Solution & Grading

Ryerson University

Department of Electrical and Computer Engineering

ELE404 (Electronic Circuits I)

Midterm Examination (W2014)

February 2014

Duration: 100 minutes

Examiner: Prof. A. Yazdani

Name:..

[Print Last Name] [Print First Name]

Student No:……………………….. Section:….

NOTES

1. This is a closed-book examination. No aids other than basic calculators are permitted.

2. The examination paper is comprised of **FIVE QUESTIONS**, *each* question is worth as indicated in the following Table. The entire examination is worth *100* marks.

Question #	Maximum Mark	Mark Earned
1	**30**	
2	**15**	
3	**20**	
4	**15**	
5	**20**	
Total	**100**	

3. Answer all questions in the booklet, within the blank spaces provided under each question in this booklet. Use the reverse if needed.

4. ***No Questions to be asked during the examination***. *If in doubt about any question, clearly state your assumptions in answering the question.*

5. Part marks for an answer will only be given if the *correct methodology* is clearly shown.

6. **DO NOT DETACH** any pages from this booklet.

Q1: In the diode circuit of **Fig. 1**, D_1 is a regular diode whose forward voltage drop is assumed to be $0.7\ V$, whereas D_2 is an LED that starts to glow when its forward voltage drop reaches about $2.2\ V$. Further, $R_1 = 1.0\ k\Omega$, $R_2 = 2.0\ k\Omega$, and $I_x = 4.0\ mA$. It is assumed that neither diode enters the breakdown region.

1a) If the voltage V_x is so negative that the LED is ~~dim~~ dark, determine the conduction state ("on" or "off") of D_1, and calculate the voltages V_3 and V_4. Summarize your findings in **Table 1a**.

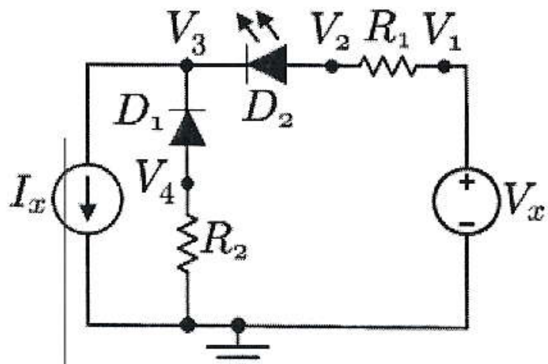


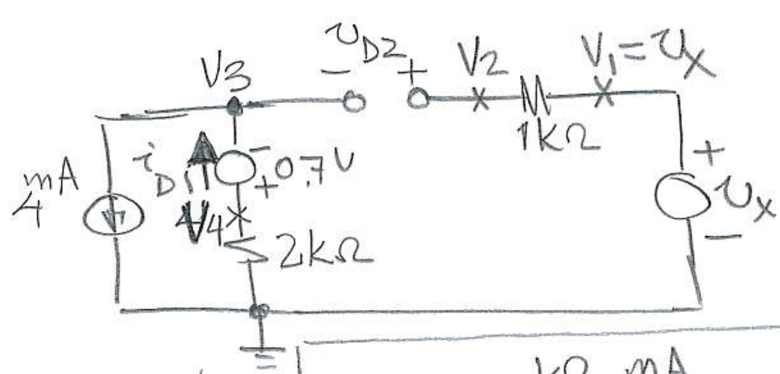
Fig. 1: Diode circuit of Q1.

Table 1a: Results of the diode circuit of Q1.

State of D_1	V_3 [V]	V_4 [V]
ON	−8.7	−8

Each item (5) marks

D2 : OFF ⇒ D1 : ON Since D1 is the only remaining path for the current I_x which is impressed.



$i_{D1} = I_x = 4\,mA$ ✓

$$\boxed{\begin{aligned} V_4 &= 0 - \overset{k\Omega}{2} \times \overset{mA}{4} = -8^{V} \\ V_3 &= V_4 - 0.7^{V} = -8 - 0.7 = -8.7^{V} \end{aligned}}$$

