Electric Lights

Contents: Home survey, reading and questions concerning artificial electric lighting.

Time: Homework plus 2 periods.

Intended use: GCSE Physics and Integrated Science. Links with work on light, current electricity, heating effect of electric current, electric discharge, efficiency of energy conversions.

Aims:

- To complement certain work on light, electricity and energy conversions
- To develop awareness of the range of different types of artificial electric lighting
- To show the role of lighting engineers in developing new methods of lighting
- To show the factors involved in making decisions on which type of lighting to use
- To provide opportunities to practise skills in reading, comprehension, data collection and data analysis.

Requirements: Students' worksheets No. 704. Examples of the different types of light to show the class — fluorescent, tungsten filament and tungsten-halogen. Other types might also be shown, for example, neon indicator lamp, light-emitting diode.

In Part 1, students carry out a survey of the different kinds of electric light in their home. It would be helpful if they could be shown beforehand examples of the three main types of light they are looking for — fluorescent, tungsten filament and tungsten-halogen. The least common will be the tungsten-halogen bulb, though these may be found in projectors and car headlamps. Students may confuse tungsten filament strip-lights with fluorescent tubes. The former, often found over bathroom mirrors, give a yellowish light and do not flicker when switched on.

Notes on some of the questions

Q.3 Other types of light might include red neon indicator lights (used to show when a socket or appliance is switched on), light-emitting diodes (in watches or calculators) and electroluminescent panels (on car dashboards).

Q.4 Tungsten filament bulbs (also called 'incadescent' bulbs) are popular because they are cheap to buy (though not to run) and cheap to install — they need no extra electrical equipment beyond a socket. They also give a warm yellowish light which is popular in British homes. In hotter climates, colder, bluish lights are more popular.

Q.5 The rattling of a 'blown' bulb is usually caused by loose pieces of filament.

The evaporation of tungsten from the filament accentuates any uneveness of thickness: the thinner parts of the filament get hotter because of their higher resistance, and therefore evaporate faster, making them thinner still. It is at one of these thin spots that breakage eventually occurs.

Q.7 The earliest filament bulbs, first demonstrated in 1879, used a carbon filament in an evacuated bulb. The high melting point and good electrical conductivity of carbon make it suitable for this purpose, but it began to be replaced by tungsten from about 1906, once the difficulties of working with this hard, high-melting metal had been overcome.

Teachers might be interested to give students some of the historical background to electric lighting. The 'incandescent' filament bulb was preceded by the arc light, but filament bulbs marked the beginning of widespread electric lighting. When they first appeared, mains electricity was of course non-existent and generators were needed. This is why electric lighting tended to be used first for ships, trains and in places which had their own power supply. (The Titanic is said to have gone down in 1912 with her electric lights burning.)

An 1883 catalogue of the Swan Electric Light Company gives the breakdown of the cost of installing electric lighting as follows:

Capital cost of boiler and dynamos	£1470
Yearly running costs:	
Wages for engine driver at 30 shillings per week	£ 78
39 tons of coal at 20 shilling per ton	£ 39
155 replacement light bulbs at 5 shillings each	£ 39

Q.8 Tungsten-halogen lights are very bright, and are also compact light sources which can be accurately focused by lenses and reflectors. This makes them particularly useful for applications such as projectors, spotlights, car headlamps and floodlights.

An explanation of the working of tungsten-halogen bulbs is given on page iii of these teachers' notes.

Tungsten-halogen bulbs are often made with the reflector as an integral part. An interesting recent development is the 'dichroic' reflector, which reflects visible light but allows infra red radiation to pass out of the back of the reflector, thus reducing the heating effect of the lamp. The reflector is made of a laminate of thin layers of zinc sulphide, sandwiched with magnesium fluoride. The thickness of the layer determines the frequency of the light it reflects. By selecting the right thicknesses for the layers, it can be arranged that only visible frequencies are reflected.

Q.10 A fluorescent tube would be bent into the shape of the initials, before evacuating the tube and treating it with phosphor. The bent tube would be run as a normal fluorescent lamp, with electrodes at each end.

