Announcements

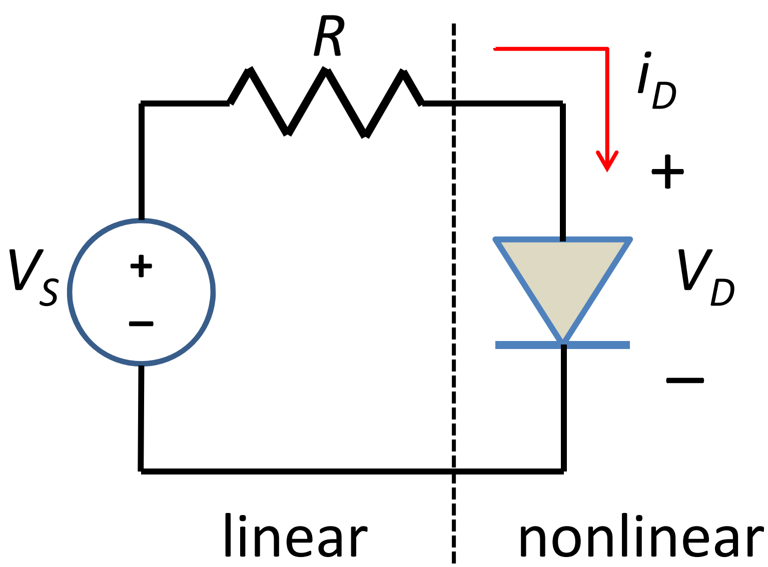
- Lab #1 this week. Read ahead of time so you are prepared.

Diode Circuit Analysis

- Goal: find quiescent operating point (Q-point) of the diode (I_D, V_D)
- Analytical tools:
  - Kirchhoff's voltage law (KVL)
  - Kirchhoff's current law (KCL)
  - Element relations
- Solution methods (Often can't solve analytically due to non-linearity)
  - Graphical methods
  - Numerical iteration
  - Linearization

Diode Circuit Analysis

- Example: Given v_D, *R*, and parameters for the diode (I_S, V_T), find Q-point (I_D, V_D).



- Linear Part (resistor, load)

$$V_S = i_D R + v_D$$

- Nonlinear part (diode)

$$i_D = I_S(e^{\frac{v_D}{V_T}} - 1)$$

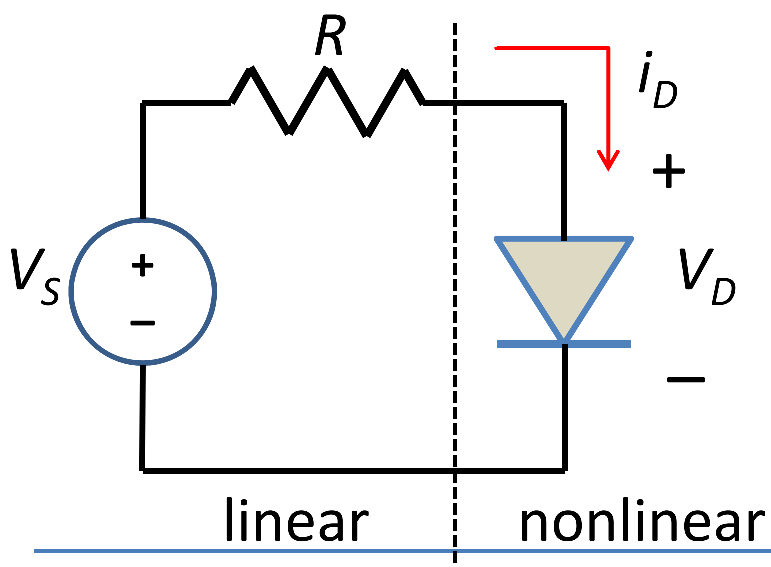
- Two equations, two unknowns I_D, V_D.

