Science 5–6

Chapter 2 — Planning and conducting

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Contents

Planning a repeatable, fair and safe investigation

Words to know investigation · variable · fair test · method · repeat · risk · ethical · permission · protocols · field observation · survey · simulation · research

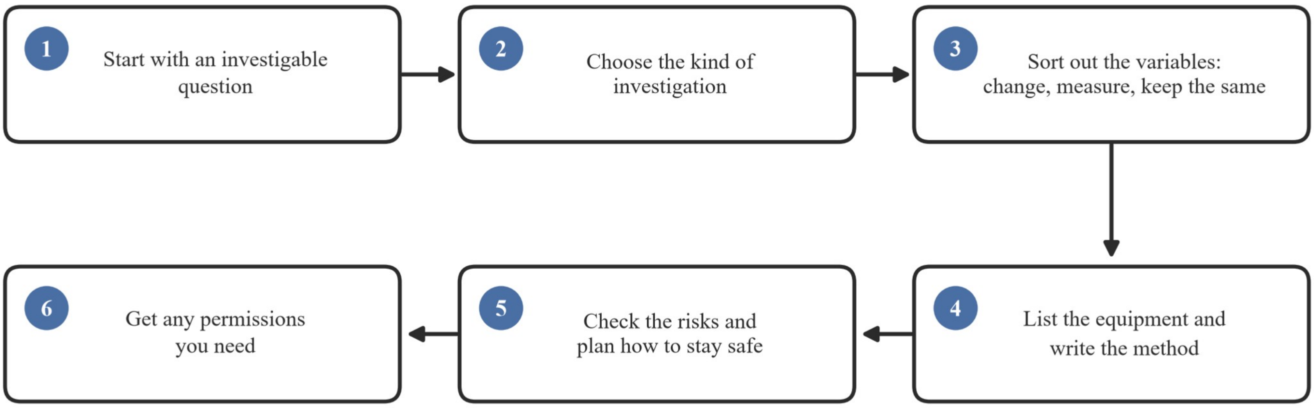
Scientists do not just rush out and try things. When a scientist wants to answer a question, the first job is to **plan**. A good plan means the work can be done again by someone else, the test is fair, everyone stays safe, and the right permissions are in place before anyone starts. In this section we learn the six planning steps and use them on real questions — in the classroom and out in the field.

Theory

The six planning steps

Every investigation in this book follows the same six steps, in the same order.

Planning an investigation, step by step



Step 6 is needed when you leave the classroom — for fieldwork in a park, on Country or in any protected place.

A flow chart of the six planning steps in order: 1 start with an investigable question; 2 choose the kind of investigation; 3 sort out the variables to change, measure and keep the same; 4 list the equipment and write the method; 5 check the risks and plan how to stay safe; 6 get any permissions you need.

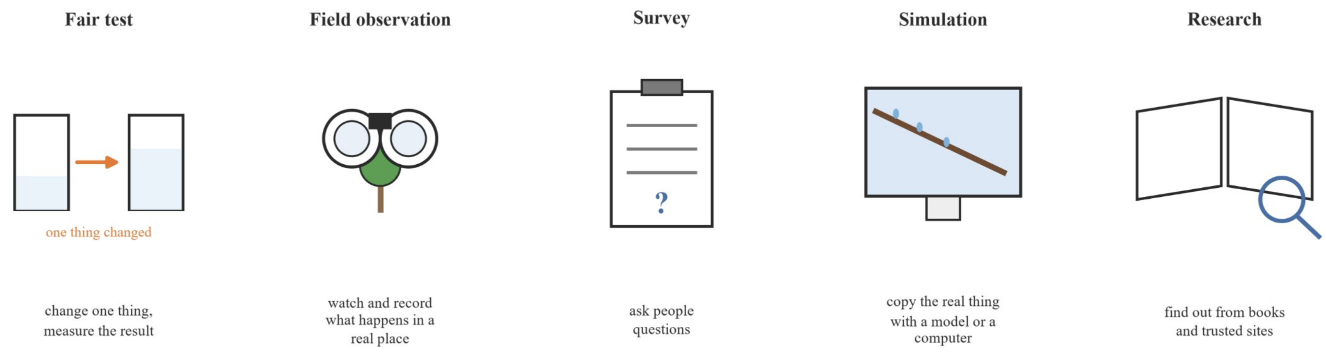
An **investigation** is a careful piece of work set up to answer a question, where we gather evidence by observing, measuring or asking. The rest of this section walks through the six steps one by one.

Step 1 — Start with an investigable question

A question is **investigable** if we can answer it with evidence — by measuring, observing or asking people. “Which paper towel soaks up the most water?” is investigable, because we can measure it. “Which paper towel is the nicest?” is not, because “nicest” is a matter of opinion and people will disagree. A good first step is to turn a big question into a small, investigable one.

Step 2 — Choose the kind of investigation

Different questions need different kinds of investigation. Five kinds do most of the work in science at this level.



Five panels, one for each kind of investigation: a fair test changes one thing and measures the result; a field observation watches and records what happens in a real place; a survey asks people questions; a simulation copies the real thing with a model or a computer; research finds out from books and trusted sites.

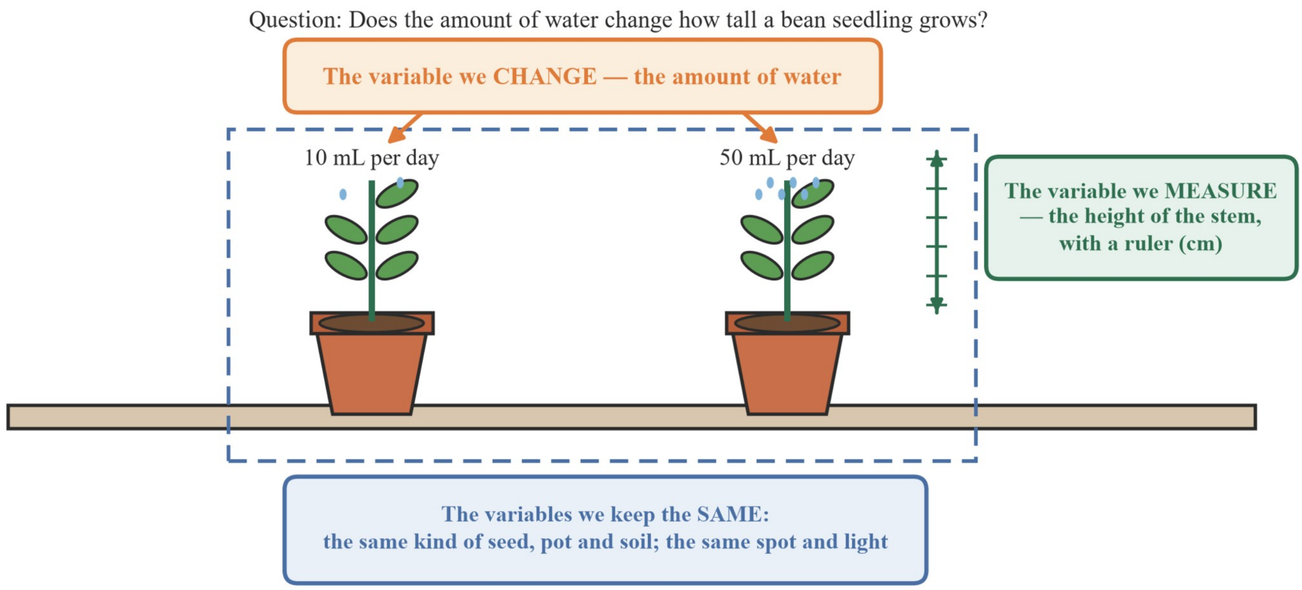
- A **fair test** changes one thing and measures the result. It is the kind to use when you can control the variables yourself, in the classroom.
- A **field observation** watches and records what happens in a real place, like a beach, a creek or a schoolyard. You observe; you do not change things.
- A **survey** asks people questions. It is the kind to use when the evidence lives in what people say they do.
- A **simulation** copies the real thing with a model or a computer. It is the kind to use when the real thing is too big, too slow, too fast or too dangerous to test directly.
- **Research** finds out from books and trusted sites what careful investigations have already shown.

Sometimes you also find things out by **trial and error** — trying something, seeing what happens, and trying again a better way. But most investigations you plan will be one of the five kinds above, and choosing the right kind now saves a lot of wasted work later.

Step 3 — Sort out the variables

A **variable** is anything that could be different from one run of the test to the next, and that might change the result. Every fair test sorts its variables into three jobs: the one we **change**, the one we **measure**, and the ones we **keep the same**.

The three kinds of variable



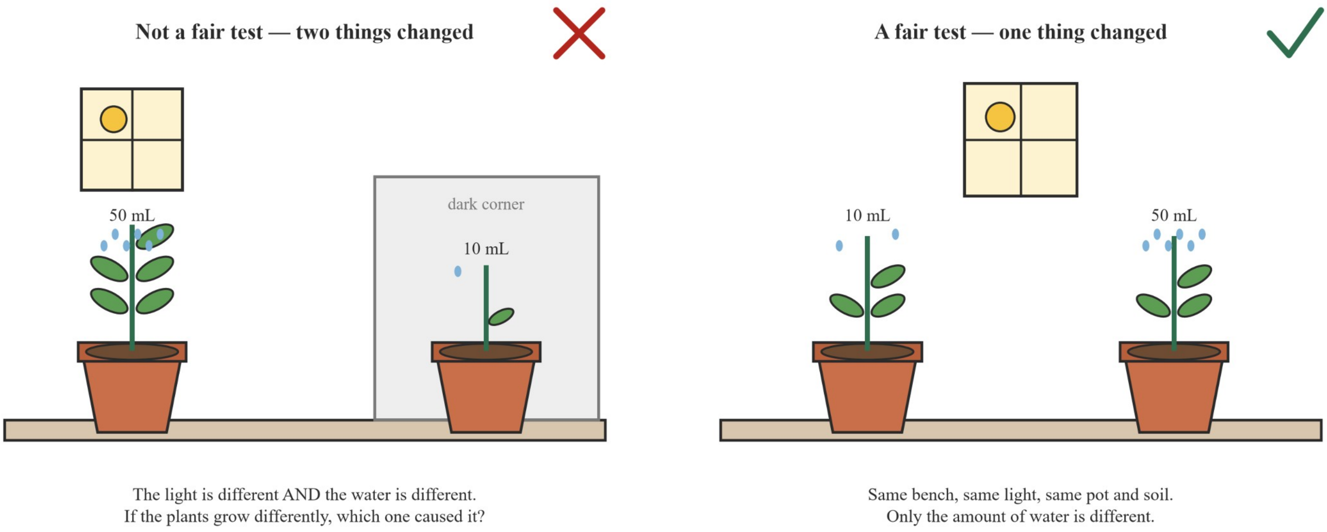
Only the amount of water is different — so anything that changes in the growth can be put down to the water.

