Problems

Section 5.2 Operational Amplifiers

5.1 The equivalent model of a certain op amp is shown in Fig. 5.43. Determine:

(a) the input resistance

(b) the output resistance

(c) the voltage gain in dB

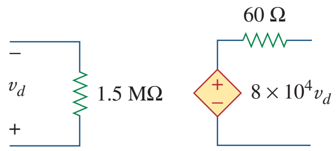


Figure 5.43
For Prob. 5.1.

5.2 The open-loop gain of an op amp is 100,000. Calculate the output voltage when there are inputs of $+10\ \mu$V on the inverting terminal and $+20\ \mu$V on the noninverting terminal.

5.3 Determine the output voltage when $-20\ \mu$V is applied to the inverting terminal of an op amp and $+30\ \mu$V to its noninverting terminal. Assume that the op amp has an open-loop gain of 200,000.

5.4 The output voltage of an op amp is -4 V when the noninverting input is 1 mV. If the open-loop gain of the op amp is 2×10^6, what is the inverting input?

5.5 For the op amp circuit of Fig. 5.44, the op amp has an open-loop gain of 100,000, an input resistance of 10 kΩ, and an output resistance of 100 Ω. Find the voltage gain v_o/v_i using the nonideal model of the op amp.

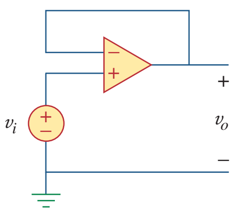


Figure 5.44
For Prob. 5.5.

5.6 Using the same parameters for the 741 op amp in Example 5.1, find v_o in the op amp circuit of Fig. 5.45.

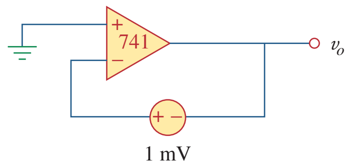


Figure 5.45
For Prob. 5.6.

5.7 The op amp in Fig. 5.46 has $R_i = 100$ kΩ, $R_o = 100\ \Omega$, $A = 100{,}000$. Find the differential voltage v_d and the output voltage v_o.

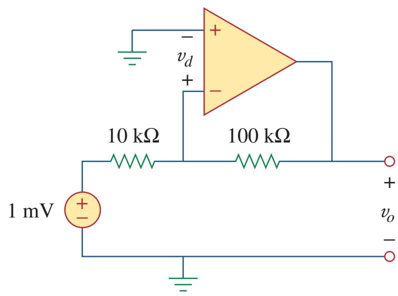


Figure 5.46
For Prob. 5.7.

Section 5.3 Ideal Op Amp

5.8 Obtain v_o for each of the op amp circuits in Fig. 5.47.

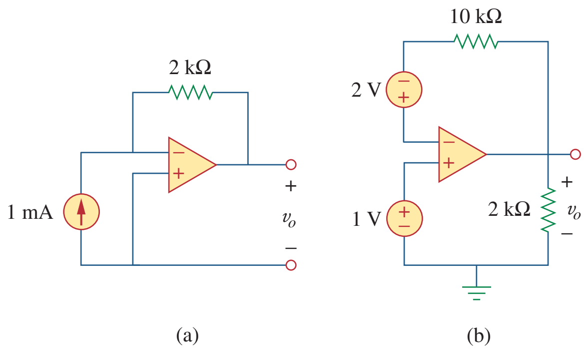


Figure 5.47
For Prob. 5.8.

5.9 Determine v_o for each of the op amp circuits in Fig. 5.48.

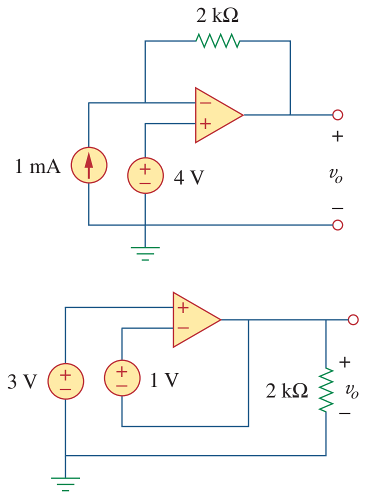


Figure 5.48
For Prob. 5.9.

