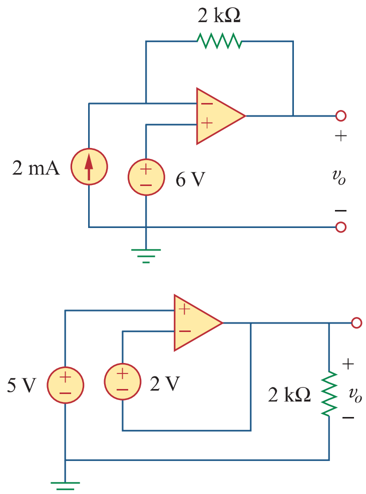

Figure 5.48
For Prob. 5.9.

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

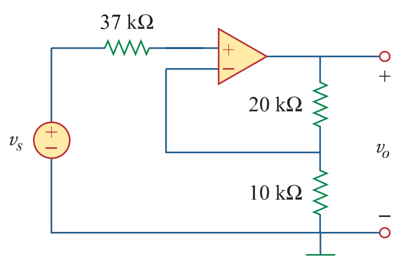

Figure 5.49
For Prob. 5.10.

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

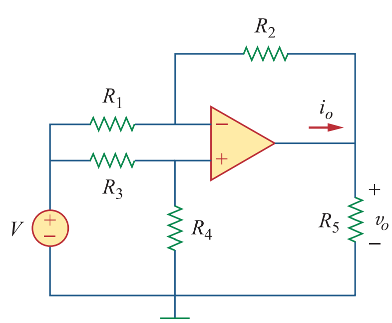

Figure 5.50
For Prob. 5.11.

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.

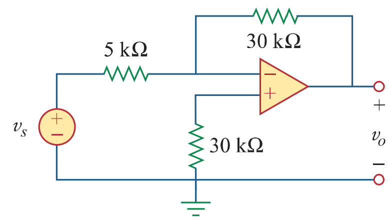

Figure 5.51
For Prob. 5.12.

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

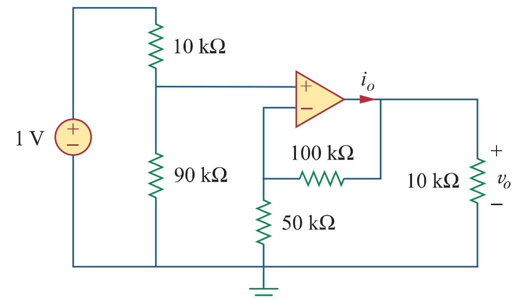

Figure 5.52
For Prob. 5.13.

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

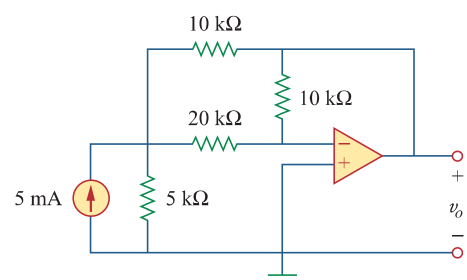

Figure 5.53
For Prob. 5.14.

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.

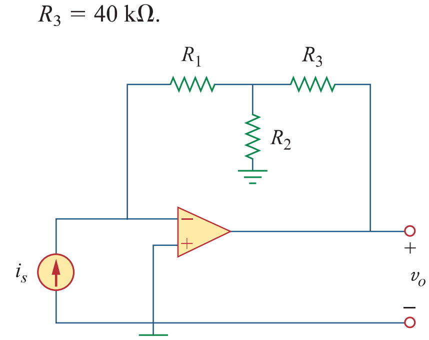

Figure 5.54
For Prob. 5.15.

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

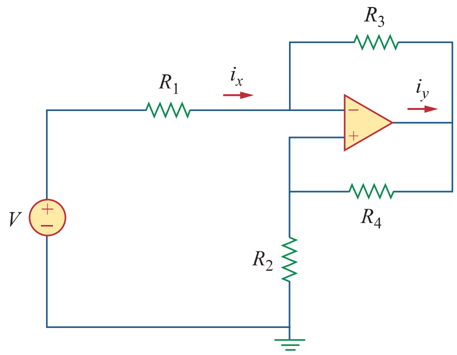

Figure 5.55
For Prob. 5.16.

