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Volume 07

Resistors



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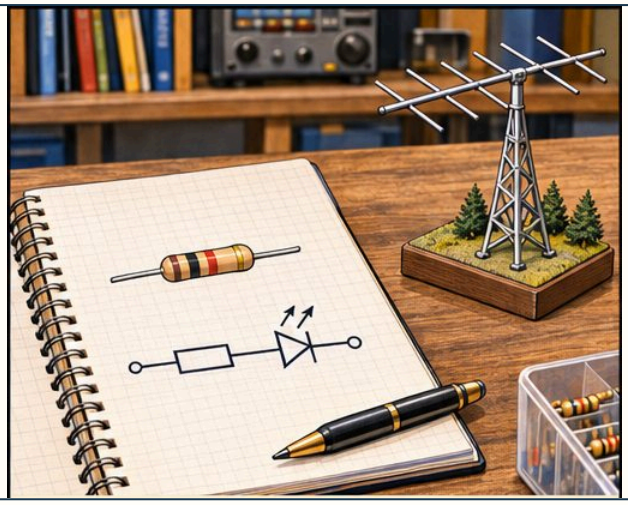
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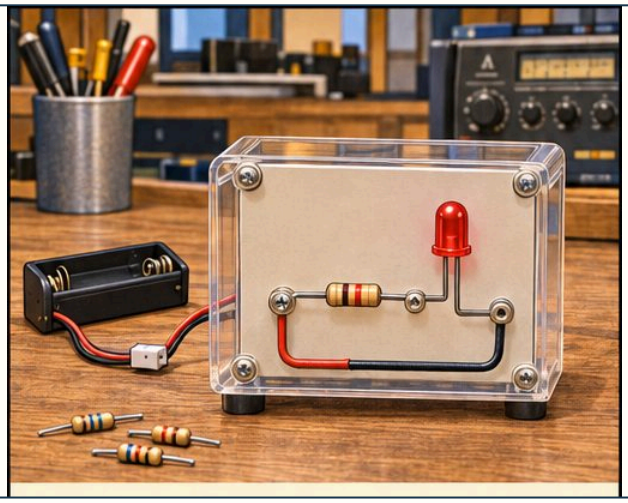
The stand's indicator



Lucas joins Henri to prepare the club's discovery stand.



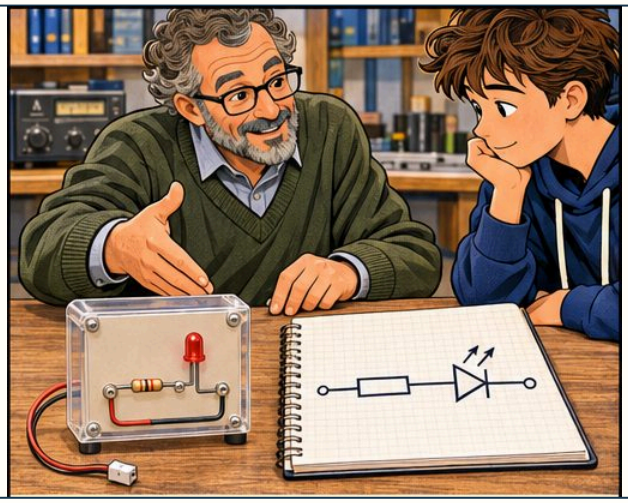
After antennas, their notebook welcomes a much smaller component.



The demonstration panel's indicator no longer lights.



"Change the LED?" Lucas suggests, opening his parts box.

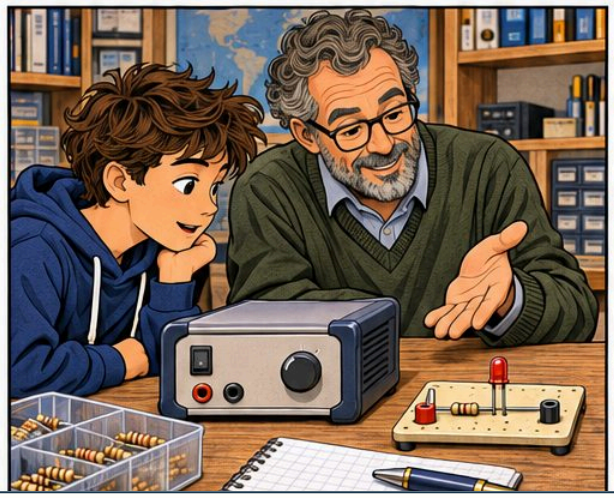


Henri wants to understand the circuit before replacing anything.

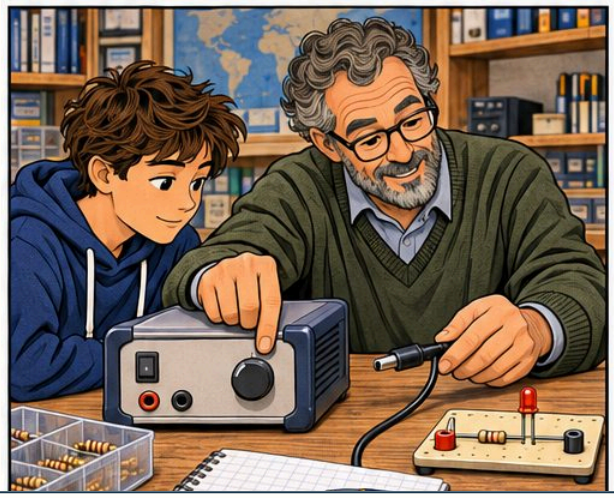


Their mission: restore a reliable indicator and explain every choice.

Disconnect before investigating



The panel uses a current-limited educational 5 V supply.



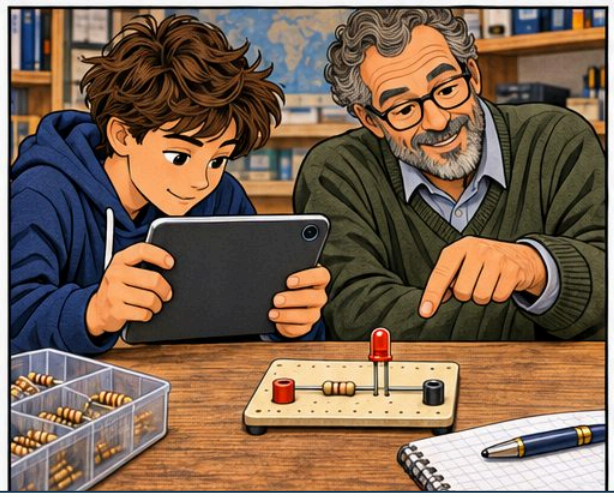
Henri switches it off and disconnects it before working.



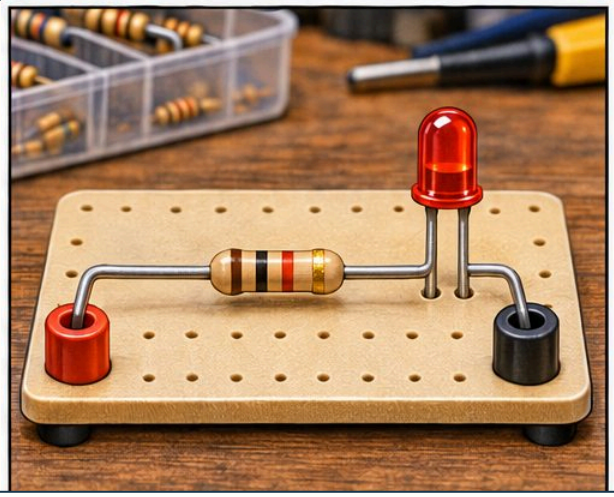
They allow the specified discharge and verify absence of voltage.



They open no mains-connected equipment in this workshop.



Lucas photographs connections and follows the panel's schematic.



A small resistor catches his attention along the LED's path.

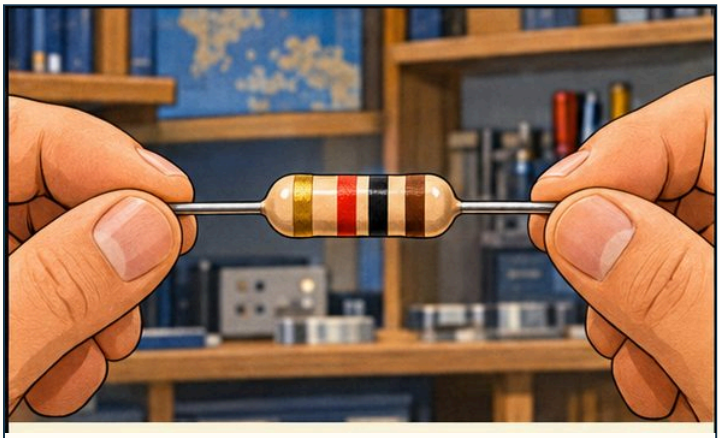
One name, two meanings



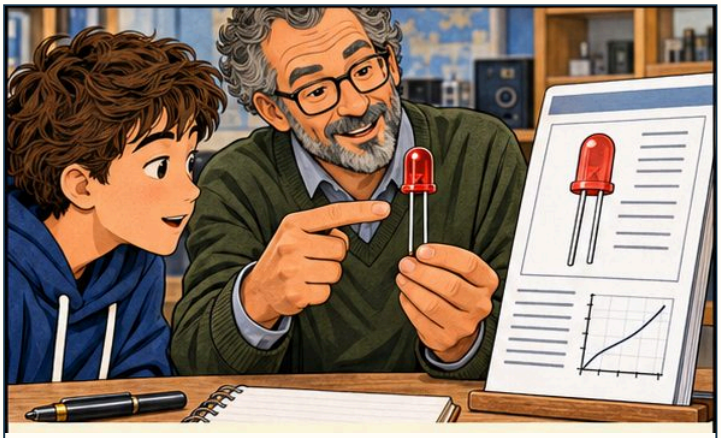
Resistance names the quantity R; a resistor is the component.



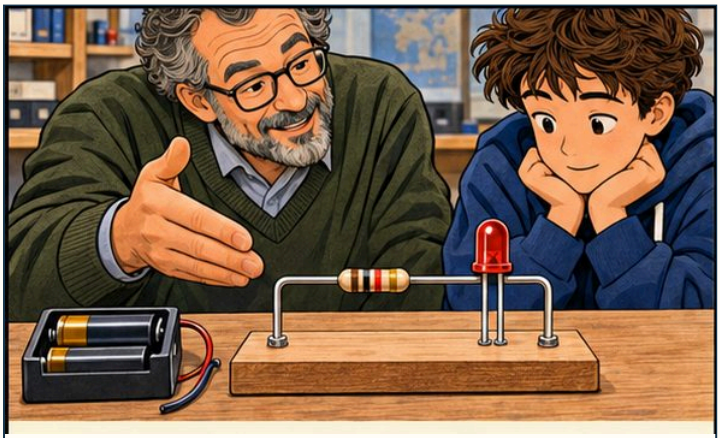
It is measured in ohms, represented by Ω.



An ordinary resistor has no required connection direction.



The LED, however, has a polarity to respect.



The series resistor helps limit current through the LED.

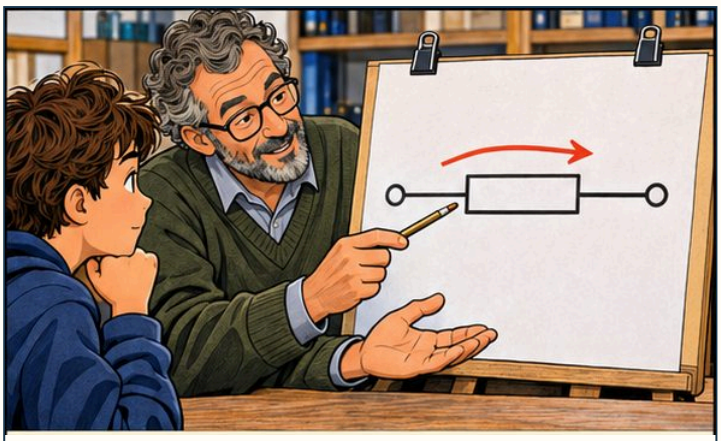


Lucas identifies each part's role before searching for the fault.

Remembering Ohm's law



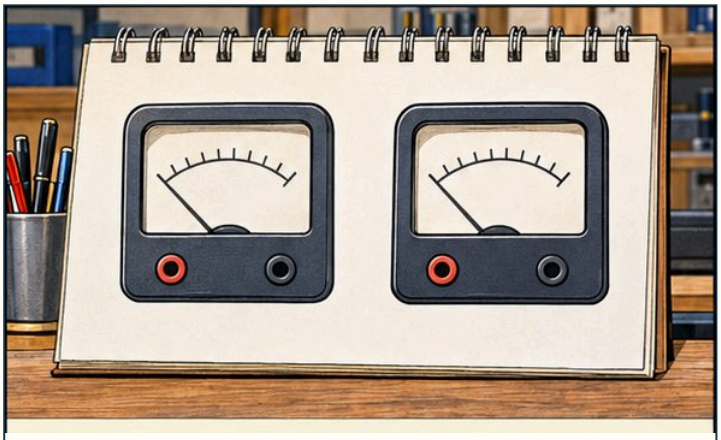
For an ohmic resistor at a given temperature, U = R × I.



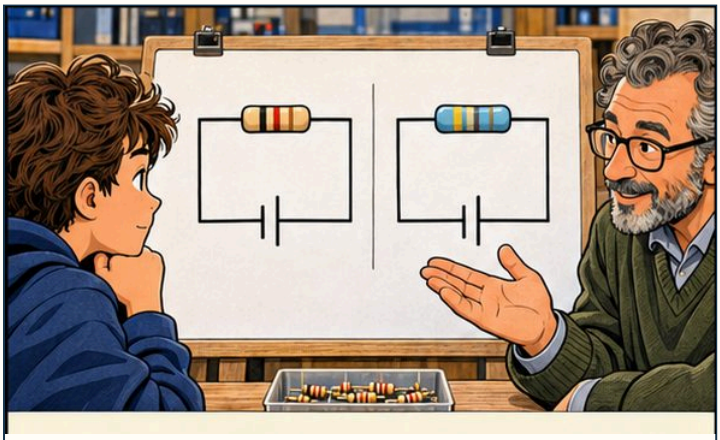
U is terminal voltage; I is current through it.



We can also write I = U / R and R = U / I.



Here, U is in volts and I in amperes.



At equal voltage, increasing R decreases current.

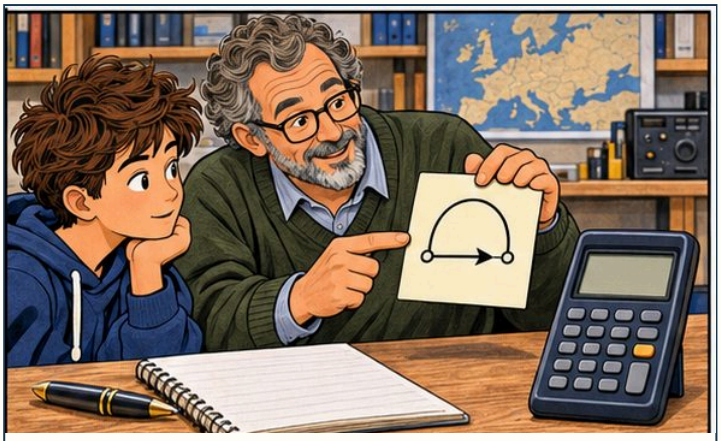


"The LED is not an ohmic resistor," Henri recalls.

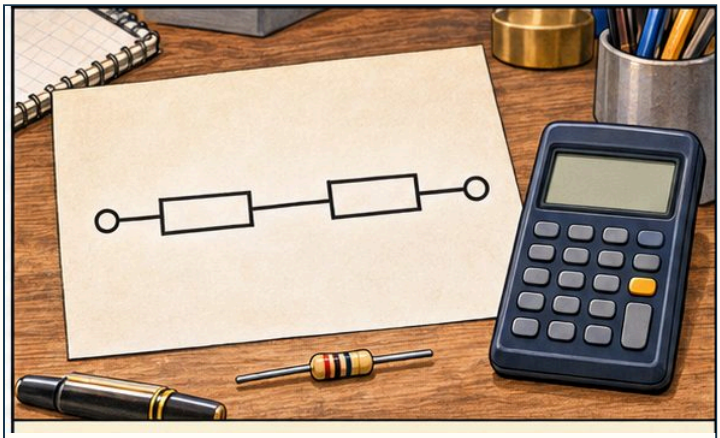
Units before numbers



1 kΩ = 1 000 Ω; 1 MΩ = 1 000 000 Ω.



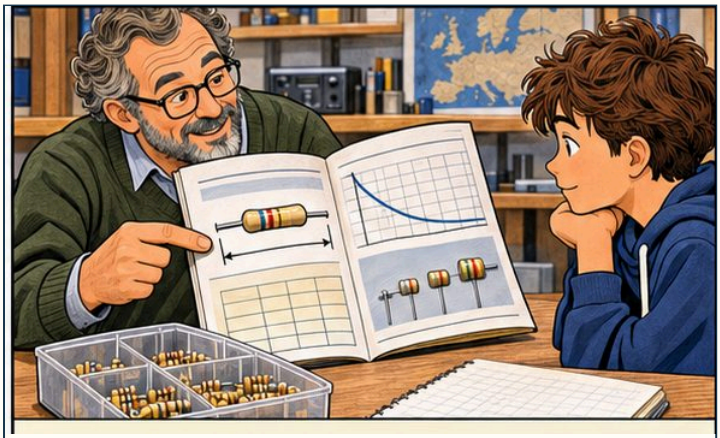
1 mA = 0.001 A: Lucas converts before using the formula.



With 5 V across 1 kΩ, the calculated current is 5 mA.



On some parts, 4K7 means 4.7 kΩ and 2R2 means 2.2 Ω.



Markings depend on the component; its documentation remains the reference.



Lucas circles units: missing a prefix can change the selection.

Read before measuring



The panel's resistor has coloured bands.



Henri brings a manufacturer's chart and magnifier.



They identify the number of bands and their spacing.



The tolerance band is often separated from the others.



If direction is unclear, they check the reference and measured value.



A poorly lit colour is insufficient for choosing a replacement.

Four bands, four roles



In the usual four-band code, the first two give two digits.



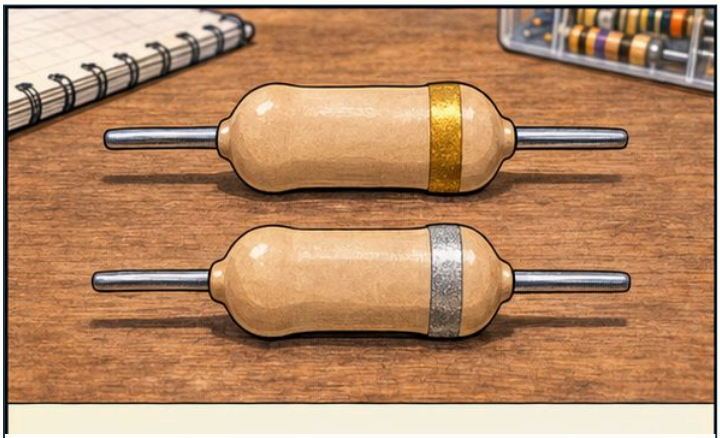
The third band is the multiplier.



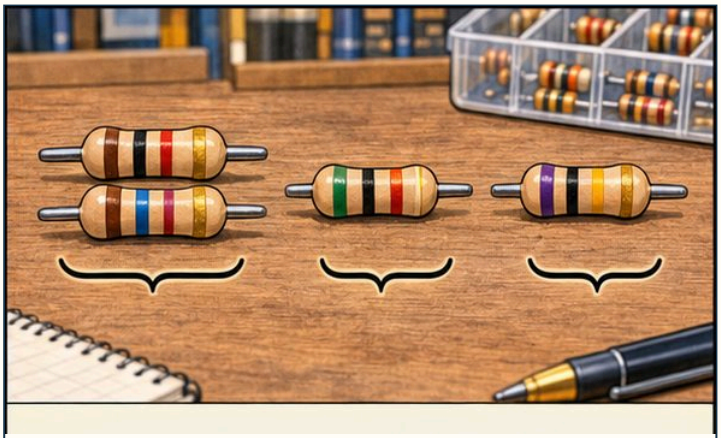
The fourth indicates the nominal value's tolerance.



They read from the end opposite the tolerance band.



Gold here means ±5%; silver means ±10%.



"Two digits, a factor and a margin," Lucas summarises.

The digit palette



Black means 0; brown 1; red 2; orange 3; yellow 4.



Green means 5; blue 6; violet 7; grey 8; white 9.



A colour's position determines its role in the code.



As multipliers, red means ×100 and orange ×1 000.



Gold and silver can also multiply by 0.1 and 0.01.



Lucas keeps the chart nearby: understanding beats guessing.

