Ohm s law practice worksheet

Fix the following issues. If you need more practice, update your browser (or close and reopen this page) for all new tracks. Introducing FreeReport a problemThis resource is designed for British teachers. See the US version. Ohm's law that the voltage V across a leader of resistance R is proportional to the current I pass through the resistance (see circuit below). The relationship is written as. V = R I Which can also be written as I = V/R and R = V/I. The units are in Volt (V) for voltage V, Amperes (A) for the current I and Ohms (Ω) for the resistance in R. Use Ohm's law to solve simple circuits Example 1 Find the current I through a resistance R = 2 Ω if the voltage across the resistance is 6 V. Solution for example 1 Replacement R with 2 and V with 6 in Ohm's Law V = R I. 6 = 2 I Solve for I = 6/2 = 3 A Example 2 In the circuit below resistors R1 and R2 are in series and have resistance of 5 Ω and 10 Ω, respectively. The voltage across resistance R1 is equal to 4 V. Find the current passing through resistance R2 and the voltage across the same resistance. Solution for example 2 We use Ohm's Law V=R I to find the current I1 passing through R1. 4 = 5 I1 Loose for I1 I1 = 4/ 5 = 0.8 A The two resistors are in series, and therefore the same current passes through them. Therefore, the current I2 through R2 is equal to 0.8 A. We now use Ohms law to find the voltage V2 across resistance R2. V2 = R2 I2 = 10 (0.8) = 8 V Example 3 In the circuit under resistances R1 and R2 are parallel and have resistors of 8 Ω and 4 Ω respectively. The current passing through R1 is 0.2 A. Find the voltage across resistance R2 and the current passing through the same resistance. Solution for example 3 Use Ohm's Law V= R I to find voltage V1 across resistance R1. V1 = 8 (0.2) = 1.6V Voltage across resistance R1 and voltage across resistance R2 is the same because R1 and R2 are parallel. We now use Ohm's law to find current I2 passes through resistance R2. 1.6 = 4 I2 Loose for I2 I2 = 1.6 / 4 = 0.4 A Example 4 The current passes through a resistance in a circuit is 0.01 A when the voltage across the same resistance is 5 V. What current passes through this resistance when the voltage across it is 7.5V? Solution for example 4 Use Ohms Law V= R I to find the resistance R in this circuit. 5 = R (0.01) Loose for R R = 5 / 0.01 = 500 Ω We now use Ohms Law V = R I and the value of R to find the power, when the voltage is 7.5. 7.5 = 500 In Solve for I = 7.5 / 500 = 0.0125 A Example 5 The graph below represents the voltage V across a resistance to the current I pass through the same resistance. What is the resistance of resistance in the circuit? Solution to example 5 Ohm's Law V = R I corresponds to the equation of lines of form y = m x, and we know that m is the slope of the line y = m x. Therefore, in the graph for V mod I given above, the slope of the graph is the resistance. We need two points from the graph to find Point Point and (1.10) form graphene can be used to find the slope and thus the resistance R. R = (10 - 0) / (1 - 0) = 10 Ω More references and LinksOhm's Law and Power Calculator Ohm's Law Question 1 Define the following concepts: energy, work and power. See the answer Work is the exertion of a force over a distance. Energy is the ability to do work. Effect is the speed of the work performed per unit time. Note: Students can find a basic physics text useful in achieving these definitions. Work is a difficult concept to accurately define, especially for students familiar with basic physics. Technically, the vector is the dot-product of force and displacement, which means that the work is equal to force times distance, whose force and distance vectors are precisely parallel to each other. In other words, if I carry a 10 kg mass (lift up against tug of war) while walking parallel to the ground (not going up or down), the force and displacement vectors are perpendicular to each other, and the work I do in carrying the mass is zero. It is only if my strength is directed exactly in the same direction as my proposal that all my efforts have been translated into work. Question 2 Voltage is commonly defined as electrical pressure. However, the volt unit can be defined in the form of more basic physical units. What are these devices and how do they relate to the device of volts? Reveal response 1 volt equals 1 joule of energy given to 1 coulomb charge (6.25 ×1018 electrons): $$V = \frac {W}{Q}$$ Where, V = Voltage (volt) W = Work, or potential energy (joule) Q = Charge (coulombs) Notes: Note that I use the letter V to denote voltage instead of E, as I usually do. This is because in general physics work, E usually stands for either Energy or Electric field. Some electronics reference books use the letter E for tension, while others use the letter V, or even use the two letters interchangeably. Question 3 Electrical current is measured in the ampere unit or ampere unit. What is the physical definition for this device? What are the basic quantities of 1 ampe electric current? Reveal answer 1 amps of electrical current is the