Practical Investigation

Variables, Uncertainties, analysing data, models and theories, nature of evidence,

Investigation analysis, Investigation report conventions

- **independent, dependent and controlled variables**
- **the physics concepts specific to the investigation and their significance, including definitions of key terms, and physics representations**
- **the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including experiments (gravity, magnetism, electricity, Newton's laws of motion, waves) and/or the construction and evaluation of a device; precision, accuracy, reliability and validity of data; and the identification of, and distinction between, uncertainty and error**
- **identification and application of relevant health and safety guidelines**
- **methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of uncertainty and error, and limitations of data and methodologies**
- **models and theories, and their use in organising and understanding observed phenomena and physics concepts including their limitations**
- **the nature of evidence that supports or refutes a hypothesis, model or theory**
- **the key findings of the selected investigation and their relationship to concepts associated with waves, fields and/or motion**
- **the conventions of scientific report writing and scientific poster presentation, including physics terminology and representations, symbols, equations and formulas, units of measurement, significant figures, standard abbreviations and acknowledgment of references.**

Paper	Multiple choice	Short Answer	Idea	Marks	%	Type
2022	20		Uncertainty definition	1	84%	Concept
		10a	Classification of terms	3	84%	Concept
		10b	Plotting graph	6	87%	Graphing
		10c	Interpreting graph	2	71%	Concept
		10d i	Substitution into formula	2	84%	Calculation
		10d ii	Evaluation of data	3	42%	Explanation
2022 NHT		20a	Definition of terms	3	NA	Concept
		20b	Data entry	2	NA	Calculation
		20c	Plotting graph	6	NA	Graphing
		20d	Gradient of graph	2	NA	Calculation
		20e	Interpreting gradient	2	NA	Calculation

2021	1		Precision, accuracy definition	1	87%	Concept
		20a	Scientific technique	1	86%	Concept
		20b	Interpreting methodology	1	17%	Concept
		20c	Interpreting methodology	3	34%	Concept
		20d	Data entry	4	61%	Calculation
		20e	Plotting graph	4	53%	Graphing
		20f	Gradient of graph	2	44%	Calculation
		20g	Interpreting gradient	2	14%	Calculation
2021 NHT	19		Definition, independent	1	NA	Concept
		18d	Drawing graph	5	NA	Concept
		18e	Gradient of graph	3	NA	Calculation
2020	19		Definition of terms	1	84%	Concept
		18a	Circuit theory	2	73%	Explanation
		18b	Definition of terms	2	70%	Concept
		18c	Interpreting data	2	37%	Concept
		18d	Data entry	2	88%	Calculation
		18e	Plotting graph	6	76%	Graphing
		18f	Interpreting graph, LOBF	2	33%	Explanation
2019	18		Definition of terms	1	83%	Concept
	19		Methodology	1	85%	Concept
		19a	Plotting graphs	6	58%	Graphing
		19b i	Interpreting graphs	2	38%	Calculation
		19b ii	Plotting graphs	2	17%	Calculation
		19c i	Interpreting graphs	2	43%	Calculation
		19c ii	Interpreting graphs	2	16%	Calculation
		19c iii	Interpreting graphs	2	21%	Calculation
		19d	Application	2	39%	Explanation
2019 NHT	20		Definition of terms	1	NA	Concept
		8a	Methodology	2	NA	Explanation
		8b	Definition of terms	3	NA	Concept
		8c i	Plotting graphs	1	NA	Calculation
		8c ii	Plotting graphs	6	NA	Graphing
		8d	Interpreting graphs	3	NA	Calculation
2018	18		Definition of terms	1	57%	Concept
	19		Methodology	1	70%	Concept
	20		Definition of terms	1	82%	Concept
		20a	Plotting graphs	5	86%	Graphing
		20b	Interpreting graphs	2	58%	Calculation
		20c	Interpreting graphs	3	38%	Calculation

2018 NHT	18		Sig figs	1	NA	Concept
	19		Definition of terms	1	NA	Concept
	20		Methodology	1	NA	Concept
		10a	Definition of terms	2	NA	Concept
		10b	Plotting graphs	6	NA	Graphing
		10c	Interpreting graphs	3	NA	Calculation
2017	18		Definition of terms	1	59%	Concept
	19		Definition of terms	1	90%	Concept
	20		Definition of terms	1	74%	Concept
		9a	Height of projectile	3	47%	Calculation
		9b	Definition of terms	3	77%	Concept
		9c	Plotting graphs	8	61%	Graphing

Practical Investigation questions can be grouped into the following ideas.

