Heating effect of a current - a favourite demonstration

We are writing this article in the hope that, by the time it is published, science teachers are celebrating a return to something approaching normality with respect to practical work. Meaningful practical work that challenges misconceptions, illustrates concepts and provokes discussion is at the core of what we do at SSERC. We think this activity does all of that.

Figure 1 - Warm water in a mug causing thermochromic film to change colour.

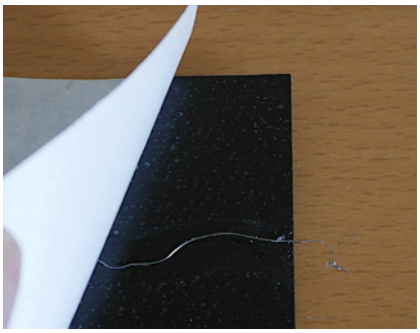

Figure 2 - Resistance wire stuck to the back of thermochromic film.

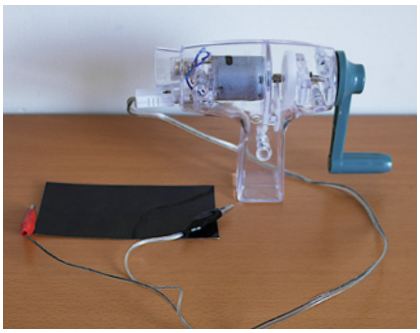

Figure 3 - Hand generator. connected.

This safe, simple activity demonstrates the heating effect of an electric current. As a bonus, it can also be used to promote discussion on the topics of energy conservation and electric vehicles.

Thermochromic film is made from encapsulated liquid crystals that change colour with temperature. The material has been used in forehead thermometers, indicators on electronic components to show overheating, and in battery strength indicators. It is available from the likes of Mindsets [1]. Figure 1 shows a piece of thermochromic film placed against a mug full of warm water.

We use thermochromic film that is sticky-backed. By peeling off the backing it is possible to run a piece of thin resistance wire, nichrome for example, from one side to the other (Figure 2). The wire we used was about 16 cm long and had a resistance of the order of 10 ohms.

We are going to pass a current through this wire. We could use a battery or power supply. If so, we would have to ensure that the wire did not overheat and damage the film. There is less risk of this happening if a hand generator is used (Figure 3). These are available from most suppliers. Power supplies that could be locked to an appropriately low voltage would also be suitable.

Having established with the learners that the film's colour changes with temperature, they can caw the handle. Figure 4 shows the result of generating a current in the resistance wire.

The heating effect is quickly and clearly seen. It is worth noting that:

- The heating is even – one end of the wire is not warmer than the other;
- There is no delay in colour change from one end of the wire to the other.

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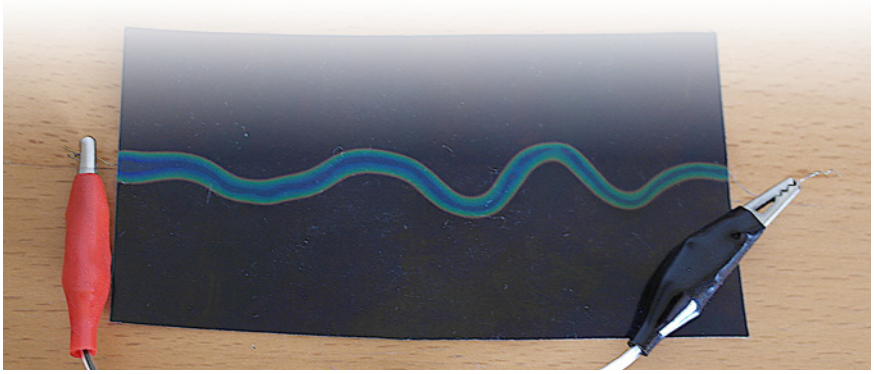

Figure 4 - Current causes heating.

These are important points. Some learners have the image of an electron starting at one side of a circuit and making its way to the other, followed by a band of its siblings. What we are seeing here is more like the motion of links in a bicycle chain. When energy is supplied, charges move together. Learners may also hold the misconception that electrons get 'tired' as they move through the circuit and might therefore expect one end of the film to be warmer than the other due to electrons having less energy at the 'end' of a circuit.

We mentioned a bonus. Compare how difficult it is to turn the generator handle when it is connected to both ends of the wire with the situation where one end is not clipped on. Electrical energy from a generator is not free. It can only be created from another form of energy. Electrified vehicles, like the hybrid car in Figure 5, exploit this.

When you brake in an non-electrified vehicle, the car's kinetic (movement) energy is turned into heat energy through friction heating as brake pads rub against brake discs. The energy is wasted. This also happens in electrified cars, but to a lesser degree. Much of the braking is done using a generator. When you press the brake pedal gently, a circuit connecting a generator to a storage battery is complete. The generator is part of the car's transmission and is linked to the wheels. Just like the hand generator was difficult to turn when it was part of a circuit, the car's generator becomes difficult to turn and slows the car down. Unlike friction braking, some energy is reclaimed and stored in the battery. This energy is available to help propel the car when required.

Figure 5 - Hybrid car.

A less welcome example of generators requiring energy to produce electricity is the bicycle dynamo. A bicycle fitted with a dynamo to power its lights will be harder to pedal when the lights are switched on than when they are not. We also recall a newspaper article many years ago about a man who was using his car to create 'free' energy for his house. He had mounted two large fans on the roof of his car, each linked to a generator wired to batteries in his boot. As he drove, the fans turned, driving the generators which charged the batteries. When he got home, he removed the batteries and used them for house lighting. He would not be told by engineers that the energy he stored in his batteries came at a cost of additional fuel needed to drive a car with greatly increased motion resistance. The extra resistance was of course due to the air having to turn the contraptions on his roof. This could make a great discussion point with learners. What other disadvantages did his system have? Is there any way it could be made efficient – pop-up fans that only generated electricity during braking?

Finally, as an aside, here is a little bit of information on how Toyota's hybrid system works. Feel free to ignore it but you may be surprised at what exactly is going on and it could provide context for some physics topics. Other hybrid systems are in use and don't exactly mirror what Toyota's does.

Toyota hybrids have both an electric motor and a petrol engine. The petrol engines operate on the Atkinson Cycle, a variant of the conventional four stroke cycle. Atkinson Cycle engines are very fuel-efficient but they are low torque, i.e. they produce a low turning force. A car with an Atkinson Cycle engine would be poor at accelerating. An electric motor, on the other hand, produces maximum torque even at very low revolutions. Pairing an electric motor and an Atkinson Cycle petrol engine, where the energy for the electric motor is harvested from braking, leads to an economical vehicle without the drawback of low torque. <<

Reference

[1] https://mindsetsonline.co.uk/shop/thermocolour-sheet/