1.2 Uncertainties & Errors

Question Paper

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

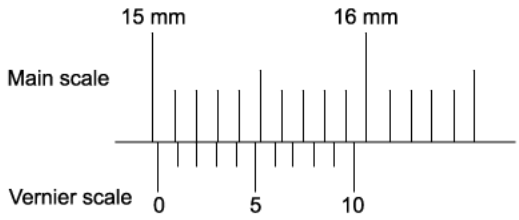
Time allowed: 80

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 ΔL 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

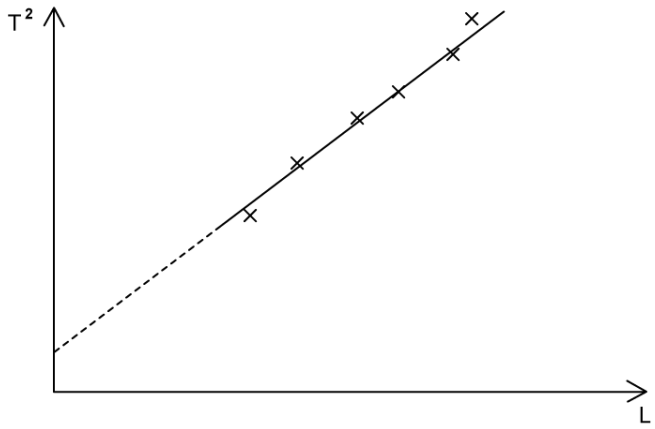
In a new experiment ,the length of the pendulum *L* is measured with an accuracy of 1.8% and the acceleration due to free-fall *g* is measured with an accuracy of 1.6%.

(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 α and the fractional error in the measurement of the mass m is β.

(d)
Determine the fractional error in the calculated value of k in terms of α and β.

[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).

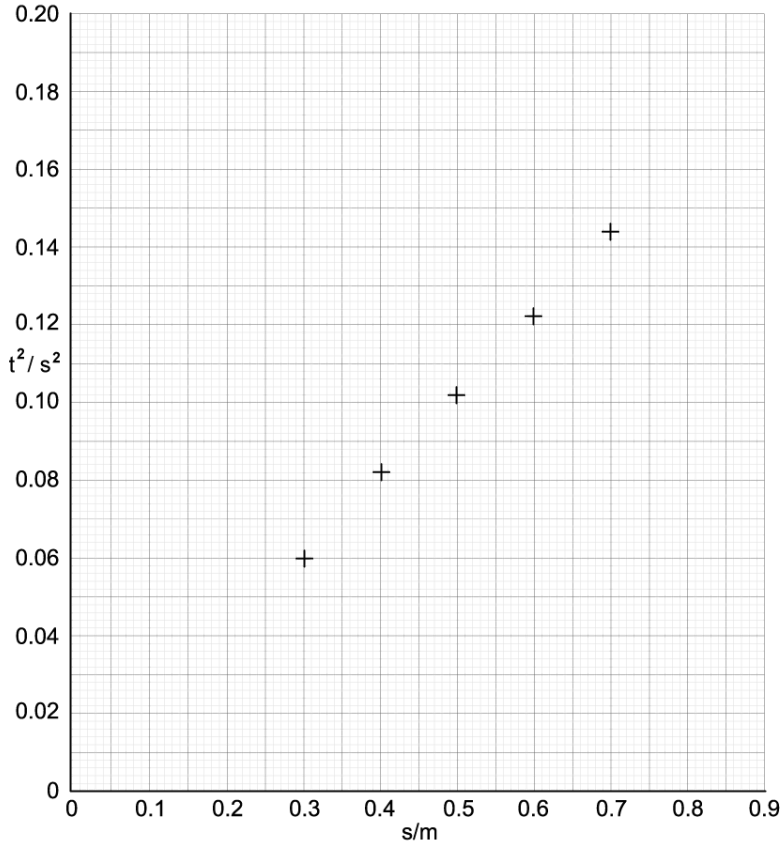
[4 marks]

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)

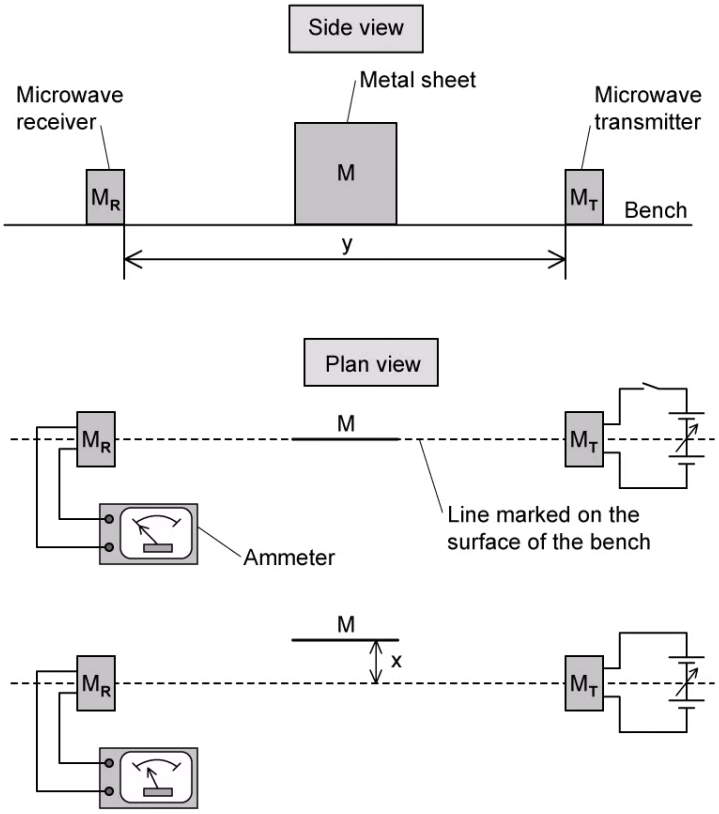
Calculate the value of *g* for this experiment.

