EXTEND. Questions 7–8

See how well you can understand and explain new ideas and evidence.

7. Table 1.2.10 gives some data from an investigation comparing the different lengths of the same wire. The values of resistance have been calculated using $V/I = R$.

   Plot a graph of the resistance against the length of the wire.

TABLE 1.2.10

Length of wire (cm)	Average voltage (V)	Average current (A)	Average resistance (Ω)
10	0.47	0.23	2.0
20	0.59	0.17	3.5
30	0.64	0.13	4.9
40	0.69	0.11	6.3
50	0.72	0.09	8.0
60	0.76	0.07	10.9
70	0.82	0.06	13.7

8. Jo is asked to construct a circuit with a battery and two parallel loops, each containing two bulbs in series. [4]

   a) Draw the circuit diagram.

   b) If the total resistance in the circuit is 20 ohms and the voltage supplied by the battery is 5 V, how much current will flow out of the battery?

   c) Show on your diagram where an ammeter could be put in the circuit to check this.

   d) Explain what will happen to the other bulbs if one of the bulbs should blow.

In this chapter you will find out

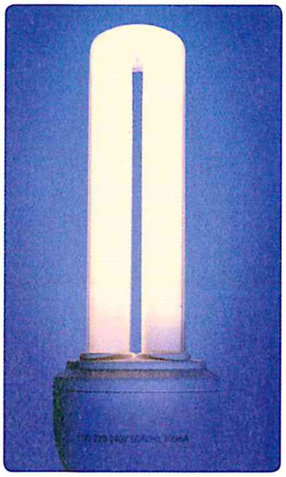
Energy stores and transfers

- Energy is transferred when changes happen, and this transfer can happen in many different ways.
- An object stores energy if it has been raised up. This is because it is affected by the Earth's gravitational force.
- When elastic materials are stretched or squashed they have more energy stored in them.

Fuels are energy stores

- Fuels are energy stored chemically. They include wood, fossil fuels and hydrogen.
- Fuels only burn if oxygen is present. The products of burning also store energy, but less than that in the fuel and oxygen.
- When a fuel is burned in oxygen, energy is transferred to the surroundings.

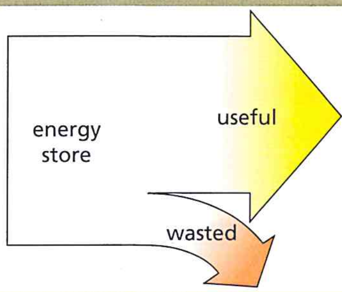
Energy in the home



- The quantity of energy transferred in a change can be measured.
- How quickly energy is transferred is the power and this can also be measured.
- Electricity is generated by using different energy resources, which each have advantages and disadvantages.
- We pay for our domestic electricity based on the amount of energy transferred.
- We can calculate the cost of home energy usage using the formula: cost = power (kW) × time (hours) × price (per kWh).

Accounting for energy

- We can describe how jobs get done using an energy model where energy is transferred from one store at the start to another store at the end.
- When energy is transferred, the energy total is conserved, but some energy is dissipated, reducing the useful energy.



Chemical reactions that happen in the body enable growth and reproduction, responses to the environment and keeping healthy. All rely on energy being transferred from chemical stores in the body's cells which, in turn, depends on the food eaten.

4. Explain how the body builds up stores of energy.

5. Explain why information about energy stored in food is useful.

6. Calculate the energy content of 100 g of the food product shown in Figure 1.3.1b.

Transfers and stores

Energy is stored in various ways, such as in a battery or in a tank of water that has been heated up. This energy can then be transferred and will end up in another store.

For example, when a fuel burns in air, energy stored in the fuel and in oxygen is transferred to the surroundings, which warm up. The energy stored in the products of combustion and the warmer surroundings equals the energy stored in the fuel and oxygen.

Similarly, warming a room with an electric heater causes a change that results in energy being transferred to the surroundings (air, walls, ceiling, furniture and so on). The total amount of energy remains the same, even though it is more spread out.

When we eat food, energy stored in food is transferred to energy stored in our bodies. This stored energy is transferred further during body processes.

When these changes happen, energy is not used up but is transferred to different places.

7. Give two other examples of changes taking place that involve energy transfer, and explain where you think the energy has been transferred to.

8. When a candle is burning:

a) How is energy being transferred?

b) Where is it being transferred from and to?

