Energy Stores

Energy stores are different ways of storing energy. Simple really...

Energy is Transferred Between Energy Stores

Energy can be transferred between and held in different energy stores. There are eight you need to know:

1) KINETIC............................. — anything moving has energy in its kinetic energy store (see below).
2) THERMAL........................... — any object — the hotter it is, the more energy it has in this store.
3) CHEMICAL.......................... — anything that can release energy by a chemical reaction, e.g. food, fuels.
4) GRAVITATIONAL POTENTIAL... — anything in a gravitational field (i.e. anything that can fall) (see below).
5) ELASTIC POTENTIAL............. — anything stretched, like springs, rubber bands, etc. (p.100).
6) ELECTROSTATIC.................. — e.g. two charges that attract or repel each other.
7) MAGNETIC.......................... — e.g. two magnets that attract or repel each other.
8) NUCLEAR........................... — atomic nuclei release energy from this store in nuclear reactions.

A Moving Object has Energy in its Kinetic Energy Store

1) When an object is moving, it has energy in its kinetic energy store.
2) Energy is transferred to this store if an object speeds up and away from this store if it slows down.
3) How much energy is in this store depends on both the object's mass and its speed.
4) The greater its mass and the faster it's going, the more energy it has in its kinetic energy store.
5) For example, a high-speed train will have a lot more energy in its kinetic energy store than you running.
6) You can find the energy in a kinetic energy store using:

$$\underset{(\text{J})}{\text{kinetic energy}} = 0.5 \times \underset{(\text{kg})}{\text{mass}} \times \underset{(\text{m/s})^2}{(\text{speed})^2}$$

or

$$KE = ½ \times m \times v^2$$

7) If you double the mass, the energy in the kinetic energy store doubles.
If you double the speed, though, the energy in the kinetic energy store quadruples (increases by a factor of 4) — it's because of the '(speed)^2' in the formula.

EXAMPLE:

A car of mass 1450 kg is travelling at 28 m/s. Calculate the energy in its kinetic energy store, giving your answer to 2 s.f.

kinetic energy = 0.5 × mass × (speed)^2
= 0.5 × 1450 × 28^2 = 568 400 = 570 000 J (to 2 s.f.)

Watch out for the (speed)^2 — that's where people tend to make mistakes and lose marks.

An Object at a Height has Energy in its Gravitational Potential Energy Store

1) When an object is at any height above the Earth's surface, it will have energy in its gravitational potential energy store.
2) You can calculate the change in energy in the gravitational potential energy store using the equation:

$$\Delta GPE = m \times g \times \Delta h$$

Change in gravitational potential energy (J)
Mass (kg)
Gravitational field strength (N/kg)
Change in vertical height (m)

Δ just means 'change in'.

There's potential for a joke here somewhere...

Hopefully this page wasn't too hard — just don't forget that squared sign when you're working and remember that the energy in an object's kinetic energy store only changes if its speed is changing. Now have a crack at this...

Q1 A 2 kg object is dropped from a height of 10 m. Calculate the speed of the object after it has fallen 5 m, assuming there is no air resistance. g = 10 N/kg. [5 marks]

Transferring Energy

Now you know about the different energy stores, it's time to find out how energy is transferred between them.

Conservation of Energy Means Energy is Never Created or Destroyed

Energy can be stored, transferred between stores, and dissipated — but it can never be created or destroyed. The total energy of a closed system has no net change.

See the next page for more on dissipation.

A closed system is just a system (a collection of objects) that can be treated completely on its own and where there is no net change in the system's total energy. If you get a question where the energy of a system increases or decreases, then it's not closed. But you can make it into a closed system by increasing the number of things you treat as part of it. E.g. a pan of water heating on a hob isn't a closed system, but the pan, the gas and the oxygen that burn to heat it, and their surroundings are a closed system.

Energy Transfers Show... well... the Transfer of Energy

Energy can be transferred between stores in four main ways:

1) Mechanically — a force acting on an object (and doing work, p.66), e.g. pushing, stretching, squashing.
2) Electrically — a charge doing work (p.72), e.g. charges moving round a circuit.
3) By heating — energy transferred from a hotter object to a colder object, e.g. heating a pan on a hob.
4) By radiation — energy transferred by waves, e.g. energy from the Sun reaching Earth by light.

