Helpful readings for this homework: Nilsson and Riedel, Chapter 5, Chapter 6, and Chapter 7.

Grading Criteria

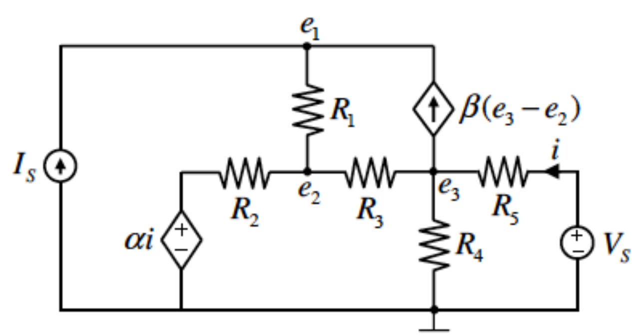
Show all work, as each problem will be graded using the grading criteria given below:

- 100% of maximum score if approach is correct and answer is also correct
- 80% of maximum score if approach is correct, but answer is incorrect due to algebraic or other math error
- 60% of maximum score if approach is mostly correct, but there is some conceptual error
- 40% of maximum score if problem has been seriously attempted, but approach is incorrect and/or there are major conceptual errors.
- 20% of maximum score if problem has been attempted, but is illegible.
- 0% of maximum score if there is no attempt to solve the problem.

Problem 3.1: ($8\frac{1}{3}$ points)

Use the node method to develop a set of simultaneous equations for the network shown on the right, which can be solved to determine the unknown node voltages. Express the set of equations in the form:

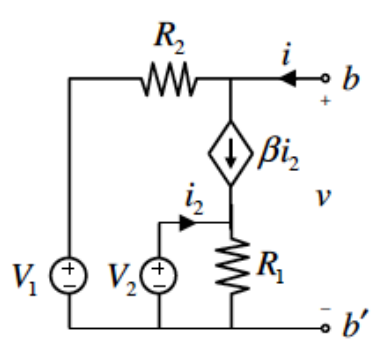
$$\boldsymbol{G}\begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} = \boldsymbol{S}$$



where $\boldsymbol{G}$ is a 3x3 matrix of conductance terms and $\boldsymbol{S}$ is a 3x1 vector of terms involving independent sources and constant parameters α and β. *You do not have to solve the set of equations for the node voltages.*

Problem 3.2: ($8\frac{1}{3}$ points)

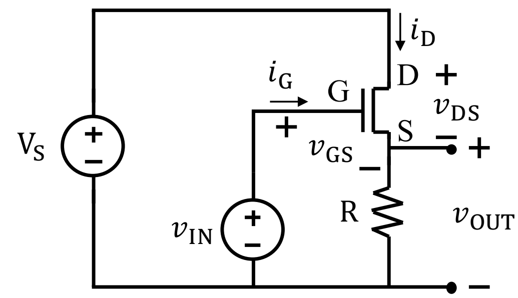
For the network shown below, determine the Thevenin equivalent circuit as seen from the port defined by the terminal pair bb'. In this circuit β is a constant parameter.



Problem 3.3: ($8\frac{1}{3}$ points)

This problem studies the MOSFET amplifier known as the "Source Follower" (also called "Common Drain"), as shown below.

Recall from lecture that the MOSFET's gate current $i_G = 0$, and in the saturation region (i.e., when $0 \le v_{GS} - V_T \le v_{DS}$), its drain current $i_D = 0.5K(v_{GS} - V_T)^2$. In this particular design, $V_S = 9$ V, $R = 1$ kΩ, $K = 1\ \text{mA/V}^2$, and $V_T = 1$ V.



