

## Performance-based assessments for basic electricity competencies

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The purpose of these assessments is for instructors to accurately measure the learning of their electronics students, in a way that melds theoretical knowledge with hands-on application. In each assessment, students are asked to predict the behavior of a circuit from a schematic diagram and component values, then they build that circuit and measure its real behavior. If the behavior matches the predictions, the student then simulates the circuit on computer and presents the three sets of values to the instructor. If not, then the student then must correct the error(s) and once again compare measurements to predictions. Grades are based on the number of attempts required before all predictions match their respective measurements.

You will notice that no component values are given in this worksheet. The *instructor* chooses component values suitable for the students' parts collections, and ideally chooses different values for each student so that no two students are analyzing and building the exact same circuit. These component values may be hand-written on the assessment sheet, printed on a separate page, or incorporated into the document by editing the graphic image.

This is the procedure I envision for managing such assessments:

1. The instructor hands out individualized assessment sheets to each student.
2. Each student predicts their circuit's behavior at their desks using pencil, paper, and calculator (if appropriate).
3. Each student builds their circuit at their desk, under such conditions that it is impossible for them to verify their predictions using test equipment. Usually this will mean the use of a multimeter only (for measuring component values), but in some cases even the use of a multimeter would not be appropriate.
4. When ready, each student brings their predictions and completed circuit up to the instructor's desk, where any necessary test equipment is already set up to operate and test the circuit. There, the student sets up their circuit and takes measurements to compare with predictions.
5. If any measurement fails to match its corresponding prediction, the student goes back to their own desk with their circuit and their predictions in hand. There, the student tries to figure out where the error is and how to correct it.
6. Students repeat these steps as many times as necessary to achieve correlation between all predictions and measurements. The instructor's task is to count the number of attempts necessary to achieve this, which will become the basis for a percentage grade.
7. (OPTIONAL) As a final verification, each student simulates the same circuit on computer, using circuit simulation software (Spice, Multisim, etc.) and presenting the results to the instructor as a final pass/fail check.

These assessments more closely mimic real-world work conditions than traditional written exams:

- Students cannot pass such assessments only knowing circuit theory or only having hands-on construction and testing skills – they must be proficient at both.
- Students do not receive the “authoritative answers” from the instructor. Rather, they learn to validate their answers through real circuit measurements.
- Just as on the job, the work isn't complete until *all errors* are corrected.
- Students must recognize and correct their own errors, rather than having someone else do it for them.
- Students must be fully prepared on exam days, bringing not only their calculator and notes, but also their tools, breadboard, and circuit components.

Instructors may elect to reveal the assessments before test day, and even use them as preparatory labwork and/or discussion questions. Remember that there is absolutely nothing wrong with “teaching to

the test” *so long as the test is valid*. Normally, it is bad to reveal test material in detail prior to test day, lest students merely memorize responses in advance. With performance-based assessments, however, there is no way to pass without truly understanding the subject(s).

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Question 1

Competency: <b>Soldered wire splice</b>	Version:
<b>Description</b>	
Strip the ends of a short length of solid copper wire, splicing the ends together so as to form a loop. Use the "Western Union" splice technique, soldering the splice as a final step.	
<b>Given conditions</b>	
Approximately 6 inches of 22-gauge (or similar) solid copper wire. 25 watt soldering iron Electrical solder Needle-nose pliers	
<b>Parameters</b>	
(Check)	
Western Union splice well-formed	<input type="checkbox"/>
Even solder coverage of splice	<input type="checkbox"/>
No excess solder on splice ( <i>can still discern shape of splice</i> )	<input type="checkbox"/>
Solder joint shiny in appearance	<input type="checkbox"/>
Splice stronger than wire	<input type="checkbox"/>

file 01716

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Answer 1

Instructor will certify quality of splice.

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Notes 1

The purpose of this exercise is to ensure students can solder a good wire splice.

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Question 2

Competency: <b>PCB soldering</b>		Version:
<b>Description</b>		
<p>Solder at least five resistors into a printed circuit board, being careful not to apply excess heat or excess solder. The resistors should lay flat on the board, with the soldered wire ends neatly trimmed.</p>		
<b>Given conditions</b>		
<p>Five resistors, 1/4 watt each Printed circuit board with copper pads 25 watt soldering iron Electrical solder, small-diameter Needle-nose pliers Miniature diagonal cutting pliers</p>		
<b>Parameters</b>	<b>(Check)</b>	
Five resistors soldered in place (flat on board)	<input type="checkbox"/>	
Even solder coverage of all pads and leads	<input type="checkbox"/>	
No excess solder on pads ( <i>solder has concave profile</i> )	<input type="checkbox"/>	
No cold solder joints	<input type="checkbox"/>	
All soldering flux cleaned off	<input type="checkbox"/>	
All leads neatly trimmed	<input type="checkbox"/>	
No overheated or lifted pads	<input type="checkbox"/>	
Good "wetting" of solder on all pads	<input type="checkbox"/>	

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Answer 2

Instructor will certify quality of solder joints.

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Notes 2

The purpose of this exercise is to ensure students can make good solder joints on a printed circuit board.

Question 3

Competency: <b>Voltmeter usage</b>	Version:
<div data-bbox="316 349 478 387" data-label="Section-Header">Description</div> <p data-bbox="478 421 1129 499">Build a simple one-source, one-lamp circuit and use a multimeter to measure the lamp voltage.</p>	
<div data-bbox="316 555 595 593" data-label="Section-Header">Schematic diagram</div> <div data-bbox="427 678 1182 797" data-label="Diagram"> </div>	
<div data-bbox="316 891 595 929" data-label="Section-Header">Pictorial diagram</div> <div data-bbox="403 1055 1171 1254" data-label="Image"> </div>	
<div data-bbox="316 1417 507 1456" data-label="Section-Header">Explanation</div> <p data-bbox="427 1473 1198 1547">Should the voltmeter be connected in <i>series</i> or in <i>parallel</i> with the lamp in order to measure voltage?</p> <p data-bbox="427 1581 1203 1655">What will happen if the meter is connected the wrong way (series vs. parallel)?</p>	

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Answer 3

Connect the voltmeter in *parallel* with the component whose voltage is to be measured.

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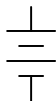


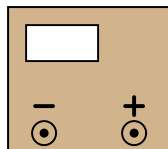
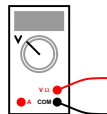

Notes 3

The purpose of this exercise is to make absolutely sure students can safely measure voltage with a multimeter.

A good extension of this assessment is to have students demonstrate competency using both digital and analog multimeters!



