February 20, 2007
P. Shields

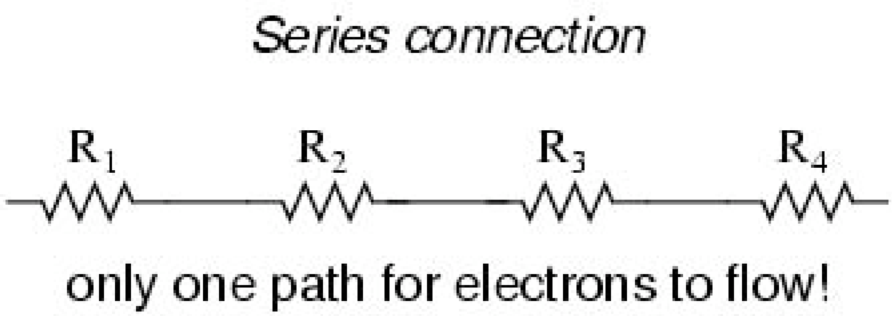
Student Handout.

Compare calculated with measured values in resistive circuits.

Attached Indices resource.

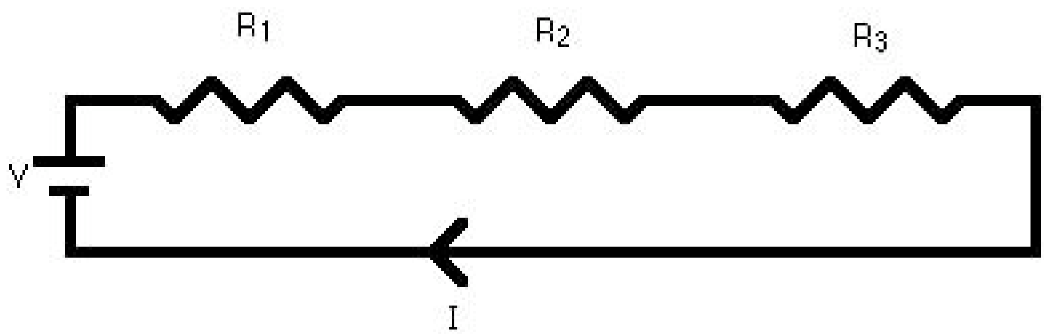
In simple circuits there may be several resistive devices arranged in series and in parallel with other resistive devices. The following circuit examples show these variations.

Series circuits



A series circuit is a circuit in which resistors are arranged in a chain, so the current has only one path to take. The current is the same through each resistor. The total resistance of the circuit is found by simply adding up the resistance values of the individual resistors:

Equivalent resistance of resistors in series: R = R1 + R2 + R3 +...



A series circuit is shown in the diagram above. The current flows through each resistor in turn. If the values of the three resistors are:

$$R_1 = 8\,\Omega,\quad R_2 = 8\,\Omega,\quad \text{and } R_3 = 4\,\Omega,\quad \text{the total resistance is } 8 + 8 + 4 = 20\,\Omega.$$

With a 10 V battery, by V = I R the total current in the circuit is:

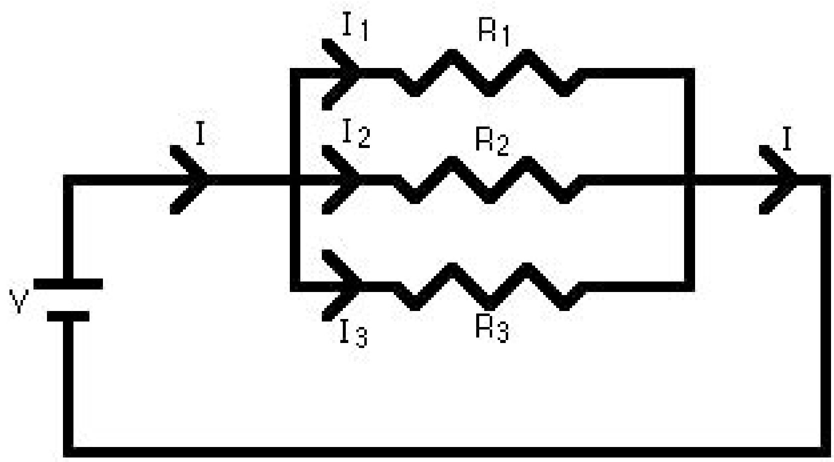
I = V / R = 10 / 20 = 0.5 A. The current through each resistor would be 0.5 A.

