EE 105 | Discussion 5

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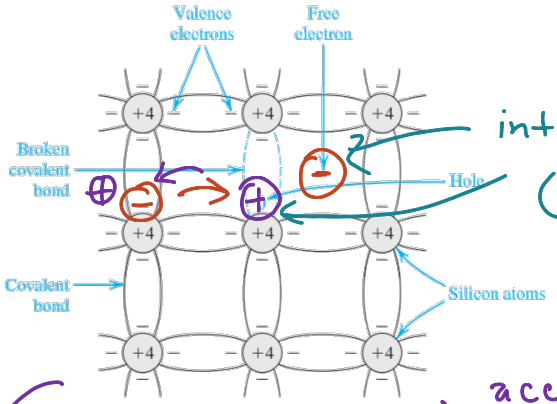
Discussion Outline

- Review of semiconductors
- Diode circuits
- Linear region MOSFETs

Semiconductor Types

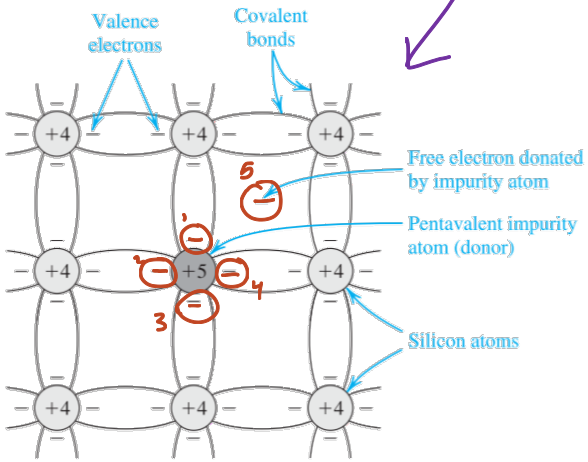
Undoped Silicon

@ room temperature



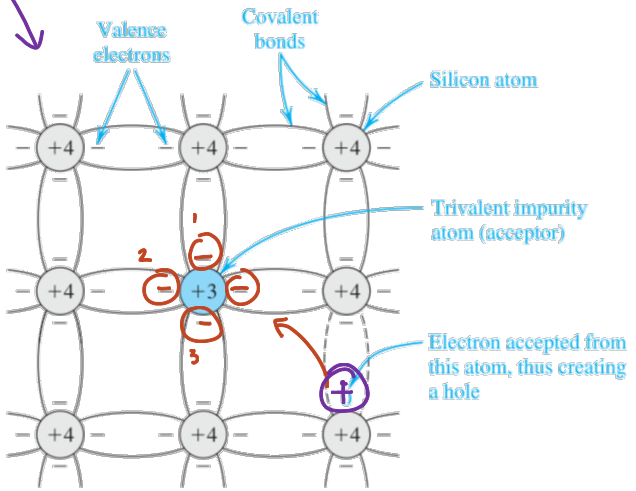
intrinsic charge carriers (intrinsic SC)

