4.5 Problems

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Problem 4.1 RHINOCEROS Write a one- or two-sentence response to each of the following questions and imperatives. The use of equations is acceptable when they appear in a sentence. Don't quote me (use your own words, other than technical terminology).

(a) Write the equivalent impedance of a resistor R and an inductor L in series. Express the result in rectangular and polar (phasor) form.
(b) How do you find the Norton equivalent resistance?
(c) Explain how a diode operates in forward-bias.
(d) In a MOSFET, how much current will flow from the drain D to the source S when the gate-source voltage is 0.3 V? Succinctly explain/justify.

Problem 4.2 FLAMINGO Write a one- or two-sentence response to each of the following questions and imperatives. The use of equations is acceptable when they appear in a sentence. Don't quote me (use your own words, other than technical terminology).

(a) Describe a couple differences between MOSFETs and opamps.
(b) If a DC source is connected to a circuit in steady state, describe how an inductor in the circuit will be operating.
(c) If a transformer increases an AC signal's voltage by a factor of 119, what happens to the signal's current?
(d) How do we determine the diode resistance for the piecewise linear model of a diode?

Problem 4.3 ASTRINGENT Write a one- or two-sentence response to each of the following questions and imperatives. The use of equations is acceptable when they appear in a sentence. Don't quote me (use your own words, other than technical terminology).

(a) If the current through an inductor is suddenly switched off, what happens?
(b) Let the output voltage of a resistor circuit be 5 V and the equivalent resistance 500 Ω. What is the Thevenin equivalent circuit?
(c) In the preceding part of this question, what is the Norton equivalent?
(d) When can we use impedance analysis?

Problem 4.4 PROLONGATE For the circuit diagram of figure 4.12, solve for $v_o(t)$ if $V_s(t) = A\cos\omega t$. Let $N = n_2/n_1$, where n_1 and n_2 are the number of turns in each coil, 1 and 2, respectively. Also let $i_L(0) = 0$ be the initial condition.

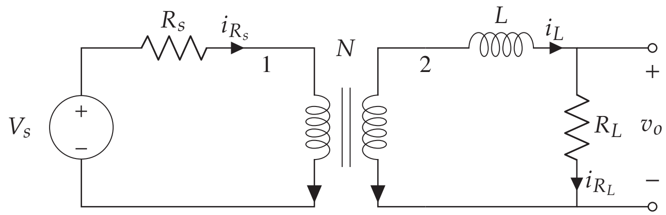


Figure 4.12. Circuit diagram for problem 4.4 and problem 4.5.

Problem 4.5 SYNOPSES Re-do Exercise 4.4, but only consider the steady-state response. Use impedance methods!

Problem 4.6 SPARTANISM When considering the steady state of circuits with only DC sources, all voltages and currents are constant and all diodes are in constant states (each is ON or OFF). The methods of section 4.2 still apply, of course, but we needn't be concerned with a time evolution.

Consider the circuits of figure 4.13. For each circuit, solve for the voltage across the 5 kΩ resistor. Treat each diode as an ideal diode.

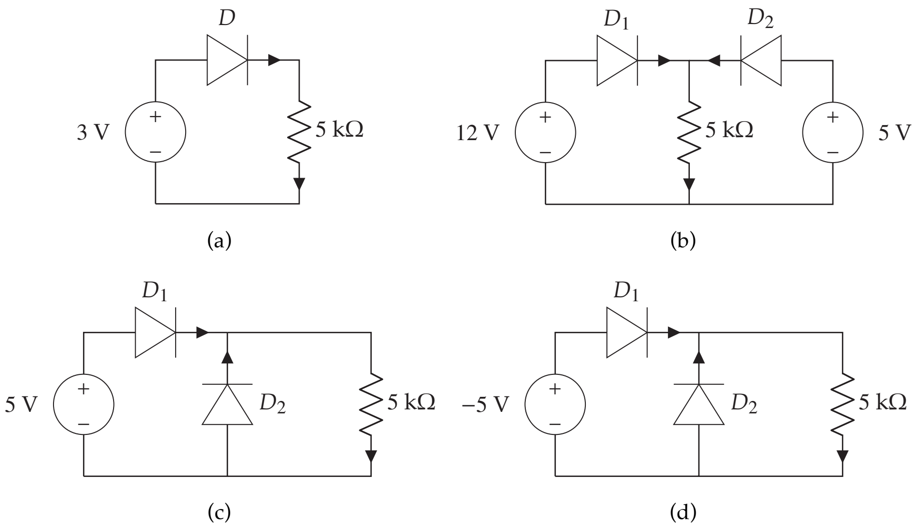


Figure 4.13. Diode circuits for Exercise 4.6.

