Section 1: What Is Energy?

• What is energy?

Energy is the ability of an object or system to produce a change or to do work. There are several units used in the measurement of energy, although some are outdated and some are only suitable for particular applications. Energy is usually measured in joules (J); 1J is equal to the energy required to apply a force of 1 newton over a distance of 1m.

A power station and its cooling towers

• Suggested Film

- Forms of Energy

Extension Questions

Q1. What is a calorie?

The calorie is an older measure of energy, which was replaced by the joule but is sometimes still used to measure the amount of energy in food. There are two different forms of this unit. Both are called ‘calorie’ but one is a thousand times bigger than the other. This is sometimes shown by writing ‘Calorie’ for the larger unit and ‘calorie’ for the smaller unit. It is now common to use kilocalorie for the larger unit and the smaller unit is rarely used. When describing the energy content of food ‘calorie’ and ‘kilocalorie’ are almost always assumed to mean the same thing. One kilocalorie is approximately equal to 4.2 kilojoules.

Q2. What is an electronvolt?

An electronvolt (eV) is a small unit of energy, equal to 1.6×10^{-19} J. It is equivalent to the amount of energy gained by an electron when it is accelerated through a potential difference of one volt. It is commonly used in nuclear physics, as this often involves working with very small amounts of energy. Molecules in the air typically have a kinetic energy of a few tens of electronvolts.

The Large Hadron Collider collides proton beams at energies of teraelectronvolts (a teraelectronvolt is a trillion electron volts or a millionth of a joule).

Q3. What does $E=mc^2$ mean?

This is probably the most famous equation in the world. It describes the relationship between mass and energy content. The ‘c’ in the equation is the speed of light in metres per second. This is a large number, around 300 million metres per second, and c^2 is a very large number (9 followed by 16 zeroes). This means that even a small mass contains an enormous amount of energy.

If the energy contained within 1kg of matter were to be released it would be approximately equivalent to the energy released by the detonation of 10 million tonnes of high explosive.

• What is perpetual motion?

A perpetual motion machine would be capable of operating indefinitely. It would either produce more energy than it consumed, which would violate the conservation of energy, or it would not lose any energy, including heat loss due to friction, which would violate the second law of thermodynamics.

Perpetual motion machines are impossible, but attempts to construct them, both practical and theoretical, were useful in formulating and testing the laws of thermodynamics, which describe how heat flows between objects.

• Suggested Film

- Perpetual Motion

Section 2: Energy Transformation

• What does conservation of energy mean?

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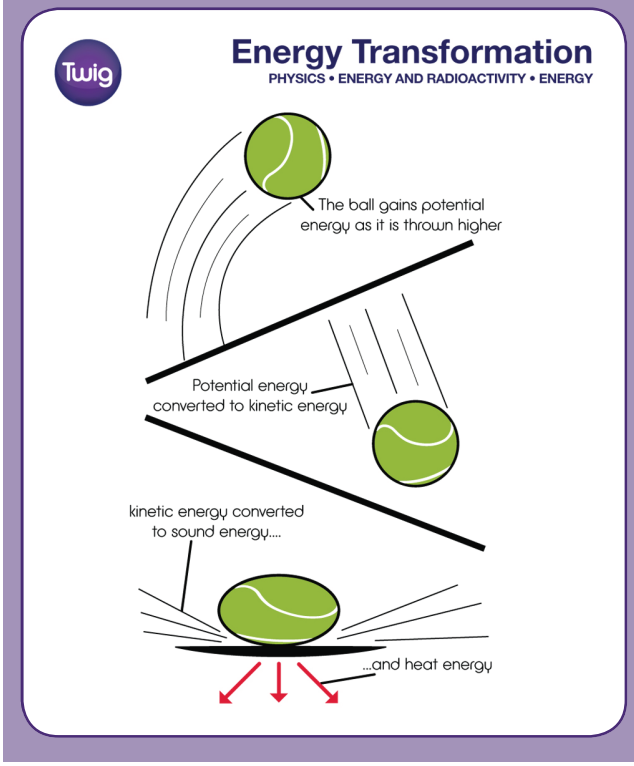


The law of conservation of energy says that the amount of energy in a closed system remains constant over time. This means that energy cannot be created or destroyed, only changed from one form to another. Commonly used names for the various types of energy are heat (or thermal) energy, chemical energy, electrical energy, light energy, sound energy and nuclear energy.

