EECS 312 Exam I (Spring 2018)

Name __________Solution______________

KUID#____________________________________

Instructions:

Please put your last name at the top of each page of the exam in addition to your full name and KUID in the cover page.

The exam is close-book, close-notes. One page of equation sheet can be used.

For answers in numerical or equation forms, please draw a box around your answer.

Calculators may be used.

Complete all calculations called for and express answers with appropriate precision and in proper engineering notation, e.g. 1mA not 0.001A.

No credit will be given for unsupported answers when reason is asked for.

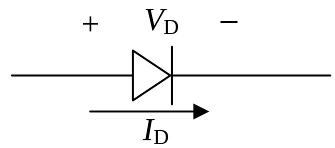
Additional blank sheets will be provided if needed.

1. ________________ (20 pts)
2. ________________ (30 pts)
3. ________________ (20 pts)
4. ________________ (10 pts)
5. ________________ (20 pts)

1. (20 pts) Circle the best answer for each question below:

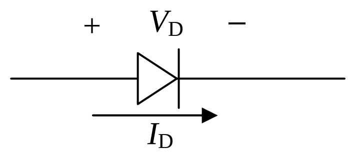
(1) Based on ***ideal*** diode model, if the current flowing through the diode is I_D = 10mA, the voltage V_D across the diode is

(a) -0.7 V (b) 1.4 V (c) undefined (d) 0V



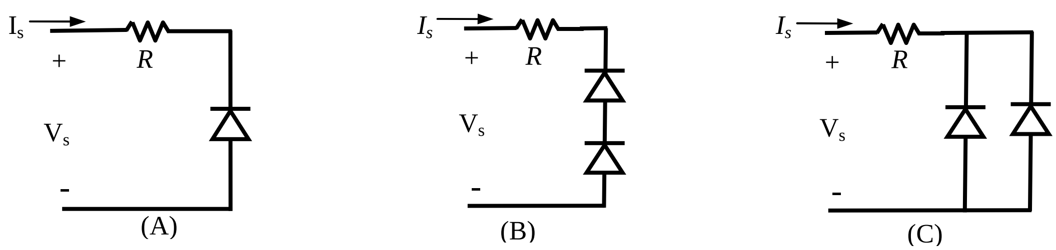
(2) For a practical diode, the current-voltage relation is $I_D = I_s[\exp(V_D / nV_T) - 1]$. If the applied voltage is V_D = -3V (directions shown in the following figure), the current I_D should be approximately

(a) -0.7mA (b) 0.7mA (c) -I_s (d) I_s



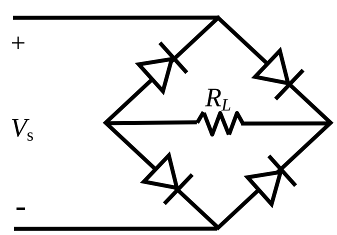
(3) For the three diode circuits (A), (B) and (C) shown below, if all the diodes are "***ideal***", then in terms of current-voltage relation

(a) Only circuit (A) is equivalent to circuit (B)
(b) Only circuit (A) is equivalent to circuit (C)
(c) Only circuit (B) is equivalent to circuit (C)
(d) All the three circuits are equivalent.



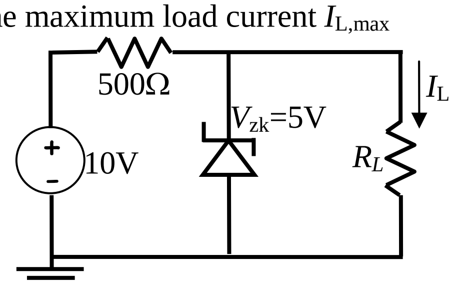
(4) For a bridge rectifier, if the input is $V_s(t) = V_p \sin \omega t$, based on CVD (0.7V) model, the output voltage on the load resistor R_L is approximately

(a) $2V_p / \pi - 1.4$
(b) $V_p / \pi - 0.7$
(c) $V_p / \pi - 1.4$
(d) $V_p / (2\pi) - 1.4$

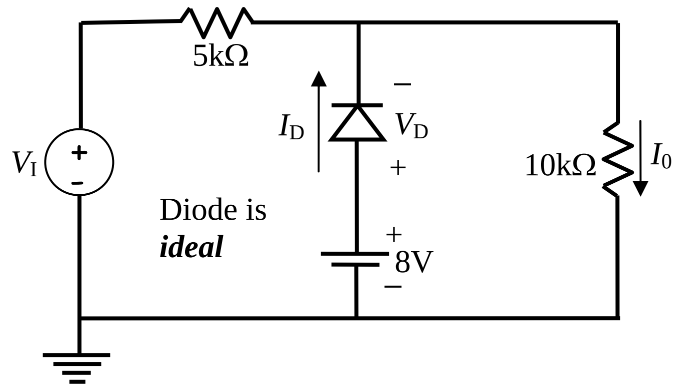


(5) For the shunt regulator, the Zener diode has a breakdown voltage V_{zk} = 5V, and the source voltage is 10V. For optimum operation, the maximum load current $I_{L,max}$ should not exceed

(a) 1mA
(b) 10mA
(c) 20mA
(d) 50mA



2, (30 pts) For the circuit on the right, the diode is ***ideal***. For the input voltage V_I of 15V and 10V, respectively, please analyze the circuit and find the corresponding values of I_0, I_D and V_D as marked in the circuit.