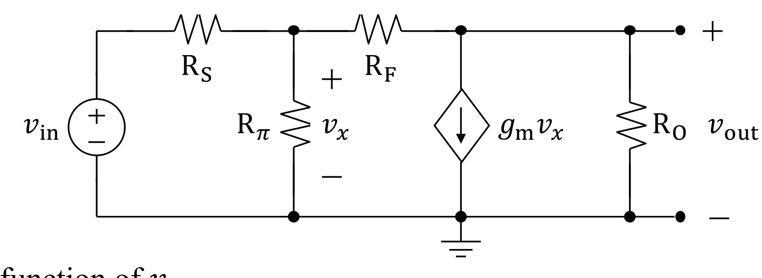
(a) Assuming that the MOSFET operates in its saturation region, determine v_{OUT} as a function of v_{IN}. (Hint: This has two solutions, only one of which is physically possible.)
(b) Determine the range of v_{IN} over which the MOSFET operates in its saturation region.

For part (c), assume that $v_{IN}(t) = V_{IN} + v_{in}(t)$ and $v_{OUT}(t) = V_{OUT} + v_{out}(t)$, where V_{IN} is a constant input voltage within the range determined in part (b), V_{OUT} is the constant output voltage in response to V_{IN}, and $v_{in}(t)$ and $v_{out}(t)$ are very small amplitude time varying voltages.

(c) Given that $V_{IN} = 8.5$ V, draw the small-signal (linear) equivalent circuit model for the given MOSFET amplifier, and determine its small-signal gain $v_{out}(t)/v_{in}(t)$.

Problem 3.4: ($8\frac{1}{3}$ points)

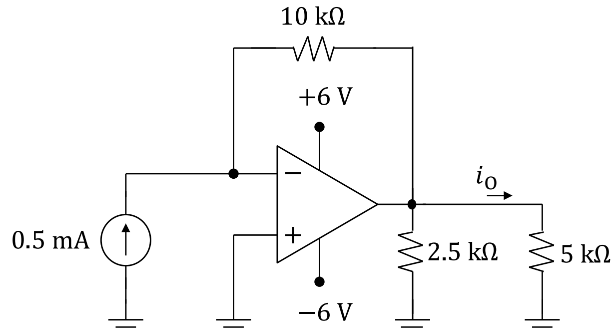
The circuit shown below is a small-signal model for a transistor-based amplifier. Assume $R_S = 50\ \Omega$, $R_\pi = 200\ \Omega$, $R_F = 1$ kΩ, $R_O = 200\ \Omega$, and the transconductance $g_m = 0.5$ S.



(a) Find v_{out} as a function of v_{in}.
(b) Determine and draw the Thevenin equivalent for this circuit when looking into its output port.
(c) Determine the value of the load resistance which when connected across its output port would extract maximum power from this circuit. Also determine the maximum extracted power $P_{out(max)}$ as a function of v_{in}.
(d) Determine the value of the Thevenin resistance R_{in} seen by the input voltage source v_{in} (also called input resistance). Also determine the power delivered to the circuit by the input source P_{in} as a function of v_{in}.
(e) Determine the maximum power gain of this amplifier ($P_{out(max)}/P_{in}$).

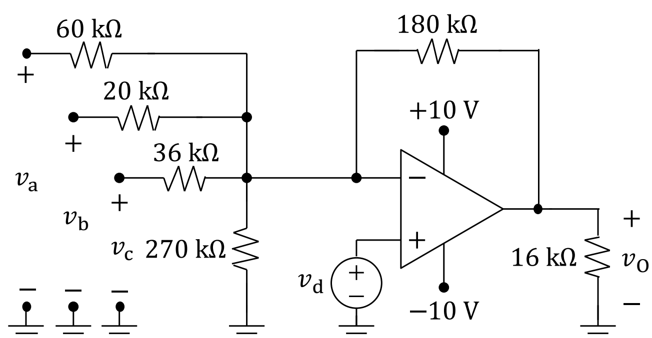
Problem 3.5: [Problem 5.5 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

Find i_O in the circuit shown below if the op-amp is ideal.



