

## 26 Science: research summaries, controls and engineering tests

Name: \_\_\_\_\_ Class: \_\_\_\_\_ Date: \_\_\_\_\_

Total: 13 marks

**KEY WORDS** controlled comparison • engineering design  
 • constraint • proposal

### Objective

- Identify independent, dependent and controlled variables across experiments
- Choose a follow-up that isolates the proposed explanation
- Apply engineering criteria and constraints to a design comparison

Original public practice; marks below are classroom self-check points, not official criteria.

### 1 Key knowledge and worked examples

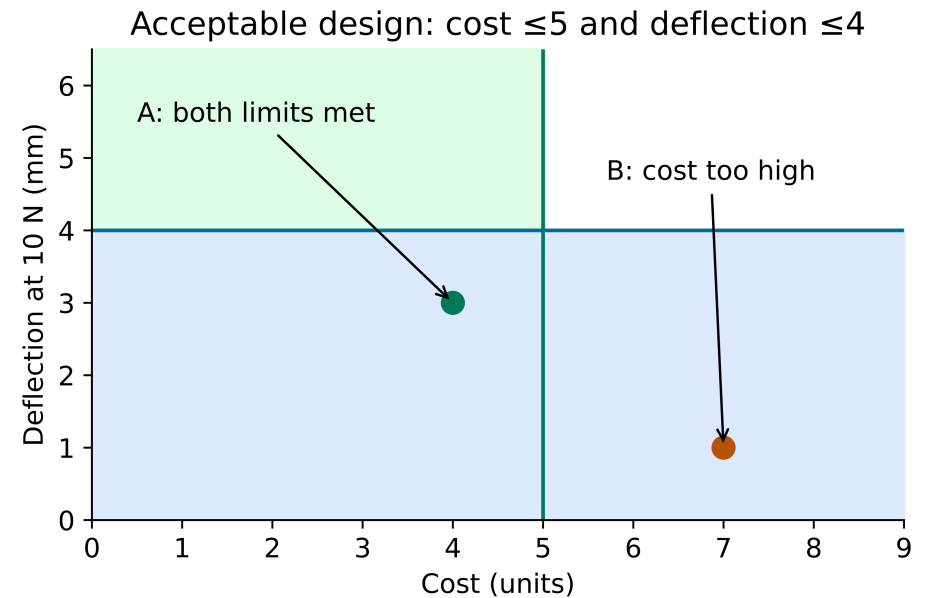
Research Summaries passages describe experiments with related but distinct designs. Make a compact table of what changed, what was measured and what stayed fixed. Compare experiment numbers carefully: the same material might be used at a different volume, temperature or duration. A control supplies a comparison for a stated effect; it is not necessarily a trial with no treatment in every possible experiment.

To isolate a variable, hold relevant alternatives constant and vary that variable deliberately. Repeated trials assess variability and reduce reliance on one observation. Random allocation can reduce systematic group differences when the design permits it. A result from one apparatus, duration or population does not automatically generalise to another.

A follow-up experiment should distinguish the proposed explanations. Predict what each would expect and choose a measurement capable of separating them. Extending a study to a new range tests generality, but changing several conditions simultaneously can prevent a causal interpretation. State whether the new task explores a relationship or isolates an explanation.

Engineering tasks add a goal, measurable criteria and constraints such as cost, mass or allowable deflection. A design is acceptable only when it satisfies the required constraints. Optimising one measurement does not necessarily make it best overall. A fair comparison applies the same test load and procedure, with repeat trials where feasible.

A controlled comparison \_\_\_\_\_ changes the proposed cause while holding alternative causes fixed. An engineering design \_\_\_\_\_ must satisfy every stated constraint \_\_\_\_\_. Repetition estimates variation; it does not undo a change of both material and thickness.



*A design is acceptable only inside both limits: cost at most 5 and deflection at most 4*

**Worked example.** Original engineering study: beams A and B are tested at a 10 N load with identical length and supports. A costs 4 units and deflects 3 mm; B costs 7 and deflects 1 mm. Required cost  $\leq 5$  and deflection  $\leq 4$  mm. A satisfies both constraints; B fails cost despite smaller deflection. To test whether thickness explains deflection, use beams of the same material, length and support geometry at several thicknesses under the same load. Testing one thick wooden beam and one thin metal beam confounds material with thickness. Repeated measurements can reveal variation, but repetition alone does not remove that confounding.

#### ■ Practice material

Original hypothetical research summary – A cooling sleeve

A laboratory team tests sleeves intended to reduce a small sensor's temperature during operation. All sensors start at 22°C. Temperature is measured after ten minutes of use with the same power setting, room conditions and measuring instrument. Sleeve A costs 4 units, B costs 7 units, and an unsleeved sensor is the control. The design brief requires a cost no greater than 5 units and a final temperature no greater than 35°C. Lower temperature alone is not the only design criterion.

Experiment 1 uses identical sensors and records three independent trials per sleeve. Final temperatures in °C are: control 41,42,43; A 33,34,35; B 30,31,32. The team resets the starting temperature and checks the sensor charge before each trial. They report the means and the full observed ranges. The ranges describe these trials, not every future result. The team has not yet measured sleeve durability.

