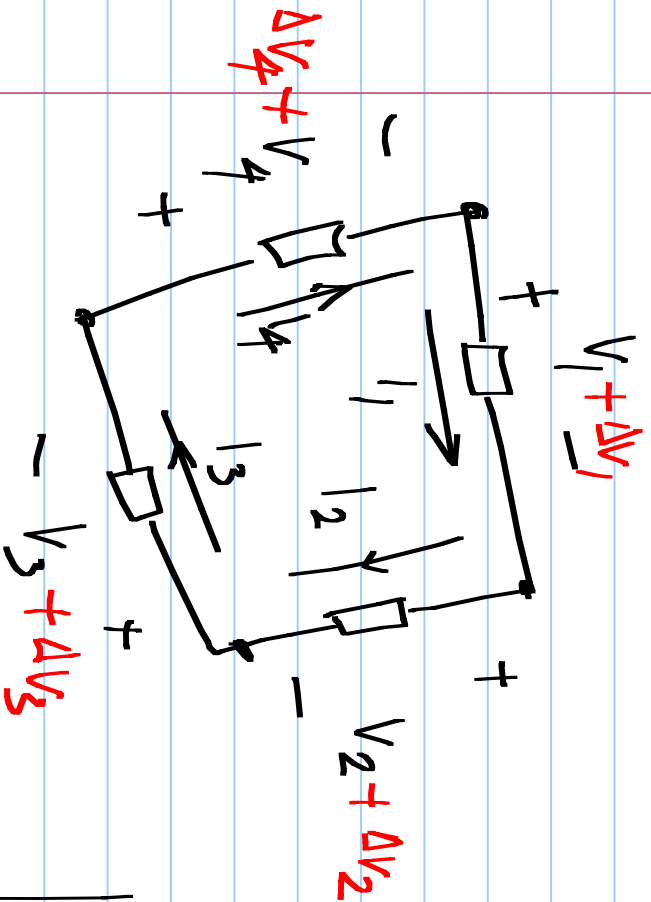


Lecture 17



$$V_1 + V_2 + V_3 + V_4 = 0$$

$$V_1 + \Delta V_1 + V_2 + \Delta V_2 + V_3 + \Delta V_3 + V_4 + \Delta V_4 = 0$$

$$\Delta V_1 + \Delta V_2 + \Delta V_3 + \Delta V_4 = 0$$

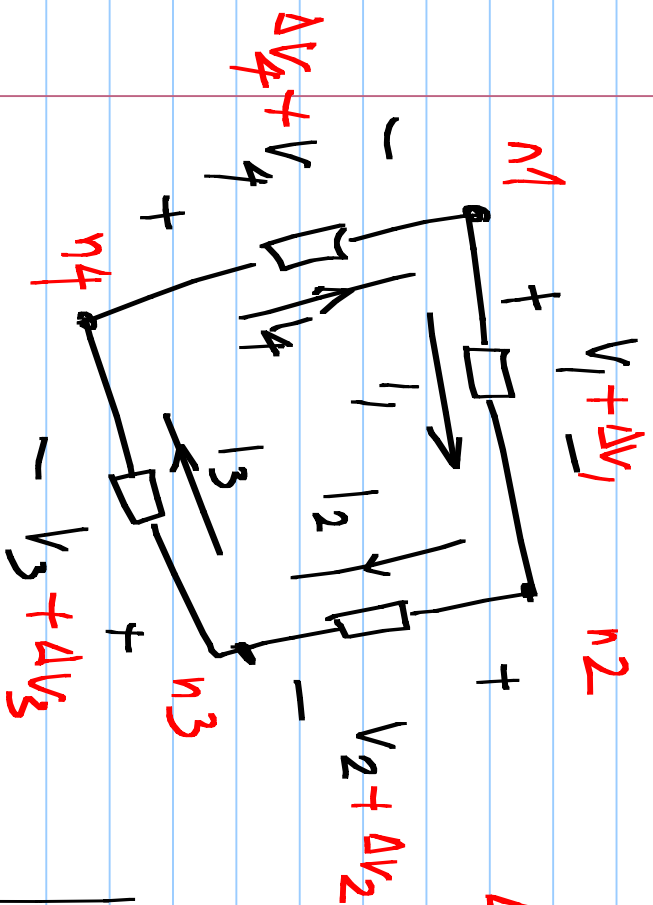
$$\Delta I_1 = f'_1 \Big|_{V_1} \cdot \Delta V_1 \quad ; \quad \Delta I_2 = f'_2 \Big|_{V_2} \cdot \Delta V_2$$