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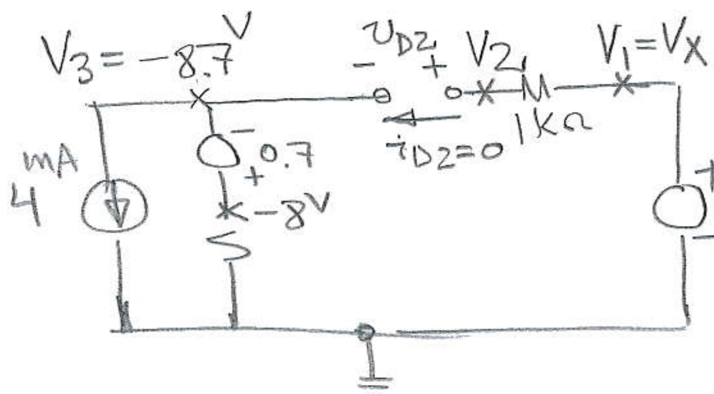
1b) Starting from a very negative voltage, as in Part (a), V_x is gradually raised until D_2 starts to glow. For this operating condition, calculate V_x, V_1, and V_2. Complete **Table 1b**.

Table 1b: voltage values corresponding to state transition of D_2 from "dim" to "glowing".

V_x [V]	V_1 [V]	V_2 [V]
−6.5	−6.5	−6.5

5 marks each

The same circuit applies here:



$$i_{D2} = 0 \Rightarrow V_2 = V_1 = V_X$$

$$v_{D2} = V_2 - V_3 = V_X - (-8.7)$$

The LED turns on when v_{D2} reaches 2.2^V

$$\Rightarrow \quad 2.2 = V_X + 8.7 \Rightarrow \boxed{V_X = -6.5^V}$$

$$\Rightarrow \boxed{V_1 = -6.5\ V}$$

$$\Rightarrow \boxed{V_2 = -6.5^V}$$

Q2: In the circuit of **Fig. 2**, $V_s = -9\ V$. If $V_O = -8\ V$ is at a temperature of 20 °C, what will V_O be the 40 Celsius? At 0 Celsius? At 80 Celsius? Explain why and/or show the calculations. Summarize your results in **Table 2.** [***Hint:*** the voltage drop across the resistor is proportional to the reverse current of the diode].

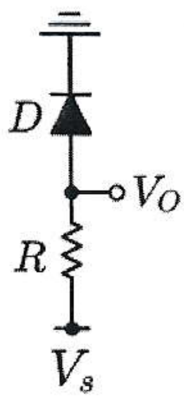
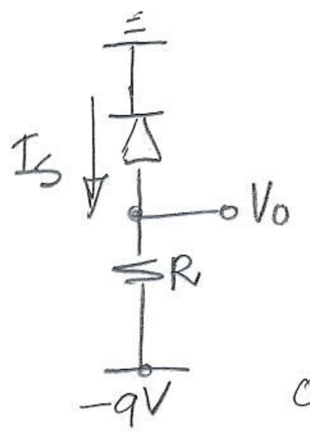


Fig. 2: Diode circuit of Q2.

Table 2: Results of the diode circuit of Q2.

T **[°C]**	**20**	**40**	**0**	**80**
$V_O[V]$	**−8**	−5	−8.75	0

5 marks each



The diode is reverse-biased. Therefore, its current, the reverse current, flows down and results in a proportional voltage drop across the resistor:

$$V_o - (-9) \propto I_s \Rightarrow V_o + 9 \propto I_s$$

On the other hand, I_s doubles for every 10°C temperature rise.

$$\theta = 40°C \Rightarrow \frac{V_o+9}{-8+9} = 2^{\left(\frac{40-20}{10}\right)} = 4 \Rightarrow \boxed{V_o = -5^V}$$

$$\theta = 0°C \Rightarrow \frac{V_o+9}{-8+9} = 2^{\left(\frac{0-20}{10}\right)} = \frac{1}{4} \Rightarrow \boxed{V_o = -8.75^V}$$

$$\theta = 80°C \Rightarrow \frac{V_o+9}{-8+9} = 2^{\left(\frac{80-20}{10}\right)} = 64 \Rightarrow V_o = 55^V \times \text{impossible}$$

Vo cannot exceed zero, as, otherwise, the diode starts to conduct and current would flow from the negative source to the ground, which is impossible $\Rightarrow \boxed{V_o \approx 0}$

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Q3: In the bridge rectifier of **Fig. 3**, the diodes are assumed to be ideal, and the source voltage v_I is a 60-Hz, 20-Vrms sinusoid. Determine the ***reading of a DC voltmeter*** of the output voltage v_O, under each of the following conditions:

(3a) Only the load R_L is connected (the smoothing capacitor C has been removed);
(3b) Only C is connected (R_L has been removed);
(3c) $R_L = 1.0\ k\Omega$ and $C = 150\ \mu F$; and
(3d) $R_L = 1.0\ k\Omega$ and $C = \infty$.