Two bean seedlings in the same pots on the same bench: one gets 10 mL of water a day and one gets 50 mL. Labels show the variable we change (the amount of water), the variable we measure (the height of the stem, with a ruler) and the variables we keep the same (the same kind of seed, pot and soil, the same spot and light).

In the plant test above, the question is: *Does the amount of water change how tall a bean seedling grows?* The variable we change is the amount of water (10 mL a day against 50 mL a day). The variable we measure is the height of the stem, in centimetres, read from a ruler. The variables we keep the same are everything else that could matter: the same kind of seed, the same pot and soil, the same spot and light. Because only the water is different, any difference in the growth can be put down to the water.

What makes a test fair

A **fair test** is a test in which only one variable is changed and every other variable is kept the same. That is the whole definition — “fair” in science has this exact, workable meaning, and it is why a fair test is also called a fair comparison.

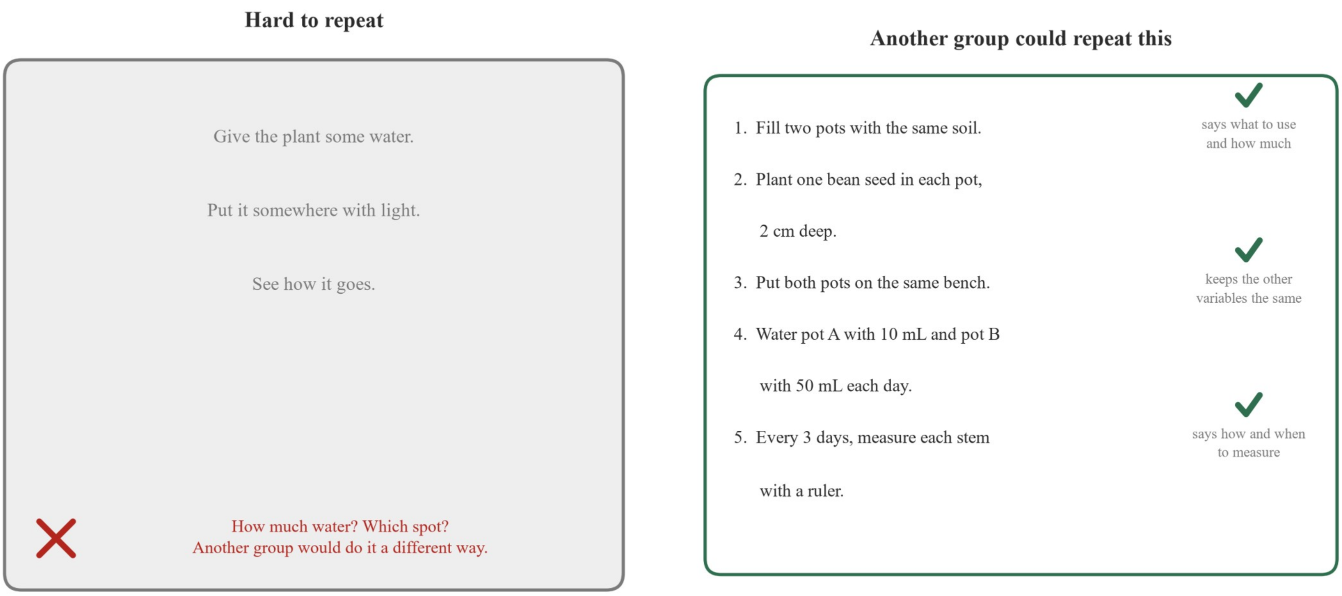


Two panels. Left: one plant in a sunny spot with 50 mL of water and one plant in a dark corner with 10 mL, marked with a cross because two things changed. Right: two plants on the same bench under the same light, one with 10 mL and one with 50 mL, marked with a tick because only the water changed.

The left-hand set-up is **not** a fair test: the light is different *and* the water is different, so if the plants grow in a different way we cannot tell which variable caused it. The right-hand set-up is fair: same bench, same light, same pot and soil — only the amount of water is different.

Step 4 — Write a method another group can repeat

The **method** is the numbered list of steps for doing the test. A method is **repeatable** when it carries enough detail — what to use, how much, what to keep the same, and how and when to measure — that another group could follow it and do the same work you did.



Two cards. Left card, marked with a cross: a vague method — give the plant some water, put it somewhere with light, see how it goes. Right card, marked with a tick: a numbered method with amounts and steps that another group could repeat.

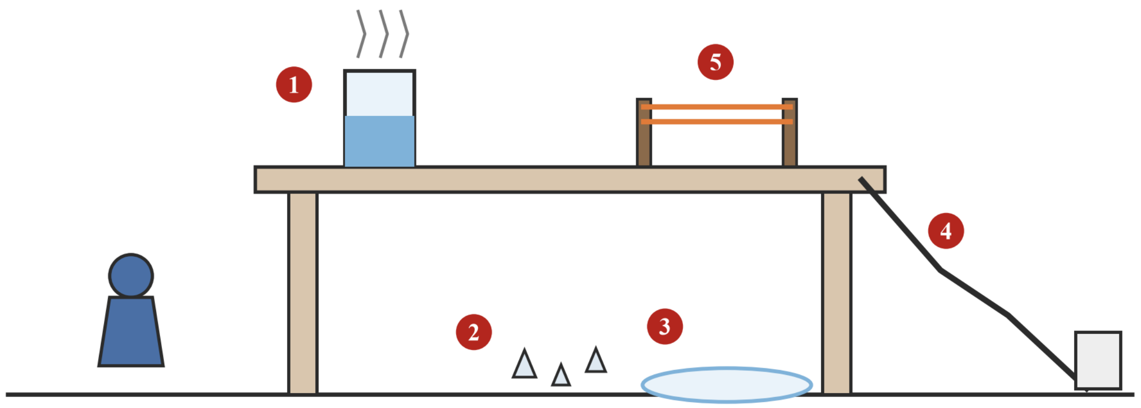
The vague card on the left would be done a different way by every group that tries it, so its results would tell us little. The card on the right says exactly what to use, how much, what stays the same, and how and when to measure — another group could repeat it step for step.

A repeatable method also says how many **trials** to do. A trial is one full run of the test. Doing three trials and comparing them is how we check that a result is one we can trust: if the trials agree with each other, the result is not a one-off. If one trial is nowhere near the others, we check what went wrong and do that trial again. We compare the trials — we do not boil them down to a single number at this level.

Step 5 — Check the risks, and plan how to stay safe

A **risk** is something in the investigation that could cause harm, together with the harm it could cause. Finding a risk is not a reason to panic; it is a reason to plan, so that the work stays safe.

Spot the risks before you start



1 hot water can scald   2 broken glass can cut   3 a spill is slippery
4 a trailing cord can trip you   5 a snapped rubber band can hit an eye

Each risk needs a plan for how to stay safe BEFORE the work starts.

A classroom scene with five numbered risks: 1 hot water that can burn; 2 broken glass that can cut; 3 a spill that is slippery; 4 a cord across the floor that can trip you; 5 a rubber band that can snap and hit an eye.

Before any practical work, we list the risks in a **risk table**: what the risk is, what could happen, and how we stay safe. The plan is agreed *before* the work starts, not after something goes wrong.

A risk table for the ramp practical

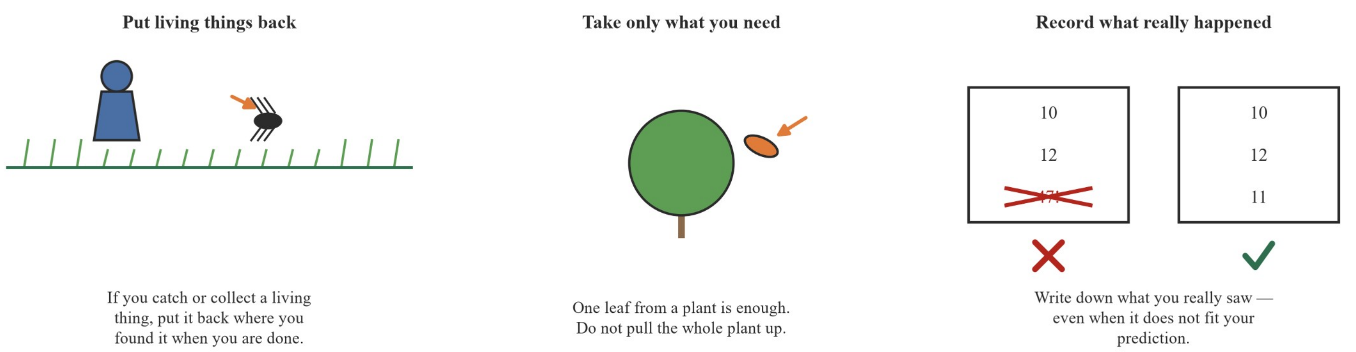
Risk	What could happen	How we stay safe
The car runs off the end of the table	It could hit someone	Put a soft stopper (a bag) at the end of the run; nobody stands in the line of the run
Bags left on the floor	Someone could trip and fall	Bags go under the tables, out of the way
The ramp slips and falls	Fingers could be squashed	Support the ramp with blocks; hold it steady when you change the height

A completed risk table for the ramp practical with three columns — risk, what could happen, how we stay safe — and three rows: the car runs off the end of the table; bags left on the floor; the ramp slips and falls.

The same thinking applies at home, especially with electricity. A broken cord on a lamp is a risk (it can give a shock or start a fire); the rule is to stop using it and tell an adult. Any electrical appliance near water is a risk; the rule is to keep electrical things away from water, always. Nothing electrical gets repaired or opened by a student — that is an adult's job.

Using living things and places ethically

To be **ethical** is to think about how your investigation affects living things and places, and to choose to treat them well. "Ethical" is one of the curriculum's own words, and at this level it has a workable meaning: no living thing or place comes to harm because of your work.



