

# IB Physics – Data-Based Questions (Paper 1B)

IB Physics SL/HL (2023 syllabus) · Total marks: 52 · Answers on the last page

This worksheet gives practice with unfamiliar experiments, uncertainty propagation and graph analysis, in the style of IB Physics Paper 1B / data-based questions. A calculator and graph paper (or graphing software) are recommended; allow about 45 minutes.

## Section A – Uncertainties (skills) (Calculator allowed)

1. A student measures the length of a wire as  $L = (25.0 \pm 0.1)$  cm.  
Calculate the percentage uncertainty in  $L$ . [2]
2. Two lengths are measured as  $l_1 = (12.4 \pm 0.2)$  cm and  $l_2 = (8.6 \pm 0.1)$  cm.  
(a) Calculate the sum  $l_1 + l_2$  with its absolute uncertainty.  
(b) State the rule used for combining uncertainties in a sum. [3]
3. A wire has diameter  $d = (0.32 \pm 0.01)$  mm and length  $L = (0.500 \pm 0.001)$  m. Its resistance is measured as  $R = (1.35 \pm 0.05) \Omega$ .  
(a) Calculate the cross-sectional area  $A$  of the wire.  
(b) Calculate the resistivity  $\rho = \frac{RA}{L}$  of the wire.  
(c) Determine the percentage uncertainty, and hence the absolute uncertainty, in  $\rho$ . [6]
4. A student uses a digital vernier caliper with a resolution of 0.01 mm to take a single measurement of a rod's diameter.  
State the absolute uncertainty that should be recorded, and explain why. [2]

## Section B – Graph analysis (exam-style) (Calculator allowed)

5. A student times 10 oscillations of a simple pendulum of length  $L = (0.850 \pm 0.002)$  m and finds the period  $T = (1.851 \pm 0.006)$  s.  
(a) Use  $g = \frac{4\pi^2 L}{T^2}$  to calculate a value for  $g$ .  
(b) Calculate the percentage uncertainty in  $g$ .  
(c) State the absolute uncertainty in  $g$ , and hence give  $g$  with its uncertainty to an appropriate number of significant figures. [6]
6. Gamma radiation passes through absorbers of thickness  $x$  and the intensity  $I$  is recorded:  
 $x/\text{cm}$ : 0, 2, 4, 6, 8, 10  
 $I/\text{counts s}^{-1}$ : 820, 610, 450, 335, 250, 185  
The intensity follows  $I = I_0 e^{-\mu x}$ .  
(a) Explain why plotting  $\ln I$  against  $x$  should give a straight line, and state the significance of the gradient and the  $y$ -intercept.  
(b) Given that the gradient of the best-fit line of  $\ln I$  against  $x$  is  $-0.149 \text{ cm}^{-1}$  and the  $y$ -intercept is 6.71, find the attenuation coefficient  $\mu$  and the value of  $I_0$ .  
(c) Calculate the half-value thickness of the absorber. [8]
7. In a timing experiment a student measures the period of a single oscillation using a hand-held stopwatch.  
Suggest one change to the method that would reduce the random uncertainty in the period, and explain why it works. [2]

8. A student measuring the resistivity of a wire notices that every resistance reading is  $0.3\,\Omega$  higher than expected because the ammeter was not zeroed before use.
- (a) State whether this is a random or a systematic error.
  - (b) Explain the effect this error has on the calculated resistivity, and how the error could be removed.
- [3]

**Section C – Extended investigation (challenge)** (Calculator allowed)

9. Small steel spheres of radius  $r$  fall at terminal velocity  $v$  through a viscous liquid. Data collected:
- $r/\text{mm}$ : 0.5, 1.0, 1.5, 2.0  
 $v/\text{cm s}^{-1}$ : 2.1, 8.3, 18.9, 33.5
- (a) Show that these data are consistent with  $v \propto r^2$ .
  - (b) The relationship is  $v = \frac{2r^2(\rho_s - \rho_f)g}{9\eta}$ , where  $\rho_s = 2500\,\text{kg m}^{-3}$  and  $\rho_f = 960\,\text{kg m}^{-3}$ . A graph of  $v$  against  $r^2$  has gradient  $8.4 \times 10^4\,\text{s}^{-1}\,\text{m}^{-1}$  (SI units). Calculate the viscosity  $\eta$  of the liquid.
- [8]
10. In the pendulum experiment of Question 5, the accepted value of  $g$  at the location is  $9.81\,\text{m s}^{-2}$ .
- (a) Calculate the percentage difference between the experimental value and the accepted value.
  - (b) State, with a reason, whether the experimental value is consistent with the accepted value.
- [3]
11. A student investigates how the period  $T$  of a pendulum depends on its length  $L$ , believing  $T = kL^n$ .
- $L/\text{m}$ : 0.20, 0.40, 0.60, 0.80, 1.00  
 $T/\text{s}$ : 0.90, 1.27, 1.55, 1.79, 2.01
- (a) Explain how plotting  $\log T$  against  $\log L$  allows  $n$  and  $k$  to be determined.
  - (b) The best-fit line through  $\log T$  vs  $\log L$  has gradient 0.498 and  $y$ -intercept 0.302. Determine  $n$  and  $k$ , giving each to an appropriate number of significant figures.
  - (c) State the physical significance of the value of  $n$  found.
- [6]
12. For the gamma-ray absorption experiment in Question 6, suggest one improvement to the experimental method that would reduce the uncertainty in the measured count rate, and justify your answer.
- [3]

