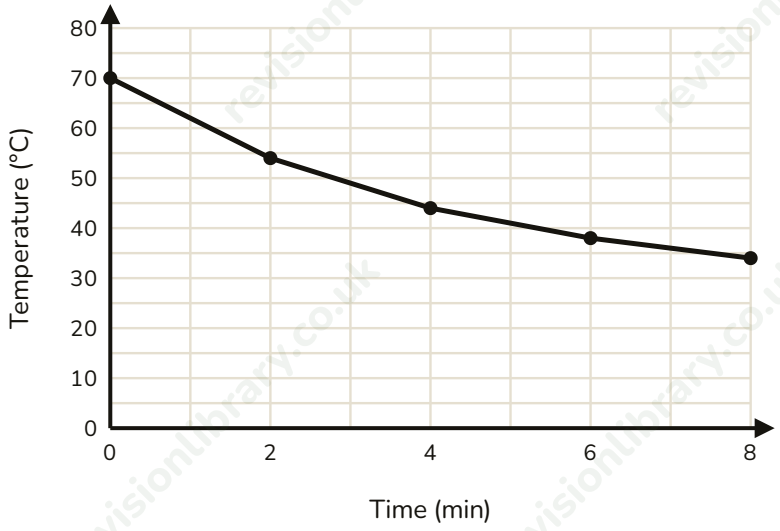
4.2 Working Scientifically: Data, Graphs and Evaluation

Calculator allowed · about 60 minutes

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 The graph shows another display of the same cooling results. Describe how the temperature changes and use the first and last two-minute intervals to decide whether cooling is getting faster or slower.



(3)

2 A ball is dropped from the same height four times. Bounce heights are 42 cm, 43 cm, 69 cm and 41 cm. Identify a possible anomaly, calculate the mean of ALL four results to one decimal place, and explain how to investigate the unusual result before deciding what to report.

(5)

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3 A balance is checked with known masses. It then shows 82 g for a sample. Identify the error pattern, estimate the corrected sample mass and explain whether simply repeating the weighing fixes the problem.

Known mass (g)	Balance reading (g)
50	52
100	102
150	152

(3)

4 Two groups each roll a toy car down the same ramp three times, using their own unchanged method and equipment. Calculate the mean and range for each group. Which set is more repeatable? Can these data alone show which group is more accurate?

Group	Run 1 (cm)	Run 2 (cm)	Run 3 (cm)
A	51	50	52
B	47	55	51

(5)

5 A pupil tests whether light affects seedling growth. One seedling is near a window and receives 10 ml of water daily. Another is in a cupboard and receives 30 ml daily. The cupboard seedling grows taller. Explain why this does not isolate the effect of light and suggest two improvements, explaining their purposes.

(3)

6 Five ponds with different depths are measured once on the same afternoon. Shade cover and water temperature are recorded. Describe the association with numerical evidence and explain why these results alone do not prove that shade caused the temperature differences.

Shade cover (%)	Water temperature (°C)
0	24
20	23
40	21
60	20
80	18

(3)

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7 A light sensor records readings at three distances from a lamp. A pupil proposes a line graph with distance labels 10, 20 and 40 equally spaced on the horizontal axis. Explain the scale error, state how far apart the last two labels should be compared with the first two, and use the data to test the claim "sensor reading is directly proportional to distance".

Distance (cm)	Sensor reading (units)
10	40
20	20
40	10

(4)

8 A ruler has millimetre divisions. A leaf tip lines up exactly with the 12.4 cm mark when its base is at zero. Choose the best record: 12 cm, 12.4 cm or 12.400 cm. Explain your choice.

(2)

9 Identical cups with equal volumes of water start at the same displayed temperature of 60 °C. Each covering is tested three times with the same thermometer and method. The table shows displayed temperatures after 10 min. A reference check finds that this thermometer reads 22 °C in water known to be at 20 °C. Evaluate the claim "Felt is always the best covering, and taking more repeats will make the results accurate". Use calculated means and observed spans (lowest to highest), discuss the strength of the evidence, explain both random uncertainty and systematic error, and propose justified improvements.

