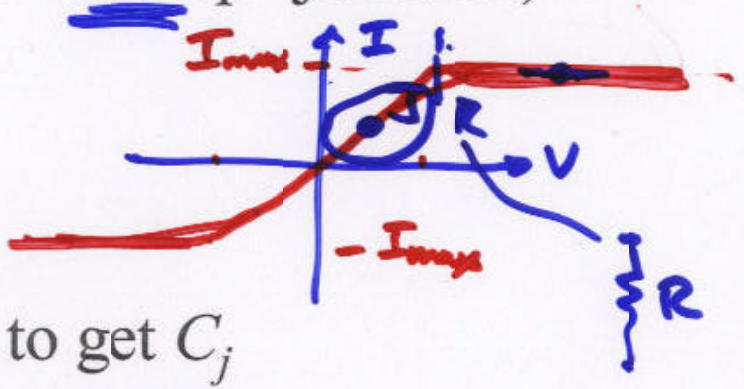
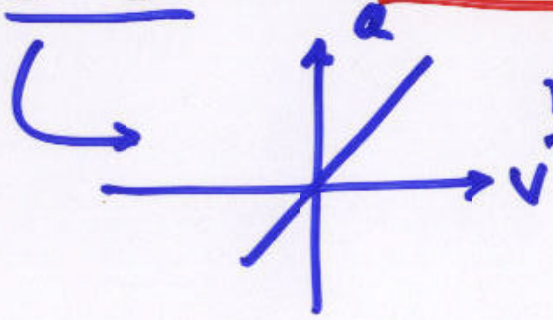
Lecture 10

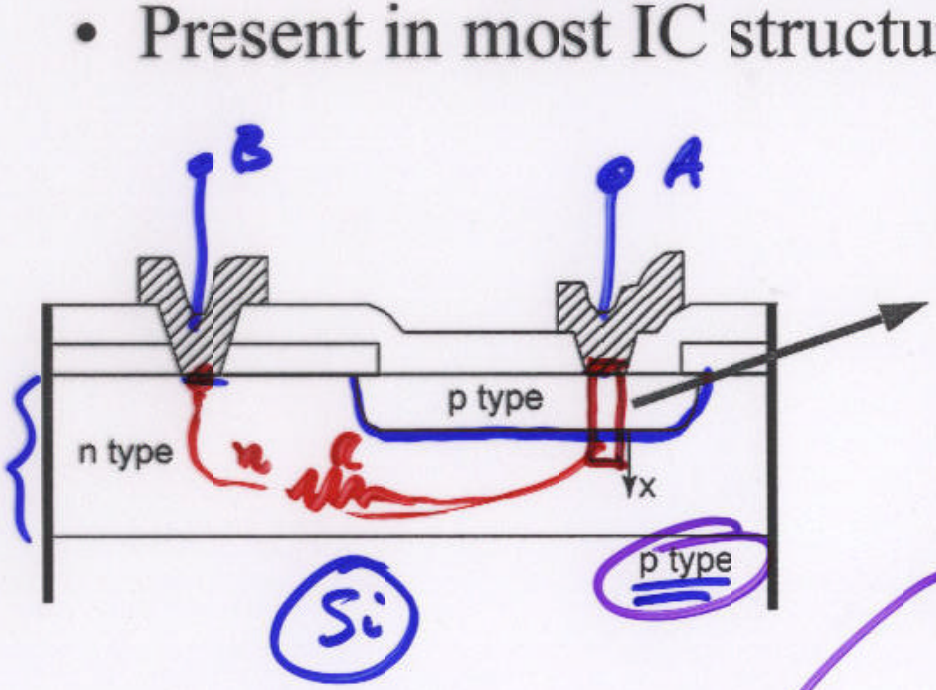
- Last time:
  - IC resistors (finish)
  - IC capacitors (metal-metal + start pn junction)
- Today :
  - pn junction: reverse bias
  - Q-V plots → linearization to get C_j