Support your answers by calculations and/or explanations. Complete **Table 3**.

Table 3: results of the circuit of Q3.

Answer to (3a)	Answer to (3b)	Answer to (3c)	Answer to (3d)
18	28.3	27.5	28.3

(5) marks each

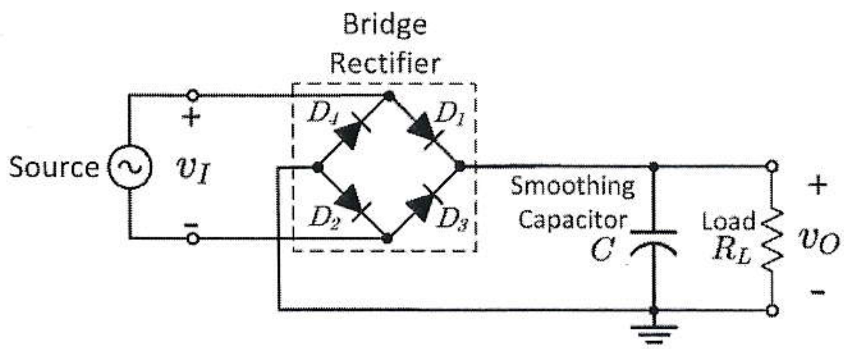
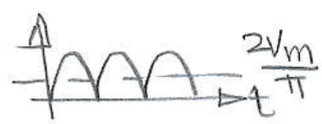


Fig. 3: Bridge rectifier of Q3.

3a)

Full-wave rectifier



$V_m = 20 \times \sqrt{2} = 28.3^V$

$$\boxed{\overline{V_O} = \frac{2V_m}{\pi} = \frac{2 \times 28.3}{\pi} = 18\ V}$$

3b)

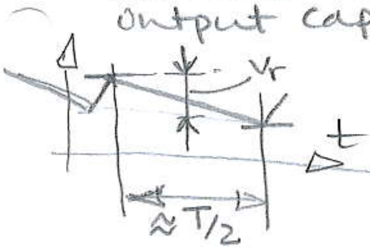
Peak Detector

$$\boxed{\overline{V_O} = V_m = 28.3^V}$$

3c)

Full-wave rectifier with output capacitor

$\left.\begin{matrix} V_m \\ V_m - V_r \end{matrix}\right\} \Rightarrow \overline{V_O} = V_m - \frac{1}{2}V_r$



$$V_r \approx \frac{I\Delta t}{C} = \frac{(V_m/R)T/2}{C} = \frac{(28.3/1000) \times 8.3 \times 10^{-3}}{150 \times 10^{-6}} = 1.56^V$$

$$\boxed{\overline{V_O} = V_m - \frac{1}{2}V_r = 28.3 - \frac{1}{2} \times 1.56 = 27.5\ V}$$

See also the back

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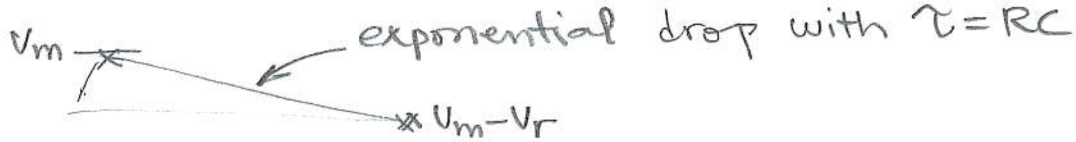
Alternative solution to (3c)



$$v_o(t) = v_o(\infty) + [v_o(0) - v_o(\infty)]e^{-t/\tau}$$

$$v_o(t) = 0 + [V_m - 0]\,e^{-t/\tau}$$

$$\tau = RC = 1000 \times 150 \times 10^{-6} = 0.15\text{ s}$$

$$t = T/2 = \frac{1}{2f} = \frac{1}{2 \times 60} = 8.3 \times 10^{-3}\text{ s}$$

$$v_o(t = T/2) = V_m - V_r$$

$$\Rightarrow V_m - V_r = V_m e^{-\frac{8.3\times10^{-3}}{0.15}} \Rightarrow V_r = \left[1 - e^{-\frac{8.3\times10^{-3}}{0.15}}\right] \times 28.3$$

$$\Rightarrow V_r = 1.5^V$$

$$\boxed{\bar{V}_o = V_m - \frac{1}{2}V_r = 28.3 - \frac{1}{2} \times 1.5 = 27.5\text{ V}}$$

3d)

Very large capacitor results in very small ripple, V_r. Therefore

$$\bar{V}_o \approx V_m \quad (\text{since } V_r \approx 0)$$

$$\Rightarrow \boxed{\bar{V}_o = 28.3^V}$$

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Q4: In the shunt voltage regulator of **Fig. 4**, $R_L = 1.0\ k\Omega$ and $R = 820\ \Omega$. According to the manufacturer, the Zener diode gives a voltage of $v_Z = V_{ZT} = 5.1\ V$ at a test current of $i_Z = I_{ZT} = 20\ mA$. Further, $r_Z = 10\ \Omega$ and $I_{ZK} = 1.5\ mA$.