[4 marks]

Question 4a

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

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



The distance *y* between $\mathbf{M_T}$ and $\mathbf{M_R}$ is recorded.

$\mathbf{M_T}$ is switched on and the output from $\mathbf{M_T}$ 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.

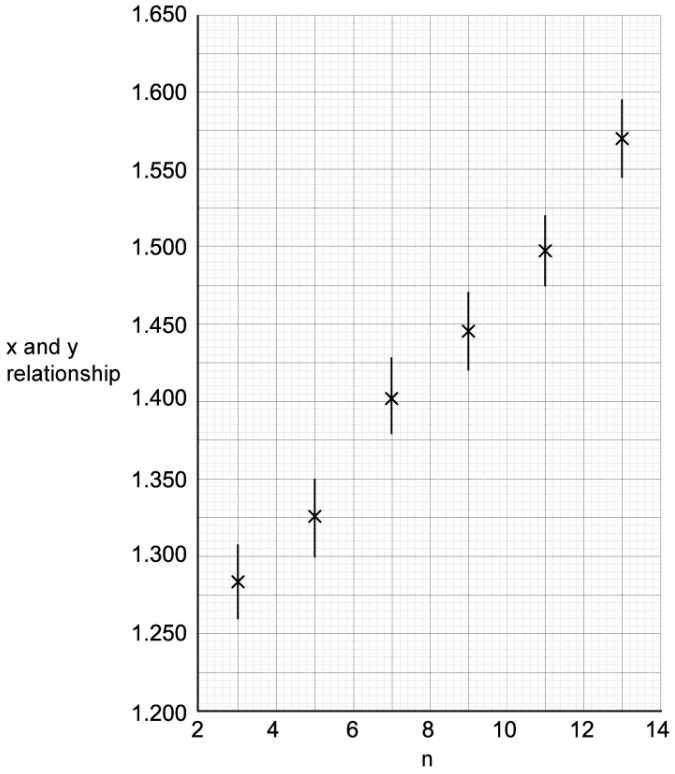
(a)
Describe one method to reduce systematic errors in the measurement of *x*. Use a sketch to aid your answer.

[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 λ is the gradient of the graph.



(b)
Determine the maximum and minimum possible values of λ.

[3 marks]

Question 4c

(c)
Determine:

(i) The value of λ

(ii) The percentage uncertainty in the value of λ.

[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 λ.

[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 λ 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

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

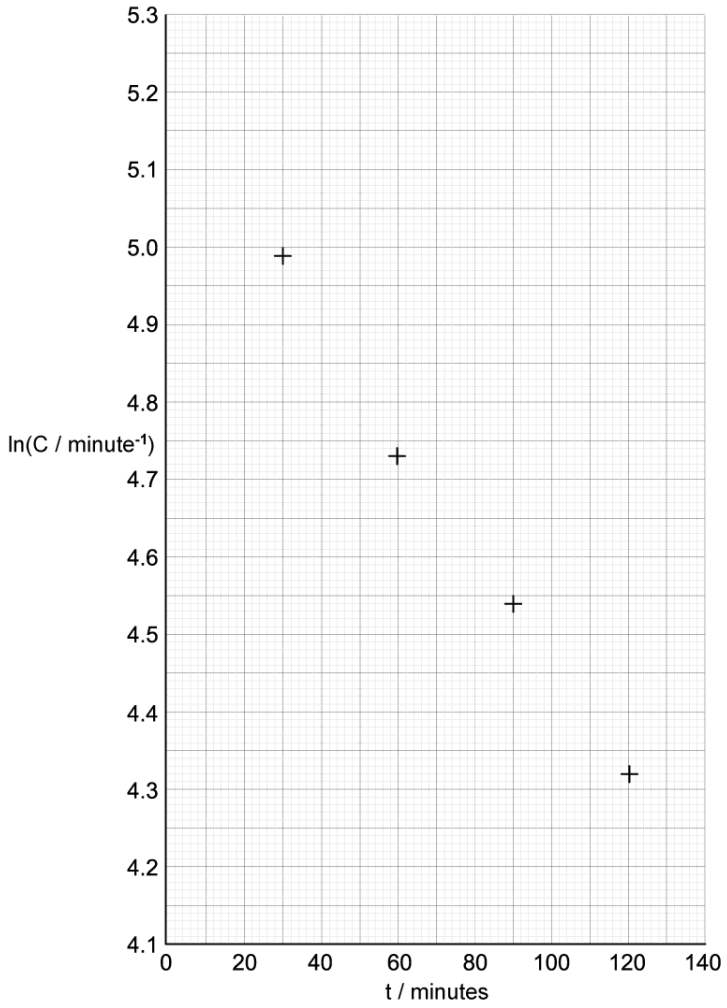
(a) Calculate the uncertainty in each value of ln C.

[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]