Resistors in series and parallel worksheet

Question 1 Don't just sit there! Build something! Learning to mathematically analyze circuits requires a lot of study and practice. Typically, students practice by working through many test problems and checking their answers against those provided by the textbook or teacher. Although this is good, it is a much better way. You will learn much more by actually building and analyzing real circuits, letting the test equipment provide answers instead of a book or another person. For successful circuit-building exercises, follow these steps: Carefully measure and record all component values before circuit building. Draw the schematic diagram for the circuit to be analyzed. Carefully build this circuit on a breadboard or other convenient medium. Check the accuracy of the circuit's construction, follow each wire to each connection point, and check these elements one by one on the diagram. Mathematically analyze the circuit, solve for all values of voltage, current, etc. Measure these quantities carefully to confirm the accuracy of the analysis. If there are any significant errors (greater than a few percent), carefully check the structure of the circuit against the diagram, and then carefully calculate the values and measure again. Avoid very high and very low resistance values, to avoid measurement errors caused by meter loading. I recommend opponent between 1 kΩ and 100 kΩ, unless, of course, the purpose of the circuit is to illustrate the effect of meter loading! One way you can save time and reduce the possibility of errors is to start with a very simple circuit and gradually add components to increase complexity after each analysis, instead of building a whole new circuit for each practice problem. Another time-saving technique is to reuse the same components in a variety of different circuit configurations. This way, you don't have to measure any component value more than once. Answer Let the electrons give you the answers to your own training problems! Note: It has been my experience that students require a lot of practice of circuit analysis to become proficient. To this end, instructors typically give students many training problems to work through, and give students answers to check their work against. Although this approach makes students proficient in circuit theory, it fails to fully educate them. Students don't just need mathematical practice. They also need real, practical practice building circuits and use test equipment. So I suggest the following alternative approach: students should build their own practice problems with real components, and try to mathematically predict the different voltage and current values. In this way, the mathematical theory comes alive, and students get practical skills they would not get just by solving equations. Another reason to follow this method of practice is to teach students scientific method: the process of a hypothesis (in this case mathematical predictions) by performing a real experiment. Students will also develop real troubleshooting skills as they occasionally make circuit construction mistakes. Spend some time with your class to review some of the rules for building circuits before they begin. Discuss these issues with your students in the same socratic way that you would normally discuss the spreadsheet questions, rather than just telling them what to and shouldn't do. I never stop being surprised at how badly students understand instructions when presented in a typical lecture (instructor monologue) format! A note to those instructors who can complain about the wasted time required to get students to build real circles instead of just mathematically analyzing theoretical circuits: What is the purpose of students taking your course? If your students want to work with real circles, they should learn in real circles whenever possible. If your goal is to educate theoretical physicists, then stick to abstract analysis, by all means! But most of us plan for our students to do something in the real world with the education we give them. The wasted time spent building real circles will pay huge dividends when it comes time for them to apply their knowledge to practical problems. Moreover, students teach to build their own practice problems them how to perform primary research, thereby empowering them to continue their electrical/electronics education autonomously. In most sciences, realistic experiments are much harder and more expensive to set up than electrical circuits. Nuclear physics, biology, geology and chemistry professors would only love to be able to have their students use advanced mathematics for real experiments that pose no security risk and cost less than a textbook. They can't, but you can. Take advantage of the convenience of your science and get your students to practice their math in many real circles! Question 2 In a serial circuit, certain general rules can be set with respect to amounts of voltage, current, resistance and current. Express these rules, using your own words: In a series of circuits, voltage . . . In a series of circuits, power . . . In a series of circuits, resistance . . . In a series of circuits, power . . . For each of these rules, explain why it is true. Answer In a serial circuit, voltage drop add equal to the total. In a serial circuit, the current is equal through all components. In a serial circuit, resistance add equal to the total. In a serial circuit, power spreads add equal to the total. Note: Rules for series and parallel circuits