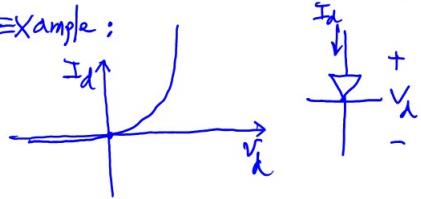


ECE 101 Fall Lecture 5 Oct 15, 2019

Linear, Nonlinear Circuits (Chap 3, 86-102)

In Nonlinear Circuits, some elements have nonlinear $i-v$ relationships.

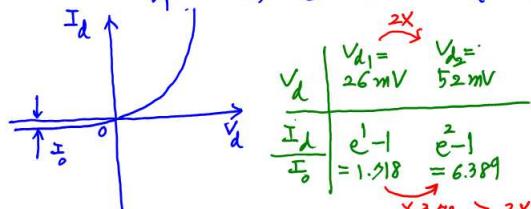
Example:



$$I_d = f(V_d) = I_0 \left(e^{\frac{V_d}{V_T}} - 1 \right)$$

where $V_T = 26 \text{ mV}$ at $T = 300 \text{ K}$.

For $\frac{V_d}{V_T} < -5$, $e^{\frac{V_d}{V_T}} \approx 0$ and $I_d = -I_0$

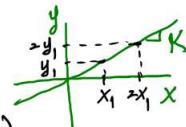


If the I_d-V_d relationship were linear, $I_{d2} = 2 I_{d1}$.

HW # 3 (for Quiz 3 on Oct 17)

- 1) Prob 3-1
- 2) prob 3-3
- 3) prob 3-7
- 4) prob 3-11
- 5) prob 3-13
- 6) prob 3-15
- 7) prob 3-17
- 8) prob 3-20

Linear function



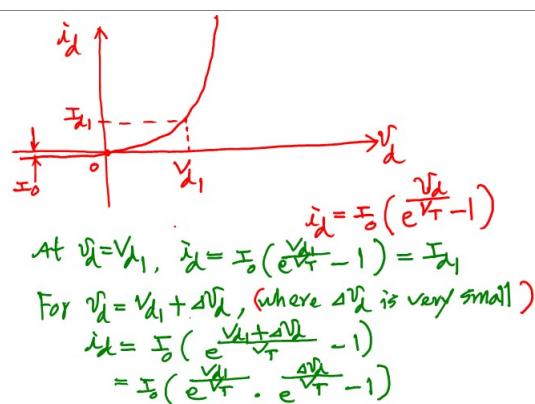
$$y_1 = f(x_1), \quad y_2 = f(x_2)$$

$$y_2 = f(Kx_2) = K f(x_2) = K y_1$$

$$x_2 = Kx_1$$

$$\text{e.g., } y_2 = 2x_1 \quad (2x)$$

$$y_2 = f(2x_1) = 2 f(x_1) = 2 y_1 \quad (2x)$$



$$At V_d = V_1, I_d = I_0 \left(e^{\frac{V_d}{V_T}} - 1 \right) = I_{d1}$$

For $V_d = V_1 + \Delta V_d$, (where ΔV_d is very small)

$$I_d = I_0 \left(e^{\frac{V_1 + \Delta V_d}{V_T}} - 1 \right)$$

$$= I_0 \left(e^{\frac{V_1}{V_T}} \cdot e^{\frac{\Delta V_d}{V_T}} - 1 \right)$$

$$e^{\frac{\Delta V_d}{V_T}} = 1 + \frac{\Delta V_d}{V_T} + \frac{(\Delta V_d)^2}{2!} + \dots$$

