Name: ____________________________ (please print)

Signature: __________________________

ECE 3355 – Exam 2
April 17, 2021
Online

1. This exam is open book, open notes. You may not consult another person, verbally or online, for help. You may not submit this exam to any online site to get help.
2. Show all work necessary to complete the problem on these pages. A solution without the work shown will receive no credit.
3. The penalty for mixed domains will be 10 points for each problem showing mixed domains.
4. Show units in intermediate and final results, and in figures.
5. If your work is sloppy or difficult to follow, points will be subtracted.

- The exam starts at 9 am. You will have 90 minutes to take the exam, and 15 minutes to scan and upload it. Blackboard will stop accepting your work at 10:45 am.
- Please turn on your video.
- When you upload, make it a single .pdf document, and be sure it is legible and complete before uploading.
- I will be available for questions during the exam. If you need to ask a question, please use the chat option on Zoom.

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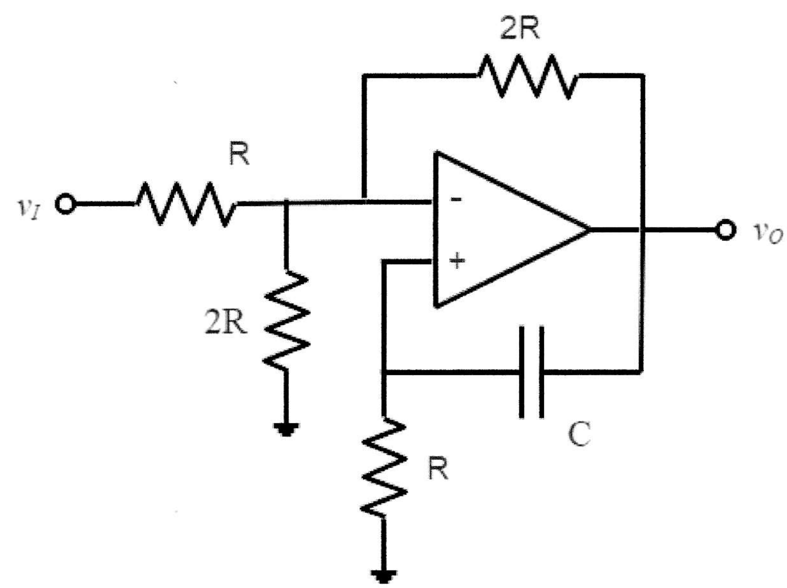
Room for extra work

1. (25 points) For the circuit below, the op amp is considered ideal.

   a. Find the transfer function $T(\omega)=\dfrac{\bar{V}_o}{\bar{V}_i}$.

   b. What value does $T(\omega)$ approach for very large frequencies?

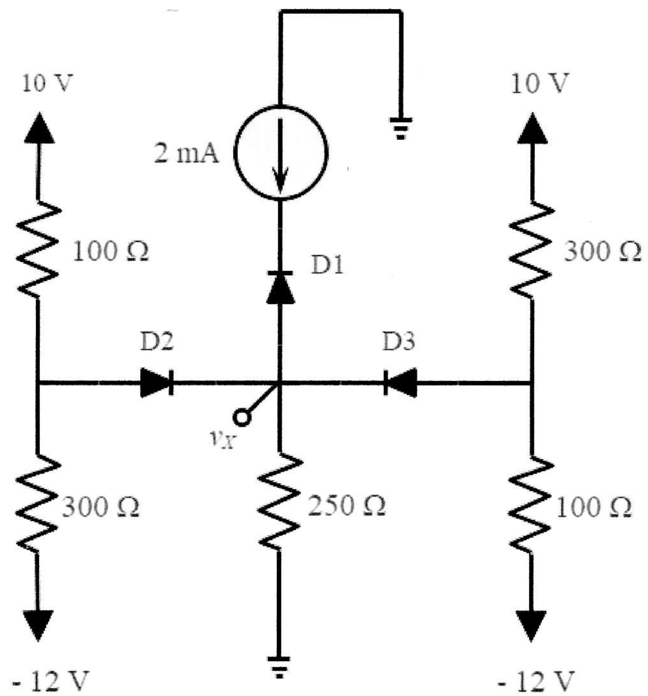
   c. What value does $T(\omega)$ approach for very small frequencies?



Room for extra work

2. (35 points) The diodes in the circuit below can be modeled with a piece-wise linear model with V_{Th}= 1 V, I_S = 5 mA, and r_D = 50 Ω. Find v_X.

You should be able to get through at least two complete guesses for the states of the diodes.