$$\Delta I_3 = f'_3 \Big|_{V_3} \cdot \Delta V_3 \quad (\text{opp})$$

$$\Delta I_4 = f'_4 \Big|_{V_4} \cdot \Delta V_4 \quad (\text{opp})$$

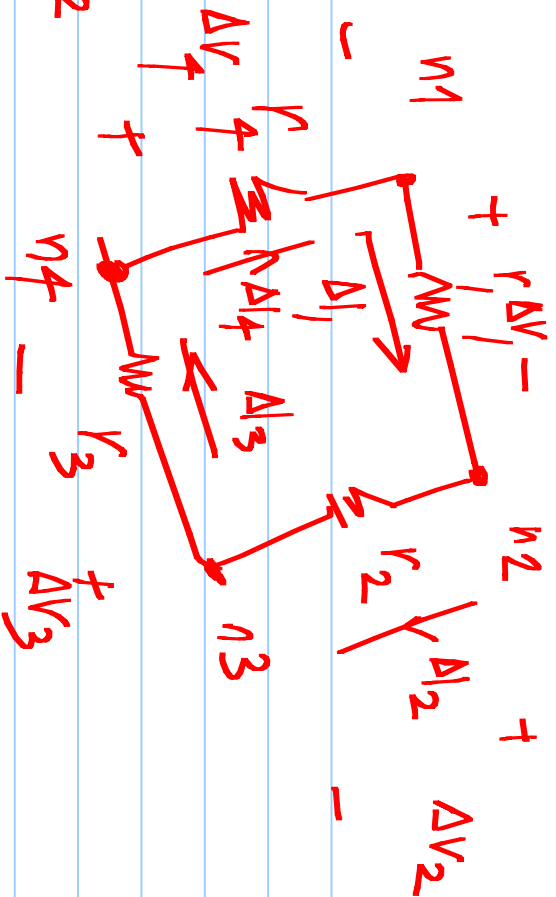
$$I_1 = f_1(V_1) \quad ; \quad I_3 = f_3(V_3)$$

$$I_2 = f_2(V_2) \quad ; \quad I_4 = f_4(V_4)$$



$$I_1 = f_1(V_1) \quad ; \quad I_3 = f_3(V_3)$$

$$I_2 = f_2(V_2) \quad ; \quad I_4 = f_4(V_4)$$

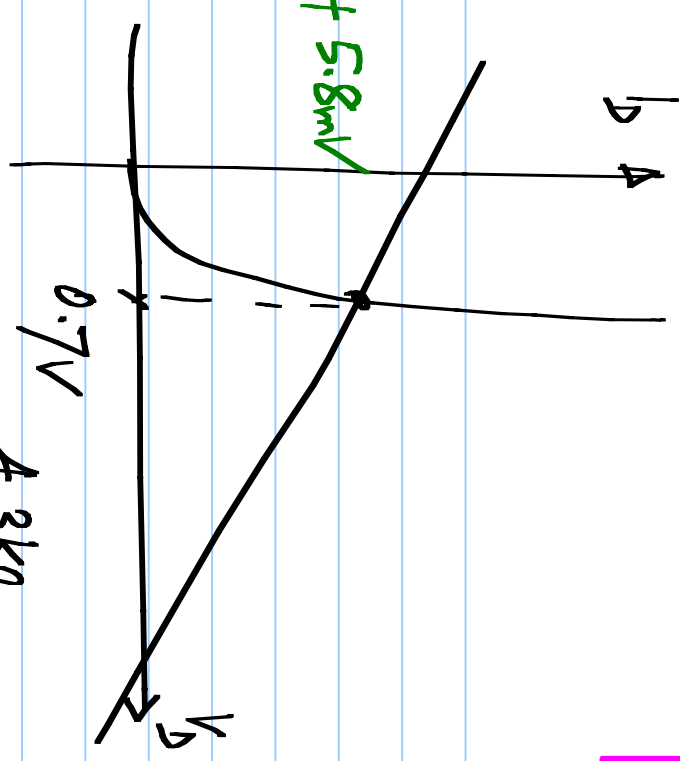
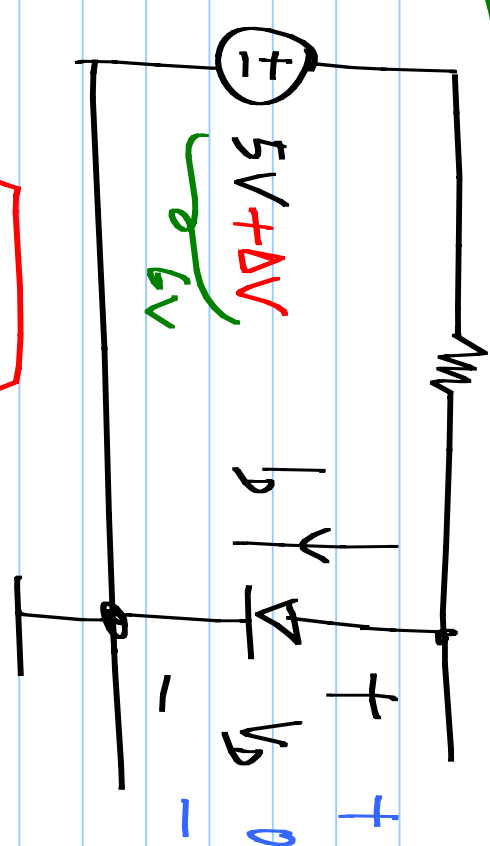


