Science 7–8

Chapter 16 — Physical sciences B: energy, transfer and efficiency

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Contents

Forms of energy — thermal, chemical, gravitational and elastic — classified as kinetic or potential, and traced through a transformation

What we teach here — `VC2S8U15` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *"energy exists in different forms, including thermal, chemical, gravitational and elastic, and may be classified as kinetic or potential; energy transfers (conduction, convection and radiation) and transformations occur in simple systems and can be analysed in terms of energy efficiency"* **This subtopic owns the first limb**: the forms of energy — thermal, chemical, gravitational and elastic — classified as kinetic or potential, and energy transformations in simple systems, traced and represented with flow diagrams. The second limb — energy transfers by conduction, convection and radiation, and analysing a simple system for efficiency — belongs to the partner subtopic **16B** († split delivery, D6). 16B studies energy on the move; here we name the forms, sort them into families, and follow them through a change. **In our words:** energy is the ability to make change happen. It comes in a handful of forms, every form belongs to one of two families — kinetic (moving now) or potential (stored) — and whenever something happens, energy is changing form or moving place. Learn to name the forms and you can trace any change from start to finish, box by box. **Achievement-standard extract served here (D13):** *"They compare different forms of energy and represent energy transfers and transformations in simple systems."* This subtopic owns `VC2S8U15` and carries the extract in full; the "represent" move is exercised here with flow diagrams (the Sankey-diagram representation of transfers belongs to 16B). **Elaborations drawn on:** `VC2S8U15.E01` (relationships between kinetic and potential energy in a roller-coaster and a Newton's cradle, represented with flow diagrams), `VC2S8U15.E04` (a Rube Goldberg machine, and the energy transfers and transformations involved in it) and `VC2S8U15.E06` (energy changes in physical events — the motion of pendulums, the lifting and dropping of objects, and car accidents). **ICIP (D10):** no Aboriginal or Torres Strait Islander content is delivered here. `VC2S8U15.E05` is reserved under the ICIP decision and is not taught; see the teacher-facing note at the foot of this subtopic. **Maths interlocks (D11):** none are listed for this subtopic — the work stays qualitative. The unit of energy, the joule, is named, but no energy arithmetic is done and no formula is used (D9 keeps energy formulas out of this band). **Authored from the CD text and the elaboration contexts (D12):** the CD names the four forms and the kinetic/potential split; the three elaborations above supply the systems traced here — the roller-coaster, the Newton's cradle, the Rube Goldberg machine, the pendulum, the lifted-and- dropped object, and the car accident. The CD's transfer-and-efficiency limb is authored by 16B.

Word watch — *energy*. In everyday talk, *energy* is a feeling: *"I have no energy today"* means you feel flat. In science, energy is not a feeling, and it is not a substance you can hold, pour or see. It is a property of things — **the ability to make change happen**. A hot cup, a moving ball, a stretched band, a battery on a shelf: each one can make something change, so each one has energy. Energy is measured in **joules** (symbol J).

Word watch — *potential*. In everyday talk, *potential* means talent not yet shown — *"a potential champion"*. In physics it keeps its older sense: **stored, waiting to be used**. Potential energy is energy that is not doing anything yet — the energy of a raised book, a stretched band, a tank of fuel — but it is ready to become something the moment conditions allow.

Word watch — *transformation* and *transfer*. These two words sound alike but name different events. In a **transformation**, the form of the energy changes — stored chemical energy becomes kinetic energy in a speeding car. In a **transfer**, the form stays the same but the energy moves place — thermal energy moves from a hot cup into your cold hands. This subtopic is mostly about transformations; the ways energy transfers are the business of subtopic 16B.

Theory

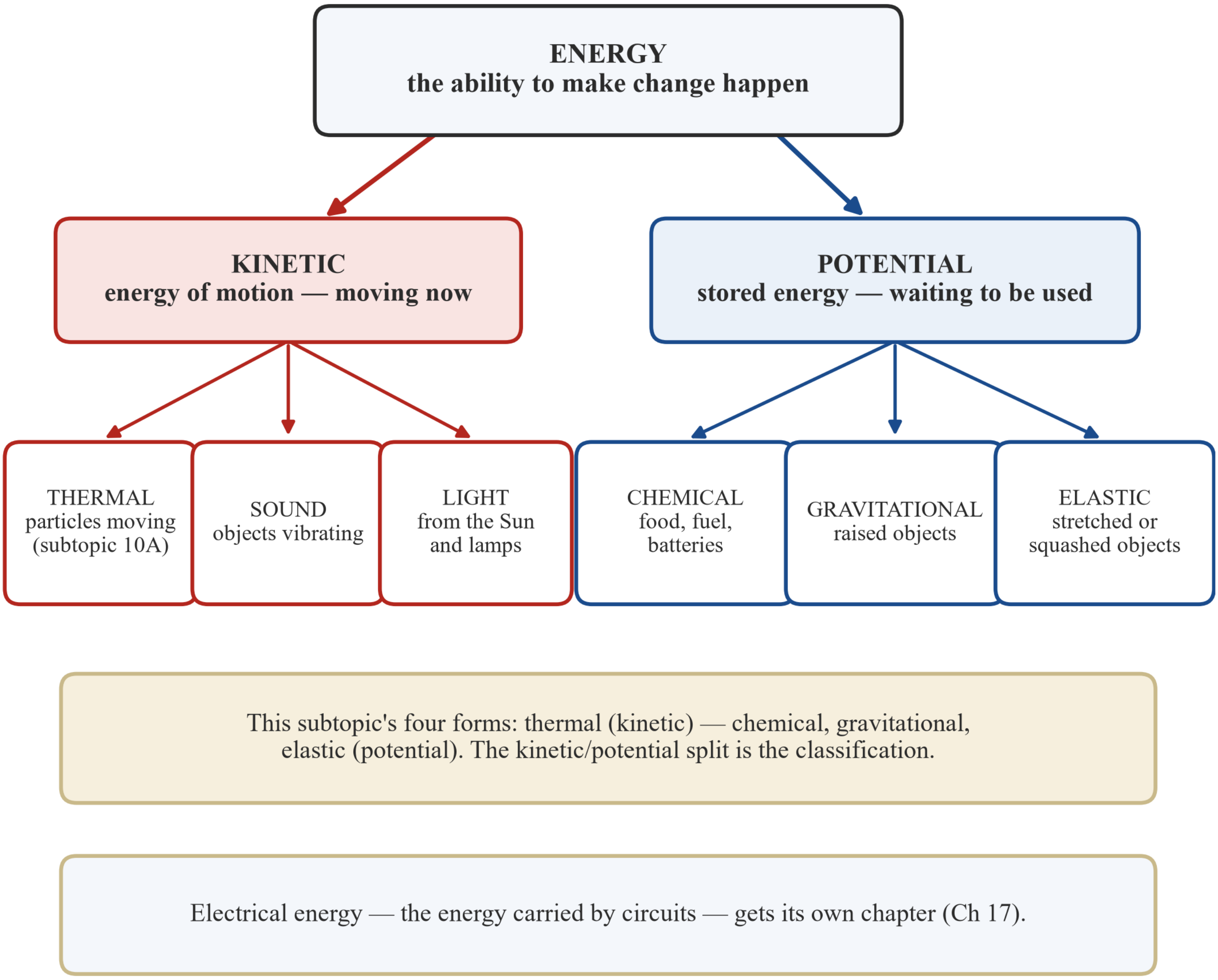
The one idea that runs the whole subtopic

Switch on a torch, drop a book, eat breakfast — in every one of these, energy is at work. Science defines energy as **the ability to make change happen**. Anything that can warm something up, set it moving, light it, stretch it or lift it has energy to give. Energy is measured in **joules** (symbol J), and one rule holds in every situation you will ever meet: **energy is never used up**. When something happens, the energy you started with is still there at the end — but it has changed form, or moved into the surroundings. The skill this subtopic builds is a tracking skill: naming the forms, sorting them into their two families, and tracing them step by step through a change.

The family tree of energy

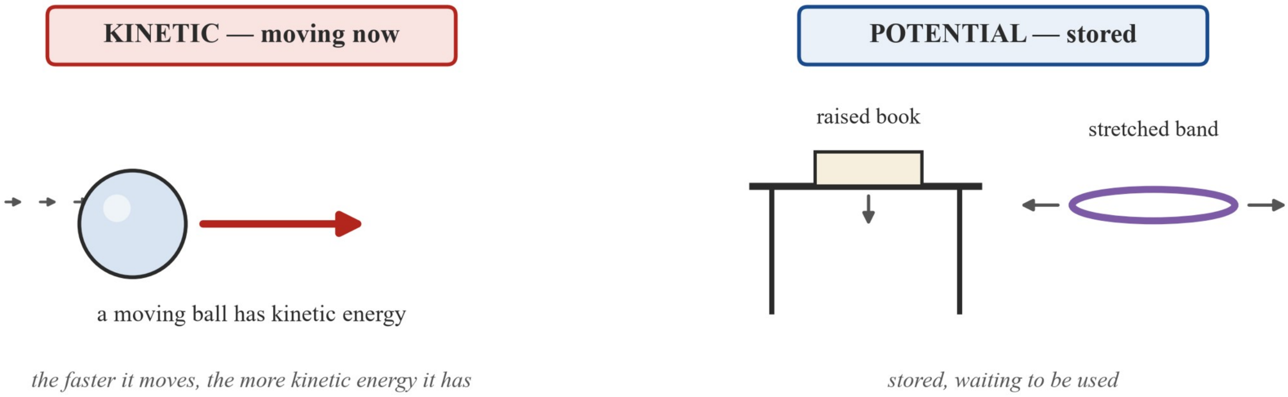
All the forms of energy sort into two families:

- **Kinetic energy** is the energy of motion — energy that is *moving now*. Anything that moves has kinetic energy: a rolling ball, a running student, the particles inside a hot cup of tea.
- **Potential energy** is stored energy — energy that is *waiting to be used*. It sits in an object because of its position or its condition: a book raised above the floor, a stretched rubber band, the fuel in a tank.



Family tree of energy: a top box reading "ENERGY — the ability to make change happen" branches into two family boxes, KINETIC (energy of motion, moving now) and POTENTIAL (stored energy, waiting to be used); the kinetic family lists thermal, sound and light, the potential family lists chemical, gravitational and elastic; a footer strip notes the four forms taught in this subtopic and that electrical energy has its own chapter

This subtopic teaches four forms in detail — **thermal**, **chemical**, **gravitational** and **elastic** — one from the kinetic family and three from the potential family. The family tree shows a few more members: sound is the kinetic energy of vibrating objects, and light reaches us from the Sun and from lamps. Electrical energy — the energy carried by circuits — is big enough to get a whole chapter of its own (Chapter 17).



The split that organises every form of energy: moving now, or stored.

Two-panel figure of the kinetic–potential split; the left panel shows a moving ball with a motion arrow, labelled KINETIC — moving now, and the right panel shows a book raised on a shelf and a stretched band, labelled POTENTIAL — stored; the caption reads "The split that organises every form of energy: moving now, or stored"

Two habits make the classification easy:

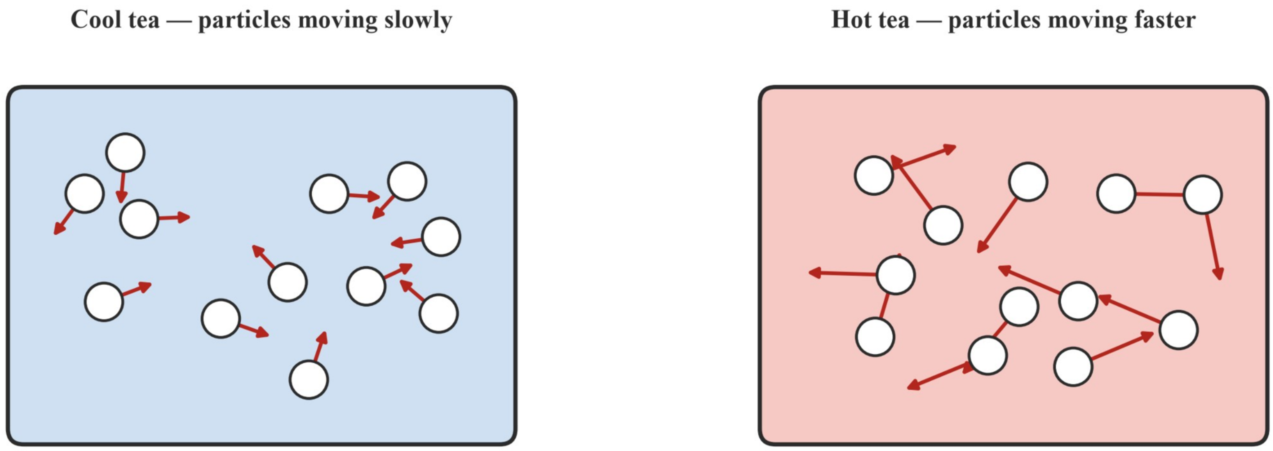
- Ask *is it moving?* If the answer is yes, you are looking at kinetic energy.
- Ask *is it stored — waiting because of where it is or how it is changed in shape?* If the answer is yes, you are looking at potential energy.

And notice the pattern hiding in the names: potential energy is always named after *what is doing the storing* — a chemical store, gravity, or something elastic. Kinetic energy is named after *what is moving* — particles, air, a ball.

Thermal energy — the energy of moving particles

Subtopic 10A built the particle model: everything is made of tiny particles, and those particles are always moving. Thermal energy is exactly that movement. **Thermal energy is the kinetic energy of particles** — so it belongs to the kinetic family.

The link to remember: **the hotter something is, the faster its particles move, and the more thermal energy it has**. A hot cup of tea holds more thermal energy than the same cup of tea after it has cooled — nothing has been poured away; the particles have simply slowed down, passing energy to the surroundings. Heating something means adding thermal energy to it, and its particles speed up.



Thermal energy is kinetic: it belongs to moving particles. Heating makes particles move faster (particle model, subtopic 10A).

Arrow length shows particle speed.

Two cups of tea drawn in the particle model; the cool cup shows particles with short speed arrows moving slowly, and the hot cup shows particles with long speed arrows moving faster; the caption notes that thermal energy is kinetic because it belongs to moving particles, and that heating makes particles move faster

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Chemical potential energy — stored in substances

Some energy is stored *inside substances themselves*, waiting for a chemical change to let it out. That store is called **chemical potential energy**, and it is the potential family's biggest everyday store. Three examples carry most of your day:

- **Food** stores chemical potential energy; your body releases it in chemical changes so your muscles can move you and keep you warm.
- **Fuels** such as petrol, gas and firewood store chemical potential energy; burning releases it as thermal energy and light.
- **Batteries** store chemical potential energy; when they are connected into a circuit, chemical changes inside release the energy to the circuit (Chapter 17).

The key idea is the same in all three: the energy sits in the substance, and it is let out when a **chemical change** happens — the starting substances become new substances (subtopic 11B). No chemical change, no release: an unlit log and an uneaten apple are both full of stored energy, doing nothing with it.

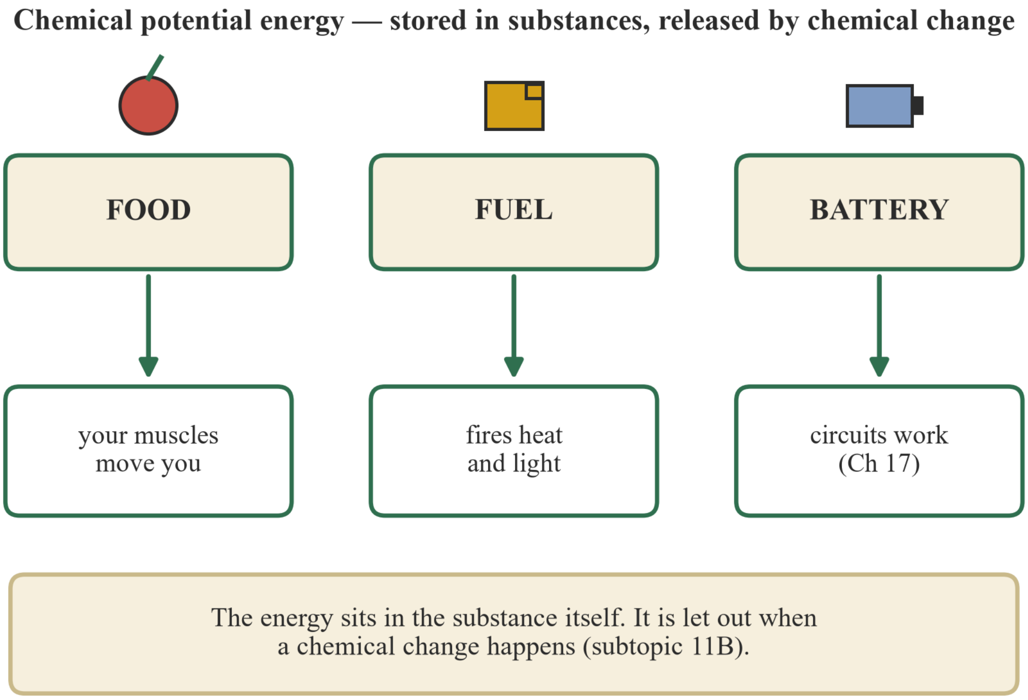

Diagram of three chemical stores labelled FOOD, FUEL and BATTERY, each with an arrow pointing down to what the released energy does — your muscles move you, fires heat and light, circuits work; a footer strip notes the energy sits in the substance itself and is let out when a chemical change happens

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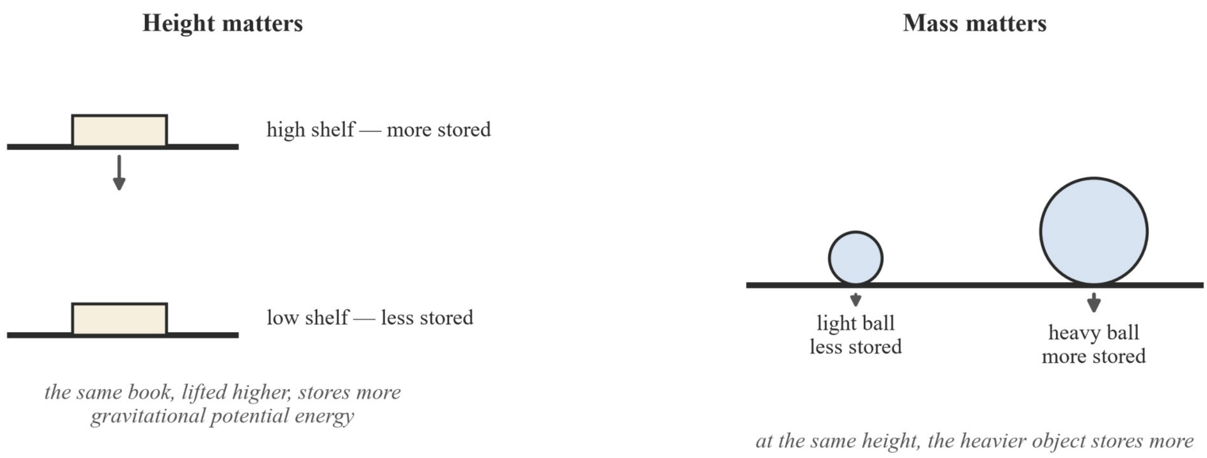
Gravitational potential energy — stored in raised objects

Subtopic 15A taught that gravity pulls every object toward Earth. Lift an object against that pull, and you store energy in it — **gravitational potential energy**. The object is not doing anything yet, but gravity is waiting: let go, and the stored energy becomes kinetic energy as the object falls.

Two things decide how much is stored, and both are simple:

- **Height.** The higher an object is lifted, the more gravitational potential energy it stores. The same book stores more on a high shelf than on a low one.
- **Mass.** At the same height, a heavier object stores more than a lighter one.

No formula is needed at this level — the pattern is qualitative: *more height, more stored; more mass, more stored.*



Gravitational potential energy: energy stored in raised objects. Gravity pulls every object toward Earth (subtopic 15A).

Two-panel figure for gravitational potential energy; the left panel, "Height matters", shows the same book storing more on a high shelf than on a low shelf, and the right panel, "Mass matters", shows a heavy ball storing more than a light ball at the same height; the caption notes that gravity pulls every object toward Earth

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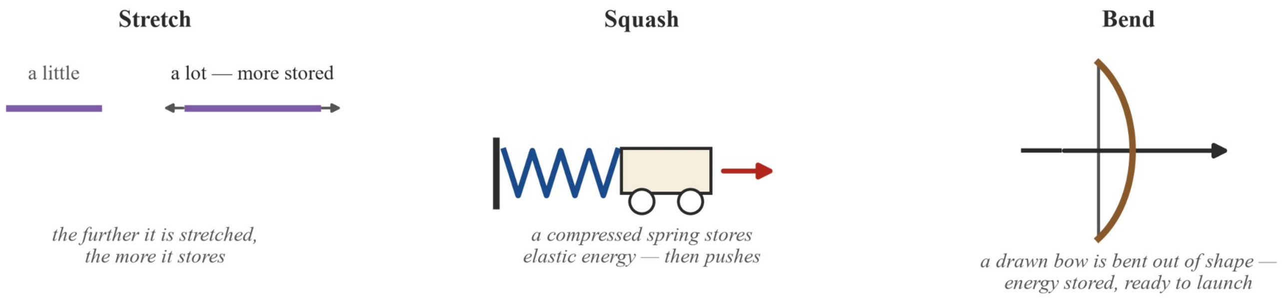
Elastic potential energy — stored in stretched, squashed and bent objects

Stretch a rubber band, squash a spring, bend a bow — each object is pushed out of its normal shape, and each one pushes back, trying to return. While it is held out of shape it stores **elastic potential energy**. Let it go, and the stored energy becomes kinetic energy: the band snaps, the spring leaps, the arrow flies.

Three ways to store it, one rule for all of them:

- **Stretch** — a rubber band or a bowstring. The further it is stretched, the more it stores.
- **Squash** — a compressed spring or a squashed ball. The harder it is compressed, the more it stores.
- **Bend** — a drawn bow or a bent diving board. The further it is bent, the more it stores.

The pattern behind all three: **the further the object is pushed out of shape, the more elastic potential energy it stores.**



Elastic potential energy: stored when objects are stretched, squashed or bent out of shape.

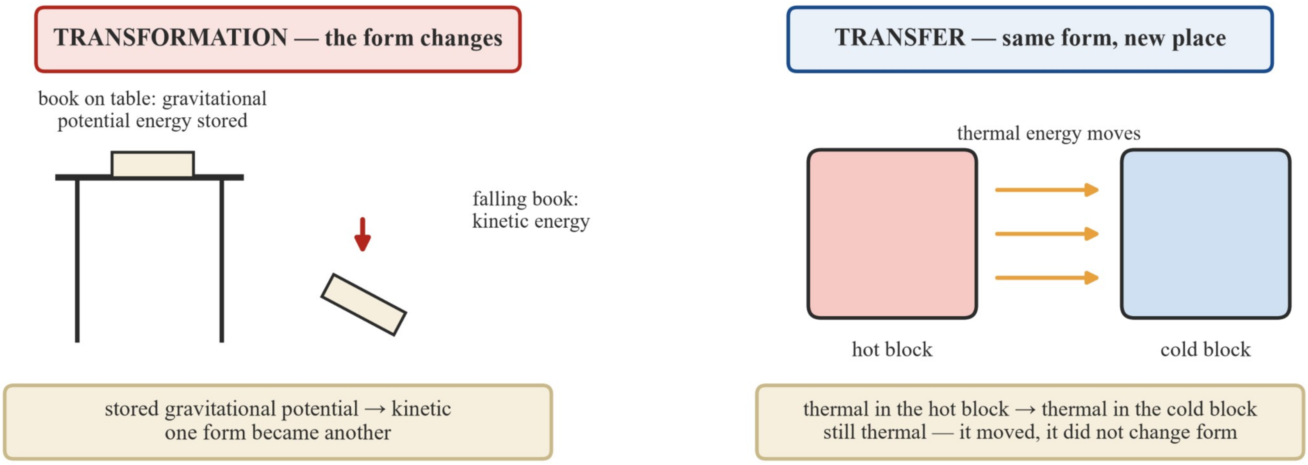
Three-panel figure for elastic potential energy; the stretch panel compares a band stretched a little with one stretched a lot, the squash panel shows a compressed spring storing energy then pushing a load, and the bend panel shows a *drawn bow bent out of shape with energy stored ready to launch; the caption reads "Elastic potential energy: stored when objects are stretched, squashed or bent out of shape"*

Transformation or transfer — know the difference

Now the two words from the word watch get their full meanings.

A **transformation** changes the *form* of the energy. Hold a book up above the floor and it stores gravitational potential energy; let it fall and, as it speeds up, that stored energy becomes kinetic energy. One form became another.

A **transfer** moves energy from place to place *without changing its form*. Touch a hot metal block to a cold one, and thermal energy moves from the hot block to the cold block — it is still thermal energy on arrival. It moved; it did not change form.



The three ways energy transfers — conduction, convection and radiation — are subtopic 16B.

Two-panel figure contrasting transformation and transfer; the transformation panel shows a book falling from a table, its stored gravitational potential energy becoming kinetic energy, and the transfer panel shows thermal energy moving by arrows from a hot block to a cold block, still thermal energy in a new place; the caption notes that the three ways energy transfers — conduction, convection and radiation — are subtopic 16B

Most real events mix the two, and tracing them is the rest of this subtopic. One honest warning before we start: in almost every real transformation, some energy ends up as thermal energy in the surroundings — rubbing, gripping and bumping all warm things slightly. That is not energy lost; it is energy spread out. Where transfers go, and how, is 16B's territory — including the three ways energy transfers (conduction, convection and radiation) and the efficiency of those transfers.

