Homework Assignment #2

ECE 0257 – Spring 2019

Name

Avery Peiffer

Collaborators

Daniel Stumpp

Book Problems (50 pts)

Sedra & Smith 4.17
Sedra & Smith 4.19
Sedra & Smith 4.23
Sedra & Smith 4.29
Sedra & Smith 4.34
Sedra & Smith 4.36
Sedra & Smith 4.41
Sedra & Smith 4.42
Sedra & Smith 4.43
Sedra & Smith 4.62
Sedra & Smith 4.87
Sedra & Smith 4.92

Simulation Problems (50 pts)

Problem 4.43 Verification (15 pts)
Problem 4.92 Verification (15 pts)
Zener Diode Analysis (20 pts)

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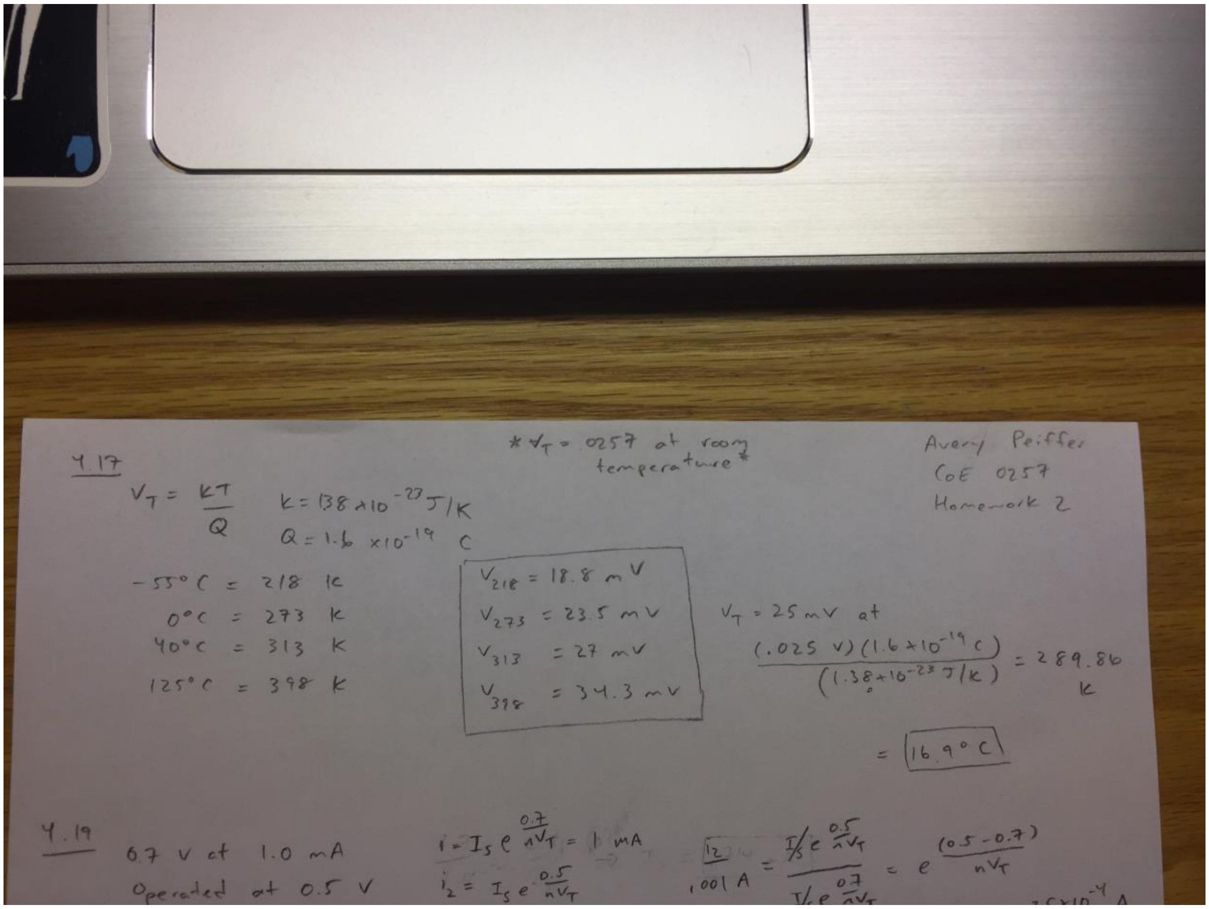
Place all your simulation project files in a single zip file and also upload that file to Courseweb

Sedra & Smith 4.17



4.17

* $V_T = .0257$ at room temperature *

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$V_T = \frac{KT}{Q}$ $K = 1.38 \times 10^{-23}\ J/K$

$Q = 1.6 \times 10^{-19}\ C$

$-55°C = 218\ K$

$0°C = 273\ K$

$40°C = 313\ K$

$125°C = 398\ K$

$$\boxed{\begin{aligned} V_{218} &= 18.8\ mV \\ V_{273} &= 23.5\ mV \\ V_{313} &= 27\ mV \\ V_{398} &= 34.3\ mV \end{aligned}}$$

$V_T = 25\ mV$ at

$$\frac{(.025\ V)(1.6 \times 10^{-19}\ C)}{(1.38 \times 10^{-23}\ J/K)} = 289.86\ K$$