Make sure you understand what's going on in these examples of energy transfers:

A BALL ROLLING UP A SLOPE:
The ball does work against the gravitational force, so energy is transferred mechanically from the kinetic energy store of the ball to its gravitational potential energy store.

A BAT HITTING A BALL:
The bat has energy in its kinetic energy store. Some of this is transferred mechanically to the ball's kinetic energy store. Some energy is also transferred mechanically to the thermal energy stores of the bat and the ball (and to the surroundings by heating). The rest is carried away by sound.

A ROCK DROPPED FROM A CLIFF:
Assuming there's no air resistance, gravity does work on the rock, so the rock constantly accelerates towards the ground. Energy is transferred mechanically from the rock's gravitational potential energy store to its kinetic energy store.

A CAR SLOWING DOWN (without braking):
Energy in the kinetic energy store of the car is transferred mechanically (due to friction between the tyres and road), and then by heating, to the thermal energy stores of the car and road.

A KETTLE BOILING WATER:
Energy is transferred electrically from the mains to the heating element of the kettle, and then by heating to the thermal energy store of the water.

You can Draw Diagrams to Show Energy Transfers

Diagrams can make it easier to see what's going on when energy is transferred. The diagram below shows the energy transferred when a ball is thrown upwards, taking air resistance into account. The boxes represent stores and the arrows show transfers:

You may have to use or draw a diagram like this in the exam, so make sure you understand what it's showing.

kinetic energy store of the ball —(mechanically — work done against gravity)→ gravitational potential energy store of the ball

kinetic energy store of the ball —(mechanically — work done against air resistance)→ thermal energy store of the ball and the surroundings

Energy can't be created or destroyed — only talked about a lot...

This is important, so remember it. Energy can only be transferred to a different store, never destroyed.

Q1 Describe the energy transfers that occur when a piece of wood is burning. [2 marks]

Efficiency

So energy is transferred between different stores. But not all of the energy is transferred to useful stores.

Most Energy Transfers Involve Some Losses, Often by Heating

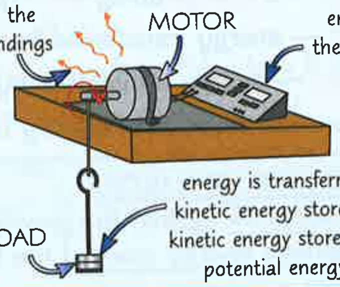
1) You've already met the principle of conservation of energy on the previous page, but another important principle you need to know is:

Energy is only useful when it is transferred from one store to a useful store.

2) Useful devices can transfer energy from one store to a useful store.
3) However, some of the input energy is always dissipated or wasted, often to thermal energy stores of the surroundings.
4) Whenever work is done mechanically (see p.25), frictional forces have to be overcome, including things like moving parts rubbing together, and air resistance. The energy needed to overcome these frictional forces is transferred to the thermal energy stores of whatever's doing the work and the surroundings.
5) This energy usually isn't useful, and is quickly dissipated.

Dissipated is a fancy way of saying the energy is spread out and so is 'lost'.

The diagram shows a motor lifting a load. The motor transfers energy usefully from its kinetic energy store to the kinetic energy store and the gravitational potential energy store of the load, but it also transfers energy mechanically to the thermal energy stores of its moving parts, and electrically to the thermal energy stores of its circuits. This energy is dissipated, heating the surroundings.



6) The conservation of energy principle means that: total energy input = useful energy output + wasted energy.
7) The less energy that's wasted, the more efficient the device is said to be. The amount of energy that's wasted can often be reduced — see next page.

You can Calculate the Efficiency of an Energy Transfer

The efficiency of any device is defined as:

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

This will give the efficiency as a decimal. To give it as a percentage, you need to multiply the answer by 100.