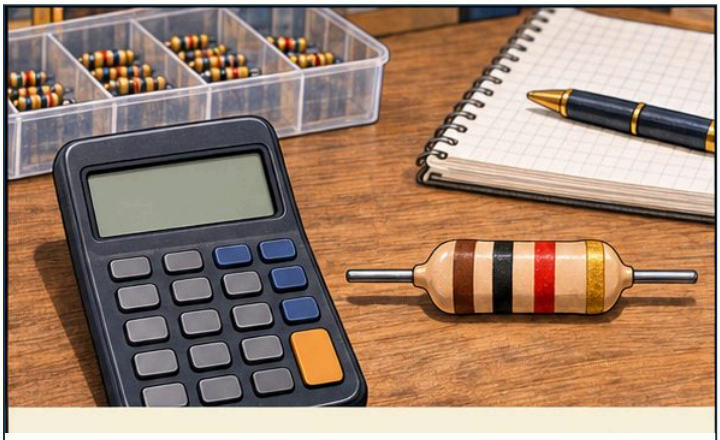
The first decoding



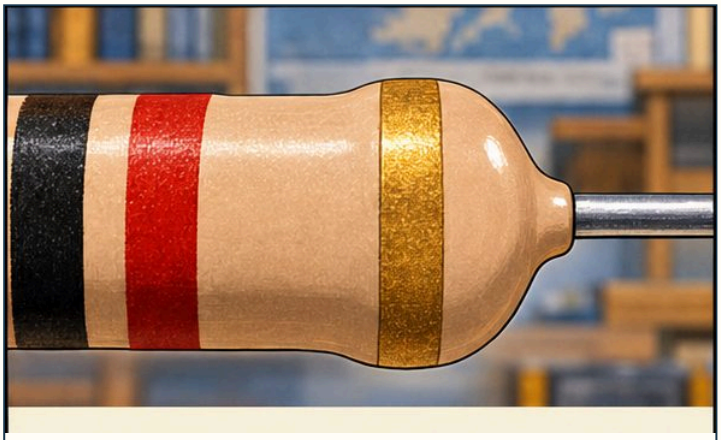
One example has brown, black, red and gold bands.



Brown then black give 10; red multiplies by 100.



10 × 100 = 1 000 Ω, or 1 kΩ.



The gold band adds a tolerance of ±5%.



The nominal value does not promise an exact value.

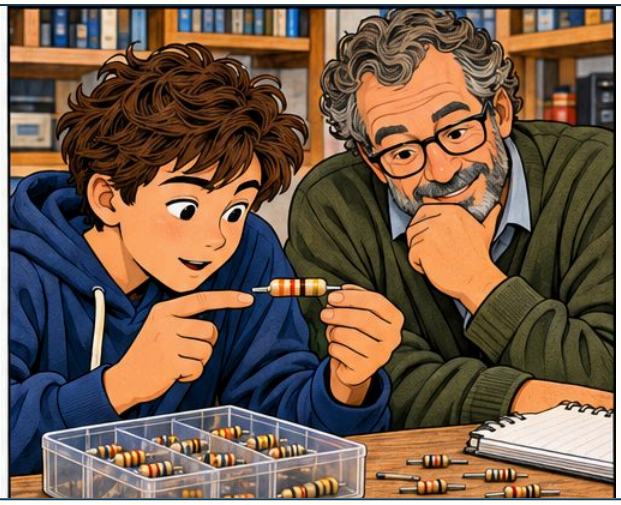


Lucas records value and tolerance separately.

The indicator's resistor



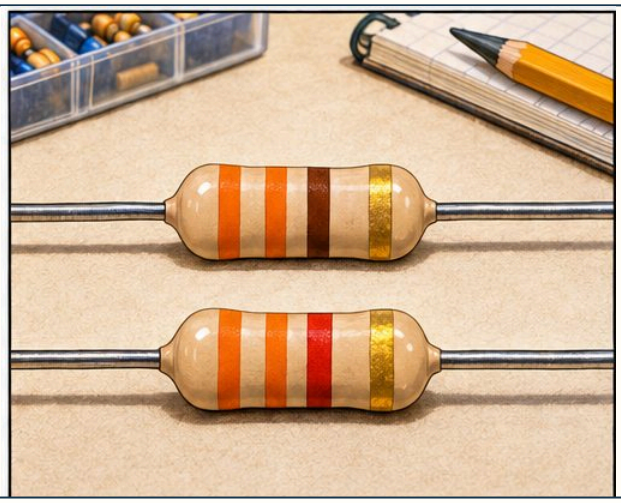
The panel specification requires orange, orange, brown and gold.



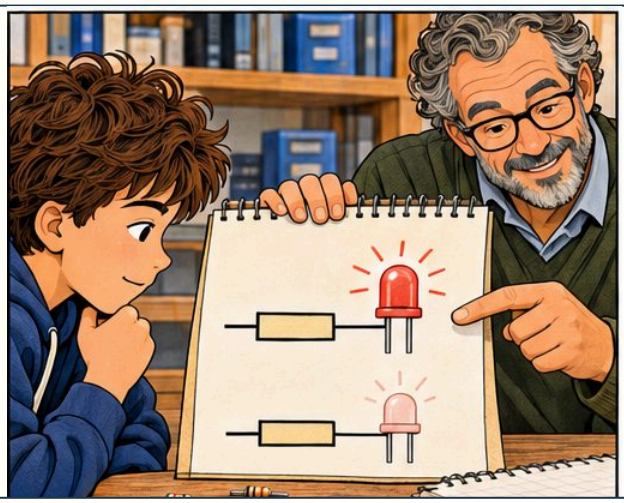
The first two bands give 33; brown means ×10.



The result is 330 Ω with a tolerance of ±5%.



A red third band would give 3 300 Ω, or 3.3 kΩ.



That confusion would greatly reduce the indicator's current.



Henri keeps both examples for the visitors' workshop.

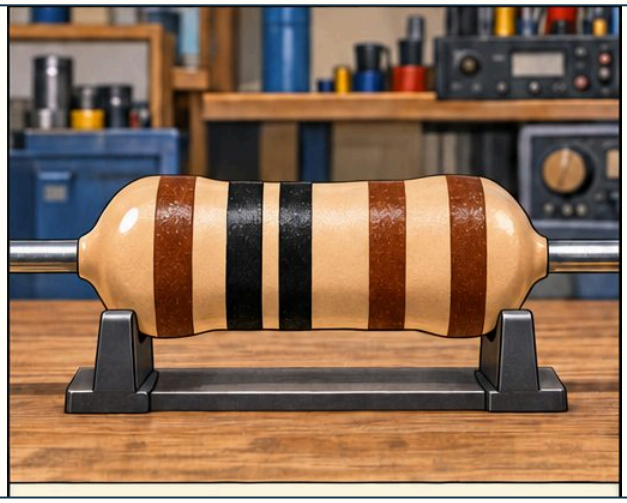
One extra band



The usual five-band code starts with three significant digits.



The fourth multiplies; the fifth indicates tolerance.



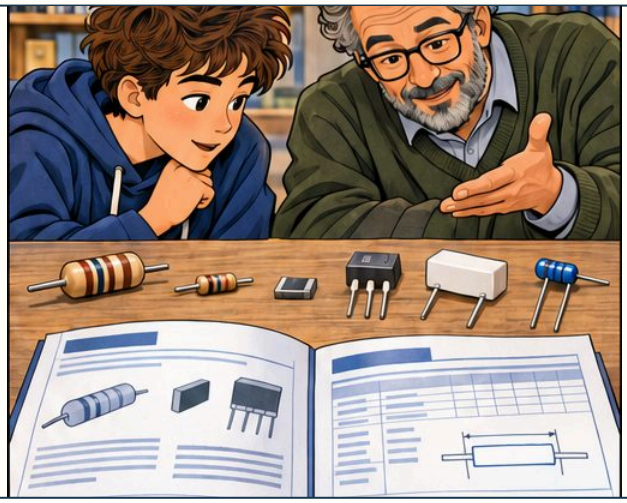
Brown, black, black, brown, brown gives 100 × 10 = 1 000 Ω.



The final brown band here means ±1%.

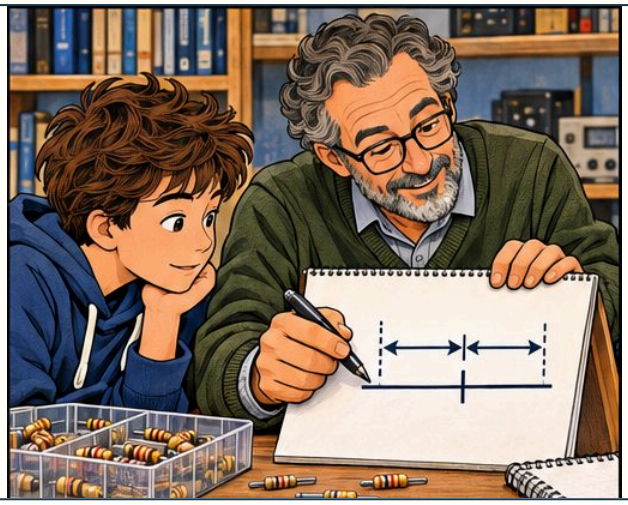


They do not read five bands as though there were four.



Other markings exist: Henri always recommends the correct datasheet.

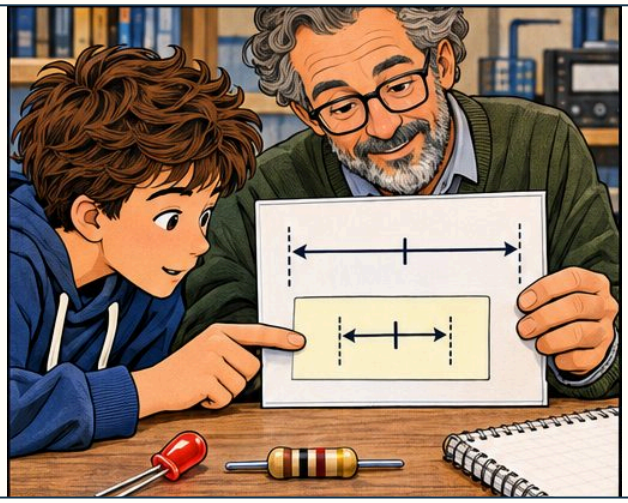
Understanding tolerance



For 1 kΩ at ±5%, maximum nominal deviation is 50 Ω.



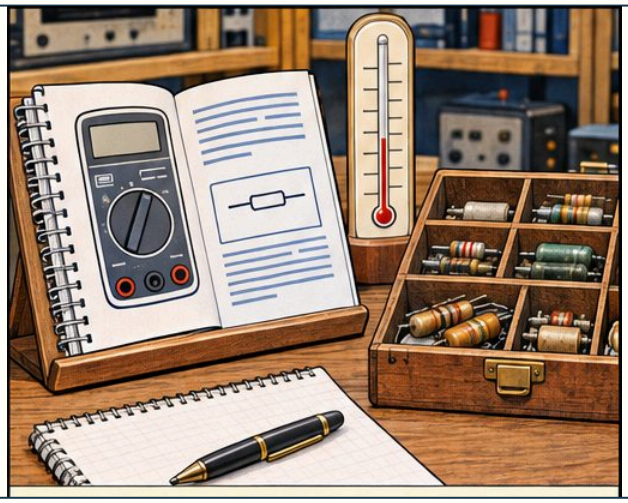
The corresponding interval runs from 950 Ω to 1 050 Ω.



For 330 Ω at ±5%, it runs from 313.5 Ω to 346.5 Ω.



These limits apply under the manufacturer's reference conditions.



Temperature, ageing and measurement uncertainty also matter.



Lucas sees why two good parts may give different readings.

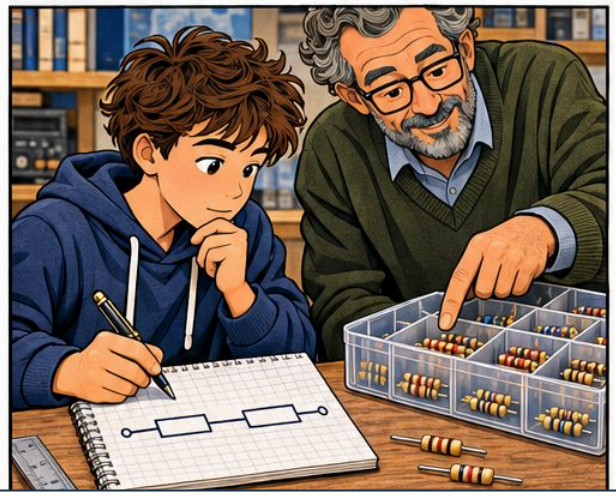
Choosing an available value



Manufacturers offer standardised resistance-value series.



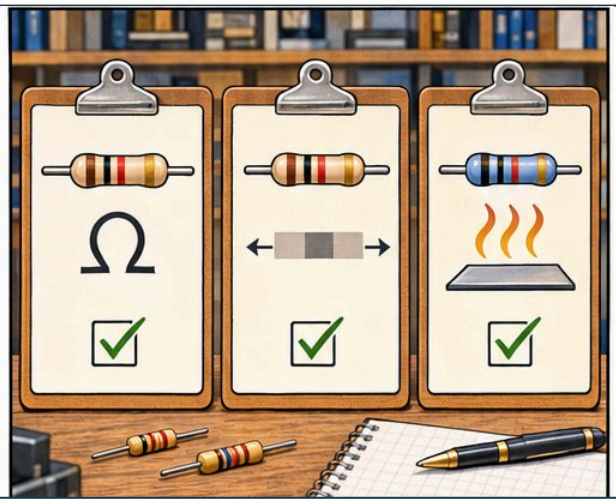
The E12 series includes 270 Ω, 330 Ω and 390 Ω.



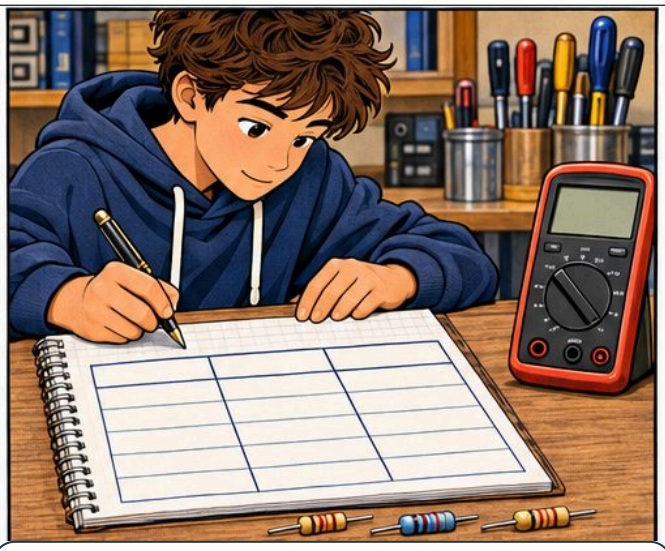
A calculated result does not always match a stocked part.



They choose for the intended function, then calculate again.



Value, tolerance and power rating are three different criteria.

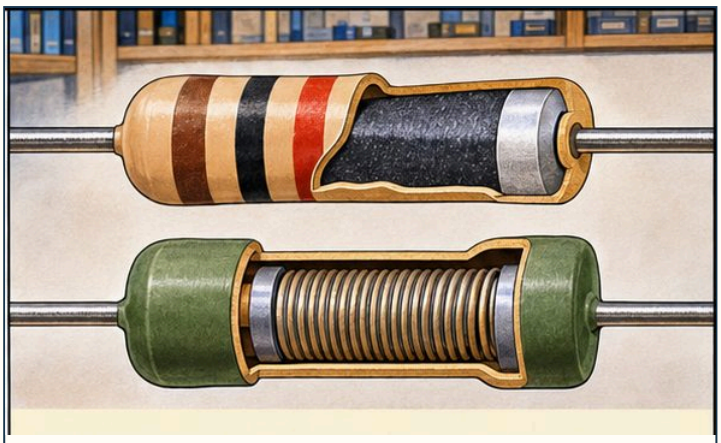


Lucas gives each its place in the parts list.

Under the same name



Resistors with equal values can have different constructions.



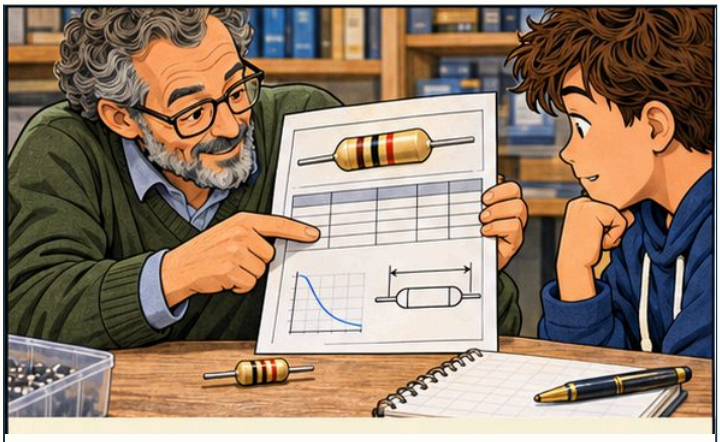
Henri presents film types and a wirewound type.



Small surface-mount resistors fit directly onto the circuit board.



Size alone reveals neither tolerance nor every limit.

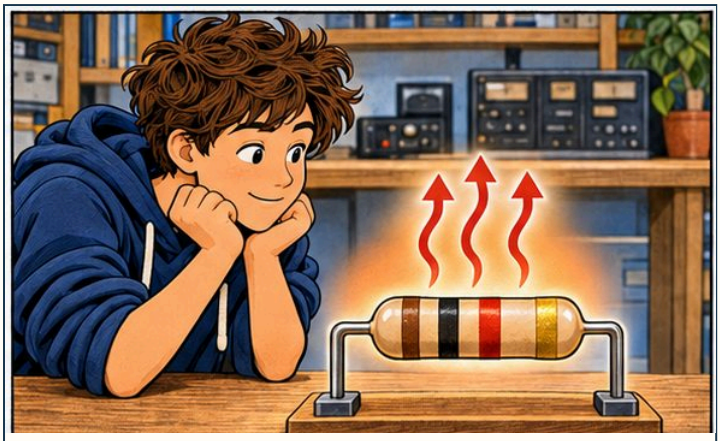


The datasheet specifies power, maximum voltage and operating conditions.

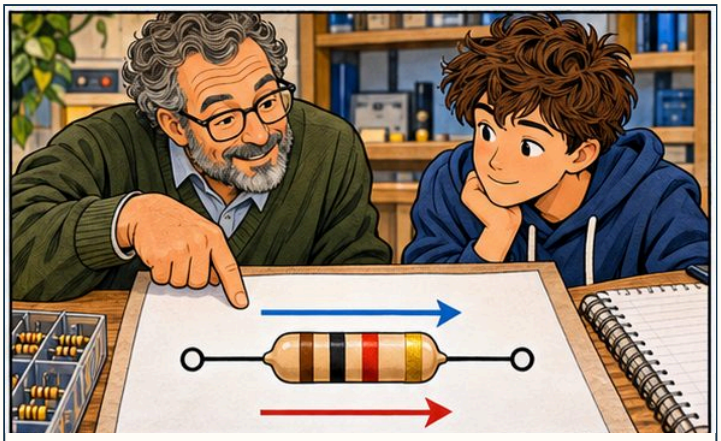


For their indicator, they select an identified, documented part.

Where does the energy go?



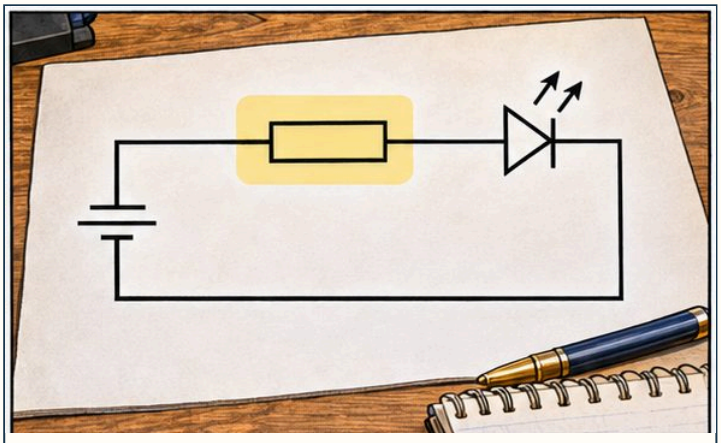
A resistor dissipates electrical energy as heat.



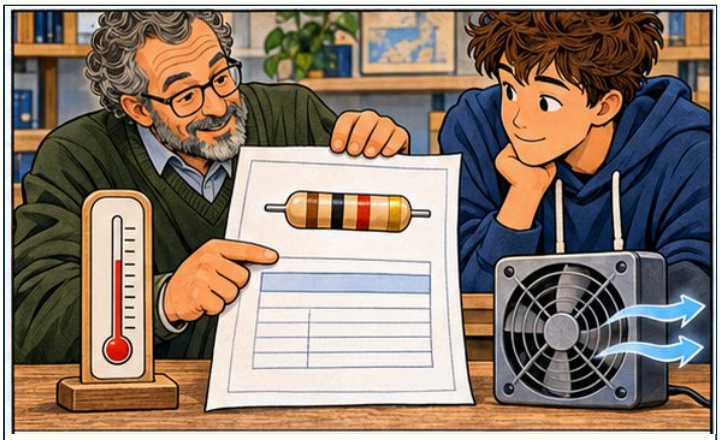
Its dissipated power is P = U × I.