$$= \boxed{16.9°C}$$

4.19

0.7 V at 1.0 mA

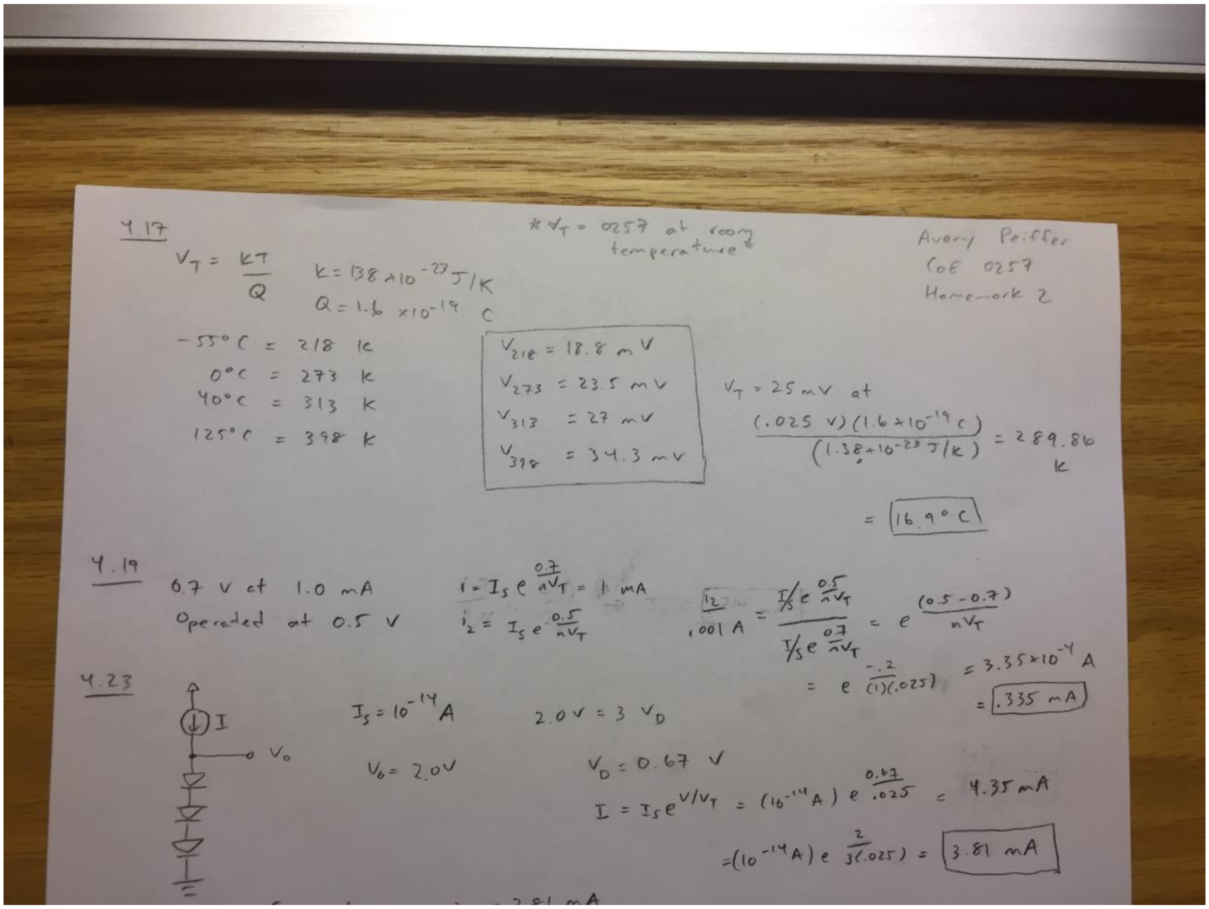
Operated at 0.5 V

$i = I_S e^{\frac{0.7}{nV_T}} = 1\ mA$

$i_2 = I_S e^{\frac{0.5}{nV_T}}$

$$\frac{i_2}{.001\ A} = \frac{\cancel{I_S} e^{\frac{0.5}{nV_T}}}{\cancel{I_S} e^{\frac{0.7}{nV_T}}} = e^{\frac{(0.5-0.7)}{nV_T}}$$

Sedra & Smith 4.19



4.17

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$$\frac{i_2}{.001\ A} = \frac{I_S e^{\frac{0.5}{nV_T}}}{I_S e^{\frac{0.7}{nV_T}}} = e^{\frac{(0.5-0.7)}{nV_T}}$$

$$= e^{\frac{-.2}{(1)(.025)}} = 3.35 \times 10^{-4}\ A$$

$= \boxed{.335\ mA}$

4.23

I
V_o

$I_S = 10^{-14}\ A$
$V_o = 2.0V$

$2.0V = 3\ V_D$
$V_D = 0.67\ V$

$I = I_S e^{V/V_T} = (10^{-14}\ A)\ e^{\frac{0.67}{.025}} = 4.35\ mA$

$= (10^{-14}\ A)\ e^{\frac{2}{3(.025)}} = \boxed{3.81\ mA}$

Sedra & Smith 4.23

$V_{398} = 34.3\ mV$

$(1.38 \times 10^{-23}\ J/K) = 289.8\ K$

$= \boxed{16.9°C}$

4.19

0.7 V at 1.0 mA

Operated at 0.5 V

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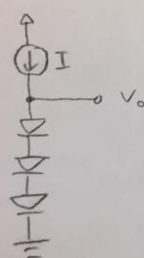
4.23



$I_s = 10^{-14} A$

$V_o = 2.0V$

$2.0V = 3V_D$

$V_D = 0.67\ V$

$I = I_s e^{V/V_T} = (10^{-14} A)\, e^{\frac{0.67}{.025}} = 4.35\ mA$

$= (10^{-14} A)\, e^{\frac{2}{3(.025)}} = \boxed{3.81\ mA}$

Current remaining = 2.81 mA

$\frac{2.81}{3.81} = e^{\frac{\Delta V_o/3}{.025}} \longrightarrow \boxed{\Delta V_o = -22.8\ mV}$

$.738 = e^{\frac{\Delta V_o}{.075}}$

4.24

I = 1 mA

at 20°C, V = −690 mV

−20°C, 85°C

$V_{T_{20}} = .0253\ V$

$V_{T_{-20}} = .0218\ V$

$I = I_s e^{V/V_T}$

$.001\ A = I_s e^{.690/.0253}$

Sedra & Smith 4.29

$$\frac{2.81}{3.81} = e^{\frac{\Delta V_o/3}{.025}} \rightarrow \boxed{\Delta V_o = -22.8\ mV}$$

$$.738 = e^{\frac{\Delta V_o}{.075}}$$

4.29

$I = 1\ mA$

at $20°C$, $V = -690\ mV$

$-20°C$, $85°C$

$V_{T_{20}} = .0253\ v$

$V_{T_{-20}} = .0218\ v$

$V_{T_{85}} = .0309\ V$

$I = I_s e^{V/V_T}$

$.001\ A = I_s e^{.690/.0253}$

$I_s = 1.43 \times 10^{-15}\ A$

V_{-20}: $.001\ A = (1.43 \times 10^{-15}\ A) e^{V/.0218}$

$$\boxed{V = 595\ mV}$$

V_{85}: $.001\ A = (1.43 \times 10^{-15}\ A) e^{V/.0309}$

$$\boxed{V = 843\ mV}$$

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$I_S = 10^{-15}\text{A} = 10^{-12}$ mA

Calculate some points

$v = 0.6\ V, \qquad i = I_S e^{v/V_T}$

$= 10^{-12} e^{0.6/0.025}$

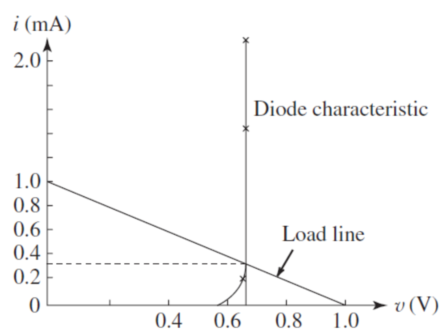
$\simeq 0.03$ mA

$v = 0.65$ V, $\qquad i \simeq 0.2$ mA

$v = 0.7$ V, $\qquad i \simeq 1.45$ mA

Make a sketch showing these points and load line and determine the operating point. The points for the load line are obtained using

$$I_D = \frac{V_{DD} - V_D}{R}$$



From this sketch one can see that the operating point must lie between $v = 0.65$ V to $v = 0.7$ V

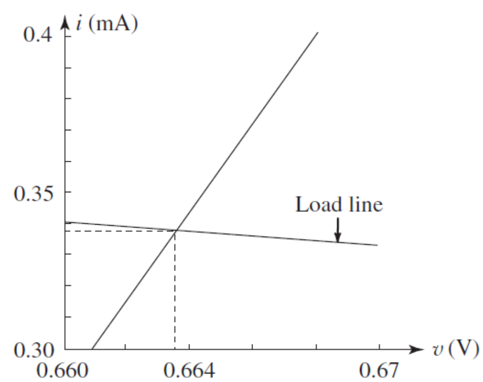
For $i = 0.3$ mA, $v = V_T \ln\left(\frac{i}{I_S}\right)$

$= 0.025 \times \ln\left(\frac{3}{10^{-12}}\right)$

$= 0.661$ V

For $i = 0.4$ mA, $v = 0.668$ V

Now we can refine the diagram to obtain a better estimate



From this graph we get the operating point

$i = 0.338$ mA, $v = 0.6635$ V

Now we compare graphical results with the exponential model.

