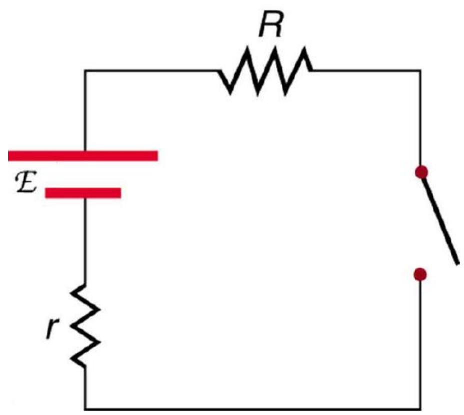
21.E: Circuits and DC Instruments (Exercise)

Conceptual Questions

21.1: Resistors in Series and Parallel

1. A switch has a variable resistance that is nearly zero when closed and extremely large when open, and it is placed in series with the device it controls. Explain the effect the switch in Figure has on current when open and when closed.



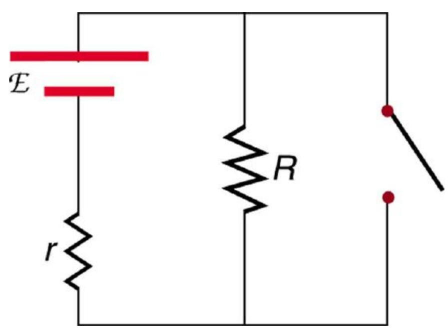
A switch is ordinarily in series with a resistance and voltage source. Ideally, the switch has nearly zero resistance when closed but has an extremely large resistance when open. (Note that in this diagram, the script E represents the voltage (or electromotive force) of the battery.)

2. What is the voltage across the open switch in Figure?

3. There is a voltage across an open switch, such as in Figure. Why, then, is the power dissipated by the open switch small?

4. Why is the power dissipated by a closed switch, such as in Figure, small?

5. A student in a physics lab mistakenly wired a light bulb, battery, and switch as shown in Figure. Explain why the bulb is on when the switch is open, and off when the switch is closed. (Do not try this—it is hard on the battery!)



A wiring mistake put this switch in parallel with the device represented by R. (Note that in this diagram, the script E represents the voltage (or electromotive force) of the battery.)

6. Knowing that the severity of a shock depends on the magnitude of the current through your body, would you prefer to be in series or parallel with a resistance, such as the heating element of a toaster, if shocked by it? Explain.

7. Would your headlights dim when you start your car's engine if the wires in your automobile were superconductors? (Do not neglect the battery's internal resistance.) Explain.

8. Some strings of holiday lights are wired in series to save wiring costs. An old version utilized bulbs that break the electrical connection, like an open switch, when they burn out. If one such bulb burns out, what happens to the others? If such a string operates on 120 V and has 40 identical bulbs, what is the normal operating voltage of each? Newer versions use bulbs that short circuit, like a closed switch, when they burn out. If one such bulb burns out, what happens to the others? If such a string operates on 120 V and has 39 remaining identical bulbs, what is then the operating voltage of each?

9. If two household lightbulbs rated 60 W and 100 W are connected in series to household power, which will be brighter? Explain.

10. Suppose you are doing a physics lab that asks you to put a resistor into a circuit, but all the resistors supplied have a larger resistance than the requested value. How would you connect the available resistances to attempt to get the smaller value asked for?

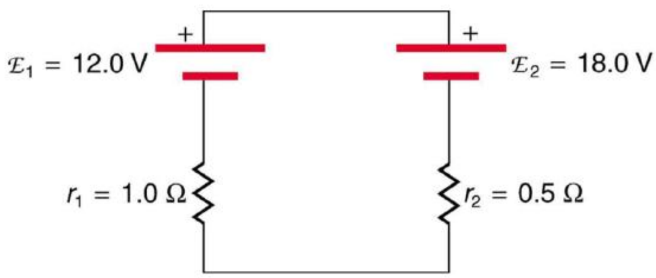
11. Before World War II, some radios got power through a "resistance cord" that had a significant resistance. Such a resistance cord reduces the voltage to a desired level for the radio's tubes and the like, and it saves the expense of a transformer. Explain why resistance cords become warm and waste energy when the radio is on.

12. Some light bulbs have three power settings (not including zero), obtained from multiple filaments that are individually switched and wired in parallel. What is the minimum number of filaments needed for three power settings?

21.2: Electromotive Force: Terminal Voltage

13. Is every emf a potential difference? Is every potential difference an emf? Explain.

14. Explain which battery is doing the charging and which is being charged in Figure.



15. Given a battery, an assortment of resistors, and a variety of voltage and current measuring devices, describe how you would determine the internal resistance of the battery.

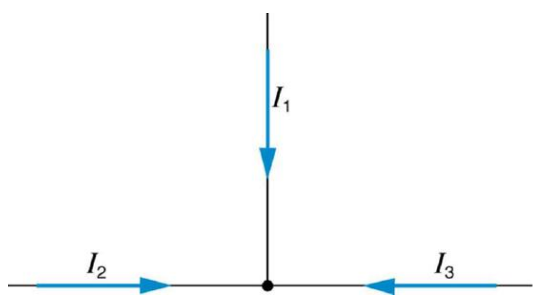
16. Two different 12-V automobile batteries on a store shelf are rated at 600 and 850 "cold cranking amps." Which has the smallest internal resistance?