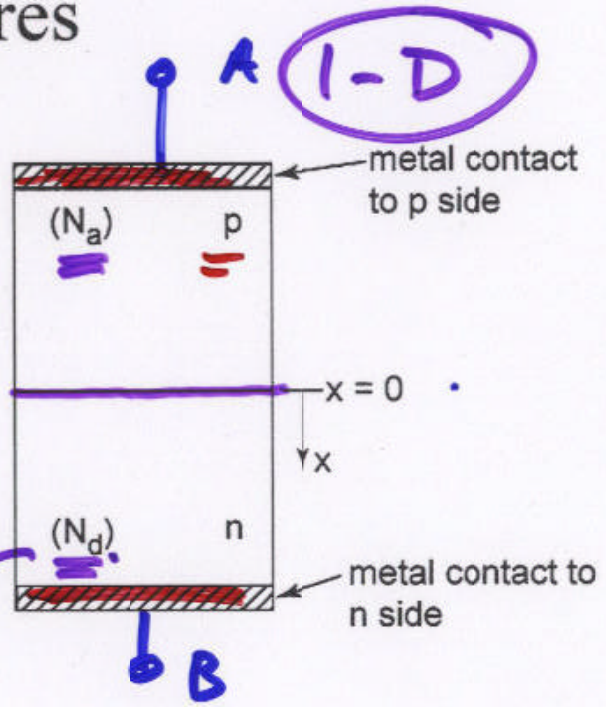


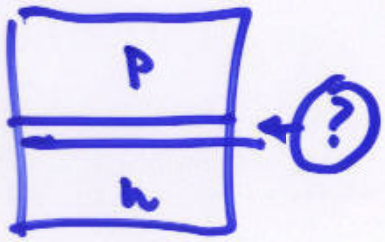


pn Junction

- Present in most IC structures







$N_{d\,net} = N_d - N_a$ SUBSTRATE.

WE UNDERSTAND THIS...
↓ WE OBSERVE IT...

Junction in Thermal Equilibrium

- Mobile electrons and holes can cross junction (huge concentration difference)
- Process creates balanced + / - charge layers because the donors and acceptors are "stuck" in the lattice and can't move.
- Limiting state with $V_D = 0$ V → thermal equilibrium
- "Built-in voltage" is about 1 V