At $i = 0.338$ mA

$v = V_T \ln\left(\frac{i}{I_S}\right) = 0.025 \times \ln\left(\frac{0.338}{10^{-12}}\right)$

$= 0.6637$ V

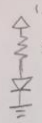
The difference between the exponential model and graphical results is $= 0.6637 - 0.6635$

$= 0.0002$ V

$= 0.2$ mV

Sedra & Smith 4.36

4.36



(a) Constant voltage drop model

$$i_D = \frac{1.0\text{ V} - 0.7\text{ V}}{500\ \Omega} = .6\text{ mA}$$

(b) Iterative Analysis

Initial Guess for V_D : 0.7 V → .6 mA

$V_2 - V_1 = 2.3\, V_T \log\left(\frac{I_2}{I_1}\right)$

$I_1 = 1$ mA , $V_1 = 0.7$ V

$I_2 = .6$ mA

$V_2 = 0.7\text{ V} + 0.060\text{ V}\left(\log_{10}\left(\frac{.6}{1}\right)\right)$

$V_2 = .687$ V

$$I_D = \frac{1 - .687}{500\ \Omega} = .63\text{ mA}$$

$I_1 = .6$ mA , $V_1 = .687$ V

$I_2 = .63$ mA

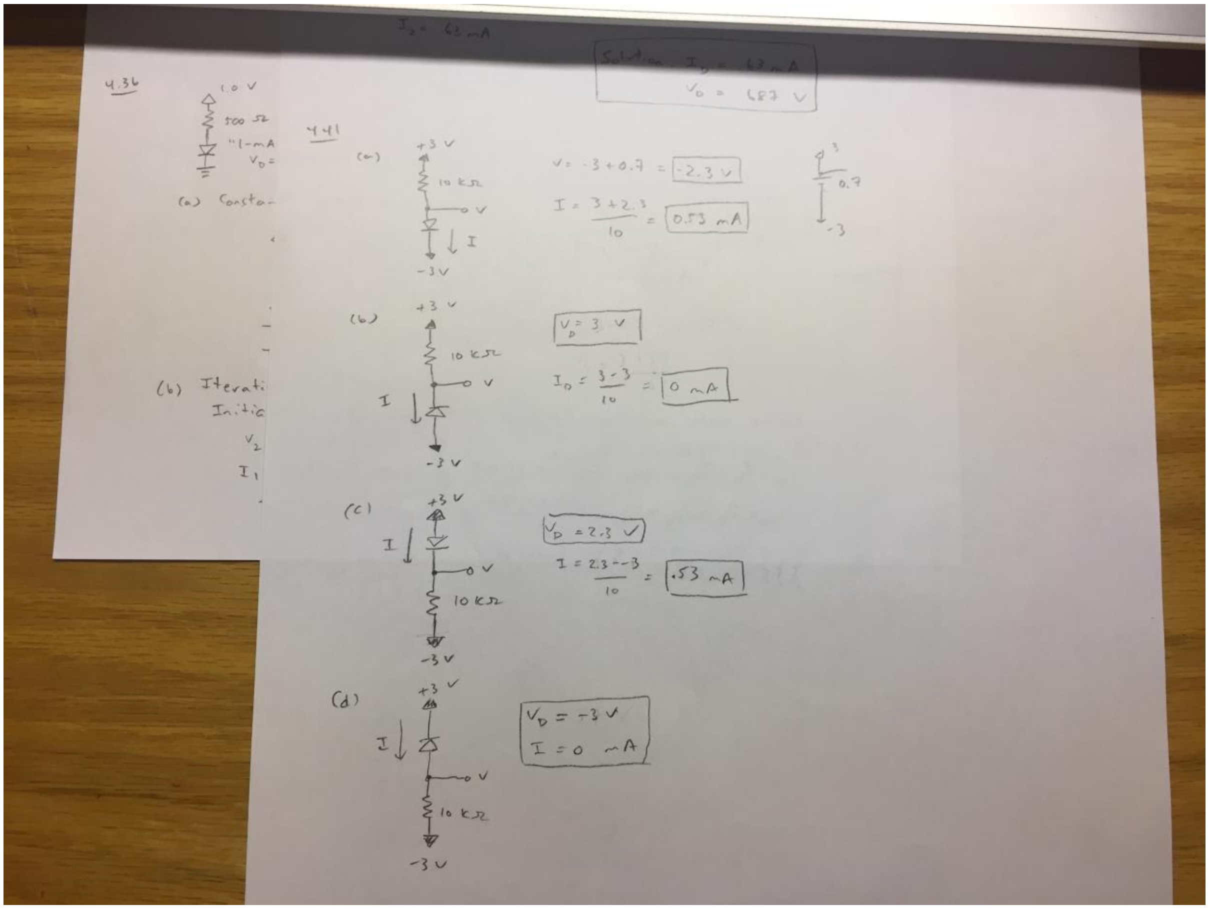
$V_2 = .687\text{ V} + 60\text{ mV}\left(\log\left(\frac{.63}{.6}\right)\right)$

