IB Physics Data Based Question Skills; SL & HL

By timthedev07, M25 Cohort

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1 Introduction

This document is dedicated to walking through the set of past paper/RevisionVillage questions that cover the skills you will need for the data-based questions in the MCQ or Paper 1B.

There will be no knowledge notes, instead it's purely focused on the questions. If this is what you are looking for, go up one directory and you will find a pdf from the Oxford Study Guide that has everything.

When going through the specimen questions, it's a good idea to bear in mind that these are easier than what you should expect in your final exam.

2 Specimen Paper 1B

2.1 Question 1

[Maximum mark: 12]

A group of students investigate the motion of a conducting ball suspended from a long string. The ball is between two vertical metal plates that have an electric potential difference V between them. The ball is touched to one plate so that it becomes electrically charged and is repelled from the plate. For a given potential difference, the ball bounces between the plates with a constant period.

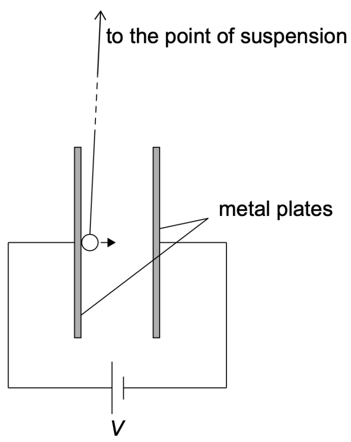

Figure 1: A diagram of the experiment.

(a) The students vary V and measure the time T for the ball to move **once** from one plate to the other. The table shows some of the data.

V / kV	*T* / s $\pm$ 0.1s
3.00	1.4
5.00	0.8
7.00	0.6

(a) V is provided by two identical power supplies connected in series. The potential difference of each of the power supplies is known with an uncertainty of 0.01 kV. State the uncertainty in the potential difference V. [1]

- Essentially, the p.d. we are talking about here is the total p.d. across the two power supplies. If each has a p.d. uncertainty of 0.01 kV, then the total p.d. uncertainty is 0.02 kV.

(b) T is measured with an electronic stopwatch that measures to the nearest 0.1 s. Describe how an uncertainty in T of less than 0.1 s can be achieved using this stopwatch. [2]

- The key idea here is that we can think of

$$T = \frac{\text{total time for } n \text{ bounces}}{n}$$

- The uncertainty here is then

$$\Delta T = \frac{\Delta(\Sigma t)}{n}$$

- So the more bounces we measure, the smaller the uncertainty in T.
- In conclusion: by measuring the time for many bounces and dividing the result by the number of bounces.

The graph shows the variation of T with V. The uncertainty in V is not plotted.

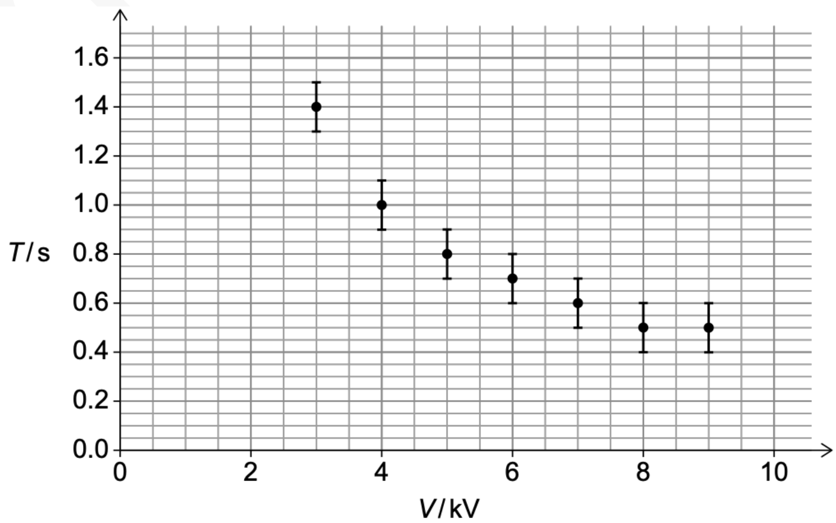

Figure 2: The graph of T against V.

(c) Outline why it is unlikely that the relationship between T and V is linear. [1]

- There is not a line of best fit that passes through all error bars.