Question 4

Competency: <b>Voltmeter usage</b>	Version:
<div>Description</div> <div>Build a simple one-source, one-lamp circuit and use two multimeters to measure the lamp voltage.</div>	
<div>Schematic diagram</div> <div><div><math>V_{\text{supply}}</math></div><div> Meter</div><div> Lamp</div></div>	
<div>Pictorial diagram</div> <div><div><math>V_{\text{supply}}</math></div><div>Meter</div><div>Lamp</div></div>	
<div>Parameters</div> <div><div><math>V_{\text{lamp}}</math> <div>Measured</div><div></div><div>(with analog meter)</div></div><div><math>V_{\text{lamp}}</math> <div>Measured</div><div></div><div>(with digital meter)</div></div></div>	
<div>Explanation</div> <div>Should the voltmeter be connected in <i>series</i> or in <i>parallel</i> with the lamp in order to measure voltage?</div> <div>What will happen if the meter is connected the wrong way (series vs. parallel)?</div>	

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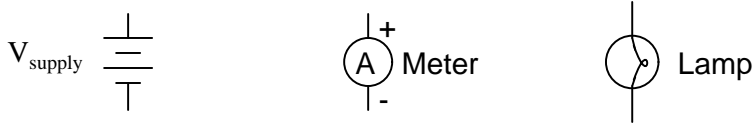
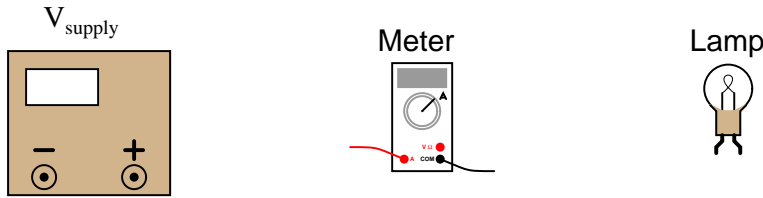
Answer 4

Connect the voltmeter in *parallel* with the component whose voltage is to be measured.

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Notes 4

The purpose of this exercise is to make absolutely sure students can safely measure voltage with a multimeter.

Competency: <b>Ammeter usage</b>	Version:
<div data-bbox="316 347 475 387">Description</div> <p data-bbox="491 421 1129 499">Build a simple one-source, one-lamp circuit and use a multimeter to measure the lamp current.</p>	
<div data-bbox="316 555 593 595">Schematic diagram</div> <div data-bbox="427 678 1184 801">  </div>	
<div data-bbox="316 891 593 931">Pictorial diagram</div> <div data-bbox="403 1059 1169 1256">  </div>	
<div data-bbox="316 1417 507 1458">Explanation</div> <p data-bbox="427 1473 1193 1552">Should the ammeter be connected in <i>series</i> or in <i>parallel</i> with the lamp in order to measure current?</p> <p data-bbox="427 1585 1201 1664">What will happen if the meter is connected the wrong way (series vs. parallel)?</p>	

**IMPORTANT NOTE:** do not actually try to connect the ammeter improperly in the circuit, as the meter may be damaged in the process!

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Answer 5

Connect the ammeter in *series* with the component whose current is to be measured.

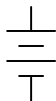
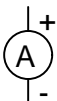

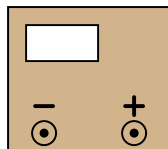
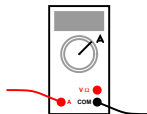

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Notes 5

The purpose of this exercise is to make absolutely sure students can safely measure current with a multimeter.

A good extension of this assessment is to have students demonstrate competency using both digital and analog multimeters!

Question 6

Competency: <b>Ammeter usage</b>	Version:
<div>Description</div> <div>Build a simple one-source, one-lamp circuit and use two multimeters to measure the lamp current.</div>	
<div>Schematic diagram</div> <div><div><math>V_{\text{supply}}</math></div><div> Meter</div><div> Lamp</div></div>	
<div>Pictorial diagram</div> <div><div><math>V_{\text{supply}}</math></div><div>Meter</div><div>Lamp</div></div>	
<div>Parameters</div> <div><div><math>I_{\text{lamp}}</math> <div>Measured</div><div></div><div>(with analog meter)</div></div><div><math>I_{\text{lamp}}</math> <div>Measured</div><div></div><div>(with digital meter)</div></div></div>	
<div>Explanation</div> <div>Should the ammeter be connected in <i>series</i> or in <i>parallel</i> with the lamp in order to measure current?</div> <div>What will happen if the meter is connected the wrong way (series vs. parallel)?</div>	

**IMPORTANT NOTE:** do not actually try to connect the ammeter improperly in the circuit, as the meter may be damaged in the process!  
[file 01714](#)

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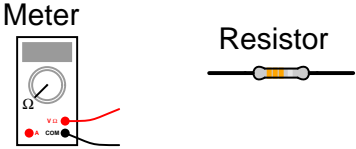
Answer 6

Connect the ammeter in *series* with the component whose current is to be measured.

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Notes 6

The purpose of this exercise is to make absolutely sure students can safely measure current with a multimeter.

Competency: <b>Ohmmeter usage</b>		Version:	
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Description</div>			
Interpret the color codes for several resistors, and then compare their rated resistances with the indication given by an ohmmeter.			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Schematic diagram</div>			
			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Pictorial diagram</div>			
			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Given conditions and parameters</div>			
	Predicted	Measured	
Resistor colors:   ___  ___  ___  ___	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	
Resistor colors:   ___  ___  ___  ___	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	
Resistor colors:   ___  ___  ___  ___	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	
Resistor colors:   ___  ___  ___  ___	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	
Resistor colors:   ___  ___  ___  ___	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	
Resistor colors:   ___  ___  ___  ___	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	

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#### Answer 7

The ohmmeter's indication is the "final word" on resistance.

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#### Notes 7

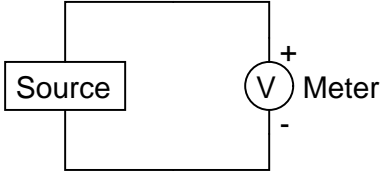
The purpose of this exercise is to make absolutely sure students can accurately measure resistance with a multimeter, and also that they can interpret resistor color codes. Select resistors that span a wide range, from less than 10 ohms to millions of ohms.

I recommend the following resistor color codes for students to try (all 5% tolerance):

- Blk, Brn, Grn, Gld
- Brn, Red, Brn, Gld
- Blu, Gry, Blk, Gld
- Red, Red, Org, Gld
- Brn, Grn, Yel, Gld
- Org, Org, Red, Gld

A good extension of this assessment is to have students demonstrate competency using both digital and analog multimeters!