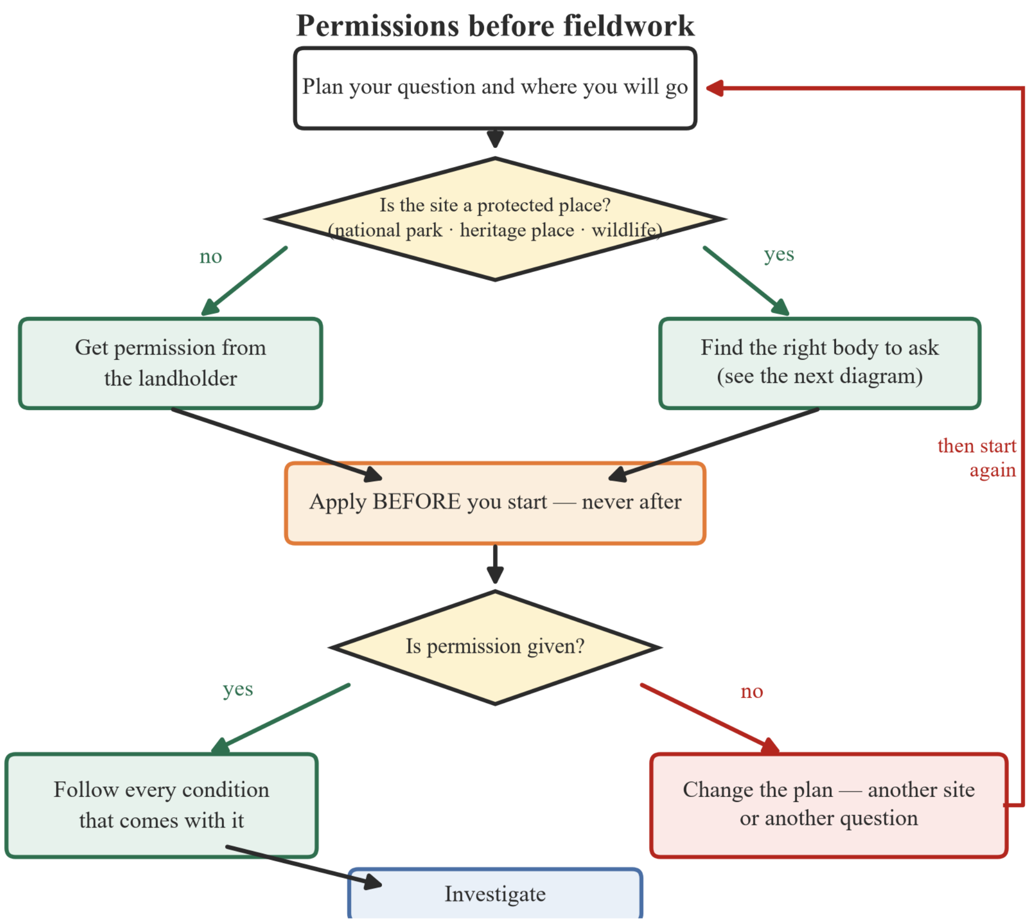
Three panels: put living things back where you found them; take only what you need, like one leaf instead of the whole plant; record what really happened, even when it does not fit your prediction.

Three habits cover most of it. If you catch or collect a living thing, put it back where you found it when you are done. Take only what you need — one leaf, not the whole plant; five snails, not twenty. And record what really happened, even when it does not fit your prediction: honest numbers are part of ethics too.

Step 6 — Get any permissions you need

The moment an investigation leaves the classroom — for a park, a creek, a farm or any protected place — it may need **permission**: someone whose job it is to say yes must say yes, before you start. Permission is both a process and, in many places, a law.

The process is always the same:

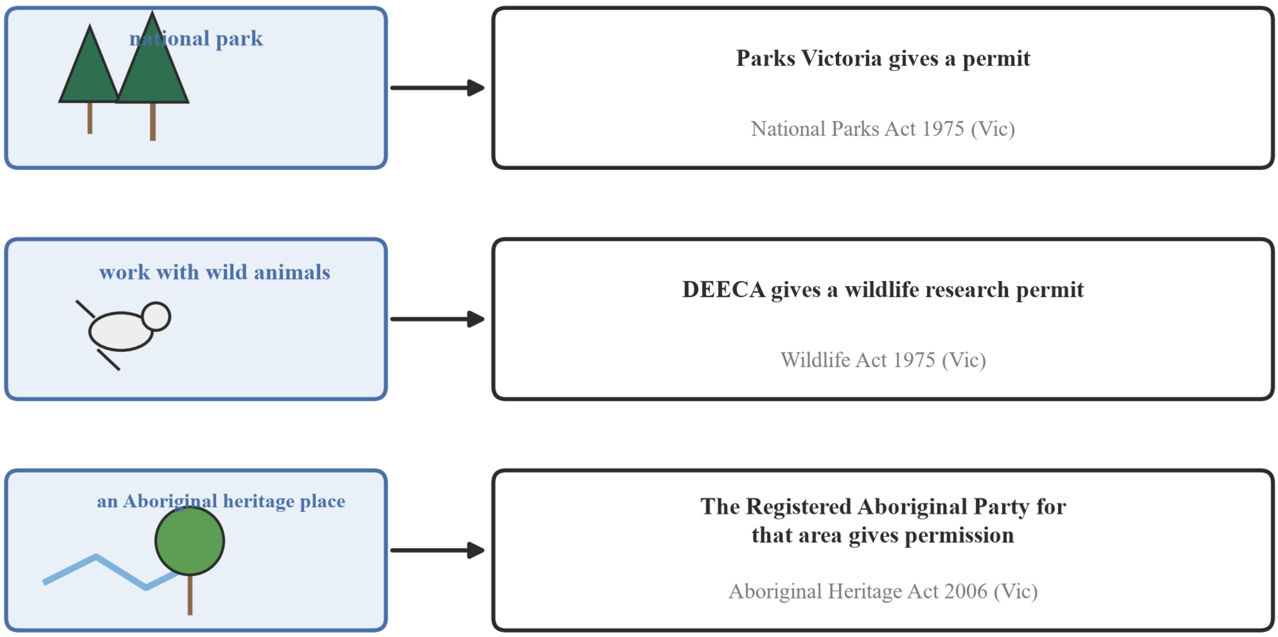


A flow chart: plan your question and where you will go; check whether the site is a protected place; if not, get permission from the landholder; if so, find the right body to ask; apply before you start; if permission is given, follow every condition and investigate; if it is refused, change the plan and start again.

Four ideas matter. **Protection can be invisible** — an Aboriginal heritage place can look like an ordinary creek bank, and wildlife can be protected even where there is no sign. **Consent can sit with a body other than the landholder** — in protected places, the law names who says yes. **Approval comes before the work starts** — permission asked for afterwards is not permission. And **access can be restricted or refused** — a refusal is an answer, not a failure, and the plan changes to another site or another question.

In Victoria, three real cases show how the law names the body that says yes:

Who gives permission in Victoria?



The Victorian Aboriginal Heritage Council runs the Registered Aboriginal Party system.
Ask before you start. Permission may be limited or refused — and that is an answer, not a failure.

Three Victorian cases: a national park — Parks Victoria gives a permit under the National Parks Act 1975 (Vic); work with wild animals — DEECA gives a wildlife research permit under the Wildlife Act 1975 (Vic); an Aboriginal heritage place — the Registered Aboriginal Party for that area gives permission under the Aboriginal Heritage Act 2006 (Vic).

- Work in a **national park** needs a permit from Parks Victoria, named in the *National Parks Act 1975* (Vic).
- Work with **wild animals** needs a wildlife research permit from DEECA, named in the *Wildlife Act 1975* (Vic).
- Work on or near an **Aboriginal heritage place** needs permission from the Registered Aboriginal Party for that area, under the *Aboriginal Heritage Act 2006* (Vic). The Victorian Aboriginal Heritage Council runs the Registered Aboriginal Party system.

On private land, the landholder is the one who says yes.

Investigations on or about Country and Place carry one more requirement: they should involve the knowledge holders for that Country, and cultural **protocols** — the rules for how to behave in or near a place, set by the people responsible for it — may restrict or even prohibit access. That is not an obstacle to science; it is part of doing science well in this country.

Source: *National Parks Act 1975* (Vic); *Wildlife Act 1975* (Vic); *Aboriginal Heritage Act 2006* (Vic) — legislation.vic.gov.au, named in this book's TOC §6 approved source list; verified 2026-08-07.

Worked examples

Example 1 — with support

A class asks: *Does the height of a ramp change how far a toy car rolls after it leaves the ramp?* Sort out the variables, and say what makes the test fair.

Working	Comment
The variable we change: the height of the ramp (1 block, then 3 blocks).	A fair test changes one variable only.

Working	Comment
The variable we measure: how far the car rolls from the end of the ramp, in cm.	The measured variable is where the evidence comes from.
The variables we keep the same: the same ramp, the same car, the same release spot, released without a push.	Every other variable that could matter stays the same.
∴ If the roll distance is different at the two heights, the difference can be put down to the height.	One thing changed, so the test is fair.

Example 2 — with support

A class wants to find out whether the bank of a creek in a national park has moved back after the winter storms. They plan to visit the bank, take photographs and measure it. (a) Which kind of investigation is this? (b) Whose permission must the class get, and under which Victorian law? (c) When must they get it?

Working	Comment
The class watches and records what happens in a real place, without changing anything.	That is a field observation.
The creek sits inside a national park — a protected place, even though the bank itself looks ordinary.	Protection can be invisible.
Parks Victoria gives the permit, under the *National Parks Act 1975* (Vic).	In a protected place, the law names the body that says yes.
The class applies before the visit, follows every condition that comes with the permit, and accepts the decision.	Approval comes before the work starts — never after.

Example 3 — by yourself

Plan a fair test to answer this question: *Does the amount of light change how tall a bean seedling grows?* Your plan must:

- name the variable you change, the variable you measure, and two variables you keep the same;
- give a repeatable method in numbered steps, with amounts and timings;
- list one risk and how you will stay safe.

Practice questions

With support

Q1. Write a sentence, in your own words, for each word: *(3 marks)* (a) investigation (b) variable (c) method

Q2. A fair test sorts its variables into three jobs. Name the three jobs. *(3 marks)*

Q3. Look at the two panels in the fair-test figure in the theory. *(3 marks)* (a) Explain why the left-hand set-up is not a fair test. (b) What is different in the right-hand set-up that makes it fair?

Q4. A method is repeatable when another group could follow it and do the same work. Give two details a method must carry to be repeatable. *(2 marks)*

Q5. The figure below shows three questions and three kinds of investigation. In your notebook, draw a line from each question to the kind that suits it best. One kind may be used more than once. *(3 marks)*

Match each question to the kind of investigation that suits it best

Q1 Which soil in our garden holds the most water?

Q2 Has the cliff at our beach moved back this year?

Q3 How do students in our school get to school?

Survey

Fair test

Field observation

Draw a line from each question to one kind. One kind may be used more than once.

A matching task: on the left, three questions; on the right, three kinds of investigation — survey, fair test, field observation. Draw a line from each question to the kind that suits it best.

Q6. Pick any two of the five numbered risks in the classroom figure and, for each, give the way to stay safe. *(2 marks)*

By yourself

Q7. A student wants to know which of two soils holds the most water. She uses two pots: sand, watered with a lot of water, and garden soil, watered with a little water. Is this a fair test? Explain your answer. *(2 marks)*

Q8. A group's method reads: "Water the plants. Put them in the light. Measure them." Give three details the group must add so that another group could repeat the method exactly. *(3 marks)*

Q9. A group does three trials of the same fair test, measuring how far a toy car rolls: 42 cm, 44 cm and 43 cm. Do the trials agree with each other, and what does that tell you about the result? *(2 marks)*

Q10. Choose the kind of investigation that suits each question best: *(4 marks)* (a) Which brand of battery lasts longest in the same torch? (b) How many birds visit the schoolyard at lunchtime? (c) How do the students in our school get to school? (d) What do trusted sites say about how cliffs move back over the years?

