Why 240 Volts?

Contents: Reading, information, questions and practical work on the choice of a suitable standard for the mains voltage.

Time: 2 to 3 periods.

Intended use: GCSE Physics and Science syllabuses. Links with work on electric power, and the heating effect of a current.

Aims:

- To complement work on electric power, current and voltage by developing a qualitative awareness of the practical significance of these concepts
- To provide an opportunity to plan and carry out a practical investigation
- To provide an opportunity to consider the balance between conflicting criteria in a context where there is no one 'right answer'.

Requirements: Students' worksheets No.1008. The requirements for the investigation are listed below.

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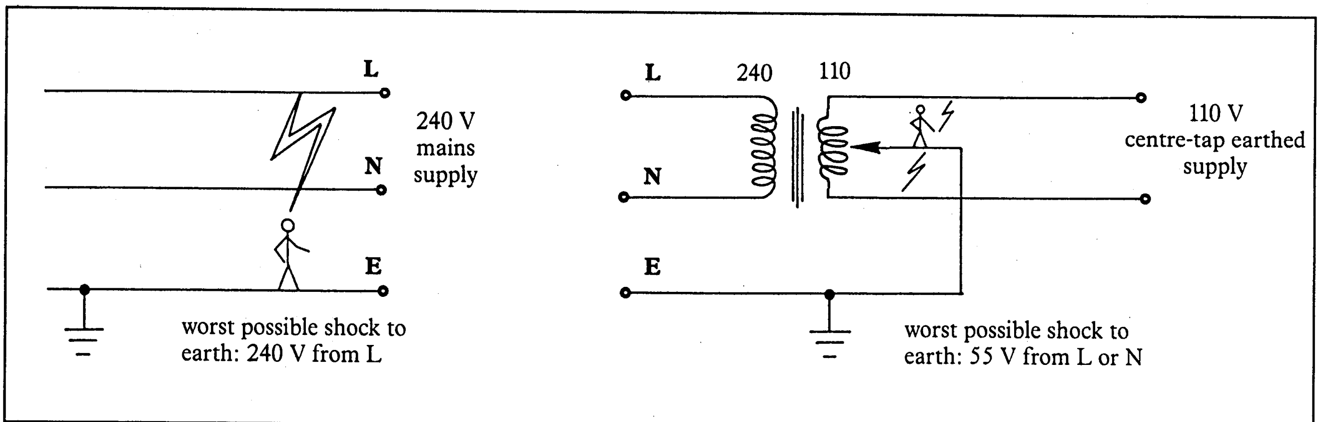
This unit is designed to follow No.1007, *240 Volts Can Kill.* It also complements unit 701, *Electricity in Your Home,* which helps to give students familiarity with the power requirements of various household appliances.

The unit is about voltage and current and the way they affect us, particularly in relation to the domestic electricity supply. There is a trade-off between voltage and current when supplying equipment with a specified power rating.

One approach to current electricity is based on Ohm's law and a constant resistance with current varying in proportion to the applied voltage. In practice the requirement is almost invariably for a stated *power,* with the current varying inversely with the supply voltage. The resistance is then chosen to match the requirements.

Introduction

The diagram below can be used to show why a 110 V centre-tap earthed supply limits the maximum shock to 55 volts.



When was 240 volts chosen?

It is easier to discover *when* 240 V was chosen as the standard than to find out *why* this particular voltage was chosen. The need for standardisation was clear. The general feeling of the supply authority was that voltages less than 200 V would cause too great a voltage drop in the cables along the street. The voltage drop is proportional to the current, which has to be higher to deliver the required power if the voltage is lower.

The original chaos of voltages arose from many companies all independently supplying electricity in competition with one another under no overall effective control. This kind of situation is often advanced as a justification for state monopoly over such concerns of national influence. It is possible that the electricity supply industry may once again become privatized; if so, it will be interesting to invite students to discuss the problems which may arise. Will we see a variety of supply voltages again?