donor



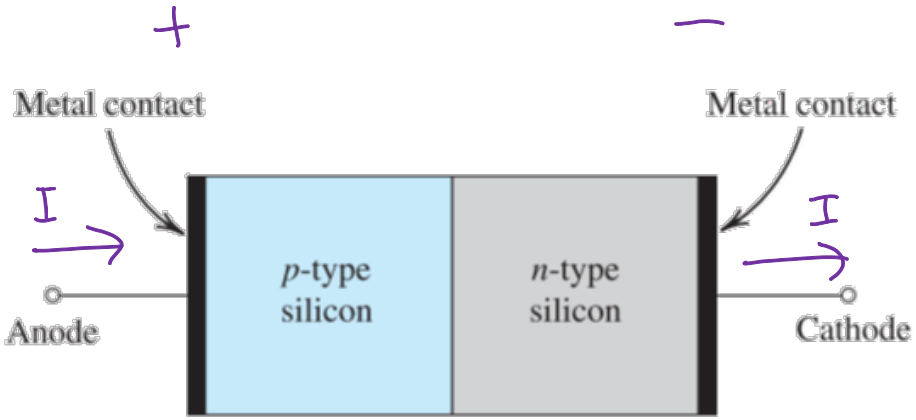
n -Type Silicon

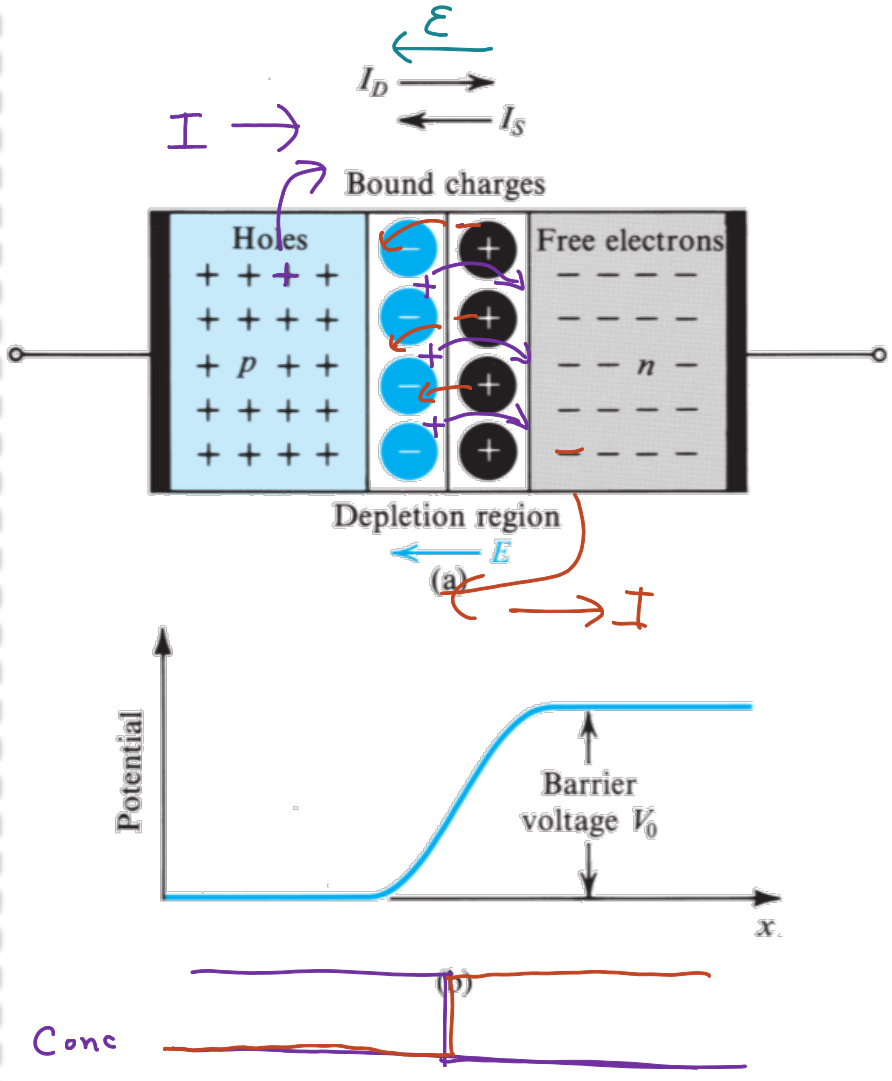
acceptor



p -Type Silicon

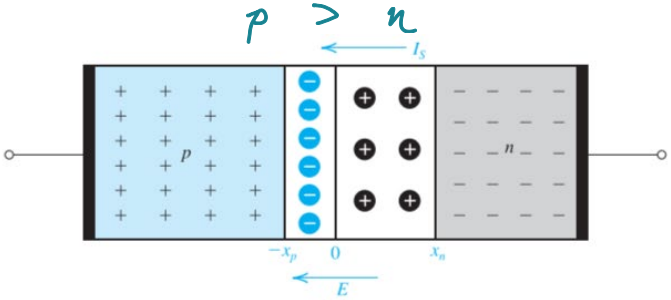
PN Junctions



