Chapter 21: circuits, bioelectricity, and dc instruments

# 21.1 resistors in series and parallel

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| 1. | *(a) What is the resistance of ten  resistors connected in series? (b) In parallel?* |
| Solution | (a)  (b)  So that |
| 2. | *(a) What is the resistance of a , a , and a  resistor connected in series? (b) In parallel?* |
| Solution | (a)  (b) |
| 3. | *What are the largest and smallest resistances you can obtain by connecting a , a , and a  resistor together?* |
| Solution | The largest resistance is obtained by connecting in series.    The smallest resistance is obtained by connecting in parallel.    So that |
| 4. | *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?* |
| Solution | (a) For the toaster,; for the pan,; for the lamp, .  (b) The toaster and frying pan together will blow the 15A fuse. |
| 5. | *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 |  |
| 6. | *(a) Given a 48.0-V battery and  and  resistors, find the current and power for each when connected in series. (b) Repeat when the resistances are in parallel.* |
| Solution | (a) so that .  Thus,  And  (b)  so that |
| 7. | *Referring to the example combining series and parallel circuits and Figure 21.6, calculate  in the following two different ways: (a) from the known values of  and ; (b) using Ohm’s law for . In both parts explicitly show how you follow the steps in the Problem-Solving Strategies for Series and Parallel Resistors.* |
| Solution | ***Step 1:*** The circuit diagram is drawn in Figure 21.6.  ***Step 2:*** Find .  ***Step 3:*** Resistors and  are in parallel. Then, resistor  is in series with the combination of  and .  ***Step 4:***  (a) Looking at the point where the wire comes into the parallel combination of  and , we see that the current coming in, , is equal to the current going out,  and , so that , or  (b) Using Ohm’s law for , and voltage for the combination of  and  , found in Example 21.3, we can determine the current:  ***Step 5:*** The result is reasonable because it is smaller than the incoming current, , and both methods produce the same answer. |
| 8. | *Referring to Figure 21.6: (a) Calculate  and note how it compares with  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.* |
| Solution | (a)  (b) |
| 9. | *Refer to Figure 21.7 and the discussion of lights dimming when a heavy appliance comes on. (a) Given the voltage source is 120 V, the wire resistance is , 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) .  Then, and .  Finally,  (b) |
| 10. | *A 240-kV power transmission line carrying  is hung from grounded metal towers by ceramic insulators, each having a  resistance. Figure 21.51. (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.* |
| Solution | (a)    (b)  (c) |
| 11. | *Show that if two resistors  and  are combined and one is much greater than the other (): (a) Their series resistance is very nearly equal to the greater resistance . (b) Their parallel resistance is very nearly equal to smaller resistance*  *.* |
| Solution | (a)  (b)  so that |
| 12. | ***Unreasonable Results*** *Two resistors, one having a resistance of , are connected in parallel to produce a total resistance of . (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)  (b) You cannot have negative resistance.  (c) The assumption that  is unreasonable. Parallel resistance must be less than any of the individual resistances. |
| 13. | ***Unreasonable Results*** *Two resistors, one having a resistance of , are connected in series to produce a total resistance of . (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)  (b) You cannot have negative resistance.  (c) The assumption that  is unreasonable. Series resistance is always greater than any of the individual resistances. |
| 21.2 electromotive force: terminal voltage | |
| 14. | *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 |  |
| 15. | *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.* |
| Solution | (a) To determine the number simply divide the 9-V by the emf of each cell:    (b) If six dry cells are put in series, the actual emf is:    (c) Internal resistance will decrease the terminal voltage because there will be voltage drops across the internal resistance that will not be useful in the operation of the 9-V battery. |
| 16. | *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 ?* |
| Solution |  |