EE 130

EE 105

THERMAL EQUILIBRIUM

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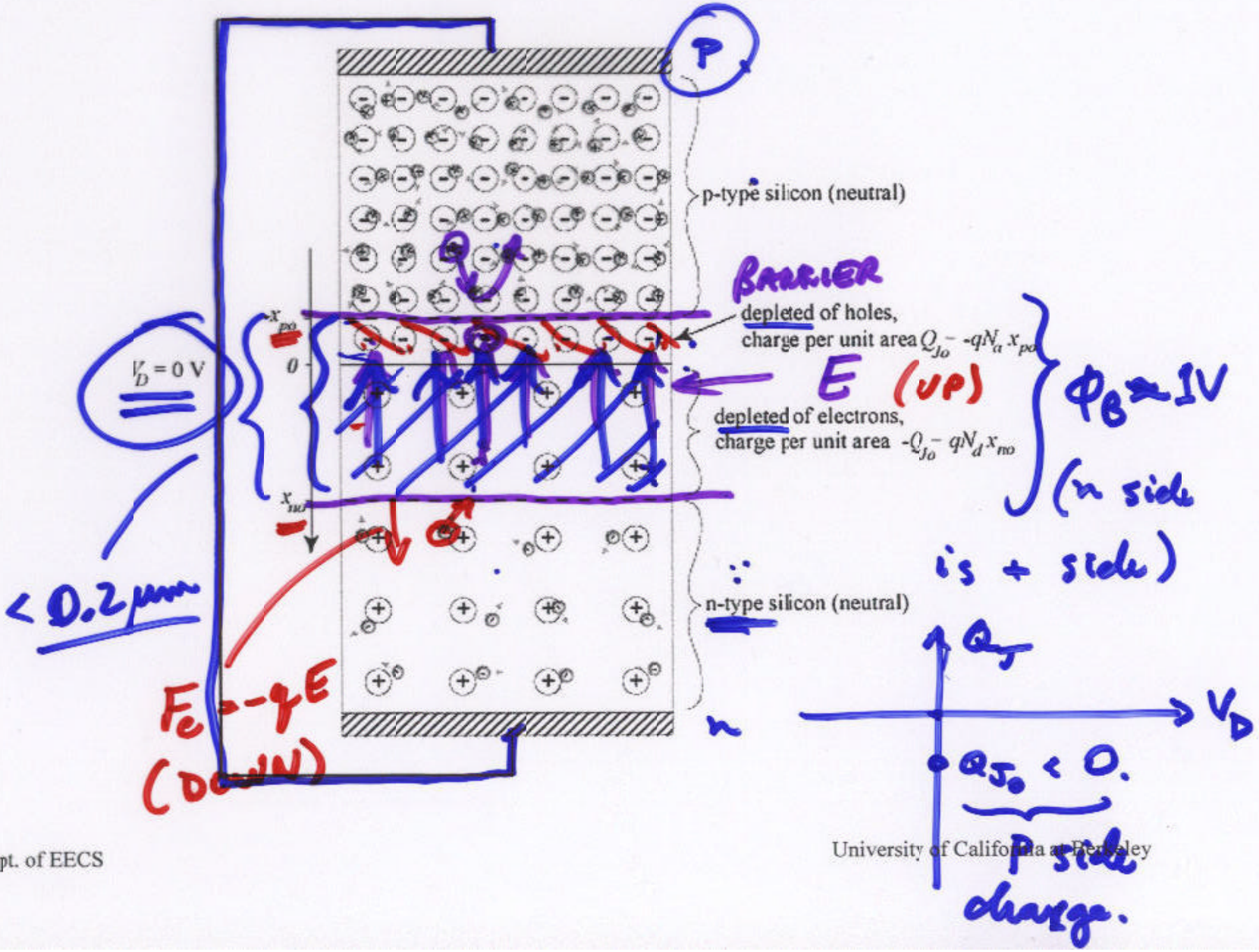
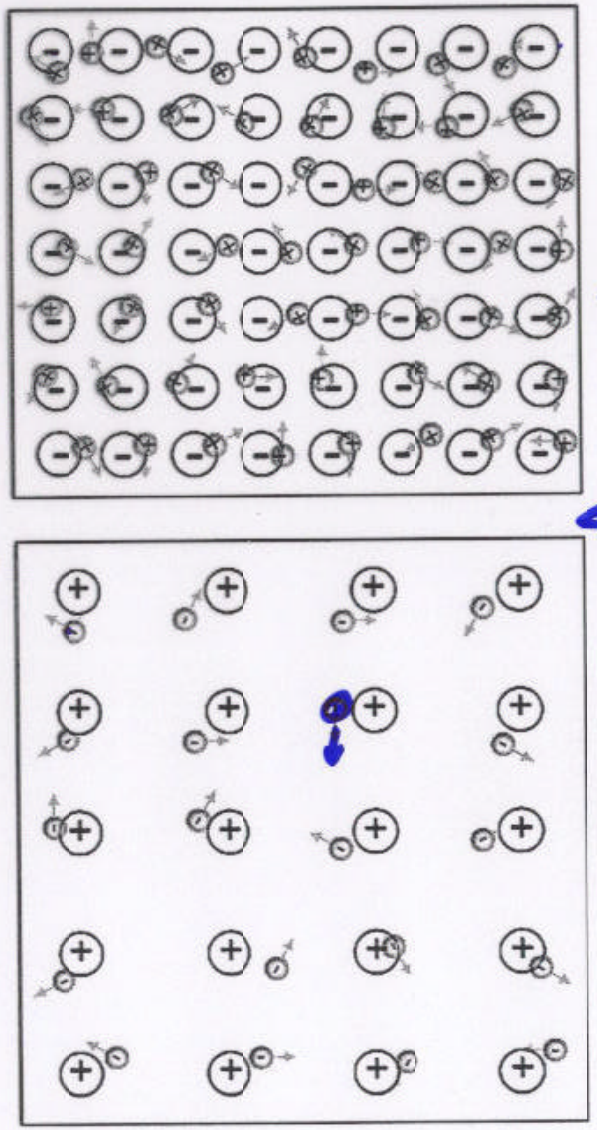




p-type silicon
⊖ ionized acceptor (fixed)
hole (mobile)

