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theme:

education & communication

job:

Helen Carmichael, Freelance Science Writer

activity outline

Pupils investigate filament light bulbs and write a magazine article to explain why they 'blow' when they're switched on, rather than when they're already on. They carry out an experiment to investigate current and resistance changes in a filament bulb, and write their article based on their findings and other information.

You are likely to need one or two lessons, provided pupils are familiar with using ammeters/voltmeters and building circuits. It may be helpful to precede the current/resistance experiment with a teacher demonstration to show how wires can get hot and glow.

The pupil sheet provides step-by-step instructions for the current/resistance experiment as well as additional information in the form of a Q&A section.

Teacher notes overview

1 **Curriculum links:** where this activity can fit with the 2008 KS3 Programme of Study and Scottish 5-14 Science Curriculum.

2 **The Video:** providing a synopsis of the video content and ideas for viewing.

3 **The Practical:** including *Equipment lists*, *Health and safety notes*, a *Possible approach* (a comprehensive, suggested way of planning the lessons) and an *Underlying science* section (providing detailed information about the various scientific principles involved).

4 **Possible extensions:** suggestions for other practical activities using the video, or extending the suggested activity.

5 **Associated jobs:** guidance on how to deliver a plenary activity (or, if you wish, a stand-alone activity) focusing on the video interviewee, including a photo of the interviewee to place at the centre of a spider diagram.

curriculum links

This lesson can be used to help teach part of the 2008 Key Stage 3 Programme of Study (England and Wales):	**Range and Content:** 3.1a, 3.1c **Attainment Targets:** AT1, AT3, AT4 **Key Concepts:** 1.1a, 1.1b, 1.2a	**Key Processes:** 2.1a, 2.1c, 2.2a, 2.3 **Curriculum Opportunities:** 4a, c, h

This lesson can be used to help teach part of the Scottish 5-14 Science Curriculum:

Main curricular links

E&F1 Properties and uses of energy

E&F2 Conversion and transfer of energy

Attainment Targets

Knowledge & understanding:

Level B
- Describe the energy conversions in the components of an electrical circuit

Level C
- Construct simple battery-operated circuits, identifying the main components

Level D
- Construct a series circuit following diagrams using conventional symbols

Level E
- Use the terms ‘voltage’, ‘current’ and ‘resistance’ in the context of simple circuits

Investigating skills:

Level C
- Select and use appropriate measurement devices

Level D
- Make an appropriate series of accurate measurements
- Make an organised report of an investigation
- Draw conclusions consistent with findings

the video

Synopsis of the video

Among other things, Helen makes these interesting points:

- Helen writes about all sorts of interesting scientific topics, but an understanding in any of the disciplines helps you.
- Helen enjoyed her chemistry degree, but preferred writing up experiments to carrying them out.
- Helen has to write for all sorts of audiences – sometimes you can be very technical, other times you have to simplify the science so younger people can understand.

Watching the video

There are a number of things you might do before showing the video to your class.

1. Preview the video and write a few quick-fire questions. Then you can tell your class that they will be tested on their observation when it's finished. This is an excellent way of encouraging them to pay attention!
2. Ask pupils to watch the video through once. Then ask them to generate one question that could be answered from the video and one question they would like to ask but the video did not answer. These questions are then exchanged with another pupil and the video is watched a second time. This gives pupils an opportunity to focus on something they may have missed first time, and provides a basis for discussion on what was learnt from the video, and what additional information is needed.
3. Ask pupils what sort of person might become a journalist. Does anyone in the class think they'd like to be a writer? When the video has been watched, ask the questions again. Has anyone changed their mind/opinions?
4. Ask pupils to spot the science in the clip.

the practical

Equipment

(per pupil/pair/group)

- variable low voltage DC supply (continuous or stepped)
- 12 V bulb in holder [You could adapt the worksheet so that different groups use different voltage/wattage bulbs, from 4.5 to 12 V, and then compare their results]
- voltmeter and ammeter compatible with voltage and current rating of bulb [If the ammeter reads mA, make sure pupils know how to convert to amps]
- 5 connecting wires

  Alternatively: data-logging equipment to monitor the rapid change in current when the bulb is switched on.

Health and safety

Though the context relates to household light bulbs, pupils must not work with mains voltage. The equivalent experiment using a mains bulb could be demonstrated, provided all connections are made before switching on. A variable HT power supply (DC or AC) will be needed.