Competency: <b>Sources of electricity</b>		Version:
<b>Schematic</b>		
		
<b>Given conditions</b>		
(Descriptions of source types; i.e. <i>photovoltaic, chemical, etc.</i> ) Source 1 = Source 2 = Source 3 =		
<b>Parameters</b>		
Greatest voltage produced	Predicted <div style="border: 1px solid black; height: 25px; width: 100%;"></div>	Measured <div style="border: 1px solid black; height: 25px; width: 100%;"></div>
	<div style="border: 1px solid black; height: 25px; width: 100%;"></div>	<div style="border: 1px solid black; height: 25px; width: 100%;"></div>
Least voltage produced	<div style="border: 1px solid black; height: 25px; width: 100%;"></div>	<div style="border: 1px solid black; height: 25px; width: 100%;"></div>

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#### Answer 8

The real-life measurements you take constitute the "final word" on which sources generate the most significant voltages.

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#### Notes 8

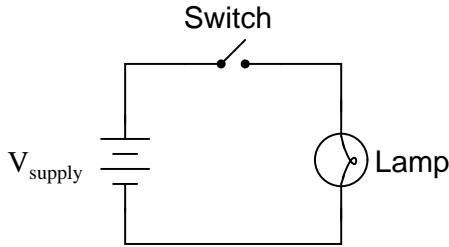
In this performance assessment, different electricity sources are suggested by way of conversion phenomena. In other words, the instructor will list such things as *photovoltaic* and *piezoelectric*, and students will have to choose the correct components to demonstrate conversion of energy into electrical form. Then, students will demonstrate each conversion for the instructor, ranking them in order of the voltage magnitude generated by each demonstration.

The purpose of this exercise is not only for students to obtain a practical understanding of electricity sources, but also to understand the relative magnitudes of each one. It is important for students to know, for instance, that thermoelectricity is a rather weak effect compared to piezoelectricity. This will help them understand the relative sensitivity of sensors and other electrical devices in the future.

Possible sources to list for student demonstration are:

- Photovoltaic
- Piezoelectric
- Electromagnetic
- Chemical
- Thermoelectric

Of course, your selection of sources for student demonstration depends on the parts and equipment available to them.

<b>Competency: Circuit with switch</b>	<b>Version:</b>																																
<b>Schematic</b>																																	
																																	
<b>Given conditions</b>																																	
$V_{\text{supply}} =$ $I_{\text{lamp}} \text{ (nominal)} =$																																	
<b>Parameters</b>																																	
<table style="width: 100%; border-collapse: collapse;"><thead><tr><th style="width: 15%;"></th><th style="width: 20%; text-align: center;">Predicted</th><th style="width: 20%; text-align: center;">Measured</th><th style="width: 45%;"></th></tr></thead><tbody><tr><td><math>V_{\text{lamp}}</math></td><td><input style="width: 100%;" type="text"/></td><td><input style="width: 100%;" type="text"/></td><td rowspan="3" style="vertical-align: middle; text-align: center;">} <i>With switch closed (on)</i></td></tr><tr><td><math>I_{\text{lamp}}</math></td><td><input style="width: 100%;" type="text"/></td><td><input style="width: 100%;" type="text"/></td></tr><tr><td><math>V_{\text{switch}}</math></td><td><input style="width: 100%;" type="text"/></td><td><input style="width: 100%;" type="text"/></td></tr><tr><td colspan="4" style="height: 20px;"></td></tr><tr><td></td><td style="text-align: center;">Predicted</td><td style="text-align: center;">Measured</td><td></td></tr><tr><td><math>V_{\text{lamp}}</math></td><td><input style="width: 100%;" type="text"/></td><td><input style="width: 100%;" type="text"/></td><td rowspan="3" style="vertical-align: middle; text-align: center;">} <i>With switch open (off)</i></td></tr><tr><td><math>I_{\text{lamp}}</math></td><td><input style="width: 100%;" type="text"/></td><td><input style="width: 100%;" type="text"/></td></tr><tr><td><math>V_{\text{switch}}</math></td><td><input style="width: 100%;" type="text"/></td><td><input style="width: 100%;" type="text"/></td></tr></tbody></table>			Predicted	Measured		$V_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>	} <i>With switch closed (on)</i>	$I_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>	$V_{\text{switch}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>						Predicted	Measured		$V_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>	} <i>With switch open (off)</i>	$I_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>	$V_{\text{switch}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>
	Predicted	Measured																															
$V_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>	} <i>With switch closed (on)</i>																														
$I_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>																															
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	Predicted	Measured																															
$V_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>	} <i>With switch open (off)</i>																														
$I_{\text{lamp}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>																															
$V_{\text{switch}}$	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>																															

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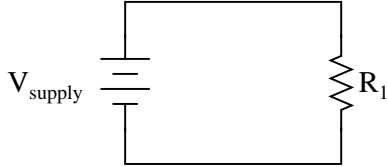
Answer 9

Use circuit simulation software to verify your predicted and measured parameter values.

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Notes 9

Use a variable-voltage, regulated power supply to supply a suitable DC voltage for the incandescent lamp.

Competency: <b>Ohm's Law</b>	Version:									
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Schematic</div>										
										
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Given conditions</div>										
$V_{\text{supply}} =$ $R_1 =$										
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Parameters</div>										
<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 10%;"></th> <th style="width: 20%; text-align: center;">Predicted</th> <th style="width: 20%; text-align: center;">Measured</th> </tr> </thead> <tbody> <tr> <td style="text-align: right;"><math>I_{\text{total}}</math></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> <tr> <td style="text-align: right;"><math>V_R</math></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> </tbody> </table>			Predicted	Measured	$I_{\text{total}}$			$V_R$		
	Predicted	Measured								
$I_{\text{total}}$										
$V_R$										
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Fault analysis</div>										
<p>Suppose component <span style="border: 1px solid black; padding: 0 5px;"><math>R_1</math></span> fails <input type="checkbox"/> open <input type="checkbox"/> other _____</p> <p><input type="checkbox"/> shorted</p> <p><i>What will happen in the circuit?</i></p>										

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Answer 10

Use circuit simulation software to verify your predicted and measured parameter values.

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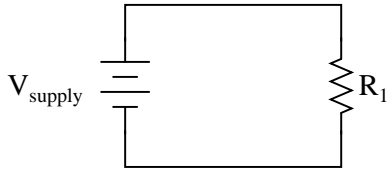
Notes 10

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify a standard resistor value, somewhere between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).

If using this question as a lab exercise rather than an assessment, I recommend specifying a voltage that is standard for batteries, so students don't necessarily have to have an adjustable power supply available to do this lab.

For example, specify  $V_{supply}$  as 6 volts and  $R_1$  as 33 k $\Omega$ . The resulting current is sufficient to provide a nice, strong needle deflection on most cheap analog ammeters, too!