$$\frac{\Delta V_d}{V_T} \ll 1 \quad \approx 1 + \frac{\Delta V_d}{V_T}$$

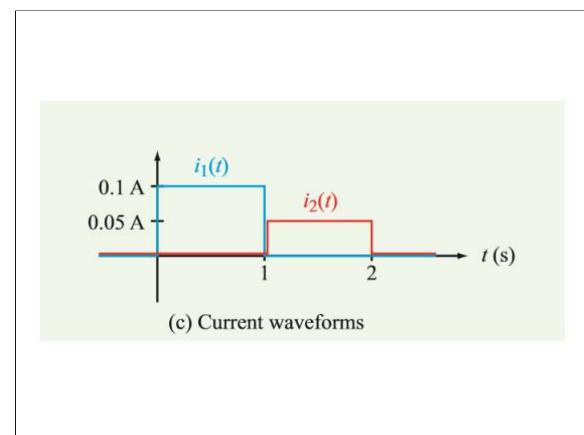
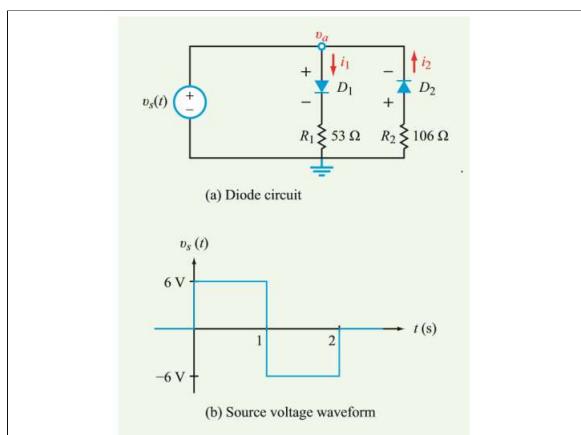
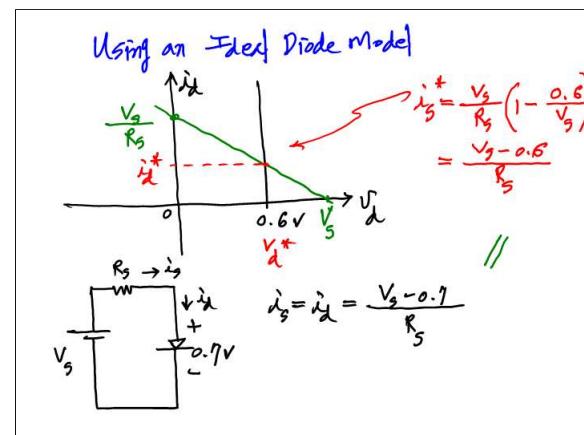
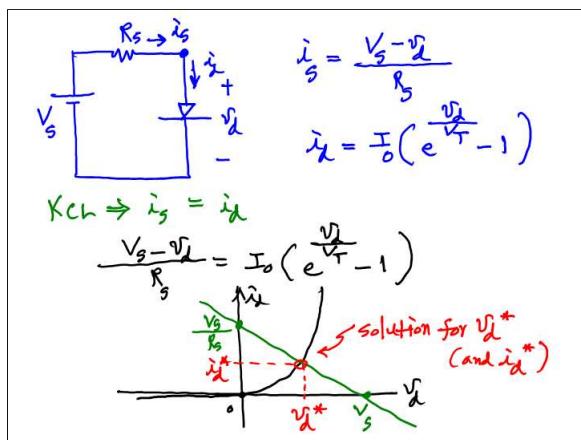
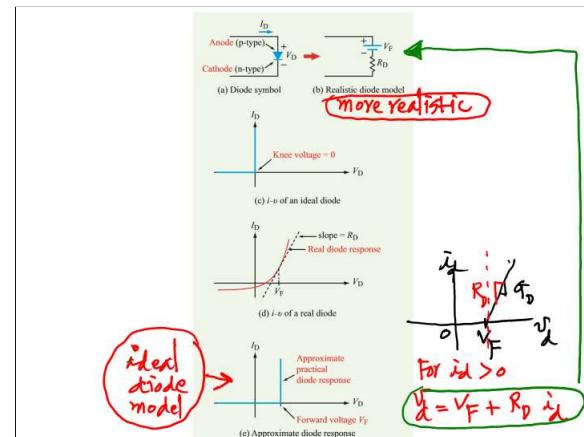
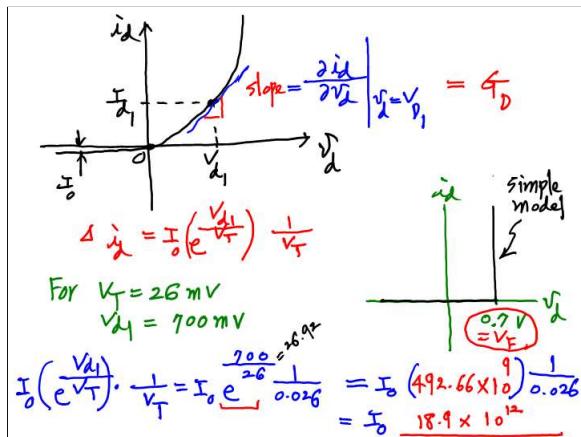
Thus