| 17. | *(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 ? (b) How much electrical power does the cell produce? (c) What power goes to its load?* |
| Solution | (a)  (b)  (c) |
| 18. | *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 |  |
| 19. | *(a) Find the terminal voltage of a 12.0-V motorcycle battery having a  internal resistance, if it is being charged by a current of 10.0 A. (b) What is the output voltage of the battery charger?* |
| Solution | (a)  (b) |
| 20. | *A car battery with a 12-V emf and an internal resistance of  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?* |
| Solution | (a) When charging, the potential across the terminal  (b) Thermal energy is being dissipated at a rate of  (c) Electric energy is being converted into chemical energy at a rate of .  (d) When the battery is supplying the starter, the terminal voltage . Thermal energy is being dissipated at the same rate of 180W. |
| 21. | *The hot resistance of a flashlight bulb is , and it is run by a 1.58-V alkaline cell having a  internal resistance. (a) What current flows? (b) Calculate the power supplied to the bulb using . (c) Is this power the same as calculated using ?* |
| Solution | (a)  (b)  (c)  Yes, the power is the same. |
| 22. | *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  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 . (c) When using alkaline cells each having an internal resistance of . (d) Does this difference seem significant, considering that the radio’s effective resistance is lowered when its volume is turned up?* |
| Solution | (a)  (b)  (c)  (d) As is lowered, the power difference decreases; therefore at higher volumes there is no significant difference. |
| 23. | *An automobile starter motor has an equivalent resistance of  and is supplied by a 12.0-V battery with a  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  to the circuit. (Significant problems are caused by even small amounts of unwanted resistance in low-voltage, high-current applications.)* |
| Solution | (a)  (b)  (c)  (d)  (i)  (ii)  (iii) |
| 24. | *A child’s electronic toy is supplied by three 1.58-V alkaline cells having internal resistances of  in series with a 1.53-V carbon-zinc dry cell having a  internal resistance. The load resistance is . (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?* |
| Solution | (a)  (b)  (c)  (d) |
| 25. | *(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)  (b) No, there is only one independent equation, so only  can be found. |
| 26. | *A person with body resistance between his hands of  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 , 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.* |
| Solution | (a)  (b) The current in his body  (c) The power dissipated in his body  (d) With  limited to 0.001A, then  (e) With low current, the power supply is still effective as low loss due to internal resistance. |
| 27. | *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 . If the water surrounding the fish has resistance of , how much current can the eel produce in water from near its head to near its tail?* |
| Solution |  |
| 28. | ***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 ) will its temperature increase if its mass is 20.0 kg and it has a specific heat of , assuming no heat escapes?* |
| Solution | (a)  (b)  (c) |
| 29. | ***Unreasonable Results*** *A 1.58-V alkaline cell with a  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)  (b)  (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. |
| 30. | ***Unreasonable Results*** *(a) What is the internal resistance of a 1.54-V dry cell that supplies 1.00 W of power to a  bulb? (b) What is unreasonable about this result? (c) Which assumptions are unreasonable or inconsistent?* |
| Solution | (a) Using the equation , we have . So using Ohm’s law and the equation , we have    (b) You cannot have negative resistance.  (c) The voltage should be less than the emf of the battery; otherwise the internal resistance comes out negative. Therefore, the power delivered is too large for the given resistance, leading to a current that is too large. |
| 21.3 kirchhoff’s rules | |
| 31. | *Apply the loop rule to loop abcdefgha in Figure 21.25.* |
| Solution | Using the loop rule for loop abcdefgha in Figure 21.25 gives: |
| 32. | *Apply the loop rule to loop aedcba in Figure 21.25.* |
| Solution |  |