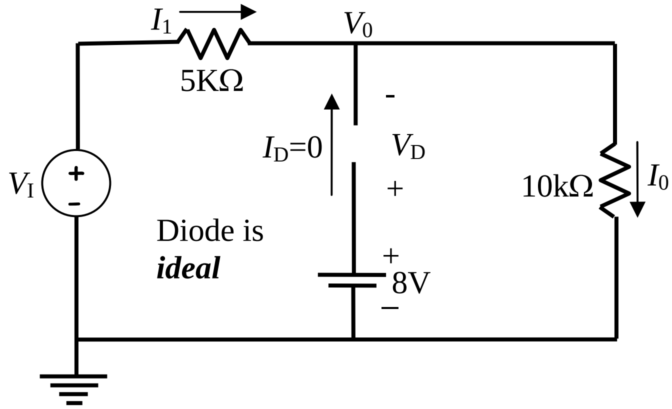
Please fill your results into the following table:

V_I (V)	I_0 (mA)	I_D (mA)	V_D (V)
15			
10			

Solution:

(a) When V_I = 15V, the ideal diode is reverse biased and the output current is:

$I_0 = V_I / 15 = 1mA$.



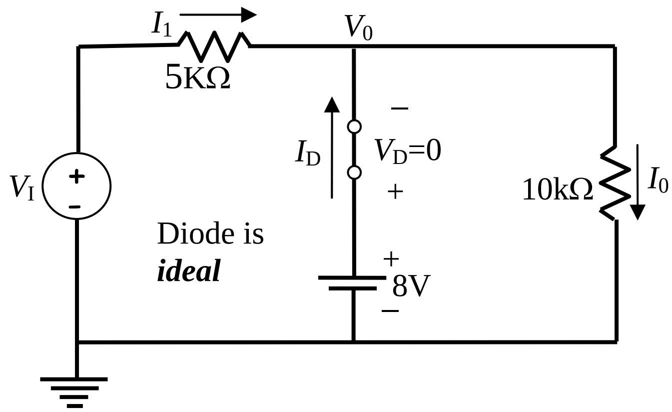
In this case the voltage across the 10kΩ load resistor is $V_0 = 10V_I / 15 = 10V$ and therefore, the voltage across the diode is $V_D = 8V - 10V = -2V$, reverse bias assumption is valid.

[Note: if you assume diode forward bias, $V_0 = 8V$, $I_0 = 0.8mA$,

$I_1 = (15V - 8V)/5k\Omega = 1.4mA$, thus $I_D = I_0 - I_1 = 0.8mA - 1.4mA = -0.6mA$.

Assumption is wrong.]

(b) When V_I = 10V, the ideal diode is forward biased and the output voltage across the 10kΩ load resistor is: $V_0 = 8V$, and therefore the output current is $I_0 = 8/10 = 0.8mA$.



The current flowing through the 5kΩ load resistor is $I_1 = (V_I - 8)/5 = 2/5 = 0.4mA$,

so that the current flowing through the diode is $I_D = I_0 - I_1 = 0.8 - 0.4 = 0.4mA > 0$ which is positive. This verifies the forward bias assumption.

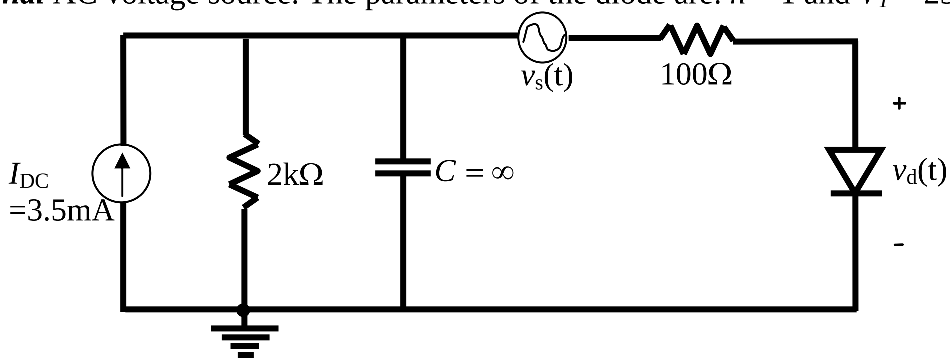
Note: if you assume diode reverse bias:

$V_0 = V_I \times 10/15 = 6.67V$, $V_D = 8 - 6.67 = 1.33V > 0$, thus the reverse bias assumption is wrong.