$$I_d = I_0 \left(\frac{V_1}{V_T} \cdot e^{\frac{\Delta V_d}{V_T}} - 1 \right)$$

$$= I_0 \left(\frac{V_1}{V_T} \cdot \left(1 + \frac{\Delta V_d}{V_T} \right) - 1 \right)$$

$$= \underbrace{I_0 \left(e^{\frac{V_1}{V_T}} - 1 \right)}_{I_{d1}} + \underbrace{I_0 \frac{V_1}{V_T} \cdot \frac{\Delta V_d}{V_T}}_{\Delta I_d}$$

$$\Delta I_d = \underbrace{\left(I_0 \frac{V_1}{V_T} \cdot \frac{1}{V_T} \right)}_{I_{d1}} \Delta V_d = \frac{\partial I_d}{\partial V_d} \Big|_{V_d = V_1} \Delta V_d$$



Exercise 2-11: Determine I in the two circuits of Fig. E2.11. Assume $V_F = 0.7$ V for all diodes.

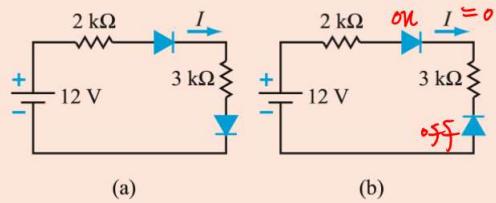


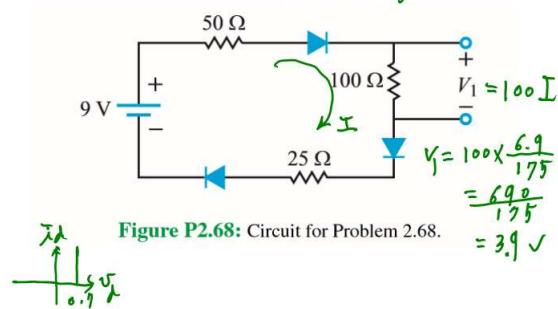
Figure E2.11

$$\frac{10.6V}{5K} = 2.12 \text{ mA}$$

Answer: (a) $I = 2.12$ mA, (b) $I = 0$. (See CAD)

Assume $V_F = +0.7$ V

$$\frac{9 - 3(0.7)}{50 + 100 + 25} = \frac{6.9}{175} = I$$



2.69 If the voltage source in the circuit of Fig. P2.69 generates a single square wave with an amplitude of 2 V, generate a plot for v_{out} for the same time period.

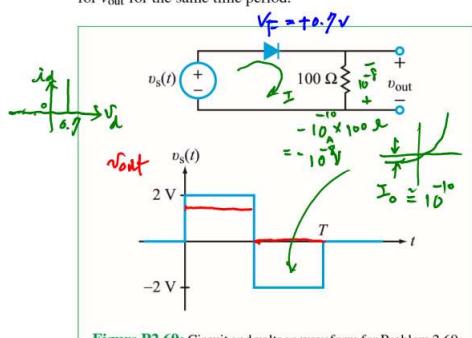


Figure P2.69: Circuit and voltage waveform for Problem 2.69.

