1 Analysing energy transfers

This unit will help you learn more about energy transfers. The unit will show you how to use an energy analysis to make predictions about what can happen and what cannot.

In the exam, you will be asked to answer questions such as the one below.

Exam-style question

1 Figure 1 shows a springy toy sitting on a desk.

When the toy is pressed down from the top, the spring inside is compressed and energy is stored.

After a while, the toy springs upwards, off the desk, due to forces produced by the spring.

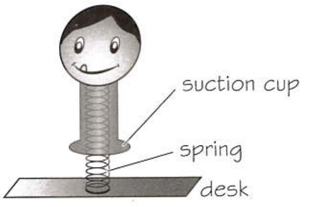

Figure 1

(a) Describe the energy transfer that takes place as the spring uncoils and the toy moves upwards to its highest point. **(3 marks)**

....

The spring constant of the spring in the toy is 50 N/m.

(b) Calculate the energy stored in the spring when it is compressed by 10 cm. **(2 marks)**

....

The mass of the toy is 60 g.

The spring in the toy has an efficiency of 0.90 when it decompresses and launches the toy upwards.

(c) Calculate the maximum height to which the toy can jump when the spring has been compressed by 10 cm. **(3 marks)**

....

You will already have done some work on energy and energy transfers. Before starting the **skills boosts**, rate your confidence for each skill. Colour in the bars.

1 How do I calculate how much energy is stored in different stores?

2 How can I use efficiency to analyse an energy transfer?

3 How can I use energy calculations to model events and make predictions?

Physics

Get started

Energy is transferred by three different processes: forces doing work, electrical currents doing work and heating effects. These processes cause one store of energy to decrease while other stores increase.

The energy decrease in one store always matches the total energy increase in other stores, so the total amount of energy is always conserved.

1 Write the process which causes energy to be transferred when:

a an object is lifted from the floor onto a shelf. ....

b an ice cube is placed into a cup of hot tea. ....

c a lamp lights up in a circuit. ....

Try not to use the term 'electricity' as it is too general. It is an electric current which transfers energy.

2 Circle the correct words to describe the energy transfer.

In a battery-operated circuit, energy is transferred to an electric motor by **an electric current / a force / heating**. The motor lifts a load through a distance and transfers energy to it by **an electric current / a force / heating**. It causes an increase in temperature by **an electric current / a force / heating**.

3 Complete this table to describe the changes in different energy stores when an energy transfer process happens.

Process	Store that decreases	Stores that increase
using a battery-powered electric motor to lift an object	chemical store of the battery	gravitational potential store of the object being lifted thermal stores of the surroundings
an object falling from a great height		kinetic store of the object falling thermal stores of the surroundings
a mechanical watch being wound up by hand	chemical store in the person winding the watch	
a kettle being used to heat water	chemical store at a power station (coal)	
an arrow being launched from a bow		

When you describe a store don't just say 'chemical store'. Make sure you say what or where that store is. For example, 'chemical store of the battery'.

4 Use the principle of conservation of energy to complete the following paragraphs.

a A student uses an electrical heater to warm up a sample of water. The heater is provided with 4000 J of energy by the electric current. The thermal store of the water increases by 3500 J while .... J is wasted by heating the surroundings.

Remember that the total energy after the transfer is equal to the total energy before the transfer.

b A lorry burns fuel with an energy content of 4.0 kJ and its kinetic store increases by 1.5 kJ. The thermal store of the truck and surroundings increases by .... kJ.

1 How do I calculate how much energy is stored in different stores?

To calculate the changes in amounts of energy in a store we take measurements of the physical properties that change. The energy stored in a spring increases when we stretch it, so we measure the change in length.

If you measure the physical properties of the store, you can calculate the amount of energy in that store. To do this you need to understand the factors that affect the sizes of the different stores.

1 Draw lines to match each energy store to the equation needed to calculate the energy in that store. One has been done for you.

Energy store	Equation
gravitational potential energy store *	$\Delta Q = m \times c \times \Delta\theta$
kinetic energy store *	$E = \frac{1}{2} \times k \times x^2$
elastic potential energy store	$Q = m \times L$
energy change during a change of state (e.g. melting)	$KE = \frac{1}{2} \times m \times v^2$
energy change when an object changes temperature	$\Delta GPE = m \times g \times \Delta h$

You need to recall the equations marked with a * because they won't be given to you on the Physics Equation Sheet.