EXAMPLE: A toaster transfers 216 000 J of energy electrically from the mains. 84 000 J of energy is transferred to the bread's thermal energy store. Calculate the efficiency of the toaster.

$$\text{efficiency} = \frac{\text{useful energy transferred by device}}{\text{total energy supplied to device}} = \frac{84\,000}{216\,000} = 0.388... = 0.39 \text{ (to 2 s.f.)}$$

This could also be written as 39% (to 2 s.f.).

All devices have an efficiency, but because some energy is always wasted, the efficiency can never be equal to or higher than 1 (or 100%).

Make sure your revising efficiency is high...

One really important thing to take from here — devices that transfer energy from one store to other stores will always transfer energy to stores that aren't useful. And when I say always, I mean always. Always. (Always.)

Q1 An electrical device wastes 420 J of energy when it has an input energy of 500 J. Calculate the efficiency of the device as a percentage. [3 marks]

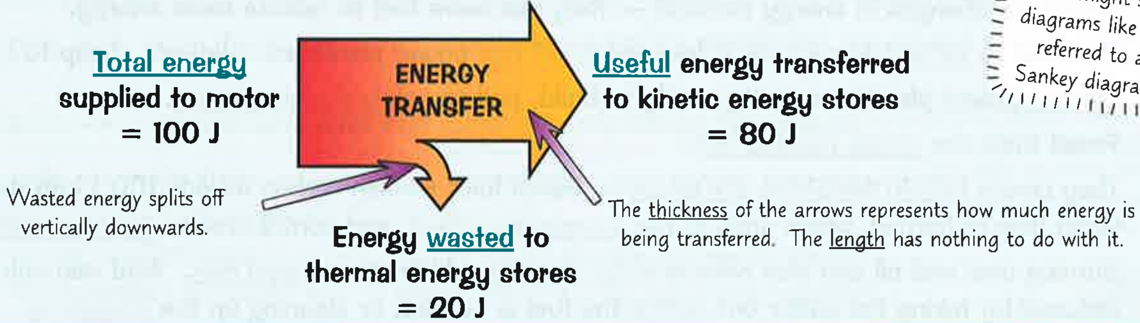
Reducing Unwanted Energy Transfers

There are many ways you can reduce the amount of energy that is wasted during a process (and so increase its efficiency) — lubrication and thermal insulation are two of the main ones that you need to know about.

You can Use Diagrams to Show Efficiency

No device is 100% efficient (see previous page), but some are more efficient than others. You can use diagrams like the one below to show the different energy transfers made by a device, and so how efficient it is:

Diagram for an electric motor with 80% efficiency:



You might see diagrams like this referred to as Sankey diagrams.

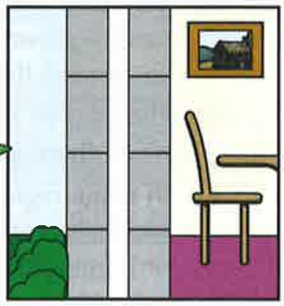
You can reduce the amount of energy that's wasted in various ways — including by lubrication and by thermal insulation. Decreasing the amount of wasted energy means that a higher proportion of the supplied energy is transferred to useful stores, so the efficiency of the process is increased.

Lubrication Reduces Energy Transferred by Friction

1) Whenever something moves, there's usually at least one frictional force acting against it.
2) This transfers energy mechanically (work is done against friction) to the thermal energy store of the objects involved, which is then dissipated by heating to the surroundings. For example, pushing a box along the ground causes energy to be transferred mechanically to the thermal energy stores of the box and the ground. This energy is then radiated away to the thermal energy store of the surroundings.
3) For objects that are touching each other, lubricants can be used to reduce the friction between the objects' surfaces when they move. Lubricants are usually liquids (like oil), so they can flow easily between objects and coat them.

