Lec. 1: assignment 1.1

In the laboratory, 2 sets of related values of current and voltage at two temperatures have been measured for the diode 1N4001:

- At 25°C : (V_{D1}, I_{D1}) = (540 mV, 1mA), and (V_{D2}, I_{D2}) = (450 mV, 0.1mA)
- At 75°C: (V_{D1}, I_{D1}) = (420 mV, 1mA), and (V_{D2}, I_{D2}) = (315 mV, 0.1mA)

a. Calculate the constants of the diode equation: n and I_s for each temperature.

b. Calculate the temperature coefficient [mV/K] of the diode at current = 1 mA.

$$\boxed{\begin{aligned} I_D &\approx I_s\, e^{\frac{V_D}{nV_T}} \\ V_D &= n\mathrm{V_T} \ln\frac{I_D}{I_s} \end{aligned}}$$

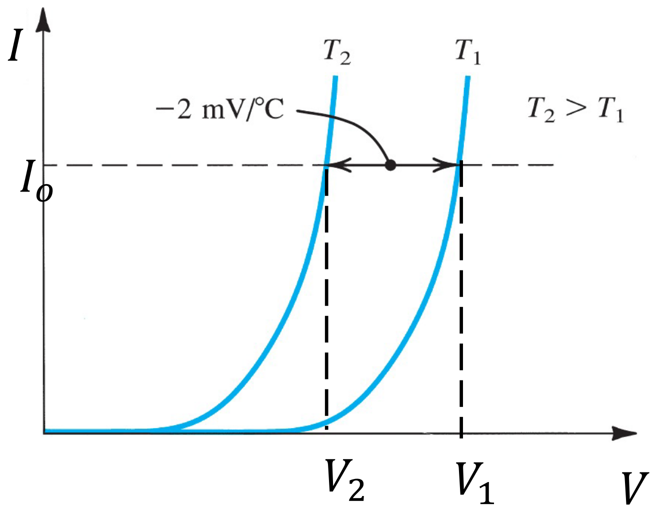
$$V_{D_2} = n\mathrm{V_T}\ln\frac{I_{D2}}{I_s} \;\&\; V_{D_1} = n\mathrm{V_T}\ln\frac{I_{D1}}{I_s} \;\rightarrow n = \frac{V_{D2}-V_{D1}}{V_T \ln\frac{I_{D2}}{I_{D1}}} \;\&\; I_s = I_{D_1}\, e^{-\frac{V_{D_1}}{nV_T}}$$

$V_T = \frac{KT_K}{q}$ → V_T(25 °C) = 25.7 mV & V_T(75 °C) = 30 mV

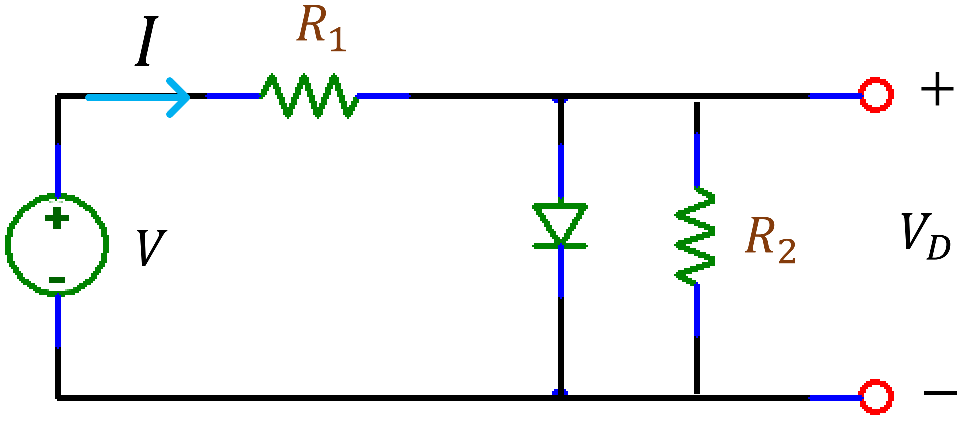
At 25 °C: $n = \frac{450\ mV - 540\ mV}{25.7\ mV \ln\frac{0.1\ mA}{1\ mA}} = 1.52$ & $I_s = 1mA\, e^{-\frac{540\ mV}{1.52 * 25.7\ mV}} = 1\ nA$

At 75 °C: $n = \frac{315\ mV - 420\ mV}{30.0\ mV \ln\frac{0.1\ mA}{1\ mA}} = 1.52$ & $I_s = 1mA\, e^{-\frac{420\ mV}{1.52 * 30.0\ mV}} = 100\ nA$

$\frac{\Delta V_D}{\Delta T} = \frac{420\ mV - 540\ mV}{75\ °C - 25\ °C}$ = -2.4 mV/ °C



Lec. 1: assignment 1.2



1. The ideal model

a. Draw the equivalent circuit and calculate I, I_{R2}, V_{R1}, V_D and V_{R2}
   - When $V < 0$
   - When $V = 0$
   - When $V > 0$

b. The I-V curve.