speed of electron motion equal to 1 coulomb per second: $$I= \frac {Q}{t}$$ Where, I = Electric current (amps) Q = Charge in motion (coulombs) t = Time (seconds) Remarks: It may be useful at this time to review the number of electrons that make up a coulomb charge: 6.25 ×1018 electrons. Technically, current mathematical definition involves calculus: $$I = \frac {dQ}{dt}$$ But students at this point may not be ready to explore derivatives yet, and so the equation give in the answer for the (average) present will suffice. Question 4 For a given amount of water pressure that will flow a greater water speed: a small (restrictive) nozzle or a large (unlimited) nozzle? Explain how this relates to the study of voltage, current and resistance in a simple electrical circuit. Afst reveal Naturally a one the nozzle will pass a greater flow rate of water through it, all other factors are equal. In an electrical circuit, less resistance will pass a greater flow rate of electrons (current) for a given amount of pressure (voltage). Note: Water flow is not a perfect analogy for electricity, but is close enough to be useful in basic electricity training. Be prepared to discuss insufficient water as an analogy with your students (i.e. How come electrons do not spill out at the end of an open wire as water spills off the end of an open hose or pipe?). Question 5 Suppose that you should build this circuit and take measurements of power through the resistance and voltage across the resistance: Recording these numerical values in a table, the results look something like this: Plot these numbers on the following graph: What mathematical ratio do you see between voltage and current in this simple circuit? See the answer This is an example of a linear function: where the plot describing the dataset tracks a straight line on a graph. From this line, and also from the numeric numbers, you should be able to distinguish a constant ratio of voltage to current. Note: The raw data numbers were made deliberately noisy in this problem to simulate the types of measurement errors encountered in real life. A tool that helps overcome interpretation problems due to noise like this is graphing. Even with noise present, the linearity of the function is clearly revealed. Your students should learn how to create graphs as tools for their own understanding of data. When relationships between numbers are represented in graphic form, it gives the data a different way of expression, which helps people apprehend patterns more easily than by reviewing rows and columns of numbers. Question 6 Explain step by step how to calculate the amount of power (I) that will go through the resistance of this circuit: Deplete answer Resistor current = 0.02553 amps, or 25.53 milliamps (mA). Note: Just a simple Ohm's law calculation here - no tricks! The point of this question, however, is to get students to think about the steps they follow in making the calculation. Many students simply want to remember procedures instead of learning why they should do what they need to do to answer such questions. It is your job as director to challenge them beyond memorization, and forward to understanding. Question 7 Plot the relationship between voltage and current for resistors of three different values (1 Ω, 2 Ω and 3 Ω), all on the same graph: What pattern do you see represented by your three plots? What ratio is there between the amount of resistance and the nature of the voltage/current function, as shown in the graph? Advanced question: In calculus, the instantaneous rate of change of an (x,y) function is expressed using the derivative notation: [dy/dx]. How would the derivative for each of these three parcels be correctly expressed using calculus notation? how derivatives of these functions relate to actual electrical quantities. The greater the response, the steeper the slope of the plotted line. Advanced answer: the right way to express the derivative of each of these plots is [dv/di]. The derivative of a linear function is a constant, and in each of these three cases that is constantly equal to the resistance of resistance in ohm. Then we can say that for simple resistance circuits, the instantaneous speed-of-change for a voltage/current function is the resistance of the circuit. Note: Students need to be comfortable with graphs, and creating their own simple graphs is an excellent way to develop this understanding. A graphic representation of Ohm's law function gives students a different view of the concept so they can more easily understand more advanced concepts such as negative resistance. If students have access to either a graph calculator or computer software that can draw 2-dimensional graphs, encourage them to plot the features using these technological resources. I've found it a good habit to sneak mathematical concepts into physics courses whenever possible. For so many people, mathematics is an abstract and confusing subject that can be understood only in the context of real life application. The studies of electricity and electronics are rich in mathematical context, so utilize