ISEB
Independent Schools Examinations Board

CE SCIENCE

ENERGY TEACHING IN THE COMMON ENTRANCE SCIENCE SPECIFICATION

The revised specification for Common Entrance points to a change in the way energy is taught and understood. The change is in line with current recommendations and the approach adopted by the National Curriculum and GCSE awarding bodies. This document is necessarily a summary; further information, teaching ideas and extensive references can be found at **BEST article teaching energy**.

THE NEW MODEL OF ENERGY

The model of energy that we are using has three key features, which are different to previous ways of teaching energy:

1. The idea of there being separate forms of energy (heat energy, light energy, electrical energy, for example) that are transformed from one form to another is no longer being taught at CE. We simply refer to energy as 'energy' in all contexts.
2. Energy is stored, until it is transferred to other energy stores. Energy is transferred between stores along pathways. These pathways may involve different processes, such as a series of chemical reactions.
3. When describing energy transfers, it is important to include the starting store, the transfer pathway (or process) and the final energy store(s).

The law of Conservation of Energy is still taught. The energy in the initial store is equal to the sum of the energy in the destination stores of energy.

There are six energy stores mentioned in the CE13+ specification and which are defined more fully later:

- **chemical store of energy** [We can refer to 'energy in a chemical store', or 'energy stored chemically'. We should not call it 'chemical energy'.]
- **gravitational store of energy** [We can refer to 'energy in a gravitational store', or 'energy stored gravitationally'. We should not call it 'gravitational energy'.]
- **kinetic store of energy** [We can refer to 'energy in a kinetic store', or 'energy stored kinetically'. We should not call it 'kinetic energy'.]
- **thermal store of energy** [We can refer to 'energy in a thermal store', or 'energy stored thermally. We should not call it 'thermal energy', a 'heat store' or 'heat energy'.]
- **elastic store of energy** [We can refer to 'energy in an elastic store', or 'energy stored elastically'. We should not call it 'elastic energy'.]
- **nuclear store of energy** [We can refer to 'energy in a nuclear store'. We should not call it 'nuclear energy'.]

In addition, there are two further stores that pupils might encounter:

- **electromagnetic store of energy** [We can refer to 'energy in an electromagnetic store', or 'energy stored electromagnetically'. We should not call it 'electromagnetic energy'.]
- **vibration store of energy** [We can refer to 'energy in a vibrational store', or 'energy stored vibrationally. We should not call it vibrational energy.]

Notice that the words traditionally associated with energy (thermal, chemical, etc) are now associated with the store, not with the word 'energy'.

Energy is transferred between stores along 'pathways', using processes. There are five pathways:

- **mechanically** (by a force acting over a distance)
- **electrically** (electric current)
- **heating** (because of a temperature difference)
- **by radiation** (waves)
- **by chemical reactions**

[Note: The Institute of Physics recommends that the electrical and mechanical pathways are associated with electrical and mechanical work, force x distance. Work is not a concept introduced at Key Stage 3 or common Entrance, so we will simply refer to the pathways as 'electrical' and 'mechanical, respectively. The radiation pathway includes electromagnetic waves (such as light waves).

Sound is an example of a mechanical pathway.]

Common Entrance, and Key Stage 3 is an entry level for pupils to this new way of thinking. To facilitate this at Common Entrance, we describe 'electricity', 'light' and 'sound' as pathways.

Helping pupils develop correct ideas about energy is challenging if misconceptions are not to develop which, once embedded, are difficult to change or modify.

A key misconception is that 'energy makes things happen'. Energy determines if a process is possible – is there enough energy in a store to allow something to happen. It will not however decide if it will happen or not.

At CE, we could say that an 'energy store is needed for something to happen'.

EXAMPLES OF THIS NEW MODEL OF ENERGY

Energy Stores

A trolley pushed along a track has a kinetic store of energy because it is moving. As the trolley slows down due to frictional forces, its kinetic store of energy is transferred to the thermal store of energy in the surroundings along a mechanical pathway, because work is being done.

The temperature of the surroundings will increase slightly because of the energy transfer.

There is the same amount of energy present before and after, but the energy is now more spread out in the thermal store of the surroundings, rather than the kinetic store of the moving trolley.

For CE, we use the following stores:

- Chemical store of energy – for example a fuel, an electrical cell or chemicals able to react.
- Gravitational store of energy – any object can have a gravitational store of energy because of its position in a gravitational field.

[Every mass is surrounded by a gravitational field although the field is generally only noticeable for very large masses, for example astronomical masses, like planets.]

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- Kinetic store of energy – any moving object will have a kinetic store of energy.
- Thermal store of energy – all materials at a temperature above absolute zero have a thermal store of energy. The temperature, the mass and type of material all determine the size of the thermal store of energy.
- Elastic store of energy – an object that is stretched, compressed, squashed or twisted has an elastic store of energy.
- Nuclear store of energy – changes to the nucleus of an atom, for example in the Sun or a nuclear reactor.