What would a lower mains voltage mean ?

By filling in Table 1, students will find that for a given power rating the current must increase if the voltage is lower. This means that thicker cables must be used. Here there is an opportunity to compare the thickness of 5 A, 13 A, 30 A and 45 A cable, if samples are available.

Students can be asked to think about the practical limits to currents for portable appliances. What would be the dangers of having high-current cables trailing about the home?

If the mains voltage were lower, it might be possible to save lives by reducing the risk of fatal electric shock. On the other hand, the current requirements of all devices would be higher, and abuse of the system could lead to more fires when cables overheat.

Question 9 raises the possibility of having high and low voltage sockets. A high voltage device will not work if plugged into a low voltage socket. A low voltage device is likely to be damaged if plugged into a high voltage socket.

Investigation How does the voltage affect the efficiency of light bulbs?

Minimum requirements:

- low voltage, 12 V d.c. supply
- 36 W car headlight bulb in holder with leads
- 40 W mains bulb in holder with mains lead and plug (the wattages of these bulbs are chosen as the nearest readily-available equivalents)
- light meter

Students may be surprised by the higher light output from the low voltage bulb. The explanation raises many physical principles and provides an interesting topic for discussion at a more advanced level.

The trade-offs to be considered when reviewing the unit can be summarized as follows:

voltage : current
risk of shock : risk of fire.

Acknowledgement Figure 1 supplied by the Central Electricity Generating Board.

WHY 240 VOLTS?

Introduction

Why is the mains voltage 240 volts? Why not 12 volts, or 100 volts, or even 1000 volts?

We know that 240 volts is dangerous. It can kill. Yet 240 volts is used to supply electricity to our homes. Why? In America they use 110 volts.

On building sites, in this country, 240 volts is not used for portable tools because it is too dangerous. The supply is 110 volts. The supply is 'centre-tap earthed'. This means that it is taken from a transformer in such a way that the maximum shock to earth is 55 volts.

Answer questions 1 to 3.

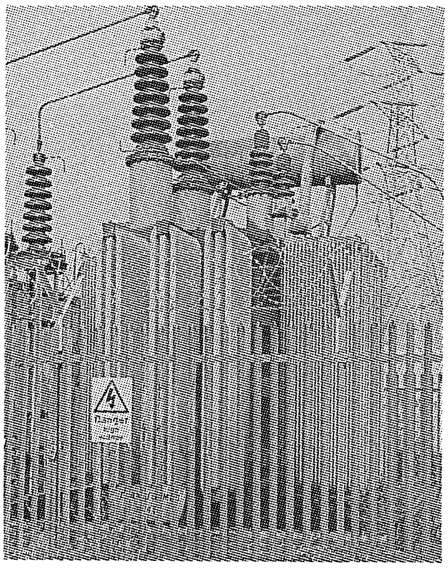


Figure 1 An electricity sub-station

When was 240 volts chosen?

The electricity supply industry was nationalized in 1948. Before that time electricity was supplied by many companies using different voltages. 100 V, 110 V, 200 V, 210 V, 220 V, 230 V, 240 V and 250 V were all used, and others too.

The new nationalised industry had to choose a standard voltage. There was a big job to be done. They had to modify many of the electric appliances in the homes affected by the change. So it was important to get the new voltage right.

There were reasons for wanting a high voltage, to avoid a large voltage drop along cables. There is a drop in voltage along a cable or wire because the cable has resistance. The voltage drops between the transformer in the street and the plugs in the house. This drop is more serious with low voltage supplies. Many experts thought that the drop would be too big if the voltage was less than 200 V. In the end they settled on 240 V, even though it is high enough to cause fatal electric shocks.

Answer questions 4 to 6 on the next page.