Covering	Trial 1 (°C)	Trial 2 (°C)	Trial 3 (°C)
None	30	32	31
Paper	37	39	38
Felt	38	40	39

(6)

10 Three seedlings have heights 14 mm, 17 mm and 17 mm. Calculate their mean height.

(2)

11 Four repeated cooling times are 42 s, 45 s, 43 s and 46 s. State the lowest and highest values, then calculate the range (highest minus lowest).

(2)

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12 Equal masses of sugar dissolve in equal volumes of water. Only water temperature is changed. Times are recorded to the nearest second. Calculate the mean time at each temperature and report each to the nearest second.

Temperature (°C)	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)
20	64	66	65
40	43	41	42
60	29	31	30

(4)

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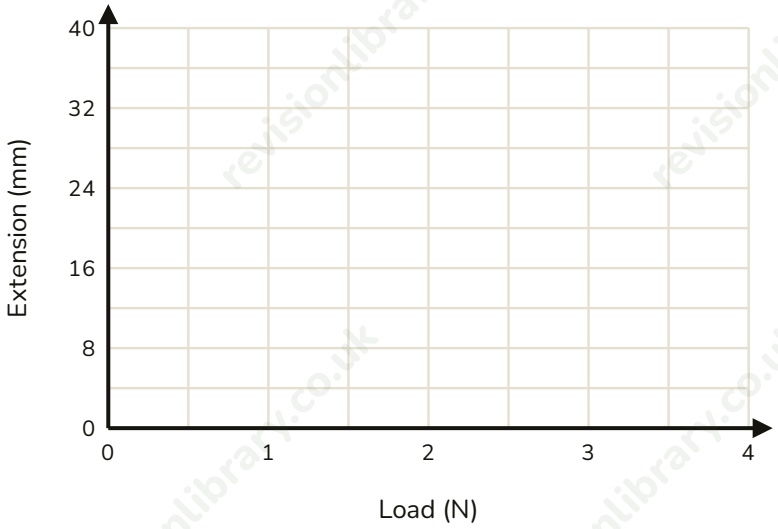
13 A cup cools. Choose a suitable graph type to show temperature changing with time, give the axis labels and suggest regular scales covering all values.

Time (min)	Temperature (°C)
0	70
2	54
4	44
6	38
8	34

(3)

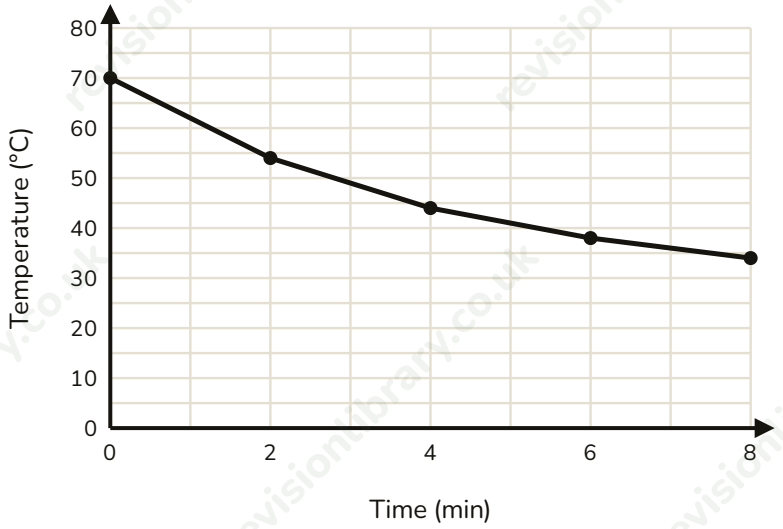
14 A spring is tested with small loads. Plot all five points on the supplied grid. Draw a straight line through the points. Use crosses for points.