Q11. A group collects twenty small snails to watch how they move, although the plan only needs five. *(3 marks)* (a) What must the group do with the snails when the work is done? (b) Which ethical rule did the group forget when it collected twenty? (c) Name one more ethical habit from the theory.

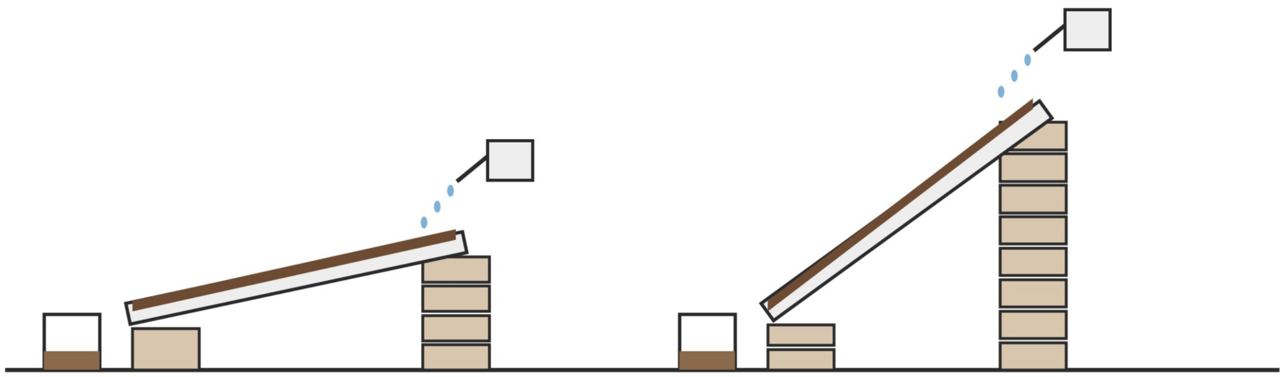
Q12. Name two electrical hazards at home, and for each give the rule that keeps people safe from it. *(4 marks)*

Q13. Maya wants to watch which birds drink at a creek. The creek runs through a farmer's paddock, on private land. *(3 marks)* (a) Whose permission does Maya need before she goes? (b) Would the answer change if the creek ran through a national park instead? Explain.

Q14. A class plans to count the nests of a protected native bird in a national park, which means quietly watching the birds at work. The class needs two permissions. Name each body that says yes, and the Victorian law behind it. *(4 marks)*

Q15. A class uses the two erosion rigs in the figure below to ask: *Does the slope of the land change how much soil washes away? (5 marks)*

The same erosion rig at two slopes



Set-up A: low slope **Set-up B: steep slope**

The same amount of water is poured from the same watering can each time.
The cup catches the soil that washes away.

A class uses these rigs to ask: Does the slope of the land change how much soil washes away?

Two soil trays on blocks: set-up A at a low slope and set-up B at a steep slope. The same amount of water is poured from the same watering can onto each tray, and an open cup on the ground catches the soil that washes away.

(a) Name the variable the class changes.
(b) Name the variable the class measures.
(c) Name two variables the class keeps the same.
(d) Explain why the same amount of water, from the same watering can, matters.

Q16. SCENARIO — A Year 6 class wants to find out whether the bank of a creek in a national park is wearing away. They plan to visit the bank, take photographs and measure it with a ruler. Answer in full sentences. *(7 marks)* (a) Which kind of investigation is this? (b) Give two risks of the visit and, for each, how the class stays safe. (c) Whose permission must the class get, and under which Victorian law? (d) What happens if permission is refused? (e) Give one ethical rule the class should follow on the visit.

Practical — how does ramp height change how far the car rolls?

> **PRACTICAL** — this page plans or analyses work done in the classroom, laboratory or field. It is not a substitute for doing it.

Question: How does the height of a ramp change how far a toy car rolls after it leaves the ramp?

Equipment: one smooth ramp (a track or a long ruler); one toy car; wooden blocks to raise the ramp; a metre ruler or tape on the floor to measure the roll; a soft bag to stop the car.

Safety: Keep your body out of the line of the run. Put bags under the tables, out of the way. Hold the ramp steady when you change the height, and release the car gently — never push it.

Risk	How we stay safe
The car runs off the end of the table	Put a soft stopper (a bag) at the end of the run; nobody stands in the line of the run.
Bags left on the floor	Bags go under the tables, out of the way.
The ramp slips and falls	Support the ramp with blocks; hold it steady when you change the height.

Variables (the things we change, measure and keep the same):

Variable	Choice
The one we change	the height of the ramp: 1 block, then 3 blocks
The one we measure	how far the car rolls from the end of the ramp (cm)

Variable	Choice
The ones we keep the same	the same ramp; the same car; the same release spot; released without a push; the same floor

Method:

1. Set the ramp on 1 block. Lay the metre ruler on the floor from the end of the ramp, and put the soft bag at the far end.
2. Hold the car at the release spot at the top of the ramp. Let it go without pushing.
3. When the car stops, read how far it rolled from the end of the ramp. Record it in your results table.
4. Repeat steps 2–3 until you have three trials at 1 block.
5. Raise the ramp to 3 blocks. Keep everything else the same.
6. Repeat steps 2–3 until you have three trials at 3 blocks.

Results: record your readings in a table like this one.

Trial	1 block (cm)	3 blocks (cm)
1		
2		
3		

Compare your three trials at each height. Do the readings agree with each other? If one trial is nowhere near the others, check what went wrong and do that trial again.

Thinking about the results:

1. Describe what happened to the roll distance when the ramp was raised from 1 block to 3 blocks.
2. Which variable did you change, and which did you measure? Say how the other variables were kept the same.
3. A group at another bench gets the same pattern as you. What does that tell you about your result?

Make a claim and defend it. Finish this writing frame in full sentences:

- I claim that raising the ramp ____ .
- My evidence is ____ .
- The trials agree / do not agree because ____ .
- If someone claimed the car rolled further because it was pushed, I would answer ____ .

Answers

Q1 (a) An investigation is a careful piece of work set up to answer a question with evidence. (b) A variable is anything that could be different from one run to the next and might change the result. (c) A method is the numbered list of steps for doing the test. **Q2** The one we change; the one we measure; the ones we keep the same. **Q3** (a) Two variables are changed (the light and the water), so a difference in growth could be caused by either — we cannot tell. (b) Only the amount of water is different; the light, bench, pot and soil are the same. **Q4** Any two of: what to use and how much; what to keep the same; how and when to measure; how many trials to do. **Q5** Q1 — fair test; Q2 — field observation; Q3 — survey. **Q6** Any two, matched: hot water can burn — handle with care, teacher help; broken glass — do not pick it up with your hands, tell the teacher; a spill is slippery — wipe it up straight away; a cord across the floor — tape it down or move it out of the walkway; a rubber band that can snap — wear safety glasses or point it away from people. **Q7** No. Two variables are changed (the kind of soil and the amount of water), so any difference could be caused by either — the test is not fair. **Q8** Any three of: how much water each plant gets; that the pots, soil and seeds are the same; the same spot and light; how and when to measure (a ruler, every few days); how many trials or plants. **Q9** Yes — 42 cm, 44 cm and 43 cm are close to each other, so the trials agree and the result is one we can trust. **Q10** (a) Fair test. (b) Field observation. (c) Survey. (d) Research. **Q11** (a) Put them back where they were found. (b) Take only what you need. (c) Any one of: put living things back; take only what you need; record what really happened. **Q12** Any two hazards with matching rules: a broken cord on a lamp — stop using it and tell an adult; an appliance near water — keep electrical things away from water; (also accept) too many plugs in one power board — an adult moves some out. **Q13** (a) The landholder — the farmer. (b) Yes: in a national park the law names Parks Victoria as the body that gives the permit, under the *National Parks Act 1975* (Vic). **Q14** Parks Victoria, under the *National Parks Act 1975* (Vic), for work in the park; and DEECA, under the *Wildlife Act 1975* (Vic), for work with wild animals. **Q15** (a) The slope of the tray (low against steep). (b) The amount of soil that washes away into the cup. (c) Any two of: the same tray and soil; the same amount of water; the same watering can; the same cup. (d) So that only the slope is different — if two things were different, the test would not be fair. **Q16** (a) A field observation. (b) Any two, matched: a slippery bank — stay back from the edge and wear grip shoes; strong sun — hats, sunscreen and water; things to trip on — watch where you walk, one person moves at a time. (c) Parks Victoria, under the *National Parks Act 1975* (Vic). (d) The class changes the plan — another site or another question; a refusal is an answer, not a failure. (e) Any one: take only what you need; leave the place as you found it; put living things back; record honestly.

Worked solutions

Q1 *(3 marks: 1 each)* (a) An investigation is a careful piece of work set up to answer a question, where evidence is gathered by observing, measuring or asking. *1 mark* (b) A variable is anything that could be different from one run of the test to the next, and that might change the result. *1 mark* (c) A method is the numbered list of steps for doing the test, written so another group could repeat it. *1 mark*

Q2 *(3 marks: 1 each)* The variable we change; the variable we measure; the variables we keep the same. *1 mark each*

Q3 *(3 marks: 2 for (a), 1 for (b))* (a) In the left-hand set-up the light is different and the water is different, so two variables are changed; *1 mark* if the plants grow in a different way we cannot tell which variable caused the difference. *1 mark* (b) In the right-hand set-up only the amount of water is different — the bench, light, pot and soil are all the same — so it is a fair test. *1 mark*

Q4 *(2 marks: 1 each)* Any two of: it says what to use and how much; it says what to keep the same; it says how and when to measure; it says how many trials to do. *1 mark each*

Q5 *(3 marks: 1 each)* Q1 — fair test (the soil is changed and the water held is measured). *1 mark* Q2 — field observation (the cliff is watched and measured in a real place over time). *1 mark* Q3 — survey (the evidence lives in what people say). *1 mark*

Q6 *(2 marks: 1 each)* Any two risks matched to a sensible way to stay safe, e.g. broken glass can cut — do not pick it up with your hands, tell the teacher; *1 mark* a spill is slippery — wipe it up straight away. *1 mark*

Q7 *(2 marks)* No, it is not a fair test. *1 mark* Two variables are changed — the kind of soil and the amount of water — so a difference in the water held could be caused by either, and the test cannot show which soil is better. *1 mark*

Q8 *(3 marks: 1 per detail)* Any three of: how much water each plant gets (e.g. 10 mL a day against 50 mL a day); that the pots, soil and seeds are the same; the same spot and light; how and when to measure (a ruler, every 3 days); how many plants or trials. *1 mark each*

Q9 *(2 marks)* Yes, the trials agree — 42 cm, 44 cm and 43 cm are close to each other. *1 mark* When the trials agree, the result is one we can trust rather than a one-off. *1 mark*

Q10 *(4 marks: 1 each)* (a) Fair test — one thing (the battery brand) is changed and the lasting time is measured. *1 mark* (b) Field observation — the birds are watched and counted in a real place. *1 mark* (c) Survey — the evidence is what people say. *1 mark* (d) Research — the answer is found in books and trusted sites. *1 mark*