Parallel circuits

A parallel circuit is a circuit in which the resistors are arranged with their heads connected together, and their tails connected together. The current in a parallel circuit breaks up, with some flowing along each parallel branch and re-combining when the branches meet again. The voltage across each resistor in parallel is the same.

The total resistance of a set of resistors in parallel is found by adding up the reciprocals of the resistance values, and then taking the reciprocal of the total:

Equivalent resistance of resistors in parallel: 1 / R = 1 / R1 + 1 / R2 + 1 / R3 +...



A parallel circuit is shown in the diagram above. In this case the current supplied by the battery splits up, and the amount going through each resistor depends on the resistance. If the values of the three resistors are:

$R_1 = 8\ \Omega$, $R_2 = 8\ \Omega$, and $R_3 = 4\ \Omega$, the total resistance is found by:

$1 / R = 1 / 8 + 1 / 8 + 1 / 4 = 1 / 2$. This gives $R = 2\ \Omega$.

With a 10 V battery, by V = I R the total current in the circuit is: I = V / R = 10 / 2 = 5 A.

The individual currents can also be found using I = V / R. The voltage across each resistor is 10 V, so:

I1 = 10 / 8 = 1.25 A

I2 = 10 / 8 = 1.25 A
I3=10 / 4 = 2.5 A

Note that the currents add together to 5A, the total current.

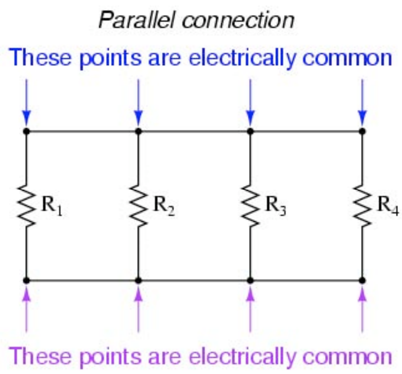
A parallel resistor short cut
If the resistors in parallel are identical, it can be very easy to work out the equivalent resistance. In this case the equivalent resistance of N identical resistors is the resistance of one resistor divided by N, the number of resistors. So, two 40-ohm resistors in parallel are equivalent to one 20-ohm resistor; five 50-ohm resistors in parallel are equivalent to one 10-ohm resistor, etc.

When calculating the equivalent resistance of a set of parallel resistors, people often forget to flip the 1/R upside down, putting 1/5 of an ohm instead of 5 ohms, for instance. Here's a way to check your answer. If you have two or more resistors in parallel, look for the one with the smallest resistance. The equivalent resistance will always be between the smallest resistance divided by the number of resistors, and the smallest resistance. Here's an example.

You have three resistors in parallel, with values 6 ohms, 9 ohms, and 18 ohms. The smallest resistance is 6 ohms, so the equivalent resistance must be between 2 ohms and 6 ohms (2 = 6 /3, where 3 is the number of resistors).

Doing the calculation gives 1/6 + 1/12 + 1/18 = 6/18. Flipping this upside down gives 18/6 = 3 ohms, which is certainly between 2 and 6.

Circuits with series and parallel components
Many circuits have a combination of series and parallel resistors. Generally, the total resistance in a circuit like this is found by reducing the different series and parallel combinations step-by-step to end up with a single equivalent resistance for the circuit. This allows the current to be determined easily. The current flowing through each resistor can then be found by undoing the reduction process.