Load (N)	Extension (mm)
0	0
1	8
2	16
3	24
4	32



(4)

15 The graph shows a cup cooling. Read its temperature at 4 min. Calculate the temperature fall from 0 to 8 min.



(3)

Mark scheme · 4.2 Working Scientifically: Data, Graphs and Evaluation

Question 1

Temperature decreases throughout the measured time.	B1
First fall = 70 - 54 = 16 °C; last fall = 38 - 34 = 4 °C.	A1
Smaller fall in the same time shows slower cooling later.	B1

Answer: **Temperature falls, with slower cooling later. It falls 16 °C from 0 to 2 min but only 4 °C from 6 to 8 min.**

Question 2

Identifies 69 cm as a possible anomaly because the other readings cluster at 41 to 43 cm.	B1
(42 + 43 + 69 + 41) / 4 = 195/4.	M1
48.8 cm to one decimal place (48.75 unrounded).	A1
Checks records/method or repeats under the same conditions to investigate.	B1
Keeps original data and requires a justified, recorded reason for any exclusion; does not delete simply for disagreeing with the trend.	B1

Answer: **69 cm is a possible anomaly. All-results mean = 48.8 cm. Keep the original record, check for recording or method problems, and repeat under the same conditions. Exclude a result only with a justified reason, documented alongside the result; being inconvenient is not a reason.**

Question 3

Systematic offset of +2 g in every check.	B1
Corrected estimate 80 g.	A1
Repeats do not remove the offset; zero/check/calibrate and remeasure.	B1

Answer: **Each reading is 2 g too high, consistent with a systematic offset. Corrected sample mass = 82 - 2 = 80 g. Repeats do not remove this bias; check/zero or calibrate the balance and remeasure.**

Question 4

Uses sum/3 for means and maximum minus minimum for ranges.	M1
Both means 51 cm.	A1
A range 2 cm and B range 8 cm.	A1
A is more repeatable: smaller spread using its own unchanged method.	B1
Cannot judge accuracy without a reference value.	B1

Answer: **Both means are 51 cm. A range = 2 cm; B range = 8 cm. A is more repeatable because its results are closer together. Accuracy cannot be judged without a trustworthy reference value.**

Question 5

Water and light both changed, so water is a confounding variable.	B1
Keep daily water equal to isolate the effect of light.	B1
Use several similar seedlings in each condition and compare means to reduce the influence of individual variation; accept another explained improvement such as matching temperature.	B1

Answer: **Both light and water changed, so the growth difference cannot be attributed to light alone. Give equal water to control that variable. Use several similar seedlings in each light condition and compare means to reduce the influence of individual variation.**

Question 6

Negative association: more shade, lower temperature.	B1
Correct numerical evidence, e.g. 24 °C at 0% and 18 °C at 80%.	B1
Depth differs and may affect temperature; no controlled test isolates shade.	B1

Answer: **Greater shade cover is associated with lower temperature: 24 °C at 0% and 18 °C at 80%. The ponds also differ in depth, which could affect temperature, so this observational association alone does not prove causation.**

Question 7

Equal spacing for unequal numerical intervals is incorrect; needs a uniform scale.	B1
20 to 40 cm gap should be twice the 10 to 20 cm gap.	B1
Doubling distance 10 to 20 cm changes reading 40 to 20 units (or 20 to 40 cm gives 20 to 10 units).	B1
Reading halves rather than doubles, so it is not directly proportional to distance.	B1

Answer: **The axis must use a uniform numerical scale. The 20 to 40 cm gap must be twice the 10 to 20 cm gap. Direct proportionality is contradicted: doubling distance from 10 to 20 cm halves the reading from 40 to 20 units, rather than doubling it.**

Question 8

Selects 12.4 cm.	B1
Links 0.1 cm to the millimetre divisions; 12 cm loses detail and 12.400 cm implies unsupported precision.	B1