Although we sometimes talk about 'energy production' when referring to power stations, in fact, energy is not being produced, it is being changed from one form to another (usually this involves changing some form of potential energy into electrical energy).

• Suggested Films

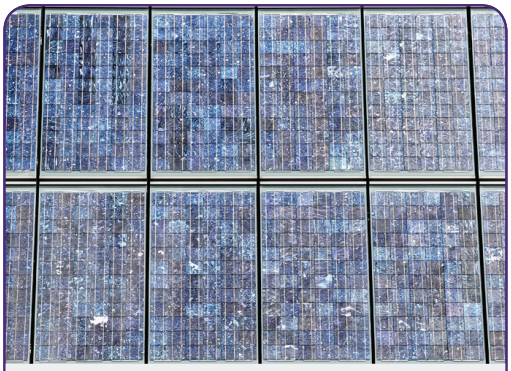
- Energy Transformation

- Forms of Energy

• What is efficiency?

Efficiency is given by the ratio of the useful output energy to the input energy. It can be expressed as a number between 0 and 1, but is often expressed as a percentage. No device can be more than 100% efficient, as this would violate the principle of conservation of energy.

Plants use the energy from sunlight to convert water and carbon dioxide into food. This process is known as photosynthesis and has an efficiency of around 6%. By comparison, commercial solar cells, which convert the energy from sunlight into electrical energy, typically have an efficiency of up to around 20%, although higher efficiencies are possible.



These solar cells in Berlin produce 25,000 kWh (kilowatt-hour) of solar-generated electricity a year

• Suggested Film

- The Energy of Formula 1

Extension Question

Q4. How efficient are engines?

Petrol and diesel engines have efficiencies of around 20%. This means that most of the energy released from the fuel is converted to heat energy, which then leaves the vehicle through the exhaust.

Electric vehicles have much higher efficiencies, around 80%. The efficiency of electric vehicles can mean it is harder to provide heating to the interior of the vehicle, as this is usually provided by waste heat.

• What is power?

Power is measured in watts (W) and is a measure of how quickly energy is changed from one form into another; 1W is equivalent to 1J per second. This unit is too small for many everyday applications. An electric kettle may have a rating of a few kilowatts (kW), a train will have a power output of a few megawatts, and a large power station will have a capacity of around a gigawatt (a billion watts). The total power consumption of the UK is around 60 gigawatts and total world energy consumption is just under 20 terawatts (20 trillion watts).

Extension Questions

Q5. What is a kilowatt hour?

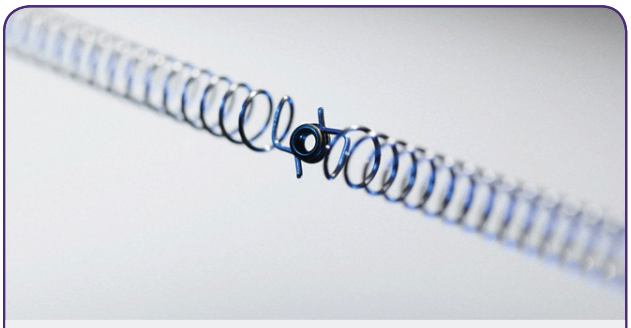
A kilowatt hour (kWh) is a unit which is commonly used to measure the amount of energy provided to homes by power companies. 1kWh is the energy used by a device which consumes 1kW if it is used for one hour. It is equivalent to 3,600,000J.

Q6. What is horsepower?

The horsepower is an older unit of measurement than the watt and was originally intended to describe the power of steam engines. There are several forms, but generally one horsepower is equivalent to around 740W. This is roughly equivalent to the power which a horse is able to sustain for long periods. Although the watt is now the most commonly used unit of power, horsepower is still sometimes used to describe engine power.

Section 3: Energy Storage

• What is potential energy?