17. What are the advantages and disadvantages of connecting batteries in series? In parallel?

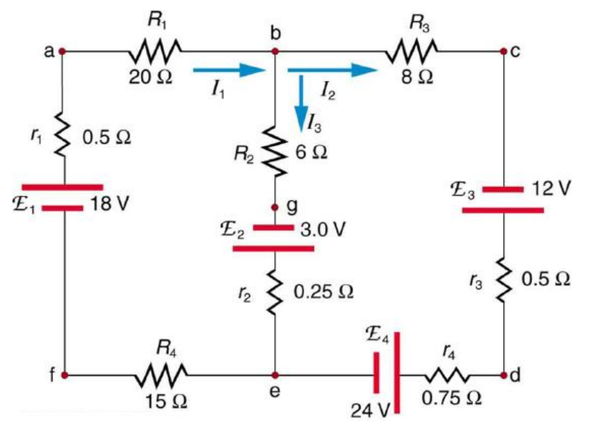
18. Semitractor trucks use four large 12-V batteries. The starter system requires 24 V, while normal operation of the truck's other electrical components utilizes 12 V. How could the four batteries be connected to produce 24 V? To produce 12 V? Why is 24 V better than 12 V for starting the truck's engine (a very heavy load)?

21.3: Kirchhoff's Rules

19. Can all of the currents going into the junction in Figure be positive? Explain.



20. Apply the junction rule to junction b in Figure. Is any new information gained by applying the junction rule at e? (In the figure, each emf is represented by script E.)



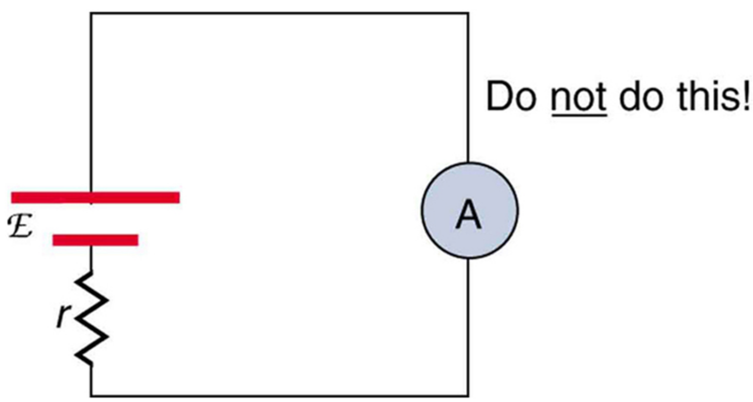
21. (a) What is the potential difference going from point a to point b in Figure? (b) What is the potential difference going from c to b? (c) From e to g? (d) From e to d?

22. Apply the loop rule to loop afedcba in Figure.

23. Apply the loop rule to loops abgefa and cbgedc in Figure.

21.4: DC Voltmeters and Ammeters

24. Why should you not connect an ammeter directly across a voltage source as shown in Figure? (Note that script E in the figure stands for emf.)



25. Suppose you are using a multimeter (one designed to measure a range of voltages, currents, and resistances) to measure current in a circuit and you inadvertently leave it in a voltmeter mode. What effect will the meter have on the circuit? What would happen if you were measuring voltage but accidentally put the meter in the ammeter mode?

26. Specify the points to which you could connect a voltmeter to measure the following potential differences in Figure:

(a) the potential difference of the voltage source;

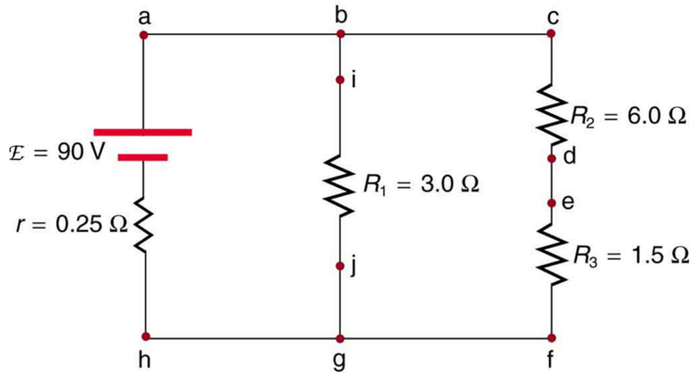
(b) the potential difference across R_1;

(c) across R_2;

(d) across R_3;

(e) across R_2 and R_3.

Note that there may be more than one answer to each part.



27. To measure currents in Figure, you would replace a wire between two points with an ammeter. Specify the points between which you would place an ammeter to measure the following:

(a) the total current;

(b) the current flowing through R_1;

(c) through R_2 ;

(d) through R_3.

Note that there may be more than one answer to each part.

21.5: Null Measurements

28. Why can a null measurement be more accurate than one using standard voltmeters and ammeters? What factors limit the accuracy of null measurements?

29. If a potentiometer is used to measure cell emfs on the order of a few volts, why is it most accurate for the standard emfs size 12{"emf" rSub { size 8{s} } } {} to be the same order of magnitude and the resistances to be in the range of a few ohms?

21.6: DC Circuits Containing Resistors and Capacitors

30. Regarding the units involved in the relationship $\tau = RC$, verify that the units of resistance times capacitance are time, that is, $\Omega \cdot F = s$.

