I_s = \frac{I_d}{\left(e^{\frac{V_d}{n \cdot V_T}} - 1 \right)}$$

Electron volt: $eV := 1.60 \cdot 10^{-19} \cdot joule$

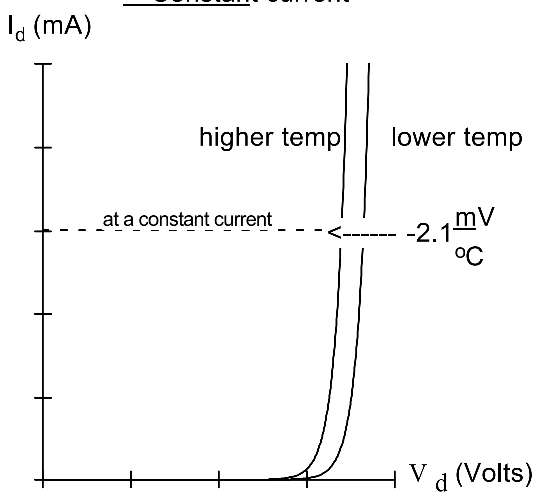
Absolute temperature: T = °C + 273

Boltzmann's constant: $k := 8.63 \cdot 10^{-5} \cdot \frac{eV}{K}$

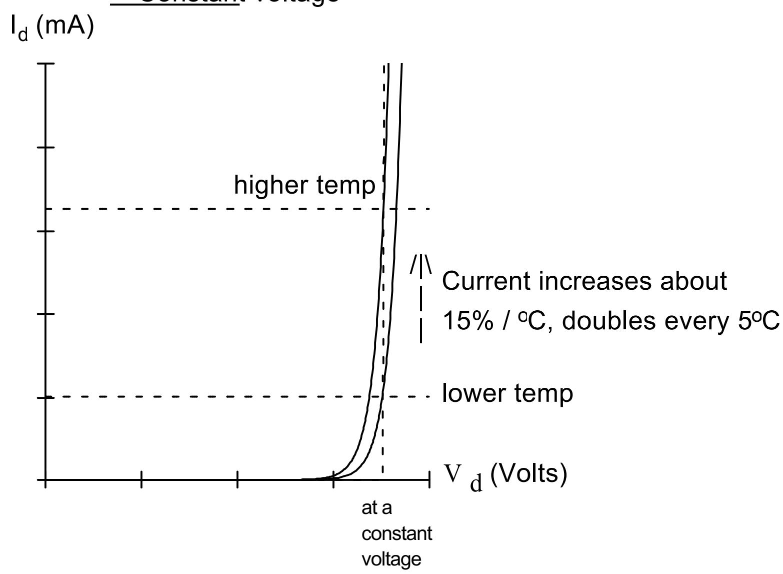
Electron charge: $q := 1.60 \cdot 10^{-19} \cdot coul$

Temperature effects

Constant current



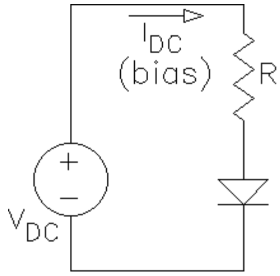
Constant voltage



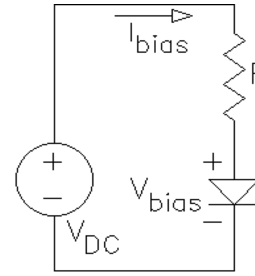
Reverse leakage current doesn't change quite as much with temperature, it increases about 7% /°C, doubles every 10°C

Small signal model

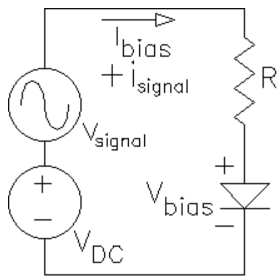
Say that we "bias" a diode into the "on" state using a DC supply.



The result would be a bias current through the diode and a bias voltage across the diode.