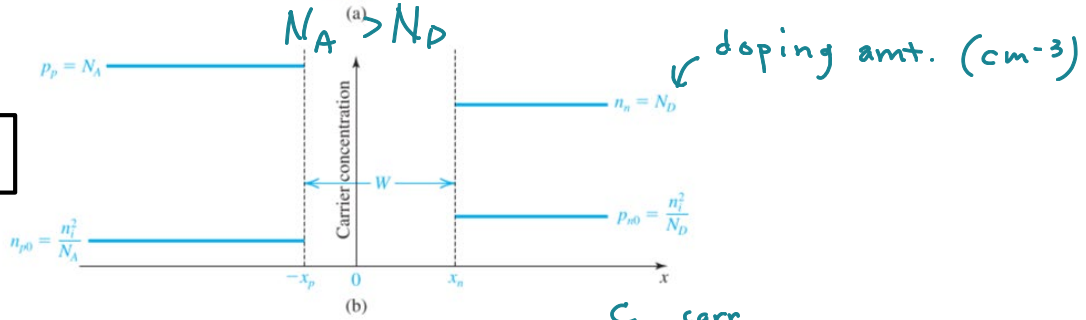


PN Junctions | No Applied Voltage

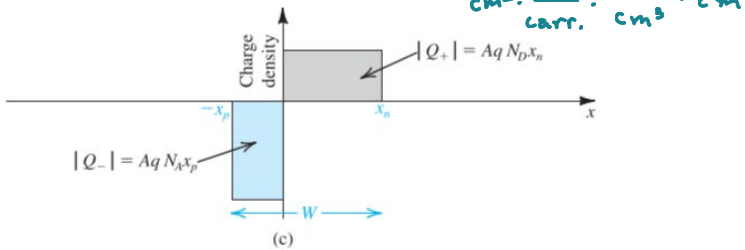
OC'd PN Junction



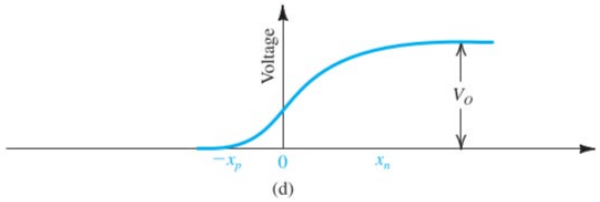
Carrier Concentrations