Using Ohm's law: $P = R \times I^2 = U^2 / R$.



These U and I belong to the resistor studied.



Rated power is a limit defined under specified conditions.



"More watts do not mean more ohms," Lucas concludes.

An example that warms up



On paper, 12 V across 1 kΩ gives 12 mA.



Power is $12^2 / 1\,000 = 0.144$ W.



A 0.25 W part may suit if operating conditions allow.



They retain a margin and check ambient temperature too.

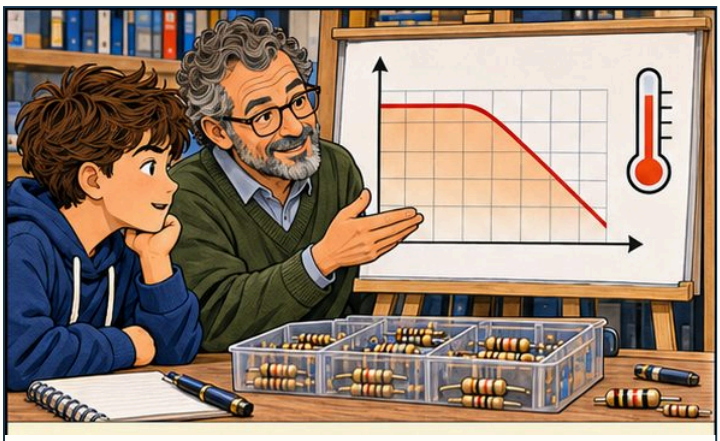


A closed enclosure or nearby heat can change the choice.



No heating experiment is needed to understand the calculation.

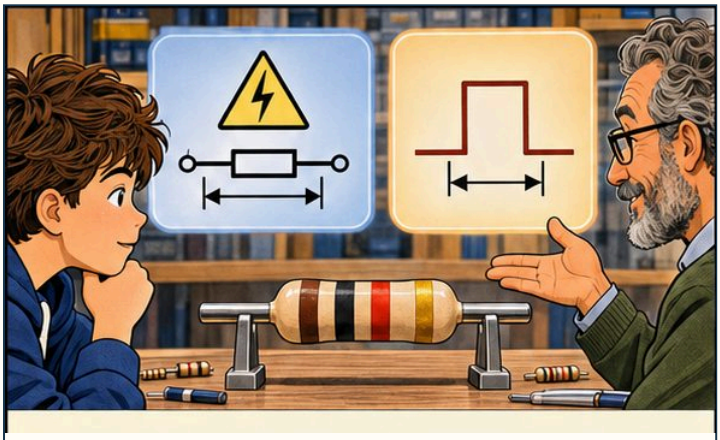
A limit is not a target



The derating curve may reduce allowable power as temperature rises.



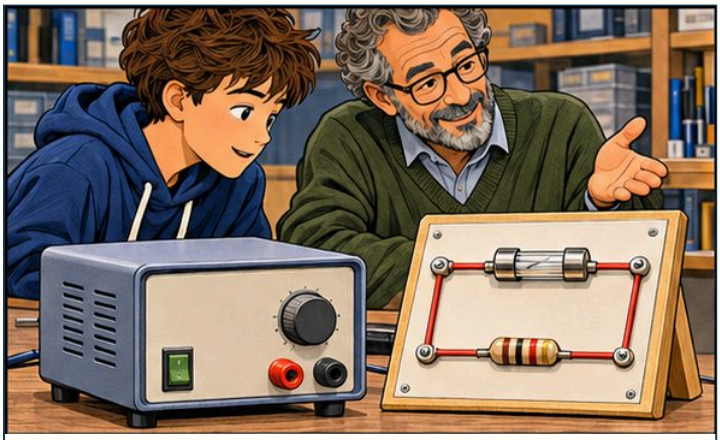
Henri shows the curve in the selected model's datasheet.



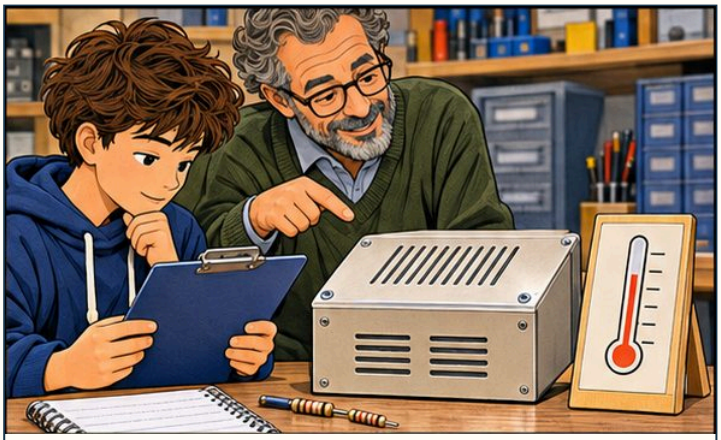
They also check working voltage and possible pulses.



A dissipating resistor does not replace a fuse.

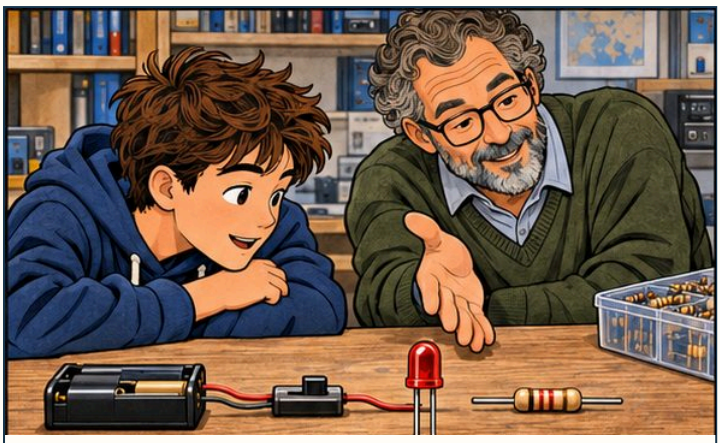


Their small panel retains its designer's protection.

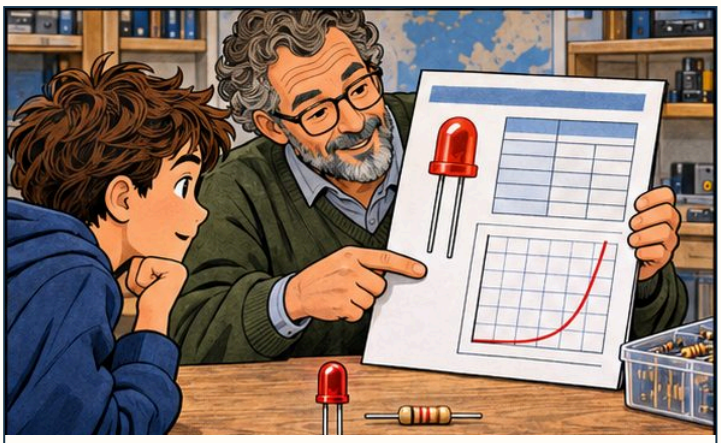


Lucas will select with a margin, then check actual conditions.

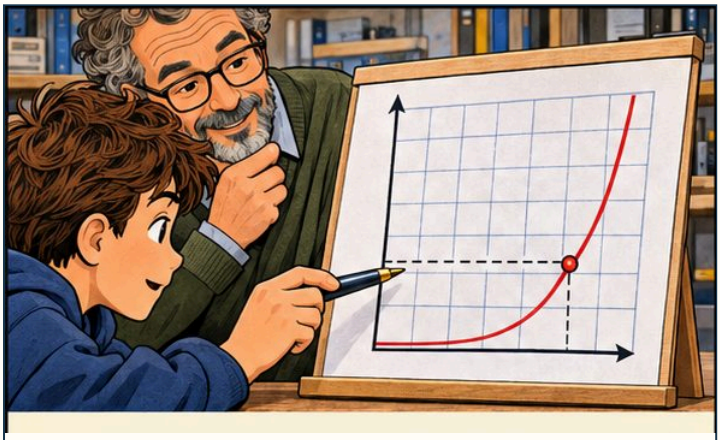
Preparing the indicator calculation



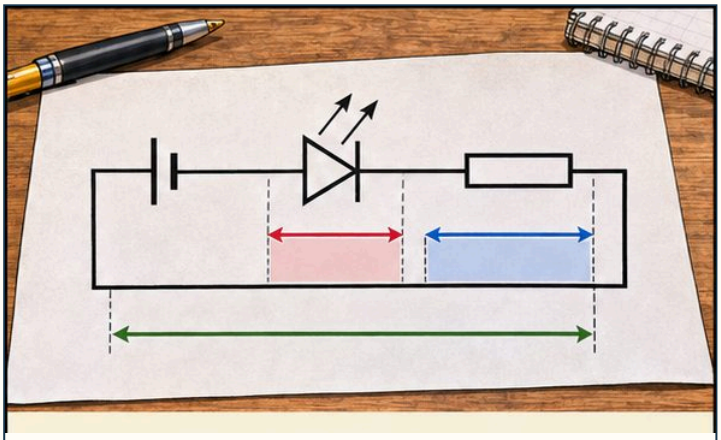
Their example uses a 5 V supply and red LED.



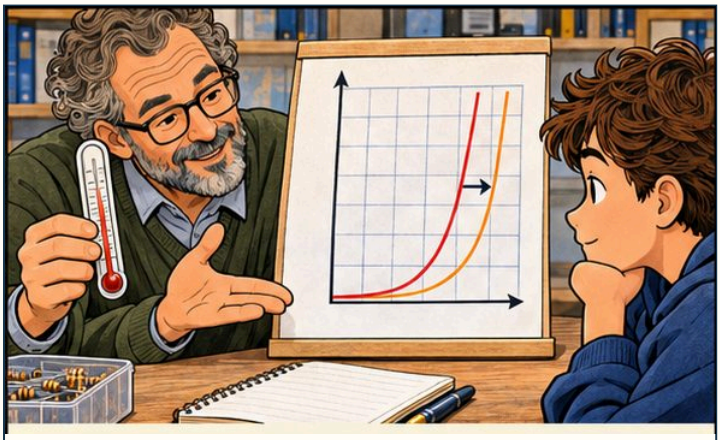
This LED's datasheet supports approximately 2 V at the studied current.



They target 10 mA, within this model's limits.



The series resistor receives approximately 5 − 2 = 3 V.

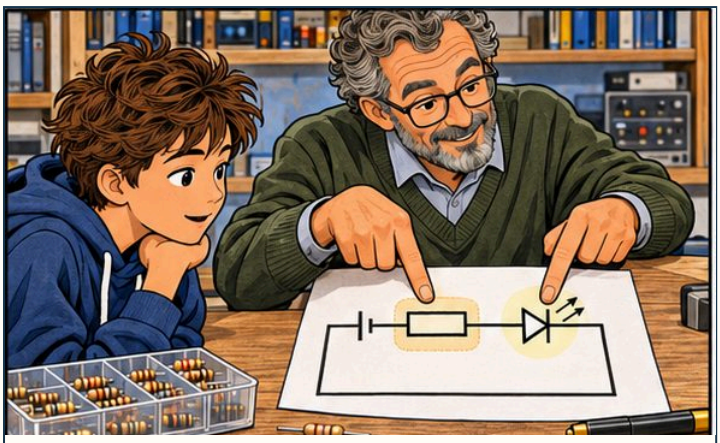


An LED's forward voltage depends on current and temperature.

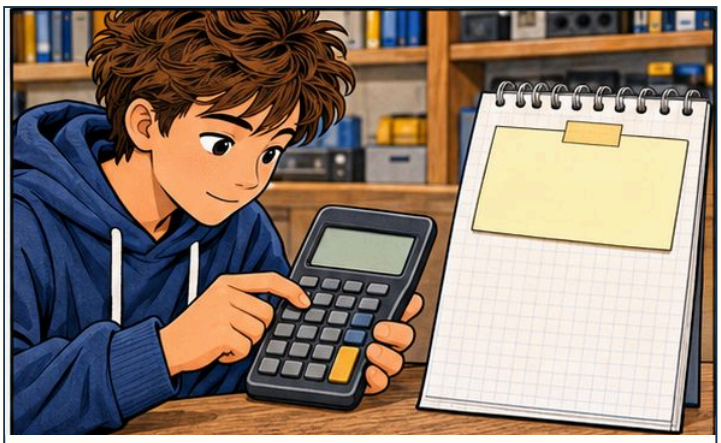


These calculation assumptions do not apply to every LED.

The theoretical value



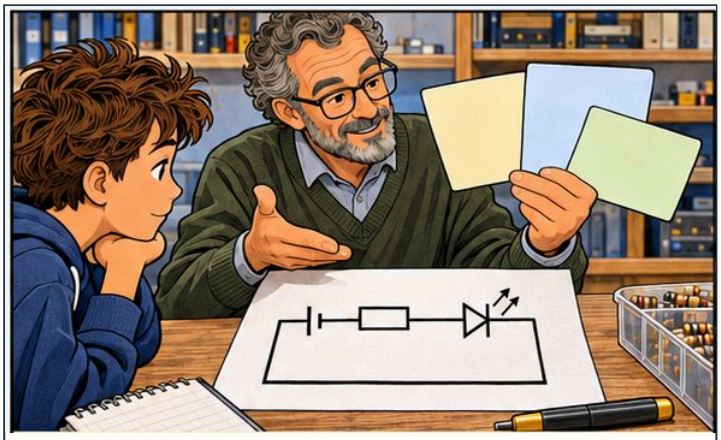
For the series resistor: R = (Usupply − ULED) / I.



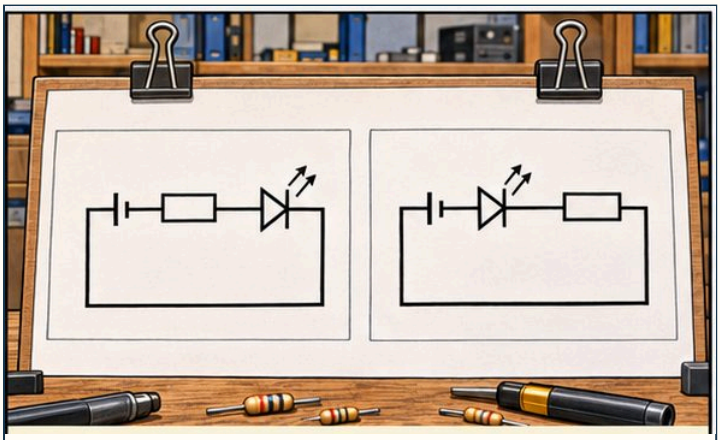
Lucas converts: 10 mA = 0.010 A.



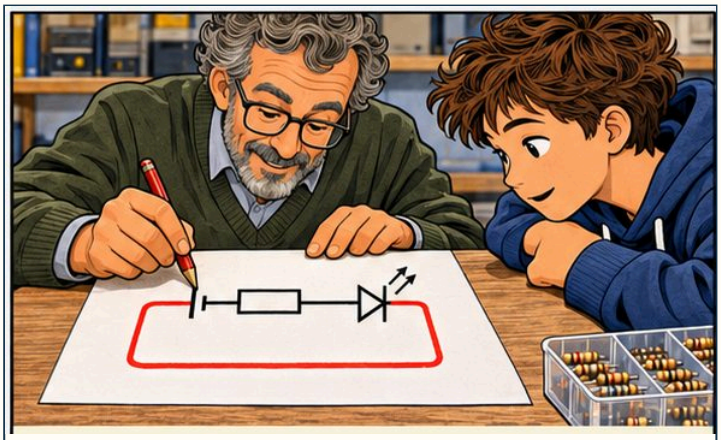
He calculates R = (5 − 2) / 0.010 = 300 Ω.



This assumes the example's voltages and target current.



The resistor may precede or follow the LED in this same series loop.

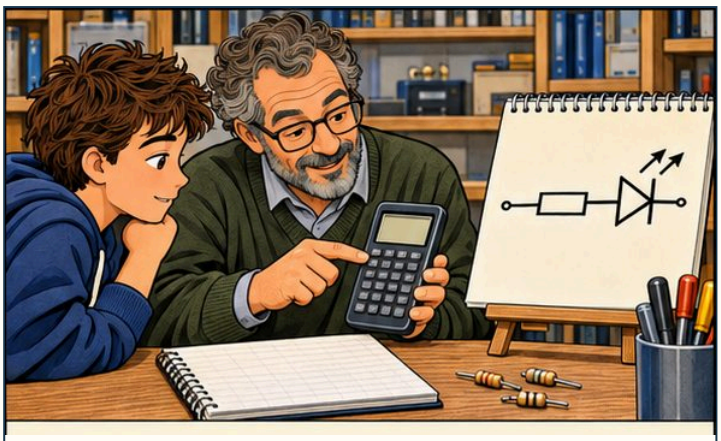


Henri checks the diagram for any path bypassing the resistor.

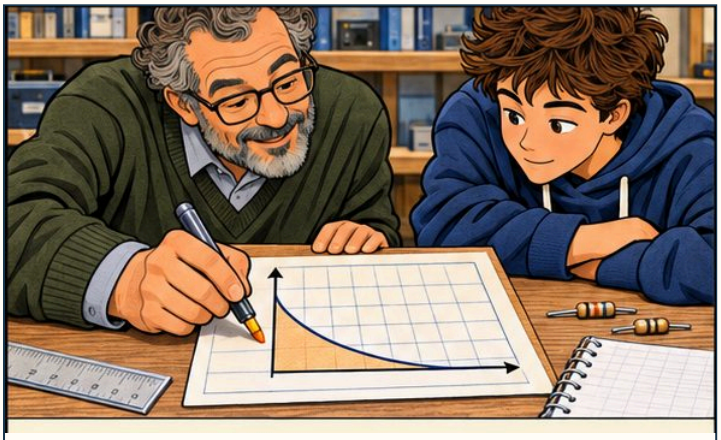
From calculation to drawer



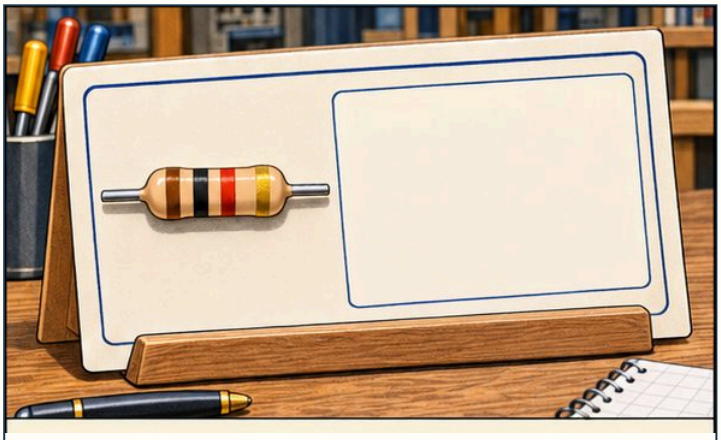
They choose 330 Ω from stock rather than 270 Ω.



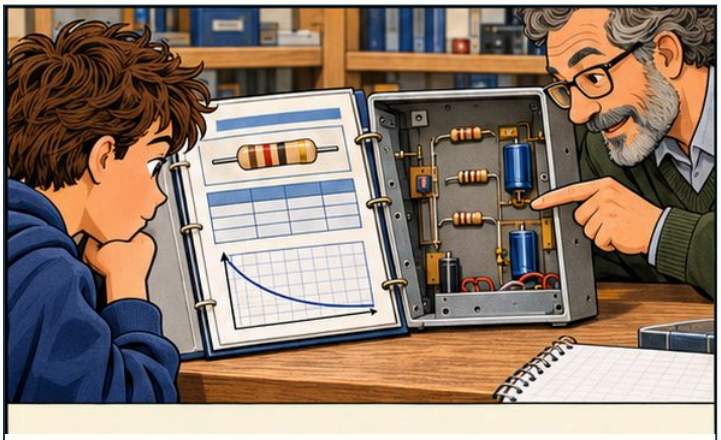
With the same assumptions, I ≈ 3 / 330 ≈ 9.1 mA.



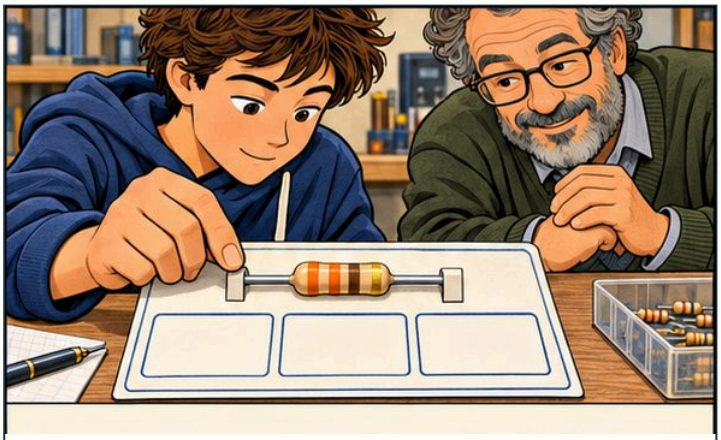
Resistor power is approximately 3^2 / 330 ≈ 0.027 W.