Flow diagrams — how to trace a transformation

The tool for tracing energy is the **flow diagram** (`VC2S8U15.E01`). Three rules build one:

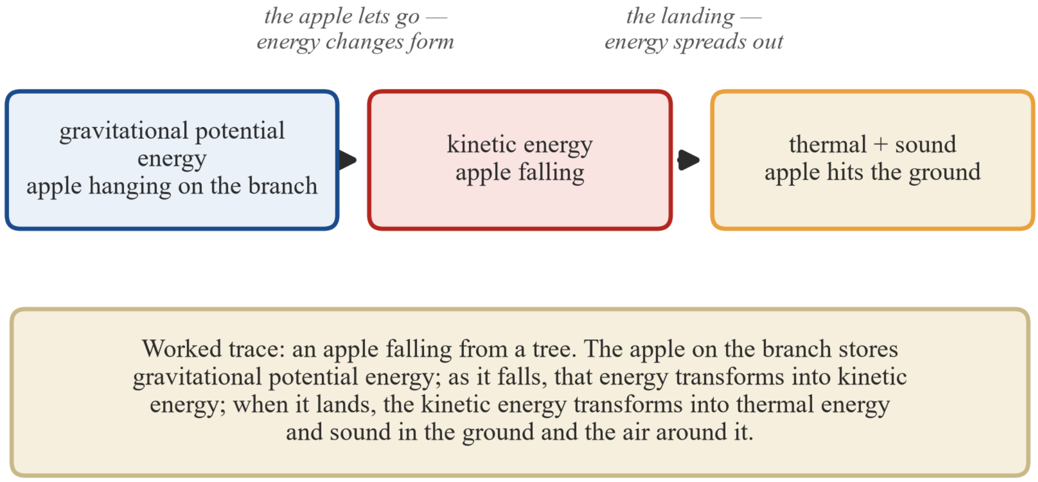
1. Each **box** is one form of energy, or one store of it.
2. Each **arrow** shows the direction the energy goes.
3. Read the chain **from left to right** — it tells the story of the change.

How to draw an energy flow diagram

1 Each box is one form of energy (or a store of it).

2 Each arrow shows the direction the energy goes.

3 Read the chain from left to right — it tells the story of the change.



How-to figure for drawing an energy flow diagram; three rules sit above a worked trace of an apple falling from a tree, in three boxes — gravitational potential energy with the apple hanging on the branch, kinetic energy with the apple falling, and thermal and sound energy as the apple hits the ground — joined by arrows, with a footer retelling the trace in words

The worked trace in the figure is the one to copy. An apple hangs on a branch: it is raised, so it stores **gravitational potential energy**. It lets go and falls: the stored energy transforms into **kinetic energy**, growing as the apple speeds up. It hits the ground: the kinetic energy transforms into **thermal energy** in the ground and the air, and into **sound**. Notice the discipline of the diagram: no energy vanishes between boxes. Whatever leaves one box arrives in the next one, in the same amount — energy is never used up, only changed or moved.

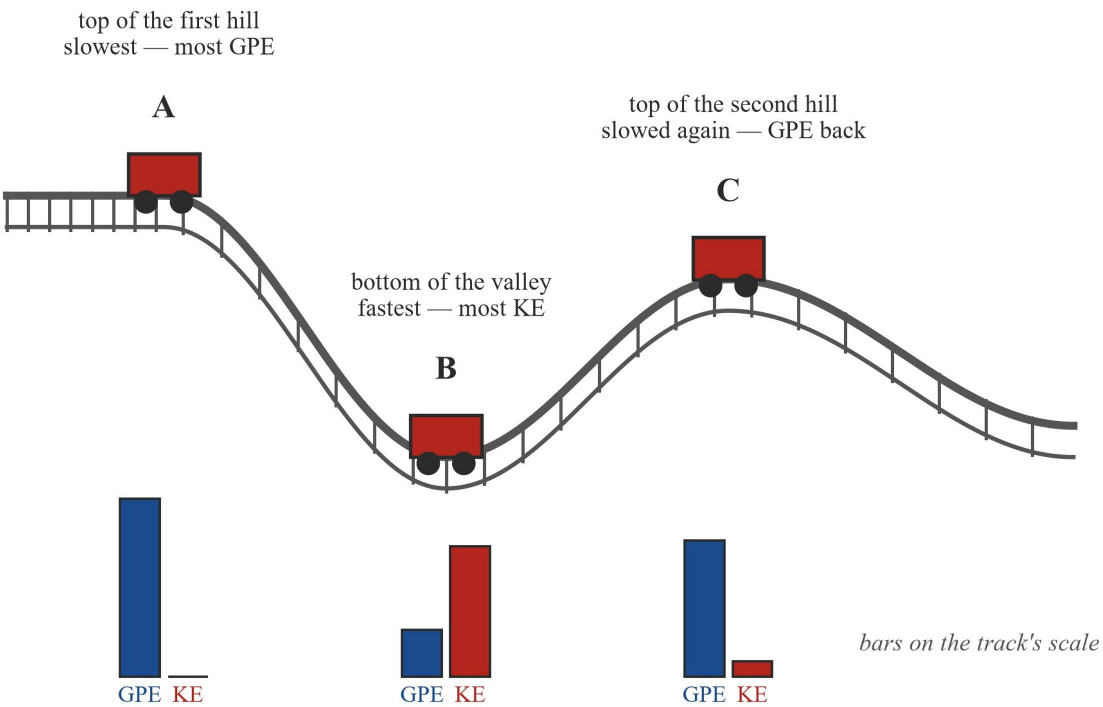
Transformations in action — the roller-coaster (`VC2S8U15.E01`)

A roller-coaster is the classic kinetic–potential swap, because it does nothing but trade height for speed and speed for height.

- At **A**, the top of the first hill, the cart is at its highest and moving slowest — it stores its **most gravitational potential energy** and has almost no kinetic energy.
- At **B**, the bottom of the valley, the cart is at its lowest and moving fastest — the stored energy has transformed into **kinetic energy**, its most of the whole ride.
- At **C**, the top of the second hill, the cart has climbed again and slowed again — kinetic energy has transformed **back into gravitational potential energy**.

The two forms keep swapping along the track, like money being paid in and out of the same account. One detail the figure makes clear: the second hill must be lower than the first. The cart can only climb as high as its stored energy allows, and by the time it reaches C some energy has already transferred to the surroundings as thermal energy through rubbing on the track.

Roller-coaster energy (VC2S8U15.E01): high place → gravitational potential; speed → kinetic. The two swap back and forth along the track.



Roller-coaster figure with a cart at three labelled positions — A at the top of the first hill, B at the bottom of the valley, and C at the top of the second hill — and a small pair of GPE and KE bars beneath each position, showing gravitational potential energy and kinetic energy swapping over and over along the track

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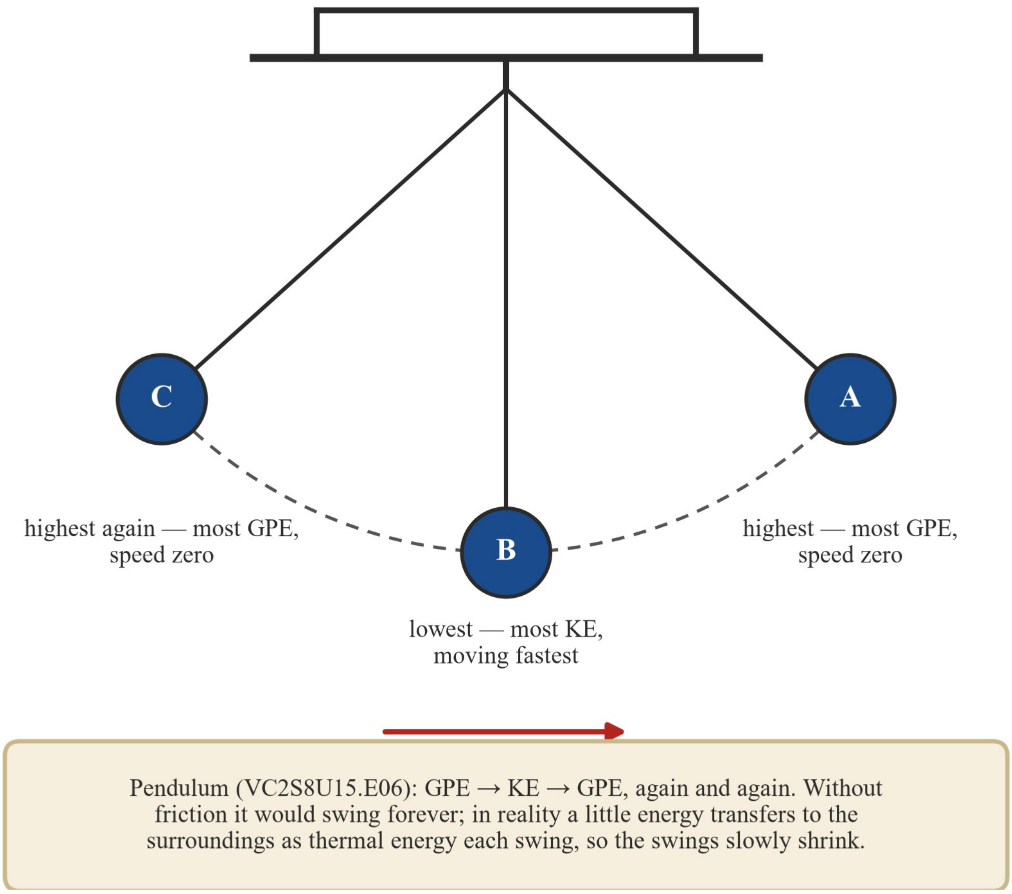
Transformations in action — the pendulum (`VC2S8U15.E06`)

A pendulum is a weight swinging on a string or rod, and it runs the same swap over and over.

- At **A**, the highest point on one side, the weight stops for a moment — speed zero, **most gravitational potential energy**.
- At **B**, the lowest point, the weight is moving fastest — **most kinetic energy**.
- At **C**, the highest point on the other side, the weight stops again — **most gravitational potential energy** once more.

Then the whole story runs backwards: C → B → A, again and again. **GPE → KE → GPE**, one full swing, repeated. In a perfect world with no rubbing at all, a pendulum would swing forever. In the real world a little energy transfers to the surroundings as thermal energy on every swing — through the air and at the pivot — so each swing reaches slightly lower than the last, and the pendulum slowly winds down. The energy has not vanished; it has spread into the air and the pivot.



Pendulum figure showing the weight at three positions — A and C at the highest points with most gravitational potential energy and speed zero, and B at the lowest point moving fastest with most kinetic energy; a footer strip traces GPE to KE to GPE and notes that a little energy transfers to the surroundings as thermal energy each swing, so the swings slowly shrink

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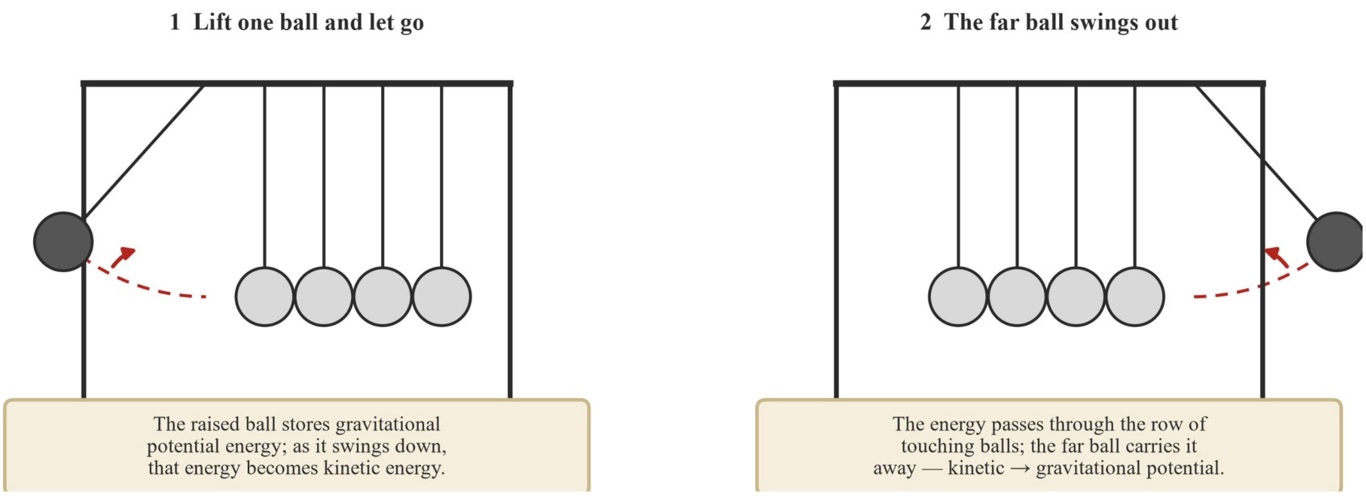
Transformations in action — Newton's cradle (`VC2S8U15.E01`)

Newton's cradle is a row of identical steel balls hanging so they just touch. Lift one ball on the end and let go, and the far ball on the other end swings out — nothing in between seems to move.

Trace the energy:

1. **Lifted ball held out:** it is raised, so it stores **gravitational potential energy**.
2. **Swinging down:** the stored energy transforms into **kinetic energy**.
3. **The strike:** the moving ball hits the row, and its kinetic energy **transfers** through the touching balls — same form, passed along the row from ball to ball.
4. **The far ball swings out:** it carries the energy away, kinetic energy transforming **back into gravitational potential energy** as it rises.

The cradle is the cleanest example in this subtopic of the transformation–transfer pair working together: transformations at both ends, a transfer through the middle.



Two-step Newton's cradle figure; step 1 shows one ball lifted and released, its stored gravitational potential energy becoming kinetic energy as it swings down, and step 2 shows the far ball swinging out as the energy passes through the row of touching balls, kinetic energy becoming gravitational potential energy again

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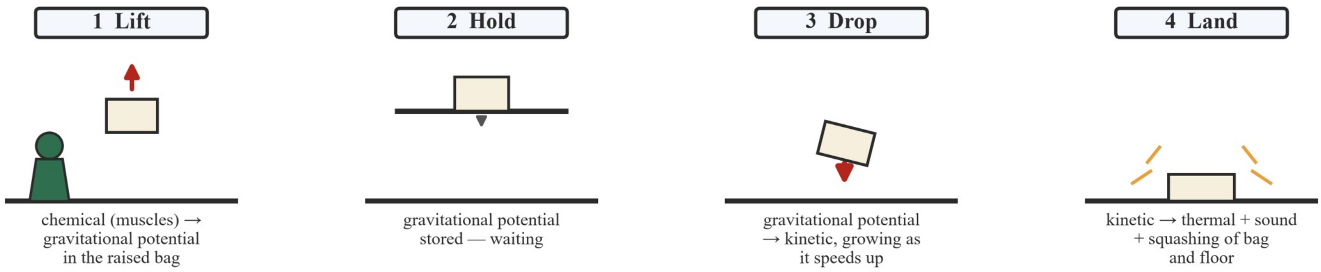
Transformations in action — lifting and dropping (`VC2S8U15.E06`)

Lift a bag, hold it, drop it. Four stages, four energy stories:

1. **Lift.** Your muscles do the lifting, and the energy comes from the **chemical potential energy** stored in your body (released from food). As the bag rises, that energy transforms into **gravitational potential energy** stored in the raised bag.
2. **Hold.** Nothing moves, but the store is full — the bag sits with its **gravitational potential energy** stored, waiting.
3. **Drop.** Let go, and the stored energy transforms into **kinetic energy**, growing all the way down as the bag speeds up.
4. **Land.** On impact, the kinetic energy transforms into **thermal energy** in the bag, the floor and the air, into **sound**, and into the squashing of the bag and floor.



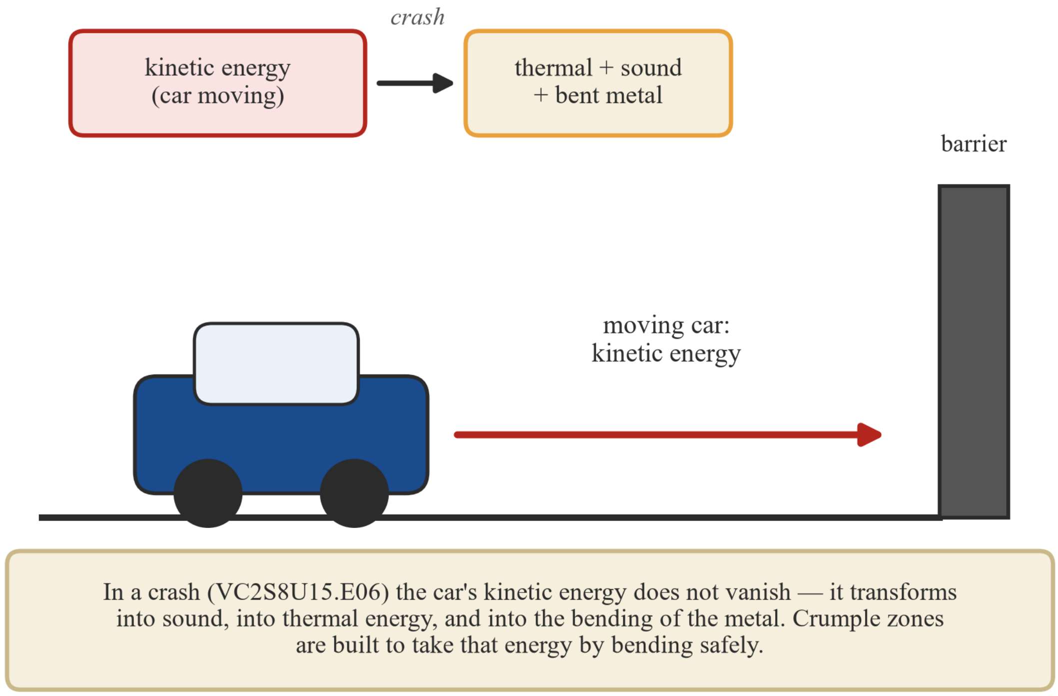
Four-panel lifting-and-dropping trace; panel 1 a person lifting a bag, chemical energy in the muscles becoming gravitational potential energy in the raised bag; panel 2 the bag held still with gravitational potential energy stored; panel 3 the bag falling, gravitational potential energy becoming kinetic energy as it speeds up; panel 4 the bag landing, kinetic energy becoming thermal energy, sound and squashing

Read the four captions in order and you have a complete flow diagram in words: **chemical → gravitational potential → kinetic → thermal** + **sound**. Every stage accounts for the energy — nothing disappears between stages.

Transformations in action — a car crash (`VC2S8U15.E06`)

A moving car has a great deal of **kinetic energy** — the more mass and the more speed, the more it carries. When the car crashes into a barrier, the car stops, but its kinetic energy cannot vanish. It transforms — into **sound**, into **thermal energy** in the metal and the air, and into the **bending and crumpling of the metal** itself.

That last destination is the one car designers work with. **Crumple zones** are sections of a car made to bend and squash in a crash — built on purpose to take the car's kinetic energy by changing shape, the way a spring does, so that less of the energy reaches the people inside.



Car-crash figure showing a moving car with kinetic energy approaching a barrier, with a two-box flow diagram above it — kinetic energy of the moving car, then, at the crash, thermal energy plus sound plus bent metal; a footer strip notes that the kinetic energy does not vanish and that crumple zones are built to take that energy by bending safely

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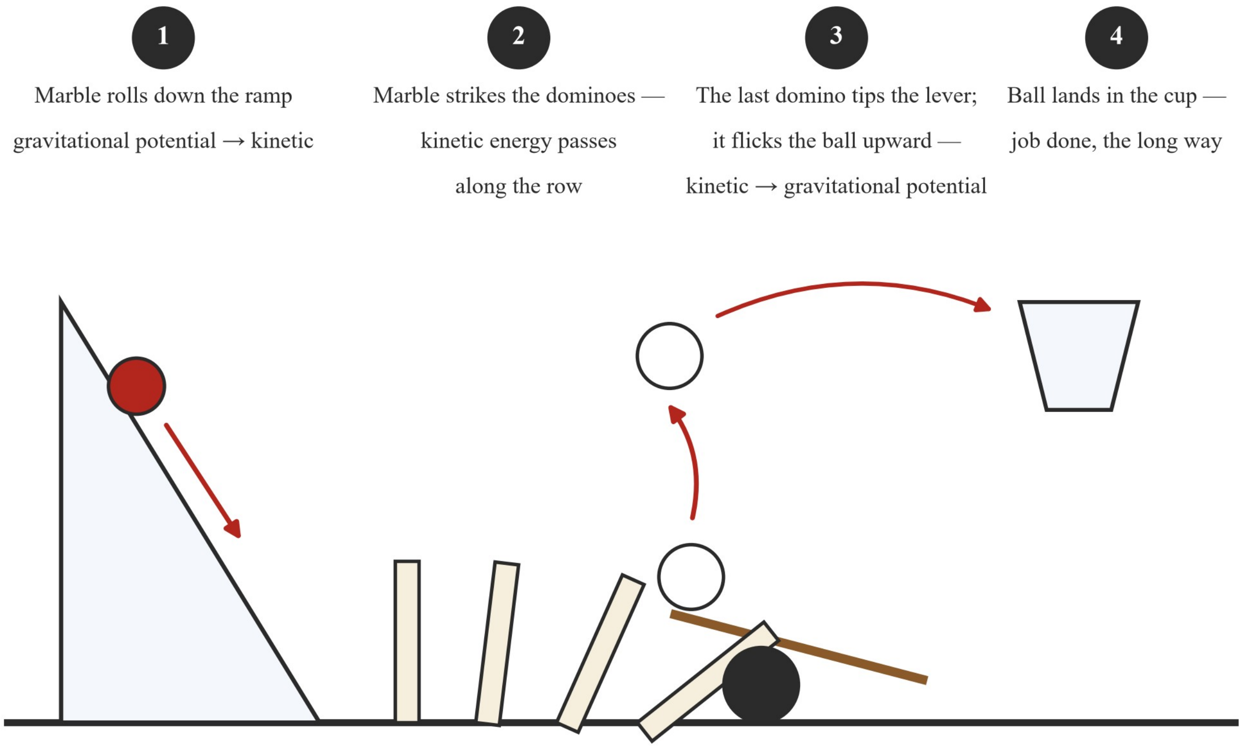
A chain of transformations — the Rube Goldberg machine (`VC2S8U15.E04`)

A Rube Goldberg machine is a chain of devices made over-complicated on purpose to do a simple job the longest way possible — rolling a ball to tip a row of dominoes to flick a lever to land a ball in a cup, where each step hands energy to the next. The job at the end is small; the physics is in every hand-over of energy along the way.

The machine below is traced stage by stage, and every stage is one of the moves you now know — a transformation, or a transfer along the chain.



A Rube Goldberg machine (VC2S8U15.E04) does a simple job the longest way possible — a chain of energy transformations.

Four-stage Rube Goldberg machine; stage 1 a marble rolls down a ramp, gravitational potential energy becoming kinetic; stage 2 the marble strikes a row of dominoes and kinetic energy passes along the row; stage 3 the last domino tips a lever that flicks a ball upward, kinetic energy becoming gravitational potential energy; stage 4 the ball lands in a cup, the job done the long way

Tracing a machine like this is the target skill of the subtopic: for every stage, name the form of energy coming in, say whether it transforms or transfers, and name the form going out. The machine is long, but the method is the one you have been using since the apple.

Try it — build a pendulum and trace its energy

You will need: about 50 cm of string, a small weight such as a metal washer or a counter, sticky tape, a ruler, and a table edge (or the back of a sturdy chair) to hang from.

1. **Build it.** Tie the weight to one end of the string. Tape the other end down to the table edge so the weight hangs down below it, clear of the table leg.
2. **Set it swinging.** Pull the weight sideways until the string is pulled tight and the weight is well above its lowest point. Let go. Watch one full swing: sideways, down through the bottom, up the other side.
3. **Trace the three positions.** At the highest points on each side, and at the bottom of the swing, decide which form of energy is greatest. Fill in the table below from your observations.
4. **Watch it wind down.** Let the pendulum swing ten times without touching it. Does it still reach the same height on each side? Measure the highest point on one side at swing 1 and again at swing 10 with the ruler.

Position of the weight	Which form of energy is greatest there?	Why?
highest point, one side		
bottom of the swing		
highest point, other side		

Check your table against the pendulum figure above — A is one high point, B the bottom, C the other high point.

Then answer:

- At which position is the kinetic energy greatest? How could you tell from watching?
- After ten swings the weight reaches a lower height than it started from. Where has that energy gone? (Hint: nothing has vanished — think about what the string rubs against, and what the air does.)
- Your pendulum swings on string tied to a table. State one way your setup differs from a clockwork pendulum swinging on a rigid rod, and say what difference that makes to the swinging.

Worked examples

Example 1 — scaffolded

Classify each item as storing **potential** energy or having **kinetic** energy, and name the form where you can.