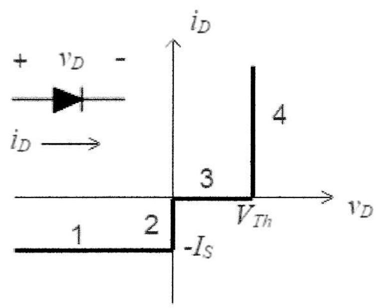


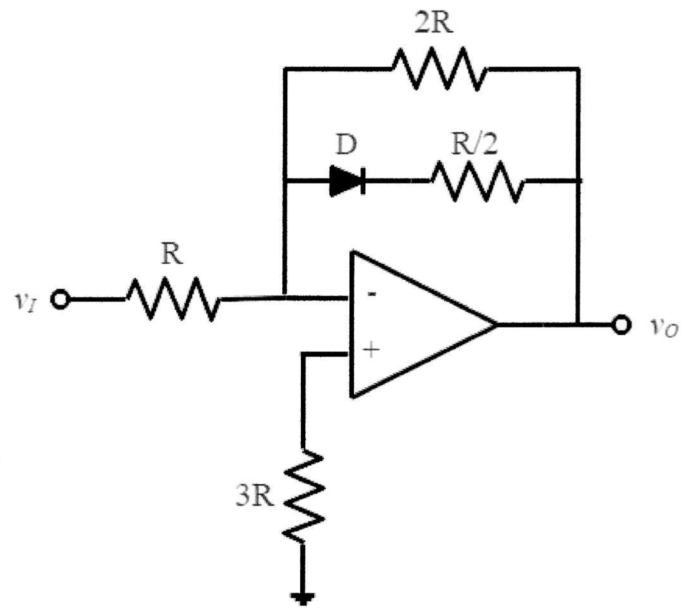
Room for extra work

3. (40 points) In the circuit below, assume an ideal op amp and a piecewise linear diode model with parameters V_{Th}= 0.5 V, I_S = 2 mA, and r_D = 0 Ω.

a) Find v_O for an input voltage of v_I = 1 V.

b) For an input voltage of v_I = -1 V, there is a range of values for R for which the diode is in the reverse-bias region, that is, region 1. Find the largest value of R such that the diode is in region 1. That is, find R such that any larger value will result in a region other than region 1.





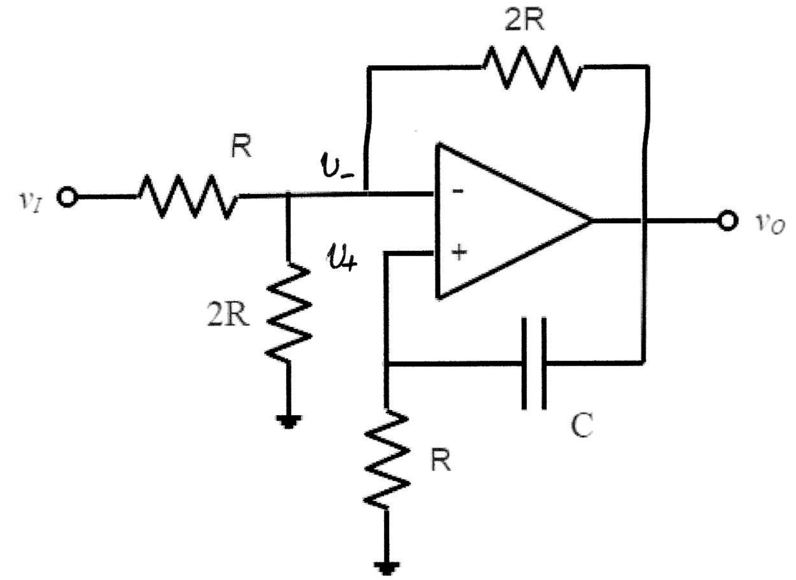
Room for extra work

1. (25 points) For the circuit below, the op amp is considered ideal.

   a. Find the transfer function $T(\omega) = \dfrac{\bar{V}_o}{\bar{V}_i}$.

   b. What value does $T(\omega)$ approach for very large frequencies?

   c. What value does $T(\omega)$ approach for very small frequencies?



a)

VDR

$$\bar{V}_+ = \bar{V}_- = \bar{V}_o \frac{R}{R + 1/j\omega C} = \bar{V}_o \frac{j\omega CR}{1 + j\omega CR}$$