Q.11

(a) Costs of 2000 hours' use:

Compact fluorescent tube $= £2 + £8 + 20 \times £0.10 = £12$

Filament bulb $= 2 \times £0.35 + 20 \times £0.50 = £10.70$

(b) Costs of 4000 hours' use:

Compact fluorescent tube $= £2 + £8 + 40 \times £0.10 = £14$

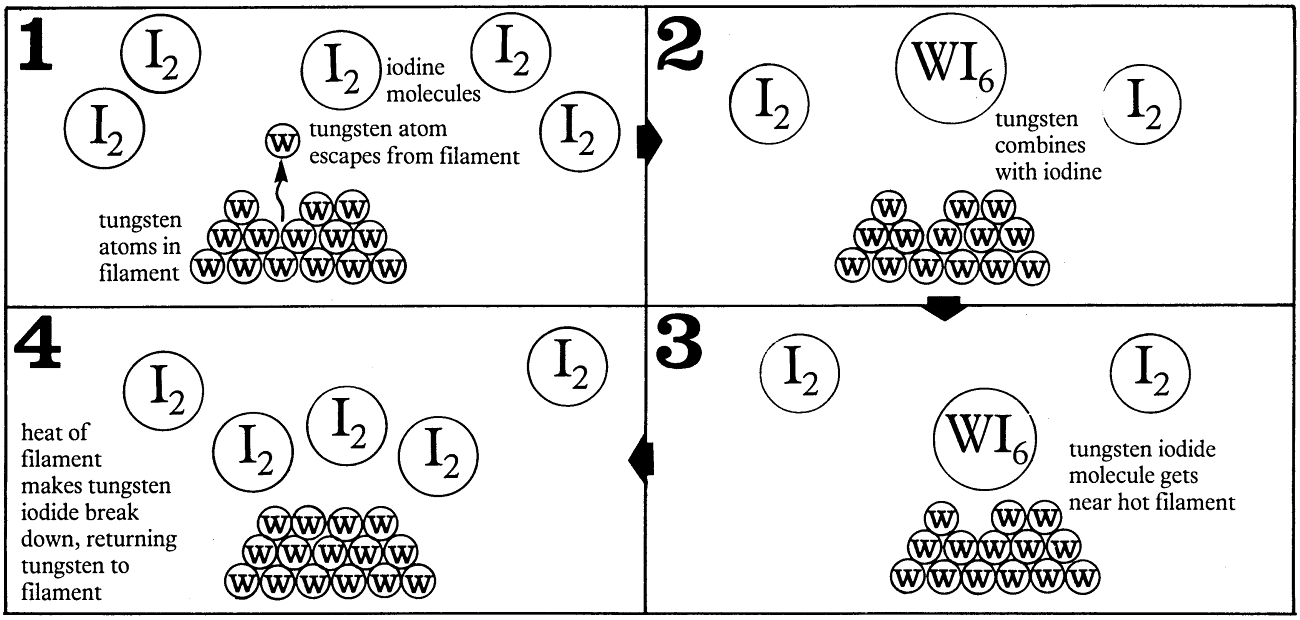
Filament bulb $= 4 \times £0.35 + 40 \times £0.50 = £21.40$

(c) Thus the fluorescent tube is cheaper if used for more than about 2200 hours — just over a year of heavy use.

Notes on the working of the tungsten-halogen bulb

The principle of the tungsten-halogen bulb is an interesting application of chemical equilibrium. The diagrams in the box below illustrate how the iodine or other halogen 'collects' evaporated tungsten atoms and returns them to the hot filament. The hotter the filament, the more tungsten gets deposited. The halogen cycle thus deposits tungsten preferentially on the hotter 'thin spots' of the filament, prolonging its life still further.

How a halogen cuts down the loss of tungsten



Further activities

1 There is plenty of scope for simple calculations on the cost of lighting. For example:

If a family leaves a 100 watt bathroom light on for 10 hours during the night, how much will this cost in electricity?