An identified 0.25 W part provides a comfortable thermal margin here.

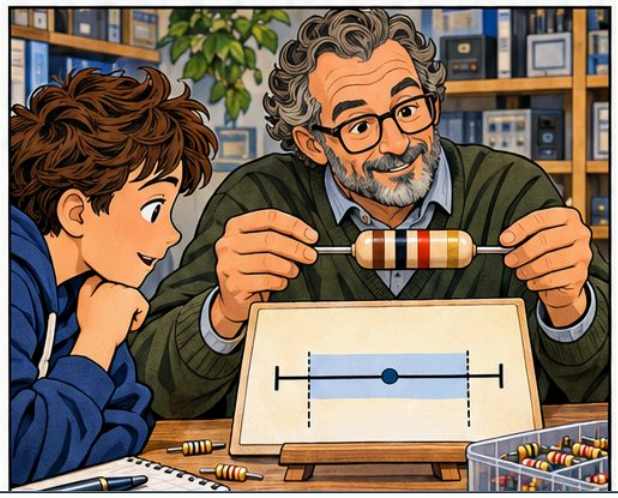


They still check its datasheet and the panel's planned conditions.

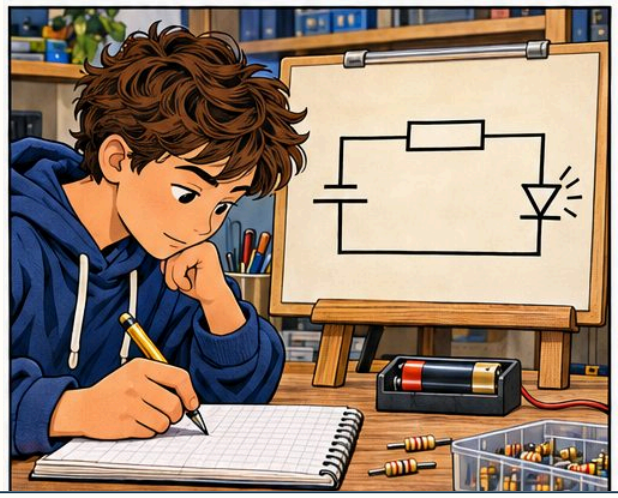


Lucas records: 330 Ω, ±5%, 0.25 W; all three criteria are specified.

Considering variations



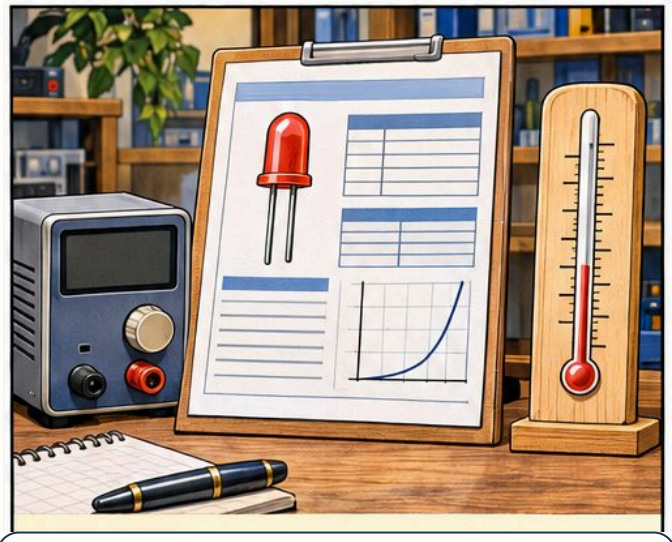
The tolerance of R already varies the calculated current.



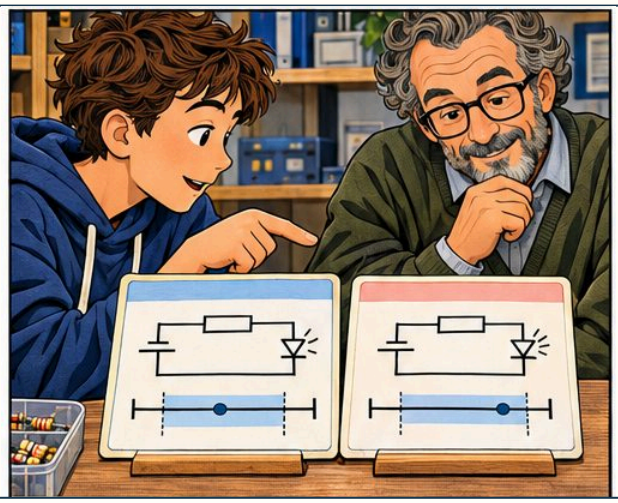
With 3 V across it, 313.5 Ω gives approximately 9.57 mA.



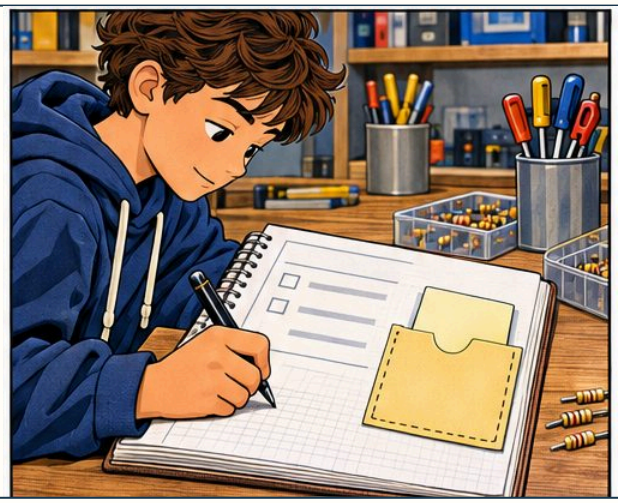
With 346.5 Ω, the result is approximately 8.66 mA.



The supply and LED voltage also vary.



For a real circuit, they check worst cases using the datasheets.



“A useful approximation keeps its assumptions,” Lucas remembers.

The right time for an ohmmeter



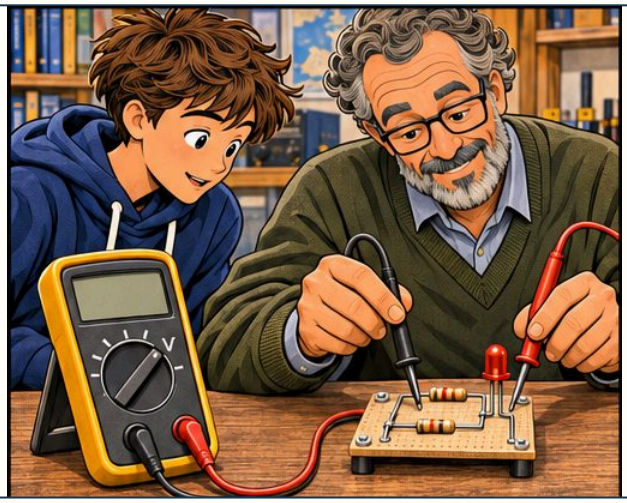
An ohmmeter injects a small signal to determine resistance.



It must not be used on a powered circuit.



Henri switches off, disconnects and follows the panel's discharge procedure.



He verifies absence of voltage with the appropriate setting.



Only after these checks do they select resistance measurement.



Lucas adds this precise sequence to his diagnostic sheet.

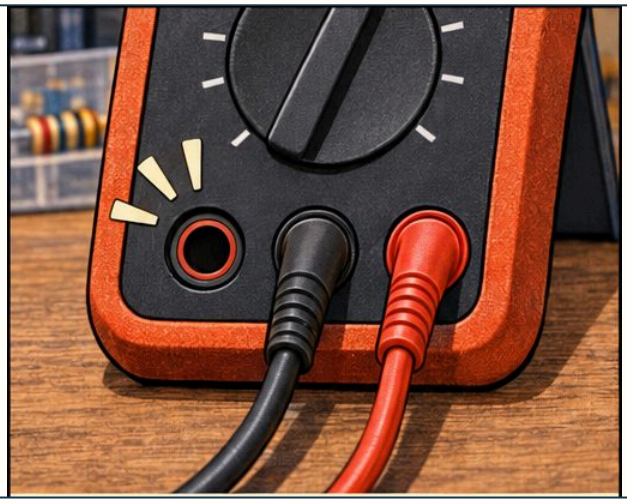
Preparing the probes



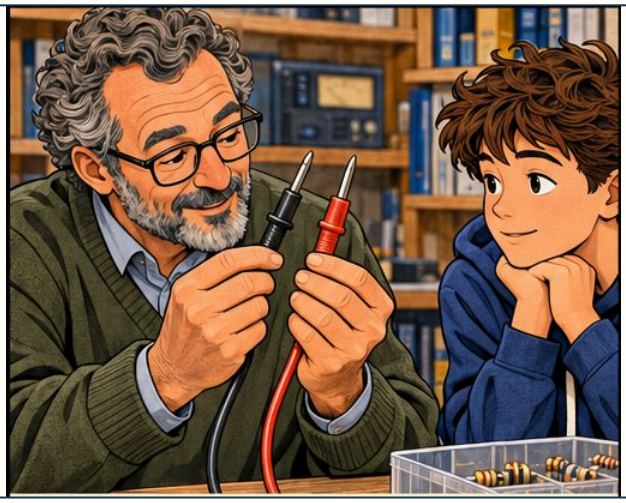
They follow the multimeter manual for sockets and range.



Black goes to COM; red to the resistance input.



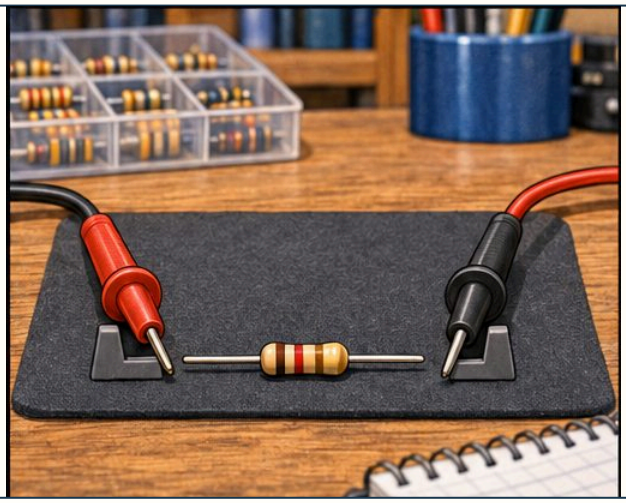
The current input is not used for this measurement.



They check the leads' condition and probe contacts.

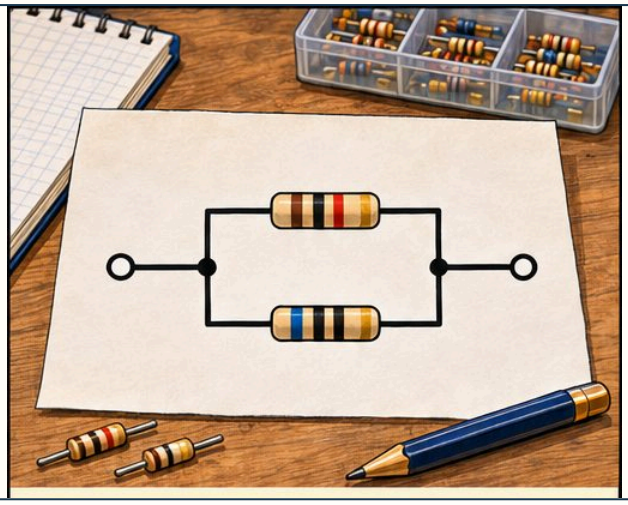


Fingers and poor contacts can distort readings, especially at high resistance.

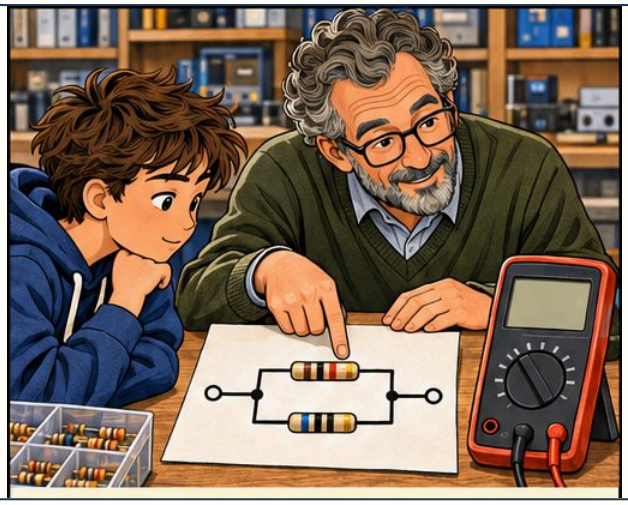


Lucas places the component on insulation and keeps his hands clear.

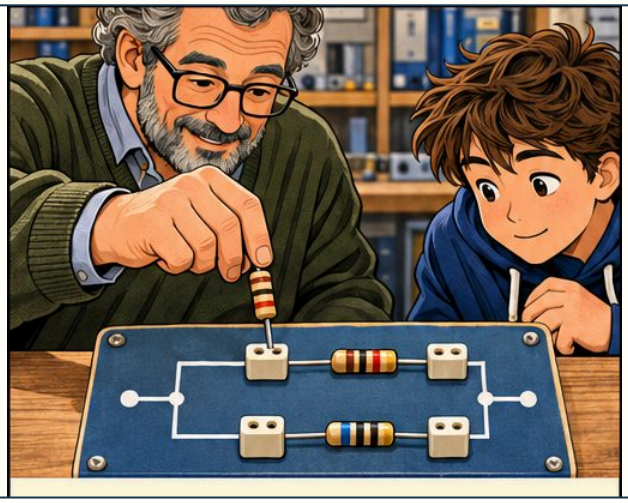
Avoiding hidden paths



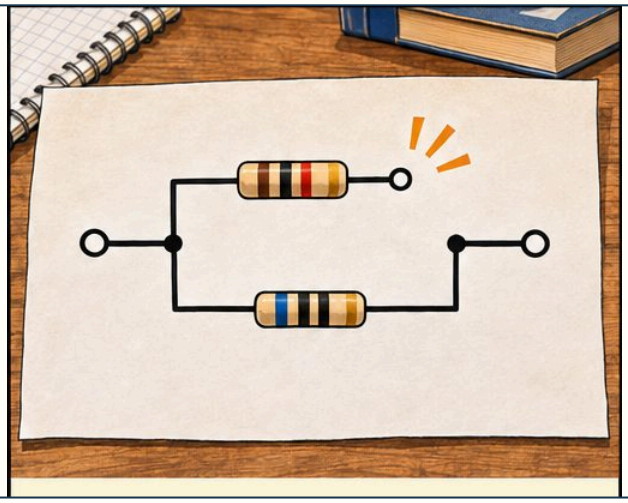
Other circuit components can provide parallel paths.



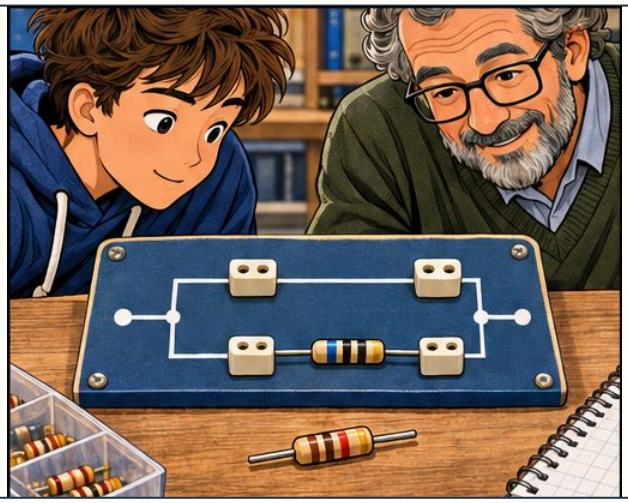
The reading may differ from the resistor's value alone.



On their unpowered plug-in panel, they remove the part from its socket.



In other circuits, isolating one terminal may be necessary.



They desolder nothing: the socket allows separation.

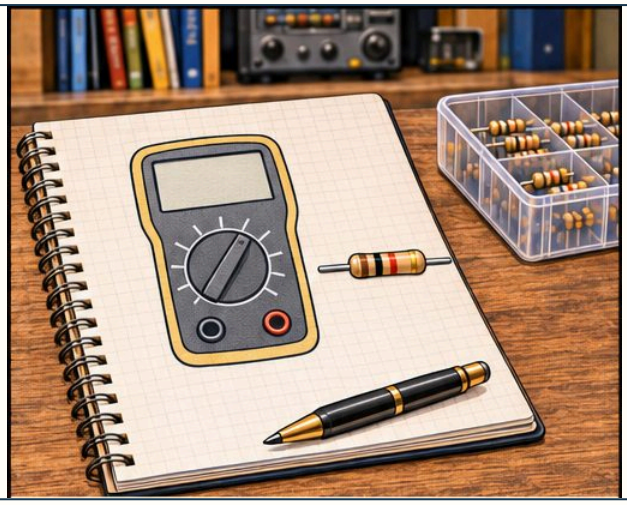


The removed resistor can now be measured alone.

Reading without overinterpreting



They first practise with a known 1 kΩ resistor at ±5%.



The notebook illustrates a possible reading: 0.998 kΩ, or 998 Ω.



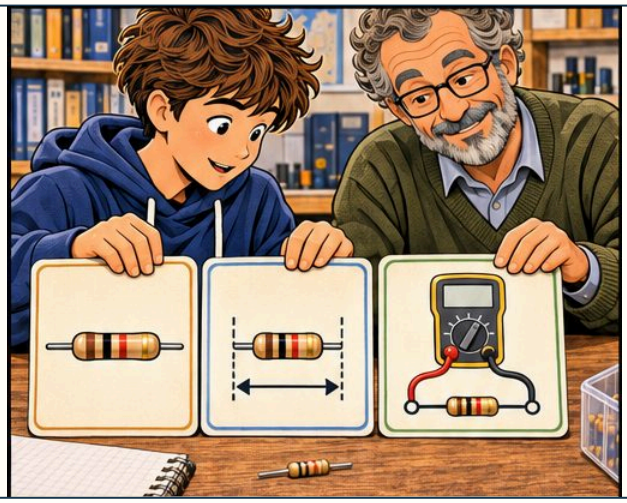
It lies within the nominal interval from 950 Ω to 1 050 Ω.



Meter accuracy and contact quality limit the conclusion.



The continuity beep does not replace numerical resistance measurement.

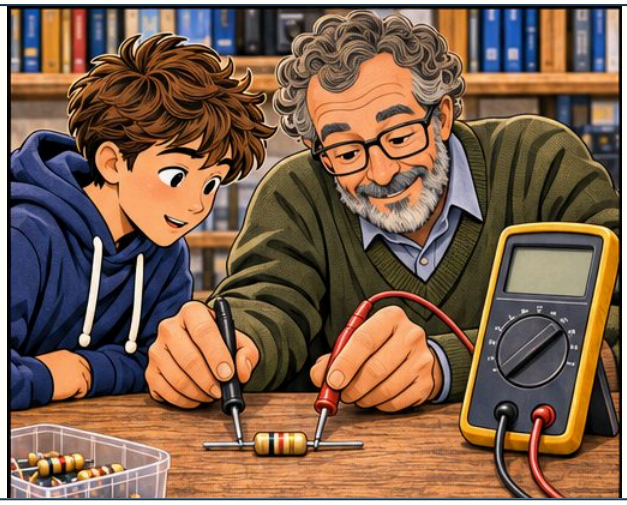


Lucas compares units, expected range and measurement conditions.

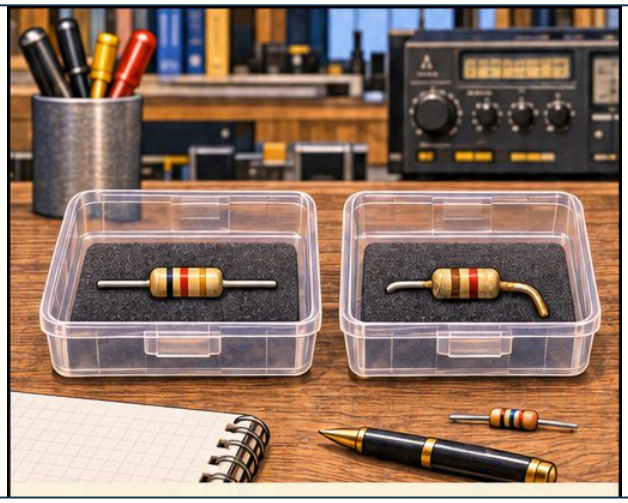
A clue, not yet a verdict



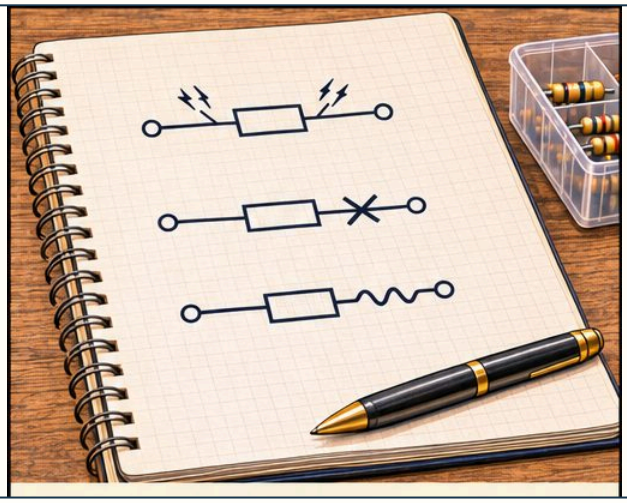
The removed indicator part has a damaged lead contact.