KCL

$$\frac{\bar{V}_-}{2R} + \frac{\bar{V}_- - \bar{V}_i}{R} + \frac{\bar{V}_- - \bar{V}_o}{2R} = 0$$

$$4\bar{V}_- - \bar{V}_o = 2\bar{V}_i$$

$$\bar{V}_o\left(\frac{4j\omega CR}{1 + j\omega CR} - 1\right) = 2\bar{V}_i$$

$$\frac{\bar{V}_o}{\bar{V}_i} = \frac{2}{\frac{4j\omega CR}{1 + j\omega CR} - 1} = \frac{2 + 2j\omega CR}{4j\omega CR - 1 - j\omega CR}$$

Room for extra work

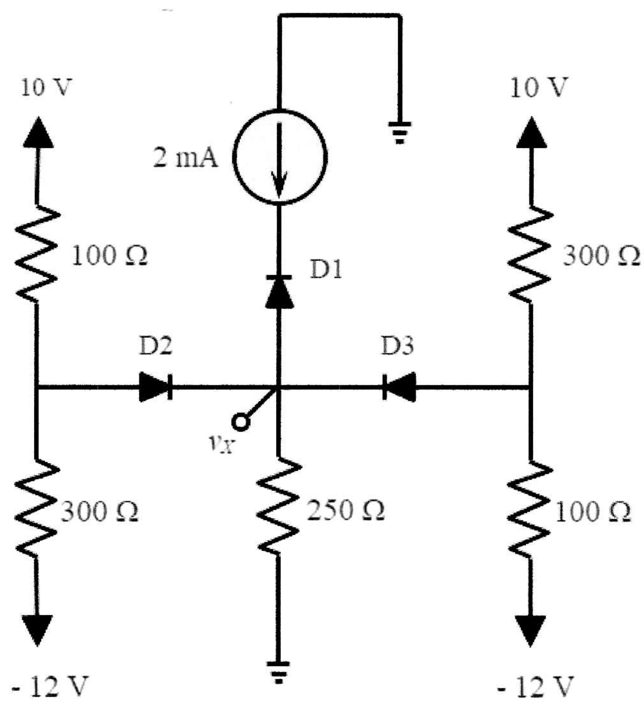
$$\frac{\bar{V}_o}{\bar{V}_i} = \frac{2 + 2j\omega CR}{3j\omega CR - 1}$$

b) $T(\omega \to \infty) \to \frac{2j\omega CR}{3j\omega CR} = \frac{2}{3}$

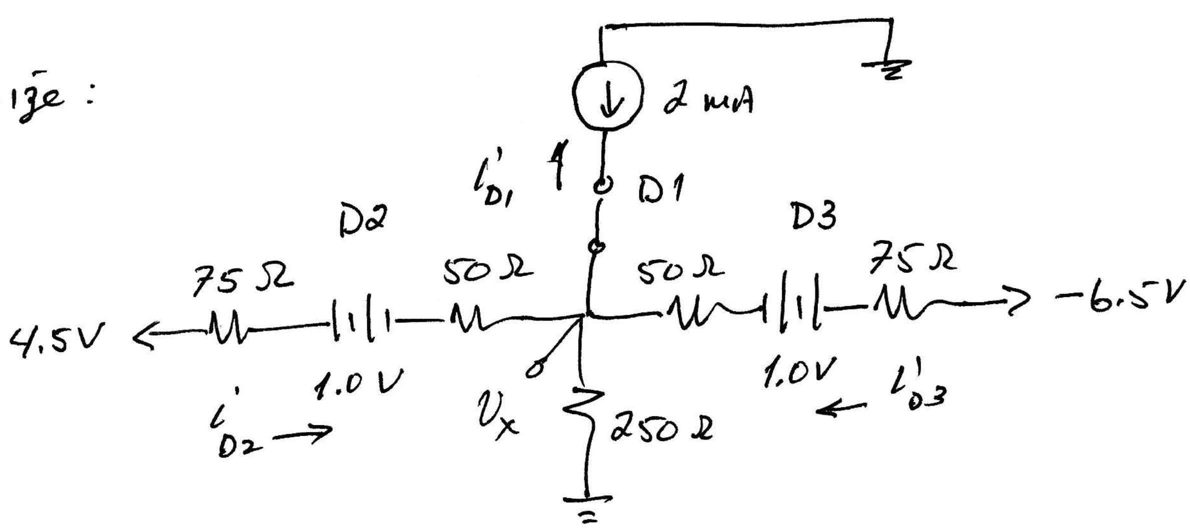
c) $T(\omega \to 0) \to \frac{2}{-1} = -2$

2. (35 points) The diodes in the circuit below can be modeled with a piece-wise linear model with V_{Th}= 1 V, I_S = 5 mA, and r_D = 50 Ω. Find v_x.

You should be able to get through at least two complete guesses for the states of the diodes.



Thevenize:



Based on the Thevenin voltages, we guess D2, D3 in forward bias (region 4). Because of the current source, D1 must be in region 2 (short).