Nutritional Information per 100 g

Protein	18.1 g
Fat	16.2 g
Of Which Saturates	(5.2 g)
Carbohydrates	26 g
Of Which Sugars	(7.2 g)
Sodium	0.468 g
Potassium	906 mg
Salt	1.2 g
Fibre	4.7 g
kCalories	322 kCal
kJoules	1347 kJ

FIGURE 1.3.1b: Energy content is given as part of the nutritional data on a food label. This shows what is contained in a 100 g serving of food.

Know this vocabulary

fuel
joule
kilojoule (kJ)
energy resource

Calculating power

We can calculate power by using the formula:

$$\text{power} = \frac{\text{energy transferred}}{\text{time taken for transfer}}$$

For example, if a light bulb transfers 1000 J of energy in 10 seconds, the power is:

$$\frac{1000}{10} = 100\,\text{W}$$

When we talk about how quickly something happens, we sometimes refer to the rate. This is the amount per second.

4. Why does a toaster have a much higher power output than a laptop computer?

5. What is the power of a bulb that transfers 600 J per minute?

6. What is the rate of energy transfer in joules per second for a 20 W laptop?

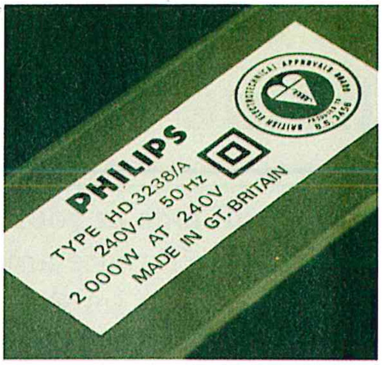


FIGURE 1.3.2d: The power rating of the electric fan heater is shown on the label. It is 2000 W.

Quantities of energy transferred

When a change happens and energy is transferred, the quantity of energy transferred can be calculated in joules (J) or kilojoules (kJ) using:

energy transferred (J or kJ) = power (W or kW) × time (s)

- A 20 W laptop computer transfers 20 J/s.
  So if it is used for one hour (1 × 60 × 60 = 3600 s), it transfers 20 × 3600 = 72 000 J = 72 kJ.
- A 2.15 kW electric oven transfers 2.15 kJ of energy per second.
  So if it is used for one hour (1 × 60 × 60 = 3600 s), it transfers 2.15 × 1000 × 3600 = 7 740 000 J = 7.74 MJ.

7. How much energy is transferred when a 1.2 kW toaster runs for three minutes?

8. Calculate the energy transferred when one store transfers energy to another store by heating it for five minutes at a rate of 15 J/s.

9. a) Calculate the energy transferred when a 10 W bulb is left on for three days.

b) Calculate the energy saved if the same light bulb is turned off every day for eight hours.

Did you know...?

Some of the ways energy is transferred by a device are more useful than others. Getting light from a bulb is great but heat less so. The more of the energy output that is useful, the more efficient we say the device is.

Know this vocabulary

power
watt
kilowatt

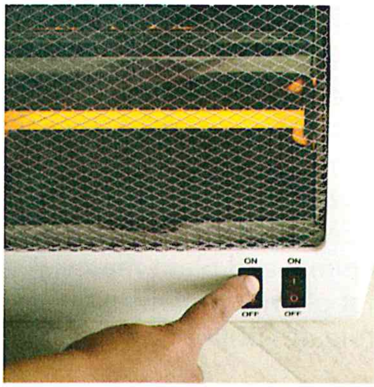
Calculating the energy used by domestic appliances

Remember that the rate at which energy is transferred is called power, measured in watts (W) – 1 watt = 1 joule per second (1 W = 1 J/s). The amount of energy used by an appliance is calculated by multiplying its power by the time for which it was used. Electricity supply companies use the energy unit kilowatt-hour (kWh), so we need to use hours, not seconds, in the calculation.

energy used (kWh) = power (kW) × time (h)

An appliance with a power rating of 500 W running for five hours transfers 0.5 × 5 = 2.5 kWh. Choosing an electrical appliance with the optimum power rating for the intended purpose is important. A more powerful electric kettle will use more energy per second but it will take less time to do the job.

4. How much energy would be used by:
   a) A 2 kW oven in 30 minutes?
   b) A 1 kW microwave in 6 minutes?
   c) A 30 W bulb in an hour?
5. Explain the difference between 'energy' and 'power'.