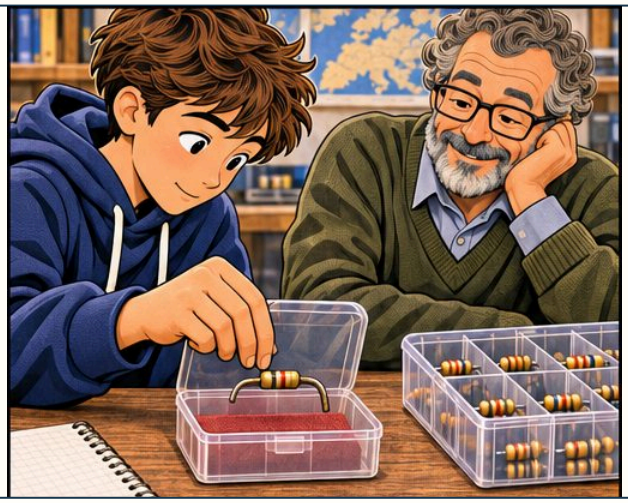
The reading remains unstable; Henri remakes the probe contacts.



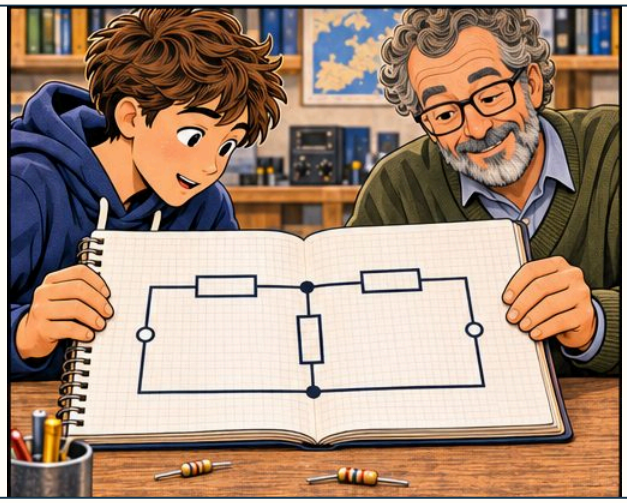
They compare this behaviour with the known part.



An out-of-range reading can arise from component, leads or contact.



They set the suspect aside without claiming the whole fault is identified.



The diagram must still explain how resistors work together.

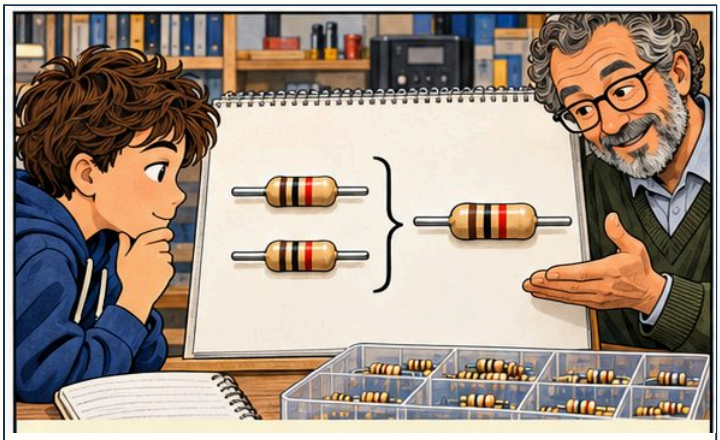
Along a single path



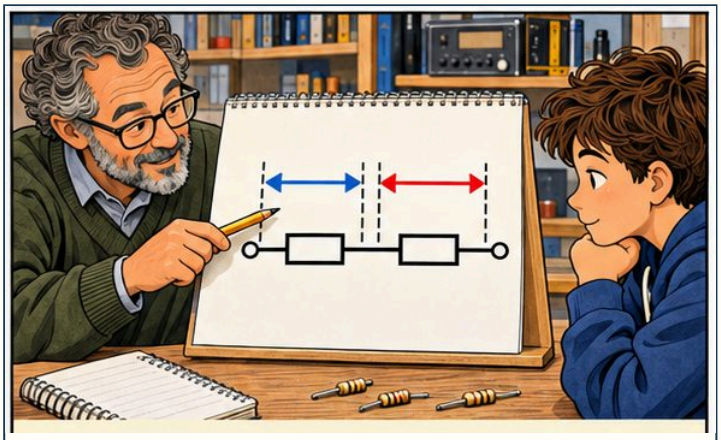
Two resistors are in series when the same current crosses both without branching.



Their equivalent resistance is R = R1 + R2.



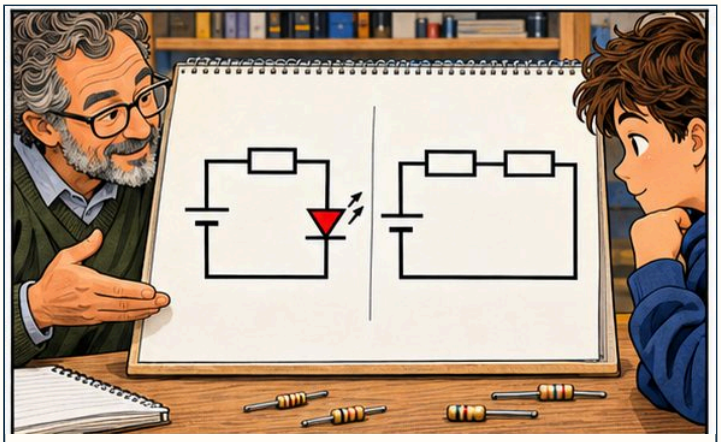
Two 1 kΩ resistors in series give 2 kΩ.



Total voltage divides between them according to their values.

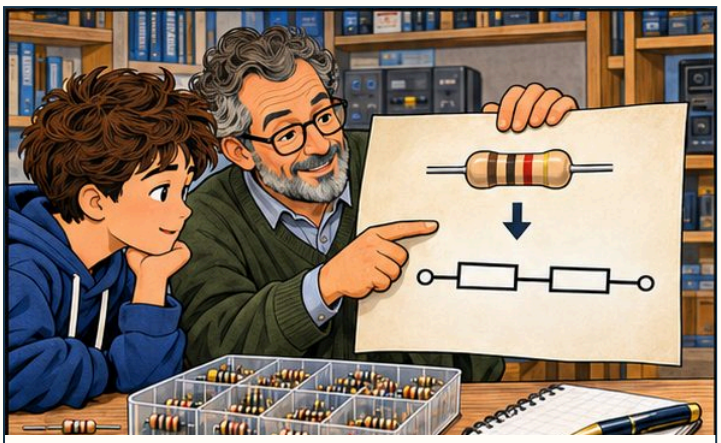


Each must withstand its own voltage and power.

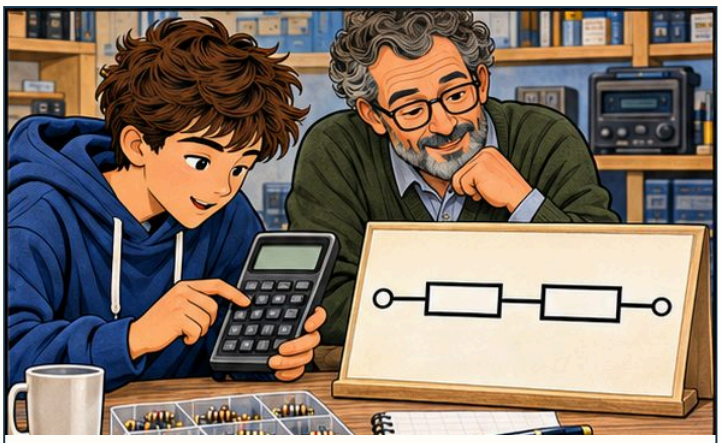


Lucas traces one path and finds the LED's series resistor.

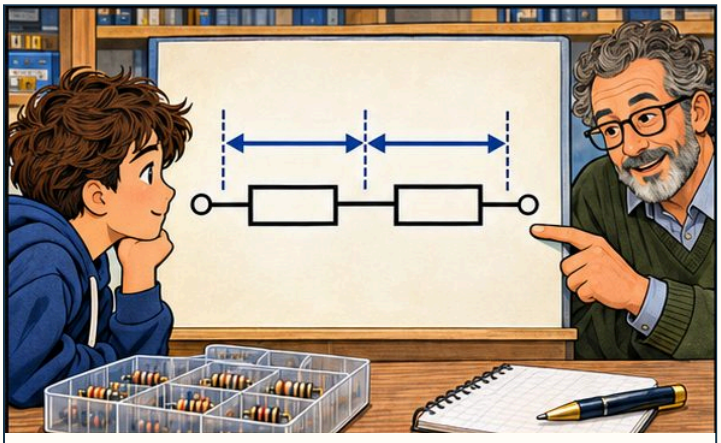
Sharing in series



On paper, 5 V supplies two identical 1 kΩ resistors in series.



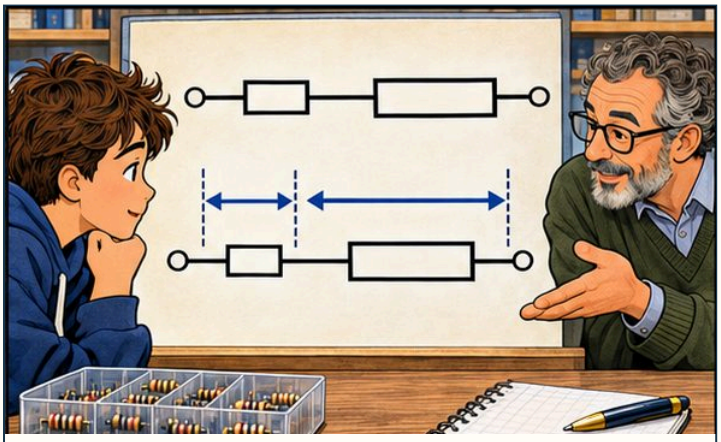
Current is 5 / 2 000 = 0.0025 A, or 2.5 mA.



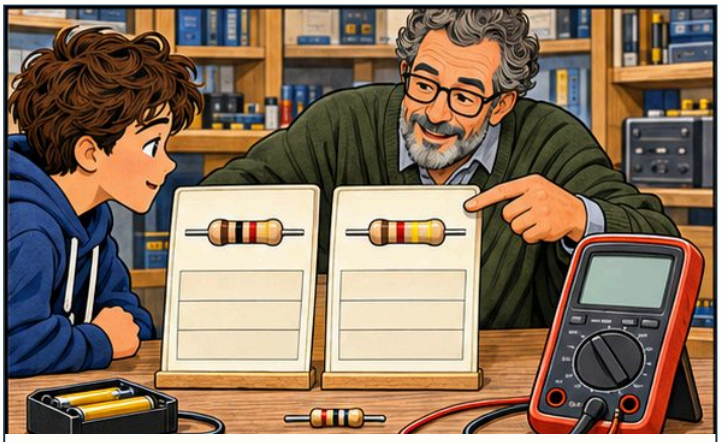
Each resistor receives 2.5 V in this ideal model.



Each dissipates 2.5 × 0.0025 = 0.00625 W.

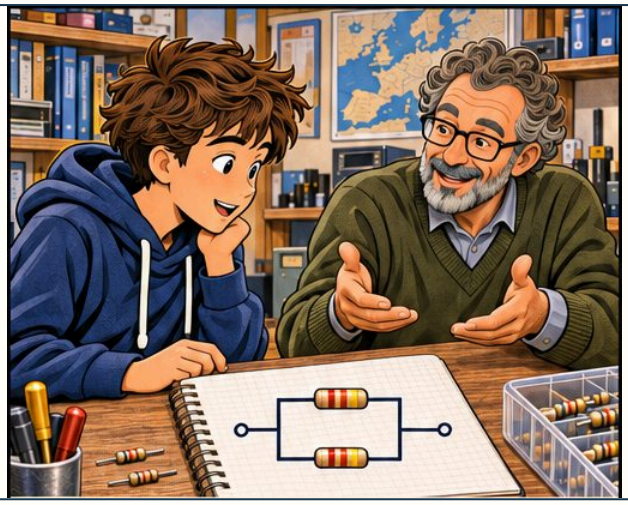


Different values would divide voltage and power differently.

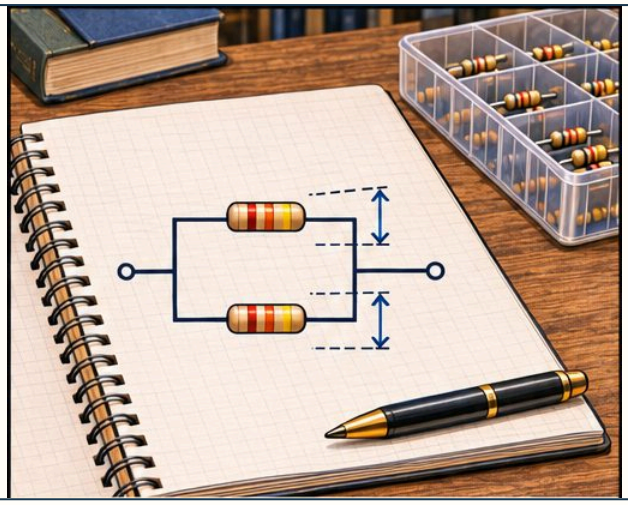


Henri stresses: adding package watt ratings does not ensure suitability.

Two paths between two terminals



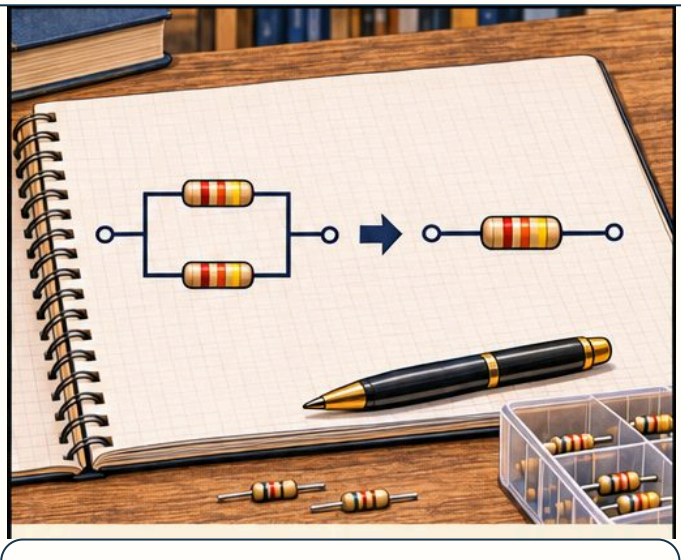
Parallel resistors connect to the same two nodes.



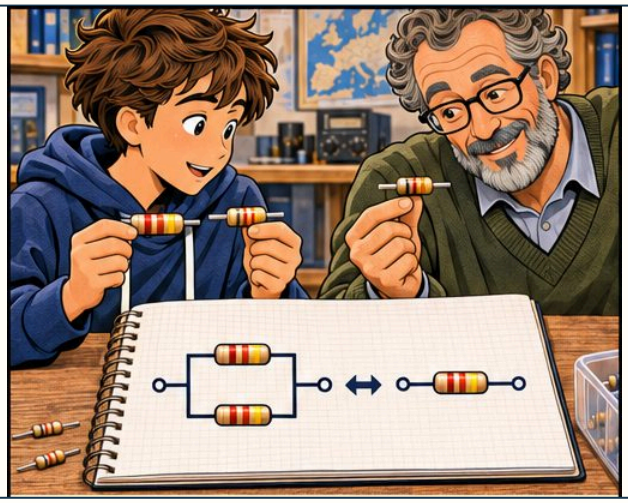
They therefore have the same terminal voltage.



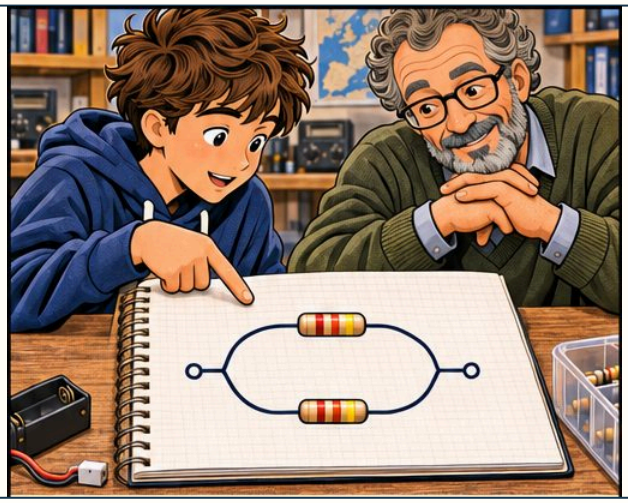
For two branches: 1 / R = 1 / R1 + 1 / R2.



Two 1 kΩ resistors in parallel give 500 Ω.

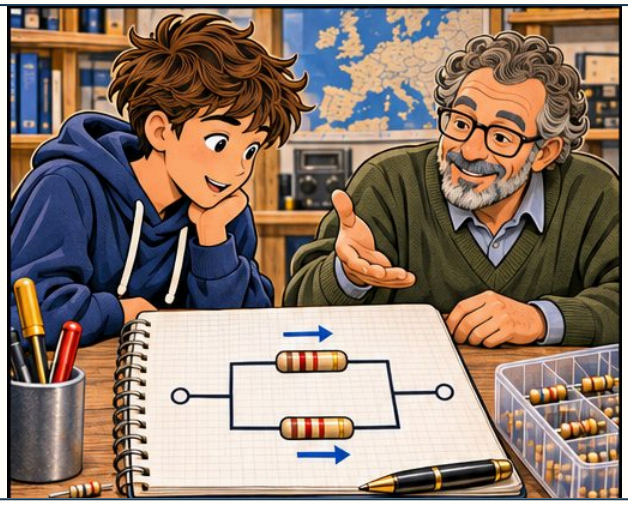


The equivalent is below the smallest positive resistance in these branches.

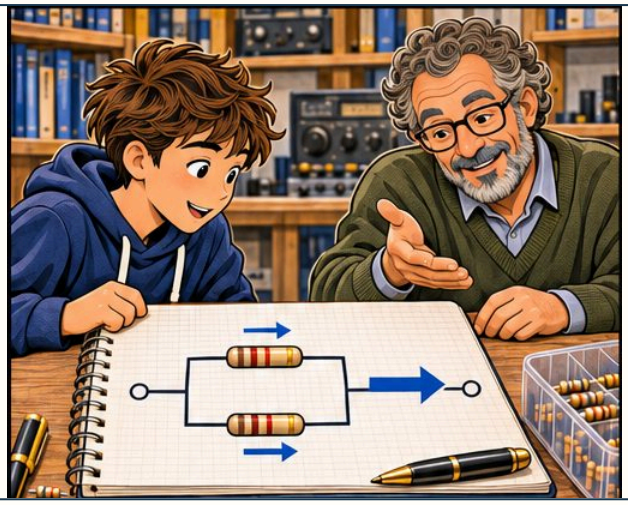


Lucas checks nodes; position on the drawing is insufficient.

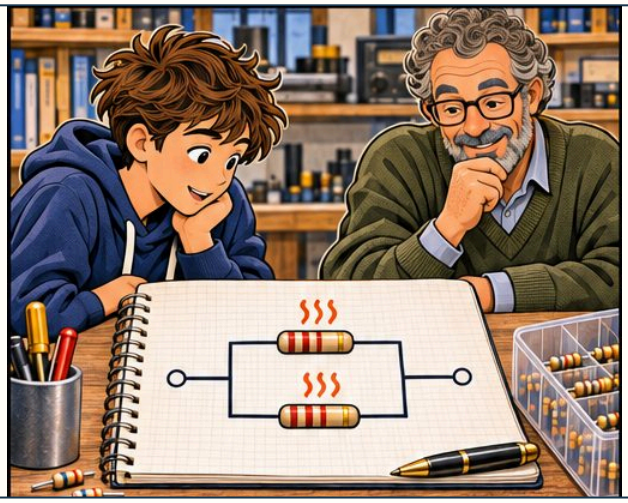
Current through the branches



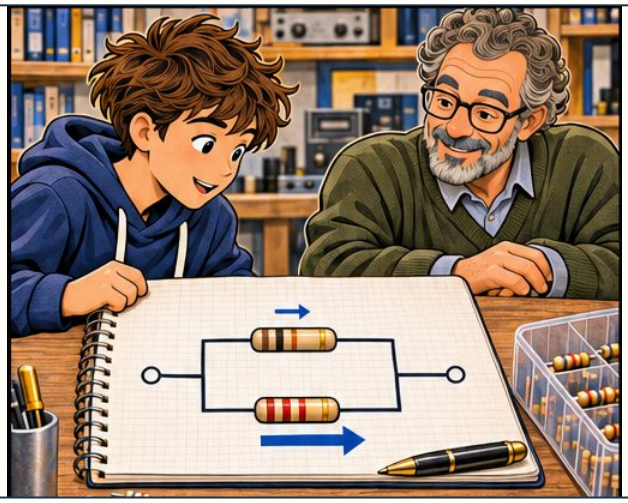
With 5 V across each 1 kΩ resistor, each branch draws 5 mA.



