

Unfamiliar data and practical evaluation

35–40 minutes independent practice + 15–20 minutes review | 36 marks

AQA AS Physics 7407 • First-year A Level 7408

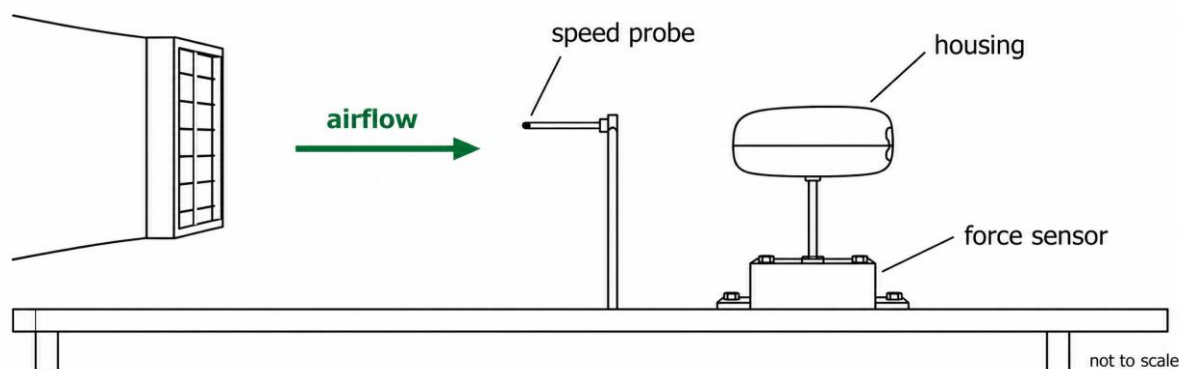
Skills practised and AQA references

AQA AS 7407 / first-year A Level 7408: 3.1.1 — units; 3.1.2 — random/systematic error, repeatability, measurement uncertainties and gradient/intercept uncertainty.

Skills: MS 1.1, 1.2 and 1.5 — significant figures, means and combined uncertainties; MS 3.1–3.4 — data, graphs, linear relationships, gradients and intercepts. Supporting context: 3.4.1.4 — drag.

Testing a housing in a wind tunnel

A team tests a protective housing for a remote environmental sensor in a wind tunnel. A force sensor measures horizontal drag and a probe measures air speed. The team must test a proposed relationship, improve the method and decide whether a redesigned housing meets a force limit.



Use $S = F + b$, where F is drag and b is a constant zero offset. Test the supplied model $F = Cv^2$, hence $S = Cv^2 + b$. Neglect mounting-rod drag. Use worst-case uncertainty rules.

1. Check the measurements [4 marks]

With the fan off, there is no horizontal drag but the force sensor consistently reads +0.040 N.

(a) Classify this zero offset as a random or systematic error. State how the team should correct a force reading before treating it as drag. [2 marks]

(b) At one fixed air speed the repeated raw readings are 0.390 N, 0.400 N and 0.410 N. Calculate the mean and estimate its absolute uncertainty using half the range. [2 marks]

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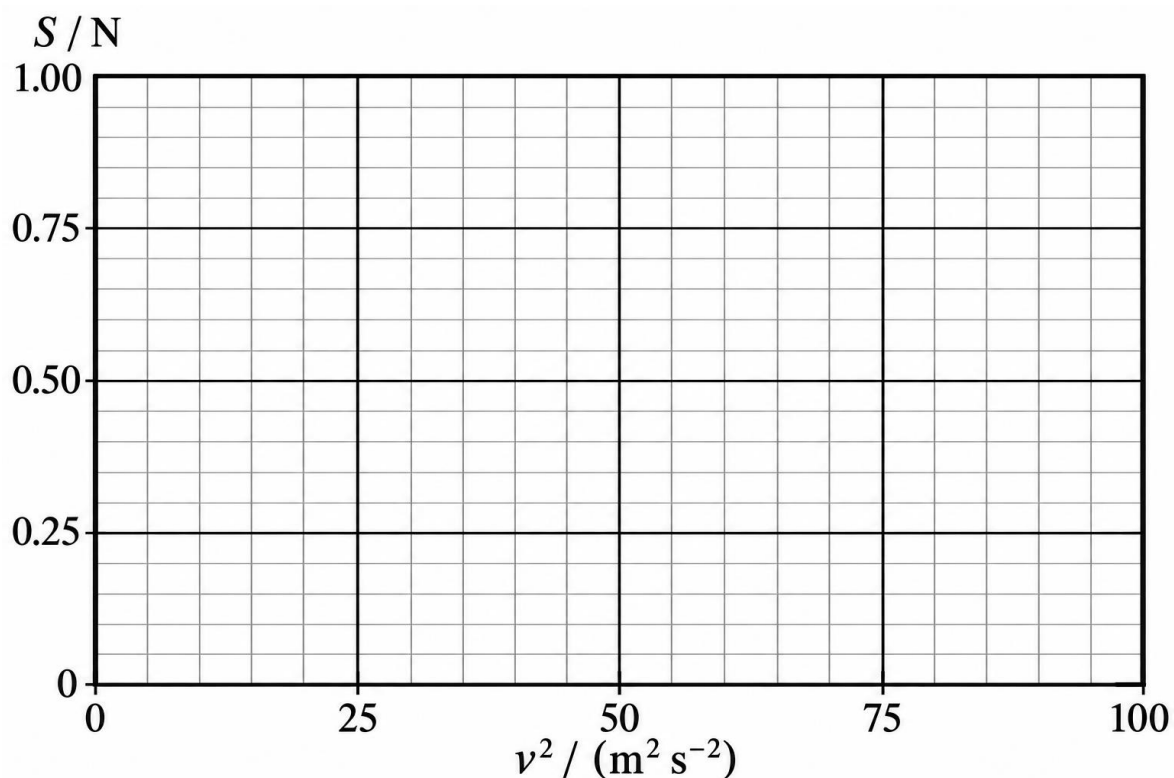
2. Test the proposed drag model [8 marks]