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

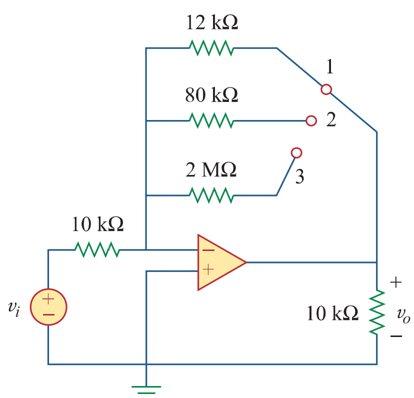

Figure 5.56
For Prob. 5.17.

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

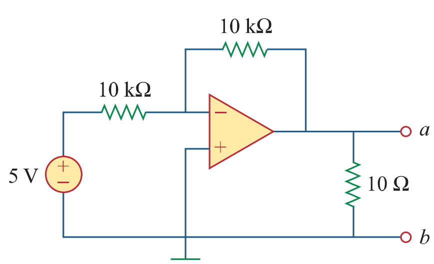

Figure 5.57
For Prob. 5.18.

5.19 Determine i_o in the circuit of Fig. 5.58.

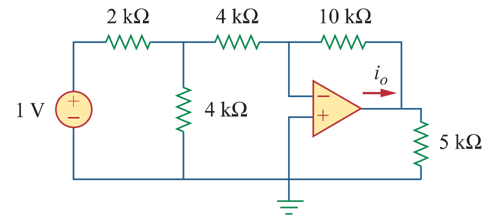

Figure 5.58
For Prob. 5.19.

5.20 In the circuit of Fig. 5.59, calculate v_o of $v_s = 0$.

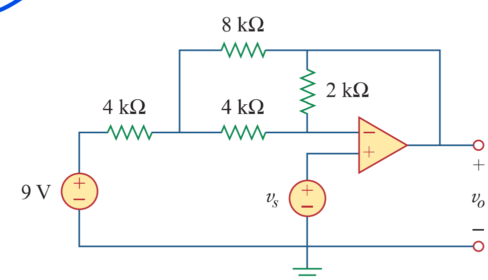

Figure 5.59
For Prob. 5.20.

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

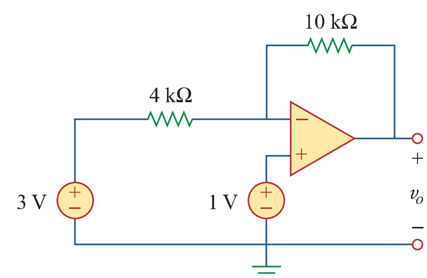

Figure 5.60
For Prob. 5.21.

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.

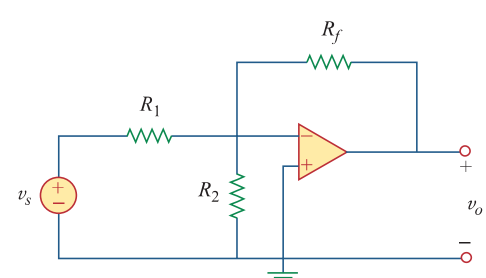

Figure 5.61
For Prob. 5.23.

* An asterisk indicates a challenging problem.

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

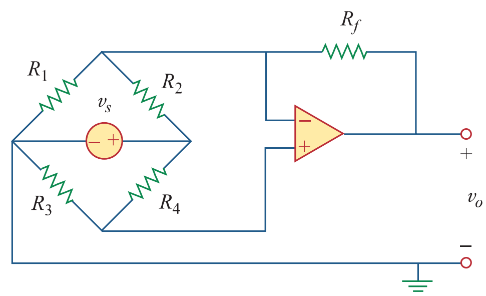

Figure 5.62
For Prob. 5.24.

Section 5.5 Noninverting Amplifier

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

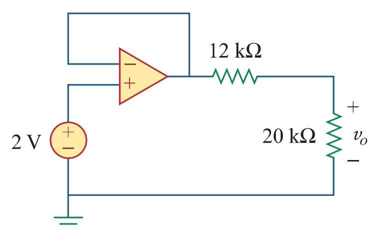

Figure 5.63
For Prob. 5.25.

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

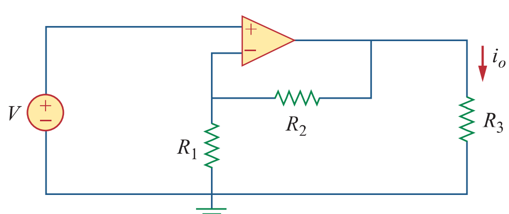

Figure 5.64
For Prob. 5.26.

