4.1 Working Scientifically: Variables, Fair Tests and Planning

Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 A hypothesis is a testable scientific idea. Which of these is a hypothesis: "Which cup looks nicest?" or "Adding a lid reduces the cooling of water because less energy is transferred to the surroundings"?

(1)

2 Callum records the temperature of cooling water at regular 30 s intervals, starting at 0 s and ending at 180 s. List all the recording times and state how many readings he will take, including the first and last.

(2)

3 Yusuf uses a measuring cylinder to prepare water for a dissolving investigation. The scale from 20 ml to 30 ml is divided into five equal intervals. The bottom of the meniscus is three intervals above 20 ml. Calculate the volume of water.

(2)

4 Priya times how long a trolley takes to travel a marked distance from one fixed ramp height. She records 1.8 s once and wants to judge how consistent this result is. Describe a suitable repeat procedure and explain what the extra readings would show.

(2)

5 A class investigates how daily water volume affects seedling growth over seven days. They have similar seedlings of one species in identical pots with the same soil. Describe how to measure growth and give two further conditions to keep the same.

(3)

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6 Erin tests how water temperature affects dissolving time. At 20°C she puts 2 g of sugar into 50 ml of water; at 40°C she puts 4 g of the same sugar into 50 ml of water. She uses identical beakers and the same stirring method and sugar grain size, and times until no grains are visible. Identify the confounding variable, explain why it prevents a clear conclusion about temperature, and suggest a specific improvement.

(3)

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7 Kwame investigates whether ramp height affects trolley travel time over a marked 1 m section. He uses trolley A at 5 cm and trolley B at 15 cm. A trial on the same level track showed that trolley B has stiffer wheels and slows down more than trolley A. He releases each trolley without pushing, using the same ramp surface and timing method. Identify the confounder, explain its effect on the comparison and propose an improvement.

(3)

8 Oliwia investigates how daily water volume affects seedling growth. She gives one group 5 ml each day in a shaded cupboard and another group 15 ml each day on a bright windowsill. Each group has six similar seedlings of the same species, soil and pot size, and both locations are kept at the same temperature. She measures stem-height increase after seven days and repeats this whole arrangement three times. Explain why these repeats do not make the water comparison fair and propose an improvement.

(3)

9 A pilot test releases a ball from heights of 10 cm, 30 cm and 50 cm onto the same firm surface. Rebound heights can be read clearly throughout this range. The teacher permits release heights from 10 cm to 50 cm inclusive. Suggest five equally spaced release heights for the main investigation, describe how to release the ball consistently and explain why testing intermediate heights is useful.

(3)

10 Noah tests whether adding a lid reduces water cooling. Identical cups each contain 100 ml of water starting at 60°C. After five minutes he records the temperature decrease. Three fresh trials give: no lid, 30°C, 32°C, 34°C; lid, 20°C, 22°C, 24°C. Room temperature, cup position and timing method are kept the same. Calculate the mean temperature decrease for each condition.

(4)

11 Amelia predicts that warmer water makes a fixed mass of sugar dissolve faster. She uses 2 g of the same sugar in 50 ml of water, identical beakers and the same stirring method. Three repeats at 20°C take 84 s, 88 s and 86 s; three at 40°C take 44 s, 48 s and 46 s. Evaluate the claim: "These results prove that sugar dissolves faster at every temperature." Use the results and suggest one next investigation step.

(3)

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12 In an investigation, a pupil writes: "The seeds given water will have a higher percentage germination after five days than the seeds given no water." Name the term for this statement of an expected result.

(1)

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13 Plan an investigation to test whether increasing the number of layers of felt around a cup reduces the temperature decrease of water over five minutes. Available apparatus includes identical cups, felt sheets, elastic bands, measuring cylinders, thermometers and stopwatches. A teacher supplies warm water at 50°C; pupils must not heat water themselves. Include a testable prediction, independent and dependent variables, a workable sequence with measurements and intervals, important controls, repeats and a relevant safety precaution. Explain how your choices make the comparison fair and the results useful.

(6)

14 Priya investigates how water volume affects seedling growth. She gives identical seedlings 5 ml, 10 ml or 15 ml of water each day. After seven days she measures the increase in stem height. Identify the independent variable.

(1)

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15 Kwame rolls the same trolley down a ramp from heights of 5 cm, 10 cm and 15 cm. He measures the time taken to travel a marked 1 m section. Identify the dependent variable.