$V_2 = .687$ V

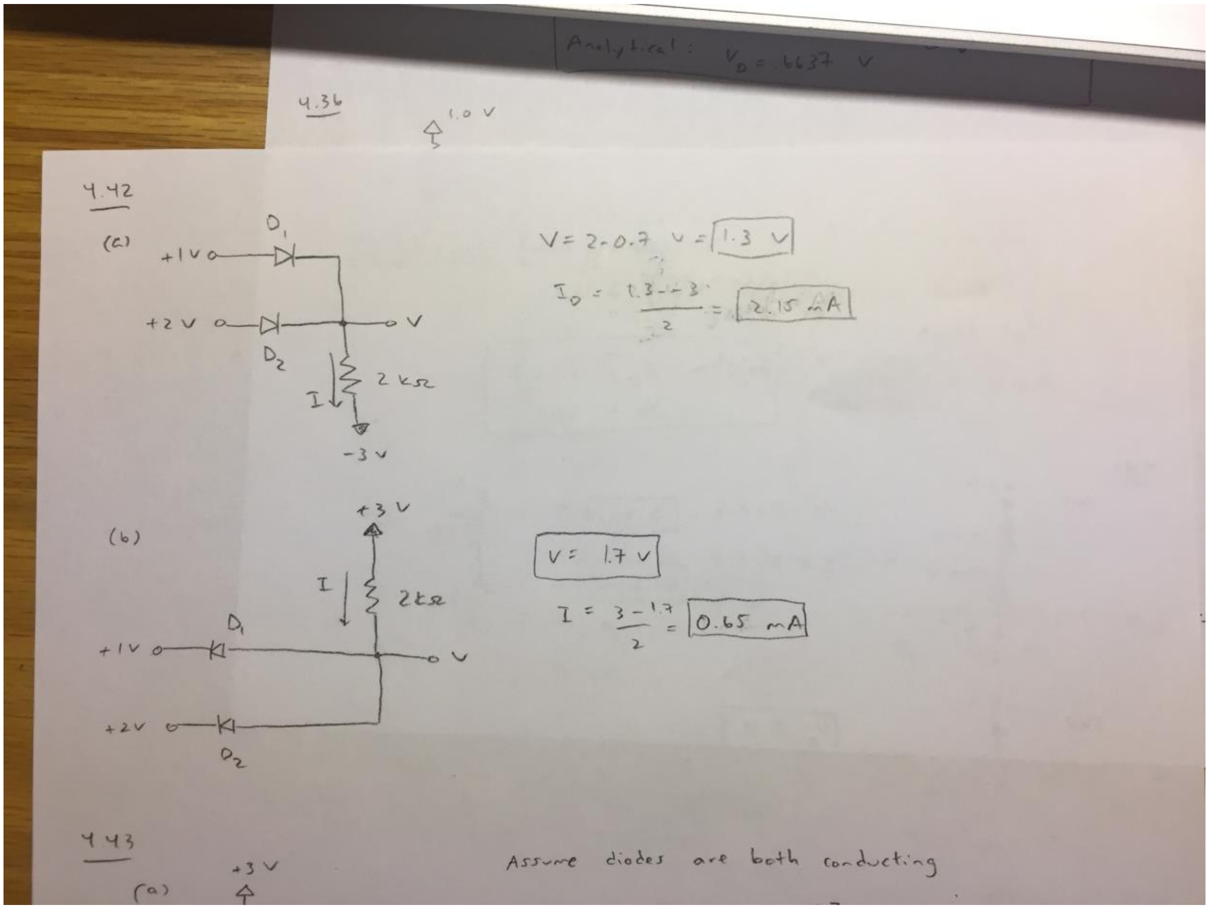
Solution : $I_D = .63$ mA

$V_D = .687$ V

Sedra & Smith 4.41



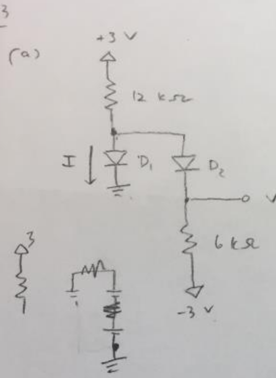
Sedra & Smith 4.42



Sedra & Smith 4.43

4.43

(a)



Assume diodes are both conducting

$i_{12} = I_{D_1} + I_{D_2}$ $\quad i_{12} = \frac{3-0.7}{12} = 0.25 \text{ mA}$

$i_{12} = I_{D_1} + I_{D_2} = I_{D_1} + \frac{(-0.7 - -3)}{6} = .38 \text{ mA}$

$I_{D_1} = -0.13 \text{ mA} \rightarrow$ Invalid

Assume D_2 conducts, D_1 doesn't

$3 - I_{D_2}(12 \text{ k}\Omega) - .7 \text{ V} - I_{D_2}(6 \text{ k}\Omega) = -3$

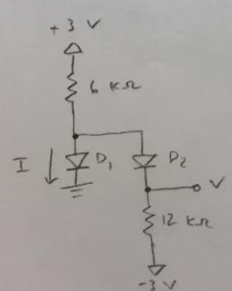
$5.3 \text{ V} = (18 \text{ k}\Omega) I_{D_2}$

$I_{D_2} = .294 \text{ mA}$

$V = 3 - (.294)(12) - .7 = \boxed{-1.228 \text{ V}}$

$\boxed{I_{D_1} = 0 \text{ mA}}$

(b)



Assume diodes are both conducting

$i_6 = I_{D_1} + I_{D_2}$ $\quad i_6 = \frac{3-0.7}{6} = .38 \text{ mA}$

$.38 \text{ mA} = I_{D_1} + 0.25 \text{ mA}$ $\quad 0.7 - 0.7 - (12 \text{ k}\Omega) I_{D_2} = -3$

