Electronics with Discrete Components 2nd edition Galvez Solutions Manual

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Electronics with Discrete Components
Solutions to Problems

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Chapter 1

The Basics

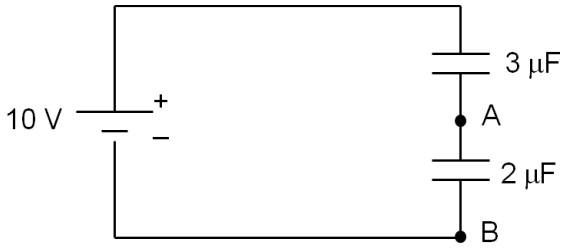
1. Two capacitors C_1 and C_2 are connected in series, with a potential V_0 across them.

   (a) If the charges on the two capacitors are the same, with a value q, find the voltages V_1 and V_2 across each capacitor in terms of the variables given.
   Solution: $V_1 = q/C_1$ and $V_2 = q/C_2$.

   (b) Find a relation between and V_0, V_1, and V_2.
   Solution: Because the are in series, $V_0 = V_1 + V_2$.

   (c) Now consider replacing the two capacitors in series by one capacitor C_0 and connect it to the supply with voltage V_0. If C_0 draws the same charge q from the supply, find a relation between C_0, C_1, and C_2.
   Solution: From (b), $V_0 = q(1/C_1 + 1/C_2) = q/C_0$. Therefore, $1/C_0 = 1/C_1 + 1/C_2$.

2. Two capacitors with capacitances 3 μF and 2 μF are initially discharged. They are connected in series, and then the two ends of the combination are connected to a 10-V battery, as shown in Figure 1.34.



   (a) If we connect a single capacitor to the same battery, what would be the capacitance of the capacitor so that it draws the same charge from the

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battery?

Solution: Since the capacitors are in series then $C = (1/3 + 1/2)^{-1} = 6/5 = 1.2\ \mu$F.

(b) How much charge does the battery deliver?

Solution: Because the two capacitors are in series, they have the same charge Q. The source delivers Q. The voltages across each capacitor add up to the source voltage $V_0 = 10$ V. Therefore $Q/C = V_0$, or $Q = 12\ \mu$C.

(c) Find the charges on each capacitor.

Solution: The charge on each capacitor is $Q = 12\ \mu$C.

(d) Find the voltage across each capacitor.

Solution: For the top capacitor: $V_{top} = Q/C_{top} = 4$ V; and for the bottom capacitor, $V_{bot} = Q/C_{bot} = 6$ V.

(e) If point B is at zero potential, what is the potential at point A between the two capacitors?

Solution: $V_A = V_B + 6\text{ V} = 6$ V.

3. A battery with potential V_0 is connected to a capacitor C. We label the charge in the top plate as q_1 and the charge in the bottom plate as q_2. Which statement is correct?

(a) $q_1 = q_2 = CV_0$

(b) $q_1 = -q_2 = CV_0$

(c) $q_1 + q_2 = CV_0$

(d) $q_1 = -q_2 = 2CV_0$

(e) $q_1 = q_2 = CV_0/2$

Solution: Answer is (b), because the capacitor's top plate has a charge Q, and the bottom plate has a charge $-Q$. Their absolute value is equal to CV_0.

4. Suppose that we have two capacitors with capacitances 0.1 μF and 0.2 μF. We connect them in parallel and apply a voltage of 10 V to their ends.

(a) What is the charge on each capacitor?

Solution: Because the capacitors are in parallel, the voltage across them is the same. If $C_1 = 0.1\ \mu$F and $C_2 = 0.2\ \mu$F, then $q_1 = C_1V_0 = 1\ \mu$C and $q_2 = C_2V_0 = 2\ \mu$C.

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(b) What is the total amount of charge that the source has to supply to charge the two capacitors?

Solution: The source has to supply charge to both capacitors: $q = q_1 + q_2 = 3\ \mu$C.