Calculating the cost of energy used

The cost of home energy usage is calculated using the formula:

cost = energy used (kWh) × price of energy per kWh

The typical price of 1 kWh of electricity is about 13p, and the typical price of 1 kWh of gas is about 4p. If you used 900 kWh of electricity and 700 kWh of gas, the cost would be:

electricity: 900 × 13 = 11 700 p = £117.00

gas: 700 × 4 = 2800 p = £28.00

So the total energy cost = £117.00 + £28.00 = £145.00

FIGURE 1.3.3b: The cost of 1 kWh of energy from electricity is roughly three times that of 1 kWh of energy from gas.

6. Alex is working out how much it will cost to cook a frozen curry using a microwave oven compared with a gas cooker.
   a) How much will it cost to use a 1 kW microwave if it takes 5 minutes and electricity is 13p/kWh?
   b) How much will it cost to use a 2 kW gas oven if it takes 30 minutes and gas is 4p/kWh?
   c) Comment on the difference in the costs.
7. Jo has just received her gas and electricity bill (Figure 1.3.3a) and has decided to find ways of reducing what she has to pay. Suggest three things she could consider doing to reduce her energy consumption.

Know this vocabulary

kilowatt-hour (kWh)

1. What other types of fossil fuel are there apart from coal?
2. What are the disadvantages of:
   a) Fossil fuel power stations? b) Nuclear power stations?

Making decisions about which generating method to use

Governments have to decide how to produce the electricity that people need. They have to think about various factors such as:

- cost of construction;
- cost of operation;
- effect on the environment;
- availability of fuel (or sun, wind, etc.);
- reliability of the supply;
- safety of operation.

Sometimes there are difficult choices to be made. A hydroelectric power station, for example, needs no fuel and produces no waste materials but is expensive to build and affects a large area of land, flooding a valley and damaging habitats.

3. What problems are caused by burning lots of fossil fuels?
4. Quite a few people are not happy at the thought of using nuclear power stations. Why might this be?
5. The supply of power needs to be reliable. Why might solar power and wind power not be suitable as a sole energy source?

Using evidence to make a decision

Table 1.3.4 shows how much it costs to produce electricity by different methods in the UK. It shows how much it costs to produce 1 MWh (this is 1000 kWh; 1 kWh will run a small electric fire for an hour). As this shows, the costs vary quite a lot and they aren't fixed for one particular energy resource but vary over a range. Nevertheless, it's clear that some methods are cheaper than others.

Type of power station	Cost: £/MWh
Gas	80
Coal	102
Coal with carbon capture	122
Nuclear	81
Offshore wind farm	118–134
Solar	169
Onshore wind farm	93–104
Biomass	117–122

TABLE 1.3.4: Taken from Electricity Generation Costs, Dept of Energy & Climate Change, 2012, 'Table 1: Levelised cost estimates for projects starting in 2012, 10% discount.'

6. Renewable generating methods don't release harmful gases or make other waste materials. Why then do some people say they damage the environment?
7. Why not build the entire electricity-generating system using gas turbine stations?
8. Why might a gas turbine power station be built 'with CO_2 capture'?
9. Why do you think offshore wind power farms are more expensive to build and run than onshore ones?
10. Coal-fired power stations are around 45% efficient whereas wind turbines are around 38% and photovoltaic cells are about 21%. Explain whether this should persuade us to use more coal.

Know this vocabulary

fossil fuel
non-renewable
renewable

Assume we can buy a fluorescent bulb for £5 and a filament bulb for £1. The fluorescent bulb is rated at 20 W and the filament bulb at 100 W, but they both give out a similar amount of light. The fluorescent bulb will be good for 10 000 hours and the filament bulb for 1000 hours. Electricity costs 13p/unit and the bulb will be used for around 3 hours a day.

Let's see what they cost to run for a year, which will be the approximate life of the filament bulb. The filament bulb costs £1 and will use 0.3 units of electricity per day, which will cost 3.9p. Over the year this will total £14.24, plus the cost of the bulb, so £15.24.

The fluorescent bulb will use 0.06 units a day, which will cost 0.78p. Over one year this comes to £2.84. We need to add in the cost of the bulb, but remember that this kind of bulb will last for 10 000 hours. In the year we've only used it for about 1000 hours so we should only count one-tenth of its cost, which is 50p. The total is therefore £3.34.

FIGURE 1.3.5b: Adverts similar to this encouraged people to buy low-energy light bulbs.