5.10 Find the gain v_o/v_s of the circuit in Fig. 5.49.

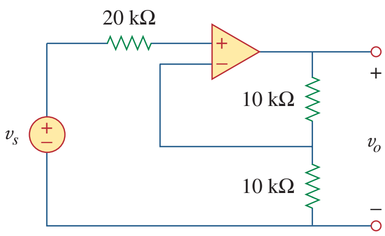


Figure 5.49
For Prob. 5.10.

5.11 Using Fig. 5.50, design a problem to help other students better understand how ideal op amps work.

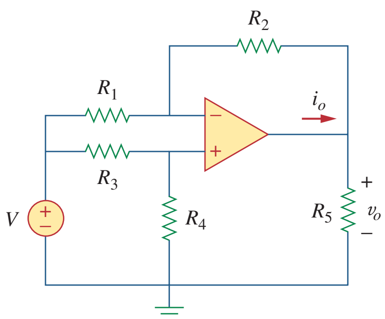


Figure 5.50
For Prob. 5.11.

5.12 Calculate the voltage ratio v_o/v_s for the op amp circuit of Fig. 5.51. Assume that the op amp is ideal.

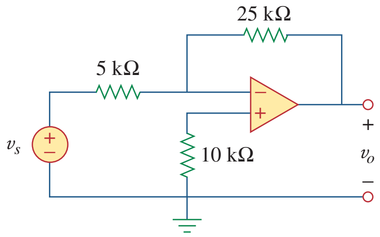


Figure 5.51
For Prob. 5.12.

5.13 Find v_o and i_o in the circuit of Fig. 5.52.

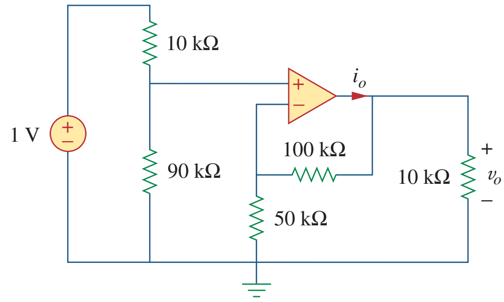


Figure 5.52
For Prob. 5.13.

5.14 Determine the output voltage v_o in the circuit of Fig. 5.53.

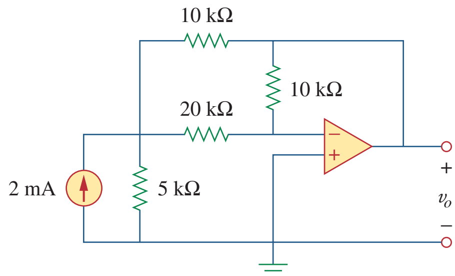


Figure 5.53
For Prob. 5.14.

Section 5.4 Inverting Amplifier

5.15 (a) Determine the ratio v_o/i_s in the op amp circuit of Fig. 5.54.

(b) Evaluate the ratio for $R_1 = 20$ kΩ, $R_2 = 25$ kΩ, $R_3 = 40$ kΩ.

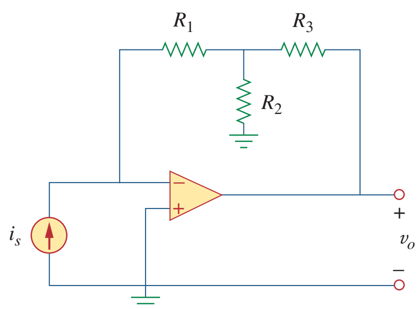


Figure 5.54
For Prob. 5.15.

5.16 Using Fig. 5.55, design a problem to help students better understand inverting op amps.

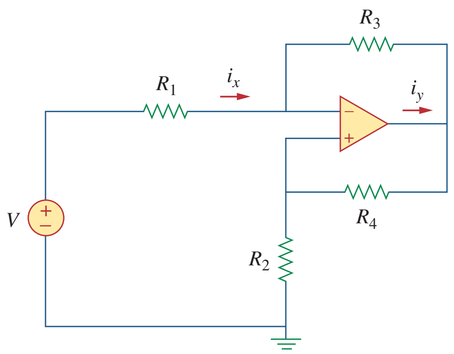


Figure 5.55
For Prob. 5.16.