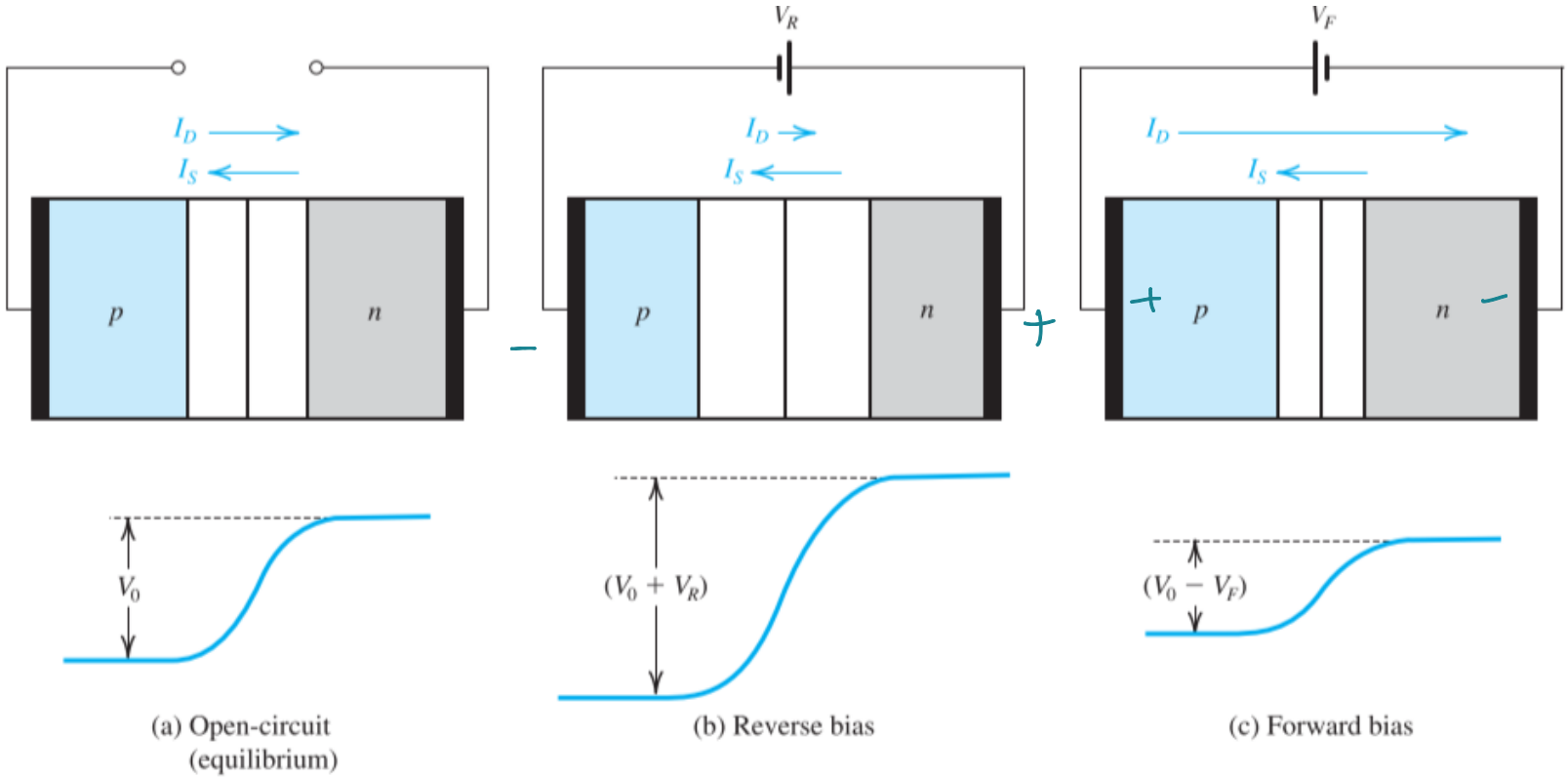
Charge Distribution



Built-in Voltage, V_0



PN Junctions | With Applied Voltage



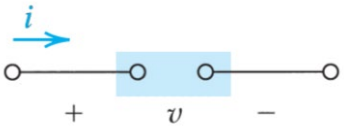
(a) Open-circuit (equilibrium)

