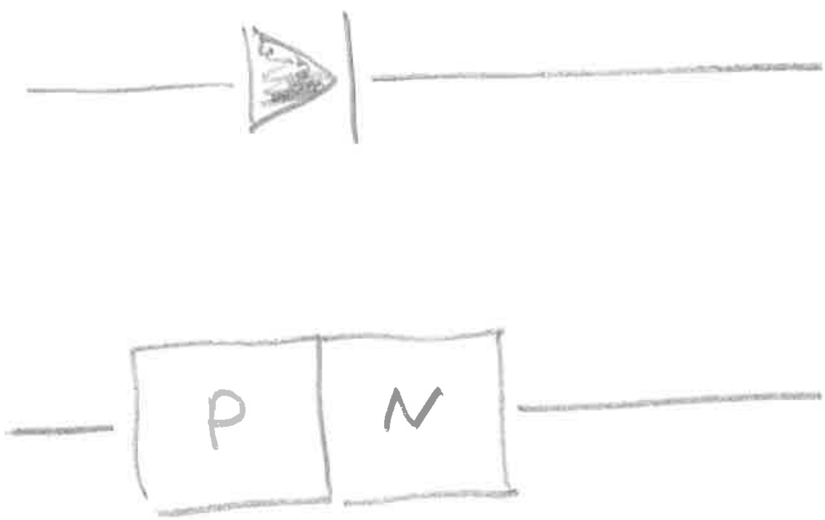
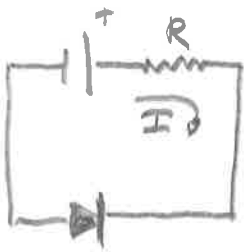
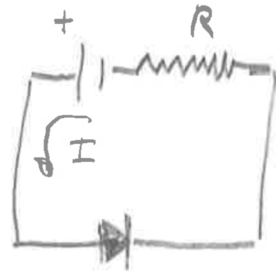
The Diode