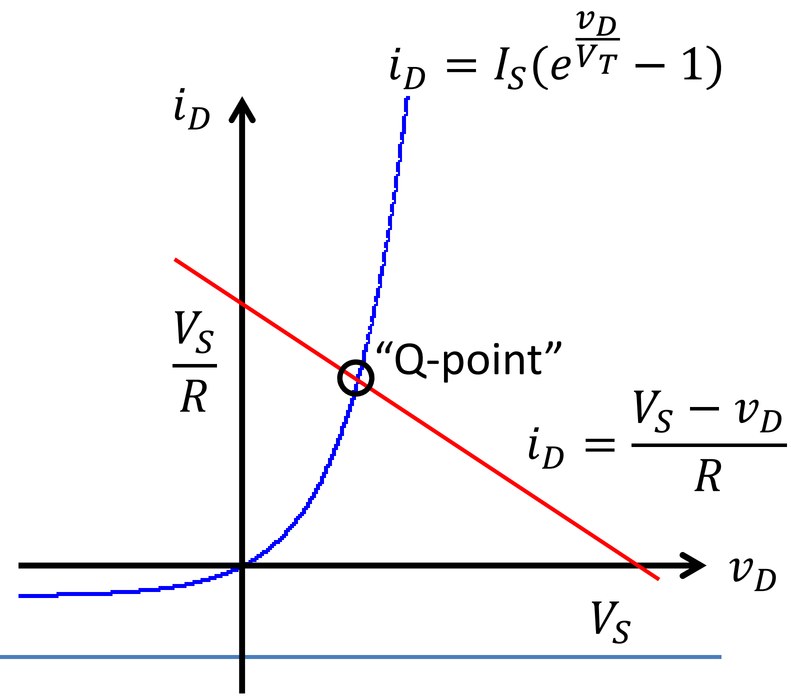
Load Line Analysis (Graphical)

- Write the two equations in the form of i_D v.s. v_D.

$$i_D = -\frac{v_D}{R} + \frac{V_S}{R}, \qquad i_D = I_S\left(e^{\frac{v_D}{V_T}} - 1\right)$$

- Plot them on a same graph, find the intersection.





Numerical Analysis

- Combining:

$$i_D = -\frac{v_D}{R} + \frac{V_S}{R}, \qquad i_D = I_S(e^{\frac{v_D}{V_T}} - 1)$$

- We have: $-\frac{v_D}{R} + \frac{V_S}{R} = I_S(e^{\frac{v_D}{V_T}} - 1)$ => $v_D = V_T \ln\left(1 + \frac{V_S - v_D}{I_S R}\right)$
- Let $R = 1\text{k}\Omega, I_S = 10^{-10}\text{A}, v_T = 26\text{ mV}, V_S = 10\text{ V}$. we have $v_D = 0.026 \ln\left(1 + \frac{10 - v_D}{10^{-7}}\right)$
- Make an initial guess ($v_D = 0.5\text{ V}$) and solve by iteration:

Iteration #	0	1	2	3
v_D (V)	0.5	0.4776	0.4777	0.4777

← converged !

$i_D = -\frac{v_D}{R} + \frac{V_S}{R} = 9.522\text{ mA}$ Q-point = (9.522 mA, 0.4777 V)

Numerical Analysis

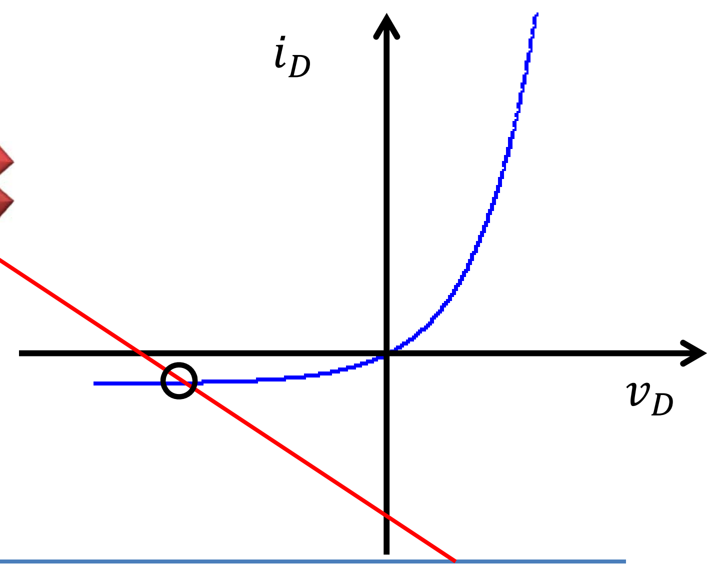
- Now use $V_S = -10\text{ V}$. Expect diode to be reverse biased.
- From graphical analysis, $i_D \approx -I_S$. Thus

$$v_D = V_S - i_D R = -10\text{ V} - 10^{-10}\text{A} \cdot 10^3\ \Omega = -10\text{ V}$$