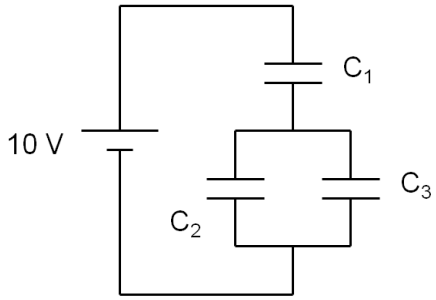
(c) If we replaced both capacitors with one so that it draws the same amount of charge from the supply, what capacitance would it have?

Solution: $C_{eq} = (q_1 + q_2)/V_0 = 0.3\mu$F.

(d) Can you generalize the previous situation for finding the equivalent capacitance of any two capacitors connected in parallel?

Solution: $C_{eq} = C_1 + C_2$.

5. In the circuit of Figure 1.35 (in the textbook, shown below), $C_1 = 0.2\ \mu$F and $C_2 = 0.15\ \mu$F. When a voltage of 10 V is applied to the system of capacitors, we find that the charge of capacitor 1 is 1 μC.



(a) Find the value of C_3, and the charge on it.

Solution: The voltage across capacitor 1 is $V_1 = q_1/C_1 = 5$ V, so the voltage across capacitors 2 and 3 must also be 5 V (to add to the supply voltage). The charge on capacitor 1 must be split onto capacitors 2 and 3 because they are in parallel (i.e., the wire that connects the bottom plate of 1 to the top plates of 2 and 3 is initially neutral, so $q_2 + q_3 - q_1 = 0$). The charge on capacitor 2 is $q_2 = (5\text{V})(0.15\mu\text{F}) = 0.75\ \mu$C. Thus $q_3 = 0.25\ \mu$C. The capacitance of 3 is then $C_3 = (0.25\mu\text{C})/(5\text{V}) = 0.05\ \mu$F.

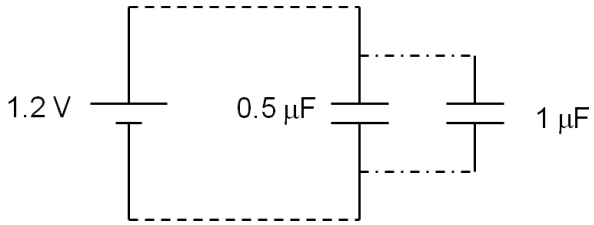
(b) What is the equivalent capacitance of the arrangement?

Solution: The capacitance of 2 and 3 in parallel is the sum of the two: $C_{23} = C_2 + C_3 = 0.2\ \mu$F. They are in series with capacitor 1, so $C_{eq} = (1/C_1 + 1/C_{23})^{-1} = 0.1\ \mu$F. Check: The source must deliver the charge $Q = C_{eq}V_0 = 1\ \mu$C, which is also equal to the charge on capacitor 1.

6. We apply 1.2 V to the 0.5 μF capacitor of Figure 1.36 (in the textbook, shown next). We then disconnect the capacitor from the power supply. Subsequently,

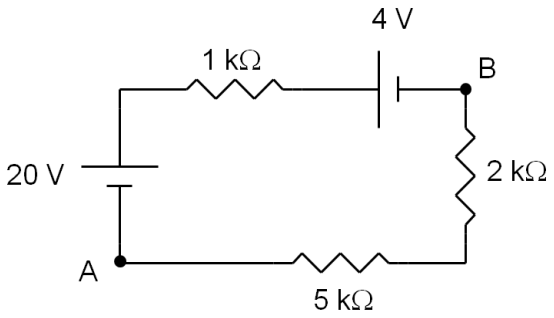
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we connect an uncharged 1-μF capacitor in parallel with the other capacitor. Find the charge on the 1-μF capacitor. (Note that the voltage across it is not 1.2 V.)



Solution: When we connect the supply to the first capacitor, it gets a charge $q_1 = (0.5\mu\text{F})(1.2\text{V}) = 0.6\ \mu\text{C}$. We then disconnect it from the supply and connect it to the second capacitor. The charges rearrange so that the two capacitors have the same voltage across them. We can also think that the two capacitors now act as a single capacitor of capacitance $C' = C_1 + C_2 = 1.5\ \mu\text{F}$. The charge on it is the initial one, so the new voltage across the capacitors is $V' = q_1/C' = 0.4$ V. The charges on each capacitor are then $q_1' = C_1V' = 0.2\ \mu\text{C}$ and $q_2 = C_2V' = 0.4\ \mu\text{C}$. Check: The two charges indeed add to the original charge.