Problem 3.6: [Problem 5.14 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

The op-amp in the circuit shown below is ideal.

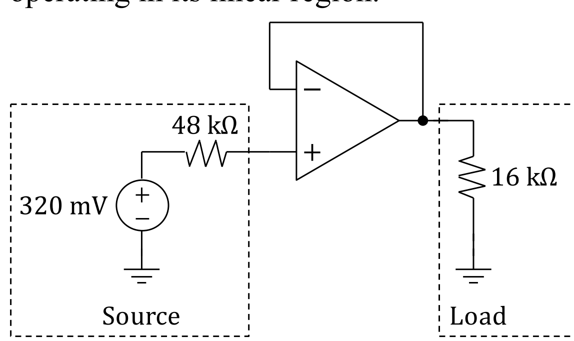


(a) Find v_O if $v_a = 3$ V, $v_b = 9$ V, $v_c = 5$ V, and $v_d = 6$ V.

(b) Assume v_a, v_b, and v_d retain their values as given in part (a). Specify the range of v_c such that the op-amp operates within its linear region.

Problem 3.7: [Problem 5.40 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

Assume that the ideal op-amp in the circuit below is operating in its linear region.



(a) Calculate the power delivered to the 16 kΩ resistor.

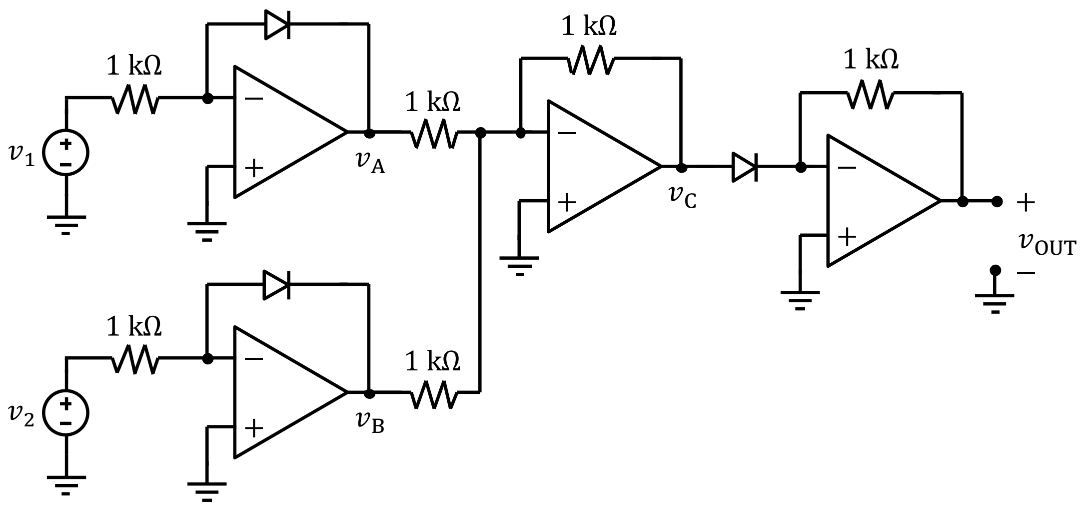
(b) Repeat part (a) with the op-amp removed from the circuit, that is, with the 16 kΩ resistor connected in series with the voltage source and the 48 kΩ resistor.

(c) Find the ratio of the power found in part (a) to that found in part (b).

(d) Does the insertion of the op-amp between the source and the load serve a useful purpose? Explain.

Problem 3.8: ($8\frac{1}{3}$ points)

Consider the op-amp circuit shown below in which the diodes have the following i-v relationship: $i_D = I_O e^{(v_D/V_T)}$.