Definitions	Worked example 1
Sig figs, standard form, substitution	Worked example 2
Methodology	Worked example 3
Completing tables of values	Worked example 4
Plotting graphs	Worked example 5
Interpreting graphical information	Worked example 6
Interpreting data, uncertainties	Worked example 8
Application questions	Worked example 7

EPI examination questions process summary

The first question is most likely to be recall of one of the definitions.

The second step is usually an explanation regarding the methodology of the investigation. This is typically followed by an incomplete data set, that requires some further calculating.

The next step is to plot the data.
Your graph is typically scored as follows:
Correct labelling of axes.
Appropriate scale on axes, (**MUST** use more than 50% of the grid).
Accurate plotting of all points.
Drawing of appropriately sized uncertainties.
Reasonable drawing of appropriate line of best fit.

Once the graph is plotted, you will be required to interpret it. This is usually either identifying the significance of either the gradient or the intercepts. The area under the graph is also a possibility.

The final question will be an application type question based on a quantity derived from the graph.

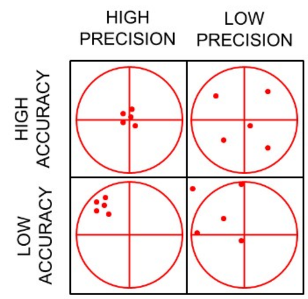
There are some easy marks in these questions, paying some attention to detail, the calculations and plotting the graphs will typically gain at least half of the marks for this question. Make sure that you allow sufficient time for this question.

Definitions

Independent, dependent and controlled variables

The independent variable is the variable that the experimenter changes, to find out what changes occur to the dependent variable. Controlled variables are unchanged throughout the experiment.

Precision, accuracy, reliability and validity of data



Precision is the closeness of the data to itself. Accuracy is the closeness to the true value.
Reliability is a measure of how close repeated experiments give the same result. Validity refers to how well a test measures what it is purported to measure.

Hypothesis, model or theory

A hypothesis is an idea that can be tested experimentally. A model is an evidence based representation of something that cannot be displayed directly. A theory is often a set of principles used to explain a set of facts or phenomena, it is based on repeated verification.

Uncertainty and error

Uncertainty is the margin of error of a measurement. Error is the difference between a measured value and the true value.

Random Errors

Caused by unknown and unpredictable changes in the experiment. Random error can occur in measuring instruments or environmental conditions. The amount of random error limits the precision of the experiment.

Systematic Errors

Systematic errors usually come from measuring instruments, for example if there is something wrong with the instrument/data handling, or if the instrument is used incorrectly. The amount of systematic error limits the accuracy of the experiment. Systematic errors can be more difficult to detect than random errors.

Uncertainties

No measurement is exact. When a quantity is measured, the outcome depends on the measuring system, the measurement procedure, the skill of the operator, the environment, and other effects. Even if the quantity were to be measured several times, in the same way and in the same circumstances, a different measured value would in general be obtained each time, assuming the measuring system has sufficient resolution to distinguish between the values.

Measuring devices: Different measuring devices have different levels of uncertainty. The standard rule is $\pm \frac{1}{2}$ the smallest division.

Scientific form and significant figures

All non-zero digits are significant.
Zeros between non-zero digits are significant.
Leading zeros are never significant.
In a number with a decimal point, trailing zeros, those to the right of the last non-zero digit, are significant.
For the purpose of the *VCE Physics Study Design*, whole numbers will have the same significant figures as number of digits, for example 400 has three significant figures while 400.0 has four."

Worked example 1: Practical Investigation: Definitions.

2017 Question 18, 1 mark

Two students, Rob and Jan, measure the current in the same circuit on separate occasions.

Rob obtains the following readings:

9.50 mA, 9.21 mA, 9.10 mA and 9.60 mA (average 9.35).

Jan obtains the following readings:

9.20 mA, 9.25 mA, 9.31 mA and 9.36 mA (average 9.28).

The true value of the current is known to be 9.35 mA.

Which one of the following best describes these two sets of measurements?

A. Rob's results are more accurate than Jan's results.

B. Both sets of results are equally accurate.

C. Rob's results are more precise than Jan's results.

D. Both sets of results are equally precise.

Solution

Accuracy is defined as the difference between the mean and the actual value. Precision is defined as the range between measurements.