| 33. | *Verify the second equation in Example 21.5 by substituting the values found for the currents  and .* |
| Solution |  |
| 34. | *Verify the third equation in Example 21.5 by substituting the values found for the currents  and .* |
| Solution |  |
| 35. | *Apply the junction rule at point a in Figure 21.52.* |
| Solution |  |
| 36. | *Apply the loop rule to loop abcdefghija in Figure 21.52.* |
| Solution |  |
| 37. | *Apply the loop rule to loop akledcba in Figure 21.52.* |
| Solution | Applying the loop rule to loop akledcba in Figure 21.52 gives: |
| 38. | *Find the currents flowing in the circuit in Figure 21.52. Explicitly show how you follow the stepsc in the Problem-Solving Strategies for Series and Parallel Resistors.* |
| Solution | First, simplify the circuit by adding up resistors in series:    Applying the junction rule to point *a* and the loop rule to loops abcdelka and aklefghija yields:   |  |  | | --- | --- | |  | (i) | |  | (ii) | |  | (iii) |   First solve Equation (ii) for  (omitting units):   |  |  | | --- | --- | |  | (iv) |   Now solve Equation (iii) for :   |  |  | | --- | --- | |  | (v) |   Substitute (iv) and (v) into (i):    Substituting this value for  into (iv) gives:  Substituting the value for  into (v) gives: |
| 39. | *Solve Example 21.5, 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 | Loop abcdefgha gives  Equations (i)–(iii) become   |  |  | | --- | --- | |  | (i) | |  | (ii) | |  | (iii) |   Solve (ii) and (iii) for  and :   |  |  | | --- | --- | |  | (iv) | |  | (v) |   Putting (iv) and (v) into (i) gives: |
| 40. | *Find the currents flowing in the circuit in Figure 21.47.* |
| Solution | Loop abcdefa:   |  |  | | --- | --- | |  | (i) |   Loop abefa:   |  |  | | --- | --- | |  | (ii) | |  | (iii) | |  | (ii) | |  | (iii) |   Substitute for   |  |  | | --- | --- | |  | (ii) | |  | (iii) | |
| 41. | ***Unreasonable Results*** *Consider the circuit in Figure 21.53, and suppose that the emfs are unknown and the currents are given to be , , and . (a) Could you find the emfs? (b) What is wrong with the assumptions?* |
| Solution | (a) No, you would get inconsistent equations to solve.  (b) . The assumed currents violate the junction rule. |
| 21.4 dc voltmeters and ammeters | |
| 42. | *What is the sensitivity of the galvanometer (that is, what current gives a full-scale deflection) inside a voltmeter that has a  resistance on its 30.0-V scale?* |
| Solution |  |
| 43. | *What is the sensitivity of the galvanometer (that is, what current gives a full-scale deflection) inside a voltmeter that has a  resistance on its 100-V scale?* |
| Solution |  |
| 44. | *Find the resistance that must be placed in series with a  galvanometer having 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 | We are given  Since the resistors are in series, the total resistance for the voltmeter is found by using  So, using Ohm’s law we can find the resistance : |
| 45. | *Find the resistance that must be placed in series with a  galvanometer having 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.* |
| Solution |  |
| 46. | *Find the resistance that must be placed in parallel with a  galvanometer having 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 |  |
| 47. | *Find the resistance that must be placed in parallel with a  galvanometer having 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.* |
| Solution |  |
| 48. | *Find the resistance that must be placed in series with a  galvanometer having 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)  (b) |
| 49. | *Find the resistance that must be placed in parallel with a  galvanometer having 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.* |
| Solution | (a)  (b) |
| 50. | *Suppose you measure the terminal voltage of a 1.585-V alkaline cell having an internal resistance of  by placing a  voltmeter across its terminals. (Figure 21.54.) (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)  Going counterclockwise around the loop using the loop rule gives:    (b) The terminal voltage is given by the equation :  Note: The answer is reported to 5 significant figures to see the difference.    (c) To calculate their ratio, divide the terminal voltage by the emf: |
| 51. | *Suppose you measure the terminal voltage of a 3.200-V lithium cell having an internal resistance of  by placing a  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.* |
| Solution | (a)  (b)  (c) |
