# 1.2 Uncertainties & Errors

## Question Paper

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|---|---|
| Course | DP IB Physics |
| Section | 1. Measurement & Uncertainties |
| Topic | 1.2 Uncertainties & Errors |
| Difficulty | Medium |

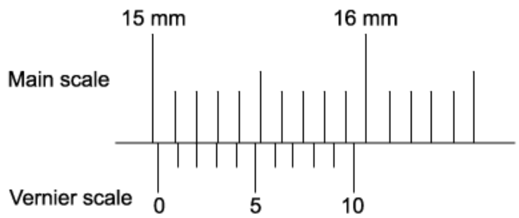
**Time allowed:** 80

**Score:** /66

**Percentage:** /100

## Question 1a

A vernier calliper is used to measure the length of a piece of copper wire.




(a)
Determine the full reading of the vernier calliper with its absolute uncertainty.

**[4 marks]**

## Question 1b

The reading from part (a) is taken after a mass has been added to the copper wire of length *L* and the wire extends.

The original length of the wire *L* was 14.9 ± 0.05 mm.

(b)
Calculate the extension Δ*L* of the copper wire after the mass has been added. Give the range of the uncertainty of this extension.

**[3 marks]**

## Question 1c

Tensile strain is a measure of the deformation of an object and is defined as the ratio between the extension of the wire and its original length.

$$\text{Tensile Strain, } \varepsilon = \frac{\Delta L}{L}$$

(c)
Deduce the tensile strain of the copper wire and its percentage uncertainty.

**[4 marks]**

## Question 1d

(d)
State two ways to reduce the systematic error in this experiment.

**[2 marks]**

## Question 2a

A student participates in an experiment to measure the Earth's gravitational field strength *g*. This is done using a simple pendulum.

The student suggests the period of oscillation *T* is related to length of the pendulum *L* and by the equation:

$$T = 2\pi\sqrt{\frac{L}{g}}$$

The table shows the period *T* recorded ten times.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 0.67 | 0.66 | 0.67 | 0.68 | 0.69 | 0.64 | 0.66 | 0.65 | 0.68 | 0.65 |

(a)
Determine the mean period of oscillation and its percentage uncertainty.

**[3 marks]**

## Question 2b

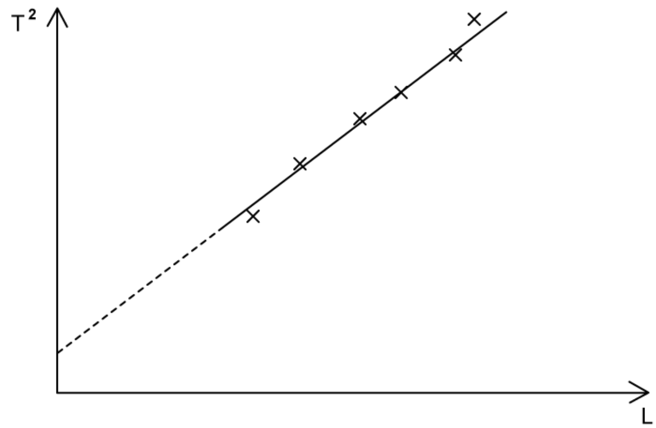
In a new experiment ,the length of the pendulum *L* is measured with an accuracy of 1.8% and the acceleration due to free-fall *g* is measured with an accuracy of 1.6%.

(b)
If the time for the pendulum to complete 20 oscillations is 18.4 s, determine the time period for one oscillation and the absolute uncertainty in this value.

**[3 marks]**

## Question 2c

Measurements of time periods for different lengths of pendula were taken using a stopwatch and plotted on a graph.




(c)
Explain how the graph indicates that the readings are subject to systematic and random uncertainties.

**[2 marks]**

## Question 2d

The period *T* for a mass *m* hanging on a spring performing simple harmonic motion is given by the equation:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

Such a system is used to determine the spring constant *k*. The fractional error in the measurement of the period *T* is $\alpha$ and the fractional error in the measurement of the mass *m* is $\beta$.

(d)
Determine the fractional error in the calculated value of *k* in terms of $\alpha$ and $\beta$.

**[2 marks]**

## Question 3a

An object falls off a cliff of height, *h*, above the ground. It takes 13.8 seconds to hit the ground.

It is estimated that there is a percentage uncertainty of ± 5% in measuring this time interval. A guidebook of the local area states the height of the cliff is 940 ± 10 m.

(a)
Calculate the acceleration of free-fall of the object and its fractional uncertainty.

