Electricity and Magnetism: Physics Narrative 05

Contents

This is the 'Physics Narrative' for this episode, that explains the physics for teachers. To develop your expertise in the episode, work with the 'Teaching and Learning Issues' and the 'Teaching Approaches'. Navigate to any part of the topic using the Topic Menu, or use the tabs below to stay within this episode..

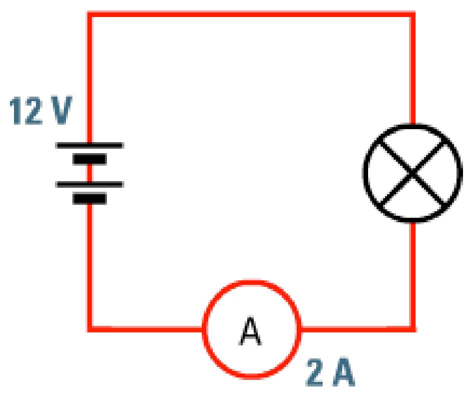
Getting started

The topic of electrical power is a satisfying one to teach for at least two reasons. Firstly, introducing the idea of electrical power involves drawing together and building on the basic ideas introduced in the preceding sections. In addition, it provides lots of opportunities for making links to the pupils' experiences of using electrical appliances outside school.

Getting started

Current and voltage leading to power

By way of introducing what we mean by electrical power, let's start with a circuit in which a 12 volt battery is connected to a single bulb:



This circuit is similar to that suggested for the BIG circuit in episode 1, where a car headlamp bulb was connected to a 12 volt supply. Assume that an ammeter connected into the circuit shows a current of 2 ampere and start by thinking about the bulb:

Current through bulb = 2 ampere.

> 2 coulomb of charge pass through the bulb each second.

Voltage across bulb = 12 volt (assuming that each coulomb of charge transfers all 12 joule of energy in the bulb).

> 12 joule of energy are transferred to the surroundings for every coulomb of charge passing through the bulb.

If these current and voltage figures are taken together, we can see that in the bulb:

- 2 coulomb of charge arrive every second
- each coulomb of charge shifts 12 joule of energy.

So 24 joule of energy are shifted by the bulb each second.

In other words, as the filament of the both lights and heats, 24 joule of energy are transferred to the surroundings each second.

Getting started

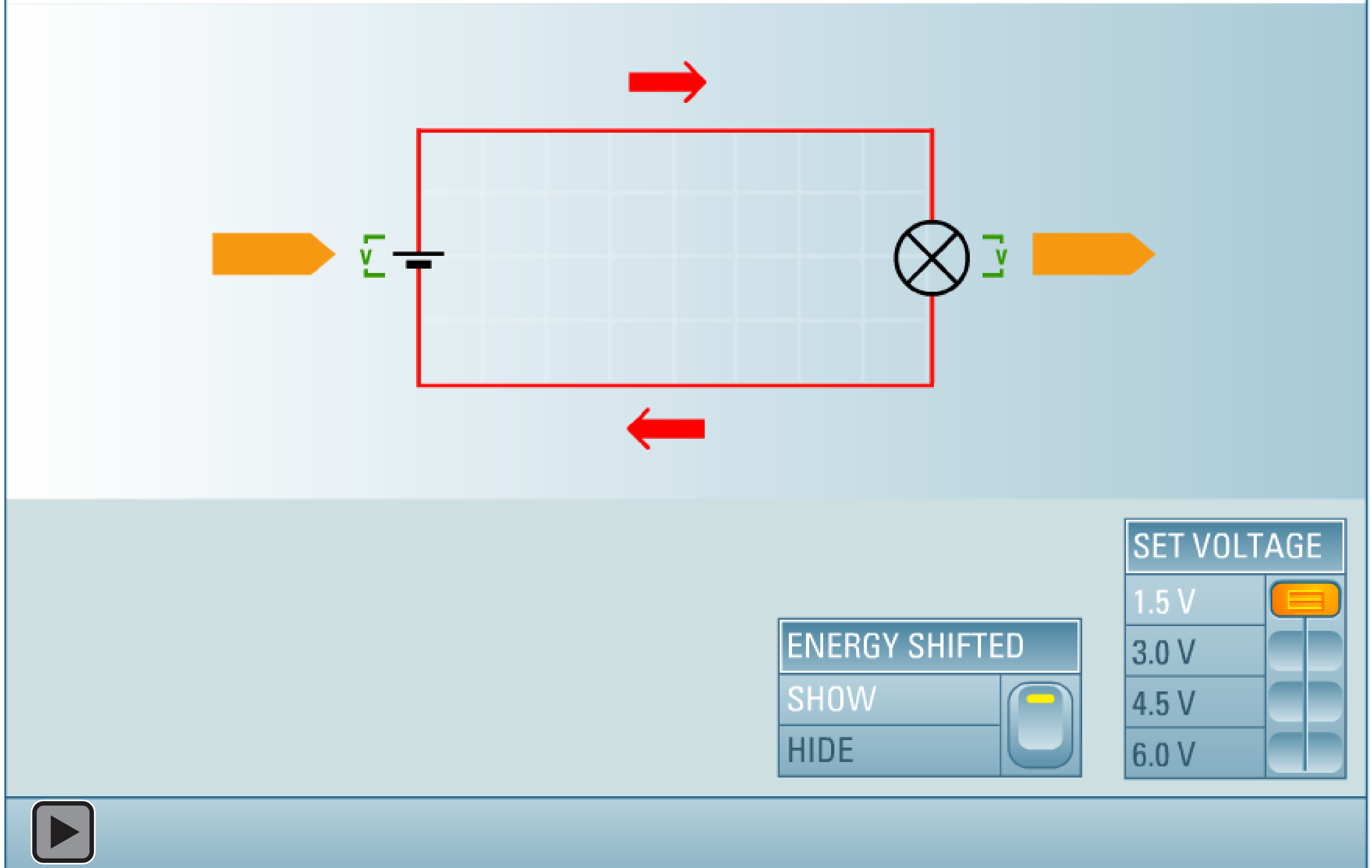
You might think of the overall energy shift (or transfer) in the circuit as being from the chemical store of the battery to the thermal store of the surroundings via heating and lighting pathways (see energy topic).