| 52. | *A certain ammeter has a resistance of  on its 3.00-A scale and contains a  galvanometer. What is the sensitivity of the galvanometer?* |
| Solution |  |
| 53. | *A  voltmeter is placed in parallel with a  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  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  resistor alone, what is the percentage decrease in voltage? (e) Are the changes found in parts (c) and (d) significant? Discuss.* |
| Solution | (a)  (b)  (c)  (d)  (e) A 7% change could be significant, so if the voltmeter is connected to the equipment, you probably would notice a slight change in power. To eliminate this effect on the equipment, either remove the voltmeter when you are not using it, or stick a big resistor in series with the voltmeter, but in parallel with the circuit. |
| 54. | *A  ammeter is placed in series with a  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  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  resistor alone, what is the percent increase in voltage? (e) Are the changes found in parts (c) and (d) significant? Discuss.* |
| Solution | (a)  (b)  (must keep four significant figures to see the effect)  (c)  (d)  (e) No, this change is definitely not significant. A change of less than 1% would not greatly affect the output of the instrument, which is good, since in order to measure the current, the ammeter must be connected while the equipment is not in use. |
| 55. | ***Unreasonable Results*** *Suppose you have a  galvanometer with 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?* |
| Solution | (a)  (b) You cannot have negative resistance.  (c) A full-scale deflection of this galvanometer requires more than 0.5 mV. |
| 56. | ***Unreasonable Results*** *(a) What resistance would you put in parallel with a  galvanometer having a  sensitivity to allow it to be used as an ammeter that has a full-scale deflection for ? (b) What is unreasonable about this result? (c) Which assumptions are responsible?* |
| Solution | (a)  (b) You cannot have negative resistance.  (c) That  is greater than  (see Figure 21.30). You cannot achieve a full-scale deflection using a current less than the sensitivity of the galvanometer. |
| 21.5 null measurements | |
| 57. | *What is the  of a cell being measured in a potentiometer, if the standard cell’s emf is 12.0 V and the potentiometer balances for  and ?* |
| Solution |  |
| 58. | *Calculate the of a dry cell for which a potentiometer is balanced when , while an alkaline standard cell with an emf of 1.600 V requires  to balance the potentiometer.* |
| Solution | We know , so that |
| 59. | *When an unknown resistance  is placed in a Wheatstone bridge, it is possible to balance the bridge by adjusting  to be . What is  if ?* |
| Solution |  |
| 60. | *To what value must you adjust  to balance a Wheatstone bridge, if the unknown resistance  is ,  is , and  is ?* |
| Solution |  |
| 61. | *(a) What is the unknown  in a potentiometer that balances when is , and balances when  is  for a standard 3.000-V emf? (b) The same is placed in the same potentiometer, which now balances when  is  for a standard emf of 3.100 V. At what resistance  will the potentiometer balance?* |
| Solution | (a)  (b) |
| 62. | *Suppose you want to measure resistances in the range from  to  using a Wheatstone bridge that has . Over what range should  be adjustable?* |
| Solution |  |
| 21.6 dc circuits containing resistors and capacitors | |
| 63. | *The timing device in an automobile’s intermittent wiper system is based on an  time constant and utilizes a  capacitor and a variable resistor. Over what range must  be made to vary to achieve time constants from 2.00 to 15.0 s?* |
| Solution | From the equation  , we know that:    Therefore, the range for  is: |
| 64. | *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?* |
| Solution |  |
| 65. | *The duration of a photographic flash is related to an  time constant, which is  for a certain camera. (a) If the resistance of the flash lamp is  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 ?* |
| Solution | (a)  (b) |
| 66. | *A 2.00- and a  capacitor can be connected in series or parallel, as can a 25.0- and a  resistor. Calculate the four  time constants possible from connecting the resulting capacitance and resistance in series.* |
| Solution |  |