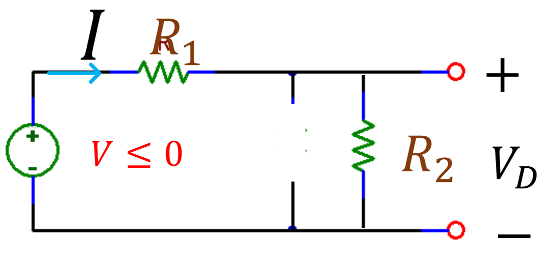
c. The I_{R2}-V curve.

d. The I_D-V curve.

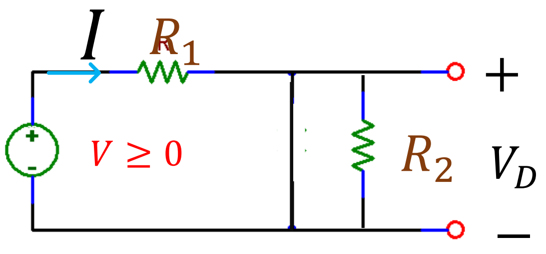
e. The V_{R1}-V curve, with V_{R1} denoting the voltage across R1.

f. The V_D-V curve, with V_D denoting the voltage across diode.

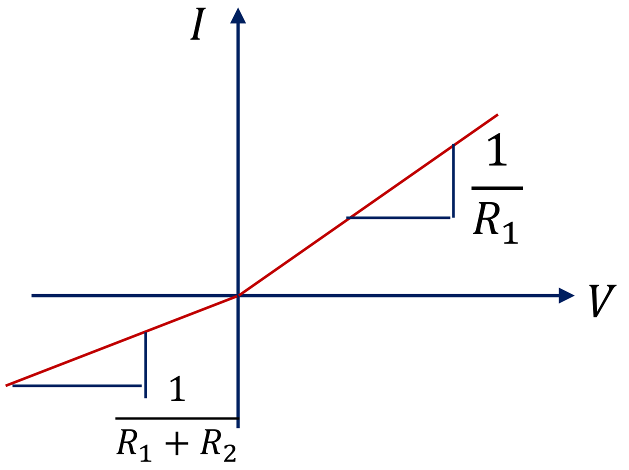
Lec. 1: assignment 1.2 –ideal model

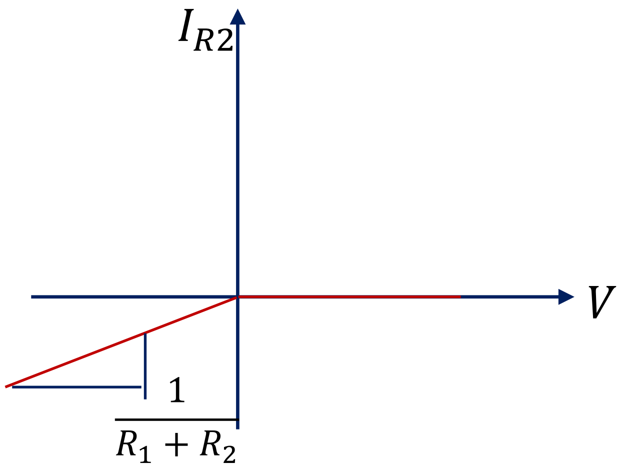


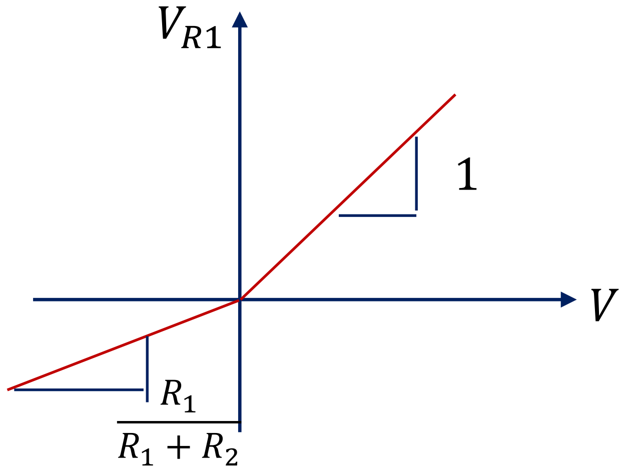
$$I = I_{R_2} = V/(R_1 + R_2)$$
$$V_{R1} = VR_1/(R_1 + R_2)$$
$$V_D = V_{R2} = VR_2/(R_1 + R_2)$$