2 If a light meter or photographic exposure meter is available, a good deal of simple experimental work can be done. For example:

(a) Comparing the light intensity at a distance of 20 cm from
(i) a filament bulb, (ii) a fluorescent tube of the same wattage.

(b) Comparing the intensity of daylight and artificial lighting in various parts of the classroom.

(c) Checking the effectiveness of a light shade in increasing the light intensity from a filament bulb. Checking the effect of lining the shade with aluminium foil.

(d) Investigating the effect of different coloured walls on light intensity in a room (use flat wooden test pieces painted different colours, and measure the intensity of light reflected from them).

3 Experiments can also be done using lights and dimmer switches, for example, to see whether using the dimmer switch saves more electricity than changing to a lower power bulb. Use a joule meter in the circuit, or an ammeter and voltmeter.

Further details of such experiments can be found in the 'Energy in the House' unit of the PLON physics project from the Netherlands. An English translation of this unit is available from: Dr Robin Millar, Education Department, University of York, York YO1 5DD.

Acknowledgement Figure 1 supplied by Thorn EMI Lighting.

ELECTRIC LIGHTS

Electric lights are everywhere. Think how many you switch on each day. In this unit we will be comparing different types of electric lights. In Part 1 you will look at the lights in your home. Part 2 has reading and questions about different types of lights.

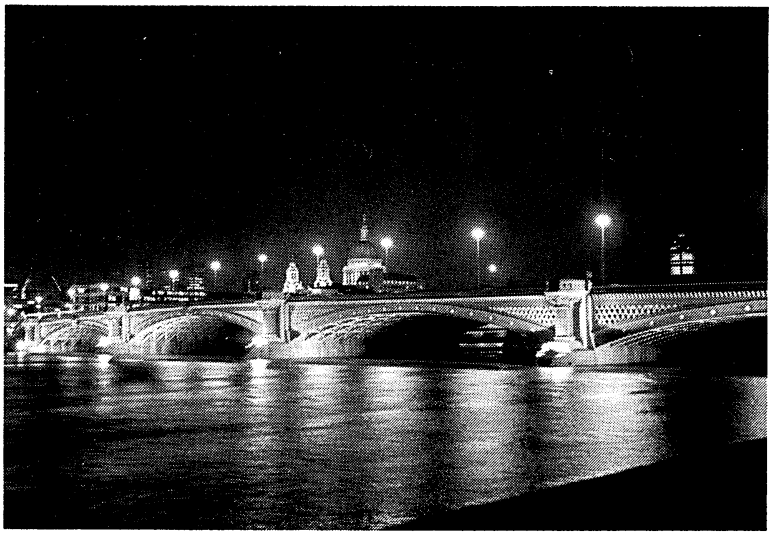
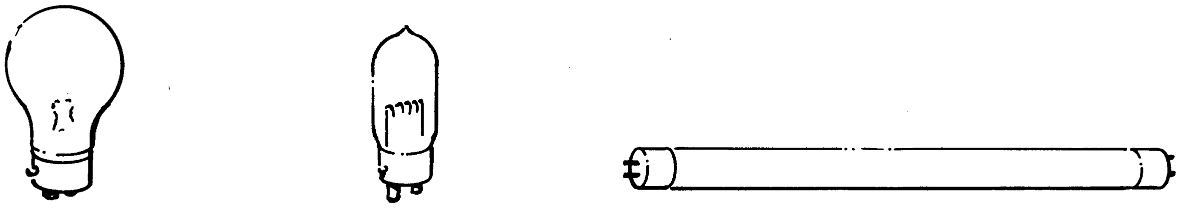


Figure 1 Electricity lights up Blackfrairs Bridge, London

Part 1 Lights in your home

See how many different electric lights there are in your home. The three most common types you are likely to find are shown in Figure 2.



(a) Ordinary tungsten filament bulb. Gives yellowish light.

(b) Tungsten-halogen bulb. Small but very bright.

(c) Fluorescent tube (may be bent into other shapes). Flickers when first switched on.

Figure 2 The most common types of electric light in homes

Draw up a table like Table 1 and fill it in. Look all around your home, including the garage and car if you have one. Remember that lights are not just fixed to ceilings and walls — they are also found in equipment such as torches.

