2. **Symptom:** The ammeter reading is zero, and all the voltmeter readings are zero.
   **Cause:**
   (a) A resistor is open.
   (b) The voltage source is turned off or faulty.
   (c) One of the resistor values is too high.

3. **Symptom:** The ammeter reading is 2.33 mA, and the voltmeter 2 reading is zero.
   **Cause:**
   (a) $R_1$ is shorted.
   (b) The voltage source is set too high.
   (c) $R_2$ is shorted.

4. **Symptom:** The ammeter reading is 0, voltmeter 1 reads 0 V, voltmeter 2 reads 5 V, and voltmeter 3 reads 5 V.
   **Cause:**
   (a) $R_1$ is shorted.
   (b) $R_1$ and $R_2$ are open.
   (c) $R_2$ and $R_3$ are open.

5. **Symptom:** The ammeter reading is 0.645 mA, the voltmeter 1 reading is too high, and the other two voltmeter readings are too low.
   **Cause:**
   (a) $R_1$ has an incorrect value of 10 kΩ.
   (b) $R_2$ has an incorrect value of 10 kΩ.
   (c) $R_3$ has an incorrect value of 10 kΩ.

### PROBLEMS
Answers to odd-numbered problems are at the end of the book.

#### BASIC PROBLEMS

**SECTION 4–1**  **Resistors in Series**

1. Connect each set of resistors in Figure 4–64 in series between points A and B.
2. Determine which resistors in Figure 4–65 are in series. Show how to interconnect the pins to put all the resistors in series.
3. Determine the resistance between pins 1 and 8 in the circuit board in Figure 4–65.
4. Determine the resistance between pins 2 and 3 in the circuit board in Figure 4–65.

![Figure 4–65](image)

SECTION 4–2 Total Series Resistance

5. An 82 Ω resistor and a 56 Ω resistor are connected in series. What is the total resistance?
6. Find the total resistance of each group of series resistors shown in Figure 4–66.

![Figure 4–66](image)

7. Determine $R_T$ for each circuit in Figure 4–67. Show how to measure $R_T$ with an ohmmeter.

![Figure 4–67](image)
8. What is the total resistance of twelve 5.6 kΩ resistors in series?

9. Six 47 Ω resistors, eight 100 Ω resistors, and two 22 Ω resistors are in series. What is the total resistance?

10. The total resistance in Figure 4–68 is 20 kΩ. What is the value of $R_5$?

![Figure 4–68](image)

11. Determine the resistance between each of the following sets of pins on the PC board in Figure 4–65.
   (a) pin 1 and pin 8   (b) pin 2 and pin 3
   (c) pin 4 and pin 7   (d) pin 5 and pin 6

12. If all the resistors in Figure 4–65 are connected in series, what is the total resistance?

SECTION 4–3 Current in a Series Circuit

13. What is the current through each of four resistors in a series circuit if the source voltage is 12 V and the total resistance is 120 Ω?

14. The current from the source in Figure 4–69 is 5 mA. How much current does each milliammeter in the circuit indicate?

![Figure 4–69](image)

SECTION 4–4 Application of Ohm’s Law

15. What is the current in each circuit of Figure 4–70? Show how to connect an ammeter in each case.

![Figure 4–70](image)

16. Determine the voltage across each resistor in Figure 4–70.

17. Three 470 Ω resistors are in series with a 48 V source.
   (a) How much current is there?
   (b) What is the voltage across each resistor?
   (c) What is the minimum power rating of the resistors?

18. Four equal-value resistors are in series with a 5 V source, and a current of 1 mA is measured. What is the value of each resistor?
SECTION 4-5 Voltage Sources in Series
19. Show how to connect four 6 V batteries to achieve a voltage of 24 V.
20. What happens if one of the batteries in Problem 19 is accidentally connected in reverse?