31. The RC time constant in heart defibrillation is crucial to limiting the time the current flows. If the capacitance in the defibrillation unit is fixed, how would you manipulate resistance in the circuit to adjust the RC constant τ? Would an adjustment of the applied voltage also be needed to ensure that the current delivered has an appropriate value?

32. When making an ECG measurement, it is important to measure voltage variations over small time intervals. The time is limited by the RC constant of the circuit—it is not possible to measure time variations shorter than RC. How would you manipulate R and C in the circuit to allow the necessary measurements?

33. Draw two graphs of charge versus time on a capacitor. Draw one for charging an initially uncharged capacitor in series with a resistor, as in the circuit in Figure, starting from $t = 0$. Draw the other for discharging a capacitor through a resistor, as in the circuit in Figure, starting at $t = 0$, with an initial charge Q_0. Show at least two intervals of τ.

34. When charging a capacitor, as discussed in conjunction with Figure, how long does it take for the voltage on the capacitor to reach emf? Is this a problem?

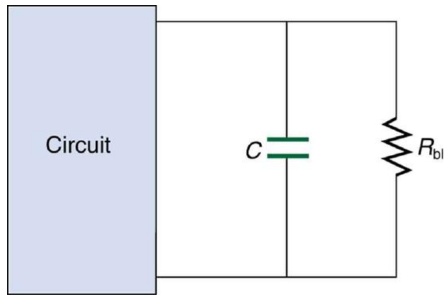
35. When discharging a capacitor, as discussed in conjunction with Figure, how long does it take for the voltage on the capacitor to reach zero? Is this a problem?

36. Referring to Figure, draw a graph of potential difference across the resistor versus time, showing at least two intervals of τ. Also draw a graph of current versus time for this situation.

37. A long, inexpensive extension cord is connected from inside the house to a refrigerator outside. The refrigerator doesn't run as it should. What might be the problem?

38. In Figure, does the graph indicate the time constant is shorter for discharging than for charging? Would you expect ionized gas to have low resistance? How would you adjust R to get a longer time between flashes? Would adjusting R affect the discharge time?

39. An electronic apparatus may have large capacitors at high voltage in the power supply section, presenting a shock hazard even when the apparatus is switched off. A "bleeder resistor" is therefore placed across such a capacitor, as shown schematically in Figure, to bleed the charge from it after the apparatus is off. Why must the bleeder resistance be much greater than the effective resistance of the rest of the circuit? How does this affect the time constant for discharging the capacitor?



A bleeder resistor R_{bl} discharges the capacitor in this electronic device once it is switched off.

Problem & Exercises

21.1: Resistors in Series and Parallel

Note: Data taken from figures can be assumed to be accurate to three significant digits.

40. (a) What is the resistance of ten $275-\Omega$ resistors connected in series?

(b) In parallel?

Solution
(a) $2.75k\Omega$
(b) 27.5Ω

41. (a) What is the resistance of a $1.00\times10^2-\Omega,$ a $2.50-k\Omega$, and a $4.00-k\Omega$ resistor connected in series?

(b) In parallel?

42. What are the largest and smallest resistances you can obtain by connecting a $36.0-\Omega$, a $50.0-\Omega$, and a $700-\Omega$ resistor together?

Solution
(a) 786Ω
(b) 20.3Ω

43. An 1800-W toaster, a 1400-W electric frying pan, and a 75-W lamp are plugged into the same outlet in a 15-A, 120-V circuit. (The three devices are in parallel when plugged into the same socket.).

(a) What current is drawn by each device?

(b) Will this combination blow the 15-A fuse?

44. Your car's 30.0-W headlight and 2.40-kW starter are ordinarily connected in parallel in a 12.0-V system. What power would one headlight and the starter consume if connected in series to a 12.0-V battery? (Neglect any other resistance in the circuit and any change in resistance in the two devices.)

Solution
$29.6W$

45. (a) Given a 48.0-V battery and $24.0-\Omega$ and $96.0-\Omega$ resistors, find the current and power for each when connected in series. (b) Repeat when the resistances are in parallel.

46. Referring to the example combining series and parallel circuits and Figure, calculate I_3 in the following two different ways:

(a) from the known values of I and I_2;

(b) using Ohm's law for R_3. In both parts explicitly show how you follow the steps in the Problem-Solving Strategies for Series and Parallel Resistors.

Solution
(a) 0.74 A
(b) 0.742 A

47. Referring to Figure:

(a) Calculate P_3 and note how it compares with P_3 found in the first two example problems in this module.

(b) Find the total power supplied by the source and compare it with the sum of the powers dissipated by the resistors.

48. Refer to Figure and the discussion of lights dimming when a heavy appliance comes on.

(a) Given the voltage source is 120 V, the wire resistance is 0.400Ω, and the bulb is nominally 75.0 W, what power will the bulb dissipate if a total of 15.0 A passes through the wires when the motor comes on? Assume negligible change in bulb resistance.

(b) What power is consumed by the motor?

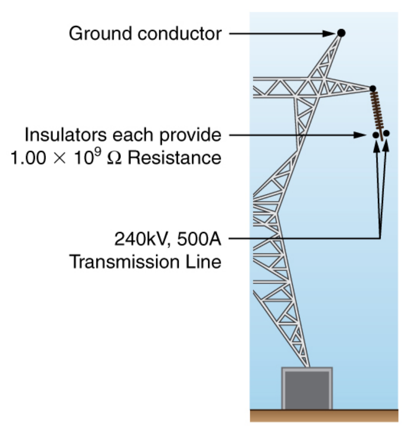
Solution
(a) 60.8 W
(b) 3.18 kW

49. A 240-kV power transmission line carrying $5.00 \times 10^2 A$ is hung from grounded metal towers by ceramic insulators, each having a $1.00 \times 10^9 - \Omega$ resistance. Figure.