| 67. | *After two time constants, what percentage of the final voltage, emf, is on an initially uncharged capacitor , charged through a resistance ?* |
| Solution |  |
| 68. | *A  resistor, an uncharged  capacitor, and a 6.16-V emf are connected in series. (a) What is the initial current? (b) What is the  time constant? (c) What is the current after one time constant? (d) What is the voltage on the capacitor after one time constant?* |
| Solution | (a)  (b)  (c)  (d) |
| 69. | *A heart defibrillator being used on a patient has an  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  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 ?* |
| Solution | (a)  (b) |
| 70. | *An ECG monitor must have an  time constant less than  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 , 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)?* |
| Solution | (a)  (b) No, in practice it would not be difficult to limit the capacitance to less than 100 nF, since typical capacitors range from fractions of a picofarad (pF) to milifarad (mF). |
| 71. | *Figure 21.55 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  through a  resistance, calculate the time it takes to rise to . (This is about two time constants.)* |
| Solution | (a)  (b)  (c) |
| 72. | *Using the exact exponential treatment, find how much time is required to discharge a  capacitor through a  resistor down to 1.00% of its original voltage.* |
| Solution |  |
| 73. | *Using the exact exponential treatment, find how much time is required to charge an initially uncharged 100-pF capacitor through a  resistor to 90.0% of its final voltage.* |
| Solution |  |
| 74. | ***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  discharge through a flash tube can limit blurring. Assuming 1.00 mm of motion during one  constant is acceptable, and given that the flash is driven by a  capacitor, what is the resistance in the flash tube?* |
| Solution | Using  and the equation for the time constant we can write the time constant as , so setting these two times equal gives an expression from which we can solve for the required resistance: |
| 75. | ***Integrated Concepts*** *A flashing lamp in a Christmas earring is based on an  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?* |
| Solution | (a)  (b)  (c)  (d) |
| 76. | ***Integrated Concepts*** *A  capacitor charged to 450 V is discharged through a  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 , 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)  (b)  (c)  (d) No, this change does not seem significant. It probably would not be noticed. |
| 77. | ***Unreasonable Results*** *(a) Calculate the capacitance needed to get an  time constant of  with a  resistor. (b) What is unreasonable about this result? (c) Which assumptions are responsible?* |
| Solution | (a)  (b) A 10,000 F capacitor is enormous (bigger than the lab)!  (c) It is unreasonable to try to get such a big time constant by starting with such a small resistor. |

# Test Prep For AP® Courses

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| 1. | [Figure\_Ch21\_S01]  *The figure above shows a circuit containing two batteries and three identical resistors with resistance R. Which of the following changes to the circuit will result in an increase in the current at point P? Select two answers.*  (a) Reversing the connections to the 14 V battery.  (b) Removing the 2 V battery and connecting the wires to close the left loop.  (c) Rearranging the resistors so all three are in series.  (d) Removing the branch containing resistor *Z*. |
| Solution | (a), (b) |
| 2. | *In a circuit, a parallel combination of six 1.6-kΩ resistors is connected in series with a parallel combination of four 2.4-kΩ resistors. If the source voltage is 24 V, what will be the percentage of total current in one of the 2.4-kΩ resistors?*   1. 10% 2. 12% 3. 20% 4. 25% |
| Solution | (d) |
| 3. | *If the circuit in the previous question is modified by removing some of the 1.6 kΩ resistors, the total current in the circuit is 24 mA. How many resistors were removed?*   1. 1 2. 2 3. 3 4. 4 |
| Solution | (b) |
| 4. | [Figure\_Ch21\_S02]  *Two resistors, with resistances R and 2R are connected to a voltage source as shown above. If the power dissipated in R is 10 W, what is the power dissipated in 2R?*   1. 1 W 2. 2.5 W 3. 5 W 4. 10 W |
| Solution | (c) |