Questions

1 *Why do we seem more concerned to protect people at work than at home? Employers are expected to protect their employees by using a safer voltage. When they get home the same people are free to risk their lives with 240 V.*

2 *Try to find the voltages used by these devices: pocket torch; hand calculator; transistor radio; car; lorry; telephone; electric kettle; TV set; table light; street light; trains on the London Underground; trains on BR Southern Region and Mersey Rail; trains with overhead power lines.*

3 *Why do you think that different voltages are used for the various devices listed in question 2?*

Power

Each of the electric appliances we use has to have enough power to do its job. More power is needed by a washing machine than a razor. More power is needed by an electric fire than by a light bulb.

The size of the current taken by an electric appliance depends on its power and on the voltage. You can usually find the power (in watts, W or kilowatts, kW) printed somewhere on the appliance.

power (watts, W) = voltage (volts, V) × current (amps, A)

This formula shows that if the supply voltage is **lower** then the current has to be **bigger** to get the same power.

What would a lower mains voltage mean?

We might save lives if the mains voltage was lower because fewer people would be killed by electric shocks. One hundred people were killed by shocks at home in 1982.

However, if the supply voltage was lower, the currents in all wires and cable would have to be higher, in order to keep the same power. You can see the effect of working at three different voltages by completing the current ratings in Table 1. Work out the values using the formula:

$$\textbf{current (A)} = \frac{\textbf{power (W)}}{\textbf{voltage (V)}}$$

The formula is the same as the one in the previous section. It has just been rearranged.

The first row of the table has already been done as an example.

Appliance	*Power rating*	*Current rating at:*		
		240 V	110 V	12 V
Clock radio	9 W	0.04 A	0.08 A	0.75 A
Light bulb	60 W			
One-bar fire	1000 W			
Kettle	3000 W			
Electric shower	7000 W			
Cooker	10 000 W			

Questions

4 *What would it be like if we still had different household voltages in different parts of the country?*

5 *Why does it matter if there is a drop in voltage along the cables connecting transformers to homes?*

6 *Very high voltages (up to 400 000 V) are used in the cables of the national grid. Why is such a high voltage used?*