IMMOBILE
B^- ⇒
N_a

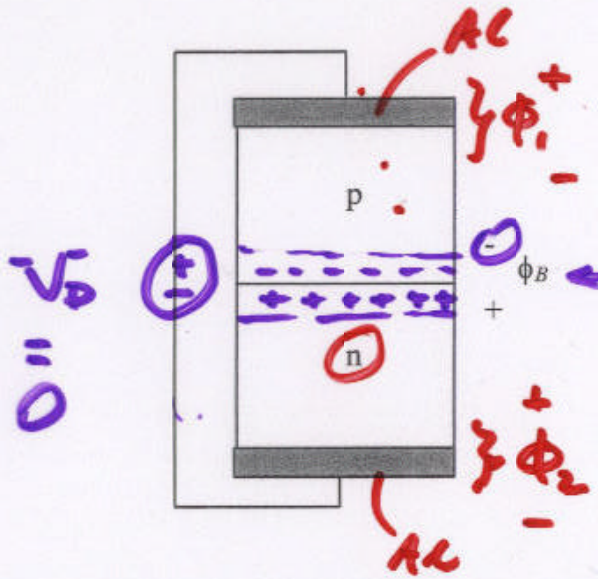
MIXING ...
holes → n-side
electrons → p-side.

n-type silicon
⊕ ionized donor (fixed)
electron (mobile)

P, N_d.

$N_d < N_a$

Voltages in Thermal Equilibrium



$\phi_B = f(N_a, N_d)$

$\approx$ 0.9V.

$V_D = 0$

KVL: where are the missing voltage drops?

WRONG! $\rightarrow$ $-V_D - \phi_B = 0$???

$-V_D + \phi_1 - \phi_B + \phi_2 = 0$

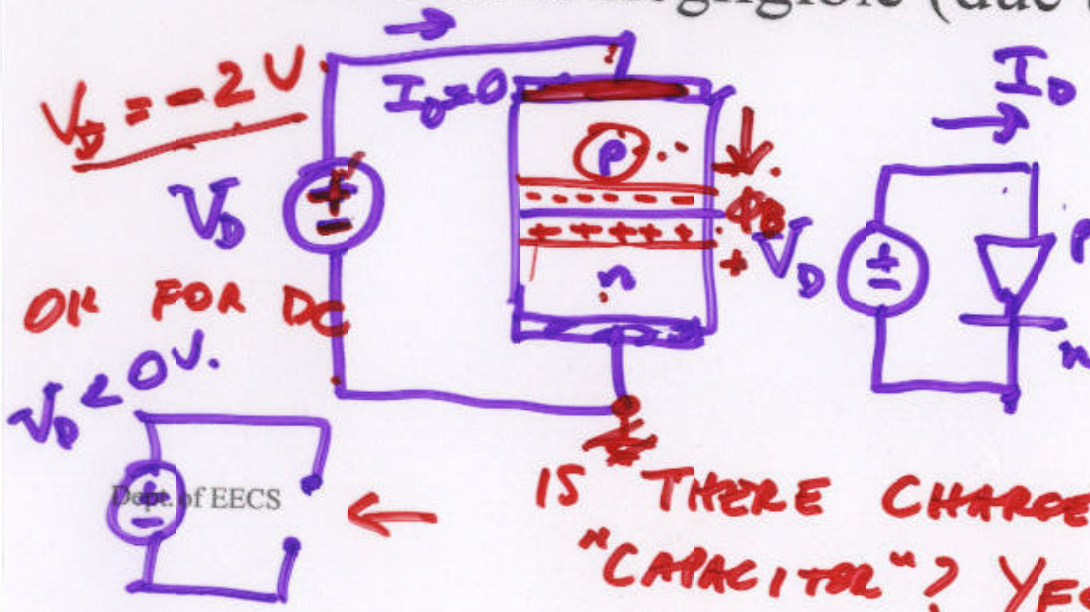
EE 130 $\rightarrow$ $\phi_1 + \phi_2 = \phi_B$ ...