| 5. | *In a circuit, a parallel combination of two 20-Ω and one 10-Ω resistors is connected in series with a 4-Ω resistor. The source voltage is 36 V.*   1. *Find the resistor(s) with the maximum current.* 2. *Find the resistor(s) with the maximum voltage drop.* 3. *Find the power dissipated in each resistor and hence the total power dissipated in all the resistors. Also find the power output of the source. Are they equal or not? Justify.* 4. *Will the answers for questions a) and b) differ if a 3 Ω resistor is added in series to the 4 Ω resistor? If yes, repeat the question(s) for the new resistor combination.* 5. *If the values of all the resistors and the source voltage are doubled, what will be the effect on the current?* |
| Solution | a) 4-Ω resistor, b) combination of 20-Ω, 20-Ω, and 10-Ω resistors, c) 20 W in each 20-Ω resistor, 40 W in 10-Ω resistor, 64 W in 4-Ω resistor, total 144W total in resistors, output power is 144 W, yes they are equal (law of conservation of energy), d) 4 Ω and 3 Ω for question a) and no change for question b), e) no effect, it will remain the same. |
| 6. | *Suppose there are two voltage sources – Sources A and B – with the same emfs but different internal resistances, i.e. internal resistance of Source A is lower than Source B. If they both supply the same current in their circuits, which of the following statements is true?*  (a) External resistance in Source A’s circuit is more than Source B’s circuit.  (b) External resistance in Source A’s circuit is less than Source B’s circuit.  (c) External resistance in Source A’s circuit is same as Source B’s circuit.  (d) Relationship between external resistances in the two circuits can’t be determined. |
| Solution | (a) |
| 7. | *Calculate the internal resistance of voltage source if the terminal voltage of the source increases by 1 V when the current supplied decreases by 4 A? Suppose this source is connected in series (in the same direction) to another source with a different voltage but same internal resistance. What will be the total internal resistance? How will the total internal resistance change if the sources are connected in the opposite direction?* |
| Solution | 0.25 Ω, 0.50 Ω, no change |
| 8a. | *An experiment was set-up with the circuit diagram shown below. Assume R1 = 10 Ω, R2 = R3 = 5 Ω, r = 0 Ω and E = 6 V.*    [Figure\_Ch21\_S06]  *One of the steps to examine the set-up is to test points with the same potential. Which of the following points can be tested?*   1. Points *b*, *c* and *d*. 2. Points *d*, *e* and *f*. 3. Points *f*, *h* and *j*. 4. Points *a*, *h* and *i*. |
| Solution | (c) |
| 8b. | *At which three points should the currents be measured so that Kirchhoff's junction rule can be directly confirmed?*   1. Points *b*, *c* and *d*. 2. Points *d*, *e* and *f*. 3. Points *f*, *h* and *j*. 4. Points *a*, *h* and *i*. |
| Solution | (c) |
| 8c. | *If the current in the branch with the voltage source is upward and currents in the other two branches are downward, i.e. Ia = Ii + Ic, identify which of the following can be true? Select two answers****.***   1. *Ii = Ij - If* 2. *Ie = Ih - Ii* 3. *Ic = Ij - Ia* 4. *Id = Ih - Ij* |
| Solution | (b), (d) |
| 8d. | *The measurements reveal that the current through R1 is 0.5 A and R3 is 0.6 A. Based on your knowledge of Kirchoff’s laws, confirm which of the following statements are true.*   1. The measured current for *R*1 is correct but for *R*3 is incorrect. 2. The measured current for *R*3is correct but for *R*1 is incorrect. 3. Both the measured currents are correct. 4. Both the measured currents are incorrect. |
| Solution | (b) |
| 8e. | *The graph shown in figure below is the energy dissipated at R1 as a function of time.*    [Figure\_Ch21\_S07]  *Which of the following shows the graph for energy dissipated at R2 as a function of time?*   1. [Figure\_Ch21\_S08a]      1. [Figure\_Ch21\_S08b]   [Figure\_Ch21\_S08c]     1. [Figure\_Ch21\_S08d] |
| Solution | (c) |
| 9a. | *For this question, consider the circuit shown in the figure below.*    [Figure\_Ch21\_S09]  *Assuming that none of the three currents (I1, I2, and I3) are equal to zero, which of the following statements is false?*   1. *I*3= *I*1+ *I*2 at point *a*. 2. *I*2= *I*3**-** *I*1 at point *e*. 3. The current through *R3* is equal to the current through *R5*. 4. The current through *R1* is equal to the current through *R5*. |
| Solution | (c) |