it whenever possible! Your students will greatly benefit. Question 8 What is the value of this resistance, in ohm (Ω)? Show response resistance value = 2700 Ω or 2.7 kΩ. One format of component value expression popular in Europe is to replace decimal characters with the metric prefix so that 2.7 kΩ would be represented as 2k7 Ω. Not only is this notation simpler, but it also transcends the interpretative difficulties that have arisen between Europeans and Americans with their opposite use of commas and decimal places. Note: Some students may not be aware that commas in Europe are used as decimals and visa-versa. Thus, two thousand seven hundred would be written as 2,700 in America and 2,700 in Europe. Conversely, the number of π would be written as 3.141593 in America, but 3.141593 in Europe. Confusing? Yes!! Question 9 A common saying about electricity is that it always goes the least resistance. Explain how this adage relates to the following circuit, where electric current from the battery encounters two alternative paths, one being less resistive than the other: Reveal answer 250 Ω the resistance will experience a current of 40 mA, while 800 Ω resistance will experience a current of 12.5 mA. Note: As an instructor, I was very surprised to hear many starting students claim that every present would go through the lesser resistance, and none through greater resistance! The adage about taking the path of least resistance really should be understood as proportionate to take the path of less resistance. People who are new to the study of electricity, such basic principles, their mistakes usually based on folk wisdom like this. It is imperative to break through these myths with hard facts. In this case, Ohm's law serves as a mathematical tool we can use to remove false ideas. Of course, a circuit as simple as this can be easily assembled and tested in class so everyone can see the truth for themselves. Question 10 A style of bulb, very different from the incandescent design that works on the principle of a super-heated thread filament emitting light, called a gas discharge pipe. In this design of the bulb, light is produced by the direct excitation of gas molecules as electric current passes between two electrodes: Both types of bulbs have interesting voltage/current plots, neither one is identical to the voltage/current plot of a resistance. First, voltage/current plot for an incandescent bulb: Next, voltage/current plot for a gas-discharge bulb: Based on these two graphs, what can you say about the electrical resistance of each bulb type over its operating range? Afse, response Contrary to a resistance that offers a relatively fixed (immutable) amount of resistance to the movement of electrons over a wide range of operating conditions, the electrical resistance of bulbs typically changes dramatically over their respective operating areas. From the graphs, it must be determined where the resistance of each type of bulb is at its maximum and where the resistance is at its minimum. Notes: Many types of electrical and electronic components experience changes in electrical resistance over their operating areas of power and voltage. Resistors, while simple to study, do not exhibit the behavior of most electronic components. It is important for students to understand that the real world of electricity and electronics is far more complex than what Ohm's law might suggest (with an implicit assumption of firm resistance). This is a concept that graphs really help to illustrate. Question 11 Draw the schema diagram of a test circuit to collect data needed to plot the voltage/voltage of a gas discharge lamp. Afse of answer Notes: One of my goals as a technical teacher is to promote the development of experimentation skills in my students. The most accurate way to get to know a device's operation or an electrical principle is to build a circuit that actually tests it. I have used this technique many times in my career to promote my knowledge of a subject and it has proven to be an invaluable skill. In this question, students are implicitly asked to identify several important things: • Where do you connect a meter to measure the lampysen. • Where a meter is connected to measure the flow of lamp. • How to make the power adjustable so that more values can be tested and plotted. In addition, students must identify which voltage/current areas will be required to test a gas discharge lamp. Note the high voltage power source shown in the Chart. Students can ask how high should this tension be? after seeing the form in the answer. Don't tell me directly. Rather, have them do some research and report the next day on typical lamp voltages! Question 12 What is negative resistance? Reveal response Negative resistance is where an electrical component passes less power as the voltage dropped across it rising. Notes: Not only do many gas discharge units exhibit negative resistance over certain parts of their operating range, but many semiconductor units do too. Question 13 When an electrical current passes through a conductor that provides some electrical