are very important for students to understand. But one trend I've noticed in many students is the habit of remembering instead of understanding these rules. Students will work hard to remember the rules without really understanding why the rules are true, and therefore often fail to remember or rules correctly. One illustrative technique I have found very useful is to have students create their own example circles there to test these rules. Simple series and parallel circuits pose little challenge to construct, and therefore serve as good learning tools. What could be better, or more authoritative, than learning principles of circuits from real experiments? This is known as primary research, and it forms the basis for scientific research. The biggest problem you want as an instructor is to encourage students to take the initiative to build these demonstration circles on their own, because they are so used to getting teachers to just tell them how things work. This is a disgrace, and it reflects poorly on the state of modern education. Question 3 From observation of this circuit (with components attached to a terminal strip), draw an appropriate schematic diagram: Answer Notes Notes: This type of question is one that lends itself well to students drawing their answers on the board in front of the class. The skill of transferring a real circle to a purely drawn schematic is one that some students struggle mightily with, but it's important. These students will want to know which technique(s) can be used to make the transfer. Students who are more spatially prolific are likely to have a few different ways of approaching a problem like this. Let them explain the rest of the class technique(s) to track the real circuit's wires into a schematic diagram. Giving students the opportunity to teach their peers is a powerful teaching method and should be encouraged at all times! Question 4 In a parallel circuit, certain general rules can be set with respect to amounts of voltage, current, resistance and current. Express these rules, using your own words: İn a parallel circuit, tension . . . İn a parallel circuit, current . . . İn a parallel circuit, resistance . . . İn a parallel circuit, current . . . For each of these rules, explain why it is true. Decline answer In a parallel circuit, the voltage is equal across all components. In a parallel circuit, flows add equal to the total. In a parallel circuit, the resistance is reduced to correspond to the total. In a parallel circuit, power spreads add equal to the total. Note: Rules for series and parallel circuits are very important for students to understand. But one trend I've noticed in many students is the habit of remembering instead of understanding these rules. Students will work hard to remember the rules without really understanding why the rules are true, and therefore often fail to remember or apply the rules correctly. One illustrative technique I have found very useful is to have students create their own example circles there to test these rules. Simple series and parallel circuits pose little challenge to construct, and therefore serve as good learning tools. What could be better, or more authoritative, than learning of circuits from real experiments? This is known as primary research, and it forms the basis for scientific research. The biggest problem you want as an instructor is to encourage students to take the initiative to build these demonstration circles on their own, because they are so used to getting teachers to just tell them how things work. This is a disgrace, and it reflects poorly on the state of modern education. Question 5 Calculate the resistance between points A and B (RAB) for the following resistance networks: Answer Figure 1: RAB = 500 Ω Figure 2: RAB = 750 Ω Figure 3: RAB = 1.511 kΩ Figure 4 RAB = 940 Ω Figure 5: RAB = 880 Ω Figure 6: RAB = 80.54 Ω Notes: Note that the circuit in Figure 4 is a trick: two of the resistors contribute absolutely nothing to RAB! Be sure to discuss why this is with your students. Discuss with students how they approached each of these issues, and let the entire class participate in the reasoning process. The point of this question, like most of the questions in the Socratic Electronics project, is not only to get the right answers, but to stimulate the understanding of how to solve problems like these. Question 6 Complete the value table for this circuit: Check answers Notes: Discuss with students what a good procedure can be to calculate the unknown values of this issue, and also how they can check their work. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 7 Complete the value table for this circuit: Answer Answer Follow-up question: how much voltage is present at the node (connection point) where R1, R2, and R3 are all connected, measured by reference to earth? Note: A notable feature of this circuit's schematic is how the power supply connections are displayed. Unlike many of my schematic charts, I do not display a battery symbol here for a voltage source. Instead, I show power supply rail symbols (flat line and a ground symbol). Let students know that this is very common symbolism in modern forms, and only saves having to draw lines to a voltage source symbol (as well as the source symbol itself). Discuss with students what a good procedure might be for calculating the unknown values of this issue, and also how they can check their work. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 8 Complete the value table for this circuit: Check answers Notes: Discuss with students what a good procedure can be to calculate the unknown values of this issue, and also how they can check their work. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 9 Complete the value table for this circuit: Selected answers Challenge questions: what circuit parameters will change if the diagonal wire in the right side of the circuit is cut? Note: Discuss with students what a good procedure might be for calculating the unknown values of this issue, and also how they can check their work. Question 10 Identify which of these components are connected directly in series with each other and are connected directly in parallel: Assume that the open thread pointing to a power source. Answer Figure 1: R2 parallel to R3. Figure 2: R1 in series with R2. Figure 3: R2 in series with R3. Figure 4: R1 in series with R2; R3 in series with R4. Figure 5: R1 parallel to R3; R2 parallel to R4. Figure 6: R1 in series with R2. Note: Collaborate with students to clearly identify rules by which series and parallel connections can be identified. This is very important for students to understand whether they are going to succeed in analyzing serial parallel networks of any kind. The most common problems I encounter as an electronics instructor, referring to serial parallels, are always related to students' inability to consistently separate serial subnets and parallel subnets in series parallel combination circuits. Question 11 Identify which of these components are connected directly in series with each other and connected directly in parallel: Assume that the open wire points are connection points to a power source. In circuits where ground symbols appear, consider the ground as the other side of the power source. Answer Figure 1: R1 in series with SW1. Figure 2: R1 in series with R2; R3 parallel to R4. Figure 3: R1 parallel to R2. Figure 4: R1 parallel to R2. Figure 5: L1 in series with C1. Figure 6: R3 parallel to R4. Challenge question: Comparing Shapes 2 and 6 shows how you only change the location(s) where the power supply connects to the network can change the series/parallel relationships of the components. But exactly what has changed? If two components are series with each other in one power source configuration, can this series relationship be changed by moving the power supply connection points? What about parallel connections? If two components are parallel to each other, can the parallel ratio only be changed by moving the points where the power source connects to the network? Explain. Note: Collaborate with students to clearly identify rules by which series and parallel connections can be identified. This is very important for students to understand whether they are going to succeed in analyzing serial parallel networks of any kind. The most common problems I encounter as an electronics instructor, referring to serial parallels, are always related to students' inability to consistently separate serial subnets and parallel subnets in series parallel combination circuits. Question 12 Identify which of these components are connected directly in series with each other and connected directly in parallel to each other: Decline answers Connected directly in series: Battery and R1. Connected directly in parallel: Lamp, C1 and D1 Notes: Students must have a firm understanding of what constitutes series versus parallel in real circles. Here's a place where some students will feel uncomfortable because the textbook definitions they memorized are easier said than It is important that students have a strong working knowledge of concepts, and not just remember definitions. Question 13 Rate these three light bulb units according to their total electrical resistance (in order of least to the largest), provided that each of the bulbs is of the same type and rating: Explain how you determined the relative resistances of these light bulb networks. Decline answer • C (least total resistance) • A • B (largest total resistance) Notes: I prefer to participate in discussion about series and parallel circuits before introducing Ohm's law. Conceptual analysis tends to be more difficult than numerical analysis in electrical circuits, but is a skill worth building, especially for effective troubleshooting. It is effective after conceptual (qualitative) analysis, though, to go through a numerical (quantitative) analysis of a circuit like this to prove that the concepts are correct, if students are advanced enough at this point to make series-parallel resistance calculations. Question 14 Which components are guaranteed to share the exact same voltage by virtue of their connections with each other? What components are guaranteed to share the exact same power by virtue of their connections with each other? Cancel answer The lamp, C1 and D1 are guaranteed to share the exact same voltage. The battery and R1 are both guaranteed to share the exact same power. Note: The important relationships between voltage, power, and component connection patterns are explored here. This serves to further define, in practical ways, what the concepts series and parallel really mean. Question 15 What components of this partial car chart are guaranteed to share the exact same voltage by virtue of their connections with each other? What components are guaranteed to share the exact same power by virtue of their connections with each other? Answer The two headlights are guaranteed to share the same voltage. So are the two brake lights. However, the voltage over the brake lights may not be the same as the