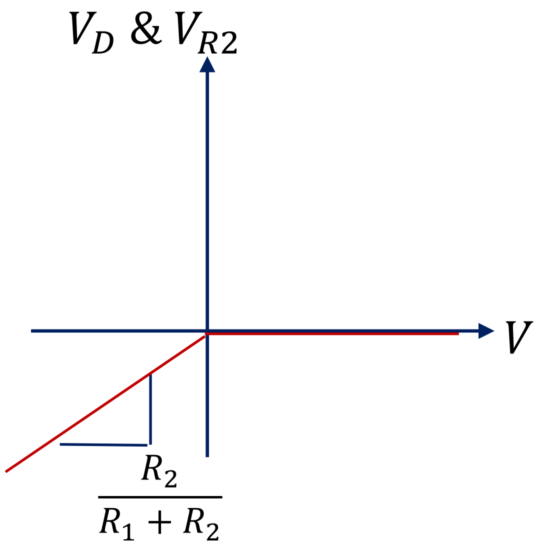


$$I = V/R_1$$
$$I_{R_2} = 0$$
$$V_{R1} = IR_1 = V$$
$$V_D = V_{R2} = 0$$

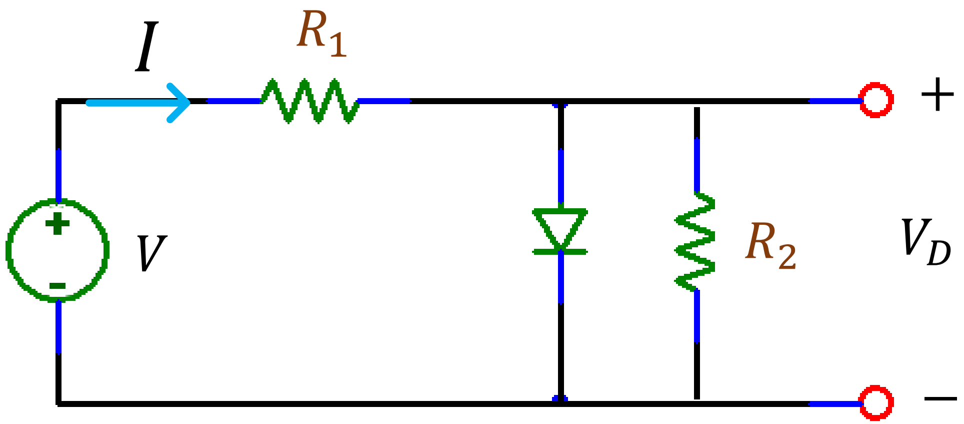








Lec. 1: assignment 1.2



2. Constant voltage drop model

Draw the equivalent circuit and calculate I, I_{R2}, V_{R1}, V_D and V_{R2}

- When V < $V_{D,on}$
- When V = $V_{D,on}$
- When V = $\frac{R_1+R_2}{R_2}V_{D,on}$
- When V > $\frac{R_1+R_2}{R_2}V_{D,on}$

a. The I-V curve.

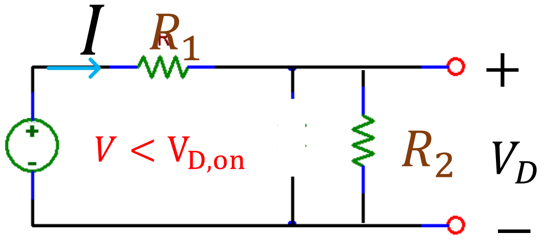
b. The I_{R2}-V curve.

c. The I_D-V curve.

d. The V_{R1}-V curve, with V_{R1} denoting the voltage across R1.

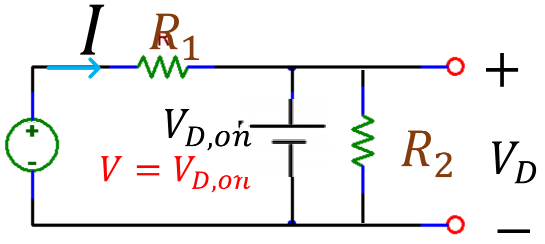
e. The V_D-V curve, with V_D denoting the voltage across diode.