General rules for doing the reduction process include:

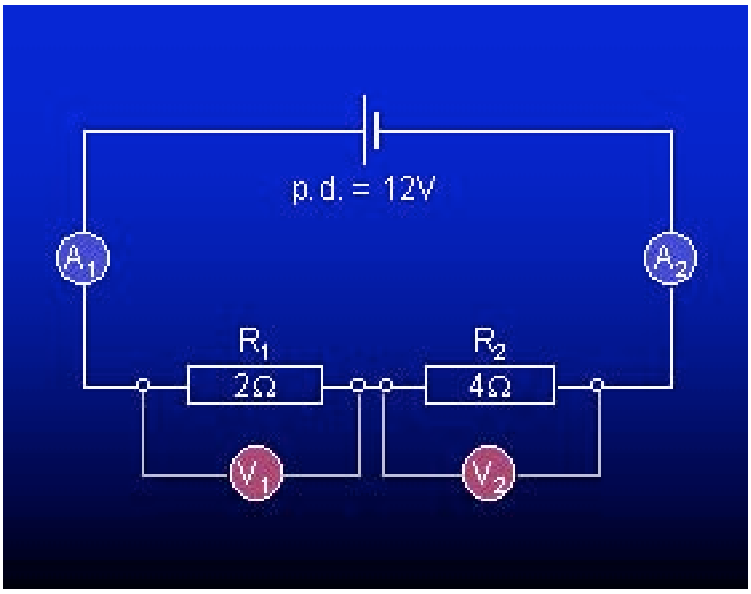
1. Two (or more) resistors with their heads directly connected together and their tails directly connected together are in parallel, and they can be reduced to one resistor using the equivalent resistance equation for resistors in parallel.

2. Two resistors connected together so that the tail of one is connected to the head of the next, with no other path for the current to take along the line connecting them, are in series and can be reduced to one equivalent resistor.

Finally, remember that for resistors in series, the current is the same for each resistor, and for resistors in parallel, the voltage is the same for each one.

Voltage and Current in the series circuit.

Because the resistances inn series with each other can be represented as R total (which in reality would also include the resistance of the conductors and other resistance in the circuit such as the internal resistance of a supply like a battery) the voltage the e.m.f.) of the supply is dissipated across R total, therefore some of the voltage is dissipated proportionally across each individual resistive component, example.



If the battery voltage supplied in the above circuit is 12V then part of the voltage is 'dropped across R1 i.e. V1 and part of the voltage is dropped across R2 i.e. V2. It also follows that we can assume for calculation of Ohms Law that we also have currents passing through the different parts of the series circuit and we can mark them as A1 and A2. Because the circuit has only series components the rule is that the current is the same throughout the circuit so A1 = A2. Using Ohms Law though we can determine the voltage drops across R1 and R2. as follows:

Current, A1

First, calculate the total resistance of circuit:

RT = R1 + R2
= 2 Ω + 4 Ω
= 6 Ω

Now use Ohm's law to calculate current:

V = I R
I = V / R
= 12 V / 6 Ω
= 2 A

The current in the wire to the left of the 2 Ω resistor = 2 A

Current, A2

In a series circuit, the current is always the same, so the current in the wire to the right of the 4 W resistor is also 2 A.

Voltage, V1

Use Ohm's law to calculate voltage across the 2Ω resistor:

V = IR
= 2 A × 2 Ω
= 4 V

The voltage V1 = 4 V

Voltage, V2

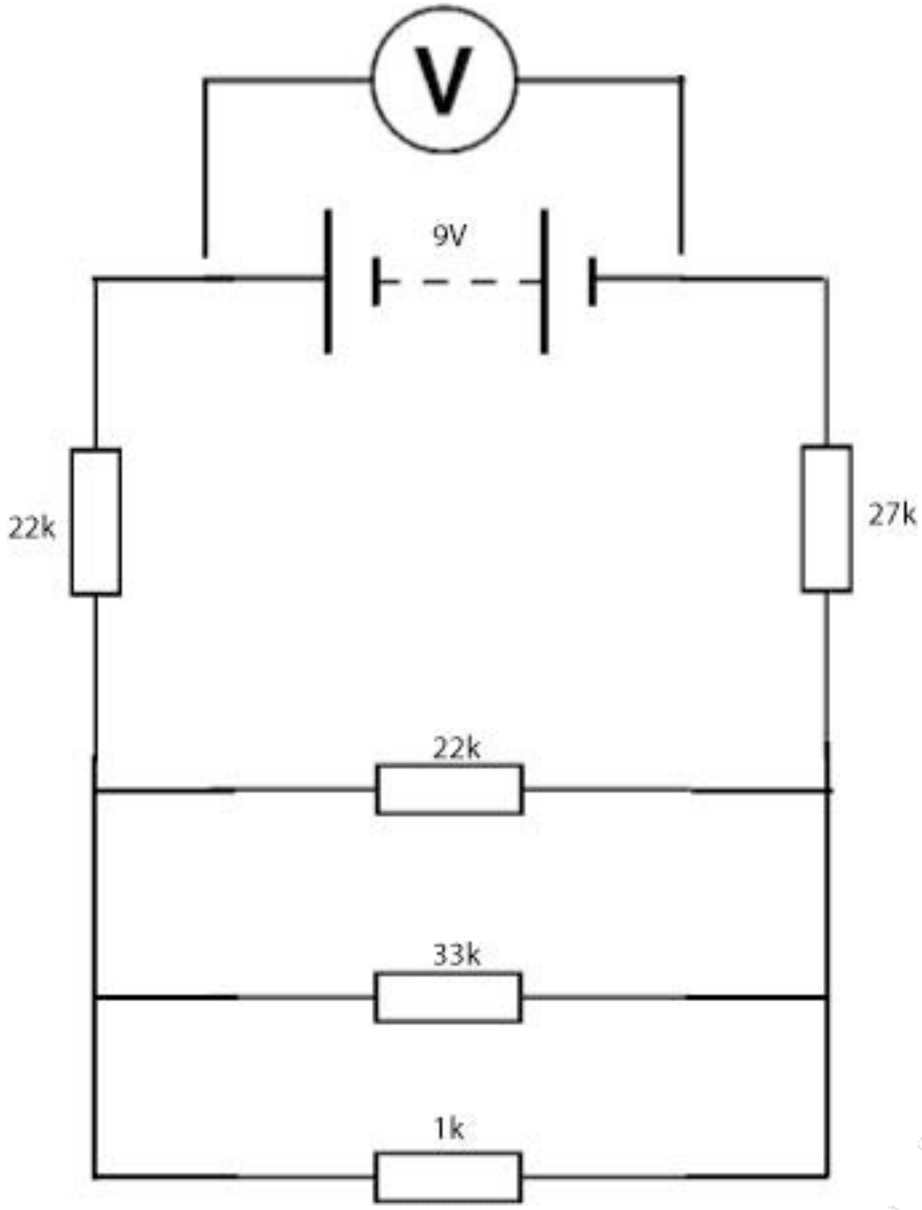
Similarly for the 4Ω resistor:

V = IR
= 2 A × 4 Ω
= 8 V

The voltage V2 = 8 V

We can see from the results that more voltage was dropped across the larger resistor, this equates to more force is required to do the work of maintaining the electron flow current) through the large resistor. The same analogy can be shown in a water circuit which has large bore pipes and smaller bore pipes, more of the water pumps work is used up in getting the water to flow through the smaller bore pipe than the larger bore pipe because the smaller bore pipe presents more resistance to the flow (current) of water.

In the previous handout we learnt how to read resistor preferred values and tolerances. The resources are provided to make the following circuits.



Student Assessment Questionnaire.

Note: This part of the assessment is open book and 100% is the required result.

1. **Ignoring the IR of the Battery and conductor resistance what is the total calculated resistance of the circuit?**

    - ___________

2. **Calculate the total current flow in the circuit?**

    - ___________
    - ___________

3. **Calculate the resistance of the resistors in parallel?**

    - ___________
    - ___________
    - ___________
    - ___________

4. **Compare the individual resister values calculated with their measured values and explain any differences?**

5. **Using Ohms Law calculate the voltage drop across the series parts of the circuit (remember the three resistors in parallel combine to form one effective resistor in series with the remaining series resistors)?**

6. **Relate the voltage drops calculated with the measured voltage drops and the measured and stated battery e.m.f. and explain the variations?**

    - ____

7. **Using Ohms Law calculate the power of the circuit and then compare it to the calculated power using the measured values of voltage and resistance.**

- ____

8. **Enter the indices value for the following prefix of measurements. ?**

- **Giga**
- **Mega**
- **kilo**
- **milli**
- **micro**
- **nano**
- **pico**

Name: _________________________________

Course: _________________________________

Date: _________________________________

NSN #: _________________________________

Tutors Signature: ____________________________