Insulation Reduces the Rate of Energy Transfer by Heating

1) When one side of an object is heated, the particles in the hotter part vibrate more and collide with each other. This transfers energy from their kinetic energy stores to other particles, which then vibrate faster.
2) This process is called conduction. It transfers energy through the object.
3) All materials have a thermal conductivity — it describes how well a material transfers energy by conduction. For example, metals have a high thermal conductivity and gases (like air) have a low thermal conductivity.
4) In a building, the lower the thermal conductivity of its walls, the slower the rate of energy transfer through them (meaning the building will cool more slowly).
5) Some houses have cavity walls, made up of an inner and an outer wall with an air gap in the middle. The air gap reduces the amount of energy transferred by conduction, because air has a very low thermal conductivity.
6) Thicker walls help too — the thicker the wall, the slower the rate of energy transfer.



Don't waste energy — turn the TV off while you revise...

Unwanted energy transfers can cost you a lot in energy bills — it's why so many people invest in home insulation.

Q1 Suggest one way to improve the efficiency of an electric motor. [1 mark]

Energy Resources

There are lots of energy resources available on Earth. They are either renewable or non-renewable resources.

Non-Renewable Energy Resources Will Run Out One Day

Non-renewable energy resources are fossil fuels and nuclear fuel (uranium and plutonium). They currently provide most of the world's energy. Fossil fuels are natural resources that form underground over millions of years that are typically burnt to provide energy. The three main fossil fuels are coal, oil and (natural) gas.

1) Fossil fuels and nuclear energy are RELIABLE. There's still plenty of fuel around to meet current demand, and power plants always have fuel in stock. This means they can respond quickly to changes in energy demand — they use more fuel to release more energy.
2) The cost to extract fossil fuels is low and fossil fuel power plants are relatively cheap to build and run.
3) Nuclear power plants are pretty costly to build, and to safely decommission.
4) Fossil fuels are slowly running out.
5) They create ENVIRONMENTAL PROBLEMS. Fossil fuels release carbon dioxide (CO_2) into the atmosphere when they're burned, which adds to the greenhouse effect, and contributes to global warming.
6) Burning coal and oil can also release sulfur dioxide, which causes acid rain. Acid rain can be reduced by taking the sulfur out before the fuel is burned, or cleaning up the emissions.
7) Oil spillages cause serious environmental problems, affecting mammals and birds that live in and around the sea. We try to avoid them, but they'll always happen.
8) Nuclear power is clean but the nuclear waste is very dangerous and difficult to dispose of. And there's always the risk of a major catastrophe like the Fukushima disaster in Japan.

Renewable Energy Resources Will Never Run Out

Renewable energy resources include:

1) Bio-fuels
2) Wind
3) The Sun (solar)
4) Hydro-electricity
5) Tides

- These will never run out — the energy can be 'renewed' as it is used.
- Most of them do damage the environment, but in less nasty ways than non-renewables.
- The trouble is they don't provide much energy and some of them are unreliable because they depend on the weather.

Bio-fuels are Made from Plants and Waste

1) Bio-fuels are renewable energy resources created from either plant products or animal dung. They can be solid, liquid or gas and can be burnt to produce electricity or run cars in the same way as fossil fuels.
2) They are supposedly carbon neutral, although there is some debate about this as it's only really true if you keep growing plants (or raising animals) at the rate that you're burning things.
3) Bio-fuels are fairly reliable, as crops take a relatively short time to grow and different crops can be grown all year round. However, they cannot respond to immediate energy demands. To combat this, bio-fuels are continuously produced and stored for when they are needed.
4) The cost to refine bio-fuels is very high and some worry that growing crops specifically for bio-fuels will mean there isn't enough space or water to meet the demands for crops that are grown for food.
5) In some regions, large areas of forest have been cleared to make room to grow bio-fuels, resulting in lots of species losing their natural habitats. The decay or burning of this cleared vegetation also increases methane and CO_2 emissions.

Burning poo... lovely...

Given our electricity-guzzling ways, it's pretty important we find ways to generate electricity without destroying the planet. Burning cow pats may not be the ultimate fix, but it's a start. See the next page for more ways.

Q1 State two renewable energy sources. [2 marks]

More Energy Resources

Renewable energy resources, like wind, solar, hydro-electricity and tides, won't run out. They don't generate as much electricity as non-renewables though — if they did we'd all be using solar-powered toasters by now.