(d) Calculate the largest fractional uncertainty in T for these data. [2]

- Recall that the fractional uncertainty is given by

$$\frac{\Delta T}{T}$$

- So, to pick the point that has the largest fractional uncertainty given that they all have the same absolute uncertainty ΔT, we must use the point that has the smallest value of T.

$$\frac{\Delta T}{T} = \frac{0.1}{0.5} = 0.2$$

(b) The students suggest the following theoretical relationship between T and V:

$$T = \frac{A}{V}$$

where A is a constant.

To verify the relationship, the variation of T with $\frac{1}{V}$ is plotted.

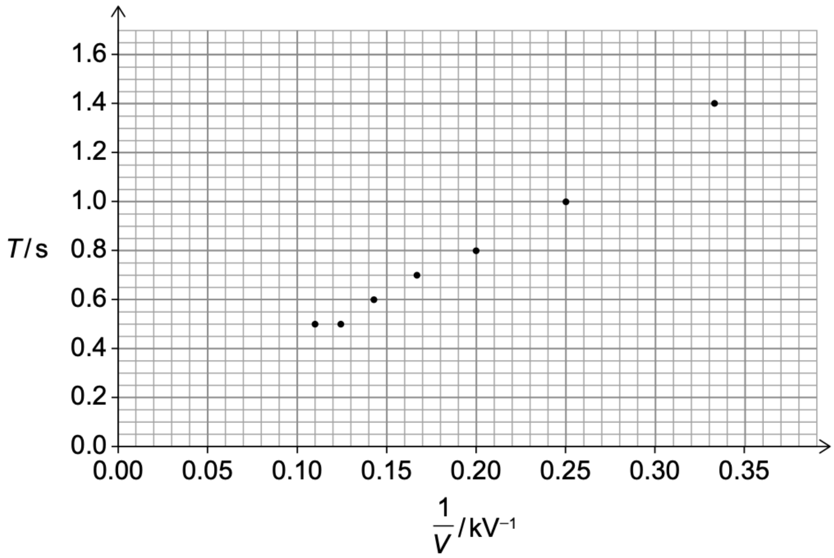

Figure 3: The graph of T against $\frac{1}{V}$.

(i) Determine A by drawing the line of best fit. [3]

- First, plot the error bars so that you can verify your line of best fit at least passes through all the data points and their error margins.
- The next mark is given for a taking a segment on the line at least half of it (e.g. from its start point to end point), and then calculating the gradient of that segment by drawing the triangle (to visualise the change in y and x).
- The third mark point is given for the gradient, A correctly calculated, e.g.

$$A = \frac{1.6 - 0}{0.40 - 0} = 4$$

(ii) State the units of A. (Note that it doesn't say "base SI units", so we do not need a conversion to base SI units.) [1]

$$V \times T \equiv \text{(kV)} \times \text{s} = \text{kV s}$$

(iii) The theoretical relationship assumes that the ball is only affected by the electric force. Suggest why, in order to test the relationship, the length of the string should be much greater than the distance between the plates. [2]

- The question is really asking for a change to the experiment that can ensure that the only force acting on the ball is the electric force, because it's a prerequisite of the theoretical relationship.
- Now let's ask ourselves the following question: What are potentially other forces acting on the ball that would violate the prerequisite?
- The ball is suspended by a string, so there is a tension force acting on the ball. Only the horizontal component of the tension force will affect the ball's motion, so let's think about ways to minmise that.
- If we think about the geometry of the situation, the higher up the point of suspension is – the smaller the angle of the string to the vertical – the smaller the horizontal component of the tension force.
- Hence, we should make the string much longer than the distance between the plates, so that the angle of the string to the vertical is very small.

2.2 Question 2

[Maximum mark: 8]

A group of students investigate the bending of a plastic ruler that is clamped horizontally at one end. A weight W attached to the other end causes the ruler to bend. The weight is contained in a scale pan.

The students fix the length L of the ruler and vary W. For each value of W, the group measures the deflection d of the end of the ruler to which the weight is attached.

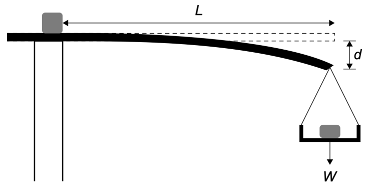

Figure 4: A diagram of the experiment.

(a) The group obtains the following repeated readings for d for **one** value of W.