(a) What is the resistance to ground of 100 of these insulators?

(b) Calculate the power dissipated by 100 of them.

(c) What fraction of the power carried by the line is this? Explicitly show how you follow the steps in the Problem-Solving Strategies for Series and Parallel Resistors.



High-voltage (240-kV) transmission line carrying $5.00 \times 10^2 A$ is hung from a grounded metal transmission tower. The row of ceramic insulators provide $1.00 \times 10^9 \Omega$ of resistance each.

50. Show that if two resistors R_1 and R_2 are combined and one is much greater than the other ($R_1 >> R_2$):

(a) Their series resistance is very nearly equal to the greater resistance R_1.

(b) Their parallel resistance is very nearly equal to smaller resistance R_2.

Solution
(a) $R_s = R_1 + R_2 \Rightarrow R_s \approx R_1 (R_1 >> R_2)$

(b) $\frac{1}{R_p} = \frac{1}{R_1} + \frac{1}{R_2} = \frac{R_1 + R_2}{R_1 R_2}$
so that
$R_p = \frac{R_1 R_2}{R_1 + R_2} \approx \frac{R_1 R_2}{R_1} = R_2 (R_1 >> R_2)$.

51. *Unreasonable Results*

Two resistors, one having a resistance of 145Ω, are connected in parallel to produce a total resistance of 150Ω.

(a) What is the value of the second resistance?

(b) What is unreasonable about this result?

(c) Which assumptions are unreasonable or inconsistent?

52. *Unreasonable Results*

Two resistors, one having a resistance of $900k\Omega$, are connected in series to produce a total resistance of $0.500M\Omega$

(a) What is the value of the second resistance?

(b) What is unreasonable about this result?

(c) Which assumptions are unreasonable or inconsistent?

Solution
(a) $-400k\Omega$
(b) Resistance cannot be negative.
(c) Series resistance is said to be less than one of the resistors, but it must be greater than any of the resistors.

21.2: Electromotive Force: Terminal Voltage

53. Standard automobile batteries have six lead-acid cells in series, creating a total emf of 12.0 V. What is the emf of an individual lead-acid cell?

Solution
2.00 V

54. Carbon-zinc dry cells (sometimes referred to as non-alkaline cells) have an emf of 1.54 V, and they are produced as single cells or in various combinations to form other voltages.

(a) How many 1.54-V cells are needed to make the common 9-V battery used in many small electronic devices?

(b) What is the actual emf of the approximately 9-V battery?

(c) Discuss how internal resistance in the series connection of cells will affect the terminal voltage of this approximately 9-V battery.

55. What is the output voltage of a 3.0000-V lithium cell in a digital wristwatch that draws 0.300 mA, if the cell's internal resistance is 2.00Ω?

Solution
2.9994 V

56. (a) What is the terminal voltage of a large 1.54-V carbon-zinc dry cell used in a physics lab to supply 2.00 A to a circuit, if the cell's internal resistance is 0.100Ω?

(b) How much electrical power does the cell produce?

(c) What power goes to its load?

57. What is the internal resistance of an automobile battery that has an emf of 12.0 V and a terminal voltage of 15.0 V while a current of 8.00 A is charging it?

Solution
0.375Ω

58. (a) Find the terminal voltage of a 12.0-V motorcycle battery having a $0.600-\Omega$ internal resistance, if it is being charged by a current of 10.0 A.

(b) What is the output voltage of the battery charger?

59. A car battery with a 12-V emf and an internal resistance of 0.050Ω is being charged with a current of 60 A. Note that in this process the battery is being charged.

(a) What is the potential difference across its terminals?

(b) At what rate is thermal energy being dissipated in the battery?

(c) At what rate is electric energy being converted to chemical energy?

(d) What are the answers to (a) and (b) when the battery is used to supply 60 A to the starter motor?

60. The hot resistance of a flashlight bulb is 2.30Ω, and it is run by a 1.58-V alkaline cell having a $0.100-\Omega$ internal resistance.

(a) What current flows?

(b) Calculate the power supplied to the bulb using I^2R_{bulb}.

(c) Is this power the same as calculated using $\frac{V^2}{R_{bulb}}$?

Solution
(a) 0.658 A
(b) 0.997 W
(c) 0.997 W; yes

61. The label on a portable radio recommends the use of rechargeable nickel-cadmium cells (nicads), although they have a 1.25-V emf while alkaline cells have a 1.58-V emf. The radio has a $3.20-\Omega$ resistance.

(a) Draw a circuit diagram of the radio and its batteries. Now, calculate the power delivered to the radio.

(b) When using Nicad cells each having an internal resistance of 0.0400Ω

(c) When using alkaline cells each having an internal resistance of 0.200Ω

(d) Does this difference seem significant, considering that the radio's effective resistance is lowered when its volume is turned up?

62. An automobile starter motor has an equivalent resistance of 0.0500Ω and is supplied by a 12.0-V battery with a $0.0100-\Omega$ internal resistance.

(a) What is the current to the motor?

(b) What voltage is applied to it?

(c) What power is supplied to the motor?