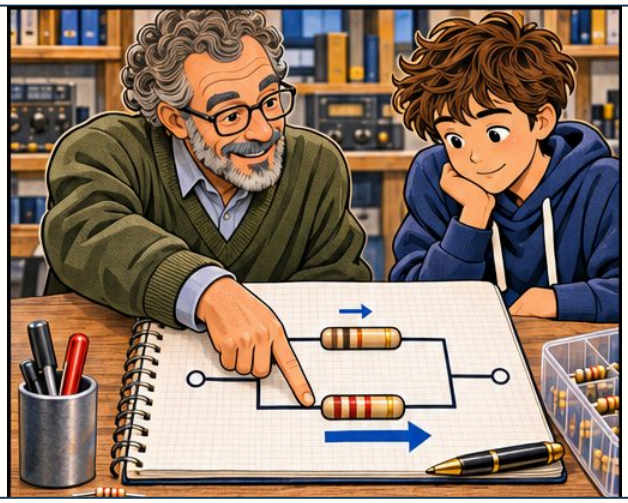
The source supplies their sum: 10 mA in this ideal example.



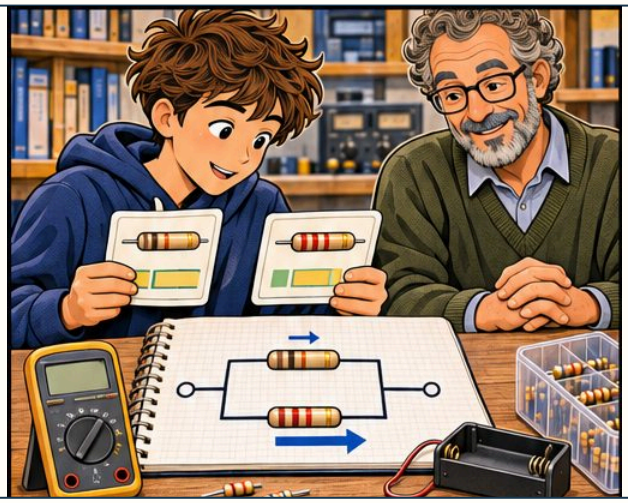
Each resistor dissipates $5^2 / 1\,000 = 0.025$ W.



Different resistance values mean unequal currents.

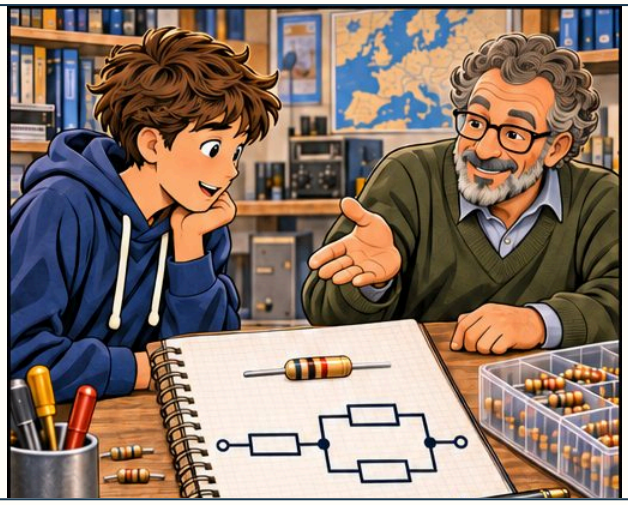


The lower-resistance branch draws more current at equal voltage.



Lucas sees why two parallel resistors require two checks.

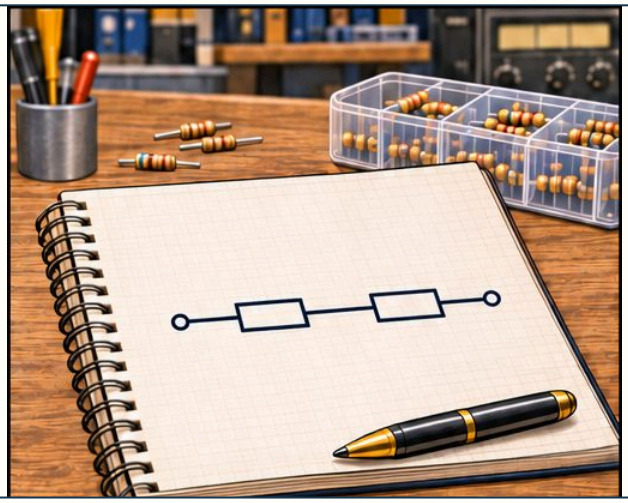
Simplifying without getting lost



Henri draws 1 kΩ in series with two parallel 1 kΩ resistors.



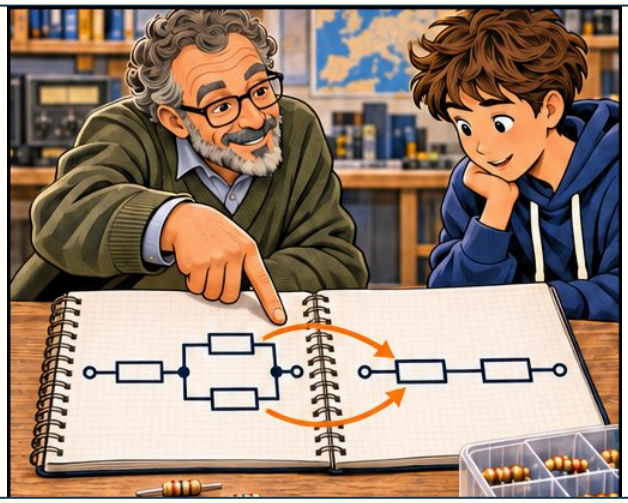
Lucas first replaces the parallel pair with 500 Ω.



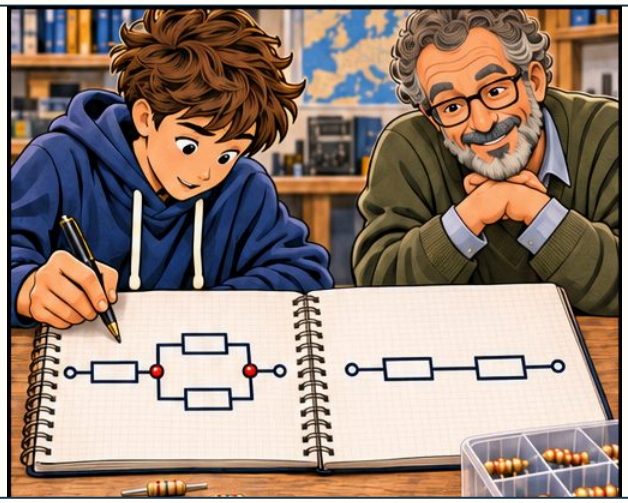
He adds the series resistor: 1 000 + 500 = 1 500 Ω.



He keeps the original drawing to recover each part's current.



An equivalent describes terminals without removing internal constraints.



The method avoids selecting formulas merely by a diagram's appearance.

Creating an intermediate voltage



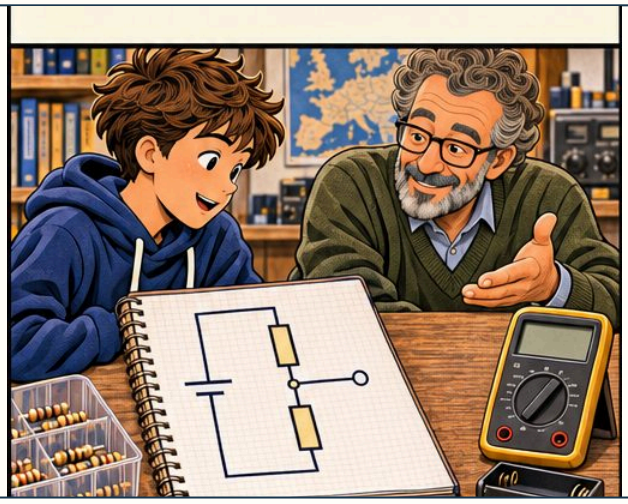
Two series resistors can form a voltage divider.



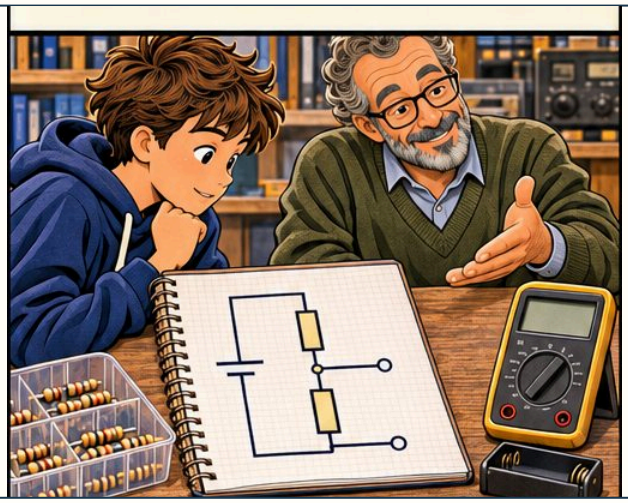
Without load: Uoutput = Uinput × R2 / (R1 + R2).



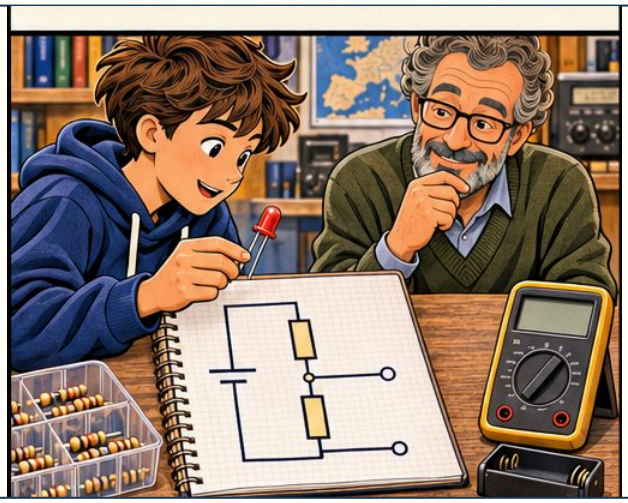
The output spans R2, from midpoint to reference.



With 5 V and two 1 kΩ resistors, it is ideally 2.5 V.

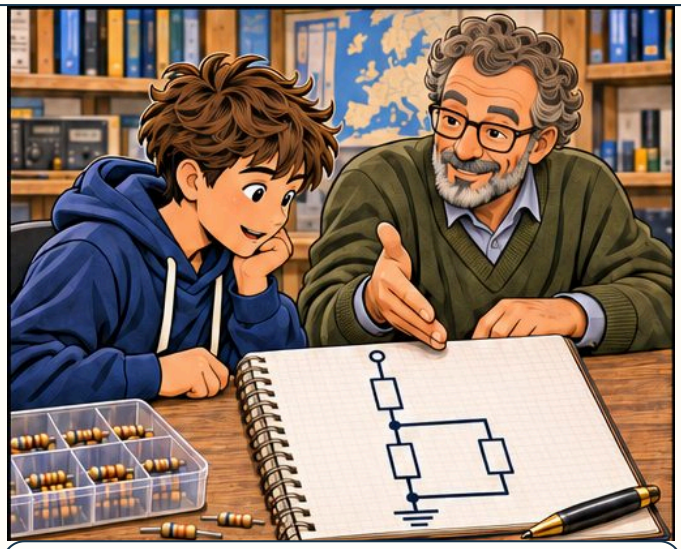


This assumes the output draws practically no current.

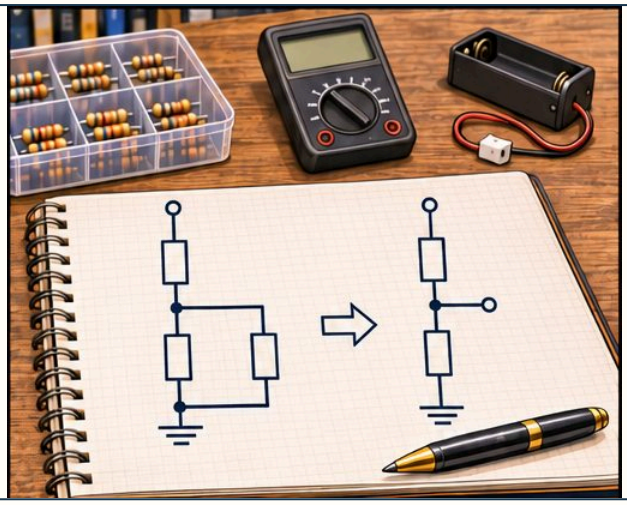


Lucas wants to connect the LED; Henri explains what would change.

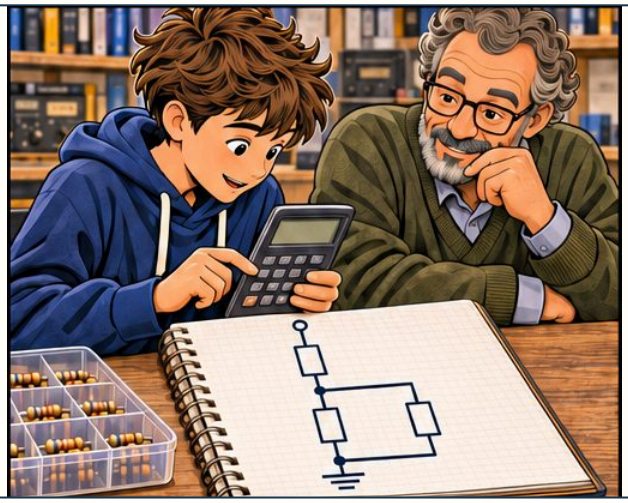
When the output is loaded



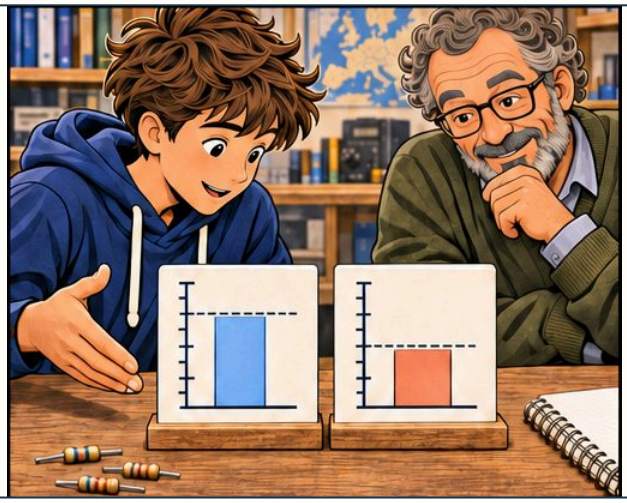
A load across the output is parallel with R2.



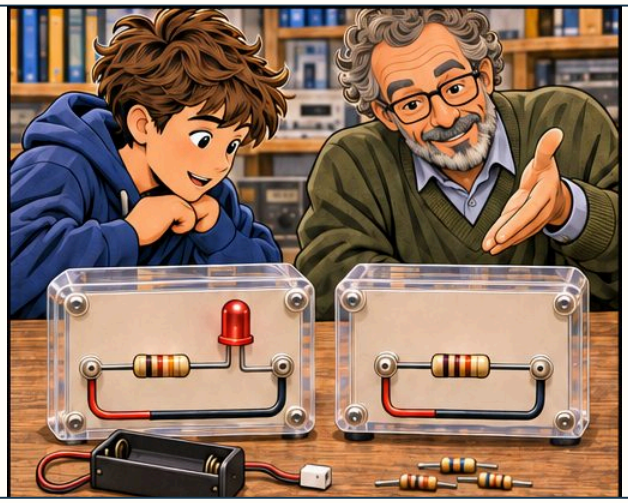
With a 1 kΩ load, R2 of 1 kΩ becomes a 500 Ω equivalent.



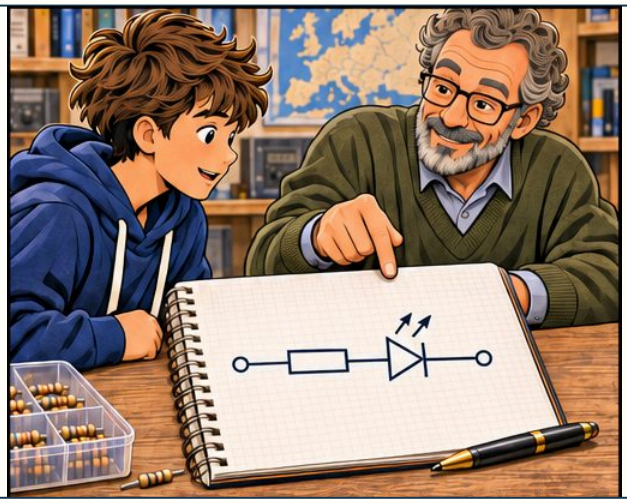
Output becomes 5 × 500 / (1 000 + 500) ≈ 1.67 V.



It is no longer 2.5 V: the load changed the divider.



An LED is not an ohmic load, so this does not describe its exact case.



They keep the intended series circuit without an improvised divider.

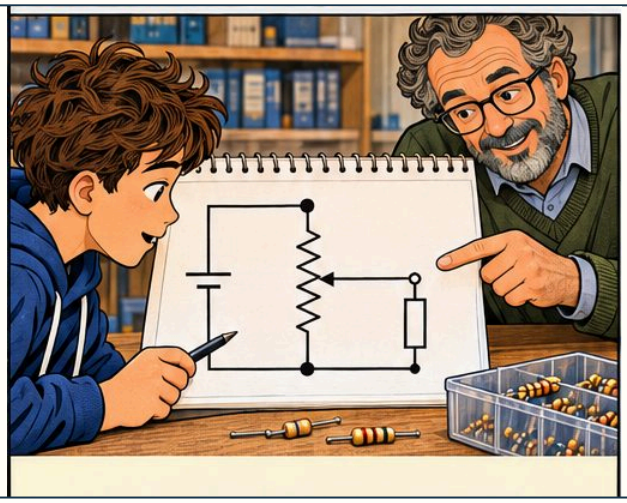
The potentiometer's wiper



A potentiometer has a resistive track and movable wiper.



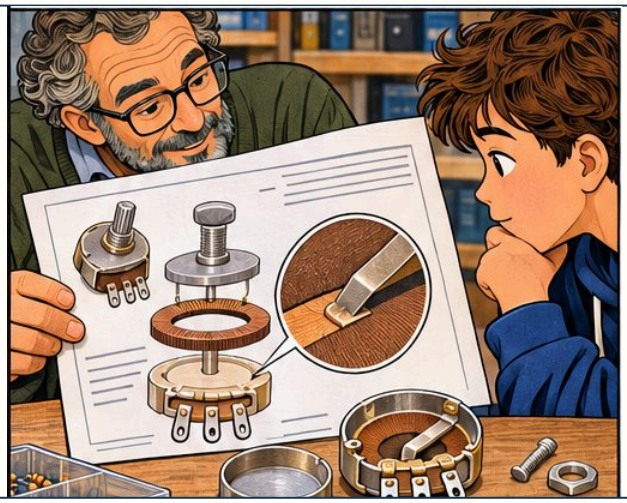
Its three terminals can form an adjustable divider.



The load also affects the voltage taken from the wiper.



With two terminals, it can act as a variable resistor, depending on the circuit.

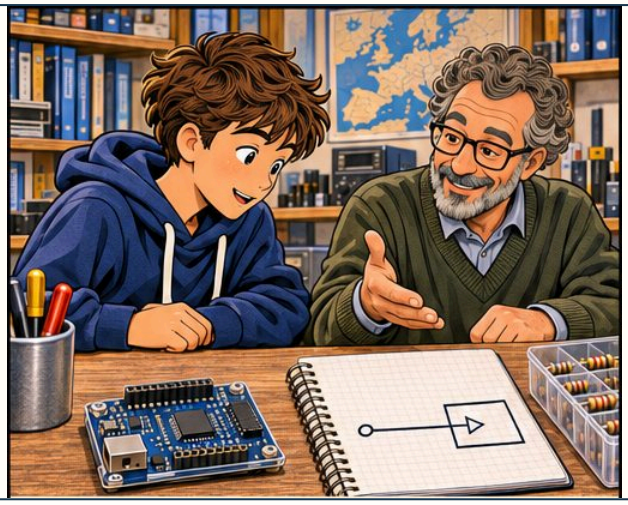


Its power, wiper current and wiring require checking.