∴ **A (ANS), (59%)**

Current study design:

2022 Question 20 (84%)

2022 Question 10a (84%)

2022 NHT Question 20a

2021 Question 1 (87%)

2021 NHT Question 19

2020 Question 19 (84%)

2020 Question 18b (70%)

2019 Question 18 (83%)

2019 NHT Question 20

2019 NHT Question 8b

2018 Question 18 (57%)

2018 Question 20 (82%)

2018 NHT Question 19

2018 NHT Question 10a

2017 Question 18 (59%)

2017 Question 19 (90%)

2017 Question 20 (63%)

2017 Question 9b (77%)

Worked example 2: Practical Investigation: Sig figs, standard form, substitution.

1968 Question 29, 1 mark

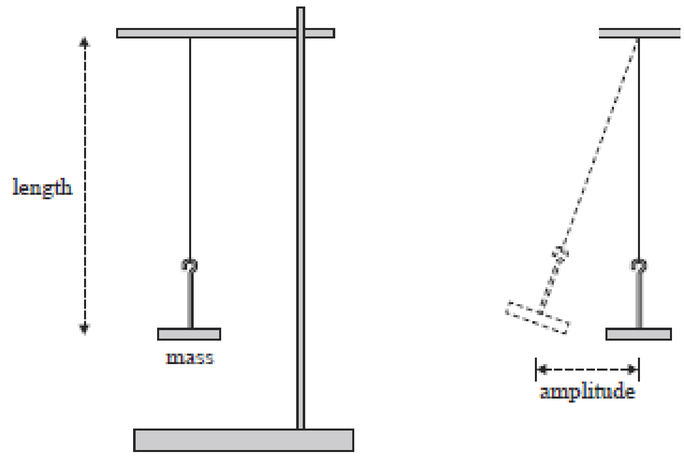
A metal rod, of length 7.6039 cm, is heated and expands to 7.6052 cm. What was its change in length **in *metres?***

Express your answer in *standard form,* to an appropriate number of significant figures.

Solution	**Current study design:**
7.6052 – 7.6039 = 0.0013 cm ∴ **1.3×10^{-5} m (ANS), (49%)**	**2022 Question 10d i (84%)** **2018 Question 19 (70%)** **2018 NHT Question 18**

Worked example 3: Practical Investigation: Methodology.

As part of an experimental investigation, Physics students use a pendulum, as shown below, to indirectly measure the magnitude of Earth's gravitational field at their location.



The students use a constant mass and a constant amplitude of swing, changing only the length of the pendulum and then measuring the time for five oscillations. They obtain four different time readings for four different lengths of the pendulum.

By using the relationship $T = 2\pi\sqrt{\frac{l}{g}}$ where *T* is the period and *l* is the length of the pendulum, the students obtain four values for the magnitude of Earth's gravitational field.

2019 Question 19, 1 mark

Which one of the following best explains why the students measured the time for five oscillations rather than the time for one oscillation?

A. One oscillation is too quick to see.

B. Five oscillations reduce the effect of air friction.

C. Five oscillations reduce the uncertainty of the measured period.

D. Five oscillations reduce the uncertainty of the measured length.

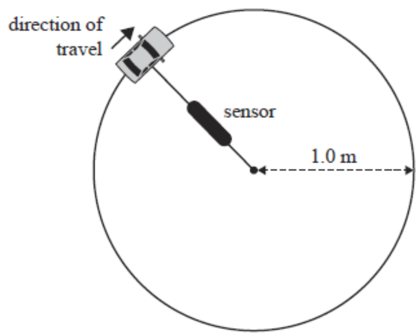
Solution	**Current study design:**
Allowing five oscillations, means that the uncertainty associated with measuring the period is reduced. ∴ **C (ANS), (85%)**	2021 Question 20a (86%) 2021 Question 20c (34%) 2019 Question 19 (85%) 2019 NHT Question 8a 2018 NHT Question 20

Worked example 4: Practical Investigation: Completing tables of values.

Students are investigating the forces involved in horizontal circular motion. Their apparatus consists of a model car that travels in a circle at constant speed. The speed of the model car can be set at different values. The car is connected by a string of length 1.0 m to the centre of the circle.

Incorporated in the string is a sensor that measures the tension (force) of the string. There is no radial friction force between the car's tyres and the surface that the car moves on.

The figure below shows the experimental arrangement viewed from above.