What you have calculated here is the energy shifted every second by the electrical working pathway - that is the power input. All of this ends up heating or lighting.

So here the power input is equal to the power output.

The energy shifted every second is the power

Use the stepper to alter the battery voltage. Use the switch to see the power.



Electrical power

Electrical power

This quantity, the amount of energy transferred by the bulb each second, is called the electrical power of the bulb.

The power of any device (whether electrical or mechanical) is defined as:

power = energy transferred per second

or

$$\text{power} = \frac{\text{energy}}{\text{time}}$$

Power, energy and time

Click on a term to make it the subject of the relationship.
Unlock a pair of variables, then drag one to see how the other varies.

$$\text{time} = \frac{\text{energy}}{\text{power}}$$

Electrical power

In other words, a device has a high power output if it fills a selected store of energy very quickly. This idea can be applied to electrical devices, mechanical machines and even to people. For example, a trained athlete is able to ride a mountain bike up a steep slope quicker than a person of average fitness (so filling a gravitational store rapidly). The same amount of energy is needed for either person (provided they're about the same mass) to ride the bike up the hill. It's the athlete's ability to perform the task in a shorter period of time that shows that their power output is greater. We don't know, from these measurements, who has emptied their chemical store most rapidly. That would be a measure of the input power.

Units: Power

The standard unit of power is the watt
The symbol used to represent the watt is: W

So:

$$\text{power (in watt)} = \frac{\text{energy (in joule)}}{\text{time (in second)}}$$

1 watt = 1 joule of energy transferred per second
100 watt = 100 joule of energy transferred per second