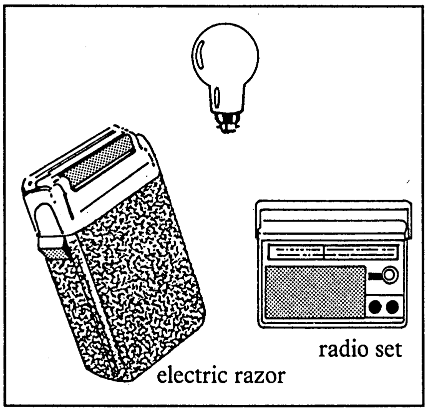


Figure 2 Low power devices

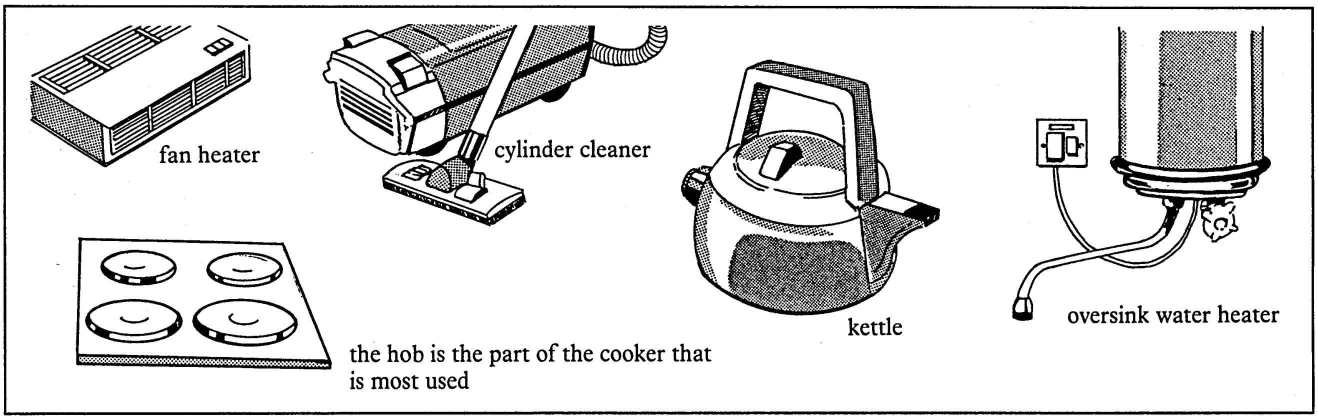


Figure 3 High power devices

An electric current heats up the wires it flows through. The bigger the current, the hotter the wire gets. There is more danger of cables overheating if the current is high. So higher currents create a fire risk. In 1983 there were 25 000 fires started by electrical faults in Britain. About 175 people died as a result.

To cut down the heating effect of high currents, thicker wires have to be used.

So if you have a lower standard voltage, like 110 V, there is a problem with high power devices. They take a high current, so they need thick cables. Thicker cables cost more, and they can be unwieldy.

One way round this problem might be to have a dual-voltage supply. Houses could be fitted with lots of low voltage sockets and a few high voltage ones. The high voltage ones would be used for high power devices like cookers and heaters.

Answer questions 7 to 9.

Questions

7 *What is the largest current which can be taken safely from a standard power point at 240 V? (Think about the fuse in the plug.)*

8 *Which of the appliances in Table 1 require a dangerously high current:*
(a) at 110 V
(b) at 12 V?

9 *Imagine living in a house fitted with high and low voltage points.*
(a) What would happen if you plugged a high voltage device into a low voltage socket? Would it be dangerous?
(b) What would happen if you plugged a low voltage device into a high voltage socket? Would it be dangerous?
(c) How could you make sure that people did not make these mistakes?
(d) Would it be inconvenient to have special sockets for high power appliances? How many special sockets would you need? Where would you choose to have them?

Investigation How does the voltage affect the efficiency of light bulbs?

Plan an investigation to compare the efficiency of different light bulbs. Which bulbs are most efficient at turning electrical energy to light?

Compare a 36 W car headlight bulb at 12 V with a similar power mains bulb at 240 V.

How will you measure the light output of the bulbs? How will you arrange to make a fair test of the different bulbs? What safety precatuions will you need to take?

Should we all install transformers in our homes to convert 240 V to 12 V so that we could use headlight bulbs? Would it be more efficient? What would be the other advantages and disadvantages of low voltage lighting systems?

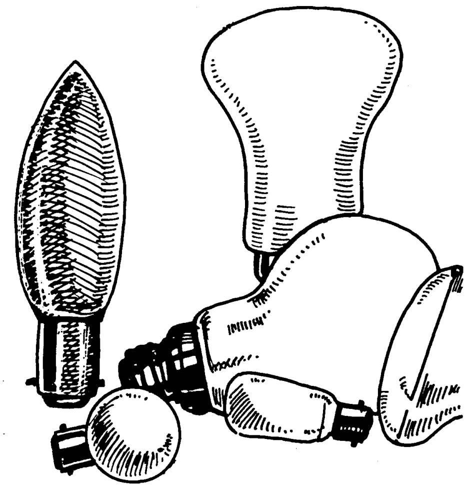


Figure 4

Further questions

10 (a) *What do you think is the* **maximum** *voltage for safety in the home? (If you have done the unit* 240 Volts Can Kill, *think about the questions you answered in that unit.)*

(b) *What do you think is the* **minimum** *possible voltage in the home? (Think about the currents needed by high power appliances.)*

11 *Imagine that you are an electrical engineer. You are in charge of a project to set up an electricity system in a country which does not yet have a power supply. What voltage would you choose for people's homes? Give your reasons.*

12 *How does your answer to question 11 compare to 240 volts? So now try to answer the question in the title of this unit:* Why 240 volts ?