$I_{D_2} = 0.25 \text{ mA}$

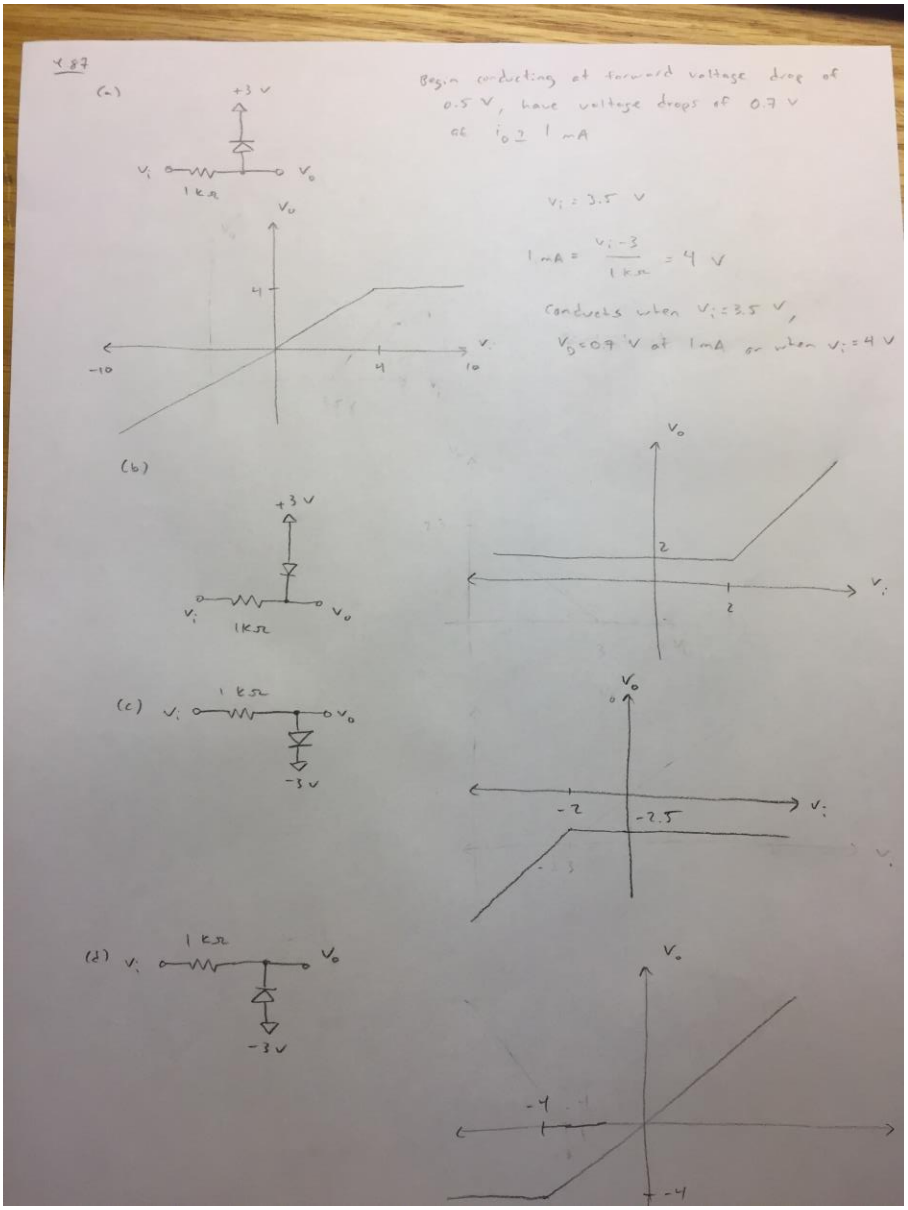
$\boxed{I_{D_1} = I = 0.13 \text{ mA}}$

$\boxed{V = 0 \text{ V}}$

Sedra & Smith 4.62

N/A due to snow

Sedra & Smith 4.87

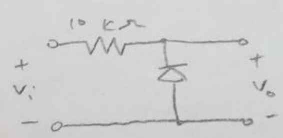


Sedra & Smith 4.92

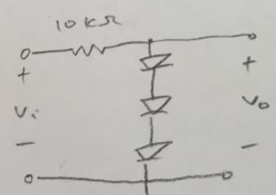
4.92

Diodes, 10 kΩ resistors

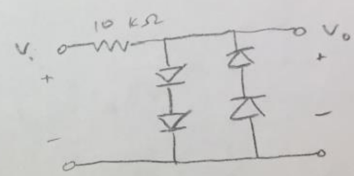
(a) −0.7 V and above



(b) +2.1 V and below



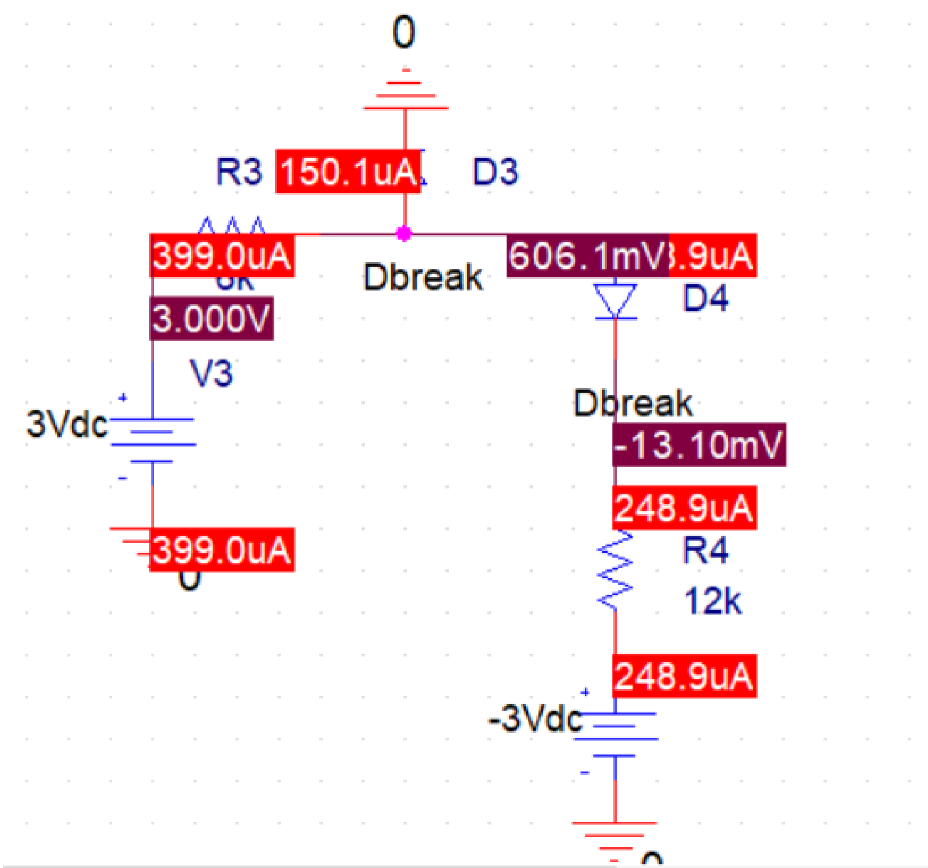
(c) ± 1.4 V



SIMULATION OF PROBLEM 4.43 Part (b)