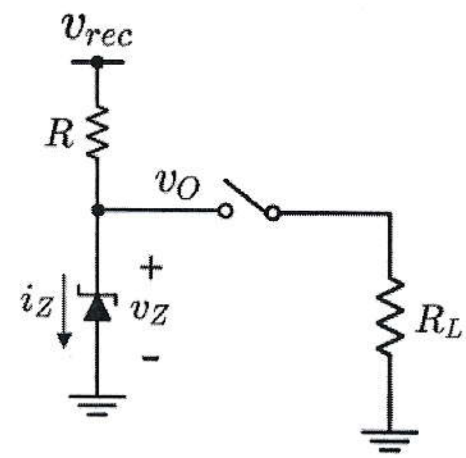
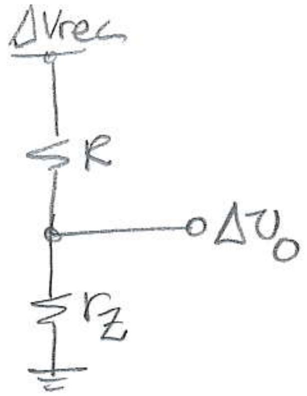


Fig. 4: Shunt regulator of Q4.

(4a) Assuming that the switch is open, determine the peak-to-peak ripple of the output voltage v_O if the unregulated voltage v_{rec} has a peak-to-peak ripple of 2.0 V. Show all the work.

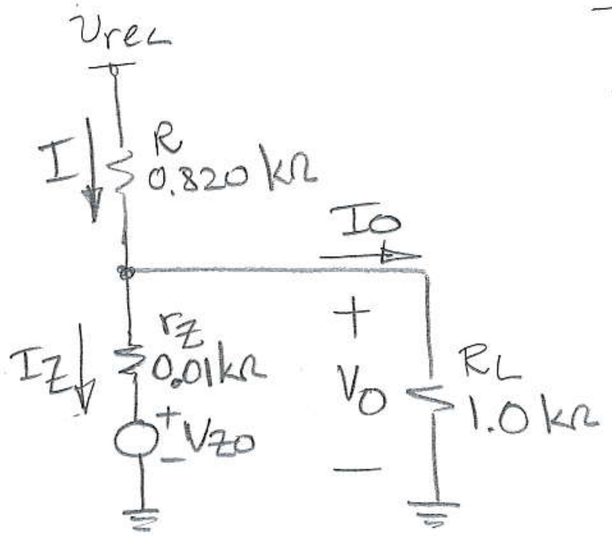


$$\Delta v_O = \frac{\Delta v_{rec}}{R + r_Z} \times r_Z$$

$$\Rightarrow \Delta v_O = \frac{2}{820 + 10} \times 10 = \boxed{0.024\ V \text{ or } 24\ mV}$$

5 marks

(4b) Assuming that the switch is closed, calculate the minimum permissible value of the unregulated voltage v_{rec}. Show all the work.



The minimum value of v_{rec} should be such that i_Z does not fall below I_{ZK}. The boundary condition, therefore, is when $i_Z = I_{ZK}$ while the load is also connected.

First calculate V_{ZO} using test data:

$$v_Z = V_{ZO} + r_Z i_Z$$

$$\underbrace{5.1 = V_{ZO} + 0.01 \times 20}_{\text{given}} \Rightarrow \underline{V_{ZO} = 4.9^V}$$

Then,

$$I_Z = I_{ZK} = 1.5^{mA} \Rightarrow V_Z = 4.9 + 0.01 \times 1.5 = 4.915^V$$

$$V_O = V_Z = 4.915^V \Rightarrow I_O = \frac{V_O}{R_L} = \frac{4.915}{1.0} = 4.915\,mA$$

$$I = I_O + I_Z = 4.915 + 1.5 = 6.415\,mA$$

$$v_{rec} = V_Z + RI = 4.915 + 0.820 \times 6.415 \cong 10.2^V$$

$$\boxed{v_{rec} = 10.2^V}$$ 10 marks

Q5: In the transistor circuit of **Fig. 5**, determine the mode of operation of the transistor and the node voltages, if $V_{CC} = 10\ V$, $R_1 = R_2 = 1.0\ k\Omega$, $R_C = 100\ \Omega$, and $R_E = 220\ \Omega$. Assume that $V_{BEon} = 0.7\ V$, $V_{CEsat} = 0.3\ V$, and $\beta = 100$.

