

# Shining a Light

## Design & Technology

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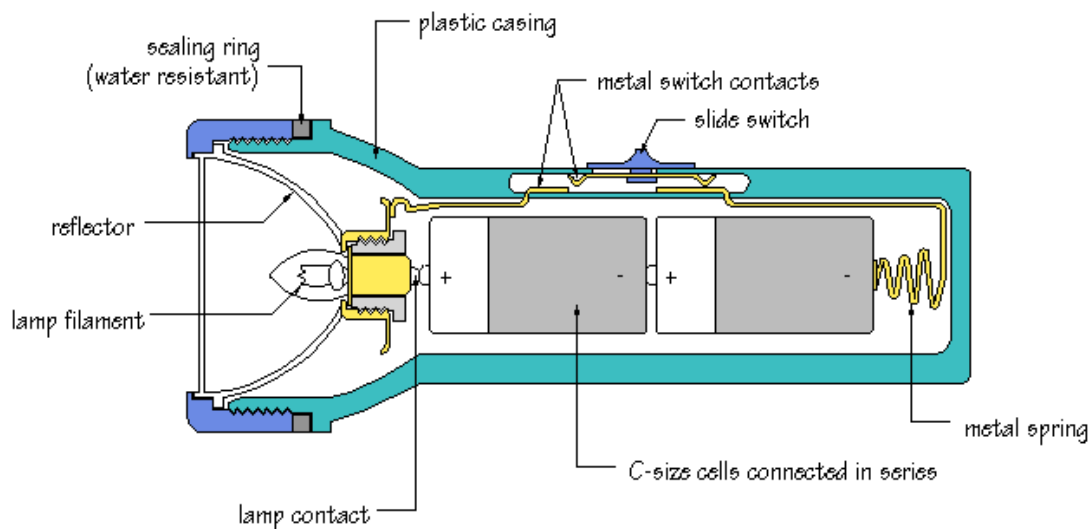


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Looking at **electronic circuits** and what is meant by **current**, **voltage**, and **resistance**.

### *Shining a Light*

Have you ever taken an electric torch to pieces to find out how it works? Look at the diagram below which shows the arrangement of parts inside one kind of torch:

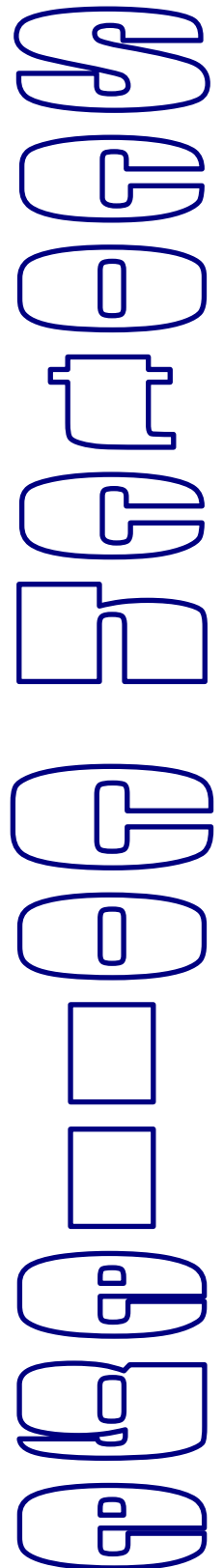


### *Structure of an electric torch*

Why did the designer choose this particular combination of materials? The metal parts of the torch must **conduct** electric current if the torch is to function, but they must also be able to stand up to physical forces. The spring holding the cells in place should stay springy, while the parts of the switch must make good electrical contact and be undamaged by repeated use.

The lamp and reflector make up an optical system, often intended to focus the light into a narrow beam. The plastic casing is an electrical **insulator**. Its shape and colour are important in making the torch attractive and easy to handle and use.

A torch is a simple product, but a lot of thought is needed to make sure that it will work well.



