VE311 Electronic Circuit Homework 2

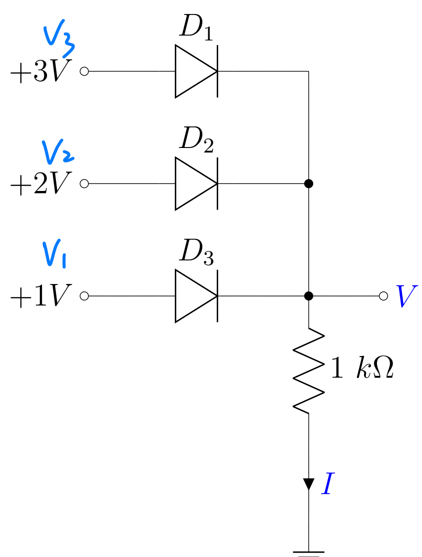
Due: **June 4th**

Note:

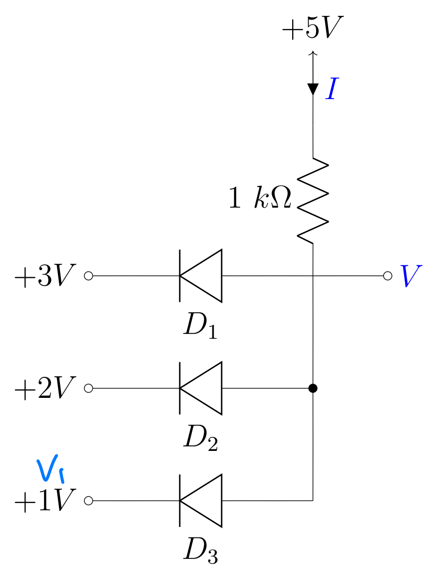
1) *Please use A4 size paper or page.*
2) *Please clearly state out your final result for each question.*
3) *Please attach the screenshot of Pspice simulation result if necessary.*

Question 1. Diode Circuit Exercise 1 (ideal model)

Find the values of I and V in the circuits shown below.



(A)



(B)

① If $V < 3V$,

then $V = V_3 = 3V$

which is impossible

② If $V > 3V$

then no current

which is also impossible

$\Rightarrow V = 3V$

$I = 3\ mA$

① If $V > 1V$,

then $V = V_1 = 1V$.

which is impossible

② If $V < 1V$,

then there is no current

which is also impossible

$\Rightarrow V = 1V$

$I = 4\ mA$

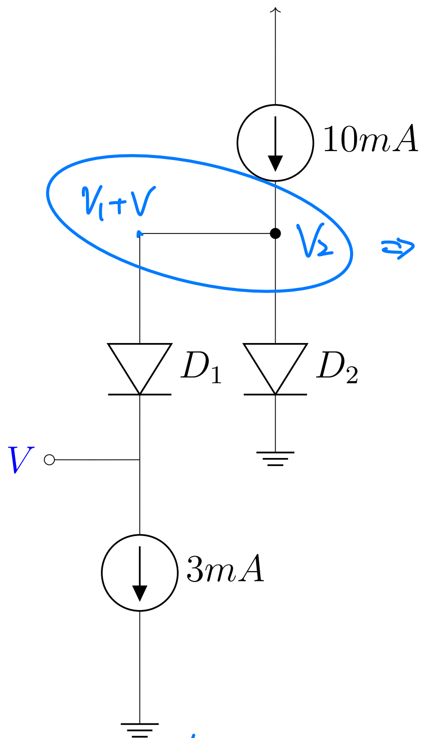
Question 2. Diode Circuit Exercise 2 (exponential model)

In the following problem, D_1 has 10 times the junction area of D_2. What value of V results? To obtain a value for V of 60mV, what current I_2 is needed.

$$\Downarrow \quad \frac{I_{S_1}}{I_{S_2}} = 10$$

$$I_{D_1} = I_{S_1} \cdot \left(e^{\frac{qV_1}{kT}} - 1\right)$$

$$I_{D_2} = I_{S_2} \cdot \left(e^{\frac{qV_2}{kT}} - 1\right)$$



$$\Rightarrow V_1 + V = V_2$$

$$\Rightarrow \frac{I_{D_1}}{I_{D_2}} = 10 \, \frac{e^{\frac{qV_1}{kT}} - 1}{e^{\frac{qV_2}{kT}} - 1}$$

$$\approx 10\, e^{\frac{q}{kT}(V_1 - V_2)}$$

① here $I_{D_1} = 3mA$

and $I_{D_2} = 7mA$

$$\Rightarrow \frac{3}{7} = 10\, e^{(V_1 - V_2)/0.026}$$

$$\Rightarrow \frac{3}{70} = e^{-V/0.026} \quad \Rightarrow V = 81.8 \text{ mV}$$

