Energy transfers in a system

4.1.2.1 · Energy · revision notes

Energy can be transferred usefully, stored or dissipated, but never created or destroyed. You need to explain where energy is wasted, how to reduce unwanted energy transfers (lubrication and insulation), and how the thickness and thermal conductivity of its walls affect how fast a building cools. GCSE Physics students also need the required practical on thermal insulators. Expect 2 to 4 mark 'describe' and 'explain' questions, and practical questions of up to 6 marks.

Key facts

- Conservation of energy: energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed
- Dissipated (wasted) energy usually ends up in the thermal store of the surroundings
- Thermal insulation → lower rate of energy transfer by heating
- Thicker walls + lower thermal conductivity → building cools more slowly
- Closed system: no net change to the total energy
- Lubrication → less friction → less energy dissipated
- Higher thermal conductivity → higher rate of energy transfer by conduction
- Insulation practical: best insulator = smallest temperature drop in the same time

Notes

Conservation of energy

- Energy can be transferred usefully, stored or dissipated, but it **cannot be created or destroyed**.
- In a **closed system** no energy enters or leaves, so there is no net change to the total energy. Energy just moves between stores.
- Example: a swinging pendulum with no air resistance. Energy moves back and forth between its kinetic and gravitational potential stores, but the total stays the same.

Dissipation (wasted energy)

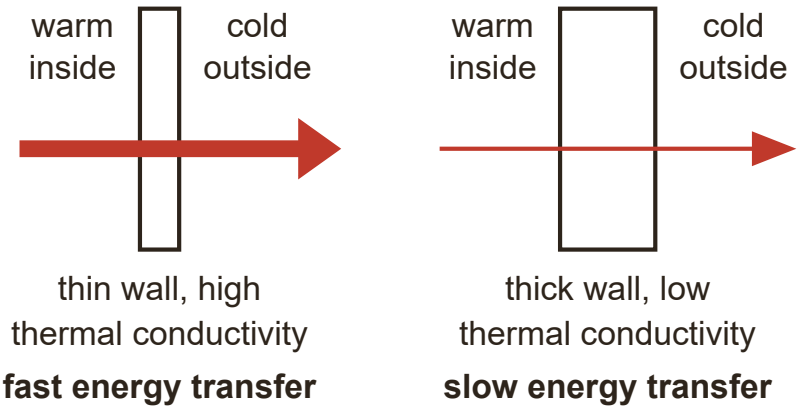
- In all system changes some energy is **dissipated**: it spreads out and ends up stored in less useful ways, usually in the thermal store of the surroundings. This is often called 'wasted' energy.
- Examples: friction heats the moving parts of a machine; air resistance heats the air around a moving car; a lamp heats the room as well as lighting it; a motor makes sound.
- Once it has spread out, dissipated energy is very hard to use again.

Reducing unwanted energy transfers

- **Lubrication**: oil or grease between moving parts reduces friction, so less work is done against friction and less energy is dissipated by heating.
- **Thermal insulation** reduces the rate of energy transfer by heating, e.g. loft insulation, cavity wall insulation and double glazing in a house.

Thermal conductivity and buildings

- The higher the **thermal conductivity** of a material, the higher the rate of energy transfer by conduction across it.
- Metals have a high thermal conductivity. Materials that trap air, such as foam, wool and fibreglass, have a low thermal conductivity, so they are good insulators.
- A building cools more slowly if its walls are **thicker** and made of a material with a **lower thermal conductivity**.

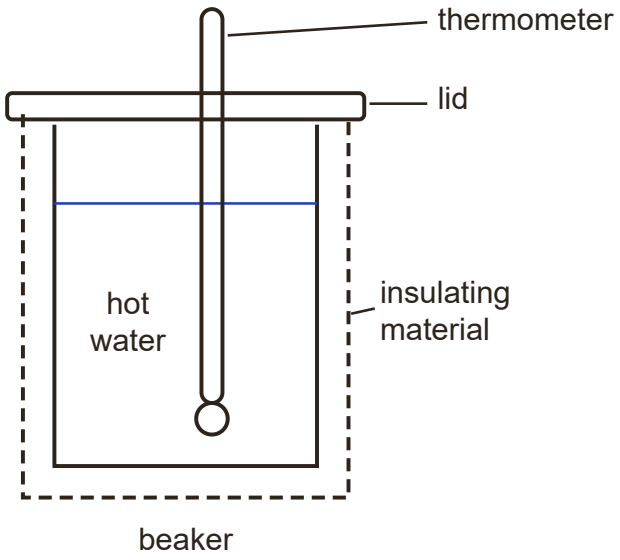


Thicker walls with a lower thermal conductivity reduce the rate of energy transfer.

- Comparing rods: heat one end of identical rods of different metals in the same way. The rod whose far end warms up fastest has the highest thermal conductivity.

Required practical: thermal insulators (GCSE Physics only)

- Put the same volume of hot water, at the same starting temperature, into identical beakers.
- Wrap each beaker in a different material of the same thickness, and put a lid on each.



Each beaker is wrapped in a different material; the one that cools least is the best insulator.