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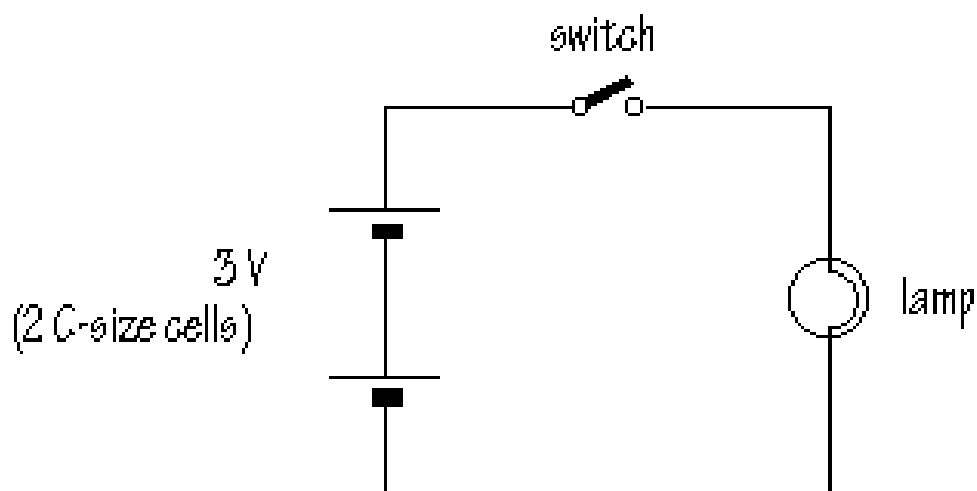
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*Can you think of other things which the designer should consider?*

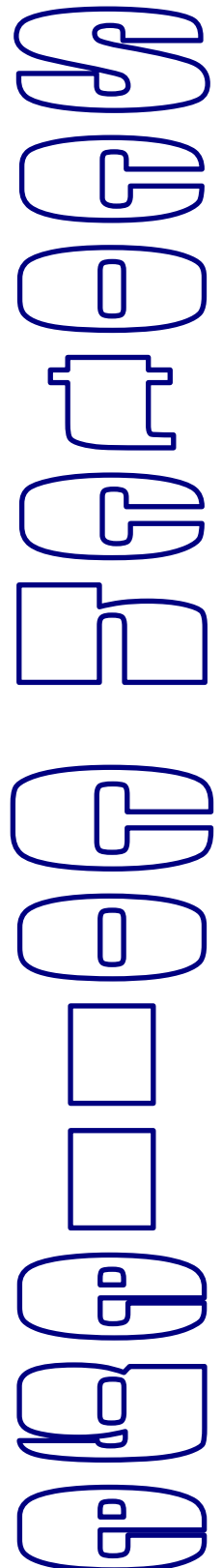
A different way of describing the torch is by using a **circuit diagram** in which the parts of the torch are represented by symbols:



*Circuit diagram of an electric torch*

There are two electric **cells** ('the battery'), a switch and a lamp (the torch bulb). The lines in the diagram represent the metal conductors which connect the system together.

A **circuit** is a **closed conducting path**. In the torch, closing the switch completes the circuit and allows current to flow. Torches sometimes fail when the metal parts of the switch do not make proper contact, or when the lamp filament is 'blown'. In either case, the circuit is incomplete.



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### Current

An **electric current** is a flow of charged particles. Inside a copper wire, current is carried by small negatively-charged particles, called **electrons**. The electrons drift in random directions until a current starts to flow. When this happens, electrons start to move in the same direction. The size of the current depends on the number of electrons passing per second.