Please fill your results into the following table:

V_I (V)	I_0 (mA)	I_D (mA)	V_D (V)
15	1	0	-2
10	0.8	0.4	0

2. (20 pts.) In the following circuit, I_{DC} = 3.5mA is a DC bias current and $v_s(t)$ is a ***small-signal*** AC voltage source. The parameters of the diode are: $n = 1$ and V_T = 25mV.

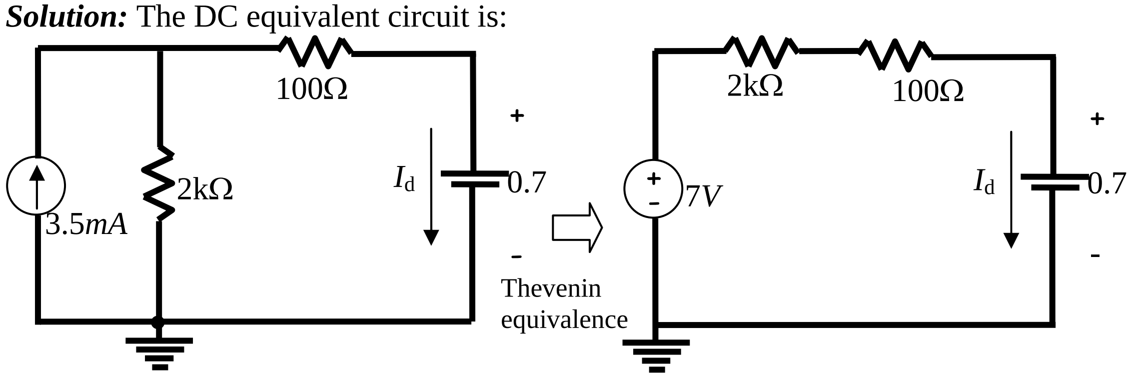


(a) Perform DC analysis and find the DC current flowing through the diode (I_d = ?)

(b) Find the small-signal resistance of the diode r_d = ?

(c) Use small-signal analysis and find the small-signal voltage gain ($v_d(t)/v_s(t)$= ?)

Solution: The DC equivalent circuit is:

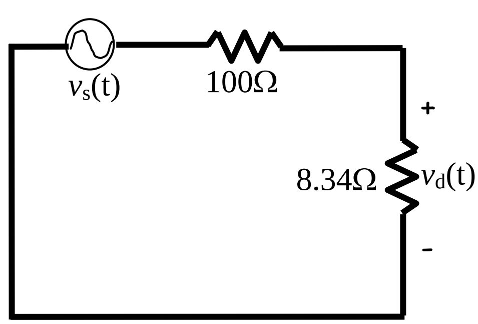


$$I_d = -\frac{7-0.7}{2.1} = 3mA$$

The equivalent small-signal resistance of diode is: $r_d = \frac{nV_T}{I_d} = \frac{25}{3} = 8.34\Omega$

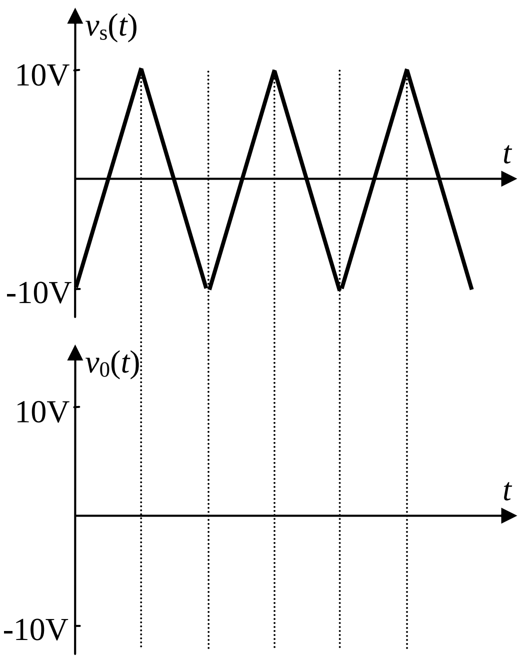
The AC small-signal voltage gain is:

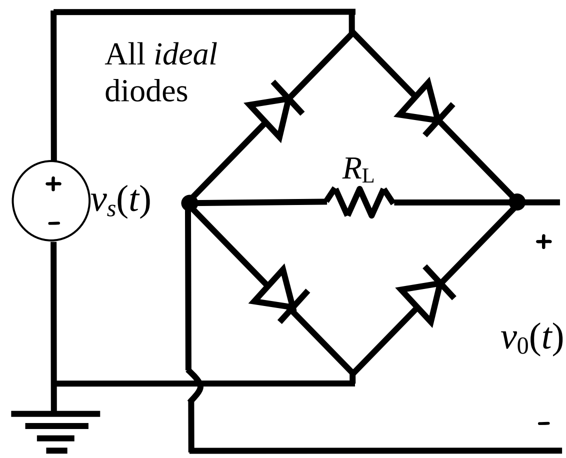
$$\frac{v_d(t)}{v_s(t)} = \frac{8.34}{108.34} = 0.077$$



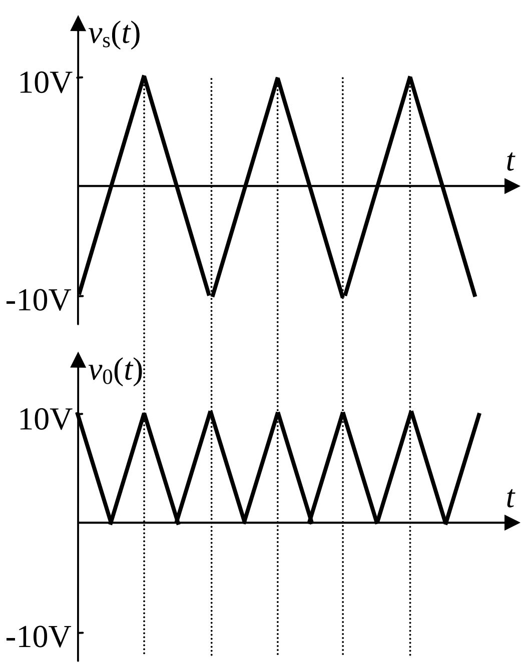
3, (10 pts) For the following bridge rectifier circuit, assume all diodes are ***ideal*** (0 voltage drop when forward biased), the input signal is a triangle wave that swings between ±10V, as shown in the figure.

(a) Please draw and label the output voltage waveform v_0(t) across the load resistor
(b) Please find the average output voltage $v_{0,ave}$ across the load resistor





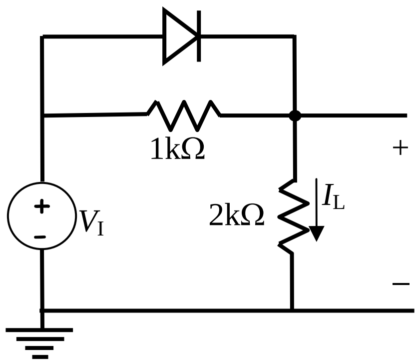
Solution:

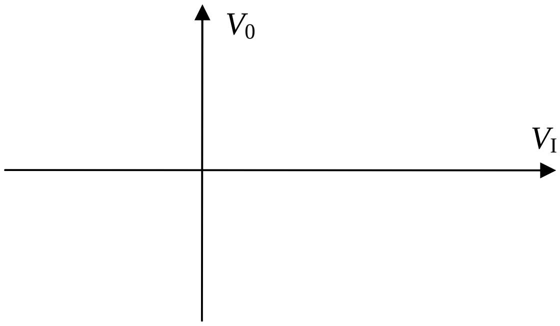


The average output voltage is $V_{0,ave}$ = 5V

4. (20 pt) For the following circuit the diode is described by a ***CVD*** (0.7V) model.

Please derive the voltage transfer function between the output and input (V_0 as the function of V_I), draw and carefully label on the plot below (label intersection points and slopes of each section).





Solution:

Assume the diode is reverse biased, $V_0 = \frac{2}{3}V_I$, $V_D = V_I - V_0 = V_I - 2V_I/3 = V_I/3$

In order for diode to be reverse biased, we need $V_I/3 < 0.7$, that is $V_I < 2.1V$

Then assume the diode is forward biased, $V_0 = V_I - 0.7V$

$I_L = \frac{V_I - 0.7}{2}$, $I_1 = \frac{0.7}{1} = 0.7mA$, $I_D = I_L - I_1 = \frac{V_I - 0.7}{2} - 0.7$

In order for diode to be forward biased, we need $I_D > 0$, that is $\frac{V_I - 0.7}{2} - 0.7 > 0$

so that $V_I > 2.1V$. Combine results: $V_0 = \begin{cases} 2V_I/3 & \text{for } V_I < 2.1V \\ V_I - 0.7 & \text{for } V_I > 2.1V \end{cases}$