4. What conclusion can you draw from the data?
5. Is the manufacturer's claim true?
6. Explain why the fluorescent bulb is cheaper to use, even though it's much more expensive to buy?
7. Instead of a fluorescent bulb you could use an LED bulb, which costs twice as much but lasts for twice as long and uses half the amount of electricity. Do the calculations for the use of the LED bulb over a year, to see how it compares.

Deciding on actions to take

Demand for electricity rises as population increases and people use more appliances. How is this dealt with? Sometimes actions are taken at national level and sometimes at local level. There are two areas to consider:

- How energy is supplied to a community. Is it being generated in a way that is not only cheap and reliable but doesn't damage the environment?
- How energy is used in the community. Are users being economical with their use of electricity, selecting efficient appliances and using them responsibly?

8. What kind of electricity generation system do you think we should be using? Justify your answer.
9. How can consumers be encouraged to use electricity more responsibly?
10. Efficient appliances, such as fridges with better insulation, sometimes cost more. How could you persuade people that they were a good idea?

Know this vocabulary

dissipated

is transferred, the higher the temperature attained by the food.

- A child on a swing. Energy is transferred from the gravitational potential energy store (at the top of the swing) to a **kinetic energy store** of movement and then back to the gravitational potential energy store (at the other end). Swinging back and forth repeatedly involves many transfers and the stores filling up and emptying repeatedly.
- A person on a trampoline. Energy is transferred from the kinetic energy store as the person moves downward and is slowed down by landing and into an **elastic energy store** as the trampoline springs are stretched. Almost immediately the energy is transferred back again into a kinetic energy store.

FIGURE 1.3.6b: Examples of stores and transfers.

3. A box falling off the shelf adds to the thermal energy store of the environment. Why is it difficult to measure this change?
4. Suggest another example of a device that stores energy in an elastic energy store.
5. Not all of the energy from the cooker will be transferred to the food; where will some of it be transferred to?
6. The kinetic energy store of the child on the swing keeps dropping to zero, at each end of the swing when they are momentarily stationary. But their gravitational potential energy store is never zero, even at the mid-point of the swing. Explain why.

Applying the model

The 'stores and transfers' model can be used to describe what is happening in a variety of situations. See if you can apply it to these:

7. A pendulum swings back and forth.
8. A ball is dropped and bounces back up again.
9. The pendulum eventually stops swinging.
10. The bouncing ball eventually comes to rest on the ground.
11. Alex says 'There's water in this jug and I can pour it into a cup. All the water is still there but it's been transferred to a different store.' How good is this way of explaining what happens to energy when it is transferred between stores?

Know this vocabulary

model
chemical energy store
gravitational potential energy store
dissipated
thermal energy store
kinetic energy store
elastic energy store

3. Write a sentence to describe the energy transfers shown in Figure 1.3.7c.
4. Draw a diagram to show how energy is transferred by:
   a) a boiling kettle;
   b) a toaster;
   c) a log fire.
5. In your answers to question 4, underline the useful energy transfers and circle the unwanted energy transfers.

Did you know...?

The amount of energy transferred to the Earth from the Sun in one minute is enough to meet the world's energy demands for one year.

Sankey diagrams

If you move a weight of 1 N through a distance of 1 m, you transfer 1 joule (1 J) of energy. One joule of energy is also needed to heat 1 cm^3 of water by 1 °C.

A **Sankey diagram** is a type of energy transfer diagram that shows the relative amounts of energy transferred by a device. The width of each arrow shows how much energy is transferred. The non-useful energy transferred is always shown pointing downwards. The greater the proportion of energy transferred that is useful, the more efficient we say the device is.

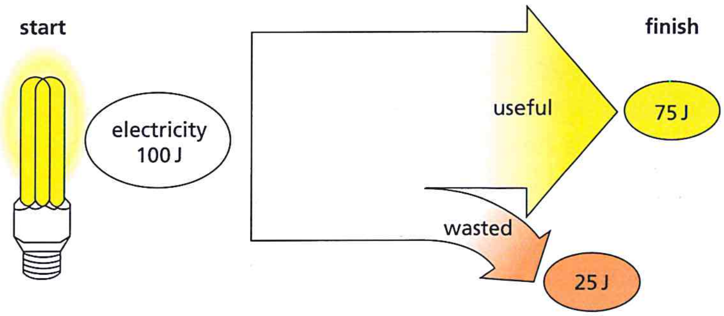


FIGURE 1.3.7d: Sankey diagram for an energy-efficient light bulb. How would the Sankey diagram for an old-style, less efficient light bulb compare with this one?

