Energy

Model answers and marking points

GCSE science 6-mark questions

This topic online

1 Priya lives in an old stone cottage in Cumbria. In winter the house cools down quickly once the heating switches off at night. She is thinking about fitting loft insulation, filling the cavity walls with foam and adding thick curtains.

Explain how these changes would reduce the energy Priya needs to keep her house warm. (6 marks)

Model answer

At night energy is transferred from the warm inside of the house to the colder air outside. The rate of this transfer depends on the materials in the walls and roof.

Loft insulation and cavity wall foam both have a low thermal conductivity, so energy is conducted through them much more slowly than through stone or an empty gap. They also trap lots of small pockets of air. Air is a poor conductor and, because it is trapped, it cannot move around, so convection currents are reduced. A thicker layer of insulation lowers the rate of energy transfer even more.

Thick curtains trap a layer of still air next to the windows. This reduces the rate at which energy is transferred through the glass to the outside.

Because energy leaves the house more slowly, the rooms stay warm for longer after the heating turns off. The heating then needs to be on for less time to keep the temperature comfortable, so less fuel or electricity is used and less energy is wasted. Priya's bills would also be lower.

Marking points (credit any 6 relevant points, linked in a sensible order)

- energy is transferred from the warm inside of the house to the colder outside
- the bigger the temperature difference, the faster the rate of energy transfer
- loft insulation and cavity foam have a low thermal conductivity
- a material with low thermal conductivity transfers energy by conduction more slowly
- foam and loft insulation trap pockets of air, and trapped air cannot move so convection is reduced
- thick curtains trap a layer of air next to the window, reducing energy transfer through the glass
- thicker layers of insulation give a lower rate of energy transfer
- the house stays warm for longer, so the heating is on for less time
- less fuel or electricity is used, so less energy is wasted and bills are lower

How it is marked

- 5-6 marks: links at least two of the changes to low thermal conductivity or trapped air, explains that this lowers the rate of energy transfer, and connects this to the heating being used less.
- 3-4 marks: explains how one or two changes slow energy loss, with some mention of conduction or trapped air, but the link to using less energy is thin.
- 1-2 marks: states that insulation keeps heat in or saves money, with no explanation of how.

What loses marks

- saying insulation stops heat escaping completely rather than reducing the rate
- writing 'cold gets in' instead of energy being transferred out
- describing each change without linking it to using the heating less

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2 An energy company in Lincolnshire can either build an offshore wind farm or a gas-fired power station.

Compare these two ways of generating electricity. (6 marks)

Model answer

Wind is a renewable energy resource because it will not run out, but natural gas is a fossil fuel, so it is non-renewable and supplies will eventually be used up.

A gas power station burns fuel, which releases carbon dioxide into the atmosphere and adds to global warming. A wind farm does not burn anything, so it releases no carbon dioxide while it is generating.

The gas power station is much more reliable. It can generate electricity at any time and can be started up quickly when demand suddenly rises, such as on a cold evening. The wind farm only generates when the wind is blowing at a suitable speed, so its output cannot be controlled to match demand.

Once a wind farm is built there are no fuel costs, while the gas station has to keep buying gas, and the price of gas can go up and down. However, many turbines are needed to produce the same power as one gas station.

Offshore turbines may affect seabirds and shipping, whereas a gas station uses land on shore and needs pipelines to bring in the fuel.

Marking points (credit any 6 relevant points, linked in a sensible order)

- wind is a renewable resource; natural gas is non-renewable and will run out
- a gas power station releases carbon dioxide, which adds to global warming; a wind farm releases none while running
- burning gas can also release other pollutants; wind turbines do not burn anything
- wind is not reliable because output depends on the wind speed; a gas station can generate whenever needed
- a gas station can be started up quickly to meet sudden rises in demand; wind output cannot be increased on request
- wind has no fuel costs; gas has ongoing fuel costs which can change with world prices
- wind farms can spoil views or affect seabirds and shipping; gas stations need pipelines and take up land
- many turbines are needed to match the output of one gas station
- both have building costs, and making and installing either one causes some carbon dioxide emissions

How it is marked

- 5-6 marks: makes at least three clear point-by-point comparisons covering environmental impact, reliability and cost or renewability, saying how each resource differs.
- 3-4 marks: gives two or three relevant differences, or several points about one resource with only some direct comparison.
- 1-2 marks: gives one or two simple facts, such as wind being renewable, without comparing.

