EID:_____

ECE 302H Hanson

Please answer ALL questions

100 points total.

Fall 2022, Midterm Exam I

Time: 700-830 PM (90 minutes) + up to an additional 90 minutes, if required, with no penalty.

28 Sept. 2022

Kirchhoff's exams laws!

"Then a miracle occurs..."

EID:_____

Question	Points
Q1	
Q2	
Q3	
Q4	
Q5	
Total:	

EID:_____

Q1. 30 Points total. This question has four parts (Part I-Part IV),

Part I: 6 Points. Consider the following components (a)-(c). In each case, state if the component is linear or non-linear and briefly explain your answer:

(a) A voltage source of magnitude $3I_0$, where I_0 is the current flowing through the source.

(b) A resistor whose value is given by $R = 3I_0$, where I_o is the current flowing through the resistor.

(c) A current source which provides a current of $5V_0$ when the voltage applied across it is V_0.

EID:_____

Q1 Part II: 6 Points: Provide examples of circuits with (i) $V_{Th} = 0$ and $R_{Th} \neq 0$; and (ii) $V_{Th} \neq 0$; $R_{Th} = 0$. In each case, the circuit must have at least one source and two resistors.

EID:_____

Q1 Part III: 8 Points: The figure below, shows the ionic current (consisting of positive potassium ions) as a function of time flowing through a single biological component (called an ion channel) when a potential difference of 60 mV is applied across it. When the ion channel is open, the current is 4 pA (1 pA = 10^{-12} A) and when the ion channel is closed, the current is zero.

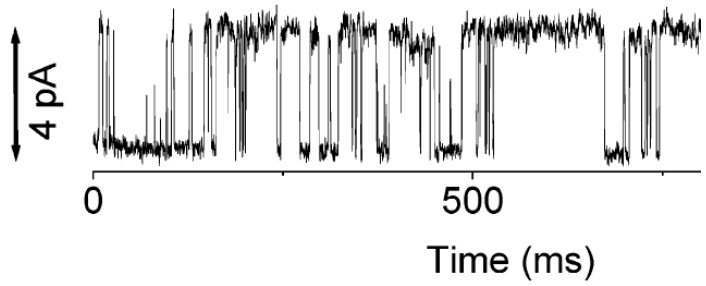


Figure for Q1 Part III

(i) Draw a simple linear circuit model (or an equivalent circuit) for the ion channel. Make sure that your equivalent circuit captures all the electrical characteristics described above.

(ii) For the time interval between t = 550 ms and t = 650 ms, calculate the total charge flowing through the ion channel, assuming it is open over the entire time interval.

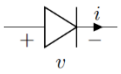
EID:_____

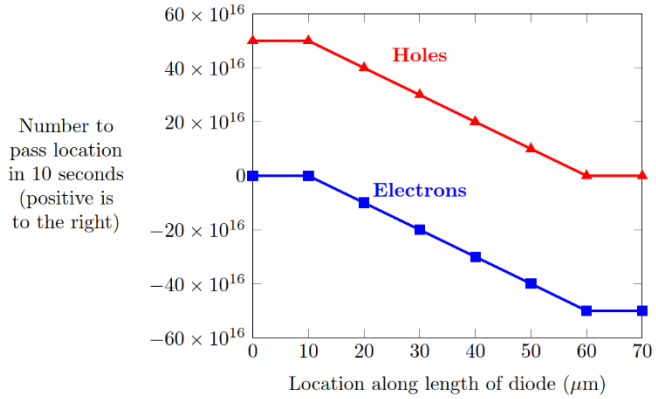
(iii) Scorpion venom blocks potassium ion channels and prevents any ions from flowing. Using your equivalent circuit proposed in (i), describe what a scorpion sting does to the ion channel.

Q1 Part IV: 10 Points A diode is a circuit component with the following I-V characteristic:

$$i = I_0 \left(\exp^{\frac{q}{nkT} v} - 1 \right)$$

where i is the current through the diode, v is the voltage across the diode, and I_0, n, k, and T are all constants.





a) Is the diode a linear component?

b) Can the following techniques be used to analyze a circuit containing diodes?

i) KVL

ii) Node Voltage Analysis

iii) Superposition

iv) Norton Equivalent Circuits

c) The charge flow in a diode is due to a combination of electrons and holes. Electrons have −1 unit of charge (−1e−) and "holes" are positive charges which have +1 unit of charge (+1e−). An experiment was performed on a diode which measured how many electrons and holes crossed certain locations along the diode's length over a time of 10 seconds (see the Figure below). Explain how KCL is obeyed in the diode even though different numbers of charges pass each location in the diode.