② If we want $V = 60mV$

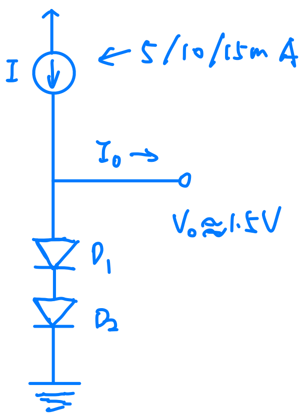
then $\frac{I_{D_2}}{10 - I_{D_2}} = \frac{1}{10}\, e^{60 \times 10^{-3}/0.026} \quad \left(= \frac{I_{D_2}}{I_{D_1}}\right)$

$$\Rightarrow I_{D_2} = 5.013 \text{ mA}$$

$$\Rightarrow I_{D_1} = 10 - I_{D_2} = 4.987 \text{ mA}$$

Question 3. Voltage Regulator

A voltage regulator consisting of two diodes in series fed with a constant-current source is used as a replacement for a single carbon-zinc cell (battery) of nominal voltage 1.5 V. The regulator load current varies from 2 mA to 7 mA. Constant-current supplies of 5 mA, 10 mA, and 15 mA are available. Which would you choose, and why? What change in output voltage would result when the load current varies over its full range?



since I_o varies from 2mA to 7mA $\Rightarrow I > 7mA \Rightarrow I = 10mA / 15mA$

① $I_o = 2mA$: $\quad I_S \cdot e^{\frac{qV_1}{2kT}} = I - 2\times10^{-3}$

② $I_2 = 7mA$: $\quad I_S \cdot e^{\frac{qV_2}{2kT}} = I - 7\times10^{-3}$

$$\Rightarrow e^{\frac{q}{2kT}(V_1 - V_2)} = \frac{I - 2\times10^{-3}}{I - 7\times10^{-3}}$$

$$\Rightarrow V_1 - V_2 = \frac{2kT}{q} \ln\left(\frac{I - 2\times10^{-3}}{I - 7\times10^{-3}}\right)$$

when $I = 10mA$, $V_1 - V_2 = 0.05\,V$

when $I = 15mA$, $V_1 - V_2 = 0.025\,V$

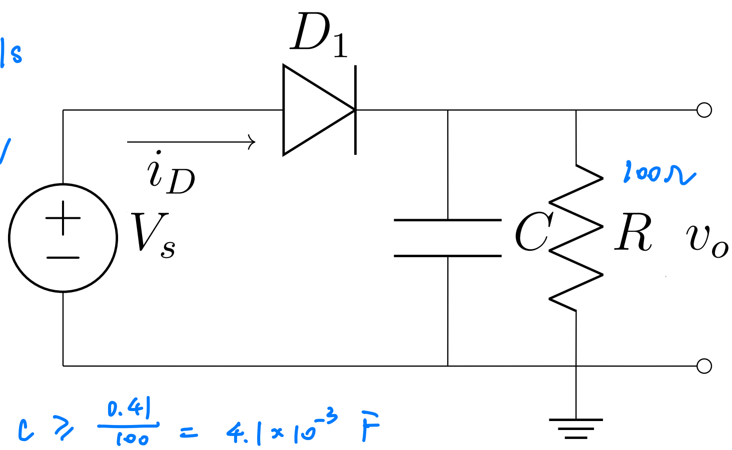
$\Rightarrow$ choose $I = 10mA$ to minimize $\frac{\partial V}{\partial I}$ since we want to obtain a battery of nominal voltage 1.5V

Question 4. Half-Wave Rectifier

Design a half-wave rectifier circuit, such as below, which can convert a sinusoidal voltage input, $V_s = 5\sin(2\pi 100\cdot \text{ time})$, to an almost constant voltage output.

1) Assuming $V_{on} = 0.9$ V and R = 100Ω, calculate C which makes the ripple voltage (V_r) is smaller than 0.1 V. Estimate V_{dc}, I_{dc}, θ_c, ΔT, I_{peak} , I_{surge} and PIV of the designed half-wave rectifier.
2) Plot V_s and V_{out} versus time on the sample graph.