Experiment 2 investigates thickness for material A. Each sleeve has the same length and fit; thicknesses are 1,2,3 mm. Mean final temperatures are 38,34,32°C respectively. All

other stated conditions match Experiment 1. Changing thickness also changes material quantity, so a future design review must measure costs instead of assuming they stay at 4 units. A student proposes testing a 3-mm sleeve in material B against a 1-mm sleeve in material A to identify thickness's effect. This comparison would change two factors at once.

Two original models explain the observed temperature pattern. Model P says final temperature depends only on thickness, regardless of material. Model Q says both thickness and material matter; at equal thickness it predicts that material B produces a lower final temperature than A under the same conditions. Both models predict lower final temperatures as thickness rises over the tested 1–3 mm interval. A decreasing trend alone therefore cannot separate them.

Experiment 3 tests new A and B sleeves, each 2 mm thick, in matched conditions. Mean final temperatures are A 34°C and B 31°C. The measuring instrument's stated resolution is 0.1°C, and the team checks its calibration with a reference. Repeated trials would still be needed to characterise variability and rule out other differences in manufacture. The result conflicts with P's material-independence prediction and is consistent with Q's direction; it is not proof that Q is the only possible explanation.

A separate time series for one sensor with sleeve A records temperatures 22,28,32,34°C at 0,2,4,6 minutes. These observations show warming with successively smaller two-minute increases. No measurements beyond six minutes are supplied in this series. A proposal to continue the first interval's slope to twelve minutes is a model assumption that later measurements may contradict, not a reading from the table.

## 2 Practice

**2.1** Original engineering study: beams A and B are tested at a 10 N load with identical length and supports. A costs 4 units and deflects 3 mm; B costs 7 and deflects 1 mm. Required cost  $\leq 5$  and deflection  $\leq 4$  mm. A satisfies both constraints; B fails cost despite smaller deflection. To test whether thickness explains deflection, use beams of the same material, length and support geometry at several thicknesses under the same load. Testing one thick wooden beam and one thin metal beam confounds material with thickness. Repeated measurements can reveal variation, but repetition alone does not remove that confounding.

Which design satisfies cost  $\leq 5$  and deflection  $\leq 4$  mm? [1]

- **A** Neither
- **B** A: cost 4, deflection 3
- **C** B: cost 7, deflection 1
- **D** Both

**2.2** To isolate thickness, which should stay fixed? [1]

- **A** Only the beam's name
- **B** Nothing if there are repeats
- **C** Material, length, supports and load
- **D** Thickness itself

**2.3** The measured beam deflection is the \_\_\_\_\_ variable: independent or dependent? [1]

**2.4** Repeating a test automatically removes a confounding variable. [1]

## 3 Exam-style questions

Use the complete original case context in section 1.

**3.1** Find mean and observed range for control, A and B in Experiment 1. Which sleeve satisfies both design constraints in these trials? [3]

**3.2** Identify the changed and measured variables in Experiment 2. Why does the student's A-versus-B proposal fail to isolate thickness? [3]

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**3.3** Propose a follow-up for the 3-mm A design that addresses a previously unmeasured requirement and preserves a fair temperature comparison. [3]

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## Solutions

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Accept equivalent correct methods and supported interpretations. The marks check reasoning; they are not an official grade.

**2.1 B** – A satisfies both inequalities; B exceeds cost. A rejects A despite both limits being met; C exceeds the cost cap; D incorrectly allows that excess merely because deflection is smaller.

Correct response linked to the given case.

**2.2 C** – Alternative causal conditions must be controlled while thickness changes. A controls a label rather than causal conditions; B mistakes repetition for control; D fixes the factor whose effect is to be tested.

Correct response linked to the given case.

**2.3 dependent** – Deflection is the measured response to changes or a test load.

Correct response linked to the given case.

**2.4 False** – It measures variability but does not untangle systematically linked changes.

Correct response linked to the given case.

**3.1** Control mean 42°C, range 41–43°C; A mean 34°C, range 33–35°C; B mean 31°C, range 30–32°C. A costs 4≤5 and reaches at most 35°C, so it meets both in these trials. B's lower temperatures do not overcome cost 7>5. This does not guarantee future durability or temperatures.

Sound conclusion or proposed method. Relevant supporting steps or textual evidence  
. Accurate conditions, checks or qualification.

**3.2** Thickness is changed and final temperature measured. Material, length, fit, starting temperature and operating conditions are controlled in Experiment 2. The proposal changes material and thickness together, so either could explain a difference; repeats would not remove that confounding.

Sound conclusion or proposed method. Relevant supporting steps or textual evidence.  
Accurate conditions, checks or qualification.

**3.3** Measure its actual cost and durability, while repeating matched final-temperature tests with the same material, length, fit, power, starting temperature and duration. The heavier sleeve's cost cannot be assumed unchanged. State acceptance limits before choosing, rather than deciding from cooling alone.

Sound conclusion or proposed method. Relevant supporting steps or textual evidence.  
Accurate conditions, checks or qualification.