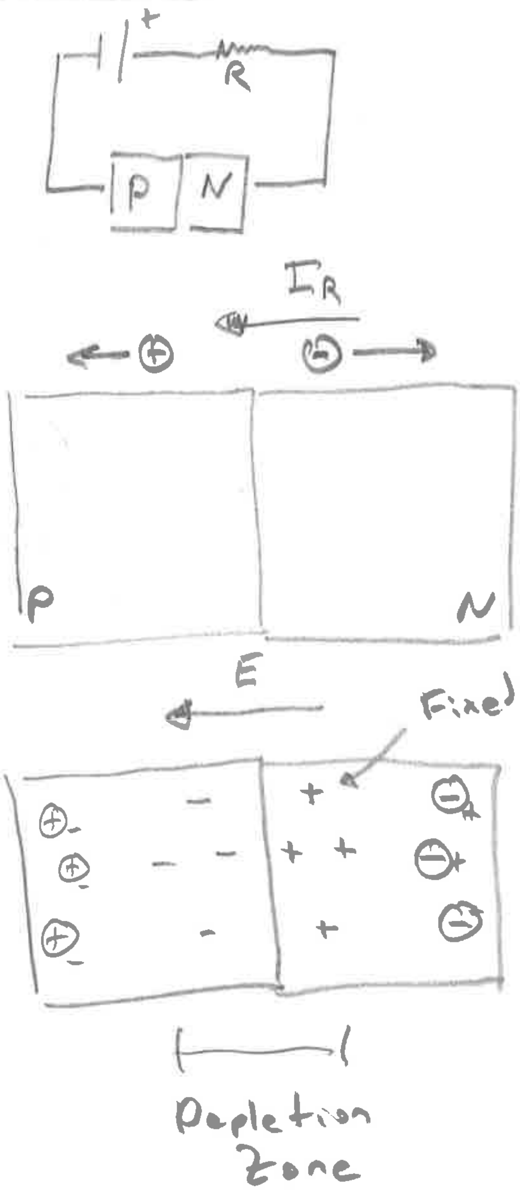


Basic Operation



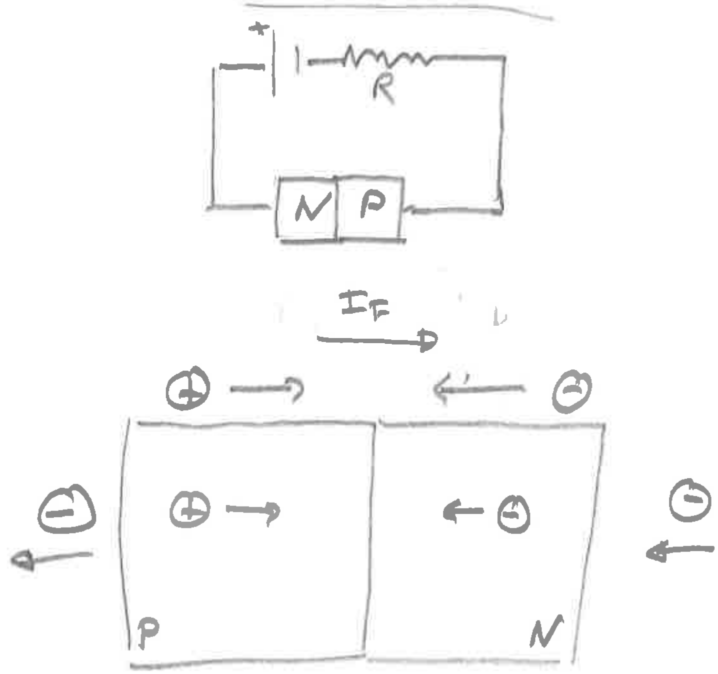


Reverse Bias