Question 11

Competency: <b>Ohm's Law</b>		Version:	
Schematic			
			
Given conditions			
$V_{\text{supply}} =$ (see multiple values given below) $R_1 =$			
Parameters			
	Given	Predicted	Measured
$V_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$I_{\text{total}}$	<input style="width: 100px; height: 25px;" type="text"/>
$V_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$I_{\text{total}}$	<input style="width: 100px; height: 25px;" type="text"/>
$V_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$I_{\text{total}}$	<input style="width: 100px; height: 25px;" type="text"/>
$V_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$I_{\text{total}}$	<input style="width: 100px; height: 25px;" type="text"/>
Fault analysis			
Suppose component <input style="width: 50px; height: 25px;" type="text"/> fails		<input type="checkbox"/> open <input type="checkbox"/> other _____ <input type="checkbox"/> shorted	
What will happen in the circuit?			

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Answer 11

Use circuit simulation software to verify your predicted and measured parameter values.

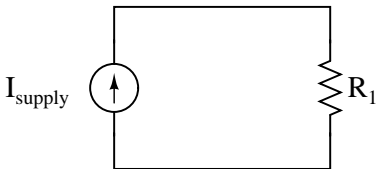
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Notes 11

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify a standard resistor value, somewhere between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).



Question 12

Competency: <b>Ohm's Law</b>		Version:	
Schematic			
			
Given conditions			
$I_{\text{supply}} =$ (see multiple values given below) $R_1 =$			
Parameters			
	Given	Predicted	Measured
$I_{\text{supply}} =$		$V_{R1}$	
$I_{\text{supply}} =$		$V_{R1}$	
$I_{\text{supply}} =$		$V_{R1}$	
$I_{\text{supply}} =$		$V_{R1}$	
Fault analysis			
Suppose component <span style="border: 1px solid black; display: inline-block; width: 50px; height: 20px; vertical-align: middle;"></span> fails		<input type="checkbox"/> open <input type="checkbox"/> other _____ <input type="checkbox"/> shorted	
<i>What will happen in the circuit?</i>			

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Answer 12

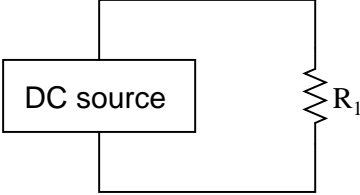
Use circuit simulation software to verify your predicted and measured parameter values.

---

Notes 12

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify a standard resistor value, somewhere between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).

When students set their power supplies for a certain amount of current, it is often helpful to have them do so while it is powering the resistor (rather than connecting their ammeter directly across the power supply to set its current output). This helps avoid the possibility of blowing the fuse in their ammeter!

Competency: <b>Ohm's Law</b>		Version:	
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Schematic</div>			
			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Given conditions</div>			
$V_{\text{supply}} =$ (see multiple values given below) $I_{\text{supply}} =$ (see multiple values given below) $R_1 =$			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Parameters</div>			
	Given	Predicted	Measured
$V_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$I_{R1}$	<input style="width: 100px; height: 25px;" type="text"/>
$V_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$I_{R1}$	<input style="width: 100px; height: 25px;" type="text"/>
$I_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$V_{R1}$	<input style="width: 100px; height: 25px;" type="text"/>
$I_{\text{supply}} =$	<input style="width: 100px; height: 25px;" type="text"/>	$V_{R1}$	<input style="width: 100px; height: 25px;" type="text"/>
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Fault analysis</div>			
Suppose component <input style="width: 60px; height: 25px;" type="text"/> fails <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> <input type="checkbox"/> open    <input type="checkbox"/> other _____  <input type="checkbox"/> shorted         </div>			
<i>What will happen in the circuit?</i>			

---

### Answer 13

Use circuit simulation software to verify your predicted and measured parameter values.

---

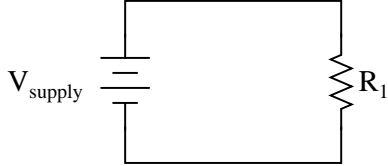
### Notes 13

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify a standard resistor value, somewhere between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).

An interesting "twist" on this exercise is to specify the value of resistor  $R_1$  in colors. For example: Red, Vio, Red, Gld instead of 2.7 k $\Omega$ .

When students set their power supplies for a certain amount of current, it is often helpful to have them do so while it is powering the resistor (rather than connecting their ammeter directly across the power supply to set its current output). This helps avoid the possibility of blowing the fuse in their ammeter!

Question 14

Competency: <b>Current-limiting resistor</b>	Version:									
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Schematic</div> <div style="text-align: center; margin-top: 20px;">  </div>										
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Given conditions</div> <div style="margin-top: 20px;"> <math>V_{\text{supply}} =</math>                      <math>I_{\text{maximum}} =</math> </div>										
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Description</div> <div style="text-align: center; margin-top: 20px;"> <p>Choose a resistor value such that the circuit current is as close as possible to <math>I_{\text{maximum}}</math> without exceeding it.</p> </div>										
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Parameters</div> <table style="width: 100%; margin-top: 20px;"> <thead> <tr> <th></th> <th style="text-align: center;">Predicted</th> <th style="text-align: center;">Measured</th> </tr> </thead> <tbody> <tr> <td style="text-align: right; padding-right: 10px;"><math>R_1</math></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> <tr> <td style="text-align: right; padding-right: 10px;"><math>I</math></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> </tbody> </table>			Predicted	Measured	$R_1$			$I$		
	Predicted	Measured								
$R_1$										
$I$										

file 01924

---

Answer 14

Use circuit simulation software to verify your predicted and measured parameter values.

---

Notes 14

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. If using this question as a lab exercise rather than an assessment, I recommend specifying a voltage that is standard for batteries, so students don't necessarily have to have an adjustable power supply available to do this lab.

In this exercise, the student must both quantitatively and qualitatively analyze the circuit, because the ideal resistor value probably does not exist. As the instructor, it is your task to choose voltage and current specifications that preclude exact solutions with common resistor values.