Problem 4.7 OUTSMART Repeat Exercise 4.6, but use the piecewise linear model of each diode.

Problem 4.8 COMBMAKER A **diode clipping circuit** is one that "clips" the tops and or bottoms of a signal. These circuits can be used to set a maximum or minimum voltage for a signal.

Consider the diode clipping circuit of figure 4.14. Source V_1 effectively adjusts the *maximum* possible load voltage v_{R_L}, and V_2 the *minimum*. Let $V_S(t) = 10\cos 4\pi t$, $V_1 = 5$ V, $V_2 = -3$ V, and $R_s = R_L = 50\ \Omega$. Solve for $v_{R_L}(t)$. Use the ideal diode model.

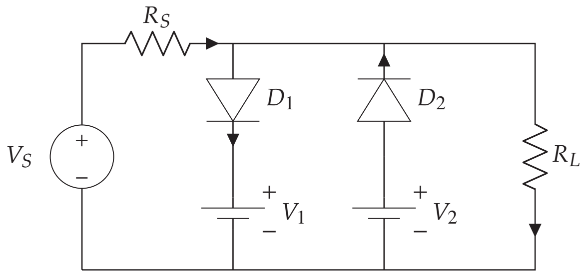


Figure 4.14. A diode clipping circuit for Exercise 4.8.

Problem 4.9 CLOISTERAL Repeat problem 4.8, but use the piecewise linear model of each diode.

Problem 4.10 DIASPORA For the circuit diagram of figure 4.15, solve for $v_o(t)$ if $V_s(t) = A$ for some given $A > 0.6$ V. Let $v_C(t)|_{t=0} = 0$ V be the initial condition. Use a piecewise linear model for the diode with some $R_d \in \mathbb{R}_{\geq 0}$. Do *not* estimate R_d.

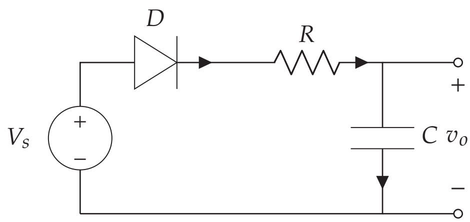


Figure 4.15. Circuit diagram for problem 4.10.

Problem 4.11 POROSITY For the circuit shown in figure 4.16, determine the voltage across the load v_{R_L} in terms of parameters and the gate voltage source voltage V_g and V_s. The parameters of the MOSFET are K and V_T. Assume MOSFET saturation operation.

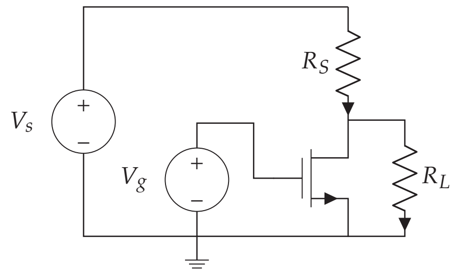


Figure 4.16. Circuit for Exercise 4.11.

Problem 4.12 OVERBROIL The opamp circuit of figure 4.17 is used as a voltage-controlled current source for the load R_L. Show that it behaves as a current source with current i_{R_L} controlled by voltage source v_i.

Use two separate methods: (a) assuming $v_+ \approx v_-$ and (b) not assuming $v_+ \approx v_-$, rather, assuming the open loop gain of the opamp A is large. Comment on the differences between the methods of (a) and (b).

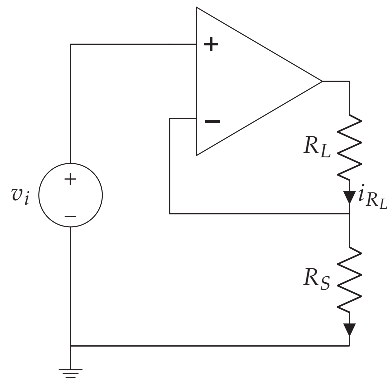


Figure 4.17. Circuit for Exercise 4.12.

Problem 4.13 POLYNUCLEATE Use the circuit diagram of figure 4.18 to answer the questions below. Use the sign convention from the diagram. Let $v_i = A\cos\omega t$ be an ac input voltage. The load Z_L impedance is not given.

(a) Write the elemental equations in terms of Z_{R_1}, Z_{R_2}, Z_{R_S} and Z_L (the impedances of the components).

(b) Write the KCL and KVL equations.

(c) Solve for the steady-state $v_o(t)$ *without inserting the values of the impedances* (that is, leave it in terms of Z_{R_1}, Z_{R_2}, Z_{R_S} and Z_L).