**[4 marks]**

## Question 3b

The only instrument used in this experiment was a stopwatch.

(b)
(i)

(ii)
Write down one possible source of systematic error and one possible source of random error in this investigation.

Explain how these errors could influence the value of acceleration of free-fall of the object from part (a).

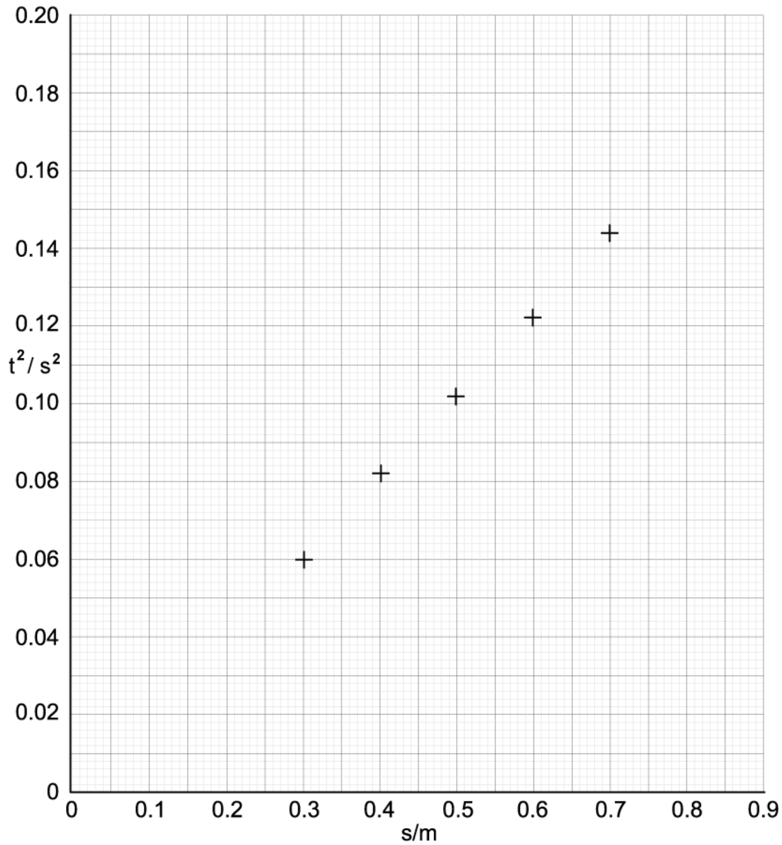
**[4 marks]**

## Question 3c

A student performs an experiment to find the acceleration due to gravity. A spherical object falling freely through measured vertical distances *s* for a time *t*. The experiment is repeated in a lab and the time is measured electronically.

| $s$ / m | $t_1$ / s | $t_2$ / s | $t_3$ / s | **mean time** $t$ / s | $t^2$ / $s^2$ |
|---|---|---|---|---|---|
| 0.100 | 0.141 | 0.138 | 0.144 | 0.141 | 0.020 |
| 0.200 | 0.201 | 0.205 | 0.209 | 0.205 | 0.042 |
| 0.300 | 0.240 | 0.246 | 0.250 | 0.245 | 0.0600 |
| 0.400 | 0.285 | 0.288 | 0.284 | 0.286 | 0.0818 |
| 0.500 | 0.315 | 0.319 | 0.323 | 0.319 | 0.102 |
| 0.600 | 0.345 | 0.349 | 0.354 | 0.349 | 0.122 |
| 0.700 | 0.376 | 0.379 | 0.382 | 0.379 | 0.144 |
| 0.800 | 0.399 | 0.405 | 0.407 | 0.404 | 0.163 |
| 0.900 | 0.426 | 0.428 | 0.432 | 0.429 | 0.184 |

(c)
Plot the data on the graph below, including error bars and a line of best fit.




**[5 marks]**

## Question 3d

(d)