Item	Classification	Reason
a cricket ball rolling across the ground		
an apple hanging on a branch		
a stretched rubber band		
a hot cup of tea		
a battery sitting on a shelf		

Working	Comment
Rolling cricket ball — **kinetic energy**.	It is moving now — motion is the mark of kinetic energy.
Apple on the branch — **potential**, gravitational.	It is raised above the ground; gravity is waiting. Let it fall and the stored energy becomes kinetic.
Stretched rubber band — **potential**, elastic.	It is stretched out of shape; let go and it snaps back.
Hot cup of tea — **kinetic**, thermal.	Thermal energy is the movement of particles — the hotter the tea, the faster they move. Thermal sits in the kinetic family.
Battery on the shelf — **potential**, chemical.	The energy is stored in the substances inside, waiting for a chemical change in a circuit. Nothing is moving yet.

The question to ask every time: *is it moving now, or is it stored?* Moving → kinetic family. Stored → potential family, named after what does the storing.

Example 2 — scaffolded

A child jumps onto a trampoline from a low platform, falls onto the fabric, sinks to the lowest point, then bounces back up. Complete the flow diagram: boxes 1 and 2 are done for you.

Box	Form of energy	Why
1	gravitational potential energy	the child is raised up on the platform
2	kinetic energy	the child is falling, moving faster and faster
3	?	the fabric of the trampoline is stretched at the lowest point
4	?	the child is moving upward again
5	?	the child reaches the highest point of

Box	Form of energy	Why
		the bounce

Working	Comment
Box 3 — **elastic potential energy**.	At the lowest point the fabric is stretched out of shape — stretched objects store elastic energy.
Box 4 — **kinetic energy**.	The stretched fabric pushes the child upward; the child is moving again.
Box 5 — **gravitational potential energy**.	The child is raised again, at the top of the bounce — stored, waiting for the next fall.

The completed chain: **gravitational potential → kinetic → elastic → kinetic → gravitational potential**. The trampoline swaps the energy between two potential stores — gravitational and elastic — with kinetic energy in between, exactly as the pendulum swaps between gravitational and kinetic.

Example 3 — unscaffolded

A skateboarder starts at rest at the top of one side of a half-pipe, rolls down and up the other side without pushing, and rolls back. Describe the energy changes for the trip from one top to the other, and explain why the skateboarder never quite reaches the same height on the other side.

At the top of the first side the skateboarder is at rest and raised up, so the energy is stored as **gravitational potential energy**. Rolling down, the height is lost and speed is gained, so the stored energy transforms into **kinetic energy**, greatest at the bottom of the pipe. Rolling up the other side, the skateboarder slows as kinetic energy transforms **back into gravitational potential energy**. The skateboarder does not reach the starting height because some energy transfers to the surroundings as **thermal energy** on the way — through rubbing between the wheels and the ramp, and against the air. The total energy is unchanged, but the amount still available for climbing is slightly less, so the top reached on the far side is slightly lower. ∴ the swap is GPE → KE → GPE, with a little spread into the surroundings at every stage.

Example 4 — unscaffolded

Design a Rube-Goldberg-style chain of at least three stages that ends by ringing a desk bell. Draw a flow diagram for your machine, naming the form of energy at each stage.

Answers will vary; a correct answer names a real energy form at every box, draws every arrow in the direction the energy travels, and includes at least three transformations. One working design:

gravitational potential (marble held at the top of a ramp) → **kinetic** (marble rolling down) → **kinetic** (marble strikes a lever; the energy transfers to the lever) → **gravitational potential** (the lever flicks a bead upward) → **kinetic** (the bead falls onto the bell) → **sound + thermal** (the bell rings and warms slightly).

The marking sits in the tracing: every stage names a form, every arrow points where the energy goes, and the chain never runs out of energy between boxes — whatever arrives at one stage leaves it in some form.

Practice questions

Scaffolded

Q1. Answer the following about energy. (a) What is energy, in science? (b) What is energy measured in? (c) Name the two families that every form of energy sorts into.

Q2. Classify each of the four forms taught in this subtopic — thermal, chemical, gravitational, elastic — as kinetic or potential, and give the reason for each.

Q3. Answer the following about thermal energy. (a) In the particle model, what is thermal energy the energy of? (b) What happens to the particles of a substance when it is heated? (c) Which has more thermal energy — a hot cup of tea, or the same cup of tea after it has cooled? Why?

Q4. Answer the following about chemical potential energy. (a) Where is chemical potential energy stored? (b) Give three examples of chemical stores. (c) What has to happen for the energy in a chemical store to be released?

Q5. Answer the following about gravitational potential energy. (a) Name the two things that decide how much gravitational potential energy an object stores. (b) The same book sits on a high shelf and then on a low shelf. At which shelf does it store more gravitational potential energy? (c) A light ball and a heavy ball sit at the same height. Which stores more gravitational potential energy?

Q6. Answer the following about elastic potential energy. (a) Name the three ways an object can be pushed out of shape so that it stores elastic energy. (b) How would you make a rubber band store more elastic potential energy? (c) Give one example of an object using stored elastic energy to do a job.

Unscaffolded

Q7. A pendulum swings from its highest point on one side, through the bottom, to its highest point on the other. Describe the energy changes across one such swing, and explain why the swings slowly grow smaller with time. *(2 marks)*

Q8. A roller-coaster cart runs over a first hill (position A), down into a valley (position B) and up over a lower second hill (position C). (a) At which position is the gravitational potential energy greatest, and why? *(1 mark)* (b) At which position is the kinetic energy greatest, and why? *(1 mark)* (c) Explain why the second hill must be lower than the first. *(1 mark)*

Q9. In a Newton's cradle, one ball on the end is lifted and released, and the far ball on the other end swings out. Trace the energy from the lifted ball to the swinging far ball, naming each change as a transformation or a transfer. *(2 marks)*

Q10. A student lifts a bag onto a bench, holds it there, then drops it to the floor. Trace the energy through all four stages — lift, hold, drop, land — naming the form of energy at each stage. *(3 marks)*

Q11. A moving car crashes into a barrier and stops. Explain where the car's kinetic energy goes, and say why cars are built with crumple zones that bend and squash in a crash. *(2 marks)*

Q12. Give one example of an energy transformation and one example of an energy transfer, and state the difference between the two. *(2 marks)*

Q13. A ball is tossed straight upward, rises to its highest point, then falls back down to the height it was released from. Draw a flow diagram for the ball's energy from just after it leaves the hand to just before it is caught. *(3 marks)*

Q14. Design a Rube-Goldberg-style machine that switches on a lamp, using at least three energy transformations. Draw a flow diagram for your design, naming the form of energy at every stage. *(3 marks)*

Answers

Q1. (a) The ability to make change happen. (b) Joules (J). (c) Kinetic and potential. **Q2.** Thermal — kinetic (moving particles). Chemical — potential (stored in substances). Gravitational — potential (stored in raised objects). Elastic — potential (stored in stretched, squashed or bent objects). **Q3.** (a) The movement of particles. (b) They move faster. (c) The hot cup — its particles are moving faster, and thermal energy is the kinetic energy of particles. **Q4.** (a) In substances — in food, fuels and batteries. (b) Any three of: food, petrol/gas/ firewood (fuels), batteries. (c) A chemical change — the starting substances must become new substances. **Q5.** (a) Height and mass. (b) The high shelf. (c) The heavy ball. **Q6.** (a) Stretching, squashing and bending. (b) Stretch it further. (c) Any valid example, e.g. a drawn bow launching an arrow, a compressed spring pushing a toy car, a trampoline bouncing a jumper. **Q7.** GPE (highest point) → KE (bottom, moving fastest) → GPE (highest point on the other side); the swings shrink because a little energy transfers to the surroundings as thermal energy each swing. **Q8.** (a) A — the cart is highest there. (b) B — the cart is moving fastest there. (c) Some energy has transferred to the surroundings as thermal energy through rubbing, so less stored energy remains available for the climb. **Q9.** Gravitational potential (lifted ball) → kinetic (swinging down) — transformation; kinetic energy transfers through the row of touching balls — transfer; kinetic → gravitational potential as the far ball rises — transformation. **Q10.** Lift: chemical (in the muscles) → gravitational potential. Hold: gravitational potential, stored. Drop: gravitational potential → kinetic. Land: kinetic → thermal + sound + squashing. **Q11.** It transforms into sound, thermal energy and the bending of the metal; crumple zones are built to take the car's kinetic energy by bending safely, so less of it reaches the people inside. **Q12.** Any valid pair, e.g. transformation: a falling book's gravitational potential energy becoming kinetic energy; transfer: thermal energy moving from a hot cup to your hands. The difference: in a transformation the form changes; in a transfer the form stays the same and the energy moves place. **Q13.** kinetic energy (ball moving upward) → gravitational potential energy (top of the rise) → kinetic energy (ball falling). **Q14.** Any valid design with at least three named transformations and arrows pointing the way the energy travels; see Worked Example 4 for the standard of tracing expected.

Fully-worked solutions

Q1. (a) In science, energy is **the ability to make change happen** — not a substance, but the property that lets something warm, move, light, stretch or lift something else. (b) Energy is measured in **joules (J)**. (c) The two families are **kinetic** (energy of motion — moving now) and **potential** (stored energy — waiting to be used).

Q2. Thermal is kinetic — thermal energy is the movement of particles, and movement is what makes energy kinetic. **Chemical is potential** — the energy is stored in substances and waits for a chemical change. **Gravitational is potential** — the energy is stored in raised objects, waiting for the fall. **Elastic is potential** — the energy is stored in objects stretched, squashed or bent out of shape, waiting to snap back.

Q3. (a) Thermal energy is the energy of **moving particles** — every substance is made of particles that are always moving, and their motion is the thermal energy. (b) When a substance is heated, thermal energy is added to it and its particles **move faster**. (c) The **hot cup of tea** has more thermal energy: its particles are moving faster than those in the cooled cup, and thermal energy is the kinetic energy of particles — so faster particles means more thermal energy.

Q4. (a) Chemical potential energy is stored **in substances themselves** — in what they are made of. (b) Three chemical stores: **food**, **fuels** (such as petrol, gas or firewood) and **batteries**. (c) A **chemical change** must happen — the starting substances become new substances, and that is what lets the energy out. An unlit log or an uneaten apple keeps its energy stored until a chemical change releases it.

Q5. (a) **Height** and **mass**: the higher an object is lifted and the more mass it has, the more gravitational potential energy it stores. (b) The book on the **high shelf** stores more, because it is raised higher above the ground. (c) The **heavy ball** stores more, because at the same height a heavier object stores more gravitational potential energy than a lighter one.

Q6. (a) An object stores elastic potential energy when it is **stretched**, **squashed** or **bent** out of shape. (b) **Stretch the rubber band further** — the further an elastic object is pushed out of shape, the more it stores. (c) One example: a **drawn bow** stores elastic potential energy when it is bent, and releases it as kinetic energy when the arrow flies (other valid examples: a compressed spring launching a toy car; a trampoline bouncing a jumper).

Q7. Across one swing the energy transforms from **gravitational potential energy** at the highest point (speed zero, most stored) into **kinetic energy** at the bottom (moving fastest), then back into **gravitational potential energy** at the highest point on the other side *(1 mark)*. The swings slowly grow smaller because on every swing a little energy **transfers to the surroundings as thermal energy** — through the air and at the pivot — so each swing has slightly less energy available for climbing *(1 mark)*.

Q8. (a) The gravitational potential energy is greatest at **A, the top of the first hill**, because the cart is highest there, and higher means more stored *(1 mark)*. (b) The kinetic energy is greatest at **B, the bottom of the valley**, because the stored energy has transformed into kinetic energy all the way down and the cart is moving fastest there *(1 mark)*. (c) The second hill must be lower because **some energy has already transferred to the surroundings as thermal energy** through rubbing on the track — the cart cannot climb back to the full starting height, so the second hill is built within the height the remaining stored energy can reach *(1 mark)*.

Q9. The lifted ball stores **gravitational potential energy**; as it swings down that transforms into **kinetic energy** — a **transformation** *(1 mark)*. The moving ball strikes the row, and its kinetic energy **transfers through the touching balls** from ball to ball — a **transfer**, same form, new place. The far ball carries the energy away and its kinetic energy transforms back into **gravitational potential energy** as it rises — a **transformation** again *(1 mark)*.

Q10. Lift: the energy starts as **chemical potential energy** in the student's muscles (from food) and transforms into **gravitational potential energy** stored in the raised bag *(1 mark)*. **Hold:** the bag sits with its **gravitational potential energy stored** — nothing moves, the store is full. **Drop:** the stored energy transforms into **kinetic energy**, growing as the bag speeds up *(1 mark)*. **Land:** on impact the kinetic energy transforms into **thermal energy** in the bag, floor and air, into **sound**, and into the **squashing** of the bag and floor *(1 mark)*.

Q11. The car's kinetic energy does not vanish — it transforms into **sound**, into **thermal energy** in the metal and the air, and into the **bending and crumpling of the metal** *(1 mark)*. Crumple zones are built to bend and squash on purpose so they **take the car's kinetic energy by changing shape safely**, which means less of that energy reaches the people inside the car *(1 mark)*.

Q12. Example of a transformation (any valid): a falling book — its stored **gravitational potential energy becomes kinetic energy** as it falls; the *form* of the energy changes *(1 mark)*. Example of a transfer (any valid): **thermal energy moving from a hot cup into your cold hands**; it is still thermal energy when it arrives. The difference: in a **transformation the form changes**; in a **transfer the form stays the same and the energy moves place** *(1 mark)*.

Q13. Just after the ball leaves the hand it is moving upward, so its energy is **kinetic energy** *(1 mark)*. As it rises it slows — kinetic energy transforms into **gravitational potential energy**, which is greatest at the highest point, where the ball stops for a moment *(1 mark)*. As it falls, the stored energy transforms back into **kinetic energy** all the way down to the catch *(1 mark)*. The chain: **kinetic → gravitational potential → kinetic**.

Q14. Award 1 mark for a chain of at least three stages ending with the lamp switching on, 1 mark for naming a real form of energy at every stage, and 1 mark for arrows pointing the way the energy travels. One acceptable design: **gravitational potential** (a weight held up) → **kinetic** (the weight falls and pulls a string) → **kinetic** (the string pulls the lamp's switch — the energy transfers along the string) → **electrical, then light + thermal** (the lamp switches on and glows). Other designs are correct if every stage names a form and every arrow shows the direction the energy goes.

Sources

All figures in this subtopic are qualitative illustrations: no measured data is plotted at all. The roller-coaster's energy bars are computed from the height of the drawn track, and the particle arrows show relative particle speed; both follow the drawing, not a data set.

Elaboration contexts used: `VC2S8U15.E01` (relationships between kinetic and potential energy in a roller-coaster and a Newton's cradle, represented with flow diagrams), `VC2S8U15.E04` (observing or constructing a Rube Goldberg machine and identifying the energy transfers and transformations involved) and `VC2S8U15.E06` (comparing energy changes in physical events — the motion of pendulums, the lifting and dropping of objects, and car accidents). The CD's transfer-and- efficiency limb — conduction, convection and radiation, and Sankey diagrams — is owned by subtopic 16B.

Teacher-facing note — reserved elaboration (not student text). `VC2S8U15.E05`, the elaboration that investigates traditional fire-starting methods used by Aboriginal and Torres Strait Islander Peoples and their understandings of the transformation of energy (friction methods — the fire drill, the fire plough and the fire saw — and the percussion method of striking stones to direct sparks to tinder), is reserved under the ICIP decision (D10; CONTENT_POLICY rule 1): no Aboriginal or Torres Strait Islander content is delivered in this book. The science it would exemplify — motion transformed into thermal energy by rubbing — is treated here in general contexts only: the pendulum winding down, the roller-coaster warming its track, and the Rube Goldberg chain. Source for the reserved context: Davidson, D.S., "Fire-Making in Australia", *American Anthropologist*, vol. 49, no. 3, pp. 426–437, 1947. DOI 10.1525/aa.1947.49.3.02a00040.

Energy on the move: conduction, convection and radiation, and analysing a simple system for efficiency with a Sankey diagram

What we teach here — `VC2S8U15` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *"energy exists in different forms, including thermal, chemical, gravitational and elastic, and may be classified as kinetic or potential; energy transfers (conduction, convection and radiation) and transformations occur in simple systems and can be analysed in terms of energy efficiency"* **This subtopic owns the second half of that line**: the three transfers — conduction, convection and radiation — and the analysis of simple systems in terms of energy efficiency, using Sankey diagrams and the idea of waste heat. The first half — the forms of energy and the kinetic/potential classification — belongs to the owner subtopic **16A** († split delivery, D6). 16A names and sorts the forms; here we follow the energy as it *moves*, and audit where it ends up. **In our words:** every time energy moves from a hotter place to a colder one it travels by only three pathways — handed along a substance by its particles (conduction), carried by the moving substance itself (convection), or sent out in straight rays that need no substance at all (radiation). And in nearly every transfer or transformation, some of the input ends up as thermal energy in the surroundings whether anyone wanted it or not — so an honest picture of any device always shows a waste branch. **Achievement-standard extract served here (D13):** cited by reference to the header of the owner subtopic 16A, where the extract appears in full. **Elaborations drawn on:** `VC2S8U15.E02` (using Sankey diagrams to show energy inputs, changes and outputs in a system) and `VC2S8U15.E03` (identifying where heat energy is produced as a by-product of energy transfer, such as in filament light bulbs, during exercise, and during battery charging and use). **Maths interlocks (D11):** substituting values into an everyday formula (`VC2M7A01`) and percentage of a quantity (`VC2M7N07`) carry the efficiency work here. Efficiency is worked out as a plain division and written as a percentage; no power or per-second quantities are used. **Authored from the CD text (D12):** none of the elaborations of `VC2S8U15` illustrate conduction, convection or radiation, so the accounts of the three pathways taught here are authored from the CD text itself — the CD names the three transfers and we build each one from particles or rays. The two elaborations above supply the Sankey-diagram and waste-heat contexts only. **Aboriginal and Torres Strait Islander content (D10):** none is prescribed for 16B; the fire-related elaboration context of `VC2S8U15` is authored in the owner subtopic 16A.

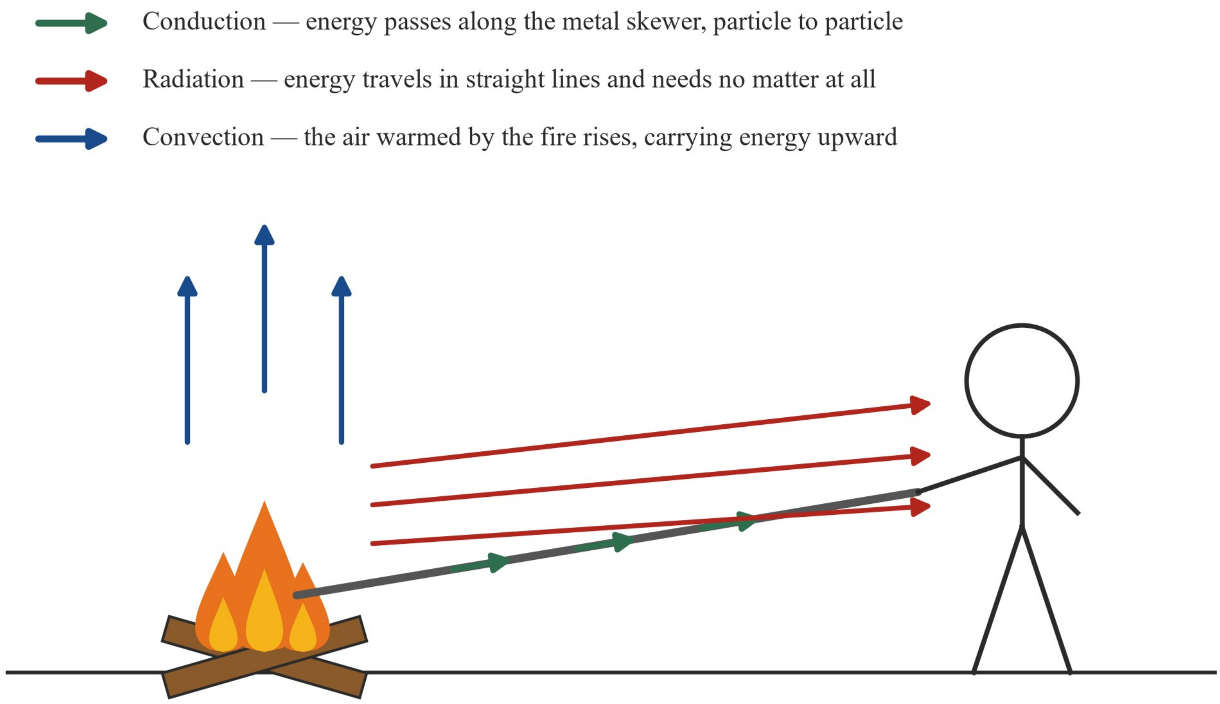
Word watch — *heat* and *thermal energy*. In everyday talk, *heat* is treated as a thing a hot object holds. In this book, the energy stored in a warm object is its **thermal energy** (16A sorts it as a form). **Heating** is the *moving* of that energy from a hotter place to a colder one. So: a cup of hot chocolate has a lot of thermal energy; your cold hands gain thermal energy by *heating* when you wrap them around the cup. The three pathways in this subtopic — conduction, convection and radiation — are the three ways heating happens.

Word watch — *waste* does not mean *destroyed*. Energy can never be destroyed, so a "waste" output on a diagram is not energy that has vanished. **Waste** means the share of the input that ends up somewhere it is not useful — almost always as thermal energy warming the surroundings. The word *lost* in "lost energy" means the same thing: lost *to usefulness*, not lost from the universe.

Theory

Three pathways out of a campfire

Stand near a campfire with a metal skewer in the flames and you can feel all three pathways at once. The handle of the skewer climbs in temperature even though your hand is far from the fire: energy is being handed along the metal, particle to particle. Your face, turned toward the flames, warms even though the air between you and the fire is not what carries it: energy is arriving in straight rays. And above the flames the air shimmers and rises, carrying energy upward: the moving substance itself is on the go. These three — **conduction**, **radiation** and **convection** — are the only pathways by which energy moves from a hotter place to a colder one, and every example of heating you will ever meet is one of the three, or a combination of them.

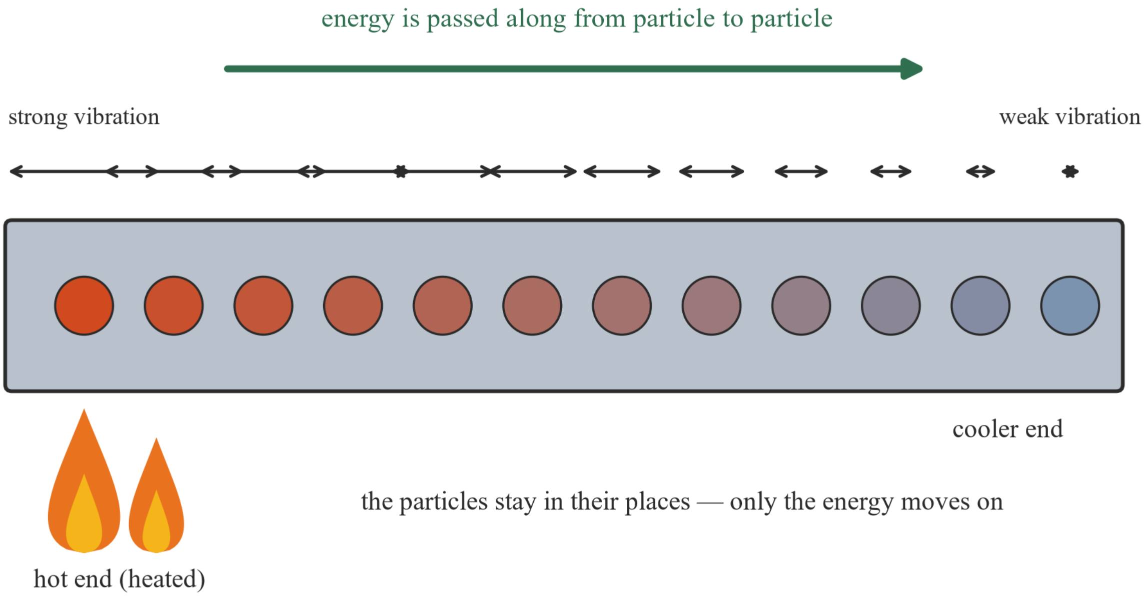


A campfire with a metal skewer in the flames and a person beside it; green arrows along the skewer show conduction handing energy from particle to particle to the hand, straight red rays from the flames to the person's face show radiation, and blue rising arrows above the flames show convection carrying energy upward in the moving air

All three pathways share one rule: they move energy **from hotter to colder**, never the other way on their own.

Conduction — energy handed along, particles staying put

In a solid, the particles are locked in place and only vibrate. When one end of a rod is heated, the particles there vibrate more strongly; they jostle their neighbours, the neighbours jostle *their* neighbours, and so the energy is handed along the rod while every particle stays in its own place. That transfer of energy through a substance, with the particles themselves staying put, is **conduction**.