Show all the work, and complete **Table 5**.

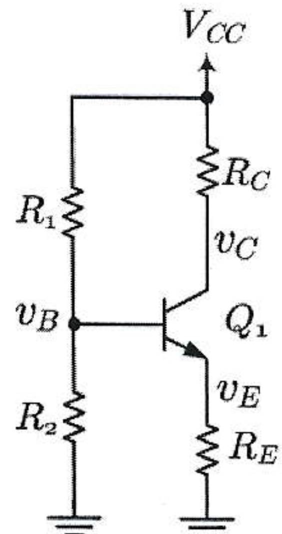


Fig. 5: Transistor circuit of Q5.

Table 5: transistor's mode of operation and the node voltages in the circuit of Q5.

Mode of Q1	$v_B[V]$	$v_C[V]$	$v_E[V]$
active	4.9	8.1	4.2

5 marks each

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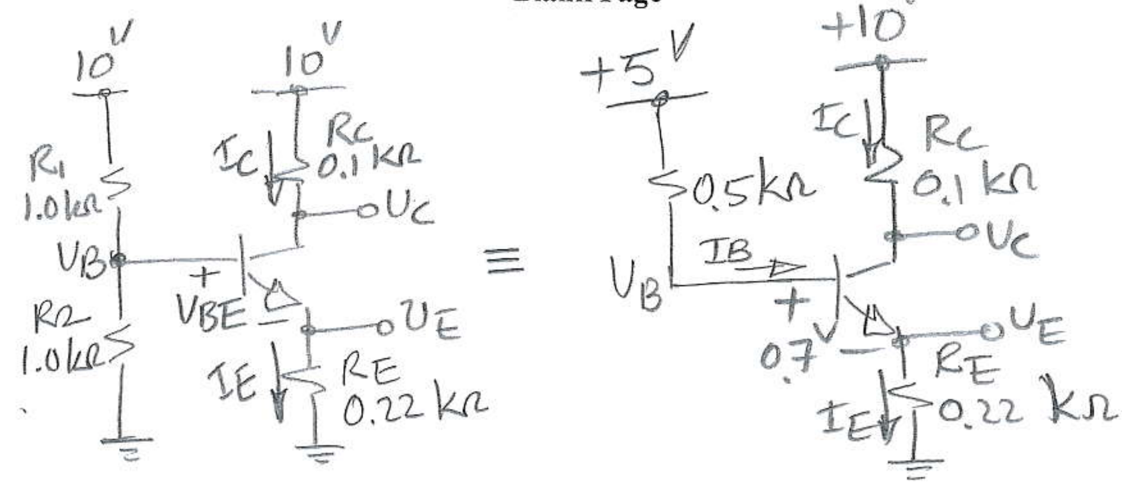

KVL: $5 - 0.5 I_B - 0.7 - 0.22 I_E = 0$

Assuming active mode: $I_B = \frac{1}{\beta} I_C$, $I_E = \frac{\beta+1}{\beta} I_C$

$$\Rightarrow 5 - \frac{0.5}{100} I_C - 0.7 - 0.22 \times \frac{101}{100} I_C = 0$$

$$\Rightarrow I_C = \frac{4.3 \times 100}{0.5 + 0.22 \times 101} = 18.9^{mA}$$

$$\Rightarrow \boxed{V_C = 10 - 0.1 \times 18.9 = 8.11^{V}}$$

$$I_E = \frac{\beta+1}{\beta} I_C = \frac{101}{100} \times 18.9 = 19.1\,mA$$

$$\Rightarrow \boxed{V_E = 0 + 0.22 \times 19.1 = 4.2^{V}}$$

$$\Rightarrow \boxed{V_B = V_E + 0.7 = 4.2 + 0.7 = 4.9^{V}}$$

Check to see whether the "active mode" assumption was right:

$$V_{CE} = V_C - V_E = 8.11 - 4.2 > 0.3^{V} \checkmark$$

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