- Check for i_D: $i_D = I_S\left(e^{\frac{v_D}{V_T}} - 1\right) \approx -I_S = -10^{-10}\text{A}$
- Q-point = (-10^{-10} A, -10 V)
- Be careful of round-off error:

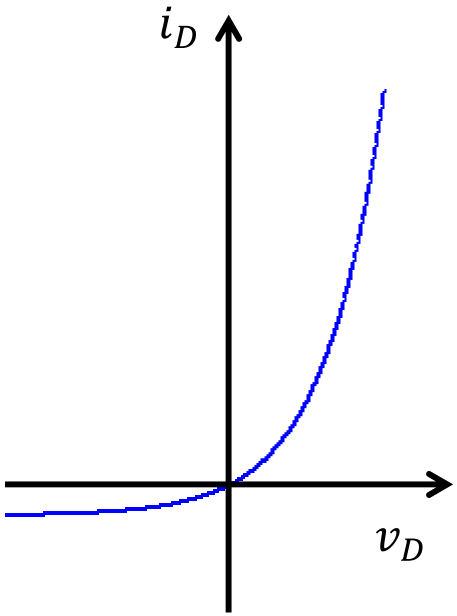
$$i_D = -\frac{v_D}{R} + \frac{V_S}{R} = \frac{10\text{ V} - 10\text{ V}}{10^3\ \Omega} = 0.00\text{A}$$