There must be no exposed conductors live at mains voltage which might be touched inadvertently. If there are, place the equipment in a plastic box or similar.

Possible approach

Before the lesson, challenge pupils to research how filament lamps (household and torch bulbs) work. They should find out which metal is used for the filament, which gas is inside the bulb and, in both cases, why.

You may wish to point pupils towards suitable sources or have information on display. The following will help:

- http://home.howstuffworks.com/light-bulb1.htm
- http://en.wikipedia.org/wiki/Image:Incandescent_light_bulb.svg
- http://invsee.asu.edu/Modules/lightbulb/meathist4.htm
- http://business.virgin.net/tom.baldwin/bulbguide.html
  (more suitable for teachers than pupils)

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In the lesson, discuss the energy transfers in a lit bulb, and energy dissipation as heat. You might also demonstrate the purpose of the glass envelope by carefully crushing a torch bulb (taking care to avoid damaging the filament) and switching it on. The filament will burn out almost instantly.

The purpose of the practical is to determine the resistance of the bulb filament when cold, dull red heat, and when white hot. It involves measuring voltage and current, and components in series and parallel.

If pupils are unfamiliar with circuit diagrams, a pictorial version could be drawn.

Different groups should use differently rated bulbs – several different voltages (4.5 to 12 V), and various wattages. They can then compare results.

The DC supply must be variable, and if possible should have its maximum voltage locked at the operating voltage of the bulb, to prevent blowing.

Discuss their results, pointing out the similarity between bulbs – in each case the resistance when cold should be around 15 times lower than at the normal (white hot) operating temperature.

Discuss resistance as the opposite of conduction. To explain the increase in resistance (decrease in conduction) with increasing temperature, the following analogy may help. Imagine (or actually try) passing a ball from one person to another from one side of a large group to the other. Is this easier when the people are standing still, or when they are bobbing about? The people represent atoms in the metal. The hotter they are, the more they vibrate back and forth. The ball represents a 'bit of electricity' (an electron, if they know what it is).

Solicit ideas from pupils about how filament resistance affects current, and thus what happens when the bulb is first switched on. Guide them towards a short-lived high current, and rapid heating – i.e. power surge and thermal shock.

Lead on to discussion about tungsten evaporating from the filament, leaving thin weak spots (and also blackening of the glass where tungsten vapour condenses and solidifies in a thin layer). Guide them towards deducing the consequences of thin weak spots – i.e. higher resistance and heating effect, so that the filament gets hot enough to melt at that point and break. When is this most likely to happen? When the current is highest – i.e. during the power surge immediately after the bulb switching on.

See also: http://www.newscientist.com/backpage.ns?id=mg18925362.400

Depending on lesson length, pupils may assemble these ideas to outline their article within the lesson, and write it for homework – or do this in the next lesson.

Pupils need to be told the required length, journalistic style and target audience for their article. Different groups, or individuals, could choose, or be allocated, different styles. Possibilities include:

- school magazine item, aimed at 14 year olds
- local newspaper article, aimed at general readers with limited scientific knowledge
- wall poster for the school open day, aimed at parents, to show that science lessons are relevant to everyday life
- an article in a consumer magazine, to complement a section on testing light bulbs
- an item for a Q&A website, responding to the question "Why do light bulbs sometimes flash and go out as soon as they are turned on?" [This could be answered at several levels, accessed by "Click here for further details".

Given time, pupils could also research information on developments designed to reduce filament breakage, extending bulb life. (See extension 3 in *Possible extensions.*)

