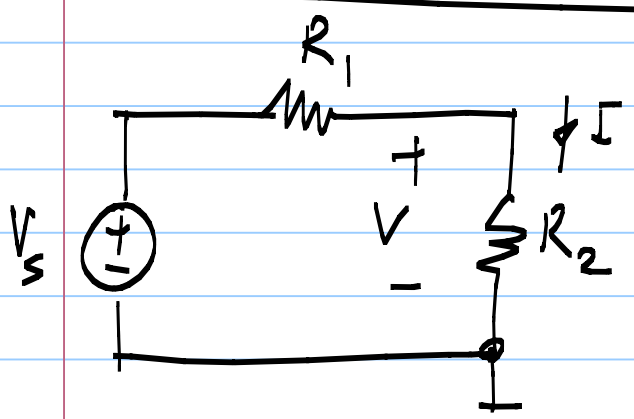
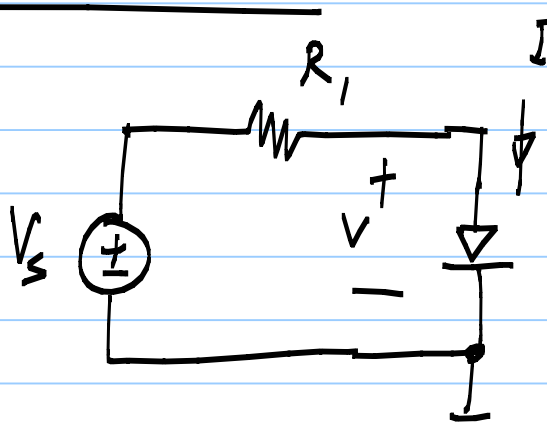
EC1010: Lecture 18

Nonlinear circuits

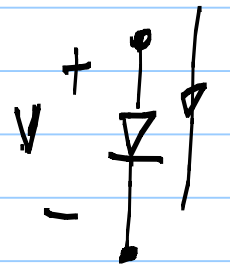


$$I = V/R_2$$

$$I = \frac{V_s - V}{R_1}$$



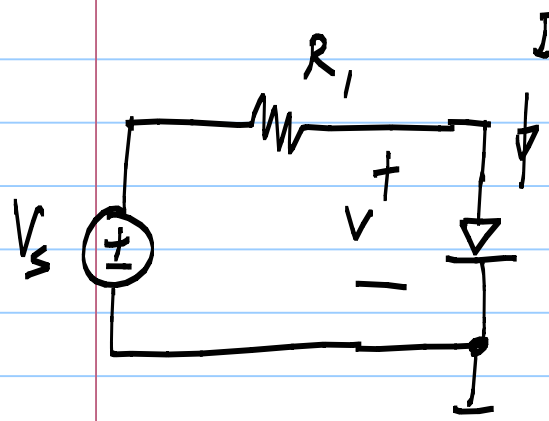
$I = f(V)$

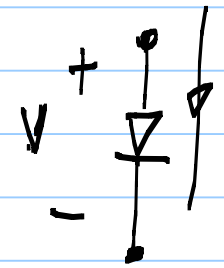


$$I = f(V)$$

$$I = \frac{V_s - V}{R_1}$$

$$V_s - V - R_1 \cdot f(V) = 0$$





Diode:

$$I = f(V) = I_s\left(\exp\left(\frac{V}{V_t}\right) - 1\right)$$

I_s: saturation current

V_t: Thermal voltage

$$V_t = \frac{kT}{q}$$

k — Boltzmann's Constant 1.38×10^{-23} J/K

T — Absolute temperature 300k

q — Electron charge 1.6×10^{-19} C

$\simeq 4 \times 10^{-21}$ J @ 300k

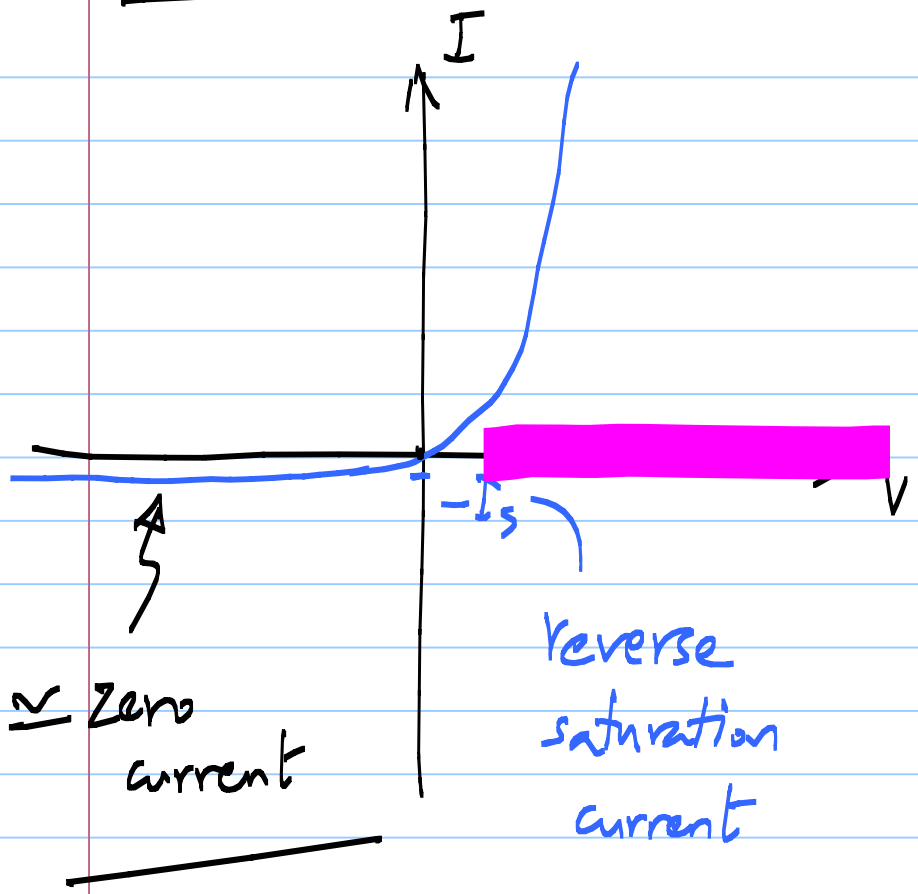
25.9 mV @ 300k

26 mV 25 mV @ room temp.

$I = f(V)$

$$I = \frac{V_s - V}{R_1}$$

Diode characteristics:



$$I = I_S\left(\exp\left(\frac{V}{V_t}\right) - 1\right) \simeq I_S \exp\left(\frac{V}{V_t}\right)$$