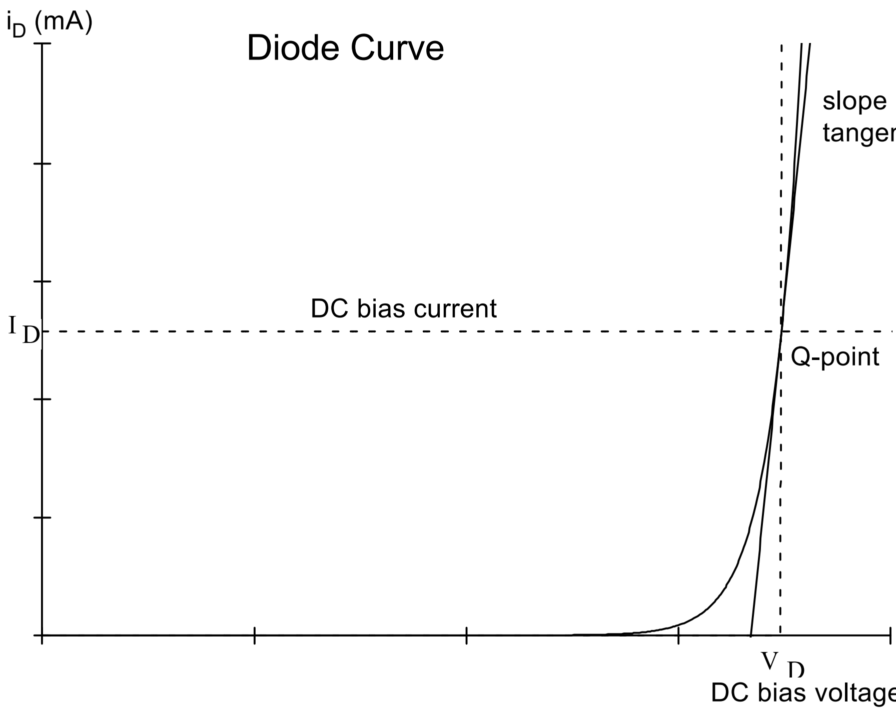
Now we add a "small signal". A signal is an AC voltage, which we'll model with a sine wave, small in comparison to the DC bias.



We'd like to use superposition to separate the DC from the AC analysis. That works OK for the large DC bias, but doesn't make much sense for the AC signal. The diode is nonlinear and behaves quite differently to a small AC voltage centered around zero than it does to one piggybacked onto a DC bias.

The trick is to find a linear model for the diode that works for a small signal centered at the DC bias. That is, what does the diode look like for small variations around the DC bias point (also called the "quiescent" or "Q-point").

Tha answer is the tangent line to the diode curve at the DC bias point. That line is by definition linear and is valid for small variations around the DC bias point.



slope of tangent is: $\frac{1}{r_d}$

v_D (Volts)

To find the tangent (slope) of a curve, simple take the derivative:

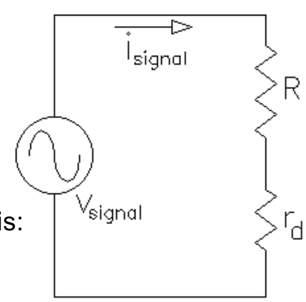
$$i_D = I_s \cdot e^{\frac{v_D}{V_T}}$$

$$\frac{d}{dv_D} i_D = \frac{d}{dv_D}\left(I_s \cdot e^{\frac{v_D}{V_T}}\right)$$

$$= \frac{1}{V_T} \cdot I_s \cdot e^{\frac{v_D}{V_T}}$$

Evaluate the derivative at the bias point: $\frac{1}{V_T} \cdot I_s \cdot e^{\frac{V_D}{V_T}} = \frac{1}{V_T} \cdot I_D = \frac{I_D}{V_T} = r_d$

Now, from the signal's point-of-view, the circuit looks like this:



The meaning of CAPITALS and lower case letters

	examples		meaning
CAP_{CAP}	V_D	I_D	DC, Bias quantity
sm_{sm}	v_d	i_d	AC, signal
sm_{CAP}	v_D	i_D	DC and AC together

This not just an academic exercise, When we get to transistors you'll see that input to a transistor is essentially a diode, so applying signals to diodes is very common.