Reading	1	2	3	4	5	6
d / cm	2.7	2.9	3.6	2.7	2.8	2.9

The group divides into two subgroups, A and B, to analyse the data.

Group A quotes the mean value of d as 2.93 cm.

Group B quotes the mean value of d as 2.8 cm.

Discuss the values that the groups have quoted. [2]

- Immediately, when reading the dataset, we can spot an outlier on the third reading, which is 3.6 cm. The fact that we are given two different mean values suggests that one of the groups has included the outlier in their calculation, and the other group has excluded it.

- Group B has excluded the outlier in their calculation, and so their mean value 2.8 is a better representation of the data.
- Group A also has the problem that the number of significant figures is not suitable for the data. The data is given to 2 s.f., so the mean value should also be given to 2 s.f. (2.9 cm).

(b) The variation of d with W is shown.

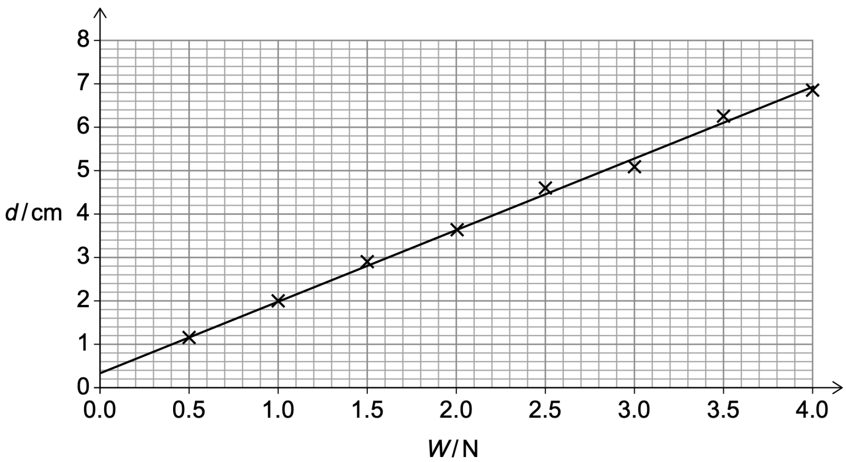

Figure 5: The graph of d against W.

Outline one experimental reason why the graph does not go through the origin. [1]

- At the point where $W = 0$ we have a non-zero deflection because the scale pan itself has a weight, and so the ruler will bend downwards even when there is no additional weight on it.
- The mark scheme also brings up the idea of a systematic error. This is a good point, but I think it is a bit too vague to be a good answer.

(c) Theory predicts that

$$d \propto \frac{W^x L^y}{EI}$$

where E and I are constants. The fundamental units of I are m^4 and those of E are $\mathrm{kg\,m^{-1}\,s^{-2}}$.

Calculate x and y. [2]

- This is a question of dimensional analysis, i.e. equating the dimensions of both sides of the equation.
  - $W \equiv \mathrm{kg\,m\,s^{-2}}$
  - $L \equiv \mathrm{m}$
- Then, we have the following eqution

$$dEI \propto W^x L^y$$
$$m\left(\mathrm{kg\,m^{-1}\,s^{-2}}\right)\left(\mathrm{m^4}\right) \equiv \mathrm{kg}^x \mathrm{m}^x \mathrm{s}^{-2x}(m^y)$$

- This looks messy, but let's do a "compare coefficients" here, and we should obtain a system of equations.
- If we look at the m powers, we have

$$1 - 1 + 4 = x + y$$

- If we look at the kg powers

$$1 = x$$

- So we have $x = 1$ and $y = 3$.

(d) The ruler has cross-sectional area $A = a \times b$, where $a = (28 \pm 1)$ mm and $b = (3.00 \pm 0.05)$ mm.

(a) Suggest an appropriate measuring instrument for determining b. [1]

- A micrometer screw gauge / Vernier caliper / travelling microscope is a good answer here, because it can measure to the nearest 0.05 mm.

(b) Calculate the percentage uncertainty in the value of A.

$$\begin{aligned}
\frac{\Delta a}{a} &= \frac{1}{28} \\
\frac{\Delta b}{b} &= \frac{0.05}{3.00} \\
\frac{\Delta A}{A} &= \frac{\Delta a}{a} + \frac{\Delta b}{b} \\
&= \frac{1}{28} + \frac{0.05}{3.00} \\
&= 0.05 = 5\%
\end{aligned}$$