(d) Repeat these calculations for when the battery connections are corroded and add 0.0900Ω to the circuit. (Significant problems are caused by even small amounts of unwanted resistance in low-voltage, high-current applications.)

Solution
(a) 200 A
(b) 10.0 V
(c) 2.00 kW
(d) $0.1000\Omega; 80.0A, 4.0V, 320W$

63. A child's electronic toy is supplied by three 1.58-V alkaline cells having internal resistances of 0.0200Ω in series with a 1.53-V carbon-zinc dry cell having a $0.100-\Omega$ internal resistance. The load resistance is 10.0Ω.

(a) Draw a circuit diagram of the toy and its batteries

(b) What current flows?

(c) How much power is supplied to the load?

(d) What is the internal resistance of the dry cell if it goes bad, resulting in only 0.500 W being supplied to the load?

64. (a) What is the internal resistance of a voltage source if its terminal voltage drops by 2.00 V when the current supplied increases by 5.00 A?

(b) Can the emf of the voltage source be found with the information supplied?

Solution
(a) 0.400Ω
(b) No, there is only one independent equation, so only $r$can be found.

65. A person with body resistance between his hands of $10.0k\Omega$ accidentally grasps the terminals of a 20.0-kV power supply. (Do NOT do this!)

(a) Draw a circuit diagram to represent the situation.

(b) If the internal resistance of the power supply is 2000Ω, what is the current through his body?

(c) What is the power dissipated in his body?

(d) If the power supply is to be made safe by increasing its internal resistance, what should the internal resistance be for the maximum current in this situation to be 1.00 mA or less?

(e) Will this modification compromise the effectiveness of the power supply for driving low-resistance devices? Explain your reasoning.

66. Electric fish generate current with biological cells called electroplaques, which are physiological emf devices. The electroplaques in the South American eel are arranged in 140 rows, each row stretching horizontally along the body and each containing 5000 electroplaques. Each electroplaque has an emf of 0.15 V and internal resistance of 0.25Ω. If the water surrounding the fish has resistance of 800Ω, how much current can the eel produce in water from near its head to near its tail?

67. *Integrated Concepts*

A 12.0-V emf automobile battery has a terminal voltage of 16.0 V when being charged by a current of 10.0 A.

(a) What is the battery's internal resistance?

(b) What power is dissipated inside the battery?

(c) At what rate (in $^{\circ}C/min$) will its temperature increase if its mass is 20.0 kg and it has a specific heat of $0.300kcal/kg\cdot{}^{\circ}C$, assuming no heat escapes?

68. *Unreasonable Results*

A 1.58-V alkaline cell with a $0.200-\Omega$ internal resistance is supplying 8.50 A to a load.

(a) What is its terminal voltage?

(b) What is the value of the load resistance?

(c) What is unreasonable about these results?

(d) Which assumptions are unreasonable or inconsistent?

Solution
(a) –0.120 V
(b) $-1.41\times10^{-2}\Omega$
(c) Negative terminal voltage; negative load resistance.
(d) The assumption that such a cell could provide 8.50 A is inconsistent with its internal resistance.

69. *Unreasonable Results*

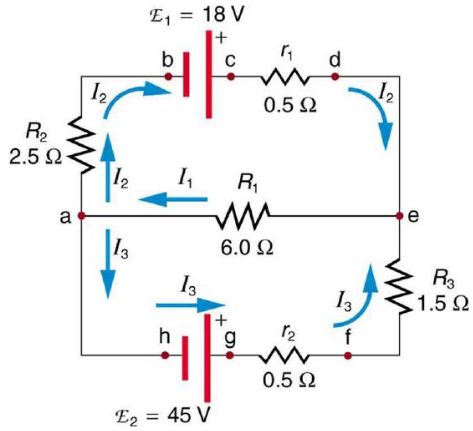
(a) What is the internal resistance of a 1.54-V dry cell that supplies 1.00 W of power to a $15.0-\Omega$ bulb?

(b) What is unreasonable about this result?

(c) Which assumptions are unreasonable or inconsistent?

21.3: Kirchhoff's Rules

70. Apply the loop rule to loop abcdefgha in Figure.



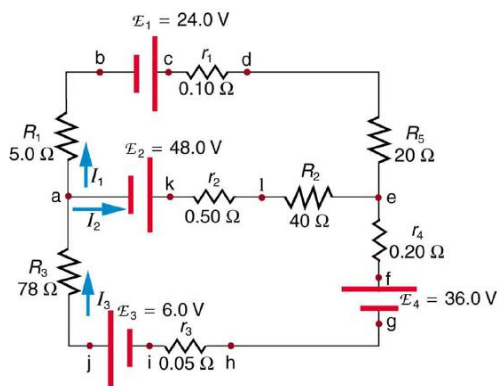
Solution
$-I_2R_2 + emf_1 - I_2r_1 + I_3R_3 + I_3r_2 - emf_2 = 0$

