Electric Vehicles

Contents: Reading and questions concerning the advantages and limitations of electric vehicles.

Time: 1 to 2 periods, depending on number of questions tackled and amount of discussion.

Intended use: GCSE Physics and Integrated Science. Links with work on electric motors, energy, power and electricity generation.

Aims:

- To complement prior work on energy and electric power
- To show some of the advantages and limitations of electric vehicles
- To illustrate the fact that all technology is limited by the laws of science
- To develop awareness of some of the wider issues associated with road transport, including consumption of fuel resources, efficiency of energy conversion and pollution
- To provide opportunities to practise skills in reading, comprehension and application of knowledge.

Requirements: Students' worksheets No. 202

Notes on some of the questions

There is a large number of questions in the unit and teachers may prefer their students to answer only a selection. This applies particularly to questions 12 to 21 at the end of the unit.

Q.9 This question establishes the remarkable fact that a petrol pump delivers chemical energy at the rate of 30 megawatts. This means a large 2000 MW power station is equivalent to just 67 petrol pumps.

Q.10 The point here, of course, is that while electric vehicles themselves cause little pollution, the energy they store in their batteries has been generated at power stations, which themselves cause pollution. It might be interesting to discuss which causes more pollution: burning primary fuel at a power station or in an internal combustion engine. The answer is probably the latter, and there is also the point that a power station discharges its emissions much higher in the atmosphere.

Q.11 Electric vehicles probably score over petrol vehicles on all these points.

Q.13 A milk float does not need to move fast, and the regular cycle of the milk round fits in well with the recharging requirement. The constant stopping and starting also gives the electric vehicle an advantage over petrol or diesel.

In some electric vehicles, braking is used to advantage, by using 'regenerative braking' to generate electricity.

Q.14 Fork lift trucks and other vehicles for interior factory use need to be quiet and must not produce toxic fumes. Another advantage of electric motors for this application is that they give high torque starting from rest, unlike petrol engines.

Other examples of electric vehicle applications include street cleaning vehicles, works fire tenders, airport support vehicles, servicing platforms, refuse collection vehicles, invalid carriages and hospital patient transporters.

Q.16 The overall efficiency of electric vehicles in the conversion of primary fuel is actually less than that of petrol vehicles, and much less than diesel vehicles, because of the large losses involved in generation and transmission of electricity.

Q.20 It seems there is little chance of introducing electric cars to any significant extent as long as the tremendously flexible petrol vehicle is cheaply available, with its long range, short refuelling time and instant availability.

Acknowledgements Figures 1 and 3 supplied by The Electricity Council; Figure 8, by Sinclair Vehicles.

ELECTRIC VEHICLES

Look at this list of advantages:

Cheap to run
Quiet-running
Cheap to maintain
Easy starting in winter
Safe
Pollution free
Ideal for stop-start driving
No road tax

These are some of the impressive advantages of electric vehicles. So why don't we see more of them on our streets? Electric milk floats, yes, but why not electric cars, lorries, buses, and bikes?

Figure 1 An electric milk float

Vehicles need energy

Vehicles need energy to accelerate. Even when a vehicle is running along at a steady speed, it needs energy to overcome resistance — air resistance and friction. Figure 2 shows the amounts of energy needed by a 1-tonne car travelling a distance of 1km at 45km/h.

To provide this energy, the vehicle needs an energy store.

Answer questions 1 to 4.

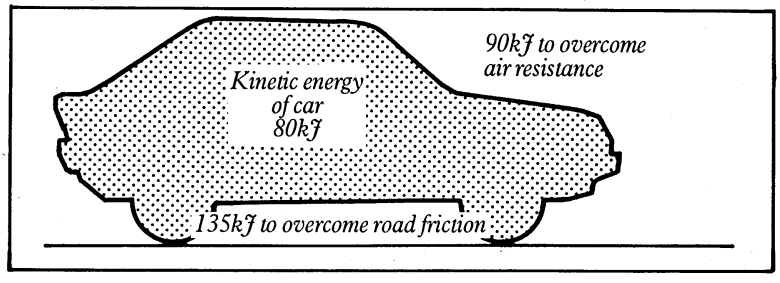

Figure 2 Energy needed by a 1-tonne car travelling 1km at 45km/h.

