Electric circuit concepts

A guide for group leaders

Hello to you, the group leader!

These notes come from the website www.scienceteachingalive.com They are designed to help you run a special kind of science teacher group meeting.

This kind of meeting is about helping teachers to feel comfortable with doing practical work, and organising their own lessons so that their students do the activities.

These notes assume that your participants know quite a lot about the topic, and now they want to make it interesting and exciting for their students. On the website you will find Teachers' Notes that give teachers information about this topic.

Also on the website there's the skeleton of a student worksheet that your group can develop.

Some personal preparation for the workshop

Watch the video right through.

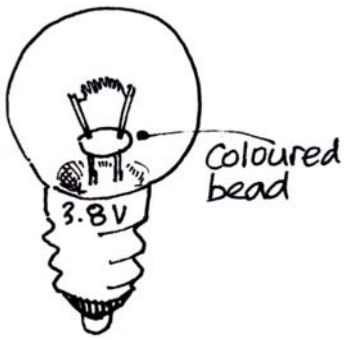
Note how Brian Gray emphasises teaching the circuit concepts **before** introducing maths and formulae.

Then look at the concept maps in the Teachers' Notes on the website.

Brian takes a new approach to teaching circuits by using bulbs of different power ratings, such as 40 watts, 60 watts and 100 watts. This is different to the usual approach in schools, where we use bulbs that are all the same in power.

To do practical work in this workshop you can use a traditional circuit board but you will need to find torch bulbs with different power ratings. This is not as hard as it sounds, because shops sell torches that use two, three or four cells. These torches then need **bulbs** that can cope with the battery voltage of two, three or four cells, and so many shops stock that range of bulbs.

Figure 1 *This bead may be white, green, blue or yellow, to indicate the voltage rating.*



The way to tell the difference between bulbs is to look at the recommended voltage rating printed on the metal part of the bulb. Typical voltage ratings[1] are 2.4 V, 3.8 V and 4.5 V. The manufacturer will use different-coloured plastic beads inside the glass to hold the wire supports apart. Typical colour-coding is blue for 2.4 V, green for 3.8 V and white for 4.5 V. Note that different manufacturers use different colours.

[1] Two new cells will give nearly 3 volts across the bulb, but as you use them, the voltage will drop. So the bulb for a two-cell torch is rated for 2.4 volts - it is very bright when the cells are new, but still bright enough as the cells get used up. By the same reasoning, a four-cell, 6 volt torch, has a bulb rated at 4.5 volts.

Usually school electricity kits have screw-in bulbs of only one voltage rating, 3.8 volts. Their power rating is usually about 1 watt.

In the video, Brian uses "mains" voltage (220 – 240 volts alternating) because that allows him to use large household globes/bulbs. For the sake of simplicity, for the students, he treats the mains voltage as though the bulbs were connected to a 220 volt battery.

> If you plan to make such a circuit board, you should insulate all the connection points and get an electrician to check your board for safety.

Suggestions for your workshop programme

A. Welcome and introduction

After the usual welcome and admin discussion, tell everyone what you hope the workshop will produce. Remind them that a workshop means participation; in workshops things get **produced** – the thing might be a new understanding, or an issue resolved, or a physical thing made or a document written. They have to produce, not just listen.

Here are three products that could come out of this workshop (you have to decide on this):

1. Choose a formula from the ones on the board in the video (**00:35** – **00:40**), and plan how to teach its meaning **without** using mathematics.
2. Produce a worksheet to use with students. (Remember that there is a worksheet-starter on the website.)
3. Produce a table that compares the cold resistance and the hot resistance of the bulbs. Use voltmeter and ammeter to measure the torch bulbs, but for household bulbs/globes, you can work out the **hot** resistance by knowing that the voltage is 220 volts and the power is the wattage printed on the glass at top of the globe.

B. Prepare the group to watch the video up to 5:45

Tell the group that this video is intended for students in Years 10, 11 and 12. With students in Years 6 to 9, it's OK to stay with bulbs of the same power rating (i.e. same voltage rating). When you use bulbs with different power ratings, you can ask the more searching questions that Brian asks in the video. That's appropriate for senior students.

Now this an important move: hand out sheets of paper to everyone. Tell them they are going to write down a prediction about what is going to happen when two globes are connected in series.

Then show the video up to **5:45**. Don't miss this stopping-point, because here Brian asks people to **predict** what they will see when he switches on the 40 W and the 60 W globe connected in series.

They should write down their predictions about the globes, because the writing makes people commit to an idea.

Now show the video from **5:45** to **6:20** and **stop there**, when Brian says “they’ll come up with various theories or hypotheses”.

Now open the discussion: Tell the group that most high school students predict that the 60 W globe will be brighter than the 40 W. (You don’t have to say this, but the majority of the teachers in your group probably predicted the same thing.) Why do students predict in this way? What reasons do students give? And how can we explain to them what is really happening?

This should lead into a lively discussion, because people in the group will have their own hypotheses.