7. The potential of point A in Figure 1.37 (in the textbook, shown below) is 0 V. Find the potential of point B.

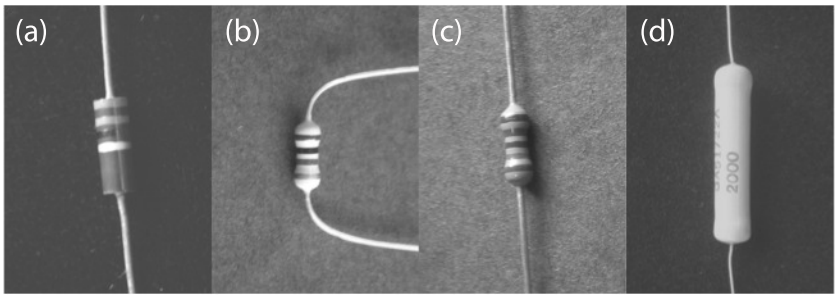


Solution: We have a single loop. The sum of voltages must add to zero. The total supply voltage is $20\text{V} - 4\text{V} = 16$ V. The voltage drops across the resistors, their value times the current, must be equal to this voltage. Since the resistors are in series in the loop, then their combined resistance is 8 kΩ. The current is then $I = (16\text{V})/(8\text{k}\Omega) = 2$ mA. The potential of B is the potential on A plus the drops on the 5-kΩ and 2-kΩ resistors, $(5\text{k}\Omega)(2\text{mA}) = 10$ V and $(2\text{k}\Omega)(2\text{mA}) = 4$ V, respectively. Therefore $V_B = 14$ V.

8. The colors of the bands of the resistors of Figure 1.7 (in the textbook, shown

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next) are: (a) Orange, orange, red, white; (b) Brown, black, red, gold; (c) Brown, red, blue, orange, green.



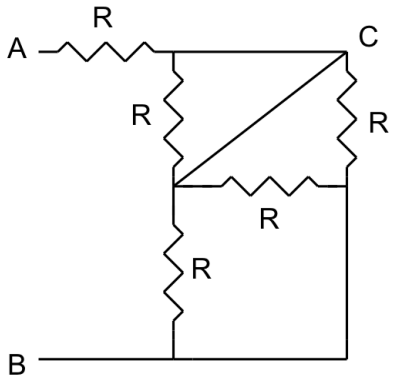
(a) Determine their value and tolerance.

Solution: (a) $33 \times 10^2\Omega = 3.3\text{k}\Omega$, 20%; (b) $10 \times 10^2\Omega = 1\text{k}\Omega$, 5%; and (c) $126 \times 10^3\Omega = 126\text{k}\Omega$, 0.5%.

(b) A measurement of the actual resistance of (b) gave 992 Ω. Should we return it as defective? Explain.

Solution: No, because the difference between the expected and measured is 0.8%, which is within the 5% tolerance of the resistor.

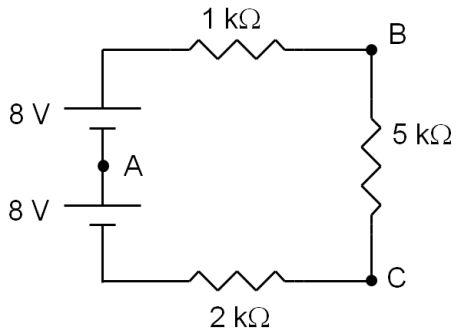
9. Calculate the equivalent resistance of the network in Figure 1.38 (in the textbook, shown below).



Solution: In the upper-right side of the circuit is a wire oriented diagonally. Notice that it meets with another wire to short a resistor. The potential of that wire is the same. Let us call this potential, V_C. Between the wire at potential A and the one at C there is only one resistor. Between C and B there are three resistors in parallel. Therefore we can reduce the arrangement as two resistors in series: R between A and C, and $R/3$ between C and B. The equivalent resistance between A and B is $4R/3$.