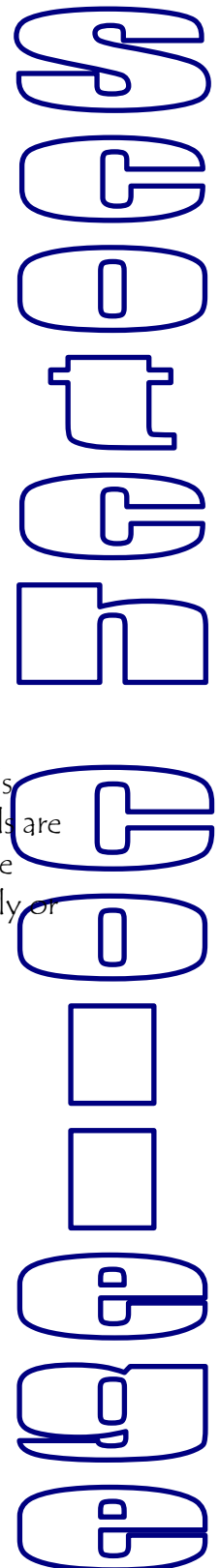
Current is represented by the symbol  $I$ , and is measured in **amperes**, or 'amps', **A**. One ampere is a flow of  $6.24 \times 10^{18}$  electrons per second past any point in a wire. That's more than six million, million, million electrons passing per second. This is a lot of electrons, but electrons are very small and each carries a very tiny charge.

In electronic circuits, currents are most often measured in **milliamps**, **mA**, that is, thousandths of an amp.

### Voltage

In the torch circuit, what causes the current to flow? The answer is that the cells provide a 'push' which makes the current flow round the circuit. When the cells are new, enough current flows to light the lamp brightly. On the other hand, if the cells have been used for some time, they may be 'flat' and the lamp glows dimly or not at all.

Each cell provides a push, called its **potential difference**, or **voltage**. This is represented by the symbol  $V$ , and is measured in **volts**, **V**.



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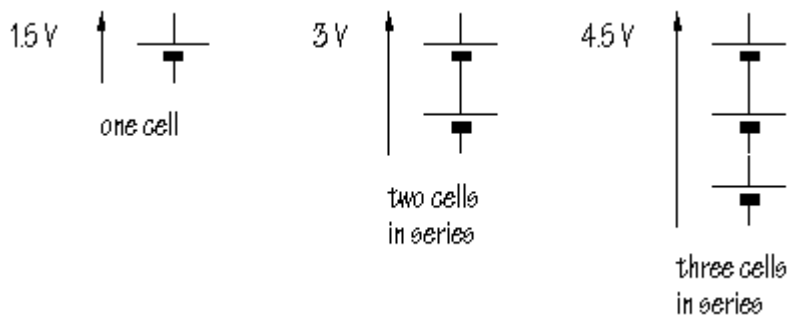
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Typically, each cell provides 1.5 V. Two cells connected one after another, in **series**, provide 3 V, while three cells would provide 4.5 V:

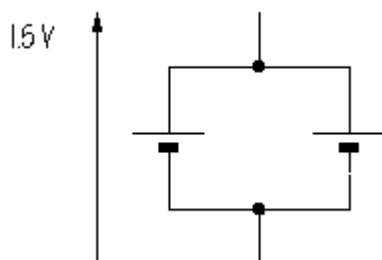


*Cells connected in series*

*Which arrangement would make the lamp glow most brightly?*

Lamps are designed to work with a particular voltage, but, other things being equal, the bigger the voltage, the brighter the lamp.

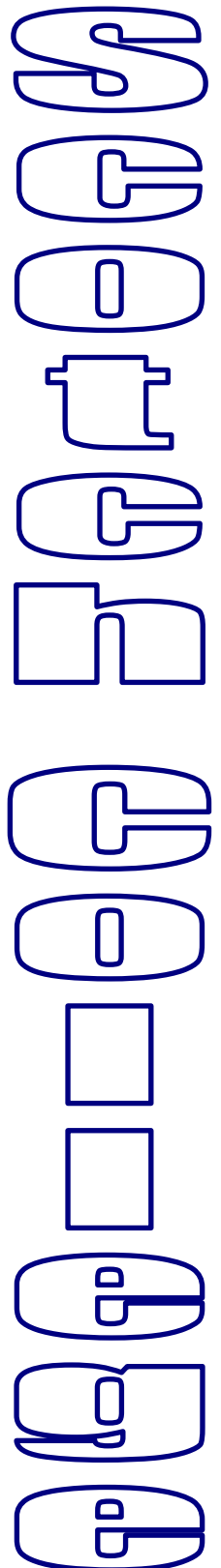
Strictly speaking, a **battery** consists of two or more cells. These can be connected in series, as is usual in a torch circuit, but it is also possible to connect the cells in **parallel**, like this:



*Cells connected in parallel*

A single cell can provide a little current for a long time, or a big current for a short time. Connecting the cells in series increases the voltage, but does not affect the useful life of the cells. On the other hand, if the cells are connected in parallel, the voltage stays at 1.5 V, but the life of the battery is doubled.

A torch lamp which uses 300 mA from C-size alkaline cells should operate for more than 20 hours before the cells are exhausted.





### Which way does the current flow?

One terminal of a cell or battery is **positive**, while the other is **negative**. It is convenient to think of current as flowing from positive to negative. This is called **conventional current**. Current arrows in circuit diagrams *always* point in the conventional direction. However, you should be aware that this is the direction of flow for a *positively-charged* particle.

In a copper wire, the charge carriers are electrons. Electrons are *negatively-charged* and therefore flow from negative to positive. This means that **electron flow** is opposite in direction to conventional current.

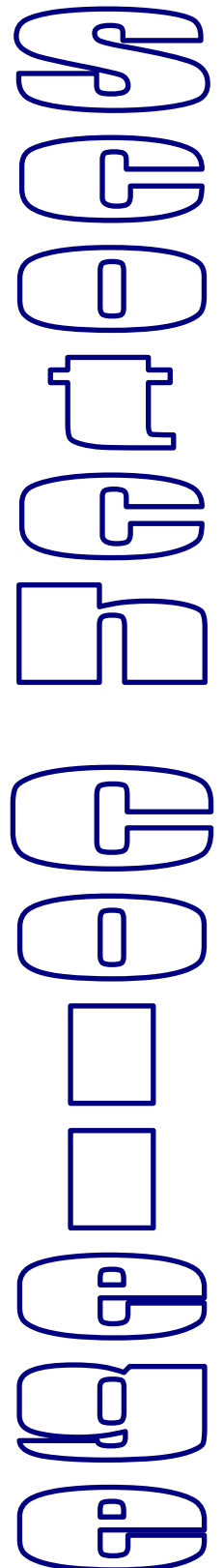
Current flow in electronic systems often involves charge carriers of both types. For example, in transistors, current can be carried by electrons and also by **holes**, which behave as positive charge carriers.

When the behaviour of a circuit is analysed, what matters is the amount of charge which is being transferred. The *effect* of the current can be accurately predicted without knowing about whether the charge carriers are positively or negatively charged.

A cell provides a steady voltage, so that current flow is always in the same direction. This is called **direct current**, or **d.c.** In contrast, the domestic mains provides a constantly changing voltage which reverses in polarity 50 times every second. This gives rise to **alternating current**, or **a.c.**, in which the charge carriers move backwards and forwards in the circuit.

☠ **MAINS VOLTAGE** ☠

For safety reasons, you must NEVER connect circuits to the mains supply.



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## Resistance

If a thick copper wire was connected from the positive terminal of a battery directly to the negative terminal, you would get a very large current for a very short time. In a torch, this does not happen.

Part of the torch circuit limits, or *resists*, the flow of current. Most of the circuit consists of thick metal conductors which allow current to flow easily. These parts, including the spring, switch plates and lamp connections, have a **low resistance**. The lamp filament, on the other hand, is made up of very thin wire. It conducts much less easily than the rest of the circuit and has a **higher resistance**.

The flow of current through the filament causes it to heat up and glow white hot. In air, the filament would quickly oxidise. This is prevented by removing all the air inside the glass of the lamp and replacing it with a non-reactive gas.