71. Apply the loop rule to loop aedcba in Figure in **Question 70.**

72. Verify the second equation in Example by substituting the values found for the currents I_1 and I_2.

73. Verify the third equation in Example by substituting the values found for the currents I_1 and I_3.

74. Apply the junction rule at point a in Figure.



Solution
$I_3 = I_1 + I_2$

75. Apply the loop rule to loop abcdefghija in Figure in **Question 74.**

76. Apply the loop rule to loop akledcba in Figure in **Question 74.**

Solution
$emf_2 - I_2r_2 - I_2R_2 + I_1R_5 + I_1r_1 - emf_1 + I_1R_1 = 0$

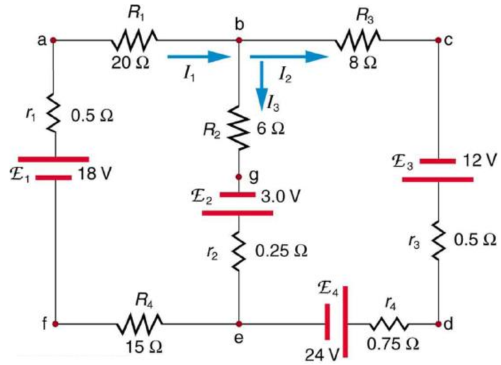
77. Find the currents flowing in the circuit in Figure in **Question 74**. Explicitly show how you follow the steps in the Problem-Solving Strategies for Series and Parallel Resistors.

78. Solve Example, but use loop abcdefgha instead of loop akledcba. Explicitly show how you follow the steps in the Problem-Solving Strategies for Series and Parallel Resistors.

Solution
(a) $I_1 = 4.75A$

(b) $I_2 = -3.5A$
(c) $I_3 = 8.25A$

79. Find the currents flowing in the circuit in Figure.

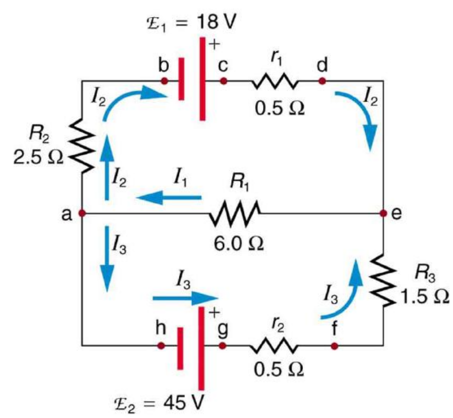


80. *Unreasonable Results*

Consider the circuit in Figure, and suppose that the emfs are unknown and the currents are given to be $I_1 = 5.00A, I_2 = 3.0A$, and $I_3 =- 2.00A$.

(a) Could you find the emfs?

(b) What is wrong with the assumptions?



Solution
(a) No, you would get inconsistent equations to solve.
(b) $I_1 \neq I_2 + I_3$. The assumed currents violate the junction rule.

21.4: DC Voltmeters and Ammeters

81. What is the sensitivity of the galvanometer (that is, what current gives a full-scale deflection) inside a voltmeter that has a $1.00 - M\Omega$ resistance on its 30.0-V scale?

Solution
$30\mu A$

82. What is the sensitivity of the galvanometer (that is, what current gives a full-scale deflection) inside a voltmeter that has a $25.0 - k\Omega$ resistance on its 100-V scale?

83. Find the resistance that must be placed in series with a $25.0 - \Omega$ galvanometer having a $50.0 - \mu A$ sensitivity (the same as the one discussed in the text) to allow it to be used as a voltmeter with a 0.100-V full-scale reading.

Solution
$1.98k\Omega$

84. Find the resistance that must be placed in series with a $25.0 - \Omega$ galvanometer having a $50.0 - \mu A$ sensitivity (the same as the one discussed in the text) to allow it to be used as a voltmeter with a 3000-V full-scale reading. Include a circuit diagram with your solution.

85. Find the resistance that must be placed in parallel with a $25.0 - \Omega$ galvanometer having a $50.0 - \mu A$ sensitivity (the same as the one discussed in the text) to allow it to be used as an ammeter with a 10.0-A full-scale reading. Include a circuit diagram with your solution.

Solution
$1.25 \times 10^{-4} \Omega$

86. Find the resistance that must be placed in parallel with a $25.0 - \Omega$ galvanometer having a $50.0 - \mu A$ sensitivity (the same as the one discussed in the text) to allow it to be used as an ammeter with a 300-mA full-scale reading.

87. Find the resistance that must be placed in series with a $10.0 - \Omega$ galvanometer having a $100 - \mu A$ sensitivity to allow it to be used as a voltmeter with:

(a) a 300-V full-scale reading, and

(b) a 0.300-V full-scale reading.

Solution
(a) $3.00 M\Omega$
(b) $2.99 k\Omega$

88. Find the resistance that must be placed in parallel with a $10.0 - \Omega$ galvanometer having a $100 - \mu A$ sensitivity to allow it to be used as an ammeter with:

(a) a 20.0-A full-scale reading, and

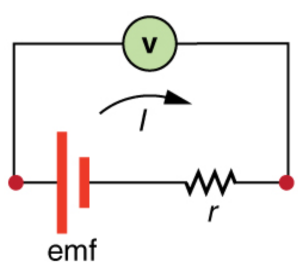
(b) a 100-mA full-scale reading.

89. Suppose you measure the terminal voltage of a 1.585-V alkaline cell having an internal resistance of 0.100Ω by placing a $1.00 - k\Omega$ voltmeter across its terminals. (See Figure.)

(a) What current flows?

(b) Find the terminal voltage.

(c) To see how close the measured terminal voltage is to the emf, calculate their ratio.



Solution
(a) 1.58 mA
(b) 1.5848 V (need four digits to see the difference)
(c) 0.99990 (need five digits to see the difference from unity)

90. Suppose you measure the terminal voltage of a 3.200-V lithium cell having an internal resistance of 5.00Ω by placing a $1.00 - k\Omega$ voltmeter across its terminals.