Table 1 Electric lights in your home

Type	*Total number*	*Places found*
(a) Ordinary tungsten filament bulbs		
(b) Tungsten-halogen bulb		
(c) Fluorescent tube		
(d) Other		

Compare your results with other members of the class, then answer questions 1 to 3.

Questions

1 *Which is the commonest type of electric light?*

2 *Whereabouts in the home are fluorescent tubes most commonly found?*

3 *Apart from the three types already described, what other types of electric light were found?*

Part 2 How do the different types of electric light work?

Figure 3 illustrates the main types of electric light.

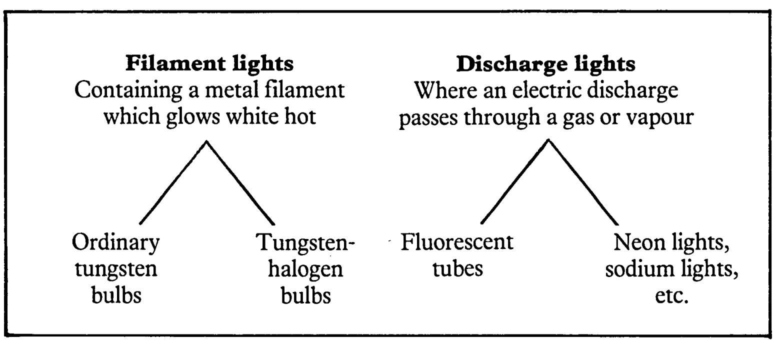


Figure 3 The main types of electric light

Table 2 compares the different types of light. The **efficiency** is a measure of how well it converts electricity to light. All electric lights produce more heat than light, but some are more efficient than others. The **lifetime** shows how long the bulb will run on average before it needs replacing.

Table 2 Comparison of different electric lights

Type of light	*Efficiency when new (%)*	*Lifetime*
Ordinary tungsten filament	3	1000 hours
Tungsten-halogen	5	2000 hours
Fluorescent tube	25	5000 hours
Sodium discharge tube	34	20 000 hours

Ordinary tungsten filament lights

Figure 4 shows what is inside one of these lights.

Electricity is passed through the tungsten filament. The filament gets hot because of its high resistance. A tungsten light filament is the hottest thing you are likely to see in normal life. It reaches 2500°C, which is hot enough to melt brick. Tungsten is used for the filaments because its melting point (3410°C) is the highest of all metals.

To get the correct resistance, the tungsten wire needs to be thinner than a human hair and over a metre long. To make it fit inside the bulb, it is made into a 'coiled coil'.

There are two problems with tungsten at such a high temperature. First, it oxidizes rapidly if exposed to air. Second, it slowly evaporates. To get over these problems, the glass bulb contains the unreactive gases argon and nitrogen, at low pressure. Even so, the tungsten still evaporates away slowly. The vaporized tungsten recondenses on the inside of the glass bulb, making it darken.

As the tungsten evaporates, the filament gets thinner. This makes its resistance higher, so it gets even hotter and evaporates even faster. Eventually the filament breaks. The bulb has then 'blown' and must be replaced.

Tungsten filament bulbs are inefficient and have a short lifetime. But they are very cheap. They work straight off the mains electricity supply with no extra equipment.

Now try to answer questions 4 to 7.

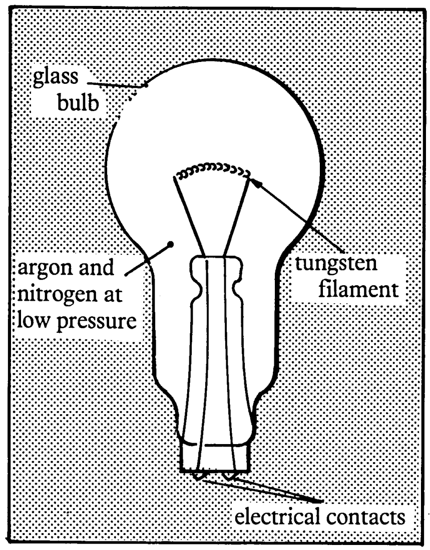


Figure 4 A tungsten filament bulb

Questions

4 *Why are ordinary tungsten filament bulbs so common, in spite of their shortcomings?*