- Measure the temperature of the water with a thermometer at the start and again after a fixed time, e.g. 10 minutes.
- The best insulator is the one where the water cools the least in the same time.
- To test thickness, use different numbers of layers of the same material.

How to answer each type of question

Describe how energy is wasted 2 to 3 marks **Grade 4**

1. Identify the useful energy transfer first, e.g. to the kinetic store of the fan blades.
2. Name the cause of the waste: friction, air resistance, the current heating wires, or sound.
3. Say where the energy ends up: the thermal store of the surroundings.

Example. An electric fan is designed to transfer energy to the kinetic store of its blades. Describe how some of the energy supplied to the fan is wasted.

Model answer. Friction in the motor and bearings heats them (1), so energy is dissipated to the thermal store of the surroundings (1). Some energy is transferred to the surroundings as sound (1).

Explain how a change reduces wasted energy

2 marks | Grade 5

1. Say what the change does: reduces friction, or reduces the rate of energy transfer by heating.
2. Say the result: less energy is dissipated to the surroundings.

Example. A cyclist puts oil on the chain of her bicycle.
Explain how this reduces the energy wasted as she cycles.

Model answer. The oil lubricates the chain, reducing the friction between the chain and the gears (1). So less work is done against friction, and less energy is dissipated to the thermal store of the chain and the surroundings (1).

Explain how walls affect the rate of cooling

3 marks | Grade 6

1. Compare thermal conductivity: lower conductivity means a lower rate of energy transfer.
2. Compare thickness: thicker walls lower the rate of energy transfer.
3. Conclude which building cools more slowly, using the word 'rate'.

Example. Two houses are the same except for their outside walls. House A has walls of material X that are 20 cm thick. House B has walls of material Y that are 30 cm thick. Material Y has a lower thermal conductivity than material X.
Explain which house will cool down more slowly on a cold night.

Model answer. Material Y has a lower thermal conductivity, so the rate of energy transfer by conduction through house B's walls is lower (1). House B's walls are also thicker, which lowers the rate of energy transfer further (1). So house B cools down more slowly (1).

6-mark: describe how to compare thermal insulators (required practical) 6 marks **Grade 5**

1. Name what you change (the material) and what you measure (the temperature drop).
2. Say what you keep the same: volume and starting temperature of the water, thickness of material, time, lid.
3. Name the instruments: thermometer, stopwatch, measuring cylinder.
4. Say how you decide the best insulator: the smallest temperature drop in the same time.

Example. Describe a method a student could use to compare how well three different materials work as thermal insulators.

Model answer.

Marked by levels. A full answer could include:

use a measuring cylinder to pour the same volume of hot water into three identical beakers

wrap each beaker in a different material of the same thickness, with a lid on each

measure the starting temperature of the water with a thermometer, making it the same each time

start a stopwatch and measure the temperature again after 10 minutes

work out the temperature drop for each material

the best insulator gives the smallest temperature drop

Top level (5 to 6 marks): a clear, ordered method that controls variables and says how the materials are compared.

Don’t lose marks

- Saying energy is 'lost' or 'used up' without saying that it is dissipated to the surroundings.
- Saying insulation 'stops' energy transfer. It reduces the rate of energy transfer.
- Writing 'insulation keeps the cold out'. Energy is transferred from the warm inside to the cold outside.
- Confusing thermal conductivity (how fast energy passes through a material) with specific heat capacity (the energy needed to warm it up).
- In the practical, not keeping the volume, starting temperature and thickness the same.

More tips

Memory tricks

- Energy never disappears: if it is not useful, it has usually gone to the thermal store of the surroundings.
- Low thermal conductivity = good insulator.
- 'Thick and low': thicker walls and a lower thermal conductivity both slow down cooling.
- Most good insulators trap air, which has a very low thermal conductivity.

Exam technique

- Use the key words: dissipated, wasted, thermal store of the surroundings, rate of energy transfer.
- When comparing materials or walls, use comparative words (higher, lower, thicker, faster) and say which is better.
- In a closed-system question, say that the total energy stays the same even though energy moves between stores.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 3 — **State the law of conservation of energy**
Energy can be transferred usefully, stored or dissipated, but cannot be created or destroyed.

Grade 4 — **Give examples of energy being dissipated**
Friction heats moving parts, air resistance heats the air, and a motor makes sound.

Grade 5 — **Explain how lubrication reduces wasted energy**
Oil reduces friction between moving parts, so less energy is dissipated by heating.

Grade 5 — **Explain how insulation reduces energy transfer**
Thermal insulation lowers the rate of energy transfer by heating, e.g. loft insulation in a house.

Grade 5 — **Plan the thermal insulation practical**
Compare how fast hot water cools when wrapped in different materials, keeping the other variables the same.

Grade 6 — **Link thermal conductivity to rate of transfer**
The higher the thermal conductivity, the higher the rate of energy transfer by conduction through a material.

Grade 6 — **Describe how walls affect a building's cooling**
Thicker walls made of a material with a lower thermal conductivity make a building cool more slowly.

Free notes, Full packs, practice papers and mock exams at chhetriacademy.com. Written for this site; not taken from past papers. Stuck? 1-to-1 tutoring with a free 30-minute trial lesson.