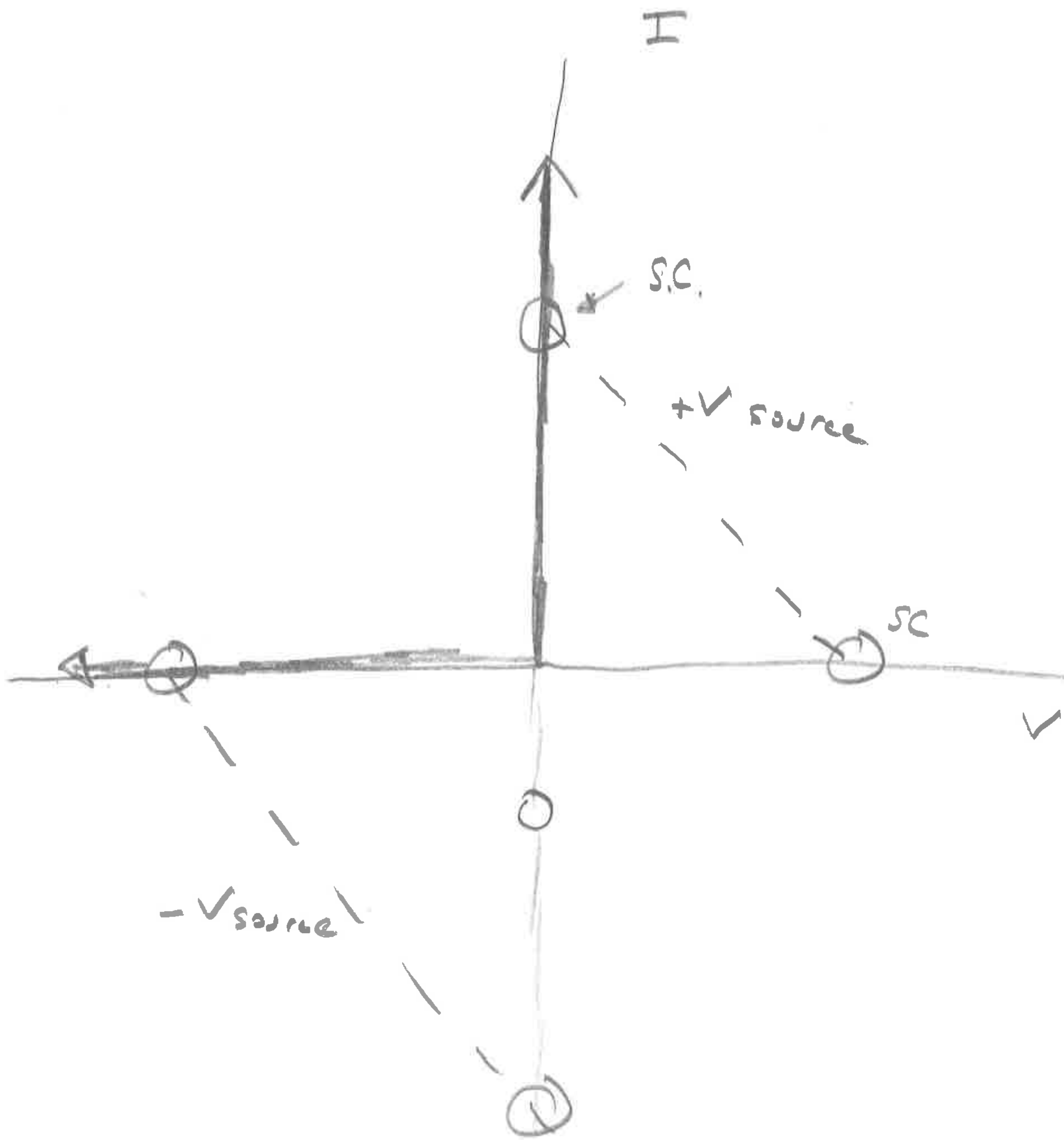
No Current

Forward Bias

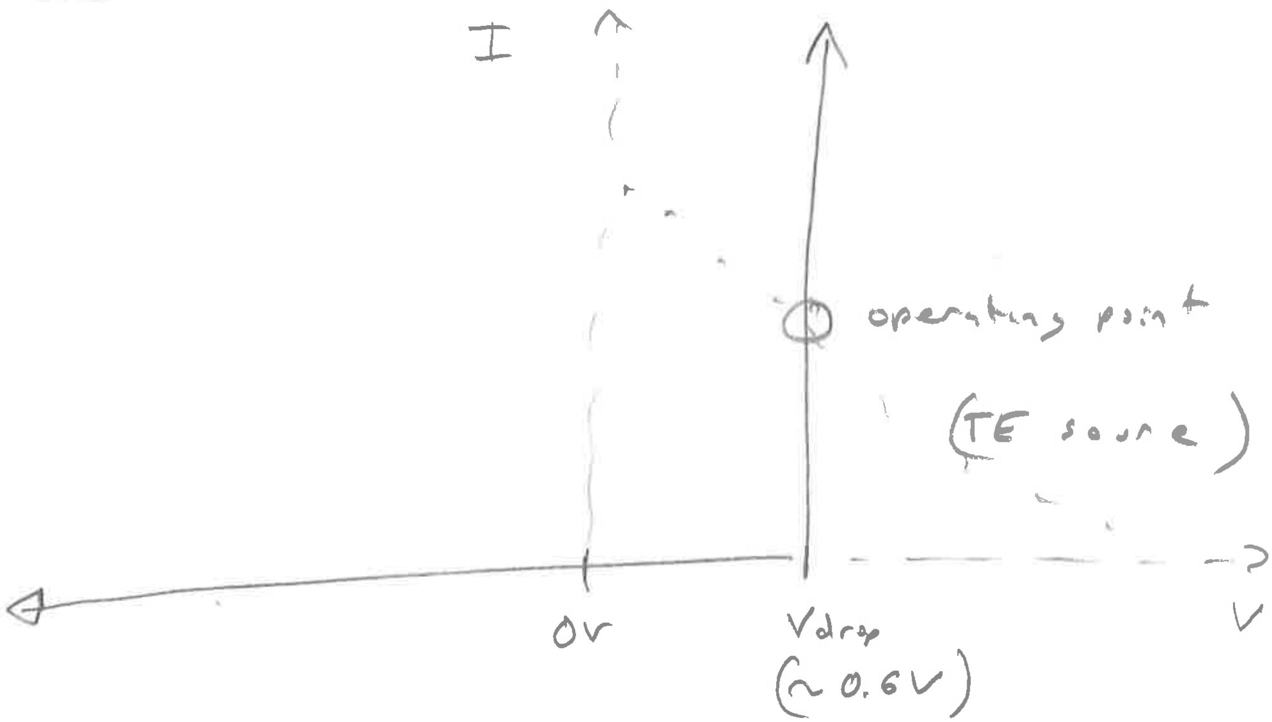


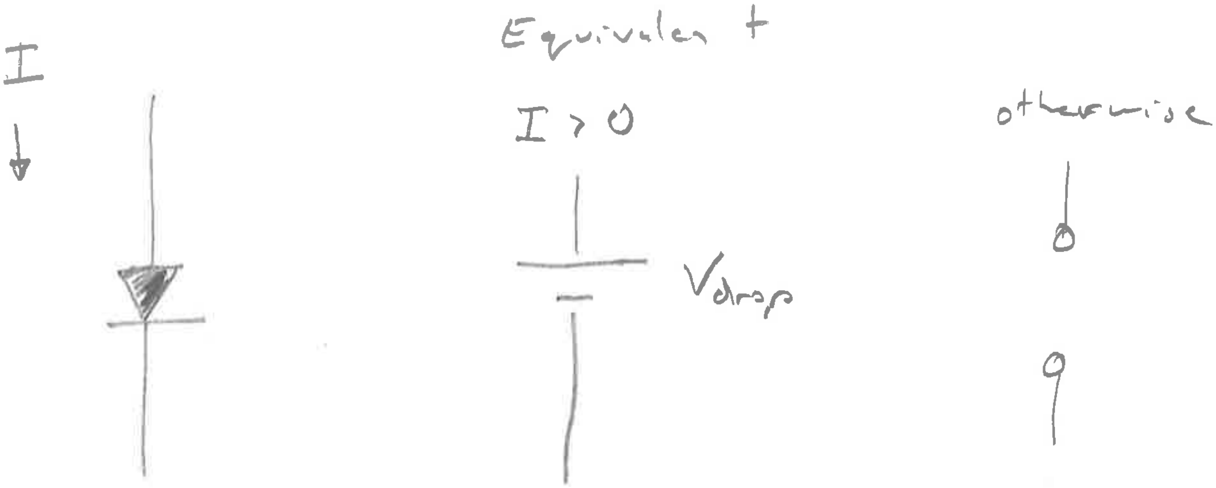
Current!