The table gives mean raw sensor readings. Do not subtract the zero offset for this graph: plot S against v^2 so that the intercept can be examined. The 8.00 m s^{-1} mean is investigated further in Question 4.

Speed $v / \text{m s}^{-1}$	$v^2 / \text{m}^2 \text{s}^{-2}$	Mean reading S / N
0.00	0	0.040
2.00	4.00	0.080
4.00		0.200
6.00	36.0	0.400
8.00		0.670
9.00	81.0	0.850

(a) Complete the two missing values of v^2 in the table. [1 mark]

(b) Plot all six points of S against v^2 on the grid. Draw one straight line of best fit rather than joining successive points. [3 marks]



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Question 2 continued

(c) Use a large triangle on your line to determine C , including its unit. Show the coordinates used. [2 marks]

(d) Is the raw reading S directly proportional to v^2 ? Explain what the graph suggests about the proposed relationship $F = Cv^2$ after zero correction. [2 marks]

3. Propagate the uncertainties [6 marks]

At $v = (6.00 \pm 0.10) \text{ m s}^{-1}$, use $S = (0.400 \pm 0.010) \text{ N}$ and $b = (0.040 \pm 0.005) \text{ N}$. Treat the quoted uncertainties as separate contributions and use worst-case addition.

(a) Calculate the zero-corrected drag and its absolute uncertainty. [2 marks]

(b) Use $C = F/v^2$ to calculate the worst-case percentage uncertainty in this single-point estimate of C . [2 marks]

(c) A separate analysis of the full graph, including force and speed uncertainties, gives limiting gradients 0.0096 and $0.0104 \text{ N s}^2 \text{ m}^{-2}$. Use their midpoint and half their range to report C with its absolute uncertainty. Is it consistent with a reference value $0.00980 \text{ N s}^2 \text{ m}^{-2}$? [2 marks]

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4. Evaluate suspect data and drift [6 marks]

At $v = 8.00 \text{ m s}^{-1}$ the recorded raw readings are 0.660 N, 0.670 N, 0.680 N and 0.940 N. The log states that the stand was knocked during the fourth run.

(a) Decide whether there is evidence to exclude a reading. Justify your decision and calculate a suitable mean for this speed. [2 marks]

(b) The mean 0.670 N is slightly below the fitted model prediction, about 0.680 N. Does this difference alone justify deleting the mean from the graph? Explain. [1 mark]

(c) The sensor zero slowly increases as it warms. All speeds are tested in increasing order. Explain how this could bias C and give one specific way to reduce or correct the effect. [2 marks]

(d) A technician uses the fitted relationship to certify performance at 12.0 m s^{-1} without further measurements. Explain why the current evidence is insufficient. [1 mark]



5. Judge a redesigned housing [5 marks]

Use $C_A = 0.0100 \text{ N s}^2 \text{ m}^{-2}$ for the original housing. For redesigned housing B, $C_B = (0.0072 \pm 0.0004) \text{ N s}^2 \text{ m}^{-2}$. Both coefficients refer to otherwise comparable tests. Treat $v = 8.00 \text{ m s}^{-1}$ as exact for this comparison; the stated coefficient uncertainty already includes the measurement contributions.

(a) Calculate the central drag estimates for A and B at this speed. Determine the percentage reduction in drag relative to A. [3 marks]

(b) The design is accepted only if the highest drag allowed by the quoted uncertainty is no greater than 0.480 N. Calculate the upper drag estimate for B and decide whether acceptance can be confirmed. [2 marks]



6. Plan a stronger investigation [7 marks]

Parts (a)–(c) scaffold a six-mark-style method. The adjustable fan, force sensor, speed probe and a calibrated force gauge are available. Explain how to obtain trustworthy evidence for the proposed drag relationship, not just how to collect more numbers.

(a) Describe the zero and calibration checks you would make on the horizontal force sensor. [2 marks]

(b) Describe the measurements, repeats and controlled conditions needed when changing air speed. [2 marks]

(c) Describe the graph and uncertainty analysis, and how you would use the evidence to make a design decision. [2 marks]

(d) State one specific precaution when adjusting the fan or changing a housing. [1 mark]

