Unit 2 Resistors in series

- When resistors are connected in series, the same current flows in all of the resistors.
- The voltage drop across the equivalent resistor R_{series} is:

$$V_{series} = IR_{series} = IR_1 + IR_2 + IR_3 + \cdots$$

$$\text{Therefore} \quad R_{series} = R_1 + R_2 + R_3 + \cdots$$

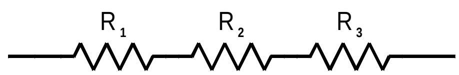

Figure 2.1: Resistors in series.

An electric current is due essentially to the movement of electrons through the conducting wires and resistors. If the wires and resistors are connected in series, there is no alternative path for the electrons. There can be no accumulation of electrons in a resistor just as there can be no accumulation of water in a pipe carrying a flow of water. Any electrons entering one end of a set of resistors, wired in series, are matched by an equal number of electrons emerging from the other end. There is a slight delay, however, before the electrons emerge from the other end which is given approximately by:

$$\text{Delay} \approx \frac{\text{Distance between ends}}{\text{Speed of light}}$$

where speed of light $= c = 3 \times 10^8\,\mathrm{m\,s^{-1}}$.

For a circuit extending over 0.3 m or one foot (the typical size of a box of electronics) the delay will be approximately $1\,\mathrm{ns} = 10^{-9}\,\mathrm{s}$ which is negligible unless you are dealing with very fast digital electronics or radio frequency circuits. Microcomputers are beginning to approach these switching times and the physical size of the circuit boards can be a problem— hence the drive towards smaller and more densely packed integrated circuits and surface mounted devices on printed circuit boards. There are other good reasons for having physically small electronic circuits but large and fast electronic circuits are not possible without using travelling wave circuit technology.

2.1 Examples

2.1 Calculate the current in the circuit of Figure 2.2, given that the voltage across the two resistors in series is 3.8 V. Calculate the current in the 100 R resistor.

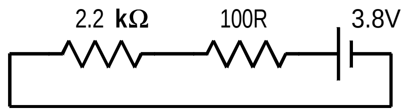

Figure 2.2: Example 2.1.

$$R_s = R_1 + R_2 = 2.2\,\mathrm{k} + 100 = 2.2 \times 10^3 + 100 = 2300\,\Omega$$

$$I = \frac{3.8\,\mathrm{V}}{2300\,\Omega} = 1.65 \times 10^{-3} = 1.65\,\mathrm{mA}$$

2.2 Calculate the current in the circuit of Figure 2.3, given that the voltage across the 1.8 kΩ resistor is 6.4 V. Calculate the voltage across the 2.7 kΩ resistor. Calculate the battery voltage.

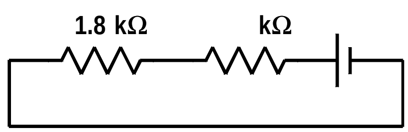

Figure 2.3: Example 2.2.

$$\text{Current } = I = \frac{6.4\,\mathrm{V}}{1.8\,\mathrm{k\Omega}} = \frac{6.4}{1800} = 3.55 \times 10^{-3} = 3.55\,\mathrm{mA}$$

$$V_{2.7\,\mathrm{k\Omega}} = 3.55\,\mathrm{mA} \times 2.7\,\mathrm{k\Omega} = 3.55 \times 10^{-3} \times 2.7 \times 10^3 = 9.6\,\mathrm{V}$$

$$V_{Battery} = 6.4\,\mathrm{V} + 9.6\,\mathrm{V} = 16\,\mathrm{V}$$

2.2 Problems

2.1 If the current is measured to be 2.3 mA, calculate the voltage across each of the resistors in the circuit in Figure 2.4. What is the total voltage across the resistors in series? Where would you insert the current meter into the circuit in order to measure the current? What current range setting would you use on the digital multimeter?

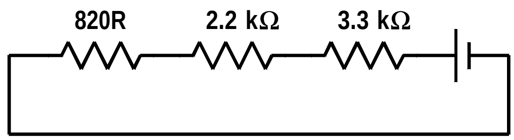

Figure 2.4: Problem 2.1.

2.2 In the circuit of Figure 2.5, a voltage of 0.36 V is measured at point B relative to ground. What is the current in the resistors? What is the voltage drop across the 4.7 kΩ resistor? What is the voltage at point A relative to ground?

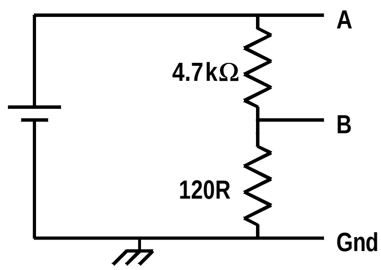

Figure 2.5: Problem 2.2.

2.3 Calculate the voltages at points A and B in the circuit of Figure 2.6.

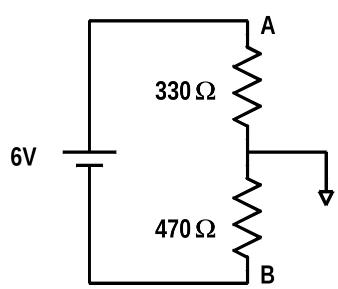

Figure 2.6: Problem 2.3.

2.4 If a digital multimeter, set to measure current, is inserted into a circuit such as that in Figure 2.4 it will be found that the current reading is not the same on all range settings. Explain why this is so.