$$\Delta V_1 + \Delta V_2 + \Delta V_3 + \Delta V_4 = 0$$

$$\Delta I_1 = f_1' \cdot \Delta V_1 \quad ; \quad \Delta I_2 = f_2' \cdot \Delta V_2$$

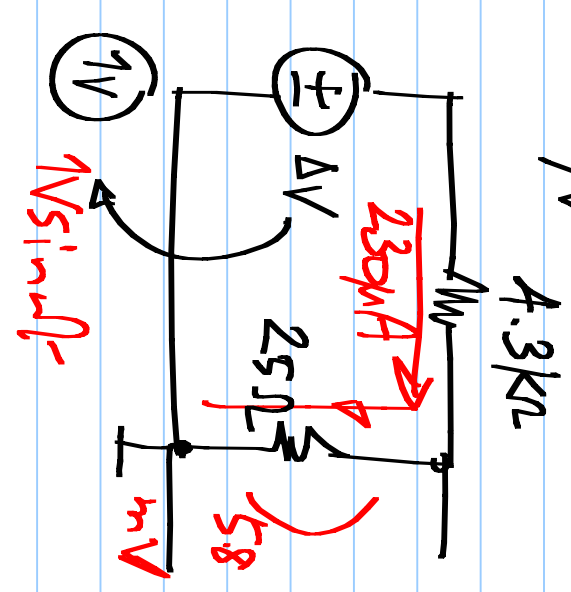
$$\Delta I_3 = f_3' \cdot \Delta V_3 \quad ; \quad \Delta I_4 = f_4' \cdot \Delta V_4$$