What loses marks

- writing two separate paragraphs, one about each resource, with no direct comparison
- saying wind farms produce no pollution at all, ignoring building and visual impact
- missing reliability, which is the biggest practical difference

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3 A secondary school in Bristol wants to cut its heating and electricity costs. The governors have two options.

	Solar panels on the roof	Biomass boiler burning wood pellets
Cost to install	£48,000	£35,000
Yearly saving on bills	£6,000	£4,000 (after buying pellets)
Works at night	No	Yes
Output in winter	Low	Can be turned up
Deliveries needed	None	Pellet lorry every 3 weeks

Evaluate the two options. Use the information in the table and your own knowledge. Give a justified recommendation.

(6 marks)

Model answer

The solar panels cost more to install, £48,000 compared with £35,000, but they save more each year. Solar pays for itself in 48,000 / 6,000 = 8 years, while the biomass boiler takes 35,000 / 4,000 = about 9 years, so solar is slightly better value over time.

However, solar panels do not work at night and give a low output in winter, which is exactly when a school needs the most heating. The biomass boiler can be turned up on cold days, so it is far more reliable for heating.

Both are renewable resources. Solar panels release no carbon dioxide while working and need no fuel. Biomass is renewable if new trees are planted, but burning pellets still releases carbon dioxide and smoke near the school, and a lorry visiting every three weeks adds traffic and more emissions.

I would recommend the solar panels, because they have the shortest payback time, no fuel costs and no pollution on site. The school could keep its existing heating as a backup for cold, dark winter days when the panels produce little.

Marking points (credit any 6 relevant points, linked in a sensible order)

- solar panels pay back their cost in 48,000 / 6,000 = 8 years
- the biomass boiler pays back in 35,000 / 4,000 = about 9 years
- solar has the bigger yearly saving but costs more to install
- solar produces electricity only in daylight and much less in winter when the school needs most heating
- the biomass boiler can be controlled to give more heat when it is cold, so it is more reliable
- biomass is renewable if trees are replanted, and is often described as close to carbon neutral
- burning pellets still releases carbon dioxide and other pollutants at the school, and delivery lorries add emissions and traffic
- solar panels have no fuel to buy and no emissions while running
- a justified conclusion that weighs payback time against reliability, for example solar for cost or biomass for winter heating

How it is marked

- 5-6 marks: uses the data to compare costs (ideally with payback times), discusses reliability and environmental effects of both options, and gives a recommendation supported by the points made.
- 3-4 marks: uses some of the data and gives advantages and disadvantages of both options, with a conclusion that is only partly justified.
- 1-2 marks: copies one or two facts from the table or picks an option with little or no reason.

What loses marks

- copying the table without working anything out, such as payback time
- giving a recommendation that ignores the disadvantages already mentioned
- saying biomass produces no carbon dioxide

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4 Kofi rides his bike to the top of a steep hill in the Peak District. He stops, then freewheels down the other side without pedalling. At the bottom he squeezes the brakes and comes to a stop.

Describe the changes to energy stores from when Kofi starts cycling up the hill to when he stops at the bottom.

(6 marks)

Model answer

As Kofi cycles up the hill, energy is transferred from the chemical energy store in his muscles, which comes from his food. Work is done raising him and the bike, so energy goes into their gravitational potential energy store. Some energy is wasted heating Kofi and the surroundings, which is why he gets hot.

At the top of the hill his gravitational potential store is at its largest and, since he has stopped, his kinetic store is zero.

As he freewheels down, his height falls so his gravitational potential store decreases. His speed increases, so his kinetic energy store increases. Not all of the gravitational energy becomes kinetic, because air resistance and friction in the wheels transfer some energy to the thermal store of the surroundings.

At the bottom he brakes. Friction between the brake pads and the wheel rims transfers energy from his kinetic store to the thermal store of the brakes, which get warm, and then to the surroundings. When he stops his kinetic store is zero.