Room for extra work

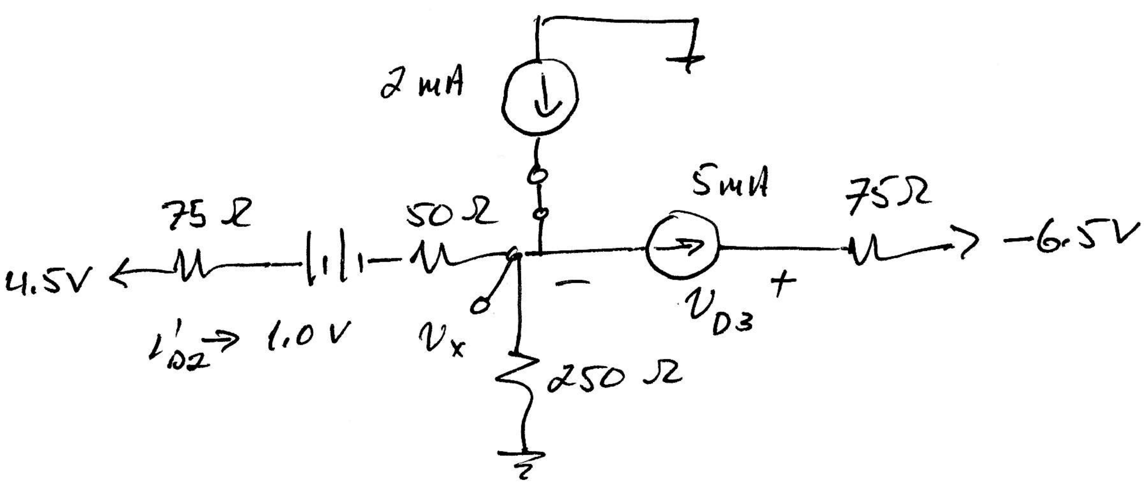
$$\frac{v_x - 4.5 + 1}{125} + \frac{v_x}{250} + \frac{v_x + 6.5 + 1}{125} - 0.002 = 0$$

$$v_x = 1.5\ V$$

$$i'_{D2} = -\frac{v_x - 4.5 + 1}{125} = 16.0\ mA \checkmark$$

$$i'_{D3} = -\frac{v_x + 6.5 + 1}{125} = -68.0\ mA \quad X$$

So our guess for D3 needs to change.



$$\frac{v_x - 4.5 + 1}{125} + \frac{v_x}{250} - 0.002 + 0.005 = 0$$

$$v_x = 2.083\ V$$

↗ pg. 2

$$i'_{D2} = -\frac{v_x - 4.5 + 1}{125} = 11.33\ mA \checkmark$$

Room for extra work

$$-v_x - v_{D3} + 0.005(75) - 6.5 = 0$$

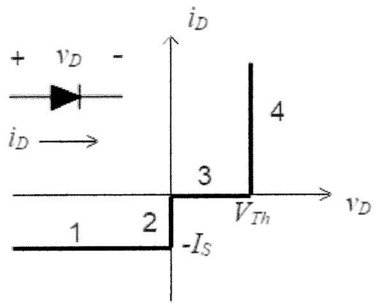
$$v_{D3} = -8.208 \text{ V}$$ ✓

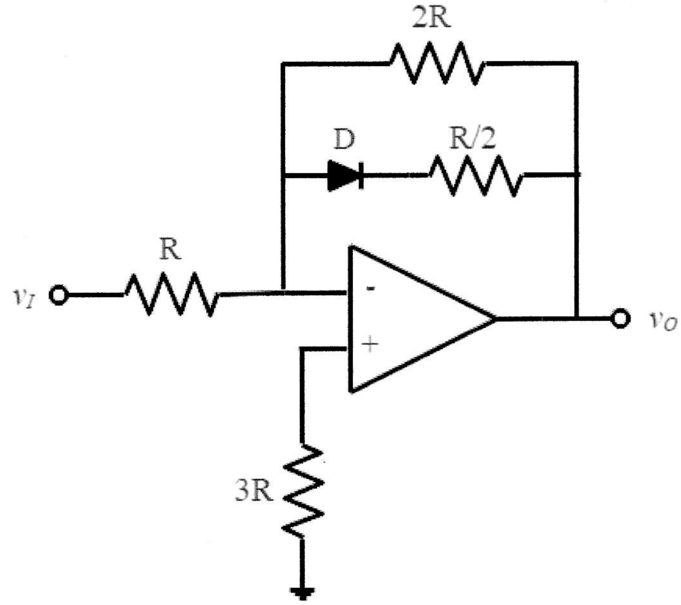
D1 needs no checking. Since we have assumed a short, we need to show $-5\text{mA} < i_{D1} < 0$ but the current source guarantees this.