Basic Operation Model



Slightly Better Model

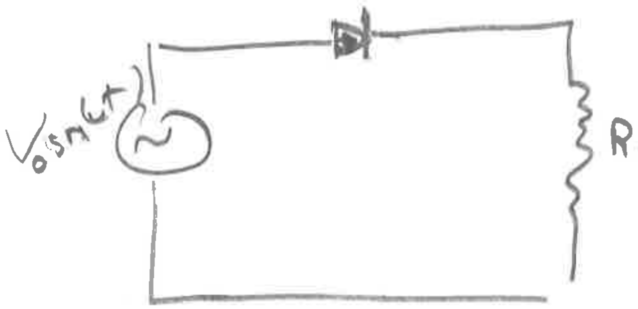


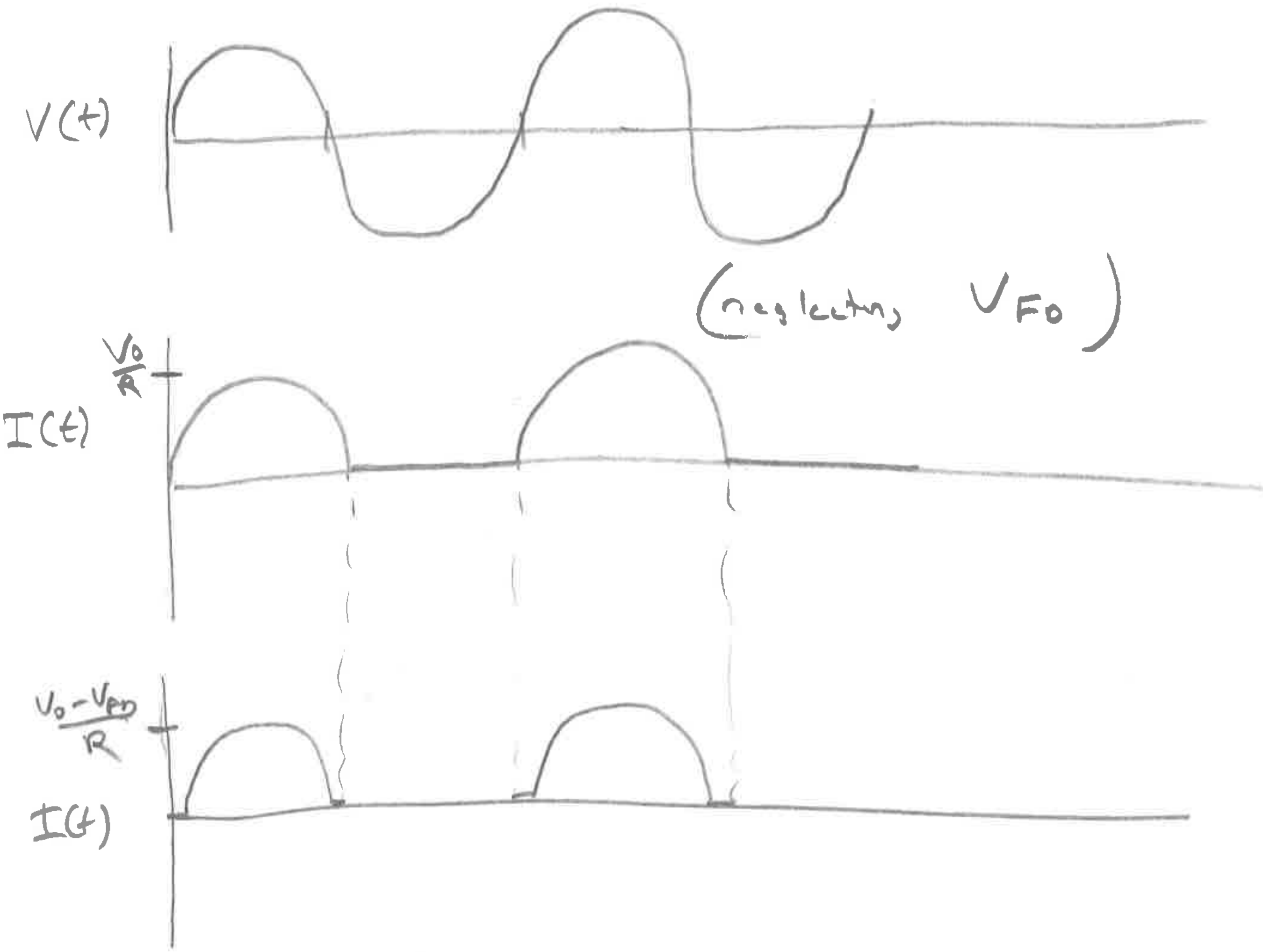


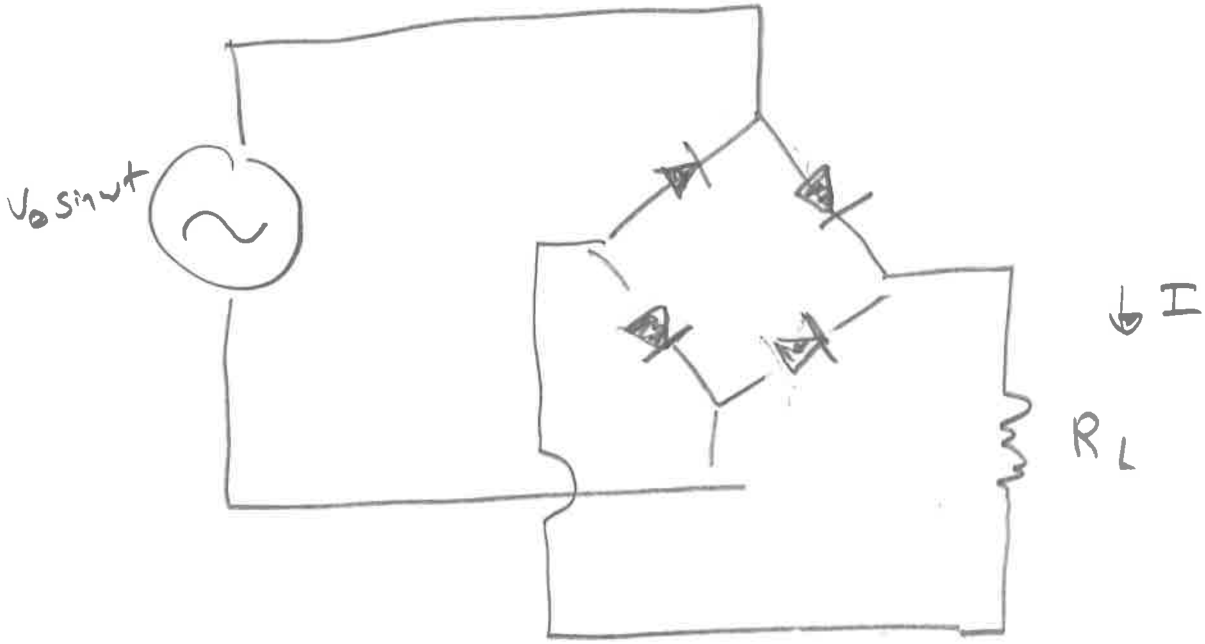
Diode allows current to flow in direction of arrow, but at a "toll" of one diode drop...

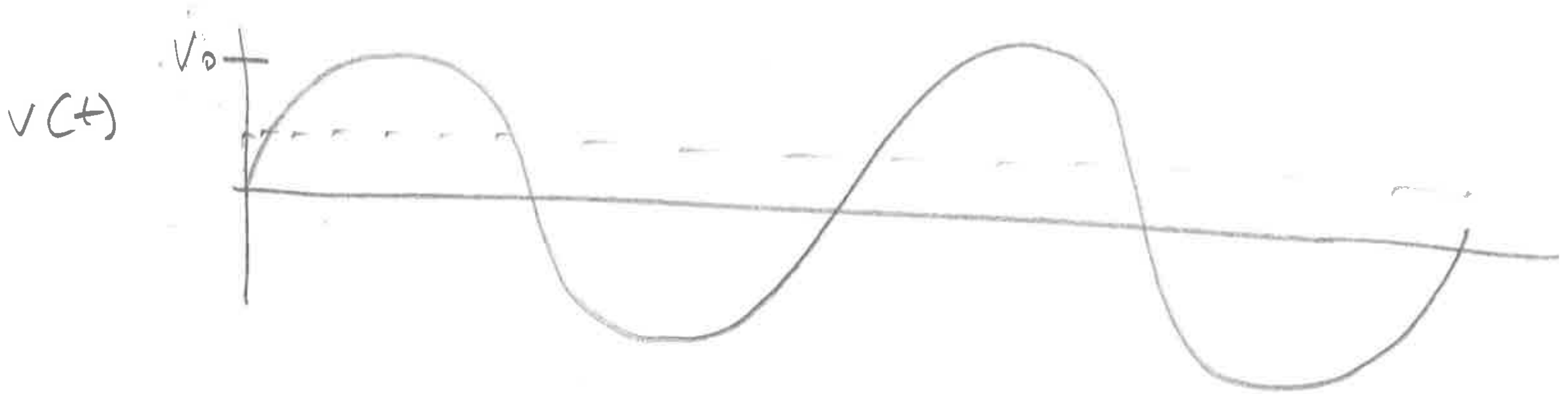
This is usually enough to understand basic diode circuits.

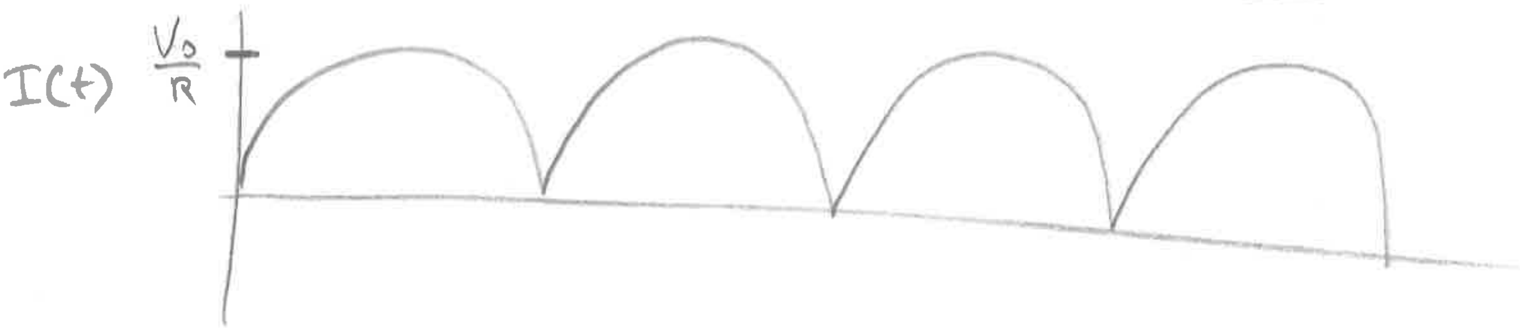
Diode Example Circuits:

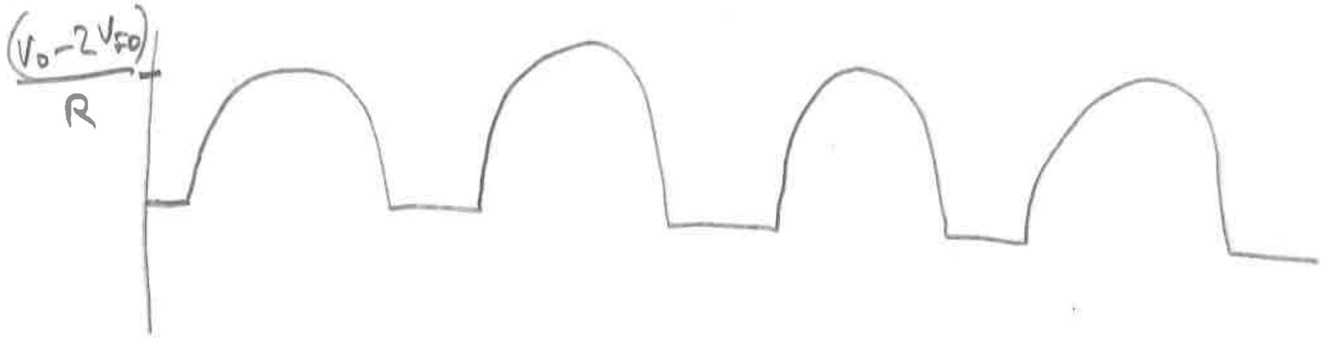


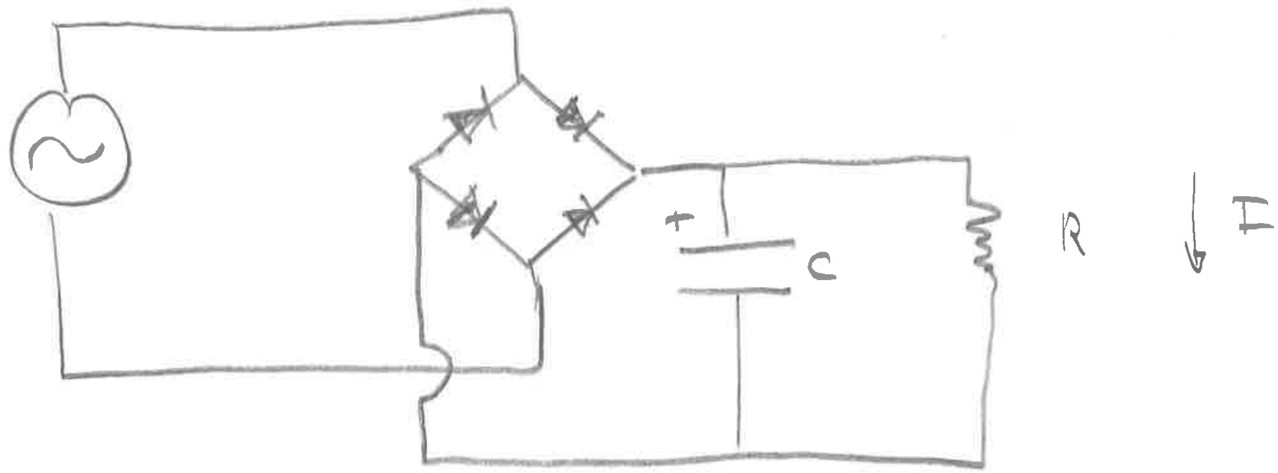



$V_0 \sin \omega t$
I
R_L

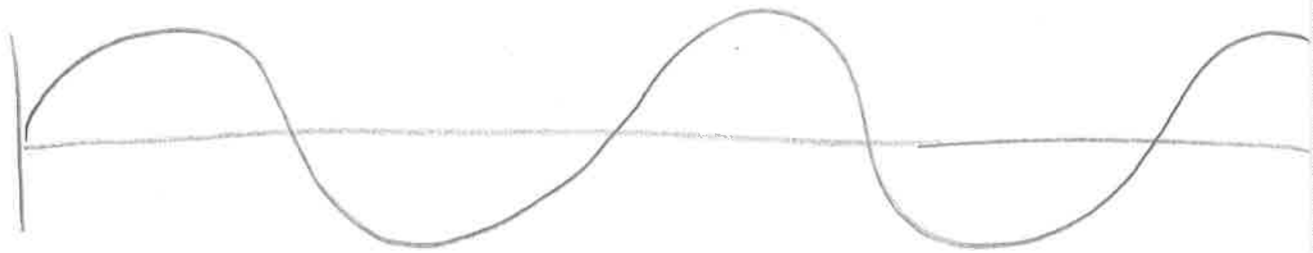

$V(t)$
V_0


$I(t)$
$\frac{V_0}{R}$

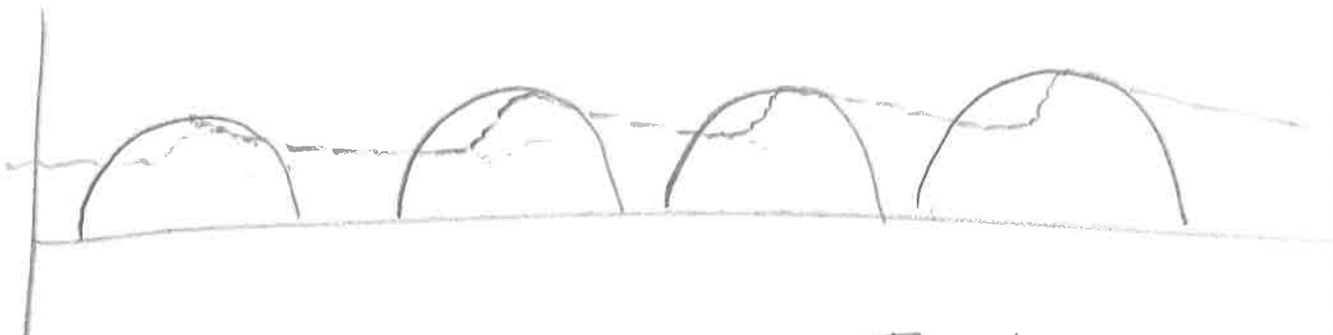

$\frac{(V_0-2V_{F0})}{R}$



V(t)



I(t)