5.17 Calculate the gain v_o/v_i when the switch in Fig. 5.56 is in:

(a) position 1 (b) position 2 (c) position 3.

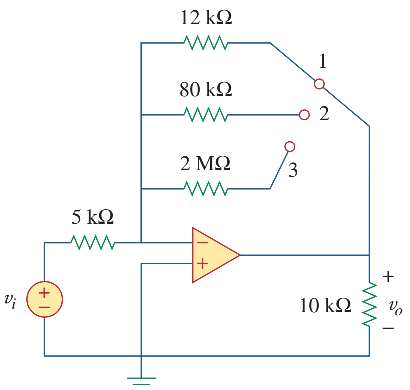


Figure 5.56
For Prob. 5.17.

***5.18** For the circuit shown in Figure 5.57, solve for the Thevenin equivalent circuit looking into terminals A and B.

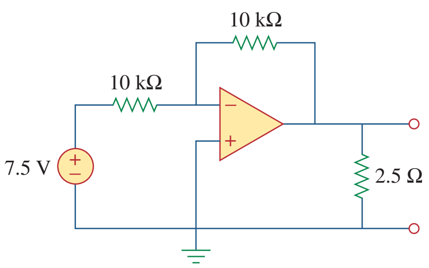


Figure 5.57
For Prob. 5.18.

5.19 Determine i_o in the circuit of Fig. 5.58.

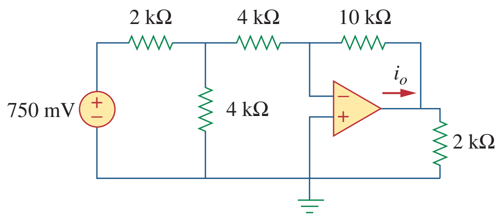


Figure 5.58
For Prob. 5.19.

5.20 In the circuit of Fig. 5.59, calculate v_o of $v_s = 2$ V.

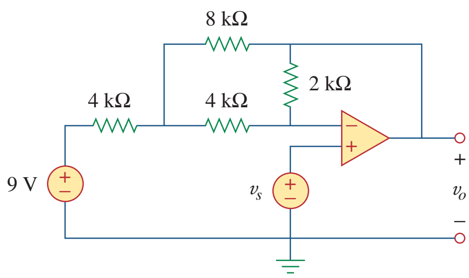


Figure 5.59
For Prob. 5.20.

5.21 Calculate v_o in the op amp circuit of Fig. 5.60.

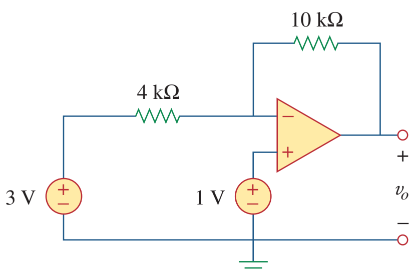


Figure 5.60
For Prob. 5.21.

5.22 Design an inverting amplifier with a gain of -15.

5.23 For the op amp circuit in Fig. 5.61, find the voltage gain v_o/v_s.

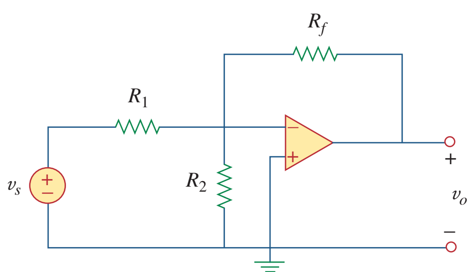


Figure 5.61
For Prob. 5.23.

* An asterisk indicates a challenging problem.