Questions

1 *What provides the energy store in an ordinary car?*
2 *What is the energy store in an electric car?*
3 *Some electric vehicles do not use an energy store. Instead they collect their energy as they go along. Give an example of such a vehicle.*
4 *Explain why a heavy vehicle needs more energy to accelerate than a light one.*

How do electric vehicles work?

Electric trains can collect their electrical energy from overhead wires or conductor rails. But other electric vehicles need to carry their energy stored in a battery. The batteries drive an electric motor. The main parts of the system are illustrated in Figure 3, which shows an electric lorry.

After the vehicle has been used for a while, the batteries have to be recharged. This takes several hours and is usually done overnight.

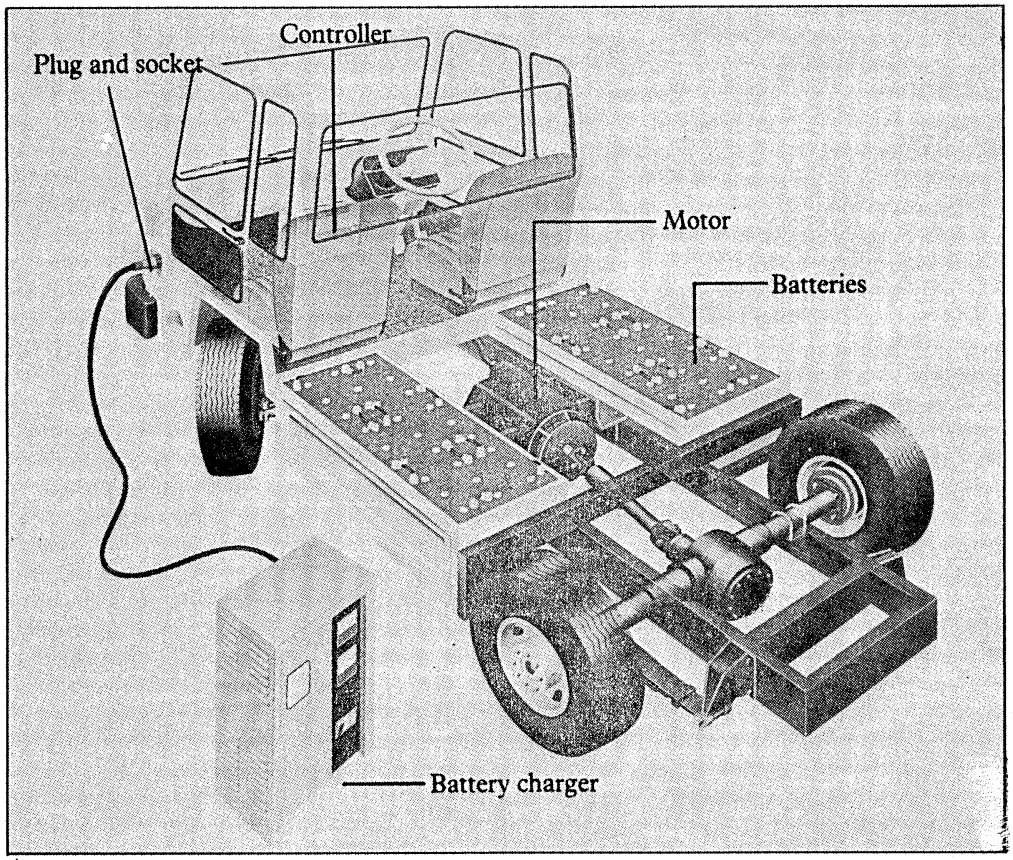

Figure 3 Charging an electric lorry

How do electric vehicles compare with petrol vehicles?

To understand why electric vehicles are still quite rare, we need to compare electricity with petrol as a source of energy. Many vehicles use diesel fuel instead of petrol, but the figures are quite similar.

1 Energy density

To store electricity, you need a battery. Batteries are usually quite heavy . The most commonly used battery is the heavy lead-acid battery. To store petrol you only need a petrol tank. We can compare the 'energy density' of petrol with that of a fully-charged lead-acid battery. The 'energy density' is the energy stored per kilogram of energy store. In the figures given in Figure 4 on the next page, energy is measured in kilojoules. Look at Figure 4, then answer Questions 5 and 6.