Ripple Voltage:

$$\Delta V = \frac{\Delta q}{C} \sim \frac{I_{max} \Delta t}{C}$$

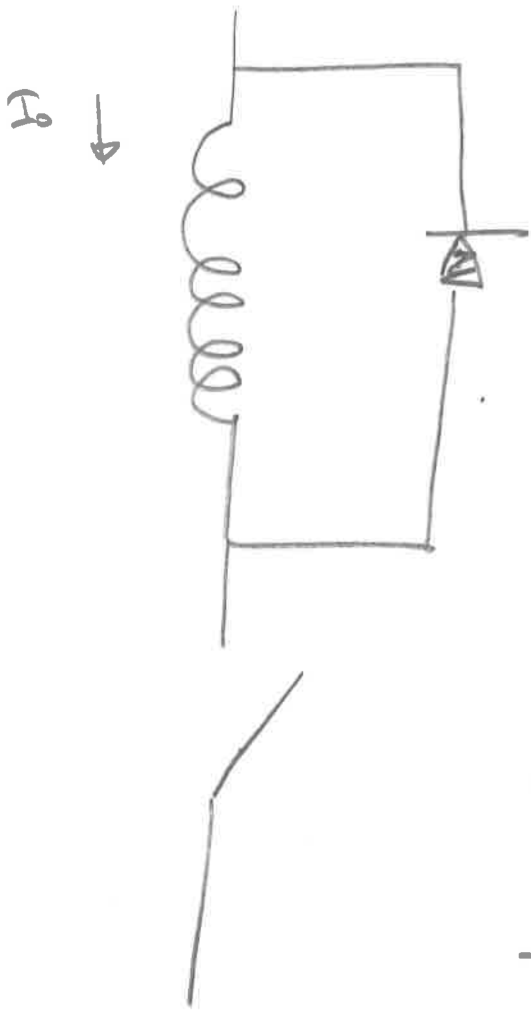
$$f \sim \frac{1}{2\Delta t} \quad \text{(full-wave)}$$

$$f \sim \frac{1}{\Delta t} \quad \text{(half-wave)}$$

$$\Delta V \sim \frac{I}{2fC} \quad \text{full-wave}$$

$$\frac{I}{fC} \quad \text{half-wave}$$

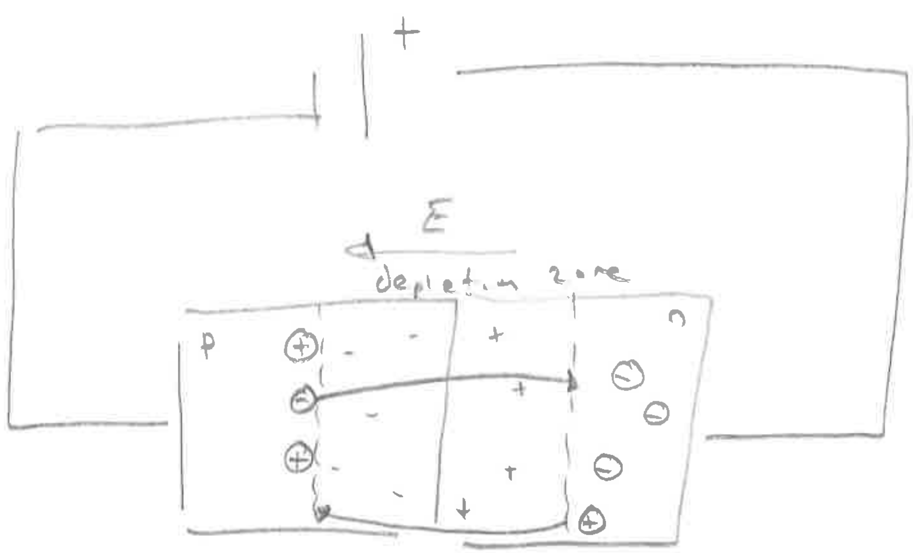
Diodes in Inductive Loads



→ Diode must not break down when switch closed

→ Diode must be rated to handle I_o current.

Saturation Current



* Minority carriers, p in n-type, n in p-type, have no trouble crossing depletion zone (it's forward bias for them!)

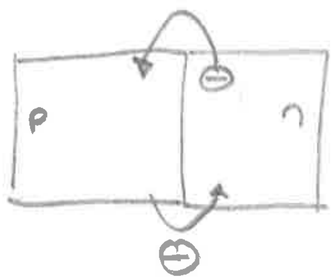
- Thermal fluctuations near depletion zone result in a small reverse bias current

- Since field propells minority carriers across the depletion zone, rate of this current is constant.

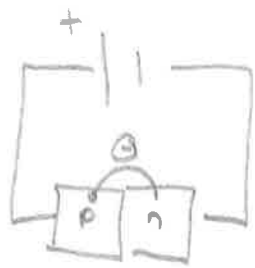
⇒ Diodes have small, nearly constant current under reverse bias.

Model of Diode in Forward Bias

At $V_{FB} = 0$, $I = 0$, system is in equilibrium. So rate of thermal generation of electron-hole pairs equals rate of recombination: ,



In Forward-Bias $V = V_{FB} > 0$



p side is at higher electric potential, so electrons in n side that combine with holes on p side now gain additional energy

$$\Delta E = q V_{FB}$$

This disturbs equilibrium ... assume generation rate is same (T hasn't changed!) so recombination increases by

$$r \sim \exp\left(\frac{\Delta E}{kT}\right) = \exp\left(\frac{q V_{FB}}{kT}\right)$$

But

$$\boxed{I \sim r \sim \exp\left(\frac{V_{FB}}{V_T}\right) \qquad V_T \equiv \frac{kT}{q}}$$

Recap:

1) $V = 0$ $I = 0$

2) $V < 0$ $I \sim \text{const} = -I_0$

3) $V > 0$ $I \sim \exp(V/V_T)$

So try:

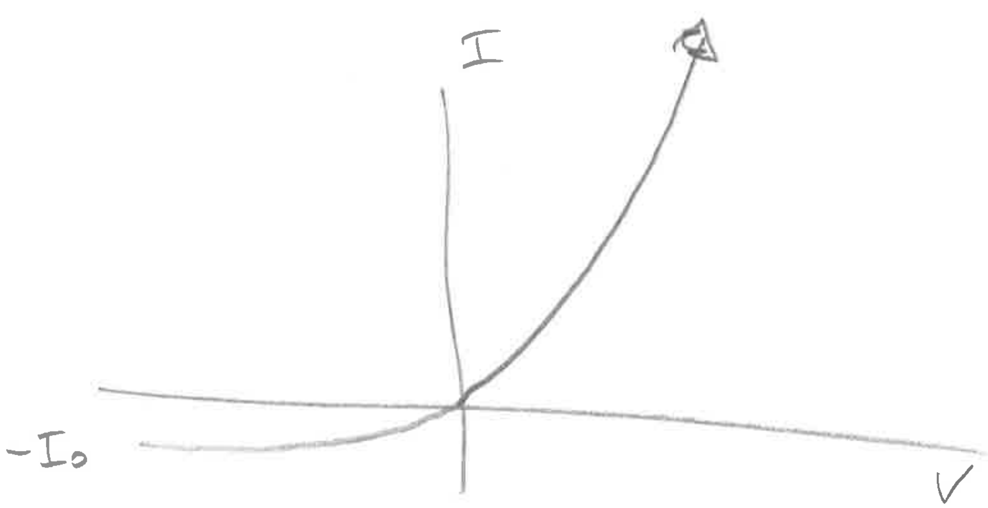
$$I = A \exp(V/V_T) + B$$

$$I(V=0) = A + B = 0 \Rightarrow A = -B$$

For $V < 0$, $|V| \gg V_T$, $\exp(V/V_T) \to 0$

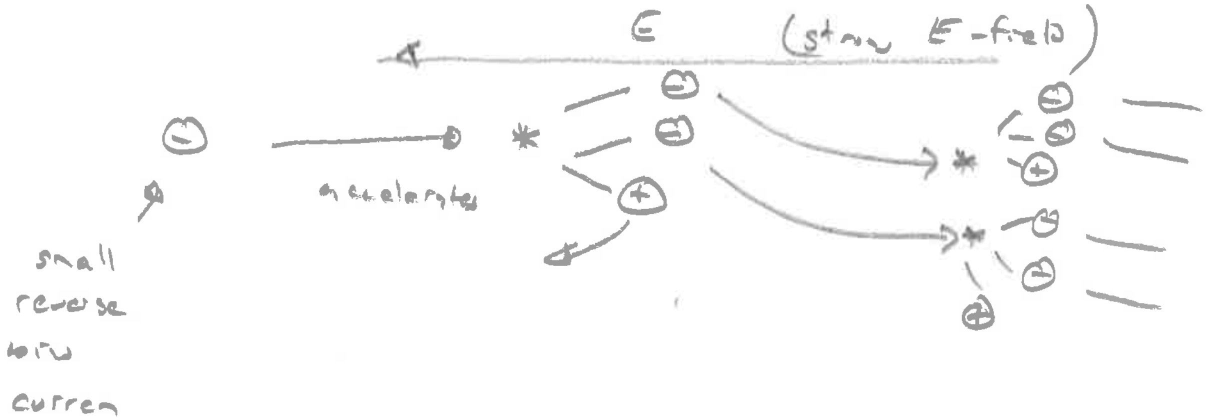
$$I = B = -I_0$$

$$\boxed{I = I_0 \left(\exp(V/V_T) - 1 \right)}$$



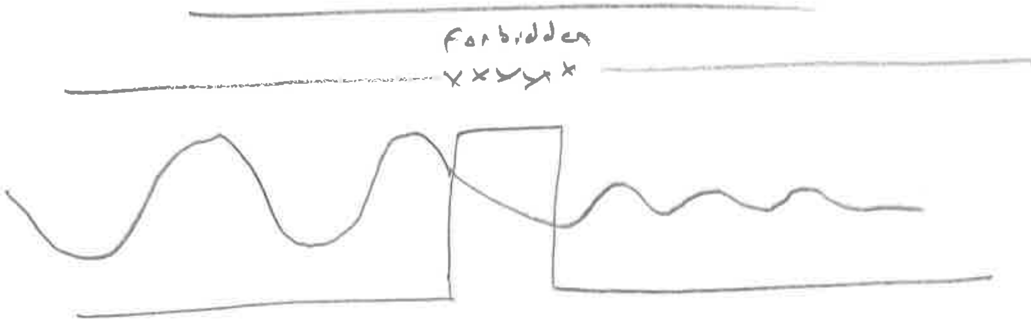
Avalanche Breakdown

If we put large enough reverse bias voltage,



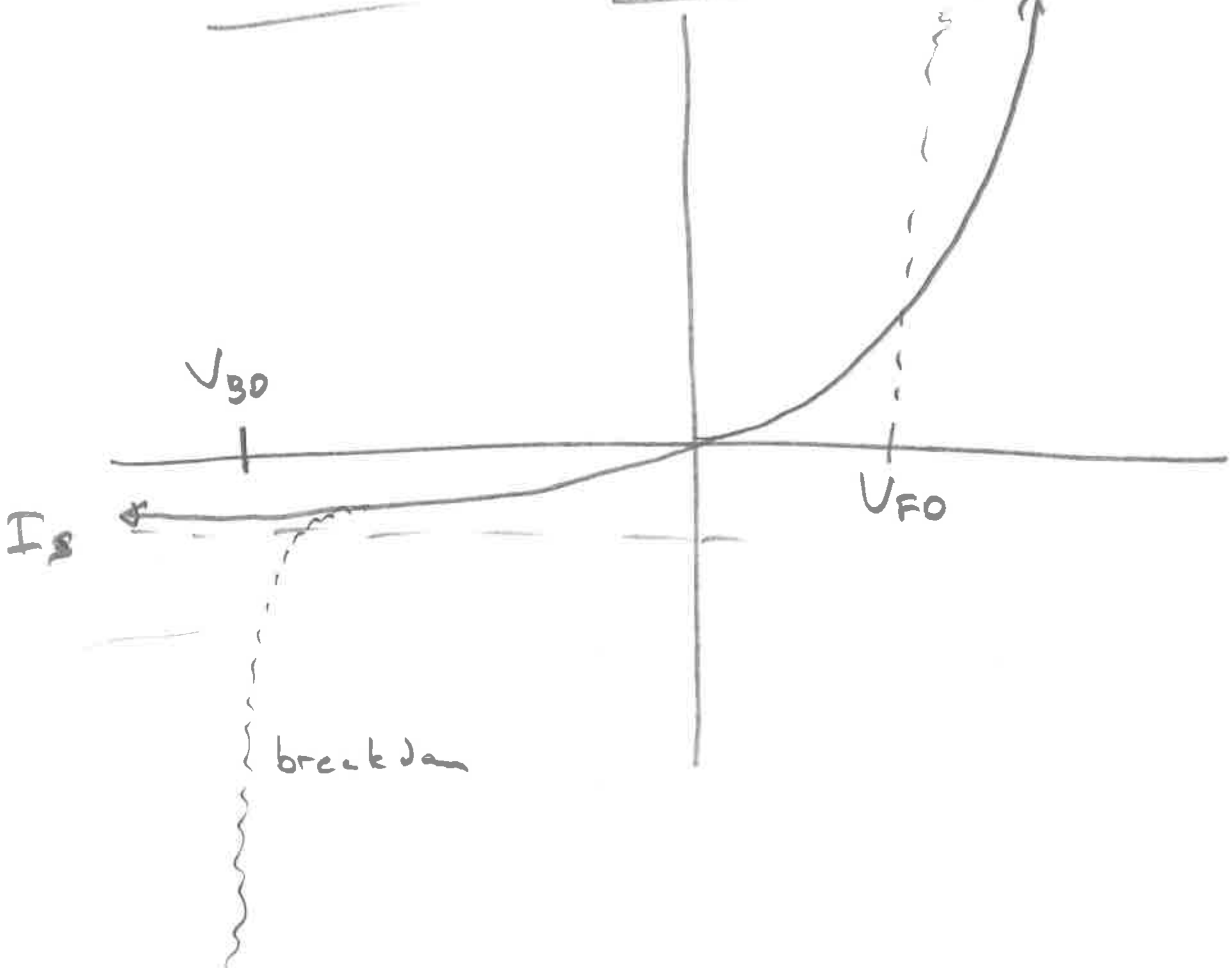
small reverse bias current is exponentially multiplied due to pair production from high energy collisions!