I = 0.13 mA

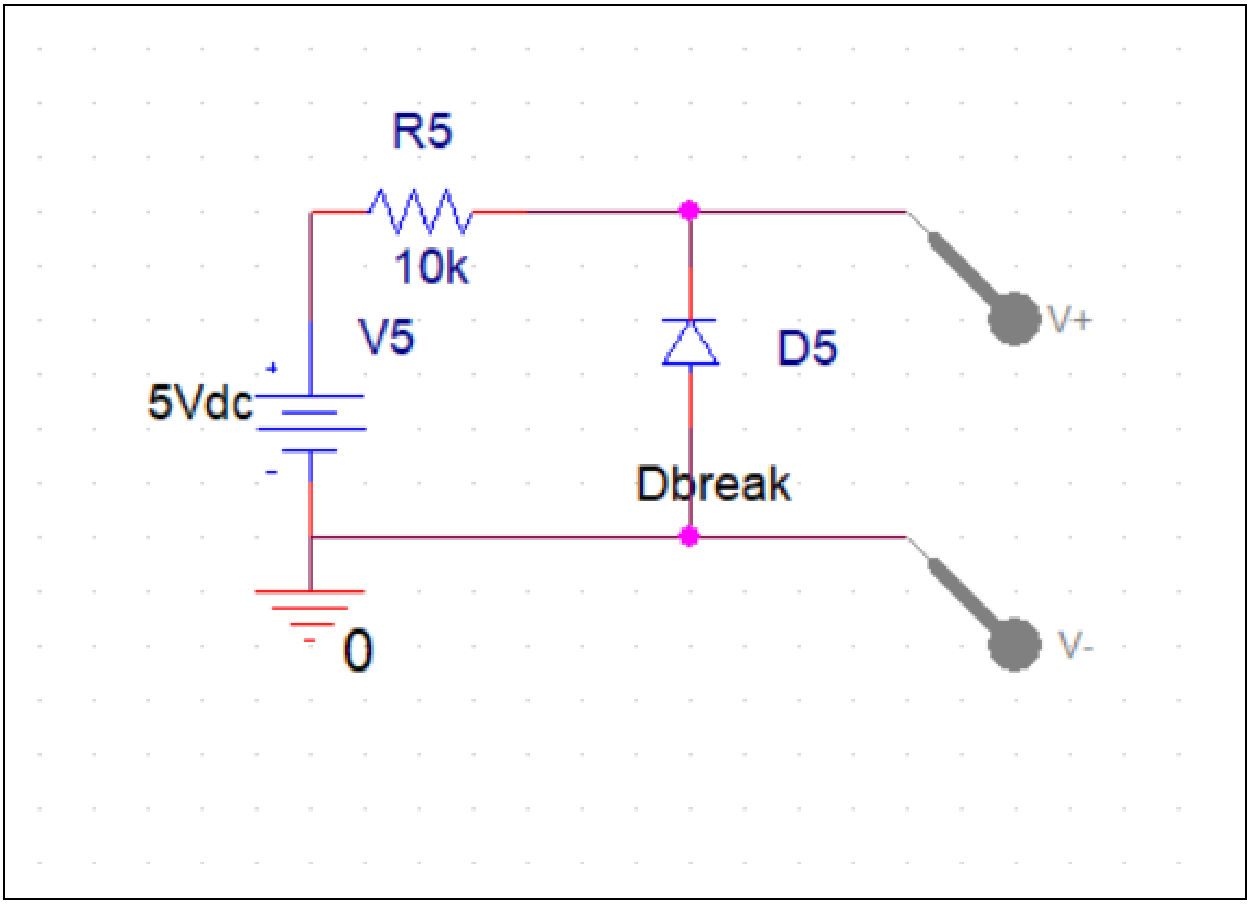
V = 0 V



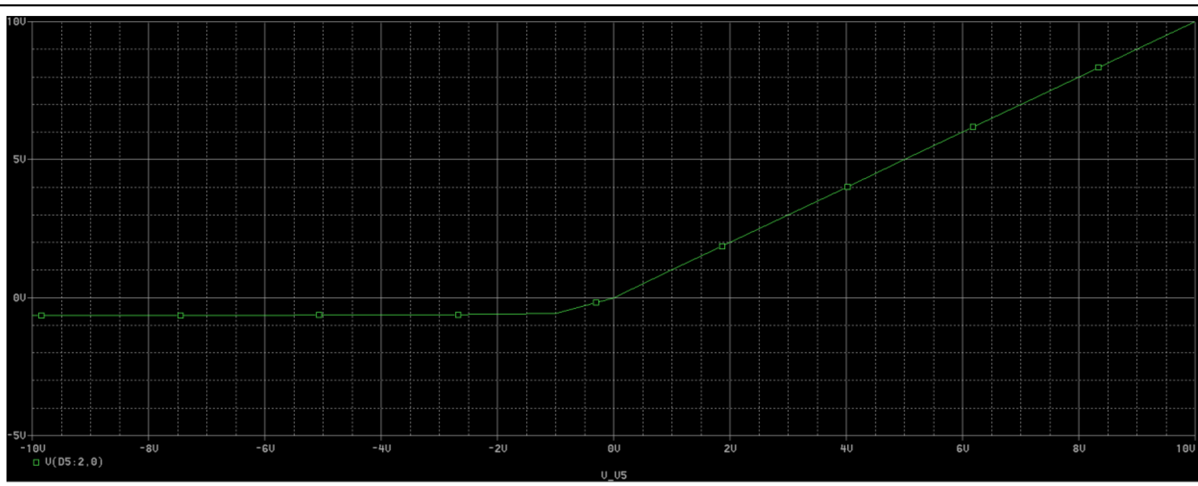
SIMULATION OF PROBLEM 4.43 Part (c)

There were differences between my calculated results and the simulated results. However, these small differences are likely due to using the constant voltage-drop model in my calculations. I felt that the differences were negligible enough that the answers can be considered the same.

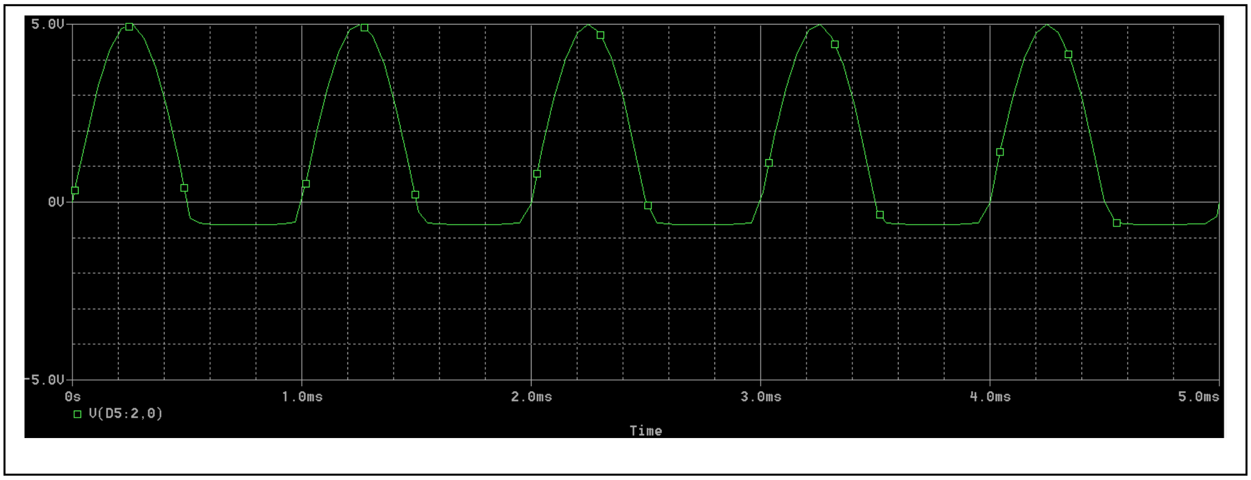
SIMULATION OF PROBLEM 4.92 Part (a)



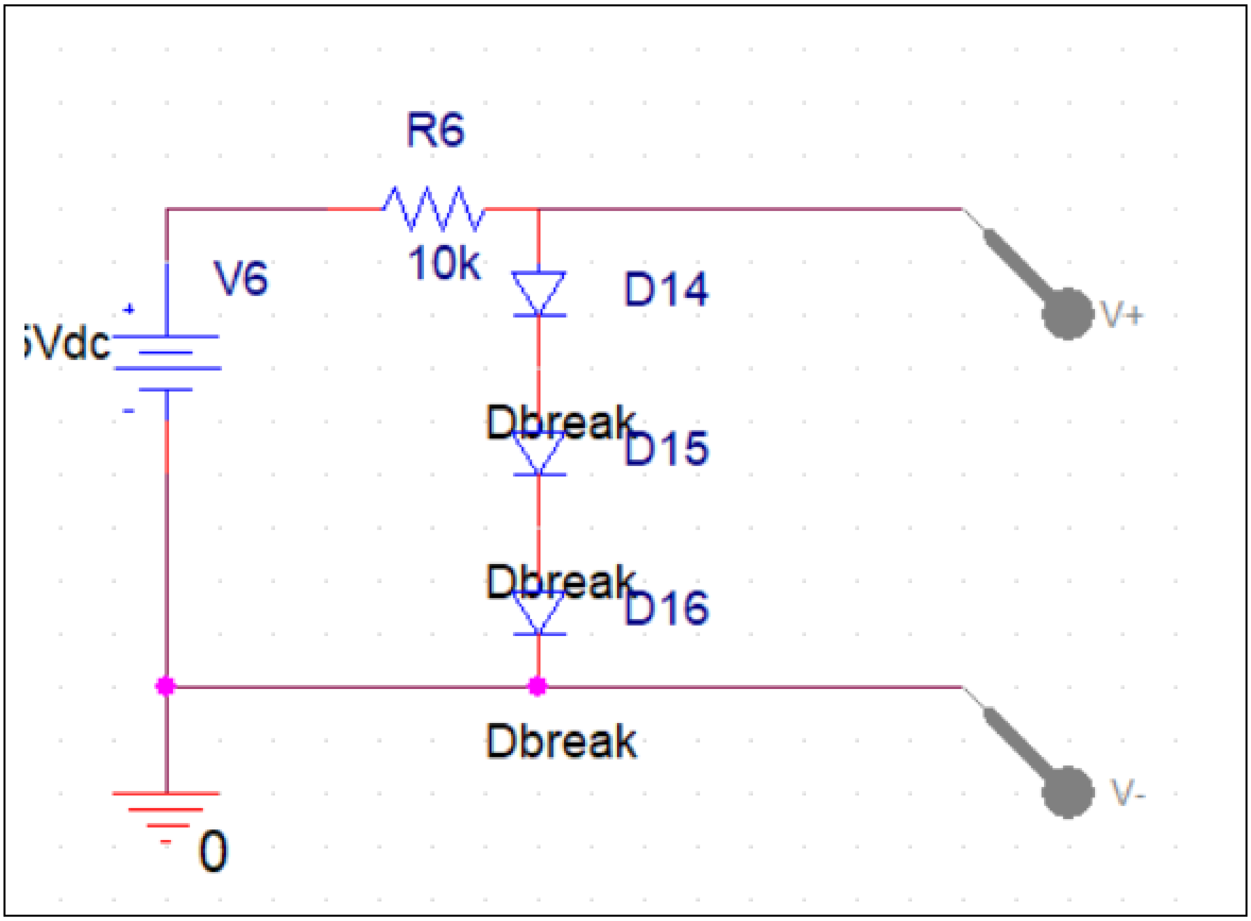
SIMULATION OF PROBLEM 4.92 Part (b)