Calculating electrical power

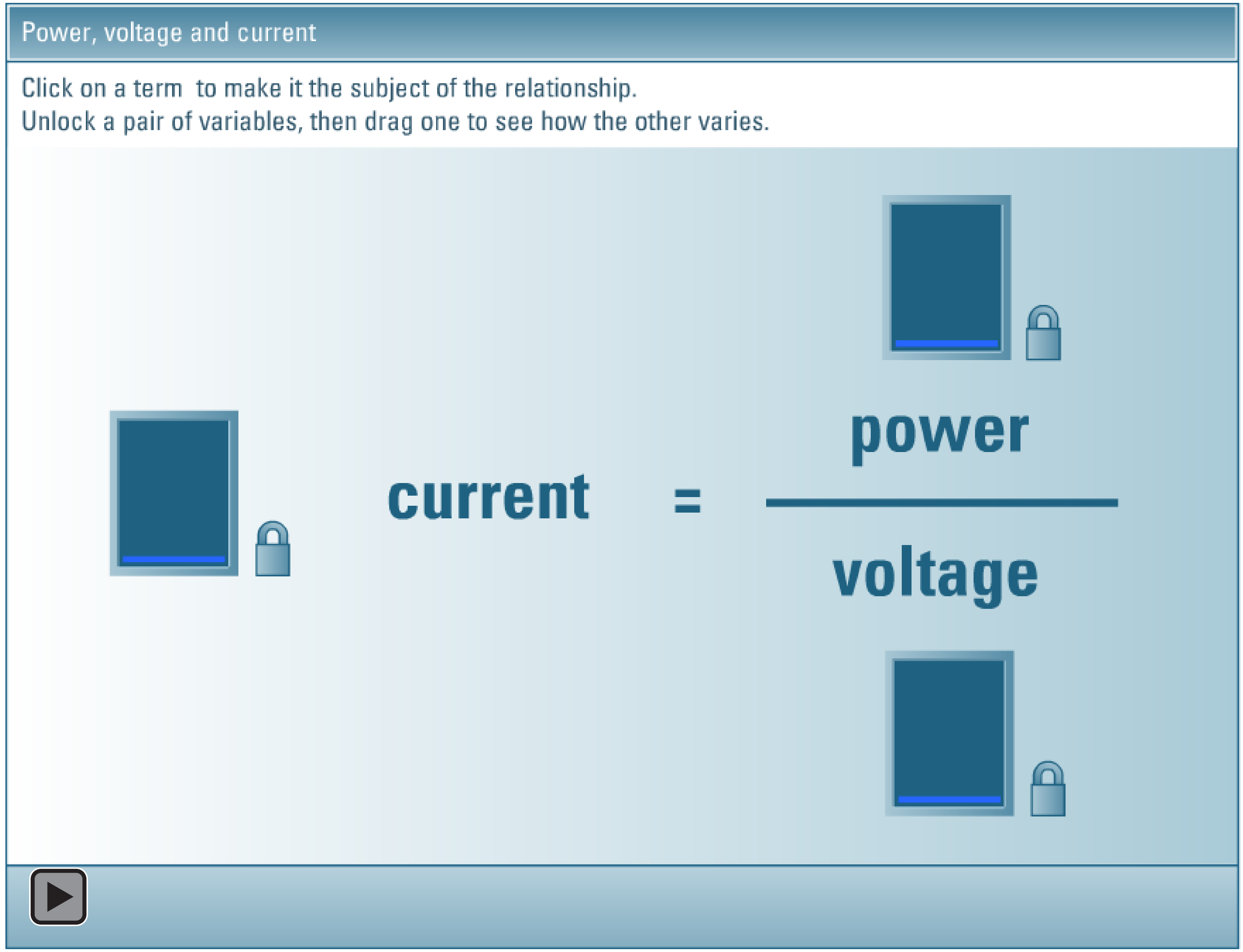
Going back to the circuit we started with, you can see that the electrical power is calculated by multiplying together the current through the bulb and the voltage across it. In general:

Power / watt = voltage / volt × current / ampere

Thus:

Voltage across bulb	=	12 volt
Current through bulb	=	2 ampere
Power of bulb	=	12 volt × 2 ampere
Power	=	24 watt

Note that the power calculated here includes the total energy shifted by the bulb through lighting and through heating. The energy shifted by the electrical working pathway does not all end up being shifted by the lighting pathway. The bulb is not as efficient as we'd like. More on this can be found in the energy topic.



Questions to check understanding

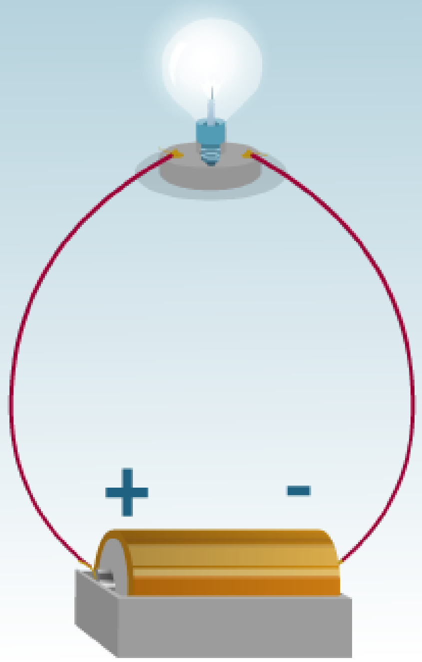
You can use the following questions to check your own understanding of this episode and your pupils' understanding.