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

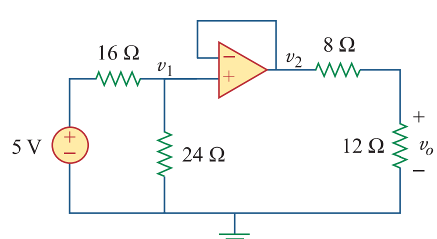

Figure 5.65
For Prob. 5.27.

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

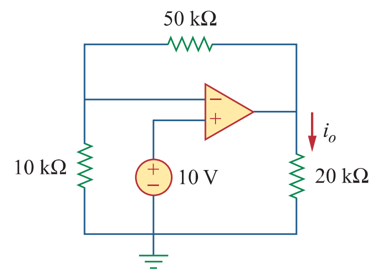

Figure 5.66
For Prob. 5.28.

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

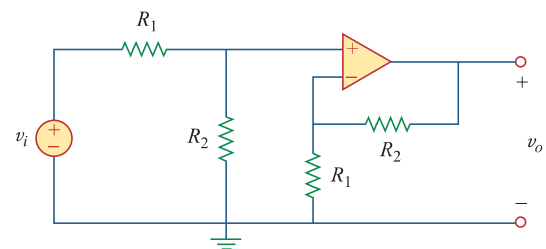

Figure 5.67
For Prob. 5.29.

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

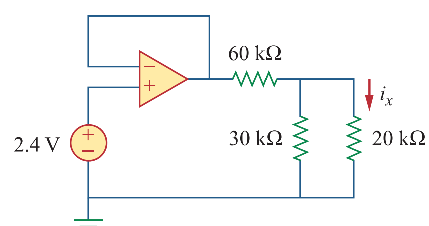

Figure 5.68
For Prob. 5.30.

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

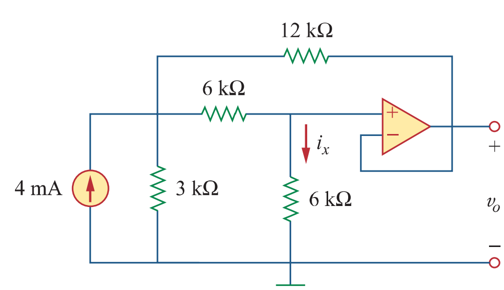

Figure 5.69
For Prob. 5.31.

5.32 Calculate i_x and v_o in the circuit of Fig. 5.70. Find the power dissipated by the 30-kΩ resistor.

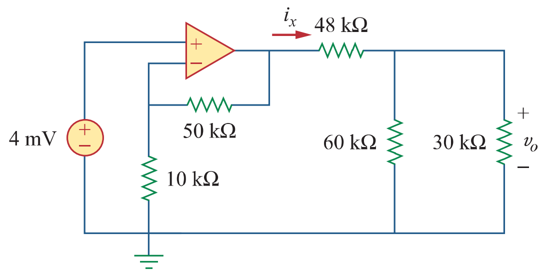

Figure 5.70
For Prob. 5.32.

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

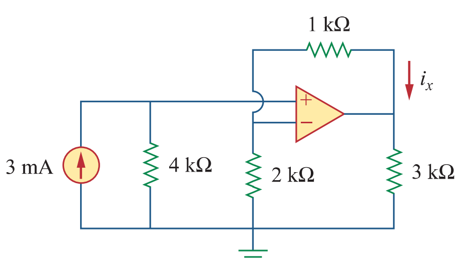

Figure 5.71
For Prob. 5.33.

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

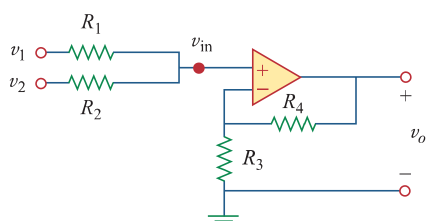

Figure 5.72
For Prob. 5.34.

5.35 Design a noninverting amplifier with a gain of 10.
e2d

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.)

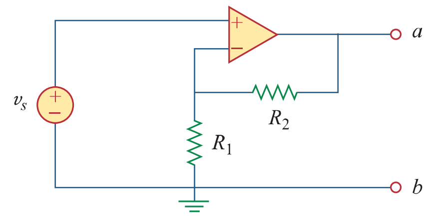

Figure 5.73
For Prob. 5.36.