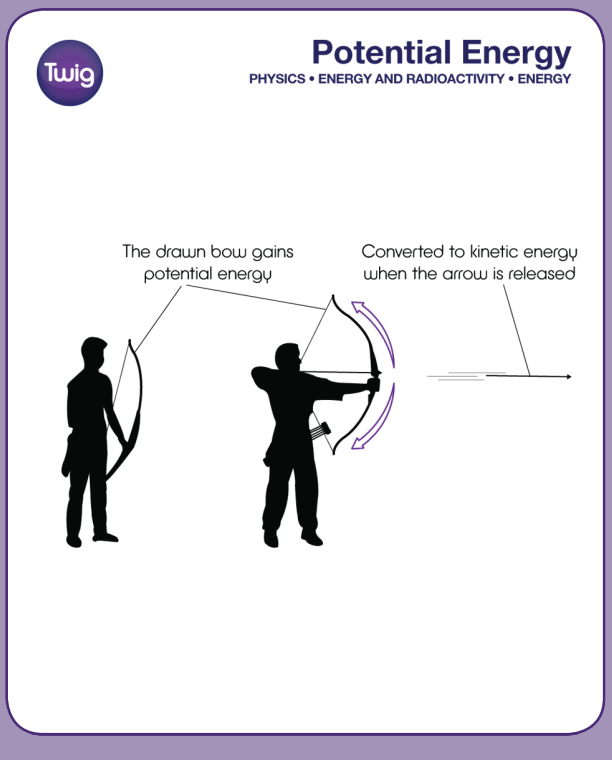


Potential energy is stored in a stretched spring

Potential energy is the energy stored in a system or object. There are several ways for energy to be stored. If an object like a bow or a spring is stretched this will result in a force which will act to restore the object's original shape. If this is allowed to happen the stored energy will released as kinetic energy.

Energy can also be stored in molecules. When bonds between atoms are formed energy is released. The burning of fuel, and formation of products, can result in a net release of energy. Most organisms use glucose as an energy source. Large numbers of glucose molecules can be combined to form starch or glycogen, which can be stored and used as required to provide energy.

DIAGRAM 02:



Potential energy can also be stored in objects due to their position in an electrical or gravitational field. For example, work has to be done to lift an object, and this energy can be released as kinetic energy by allowing the object to fall back to the ground.

• Suggested Film

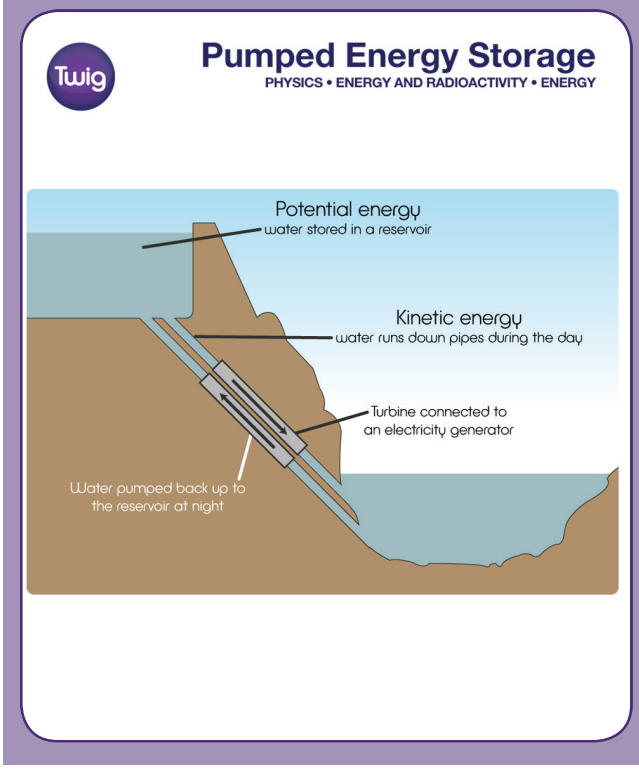
- Potential Energy

• How can energy be stored?

It is difficult to store large amounts of energy. On large scales, batteries are not economical, although if large numbers of electric vehicles were used across the country it has been suggested that while they are plugged in for charging, their batteries could be used to provide energy to the electrical grid, if required, for short periods.

Pumped energy storage is often used. When extra electrical energy is being generated it can be used to pump water from a low reservoir into a raised reservoir. When the energy is required the water is allowed to flow back down, passing through turbines and generating electricity.

DIAGRAM 03:



Extension Questions

Q7. Why is energy storage an issue in power generation?

There are often times when power stations generate electricity which is not required. If this energy can be stored, it can be used at times when more energy is needed than is being produced. Solar and wind energy are intermittent and if, in the future, solar cells and wind turbines are to be used to provide large quantities of energy a large energy storage capacity will be required. If this is not available, power stations burning fossil fuels or using nuclear power will have to be used to make up for shortfall whenever the wind drops or sunlight is not falling on the solar cells.

Q8. What are fossil fuels?