Throughout, the total energy is conserved. It has not been destroyed but has been dissipated into the surroundings.

Marking points (credit any 6 relevant points, linked in a sensible order)

- going up the hill, energy is transferred from Kofi's chemical store (from food) by his muscles
- this energy goes to the gravitational potential store of Kofi and the bike as height increases
- some energy is wasted heating Kofi, his surroundings and the bike parts
- at the top his gravitational potential store is at its highest
- freewheeling down, the gravitational potential store decreases
- the kinetic store increases as his speed increases
- air resistance and friction transfer some energy to the thermal store of the surroundings, so not all of the gravitational energy becomes kinetic
- braking, friction between brake pads and wheel transfers the kinetic store to the thermal store of the brakes and surroundings
- at the end the energy has been dissipated to the surroundings, and the total energy is conserved throughout

How it is marked

- 5-6 marks: describes the full sequence in order, from chemical to gravitational potential, gravitational potential to kinetic, then kinetic to thermal when braking, including wasted energy and conservation.
- 3-4 marks: describes two of the three stages correctly with named stores, but misses wasted energy or one stage.
- 1-2 marks: names one or two stores, such as kinetic, with little sense of the sequence.

What loses marks

- saying energy is 'used up' or 'lost' instead of transferred or dissipated
- forgetting the chemical store at the start
- describing braking as kinetic energy turning into sound only

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5 Sofia drops a tennis ball of mass 0.15 kg from a height of 2.0 m. A light gate just above the floor measures its speed as 5.9 m/s.

Gravitational field strength = 9.8 N/kg.

Use the data to calculate the speed the ball would reach if no energy were wasted. Compare this with the measured speed, work out how efficiently the gravitational potential energy was transferred to kinetic energy, and explain the difference. (6 marks)

Model answer

Gravitational potential energy at the start = mgh = 0.15 x 9.8 x 2.0 = 2.94 J.

If no energy were wasted, all of this would become kinetic energy. Rearranging $E = 1/2\ m\ v^2$ gives v = square root of (2E / m).

v = square root of (2 x 2.94 / 0.15) = square root of 39.2 = 6.3 m/s (2 s.f.).

The measured speed of 5.9 m/s is lower. The actual kinetic energy is $0.5 \times 0.15 \times 5.9^2 = 2.61$ J.

Efficiency = useful energy out / total energy in = 2.61 / 2.94 = 0.89, which is 89%.

So about 0.33 J of the energy did not end up in the ball's kinetic store. As the ball falls, air resistance acts upwards on it and work is done against this force. This transfers energy to the thermal store of the air and the ball, so the energy is dissipated to the surroundings. That is why the ball reaches a lower speed than the ideal value.

Marking points (credit any 6 relevant points, linked in a sensible order)

- gravitational potential energy at the start = mgh = 0.15 x 9.8 x 2.0 = 2.94 J
- if no energy is wasted, all 2.94 J becomes kinetic energy
- rearrange E = 1/2 m v squared to give v = square root of (2E / m)
- v = square root of (2 x 2.94 / 0.15) = square root of 39.2 = about 6.3 m/s
- measured kinetic energy = 0.5 x 0.15 x 5.9 squared = about 2.61 J
- efficiency = useful output / total input = 2.61 / 2.94 = about 0.89 or 89%
- the measured speed is lower than the ideal speed
- air resistance acts on the ball as it falls, doing work against it
- about 0.33 J is transferred to the thermal store of the air and ball, so less energy ends up in the kinetic store

How it is marked

- 5-6 marks: correctly calculates the starting energy, the ideal speed and the efficiency, and explains the shortfall in terms of air resistance transferring energy to the surroundings.
- 3-4 marks: calculates the gravitational potential energy and one further value correctly, or makes a calculation error but gives a sound explanation.
- 1-2 marks: calculates the gravitational potential energy only, or gives air resistance as a reason with no correct working.

What loses marks

- forgetting to square the speed or to take the square root at the end
- using 10 N/kg when 9.8 N/kg is given
- writing efficiency above 100% by dividing the wrong way round

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