5 *When a bulb of this kind has 'blown', it often rattles when shaken. Why is this?*

6 *The efficiency of an ordinary tungsten filament bulb is 3 per cent. In a 100W ordinary tungsten filament bulb, how many watts of visible light are given out? What happens to the rest of the electrical energy used by the bulb?*

7 *The first light bulbs used carbon for the filament instead of tungsten. What property of carbon makes it suitable for this use?*

Tungsten-halogen bulbs

Lighting engineers soon realized that the evaporation of tungsten was a real nuisance. It cuts down the life of a bulb. It also means the filament cannot be allowed to get as hot as engineers would have liked. Higher filament temperature would give a brighter and more efficient light.

Lighting engineers solved this problem by developing the tungsten-halogen light (Figure 5). As well as argon and nitrogen, the gas inside the bulb contains a halogen such as bromine or iodine. This halogen helps cut down the loss of tungsten through evaporation.

This means the filament can run at a higher temperature, so the light is brighter and more efficient. It also lasts longer, though the bulbs are more expensive than ordinary filament bulbs.

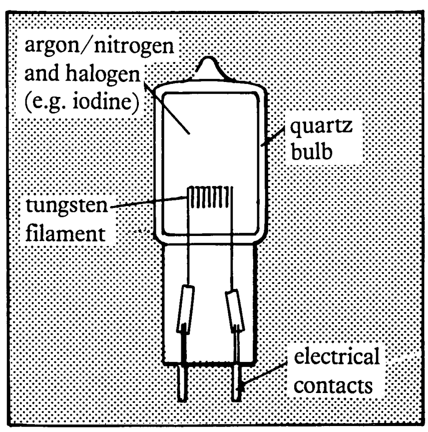


Figure 5 A typical tungsten-halogen bulb

With the filament at such a high temperature, the bulb would crack or even melt if it was made from ordinary glass. To get over this, the bulb is made from quartz instead. These bulbs are sometimes called 'quartz-iodine' bulbs. Quartz is tougher and expands less than glass. But it is very hard, and has to be cut by laser.

Answer questions 8 and 9.

Questions

8 *Tungsten-halogen bulbs are often used in projectors and car headlamps. Why are they especially useful in these cases?*

9 *People do not often use tungsten-halogen bulbs to light rooms inside their homes. Apart from cost, what reason can you suggest for this?*

Discharge lights

In a discharge tube, a voltage is applied to a gas at low pressure (Figure 6). If the voltage is high, a current flows through the gas and the gas glows. The colour of the glow depends on the gas. For example, neon glows red. Neon lights are used in advertising signs. Sometimes a metal vapour is used instead of a gas. Mercury vapour gives a bluish glow and also gives off a lot of ultra-violet light. Sodium vapour glows yellow.

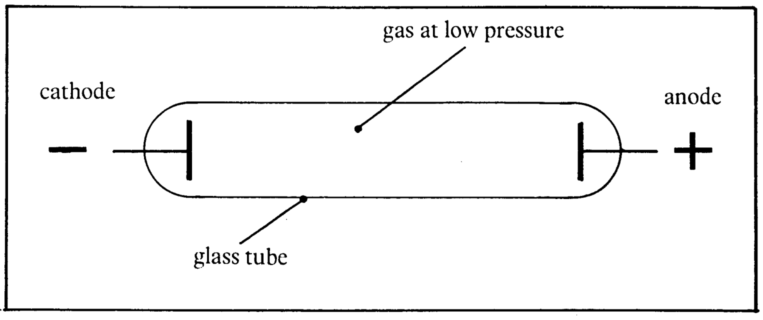


Figure 6 A gas discharge tube

Sodium vapour lights are very efficient. They are often used in street lighting. When first turned on, sodium vapour lights glow red. This is because they contain neon to get them started. When they are hot enough to vaporize the sodium they give their normal yellow colour. Sodium is a very reactive metal, and sodium vapour at 800°C is particularly reactive. There are difficult engineering problems to be solved in designing lights that contain this vapour.