Questions to check your understanding - best word

Question 1 of 9

(a) When the bulb is lit, there is ______________ going through it.

In this circuit, a bulb is connected to a battery. The bulb is lit.



	CORRECT	INCORRECT	DON'T KNOW
a) Electricity			
b) An electric current			
c) Energy			
d) Voltage			

Once you are happy with your answer click "check it" to continue

CHECK IT

Final review

In this final part of the electricity unit we bring together all of the ideas introduced in the preceding episodes to think through a range of different circuits. For each circuit you will be asked to consider 5 key questions, starting with what actually happens when the circuit is completed:

1. What happens?

What do you see happening when the circuit is completed?

2. Can you produce a description in terms of the electric circuit model?

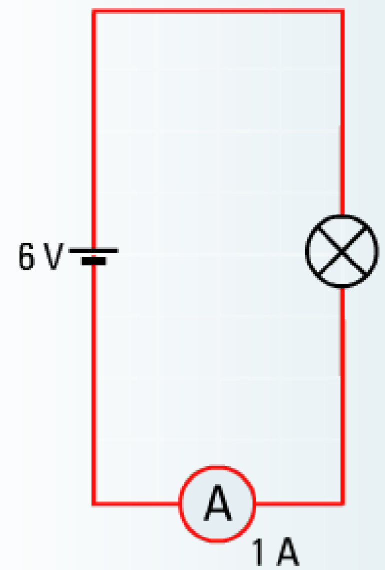
Explain what happens in terms of the charges moving around the circuit and the transfer of energy.

3. Can you produce a description in terms of a teaching analogy?

How would you draw on the rope loop teaching analogy to help explain this circuit to pupils?
How would you draw on the supermarket picture teaching analogy to help explain this circuit to pupils?

The simple circuit: A summary

Use the stepper to reveal a commentary after you have considered your own response



COMMENTARIES

- CIRCUIT
- WHAT HAPPENS?
- IN TERMS OF THE ELECTRIC CIRCUIT MODEL?
- IN TERMS OF A TEACHING ANALOGY?
- IN TERMS OF CURRENT, VOLTAGE?
- POWER OUTPUT FROM BULB?

Final review

4. Can you produce a description in terms of current, voltage?

What is the electric current in different parts of this circuit? Explain the value of the electric current in the different parts. What is the voltage drop across each bulb in this circuit? Explain the value of the voltage drop across each bulb.

5. Can you predict the power output from bulb?

What is the power output of each bulb in this circuit? Explain the value of the power output from each bulb.

Final review

How long will the batteries last in each circuit?

We have seen that as the bulbs are connected in the different circuits their brightness and power outputs change.

Given that the energy output from the circuit to the surroundings must be balanced by the energy input from the battery, it is the case that the battery must run down at different rates in the different circuits.

Let's examine this a little more closely:

Circuit	Power output per bulb	Total power output from circuit
Starter circuit	6 watt	6 watt
Two bulbs in series	1.5 watt	3 watt
Double voltage battery	24 watt	24 watt
Two bulbs in parallel	6 watt	12 watt

- Energy is shifted most quickly (at the rate of 24 joule per second) in the circuit with the double voltage battery.
- Energy is shifted least quickly (at the rate of 3 joule per second) with the two bulbs in series.

This makes sense.

In the double voltage circuit you might picture the charges moving around relatively quickly, with each charge shifting a lot of energy, in the single bulb.

Conversely, with the two bulbs in series the movement of the charges is slowed right down and the energy of each charge is shared between the two bulbs.

The battery runs flat eight times more quickly with the double voltage single bulb circuit, compared to the standard voltage with two bulbs in series.

Adding a bulb in parallel results in doubling the total power output from circuit (from 6 to 12 watt). As pointed out earlier the good news is that we have two bulbs of equal normal brightness. The bad news is that the battery runs down twice as quickly.