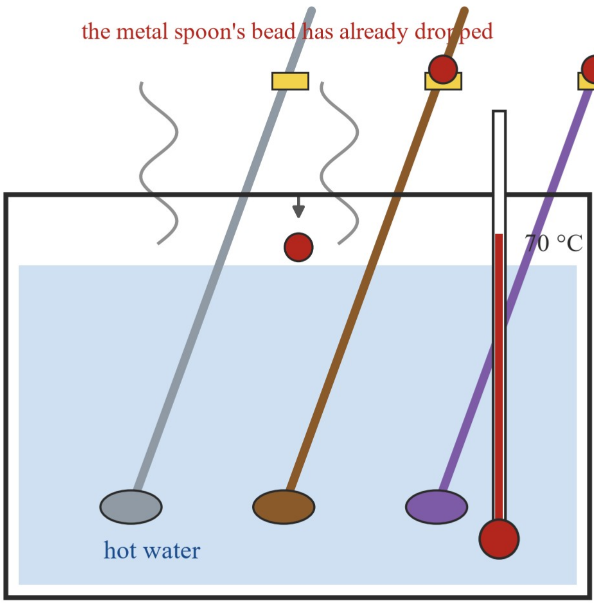
A metal rod heated at the left end, drawn with twelve particles coloured from red at the hot end to blue at the cold end; double-headed vibration arrows shrink in size from the hot end to the cold end, and a caption notes that the particles stay in their places while only the energy moves on

Some substances hand the energy along quickly and some slowly. **Metals** such as copper, aluminium and steel are **good conductors**; wood, plastic, glass and still air are **poor conductors** (often called **insulators**). That is why a saucepan has a metal body and a plastic handle, and why a metal seat buckle feels hotter than the cloth seat on the same warm day.

Try it — the spoon race (`VC2S8U15`, conduction authored from the CD text, D12)

- **Equipment:** a beaker of hot water at about 70 °C (teacher-prepared), one metal spoon, one wooden spoon and one plastic spoon of similar size, three small beads, a little butter, a thermometer, safety glasses.
- **Risk:** a low-risk activity, run with the risk-management guidance from Science ASSIST (see Sources): wear safety glasses as for any lab work, taste nothing in the lab, wipe spills straight away so nobody slips, and handle glass with care. The water is hot — let the beaker sit where it cannot be knocked, and let everything cool before packing away.

1. With a small dot of butter, stick one bead on each spoon handle at the **same height**.
2. Rest the three spoons in the beaker so all three bowls sit in the hot water, handles leaning out.
3. Watch for two or three minutes. Record the order in which the beads drop.



after a few minutes the beads on the wood and plastic spoons are still in place —
metal conducts thermal energy far better than wood or plastic

A beaker of hot water at 70 degrees Celsius with a thermometer, holding a metal, a wooden and a plastic spoon; each handle carries a bead stuck on with a dot of butter at the same height, and the metal spoon's bead has already dropped while the other two beads are still in place

What you saw	What it shows
The bead on the metal spoon dropped first	Metal hands energy along quickly — a good conductor
The beads on the wood and plastic spoons stayed put	Wood and plastic hand energy along slowly — poor conductors
All three spoons sat in the same water	The difference is the substance, not the heating

Ask yourself:

- The energy that melted the butter travelled along the handle without the handle itself moving. Which particle story above explains that?
- Why is it fairer to put all three beads at the same height than at different heights?

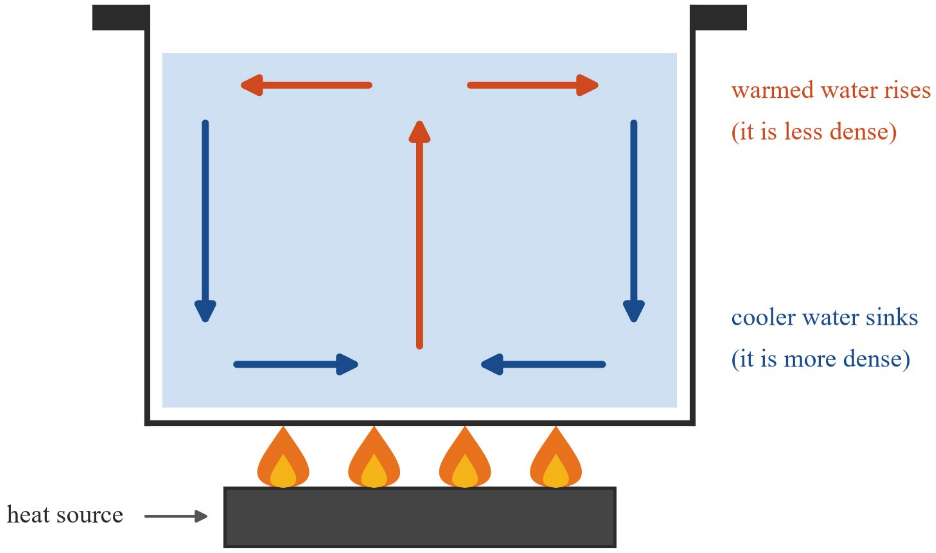
Convection — the substance itself on the move

Liquids and gases can flow, so they have a pathway solids do not: the heated substance itself can pick up and travel. Warm a pot of water from below and the water near the base warms, rises, crosses the top, cools, sinks down the sides and returns along the bottom to be warmed again — a looping current called a **convection** current. Convection is the transfer of energy by the *movement of the heated substance itself*.

Try it — watching a convection current (`VC2S8U15`, convection authored from the CD text, D12)

- **Equipment:** a deep saucepan of water, a pinch of dried tea leaves or pepper flakes, an electric hotplate (teacher-operated), safety glasses.
- **Risk:** a low-risk activity, run with the risk-management guidance from Science ASSIST (see Sources): wear safety glasses as for any lab work, taste nothing in the lab, wipe spills straight away so nobody slips, and handle glass with care. The hotplate and saucepan stay hot after switching off — the teacher switches the hotplate on and off, and everything is left to cool before packing away.

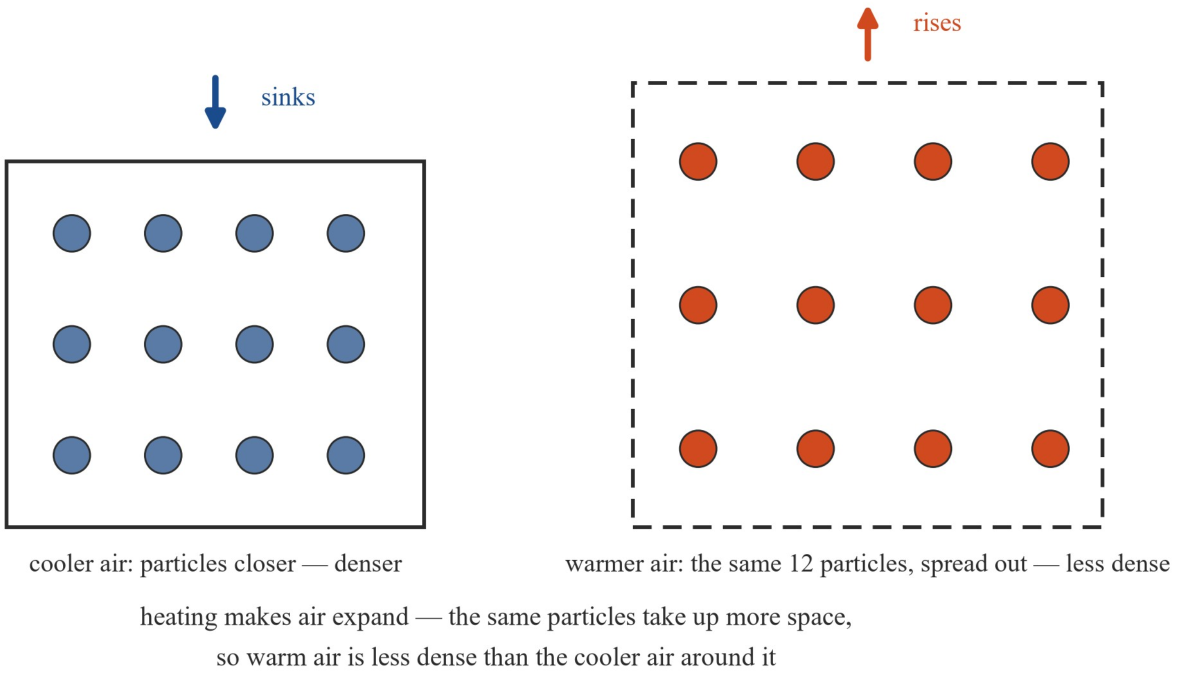
1. Sprinkle the tea leaves or pepper flakes over the water and let them settle.
2. With the teacher's help, heat the saucepan gently from the middle of its base.
3. Watch the flecks. Sketch the path they follow once the water starts to move.



A saucepan of water heated at the middle of its base; arrows show a convection loop, with water warming and rising above the heat source, crossing the top, cooling and sinking down the sides, and returning along the bottom to be warmed again

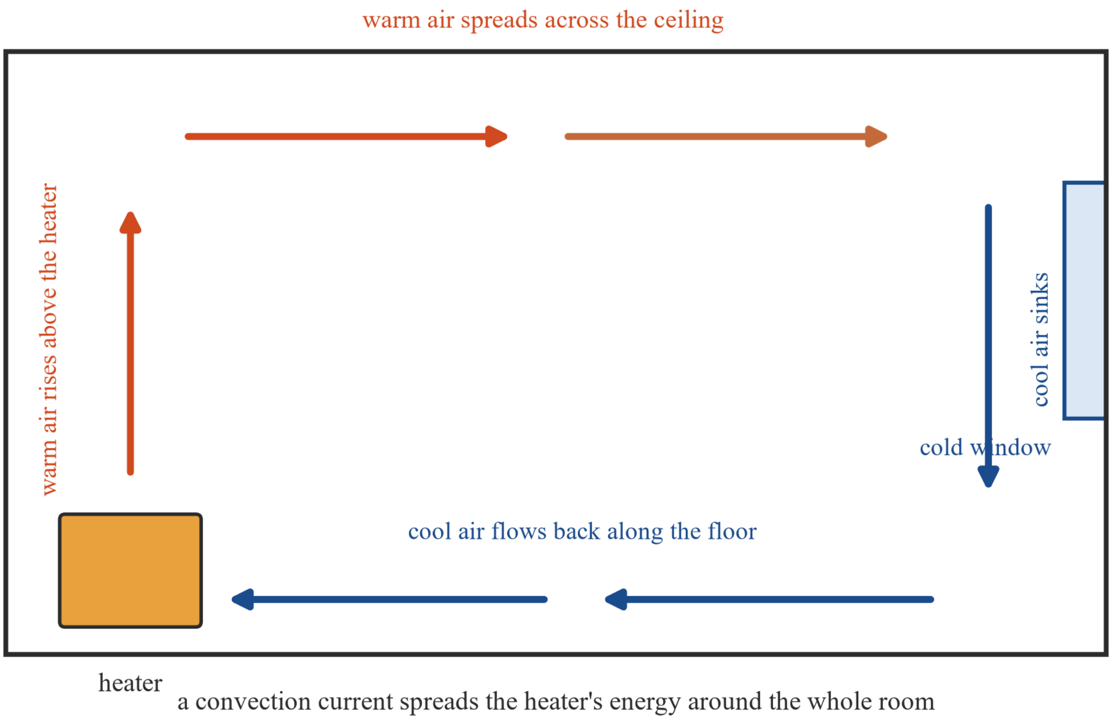
What you saw	What it shows
Flecks above the heat source rose, then crossed the top	Warmed water rises and travels
Flecks sank down the sides and returned along the bottom	Cooled water sinks and returns to be warmed
The flecks kept circling while the base was heated	Convection is a loop, not a one-way trip

Why warm air rises. The same loop runs in gases. The picture below shows the *same twelve* air particles twice: cool on the left, sitting close together, and warm on the right, jostling and spread over a bigger space. The same number of particles in a bigger space means the warm air is lighter for its size than the cool air around it, so the cool air sinks in under it and the warm air is pushed up — exactly as a cork is pushed up by the water around it. That is why heaters sit low, why freezers sit at the top of a fridge, and why the ceiling is the warmest place in a room.



Two boxes holding the same twelve air particles: in the cool box the particles sit close together and the box is labelled "sinks", while in the warm box the same particles are spread over a bigger space and the box is labelled "rises"

Put a heater in a room with a cold window and the whole room turns into one big convection loop: air warms at the heater and rises, crosses the ceiling, cools at the cold window and sinks, and returns along the floor to the heater. The room is heated the way the saucepan was — by the moving substance itself.



A room with a heater on the left and a cold window on the right; arrows show warm air rising above the heater, crossing the ceiling, cooling and sinking at the cold window, and returning along the floor to the heater as one loop

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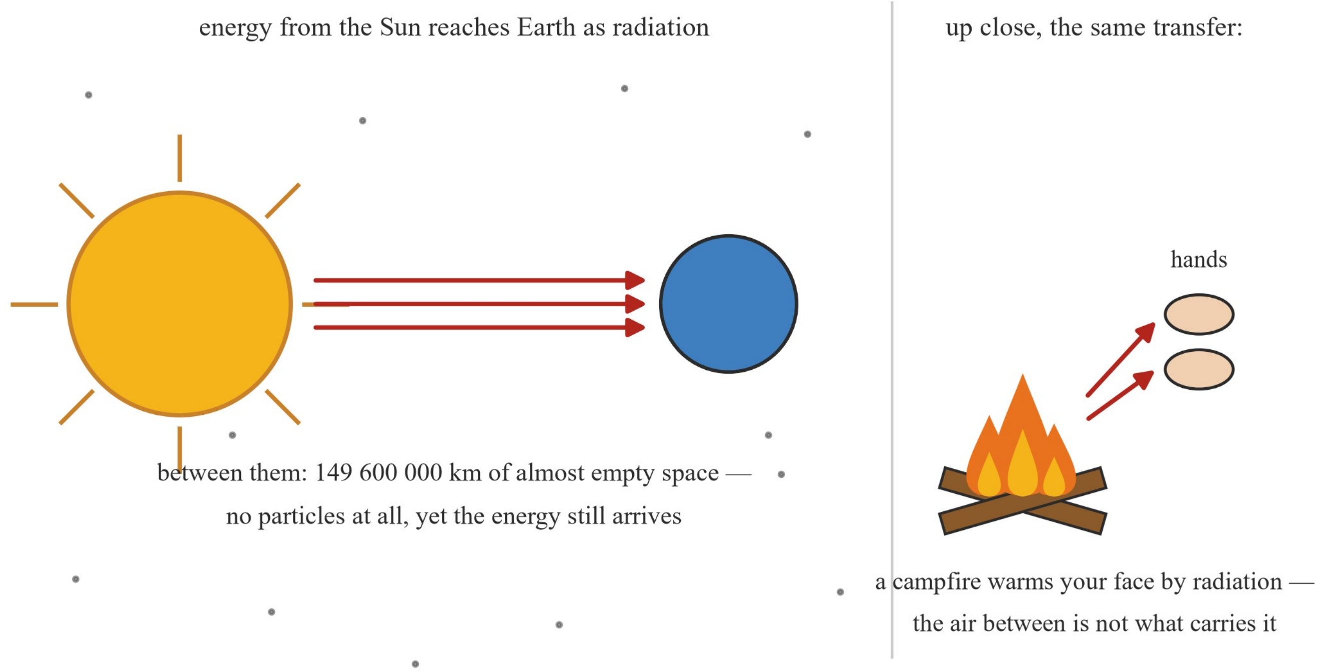
Radiation — energy that crosses empty space

Conduction needs a substance to hand the energy along; convection needs a substance to carry it. Yet energy from the Sun reaches Earth across 149 600 000 km of almost empty space — no particles at all, and still the energy arrives. The pathway that needs no substance is **radiation**: energy sent out in straight rays from a source, travelling until something in its path takes it in. Hold your hands beside a campfire — not above it — and they warm by radiation: the air between you and the flames is not what carries the energy.



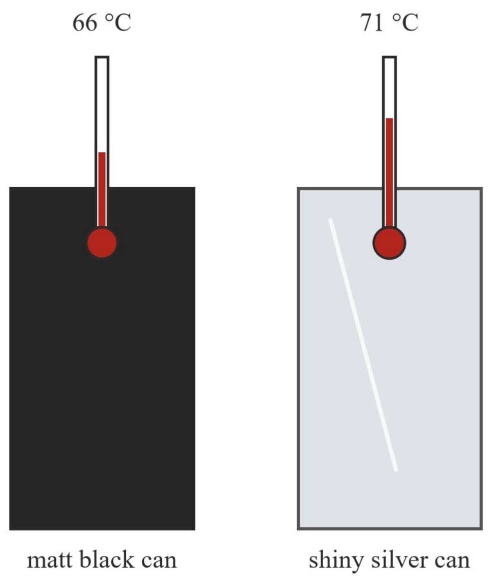
Left: the Sun and Earth drawn with straight red rays between them across 149 600 000 km of almost empty space, with a note that no particles are needed for the energy to arrive; right: a campfire warming a pair of hands by straight red rays, with a note that the air between is not what carries it

Every hot object sends energy out by radiation, and every surface takes some in. How much a surface sends or takes depends on its surface: **matt black** surfaces are the best at both giving radiation away and taking it in, while **shiny silver** surfaces are the poorest — they keep radiation off like a mirror keeps an image off.

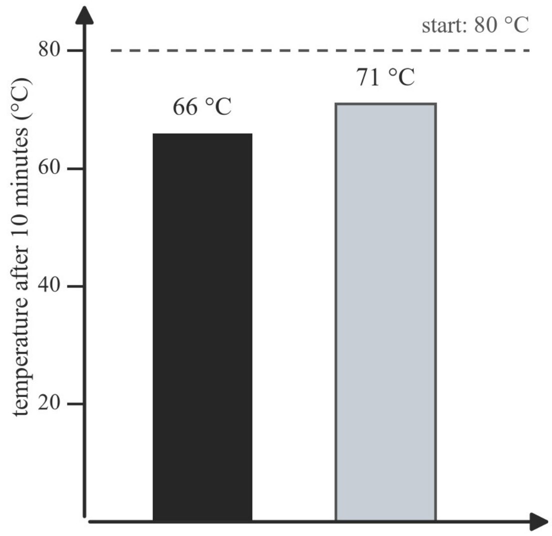
Try it — dark against shiny (`VC2S8U15`, radiation authored from the CD text, D12)

- **Equipment:** two identical cans, one painted matt black and one left shiny silver (or wrapped in foil), two thermometers, hot water at about 80 °C (teacher-prepared), a stopwatch, safety glasses.
- **Risk:** a low-risk activity, run with the risk-management guidance from Science ASSIST (see Sources): wear safety glasses as for any lab work, taste nothing in the lab, wipe spills straight away so nobody slips, and handle glass with care. The water is hot — the teacher pours it, and the cans are left to cool before packing away.

1. Fill both cans with the same volume of hot water and read both thermometers at the start (about 80 °C).
2. Record both temperatures every two minutes for ten minutes.
3. Compare your results with the pair below. Which can gave energy away faster, and by which pathway?



both cans hold the same hot water, starting at 80 °C;
after 10 minutes the matt black can has cooled more
(simulated data for practice)



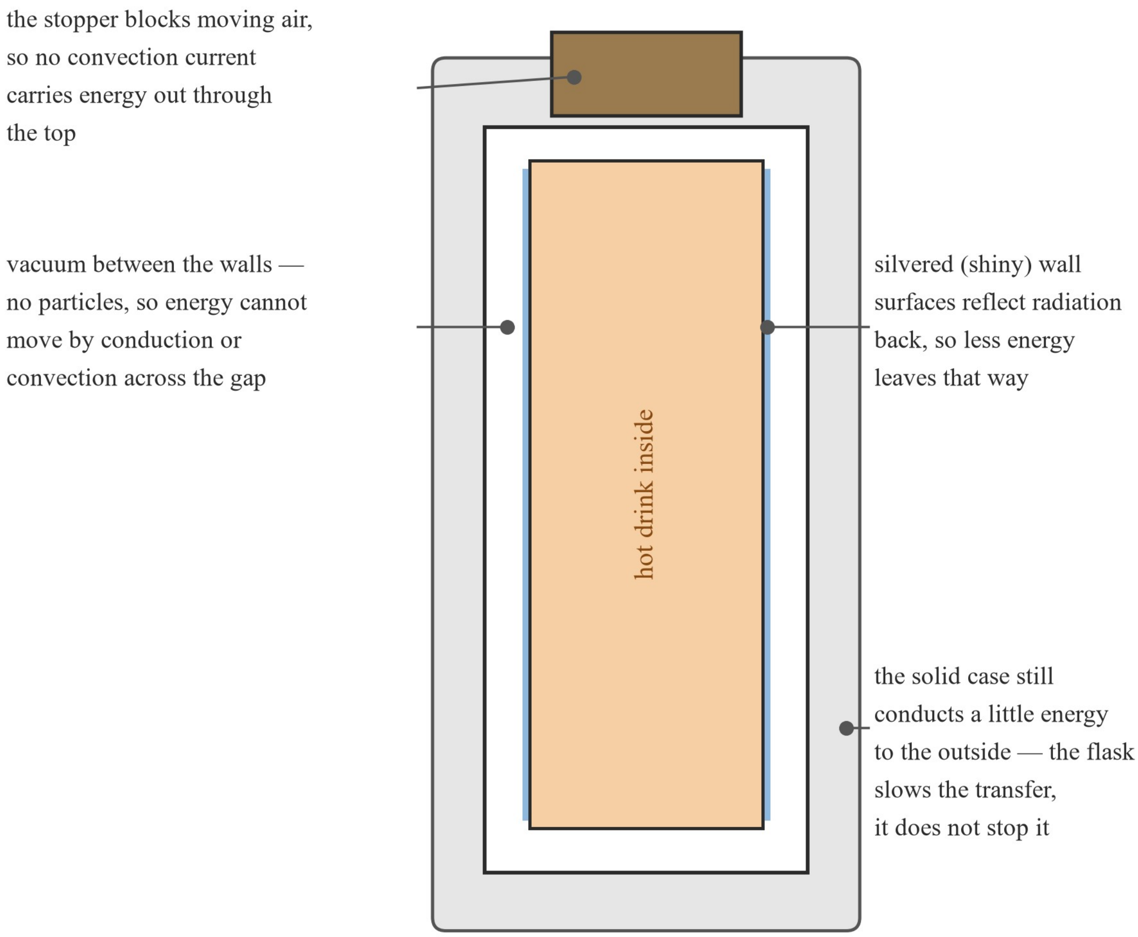
the matt black surface radiates energy away faster,
so it cools quicker than the shiny surface

Left: a matt black can and a shiny silver can, each holding the same hot water starting at 80 degrees Celsius, with thermometers reading 66 degrees Celsius in the black can and 71 degrees Celsius in the silver can after 10 minutes; right: a bar chart of the two final temperatures against the 80 degree start, showing the matt black surface radiates energy away faster than the shiny surface (simulated data for practice)

(Simulated data for practice.) The matt black can cools quicker because a matt black surface gives radiation away faster than a shiny one. The same rule works in reverse in sunlight: the black can would warm up faster, because it also takes radiation in better. Shiny silver does the opposite both ways.

Keeping energy in — the vacuum flask

A vacuum flask (like a thermos) is what you get when you block all three pathways at once, one feature per pathway.



a vacuum flask is built to slow all three pathways of energy transfer

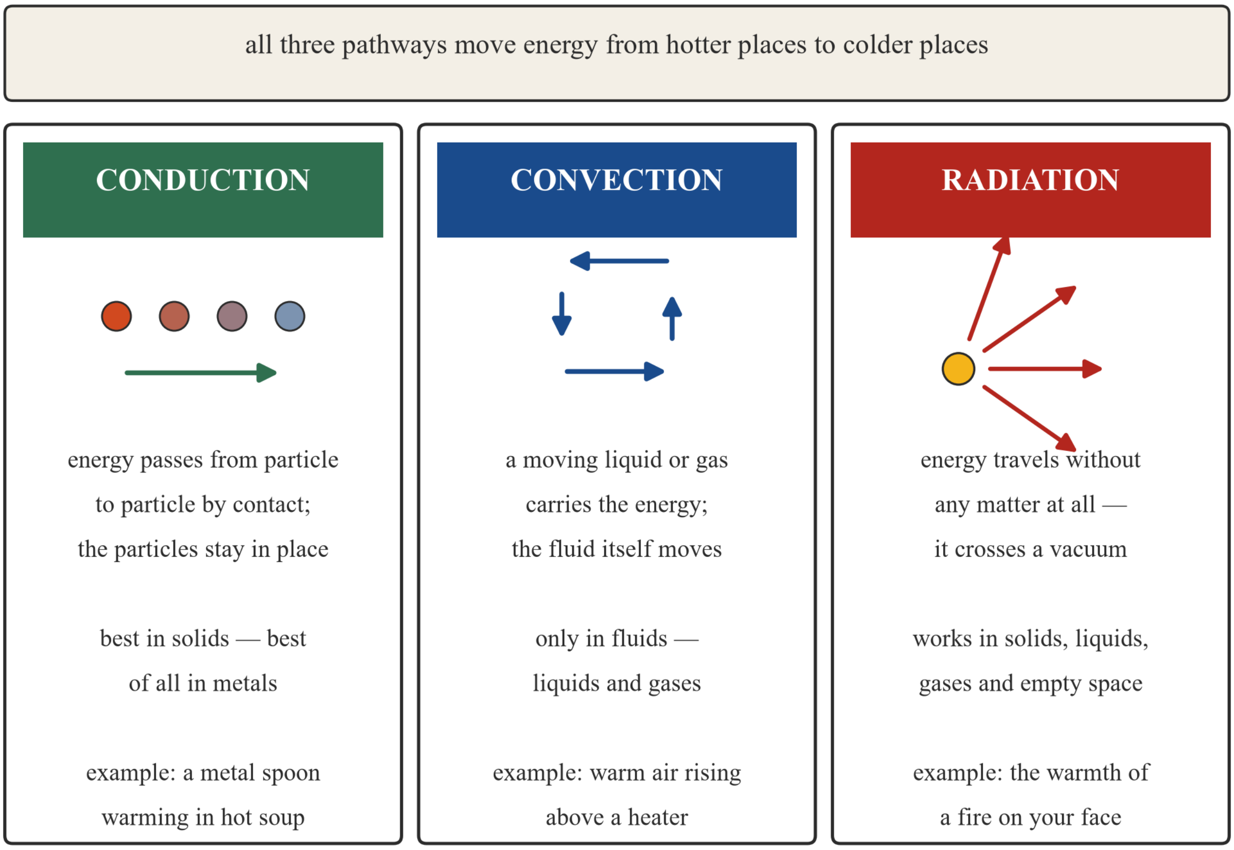
Cut-away of a vacuum flask: an outer case, an outer wall, an inner wall with silvered surfaces, a vacuum gap between the walls, and a stopper in the neck; four callouts link the vacuum gap to stopping conduction and convection, the silvered surfaces to stopping radiation, the stopper to stopping conduction and convection out of the mouth, and the case to keeping the walls safe

Feature	Pathway it blocks	How
Vacuum gap between the walls	conduction and convection	A vacuum has no particles, so there is nothing to hand energy along and nothing to carry it
Silvered surfaces on the walls	radiation	Shiny silver surfaces are the poorest at giving radiation away, so little crosses the gap
Stopper in the mouth	conduction and convection	It stops warm liquid and vapour escaping and keeps the air inside from swapping with the air outside

The flask does not “keep the cold out” or “keep the heat in” by magic — it simply closes the three doors energy can leave through. With all three closed, the drink inside changes temperature very slowly.