voltage over the headlights at all times! As long as the fusible connector is not blown, the generator and battery will share approximately the same voltage. The ammeter, fusible link and generator are all guaranteed to share the same power. Note: The important relationships between voltage, power, and component connection patterns are explored here. This serves to further define, in practical ways, what the concepts series and parallel really mean. This question also provides the opportunity to discuss what a fusible link is and how it can be compared to fuses and circuit breakers as an overcurrent protection device. Question 16 In this series-parallel circuit, opponents R1 and R2 are in series with each other, but resistance R3 is neither in series nor parallel to either R1 or R2: Normally, the first step in mathematical analysis of a circuit like this is to determine the total Resistance. In other words, we need to calculate how much resistance the voltage source sees in the network formed by R1, R2 and R3. If the circuit was a simple serial configuration, our task would be simple: Similarly, if the circuit was a simple parallel configuration, we would have no difficulty calculating total resistance: Due to the fact that our given circuit is neither clean series nor purely parallel, the calculation of total resistance is not a simple one-step operation. However, there is a way we can simplify the circuit of something that is either simple series or simple parallel. Describe how this can be done, and display using numeric values for opponents R1, R2, and R3. Answer Assume we had these resistance values: • R1 = 3000 Ω • R2 = 2000 Ω • R3 = 5000 Ω The total resistance in this case will be 2500 Ω. I'll let you figure out how to do this! Tip: 2.5k is exactly half of 5k Notes: Figuring out how to calculate total resistance in a series-parallel network is an exercise in problem solving. Students need to figure out how to convert a complex problem into more, simpler problems that they can then solve with the tools they have. This type of training is also useful for getting students to think in terms of incremental problem solving. Being able to take parts of a circuit and reduce them to corresponding component values to make the circuit easier and easier to analyze is a very important skill in electronics. Question 17 Rate these five light bulb units according to their total electrical resistance (in order of least to the largest), provided that each of the bulbs is of the same type and rating: Explain how you determined the relative resistances of these light bulb networks. Answer • C (least total resistance) • D • A • E • B (maximum total resistance) Notes: I prefer to enter into discussion about series and parallel circuits before introducing Ohm's law. Conceptual analysis tends to be more difficult than numerical analysis in electrical circuits, but is a skill worth building, especially for effective troubleshooting. It is effective after conceptual (qualitative) analysis, though, to go through a numerical (quantitative) analysis of a circuit like this to prove that the concepts are correct, if students are advanced enough at this point to make series-parallel resistance calculations. Question 18 Determine the amount of electrical resistance indicated by an ohmmeter connected between the following points in this circuit: • Between points A and B = • Between points A and C = • Between points C and D = • Between points D and B = • Between points B and C = Explain whether it makes sense to talk about a total resistance for this network. Densed answers • Between points A and B = 2.41 kΩ • Between points A and C = 2.89 kΩ • Between points C and D = 1.32 kΩ • Between points D and B = 2.10 kΩ • Between points B and C = 2.75 kΩ Notes: The purpose of this is to make students realize that the resistance looks into different areas of a resilient network depends on what these areas are. Question 19 Calculate the voltage that falls over resistance R2: Also note the current direction through it and the polarity of the voltage drop above it. Answer VR2 = 12.11 volts, positive on top and negative at the bottom. If you follow conventional flow notation, this means that the current goes down through resistance R2. However, the actual flow of electrons through R2 is up. Note: Discuss with students how they answered this question. Reasoning and procedures are far more important than the answer itself. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 20 Antique American cars often used 6 volt electrical systems instead of the 12 volt components found in more modern cars and trucks. People who restore these old vehicles may have trouble finding old 6-volt generators and batteries to replace the defective, original devices. A simple solution is to update the car's generator and battery with modern (12 volt) components, but then another problem arises. A 12 volt generator and 12 volt battery will overpower the old 6 volt headlights, brake lights and other electrical loads in the vehicle. One solution used by antique car restaurateurs is to connect resistors between the 12-volt generator system and the 6-volt loads, like this: Explain why this solution works, and also discuss some of the disadvantages of using resistors to adapt the new (12 volts) to the old (6 volts) components. Reveal the purpose of the resistances is to drop half the voltage supplied by the generator and battery, so that the loads (light bulbs, in this case) only receive 6 volts instead of 12 volts. One drawback of using