5.24 In the circuit shown in Fig. 5.62, find k in the voltage transfer function $v_o = kv_s$.

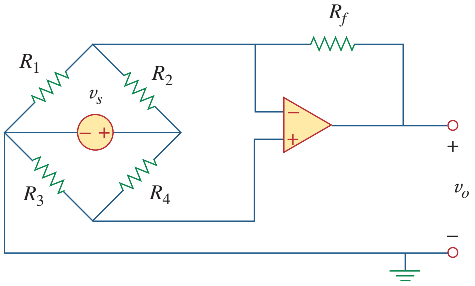


Figure 5.62
For Prob. 5.24.

Section 5.5 Noninverting Amplifier

5.25 Calculate v_o in the op amp circuit of Fig. 5.63.

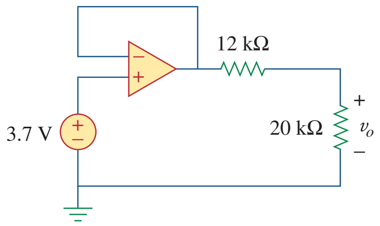


Figure 5.63
For Prob. 5.25.

5.26 Using Fig. 5.64, design a problem to help other students better understand noninverting op amps.

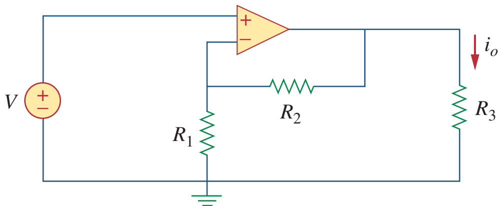


Figure 5.64
For Prob. 5.26.

5.27 Find v_o in the op amp circuit of Fig. 5.65.

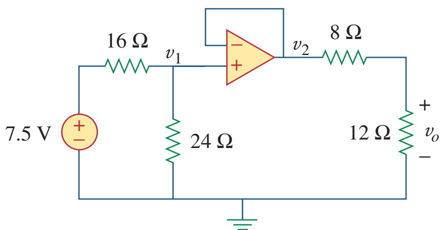


Figure 5.65
For Prob. 5.27.

5.28 Find i_o in the op amp circuit of Fig. 5.66.

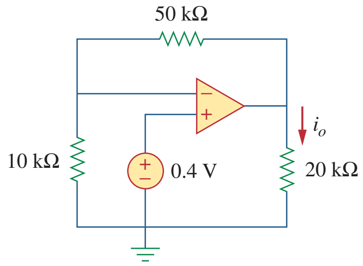


Figure 5.66
For Prob. 5.28.

5.29 Determine the voltage gain v_o/v_i of the op amp circuit in Fig. 5.67.

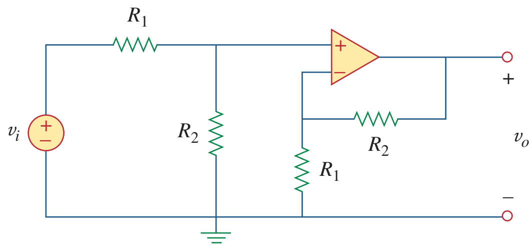


Figure 5.67
For Prob. 5.29.

5.30 In the circuit shown in Fig. 5.68, find i_x and the power absorbed by the 20-kΩ resistor.

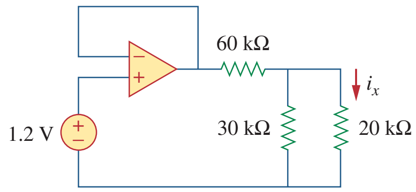


Figure 5.68
For Prob. 5.30.

5.31 For the circuit in Fig. 5.69, find i_x.

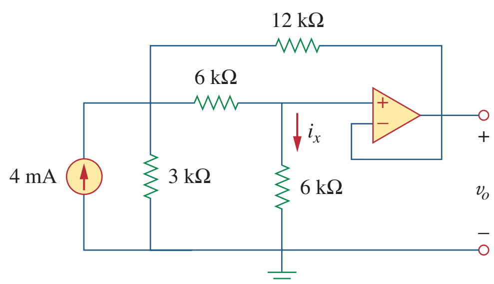


Figure 5.69
For Prob. 5.31.