Q11 *(3 marks: 1 each)* (a) Put the snails back where they were found. *1 mark* (b) Take only what you need — five were enough, so twenty were too many. *1 mark* (c) Any one of: put living things back; take only what you need; record what really happened, even when it does not fit the prediction. *1 mark*

Q12 *(4 marks: 1 per hazard, 1 per matching rule)* A broken cord on a lamp is a hazard (shock or fire); *1 mark* the rule is to stop using it and tell an adult. *1 mark* An electrical appliance near water is a hazard; *1 mark* the rule is to keep electrical things away from water, always. *1 mark*

Q13 *(3 marks: 1 for (a), 2 for (b))* (a) The landholder — in this case the farmer. *1 mark* (b) Yes. *1 mark* In a national park the law names Parks Victoria as the body that gives the permit, under the *National Parks Act 1975* (Vic) — consent sits with a body other than the landholder. *1 mark*

Q14 *(4 marks: 1 per body, 1 per law)* Parks Victoria, because the work is in a national park; *1 mark* under the *National Parks Act 1975* (Vic). *1 mark* DEECA, because the work is with wild animals; *1 mark* under the *Wildlife Act 1975* (Vic). *1 mark*

Q15 *(5 marks)* (a) The slope of the tray — low in set-up A, steep in set-up B. *1 mark* (b) The amount of soil that washes away, caught in the cup. *1 mark* (c) Any two of: the same tray and the same soil; the same amount of water; the same watering can; the same cup. *1 mark each (2)* (d) So that only the slope is different; if the water were different too, a difference in the washed soil could be caused by either, and the test would not be fair. *1 mark*

Q16 *(7 marks)* (a) A field observation — the bank is watched, photographed and measured in a real place, without changing anything. *1 mark* (b) Any two risks with matching plans, e.g. a slippery bank — stay back from the edge and wear shoes with grip; *1 mark* strong sun — hats, sunscreen and water to drink. *1 mark* (c) Parks Victoria; *1 mark* under the *National Parks Act 1975* (Vic). *1 mark* (d) The class changes the plan — another site or another question — and starts the process again; a refusal is an answer, not a failure. *1 mark* (e) Any one: take only what you need; leave the place as you found it; put living things back; record what really happened. *1 mark*

Example 3 *(a plan should carry all of these)* Change: the amount of light (one pot on a sunny bench, one in a dark cupboard). Measure: the height of the stem in cm, with a ruler, every 3 days. Keep the same: the same kind of seed, pot and soil; the same amount of water each day. Method: numbered steps that say what to use, how much, and how and when to measure, with three trials or more. Risk: any sensible one with a matching way to stay safe (e.g. water on the bench — wipe spills up straight away).

Measuring and recording with reasonable precision

Words to know reading · unit · metre (m) · gram (g) · litre (L) · second (s) · degree Celsius (°C) · volt (V) · ampere (A) · kilo- · milli- · precision · repeat · trial · parallax · probe · spreadsheet

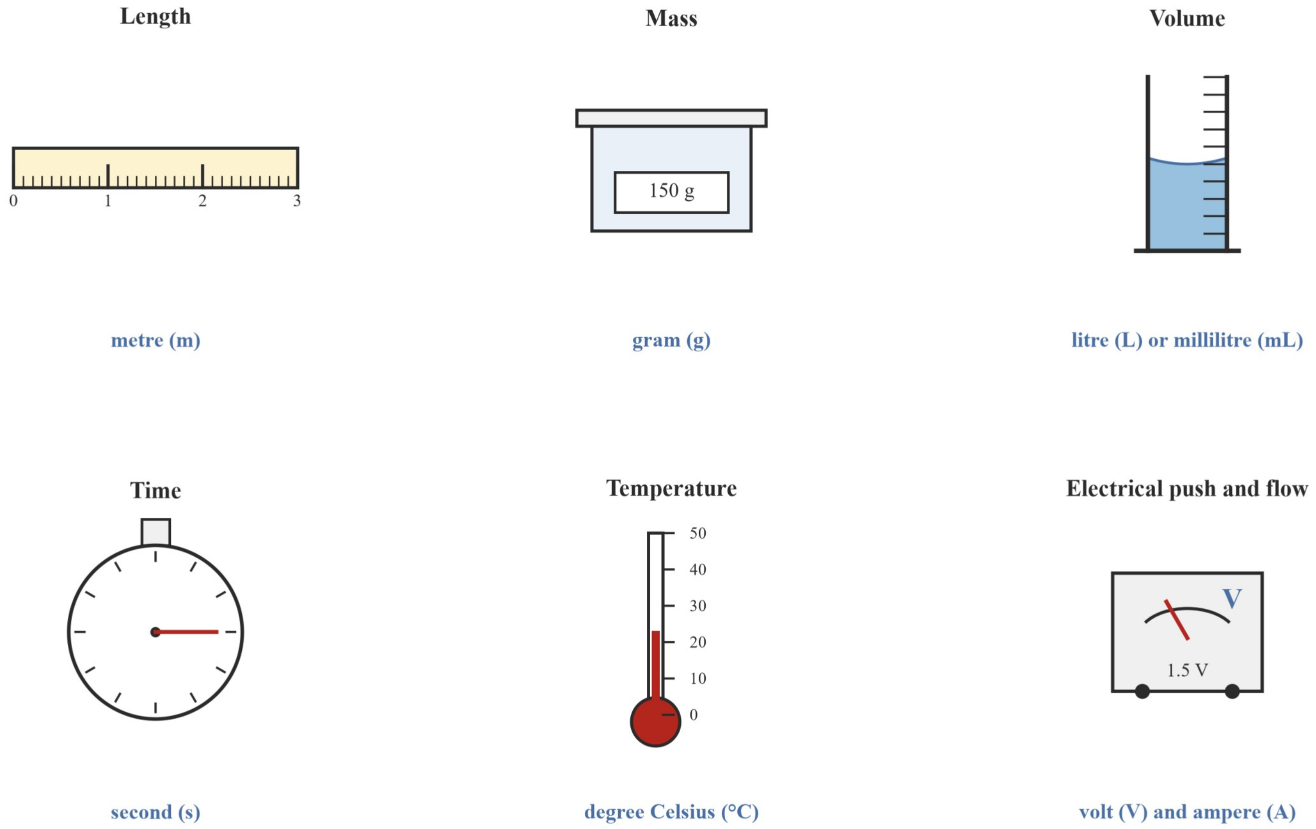
Science is a way of finding things out, and finding things out means measuring. The number and unit an instrument shows is called a **reading**. How long is the seed pod? How much water is in the cylinder? How warm is the soil? Each question is answered by choosing the right instrument, reading its scale carefully and writing the reading down so it can be trusted. In this section we learn to measure and record with reasonable **precision** — as carefully as the job needs.

Theory

What we measure and what we measure it with

The things we measure are called **quantities**: length, mass, volume, time, temperature, and the push and flow of electricity. A **quantity** is anything that can be measured with a number and a unit.

Each quantity has an instrument that suits it.



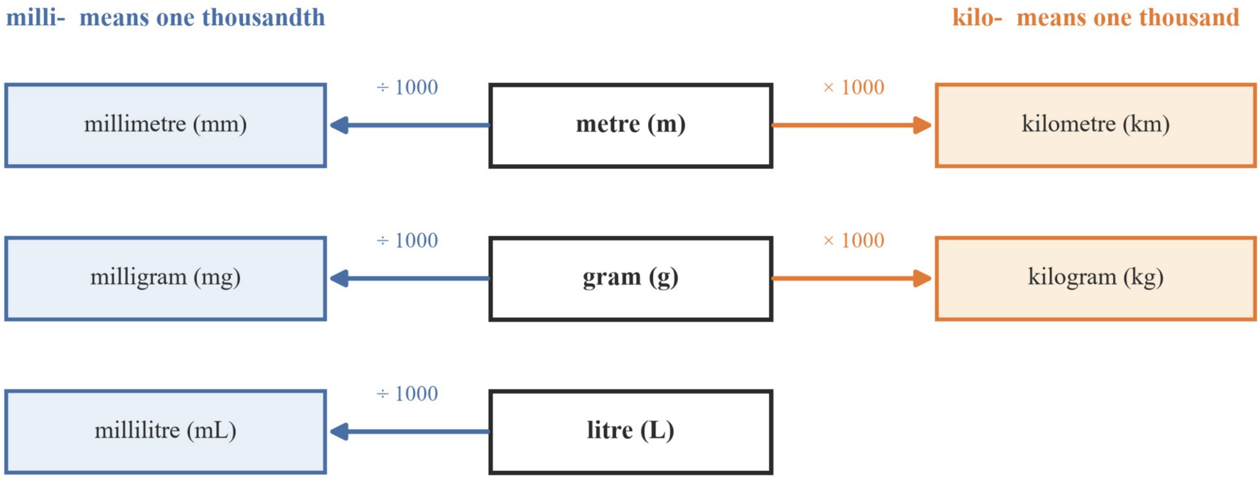
Six panels match each quantity to its instrument and unit: a ruler for length in metres (m); a balance for mass in grams (g); a measuring cylinder for volume in litres (L) or millilitres (mL); a stopwatch for time in seconds (s); a thermometer for temperature in degrees Celsius (°C); and a meter for the electrical push and flow, in volts (V) and amperes (A).

- **Length** is how long something is. It is measured with a ruler or a tape, in **metres (m)**.
- **Mass** is how much matter something has. It is measured with a **balance**, in **grams (g)**.
- **Volume** is the space something takes up. It is measured with a measuring cylinder, in **litres (L)** or **millilitres (mL)**.
- **Time** is measured with a stopwatch or a timer, in **seconds (s)**.
- **Temperature** is how hot something is. It is measured with a thermometer, in **degrees Celsius (°C)**.
- The push and flow of electricity are measured with meters, in **volts (V)** and **amperes (A)**.

The **unit** is part of the reading. “5” on its own means nothing: 5 cm, 5 m and 5 km are three very different lengths. So every reading we record is a number **and** a unit.

kilo- and milli-: one system for big and small

The same two prefixes join onto our units to make big units and small units.



The same prefixes join onto any unit — they always mean the same thing.