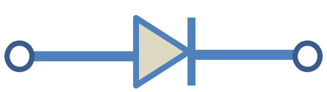
should be 9.999999999 V



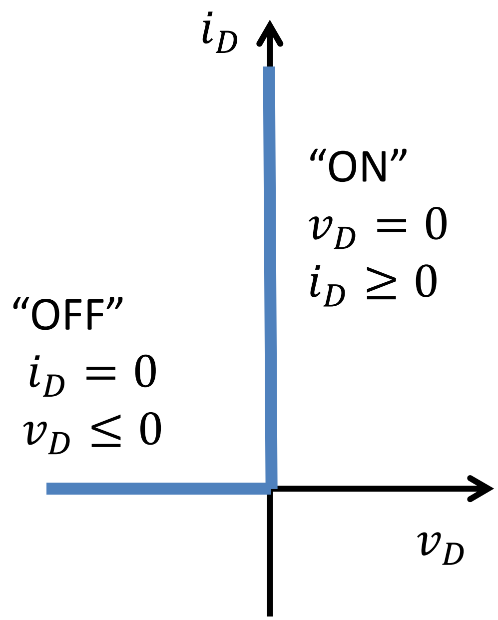
Simplified Diode Models

General diode





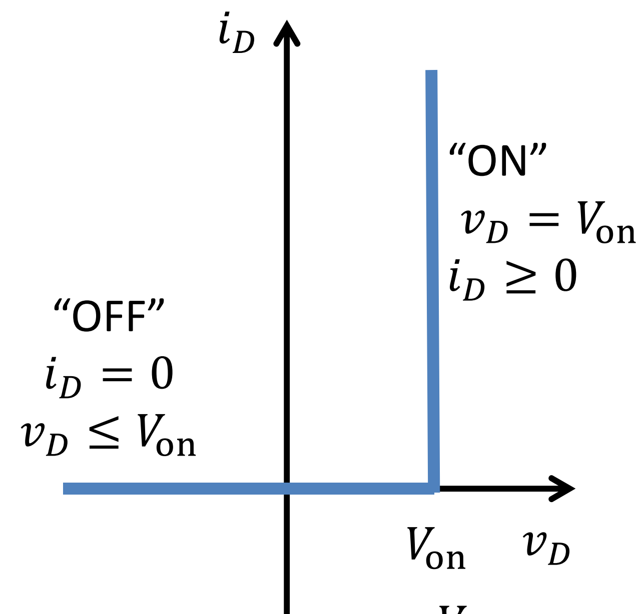
Ideal diode



ON: short circuit

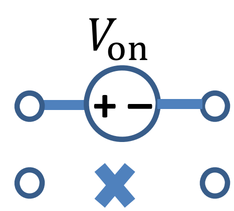
OFF: open circuit

Constant voltage drop



ON: voltage source

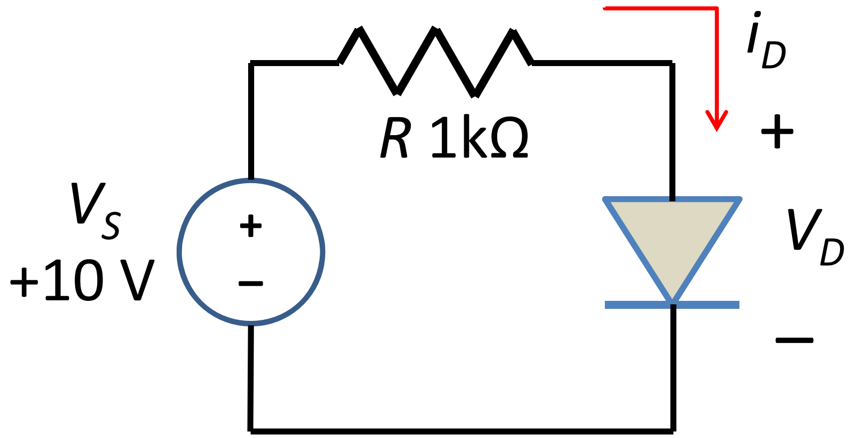
OFF: open circuit



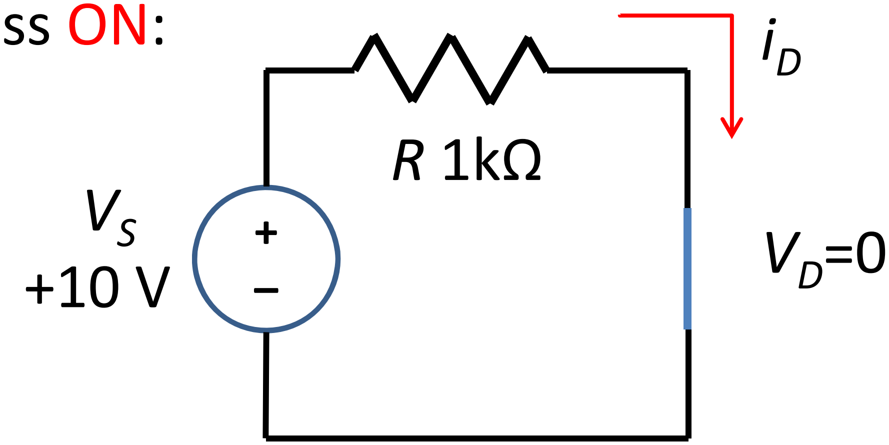
Diode Circuit Analysis – simplified model

- Analysis Method:
  - Guess a state for the diode, ON or OFF
  - Replace the diode by its equivalent model for this state
  - Analyze the circuit using this equivalent model
  - Verify that the guess was correct

Diode Circuit Analysis
Ideal model



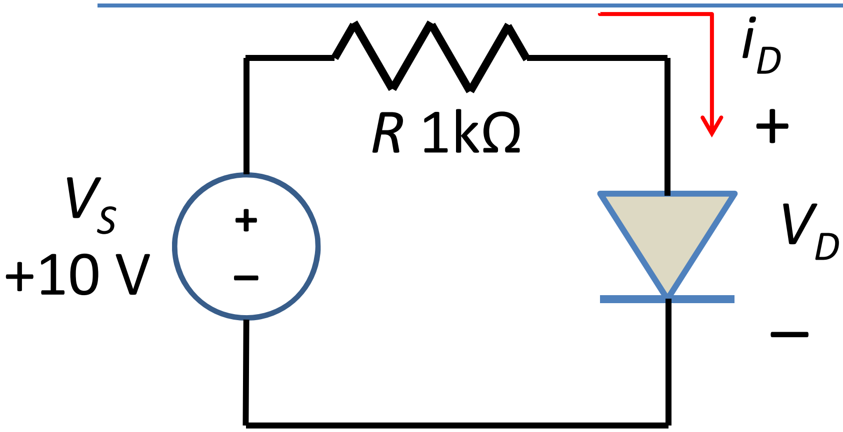
Guess ON:



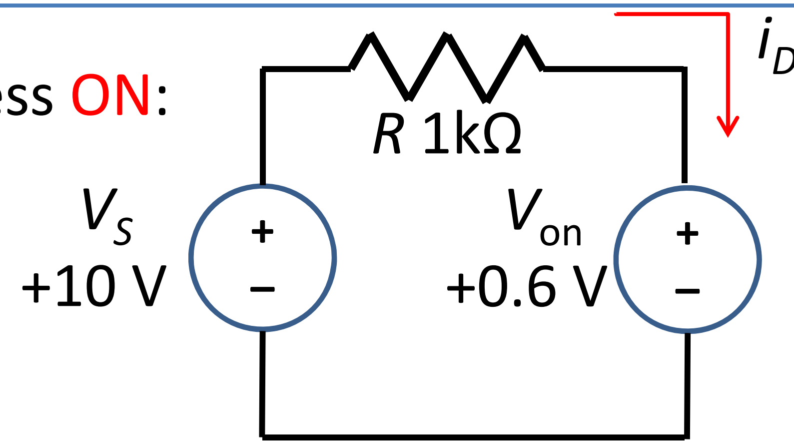
Since I_D = 10 mA ≥ 0, D = ON correct

"ON" condition: $v_D = 0, i_D \geq 0$

Diode Circuit Analysis
LVD model



Guess ON:

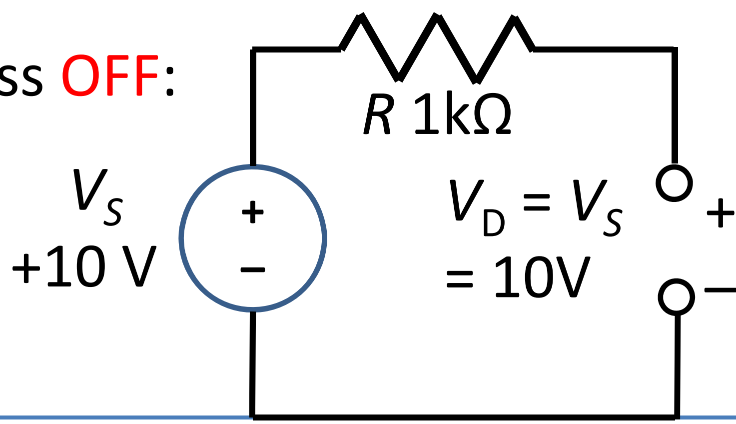


$V_{\mathrm{on}} = 0.6\ \mathrm{V}$

Since I_D = 9.4 mA ≥ 0, D = ON correct

"ON" condition: $v_D = V_{\mathrm{on}},\ i_D \geq 0$

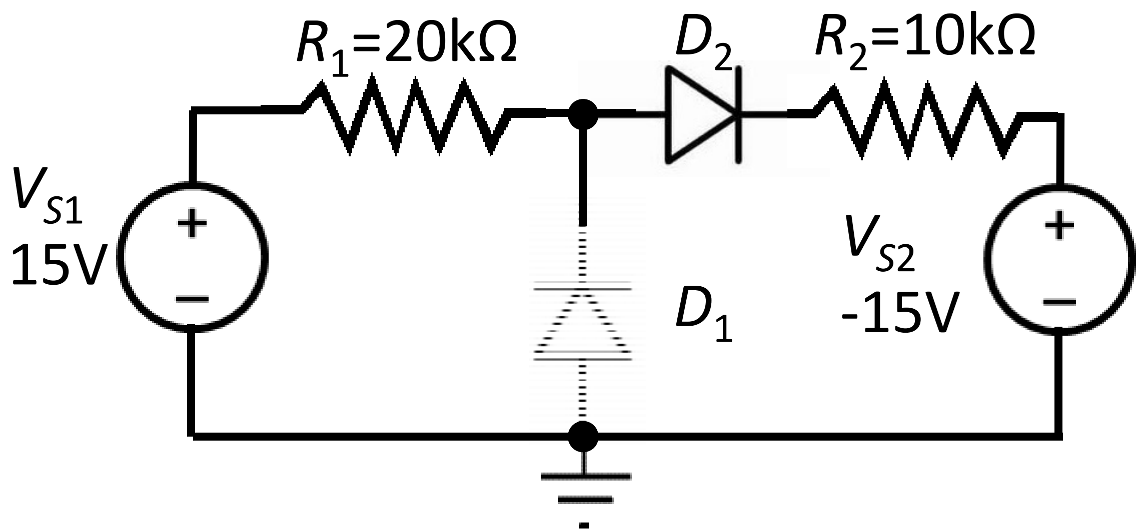
Guess OFF:



Since V_D = 10 V ≥ V_{on}, D = OFF wrong!