The three pathways in one picture

Every heating you meet is one of the three pathways or a mix of them. Sort any example by asking: is a substance handing the energy along while staying put (conduction)? Is the substance itself moving (convection)? Or is the energy arriving in straight rays, with no substance needed (radiation)?



Three panels side by side: a hand on a metal skewer in a flame with arrows along the metal for conduction, a pot of water with a circulating loop of arrows for convection, and the Sun sending straight rays to Earth for radiation; a banner across the top notes that all three pathways move energy from hotter places to colder places

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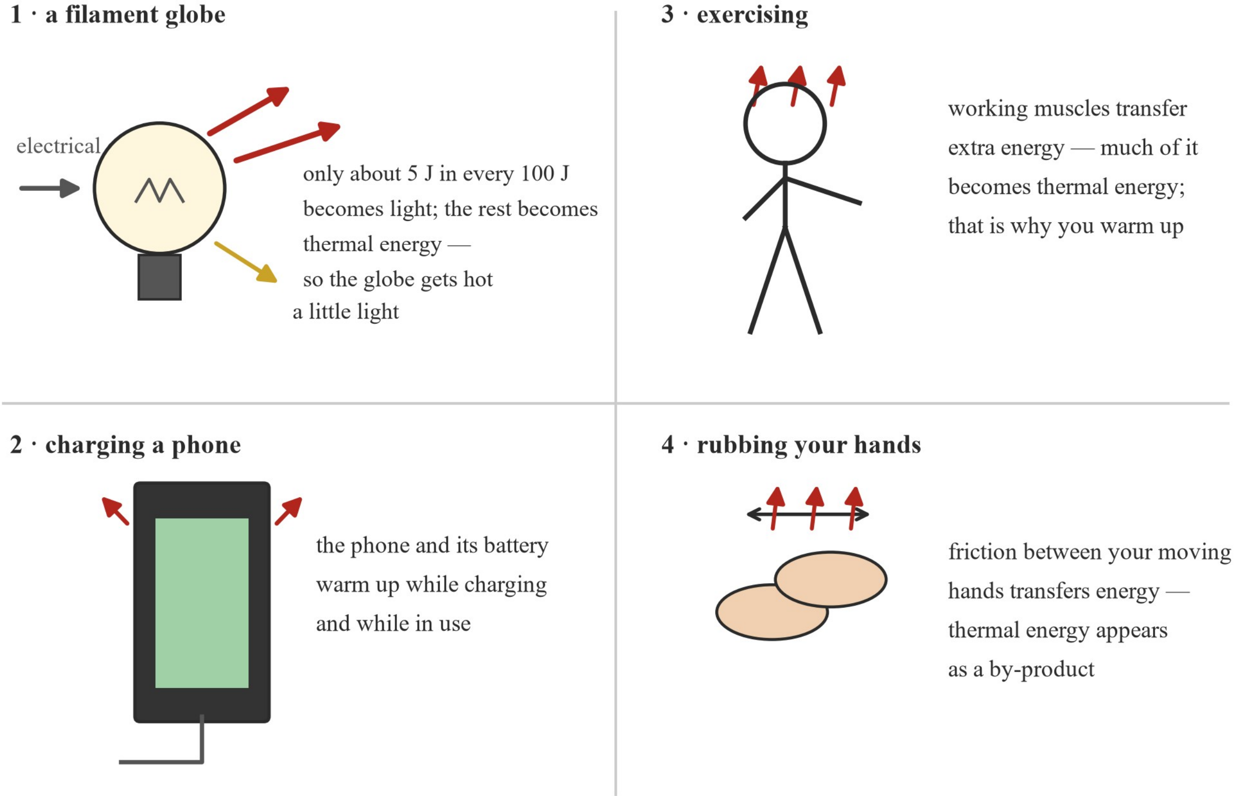
Waste heat — the by-product in almost every transfer (`VC2S8U15.E03`)

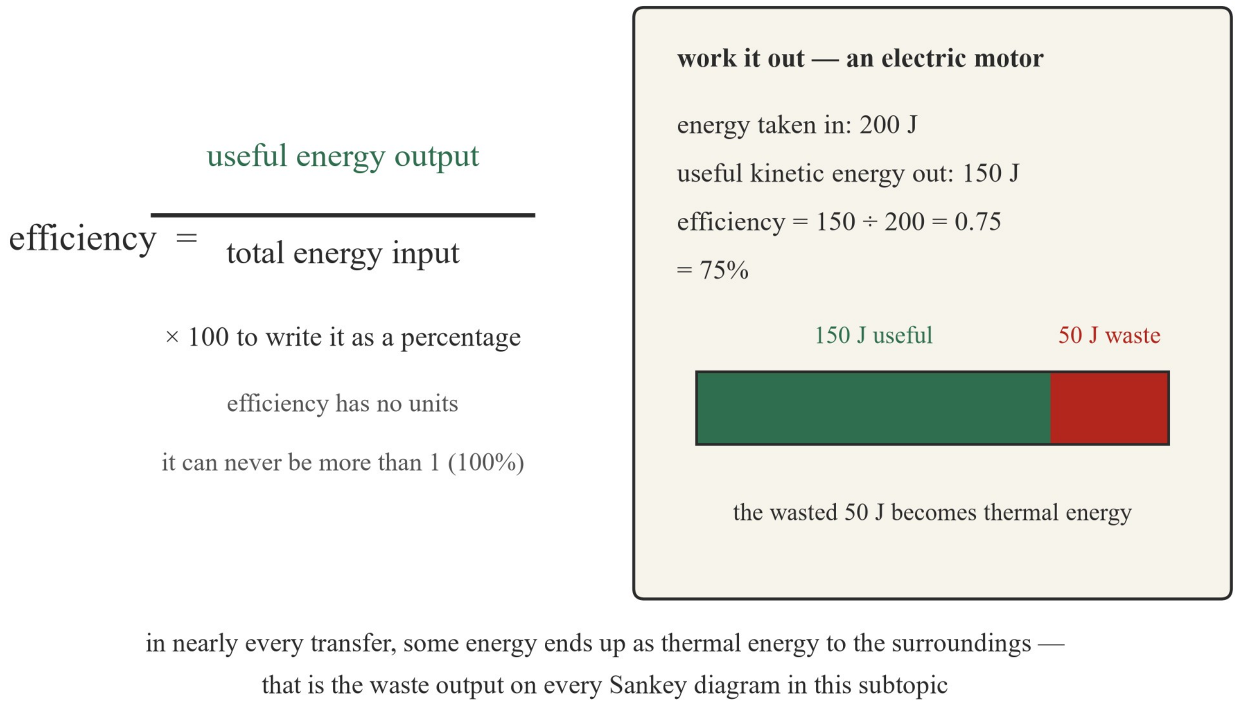
Run any device, do any activity, and look for the warmth: it is nearly always there, whether it was wanted or not. A filament globe is meant to make light, yet of every 100 J of electrical energy in, only about 5 J become light — the other 95 J or so become thermal energy, which is why the globe gets too hot to touch. A phone and its battery warm up while charging and while in use. Working muscles transfer extra energy while exercising, and much of it becomes thermal energy — that is why you warm up. Even rubbing your hands together transfers energy, with thermal energy appearing as a by-product. In each case the thermal energy is **produced as a by-product of the transfer** — an output nobody asked for, spreading out into the surroundings. That unwanted output is the **waste** branch we will draw on every diagram below.



Four panels: 1, a filament globe taking in electrical energy, with only about 5 J in every 100 J becoming light and the rest becoming thermal energy so the globe gets hot; 2, a phone and its battery warming while charging and in use; 3, a person exercising, whose working muscles transfer extra energy much of which becomes thermal energy; 4, two hands being rubbed together, with thermal energy appearing as a by-product of the friction

Efficiency — the useful share of the input

Because waste appears in nearly every transfer, we judge a device by its **efficiency**: the share of the input energy that ends up in the useful form.



The efficiency formula: efficiency equals useful energy output divided by total energy input, multiplied by 100 to write it as a percentage; notes that efficiency has no units and can never be more than 1 (100 percent); beside it, a worked box for an electric motor taking in 200 J with 150 J of useful kinetic energy out, giving efficiency 150 divided by 200 equals 0.75, or 75 percent, drawn as a bar of 150 J useful and 50 J waste

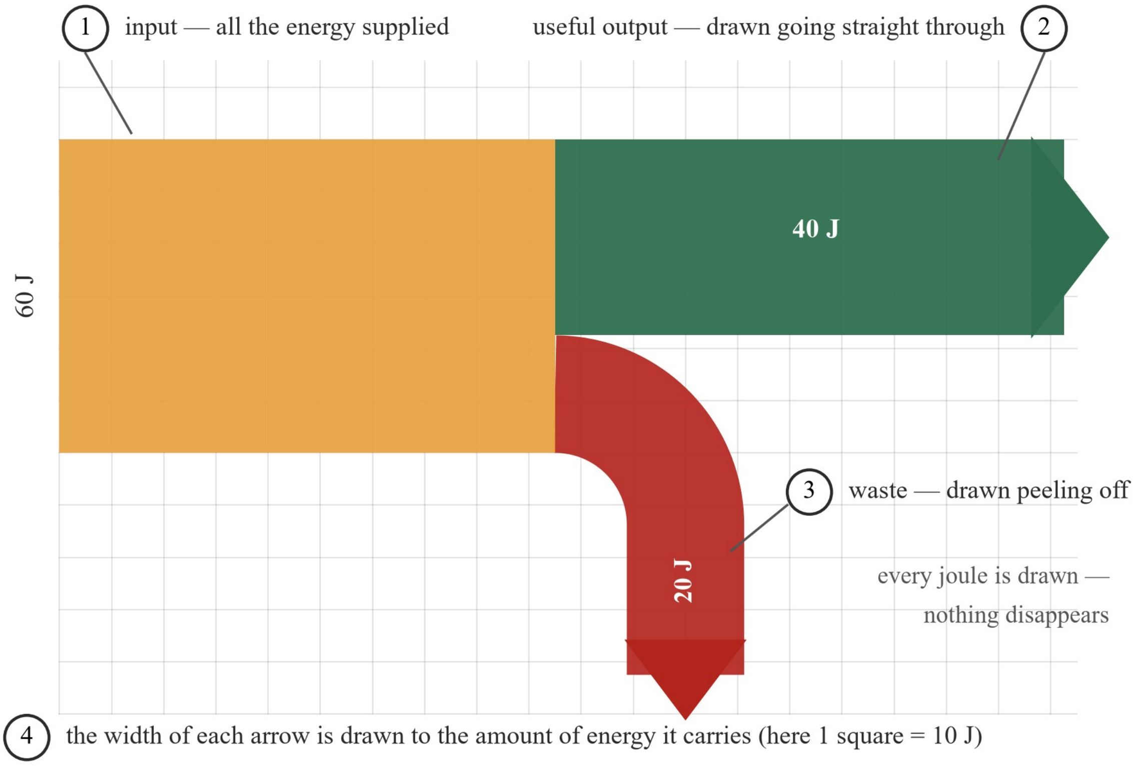
efficiency = useful energy output ÷ total energy input

With both energies in joules, the units cancel, so efficiency is a plain number between 0 and 1; multiply by 100 to write it as a percentage (substituting the values is `VC2M7A01`; writing one quantity as a percentage of another is `VC2M7N07`). No device can ever return more useful energy than it was given, so efficiency can never be more than 1 (100%) — and because waste heat appears in nearly every transfer, real devices sit well below that.

Sankey diagrams — energy drawn to scale (`VC2S8U15.E02`)

A **Sankey diagram** shows the inputs, changes and outputs of energy in a system with arrows drawn **to scale**: the wider the arrow, the more energy it carries. The diagram below accounts for a device taking in 60 J.

energy is conserved: input = useful output + waste

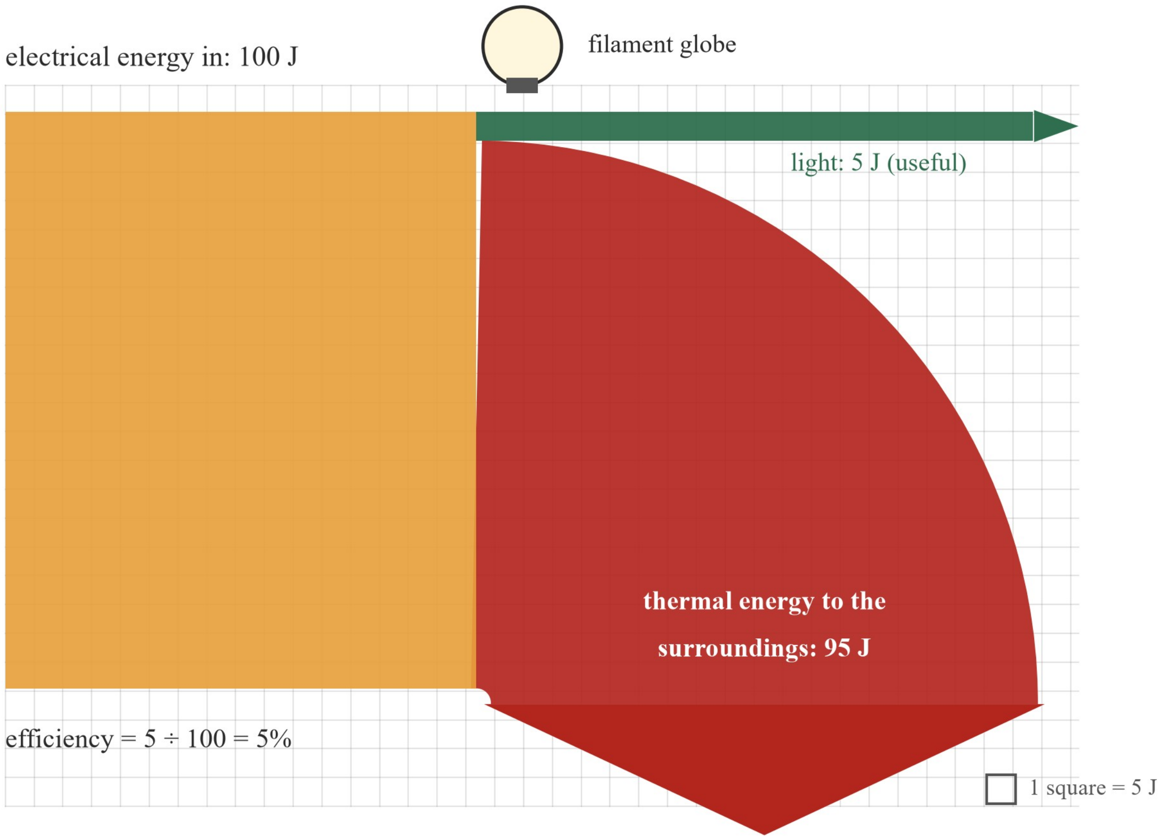


A Sankey diagram on a square grid where 1 square equals 10 J: an input arrow 6 squares wide labelled 60 J in enters a box, a useful output arrow 4 squares wide labelled 40 J useful leaves to the right, and a waste arrow 2 squares wide labelled 20 J waste bends downward; numbered features mark the input arrow, the useful arrow, the downward waste arrow and the square grid, and a caption notes that energy is conserved: input equals useful output plus waste

Four features to read in any Sankey diagram:

1. **The input arrow** carries the total energy in; its width is the whole amount.
2. **The useful output arrow** runs straight on; its width is the useful share.
3. **The waste arrow** bends away (down, by house habit); its width is the wasted share, almost always thermal energy to the surroundings.
4. **Widths are proportional.** On the grid above, 1 square = 10 J, so 60 J in is 6 squares wide, 40 J useful is 4 squares, and 20 J waste is 2 squares. Because energy is never destroyed, the widths must balance: **input = useful output + waste**.

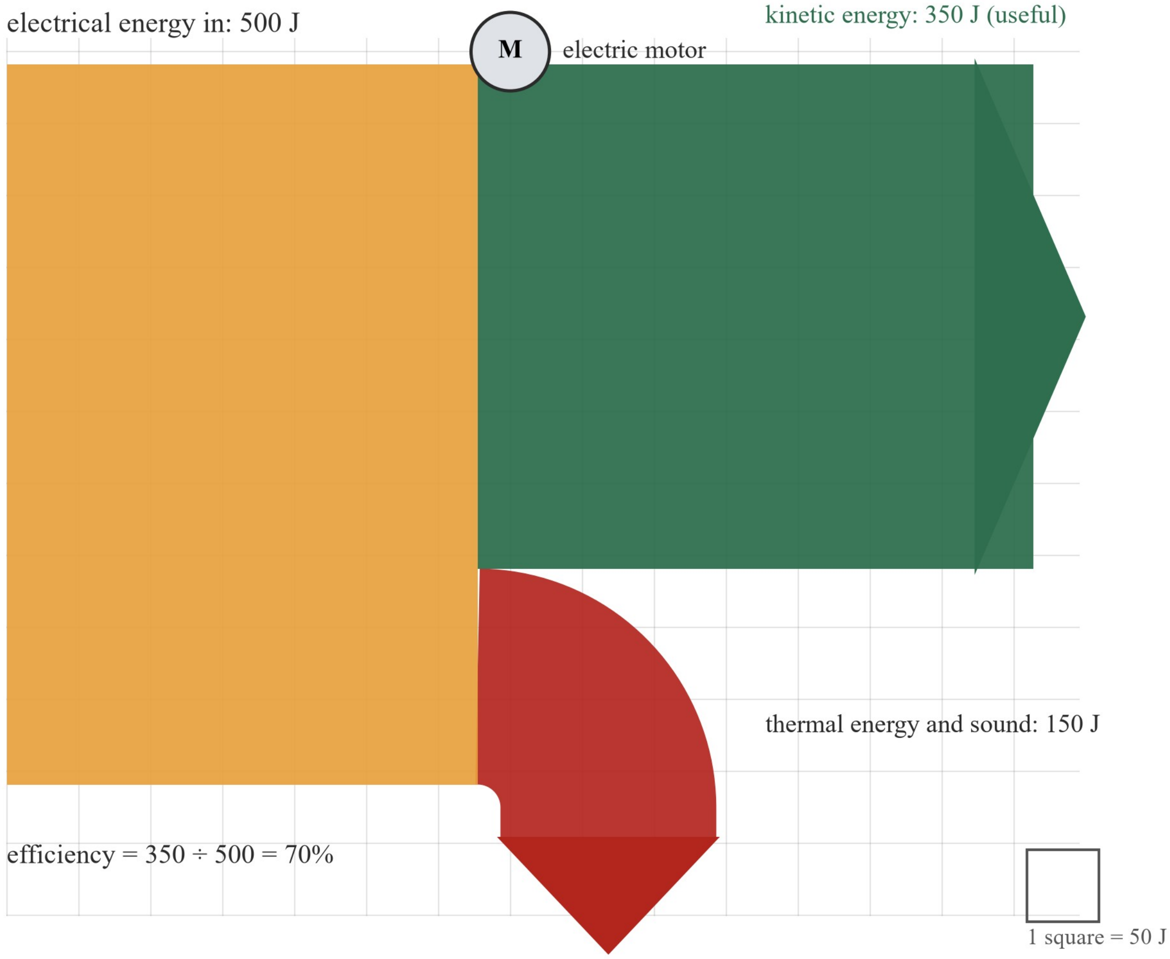
Now the filament globe of the waste-heat picture above, on a grid where 1 square = 5 J:



A Sankey diagram where 1 square equals 5 J: an input arrow 20 squares wide labelled 100 J of electrical energy enters a filament globe box; a thin useful arrow 1 square wide labelled 5 J of light runs straight on, and a wide waste arrow 19 squares wide labelled 95 J of thermal energy bends downward; the efficiency is noted as 5 percent

100 J in, 5 J of useful light out, 95 J of thermal energy wasted: efficiency = 5 ÷ 100 = 0.05 = **5%**. The picture says it at a glance — the waste branch *is* the device's story.

And an electric motor, on a grid where 1 square = 50 J:



A Sankey diagram where 1 square equals 50 J: an input arrow 10 squares wide labelled 500 J of electrical energy enters an electric motor; a useful arrow 7 squares wide labelled 350 J of kinetic energy runs straight on, and a waste arrow 3 squares wide labelled 150 J of thermal energy and sound bends downward; the efficiency is noted as 350 divided by 500 equals 70 percent

500 J in, 350 J of useful kinetic energy out, 150 J wasted as thermal energy and sound: efficiency = 350 ÷ 500 = 0.7 = **70%**. Same input rule, same balancing widths — the motor simply wastes a smaller share than the globe.

The whole story in four sentences

Energy moves from hotter to colder by exactly three pathways: conduction hands it along a substance while the particles stay put, convection carries it in the moving substance itself, and radiation sends it in straight rays that need no substance at all. Surfaces matter for radiation — matt black gives and takes it best, shiny silver least — and closing all three pathways at once is exactly how a vacuum flask works. In nearly every transfer or transformation, some of the input ends up as thermal energy in the surroundings whether it was wanted or not, which is why a filament globe gets hot and why you warm up when you exercise. A Sankey diagram draws that whole account to scale — input on the left, useful output straight on, waste bending away, widths balancing because energy is never destroyed — and efficiency names the useful share of the input as a percentage.

Worked examples

Example 1 — scaffolded

The Sankey diagram of a filament globe shows 100 J of electrical energy in, 5 J of light out and 95 J of thermal energy wasted.

(a) State the total energy input.

(b) State the useful energy output.
(c) Check the waste output by subtraction.
(d) Calculate the efficiency as a percentage.

Working	Comment
(a) Total input = 100 J.	The input arrow is the whole amount; on the grid, 20 squares × 5 J.
(b) Useful output = 5 J.	Light is what a globe is *for*, so the light arrow is the useful one.
(c) 100 − 5 = 95 J.	Energy is never destroyed, so input − useful = waste.
(d) efficiency = 5 ÷ 100 = 0.05; 0.05 × 100 = **5%**.	Useful ÷ total, then × 100 for the percentage (`VC2M7A01`, `VC2M7N07`).

Example 2 — scaffolded

A phone charger takes in 50 J of electrical energy and passes 40 J on to the battery; the rest warms the charger and the air around it.

(a) State the useful energy output.
(b) Calculate the waste output.
(c) Calculate the efficiency as a percentage.

Working	Comment
(a) Useful output = 40 J.	Charging the battery is the job, so energy reaching the battery is useful.
(b) 50 − 40 = 10 J.	Input = useful + waste, so waste = input − useful.
(c) efficiency = 40 ÷ 50 = 0.8; 0.8 × 100 = **80%**.	Substitute the values (`VC2M7A01`), then write 40 as a percentage of 50 (`VC2M7N07`).

Example 3 — unscaffolded

An electric fan takes in 200 J of electrical energy. Of this, 140 J becomes the kinetic energy of the spinning blades; the rest becomes thermal energy and sound. Draw (or describe) the fan's Sankey diagram on a grid where 1 square = 20 J, and state the fan's efficiency.

On a grid where 1 square = 20 J, the input of 200 J is 200 ÷ 20 = 10 squares wide. The useful output (kinetic, 140 J) is 140 ÷ 20 = 7 squares wide and runs straight on. The waste is 200 − 140 = 60 J, which is 60 ÷ 20 = 3 squares wide, bending downward as thermal energy and sound. The widths balance: 10 squares in = 7 squares useful + 3 squares waste, because energy is never destroyed. ∴ efficiency = 140 ÷ 200 = 0.7 = **70%** — the same efficiency as the motor diagrammed above, because both turn 7 useful squares out of every 10 in.

Example 4 — unscaffolded

A student looks at the filament globe's Sankey diagram and says: *"The globe wastes 95 J, so that energy is destroyed. Only 5 J is left at the end."* Evaluate this claim, using the balancing rule of Sankey diagrams.