an opponent to do this is that the resistances waste a lot of electric power in the form of heat. Note: Make sure students understand the concept of load: any electrical or electronic component that uses power from a Source. Usually, loading the end-use components of a circuit: light bulbs, motors, magnets, speakers, etc. In this case, the resistances can be considered loads as well as the light bulbs, but since the light bulbs are the only components that perform useful work from the power source, it is common to think about them when the word load is used, instead of the resistances. Question 21 Draw a schematic diagram of this breadboard circuit: Check answers Notes: If students are not yet aware of how solderless breadboard holes are connected, this is a good time to introduce them! Question 22 Think of a way to re-wire the electrical system of this old car (with 6-volt light bulbs) so as not to require resistors between the loads and the generator / battery part of the circuit (operating at 12 volts each). Reveal answers Connect the light bulb pairs in series instead of parallel. In this way, each light bulb will receive 6 volts, with a total system voltage of 12 volts. Follow-up question: However, there is a downside to this strategy, and it concerns the safety of operating the car. Explain what this disadvantage is. Note: This solution works only because the load sets are pairs, and because 6 6 = 12. An advantage of this solution is greater efficiency, as there is no resistance in the circuit to waste power by spreading it in the form of heat. However, it is a disadvantage to do things in this way, as indicated by the follow-up question. Discuss this disadvantage with your students, and reinforce the idea that the most effective technical solutions may not be the best when assessed from other perspectives, such as safety! Question 23 Calculate the VAB, VBC, and VCD voltage drops in the following circuit: Determine answer VAB = 461 mV VBC = 0 V VCD = 1.039 V Follow-up question: explain why the voltage between points A and B (VAB) would increase if 1200 Ω resistance were to fail short-circuited. Hint: Imagine a jumper wire connected over that resistance to simulate a short error. Challenge question: Explain how you can calculate the same answers without having to calculate total circuit current. Note: Ask students how they can tell VBC must be zero, just by examining the circuit (without doing any math). If some students experience difficulty answering this question on their own, ask them to translate the drawing into a correct schematic chart. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to work out. Rather, outline the steps they would take, in the order in which they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 24 Calculate voltage size and polarity between points A and D in this circuit, provided an output voltage of 10.5 volts: Also calculate the total power output with the power supply when providing energy to this resistance network. Answer VAD = 7.31 volts, One positive and D negative. The total power supply is 4.36 mA. Follow-up question: explain why the voltage over the 4.7 kΩ resistance would go to zero if the 1.5 kΩ resistance were to be opened. Note: Although some students may not realize it at first, there is no serial-parallel analysis necessary to get the voltage drop VAD. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. As a follow-up to the follow-up question, students ask what other resistance in this circle would completely lose the tension given an open failure of 1.5 kΩ resistance. Question 25 Calculate the power supply output current (total) current: Answer Itotal = 4.69 mA Follow-up question: explain why the voltage above 1500 Ω the resistance would remain unchanged if the 4700 Ω the resistance were to fail open. Challenge question: What are the key assumptions in the calculated number shown here? In other words, what unknown quantities can affect the accuracy of our expected current value? Note: This is an interesting series-parallel circuit problem to solve, and it again shows how a good understanding of circuit theory allows unsotted variables to be deduced. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 26 Complete the value table for this circuit: Check answers Notes: Discuss with students what a good procedure can be to calculate the unknown values of this issue, and also how they can check their work. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 27 Complete the value table for this circuit: Check answers Notes: Discuss with students what a good procedure can be to calculate the unknown values of this issue, and also how they can check their work. Question 28 Complete the value table for this circuit: Decline answers Notes: Ask students to identify components in this series parallel circuit that are guaranteed to share the same voltage, and components guaranteed to share the same power, without reference to any calculations. This is a good exercise in identifying parallel and serial connections, respectively. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. A teaching technique I have found very useful is to students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 29 What would happen to the voltage drops over each resistance in this circuit if resistance R1 were to fail open? Answer If resistance R1 were to be opened (internally), it would release the entire battery voltage over the terminals so that no voltage is left for R2 or R3. Note: In most dc circuit error scenarios, the effect of open or short errors can be estimated or even accurately predicted without having to perform mathematical calculations. Of course, you can calculate the effects by using extremely large values for open opponents and 0 for short-edged opponents, but it would be an ineffective use of time! Question 30 What would happen to the voltage drops over each resistance in this circuit if either resistance R2 or R3 were to fail open? Answer If either resistance R2 or R3 were to be opened (internally), the voltage over both R2 and R3 would increase (but not to full battery voltage), causing less voltage to fall over R1. Follow-up question: explain why it does not matter which resistance (R2 or R3) fails open - the qualitative results for tension (voltage increases or decreases, but not by any particular amount) will be the same. Note: I have found in teaching that many students abhor qualitative analysis, because they can not let their calculators do the thinking for them. But being able to judge whether a circuit parameter will increase, decrease or remain the same after a component error is an important skill for skillful troubleshooting. Question 31 What will happen to each resistance voltage and current in this circuit if resistance R1 does not open? Give individual answers for each opponent, please. Release answer If resistance R1 does not open . . . • VR1 will increase to full supply voltage, IR1 will be reduced to zero • VR2 will decrease to zero, IR2 will decrease to zero • VR3 will decrease to zero, IR3 will decrease to zero • VR4 will decrease to zero, IR4 will decrease to zero Follow-up questions: Mark the order I show the qualitative effects of R2's abbreviated errors. Reading from the top of the list to the bottom reveals the sequence of my reasoning. Explain why I would come to the conclusions I did, in the order I did. Note: I have found in teaching that many students abhor qualitative analysis, because they can not let their calculators do the thinking for them. But being able to judge whether a circuit parameter will increase, decrease or remain the same after a component error is an important skill for skillful troubleshooting. Question 32 What will happen to each resistance voltage and current in this circuit if resistance R2 fails short-circuited? Give individual answers for each opponent, please. Release answer If resistance R2 fails briefly . . . • VR2 will decrease to zero, IR2 will increase • VR1 will increase to full supply voltage, IR1 will increase • VR3 will decrease to zero, IR3 will decrease to zero • VR4 will decrease to zero, IR4 will decrease to zero Follow-up question: Note the order I show the qualitative effects of R2's short-cut errors. Reading from the top of the list to the bottom reveals the sequence of my reasoning. Explain why I would come to the conclusions I did, in the order I did. Note: I have found in teaching that many students abhor qualitative analysis, because they can not let their calculators do the thinking for them. But being able to judge whether a circuit parameter will increase, decrease or remain the same after a component error is an important skill for skillful troubleshooting. Question 33 What will happen to each resistance voltage in this circuit if resistance R4 fails short-circuited? Give individual answers for each opponent, please. Also commenting on the practical likelihood of an opposition failing shorted, as opposed to failing open. Answer If Resistance R4 fails briefly . . • VR4 will decrease to zero • VR1 will increase • VR2 will decrease • VR3 will increase the follow-up question: opponents are actually far less likely to fail cards as they should fail open. However, this means nothing else on a circuit board can't go wrong to make it look like a resistance failed short-circuited! An example of such a bug is called a solder bridge. Explain what this is, why it can give the same effect as an opponent failing shorted. Note: I have found in teaching that many students abhor qualitative analysis, because they can not let their calculators do the thinking for them. But being able to judge whether a circuit parameter will increase, decrease or remain the same after a component error is an important skill for skillful troubleshooting. Question 34 A student built this resistance circuit on a soldered breadboard, but made a mistake positioning resistance R3. It should be located one hole to the left instead of where it is right now: Determine what the voltage drop will be above each resistance, in this defective configuration, provided that the battery outputs 9 volts. • R1 = 2 k Ω VR1 = • R2 = 1 k Ω VR2 = • R3 = 3.3k Ω VR3 = • R4 = 4.7 k Ω VR4 = • R5 = 4.7 k Ω VR5 = Answer instead of telling you every voltage drop, I'll give you this one hint: there's only one resistance in this breadboard circuit that has excitement over it! All the other resistances in this circuit are de-energized, thanks to the misplacement of resistance R3. Note: Tell your students that the error shown in this is quite typical. The hole distances on solderless bread plates are small enough that it is surprisingly easy to mislocate a component in the way shown. Please tell your students (if they haven't already noticed) that no calculations are necessary to answer this question! It can be answered through simple, qualitative analysis alone. Q35 Assume that you designed a circuit that required two LEDs for power on indication. The power supply voltage is 15 volts, and each LED is rated at 1.6 volts and 20 mA. Calculate the declining resistance