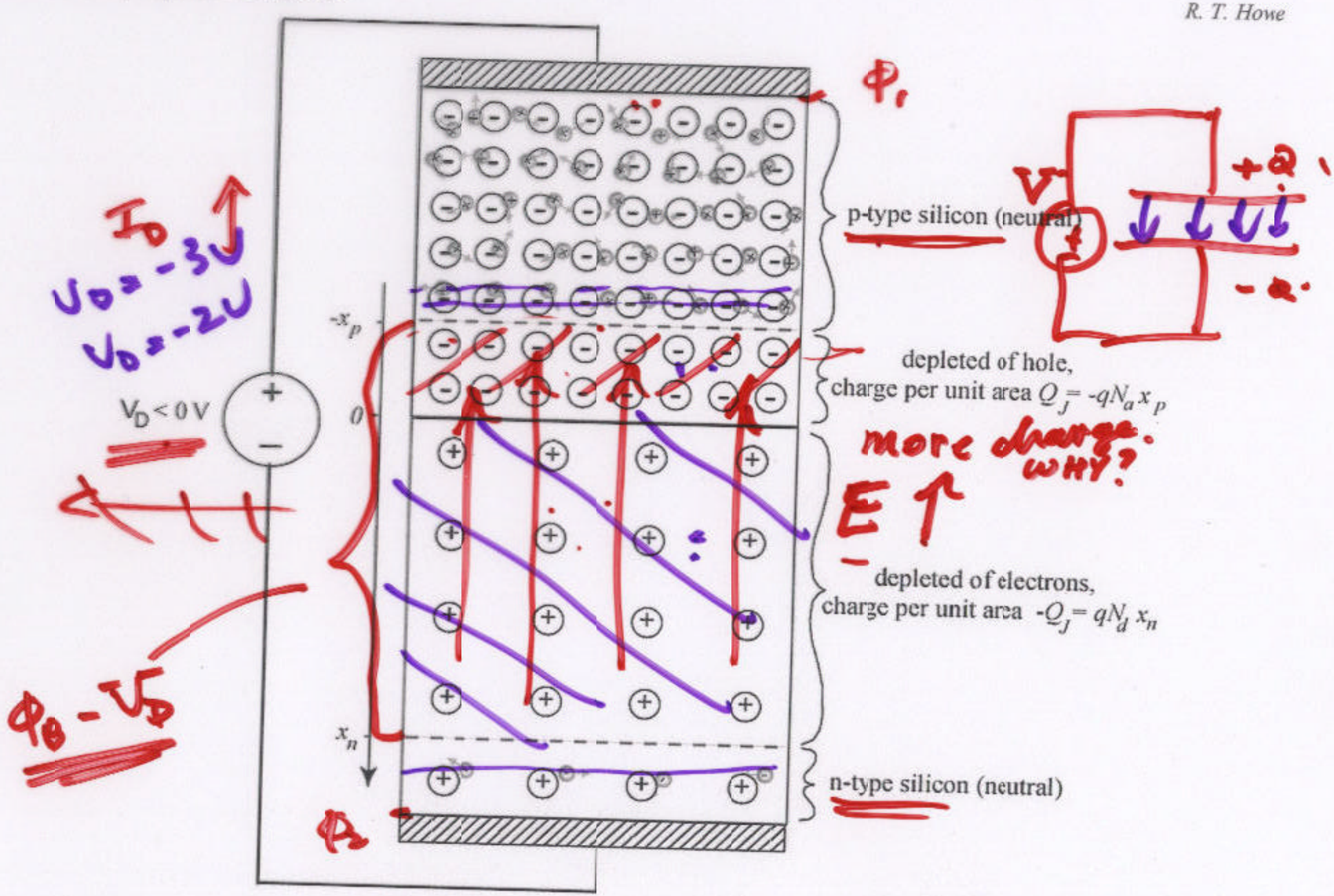
Reverse Applied Bias ($V_D < 0$ V)

- Polarity increases charge stored in junction
  → increases barrier between p and n regions

→ $\phi_J = \phi_B - V_D = 1V - (-2)V = 3V.$

- Current is negligible (due to high barrier)




p-type silicon (neutral)
depleted of hole,
charge per unit area $Q_J = -qN_a x_p$
depleted of electrons,
charge per unit area $-Q_J = qN_d x_n$
n-type silicon (neutral)
$-x_p$
0
x_n
$V_D < 0$ V
more charge. WHY?
E ↑
CHARGE STORAGE DEVICE ...