SECTION 4-6 Kirchhoff's Voltage Law
21. The following voltage drops are measured across each of three resistors in series: 5.5 V, 8.2 V, and 12.3 V. What is the value of the source voltage to which these resistors are connected?
22. Five resistors are in series with a 20 V source. The voltage drops across four of the resistors are 1.5 V, 5.5 V, 3 V, and 6 V. How much voltage is across the fifth resistor?
23. Determine the unspecified voltage drop(s) in each circuit of Figure 4-71. Show how to connect a voltmeter to measure each unknown voltage drop.

![Figure 4-71]

SECTION 4-7 Voltage Dividers
24. The total resistance of a series circuit is 500 Ω. What percentage of the total voltage appears across a 22 Ω resistor in the series circuit?
25. Find the voltage between A and B in each voltage divider of Figure 4-72.

![Figure 4-72]

26. Determine the voltage with respect to ground for output A, B, and C in Figure 4-73(a).
27. Determine the minimum and maximum output voltage from the voltage divider in Figure 4-73(b).
28. What is the voltage across each resistor in Figure 4–74? R is the lowest value and all others are multiples of that value as indicated.

![Figure 4–74](image)

29. What is the voltage across each resistor on the protoboard in Figure 4–75(b)?

![Figure 4–75](image)

(a) Meter with leads going to protoboard

(b) Protoboard with meter leads (yellow and green) and power supply leads (red and black) connected

SECTION 4–8 Power in Series Circuits

30. Five series resistors each dissipate 50 mW of power. What is the total power?

31. Find the total power in Figure 4–75.

SECTION 4–9 Voltage Measurements

32. Determine the voltage at each point with respect to ground in Figure 4–76.

![Figure 4–76](image)
42. Find all the unknown quantities (shown in red) in Figure 4–82.

43. There are 250 mA in a series circuit with a total resistance of 1.5 kΩ. The current must be reduced by 25%. Determine how much resistance must be added in order to accomplish this reduction in current.

44. Four ½ W resistors are in series: 47 Ω, 68 Ω, 100 Ω, and 120 Ω. To what maximum value can the current be raised before the power rating of one of the resistors is exceeded? Which resistor will burn out first if the current is increased above the maximum?

45. A certain series circuit is made up of a ½ W resistor, a ¼ W resistor, and a ½ W resistor. The total resistance is 2400 Ω. If each of the resistors is operating at its maximum power level, determine the following:
   (a) $I$  (b) $V_5$  (c) the value of each resistor

46. Using 1.5 V batteries, a switch, and three lamps, devise a circuit to apply 4.5 V across one lamp, two lamps in series, or three lamps in series with a single control switch. Draw the schematic.

47. Develop a variable voltage divider to provide output voltages ranging from a minimum of 10 V to a maximum of 100 V using a 120 V source. The maximum voltage must be at the maximum resistance setting of the potentiometer. The minimum voltage must be at the minimum resistance (zero ohms) setting. The current is to be 10 mA.

48. Using the standard resistor values given in Appendix A, design a voltage divider to provide the following approximate voltages with respect to the negative terminal of a 30 V source: 8.18 V, 14.7 V, and 24.6 V. The current drain on the source must be limited to no more than 1 mA. The number of resistors, their resistance values, and their power ratings must be specified. Draw a schematic showing the circuit with all resistor values indicated.

49. On the double-sided PC board in Figure 4–83, identify each group of series resistors and determine its total resistance. Note that many of the interconnections feed through the board from the top side to the bottom side.
50. What is the total resistance from A to B for each switch position in Figure 4–84?

![Figure 4–84](image)

51. Determine the current measured by the meter in Figure 4–85 for each switch position.

![Figure 4–85](image)

52. Determine the current measured by the meter in Figure 4–86 for each position of the ganged switch.

![Figure 4–86](image)

53. Determine the voltage across each resistor in Figure 4–87 for each switch position if the current through R5 is 6 mA when the switch is in the D position.

![Figure 4–87](image)