sizes and power ratings: After doing this, a colleague looks at your circuit and suggests a modification. Why not use a single drop resistance for both LEDs, finance the number of components necessary? Re-calculate dropping resistance ratings (resistance and power) for the new design. Answer With two opponents: R1 = R2 = 670 Ω, rated for at least 0.268 watts (1/2 watts would be a practical rating). With a resistance: R1 = 335 Ω, rated for at least 0.536 watts (1 watt would be a practical rating). Follow-up question: If there was no perfect size resistors size to choose from (which it most likely won't be!), would it be safer to choose a higher value resistance or a lower value resistance for these programs? For example, if you needed 670 Ω but the closest options on hand were 680 Ω and 500 Ω, what resistance value would you choose? Explain your answer. Note: If students are not yet familiar with the V symbol used to denote the positive power supply connection in this schematic, let them know that this is a very common practice in electronic notation, just as it is common to use the ground symbol as a power supply connection symbol. The follow-up question is very convenient, because it is rare that you have the exact components on hand to match the requirements of a circuit you are building. It's important to understand which way is safer to fail (too big or too small) when doing as-built design work. Question 36 Calculate all voltages and currents in this circuit: The battery voltage is 15 volts, and resistance values are as follows: R1 = 1 kΩ R2 = 3.3 kΩ R3 = 4.7 kΩ R4 = 2.5 kΩ R5 = 10 kΩ R6 = 1.5 kΩ R7 = 500 Ω answer R1 = 1 kΩ ER1 = 4.016 V IR1 = 4,016 mA R2 = 3.3 kΩ ER2 = 6,522 V IR2 = 1.976 mA R3 = 4.7 kΩ ER 3 = 6,522 V IR3 = 1,388 mA R4 = 2.5 kΩ ER4 = 4,462 V IR4 = 1,785 mA R5 = 10 kΩ ER5 = 6,522 V IR5 = 652 µA R 6 = 1.5 kΩ ER6 = 3,347 V IR6 = 2,231 mA R7 = 500 Ω ER7 = 1,116 V IR7 = 2,231 mA Notes: Students will benefit greatly from having a purely schematic chart to work by. But don't give this for them! Let them figure out how to derive a schematic chart from the illustrated circuit. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you to show them, it is bad for you to show them too that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 37 Examine these two reostat networks with variable resistance (reostat), each with a large-pull potentiometer and a short-range potentiometer: For each network, determine which pot is rough alignment and which pot is fine-tuning for total resistance. Show Answers Series Network 100k = Rough Alignment ; 5k = Fine-tuning Parallel network 5k = Rough alignment; 100k = Fine tuning Notes: The purpose of this question is for students to identify the dominant resistance values in series versus parallel circuits. If necessary, remind your students that Rtotal > Series Rn and Rtotal < Rn for parallel (where Rn represents a specific opponent in the network). Question 38 Identify which of these components are connected directly in series with each other and connected directly in parallel to each other: Answer Connected directly in series: Battery, R1, and SW1. Connected directly in parallel: Neon lamp and L1. Note: Students must have a firm understanding of what constitutes series versus parallel in real circles. Here's a place where some students will feel uncomfortable because the textbook definitions they memorized are easier said than used. It is important that students have a strong working knowledge of concepts, and not just remember definitions. Question 39 Complete the value table for this circuit: Check answers Notes: Discuss with students what a good procedure can be to calculate the unknown values of this issue, and also how they can check their work. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 40 Complete the value table for this circuit: Check answers Notes: Discuss with students what a good procedure can be to calculate the unknown values of this issue, and also how they can check their work. Students often have trouble formulating a solution method: deciding what steps to take to get from the given conditions to a final answer. Although it is useful at the beginning for you (the instructor) to show them, it is bad for you to show them too often, so that they should not stop thinking for themselves and just follow your lead. One teaching technique I have found very useful is to get students to come up to the board (alone or in teams) in front of the class to write their problem-solving strategies for all the others to see. They don't have to actually do the math, but rather outline the steps they would take, in the order they would take them. By allowing students to outline their problem-solving strategies, everyone will have the opportunity to see more solution methods, and you (the teacher) will see how (and if!) students think. A particularly good point to emphasize in these open thinking activities is how to check your work to see if any mistakes were made. Question 41 Determine which light bulbs will brighten brightly, and which light bulbs will light slightly (provided that all light bulbs are identical). Reveal answers Bulbs A and C will glow brightly, while bulbs B and D will glow faintly. Follow-up question: explain why bulbs A and C will become dimmer (less bright) if the filament in bulb D does not open. Note: This question provides an opportunity to discuss current in series versus parallel connected components. The follow-up question challenges students to analyze the circuit qualitatively. Circuit.