(1)

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16 Erin compares how quickly 2 g of sugar dissolves in 50 ml of water at different temperatures. She uses the same type of sugar, beaker and stirring method. Identify two variables she has kept constant.

(2)

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17 Noah needs to measure 25 ml of water and the time for a sugar sample to dissolve. Choose an appropriate measuring instrument for each measurement. Available instruments are a ruler, a measuring cylinder, a balance and a stopwatch.

(2)

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18 A class proposes this hypothesis: "Seeds need water to germinate because water is needed to start growth." They put ten seeds of the same species on damp cotton wool and ten on dry cotton wool, at the same temperature. They count germinated seeds after five days. Write a prediction and identify the variable they deliberately change.

(2)

19 Oliwia investigates how the length of a pendulum affects its swing time. She uses lengths of 20 cm, 40 cm and 60 cm and times ten complete swings at each length. She uses the same bob and releases it from the same small angle. Identify the independent variable, the dependent variable actually measured and one control variable.

(3)

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20 Amelia compares the time for 2 g of sugar to dissolve in 50 ml of water at 20°C and 40°C. She uses the same sugar grain size, beaker and stirring method. Explain why keeping the mass of sugar the same helps make this a fair test.

(2)

Mark scheme · 4.1 Working Scientifically: Variables, Fair Tests and Planning

Question 1

Selects the statement about adding a lid and cooling. **B1**

Answer: **Adding a lid reduces the cooling of water because less energy is transferred to the surroundings.**

Question 2

All seven times in the correct sequence, including 0 s and 180 s. **B1**

Seven readings, including both endpoints. **B1**

Answer: **0, 30, 60, 90, 120, 150 and 180 s; seven readings.**

Question 3

Finds the interval size using (30 - 20) / 5 = 2 ml. **M1**

26 ml, from 20 + 3 x 2, dependent on a correct method. **A1**

Answer: **26 ml.**

Question 4

Repeats under the same conditions, including the same height and measured distance. **B1**

Uses the spread or agreement of repeated times to assess consistency; allow spotting a possible anomalous result for checking. **B1**

Answer: **Repeat the timing at the same height and distance with the same trolley and release method. Compare the times to judge their spread and identify a result that may need checking.**

Question 5

Measures start and end stem heights from the same reference point and uses the increase in height. **B1**

One valid further control: light exposure, temperature or growth period. **B1**

A second distinct further control from that list; allow other justified conditions affecting growth except daily water volume. **B1**

Answer: **Measure each stem height at the start and after seven days and find the increase. Keep light exposure and temperature the same.**

Question 6

Sugar mass changes from 2 g to 4 g alongside temperature. **B1**

Sugar mass can also affect dissolving time, so its effect cannot be separated from temperature here. **B1**

Uses the same sugar mass at both temperatures, e.g. 2 g in each; allow 4 g in each. Repeats alone do not remove this confounder. **B1**

Answer: **Sugar mass is a confounder. Both mass and temperature change, so dissolving-time differences cannot be attributed to temperature alone. Use 2 g of sugar at both temperatures.**

Question 7

Different trolley or wheel resistance is confounded with ramp height. **B1**

Wheel resistance affects travel time, so the time difference cannot be assigned to height alone. **B1**

Uses the same trolley at both heights; allow testing both trolleys at every height and comparing each trolley with itself. Repeats of the original pair alone do not fix it. **B1**

Answer: **Trolley identity, with different wheel resistance, changes with height. Wheel resistance can also change travel time, so height is not the only explanation. Use the same trolley at both heights.**

Question 8

Light exposure differs between water groups and can affect growth. **B1**

Repeating the same arrangement retains the light difference and cannot separate its effect from water volume. **B1**

Places both groups under equal light, e.g. next to each other under the same lamp with positions rotated. Accept a design testing each water volume under each light condition. **B1**

Answer: **Light exposure changes with water volume and can affect growth, so either could explain a growth difference. Repeating the same arrangement retains that confounder. Give both water-volume groups the same light exposure.**

Question 9

10, 20, 30, 40 and 50 cm, equally spaced across the permitted range. **B1**

Uses a consistent release without pushing, measuring height from the same point on the ball each time. **B1**

Intermediate heights give more detail about the relationship or reveal changes in the pattern. **B1**

Answer: **10, 20, 30, 40 and 50 cm. Release the same ball without pushing from a consistent reference point. Intermediate heights show whether the pattern continues between the pilot values.**