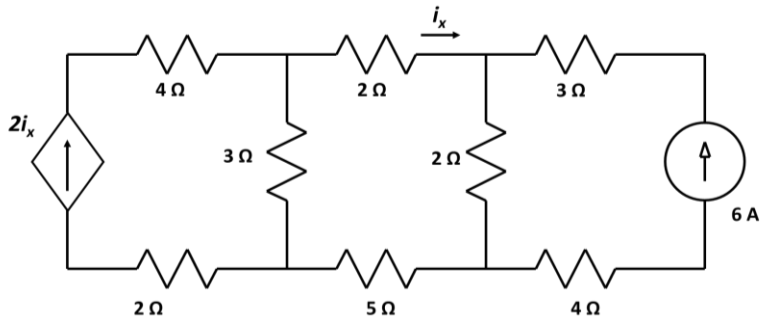
EID:_____

d) What is the current in the diode described above? Express your answer in Amperes with an appropriate SI prefix (μ, m, k, M). Recall that 1 Coulomb has the same amount of charge as 6.24×10^{18} electrons.

EID:_____

Q2. 15 Points. Consider the circuit shown below.

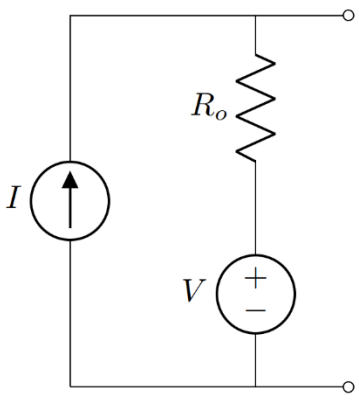
(i) Calculate i_x
(ii) Is the dependent source supplying or receiving power? Briefly justify your answer.
(iii) Calculate the power received/supplied by the dependent source.



EID:_____

EID:_____

Q3. 15 Points. A solar cell can be approximately modeled by the circuit in the Figure at right.



a) Suppose that two identical solar cells are connected in series with each other and with a load resistor R_L (not shown in the figure). Calculate the voltage across R_L.

b) Suppose that two identical solar cells are connected in parallel with each other and with a load resistor R_L. Calculate the current through R_L.

EID:_____

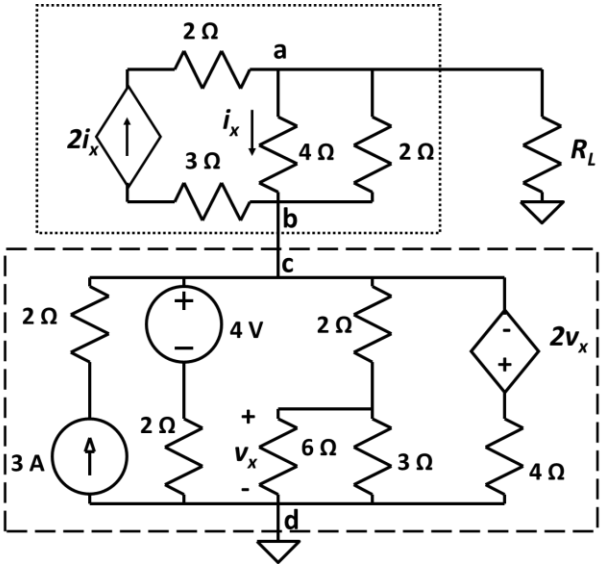
EID:_____

Q4. 20 Points. Consider the figure in the circuit shown below:

i) Calculate the Thevenin Equivalent circuit between a and b of the part of the whole circuit that is enclosed within the box with **dotted** lines.

ii) Calculate the Thevenin Equivalent circuit between c and d of the part of the whole circuit that is enclosed within box with dashed lines.

iii) For what value of R_L is the power transferred from the rest of the circuit to R_L a maximum? Calculate the power dissipated in R_L.

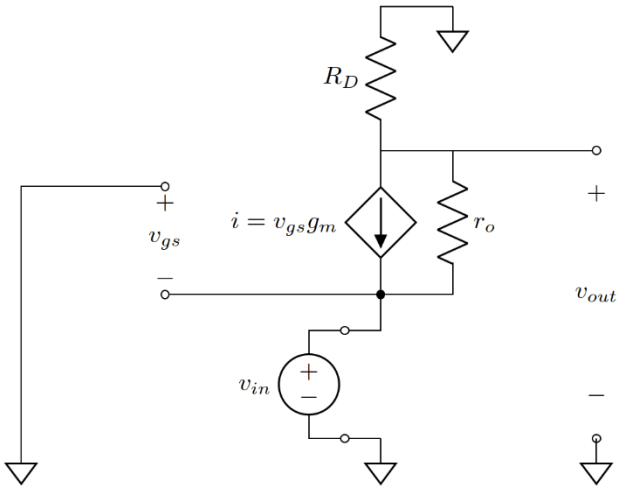


EID:_____

EID:_____

Q5. 20 Points.

Consider the circuit in the diagram.



(i) Calculate the gain of the circuit, v_{out}/v_{in}, when the output is open circuited as shown in the figure.

(ii) Find the Thevenin equivalent circuit that represents the circuit's behavior at the v_{out} port.

(iii) What does the Thevenin resistance in (ii) become if $g_m \to \infty$?

(iv) What is the Thevenin equivalent circuit that represents the circuit's behavior at the *input* port? (i.e., everything except the v_{in} voltage source, with the output open circuited)

(v) What does the Thevenin resistance in (iv) become if $g_m \to \infty$?

EID:_____

EID:_____