Wind Power — Lots of Little Wind Turbines

1) Each wind turbine has a generator inside it — wind rotates the blades, which turn the generator and produce electricity. So there's no pollution.
2) Initial costs are quite high, but running costs are minimal.
3) But lots of them are needed to produce as much power as, for example, a coal power plant. This means they can spoil the view. They can also be noisy, which can be annoying for people living nearby.
4) They only work when it's windy, so you can't always supply electricity, or respond to high demand.

Solar Cells — Expensive but No Environmental Damage

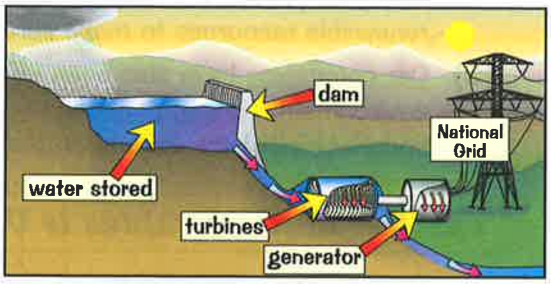
There's some pollution when the energy resources on this page are made, but not when they're in use.

1) Solar cells are made from materials that use energy transferred by light to create an electric current.
2) Solar power is often used in remote places where there's not much choice (e.g. the Australian outback) and to power electric road signs and satellites.
3) There's no pollution. (Although they do use quite a lot of energy to make.)
4) Initial costs are high, but there are basically no running costs.
5) They're mainly used to generate electricity on a relatively small scale, e.g. in homes.
6) Solar power is most suitable for sunny countries, but it can be used in cloudy countries like Britain.
7) And of course, you can't make solar power at night or increase production when there's extra demand.

Time to recharge.

Hydro-electricity — Building Dams and Flooding Valleys

1) Producing hydro-electricity usually involves flooding a valley by building a big dam. Rainwater is caught and allowed out through turbines. There is no pollution (as such).
2) There is a big impact on the environment due to the flooding of the valley and possible loss of habitat for some species.
3) A big advantage is it can immediately respond to increased electricity demand — more water can be let out through the turbines to generate more electricity.



4) Initial costs are often high but there are minimal running costs and it's generally a reliable energy source.

Tidal Barrages — Using the Sun and Moon's Gravity

1) Tidal barrages are big dams built across river estuaries with turbines in them.
2) As the tide comes in it fills up the estuary. The water is then let out through turbines at a controlled speed to generate electricity.
3) There is no pollution but they affect boat access, can spoil the view and they alter the habitat for wildlife, e.g. wading birds.
4) Tides are pretty reliable (they always happen twice a day). But the height of the tides is variable and barrages don't work when the water level is the same either side.
5) Initial costs are moderately high, but there are no fuel costs and minimal running costs.

The hydro-electric power you're supplying — it's electrifying...

There are pros and cons to all energy resources. Make sure you know them for solar, wind and water.

Q1 The government is considering closing down a traditional coal-fired power station. Explain the benefits and disadvantages of replacing the power station with a wind farm. [4 marks]

Trends in Energy Resource Use

Over time, the types of energy resources we use change. There are lots of reasons for this — breakthroughs in technology, understanding more about how they affect the environment or changes in cost are just a few.

Currently We Still Depend on Fossil Fuels

1) Over the 20th century, the electricity use of the UK hugely increased as the population got bigger and people began to use electricity for more and more things.
2) Since the beginning of the 21st century, electricity use in the UK has been decreasing (slowly), as we get better at making appliances more efficient (p.26) and try to be more careful with energy use in our homes.
3) Some of our electricity is produced using fossil fuels and from nuclear power. The rest is generated using renewable energy resources like wind power .
4) Generating electricity isn't the only reason we burn fossil fuels — oil (diesel and petrol) is used to fuel cars, and gas is used to heat homes and cook food.
5) However, renewable energy resources can be used for these purposes as well. Bio-fuels can be used to exclusively power vehicles, and solar water heaters can be used to heat buildings.
6) We are trying to increase our use of renewable energy resources. This move towards renewable energy resources has been triggered by many things...