For example, in Figure 1.3.7d, 100 J of energy is transferred to the light bulb by electric current. It transfers 75 J by light (useful) and 25 J by heating the surroundings (wasted). If you draw these on graph paper, you can accurately represent the proportions of energy involved.

6. What is the percentage of energy wasted in the light bulb in Fig 1.3.7d?
7. On graph paper, draw a Sankey diagram for an electric drill that transfers 500 J of energy. 300 J of energy is transferred as movement and 200 J are transferred to the environment. You will need to decide which of the outputs are useful and which are useless.
8. What would make the drill in question 7 more efficient?

Know this vocabulary

energy transfer diagram
efficient
Sankey diagram

3. A tennis ball falls from the following heights:
   i) 10 mm ii) 10 cm iii) 10 m
   a) Represent this by an energy transfer diagram showing stores and transfers.
   b) Which fall will transfer the most energy?
4. Look at Table 1.3.8. If a tennis ball is dropped from the same height on each planet, on which planet will it reach the highest speed?

TABLE 1.3.8: Gravitational field strengths on different planets.

Planet	Gravitational field strength (N/kg)
Earth	10
Mars	3.7
Saturn	11

Conservation of energy in falling objects

Gravitational potential energy is transferred by movement and heating the surroundings. As a falling object drops lower, its gravitational potential energy decreases and the amount of energy transferred to kinetic energy increases. Some energy will also be transferred by heating the surroundings, due to friction with the air particles during the fall. The faster the object falls, the greater the energy transferred by heating. When the object hits the ground, some of the kinetic energy may stay in it if it bounces back up but the rest is transferred by heating and sound to the surroundings.

5. Look at Figure 1.3.8c of a ball falling from a height. In which position (A, B or C) does the ball have:
   a) The greatest amount of energy in the gravitational potential energy store?
   b) The least amount of energy in the gravitational potential energy store?
   c) The least amount of energy in the kinetic energy store?
   d) The greatest amount of energy in the kinetic energy store?
6. Sketch two graphs to show how the energy levels in the gravitational potential energy store and the kinetic energy store of the ball in Fig 1.3.8c change during the fall.

Did you know...?

The Stealth roller coaster at Thorpe Park has the greatest acceleration of any such ride in the UK. Riders accelerate from rest to 130 km/h in under 2 seconds, propelling them to a height of 62.5 m. Occasionally energy losses mean the train fails to reach the peak and (safely) rolls back.

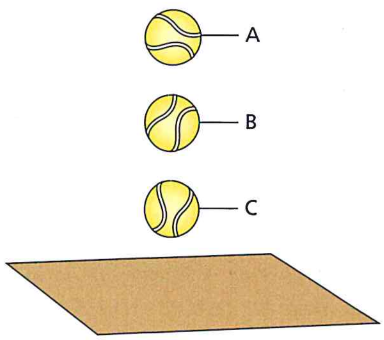


FIGURE 1.3.8c: A ball transferring gravitational potential energy.

Know this vocabulary

gravitational potential energy store
kinetic energy store

3. Some students are testing two different elastic materials for use in a catapult. They want to find out which would transfer more energy.

   a) How should they make the investigation a fair test?

   b) What should they measure to collect evidence?

4. Describe the energy transfers in a wind-up clock and represent this on an energy transfer diagram showing stores and transfers.

Explaining elastic energy

Elastic materials, such as rubber, are made up of **molecules** that are bound together. When the material is stretched, the bonds between the molecules store energy.

In its relaxed state, rubber consists of long strands of molecules which are all coiled up. When the rubber is stretched, the coils become elongated and straightened, enabling the rubber to extend in length. When the stretching force is removed, the molecules return to their coiled-up state and the material returns to its original length.

Did you know...?

Many elastic materials can stretch up to five times their original length. The first type of elastic material was natural rubber, made from the sap of rubber trees. Scientists have recently invented a gel material that can stretch up to 20 times its original length and still recover. It has a possible application as artificial cartilage, because it is also extremely strong.