Competency: <b>4-wire "Kelvin" resistance measurement</b> Version:											
Schematic											
Given conditions											
$I_{\text{supply}} =$											
Parameters											
<table style="margin: auto;"> <tr> <td></td> <td style="text-align: center;">Measured</td> </tr> <tr> <td style="text-align: right;"><math>V_{\text{meter}}</math></td> <td style="border: 1px solid black; width: 100px; height: 20px;"></td> </tr> <tr> <td style="text-align: right;"><math>R_x</math></td> <td> <table style="display: inline-table; vertical-align: middle;"> <tr> <td style="text-align: center;">"Kelvin" Measured</td> <td style="text-align: center;">Directly Measured (or revealed by instructor)</td> </tr> <tr> <td style="border: 1px solid black; width: 100px; height: 20px;"></td> <td style="border: 1px solid black; width: 100px; height: 20px;"></td> </tr> </table> </td> </tr> </table>			Measured	$V_{\text{meter}}$		$R_x$	<table style="display: inline-table; vertical-align: middle;"> <tr> <td style="text-align: center;">"Kelvin" Measured</td> <td style="text-align: center;">Directly Measured (or revealed by instructor)</td> </tr> <tr> <td style="border: 1px solid black; width: 100px; height: 20px;"></td> <td style="border: 1px solid black; width: 100px; height: 20px;"></td> </tr> </table>	"Kelvin" Measured	Directly Measured (or revealed by instructor)		
	Measured										
$V_{\text{meter}}$											
$R_x$	<table style="display: inline-table; vertical-align: middle;"> <tr> <td style="text-align: center;">"Kelvin" Measured</td> <td style="text-align: center;">Directly Measured (or revealed by instructor)</td> </tr> <tr> <td style="border: 1px solid black; width: 100px; height: 20px;"></td> <td style="border: 1px solid black; width: 100px; height: 20px;"></td> </tr> </table>	"Kelvin" Measured	Directly Measured (or revealed by instructor)								
"Kelvin" Measured	Directly Measured (or revealed by instructor)										

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Answer 15

Use circuit simulation software to verify your predicted and measured parameter values.

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Notes 15

You will need to provide some low-resistance specimens for your students to measure using this technique. Motor armature coils work well for this purpose, as do large power resistors with the labels scratched off.

When students set their power supplies for a certain amount of current, it is often helpful to have them do so while it is powering the resistor (rather than connecting their ammeter directly across the power supply to set its current output). This helps avoid the possibility of blowing the fuse in their ammeter!



Competency: <b>Determining wire length by resistance</b>		Version:												
Schematic														
Given conditions														
$T_{\text{room}} =$	$I_{\text{supply}} =$													
Parameters														
<table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;"></td> <td style="width: 30%; text-align: center;">Measured</td> <td style="width: 40%;"></td> </tr> <tr> <td style="text-align: right;"><math>V_{\text{meter}}</math></td> <td></td> <td><input style="width: 100%;" type="text"/></td> </tr> <tr> <td style="text-align: right;"><math>R_{\text{wire}}</math></td> <td style="text-align: center;">                     "Kelvin" Measured                 </td> <td style="text-align: center;">                     Directly Measured (or revealed by instructor)                 </td> </tr> <tr> <td></td> <td><input style="width: 100%;" type="text"/></td> <td><input style="width: 100%;" type="text"/></td> </tr> </table>				Measured		$V_{\text{meter}}$		<input style="width: 100%;" type="text"/>	$R_{\text{wire}}$	"Kelvin" Measured	Directly Measured (or revealed by instructor)		<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>
	Measured													
$V_{\text{meter}}$		<input style="width: 100%;" type="text"/>												
$R_{\text{wire}}$	"Kelvin" Measured	Directly Measured (or revealed by instructor)												
	<input style="width: 100%;" type="text"/>	<input style="width: 100%;" type="text"/>												

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Answer 16

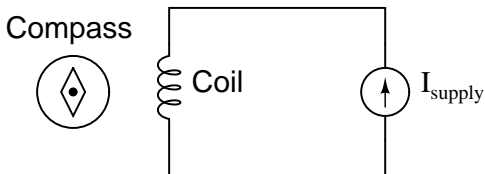
Measure the wire length to check your calculation!

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Notes 16

You will need to provide some spools of wire for your students to measure using this technique. Your students will need to find wire tables correlating length with resistance (at different temperatures, if the room temperature is significantly different from the standard temperature given in the table).

When students set their power supplies for a certain amount of current, it is often helpful to have them do so while it is powering the wire (rather than connecting their ammeter directly across the power supply to set its current output). This helps avoid the possibility of blowing the fuse in their ammeter!

Competency: <b>Electromagnetism</b>	Version:																		
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Schematic</div> <div style="text-align: center; margin-top: 20px;">  </div>																			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Given conditions</div> <p style="text-align: center; margin-top: 10px;">Vary the power supply current, and also switch polarity, noting the effects on the compass needle.</p>																			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Parameters</div> <table style="width: 100%; margin-top: 10px;"> <thead> <tr> <th></th> <th colspan="2" style="text-align: center;"><i>Qualitative answers only</i></th> </tr> <tr> <th></th> <th style="text-align: center;">Predicted</th> <th style="text-align: center;">Measured</th> </tr> </thead> <tbody> <tr> <td style="text-align: right;">Low current</td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> <tr> <td style="text-align: right;">Higher current</td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> <tr> <td style="text-align: right;">Reverse polarity Low current</td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> <tr> <td style="text-align: right;">Reverse polarity Higher current</td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> <td style="border: 1px solid black; width: 100px; height: 30px;"></td> </tr> </tbody> </table>			<i>Qualitative answers only</i>			Predicted	Measured	Low current			Higher current			Reverse polarity Low current			Reverse polarity Higher current		
	<i>Qualitative answers only</i>																		
	Predicted	Measured																	
Low current																			
Higher current																			
Reverse polarity Low current																			
Reverse polarity Higher current																			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Analysis</div> <p style="text-align: center; margin-top: 10px;">Identify the places on the coil where the field is strongest.</p>																			

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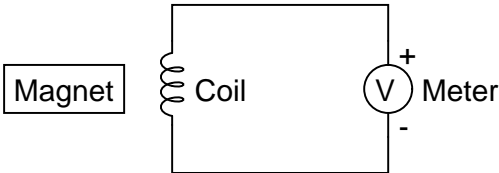
#### Answer 17

I won't reveal the answer here as to what effect magnitude has on magnetic field strength, but I will suggest a way to test for strength: place the compass at a distance from the coil, where the coil's field has a relatively small effect on the needle position in relation to the ambient magnetic field.

---

#### Notes 17

Old solenoid valve coils work very well for this exercise, as do spools of wire with large steel bolts passed through the center. Students may also wind their own coils using small-gauge magnet wire and a steel bolt. If the coils are hollow, you may experiment with and without ferrous cores, to demonstrate the effects of a ferromagnetic flux path on the field strength produced.

