Unit 1 Ohm's law

- The voltage (volts) measured across a resistor is equal to the current (amps) through the resistor multiplied by the resistance (ohms).

$$V = I \times R$$

Ohm's law was first stated by Georg Simon Ohm, in a pamphlet entitled *Die galvanische Kette, mathematisch bearbeitet* (The galvanic circuit investigated mathematically) which was published in 1827 in Cologne, Germany. As originally stated, the law related the voltage across a metallic conductor to the current through the conductor by a relationship, $V = I \times R$, where R is the resistance of the metallic conductor. Ohm's law, even as applied to metallic conductors, is an idealization, since the resistance of metals depends on the temperature. When Ohm's law is applied to nonmetallic conductors, the value of R is frequently not constant and as applied to structured devices such as diodes the deviations are such that the law can only be considered to apply over very small regions.

Electronic components which obey Ohm's law are so useful that significant effort has been expended in developing resistors which obey the law as closely as possible and which, when used in electronic circuits, will operate in a fully predictable manner. The result is that Ohm's law is probably the most important law in electronics and is certainly the most used.

Given any two of the three variables, the third value can be calculated immediately so, in trying to analyze a circuit, you should always concentrate on any resistor for which you can obtain or deduce two of the three terms used in Ohm's law.

Most modern discrete resistors are made using a metal film deposition process with the resistor encapsulated in a robust housing with connecting

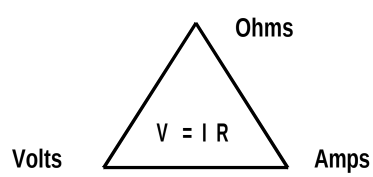

Figure 1.1: Given any two quantities, the third is determined.

wires; hence the circuit symbol of a rectangle shown in Figure 1.2. However, in the early days of electronics, the resistors were made from thin wires wound in a zig-zag pattern on a former and this led to the representation of resistors by the second symbol shown in the diagram. We use this symbol in the text since it is preferred by scientists and engineers because it is quicker to sketch. Being able to draw circuits quickly is an important aspect of learning electronics as it helps you to recognize and understand the shapes of circuits. When the circuit finally works, then you can use the formal drawing office representation of resistors for the archival drawing.

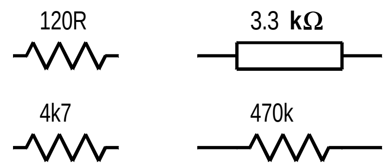

Figure 1.2: Circuit symbols for resistors.

On the circuit diagram, the value of the resistor is printed beside the symbol as 120 R, 3.3 kΩ, 4k7, 470 k. One convention is to put the multiplier, R, k or M, in the position of the decimal point which helps to avoid any ambiguity between 4.7 kΩ and 47 kΩ due to the decimal point becoming indistinct on a worn diagram. In many circuit diagrams you will find that the Ω symbol identifying the units as ohms is left out as it is considered obvious that the number beside a resistance represents units of ohms.

Resistors are usually too small for the value of the resistance to be printed on the component so the values are denoted by coloured bands on the component with the colours representing the numerical digits. This is shown in Figure 1.3. Beware of one problem: about 5% of men are colour blind and they should take care to use new resistors out of marked packages or else to check the value of the resistors with a multimeter before using them.

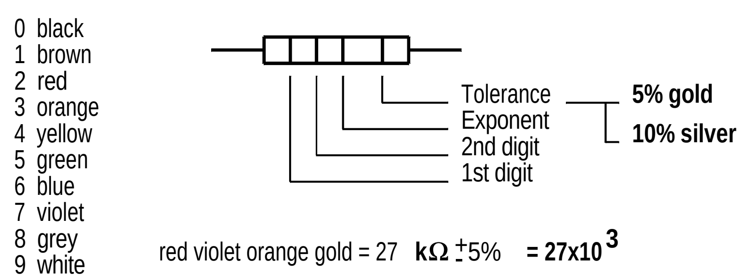

Figure 1.3: Resistor colour code marking method.

When resistors are manufactured, there is a tolerance on the actual values of the resistors. The typical resistor used in electronics has a tolerance of $\pm 5\%$. This has one important implication for anyone learning electronics. There is no point trying to calculate resistor values to a percentage accuracy greater than 5% since the components are only rated at this accuracy. If you need resistors having an accuracy better than 5% in a circuit then you should usually build in trimmer resistors which can be adjusted to tune the circuit after it is assembled.

If you look at the rack of drawers containing resistors in the lab or the range of resistors which are available from the electronic component suppliers, then you will find that resistors come in strange numerical values which are multiples of 10 of the values 10, 12, 15, 18, 22, 27, 33 etc. This gives the set of preferred values for resistors. In the early days the manufacturers made the resistors and then classified them. By using successive nominal values which were 120% of the lower value it was possible to classify any resistor into a nominal value $\pm 10\%$ and thus sell any resistor made! Even though resistor manufacturing technology has improved, the same set of preferred values still remain in use. The other more relevant advantage of these values is that when you design a circuit and calculate the resistor values, you will always be able to find a preferred value within 5% or 10% of whatever value you calculate.

To return to Ohm's law, $V = I \times R$, the crucial thing to remember is that we use the voltage difference between one end of the resistor and the other—visualize a voltmeter connected across the resistor. We also use the current flowing through the resistor. These points will be illustrated in some of the examples.