Answer: **12.4 cm. A millimetre is 0.1 cm, so one decimal place in cm matches the ruler divisions; extra zeroes imply unsupported precision.**

Question 9

Level 0 No relevant content.	**0**
Level 1 Gives isolated relevant statements about coverings, repeats or thermometer error, with little correct use of data or justification.	**1-2**
Level 2 Uses some correct means or spans to compare coverings and explains a limitation or improvement. Links some evidence to the claim, but treatment of uncertainty or systematic error is incomplete.	**3-4**
Level 3 Develops a coherent evaluation using correct means and overlapping spans, limits the claim to these conditions, distinguishes reduced random uncertainty from persistent systematic error, and links practical improvements to identified limitations. Award 6 for a thorough, well-supported response; 5 for a mostly complete response.	**5-6**

Indicative content:

- Mean displayed temperatures: none (30 + 32 + 31)/3 = 31 °C; paper (37 + 39 + 38)/3 = 38 °C; felt (38 + 40 + 39)/3 = 39 °C.
- Observed spans: none 30 to 32 °C; paper 37 to 39 °C; felt 38 to 40 °C.
- Felt has the highest mean final temperature, so it retained warmth best on average in these tests; paper and felt spans overlap from 38 to 39 °C.
- The felt-paper mean difference is only 1 °C and the evidence is limited to three trials per covering and these conditions, so always is too strong. Overlap alone does not prove equal performance.
- More repeats and means reduce random uncertainty; they do not remove systematic error.
- The reference check suggests a +2 °C systematic offset. Check/calibrate or replace the thermometer against references across the working range and repeat; a single check does not establish its behaviour at every temperature.
- If a constant +2 °C offset applies to all readings, subtracting 2 gives corrected mean estimates 29, 36 and 37 °C; the felt-paper difference remains 1 °C. The offset does not by itself explain that difference.
- Use more trials per covering to assess spread and the small difference. Keep starting temperature, volume, cup size, covering thickness and room conditions matched so other changes do not explain the comparison. Do not remove an inconvenient reading without investigation and a documented reason.

Question 10

Adds 14 + 17 + 17 and divides by 3.	**M1**
16 mm.	**A1**

Answer: **16 mm.**

Question 11

Lowest 42 s and highest 46 s.	**B1**
Range = 46 - 42 = 4 s.	**A1**

Answer: **Lowest 42 s; highest 46 s; range 4 s.**

Question 12

Uses sum of three trial times divided by 3.	**M1**
At 20 °C: 65 s.	**A1**
At 40 °C: 42 s.	**A1**
At 60 °C: 30 s; all means reported to whole seconds.	**A1**

Answer: **20 °C: 65 s; 40 °C: 42 s; 60 °C: 30 s.**

Question 13

Line graph, or scatter graph with a suitable trend line, for two continuous variables.	**B1**
Time (min) horizontal and Temperature (°C) vertical.	**B1**
Regular numerical scales covering all data; accepts other sensible scales.	**B1**

Answer: **A line graph: Time (min) horizontally, Temperature (°C) vertically. For example, x from 0 to 8 in steps of 2 min; y from 0 to 80 in steps of 10 °C.**

Question 14

Plots (0, 0) and (1, 8) correctly.	**B1**
Plots (2, 16) and (3, 24) correctly.	**B1**
Plots (4, 32) correctly.	**B1**
Draws the straight line through the plotted points; allow plotting within half a small grid division.	**B1**

Answer: **Points (0, 0), (1, 8), (2, 16), (3, 24), (4, 32), joined by a straight line from (0, 0) to (4, 32).**

Question 15

44 °C; allow 43 to 45 °C when reading.	**B1**
Subtracts final temperature from initial: 70 - 34.	**M1**
36 °C fall.	**A1**

Answer: **44 °C at 4 min; fall = 70 - 34 = 36 °C.**