resistance, the temperature of that conductor rises above the surrounding. Why is this? What is the practical significance of this effect? Check off electrical resistance is similar to mechanical friction: Electrons cannot flow freely through a resistance, and the friction they encounter translates some of their energy into heat, just as the friction of a worn mechanical bearing translates some of the kinetic energy in its rotation to heat, or the friction between a person's hands while rubbing them together on a cold day translates some of the movement into heat. Note: This is a good starting point for a discussion about work, energy and power. Power, of course, can be calculated directly by multiplying voltage by current, and measured in watts. It also provides an opportunity to discuss some of the practical limitations of electrical conductors. Question 14 For a given amount of electrical current, as resistance will disperse the greatest amount of power: a small value (low resistance) resistance, or a high value (high resistance) resistance? Explain your answer. Desee the answer A resistance with a high resistance degree (many ohm of resistance) will dissipate more thermal power than a lower valued resistance, since the same amount of electrical current through it. Note: This question is designed to make students think qualitatively about the relationship between power, resistance and power. I have found that qualitative (non-numerical) analysis is often more challenging than asking students to calculate the answers quantitatively (by numbers). Often simple mathematics is a kind of barrier behind which students seek refuge from true understanding of a subject. In other words, it's easier to punch keys on a calculator (or even perform calculations with paper and pencil) than to really think about the interrelationships of variables in a physical problem. However, a qualitative understanding of electrical systems is essential for rapid and efficient troubleshooting. Question 15 Plot the relationship between power and power for a 2 Ω resistance on this graph: What pattern do you see represented by plot? How does this compare to the graphical ratio of voltage and current for a resistance? The more power through the resistance, the more power spreads. But this is not a linear feature! Notes: Students must comfortable with graphs, and creating their own simple graphs is an excellent way to develop this understanding. A graphic representation of Ohm's law (actually, Joule's law) power function gives students a different view of the concept. If students have access to either a graph calculator or computer software that can draw 2-dimensional graphs, encourage them to plot the features using these technological resources. Question 16 Shown here is a schematic diagram for a simple battery-powered flashlight: What can be changed at the circuit or its components to make the flashlight provide more light when it is turned on? Afs reveal response Somehow, power spread by the bulb must be increased. Perhaps the most obvious way to increase power diversion is to use a battery with a larger voltage output, providing greater bulb power and greater power. But this is not the only option! Think of another way the flashlight output can be increased. Note: The obvious solution is a direct application of Ohm's law. Other solutions may not be so direct, but they will all relate back to Ohm's law somehow. Question 17 There are two basic Ohm's law equations: one relating to voltage, current and resistance; and the second regarding voltage, power and power (the latter equation is sometimes known as Joule's Law instead of Ohm's Law): $$E = IR$$ $$P = IE$$ In electronics textbooks and reference books, you will find twelve different variations of these two equations, a solution for each variable in the form of a unique pair of two other variables. But you don't remember all twelve equations if you have the ability to algebraically manipulate the two simple equations shown above. Demonstrate how algebra is used to infer the ten other forms of the two Ohm's law/Joule's law equations shown here. See the answer I won't show you how to do the algebraic manipulations, but I'll show you the ten other equations. First, the equations that can be derived strictly from $E = IR$: $$I= \frac {E}{R}$$ $$R= \frac {E}{I}$$ Next, equations that can be derived strictly from $P = I E$: $$I= \frac {P}{E}$$ $$E= \frac {P}{I}$$ N ekey, the equations, which can be derived by using algebraic substitution between the original two equations specified in the question: $$P=I^2R$$ $$P= \frac {E^2}{R}$$ And finally the equations that can be derived from manipulating the last two power equations: $$R= \frac {P}{I^2}$$ $$I=\sqrt{\frac{P}{R}}$$ $$E=\sqrt{PR}$$ $$R= \frac {E^2}{P}$$ Notes: Algebra is an extremely important tool in many technical fields. A good thing about the study of electronics is that it provides a fairly simple context in which basic algebraic principles can be learned (or at least illuminated). The same can be said of calculus concepts as well: basic principles of