(b) Reverse bias

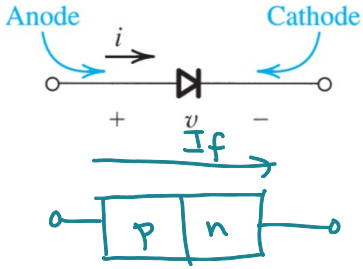
(c) Forward bias

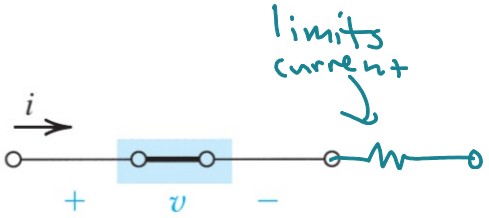
Diodes

Ideal diode

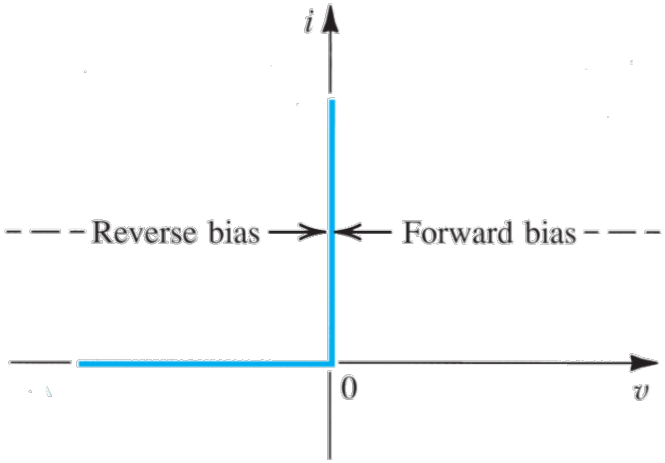


$v < 0 \Rightarrow i = 0$

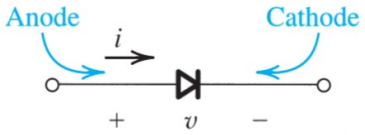




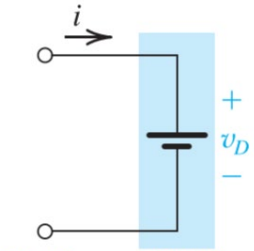
$i > 0 \Rightarrow v = 0$



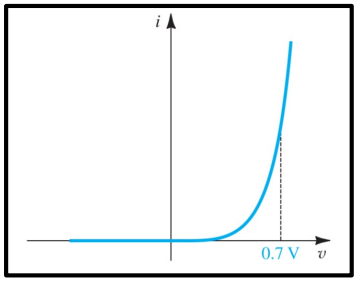
Constant Voltage Drop Model

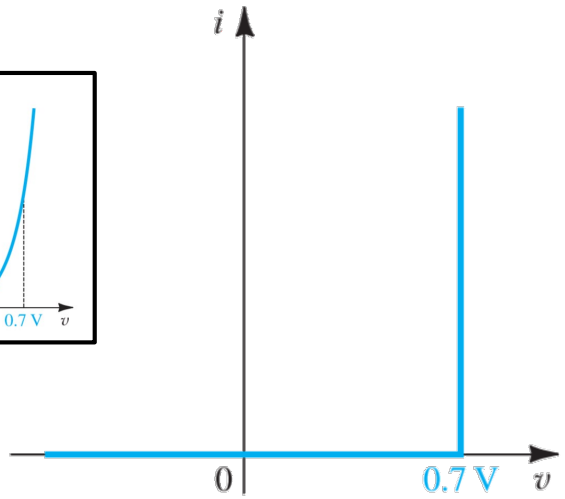


$V_D > V_f = i > 0$

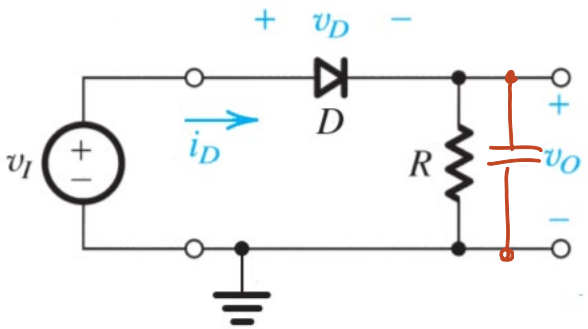