5.32 Calculate i_x and v_o in the circuit of Fig. 5.70. Find the power dissipated by the 60-kΩ resistor.

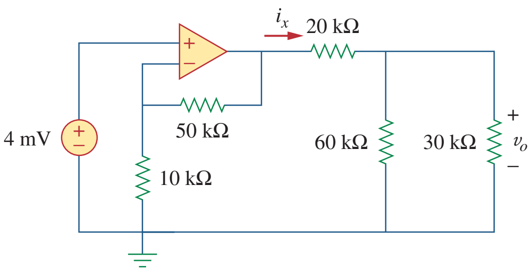


Figure 5.70
For Prob. 5.32.

5.33 Refer to the op amp circuit in Fig. 5.71. Calculate i_x and the power absorbed by the 3-kΩ resistor.

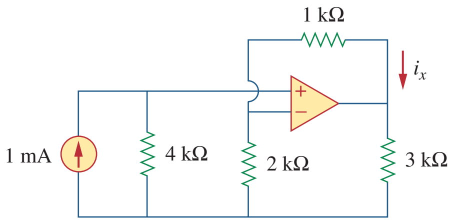


Figure 5.71
For Prob. 5.33.

5.34 Given the op amp circuit shown in Fig. 5.72, express v_o in terms of v_1 and v_2.

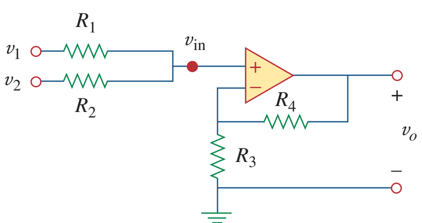


Figure 5.72
For Prob. 5.34.

5.35 Design a noninverting amplifier with a gain of 7.5.

5.36 For the circuit shown in Fig. 5.73, find the Thevenin equivalent at terminals *a-b*. (*Hint:* To find R_{Th}, apply a current source i_o and calculate v_o.)

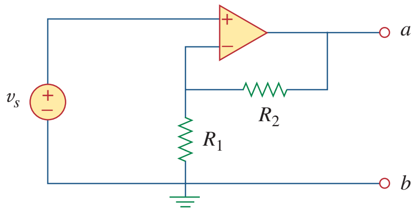


Figure 5.73
For Prob. 5.36.

Section 5.6 Summing Amplifier

5.37 Determine the output of the summing amplifier in Fig. 5.74.

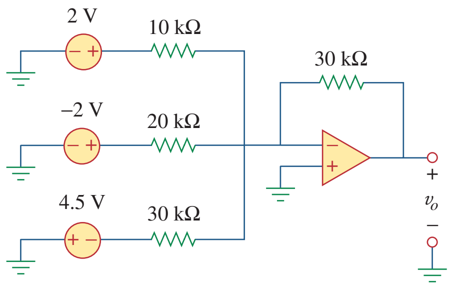


Figure 5.74
For Prob. 5.37.

5.38 Using Fig. 5.75, design a problem to help other students better understand summing amplifiers.

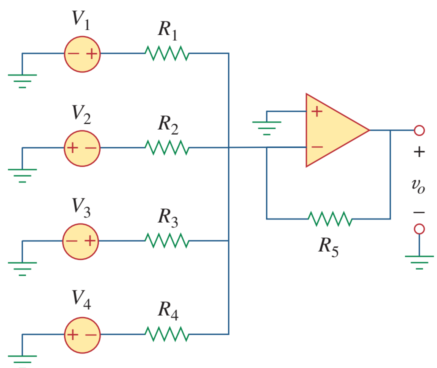


Figure 5.75
For Prob. 5.38.

5.39 For the op amp circuit in Fig. 5.76, determine the value of v_2 in order to make $v_o = -16.5$ V.

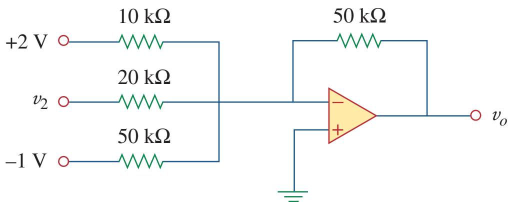


Figure 5.76
For Prob. 5.39.