Competency: <b>Electromagnetic induction</b>	Version:																		
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Schematic</div> <div style="text-align: center; margin-top: 20px;">  </div>																			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Given conditions</div> <p style="text-align: center; margin-top: 10px;">Set voltmeter to the most sensitive range possible!</p> <p style="text-align: center;">Move the magnet slowly toward the coil, and then slowly away</p> <p style="text-align: center;">Move the magnet quickly toward the coil, and then quickly away</p>																			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Parameters</div> <table style="width: 100%; margin-top: 10px;"> <thead> <tr> <th></th> <th colspan="2" style="text-align: center;"><i>Qualitative answers only</i></th> </tr> <tr> <th></th> <th style="text-align: center;">Predicted</th> <th style="text-align: center;">Measured</th> </tr> </thead> <tbody> <tr> <td style="text-align: center;"><math>V_{\text{coil}}</math> Slowly, toward</td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> </tr> <tr> <td style="text-align: center;"><math>V_{\text{coil}}</math> Slowly, away</td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> </tr> <tr> <td style="text-align: center;"><math>V_{\text{coil}}</math> Quickly, toward</td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> </tr> <tr> <td style="text-align: center;"><math>V_{\text{coil}}</math> Quickly, away</td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> <td style="text-align: center;"><div style="border: 1px solid black; width: 100px; height: 30px;"></div></td> </tr> </tbody> </table>			<i>Qualitative answers only</i>			Predicted	Measured	$V_{\text{coil}}$ Slowly, toward	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	$V_{\text{coil}}$ Slowly, away	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	$V_{\text{coil}}$ Quickly, toward	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	$V_{\text{coil}}$ Quickly, away	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>
	<i>Qualitative answers only</i>																		
	Predicted	Measured																	
$V_{\text{coil}}$ Slowly, toward	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>																	
$V_{\text{coil}}$ Slowly, away	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>																	
$V_{\text{coil}}$ Quickly, toward	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>																	
$V_{\text{coil}}$ Quickly, away	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>	<div style="border: 1px solid black; width: 100px; height: 30px;"></div>																	
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Analysis</div> <p style="margin-top: 10px;">Does the orientation of the magnet have any effect on the polarity or magnitude of the induced voltage?</p> <p style="margin-top: 10px;">Does the direction of approach to the coil have any effect on the magnitude of the induced voltage?</p>																			

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Answer 18

The magnitude of the induced voltage is a direct function of the magnetic flux's rate of change over time ( $\frac{d\phi}{dt}$ ).

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Notes 18

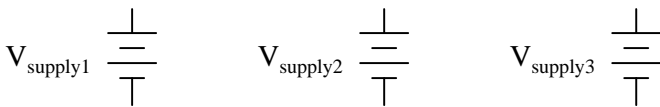
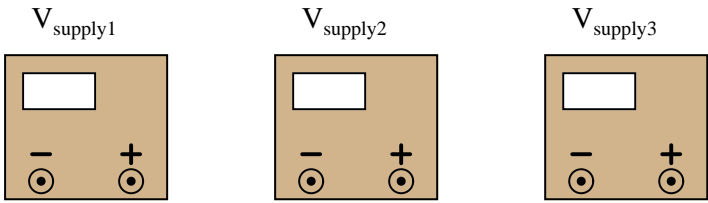
Old solenoid valve coils work very well for this exercise, as do spools of wire with large steel bolts passed through the center. Students may also wind their own coils using small-gauge magnet wire and a steel bolt.

Please note that students will not be able to *predict* the polarity of the induced voltage unless they know the rotation of the coil windings and the polarity of their magnet. This will only be possible if the windings are exposed to view or if the students wind their own coils, and if the magnet has its poles labeled "North" and "South" (or if this is determined experimentally by using the magnet as a compass).

Use magnets that are as strong as possible, and that have their poles on the physical ends. This may seem like a strange request, but I've seen students bring some unusual magnets to class for this experiment, whose poles are *not* located on the ends. One type of magnet that works well is the so-called "cow magnet," used by cattle ranchers to protect cows' multiple stomachs from injury from ingestion of fence staples and other ferromagnetic objects. These are a few inches long, cylindrical in shape (so the cow can swallow it like a big pill), and quite strong.

If students are using analog multimeters to measure the coil's induced voltage, be sure to keep the multimeter far away from the magnet. Analog meter movements are generally quite sensitive to external magnetic fields and may register falsely if positioned too close to a strong magnet.

Question 19

Competency: <b>Series DC voltages</b>	Version:
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Description</div> <p style="text-align: center; margin-top: 10px;">Connect three DC power sources together to achieve the specified total voltage.</p>	
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Given conditions</div> <div style="display: flex; justify-content: space-around; margin-top: 10px;"> <div style="text-align: center;"> <math>V_{\text{supply1}} =</math>  <math>V_{\text{supply2}} =</math>  <math>V_{\text{supply3}} =</math> </div> <div style="text-align: center;"> <math>V_{\text{total}} =</math> </div> </div>	
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Schematic diagram</div> <div style="text-align: center; margin-top: 20px;">  </div>	
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Pictorial diagram</div> <div style="text-align: center; margin-top: 20px;">  </div>	

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Answer 19

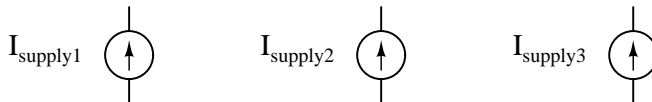
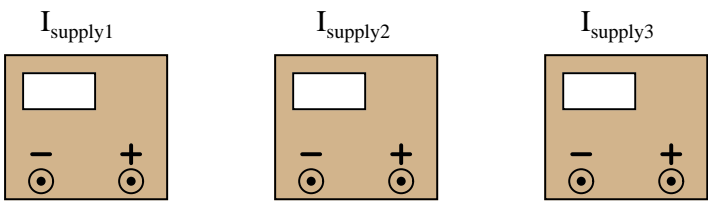
Use circuit simulation software to verify schematic diagram. Your real circuit will verify the pictorial diagram.

---

Notes 19

Use variable-voltage, regulated power supplies to supply any amount of DC voltage below 30 volts.



Competency: <b>Parallel DC currents</b>	Version:
<b>Description</b>	
Connect three DC power sources together to achieve the specified total current.	
<b>Given conditions</b>	
$I_{\text{supply1}} =$	$I_{\text{total}} =$
$I_{\text{supply2}} =$	
$I_{\text{supply3}} =$	
<b>Schematic diagram</b>	
	
<b>Pictorial diagram</b>	
	

**Caution!** Consult your instructor to see how to set up each power supply to be a *safe* current source before attempting to connect them together!

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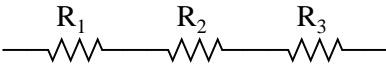
Answer 20

Use circuit simulation software to verify schematic diagram. Your real circuit will verify the pictorial diagram.

---

Notes 20

Use regulated power supplies with adjustable current limits to act as current sources (voltage adjustments set to "full" while current adjustments set the desired output current for each). Keep the currents less than one amp for each supply.