The claim is wrong on both halves. The 95 J is not destroyed — it is still there at the end, as thermal energy warming the globe and the air around it; that is exactly what the waste arrow draws, and it is why the globe is hot to touch. And "only 5 J left" confuses *useful* with *remaining*: all 100 J of the input is still accounted for at the output end — 5 J as light and 95 J as thermal energy. The balancing rule says it plainly: input = useful output + waste, 100 J = 5 J + 95 J. ∴ the waste arrow is not energy vanishing; it is energy arriving somewhere it is not useful, and the diagram conserves every joule.

Practice questions

Scaffolded

Q1. Name the pathway (conduction, convection or radiation) in each case. (a) A metal skewer left in a campfire gets hot along its handle. (b) Your face warms when turned toward a campfire, even though the air between does not carry it. (c) The air directly above a campfire shimmers and rises. (d) The metal base of a saucepan gets hot on a stove.

Q2. Complete the particle story of conduction: "When one end of a rod is heated, the particles there vibrate …, jostle their …, and the energy is handed along the rod while the particles themselves …"

Q3. Put the four steps of a convection loop in a pot of water in order, starting from "the water near the base is warmed". (a) The cooled water sinks down the sides. (b) The water near the base is warmed. (c) The warmed water rises and crosses the top. (d) The water returns along the bottom to be warmed again.

Q4. Match each feature of a vacuum flask to the pathway or pathways it blocks. (a) The vacuum gap between the walls. (b) The silvered surfaces on the walls. (c) The stopper in the mouth.

Q5. Read the filament globe's Sankey diagram (1 square = 5 J). (a) State the total energy input. (b) State the useful energy output. (c) State the waste output. (d) State the efficiency as a percentage.

Q6. Read the electric motor's Sankey diagram (1 square = 50 J). (a) State the total energy input. (b) State the useful energy output. (c) Check the waste output by subtraction. (d) Calculate the efficiency as a percentage.

Unscaffolded

Q7. A metal spoon and a wooden spoon have sat in the same cool room all day, so both are at room temperature. When you hold them, the metal one *feels* cooler. Explain why, using conduction. *(2 marks)*

Q8. A heater sits under a window-less wall of a room whose only window is on the opposite side and is cold on a winter night. Explain, step by step, how convection warms the whole room, and say where in the room the coolest air will be. *(3 marks)*

Q9. In the dark-against-shiny Try-it, the matt black can cooled from 80 °C to 66 °C in ten minutes while the shiny can cooled only to 71 °C. Explain the difference, and predict which can would warm up faster if both stood in strong sunlight, giving the reason. *(2 marks)*

Q10. Explain how a vacuum flask keeps a drink hot for hours, naming each of the three pathways and the feature of the flask that blocks it. *(3 marks)*

Q11. A student draws a Sankey diagram for a device with 100 J in, showing a useful arrow of 60 J and a waste arrow of 60 J. Identify the error and describe the corrected diagram, including the width of each arrow on a grid where 1 square = 20 J. *(2 marks)*

Q12. A blender takes in 600 J of electrical energy; 150 J becomes the kinetic energy of the blades and the rest becomes thermal energy and sound. Calculate the blender's efficiency as a percentage, and state what happens to the wasted energy. *(2 marks)*

Q13. Name the by-product in each case, and say where it ends up. (a) A phone battery charging while you sleep. (b) Your muscles during a long run. *(2 marks)*

Q14. A student says: *"A filament globe is only 5% efficient, so 95% of the energy disappears. That is why the globe should be replaced."* Evaluate the claim: what is right in it, and what is wrong? *(3 marks)*

Answers

Q1. (a) Conduction. (b) Radiation. (c) Convection. (d) Conduction. **Q2.** …more (strongly); …neighbours; …stay in their places (do not move along the rod). **Q3.** (b) → (c) → (a) → (d). **Q4.** (a) Conduction and convection. (b) Radiation. (c) Conduction and convection (it also stops warm liquid and vapour escaping). **Q5.** (a) 100 J. (b) 5 J. (c) 95 J. (d) 5%. **Q6.** (a) 500 J. (b) 350 J. (c) 500 − 350 = 150 J. (d) 350 ÷ 500 = 0.7 = 70%. **Q7.** Both spoons are at the same temperature, but metal conducts energy away from your warm hand far faster than wood, so your hand loses thermal energy faster on the metal spoon and it feels cooler. **Q8.** Air warms at the heater and rises; it crosses the ceiling; at the cold window it cools and sinks; it returns along the floor to the heater, making one loop that carries energy around the room. The coolest air is at the floor near the cold window. **Q9.** A matt black surface gives radiation away faster than a shiny silver one, so the black can cooled quicker. In sunlight the black can would warm faster too, because matt black also takes radiation in better. **Q10.** The vacuum gap blocks conduction and convection (no particles to hand energy along or carry it); the silvered surfaces block radiation (shiny silver is the poorest at giving radiation away); the stopper blocks conduction and convection out of the mouth. With all three pathways closed, energy leaves only very slowly. **Q11.** The widths do not balance: 60 + 60 = 120 J out against only 100 J in, and energy can never be created. The waste arrow must be 100 − 60 = 40 J. On the grid: input 5 squares, useful 3 squares, waste 2 squares. **Q12.** efficiency = 150 ÷ 600 = 0.25 = 25%. The wasted 450 J becomes thermal energy and sound in the surroundings. **Q13.** (a) Thermal energy from the phone and battery, spreading into the surrounding air. (b) Thermal energy from the working muscles, warming you and then spreading to the surroundings. **Q14.** Right: the globe really is only 5% efficient, and replacing it with a more efficient lamp wastes less electrical energy for the same light. Wrong: nothing disappears — the other 95 J in every 100 J becomes thermal energy, which is why the globe gets hot; energy is conserved, not destroyed.

Fully-worked solutions

Q1. (a) **Conduction** — energy handed along the metal while its particles stay put *(1 mark each)*. (b) **Radiation** — straight rays from the flames; no substance carries them. (c) **Convection** — the heated air itself rises. (d) **Conduction** — energy handed through the metal base.

Q2. …vibrate **more (more strongly)**, jostle their **neighbours**, and the particles themselves **stay in their places —** only the energy moves on *(1 mark)*.

Q3. (b) → (c) → (a) → (d) *(1 mark)*: warmed at the base, the water rises and crosses the top, cools and sinks down the sides, and returns along the bottom to be warmed again.

Q4. (a) **Conduction and convection** — a vacuum has no particles to hand energy along or carry it. (b) **Radiation** — shiny silver surfaces are the poorest at giving radiation away. (c) **Conduction and convection —** the stopper closes the mouth so warm liquid, vapour and air cannot swap with the outside *(1 mark each)*.

Q5. (a) **100 J** in. (b) **5 J** of useful light. (c) **95 J** of thermal energy (100 − 5). (d) 5 ÷ 100 = 0.05 = **5%** *(1 mark each)*.

Q6. (a) **500 J** in (10 squares × 50 J). (b) **350 J** of kinetic energy (7 squares). (c) 500 − 350 = **150 J** wasted. (d) 350 ÷ 500 = 0.7 = **70%** *(1 mark each)*.

Q7. Both spoons are at room temperature, so the difference is not their temperature *(the room sees to that)*. Your hand is warmer than the spoons, and **metal conducts energy away from your hand far faster than wood** *(1 mark)*, so your hand loses thermal energy faster on the metal spoon — and a hand losing energy quickly *feels* cool *(1 mark)*.

Q8. Air **warms at the heater and rises** *(1 mark)*; crossing the ceiling it reaches the window side, where it **cools at the cold window and sinks** *(1 mark)*; it then **returns along the floor to the heater**, closing a loop that carries energy around the whole room. The **coolest air sits low, near the cold window**, where the sinking cooled air arrives *(1 mark)*.

Q9. A **matt black surface gives radiation away faster** than a shiny silver one, so the black can lost energy faster and cooled more *(1 mark)*. In sunlight the **black can would warm faster**, because the same rule runs in reverse: matt black **takes radiation in** better than shiny silver *(1 mark)*.

Q10. Conduction and convection are blocked by the **vacuum gap** — with no particles between the walls there is nothing to hand energy along and nothing to carry it *(1 mark)*. **Radiation** is blocked by the **silvered surfaces**, because shiny silver is the poorest surface for giving radiation away *(1 mark)*. **Conduction and convection** out of the mouth are blocked by the **stopper**, so warm liquid and vapour cannot escape. With all three pathways closed, the drink's thermal energy leaves only very slowly *(1 mark)*.

Q11. The error: the outputs do not balance the input — 60 J + 60 J = 120 J out against 100 J in, and energy can never be created, so the widths are impossible *(1 mark)*. Corrected on the 20 J grid: input 100 J = **5 squares**, useful 60 J = **3 squares** straight on, waste 100 − 60 = 40 J = **2 squares** bending down *(1 mark)*.

Q12. efficiency = useful ÷ total = 150 ÷ 600 = 0.25; 0.25 × 100 = **25%** *(1 mark)*. The wasted 600 − 150 = 450 J becomes **thermal energy and sound in the surroundings** — it warms the blender and the air, which is the by-product of E03 *(1 mark)*.

Q13. (a) **Thermal energy** produced as the battery charges; it ends up **warming the phone, the charger and the air around them** *(1 mark)*. (b) **Thermal energy** from the working muscles; it warms you and then **spreads to the surroundings** as you cool down *(1 mark)*.

Q14. What is right: the globe really is only **5% efficient**, and a more efficient lamp gives the same light while drawing far less electrical energy — so replacing it is sensible *(1 mark)*. What is wrong: **nothing disappears** *(1 mark)* — in every 100 J, 95 J becomes thermal energy (which is why the globe is hot to touch), so the energy is **conserved, not destroyed**; "waste" means "not useful", not "gone" *(1 mark)*.

Sources

Web sources below were retrieved 2026-08-20.

- Science ASSIST (Australian Science Teachers' Association), "Risk management", n.d. asta.edu.au
- Wikipedia, "Incandescent light bulb", 2026. en.wikipedia.org
- Wikipedia, "Sun", 2026. en.wikipedia.org
- Victorian Curriculum and Assessment Authority, *Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8*, content description `VC2S8U15` and its elaborations, 2026. vcaa.vic.edu.au

The filament globe's split — about 5 J of light in every 100 J of electrical energy in, the rest becoming thermal energy — is as given in Wikipedia, "Incandescent light bulb" (fewer than 5% of the input becomes visible light). The Sun–Earth mean distance of 149 600 000 km is as given in Wikipedia, "Sun". The Sankey diagrams' values (60 J/40 J/20 J, 100 J/5 J/95 J, 500 J/350 J/150 J, and the worked examples' 50 J/40 J, 200 J/140 J and 600 J/150 J) are **teaching values chosen for clean squares on the stated grids**, and the dark-against-shiny can temperatures (80 °C falling to 66 °C and 71 °C after 10 minutes) are **simulated data for practice**; the patterns they show — waste heat in nearly every transfer, low filament-globe efficiency, and matt black surfaces giving and taking radiation better than shiny ones — are the real behaviour.

Elaboration contexts used: `VC2S8U15.E02` (using Sankey diagrams to show energy inputs, changes and outputs in a system) and `VC2S8U15.E03` (identifying where heat energy is produced as a by-product of energy transfer, such as in filament light bulbs, during exercise, and during battery charging and use). Conduction, convection and radiation are authored from the CD text per D12; no Aboriginal or Torres Strait Islander content is prescribed for 16B (D10).

The household energy audit: appliance choice and star ratings, building design and materials, season and climate

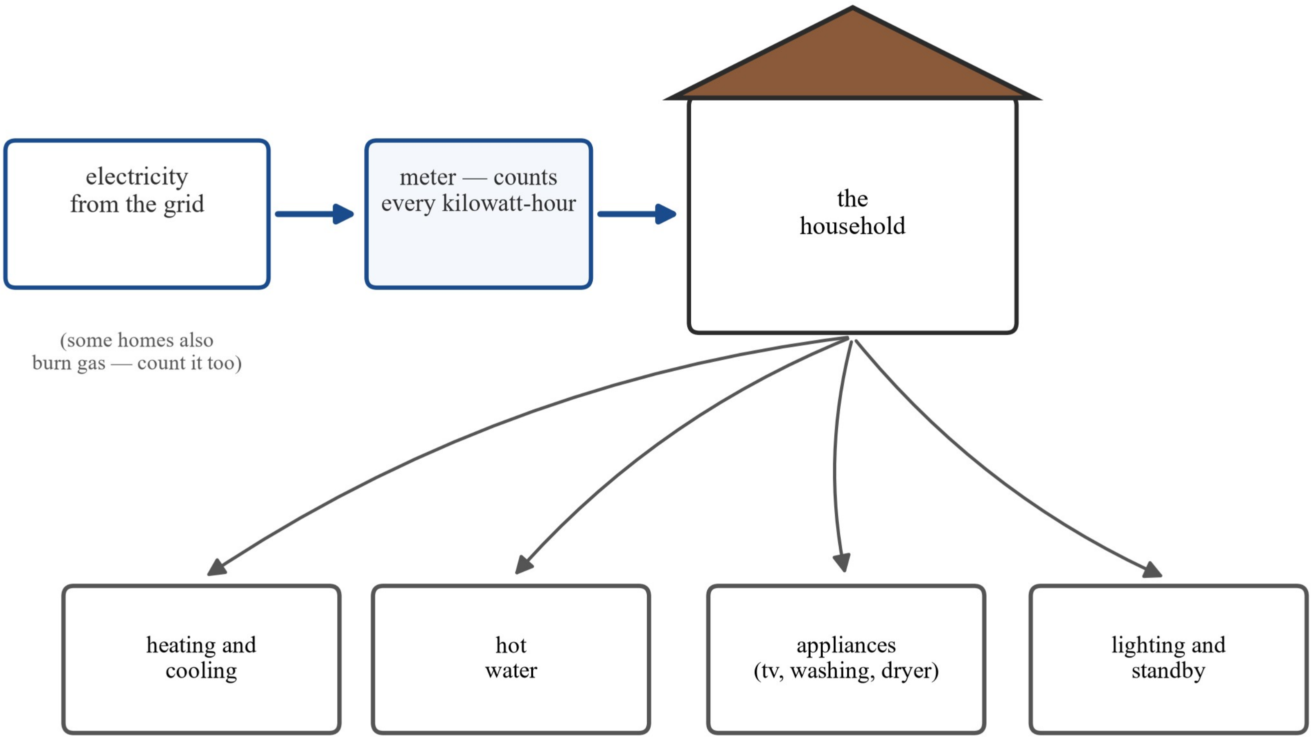
What we teach here — `VC2S8U16` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *household energy consumption can be analysed using an energy audit and is affected by appliance choice, building design, season and climate* 16C owns this content description whole — 16A and 16B teach the heat-transfer and energy-form ideas that 16C applies to the home. **In our words:** a home's energy use can be added up appliance by appliance, and once you can see where the energy goes, you can make the total smaller — by choosing efficient appliances, by designing and building the house well, and by understanding how season and climate change what the household needs. **Achievement-standard extract served here (D13):** *They undertake a household energy audit and propose ways to decrease energy consumption.* **Elaborations drawn on:** `.E01` conducting an energy audit; `.E02` the meaning of star ratings and the criteria behind them; `.E03` passive solar design and modelling it; `.E04` house design in different climates, including the Queenslander; `.E05` building materials such as mudbrick, polystyrene panels and insulation; `.E06` how use varies with time of day and time of year, and what that means for storage or generation. **Maths interlocks (D11):** `VC2M7N07` percentage of a quantity (each appliance's share of the audit total); `VC2M7N06` the four operations with positive rational numbers (the audit arithmetic); maintained from primary: `VC2M6M01` metric conversion (watts → kilowatts), proportional reasoning (consumption per appliance per year), and estimation and reasonableness — does the audit total make sense against the meter and the quarterly bill? **Scope ceiling (D9):** the audit uses energy = power × time with the power read from the label. No circuit formulas (no $V = I \times R$, no $P = V \times I$), no scientific notation, and graphs in this subtopic are read qualitatively only. **Authored from the CD text and the elaboration contexts (D12).**

Word watch — *power* and *energy*. Power is how fast an appliance uses energy *right now*, measured in watts (W) or kilowatts (kW). Energy is how much it used *in total* over a time, and homes are billed in kilowatt-hours (kWh). A 2 000 W heater has a bigger power than a 100 W TV — but a TV left on for 20 hours can use more energy than the heater ran for 5 minutes. The audit counts energy; the label shows power.

Theory

Energy into a home — where the energy goes. Electricity from the grid passes through a meter that counts every kilowatt-hour, then spreads out across the household: heating and cooling, hot water, appliances, and lighting and standby. (Some homes also burn gas — a full audit counts that too, in megajoules or on the gas bill; this subtopic sticks to electricity.) An energy audit (E01) is simply a careful list of where that energy goes, so the household can see its biggest users and act on them.

Energy into a home — the audit's map

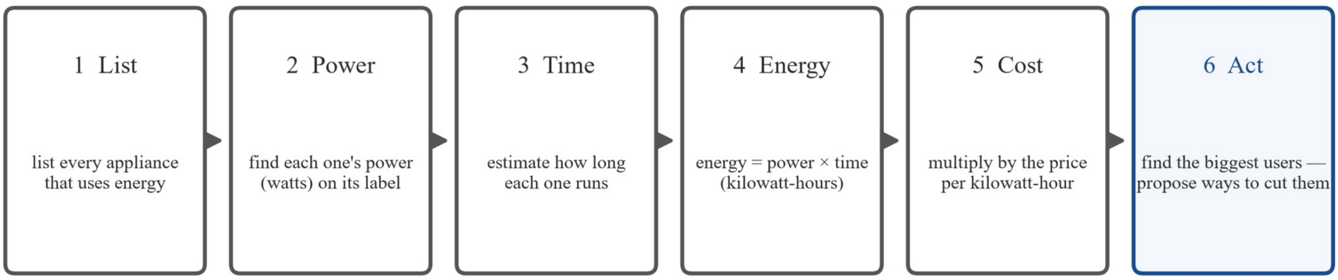


An energy audit asks: how much energy does each of these use — and where could the household use less?

Flow map of energy into a home: grid electricity passes through a meter that counts every kilowatt-hour into the household, then spreads out to heating and cooling, hot water, appliances, and lighting and standby; an audit asks how much each part uses and where the household could use less.

The five steps of an audit. Every audit, from a school project to a professional one, follows the same shape: list the energy users, gather each one's power and running time, work out the kilowatt-hours, work out the cost, then compare and propose savings.

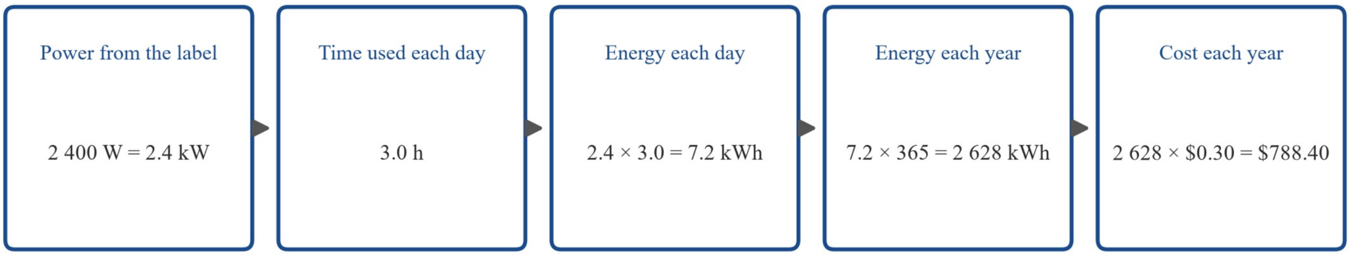
How to run a household energy audit



The five steps of an energy audit in a numbered flow chart: list the energy users; gather power and running time; work out kilowatt-hours; work out cost; compare and propose savings.

The one calculation the audit needs. Energy (kWh) = power (kW) × time (h). Two conversions do all the work: watts to kilowatts is divide by 1 000 (VC2M6M01), and the bill counts kilowatt-hours, so cost = kWh × price per kWh. The worked strip below follows one 2 400 W appliance running 3.0 h every day for a year.

From the label to the yearly cost — a fan heater, 2 400 W, 3.0 h a day (practice price $0.30/kWh)



watts ÷ 1 000 gives kilowatts; energy (kWh) = power (kW) × time (h)

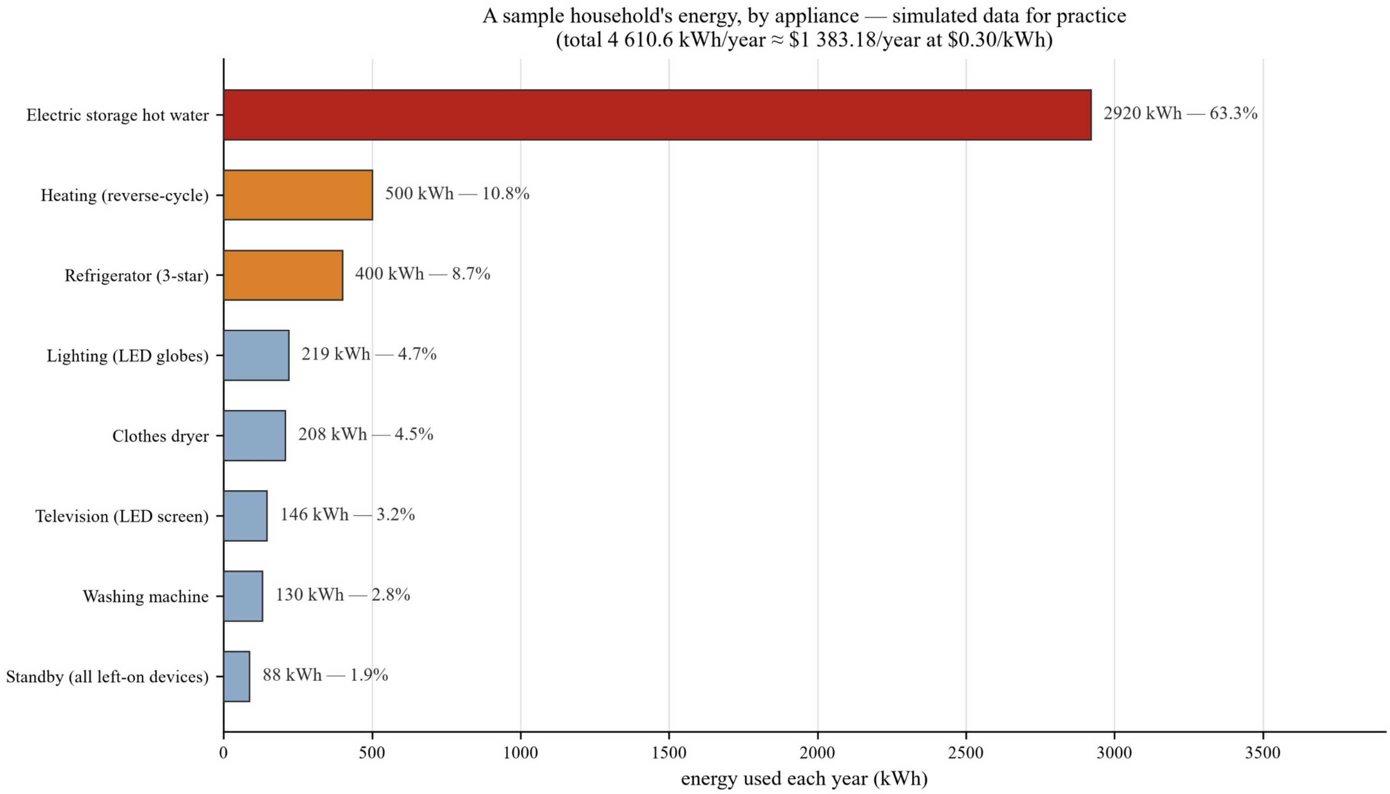
Worked calculation strip: 2 400 W is 2.4 kW; times 3.0 hours a day gives 7.2 kWh a day; times 365 days gives 2 628 kWh a year; times $0.30 per kWh gives $788.40 a year.

A simulated audit, appliance by appliance. The table below is one simulated all-electric household in Melbourne, priced at a round practice rate of $0.30 per kWh. Add the shares: they must total 100%. Add the costs: they must total the cost for the year.