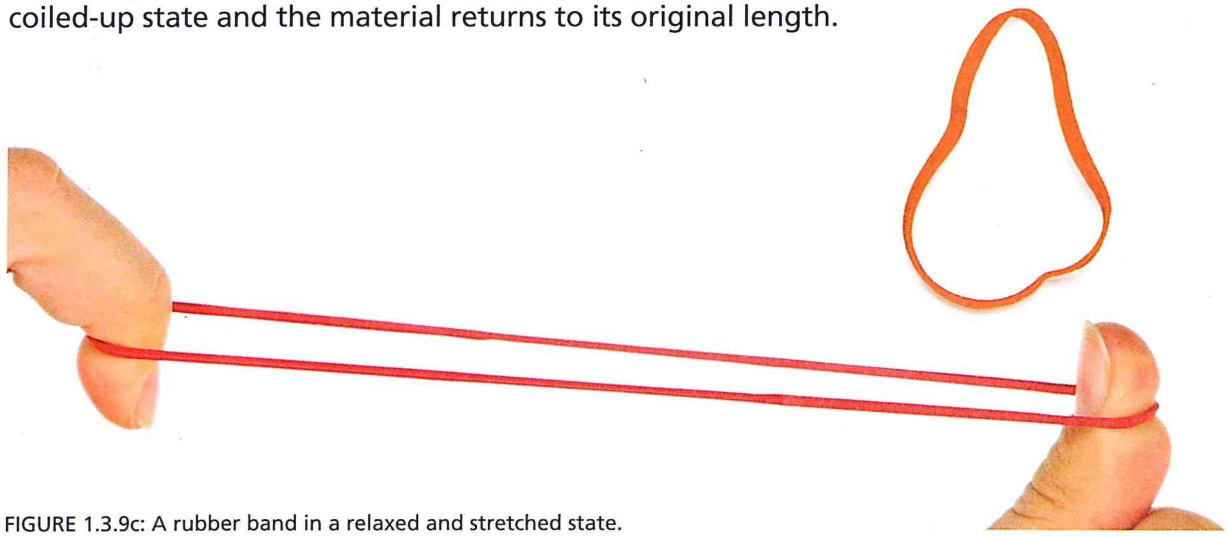


FIGURE 1.3.9c: A rubber band in a relaxed and stretched state.

The elastic energy stored in a rubber band or a spring is equal to the energy transferred in stretching it. This energy can be transferred as kinetic energy when the stretching force is removed.

5. Can all materials store elastic energy? Explain your answer.

6. How would you test which had more elastic energy – a coiled metal spring or an elastic band?

Know this vocabulary

elastic energy store
molecules

☐ Identify simple energy transfers that involve gravitational potential, elastic, kinetic, thermal and chemical energy.	☐ Explain how energy is transferred using elastic, chemical and gravitational potential energy.	☐ Analyse changes in gravitational potential energy in different situations.
☐ Recognise that electricity is generated in a variety of ways.	☐ Describe advantages and disadvantages of various ways of generating electricity.	☐ Use data to evaluate social, economic and environmental consequences of a particular way of generating electricity.
☐ Give examples of renewable and non-renewable energy resources.	☐ Explain the advantages and disadvantages of renewable and non-renewable energy resources.	☐ Explain the challenges involved in moving towards a more renewable energy supply system.
☐ Identify how appliances that transfer energy result in some energy being dissipated, reducing the useful energy.	☐ Suggest ways in which energy dissipation in a process could be reduced.	☐ Suggest ways in which a home energy bill could be reduced.
☐ Understand that food is a fuel.	☐ Explain that food labels provide information about the different amounts of energy in various foods.	☐ Explain that energy is transferred from the chemical energy store when we perform physical activities.

EXTEND. Questions 8–10

See how well you can understand and explain new ideas and evidence.

8. Julia's science teacher tells her that 'energy-efficient' light bulbs are better to use because they waste less energy through heating the surroundings. But Julia knows that her mother, who is a farmer, uses old-fashioned filament light bulbs to keep newly hatched chicks warm in winter. Which of these statements is correct? [1]

a) Julia's teacher is right – bulbs that transfer most of the energy by heating the surroundings are always wasteful.

b) The chicks don't need heating – they just need to see where they are going.

c) Heating the surroundings is only wasteful if you don't make use of it.

d) Julia's mother should switch to energy-efficient light bulbs.

9. Explain why an electric kettle has a power rating of 2000 W, but a small TV has a power rating of 65 W. [1]

10. You are looking for the best possible fuel source for the future. Use the data in the table to make your choice. Give reasons for your answer. [2]

Fuel	Energy per gram (J/g)	State	Harmful products of combustion	Availability
coal	24	solid	carbon dioxide, soot, acid rain	running out
hydrogen	123	gas	none	plenty
petrol	46	liquid	carbon dioxide	running out
biofuel	33	liquid	carbon dioxide	renewable