The students obtain a number of measurements by varying the setting for the period of rotation, *T*, and then recording the force, F_T , in the string. They know *T* with great accuracy but the sensor has an experimental uncertainty of ± 0.4 N.

2019 NHT Question 8c i, 1 mark

The students have recorded the data for the period of rotation, *T*, and the force, F_T , in the table below. The radius of the circle is 1.0 m.

Calculate the values of $\frac{1}{T^2}$ and write them in the table below

Period T (s)	$\frac{1}{T^2}$ **(s^{-2})**	**Force F_T (N)**
5.00		8
10.0		2
15.0		0.9
20.0		0.5

Solution

Period T (s)	$\frac{1}{T^2}$ **(s^{-2})**	$\frac{1}{T^2}$ **(s^{-2})**
5.00	0.04	4.00×10^{-2}
10.0	0.01	1.00×10^{-2}
15.0	0.004	4.44×10^{-3}
20.0	0.0025	2.50×10^{-3}

Current study design:

2022 NHT Question 20b

2021 Question 20d (61%)

2020 Question 18d (88%)

2019 NHT Question 8c i

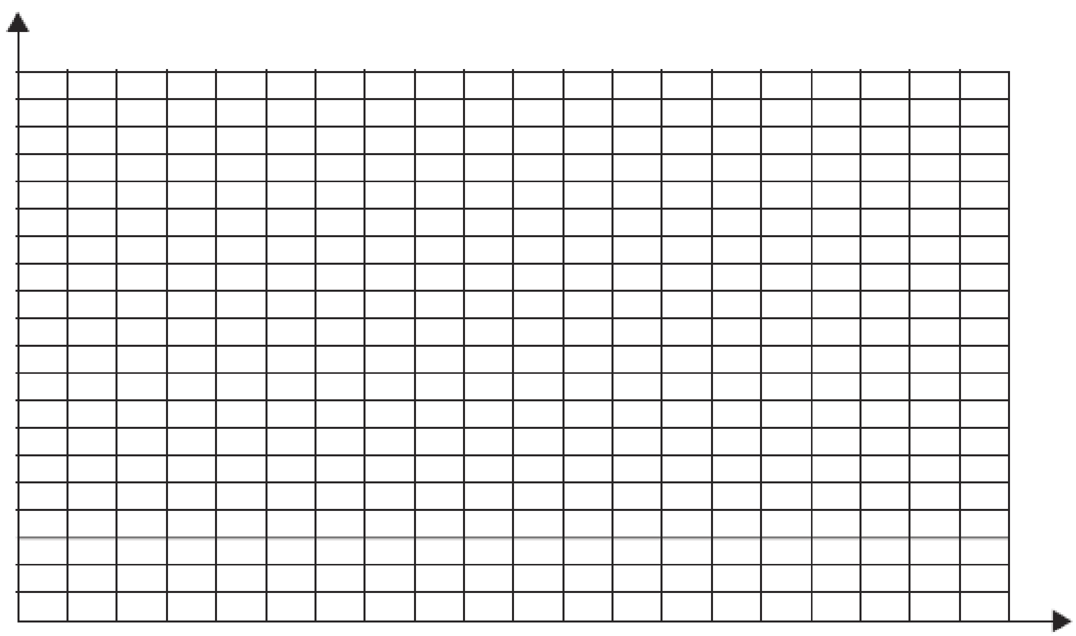
Worked example 5: Practical Investigation: Plotting graphs.

2019 NHT Question 8c ii, 6 marks

The relationship between F_T and T is given by the formula $F_T = \frac{4\pi^2 mr}{T^2}$

On the axes provided below:

- plot a graph of F_T versus $\frac{1}{T^2}$ using the data in the table in **part c.i.**
- include the correct uncertainty bars for the F_T values
- label each of the axes correctly
- draw a line of best fi t.