5.40 Referring to the circuit shown in Fig. 5.77, determine V_o in terms of V_1 and V_2.

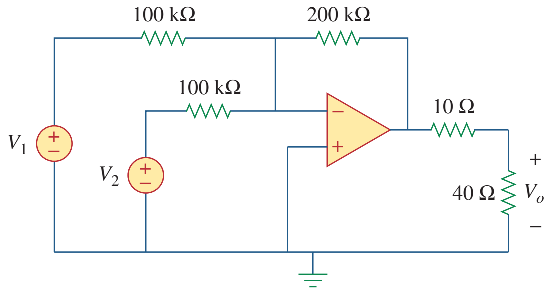


Figure 5.77
For Prob. 5.40.

5.41 An *averaging amplifier* is a summer that provides an output equal to the average of the inputs. By using proper input and feedback resistor values, one can get

$$-v_{\text{out}} = \tfrac{1}{4}(v_1 + v_2 + v_3 + v_4)$$

Using a feedback resistor of 10 kΩ, design an averaging amplifier with four inputs.

5.42 A three-input summing amplifier has input resistors with $R_1 = R_2 = R_3 = 75$ kΩ. To produce an averaging amplifier, what value of feedback resistor is needed?

5.43 A four-input summing amplifier has $R_1 = R_2 = R_3 = R_4 = 80$ kΩ. What value of feedback resistor is needed to make it an averaging amplifier?

5.44 Show that the output voltage v_o of the circuit in Fig. 5.78 is

$$v_o = \frac{(R_3 + R_4)}{R_3(R_1 + R_2)}(R_2 v_1 + R_1 v_2)$$

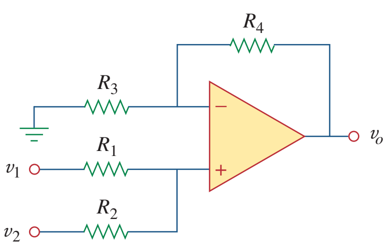


Figure 5.78
For Prob. 5.44.

5.45 Design an op amp circuit to perform the following operation:

$$v_o = 3v_1 - 2v_2$$

All resistances must be ≤ 100 kΩ.

5.46 Using only two op amps, design a circuit to solve

$$-v_{\text{out}} = \frac{v_1 - v_2}{3} + \frac{v_3}{2}$$

Section 5.7 Difference Amplifier

5.47 The circuit in Fig. 5.79 is for a difference amplifier. Find v_o given that $v_1 = 1$ V and $v_2 = 2$ V.

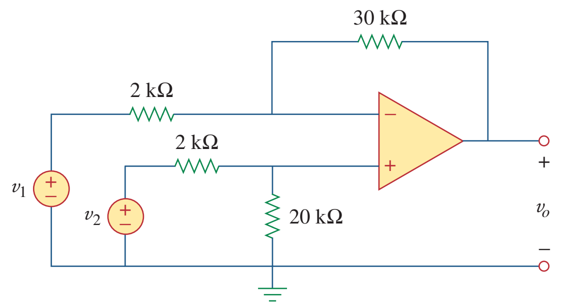


Figure 5.79
For Prob. 5.47.

5.48 The circuit in Fig. 5.80 is a differential amplifier driven by a bridge. Find v_o.

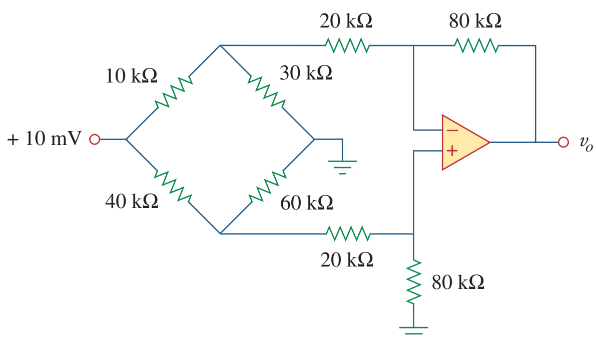


Figure 5.80
For Prob. 5.48.