(a) What current flows?

(b) Find the terminal voltage.

(c) To see how close the measured terminal voltage is to the emf, calculate their ratio.

91. A certain ammeter has a resistance of $5.00 \times 10^{-5} \Omega$ on its 3.00-A scale and contains a $10.0 - \Omega$ galvanometer. What is the sensitivity of the galvanometer?

Solution
$15.0 \mu A$

92. A $1.00 - M\Omega$ voltmeter is placed in parallel with a $75.0 - k\Omega$ resistor in a circuit.

(a) Draw a circuit diagram of the connection.

(b) What is the resistance of the combination?

(c) If the voltage across the combination is kept the same as it was across the $75.0 - k\Omega$ resistor alone, what is the percent increase in current?

(d) If the current through the combination is kept the same as it was through the $75.0 - k\Omega$ resistor alone, what is the percentage decrease in voltage?

(e) Are the changes found in parts (c) and (d) significant? Discuss.

93. A $0.0200 - \Omega$ ammeter is placed in series with a $10.00 - \Omega$ resistor in a circuit.

(a) Draw a circuit diagram of the connection.

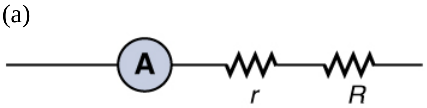
(b) Calculate the resistance of the combination.

(c) If the voltage is kept the same across the combination as it was through the $10.00 - \Omega$ resistor alone, what is the percent decrease in current?

(d) If the current is kept the same through the combination as it was through the $10.00 - \Omega$ resistor alone, what is the percent increase in voltage?

(e) Are the changes found in parts (c) and (d) significant? Discuss.

Solution
(a)



(b) 10.02Ω
(c) 0.9980, or a 2.0×10^{-1} percent decrease
(d) 1.002, or a 2.0×10^{-1} percent increase
(e) Not significant.

94. *Unreasonable Results*

Suppose you have a $40.0 - \Omega$ galvanometer with a $25.0 - \mu A$ sensitivity.

(a) What resistance would you put in series with it to allow it to be used as a voltmeter that has a full-scale deflection for 0.500 mV?

(b) What is unreasonable about this result?

(c) Which assumptions are responsible?

95. *Unreasonable Results*

(a) What resistance would you put in parallel with a $40.0 - \Omega$ galvanometer having a 25.0-μA sensitivity to allow it to be used as an ammeter that has a full-scale deflection for $10.0 - \mu A$?

(b) What is unreasonable about this result?

(c) Which assumptions are responsible?

Solution
(a) -66.7Ω
(b) You can’t have negative resistance.

(c) It is unreasonable that I_G is greater than I_{tot} (see Figure). You cannot achieve a full-scale deflection using a current less than the sensitivity of the galvanometer.

21.5: Null Measurements

96. What is the emf_x of a cell being measured in a potentiometer, if the standard cell's emf is 12.0 V and the potentiometer balances for $R_x = 5.000\Omega$ and $R_s = 2.500\Omega$?

Solution

24.0 V

97. Calculate the emf_x of a dry cell for which a potentiometer is balanced when $R_x = 1.200\Omega$, while an alkaline standard cell with an emf of 1.600 V requires $R_s = 1.247\Omega$ to balance the potentiometer.

98. When an unknown resistance R_x is placed in a Wheatstone bridge, it is possible to balance the bridge by adjusting R_3 to be 2500Ω. What is R_x if $\frac{R_2}{R_1} = 0.625$?

Solution

$1.56k\Omega$

99. To what value must you adjust R_3 to balance a Wheatstone bridge, if the unknown resistance R_x is 100Ω, $R1$ is 50.0Ω, and R_2 is 175Ω?

100. (a) What is the unknown emf_x in a potentiometer that balances when R_x is 10.0Ω, and balances when R_s is 15.0Ω for a standard 3.000-V emf?

(b) The same emf_x is placed in the same potentiometer, which now balances when R_s is 15.0Ω for a standard emf of 3.100 V. At what resistance R_x will the potentiometer balance?

Solution

(a) 2.00 V

(b) 9.68Ω

101. Suppose you want to measure resistances in the range from 10.0Ω to $10.0k\Omega$ using a Wheatstone bridge that has $\frac{R_2}{R_1} = 2.000$. Over what range should R_3 be adjustable?

Solution

Range = 5.00Ω to 5.00kΩ

21.6: DC Circuits Containing Resistors and Capacitors

102. The timing device in an automobile's intermittent wiper system is based on an RC time constant and utilizes a $0.500 - \mu F$ capacitor and a variable resistor. Over what range must R be made to vary to achieve time constants from 2.00 to 15.0 s?

Solution

range 4.00 to $30.0 M\Omega$

103. A heart pacemaker fires 72 times a minute, each time a 25.0-nF capacitor is charged (by a battery in series with a resistor) to 0.632 of its full voltage. What is the value of the resistance?

104. The duration of a photographic flash is related to an RC time constant, which is $0.100\mu s$ for a certain camera.

(a) If the resistance of the flash lamp is 0.0400Ω during discharge, what is the size of the capacitor supplying its energy?

(b) What is the time constant for charging the capacitor, if the charging resistance is $800k\Omega$?