## Answers

Check your working against these. If an answer does not match, try the question again before looking for the method.

- $\frac{0.1}{25.0} \times 100\% = 0.4\%$
- (a)  $l_1 + l_2 = (21.0 \pm 0.3) \text{ cm}$   
(b) For a sum or difference, absolute uncertainties are added:  $\Delta(l_1 + l_2) = \Delta l_1 + \Delta l_2$ .
- (a)  $A = \pi(d/2)^2 = 8.04 \times 10^{-8} \text{ m}^2$   
(b)  $\rho = 2.17 \times 10^{-7} \Omega \text{ m}$   
(c)  $\frac{\Delta \rho}{\rho} = \frac{\Delta R}{R} + 2\frac{\Delta d}{d} + \frac{\Delta L}{L} = 3.70\% + 6.25\% + 0.20\% = 10.2\%$ , so  $\Delta \rho \approx 2.2 \times 10^{-8} \Omega \text{ m}$ ;  $\rho = (2.17 \pm 0.22) \times 10^{-7} \Omega \text{ m}$
- $\pm 0.01 \text{ mm}$  (i.e.  $\pm$  half of the smallest scale division, or the instrument's stated resolution) – for a single reading this is the smallest interval the instrument can distinguish.
- (a)  $g = 9.79 \text{ m s}^{-2}$   
(b)  $\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta T}{T} = 0.24\% + 0.65\% = 0.88\%$   
(c)  $\Delta g \approx 0.09 \text{ m s}^{-2}$ , so  $g = (9.79 \pm 0.09) \text{ m s}^{-2}$
- (a) Taking logs:  $\ln I = \ln I_0 - \mu x$ , which has the form  $y = mx + c$  with  $y = \ln I$ ,  $x = x$ , gradient  $m = -\mu$  and intercept  $c = \ln I_0$ .  
(b)  $\mu = 0.149 \text{ cm}^{-1}$ ;  $I_0 = e^{6.71} = 820 \text{ counts s}^{-1}$   
(c)  $x_{1/2} = \frac{\ln 2}{\mu} = 4.66 \text{ cm}$
- Time a large number of oscillations (e.g. 20) and divide the total time by that number: the fixed reaction-time uncertainty in starting/stopping the stopwatch is then divided by the number of oscillations, reducing the uncertainty in a single period.
- (a) Systematic error.  
(b) It shifts every resistance value up by the same fixed amount, so the calculated resistivity is too high by a constant fraction; it does not increase the scatter/uncertainty. It can be removed by zeroing (checking for zero error on) the ammeter before taking readings, or by subtracting the known offset from every reading.
- (a)  $v/r^2$  is constant (8.4, 8.3, 8.4, 8.4  $\text{cm s}^{-1} \text{ mm}^{-2}$  to 2 s.f.), confirming  $v \propto r^2$ .  
(b)  $\eta = \frac{2(\rho_s - \rho_f)g}{9 \times (\text{gradient})} = 4.0 \times 10^{-2} \text{ Pa s}$
- (a)  $\frac{|9.79 - 9.81|}{9.81} \times 100\% = 0.2\%$   
(b) Yes – the percentage difference (0.2%) is smaller than the percentage uncertainty in the experimental value (0.9%), so the accepted value lies within the experimental uncertainty range  $(9.79 \pm 0.09) \text{ m s}^{-2}$ .
- (a) Taking logs of  $T = kL^n$  gives  $\log T = n \log L + \log k$ , of the form  $y = mx + c$ : the gradient equals the power  $n$  and the intercept equals  $\log k$ , so both can be read from a straight-line graph.  
(b)  $n = 0.498 \approx 0.50$ ;  $k = 10^{0.302} = 2.00$   
(c)  $n \approx \frac{1}{2}$  confirms  $T \propto \sqrt{L}$ , consistent with  $T = 2\pi\sqrt{L/g}$ .
- Take counts over a longer time interval (or repeat and average several counts) at each thickness, and subtract the background count rate measured with no absorber present: radioactive decay

is random, so longer counting times and background subtraction reduce the statistical (Poisson) uncertainty and remove a systematic offset from background radiation.

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