derived and integrated (in terms of time) can be easily applied to capacitor and inductor circuits that provide students with an accessible context which these otherwise abstract concepts can be understood. But calculus is a topic for later spreadsheet issues . . . Question 18 In this circuit, three resistors receive the same amount of power (4 amps) from a single source. Calculate the amount of excitement dropped by each resistance, as well as the amount of power dispersed by each resistance: Reveal response E1 Ω = 4 volts E2 Ω = 8 volts E3 Ω = 12 volts P1 Ω = 16 watts of P2 Ω = 32 watts of P3 Ω = 48 watts Follow-up question: Compare the direction of power through all components of this circuit with the polarities of their respective voltage drop. What do you notice about the relationship between current direction and voltage polarity for the battery, versus for all resistors? How does this relate to the identification of these components as either sources or loads? Note: The answers to this question should not create any surprises, especially when students understand electrical resistance in terms of friction: resistors with greater resistance (more friction to electron motion) require greater voltage (push) to get the same amount of power through them. Resistors with greater resistance (friction) will also dissipate more power in the form of heat, since the same amount of power. Another purpose of this question is to instill in students' minds the concept of components of a simple series circuit all sharing the same amount of power. Challenge your students to recognize any mathematical patterns in the respective voltage drop and power dissipations. What can one say, mathematically, about the voltage drop across 2 Ω against 1 Ω, for example? Question 19 In this circuit, three resistors get the same voltage (24 volts) from a single source. Calculate the amount of power drawn by each resistance, as well as the amount of power spread by each resistance: Reveal answer I1 Ω = 24 amps I2 Ω = 12 amps I3 Ω = 8 amps P1 Ω = 576 watts P2 Ω = 288 watts P3 Ω = 192 watt Notes: The answers to this question may seem paradoxical to students: the lowest value of resistor spreads the greatest power. Math doesn't lie, though. Another purpose of this question is to instill in the students' minds the concept of components of a simple parallel circuit all share the same amount of excitement. Challenge your students to recognize any mathematical patterns in the respective currents and power dissipations. What can one say, mathematically, whether the present pulled by the 2 Ω against 1 Ω, for example? You might mention that in electrical parlance, a heavy load is one that draws a large amount of power, and thus has a great resistance. This circuit, which shows how the lowest resistance in a parallel circuit uses the most current, provides practical support for the term heavy used to describe loads. Question 20 The brightness of a bulb - or the effect that, for that matter, disappears for that matter - can be varied by inserting a resistance in the circuit, like this: This method of electrical power management is not without drawbacks, though. Consider an example where the circuit current is 5 amps, the variable resistance is 2 Ω, and the lamp drops 20 volt voltage across its terminals. The power dispersed by the lamp, the power dispersed by the variable resistance and the total power supplied by the voltage source. Then explain why this power management method is not ideal. Reveal answer Plamp = 100 watts Presistance = 50 watts Ptotal = 150 watts Follow-up question: Note how in the original question I offered a set of hypothetical values to use in figuring out why a series rheostat (variable resistance) is not an effective means of controlling lamp power. Explain how the assumption of certain values is a useful problem-solving technique in cases where you don't get any values. Note: Discuss the concept of energy savings: that energy can neither be created nor destroyed, but simply change between different forms. On the basis of this principle, the sum of all power diversions in a circuit shall correspond to the total amount of power supplied by the energy source, regardless of how the components are connected together. Question 21 A modern electrical power management method involves inserting a fast switch in accordance with an electrical load so that the power is switched on and off very quickly over time. Normally, a solid-state device is used as a transistor: This circuit has been greatly simplified from a genuine, pulse-control power circuit. Just the transistor is shown (and not the pulse circuit, which is necessary to command it to turn on and off) for simplicity. All you need to be aware of is the fact that the transistor acts as a simple, single-pole single-throw (SPST) switch, except that it is controlled by an electric current rather than by a mechanical force, and that it is able to turn on and off millions of times per second without wear or fatigue. If the transistor pulsates on and off fast enough, the flow to the bulb can be varied as