Competency: <b>Series resistances</b>		Version:
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Schematic</div>		
		
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Given conditions</div>		
$R_1 =$	$R_2 =$	$R_3 =$
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Parameters</div>		
$R_{\text{total}}$	<div style="display: inline-block; text-align: center;">Predicted <div style="border: 1px solid black; width: 80px; height: 25px; margin: 0 auto;"></div></div>	<div style="display: inline-block; text-align: center;">Measured <div style="border: 1px solid black; width: 80px; height: 25px; margin: 0 auto;"></div></div>
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Analysis</div>		
<div style="text-align: center;">Equation used to calculate <math>R_{\text{total}}</math> :</div>		

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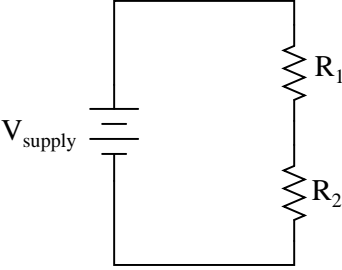
Answer 21

Use circuit simulation software to verify schematic diagram. Your real circuit will verify the pictorial diagram.

---

Notes 21

Specify standard resistor values, all between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).

Competency: <b>Series DC resistor circuit</b>		Version:																						
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Schematic</div>																								
																								
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Given conditions</div>																								
$V_{\text{supply}} =$ $R_1 =$ $R_2 =$																								
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Parameters</div>																								
<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;"></th> <th style="width: 20%; text-align: center;">Predicted</th> <th style="width: 20%; text-align: center;">Measured</th> </tr> </thead> <tbody> <tr> <td><math>I_{\text{supply}}</math></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> </tr> <tr> <td><math>V_{R1}</math></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> </tr> <tr> <td><math>V_{R2}</math></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> </tr> </tbody> </table>			Predicted	Measured	$I_{\text{supply}}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	$V_{R1}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	$V_{R2}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 15%;"></th> <th style="width: 20%; text-align: center;">Predicted</th> <th style="width: 20%; text-align: center;">Measured</th> </tr> </thead> <tbody> <tr> <td><math>I_{R1}</math></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> </tr> <tr> <td><math>I_{R2}</math></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> <td><div style="border: 1px solid black; width: 100px; height: 25px;"></div></td> </tr> </tbody> </table>			Predicted	Measured	$I_{R1}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	$I_{R2}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>
	Predicted	Measured																						
$I_{\text{supply}}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>																						
$V_{R1}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>																						
$V_{R2}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>																						
	Predicted	Measured																						
$I_{R1}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>																						
$I_{R2}$	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>	<div style="border: 1px solid black; width: 100px; height: 25px;"></div>																						
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Analysis</div>																								
<p style="text-align: center;">Relationship between resistor voltage drops and total voltage:</p>																								
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Fault analysis</div>																								
<p>Suppose component <div style="border: 1px solid black; width: 60px; height: 25px; display: inline-block;"></div> fails</p> <div style="display: flex; justify-content: space-around; align-items: flex-start;"> <div style="text-align: center;"> <input type="checkbox"/> open <input type="checkbox"/> shorted         </div> <div style="text-align: center;"> <input type="checkbox"/> other _____         </div> </div> <p><i>What will happen in the circuit?</i></p>																								

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#### Answer 22

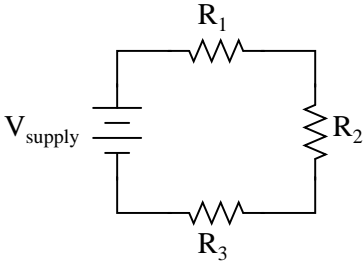
Use circuit simulation software to verify your predicted and measured parameter values.

---

#### Notes 22

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify standard resistor values, all between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.

Competency: <b>Series DC resistor circuit</b>		Version:	
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Schematic</div>			
			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Given conditions</div>			
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$	$R_3 =$
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Parameters</div>			
	Predicted	Measured	
$I_{\text{supply}}$			$I_{R1}$
$V_{R1}$			$I_{R2}$
$V_{R2}$			$I_{R3}$
$V_{R3}$			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Analysis</div>			
Relationship between resistor voltage drops and total voltage:			
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px;">Fault analysis</div>			
Suppose component <span style="border: 1px solid black; display: inline-block; width: 50px; height: 20px; vertical-align: middle;"></span> fails <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> <input type="checkbox"/> open    <input type="checkbox"/> other _____  <input type="checkbox"/> shorted         </div>			
<i>What will happen in the circuit?</i>			

---

#### Answer 23

Use circuit simulation software to verify your predicted and measured parameter values.

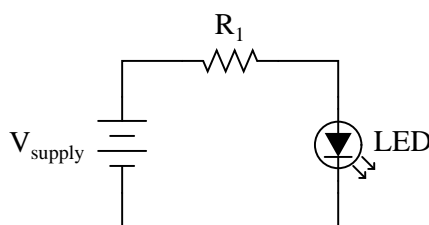
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#### Notes 23

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify standard resistor values, all between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 8k2, 10k, 22k, 33k, 39k, 47k, 68k, 82k, etc.).

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.



Competency: <b>Series dropping resistor for LED</b>	Version:																					
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Schematic</div> <div style="text-align: center; margin-top: 20px;">  </div>																						
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Given conditions</div> <div style="margin-top: 20px;"> <math>V_{\text{supply}} =</math> <math>I_{\text{LED}} =</math> </div>																						
<div style="border: 1px solid black; display: inline-block; padding: 2px 5px; margin-bottom: 5px;">Parameters</div> <div style="margin-top: 20px;"> <table style="width: 100%; border-collapse: collapse;"> <tr> <td style="width: 30%;"></td> <td style="width: 30%; text-align: center;">Measured</td> <td style="width: 40%;"></td> </tr> <tr> <td><math>V_{\text{LED}} @ I_{\text{LED}}</math></td> <td style="text-align: center;"><input style="width: 80%;" type="text"/></td> <td></td> </tr> <tr> <td></td> <td></td> <td style="text-align: center;">Predicted</td> </tr> <tr> <td></td> <td style="text-align: center;"><math>R_1</math></td> <td style="text-align: center;"><input style="width: 80%;" type="text"/></td> </tr> <tr> <td></td> <td style="text-align: center;">Predicted</td> <td style="text-align: center;">Measured</td> </tr> <tr> <td><math>I_{\text{total}}</math></td> <td style="text-align: center;"><input style="width: 80%;" type="text"/></td> <td style="text-align: center;"><input style="width: 80%;" type="text"/></td> </tr> <tr> <td><math>P_{R1}</math></td> <td style="text-align: center;"><input style="width: 80%;" type="text"/></td> <td></td> </tr> </table> </div>			Measured		$V_{\text{LED}} @ I_{\text{LED}}$	<input style="width: 80%;" type="text"/>				Predicted		$R_1$	<input style="width: 80%;" type="text"/>		Predicted	Measured	$I_{\text{total}}$	<input style="width: 80%;" type="text"/>	<input style="width: 80%;" type="text"/>	$P_{R1}$	<input style="width: 80%;" type="text"/>	
	Measured																					
$V_{\text{LED}} @ I_{\text{LED}}$	<input style="width: 80%;" type="text"/>																					
		Predicted																				
	$R_1$	<input style="width: 80%;" type="text"/>																				
	Predicted	Measured																				
$I_{\text{total}}$	<input style="width: 80%;" type="text"/>	<input style="width: 80%;" type="text"/>																				
$P_{R1}$	<input style="width: 80%;" type="text"/>																					

file 01636

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Answer 24

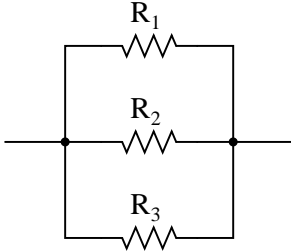
Note: be careful to choose a resistor with an adequate power rating (Watts)!