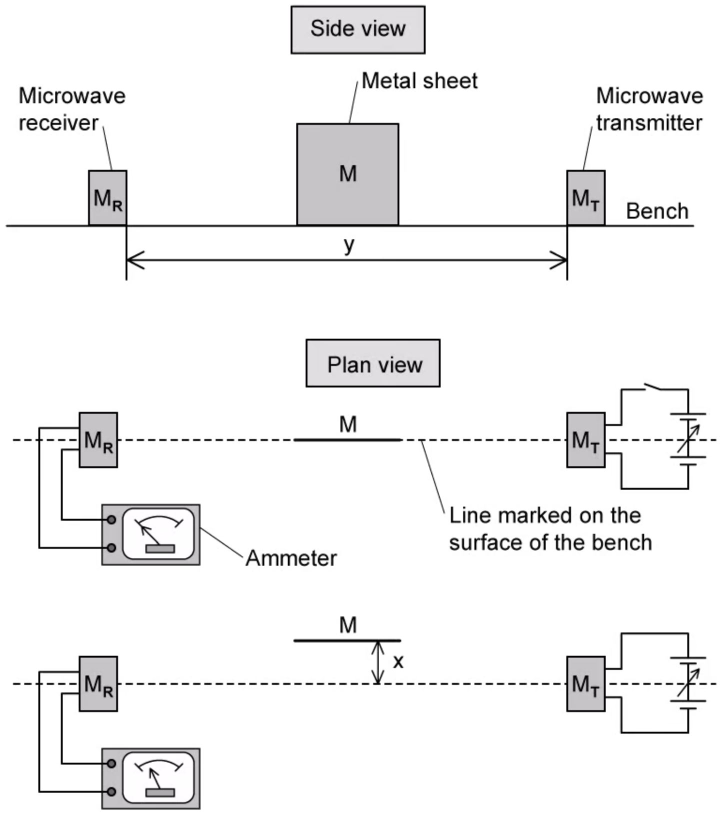
Calculate the value of *g* for this experiment.

**[4 marks]**

## Question 4a

The diagram shows the side and plan views of a microwave transmitter $M_T$ and a receiver $M_R$ arranged on a line marked on the bench.

The circuit connected to $M_T$ and the ammeter connected to $M_R$ are only shown in the plan view.




The distance *y* between $M_T$ and $M_R$ is recorded.

$M_T$ is switched on and the output from $M_T$ is adjusted so a reading is produced on the ammeter.

**M** is kept parallel to the marked line and moved slowly away. The perpendicular distance *x* between the marked line and **M** is recorded.

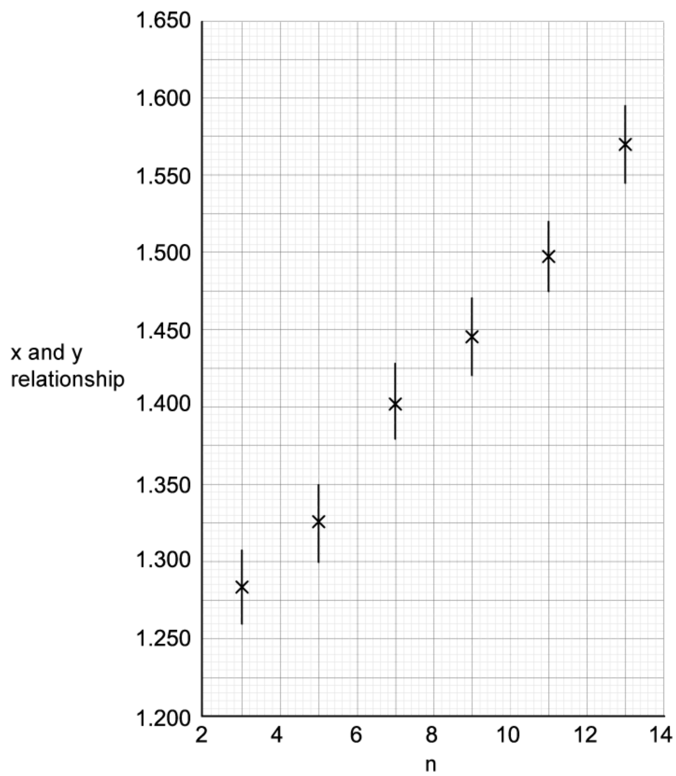
(a)
Describe one method to reduce systematic errors in the measurement of *x*. Use a sketch to aid your answer.

**[4 marks]**

## Question 4b

At the first minimum position, a student labels the minimum $n = 1$ and records the value of $x$. The next minimum position is labelled $n = 2$ and the new value of $x$ is recorded. Several positions of maxima and minima are produced.

A relationship between $x$ and $y$ against $n$ is shown on the graph. The wavelength $\lambda$ is the gradient of the graph.




(b)

Determine the maximum and minimum possible values of $\lambda$.

**[3 marks]**

## Question 4c

(c)
Determine:

(i) The value of $\lambda$

(ii) The percentage uncertainty in the value of $\lambda$.

**[4 marks]**

## Question 4d

Another student conducted a similar experiment but determined the uncertainty in the relationship of $x$ and $y$ to be 0.010 m for each term.

(d)
Explain the effect this would have on the uncertainty in $\lambda$.