Fossil fuels, like coal, oil and gas, are produced when dead organisms decompose over millions of years. The vast majority of world energy consumption, over 80%, is dependent upon the burning of fossil fuels. This burning releases the energy stored by the organisms while they were alive but also produces carbon dioxide. The increased amount of carbon dioxide in the atmosphere, which has resulted from this, is thought to be the main factor causing global warming.

• Suggested Film

- Steam Power

• How much energy do humans require?

The amount of energy required each day varies from person to person, but is around 10 million joules (approximately 2500 calories). This is obtained from food, which contains large amounts of energy. In fact, 1kg of sugar contains around 16 million joules of energy, and 1kg of fat contains more than twice this amount.

Humans obtain energy from the food they eat

Extension Questions

Q9. Does high explosive contain a lot of energy?

High explosive does not get its name from the amount of energy it is able to release, but from the speed at which it is released. In fact, many types of food contain more energy per kilogram than high explosive. In general, ice cream contains more energy than TNT.

• Suggested Films

- Rollercoasters

- FactPack: Horsepower

Q10. How much energy does petrol contain?

Both petrol and diesel have very high energy densities. They each contain around 46 billion joules per kilogram, around twice as much as pure sugar. Hydrogen, often suggested as an alternative fuel for transport, contains around three times as much energy per kilogram, but the storage of a kilogram of hydrogen requires far more space than a kilogram of petrol or diesel.

• Quizzes

Forms of Energy

Basic

• What is energy?

A – the amount of charge stored in an object

B – the force on one kilogram of matter

C – the work done per second

D – the capacity to do work

• What does a generator do?

A – converts electrical energy into light energy

B – converts electrical energy into mechanical energy

C – converts mechanical energy into electrical energy

D – converts light energy into mechanical energy

• What units are used to measure energy?

A – watts

B – amperes

C – joules

D – volts

• Which of the following is not a type of energy?

A – light

B – power

C – heat

D – sound

Advanced

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Forms of Energy

Basic

- Where do we get our energy?

  A – from our food

  B – from exercising

  C – from the Sun

  D – from sleeping

Advanced

- Where do we get our energy?

  A – from our food

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Energy Transformation

Basic

• Where does almost all energy used on Earth come from?

A – the Sun

B – the Earth's gravitational field

C – the centre of the Earth

D – the gravitational pull due to the Moon

• What is the energy conversion process in plants called?

A – diffusion

B – hysteresis

C – photosynthesis

D – osmosis

• What kind of energy do power stations convert other forms of energy into?

A – heat energy

B – chemical energy

C – kinetic energy

D – electrical energy

• In an engine, how much of the energy in the fuel is converted into kinetic energy?

A – 90%

B – 60%

C – 20%

D – 5%

Advanced

• What is done during the energy conversion process in plants?

A – light energy is converted into chemical energy

B – light energy is converted into kinetic energy

C – chemical energy is converted into light energy

D – kinetic energy is converted into chemical energy

• What energy conversion takes place in our bodies?

A – kinetic energy is converted into chemical energy

B – chemical energy is converted into heat and kinetic energy

C – kinetic energy is converted into heat energy

D – heat energy is converted into chemical energy

• What does the first law of thermodynamics say about energy?

A – heat energy cannot be converted into other forms of energy

B – some energy is always destroyed during any conversion process

C – energy cannot be created or destroyed

D – no process which changes the form of energy can be 100% efficient

• How is efficiency calculated?

A – by dividing the total energy output by the total input

B – by dividing the total energy input by the total energy output

C – by dividing the total energy input by the useful energy output

D – by dividing the useful energy output by the total input

Potential Energy

Basic

• Which of these statements is not true?

A – in dams, potential energy is stored in water which is raised to a height

B – in a battery, chemicals are used to stored energy

C – fossil fuels contain stored energy from dead animals and plants

D – plants store energy they get from the soil

• Which of the following is not a form of potential energy?

A – chemical

B – heat

C – elastic

D – gravitational

• What is gravitational potential energy?

A – energy stored when electrical charge is stored in a capacitor

B – energy stored when an object is raised to a greater height

C – energy stored when a material is deformed

D – energy stored in the bonds within molecules

Advanced

• What is chemical energy?

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• When is energy stored as elastic potential energy?

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• What energy conversion process drives a turbine?

A – potential energy is converted into kinetic energy

B – kinetic energy is converted into electrical energy

C – kinetic energy is converted into potential energy

D – electrical energy is converted into kinetic energy

• Answers

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