3. (40 points) In the circuit below, assume an ideal op amp and a piecewise linear diode model with parameters $V_{Th} = 0.5$ V, $I_S = 2$ mA, and $r_D = 0\ \Omega$.

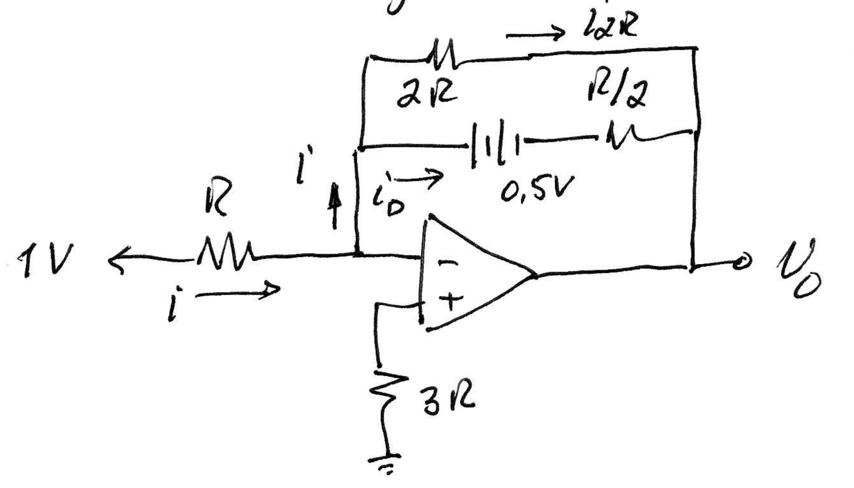
a) Find v_O for an input voltage of $v_I = 1$ V.

b) For an input voltage of $v_I = -1$ V, there is a range of values for R for which the diode is in the reverse-bias region, that is, region 1. Find the largest value of R such that the diode is in region 1. That is, find R such that any larger value will result in a region other than region 1.





a) with $v_I = 1$ V, we have positive current going into the feedback network, so we'll guess D is in region 4.



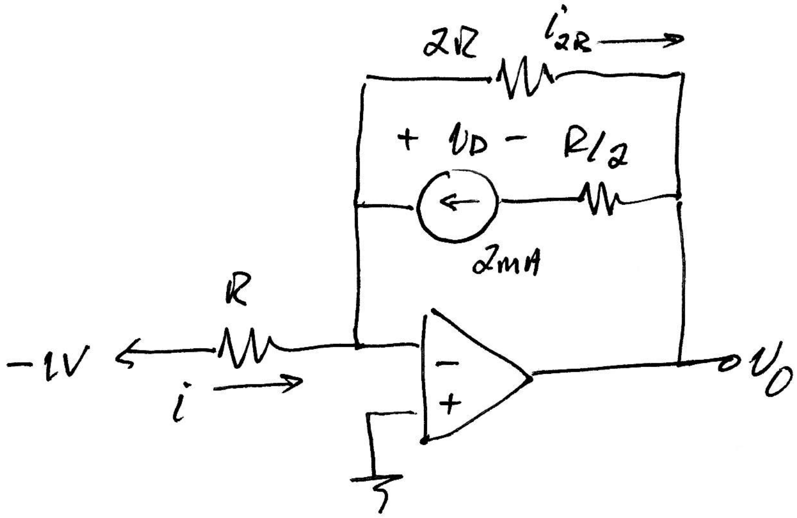
$i' = i'_D + i'_{2R}$

Room for extra work

$$\frac{v_I}{R} = \frac{-v_O}{2R} + \frac{-v_O - 0.5}{R/2}$$

$$v_I = 1\,V \Rightarrow \boxed{v_O = -\frac{4}{5}\,V}$$

b) D will be in region 1 if $v_D < 0$



$$i = -\frac{1}{R} = i_{2R} - 0.002$$

$$i_{2R} = -\frac{1}{R} + 0.002$$

$$v_O + i_{2R} \cdot 2R = 0 \Rightarrow v_O + 2R\left(-\frac{1}{R} + 0.002\right) = 0$$

$$\Rightarrow v_O = 2 - 0.004R$$

$$v_O + v_D - 0.002\,\frac{R}{2} = 0$$

$$v_D = 0.001R - v_O = 0.001R - 2 + 0.004R$$

$$v_D = 0.005R - 2 < 0 \Rightarrow \boxed{R < 400\,\Omega}$$