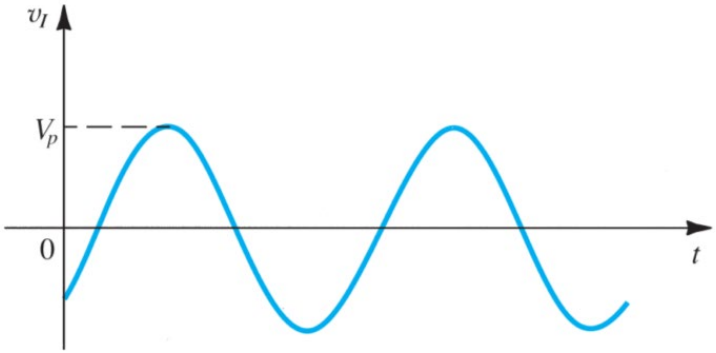
$i > 0,\ v_D = 0.7\ \text{V}$

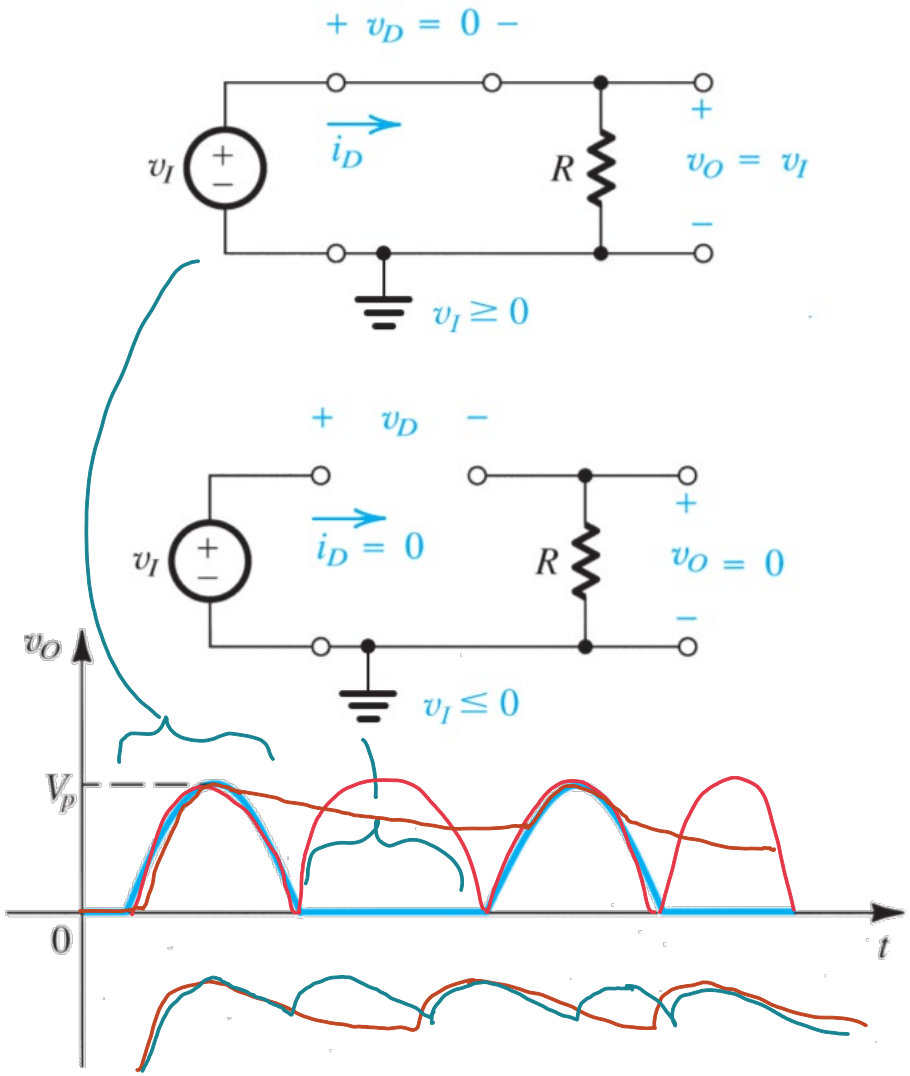




Diode Circuits | Rectifiers

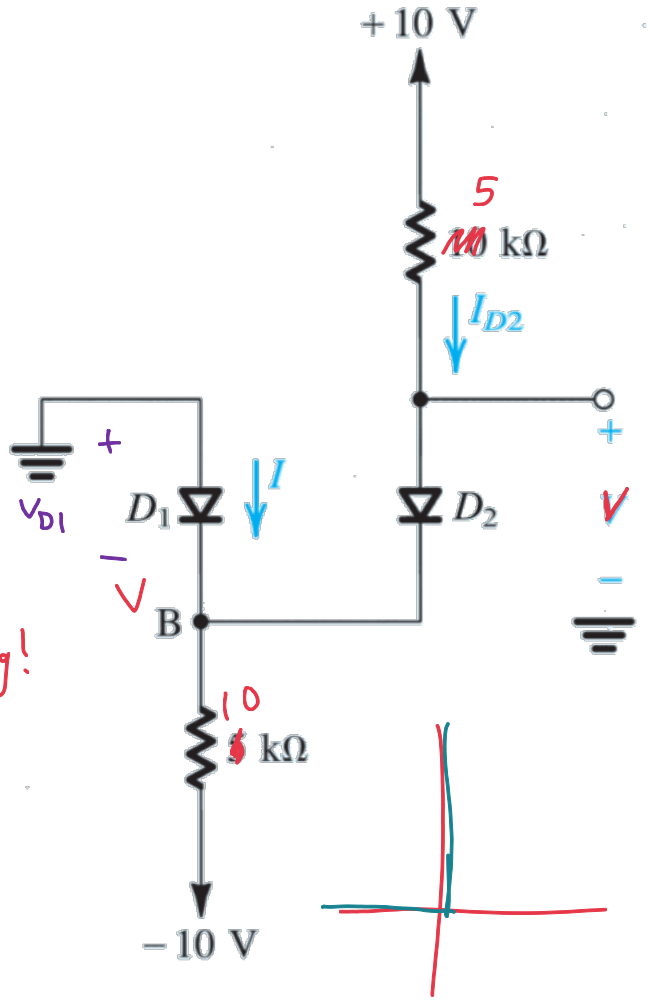






Diode Circuits | Rectifiers

Assuming the diodes to be ideal, find the values of I & V in the circuit below



① Assume D_1, D_2 ON

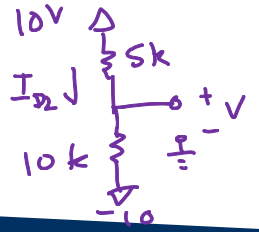
$V_B = 0^V$, $V = 0^V$

$I_{D2} = \frac{(10-0)V}{5k\Omega} = 2mA$

$I + 2mA = \frac{[0-(-10)]V}{5k\Omega}$

$I = 2mA - 2mA = 0A$ ✗ → assumption was wrong!