Underlying science: Basic principles

- When an electric current flows through a conductor, some of the energy is converted into heat. For a given current, the higher the resistance of the conductor, the greater the heating effect.
- For a given conductor, the resistance increases with length and decreases with cross-sectional area. (In simplistic terms, the current has more difficulty squeezing through a narrow conductor.)
- The lamp filament is deliberately made long and extremely thin (typically about 600 mm x 0.05 mm for a coiled coil 60 W filament) to increase its resistance, to produce a strong heating effect.
- The hotter the filament temperature, the brighter and whiter the light emitted.
- Tungsten is used because it has the highest melting point of all metals. It can glow hotter than any other without melting.
- The filament would burn if exposed to air or oxygen, so the glass bulb is filled with an unreactive gas. Argon is most commonly used.
- In the circuit:
  - to measure the current through the bulb, the ammeter must be in series, so the same current flows through the bulb and meter
  - to measure the voltage drop across the bulb, as opposed to across the whole circuit, the voltmeter must be in parallel.
- The first readings are taken with the lowest available voltage, so that the current is minimal, to keep the filament as cool as possible.
- Other readings are taken at full operating voltage, and thus maximum current and filament temperature, and also at an intermediate setting.
- The filament resistance is calculated using Ohm's Law ($V= IR$). It should be about 15 times lower when cold than at the normal white-hot operating temperature.
- In normal use, the bulb is switched on at full voltage. The resulting current depends on the resistance in the circuit ($I = V/R$). When first switched on, the relatively low resistance of the cold filament causes a high current. This causes a power surge through the lamp ($P = VI$).
- Although the surge lasts only about 0.1 s, the sudden heating effect and thermal shock that it produces may cause the filament to burn out at a weak point. The sudden thermal expansion also contributes to the effect.
- Weak points are where the filament has become thinner, due to tungsten gradually evaporating

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at white heat over many hundreds of hours of use.

- The heating effect of the current is greater at the weak point because of the reduced cross-section. The weak point thus becomes a hot-spot. The local temperature rises; the filament melts and parts company.

- As the filament breaks, arcing across the gap may occur briefly.

- Quartz halogen bulbs use a reversible chemical reaction to counteract evaporation of the filament. The glass bulb contains a halogen, usually iodine, which reacts with tungsten vapour. The tungsten halide formed decomposes at higher temperatures.

  $$\text{tungsten} + \text{halogen} \rightleftharpoons \text{tungsten halide}$$

  So when the halide meets the white hot filament, it decomposes, depositing tungsten metal back onto its surface.

- This prolongs the life of the filament, but it still fails eventually, since the tungsten is unlikely to be deposited in the position it evaporated from. Thus, weak points still arise.

possible extensions

1 **Historical development of light bulbs**
The filaments in the first practical light bulbs were not made of metal. What were they? Pupils research the work of Swan, Edison, Coolidge *et al.* See, for example:

- http://en.wikipedia.org/wiki/Incandescent_light_bulb
- http://invsee.asu.edu/Modules/lightbulb/meathisttime.htm

2 **Design a bulb**
From their measurements, and using V=IR and P=VI, pupils work out the filament resistance needed to make bulbs of specified ratings, e.g. 12 V, 21 W car stop-light and 230 V, 100 W household bulb.

3 **Reducing the incidence of filament breakage**
Pupils research scientific/technological developments in lighting systems that help to prolong filament life, such as:

- the effect of using different unreactive gases (nitrogen, argon, krypton) inside the glass envelope – denser gases reduce evaporation of tungsten
- quartz-halogen bulbs - a reversible reaction with the halogen re-deposits tungsten on the filament (see *Basic principles* above)
- using a dimmer switch, so that the voltage increases slowly, avoiding the power surge.

Note: Advise pupils **not** to research long-life low-energy (compact fluorescent) bulbs. These have no filament, which avoids the problem, but introduces others.

associated jobs

A STEM (Science, Technology, Engineering and Maths) education provides pupils with skills and knowledge that are useful in all sorts of careers. The video demonstrates how Helen, a Freelance Science Writer, uses her STEM knowledge on a daily basis.

Helen works with numerous people – some directly, some indirectly. Some use STEM skills, others don't. By exploring this network of associated jobs, pupils will, hopefully, begin to see that even those in non-STEM jobs will find STEM skills useful – if they're communicating with someone "in-STEM", for example, some knowledge of their work will be a great help.

Helen´s spider diagram

Try placing Helen at the centre of a spider diagram (we've provided a photo of Helen which you could use – see overleaf). You could either create worksheets for pupils to complete themselves, or create the diagram on your whiteboard and then pool ideas.

Ask pupils: "who does Helen work with". They may draw information from the video – Helen mentions editors for example – or they may come up with new ideas, such as the various experts that a journalist needs to contact to help collect information for their stories. Other, less obvious, suggestions might include photographers, sub-editors and designers, people who print the magazines, or even web-designers and editors.

Now ask pupils which of those jobs are clearly "in-STEM". Who else might find some STEM skills helpful? Why?

You could extend this by taking any one of the associated jobs and placing them at the centre of a spider diagram, and starting the process again.

theme: **education & communication**

Helen Carmichael, Freelance Science Writer

Studying science and maths can transform your career options. Future Morph: become someone.