Questions

5 *Use the figures in Figure 4 to explain why electric vehicles need charging every night.*

6 *A new lightweight battery, called the sodium-sulphur battery, has been developed. It weighs a fifth of the weight of a lead-acid battery storing the same amount of energy. Calculate the energy density of a sodium-sulphur battery.*

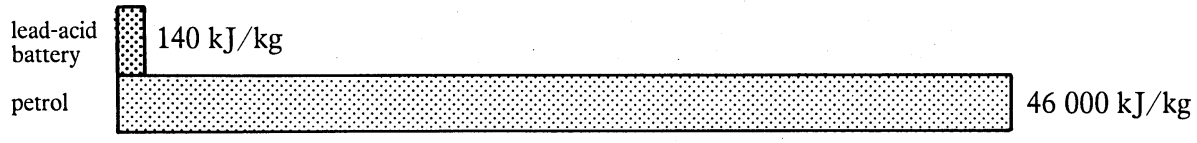

Figure 4 Energy density of lead-acid battery and petrol

2 Efficiency

In any vehicle, stored energy has to be converted to kinetic energy. This is never completely efficient. Some of the stored energy always gets wasted as heat. The *percentage efficiency* gives the percentage of stored energy that gets turned into kinetic energy (Figure 5).

Figure 5 Percentage efficiency of electric and petrol vehicles

Because it is more efficient, the electric vehicle does not need to store as much energy as a petrol vehicle in order to travel a given distance. Even so, petrol is still a much more concentrated energy store. Petrol vehicles can go much further on one tankful than electric vehicles can on one charge.

Question

7 *Explain why it is not possible to travel more than about 50 miles per day in an electric vehicle.*

3 Range

The distance a vehicle can travel on one charging or one tank refill is called its range. Figure 6 compares the range of a typical petrol vehicle and a typical electric vehicle. Answer Question 7.

Figure 6 Range of electric and petrol vehicles

4 Recharging

Electric vehicles need to have their batteries recharged each night. They are charged from the ordinary electricity supply. Electricity is generated in power stations, so it is really the power station that is providing energy for the batteries (Figure 7).

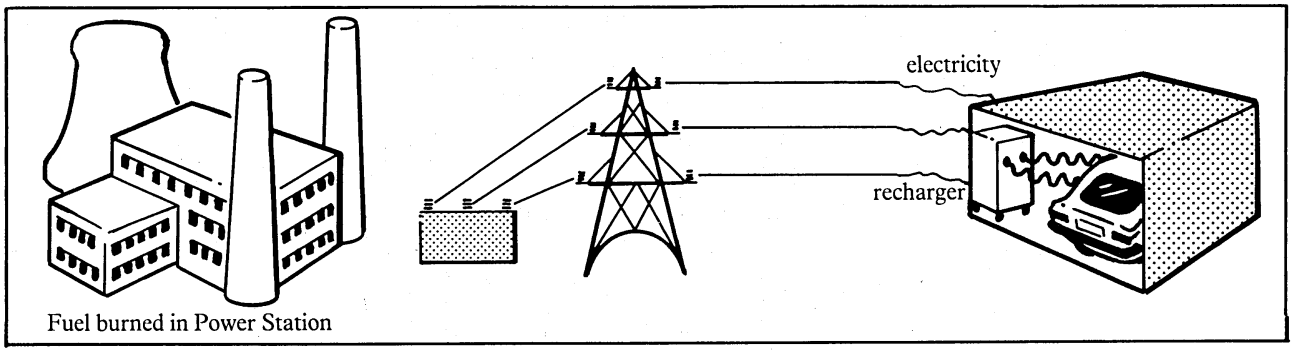

Figure 7 Recharging an electric vehicle

One of the problems with recharging a vehicle's batteries is that it is very slow. A 13-amp socket in your house can supply 3kW, or 3kJ per second. Compare that with a petrol pump, which delivers nearly a kilogram of petrol every second. The amount of energy stored in this petrol is 30 000 kJ, so a petrol pump delivers energy much, much faster than a 13-amp socket. In fact, it takes 17 000 13-amp sockets to deliver energy as fast as one petrol pump! To deliver energy this fast through a single cable would need a cable 40cm thick! Answer Questions 8 and 9.