evenly as if it is controlled by a variable resistance. But there is very little energy wasted when using a fast-switching transistor to control electrical current, as opposed to when a variable resistance is used for the same task. This state of electrical power control is commonly referred to as Pulse-Width Modulation, or PWM. Explain why PWM power management is far more efficient than controlling load power using a series resistance. See the answer When the transistor is turned on, acting as a closed switch: passing full load of power, but drops little voltage. Thus, its ON power $(P = I E)$ spread is minimal. Conversely, when the transistor is turned off, it acts as an open switch: passing no power at all. Thus, its OFF power diversion $(P = I E)$ is zero. The power dispersed by the load (bulb) is the average power spread between the ON and OFF. Thus thus power is controlled without wasting power across the controller. Note: Students may find it difficult to understand how a light bulb can be dimmed by turning it on and off really quickly. The key to understanding this concept is to realize that the transistor's coupling time must be much faster than the time it takes for the bulb filament to heat completely or completely cool. The situation is similar to limiting the speed of a car by quickly pumping the accelerator. If done slowly, the result is a varying car speed. If done fast enough, although the car's mass averages ON/OFF cycling of the pedal and results in an almost stable speed. This technique is very popular in industrial power control, and is gaining popularity as a sound amplification technique (known as class D). The benefits of minimal wasted power from the controller are many. Question 22 What happens to the brightness of the light bulb if the switch in this circuit is suddenly closed? Check the answer Ideally, there will be no change whatsoever in the brightness of the bulb when the switch is closed, because voltage sources are supposed to maintain constant voltage output regardless of load. As you may have assumed, although the extra power pulled by the resistance when the switch is closed can actually cause the lamp to dim slightly, due to battery voltage sagging under the extra load. If the battery is well oversized for application, though, the degree of voltage case will be inconsequential. Note: This question illustrates a difference between the ideal conditions generally assumed for theoretical calculations and those that arise in real life. Truly, that's the purpose of a voltage source to maintain a constant output voltage regardless of load (power drawn from it), but in real life it's almost impossible. Most voltage sources exhibit a certain degree of case in their output over a number of load currents, some worse than others. In this example, it is impossible to say how much the voltage source output will sink when the switch is closed, because we have no idea what the current pull of the resistance will be compared to that of the bulb or what the voltage source's nominal output current is. All we can say is that theoretically there will be no effect from closing the switch, but that in real life there will be some degree of damping when the switch is closed. Question 23 What would happen if a cord that had no resistance at all (0 Ω) was connected directly across the terminals of a 6-volt battery? How much power would result, according to Ohm's law? Suppose we should short-circuit a 6-volt battery in the way just described and measure 8 amps of power. Why do the calculated figures from the previous paragraph not agree with the actual measurement? Reveal response Ohm's law suggests an infinite current (current = voltage divided by zero resistance). However, the described experiment only modestly current amount. If you believe that the wire used in the experiment is not resistance-free (i.e. it has resistance) and that it accounts for the difference between the expected and measured amounts of power, you are partially correct. Realistically, a small piece of thread like that used in the experiment will have a few tenths of an ohm of resistance. However, if you recalculate power with a wire resistance of 0.1 Ω, you will still find a big difference between your prediction and the actual measured current in this short circuit. Follow-up questions #1: explain why wire resistance alone does not explain the modest short circuit flow. Follow-up questions #2: identify at least one security risk associated with a real experiment like this. Note: Remind students that short-circuit testing of electrical energy sources can be dangerous. A student of mine once stuffed a 6-volt lantern battery into his tool bag, only to get it discharge smoke an hour later after the battery terminals had been short-circuited together by a wrench handle! No, Ohm's law is not being cheated here: short-circuiting a voltage source with a 0 Ω leader will not result in infinite power because there are other sources of resistance in such a circuit. The task here is to determine where these sources can be and how they can be located. Located.