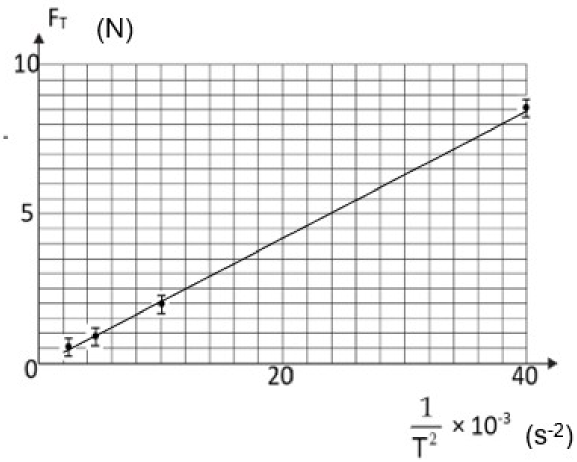


Solution

Force F_T (N)	$\frac{1}{T^2}$ (s^{-2})
8	4.00×10^{-2}
2	1.00×10^{-2}
0.9	4.44×10^{-3}
0.5	2.50×10^{-3}

Current study design:

2022 Question 10b (87%)
2022 NHT Question 20c
2021 Question 20e (53%)
2021 NHT Question 18d
2020 Question 18e (76%)
2019 Question 19a (58%)
2019 NHT Question 8c ii
2018 Question 20a (86%)
2018 NHT Question 10b
2017 Question 9c (81%)



F_T (N)
10
5
0
20
40
$\frac{1}{T^2} \times 10^{-3}$ (s^{-2})

Worked example 6: Practical Investigation: Interpreting graphical information.

2019 NHT Question 8d, 3 marks

Using the line of best fit and the formula from **part c.ii.**, determine the value of *m*, the mass of the car. Show your working.

Solution

Since $F = \frac{4\pi^2 mr}{T^2}$ **then the gradient of the** F_T **vs** $\frac{1}{T^2}$ **graph is** $4\pi^2 mr$**.**

$\therefore 4\pi^2 mr = \frac{8 - 0.5}{(40 - 2.5) \times 10^{-3}}$

$\therefore 4\pi^2 mr = 200$

$\therefore m = \frac{200}{4\pi^2 \times 1.0}$

$\therefore m = 5.07$

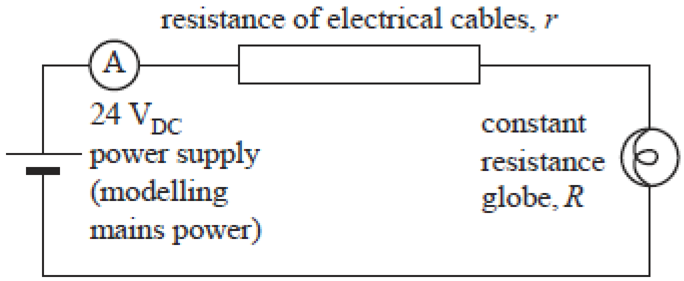
$\therefore$ **m = 5.1 kg (ANS)**

Current study design:

2022 Question 10c (71%)
2022 NHT Question 20d
2021 Question 20f (44%)
2021 NHT Question 18e
2020 Question 18f (33%)
2019 Question 19b i (38%)
2019 Question 19b ii (17%)
2019 Question 19c i (43%)
2019 Question 19c ii (16%)
2019 Question 19c iii (21%)
2019 NHT Question 8d
2018 Question 20b (58%)
2018 NHT Question 10c

Worked example 7: Practical Investigation: Application questions.

Students are modelling the effect of the resistance of electrical cables, *r*, on the transmission of electrical power. They model the cables using the circuit shown below.



2020 Question 18a, 2 marks

The 24 VDC power supply models the mains power.

Describe the effect of increasing the resistance of the electrical cables, *r*, on the brightness of the constant resistance globe, *R*.

Solution

In series circuits, if the resistance of the electrical cables increases then the total resistance of the circuit increases. With a constant voltage supply, the current in circuit will decrease. This power dissipated in the globe is given by i^2r. If the current is lower, then the power (brightness) of the globe diminishes. (73%)

Current study design:

2021 Question 20b (17%)
2020 Question 18a (73%)
2019 Question 19d (39%)
2017 Question 9a (47%)

Worked example 8: Practical Investigation: Interpreting data, uncertainties.

2020 Question 18c, 2 marks

To analyse the data, the students use the following equation to calculate the resistance of the cables for the circuit.

$$r = \frac{24}{i} - R$$

Show that this equation is true for the circuit shown above. Show your working.

Solution

For the circuit

$V = i(r + R)$

$\therefore$ **24 = i(r + R)**

$\therefore$ $\frac{24}{i}$ **= r + R**

$\therefore$ **r =** $\frac{24}{i}$ **- R**

Current study design:

2022 Question 10d ii (42%)
2022 NHT Question 20e
2021 Question 20g (14%)
2020 Question 18c (37%)
2018 Question 20c (38%)