5.49 Design a difference amplifier to have a gain of 4 and a common-mode input resistance of 20 kΩ at each input.

5.50 Design a circuit to amplify the difference between two inputs by 2.5.

(a) Use only one op amp.

(b) Use two op amps.

5.51 Using two op amps, design a subtractor.
ed

***5.52** Design an op amp circuit such that
ed

$$v_o = 4v_1 + 6v_2 - 3v_3 - 5v_4$$

Let all the resistors be in the range of 20 to 200 kΩ.

***5.53** The ordinary difference amplifier for fixed-gain operation is shown in Fig. 5.81(a). It is simple and reliable unless gain is made variable. One way of providing gain adjustment without losing simplicity and accuracy is to use the circuit in Fig. 5.81(b). Another way is to use the circuit in Fig. 5.81(c). Show that:

(a) for the circuit in Fig. 5.81(a),

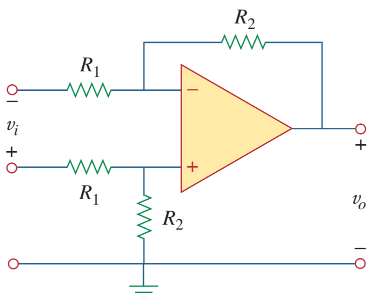
$$\frac{v_o}{v_i} = \frac{R_2}{R_1}$$

(b) for the circuit in Fig. 5.81(b),

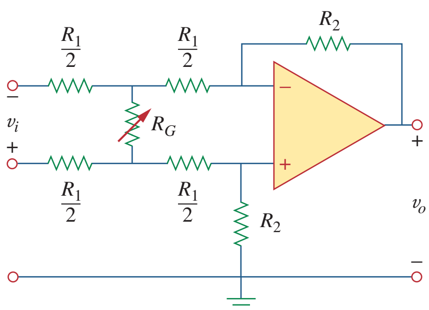
$$\frac{v_o}{v_i} = \frac{R_2}{R_1}\frac{1}{1 + \dfrac{R_1}{2R_G}}$$

(c) for the circuit in Fig. 5.81(c),

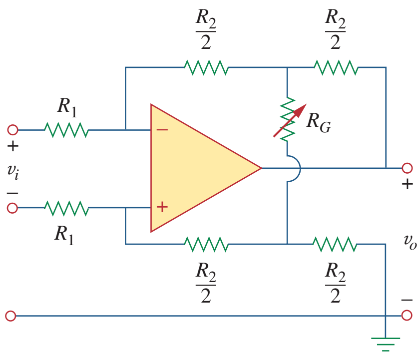
$$\frac{v_o}{v_i} = \frac{R_2}{R_1}\left(1 + \frac{R_2}{2R_G}\right)$$



(a)



(b)



(c)

Figure 5.81
For Prob. 5.53.

Section 5.8 Cascaded Op Amp Circuits

5.54 Determine the voltage transfer ratio v_o/v_s in the op amp circuit of Fig. 5.82, where R = 10 kΩ.

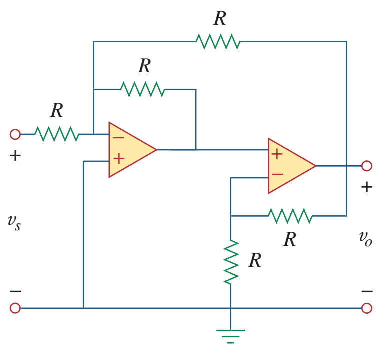


Figure 5.82
For Prob. 5.54.

5.55 In a certain electronic device, a three-stage amplifier is desired, whose overall voltage gain is 42 dB. The individual voltage gains of the first two stages are to be equal, while the gain of the third is to be one-fourth of each of the first two. Calculate the voltage gain of each.

5.56 Using Fig. 5.83, design a problem to help other students better understand cascaded op amps.
ed

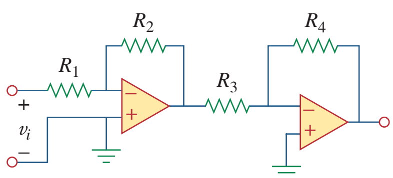


Figure 5.83
For Prob. 5.56.