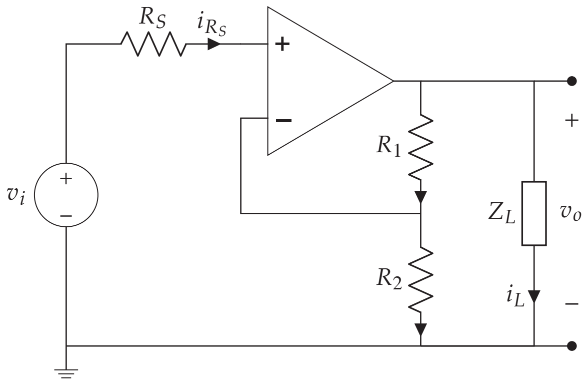


Figure 4.18. Circuit for Exercise 4.13.

Problem 4.14 ↻LUSH Consider the circuit in figure 4.19. Solve for $v_o(t)$ for input voltage $v_i(t) = 5$ V, a sine wave of $v_i(t) = 5\sin 25t$, and a sine wave of $v_i(t) = 5\sin 2525t$. Let $R_1 = 50\ \Omega$, $R_2 = 10\ \text{k}\Omega$, $C = 10\ \mu$F, and the opamp open-loop gain be $A = 10^5$. Let the initial condition be $v_C(t) = 0$ V. In each case, plot the solution to show the transient response until it reaches steady-state.

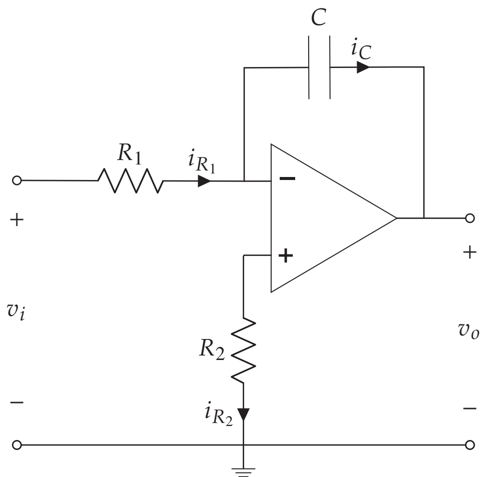


Figure 4.19. Opamp circuit for Exercise 4.14

Problem 4.15 HOGWASH Consider the circuit in figure 4.20. Solve for $v_o(t)$ for a known input voltage $v_i(t)$.

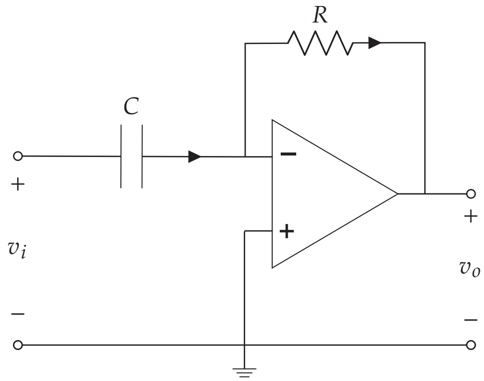


Figure 4.20. Opamp circuit for Exercise 4.15

Problem 4.16 VIRTUE In each of the figures of figure 4.21, solve for the voltage v_{100} across the 100 Ω resistor. Use the assumptions in the associated caption. Clearly justify each response.

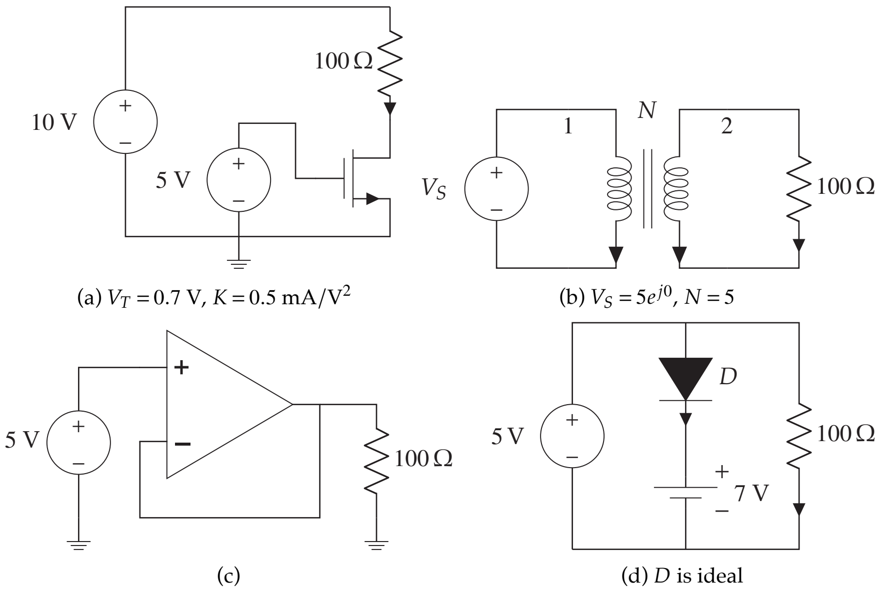
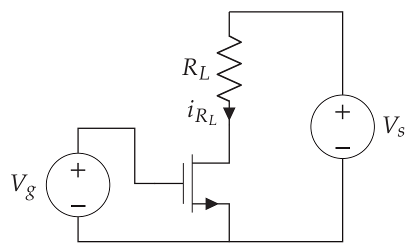
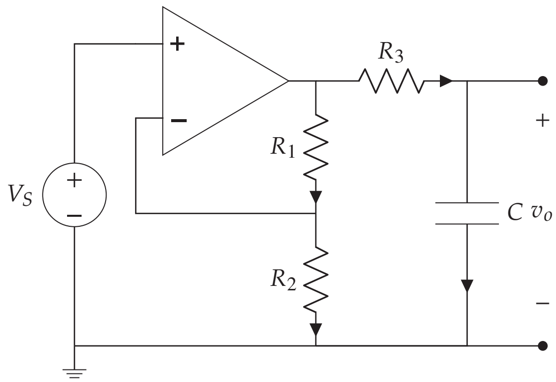