Solution

(a) $2.50\mu F$

(b) 2.00 s

105. A 2.00- and a $7.50 - \mu F$ capacitor can be connected in series or parallel, as can a 25.0- and a $100 - k\Omega$ resistor. Calculate the four RC time constants possible from connecting the resulting capacitance and resistance in series.

106. After two time constants, what percentage of the final voltage, emf, is on an initially uncharged capacitor C, charged through a resistance R?

Solution
86.5%

107. A $500-\Omega$ resistor, an uncharged $1.50-\mu F$ capacitor, and a 6.16-V emf are connected in series.

(a) What is the initial current?

(b) What is the RC time constant?

(c) What is the current after one time constant?

(d) What is the voltage on the capacitor after one time constant?

108. A heart defibrillator being used on a patient has an RC time constant of 10.0 ms due to the resistance of the patient and the capacitance of the defibrillator.

(a) If the defibrillator has an $8.00-\mu F$ capacitance, what is the resistance of the path through the patient? (You may neglect the capacitance of the patient and the resistance of the defibrillator.)

(b) If the initial voltage is 12.0 kV, how long does it take to decline to $6.00\times 10^2 V$?

Solution
(a) $1.25k\Omega$
(b) 30.0 ms

109. An ECG monitor must have an RC time constant less than $1.00\times 10^2 \mu s$ to be able to measure variations in voltage over small time intervals.

(a) If the resistance of the circuit (due mostly to that of the patient's chest) is $1.00k\Omega$, what is the maximum capacitance of the circuit?

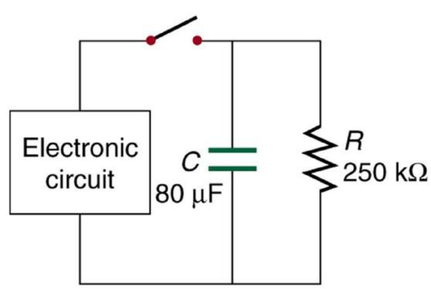
(b) Would it be difficult in practice to limit the capacitance to less than the value found in (a)?

110. Figure shows how a bleeder resistor is used to discharge a capacitor after an electronic device is shut off, allowing a person to work on the electronics with less risk of shock.

(a) What is the time constant?

(b) How long will it take to reduce the voltage on the capacitor to 0.250% (5% of 5%) of its full value once discharge begins?

(c) If the capacitor is charged to a voltage V_0 through a $100-\Omega$ resistance, calculate the time it takes to rise to $0.865V_0$ (This is about two time constants.)



Solution
(a) 20.0 s
(b) 120 s
(c) 16.0 ms

111. Using the exact exponential treatment, find how much time is required to discharge a $250-\mu F$ capacitor through a $500-\Omega$ resistor down to 1.00% of its original voltage.

112. Using the exact exponential treatment, find how much time is required to charge an initially uncharged 100-pF capacitor through a $75.0 - M\Omega$ resistor to 90.0% of its final voltage.

Solution

$1.73 \times 10^{-2} s$

113. *Integrated Concepts*

If you wish to take a picture of a bullet traveling at 500 m/s, then a very brief flash of light produced by an RC discharge through a flash tube can limit blurring. Assuming 1.00 mm of motion during one RC constant is acceptable, and given that the flash is driven by a $600 - \mu F$ capacitor, what is the resistance in the flash tube?

Solution

$3.33 \times 10^{-3} \Omega$

114. *Integrated Concepts*

A flashing lamp in a Christmas earring is based on an RC discharge of a capacitor through its resistance. The effective duration of the flash is 0.250 s, during which it produces an average 0.500 W from an average 3.00 V.

(a) What energy does it dissipate?

(b) How much charge moves through the lamp?

(c) Find the capacitance.

(d) What is the resistance of the lamp?

115. *Integrated Concepts*

A $160 - \mu F$ capacitor charged to 450 V is discharged through a $31.2 - k\Omega$ resistor.

(a) Find the time constant.

(b) Calculate the temperature increase of the resistor, given that its mass is 2.50 g and its specific heat is $1.67 \frac{kJ}{kg \cdot {}^{\circ}C}$, noting that most of the thermal energy is retained in the short time of the discharge.

(c) Calculate the new resistance, assuming it is pure carbon.

(d) Does this change in resistance seem significant?

Solution

(a) 4.99 s

(b) $3.87^{\circ}C$

(c) $31.1 k\Omega$

(d) No

116. *Unreasonable Results*

(a) Calculate the capacitance needed to get an RC time constant of $1.00 \times 10^{3} s$ with a $0.100 - \Omega$ resistor.

(b) What is unreasonable about this result?

(c) Which assumptions are responsible?

117. *Construct Your Own Problem*

Consider a camera's flash unit. Construct a problem in which you calculate the size of the capacitor that stores energy for the flash lamp. Among the things to be considered are the voltage applied to the capacitor, the energy needed in the flash and the associated charge needed on the capacitor, the resistance of the flash lamp during discharge, and the desired RC size 12{ ital "RC"} {} time constant.

118. *Construct Your Own Problem*

Consider a rechargeable lithium cell that is to be used to power a camcorder. Construct a problem in which you calculate the internal resistance of the cell during normal operation. Also, calculate the minimum voltage output of a battery charger to be used to recharge your lithium cell. Among the things to be considered are the emf and useful terminal voltage of a lithium cell and the current it should be able to supply to a camcorder.

Contributors and Attributions

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