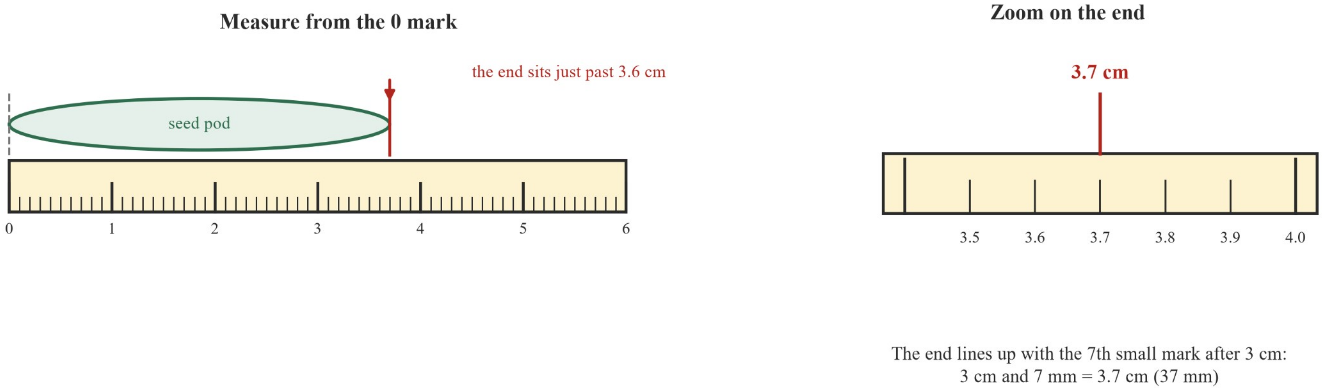
The prefix system: kilo- means one thousand and milli- means one thousandth, and the same prefixes join onto any unit. Metre (m) steps up by × 1000 to kilometre (km) and down by ÷ 1000 to millimetre (mm); gram (g) steps to kilogram (kg) and milligram (mg); litre (L) steps down to millilitre (mL). The prefixes always mean the same thing.

kilo- means one thousand: 1000 metres make 1 **kilometre (km)**, and 1000 grams make 1 **kilogram (kg)**. **milli-** means one thousandth: cut 1 metre into 1000 equal pieces and each piece is 1 **millimetre (mm)**; cut 1 litre into 1000 equal pieces and each piece is 1 **millilitre (mL)**; and 1000 milligrams (mg) make 1 gram.

The clever part is that a prefix means the same thing whatever unit it joins onto. Learn the system once and it works the same for length, mass and volume.

Reading a scale carefully

A ruler has big marks for centimetres and small marks for millimetres. Line the object up with the 0 mark, and read the end to the nearest small mark.



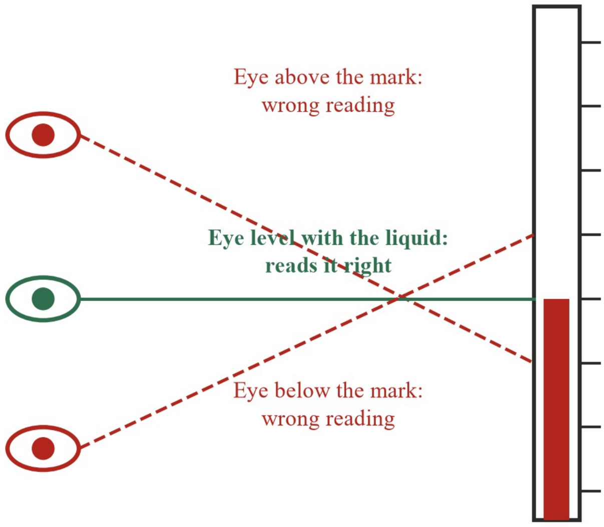
Reading a ruler: a seed pod is lined up with the 0 mark of a ruler; a zoom on the end shows it in line with the 7th small mark after 3 cm, so the reading is 3 cm and 7 mm, which is 3.7 cm (37 mm).

In the figure the pod starts at 0 and its end lines up with the 7th small mark after 3 cm, so the reading is 3.7 cm (37 mm).

Two habits keep scale readings trustworthy.

Line your eye up with the mark. Looking from above or below makes the reading land on the wrong mark. This trick of the eye is called **parallax**.

Read a scale with your eye level with the mark you are reading.

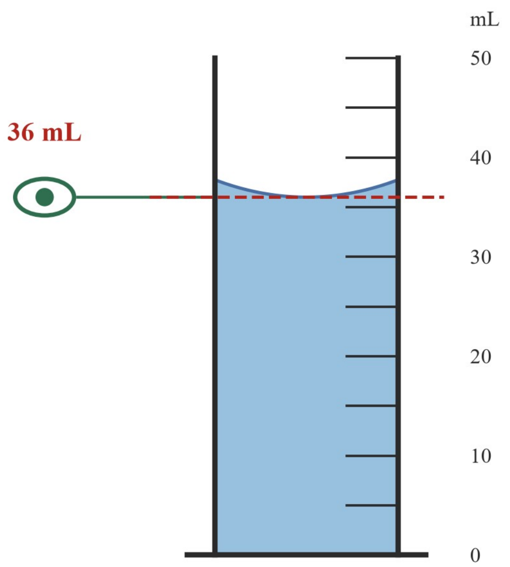


Looking from an angle gives a reading that does not match the mark — this is called parallax.

Parallax: three eyes look at the same scale. The eye above the mark and the eye below the mark each get a wrong reading, while the eye level with the liquid reads it right. Looking from an angle gives a reading that does not match the mark.

Read a liquid at the bottom of its curved surface. Water curves up where it touches the glass. The reading is taken where the middle of the surface sits, with your eye level with it.

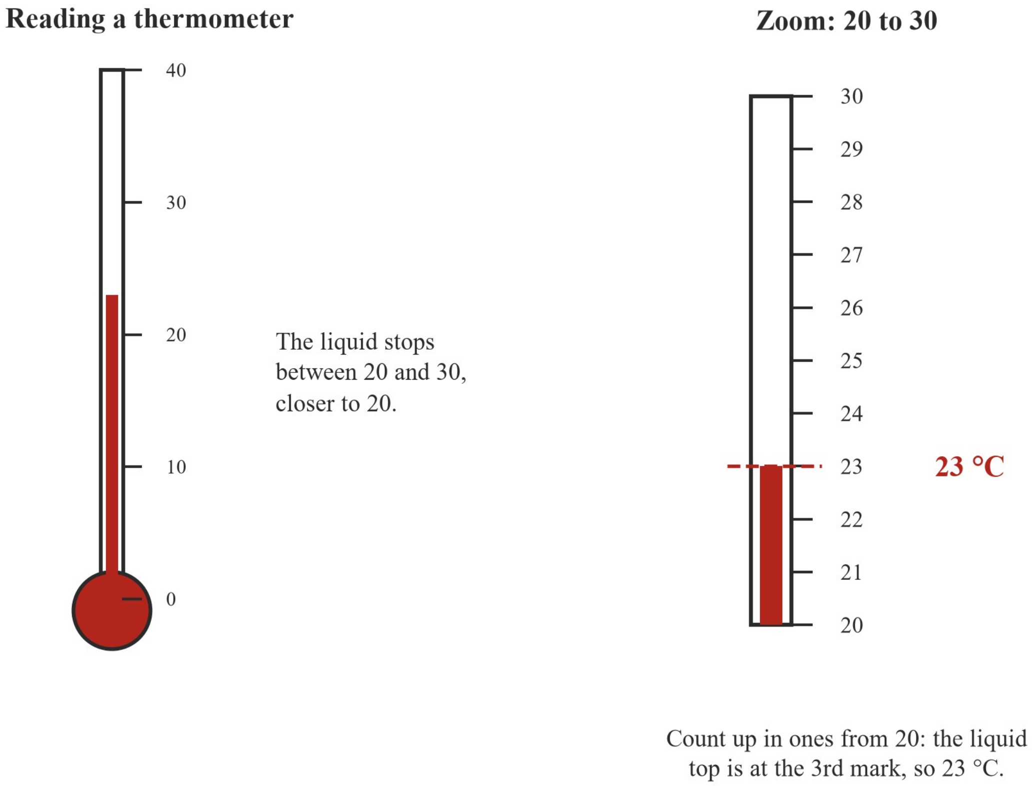
Read the bottom of the curved surface



The water curves up at the glass. Read where the middle of the surface sits, with your eye level with it. Here: 36 mL.

Reading a measuring cylinder: the water surface curves up at the glass, and a dashed line at the bottom of the curve, level with the eye, shows the reading of 36 mL on a cylinder marked from 0 to 50 mL in steps of 5.

A thermometer is read the same careful way: find the two labelled marks the liquid sits between, then count up the small marks.



Reading a thermometer: on a 0 to 40 °C thermometer the liquid stops between 20 and 30, closer to 20; a zoom from 20 to 30 with a mark for every degree shows the liquid top at the 3rd mark, so the reading is 23 °C.

Recording readings so they can be trusted

Write each reading down the moment you take it, in a table with the unit in the column heading. Then the numbers stay clean and nobody has to guess the unit later.

A	B
Trial	**Time (s)**
1	3.2
2	3.3
3	3.2

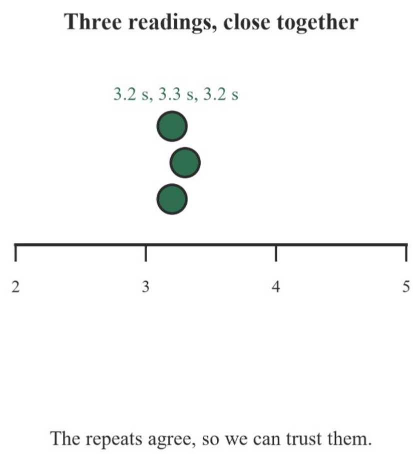
The unit (s) goes in the column heading, and each reading is written to the precision of the stopwatch — here, one place after the dot.

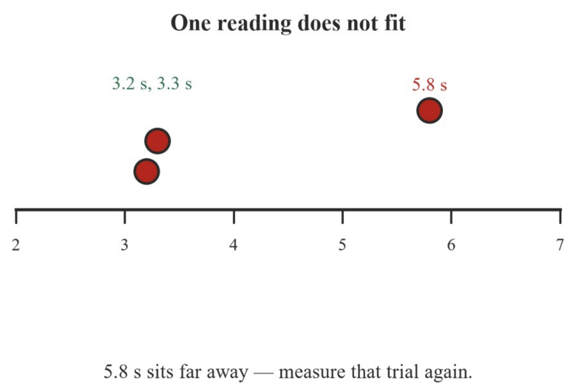
A spreadsheet-style results table with columns A and B: the headings are Trial and Time (s), and three trials are recorded as 3.2, 3.3 and 3.2. The unit sits in the column heading, and each reading is written to the precision of the stopwatch — one place after the dot.

Before you trust a reading, ask: **is it believable?** A desk recorded as 3 m tall, a cup recorded as holding 40 L, a classroom recorded at 90 °C — something has gone wrong, so measure again. A quick guess of the size first (an **estimate**) tells you what sort of number to expect, so a wrong reading stands out.

Repeats: measure more than once

Measure once and you cannot tell whether the reading is right. Measure the same thing again and the readings can be compared. Each repeat measurement is a **trial**, and the extra trials are **repeats**.





Repeat readings on number lines: on the left, three readings of 3.2 s, 3.3 s and 3.2 s sit close together, so the repeats agree and can be trusted; on the right, readings of 3.2 s, 3.3 s and 5.8 s, where 5.8 s sits far away and does not fit, so that trial is measured again.