In specifying a voltage the voltage measurement is usually quoted as either a voltage difference across a component such as a resistor or a voltage difference from a point to a reference common or ground point. In most cases we will assume that the reference common or ground is the reference line at the bottom of the circuit diagram as shown in Figure 1.4 (a). In a more

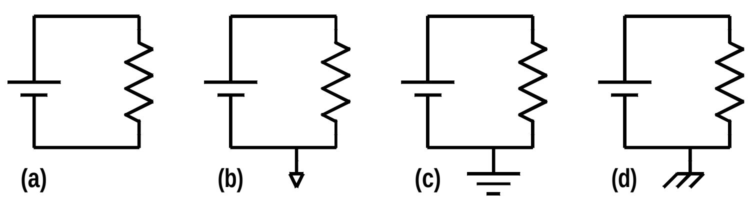

Figure 1.4: Common, ground and earth symbols.

complex circuit, where a single ground line in the diagram would unduly complicate the diagram, the reference ground may be indicated by an arrow as shown in Figure 1.4 (b) and connections may be made to ground from any point in the circuit diagram by use of this symbol. When it is necessary to make a connection to ground for safety reasons such as the ground connection in a three pin mains plug, then this is indicated by the symbol in Figure 1.4 (c). In situations where a very substantial ground may be needed, such as the ground in a radio transmitter antenna, then the symbol in Figure 1.4 (d) may be used. This graduation of grounding efficiency from local reference to substantial amounts of buried metallic conductors may not always be of significance in all circuits encountered but the possibility should be borne in mind.

1.1 Examples

1.1 If a current of 1.2 A flows in the resistor in the circuit in Figure 1.5, calculate the voltage drop across the resistor.

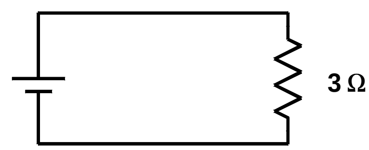

Figure 1.5: Example 1.1.

Voltage across resistor is $V = I \times R = 1.2\,\mathrm{A} \times 3\,\Omega = 3.6\,\mathrm{V}$

1.2 In the circuit in Figure 1.6, if the voltage across the $17\,\Omega$ resistor is measured to be 34.0 V, calculate the current in the resistor.

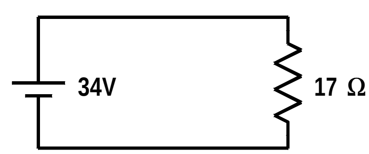

Figure 1.6: Example 1.2.

The current, $I = \frac{V}{R} = \frac{34.0\,\mathrm{V}}{17\,\Omega} = 2.0\,\mathrm{A}$.

1.2 Problems

1.1 If a current of 3.2×10^{-6} A flows through a $4.7 \times 10^{3}\,\Omega$ or $4.7\,\mathrm{k}\Omega$ resistor, calculate the voltage across the resistor.

1.2 If the voltage across a resistor is 23 V and the current flowing is 1.9 mA or 1.9×10^{-3} A, calculate the value of the resistance.

1.3 What are the maximum and minimum values for a 5% tolerance 68 kΩ resistor? If the voltage across this 68 kΩ resistor is measured to be 21.3 V, calculate the nominal, the maximum and the minimum values of the current flowing through the resistor.

1.4 If the voltage at one end of a 4.7 kΩ resistor, measured with respect to (wrt) ground, is +49 V and the voltage at the other end, measured wrt ground, is +58 V, calculate the voltage difference or potential difference across the resistor.
Calculate the current flowing through the resistor.
A possible circuit is shown in Figure 1.7.
Where would you connect a voltmeter in order to measure the voltage across the resistor?

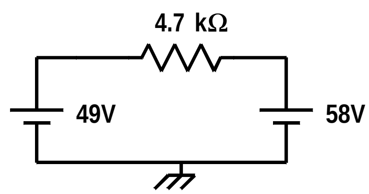

Figure 1.7: Problem 1.4.

1.5 Redraw the circuit shown in Figure 1.8 and show where you would connect a current meter so as to measure the current in the 4.7 kΩ resistor. Use a circle with an A in it to represent the current meter. What value of current would you expect to obtain?

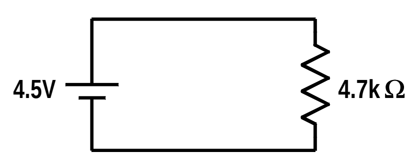

Figure 1.8: Problem 1.5.

1.6 What is the resistance of a digital multimeter set to measure volts?

1.7 What is the resistance of a digital multimeter set to measure amps?

1.8 What are the colour code markings on resistors having the following values: 22 k$\Omega\pm$5%, 1.5 M$\Omega\pm$10%, 47 k$\Omega\pm$5%, 560 k$\Omega\pm$10%, 68 $\Omega\pm$5%?

1.9 Redraw the circuit shown in Figure 1.9 and show where you would connect a voltmeter to measure the voltage across the 1.8 kΩ resistor. Use a circle with a V in it to represent the voltmeter.

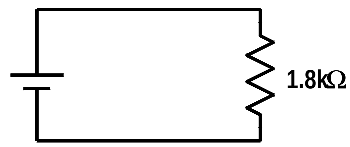

Figure 1.9: Problem 1.9.

1.10 What are the values of resistors having these markings?

Band 1	Band 2	Band 3	Band 4	Value
Orange	White	Red	Gold	......
Orange	Orange	Orange	Gold	......
Violet	Green	Brown	Gold	......
Brown	Black	Brown	Silver	......
Grey	Red	Yellow	Gold	......

1.11 The resistivity of nichrome alloy is $1.0 \times 10^{-6}\,\Omega$m. A 4.7 k$\Omega$ resistor is to be fabricated as a 12 mm long, 10 μm wide track of nichrome film on an insulating substrate. Calculate the required thickness of the nichrome film.