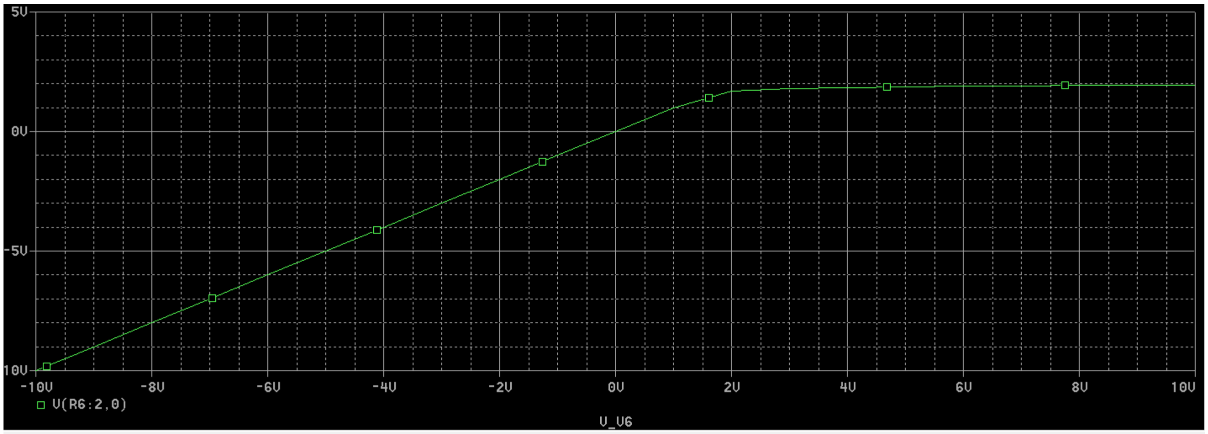
SIMULATION OF PROBLEM 4.92 Part (c)



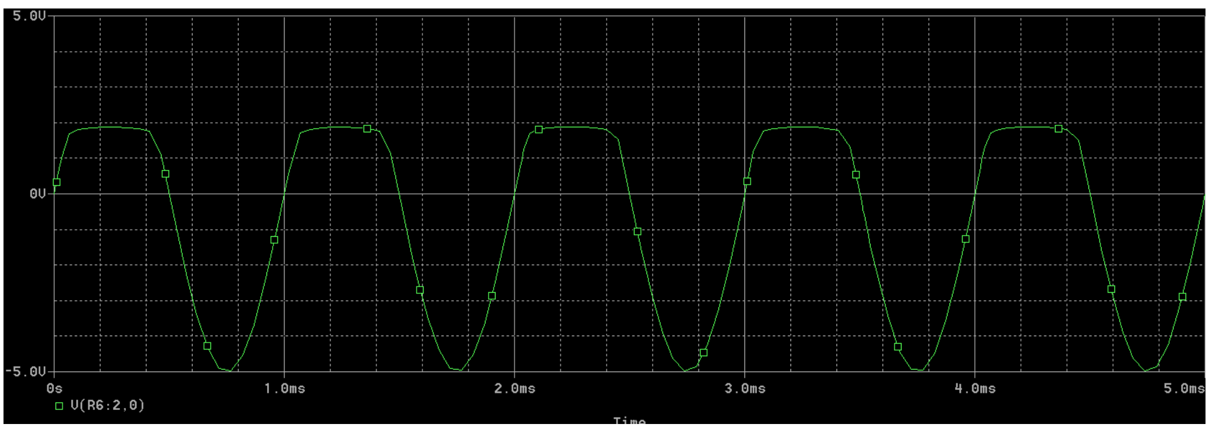
SIMULATION OF PROBLEM 4.92 Part (d)



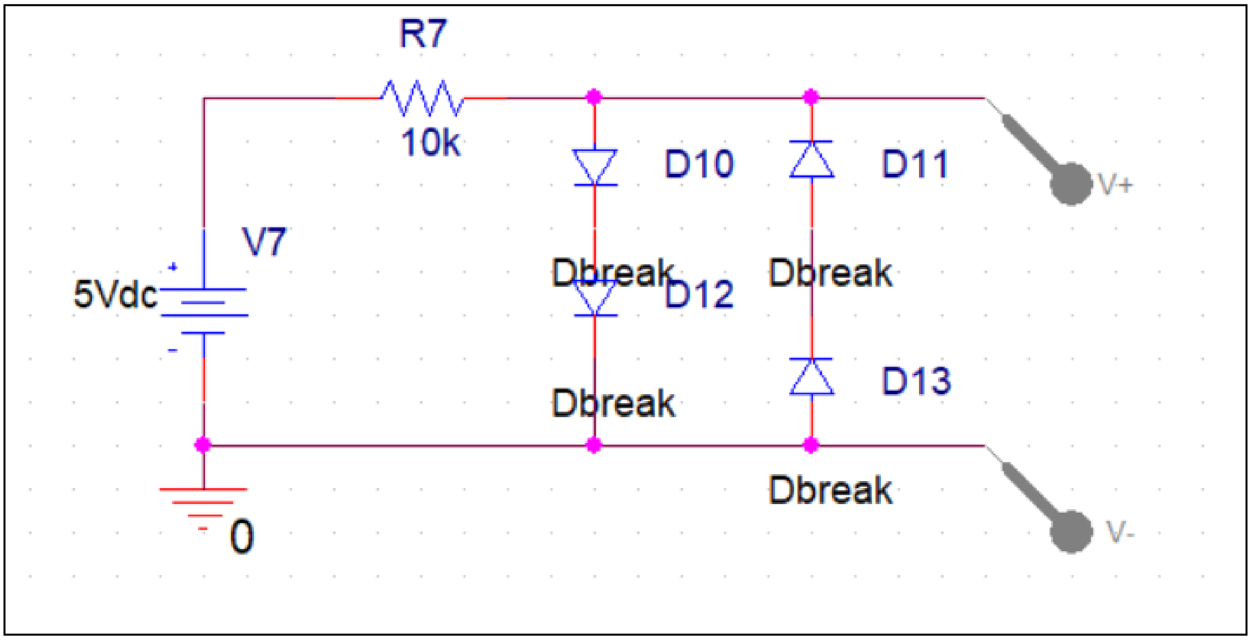
SIMULATION OF PROBLEM 4.92 Part (e)



