edexcel

INTERNATIONAL GCSE (9-1)

Physics (4PH1)

First teaching 2017

TOPIC GUIDE:

Energy stores and transfers

Pearson Edexcel International GCSE in Physics (4PH1) and Science (4SD0 and 4SS0)

Pearson

Introduction

In the revised specification for International GCSE Physics, there has been a change in the way energy is described. This is in response to suggestions from the Institute of Physics relating to how energy is presented at this level. The new description of energy was adopted because it was felt that this revised approach gives students a better understanding of what is meant by energy and also helps those who chose to study Physics at a higher level.

These notes are intended to provide further details about what the changes mean and how they might impact on questions relating this topic.

The specification

In the existing (2011) specification, the relevant statement is:

4.2 describe energy transfers involving the following forms of energy: thermal (heat), light, electrical, sound, kinetic, chemical, nuclear and potential (elastic and gravitational)

This has changed to:

4.2 describe energy transfers involving energy stores:

- *energy stores: chemical, kinetic, gravitational, elastic, thermal, magnetic, electrostatic, nuclear*
- *energy transfers: mechanically, electrically, by heating, by radiation (light and sound)*

Why make the change?

The reason for the change is to try and get away from the erroneous idea that energy is something that flows during a transfer; and also to provide a stronger link between energy, work, radiation and heating. The important thing is energy is just a number which can be quantified and calculated. It is misleading to talk about light, electrical and sound as types of energy as these are processes by which energy is transferred between stores. In the new interpretation, we identify eight energy stores for which energy values can be calculated. Energy can be lost by a store and gained by another but the total energy in all the stores involved in an interaction remains constant.

Energy is transferred from one store to another by:

- mechanical working (mechanically)
- electrical working (electrically)
- heating
- radiation (light and sound)

With all of these transfers, we are interested in the rate at which energy is being transferred and not the amount stored. For example, if a 60 W lamp is connected to the mains supply it is useful to know that energy is being transferred electrically at a rate of 60 J s^{-1} but asking about stored energy is not relevant as the energy is not stored electrically.

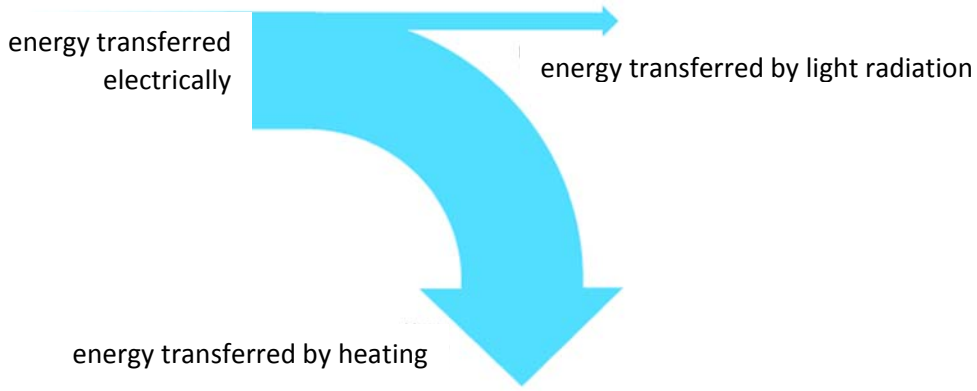
In many text books energy is described as the capacity to do work. This is misleading because energy does not just enable work to be done, it also enables heating and radiation to take place. It is therefore preferable to say energy allows things to happen such as work, radiation and heating. It does not however, explain why things happen; this is done using physical processes and mechanisms. Energy is a very useful property because in any interaction the total energy remains constant. This means energy is a quantity that can be quantified and calculated; the total energy has the same value before and after a change.

Sankey Diagrams

Energy transfers can be shown by Sankey diagrams using the new terminology. These are similar to those shown using the approach from the existing specification, there is just a change in the way they are labelled.

Sankey Diagram for a lamp

Energy is transferred electrically to a lamp where 10% of the energy is transferred usefully by light radiation.



The width of the arrows represents a rate of energy transfer.

Using the New Terminology

Example 1: In an electrical circuit containing a lamp and a battery connected in series, chemical energy stored in the battery is transferred by electrical working (electrically) to the lamp where it is transferred usefully by light radiation and not usefully by heating of the surroundings.

Example 2: When a ball is released so that it falls to the ground, gravitational potential energy stored in the ball and Earth system decreases as mechanical work is done by the gravitational force on the ball. This work results in the kinetic energy stored in the ball increasing. If air resistance is present, then the ball has to do work due to frictional forces and energy is transferred due to heating of the surroundings resulting in the increase of stored kinetic energy of the ball being less than the decrease in gravitational potential energy stored in the ball and Earth system.

In this example reference is made to the gravitational potential energy of the ball and Earth system. This is correct terminology but at this level it is more helpful not to refer to the system and express this as: when the ball is raised above the ground the gravitational potential energy increases.

Example 3: When a mass is hung from a spring the spring extends. The gravitational potential energy stored decreases as the mass moves downwards. This is because the gravitational force does mechanical work extending the spring. This results in the elastic potential energy stored in the spring increasing. If no heating occurs as the spring stretches, the decrease in gravitational potential energy is equal to the increase in elastic potential energy.

Example 4: When a firework explodes, stored chemical energy of the substances in the firework decreases due to energy being transferred by heating of the surroundings, by radiation (sound and light) and by mechanical working on the pieces of the firework that fly away from the explosion site. It is worth noting that in some books transfer by sound is referred to as mechanical working but it is felt that at this level treating it as a radiation transfer is more helpful to students.

Example 5: In a microwave oven energy from the mains supply is transferred by electrical working (electrically) to the microwave transmitter. Energy is transferred from the transmitter to the food in the oven by microwave radiation. The thermal energy stored in the food increases resulting in a rise in temperature of the food.

Example 6: In a hydroelectric power station, gravitational potential energy is stored because the water reservoir is above the generating station. When water flows from the upper reservoir, work done by the gravitational force results in the stored gravitational potential energy decreasing and stored kinetic energy of the water increasing. The water has to do work against frictional forces resulting in heating of the surroundings. As a consequence of this the increase in stored kinetic energy of the water is less that the loss of stored potential energy. The water flows through a turbine doing mechanical work which decreases the stored kinetic energy of the water, but increases the stored kinetic energy of the turbine.

Example 7: When a cyclist travels along a horizontal road, the cyclist's stored chemical energy decreases due to the mechanical work that is done. Energy is transferred to stored kinetic energy of the bike and rider. As they continue to pedal chemical energy decreases and kinetic energy increases. The cyclist also has to do mechanical work due to the frictional forces and air resistance. This results in energy being transferred by heating of the surroundings. Air resistance increases with speed and eventually the mechanical work that is done overcoming air resistance and friction is equal to the decrease in the cyclist's chemical energy and so all the energy is transferred by heating and there is no increase in stored kinetic energy.

Using the Language of the Existing Specification

It is fully appreciated that candidates may have used textbooks which treat energy in a similar way to the existing specification and it would be unfair to penalise them if they answer questions using this approach. Consequently, candidates will receive full credit for a correct response, whichever route they take. For example, in the Sankey diagram for the lamp candidates would receive full credit if they labelled the arrows as electrical energy, light energy and thermal energy. It is hoped however, that centres will appreciate the benefits of using the approach set out in the revised specification and encourage students to use it in their responses.