Zener Breakdown

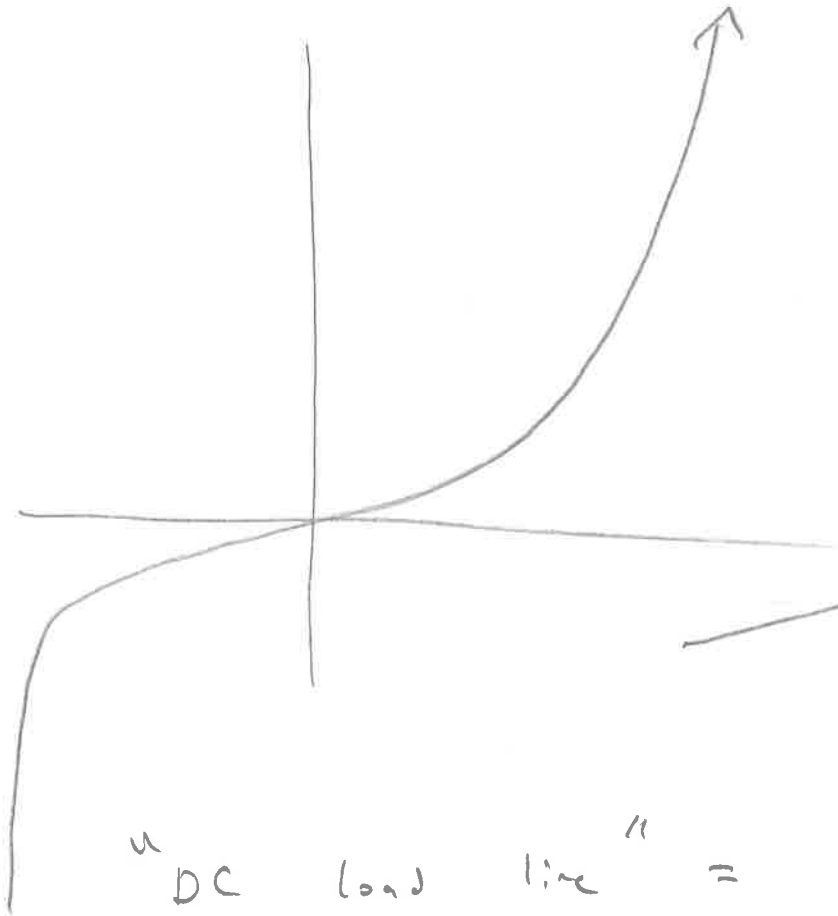


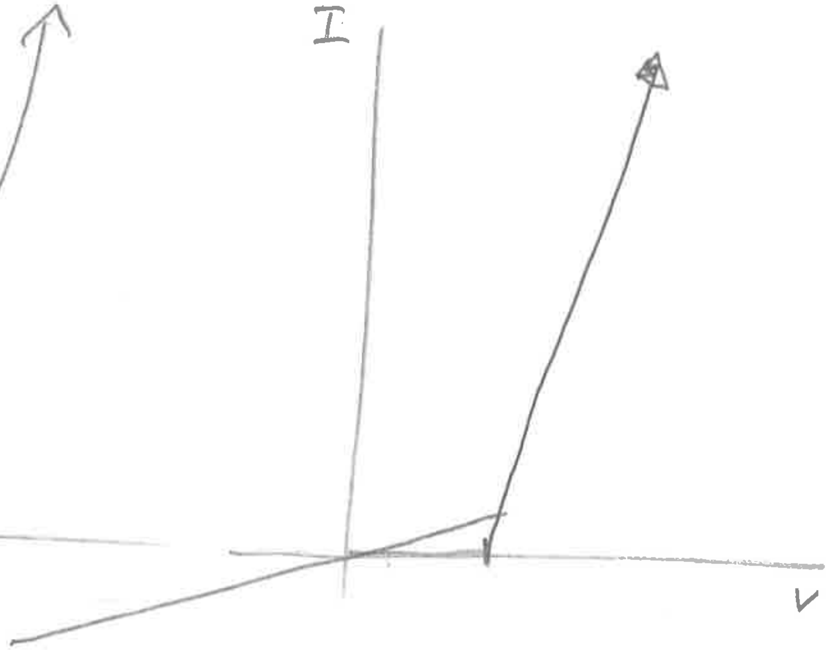
Quantum tunnelling effects can allow a current to flow through the depletion region, just as a quantum mechanical particle can tunnel through a classically forbidden region.

Realistic Diode Curve



Piece-wise Linear Approximations





"DC load line" = T.E. for non-diode