$230\mu A + 1mA$ $4.3k\Omega$



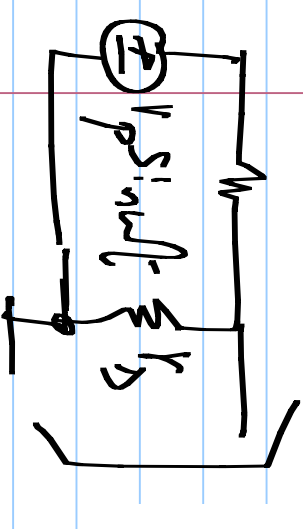
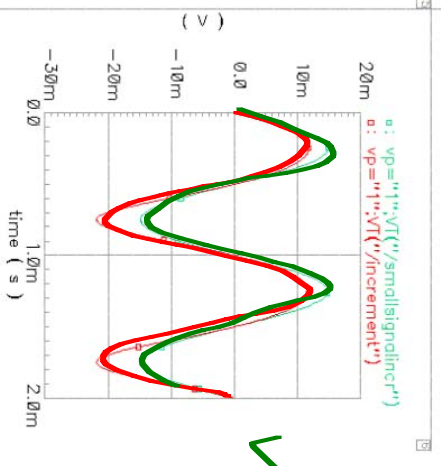
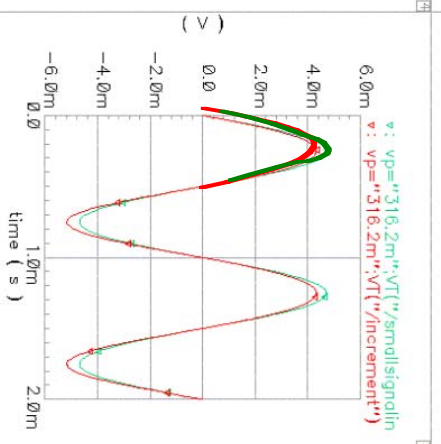
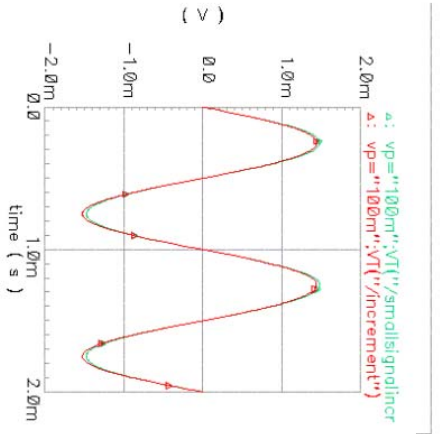
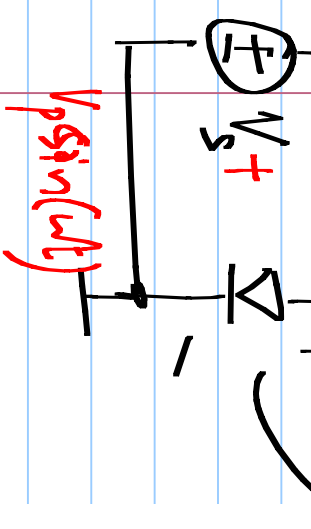
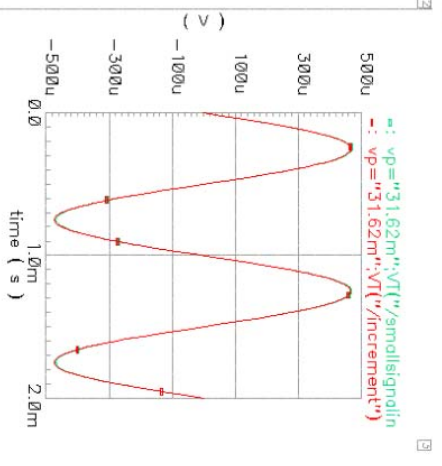
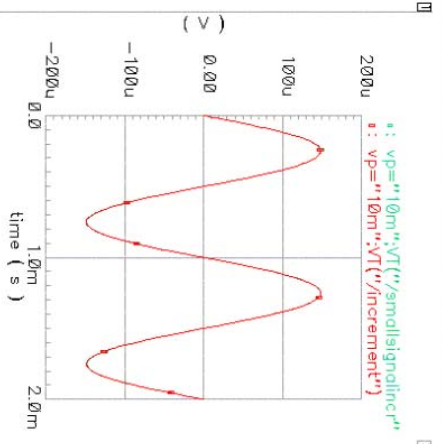
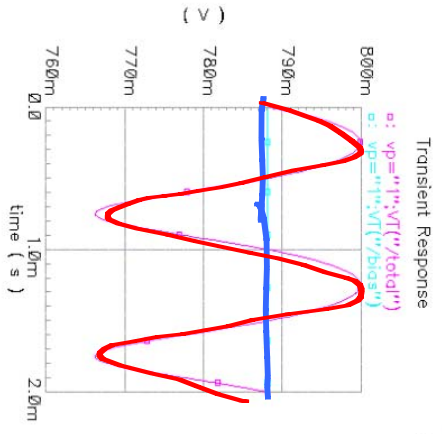
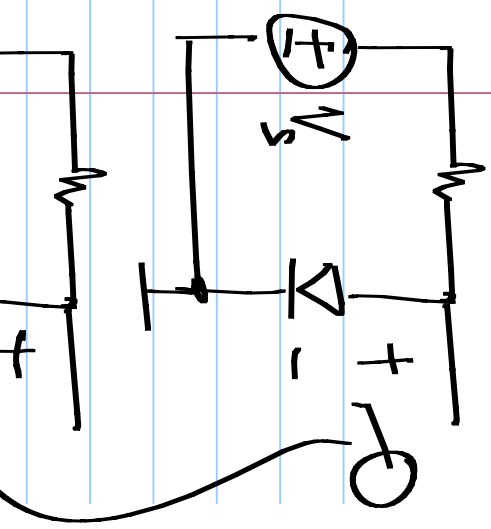
$$I_D = I_S \left(\exp\left(\frac{V_D}{V_T}\right) - 1 \right) \approx I_S \exp\left(\frac{V_D}{V_T}\right)$$