When something happens, the amount of energy in one or more of these stores of energy will decrease and other stores will increase. This transfer always occurs via an energy pathway.

Note that some of the 'forms' of energy, such as light, sound and electricity, that have been used in the past are not listed as stores. This is because they are pathways or the process by which energy is transferred from one store to another.

EXAMPLES OF THIS NEW MODEL OF ENERGY

Energy Pathways

An energy pathway is a means or process by which energy is transferred from one store to another.
The pathways we shall use in CE are:

- electricity (electric current – electrical work),
- light (electromagnetic radiation),
- mechanical (including sound and water waves)
- chemical reactions.

For example:

- In photosynthesis, the nuclear store of energy in the Sun decreases as electromagnetic radiation is transferred to a chemical store of energy in a plant by the chemical reactions of photosynthesis. We can say that photosynthesis is able to happen because the plant receives light transferred from the Sun, but it is incorrect to say that 'light energy from the Sun causes photosynthesis'. Do not say that chlorophyll captures light energy.
- Respiration is a chemical process that allows energy in the chemical store of glucose to be transferred to other chemical stores in the body. The energy in these stores is used for life processes, which keep the organism alive. At the same time, energy transfers increase the thermal stores of the body and the surroundings.
- In an electric motor connected to a cell, a chemical store of energy in the cell is transferred electrically to a kinetic store of energy in the motor as it increases its speed of rotation.
- There are other possible transfers involved. For example, energy might also be transferred mechanically (by work) to a gravitational store if it is used to lift a mass away from the Earth. Energy may also be transferred to the kinetic store of an object by mechanical work if it is causing the object to increase in speed.
- In a lamp connected to a cell, a chemical store of energy in the cell is transferred by electricity to a thermal store of energy in the lamp. This increased thermal store will radiate electromagnetic waves (light) into the surroundings. This will increase the thermal store in the surroundings, which can be detected as an increase in temperature.

[If a person sees the light, energy is transferred to the eyes, increasing the chemical stores in the cells of the retinas of the eyes.]

For LEDs we would not include the thermal store of energy in the lamp since the transfer from one pathway to another is more direct in a LED. The energy transferred electrically into the LED is then transferred by electromagnetic radiation out of the LED.

- In a loudspeaker, energy transferred electrically to the speaker causes it to vibrate, increasing its kinetic store* of energy. Energy is transferred from this store along a sound pathway. A mechanical wave transfers away from the speaker to the surroundings. This increases the thermal store of the surroundings. If the energy is transferred to our ears, it increases the kinetic store in our ears. This, too, will quickly be transferred to the thermal store of the surroundings (in this case inside our ears).

[* Some physicists call this store a 'vibrational store', but at Common Entrance we will use 'kinetic store.']

- In a falling ball, a gravitational store of energy is transferred to a kinetic store of energy by mechanical pathway (work being done by the weight of the ball).

When it hits the ground, the kinetic store of energy is transferred to an elastic store by the mechanical pathway (work) that squashes the ball.

When the ball bounces back, this elastic store is transferred by the mechanical pathways (work) to the kinetic store, which is transferred by mechanical pathway (work) to the gravitational store of the ball. In the processes, some energy is transferred to the thermal store of energy in the surroundings, some by the mechanical pathway (work against friction) and some by the sound pathway.

- When a piece of magnesium ribbon burns, energy is transferred from the chemical store of the magnesium and oxygen, increasing the thermal store of the surroundings. Some energy is transferred by the light pathway (electromagnetic radiation) to the surroundings. This increases the thermal store of the surroundings.

We experience light, heating (as a rise in temperature) and the appearance of the white oxide powder. We can still use the words 'light' and 'heating' when we are referring to observable phenomena, but NOT when we are discussing energy changes. We must then use the language of energy transfers.

NB – electrical appliances that are plugged into the mains. It is very difficult to identify the original store in this situation. It might have been the kinetic store of the wind, it might have been the nuclear store of the uranium in the power station, it might have been the nuclear store of the sun for solar panels. In this situation, we say that the system starts with an energy transfer that is electrical from the socket and acknowledge that is isn't possible to know which of the stores was the starting point.

CONCLUSION

Teachers familiar with the use of 'forms' of energy will need to make changes to the language and ideas used in teaching energy in order to comply with the requirements of the revised CE specification. Pupils introduced to the concepts as outlined above should be able to understand the ideas and approach quickly and will not have to 'unlearn' misconceptions later. A suggestion for using an 'orange liquid' model for energy teaching is included in the reference given above. This approach may also help to emphasise that energy changes are quantitative and can be calculated.