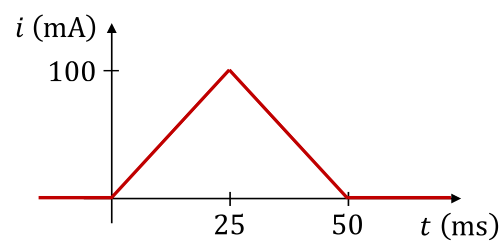


Assume that $v_1 > 0$ and $v_2 > 0$, and remember that: $ln(x) + ln(y) = ln(xy)$.

(a) Determine v_A and v_B in terms of v_1 and v_2.
(b) Determine v_C in terms of v_1 and v_2.
(c) Determine v_{OUT} in terms of v_1 and v_2. What function does this circuit implement?

Problem 3.9: [Problem 6.2 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

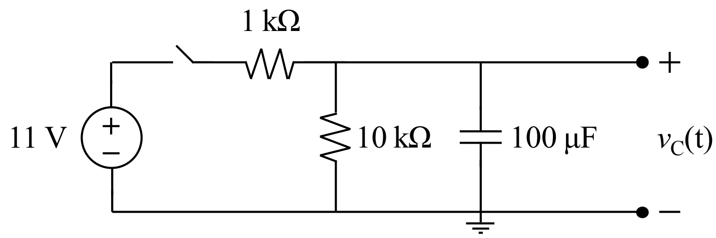
The triangular current pulse shown below is applied to a 500 mH inductor.



(a) Write the expressions that describe $i(t)$ in the four time intervals: (i) $t < 0$, (ii) $0 \le t \le 25$ ms, (iii) 25 ms $\le t \le 50$ ms, and (iv) $t > 50$ ms.
(b) Derive the expressions for the inductor voltage, power, and energy. Use the passive sign convention.

Problem 3.10: ($8\frac{1}{3}$ points)

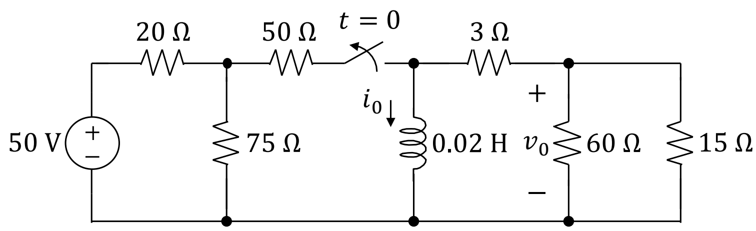
In the circuit shown below, the switch has been left at the open (i.e., off) position for a long time. The switch is closed (i.e., turned on) at time $t = 0$ and then opened (i.e., turned off) again at $t = 1$ second.



(a) Find the capacitor voltage $v_C(t)$ for $0 \le t \le 1$ second.
(b) Find the capacitor voltage $v_C(t)$ for $t \ge 1$ second.
(c) Plot the capacitor voltage $v_C(t)$ for $0 \le t \le 6$ seconds.

Problem 3.11: [Problem 7.2 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

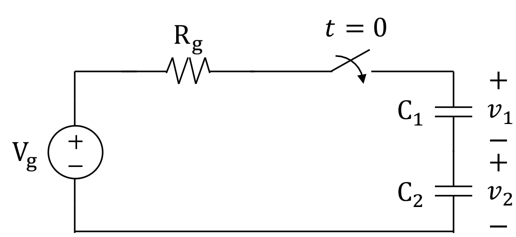
The switch in the circuit shown below has been closed for a long time. At $t = 0$ the switch is opened.



(a) Write the expression for $i_O(t)$ for $t \ge 0$.
(b) Write the expression for $v_O(t)$ for $t \ge 0^+$.

Problem 3.12: [Problem 7.66 from Nilsson and Riedel] ($8\frac{1}{3}$ points)

There is no energy stored in the capacitors C_1 and C_2 at the time the switch is closed in the circuit shown below.



(a) Derive the expressions for $v_1(t)$ and $v_2(t)$ for $t \ge 0$.
(b) Use the expressions derived in part (a) to find $v_1(\infty)$ and $v_2(\infty)$.