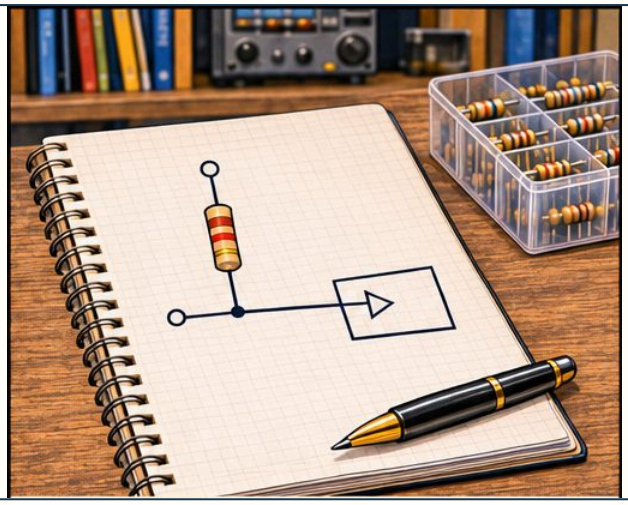


Lucas refuses to remove their LED's fixed protective resistor.

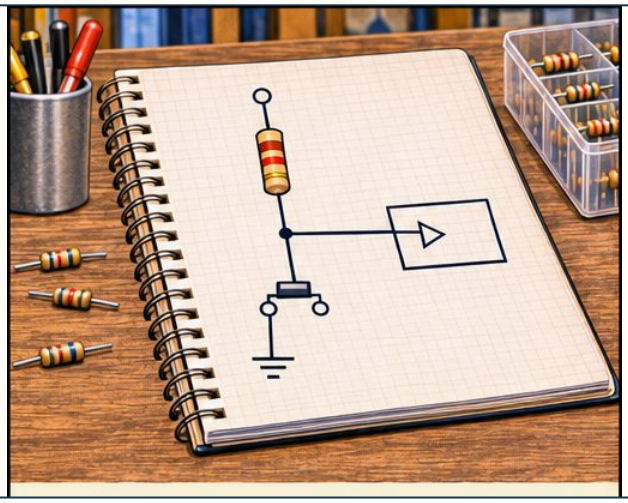
Giving an input a state



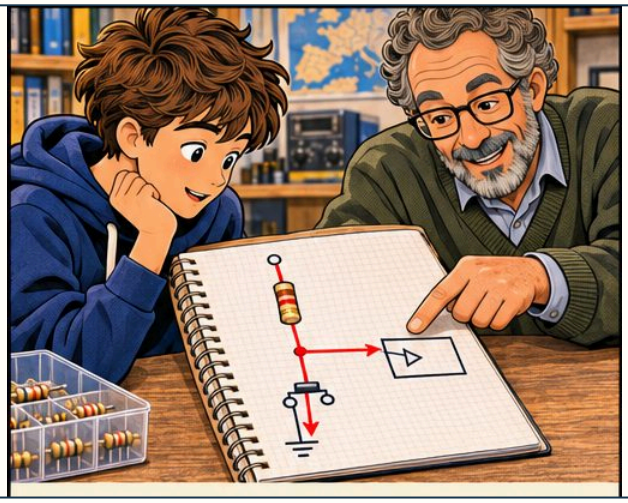
On an educational board, a floating input may read an uncertain state.



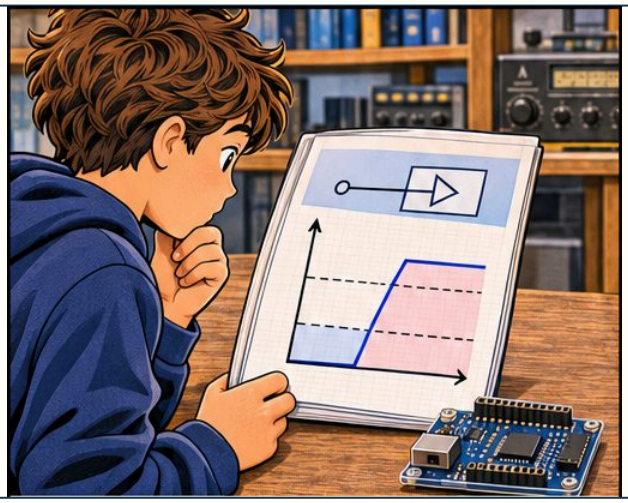
A pull-up resistor establishes a high idle state.



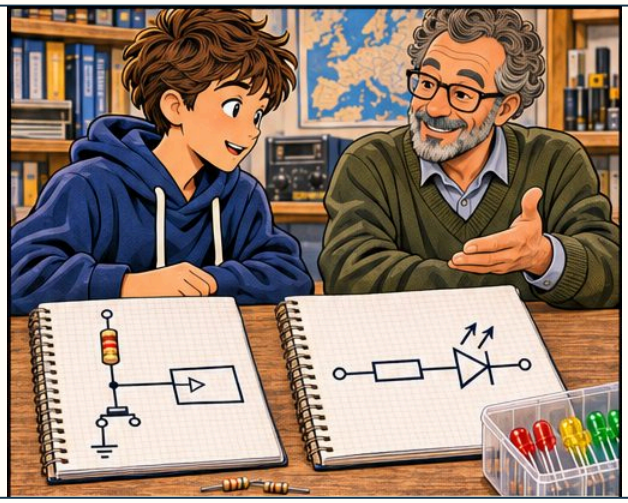
A button to the reference imposes a low state when closed.



The resistor limits current between supply and button.



Its value depends on the input, thresholds and documentation.

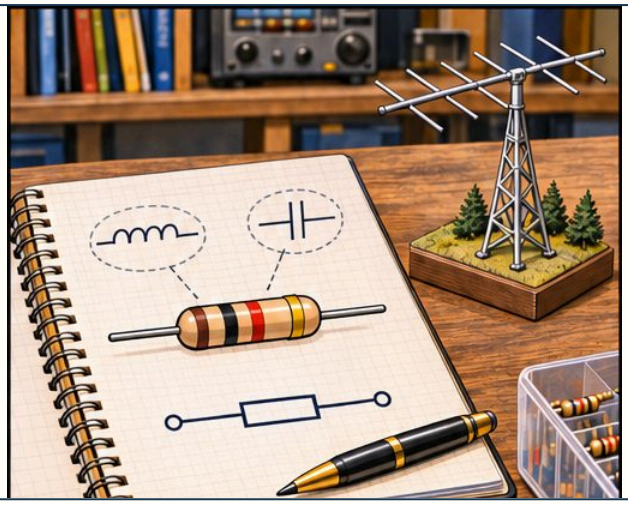


Henri uses a drawing; the indicator retains its simple circuit.

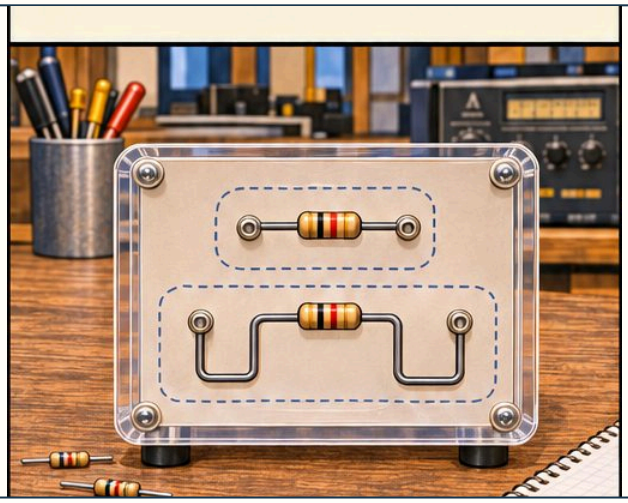
In radio, the model has limits



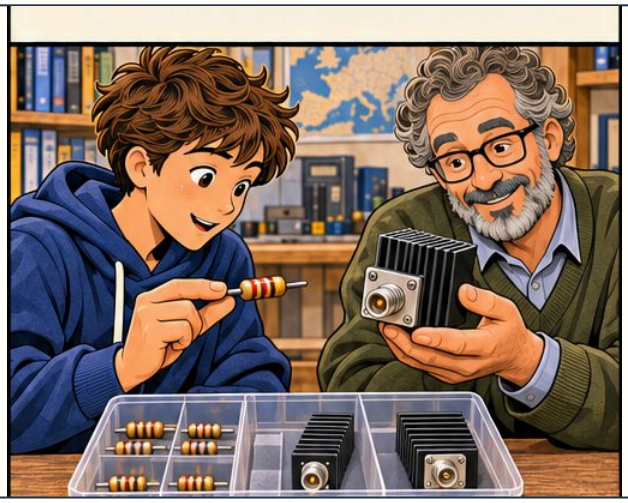
Resistors provide biasing, attenuation or termination in radio circuits.



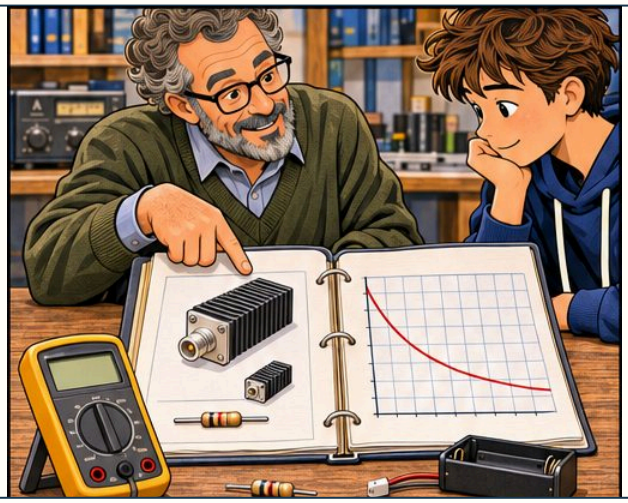
At high frequency, parasitic inductance and capacitance can matter.



Connections and layout add their own effects.



An arbitrary 50 Ω resistor is not necessarily a good RF load.



Frequency range, power and construction must suit the application.



Lucas stores the RF examples: their workshop transmits nothing.

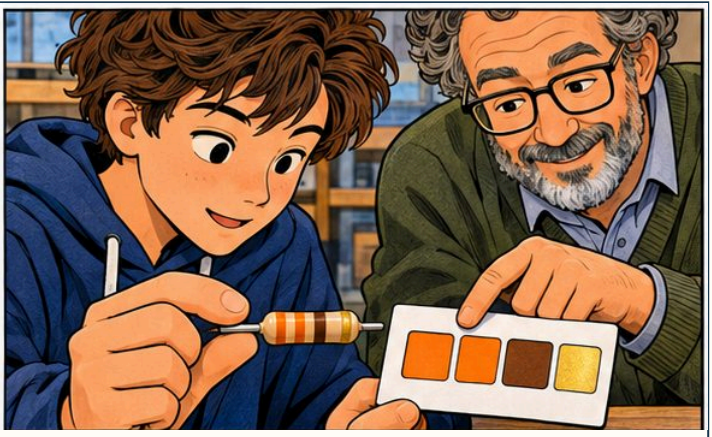
The replacement sheet



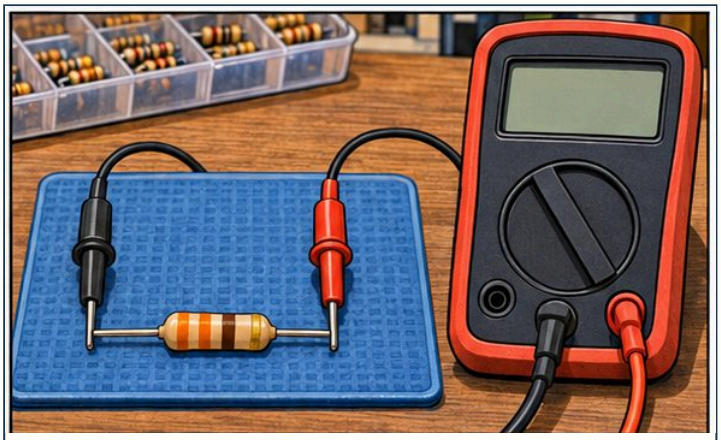
Lucas gathers the schematic and LED and resistor references.



The choice remains 330 Ω, ±5%, 0.25 W for this documented example.



He confirms orange, orange, brown and gold using the chart.



The new resistor is measured alone, outside any powered circuit.



Its reading must fit the tolerance and multimeter uncertainty.

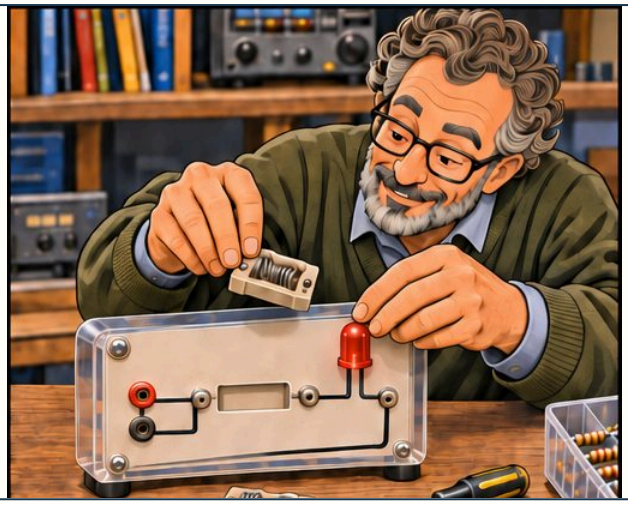


Henri checks the file: calculation and measurement complement each other.

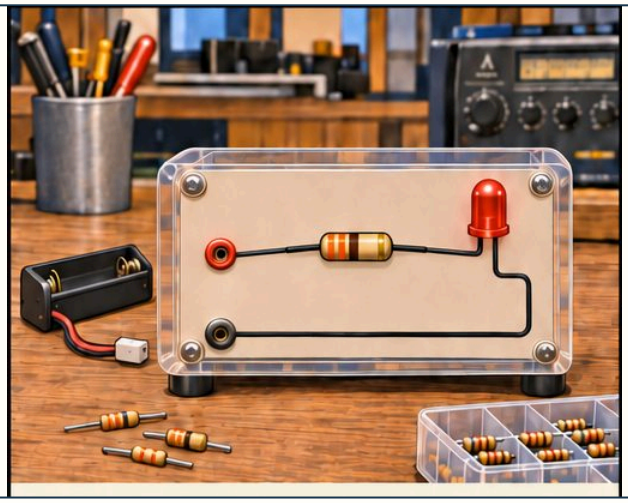
Rebuilding methodically



The panel stays disconnected throughout replacement.



Henri checks the damaged socket and replaces the intended connector element.



They insert the new resistor without force or loose wire.



Lucas follows the loop: supply, resistor, LED, return.

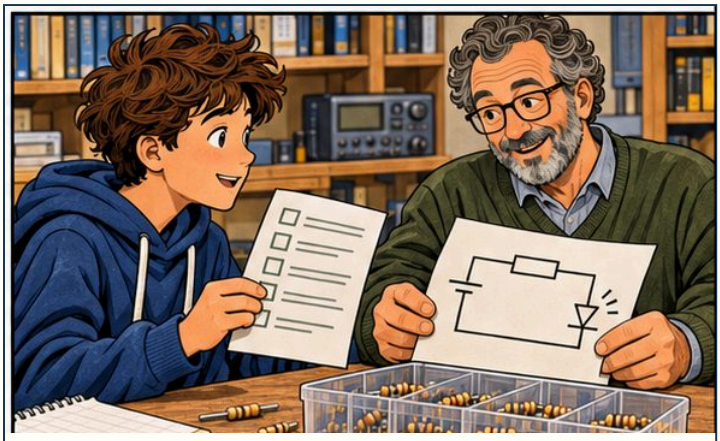


LED polarity matches the schematic and datasheet.

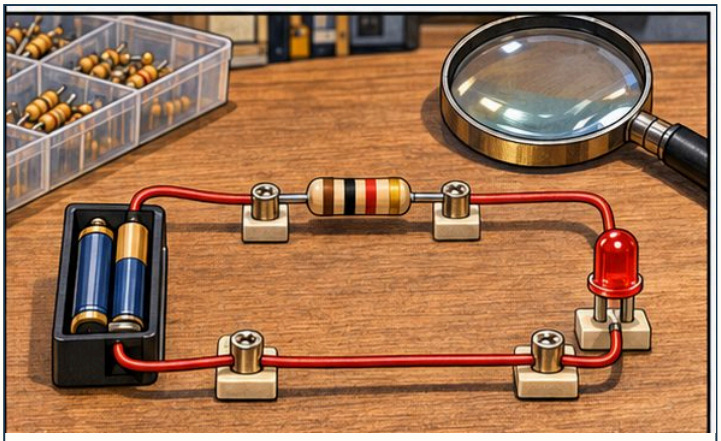


The suspect part stays separate with observations, without reuse.

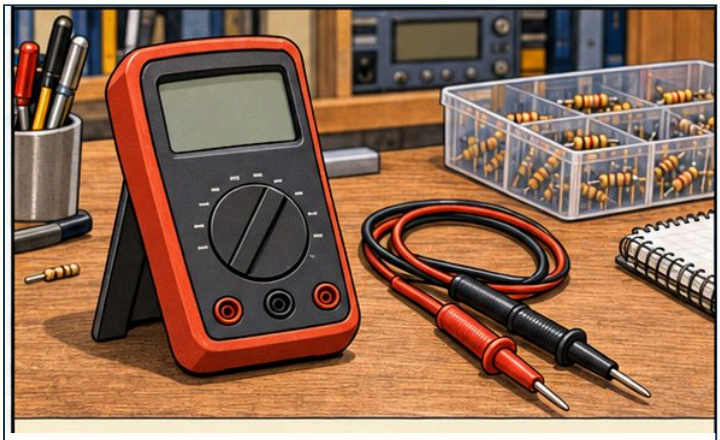
The cross-check



Before powering up, each reviews the other's work.



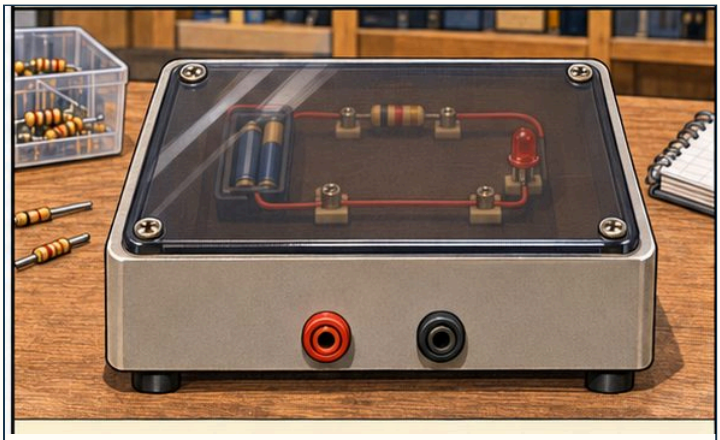
They seek shorts, omissions or connections bypassing the resistor.



The ohmmeter leads are removed from the panel.



Henri prepares the supply set to 5 V with suitable current limiting.

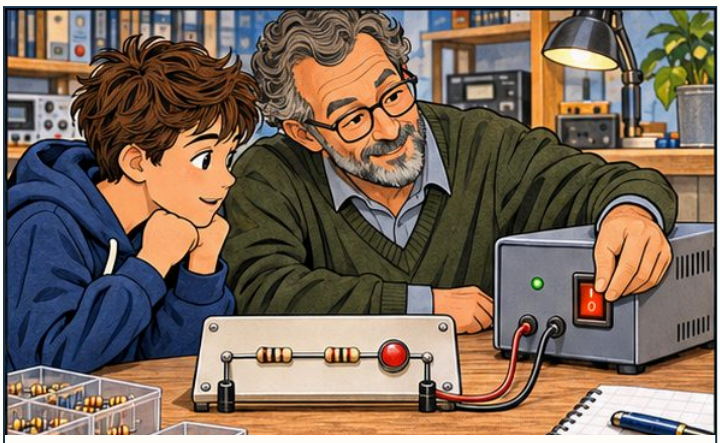


The panel is closed following its manual; connections stay protected.



Lucas expects a visible indicator with moderate current.

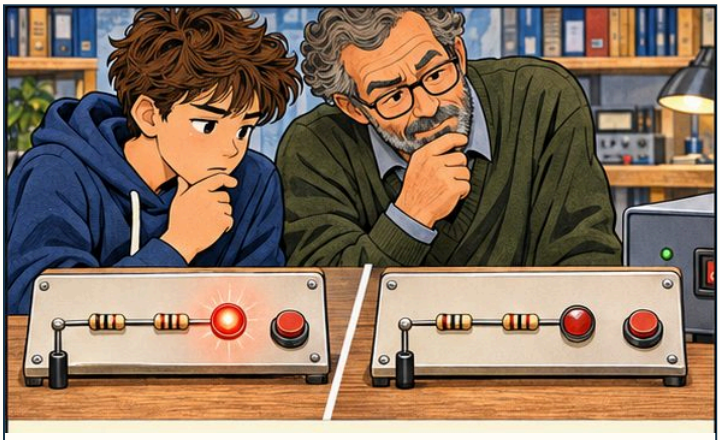
A careful first trial



Henri powers the closed panel; nobody moves connections.