Remember

Symbol	Stands for	Unit
m	mass	kg
h	height	m
c	specific heat capacity	J/kg °C
$\Delta\theta$	change in temperature	°C
k	spring constant	N/m
x	extension	m
L	specific latent heat	J/kg
v	speed	m/s
g	gravitational field strength	N/kg

We use different equations to calculate the amount of stored energy, depending on the energy store involved. It is important to select the right equation for the calculation. To answer questions involving energy, you will have to use the equations shown in question **1**.

2 Follow the method shown in the example to calculate the energy.

	Example	Your turn
Highlight the key data in the question	Calculate the energy change when a 4.00 kg block of aluminium with specific heat capacity of 902 J/kg °C is heated so that its temperature rises from 5.0 °C to 40.0 °C	Calculate the energy change when a remote-controlled toy car of mass 3.0 kg accelerates from rest (0 m/s) to 2.0 m/s
Select correct energy equation	$\Delta Q = m \times c \times \Delta\theta$	
Substitute in correct values from question	$\Delta Q = 4.00 \times 902 \times (40 - 5)$	
Calculate answer	$\Delta Q = 126\,280$	
Choose correct number of significant figures, add units	$\Delta Q = 126$ kJ	

Physics

2 How can I use efficiency to analyse an energy transfer?

The efficiency of an energy transfer tells us how much energy a useful process transfers and how much energy a process that is not useful transfers.

You need to memorise the efficiency equation:

$$\text{efficiency} = \frac{\text{useful energy transferred by the device}}{\text{total energy supplied to the device}}$$

1 A toy uses a spring to launch sponge darts through the air. The spring used to launch the darts has a spring constant of 200 N/m. When a dart is launched, the spring is compressed by 0.50 m. The efficiency of the spring launcher is 0.90. Calculate the kinetic energy of the dart.

We call the energy transferred by the process we want to happen 'useful energy'.

We call the energy transferred by a process we don't want to happen 'wasted energy'.

a Show the important data in the question.

i Circle Ⓐ the two pieces of data that allow you to calculate the energy stored in the spring.

ii Underline Ⓐ the efficiency of the energy transfer.

b Circle Ⓐ the equation that allows you to calculate the energy stored in the spring.

$\Delta Q = m \times c \times \Delta\theta$	$E = \frac{1}{2} \times k \times x^2$	$Q = m \times L$
$KE = \frac{1}{2} \times m \times v^2$	$\Delta GPE = m \times g \times \Delta h$	

You do not have to memorise this equation, but you do need to select it from the Physics Equation Sheet in the exam and use it.

c Use the equation to calculate the energy stored in the spring when it is compressed.

....

....

Remember k represents the spring constant and x the extension or compression.

d Use the efficiency equation to calculate the energy transferred to the dart by the spring during a launch.

....

....

....

3 How can I use energy calculations to model events and make predictions?

The principle of conservation of energy states that the total amount of energy stays the same during **any** energy transfer. We use this principle to calculate the amount of change that can happen between the **start** and the **end** of any process using different energy equations.

One of the most common examples of using energy equations is analysing a fall.

Imagine an apple with mass 0.15 kg hanging from a tree at a height of 2.5 m above the ground.

We can calculate the energy stored gravitationally by the apple using an equation.

1. Name the equation you should use to calculate the gravitational potential energy of the apple.

   ....

2. Use this equation to calculate the energy stored. The gravitational field strength is 10 N/kg.

   ....

   ....

3. Complete the following sentence using the words **increases** and **decreases**.

   As the apple falls, its gravitational potential energy .... but its kinetic energy ....

The principle of conservation of energy tells us that the kinetic energy increases by the same amount that the gravitational energy decreases.

4. Use the principle of conservation of energy to write down the amount of kinetic energy just before the apple hits the ground.

   ....

Now we use a second energy equation to find the speed of the apple as it hits the ground.

5. Fill in the correct equation for kinetic energy in the sentence below.

   The apple is moving so we use the kinetic energy equation, which is ....

This equation can be rearranged to give $v^2 = \frac{2 \times KE}{m}$, showing us how to use the energy to find the speed.

6. Use this relationship to find v^2 using the mass of the apple and the kinetic energy.

   ....

   ....

Rearranging this equation is quite difficult. Here, it has been done for you, but it is very useful if you can do this yourself in the exam.

The answer to question 6 does not give the speed of the apple, so you need to work it out.

7. Find the speed of the apple just before it hits the ground.

   ....

   ....

Make sure that you give the correct units for speed and that your answer has a sensible number of significant figures.

We can also use other energy equations to analyse situations such as being launched from a catapult or even heating and cooling.

Sample response

Here are some exam-style questions. Use the student responses to these questions to improve your understanding of describing and calculating energy changes.