1) $T = \frac{2\pi}{2\pi\cdot 100} = 0.01s$



$V_s - V_{on} = 5V - 0.9V$

$= 4.1\ V$

$\Rightarrow V_r = 4.1 \cdot \frac{0.01}{100\cdot C}$

when $V_r \leq 0.1 \Rightarrow$ $C \geq \frac{0.41}{100} = 4.1\times 10^{-3}\ F$

$V_{dc} = V_s - V_{on} = 4.1\ V$

$I_{dc} = \frac{4.1V}{100\ \Omega} = 0.041\ A$

$\theta_c = \sqrt{\frac{2V_r}{V_s}} = \sqrt{\frac{0.2}{5}} = 0.2$

$\Delta T = \frac{0.2}{2\pi\cdot 100} = \frac{10^{-3}}{\pi}$

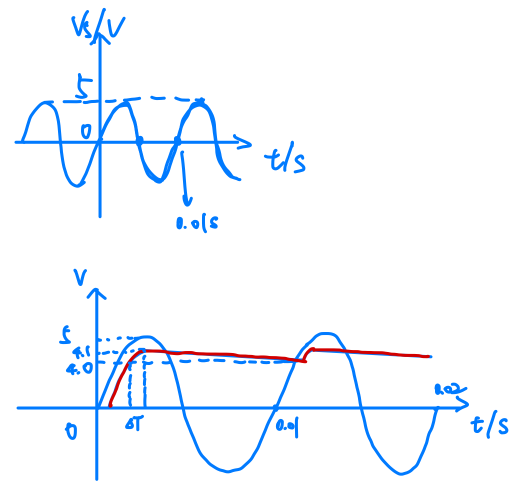
$I_{peak} = 2\frac{I_{dc}T}{\Delta T} = 2\cdot\frac{0.041\cdot 0.01}{\frac{10^{-3}}{\pi}} = 0.82\pi$

$I_{surge} = 2\pi\cdot 100\cdot 4.1\times 10^{-3}\cdot 5 = 4.1\pi$

$PIC = 2V_s - V_{on} = 9.1\ V$

2)

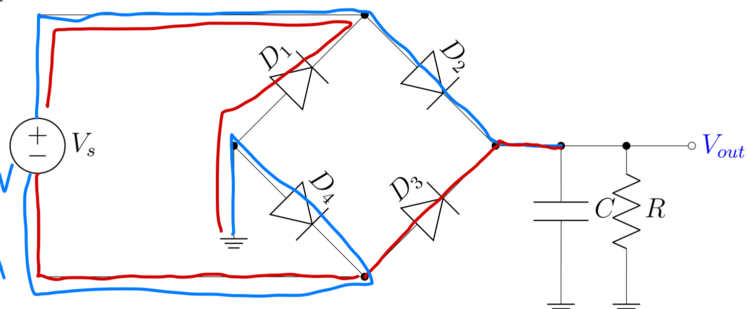
V_s :



Question 5. Full-Wave Bridge Rectifier

Design a full-wave bridge rectifier circuit, such as below, which can convert a sinusoidal voltage input, $V_s = 5\sin(2\pi 100\cdot \text{time})$, to an almost constant voltage output.

1) Assuming $V_{on} = 0.9$ V and R = 100Ω, calculate C which makes the ripple voltage (V_r) smaller than 0.1 V. Estimate $V_{dc}, I_{dc}, \theta_c, \Delta T, I_{peak}, I_{surge}$ and PIV of the designed full-wave bridge rectifier.
2) Plot V_s (using "voltage differential marker" function) and V_{out} versus time on the sample graph.



1)

$$T = \frac{2\pi}{2\pi\cdot 100} = 0.01s$$

$$V_{dc} = 5 - 0.9\times 2 = 3.2V$$

$$I_{dc} = \frac{3.2V}{100\Omega} = 0.032\,A$$

$$V_r = V_{dc}\cdot\frac{T}{2RC} = 3.2\cdot\frac{0.01}{200\cdot C}$$

if $V_r \le 0.1$, then $C \ge 1.6\times 10^{-3}F$

$$\theta_c = \sqrt{\frac{2V_r}{V_s}} = \sqrt{\frac{0.2}{5}} = 0.2$$

$$\Delta T = \frac{\theta_c}{w} = \frac{1}{200\pi}\cdot 0.2 = \frac{10^{-3}}{\pi}$$

$$I_{peak} = \frac{I_{dc}\,T}{\Delta T} = \frac{0.032\cdot 0.01\cdot\pi}{10^{-3}} = 1.005\,A$$

$$I_{surge} = wC\cdot V_s = 2\pi\cdot 100\cdot 1.6\times 10^{-3}\cdot 5 = 5.03\,\pi$$

$$PIV = V_s - V_{on} = 5 - 0.9 = 4.1\,V$$

2)

Vs :

Vs :