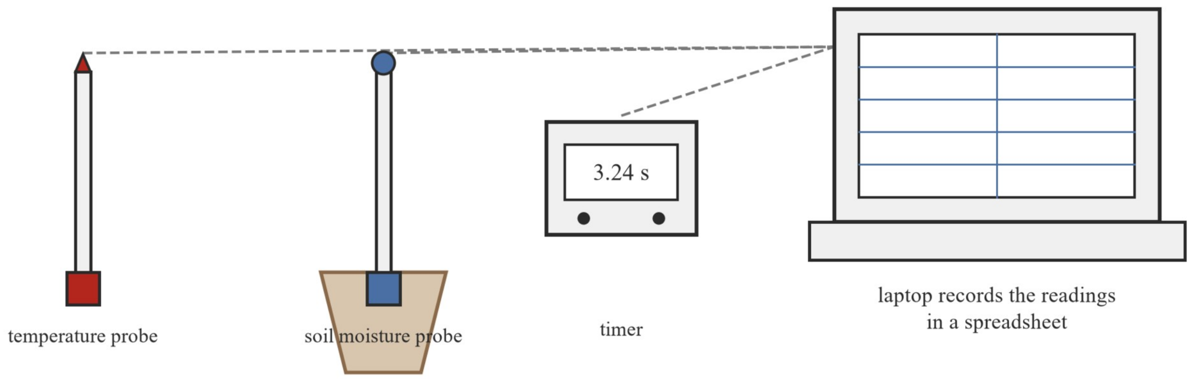
- If the repeats sit close together, they agree, and the data can be trusted.
- If one reading sits far away from the others, it does not fit. Do not just keep it — measure that trial again and check.

Notice what we do **not** do: we do not squeeze the repeats into one number by averaging. Comparing the readings, judging how close they are and spotting the one that does not fit is the skill in this section.

Digital tools

Digital instruments show the reading as a number on a screen, so there is no scale to misread. A **probe** is a small tool you put where you want to measure — in the soil, in a cup of water, in the air. Connected to a laptop, digital tools can take many readings over time and record them straight into a **spreadsheet**, a table on a screen, while you get on with the science.

Digital tools can take many readings over time and log them by themselves.



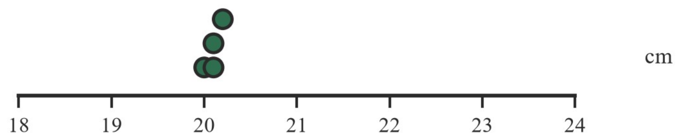
Digital tools: a temperature probe, a soil moisture probe standing in a pot, and a digital timer with a screen reading 3.24 s are each joined by a lead to a laptop, which records the readings in a spreadsheet. Digital tools can take many readings over time and log them by themselves.

A probe in the soil can record the moisture every hour for a week, day and night, without anyone being there. That is a lot of careful readings no person could have written down by hand.

How precise is precise enough?

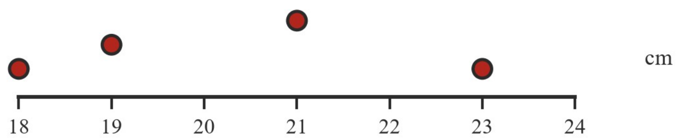
Precision is how carefully something is measured — how close the repeat readings sit together, and how fine the marks on the instrument are.

Group A — shadow length, four repeats



The readings sit close together — this set is more precise.

Group B — shadow length, four repeats



The readings are spread out — this set is less precise.

Comparing precision: two groups each record four repeats of the same shadow length on number lines from 18 to 24 cm. Group A's readings (about 20.0 to 20.2 cm) sit close together, so that set is more precise; Group B's readings (18, 19, 21 and 23 cm) are spread out, so that set is less precise.

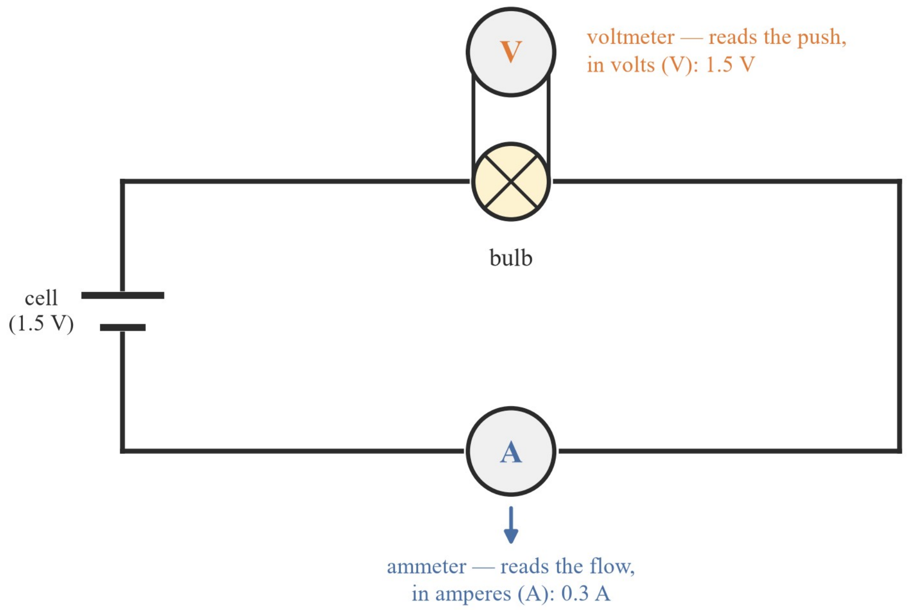
Group A’s repeats sit close together, so their set is more precise. Group B’s repeats are spread out, so their set is less precise.

Reasonable precision means matching the care to the job. A ruler that reads to the nearest millimetre is right for a seed pod. You would not measure a playground in millimetres, and you would not measure a cup of medicine with a bucket. The instrument also sets a limit: a ruler with millimetre marks cannot honestly give a reading between the marks. So we read to the nearest mark the instrument gives us, we repeat, and we record what we saw — not the number we wish we saw.

Volts and amperes

Electricity flows around a loop of wire called a **circuit**. The electricity has a push and a flow: the push is measured in **volts (V)** and the flow is measured in **amperes (A)**. A **voltmeter** reads the push and an **ammeter** reads the flow.

Meters read the volts and the amps in a circuit (we use cells of 6 V or less).



The ammeter sits in the loop; the voltmeter sits across the part it reads. Circuits are explored more in 9B.

A circuit drawn as a loop of wire holding a 1.5 V cell and a bulb: an ammeter (A) sits in the loop and reads the flow, 0.3 A, while a voltmeter (V) sits across the bulb and reads the push, 1.5 V. Meters read the volts and the amperes, using cells of 6 V or less.

The ammeter sits in the loop, so the flow goes through it; the voltmeter sits across the part it reads. In this book we only meet the two units — circuits themselves are explored in 9B. We always use cells of 6 V or less.

Worked examples

Example 1 — with support

Use the prefix system to fill the gaps: (a) 2 km = ? m; (b) 3000 g = ? kg; (c) 5 L = ? mL; (d) 6000 mm = ? m.

Working	Comment
(a) kilo- means 1000, so 1 km = 1000 m.	The prefix tells you the step.
2 km = 2 × 1000 m = 2000 m.	Two thousands of metres.
(b) 1000 g make 1 kg, so 3000 g = 3 kg.	Count the thousands: 3000 g is 3 lots of 1000 g.
(c) milli- means one thousandth, so 1 L = 1000 mL.	The same system, the other direction.
5 L = 5 × 1000 mL = 5000 mL.	Five thousands of millilitres.

Working	Comment
(d) 1000 mm make 1 m, so 6000 mm = 6 m.	Count the thousands again.
∴ 2 km = 2000 m; 3000 g = 3 kg; 5 L = 5000 mL; 6000 mm = 6 m.	kilo- and milli- mean the same thing on every unit.

Example 2 — with support

A group times a toy car down a ramp four times: 3.6 s, 3.7 s, 3.6 s and 5.9 s. (a) Do the repeats agree? (b) What should the group do next?

Working	Comment
Three readings sit close together: 3.6 s, 3.6 s and 3.7 s.	Close together — they agree.
One reading sits far away: 5.9 s.	It does not fit the others.
The group measures that trial again and checks it.	A reading that does not fit gets measured again, not just kept.
∴ Three trials agree (3.6–3.7 s); 5.9 s does not fit, so that trial is measured again.	Repeats let a group check its own measuring.

Example 3 — by yourself

Two groups each measure the same plant's height four times, with the same ruler. Group 1 records 24.1 cm, 24.2 cm, 24.1 cm and 24.2 cm. Group 2 records 23 cm, 25 cm, 24 cm and 26 cm. Which group's measuring was more precise? Explain how the repeats tell you, without squeezing each set into one number.

Practice questions

With support

Q1. Write a sentence of your own for each word: *(3 marks)* (a) reading (b) unit (c) repeat

Q2. Choose the right unit (m, g, L, s, °C, V, A) for each: *(4 marks)* (a) the length of a desk (b) the temperature of a cup of tea (c) the volume of juice in a bottle (d) the mass of an apple

Q3. Use the prefix system: *(4 marks)* (a) kilo- means ______ (b) milli- means ______ (c) 1000 m make 1 ______ (d) 1000 mL make 1 ______

Q4. A student records "the pod is 5 long." *(2 marks)* (a) What is missing from the reading? (b) Why does it matter? Give two different lengths "5" could mean.

Q5. You are reading a measuring cylinder. *(2 marks)* (a) Where should your eye be? (b) Which part of the curved surface do you read?

Q6. A group's three trials are 6.2 s, 6.3 s and 6.2 s. *(2 marks)* (a) Do the repeats agree? How can you tell? (b) What can the group now say about its data?

By yourself

Q7. Use the prefix system to fill the gaps: *(4 marks)* (a) 3 km = ? m (b) 7 L = ? mL (c) 4000 g = ? kg (d) 2000 mm = ? m

Q8. Choose the better instrument and say why: *(2 marks)* (a) the volume of water in a cup — a measuring cylinder, or a ruler? (b) the length of a seed pod — a ruler with millimetre marks, or a tape with a mark every 10 cm?

Q9. A student records the height of a classroom desk as 3 m. *(2 marks)* (a) Is this reading believable? Explain. (b) What should the student do?