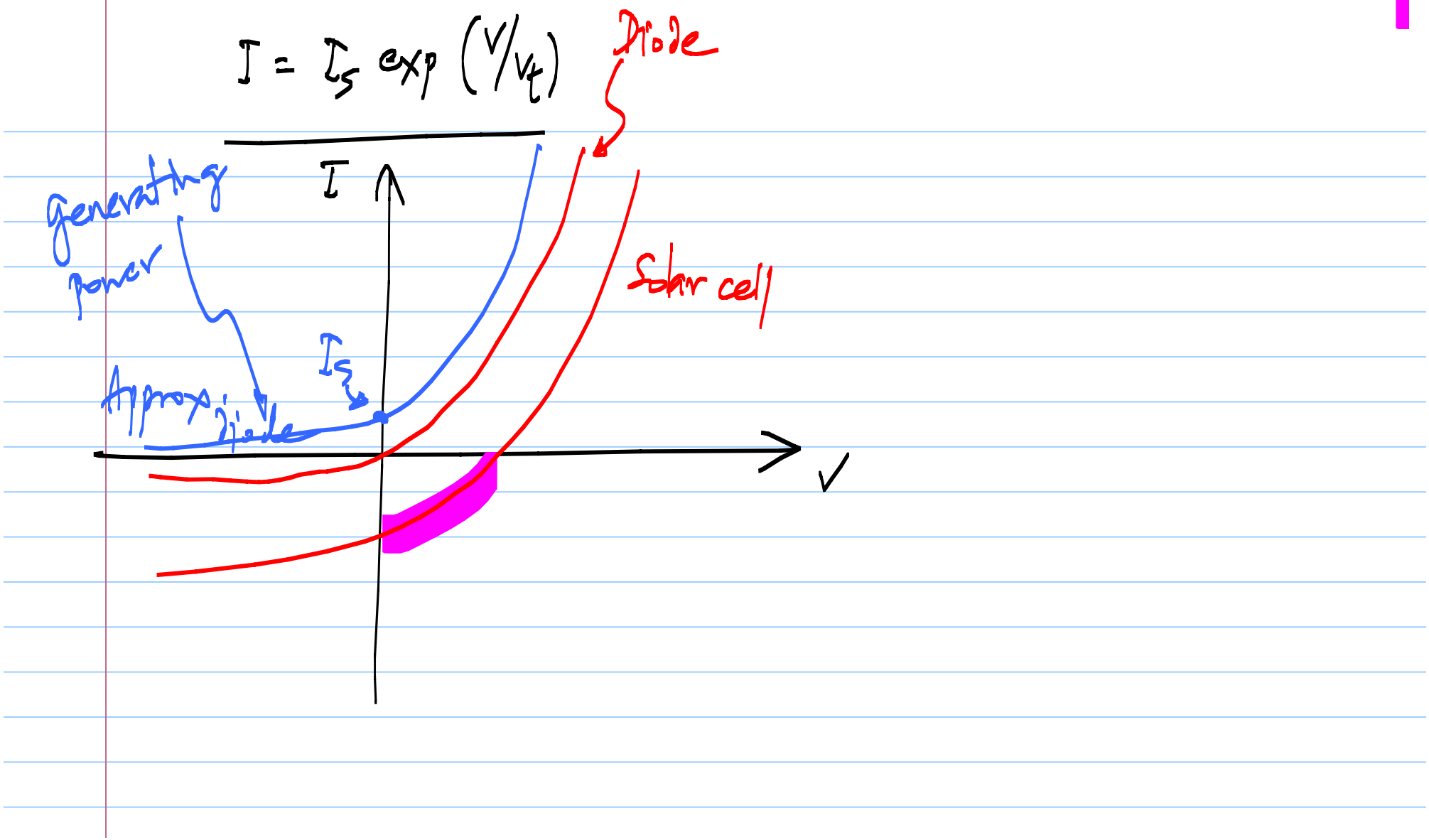
$\gg 1$

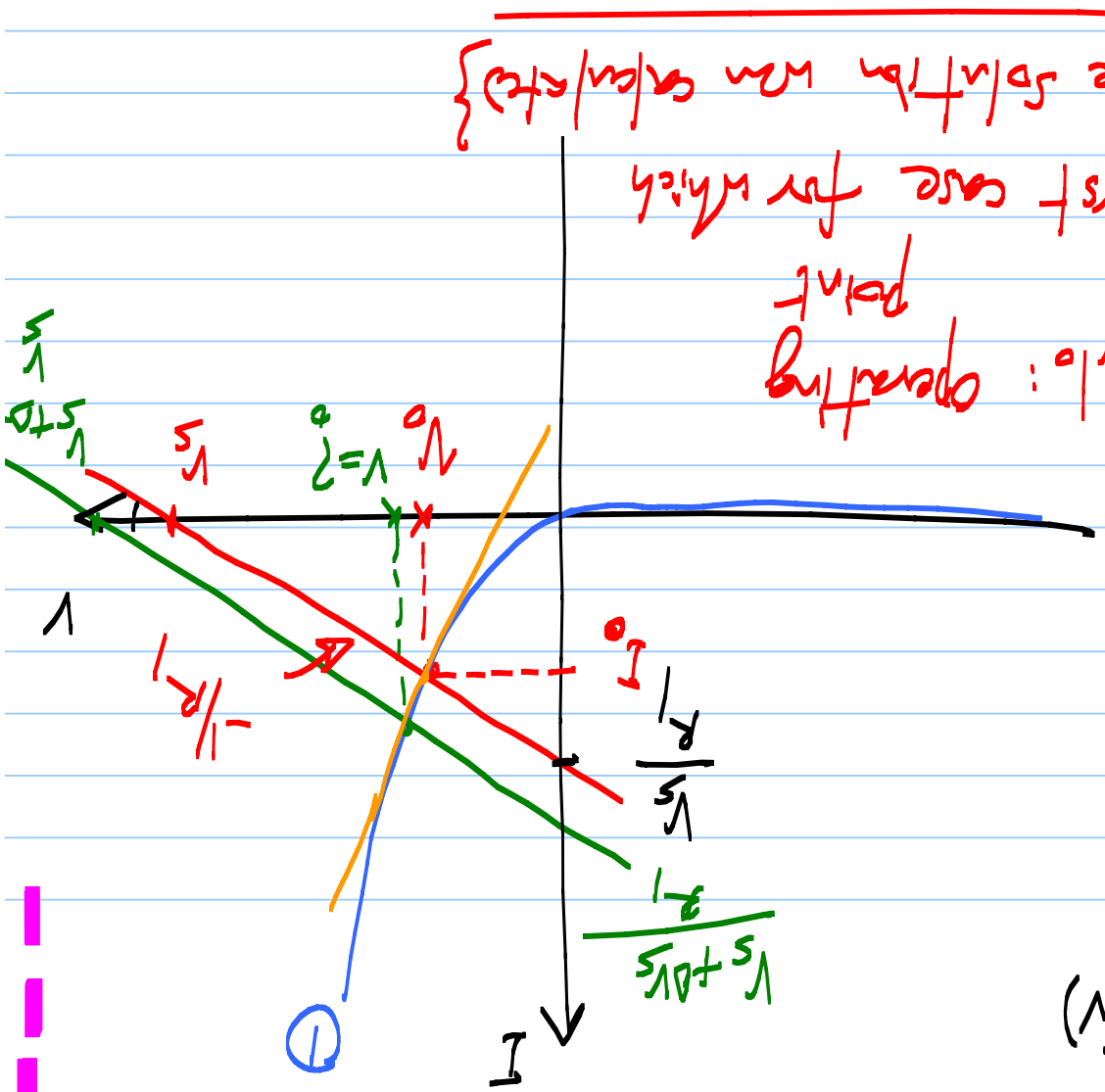
$I_S : 10^{-15}\,A$

$I = 1mA \sim$ $\quad V : ?$

I	V
100μA	630mV
1mA	690mV
10mA	750mV

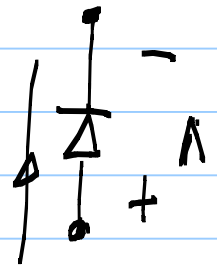
$V_t \simeq 25mV$


$I = I_s \exp(V/V_t)$
Diode
I
generating power
Solar cell
I_s
Approx diode
V



V_o, I_o : operating point

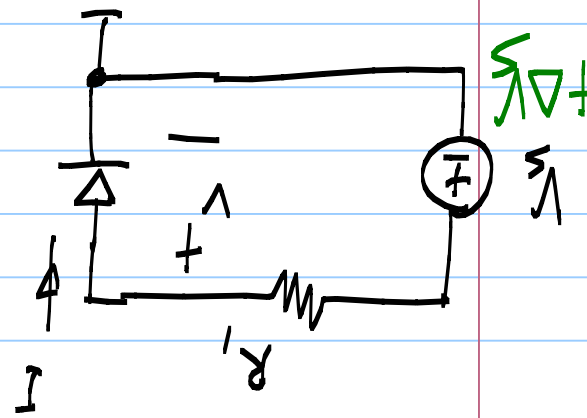
{First case for which the solution was calculated}