Exam-style question

1 A coconut of mass 1.0 kg falls from a height of 3.6 m.
Calculate the maximum speed that the coconut will reach before hitting the ground.
The gravitational field strength is 10 N/kg.

Gravitational potential energy $= m \times h = 1.0 \times 3.6 = 3.6$

Speed $v = \frac{2KE}{m} = \frac{2 \times 3.6}{1.0} = 7.2\,m/s$

(3 marks)

1 The student has used the wrong equation for gravitational potential energy. Write out the correct version of this equation and calculate the correct value.

....

....

2 The student has also made a mistake with the rearrangement of the equation linking speed to kinetic energy. Describe this mistake. ....

3 Use the correct version of the equation to calculate the speed.

....

....

Exam-style question

2 An electric kettle is provided with 30 000 J of energy by an electric current.
The heating element has an efficiency of 0.90 and is used to heat 0.5 kg of water.
Water has a specific heat capacity of 4200 J/kg °C.

(a) Calculate the change in temperature for the water during this heating process.

Temperature change $= 14.3\,°C$

(3 marks)

The student has not shown their working for this answer and they have missed out a stage and so their answer is incorrect. If they had shown correct working they would have gained some of the marks, even if their final answer was incorrect.

4 Answer these questions to show the correct stages to go through and find the correct answer.

a What is the value of the energy transferred to the water, taking into account the efficiency of the transfer? ....

b What is the correct relationship between the temperature rise, specific heat capacity, mass and energy transferred? $\Delta\theta =$ ....

c What is the correct unit for temperature change? ....

d What is the correct answer (to two significant figures)? ....

Your turn!

It is now time to use what you have learned to answer the exam-style question from page 113.
Remember to read the question thoroughly, looking for information that may help you.
Make good use of your knowledge from other areas of physics.

Exam-style question

1 Figure 1 shows a springy toy sitting on a desk.

When the toy is pressed down from the top, the spring inside is compressed and energy is stored.

After a while, the toy springs upwards, off the desk, due to forces produced by the spring.

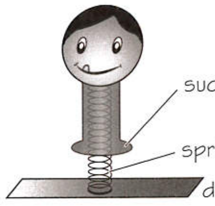

Figure 1

(a) Describe the energy transfer that takes place as the spring uncoils and the toy moves upwards to its highest point.

....

....

.... **(3 marks)**

Use the idea of energy stored by the spring, then energy stored by movement, then finally energy because an object is above the ground.

The spring constant of the spring in the toy is 50 N/m.

(b) Calculate the energy stored in the spring when it is compressed by 10 cm.

....

.... **(2 marks)**

You will need to use the equation for elastic potential energy here.

The mass of the toy is 60 g.

The spring in the toy has an efficiency of 0.90 when it decompresses and launches the toy upwards.

(c) Calculate the maximum height to which the toy can jump when the spring has been compressed by 10 cm. State your answer to two significant figures.

....

....

.... **(3 marks)**

There are two possible approaches here. Either find the height if the spring was totally efficient using the gravitational potential energy equation, and then use the efficiency equation on this value, or find 0.90 of the energy store and use this amount to calculate the height.

Physics

Need more practice?

Exam questions may ask about different parts of a topic, or parts of more than one topic. Questions about energy transfer could occur as:

- questions about that topic only
- part of a question on how objects move or have their temperature changed
- part of a question about an experiment or investigation.

Have a go at this exam-style question.

Exam-style question

1 A student is investigating the efficiency of different bouncing balls by dropping them from a height of 2.0 m and measuring the height to which they bounce back up.

The student drops a football of mass 0.40 kg. After the first bounce, it bounces back to a height of 1.40 m.

The gravitational field strength is 10 N/kg.

(a) Calculate the gravitational potential energy of the football before it is dropped.

....

.... (2 marks)

(b) Calculate the maximum speed the football could be travelling at just before it hits the ground.

....

.... (3 marks)

(c) Describe the energy transfers during the bounce when the ball is in contact with the ground.

....

.... (2 marks)

(d) The efficiency of the bounce is less than 1. Calculate the efficiency of the bounce.

....

.... (3 marks)

Boost your grade

To boost your grade, make sure that you know the list of energy equations in the specification and how to rearrange them. You need to recall (memorise) some of the energy equations (kinetic and gravitational) but you are given the relationships for energy stored elastically or thermally. You also need to recall the efficiency equations.

How confident do you feel about each of these **skills**? Colour in the bars.

1 How do I calculate how much energy is stored in different stores?

2 How can I use efficiency to analyse an energy transfer?

3 How can I use energy calculations to model events and make predictions?