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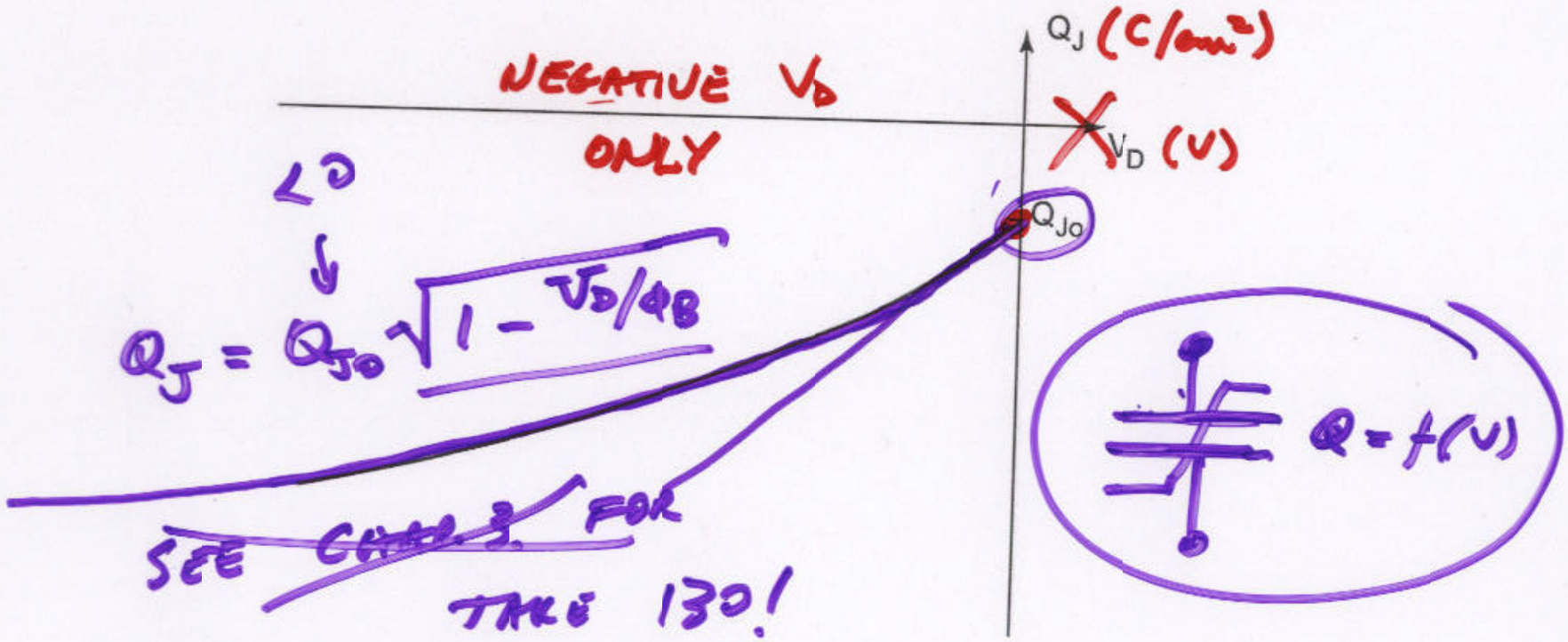
Qualitative Charge-Voltage Plot



Why isn't the plot linear?

Quantitative Charge-Voltage Plot

Approximations are needed … see EE 130

Lengthy derivation in HS 3.4-3.5 (not assigned)

Result: $Q_J = Q_{Jo}\sqrt{1 - V_D/\phi_B}$ ✓

(p side) …

Built-in voltage $\phi_B \approx 1V$.