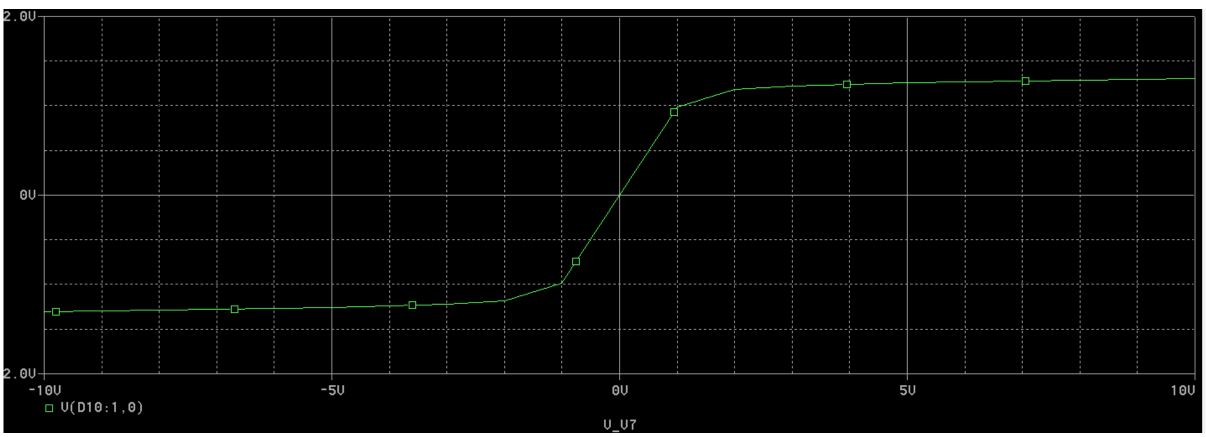
SIMULATION OF PROBLEM 4.92 Part (f)



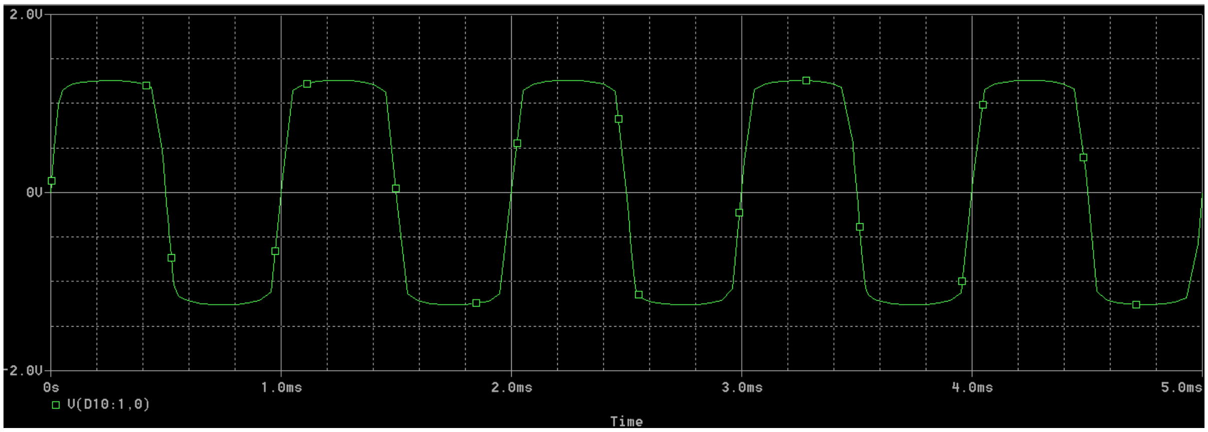
SIMULATION OF PROBLEM 4.92 Part (g)



SIMULATION OF PROBLEM 4.92 Part (h)



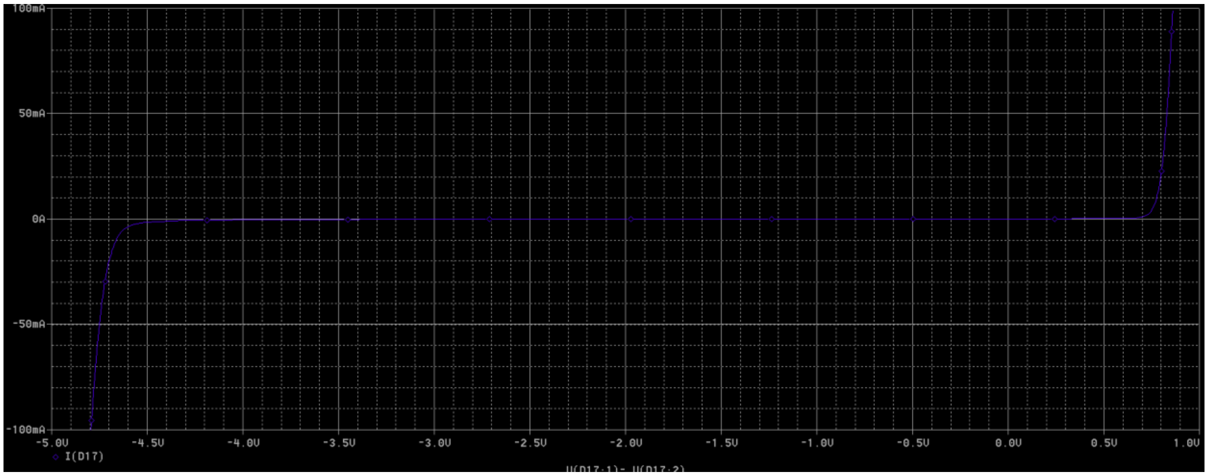
SIMULATION OF PROBLEM 4.92 Part (i)



SIMULATION OF PROBLEM 4.92 Part (j)

There were small differences between my calculated results and the simulated results. I think the primary difference is due to the simulator working on a discrete scale, meaning it can not generate purely smooth curves. Additionally, using the constant voltage drop model to work with the diodes will slightly affect the answers obtained from calculations.

SIMULATION Zener Diode Part (a) – IV Characteristic curve



SIMULATION Zener Diode Part (a) - Measurements

I_s = 220 nA

V_{zk} = -4.60 V

V_z = -4.74 V

SIMULATION Zener Diode Part (b)

From the data sheet, the Zener voltage value is 4.7 V, which agrees with the measurement I made.

SIMULATION Zener Diode Part (d)

As the current went from -20 mA to -200 mA, the voltage went from about -4.70 V to -4.85 V. The voltage difference was .15 V for a percent change of 3%.

SIMULATION Zener Diode Part (e)

This behavior is useful in circuits where the current can fluctuate but it is necessary to keep the voltage within a specified range of values. Because very large changes in current are accompanied by very small changes in voltage, the zener diode serves excellently as a voltage regulator.