$$\frac{\partial I_D}{\partial V_D} = \frac{I_S}{V_T} \exp\left(\frac{V_D}{V_T}\right) = \frac{I_D}{V_T} = 40mA/V$$

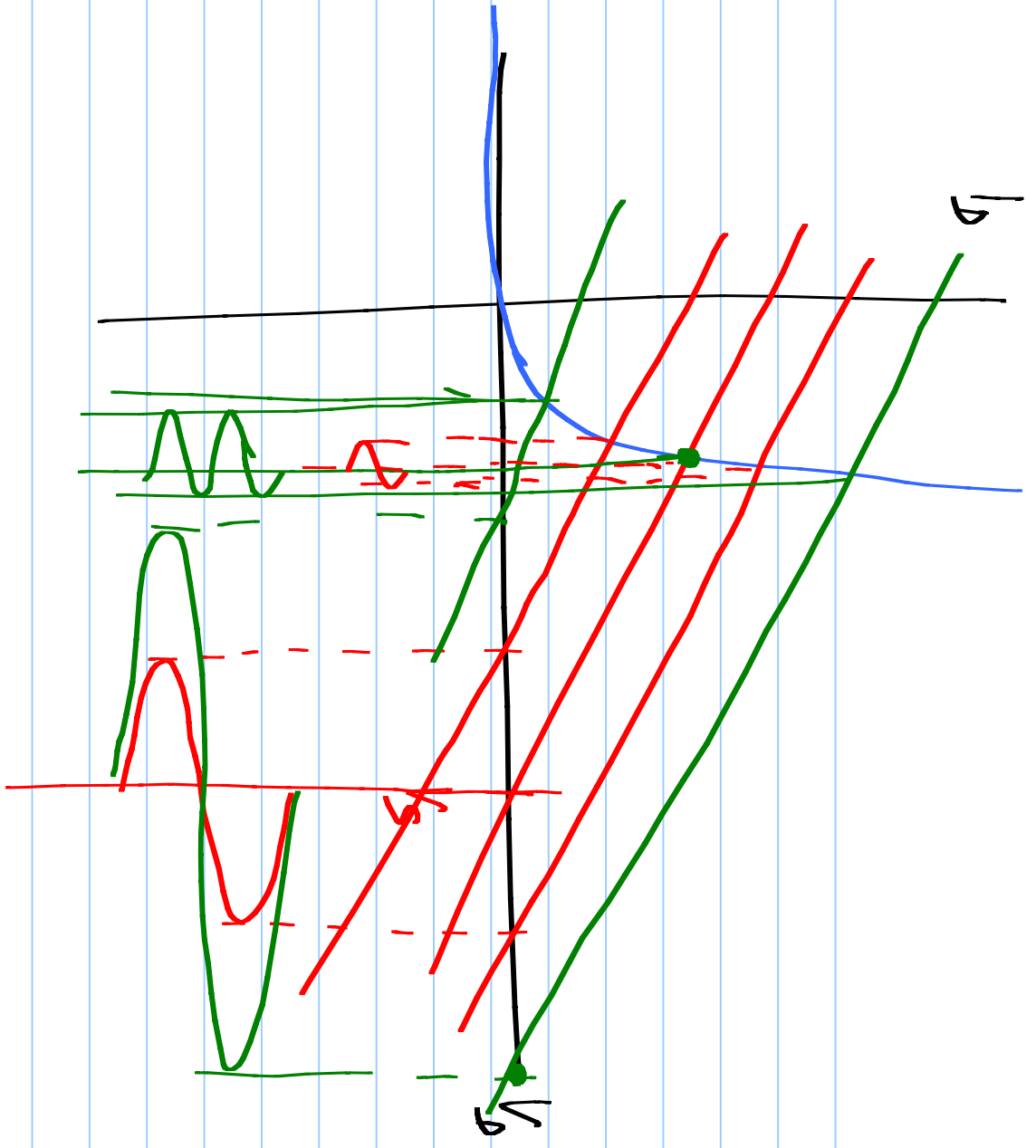


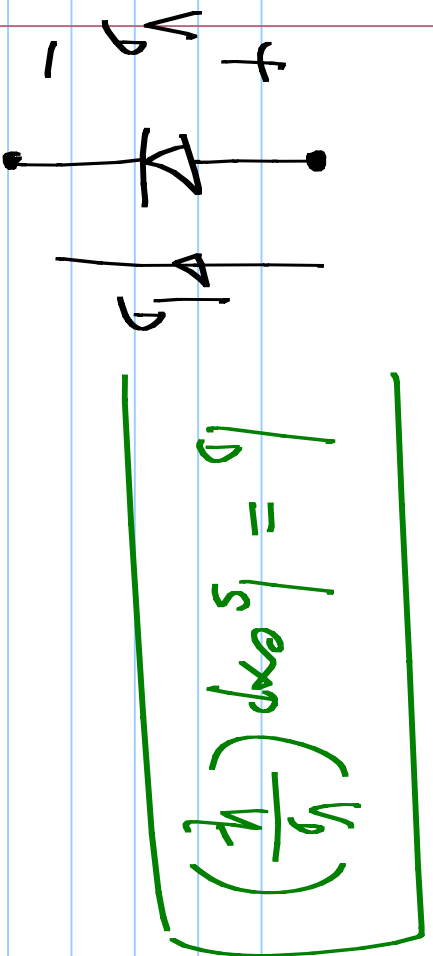
$$\begin{aligned} \exp\left(\frac{V_D + \Delta V_D}{V_T}\right) &= \exp\left(\frac{V_D}{V_T}\right) \cdot \exp\left(\frac{\Delta V_D}{V_T}\right) \\ &= \exp\left(\frac{V_D}{V_T}\right) \left[1 + \frac{\Delta V_D}{V_T} + \frac{1}{2} \left(\frac{\Delta V_D}{V_T}\right)^2 + \dots \right] \end{aligned}$$