Energy Resources are Chosen for their Effect on the Environment

1) We now know that burning fossil fuels has a lot of negative effects on the environment (p.28). This has led to many people wanting to use more renewable energy resources that have less of an effect on the environment.
2) Pressure from other countries and the public has meant that governments have begun to introduce targets for using renewable resources. This in turn puts pressure on energy providers to build new power plants that use renewable resources to make sure they do not lose business and money.
3) Car companies have also been affected by this change in attitude towards the environment. Electric cars and hybrids (cars powered by two fuels, e.g. petrol and electricity) are already on the market and their popularity is increasing.

The Use of Renewables is Usually Limited by Reliability and Money

1) Building new renewable power plants costs money, so some smaller energy providers are reluctant to do this — especially when fossil fuels are such a cost effective way of meeting demand.
2) Even if new power plants are built, there are a lot of arguments over where they should be. E.g. many people don't want to live next to a wind farm, which can lead to protests.
3) Some energy resources like wind power are not as reliable as traditional fossil fuels, whilst others cannot increase their power output on demand. This would mean either having to use a combination of different power plants (which would be expensive) or researching ways to improve reliability.
4) Research into improving the reliability and cost of renewable resources takes time and money. This means that, even with funding, it might be years before improvements are made. In the meantime, dependable, non-renewable power stations have to be used.
5) Making personal changes can also be quite expensive. Hybrid cars are generally more expensive than equivalent petrol cars and things like solar panels for your home are still quite pricey. The cost of these things is slowly going down, but they are still not an option for many people.

Going green is on-trend this season...

So with more people wanting to help the environment, others not wanting to be inconvenienced and greener alternatives being expensive to set up, the energy resources we use are changing. Just not particularly quickly.

Q1 Give two reasons we currently do not use more renewable energy resources in the UK. [2 marks]

Revision Questions for Section 1

Wow, that was a whole lot of Physics in one place — time to see how much of it you can remember.

- Try these questions and tick off each one when you get it right.
- When you've done all the questions under a heading and are completely happy, tick it off.

Motion (p.12-15)

1) What is the difference between a scalar and a vector quantity? Give two examples of each.
2) Give the equation relating distance, speed and time.
3) Estimate typical speeds for a) walking, b) running, c) a car in a built-up area.
4) Define acceleration in terms of velocity and time.
5) What does the gradient represent for a) a distance/time graph? b) a velocity/time graph?
6) How would you find the distance travelled by an object from its velocity/time graph?

Newton's Laws, Forces and Momentum (p.16-21)

7) State Newton's First and Second Laws of Motion.
8) Explain why cars have safety features to reduce the decelerations experienced by passengers.
9) What is the formula for calculating the weight of an object?
10) Explain why there must be a force acting to produce circular motion. What is the name of the force?
11) Describe an experiment to investigate Newton's Second Law of Motion.
12) What is inertia?
13) What is Newton's Third Law of Motion? Give an example of it in action.
14) State the formula used to calculate an object's momentum.
15) Explain the link between Newton's Third Law and conservation of momentum.

Car Safety (p.22-23)

16) What is meant by a person's reaction time? Describe an experiment to measure reaction time.
17) State two factors that can affect the thinking distance for a stopping car.
18) State four things that can affect the braking distance of a vehicle.

Energy Stores, Transfers and Efficiency (p.24-27)

19) What is the equation for calculating the energy in a moving object's kinetic energy store?
20) State the conservation of energy principle.
21) What is meant by the 'dissipation' of energy?
22) Describe the energy transfers when a ball is rolled up a slope.
23) Describe the energy transfers when a hair dryer is switched on.
24) Give the equation for the efficiency of a device.
25) How can you reduce unwanted energy transfers in a machine with moving, touching components?
26) How does the thermal conductivity of a wall affect its rate of energy transfer?

Energy Resources and Trends in their Use (p.28-30)

27) What is the difference between renewable and non-renewable energy resources?
28) What are bio-fuels made from? Explain the benefits and drawbacks of using bio-fuels.
29) Give two benefits and two disadvantages of solar and wind power.
30) Explain why the UK plans to use more renewable energy resources in the future.