Lec. 1: assignment 1.2 –constant voltage drop



$V < V_{D,on}$

$$I = I_{R_2} = V/(R_1 + R_2)$$
$$V_{R1} = VR_1/(R_1 + R_2)$$
$$V_D = V_{R2} = VR_2/(R_1 + R_2)$$



If we assume $V = V_{D,on}$, *the diode is on* → *the voltage drop across* R_1 *will be 0* → $I = 0$ *(1)*

The diode is about to turn on → $I_D = 0$

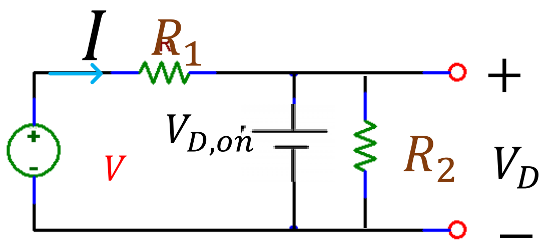
However, $I_{R2} = \frac{V_{D,on}}{R_2} \neq 0$

And $I = I_D + I_{R2} \neq 0$ *(2)*

(1) And (2) conflicts → *the diode should be off* → *same results as for* $V < V_{D,on}$

$$I = I_{R_2} = V/(R_1 + R_2)$$
$$V_{R1} = VR_1/(R_1 + R_2)$$
$$V_D = V_{R2} = VR_2/(R_1 + R_2)$$

Lec. 1: assignment 1.2 –constant voltage drop



$$V = \frac{R_1 + R_2}{R_2} V_{D,on}$$

If we assume $V = V_{D,on}$, *the diode is on* → $I = \frac{V - V_{D,on}}{R_1} = \frac{V_{D,on}}{R_2}$

(1)

The diode is about to turn on → $I_D = 0$

And, $I_{R2} = \frac{V_{D,on}}{R_2}$

And $I = I_D + I_{R2} = \frac{V_{D,on}}{R_2}$ *(2)*

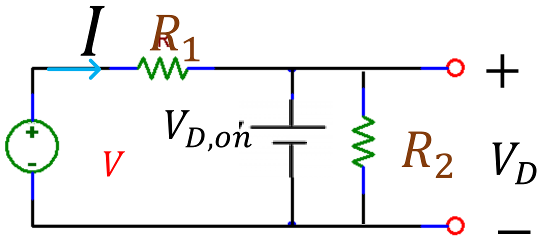
(1) And (2) true → *the diode should be on*