Appliance	Energy per year (kWh)	Share of total	Cost per year at $0.30/kWh
Electric storage hot water	2 920.0	63.3%	$876.00
Heating (reverse-cycle air conditioner)	500.0	10.8%	$150.00
Refrigerator (3-star)	400.0	8.7%	$120.00
Lighting (LED globes)	219.0	4.7%	$65.70
Clothes dryer	208.0	4.5%	$62.40
Television (LED screen)	146.0	3.2%	$43.80
Washing machine	130.0	2.8%	$39.00
Standby (all left-on devices)	87.6	1.9%	$26.28
Total	**4 610.6**	**100%**	**$1 383.18**

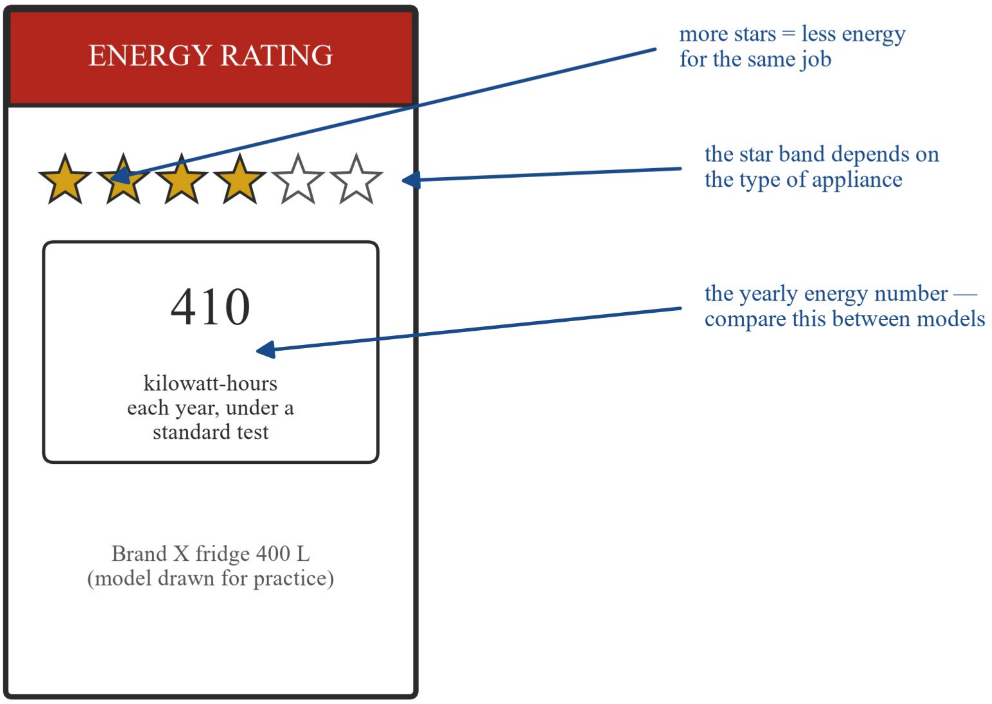
(Simulated household, values chosen for practice.)

The total is 4 610.6 kWh a year, which costs $1 383.18 — about $345.80 a quarter. Two reasonableness checks: the meter for this simulated year read 4 595 kWh, close to the appliance-by-appliance total of 4 610.6 kWh, so the audit hangs together (a big gap between the two would mean a missed appliance or a wrong estimate); and $345.80 sits where a real Victorian quarterly bill for an all-electric home sits, so the total makes sense. The story the audit tells is typical of older all-electric homes: hot water is by far the biggest user, nearly two-thirds of everything.



Bar chart of the simulated audit: hot water 63.3%, heating 10.8%, refrigerator 8.7%, lighting 4.7%, dryer 4.5%, television 3.2%, washing machine 2.8%, standby 1.9% — a total of $1 383 a year at $0.30 per kWh.

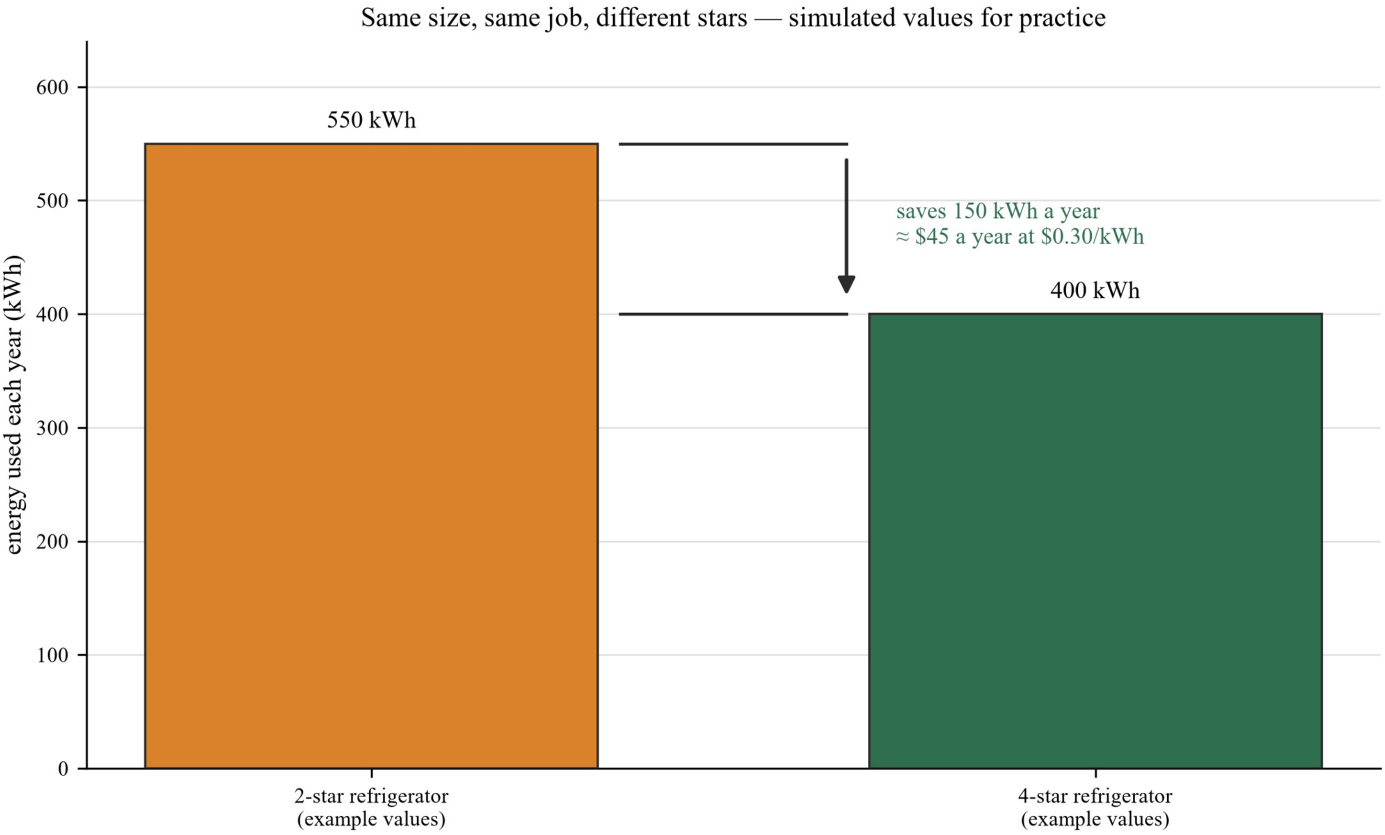
Star ratings — what they mean (E02). In Australia, appliances such as refrigerators and washing machines carry an Energy Rating Label with stars and an energy number for one year. The rules to teach are: stars compare appliances that do the *same job at the same size* — more stars means less energy for the same job; the kilowatt-hour number for a year is the one to use in an audit; and the star band that counts as “good” depends on the type of appliance. The label below is a drawn practice example.



Drawn example for practice — Australian appliances carry the
Energy Rating Label of the Equipment Energy Efficiency (E3) programme.

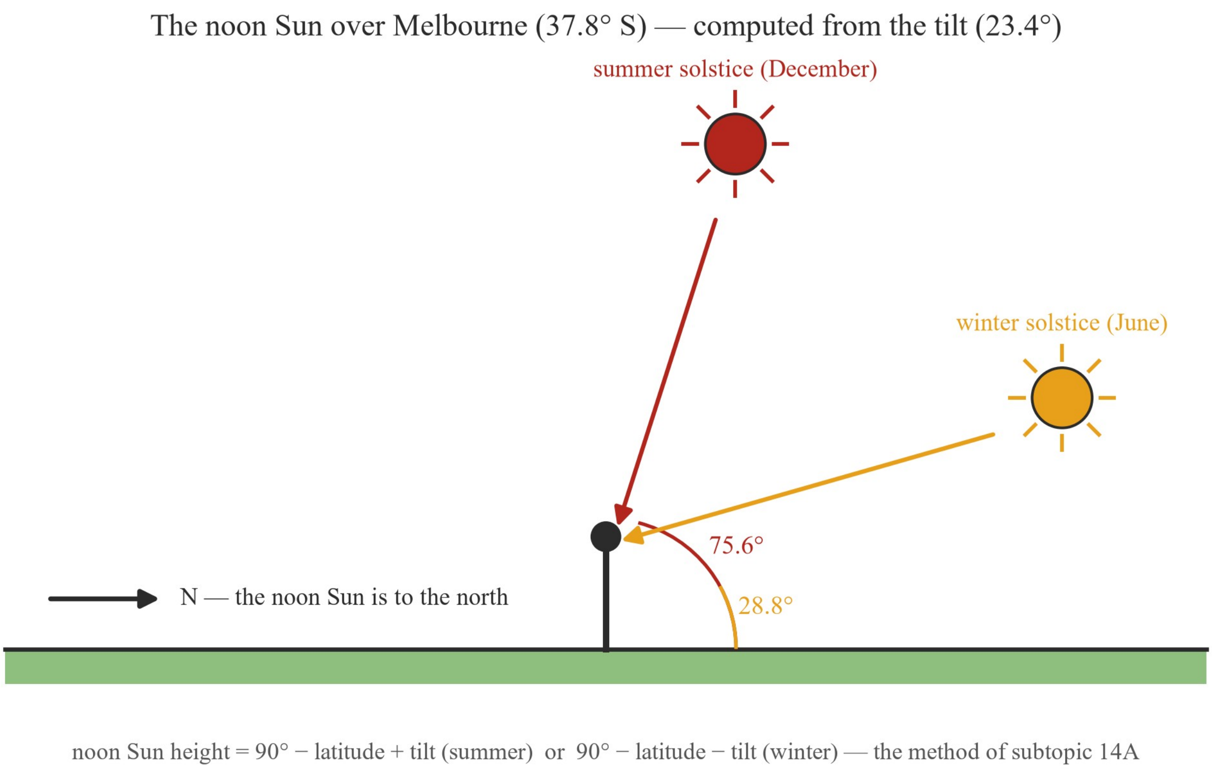
A drawn practice energy rating label for a 400 L refrigerator: four of six stars filled in, and 410 kilowatt-hours each year under a standard test; callouts explain that more stars means less energy for the same job, that the star band depends on the type of appliance, and that the energy number for a year is the one to compare between models.

How the ratings are set. The numbers on a label come from a standard test — every model of fridge is run the same way, in the same conditions, and then compared with other fridges of similar size and type. That is what makes the stars fair: they rate efficiency against the class, not raw size. Houses get stars too: the Nationwide House Energy Rating Scheme (NatHERS) rates a home’s thermal performance out of 10 stars, and the National Construction Code sets a minimum star rating for new homes (6 stars across most of Australia, 7 in South Australia).



Bar chart with simulated values: a 2-star refrigerator uses 550 kWh each year while a same-size 4-star refrigerator uses 400 kWh each year — a saving of 150 kWh a year, about $45 a year at $0.30 per kWh.

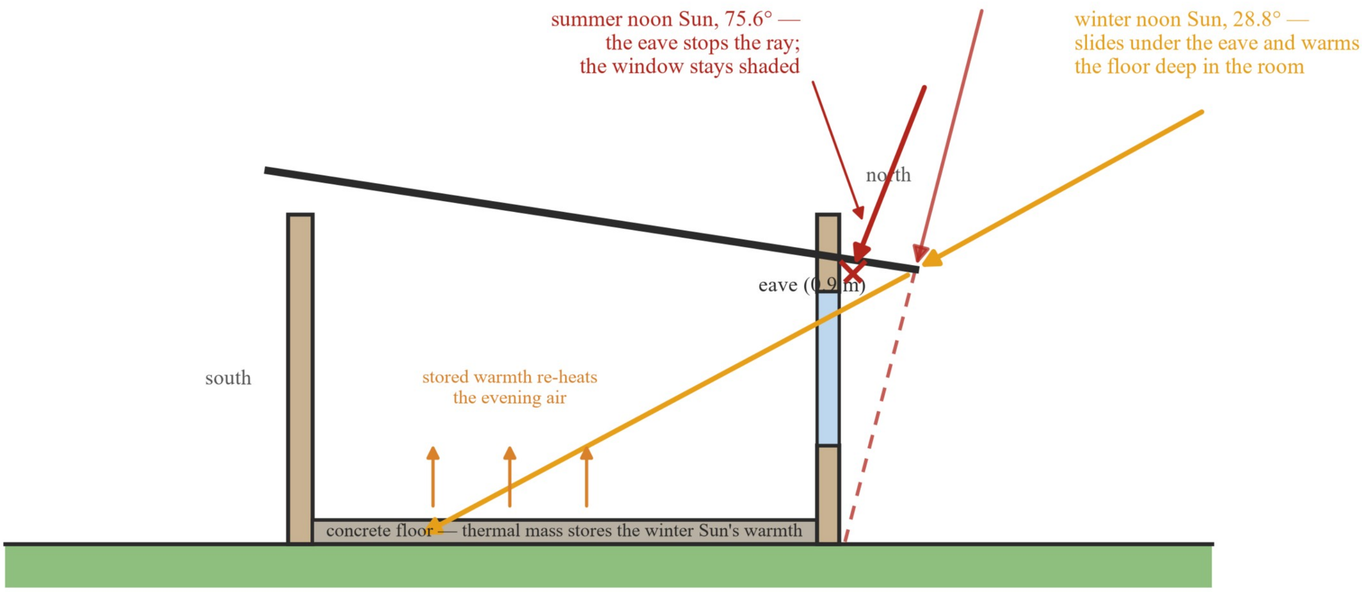
Passive solar design (E03) — build with the Sun, not against it. In Melbourne (latitude 37.8° south) the midday Sun stands 75.6° above the horizon at the summer solstice and only 28.8° at the winter solstice — the 23.4° tilt of Earth's axis swings it through the sky (the same geometry taught in 14A). Because Australia is in the southern hemisphere, the midday Sun is in the *north*, so a house that wants free winter heating puts its big windows on the north side.



Two panels for Melbourne at latitude 37.8 degrees south: the midday summer Sun stands 75.6 degrees above the horizon and the midday winter Sun only 28.8 degrees.

A passive solar house uses three ideas: **north-facing glazing** to catch the winter Sun; an **eave** (the roof edge above the window) sized for the latitude so the high summer Sun is blocked while the low winter Sun reaches inside; and **thermal mass** — a heavy concrete slab or brick wall inside — that soaks up winter sunshine by day and gives the warmth back at night. No machines, no running cost: the design does the work.

Passive solar design for Melbourne — the eaves do the switching

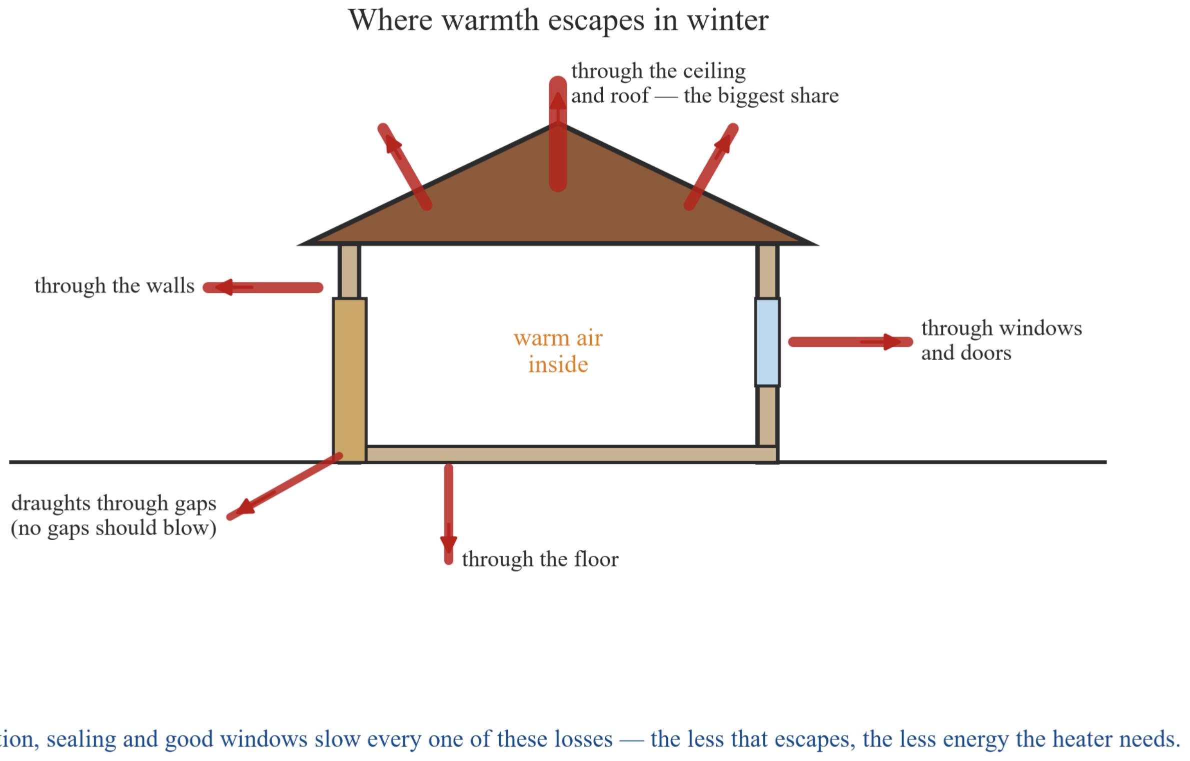


All points where the rays meet the house are computed from the two Sun heights of subtopic 14A (90° − 37.8° ± 23.4° → 75.6° and 28.8°).

Cross-section of a passive solar house in southern Australia: a north-facing window under an eave sized so the high summer Sun (75.6 degrees) is blocked by the eave while the low winter Sun (28.8 degrees) passes under it and warms the thermal-mass floor inside.

> **Activity — model a passive solar house (E03).** *Equipment:* two identical shoeboxes, a small black-painted jar of water (the thermal mass), a cardboard eave, a lamp as the Sun, two thermometers. *Method:* cut a “north” window in each box; fit the eave to one; put the jar and a thermometer inside each; shine the lamp low (winter angle) and then high (summer angle); record the temperatures. *Risk:* low — lamp bulbs get warm, so handle with care and let the bulb cool before packing up. *Ask:* which box warms more at the winter angle? At the summer angle, what does the eave change?

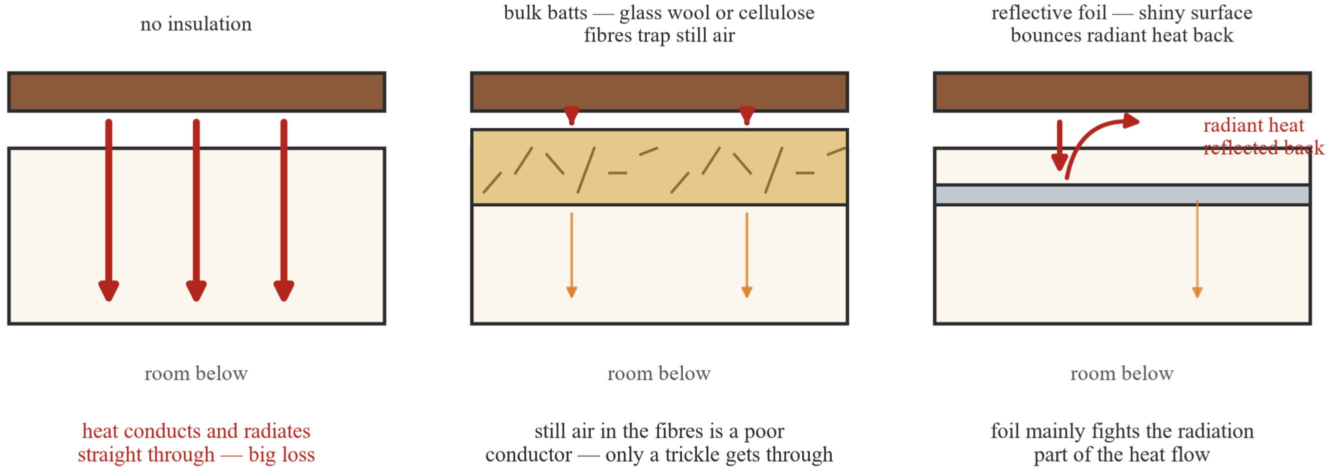
Where warmth escapes. A heated house loses warmth through every surface — the ceiling and roof usually the biggest share, then walls, windows and doors, the floor, and draughts through gaps. Every kilowatt-hour that escapes has to be replaced by the heater, so slowing the losses is the same as shrinking the bill. (The heat-transfer modes doing this are the ones taught in 16B.)



House cross-section with arrows showing winter warmth escaping through the ceiling and roof (the biggest share), the walls, the windows and doors, the floor, and draughts through gaps; insulation, sealing and good windows slow every one of these losses.

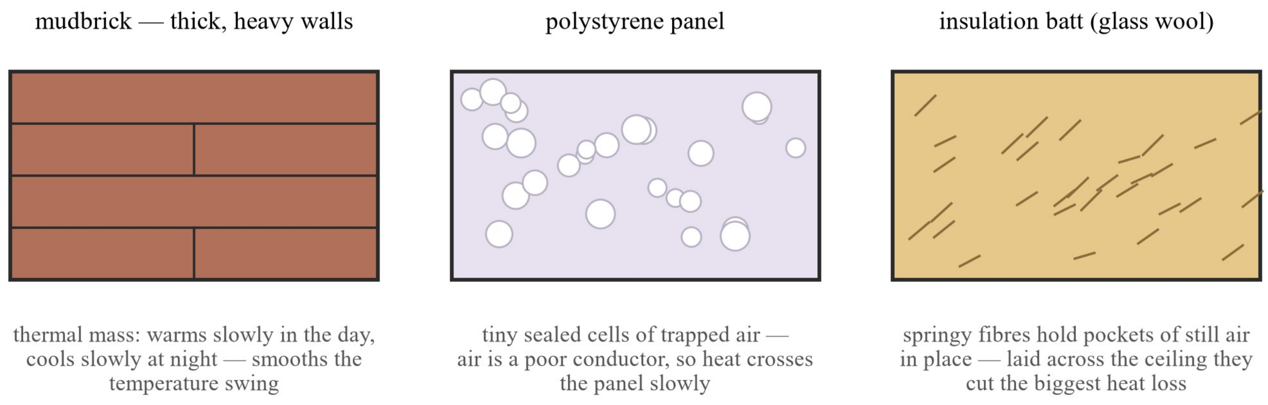
Materials matter (E05). Insulation slows heat flow by trapping still air — bulk insulation such as glass wool, cellulose or polystyrene panels in the walls and ceiling, and reflective foil that bounces radiant heat back. Heavy materials play a different role: mudbrick and concrete store heat as thermal mass, evening out the temperature between day and night. A well-chosen house uses both: mass inside to store, insulation outside to keep.

Three ways to slow heat flow through a ceiling (the heat transfer modes are from subtopic 16B)



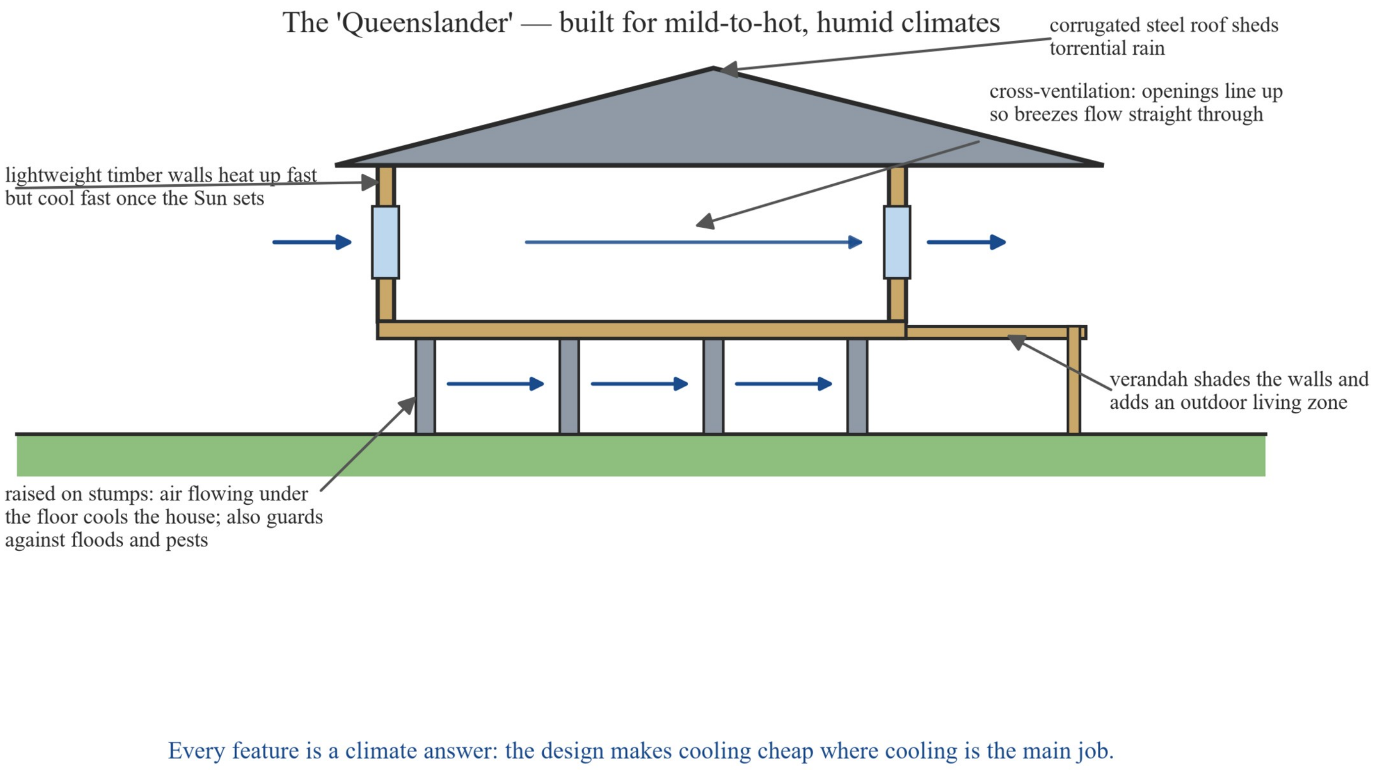
Three wall cross-sections comparing an uninsulated wall with walls fitted with bulk insulation and a reflective foil layer: trapped still air and the foil slow the heat flow through the wall.