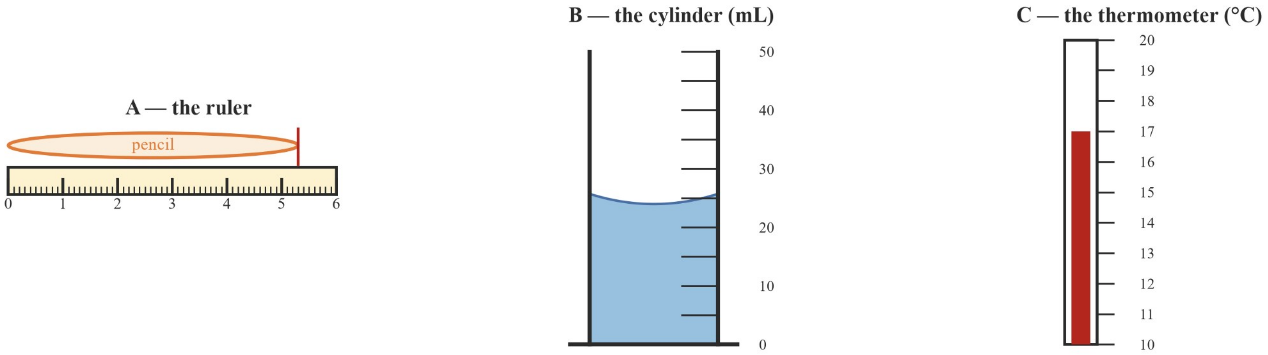
Q10. Explain, in two or three sentences, why scientists take repeat readings instead of measuring once. *(2 marks)*

Q11. Name two digital tools from the figure in this section, and say one thing digital tools can do over time that makes them useful. *(2 marks)*

Q12. A results table has the heading "Time (s)". *(2 marks)* (a) What does the (s) tell you? (b) Why is that better than writing the unit after every number?

Q13. Two groups each time the same ball rolling 1 m, four trials. Group X: 1.9 s, 2.0 s, 1.9 s, 2.0 s. Group Y: 1.5 s, 2.4 s, 1.8 s, 2.3 s. Which group's set is more precise? How do you know? *(2 marks)*

Q14. Read the three scales in the figure below. *(3 marks)*



Three scales to read: A, a ruler with a pencil lined up from 0, its end marked between 5 and 6 cm; B, a measuring cylinder marked 0 to 50 mL with the water between 20 and 30; C, a thermometer marked 10 to 20 °C with the liquid between 16 and 18.

(a) the length of the pencil (A)
(b) the volume of the water (B)
(c) the temperature (C)

Q15. SCENARIO — A class rolls a marble down a ramp and times it with a stopwatch. Four trials give:

Trial	Time (s)
1	2.4
2	2.5
3	4.1
4	2.4

(a) Which reading does not fit? *(1 mark)*
(b) What should the class do about it? *(1 mark)*
(c) Do the other three readings agree? What does that tell you? *(1 mark)*

Q16. A circuit uses one cell of 1.5 V. *(3 marks)* (a) Which unit measures the push? Give its symbol. (b) Which unit measures the flow? Give its symbol. (c) Which meter sits in the loop, and which sits across the part it reads?

Practical — how close are our repeat times?

> **PRACTICAL** — this page plans or analyses work done in the classroom, laboratory or field. It is not a substitute for doing it.

Question: How close together are our repeat readings when we time a marble rolling down a ramp?

Equipment: a smooth ramp (a board rested on a pile of books); one marble; a stopwatch or timer that reads to 0.1 s; a ruler to mark the start line; a book or box at the bottom to catch the marble; something to record with.

Safety: Marbles roll. Catch the marble at the bottom every time, and pick up any marble that gets away straight away. Set the ramp up so it cannot slip mid-roll.

Risk	How we stay safe
A marble rolling onto the floor	Catch it with the book or box at the bottom of the ramp.
Someone slipping on a marble that got away	Pick up escapees straight away; keep the floor clear.

Risk	How we stay safe
The ramp slipping mid-roll	Rest the board on the books so it cannot move, and hold it still while the marble rolls.

The things we change, measure and keep the same:

Thing	Choice
The one we measure	the time for the marble to roll down the ramp (s)
The ones we keep the same	the same ramp and slope; the same marble; the same start line; the same person on the stopwatch
The one we change	nothing — we repeat the same measurement to check our precision

Method:

1. Set the ramp on the books and use the ruler to mark a start line near the top. Put the catching book at the bottom.
2. One person works the stopwatch. Hold the marble still on the start line.
3. Let the marble go and start the watch at the same moment.
4. Stop the watch when the marble reaches the bottom. Record the time to one place after the dot.
5. Repeat steps 2–4 until you have three trials.
6. If one reading sits far from the others, measure that trial again.

Results: record your readings in a table like this one.

Trial	Time (s)
1	
2	
3	

Compare your trials. Do they sit close together?

Thinking about the results:

1. Write your three readings from smallest to largest. What is the gap between the smallest and the largest readings?
2. Did any reading not fit? If it did, what did you do?
3. Name one thing that made the times hard to read exactly, and one thing you could do to bring your repeats even closer together.

Make a claim and back it up. Finish this writing frame in full sentences:

- I claim that our timing is / is not precise enough, because ____ .
- My evidence is ____ (use your readings).
- If someone said one trial was enough, I would answer ____ .

Answers

Q1 (a) A reading is the number and unit an instrument shows. (b) A unit is the standard amount a quantity is measured in, such as the metre. (c) A repeat is an extra trial of the same measurement, used to check the data. **Q2** (a) m. (b) °C. (c) L. (d) g. **Q3** (a) One thousand. (b) One thousandth. (c) kilometre (km). (d) litre (L). **Q4** (a) The unit. (b) 5 cm and 5 m are very different lengths, so without the unit nobody knows what was measured. **Q5** (a) Level with the mark being read. (b) The bottom (middle) of the curved surface. **Q6** (a) Yes — all three sit within 0.1 s of each other. (b) The repeats agree, so the data can be trusted. **Q7** (a) 3000 m. (b) 7000 mL. (c) 4 kg. (d) 2 m. **Q8** (a) The measuring cylinder — it measures volume; a ruler measures length. (b) The ruler with millimetre marks — its small marks give a more precise reading for something small. **Q9** (a) No — a desk is about 0.7–0.8 m tall, so 3 m does not fit. (b) Measure again and check the unit. **Q10** One reading might be wrong and you would not know; repeats let you compare readings, see if they agree, and spot a reading that does not fit. **Q11** Any two of: temperature probe, soil moisture probe, digital timer, laptop with a spreadsheet. They can take many readings over time and log them by themselves. **Q12** (a) Every number in the column is in seconds. (b) The numbers stay clean and the unit cannot be missed or guessed wrong. **Q13** Group X — its repeats sit within 0.1 s of each other, while Group Y's spread by 0.9 s; closer repeats mean more precision. **Q14** (a) 5.3 cm (53 mm). (b) 24 mL. (c) 17 °C. **Q15** (a) 4.1 s. (b) Measure that trial again and check it. (c) Yes — 2.4 s, 2.5 s and 2.4 s sit close together, so those trials agree and can be trusted. **Q16** (a) The volt, V. (b) The ampere, A. (c) The ammeter sits in the loop; the voltmeter sits across the part it reads.

Worked solutions

Example 3 *(model answer)* Group 1's repeats sit within 0.1 cm of each other (24.1–24.2 cm); Group 2's spread over 3 cm (23–26 cm). Closer repeats mean more careful measuring, so Group 1's measuring was more precise. No combining into one number is needed — the spread of the repeats itself is the evidence.

Q1 *(3 marks: 1 each)* (a) A reading is the number and unit an instrument shows when you measure. *1 mark* (b) A unit is the standard amount a quantity is measured in — the metre for length, the gram for mass. *1 mark* (c) A repeat is an extra trial of the same measurement; repeats let you check the data by comparing readings. *1 mark*

Q2 *(4 marks: 1 each)* (a) Length is measured in metres (m). *1 mark* (b) Temperature in degrees Celsius (°C). *1 mark* (c) Volume in litres (L). *1 mark* (d) Mass in grams (g). *1 mark*

Q3 *(4 marks: 1 each)* (a) kilo- means one thousand. (b) milli- means one thousandth. (c) 1000 m make 1 kilometre (km). (d) 1000 mL make 1 litre (L). *1 mark each*

Q4 *(2 marks)* (a) The unit is missing — "5" is not a reading until it has one. *1 mark* (b) 5 cm is a finger length and 5 m is longer than a car, so without the unit the reading could mean very different things. *1 mark*

Q5 *(2 marks)* (a) Your eye should be level with the mark you are reading, so parallax cannot give a wrong reading. *1 mark* (b) Read the bottom (the middle) of the curved surface, not the edges where the water climbs the glass. *1 mark*

Q6 *(2 marks)* (a) Yes — 6.2 s, 6.3 s, 6.2 s all sit within 0.1 s of each other, so they agree. *1 mark* (b) The repeats agree, so the group's data can be trusted. *1 mark*

Q7 *(4 marks: 1 each)* (a) 3 km = 3 × 1000 m = 3000 m. *1 mark* (b) 7 L = 7 × 1000 mL = 7000 mL. *1 mark* (c) 4000 g is 4 lots of 1000 g = 4 kg. *1 mark* (d) 2000 mm is 2 lots of 1000 mm = 2 m. *1 mark*

Q8 *(2 marks: 1 each)* (a) The measuring cylinder, because volume is what is being measured and a cylinder is made to read it; a ruler reads length. *1 mark* (b) The ruler with millimetre marks, because a seed pod is small and the small marks give a more precise reading than a tape with a mark every 10 cm. *1 mark*

Q9 *(2 marks)* (a) No — a classroom desk comes up to about your waist, near 0.7–0.8 m, so 3 m is not believable. *1 mark* (b) Measure again, and check the unit was read and written correctly. *1 mark*

Q10 *(2 marks)* A single reading might be wrong, and with only one there is nothing to compare it with. *1 mark* Repeats let you see whether the readings agree and spot any reading that does not fit, so the data can be trusted. *1 mark*

Q11 *(2 marks)* Any two from the figure: temperature probe; soil moisture probe; digital timer; laptop recording into a spreadsheet. *1 mark* Over time they can take many readings and log them by themselves — for example every hour for a week — which no person could keep up by hand. *1 mark*

Q12 *(2 marks: 1 each)* (a) The (s) says every number in that column is a time in seconds. *1 mark* (b) With the unit in the heading the numbers stay clean, and the unit cannot be left off, missed or guessed wrong later. *1 mark*

Q13 *(2 marks)* Group X is more precise. *1 mark* Its repeats sit within 0.1 s of each other, while Group Y's spread from 1.5 s to 2.4 s — a set of close repeats is a more precise set. *1 mark*

Q14 *(3 marks: 1 each)* (a) The pencil ends at the 3rd small mark after 5 cm: 5.3 cm (53 mm). *1 mark* (b) The bottom of the curved surface sits at 24 mL. *1 mark* (c) The liquid top is at the 7th mark above 10: 17 °C. *1 mark*

Q15 *(3 marks: 1 each)* (a) 4.1 s — it sits far away from the other three readings. *1 mark* (b) Measure that trial again and check the new reading against the others. *1 mark* (c) Yes — 2.4 s, 2.5 s and 2.4 s sit close together, so those trials agree and that part of the data can be trusted. *1 mark*

Q16 *(3 marks: 1 each)* (a) The push is measured in volts, symbol V. *1 mark* (b) The flow is measured in amperes, symbol A. *1 mark* (c) The ammeter sits in the loop so the flow goes through it; the voltmeter sits across the part it reads. *1 mark*