$$I = I_{R2} = \frac{V_{D,on}}{R_2}$$

$$V_{R1} = IR_1 = \frac{R_1 V_{D,on}}{R_2}$$

$$V_D = V_{R2} = V_{D,on}$$

Lec. 1: assignment 1.2 –constant voltage drop



$$V > \frac{R_1 + R_2}{R_2} V_{D,on}$$

$$the\ diode\ is\ on \rightarrow I = \frac{V - V_{D,on}}{R_1}$$

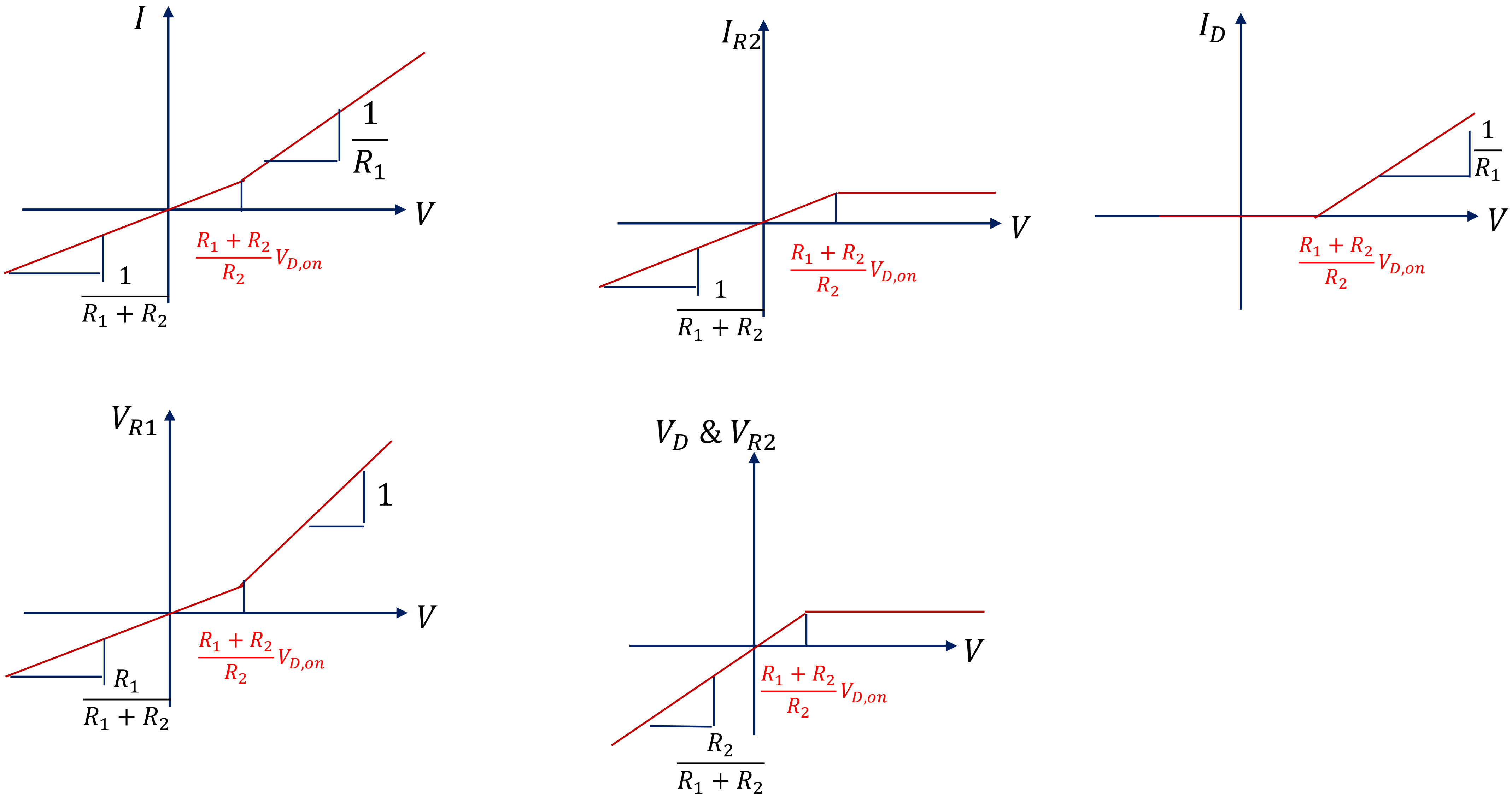
$$I_{R2} = \frac{V_{D,on}}{R_2}$$

$$I_D = I - I_{R2} = \frac{V - V_{D,on}}{R_1} - \frac{V_{D,on}}{R_2}$$

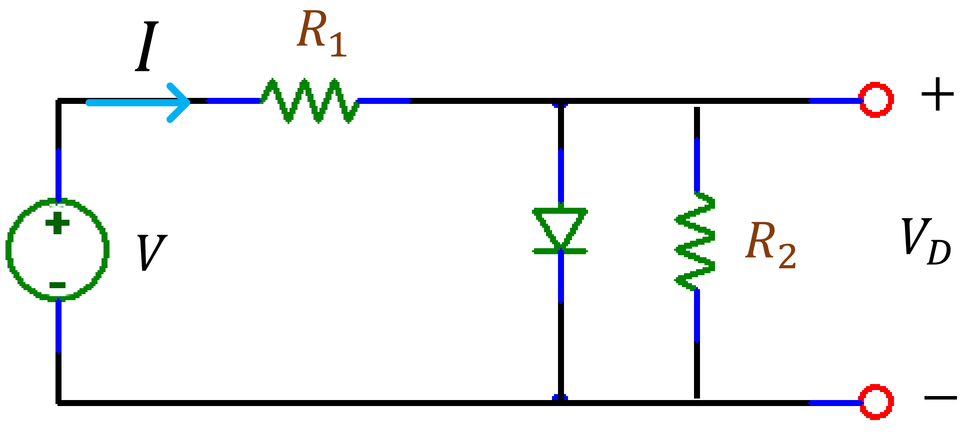
$$V_{R1} = IR_1 = V - V_{D,on}$$

$$V_D = V_{R2} = V_{D,on}$$

Lec. 1: assignment 1.2 –constant voltage drop



Lec. 1: assignment 1.3



Assuming the constant voltage drop model and the diode in reverse and forward bias regions,

a. The I-V curve.
b. The I_{R2}-V curve.
c. The I_D-V curve.
d. The V_{R1}-V curve, with V_{R1} denoting the voltage across R1.
e. The V_D-V curve, with V_D denoting the voltage across diode.
f. The V_{R2}-V curve, with V_{R2} denoting the voltage across R2.