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10. If point A is at zero potential in Figure 1.39 (in the textbook, shown next), what is the potential at points B and C?



Solution: We can calculate the current flowing through the loop by adding the voltage sources, 16 V, and dividing that by the equivalent resistance of three resistors in series, or 8 kΩ. We get $I = 2$ mA. The potential of the positive side of the battery above A is 8 V. The potential of point B is one resistor drop below: $V_B = 8\text{V} - (1\text{k}\Omega)(2\text{mA}) = 6$ V. Point C is another resistor drop below B: $V_C = V_B - (5\text{k}\Omega)(2\text{mA}) = -4$ V. Check: The potential of the negative side of the battery below A is -8 V. The potential of point C is one resistor drop *above* this: $V_C = -8\text{V} + (2\text{k}\Omega)(2\text{mA}) = -4$ V.

11. Many of the circuits that you will use in the lab will be powered by +12 V power supplies. What is the smallest value 1/8-W resistor that we can apply the full voltage of the power supply without burning it?

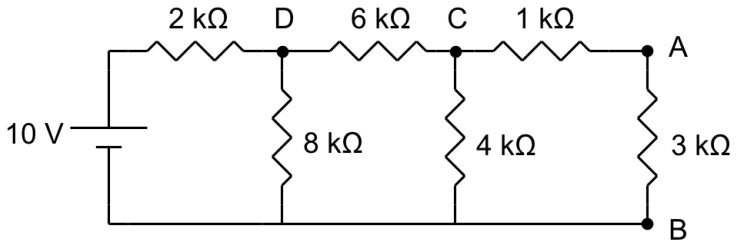
Solution: Given are: $V_0 = 12$ V, and $P_{max} = 0.125$ W. We know that $P = V^2/R$, so $R_{min} = V^2/P_{max} = 1152\Omega$.

12. Be aware of the dangers of electricity. Human skin can exhibit large variations in electrical resistance. Although dry skin may have a resistance of 100 kΩ, wet and tender skin may have resistances as low as 1 kΩ. If electrocution is caused by currents above 50 mA, what applied voltages would cause electrocution for (a) dry and (b) wet skin?

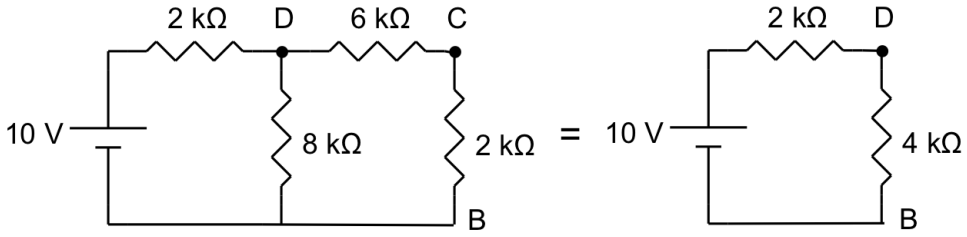
Solution: Lethal current is $I_{\text{leth}} = 50$ mA. (a) For dry skin $V_{\text{leth}} = (50\text{mA})(100\text{k}\Omega) = 5000$ V. (b) For wet skin $V_{\text{leth}} = (50\text{mA})(1\text{k}\Omega) = 50$ V.

13. Using *only* the concepts of equivalent resistance and voltage divider, calculate the voltage between points A and B of Figure 1.40 (in the textbook, shown below). Hint: First find the voltage drop across the 8 k resistor, but do not ignore the resistor ladder to the right of it.

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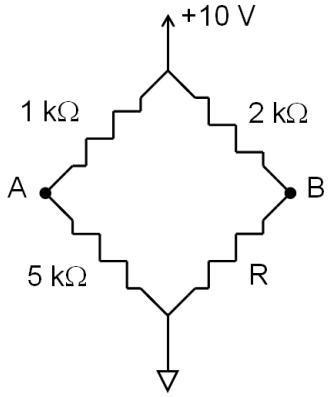


Solution: The two resistors of branch CAB are in parallel with the 4 kΩ resistor, so the resistance between C and B is $R_{CB} = 2\text{k}\Omega$ (see the figure below).