**[2 marks]**

## Question 5a

The decay of a radioactive substance can be represented by the equation:

$$C = C_0 e^{-\lambda t}$$

where C is the count rate of the sample at time $t$, $C_0$ is the initial count rate at time $t = 0$ and $\lambda$ is the decay constant.

The half-life, $t_{½}$ of the radioactive substance is given by

$$t_{1/2} = \frac{\ln 2}{\lambda}$$

An experiment was performed to determine the half-life of a radioactive substance which was a beta emitter. The radioactive source was placed close to a detector.

The results in the table show the total count for exactly 5 minutes, repeated at 15 minute intervals.

| time, t / minutes | total count, recorded in 5 minutes | Count rate, C / counts minute$^{-1}$ | ln (C / minute$^{-1}$) |
|---|---|---|---|
| 0 | 1016 | 183 | 5.21 |
| 15 | 920 | 164 | 5.10 |
| 30 | 835 | 147 | 4.99 |
| 45 | 758 | 132 | 4.88 |
| 60 | 665 | 113 | 4.73 |
| 75 | 623 | 105 | 4.65 |
| 90 | 568 | 94 | 4.54 |
| 105 | 520 | 84 | 4.43 |
| 120 | 476 | 75 | 4.32 |
| 135 | 437 | 67 | 4.21 |

The uncertainty in the count rate, C, is given by

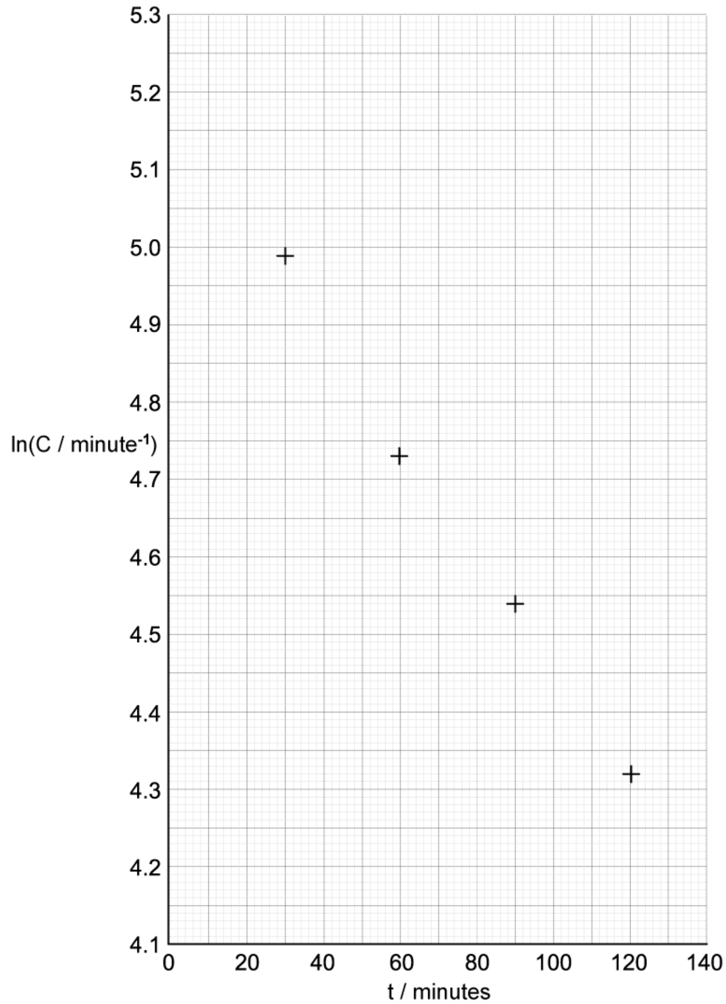
$$\Delta C = \pm\sqrt{C}$$

(a) Calculate the uncertainty in each value of ln C.

**[2 marks]**

## Question 5b

(b)
Draw a line of best fit and error bars for each point on the graph.




**[3 marks]**

## Question 5c

The activity of the sample $\lambda = -\frac{\ln C}{t}$

(c)
Calculate the activity of the sample and its percentage uncertainty.

**[5 marks]**

## Question 5d

Another student performed the same experiment with identical equipment but took total counts over a 1-minute period rather than a 5-minute period. The total count, C, at 140 minutes was equal to 54 counts.

(d)
Use the relationship

$$\ln(x) = y \text{ so } x = e^y$$

to estimate the percentage uncertainty in this total count and explain the advantage of using a larger time.

**[3 marks]**