| 9b. | *Which of the following statements is true?*   1. *E1 + E2 + I1R1 - I2R2 + I1r1 - I2r2 + I1R5* = 0 2. *- E1 + E2 + I1R1 - I2R2 + I1r1 - I2r2 - I1R5* = 0 3. *E1 - E2 - I1R1 + I2R2 - I1r1 +I2r2 - I1R5* = 0 4. *E1 + E2 - I1R1 + I2R2 - I1r1 + I2r2 + I1R5* = 0 |
| Solution | (c) |
| 9c. | *If I1 = 5 A and I3 = -2 A, which of the following statements is false?*   1. The current through *R1* will flow from *a* to *b* and will be equal to 5 A. 2. The current through *R3* will flow from *a* to *j* and will be equal to 2 A. 3. The current through *R5* will flow from *d* to *e* and will be equal to 5 A. 4. None of the above. |
| Solution | (d) |
| 9d. | *If I1 = 5 A and I3 = -2 A, I2 will be equal to*   1. 3 A 2. -3 A 3. 7 A 4. -7 A |
| Solution | (d) |
| 10. | [Figure\_Ch21\_S10]  *In an experiment the circuit shown above is set up. Three ammeters are used to record the currents in the three vertical branches (with R1, R2, and E). The readings of the ammeters in the resistor branches (i.e. currents in R1 and R2) are 2 A and 3 A respectively.*   1. *Find the equation obtained by applying Kirchhoff's loop rule in the loop involving R1 and R2.* 2. *What will be the reading of the third ammeter (i.e. the branch with E)? If E was replaced by 3E, how will this reading change?* 3. *If the original circuit is modified by adding another voltage source (as shown below), find the readings of the three ammeters.*     [Figure\_Ch21\_S11] |
| Solution | a) 2R1 = 3R2, b) 5 A, it will become 15 A, c) 2 A in branch with R1, 9 A in branch with R2, 11 A in branch with E |
| 11. | [Figure\_Ch21\_S012]  *In the circuit shown above, assume the currents through R1, R2 and R3 are I1, I2 and I3 respectively and all are flowing in the clockwise direction.*   1. *Find the equation obtained by applying Kirchhoff's junction rule at point A.* 2. *Find the equations obtained by applying Kirchhoff's loop rule in the upper and lower loops.* 3. *Assume R1 = R2 = 6 Ω, R3 = 12 Ω and r1 = r2 = 0 Ω and E1 = 6 V and E2 = 4 V, calculate I1, I2 and I3.* 4. *If E2 is replaced by a closed switch, repeat steps a) and b). Using the values for R1, R2, R3, r1 and E1 from part c) calculate the currents through the three resistors.* 5. *For the circuit in part d) calculate the output power of the voltage source and across all the resistors. Examine if energy is conserved in the circuit.* 6. *A student implemented the circuit of part d) in the lab and measured the current though one of the resistors as 0.19 A. According to the results calculated in part d) identify the resistor(s). Justify any difference in measured and calculated value.* |
| Solution | 1. *I1 + I3 = I2* 2. *E1 - I1R1 - I2R2 - I1r1* = 0; **-** *E2 + I1R1 - I3R3 - I3r2* = 0 3. *I1* = 8/15 A, *I2* = 7/15 A and *I3* = **-**1/15 A 4. *I1* = 2/5 A, *I2* = 3/5 A and *I3* = 1/5 A 5. *PE1* = 18/5 W and *PR1* = 24/25 W, *PR2* = 54/25 W, *PR3* = 12/25 W. Yes, *PE1* = *PR1*+ *PR2* + *PR3* 6. *R3,* losses in the circuit |
| 12. | *A battery is connected to a resistor and an uncharged capacitor. The switch for the circuit is closed at t = 0 s.*   1. *While the capacitor is being charged, which of the following is true?*    1. Current through and voltage across the resistor increase.    2. Current through and voltage across the resistor decrease.    3. Current through and voltage across the resistor first increase and then decrease.    4. Current through and voltage across the resistor first decrease and then increase. 2. *When the capacitor is fully charged, which of the following is NOT zero?*    1. Current in the resistor.    2. Voltage across the resistor.    3. Current in the capacitor.    4. None of the above. |
| Solution | a: (b); b: (d) |
| 13. | *An uncharged capacitor, C is connected in series (with a switch) to a resistor R1 and a voltage source E. Assume E = 24 V, R1 = 1.2 kΩ and C = 1 mF.*   1. *What will be the current through the circuit as the switch is closed? Draw a circuit diagram and show the direction of current after the switch is closed. How long will it take for the capacitor to be 99% charged?* 2. *After full charging, this capacitor is connected in series to another resistor, R2 = 1 kΩ. What will be the current in the circuit as soon as it’s connected? Draw a circuit diagram and show the direction of current. How long will it take for the capacitor voltage to reach 3.24 V?* |
| Solution | a) 20 mA, Figure 21.38, 5.5 s;  b) 24 mA, Figure 21.29, 2 s |

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