Now show the next part of the video, from **6:20** to **6:57**. Stop there and let people discuss the explanation Brian gives. The key point he makes is that in a series circuit, the highest resistance gets most of the energy transfer (i.e. it get the biggest potential difference).

C. Then go through it again, but ask a question before you show each section

0:30 – 1:10 **Ask**: What does Brian say about using formulae and doing calculations in teaching electricity?

3:40 – 4:15 **Ask**: How does Brian lead up to the concept of resistance?

Brian uses the difference in brightness of the two globes to lead to the concept of resistance, and he goes via the concept of power (or brightness). The 60 watt globe at 220 volts is brighter than the 40 watt globe at 220 volts, and therefore it must be passing more joules per second, which means that it is passing more current, which means that it has **less resistance** than the 40 watt globe.

5:35 – 6:58 **Ask**: Why do students get the idea that the first globe in series should be brighter than the second globe? How can we deal with that misconception?

In this section Brian is probing for the common **mis-conception** that if two bulbs are in series, the first bulb (the one nearest the positive terminal) get the current first, and the next bulb should be dimmer, because it gets only the left-over current from the first bulb. In your classes, about half your students could hold this idea.

6:00 – 6:37 **Ask**: Surely we buy 60 watt globes for the reason that they are brighter than 40 watt globes? Why was the 60 watt globe so dim?

Notice how Brian stays with the resistance concept here – the 40 watt globe has higher resistance than the 60 watt

> **How can the 40 watt globe now be brighter than the 60 watt globe?** Don’t we buy 60 watt globes just because they are brighter than 40 watt globes?
>
> Well, the 40 W globe is brighter here because it is connected **in series** with the 60 watt globe, and it gets the greater potential difference because it has the higher resistance.
>
> Normally, in a house, globes are connected **in parallel**, so each globe gets the full 220 volts, and then the 60 watt globe, with its lower resistance, draws more current, and transfers more joules per second, and is brighter.

globe. The **current** is the same through all series resistors but the resistor that gets the most voltage is the one with the highest resistance. So in the video you see the 40 watt globe being the brightest because it has the highest **resistance**.

7:00 – 7:24 Ask: Why do the 40 W and 60 W globes glow as brightly as we expect them to, when they are connected in parallel?

The camera that made this video could not could not clearly show the difference in brightness between the 40 watt and 60 watt globes. However, the difference will be the same as you see in **2:30 – 3:44** because resistors in parallel get the same voltage, no matter what their resistance is.

8:20 – 8:34 Stop the video at 8:24 and Ask: Look at the globes and predict how bright they will be. Give a reason.

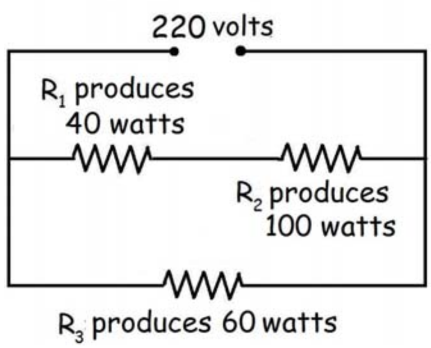
Figure 2 *At 8:34 the 100 W globe is the dimmest. Why?*

After people have predicted and given reasons, start the video again. Note how dim the 100 watt globe is.

How many predicted correctly? Ask for ideas about why the 100 watt globe is so dim.

8:35 – 8:55 Stop the video at 8:40 and repeat the information – the 40 W and 100 W globes are connected in series, and the 60 W globe is connected in parallel with the first two globes. **Figure 3** shows you the arrangement. Remind everyone that the wattage printed on the bulbs refers to the situation when they are normally connected in parallel to 220 volts, in a house.

Figure 3 *Resistors R_1, R_2 and R_3 are light-globes. They NORMALLY produce the power that you see here, but ONLY if they are connected in parallel, the way they are in your house.*



Ask: How will the brightness of the globes compare? Can you give a reason?

Note how dim the 100 W globe (R_2) is, again. The reason is that it is in series with the 40 watt globe (R_1) which has a much higher resistance and therefore gets much more of the voltage across the two globes. The voltage across the 60 watt globe (R_3) is the full 220 volts, and therefore it is as bright as it was in **3:40 – 3:50**.

D. Hand out the materials and equipment

Activity 1 Use bulbs of different rating, in parallel

The traditional lesson with a circuit board uses three identical bulbs in parallel and the students note that they are equally bright, and they are each as bright as a single bulb in series.

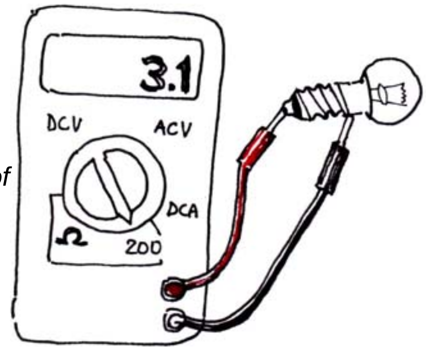
Now you can create a situation in which the students can only escape by thinking. Set up a circuit board with 3 cells and three bulbs of different voltage ratings (say 2.4 V, 3.8 v and 4.5 V) **in parallel**. Each bulb will produce different power (that is, will be different in brightness) even though they are in parallel.