Section 5.6 Summing Amplifier

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

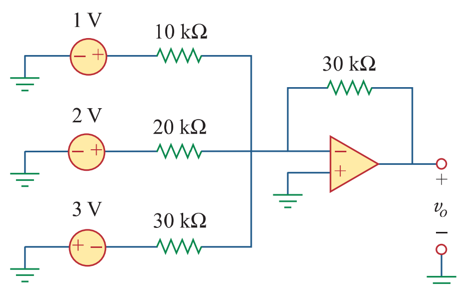

Figure 5.74
For Prob. 5.37.

5.38 Using Fig. 5.75, design a problem to help other students better understand summing amplifiers.
e2d

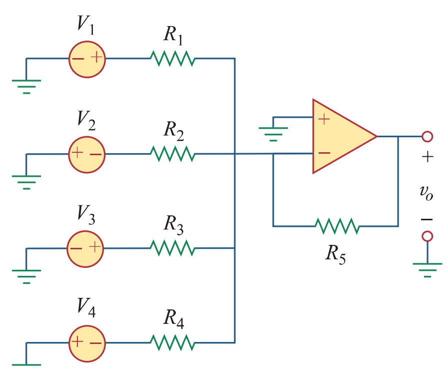

Figure 5.75
For Prob. 5.38.

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.

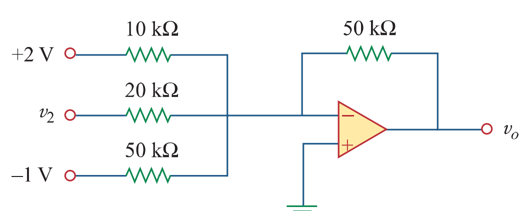

Figure 5.76
For Prob. 5.39.

5.40 Find v_o in terms of v_1, v_2, and v_3 in the circuit of Fig. 5.77.

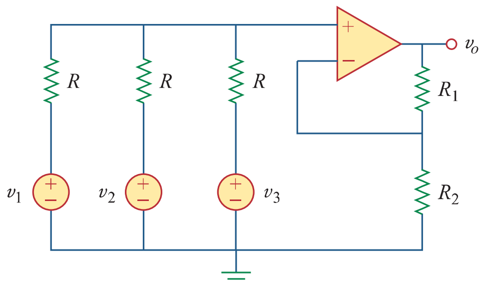

Figure 5.77
For Prob. 5.40.

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

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

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 $R_1 = R_2 = R_3 = 30$ kΩ. To produce an averaging amplifier, what value of feedback resistor is needed?

5.43 A four-input summing amplifier has $R_1 = R_2 = R_3 = R_4 = 12$ 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

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

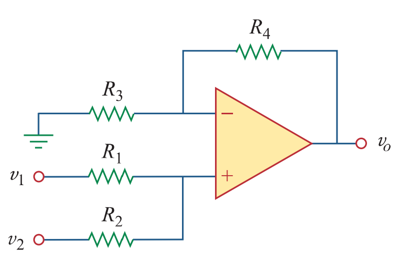

Figure 5.78
For Prob. 5.44.

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

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

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.

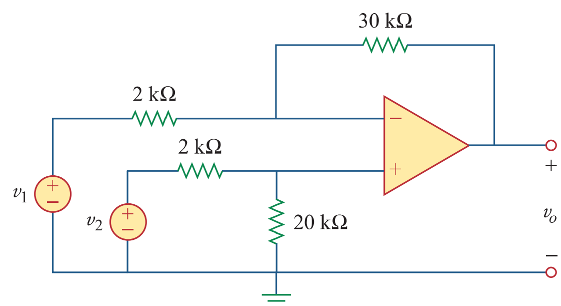

Figure 5.79
For Prob. 5.47.

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

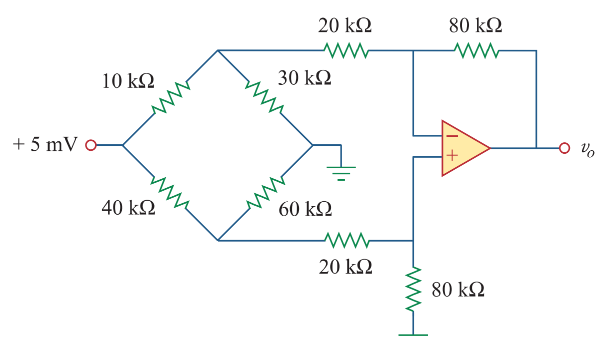

Figure 5.80
For Prob. 5.48.

5.49 Design a difference amplifier to have a gain of 2 and a common-mode input resistance of 10 kΩ at each input.

5.50 Design a circuit to amplify the difference between two inputs by 2.

(a) Use only one op amp.

(b) Use two op amps.