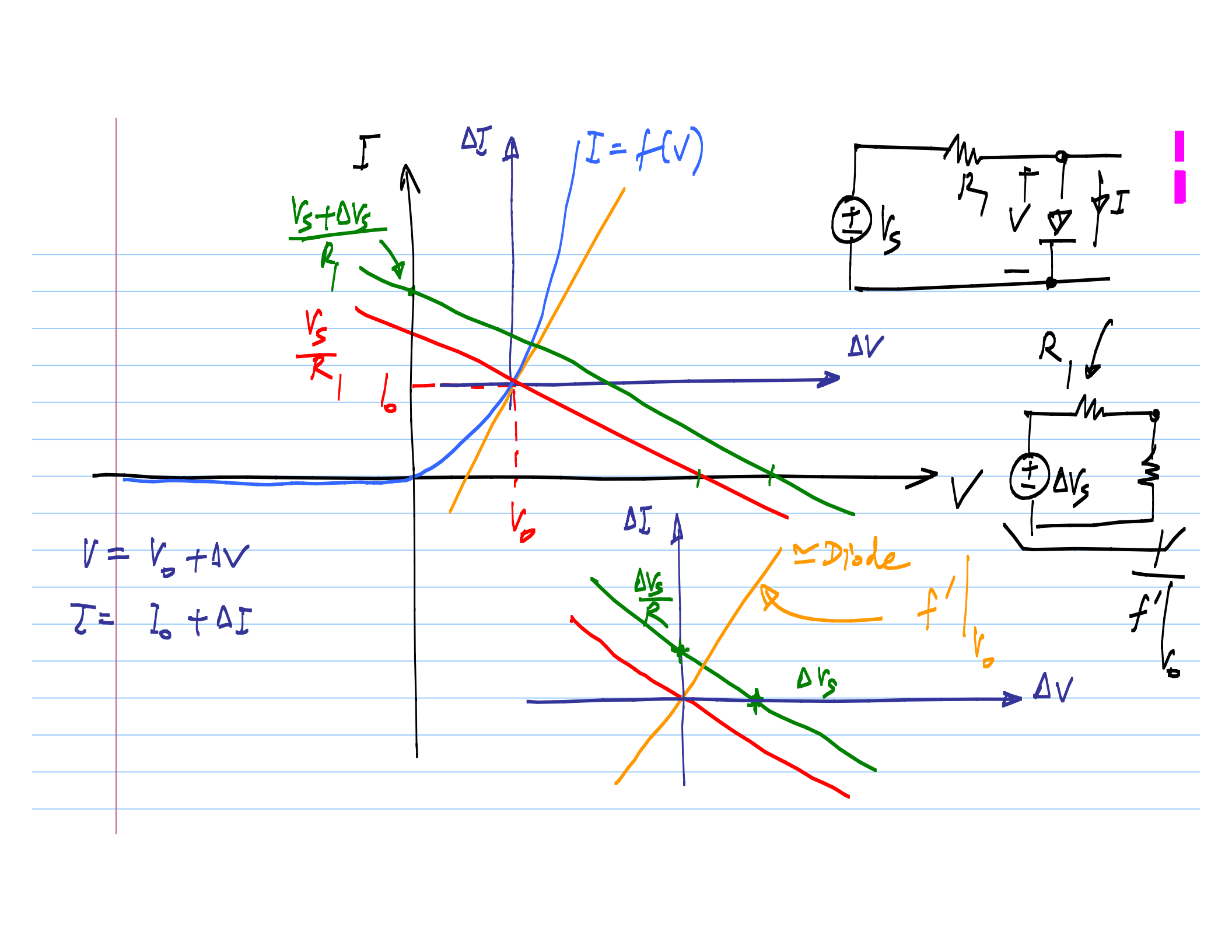


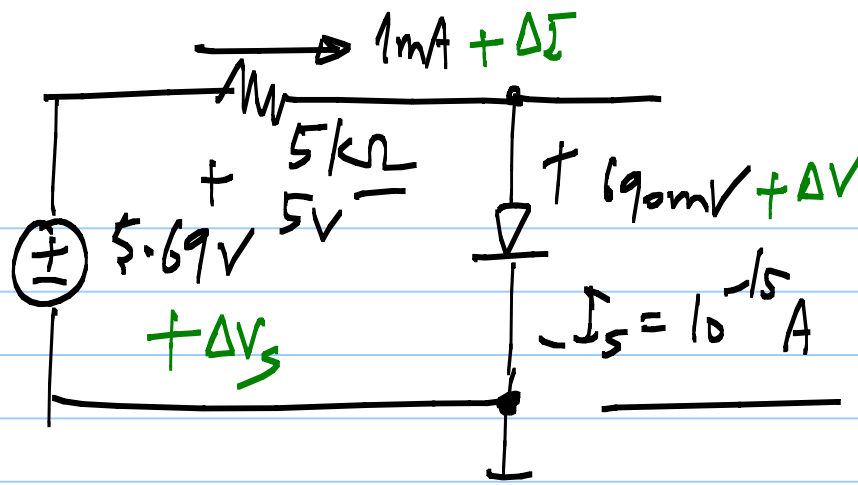
$I = f(V)$

② $I = \frac{V_s - V}{R_1}$

① $I = f(V)$




I
ΔI
I = f(V)
$\frac{V_S+\Delta V_S}{R_1}$
$\frac{V_S}{R_1}$
I_0
V_0
ΔV
V
$V = V_0 + \Delta V$
$I = I_0 + \Delta I$
R
V
I
V_S
R_1
ΔV_S
ΔI
$\frac{\Delta V_S}{R}$
≃ Diode
$f'|_{V_0}$
ΔV_S
ΔV



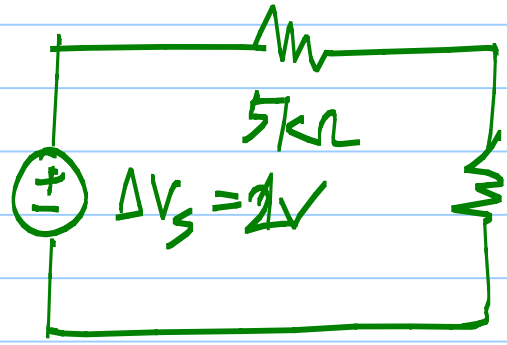
$V_0 = 690\text{mV}$

$I_0 = 1\text{mA}$

$\left.\frac{1}{f'}\right|_{V_0}$: incremental resistance

$\frac{V_t}{I_0}$

I	V
100μA	630mV
1mA	690mV
10mA	750mV



? ≈25Ω

Incremental conductance $\left.f'\right|_{V_0}$

$$f(V) = I_S\left[\exp\left(\frac{V}{V_t}\right) - 1\right] \simeq I_S \exp\left(\frac{V}{V_t}\right)$$

$$\frac{I_S}{V_t}\exp\left(\frac{V_0}{V_t}\right) = \frac{I_0}{V_t}$$