The group's activity is to (a) predict how bright the bulbs will be, before switching on and then (b) switch on, check the predictions and (c) discuss how you think students will react to the new observation. Then (d) discuss what questions you could ask the students to help them think through the unexpected observation.

Activity 2 Find the resistances and power of different bulbs

Measure the **cold** resistance of each torch bulb as follows.

Figure 4 *You can also use a multimeter to measure the cold resistance of each bulb. Set the meter to read 20 ohms maximum.*



Connect all three torch bulbs (rated for 2.4 V, 3.8 V and 4.5 V) in series and use just one cell to pass a small current through the bulbs. The combined resistance of three bulbs will reduce the current and so the bulbs will stay cold. Measure the current, and the voltage across each bulb. The voltages will be different because the bulbs' resistances differ.

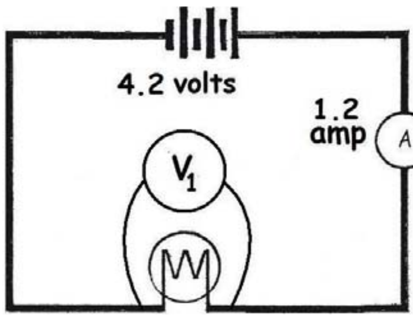
Now measure the **hot** resistance of each bulb, separately, as follows.

Take one bulb and make it hot and bright (use enough cells). Measure the current in the circuit and the voltage across the bulb. Then calculate the **hot** resistance. Calculate the power of each bulb, by $P = I \times V$.

Repeat with the other bulbs, adding cells as needed so that the bulbs are all equally hot.

Compare the cold resistance, the hot resistance and the power of each bulb.

Figure 5 *Measure voltage across and current through the bulb. Then calculate the hot resistance.*



Bulb	Cold resistance [in ohms]	Hot resistance (at normal operating temperature)	Power as calculated or printed on the bulb [in watts]
Rated 2.4 V			
Rated 3.8 V			
Rated 4.5 V			

Activity 3 Compare the resistances and power of household appliances

First, use a multimeter (or voltmeter and ammeter plus a few cells) to measure the cold resistance of household globes and a kettle. Compare the cold resistances with the rated power of each. What pattern do you find?

Next, calculate the current that each device draws, and then work out the hot resistance. Again, do you find a pattern linking the power and the hot resistance?

Globe or heating-element	Power rating printed on device	Cold resistance	Hot resistance (at normal operating temperature) as calculated.
Globe rated 220 V	e.g. 40 watts		
Globe rated 220 V	e.g. 60 watts		
Globe rated 220 V	e.g. 100 watts		
Kettle rated 220 V	e.g. 2 500 watts		

Warning Don't connect ammeters or voltmeters to any part of a circuit that is connected to the 220 volt "mains". It's dangerous. You could also blow the meter.

By the way, the curly heating-element that you see in a kettle is a metal tube that is **not** connected to the mains supply! The actual heating wire is inside the curly metal tube, surrounded by insulating material, and does not touch the curly tube anywhere. That's why you don't get a 220 volt shock if you touch the water.

E. When most people have completed the activities, sum up in a discussion:

- can we use activities like this in our classrooms? If not, why not?
- What questions will we use to focus the students' activities?
- How do the activities we have done relate to what's in the students' textbooks?

F. Now move to the final product of the workshop – a student worksheet.

You will find a suggestion on how to design this, if you look at the menu on the website. Teachers will want to take a copy of the worksheet you produce in the meeting, so try to have a photocopier available, or provide pens and sheets of blank paper.

What to prepare

Items	Where to get them
Computer with a large screen, or else a data-projector.	This depends on the school or the facilities in the area where you run the workshop.
Mains electricity to run the computer and projector.	Sorry if this sounds obvious, but in some places you have electricity for only certain hours of the day.
Copies of the Teachers' Notes and copies of the Student Worksheet-starter - enough for each teacher	

Torch bulbs/globes, rated for 2.4 V, 3.8 V and 4.5 V, so that they will have different brightness at the same voltage. You might have to hunt for the bulbs, because many torches now use Light-Emitting Diodes (LEDs) instead of bulbs.	Shops that sell torches. These may be general dealers, hardware shops, bicycle shops, motor-car spares dealers or toy shops.
Household globes that you see in the video, rated at different power. For example, 40 watt, 60 watt, 100 watt, 150 watt, 200 watt.	General dealers and supermarkets. Hardware stores.
Torch cells, 1.5 volt, at least 4. Again, this sounds obvious, but chances are that the cells in the school will be old and won't work.	General dealers and supermarkets. Hardware stores.
Electricity kits with circuit boards, cell-holders, switches, bulb-holders, wires, ammeter, voltmeter.	Schools or school suppliers.
Multimeters, at least one. It's an electronic meter that can be set to read volts, amps or ohms.	These come with certain school electricity kits.