The indicator lights, then goes out when the button is released.



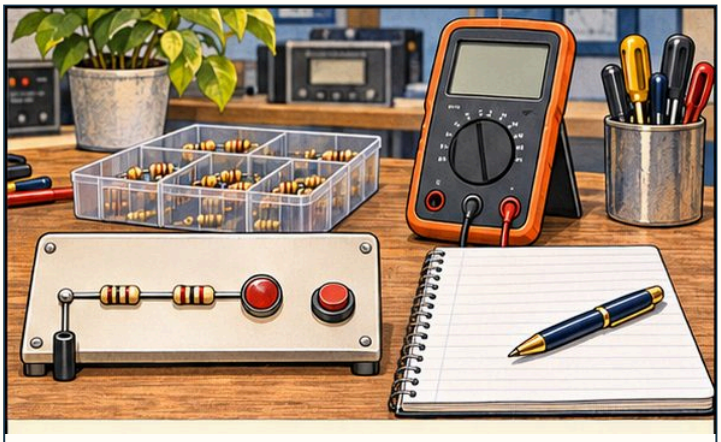
The next trial reveals hesitation in its operation.



Lucas suggests raising voltage, then remembers their method.



They switch off and disconnect before resuming diagnosis.

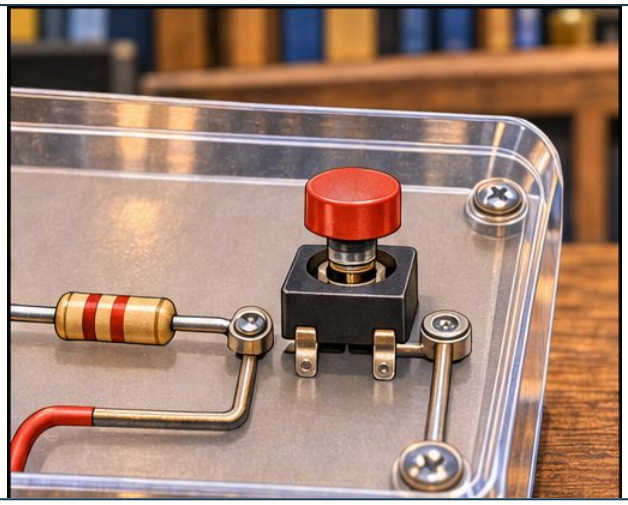


One glimpse of light does not prove the panel is ready.

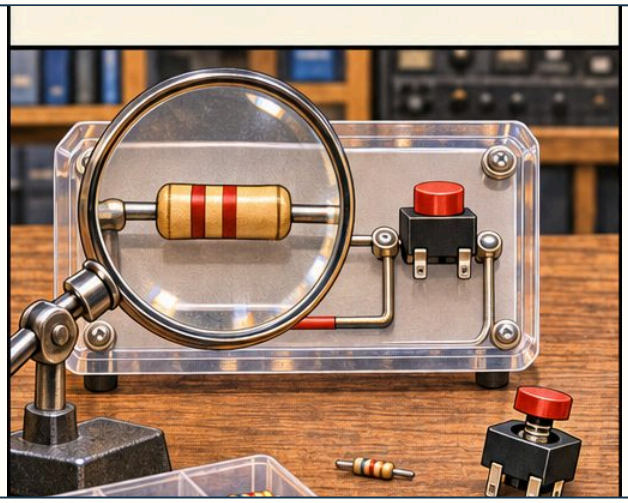
A second cause



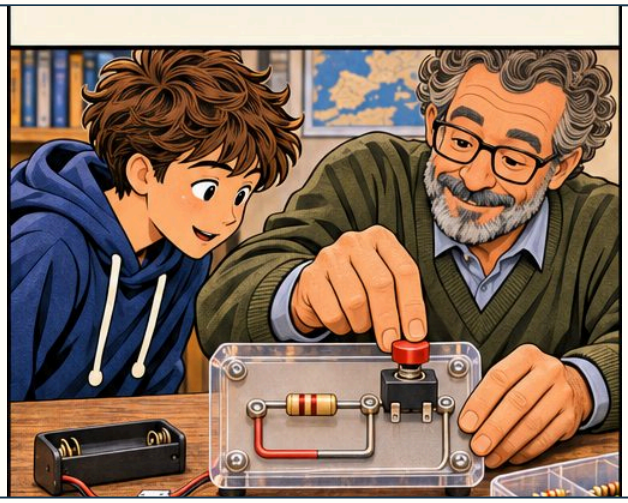
After safety checks, they inspect the current path without power.



A removable button connector is not fully seated.



The right resistor alone cannot correct a poor connection.



Henri reseats the connector and checks its retention.



Lucas records suspect part and connection fault as separate clues.

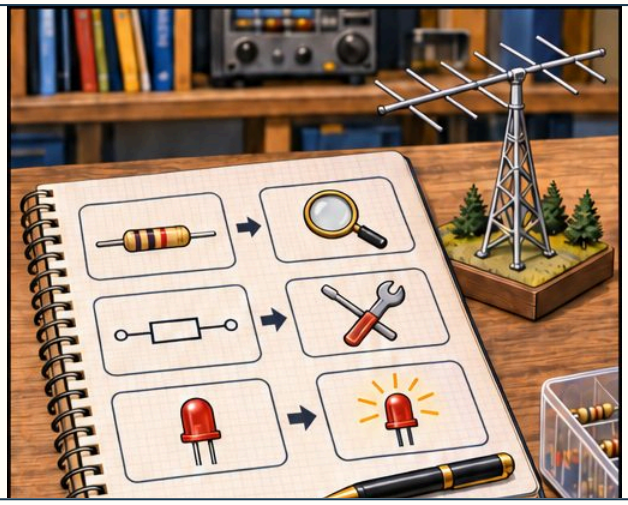


They repeat the full inspection before another trial.

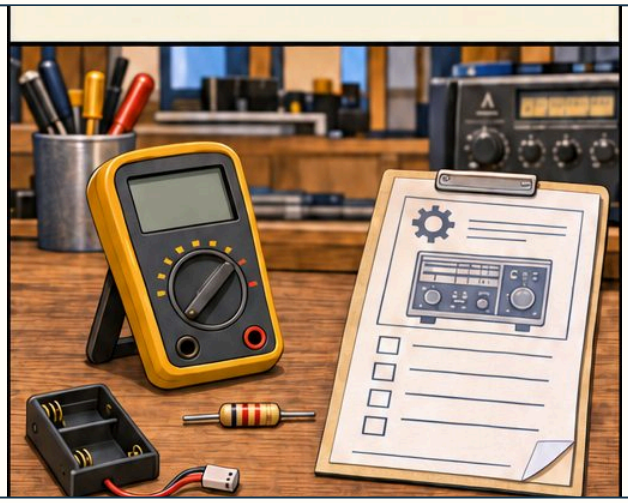
Observe one thing at a time



They no longer change several parts simultaneously.



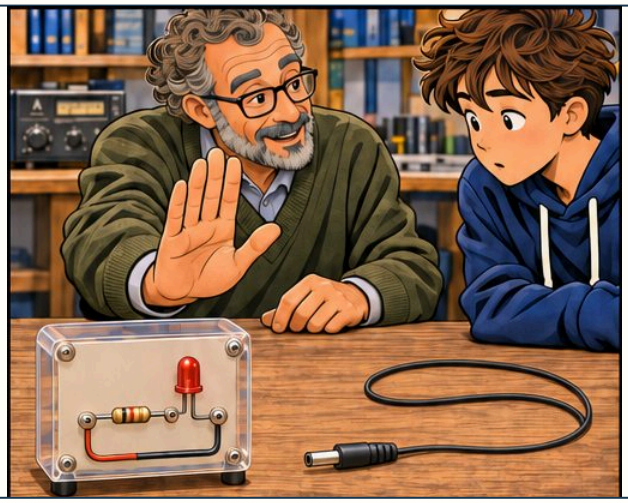
The notebook records symptoms and checks at every stage.



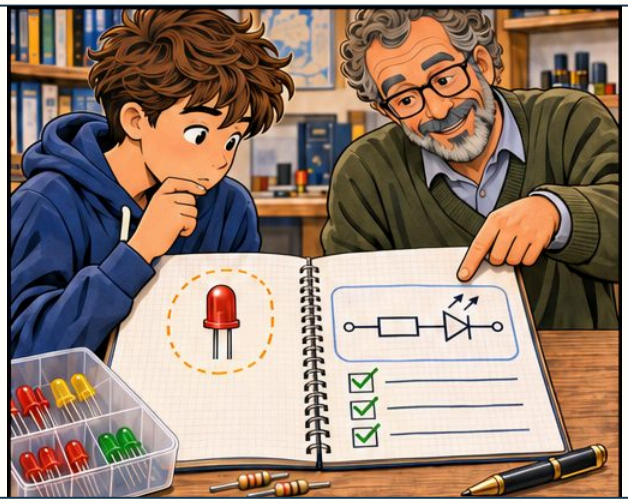
A correct ohmmeter value does not guarantee every operating behaviour.



Inspection, component limits and the planned trial complement measurement.

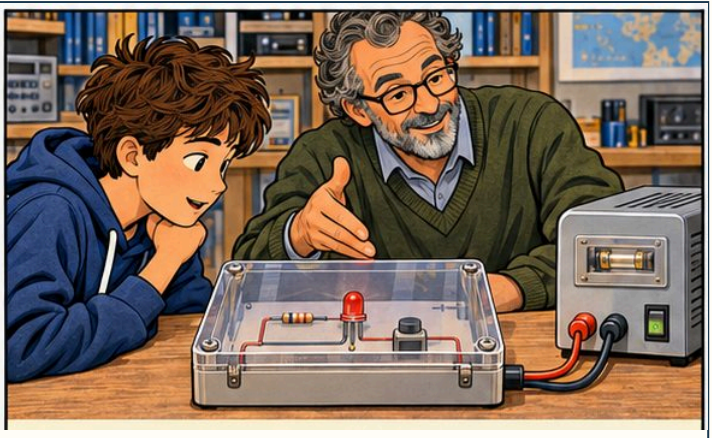


If anything abnormal appears, they stop and investigate without power.



Lucas can explain why his first idea was too hasty.

The indicator fulfils its promise



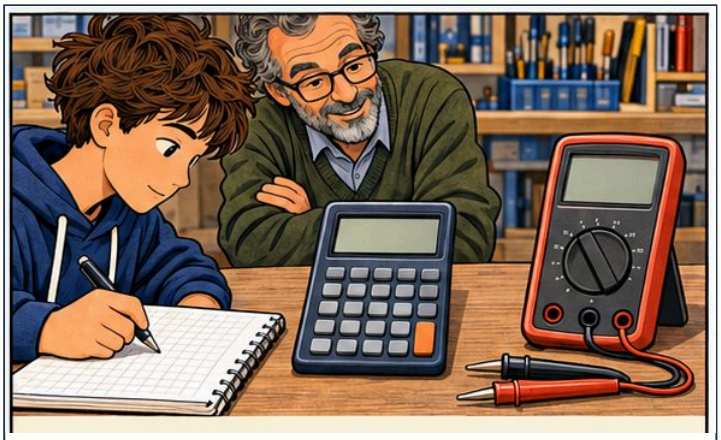
The reclosed panel is powered again following the procedure.



In their demonstration, the indicator now responds consistently to the button.



Henri monitors operation; Lucas compares it with expectations.



They do not present calculated current as a measurement.



The notebook separates calculations, checks and trial observations.

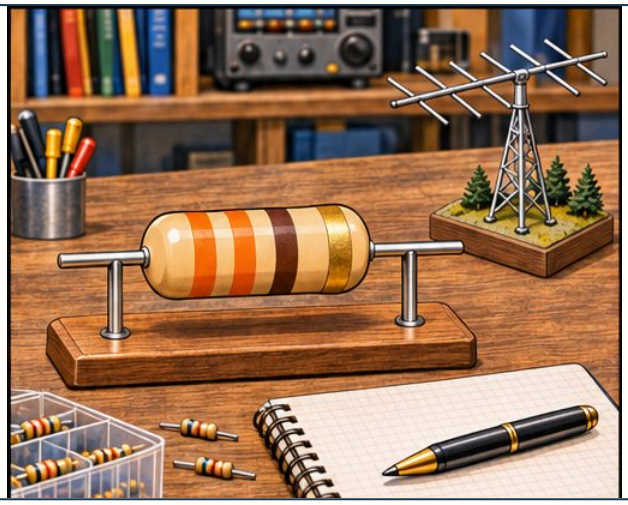


They switch off before preparing transport to the stand.

Explaining the choice



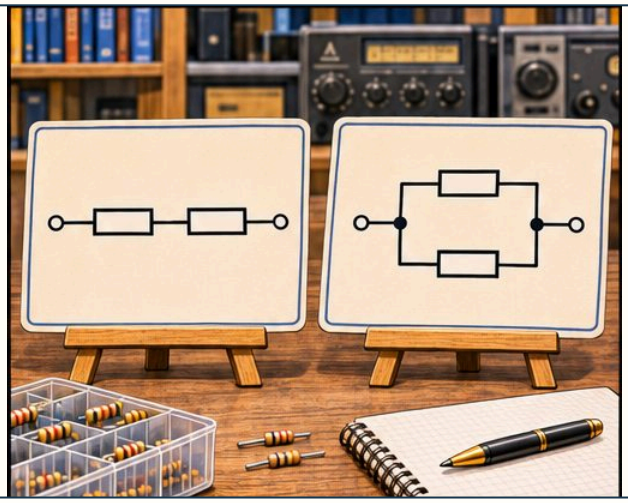
At the stand, Lucas presents an enlarged resistor to visitors.



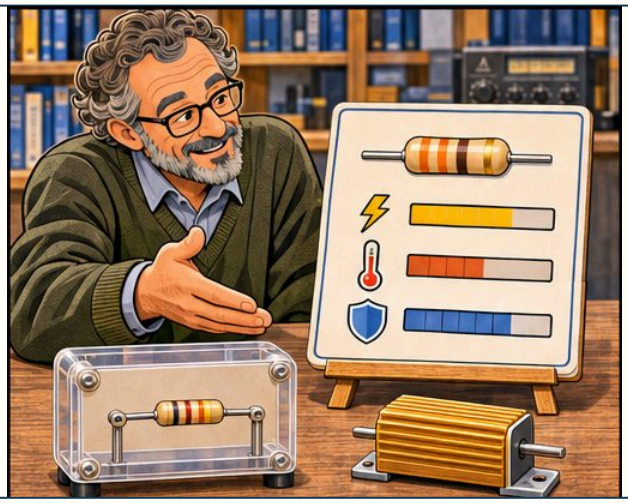
He explains bands, nominal value and tolerance.



His drawing shows the series resistor limiting LED current.



Another drawing compares series and parallel connections.



Henri asks why he checked power and operating conditions.

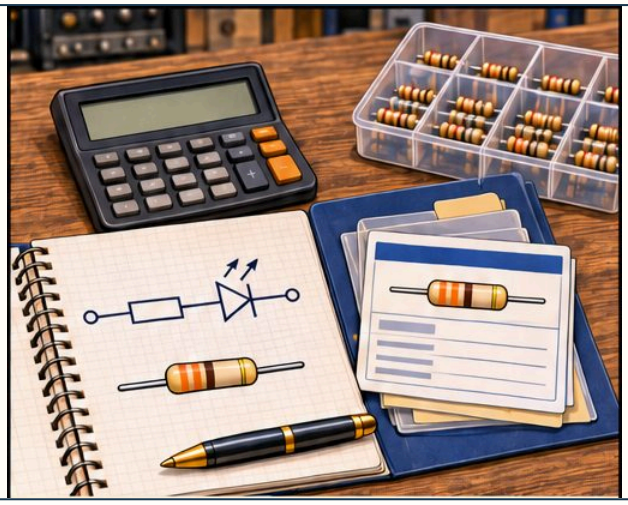


"To select a part that suits the circuit," Lucas replies.

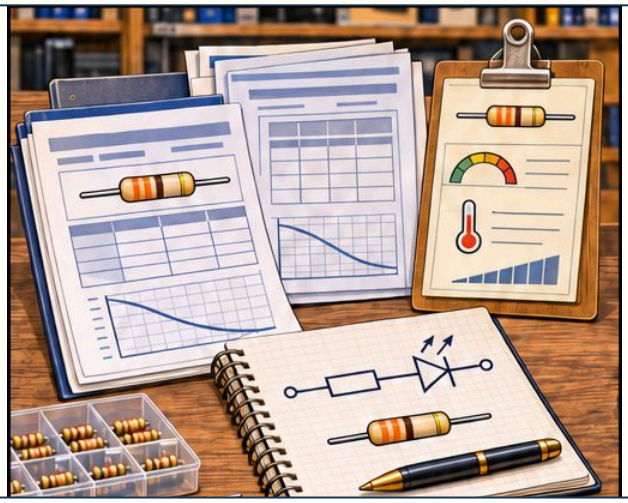
A notebook for the next learner



The sheet starts with the need: an indicator for the discovery panel.



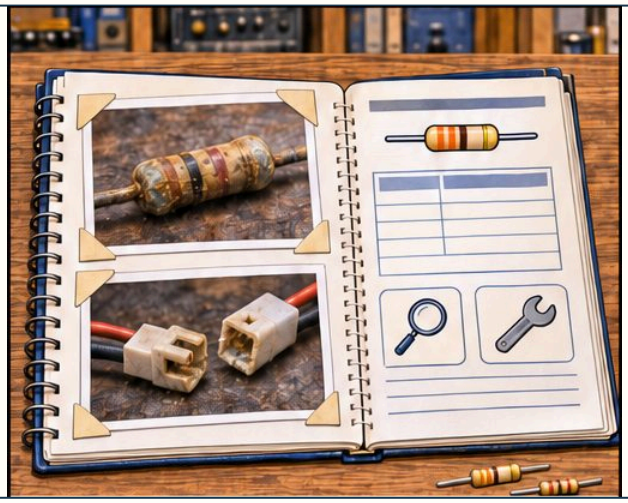
It preserves assumptions, formula and the choice of 330 Ω.



Tolerance, power and component references stay with the schematic.



The procedure recalls measuring resistance unpowered and isolated when necessary.



Fault observations will help the next workshop investigate methodically.

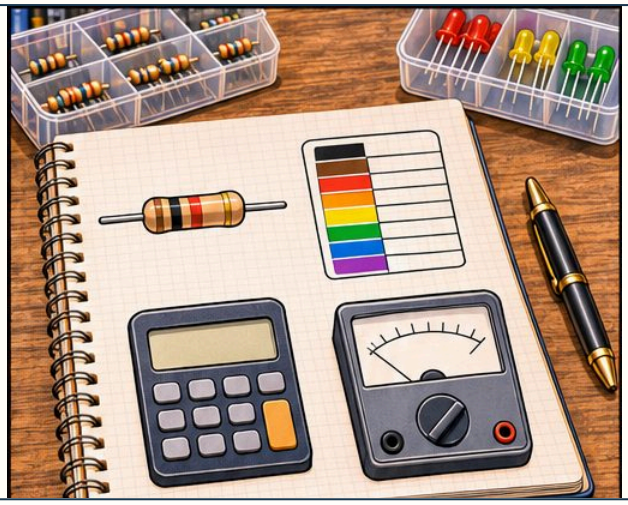


Henri lets Lucas file the records: learning has become sharing.

A small component, a great method



The stand is ready; Lucas sees the small resistor differently.



Read, calculate, choose, measure: each stage answers a question.



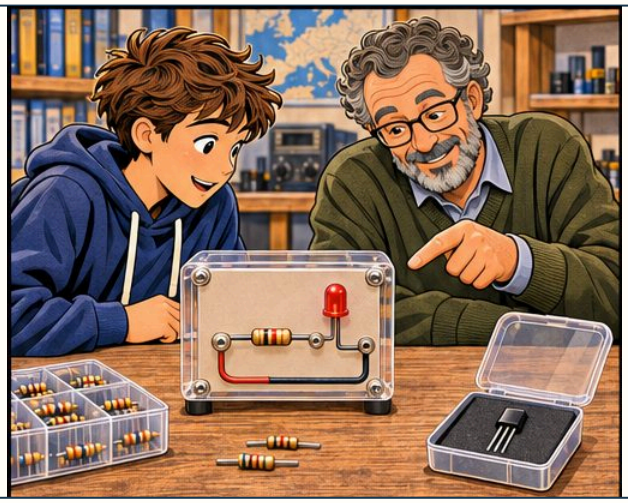
The indicator is more than light: it is an explanation he can share.



In another box, Henri shows him a three-legged component.



"Can it control a larger current?" Lucas asks.



Their next investigation awaits in volume 08: transistors.