Questions

8 *A typical electric vehicle stores 45 000kJ in its batteries. How long would it take to charge on a 13-amp socket?*

9 *(a) What is the power in megawatts of a petrol pump like the one described above?*

(b) A large power station has a power of 2000 megawatts. How many petrol pumps is this equivalent to?

5 Weight

Electric vehicles have a weight disadvantage compared with petrol vehicles. Electric motors are four or five times heavier than equivalent petrol motors. What is more, the electric vehicle has to carry around a heavy battery. This is one of the reasons why electric vehicles like milk floats are often slow.

6 Cost

The fuel cost per kilometre of an electric vehicle is about half that of a petrol vehicle. This is mainly because petrol is heavily taxed.

7 Pollution

Electric vehicles cause hardly any pollution on the streets. Petrol vehicles give off a great deal of polluting gases such as sulphur and nitrogen oxides. Exhaust from petrol vehicles is thought to be one of the major causes of acid rain. Answer Question 10.

Questions

10 *An expert on pollution has said: 'Electric vehicles cause no pollution on the street. They shift all their pollution to power stations'. What did she mean?*

11 *How do you think electric vehicles and petrol vehicles compare for: (a) quietness; (b) safety; (c) ease of starting in cold weather; (d) servicing and maintenance costs? Explain your answers.*

Future developments

A lot of money is spent on research into new and better electric vehicles. Yet in spite of this, there are still few of them on our streets — and these all use the same basic technology of a lead-acid battery and an electric motor. They all have the same basic limitations of short range and long recharging time.

The best hope for electric vehicles seems to lie with lightweight batteries. A great deal of research is being done on new battery technology, and the breakthrough may come when a cheap, light rechargeable battery is developed.

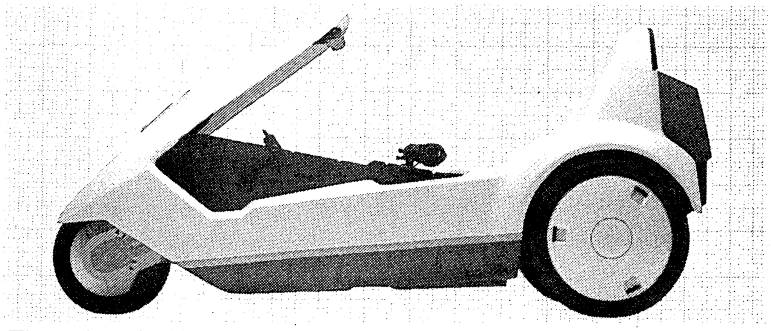

Figure 8 The Sinclair C5 electric tricycle. Brought out in 1985 with much publicity — yet it basically uses milk float technology.

More questions to answer and discuss

12 *Using the ideas you have just read, sum up briefly the reasons why electric vehicles are still uncommon, in spite of their advantages.*

13 *There are about 30 000 electric vehicles in Britain, and 27 000 of them are milk floats. What is it about a milk round that makes an electric vehicle so suitable?*

14 *Fork-lift trucks are used in factories to carry goods around. They are practically always electric. Why is electricity particularly suitable for this use?*

15 *Look back at the section on recharging. Explain in your own words why electric vehicles really get their energy from the fuel burned in power stations.*

16 *Power stations are never 100 per cent efficient. Only 30 per cent of the energy released by burning fuel is turned to electricity. Half of this electricity is lost in transmitting it to the users. So the overall efficiency of a power station is only 15 per cent.*

What does this mean for the overall efficiency of electric vehicles? (Look back at the section on efficiency.)

17 *An expert on electric vehicles has said: 'Electric vehicles are a way we can burn coal and nuclear fuel on our streets.' What did he mean?*

18 *It has been suggested that one way to make electric vehicles more attractive would be to run 'battery exchange stations'. In these stations you would be able to exchange a discharged battery for a fully charged one. Why would this help? What problems might there be?*

19 **Hybrid vehicles** *are vehicles that have both petrol and electric motors. They can run on electricity or petrol. What might be the advantage of such a vehicle?*

20 *An expert on electric vehicles has said: 'As long as we have plenty of petrol available, people are never going to reorganize their life styles to use battery electric vehicles.' What difference would it make to an average family's life style if they had to change their petrol driven car for a battery vehicle?*

21 *Invalid carriages are often electrically powered. Why is electricity particularly suitable for this type of vehicle?*