The resistance between D and B is the resistance in the branch DCB in parallel with the 8 kΩ resistor. The equivalent resistance between D and B is then $R_{DB} = 4\text{k}\Omega$ (see the figure above). Applying the voltage divider argument in the reduced one-loop circuit, we get $V_{DB} = (4/6)V_0 = 6.67$ V. Applying the voltage divider argument between D and B, we get $V_{CB} = (2/8)V_{DB} = (1/6)V_0 = 1.67$ V. Finally, Applying the voltage divider argument between C and B, we get $V_{AB} = (3/4)V_{CB} = (1/8)V_0 = 1.25$ V.

14. Find the value of R in the circuit of Figure 1.31 (in the textbook, shown below) if points A and B are at the same potential.



Solution: The ratio of the resistance on the two branches must be the same:

$$\frac{1\text{k}\Omega}{5\text{k}\Omega} = \frac{2\text{k}\Omega}{R}$$

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or $R = 10$ kΩ.

15. Two resistors are connected in series to a 20-V battery. The ratio of their resistances is 1:4.

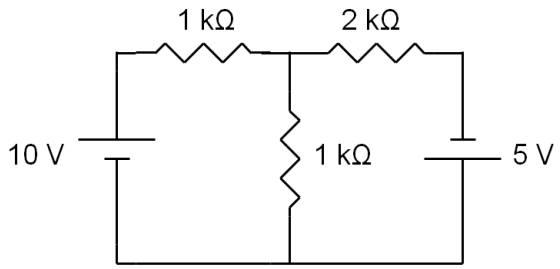
    (a) Find the voltage across the larger resistor.

    Solution: If one resistor has a resistance R and the other one $4R$, then the voltage across the larger one is $V = (4R/5R)(20\text{V}) = 16$ V.

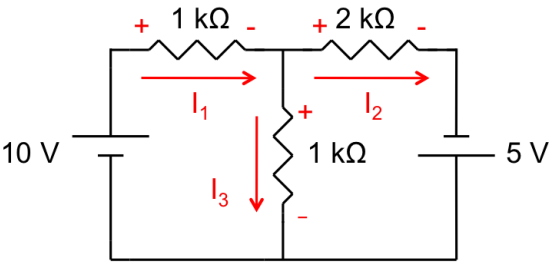
    (b) If the total current flowing through the resistors is 10 mA, what is the value of the smaller resistor?

    Solution: The voltage across the smaller resistor (of resistance R) is 4 V. Then $R = (4\text{V})/(10\text{mA}) = 400\ \Omega$.

16. Find the current flowing through each resistor, and the voltage drop across the resistor in the middle branch of the circuit of Figure 1.42 (in the textbook, shown on the left below).



Solution: Let us assume that the currents are given in mA, resistances in kΩ and voltages in V. We assume directions for the currents, and label the polarity of the potential drops:



The equations for the left-hand and right-hand loops are respectively:

$$10 - I_1 - I_3 = 0$$

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and

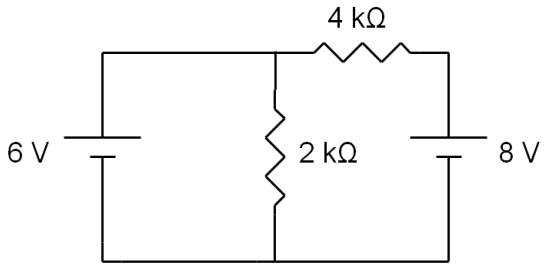
$$5 - I_3 - 2I_2 = 0.$$

The equation for the currents is

$$I_1 = I_2 + I_3.$$

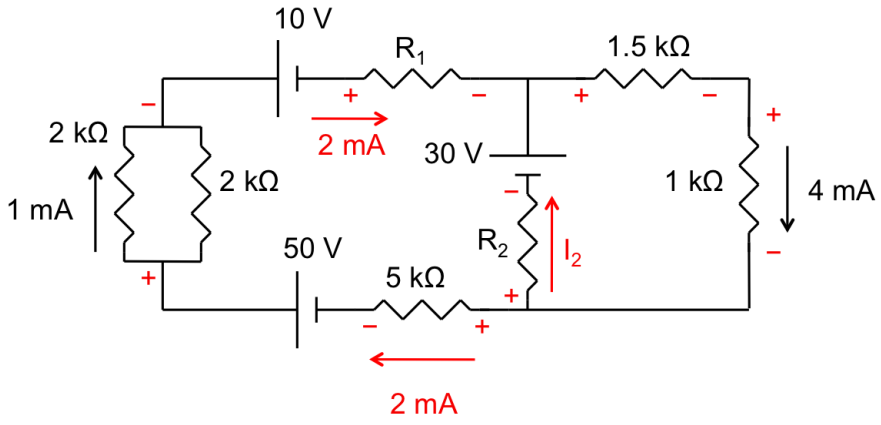
Solving the system of equations, we get $I_1 = 7$ mA, $I_2 = 4$ mA and $I_3 = 3$ mA. The voltage drops across the middle resistor is $(1\text{k}\Omega)(3\text{mA}) = 3$ V.

17. Find the current flowing through the 4-kΩ resistor in Figure 1.43 (in the textbook, shown below).



Solution: The 6-V supply is straight across the 2-kΩ resistor, so the voltage across the 4-kΩ resistor is 2 V. The current is then $(2\text{V})/(4\text{k}\Omega) = 0.5$ mA.

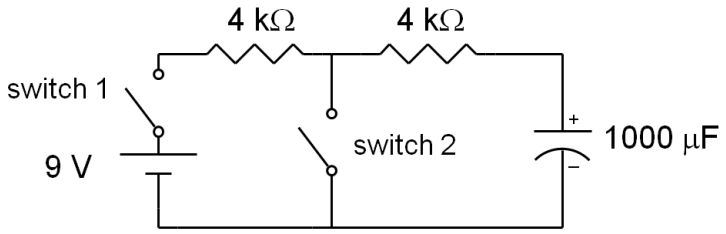
18. Find the value of the resistors R_1 and R_2 in Figure 1.44 (in the textbook, shown below with solution).



Solution: We can calculate the voltage across the right branch (of total resistance 2.5 kΩ): $(4\text{mA})(2.5\text{k}\Omega) = 10$ V. Next we focus on the two resistors in parallel in the left-most vertical branch. The resistors have the same resistance, so if the current on the left resistor is 1 mA, then the right resistor carries the

same current. The voltage drop across them is 2 V. Up to this point we know all the drops on the left loop, so we can find the voltage across R_2: 18 V. Its value is then $R_1 = 9$ kΩ. From the sum of currents at the joints we get that $I_2 = 2$ mA. The voltage across R_2 is 20 V, so $R_2 = 10$ kΩ.

19. The capacitor in the circuit of Figure 1.45 (in the textbook, shown below) is discharged.



(a) Switch 1 is closed at $t = 0$. At what time will the voltage across the capacitor reach 6 V?

Solution: The equation for charging the capacitor is: $V_C = (9\text{V})(1 - e^{-t/RC})$, where $RC = (8\text{k}\Omega)(1000\mu\text{F}) = 8$ s. We solve for t when $V_C = 6$ V: $t = -(8\text{s})\ln(1 - 6/9) = 8.8$ s.

(b) Switch 1 is opened when the voltage across the capacitor reaches 6 V. What was the current flowing through the circuit before the switch was opened?

Solution: The drop across each resistor is 1.5 V, so the current flowing through them is $I = (1.5\text{V})/(4\text{k}\Omega) = 0.375$ mA.

(c) We close switch 2. At what time after closing the switch is the voltage across the capacitor equal to 3 V?

Solution: The time constant for the discharge of the capacitor is 4 s. The time is: $t = -(4\text{s})\ln(3/6) = 2.8$ s.

20. At $t = 0$, the switch of Figure 1.46 (in the textbook, shown below) is closed. At $t = 80$ ms, the voltage across the capacitor is 5 V. Calculate V_0.

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