Building materials and the job each does (VC2S8U16.E05)

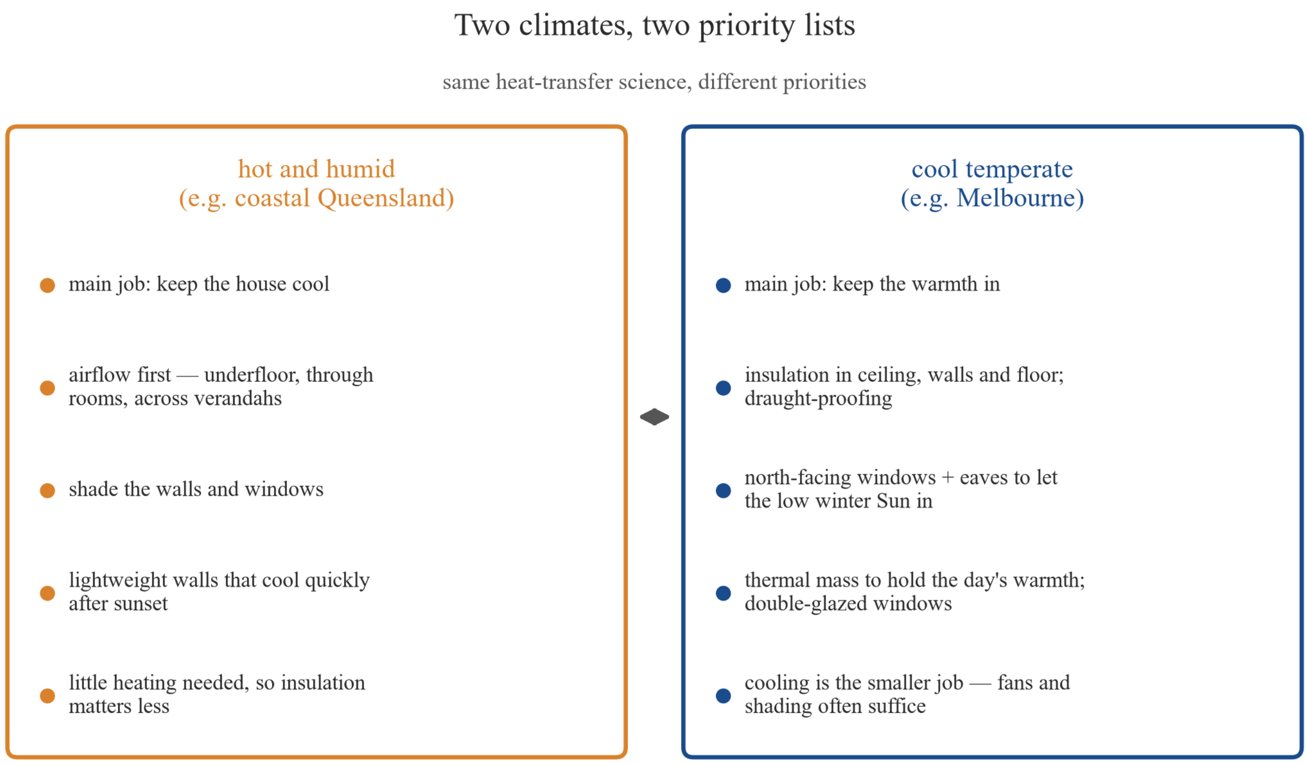


Building materials and the job each does in an efficient house: heavy mudbrick stores heat as thermal mass, polystyrene panels and batts trap still air as insulation, and foil reflects radiant heat.

Design follows climate (E04). The same heat-transfer science applies everywhere, but different climates set different priorities, so the efficient house looks different in each place. In a cool southern climate the wins are compact shape, good insulation, and north glass for winter Sun. In Queensland's hot, humid climate the classic **Queenslander** solves the opposite problem — staying cool without air conditioning: the house is raised on stumps so air flows under the floor, lightweight timber walls heat up fast but also cool fast once the Sun sets, wide verandahs shade the walls, and windows on opposite sides let breezes blow straight through.

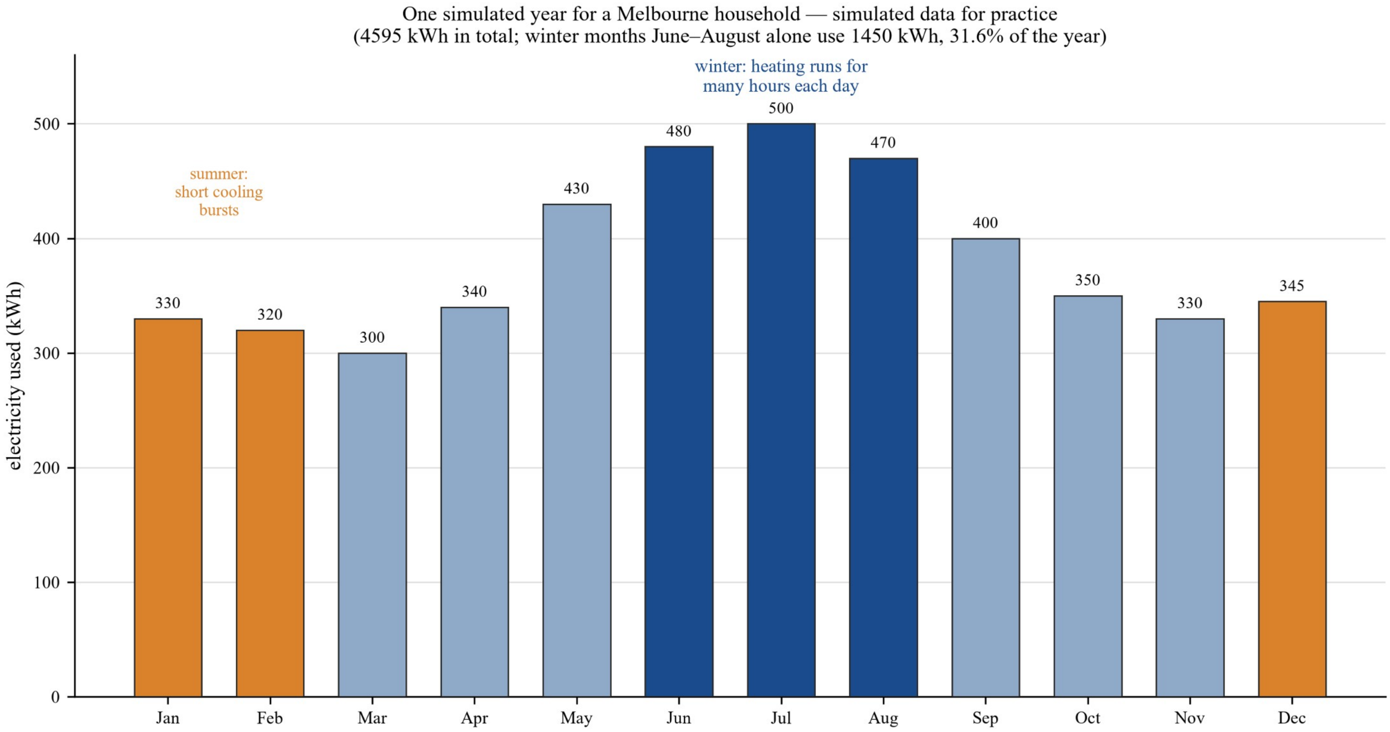


Labelled sketch of a Queenslander house: raised on stumps so air flowing under the floor cools the house, lightweight timber walls, wide verandahs for shade, a corrugated iron roof, and windows on opposite sides for cross-ventilation.

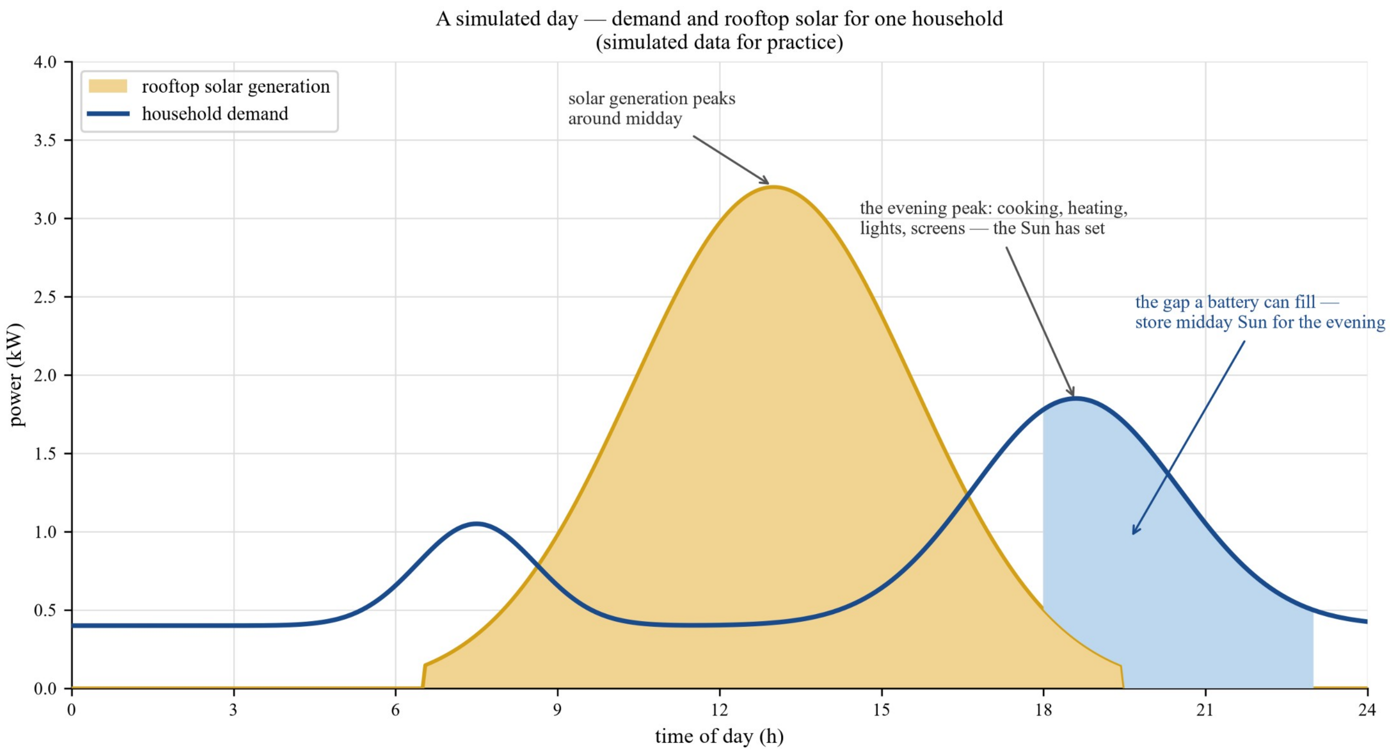


Two house designs side by side — a compact, insulated, north-facing house for a cool climate and a raised, shaded, breezy house for a hot humid climate — built on the same heat-transfer science with different priorities.

Season and time of day (E06). Meter readings for the simulated household climb through the cold months — heating pushes June, July and August to about a third (31.6%) of the whole year's 4 595 kWh — and fall again in the milder months. Melbourne's climate explains the shape: January's mean maximum is 26.8 °C while July's is 14.5 °C (BOM, Melbourne Olympic Park), so winter heating, not summer cooling, drives this household's peak. Within a single day the shape changes again: demand peaks in the morning and evening when people are home, and dips in the middle of the day.

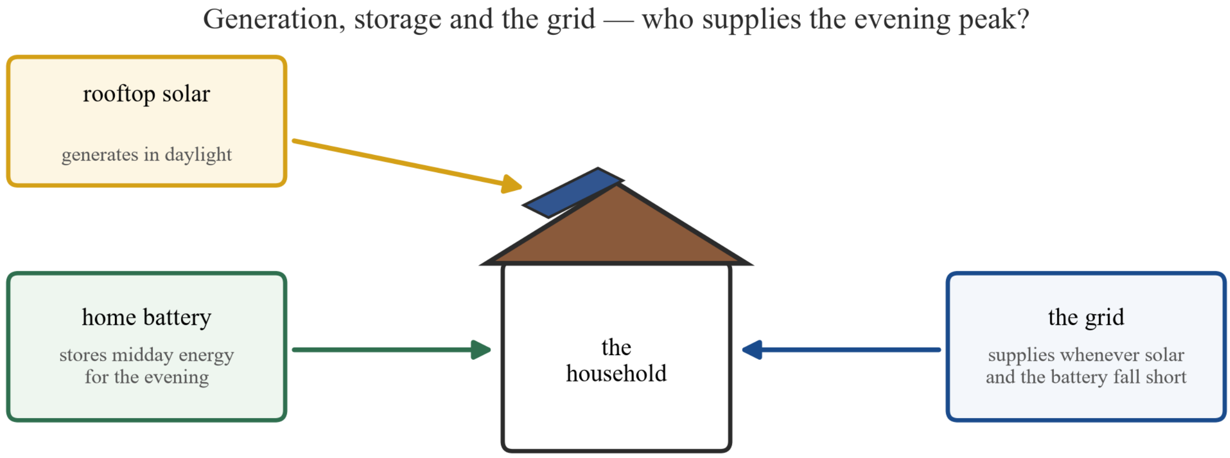


Bar chart of simulated monthly electricity use for one household: use climbs through the winter months of June, July and August to about 500 kWh a month and falls in the milder months; the three winter months hold 31.6% of the year's 4 595 kWh.



Sketch of a household's electricity use across one day: peaks in the morning and evening when people are home and a low dip in the middle of the day.

What that means for storage and generation. A rooftop solar system generates most at midday — exactly when this household uses least. The leftover midday energy can be exported to the grid or kept in a home battery, then used across the evening peak. That is the link E06 asks for: the *timing* of household use, not just the total, is what creates the need for energy storage or generation.



Energy generated at midday can be used at once, stored for later, or the grid can top up the difference — the household's needs change with the time of day and the season.

Sketch of rooftop solar generation peaking at midday against household demand peaking in the morning and evening; the mismatch between the two is why households add battery storage or export the midday surplus to the grid.

Decreasing consumption — the pay-off of the audit. The achievement standard asks for proposals, and the audit shows where they bite: choose a higher-star appliance of the right size when one needs replacing; cut standby by switching devices off at the wall; line-dry on the days the weather allows; insulate the ceiling, seal the draughts, and let the eave and the north windows do the heating and cooling. Every proposal works the same way — it shrinks one line of the audit table, and the total follows.

Words to know in 16C

Word	Meaning
energy audit	a careful list of where a household’s energy goes, used to find savings
kilowatt-hour (kWh)	the unit energy bills use: the energy a 1 000 W device uses in one hour
power (W, kW)	how fast an appliance uses energy right now
star rating	a label score comparing how much energy an appliance (or house) uses for the same job
passive solar design	designing a building to heat and cool itself using the Sun’s path, with no machines
eave	the edge of a roof that overhangs the wall, shading windows from high summer Sun
thermal mass	heavy material (concrete, brick, mudbrick) that stores heat and releases it later
insulation	material that slows heat flow by trapping still air (batts, polystyrene, foil)
standby power	energy used by appliances that are left on instead of

Word	Meaning
	switched off at the wall
glazing	the glass in a building's windows

Worked examples

Example 1 — scaffolded

A reverse-cycle heater draws an average power of 2.0 kW. The household runs it 3.0 h each day on the 90 coldest days of the year. What does that heating cost at $0.30 per kWh?

Working	Comment
E (per day) = 2.0 kW × 3.0 h = 6.0 kWh	energy = power × time
E (90 days) = 6.0 kWh × 90 = 540.0 kWh	scale the day up to the season
cost = 540.0 kWh × $0.30 = $162.00	cost = kWh × price

∴ The heater uses 540.0 kWh and costs **$162.00** for the season.

Example 2 — scaffolded

A household replaces an old 2-star refrigerator (550 kWh a year) with a same-size 4-star model (400 kWh a year). At $0.30 per kWh, how much energy and money does it save in one year — and over the 10 years the new fridge will run?

Working	Comment
saving = 550 − 400 = 150 kWh per year	same size, same job, different stars
money (1 yr) = 150 kWh × $0.30 = $45.00	cost = kWh × price
money (10 yr) = $45.00 × 10 = $450.00	stars keep saving every year

∴ The upgrade saves 150 kWh a year — **$45.00 a year and about $450 over 10 years**. Appliance choice is a decision the audit makes visible.

Example 3 — unscaffolded

An electric hot-water system heats its tank with a 2 400 W element that runs for 3.0 h each day. At $0.30 per kWh, find the system's energy use and cost for one year, and compare your answer with the hot-water line of the audit table.

2 400 W is 2.4 kW; × 3.0 h gives 7.2 kWh a day; × 365 gives 2 628 kWh a year; × $0.30 gives **$788.40 a year**. That lands close to the audit table's hot-water line of 2 920.0 kWh — the small difference is because that household's element runs a little longer each day — and the two numbers agree that hot water is by far the biggest user.

Example 4 — unscaffolded

The standby line of the audit came from devices drawing a total of 12 W, left on for 20 h out of every 24. Show the standby energy per day and per year, and the cost for a year at $0.30 per kWh.

12 W is 0.012 kW; × 20 h gives 0.24 kWh a day; × 365 gives 87.6 kWh a year — exactly the standby line of the audit table; × $0.30 gives **$26.28 a year**. A household that switches those devices off at the wall keeps that money.

Practice questions

Scaffolded

Q1. Convert 2 400 W to kilowatts. *(1 mark)*

Q2. A 1.5 kW heater runs for 4.0 h. How many kilowatt-hours does it use? *(1 mark)*

Q3. What does the energy of Q2 cost at $0.30 per kWh? *(1 mark)*

Q4. Read the practice energy rating label in the theory: under the standard test, how many kilowatt-hours does the 400 L Brand X fridge use each year? *(1 mark)*

Q5. In the simulated audit, which single appliance uses the most energy, and what share of the total is it? *(1 mark)*

Q6. In Melbourne, how high above the horizon does the midday Sun stand at the winter solstice? *(1 mark)*

Unscaffolded

Q7. A 3 000 W portable electric heater runs 2.5 h a day for the 120 coldest days of the year. Find (a) the energy per day, (b) the energy over the 120 days, and (c) the cost at $0.30 per kWh. *(3 marks)*

Q8. A household's old refrigerator uses 550 kWh a year. A same-size new model uses 400 kWh a year. At $0.30 per kWh, find the money saved over the 12 years the new fridge will run. *(2 marks)*

Q9. In the simulated audit, heating used 500.0 kWh of the 4 610.6 kWh total. Show, by calculation, that heating's share is about 10.8%. *(2 marks)*

Q10. The simulated meter read 4 595 kWh for the year, and June–August used 1 450 kWh. Calculate the winter share of the year as a percentage to one decimal place, and explain in one sentence why a winter peak makes sense in Melbourne. *(2 marks)*

Q11. Explain why a north-facing window with a well-sized eave lets the winter Sun in but keeps the summer Sun out of a Melbourne house. Use the two midday Sun heights (75.6° and 28.8°) in your answer. *(3 marks)*

Q12. A house in a cool climate gets strong winter sunshine through its north windows. Explain why a mudbrick floor inside the living room helps keep the house warm at night. *(2 marks)*

Q13. Name two design features of the Queenslander and explain how one of them cools the house in a hot, humid climate. *(2 marks)*

Q14. In the audit, the clothes dryer used 208.0 kWh in the year. The household decides to line-dry on half of its drying days, halving the dryer's energy. Find the energy saved per year and the money saved at $0.30 per kWh, and give one other proposal from the theory that would shrink a different line of the audit table. *(2 marks)*

Answers

Q1. 2.4 kW **Q2.** 6.0 kWh **Q3.** $1.80 **Q4.** 410 kWh **Q5.** electric storage hot water, 63.3% **Q6.** 28.8° **Q7.** (a) 7.5 kWh (b) 900.0 kWh (c) $270.00 **Q8.** $540.00 **Q9.** 500.0 ÷ 4 610.6 × 100 ≈ 10.8% **Q10.** 31.6%; Melbourne winters are cold enough to need heating (July mean maximum 14.5 °C) **Q11.** see solutions **Q12.** see solutions **Q13.** see solutions **Q14.** 104.0 kWh; $31.20; e.g. switch standby devices off at the wall

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Fully-worked solutions

Q1. 2 400 W ÷ 1 000 = **2.4 kW** — divide by 1 000 to go from watts to kilowatts. *(1 mark)*

Q2. E = 1.5 kW × 4.0 h = **6.0 kWh**. *(1 mark)*

Q3. 6.0 kWh × $0.30 = **$1.80**. *(1 mark)*

Q4. The label's energy number for a year reads **410 kWh** under the standard test. *(1 mark)*

Q5. Electric storage hot water, at 63.3% of the total — nearly two-thirds of everything the house uses. *(1 mark)*

Q6. 28.8° above the horizon — low enough that winter Sun slides under a well-sized eave. *(1 mark)*

Q7. (a) 3 000 W = 3.0 kW; E = 3.0 kW × 2.5 h = 7.5 kWh per day. *(1 mark)* (b) 7.5 kWh × 120 = 900.0 kWh. *(1 mark)* (c) 900.0 kWh × $0.30 = **$270.00**. *(1 mark)*

Q8. Saving = 550 − 400 = 150 kWh a year; 150 × $0.30 = $45.00 a year; $45.00 × 12 = **$540.00** over 12 years. *(2 marks: 1 for the saving per year, 1 for the 12-year total)*

Q9. Share = 500.0 ÷ 4 610.6 = 0.1084…; × 100 ≈ **10.8%**, matching the audit table. *(2 marks: 1 for the division, 1 for the percentage)*

Q10. 1 450 ÷ 4 595 = 0.3156…; × 100 ≈ **31.6%**. The peak makes sense because Melbourne's winter (July mean maximum 14.5 °C) is cold enough that heating runs hard, while the milder summer needs little cooling in this household. *(2 marks: 1 for the percentage, 1 for the explanation)*

Q11. At the summer solstice the midday Sun stands 75.6° high, so its rays fall almost straight down and strike the eave, shading the window. *(1 mark)* At the winter solstice the midday Sun is only 28.8° high, so its rays arrive at a shallow angle and pass under the same eave through the north-facing window. *(1 mark)* The same window and eave therefore admit winter sunshine to warm the house and block summer sunshine that would overheat it. *(1 mark)*

Q12. Mudbrick has a large thermal mass: by day it soaks up the winter sunshine coming through the north windows and stores it as heat. *(1 mark)* At night, as the room cools, the brick gives the stored warmth back, keeping the house warm longer and cutting the heater's run time. *(1 mark)*

Q13. Any two of: raised on stumps so air flows under the floor; wide verandahs that shade the walls; windows on opposite sides for cross-ventilation; lightweight timber walls. *(1 mark)* Explanation, e.g. cross-ventilation: with windows open on opposite sides, breezes blow straight through the rooms and carry the warm air away, cooling the house without a machine. *(1 mark)*

Q14. Energy saved = 208.0 ÷ 2 = 104.0 kWh; money saved = 104.0 × $0.30 = **$31.20** a year. *(1 mark)* One other proposal, e.g. switching standby devices off at the wall (cuts the 87.6 kWh standby line), insulating the ceiling, or choosing a higher-star model when the fridge next needs replacing. *(1 mark)*

Sources

Web sources below were retrieved 2026-08-21.

- Wikipedia, *Nationwide House Energy Rating Scheme* — NatHERS rates homes out of 10 stars; the National Construction Code minimum is 6 stars across most of Australia and 7 in South Australia.

- Wikipedia, *Queenslander (architecture)* — timber and corrugated iron, raised on stumps, verandahs, underfloor air flow and cross-ventilation for a hot, humid climate.
- Wikipedia, *Passive solar building design* — north-facing glazing in the southern hemisphere, eaves sized to the latitude, thermal mass.
- Wikipedia, *Building insulation* — bulk insulation (glass wool, cellulose, rock wool, polystyrene) traps still air; reflective foil bounces radiant heat back.
- Bureau of Meteorology, Melbourne Olympic Park (station 086338): January mean maximum 26.8 °C, July mean maximum 14.5 °C; Melbourne latitude 37.8° south; Earth's axial tilt 23.4° — via the 14A source set, retrieved 2026-08-20. Midday Sun heights 75.6° (summer) and 28.8° (winter) computed as $90° - 37.8° \pm 23.4°$.

The audit table, the monthly meter readings, the star-label drawing and the star comparison are **simulated values chosen for practice**, and are labelled as such in the text and figures; the $0.30/kWh price is a round practice rate. The Australian government's appliance energy-rating site (energyrating.gov.au) was not retrievable at authoring time, so the label is drawn as a practice example showing the label's two real parts — stars and a kilowatt-hour number per year under a standard test.

Elaboration contexts used: `.E01` (audit method and simulated audit), `.E02` (star meaning and criteria), `.E03` (passive solar principles and the model activity), `.E04` (Queenslander and climate comparison), `.E05` (mudbrick, polystyrene, insulation), `.E06` (seasonal and daily variation, storage and generation).