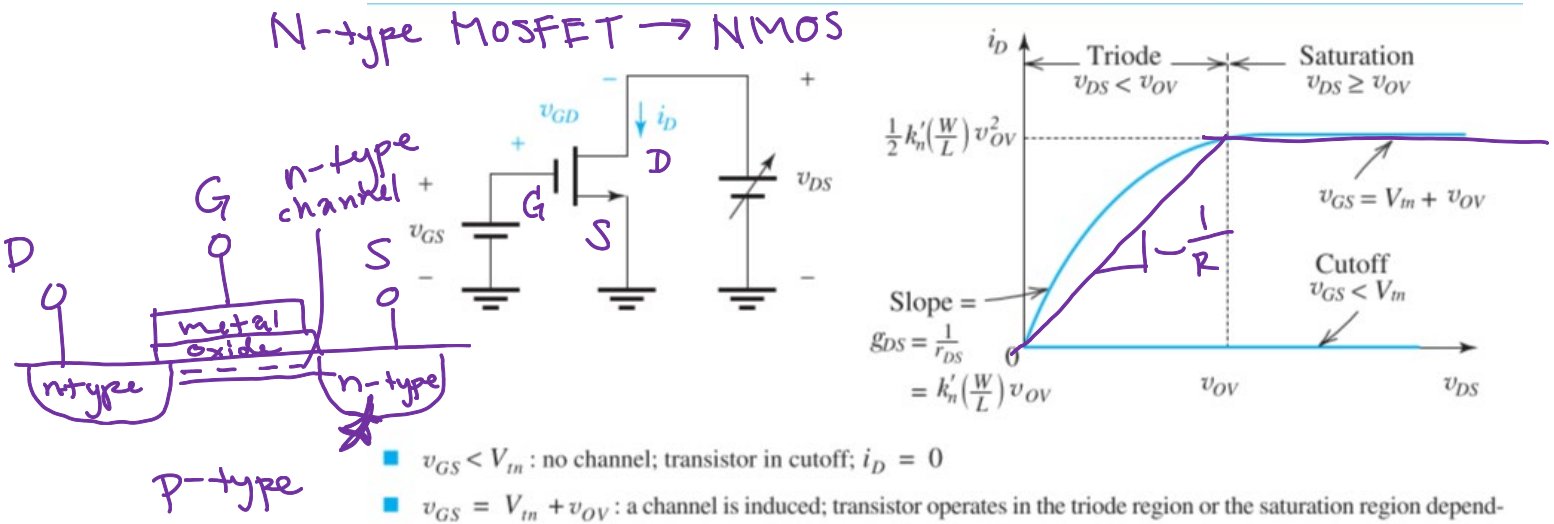
② D_1 OFF, D_2 ON



$V = 3.3V = V_B \rightarrow V_{D1} = -3.3V$

$I_{D2} = 1.33\,mA$

MOSFETs| Regions of Operation



- $v_{GS} < V_{tn}$: no channel; transistor in cutoff; $i_D = 0$
- $v_{GS} = V_{tn} + v_{OV}$: a channel is induced; transistor operates in the triode region or the saturation region depending on whether the channel is continuous or pinched off at the drain end;

Triode Region

Continuous channel, obtained by:

$$v_{GD} > V_{tn}$$

or equivalently:

$$v_{DS} < v_{OV}$$

Then,

$$i_D = k_n'\left(\frac{W}{L}\right)\left[(v_{GS} - V_{tn})v_{DS} - \frac{1}{2}v_{DS}^2\right]$$

or equivalently,

$$i_D = k_n'\left(\frac{W}{L}\right)\left(v_{OV} - \frac{1}{2}v_{DS}\right)v_{DS}$$

Saturation Region

Pinched-off channel, obtained by:

$$v_{GD} \leq V_{tn}$$

or equivalently:

$$v_{DS} \geq v_{OV}$$

Then

$$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)(v_{GS} - V_{tn})^2$$

or equivalently,

$$i_D = \frac{1}{2}k_n'\left(\frac{W}{L}\right)v_{OV}^2$$

MOSFETs| Linear Region