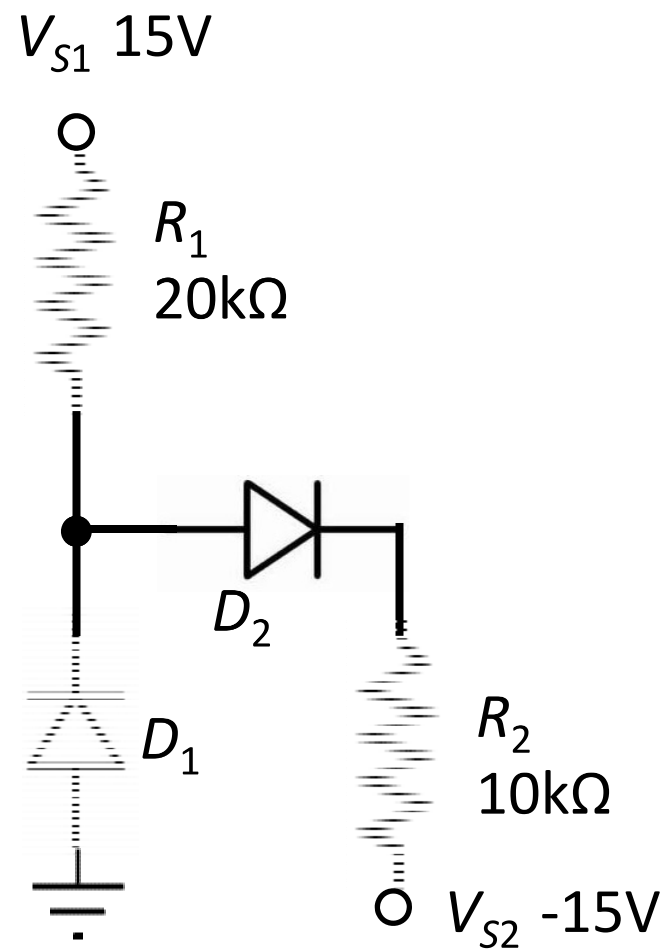
"OFF" condition: $i_D = 0,\ v_D \leq V_{\mathrm{on}}$

Multiple Diode Circuits



D_1, D_2 = Ideal diodes

Textbook Schematic



Engineering Schematic

Multiple Diode Circuits

Guess: D_1, D_2 both ON

$$i_{R1} = \frac{15\text{ V} - 0\text{V}}{20\text{ k}\Omega} = 0.75\text{ mA}$$

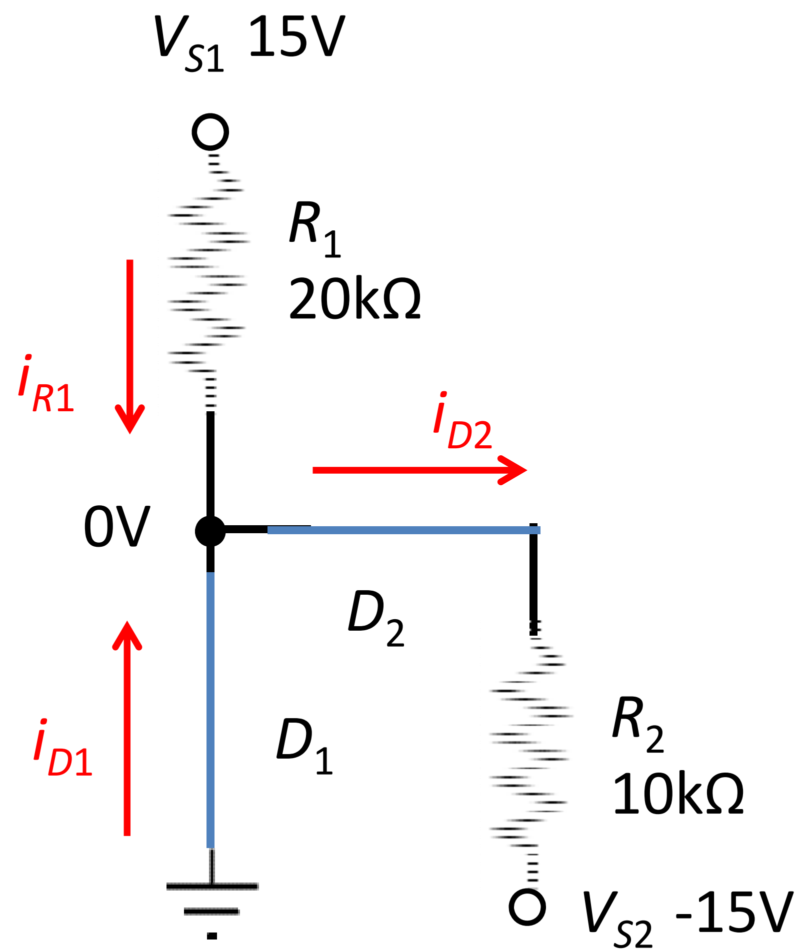
$$i_{D2} = \frac{0\text{ V} - (-15)\text{V}}{10\text{ k}\Omega} = 1.50\text{ mA}$$

$$i_{D1} = i_{D2} - i_{R1} = 0.75\text{ mA}$$

Check:

$i_{D1} \geq 0$, $i_{D2} \geq 0$

both D_1 and D_2 are ON. Correct!



Multiple Diode Circuits

Now: Swap resistors

Guess: D_1, D_2 both ON

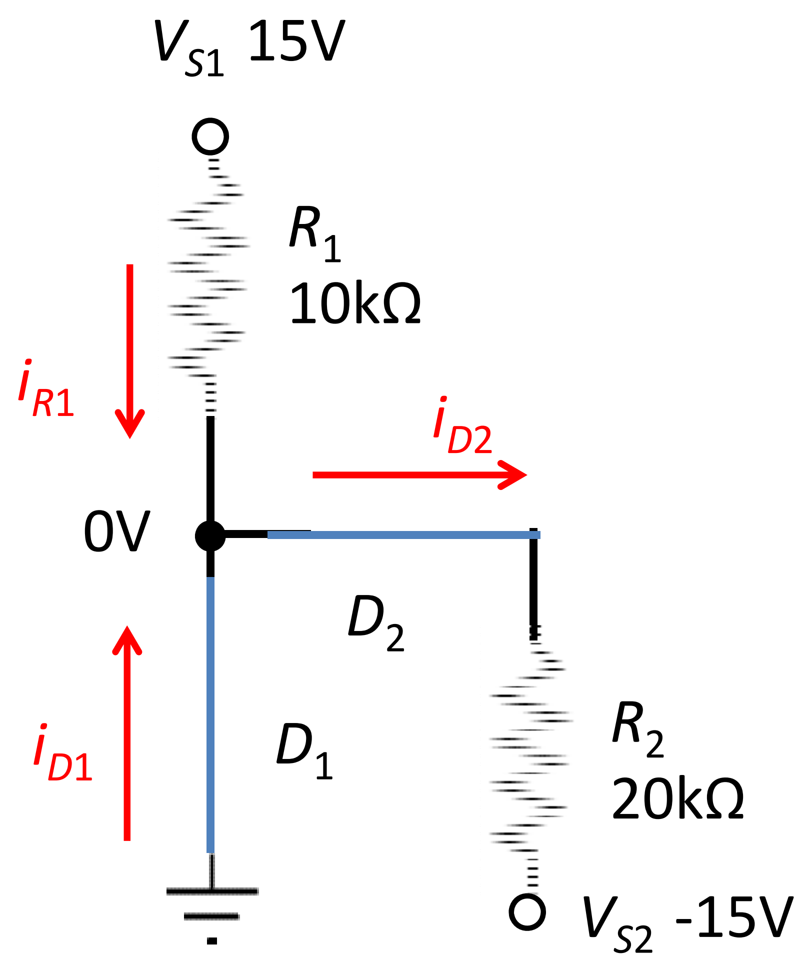
$$i_{R1} = \frac{15\text{ V} - 0\text{V}}{10\text{ k}\Omega} = 1.50\text{ mA}$$

$$i_{D2} = \frac{0\text{ V} - (-15)\text{V}}{20\text{ k}\Omega} = 0.75\text{ mA}$$

$$i_{D1} = i_{D2} - i_{R1} = -0.75\text{ mA}$$

Check:

$i_{D1} < 0$ => Contrary to D_1 ON!



Multiple Diode Circuits

Guess: D_1 OFF, D_2 ON

$$i_{R1} = i_{D2} \frac{15\text{ V} - (-15)\text{V}}{30\text{ k}\Omega} = 1.00\text{ mA}$$

$$v_A = 15\text{ V} - 10\text{ k}\Omega \cdot 1\text{mA} = 5\text{ V}$$

$$v_{D1} = 0 - v_A = -5\text{ V}$$

Check:

$v_{D1} < 0$ => D_1 off. Correct.

$i_{D2} > 0$ => D_2 on. Correct.