Figure 4.21. Circuits for problem 4.16.

Problem 4.17 NONABSTRACT Consider the circuit below with input voltage sources V_S and V_g. Determine V_g such that the load voltage $v_{R_L} = 10$ V. Let $R_L = 2$ kΩ, $K = 0.5$ mA/V^2, $V_T = 0.7$ V, $V_s = 20$ V.



Problem 4.18 EAR Consider the circuit below with input voltage source $V_S(t) = A$ where $A > 0$ is a known (but unspecified) constant. Perform a circuit analysis to solve for $v_o(t)$ for the initial condition $v_C(0) = 0$. Hint: it is easier if you realize the opamp output voltage is effectively an ideal voltage source (so it does *not depend* on v_{R_3} and v_C) and you can therefore treat the two parts of the circuit separately.



Problem 4.19 SATISFIED In each of the figures of figure 4.22, solve for the voltage v_{1k} across the 1 $k\Omega$ resistor. Use the assumptions in the associated caption. Clearly justify each response.

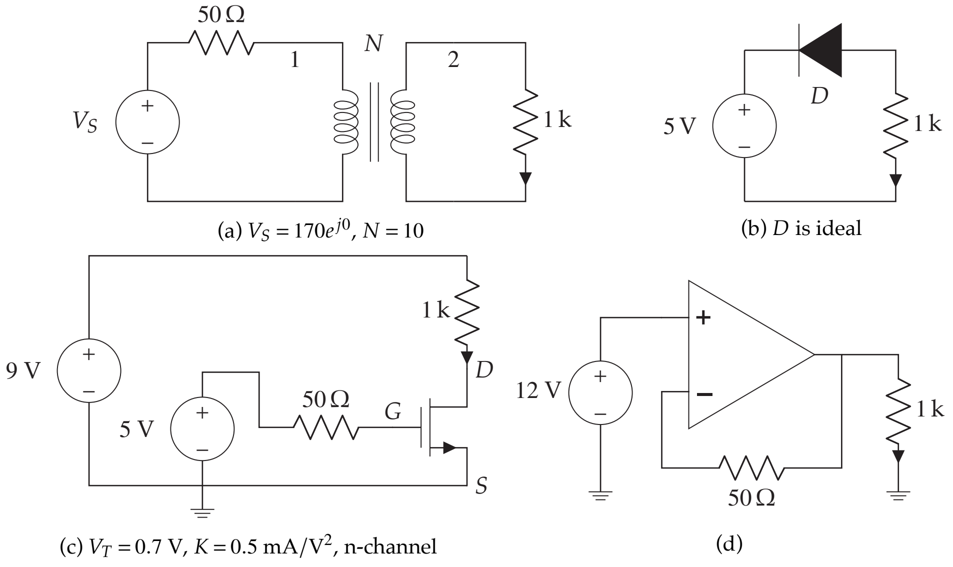


Figure 4.22. Circuits for problem 4.19.

Problem 4.20 HAUNT Write a one- or two-sentence response to each of the following questions and imperatives. The use of equations is acceptable when they appear in a sentence. Don't quote me (use your own words, other than technical terminology).

(a) Give an example of an application of a transformer and explain how the transformer functions for this application.
(b) Let the output current of a resistor circuit be 1 A and the equivalent resistance 100 Ω. What is the Norton equivalent circuit?
(c) In the preceding part of this question, what is the Thevenin equivalent?
(d) If a wire is connected between the terminals of a battery, what happens?

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