Fluorescent lights

Most people like white or pale yellow light in their homes, so sodium lights and neon lights are not often used indoors. Instead fluorescent tubes are used (Figure 7).

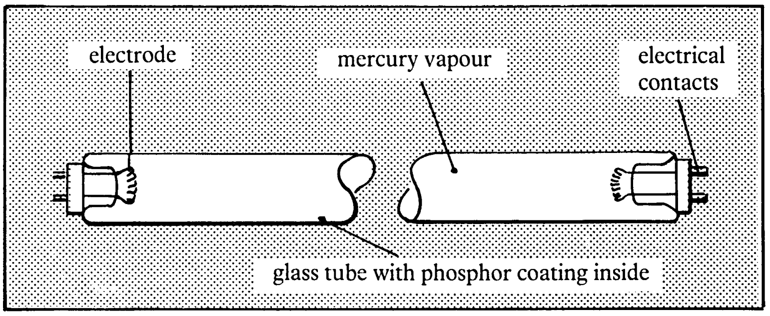


Figure 7 A fluorescent tube

The tube contains mercury vapour. When a voltage is applied, the mercury vapour gives out ultra-violet radiation. The inside of the tube is coated with a **phosphor** powder. The phosphor absorbs ultra-violet radiation, and gives it out again as visible light. This is called **fluorescence**. The light is bluish-white, which is very suitable for shops and offices. However, for homes people prefer a warmer, yellower colour, which can be produced by adding certain chemicals to the phosphor powder.

Fluorescent tubes cast very little shadow, so they are very suitable for working areas like factories, shops, offices and kitchens. They are more efficient than filament lamps, and they last longer.

However, fluorescent tubes cannot be run straight off the ordinary mains supply. They need thousands of volts to start the discharge. This requires special equipment to adapt the mains. Special equipment is also needed to limit the current once it has started. This adds to the cost of installing the tube, but the lower running costs usually make up for it.

Now answer question 10.

Figure 8 shows a compact fluorescent tube that can be used to replace tungsten filament bulbs. Table 3 gives some information about its cost compared with an ordinary tungsten filament bulb with the same output.

Use Table 3 to answer question 11.

Table 3 Costs of a compact fluorescent tube and an ordinary filament bulb

Compact tube	
Cost of the tube	£2.00
Cost of extra electrical equipment for tube (once bought, lasts indefinitely)	£8.00
Cost of electricity to run tube for 100 hours	£0.10
Lifetime of tube	5000 hours
Filament bulb with same light output	
Cost of bulb	£0.35
Cost of electricity to run bulb for 100 hours	£0.50
Lifetime of bulb	1000 hours

Question

10 Suppose you wanted to display your initials in fluorescent light on the front of your school. Sketch a modified version of Figure 7 to show how you would do it.

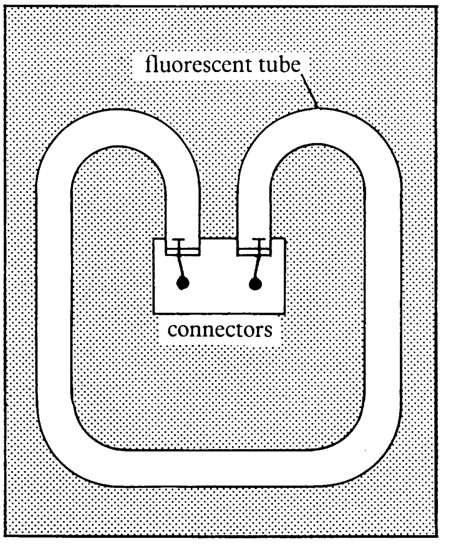


Figure 8 A compact fluorescent tube

Question

11 Using Table 3,
(a) Work out the cost of buying and running each light for 2000 hours (this is about a year's heavy use).
(b) Work out the cost of buying and running each light for 4000 hours.
(c) Is it worth buying the fluorescent tube? Explain your answer.