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✓

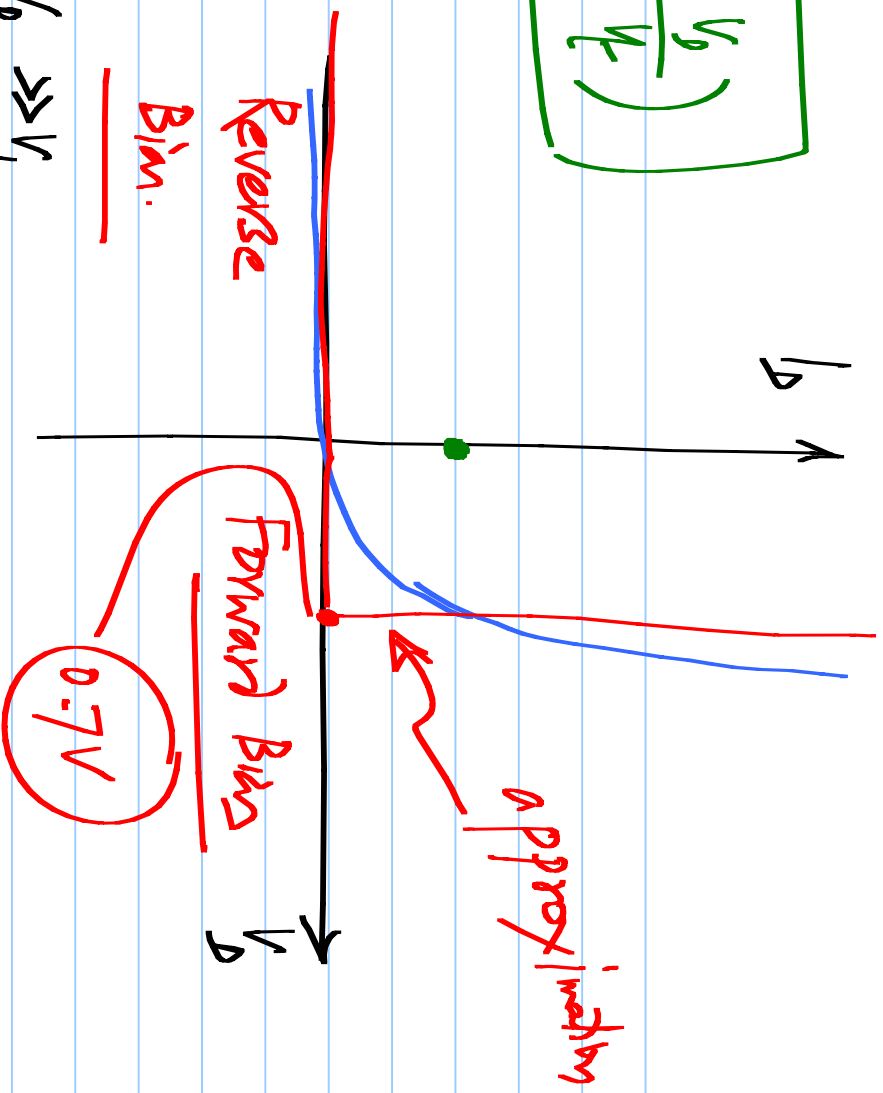


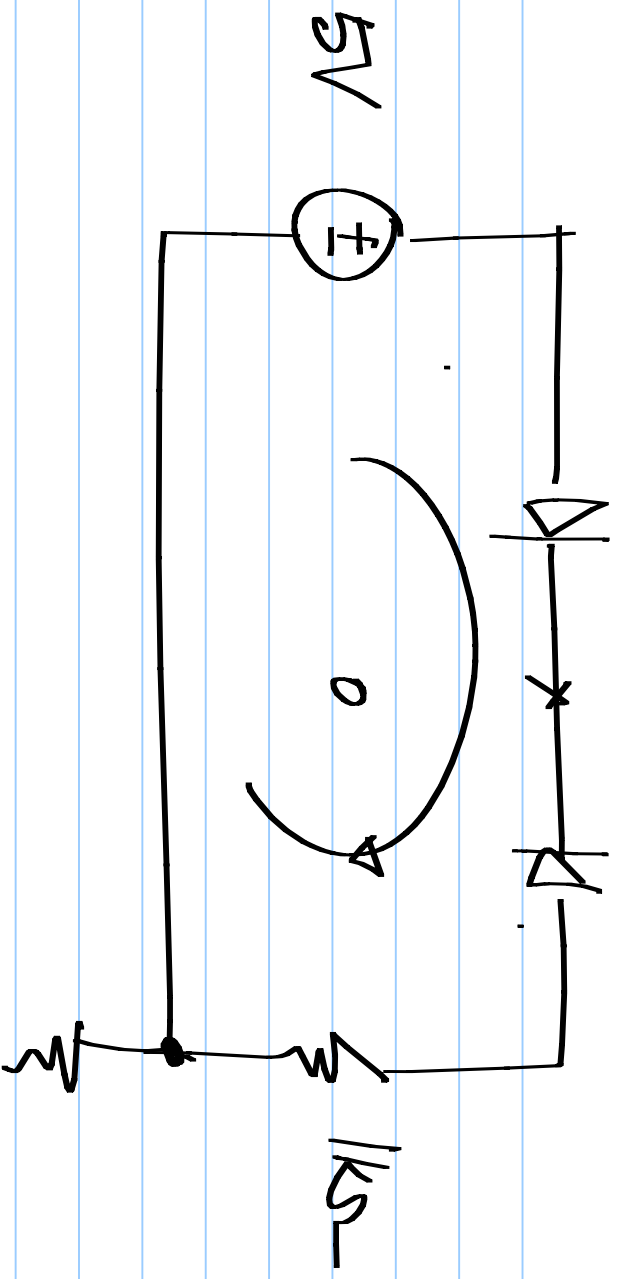


$$I_D = I_S \left(\exp\left(\frac{V_D}{V_T}\right) - 1 \right)$$

$$\approx I_S \exp\left(\frac{V_D}{V_T}\right) \quad V_D \gg V_T$$

$$\approx -I_S \approx 0 \quad V_D < 0 ; \left| \frac{V_D}{V_T} \right| > 1$$





$$I_D = I_S \left[\exp\left(\frac{V_D}{V_T}\right) - 1 \right]$$

Boltzmann's
constant

A_{65}

Temp.

Thermal voltage = $\frac{kT}{q}$

Book

$$\frac{kT}{q} \approx 25\text{mV}$$

electron-charge