Question 10

Adds 30 + 32 + 34 and divides by 3. **M1**

32°C for no lid, dependent on the first method. **A1**

Adds 20 + 22 + 24 and divides by 3. **M1**

22°C for lid, dependent on the second method. **A1**

Answer: **No lid: 32°C; lid: 22°C.**

Question 11

Uses the shorter times at 40°C as evidence supporting faster dissolving for the tested conditions. **B1**

Rejects proof at every temperature because only 20°C and 40°C were tested; allow recognition that evidence supports rather than proves a universal claim. **B1**

Tests additional temperatures with the other conditions controlled and repeated measurements. **B1**

Answer: **All three times at 40°C are shorter than those at 20°C, supporting the prediction for these conditions. Two temperatures cannot establish a pattern at every temperature. Test additional water temperatures with the same controls and repeats.**

Question 12

Prediction; allow a testable prediction. **B1**

Answer: **Prediction.**

Question 13

Level 1 Gives isolated relevant planning points, such as a variable or apparatus, but the method has major gaps. Award 0 if nothing is creditworthy. **1-2**

Level 2 Describes a partly workable comparison of felt layers and temperature decrease, with measurements and some controls. Includes some detail about repeats or safety, with limited explanation of how the choices help. **3-4**

Level 3 Gives a coherent, workable plan with a testable prediction, correct variables, a range of layers, timed temperature measurements, relevant controls, repeats and safety. Explains how controls isolate the effect of layers and repeats help assess consistency. Use the upper mark for a complete, clearly linked plan. **5-6**

Indicative content:

- Predict that more felt layers will give a smaller temperature decrease over five minutes, because the insulation reduces energy transfer to the surroundings. Accept a different testable prediction if scientifically reasoned.
- Change only the number of felt layers, e.g. 0, 1, 2 and 3. Measure temperature decrease over five minutes as the dependent variable.
- Use the same cup or identical cups; use a measuring cylinder to put 100 ml of water into each cup and a thermometer to check each starts at 50°C.
- Wrap equal-sized felt sheets around the same area of each cup and secure them with elastic bands. Leave the top equally open for every condition.
- Start the stopwatch at the initial reading. Record temperature at 0, 1, 2, 3, 4 and 5 minutes, keeping the thermometer bulb in the water at the same depth without touching the cup. Accept initial and final readings alone if the five-minute interval is clear.
- Subtract the five-minute reading from the initial reading to find the temperature decrease. Compare decreases for different layer numbers.
- Keep water volume, starting temperature, cup type, room conditions, exposed area and cooling duration constant, so they do not provide alternative explanations for a difference.
- Repeat each layer condition with fresh water at the same starting temperature, ideally three times; compare the spread and calculate a mean decrease. Check an unusual result rather than automatically removing it.
- Keep cups stable on a tray away from the bench edge, handle warm water carefully and report spills promptly. The teacher supplies the warm water; do not heat it.

Question 14

Volume of water given each day; allow daily water volume. **B1**

Answer: **Volume of water given each day, in ml.**

Question 15

Time to travel the marked section; do not accept ramp height or distance travelled. **B1**

Answer: **Time taken to travel the marked 1 m section, in seconds.**

Question 16

One valid control: sugar mass, water volume, sugar type, beaker or stirring method. **B1**

A second distinct valid control from that list; allow sugar grain size if explained as the same type of sugar. **B1**

Answer: **Mass of sugar and volume of water.**

Question 17

Measuring cylinder for the volume. **B1**

Stopwatch for the time. **B1**

Answer: **Measuring cylinder for water volume; stopwatch for dissolving time.**

Question 18

Predicts more germinated seeds in the damp condition; allow none in dry and some in damp. **B1**

Water availability or damp versus dry cotton wool. **B1**

Answer: **More seeds will germinate on damp cotton wool than on dry cotton wool; water availability is changed.**

Question 19

Independent variable is pendulum length. **B1**

Dependent variable is the time for ten swings; allow swing time if clearly linked to ten swings. **B1**

Same bob or same release angle; allow same number of swings timed. **B1**

Answer: **Independent: pendulum length. Dependent: time for ten complete swings. Control: bob or release angle.**

Question 20

Changing sugar mass could change dissolving time. **B1**

Keeping mass constant allows the effect of temperature to be compared without that alternative explanation. **B1**

Answer: **Sugar mass can also affect dissolving time. Keeping it constant makes the comparison about water temperature.**