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Notes 24

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. For added challenge, set the power supply voltage high enough (at least 15 volts) that a 1/4 watt resistor will be inadequately rated for the power dissipation.

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.

<b>Competency: Parallel resistances</b>		Version:
<b>Schematic</b>		
		
<b>Given conditions</b>		
$R_1 =$	$R_2 =$	$R_3 =$
<b>Parameters</b>		
$R_{\text{total}}$	Predicted <input style="width: 80px; height: 25px;" type="text"/>	Measured <input style="width: 80px; height: 25px;" type="text"/>
<b>Analysis</b>		
Equation used to calculate $R_{\text{total}}$ :		

---

Answer 25

Use circuit simulation software to verify schematic diagram. Your real circuit will verify the pictorial diagram.

---

Notes 25

Specify standard resistor values, all between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).

Competency: <b>Parallel DC resistor circuit</b>		Version:	
Schematic			
Given conditions			
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$	
Parameters			
	Predicted	Measured	
$I_{\text{supply}}$	<input type="text"/>	<input type="text"/>	
$V_{R1}$	<input type="text"/>	<input type="text"/>	
$V_{R2}$	<input type="text"/>	<input type="text"/>	
	Predicted	Measured	
$I_{R1}$	<input type="text"/>	<input type="text"/>	
$I_{R2}$	<input type="text"/>	<input type="text"/>	
Analysis			
Relationship between resistor (branch) currents and total current:			
Fault analysis			
Suppose component <input type="text"/> fails <input type="checkbox"/> open <input type="checkbox"/> other _____ <input type="checkbox"/> shorted What will happen in the circuit?			

---

Answer 26

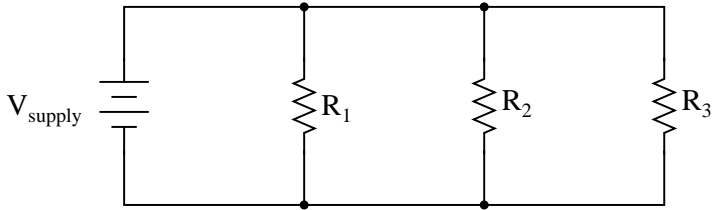
Use circuit simulation software to verify your predicted and measured parameter values.

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Notes 26

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify standard resistor values, all between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 10k, 22k, 33k, 39k 47k, 68k, etc.).

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.

Competency: <b>Parallel DC resistor circuit</b>		Version:	
<b>Schematic</b>			
			
<b>Given conditions</b>			
$V_{\text{supply}} =$	$R_1 =$	$R_2 =$	$R_3 =$
<b>Parameters</b>			
	Predicted	Measured	
$I_{\text{supply}}$			$I_{R1}$
$V_{R1}$			$I_{R2}$
$V_{R2}$			$I_{R3}$
$V_{R3}$			
<b>Analysis</b>			
Relationship between resistor (branch) currents and total current:			
<b>Fault analysis</b>			
Suppose component <span style="border: 1px solid black; display: inline-block; width: 50px; height: 20px; vertical-align: middle;"></span> fails <div style="display: inline-block; vertical-align: middle; margin-left: 10px;"> <input type="checkbox"/> open    <input type="checkbox"/> other _____  <input type="checkbox"/> shorted         </div>			
What will happen in the circuit?			

---

Answer 27

Use circuit simulation software to verify your predicted and measured parameter values.

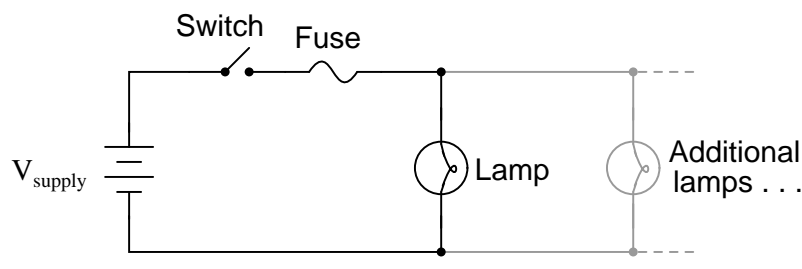
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Notes 27

Use a variable-voltage, regulated power supply to supply any amount of DC voltage below 30 volts. Specify standard resistor values, all between 1 k $\Omega$  and 100 k $\Omega$  (1k5, 2k2, 2k7, 3k3, 4k7, 5k1, 6k8, 8k2, 10k, 22k, 33k, 39k, 47k, 68k, 82k, etc.).

An extension of this exercise is to incorporate troubleshooting questions. Whether using this exercise as a performance assessment or simply as a concept-building lab, you might want to follow up your students' results by asking them to predict the consequences of certain circuit faults.



<b>Competency: Parallel loads with fuse protection</b>		Version:
<b>Schematic</b>		
		
<b>Given conditions</b>		
$V_{\text{supply}} =$	$I_{\text{lamp}} \text{ (nominal)} =$	Fuse rating =
<b>Parameters</b>		
Maximum # of lamps	Predicted <div style="border: 1px solid black; width: 100px; height: 30px; margin: 0 auto;"></div>	Tested <div style="border: 1px solid black; width: 100px; height: 30px; margin: 0 auto;"></div>

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Answer 28

Use circuit simulation software to verify your predicted and measured parameter values.

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Notes 28

Use a variable-voltage, regulated power supply to supply a suitable DC voltage for the incandescent lamp. Set the power supply current limit such that it outputs enough to blow the fuse, but not enough to damage anything else. The fuse needs to be rated for a current value practical for a reasonable number of parallel-connected lamps.

(Template)

Competency:		Version:	
Schematic			
Given conditions			
Parameters			
Predicted		Measured	
<div></div>	<div></div>	<div></div>	<div></div>
<div></div>	<div></div>	<div></div>	<div></div>

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Answer 29

Here, you would indicate where or how to obtain answers for the requested parameters, but not actually give the figures. My stock answer here is “use circuit simulation software” (Spice, Multisim, etc.).

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Notes 29

Any relevant notes for the assessment activity go here.