Name: ________________________________ (   )   Class: 4 - _____

Catholic High School
2023 Level 4
Physics Practical Planning

(1) Singapore-Cambridge General Certificate of Education Ordinary Level (2018) (Syllabus 6091 - Physics)

SCHEME OF ASSESSMENT

Candidates are required to enter for Papers 1, 2 and 3.

Paper	Type of Paper	Duration	Marks	Weighting
1	Multiple Choice	1 h	40	30 %
2	Structured and Free Response	1 h 45 min	80	50 %
3	Practical	1 h 50 min	40	20 %

Theory papers

Paper 1 (1 h, 40 marks)
This paper will consist of 40 compulsory multiple choice items of the direct choice type.

Paper 2 (1 h 45 min, 80 marks)
This paper will consist of 2 sections.

Section A will carry 50 marks and will consist of a variable number of compulsory structured questions.

Section B will carry 30 marks and will consist of three questions. The first two questions are compulsory questions, one of which will be a data-based question requiring candidates to interpret, evaluate or solve problems using a stem of information. This question will carry 8–12 marks. The last question will be presented in an either/or form and will carry 10 marks.

Practical assessment

Paper 3 (1 h 50 min, 40 marks)

This paper will consist of 2 sections.

Section A will carry 20 marks and will consist of 1–2 compulsory practical experiment questions with a total duration of 55 min.

Section B will carry 20 marks and will consist of one compulsory 55 min practical experiment question.

One or more of the questions may incorporate assessment of Planning (P) and require candidates to apply and integrate knowledge and understanding from different sections of the syllabus. The assessment of PDO and ACE may include questions on data-analysis which do not require practical equipment and apparatus.

Candidates would be allocated a specified time for access to apparatus and materials of specific questions

Candidates are not allowed to refer to notebooks, textbooks or any other information during the assessment.

PRACTICAL ASSESSMENT

Scientific subjects are, by their nature, experimental. It is therefore important that an assessment of a candidate's knowledge and understanding of Science should include a component relating to practical work and experimental skills.

This assessment is provided in Paper 3 as a formal practical test and is outlined in the Scheme of Assessment.

Paper 3
This paper is designed to assess a candidate's competence in those practical skills which can realistically be assessed within the context of a formal test of limited duration.

Candidates will be assessed in the following skill areas:

(a) Planning (P)

Candidates should be able to

- identify key variables for a given question/problem
- outline an experimental procedure to investigate the question/problem
- describe how the data should be used in order to reach a conclusion
- identify the risks of the experiment and state precautions that should be taken to keep risks to a minimum

(b) Manipulation, measurement and observation (MMO)

Candidates should be able to

- set up apparatus correctly by following written instructions or diagrams
- use common laboratory apparatus and techniques to collect data and make observations
- describe and explain how apparatus and techniques are used correctly
- make and record accurate observations with good details and measurements to an appropriate degree of precision
- make appropriate decisions about measurements or observations

(c) Presentation of data and observations (PDO)

Candidates should be able to

- present all information in an appropriate form
- manipulate measurements effectively for analysis
- present all quantitative data to an appropriate number of decimal places/significant figures

(d) Analysis, conclusions and evaluation (ACE)

Candidates should be able to

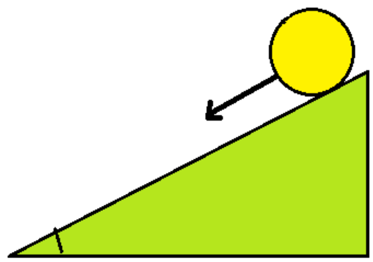
- analyse and interpret data or observations appropriately in relation to the task
- draw conclusion(s) from the interpretation of experimental data or observations and underlying principles
- make predictions based on their data and conclusions
- identify significant sources of errors and explain how they affect the results
- state and explain how significant errors may be overcome or reduced, as appropriate, including how experimental procedures may be improved.

One, or more, of the questions may incorporate some assessment of skill area P, set in the context of the syllabus content, requiring candidates to apply and integrate knowledge and understanding from different sections of the syllabus. It may also require the treatment of given experimental data in drawing relevant conclusion and analysis of proposed plan.

(2) Planning Content

Planning questions are generally extension of existing short practical questions. Hence, students will need to be familiar with the procedure outlined in order to answer the planning question. These questions typically require the students to verify a hypothesis or relationship that may be based on an equation.

For example, students may have already measured the time taken for a rod to roll down a slope as shown.



The planning question may be as follows:

EXAMPLE

It has been suggested that the distance travelled by the rod along the slope and the time it takes is given by:

$$t^2 = \frac{2D}{a}$$

where *D* is the distance rolled down by the rod,
t is the time taken for the rod to reach the bottom, and
a is the acceleration of the rod along the slope.

Plan an experiment to investigate the equation given. In your plan, you should:

- identify the constant variables
- describe how you will perform the experiment
- sketch the graph that you will obtain if the suggested relationship is correct
- explain how you will find *a* from the graph.

In the next few sections, we will learn how to answer a planning question using the example above.

(A) Identify linear relationship of given equation

When the question involves the investigation of an equation, students are expected to recall the standard linear form,

$$y = mx + c$$

They are also expected to rearrange relationships into linear form where appropriate.

In general, the independent variable is contained within the expression for x, while the dependent variable is contained within the expression for y (see Section B for more details).

EXAMPLE

For the equation in the example above, we compare it against the linear form as follows:

$$\begin{array}{ccccc} y & = & m\,x & + & c \\ t^2 & = & \frac{2}{a}D & + & 0 \end{array}$$

Hence, we have

$$y = t^2$$
$$x = D$$
$$m = \frac{2}{a}$$
$$c = 0$$

PRACTICE A1

Investigate the relationship between the object distance and image distance for a given lens, given by the lens equation

$$\frac{1}{f} = \frac{1}{u} + \frac{1}{v}$$

where f is the focal length of the lens,
u is the distance of the object from the lens i.e. object distance
v is the distance of the image from the lens i.e. image distance

Rearrange the given equation to the standard linear form and express y, m, x and c in terms of f, u and / or v.

Rearranging into standard linear form

$$\frac{1}{v} = -\frac{1}{u} + \frac{1}{f}$$

Hence, we have

$$y = \frac{1}{v}$$
$$x = \frac{1}{u}$$
$$m = -1$$
$$c = \frac{1}{f}$$

(B) Identifying key variables for a given question / problem

There are 3 types of variables in a question or problem.

1. Independent variable: a variable with values that are selected or changed by the investigator. It is the variable drawn on the x-axis.

2. Dependent variable: a variable with values that are measured for each change in the independent variable. It is the variable drawn on the y-axis.

3. Control variable(s): a variable which could affect the independent variable and has to be kept constant to ensure a fair test. It is **not** necessary that every planning question will require students to list down the constant variables. In addition, it is also **not** necessary to describe how to keep those variables constant unless the question requires it.

EXAMPLE

For the rod rolling down the slope, the variables are given as follows:

Independent variable: ***Distance rolled by the rod***

Dependent variable: ***Time taken to roll the distance***

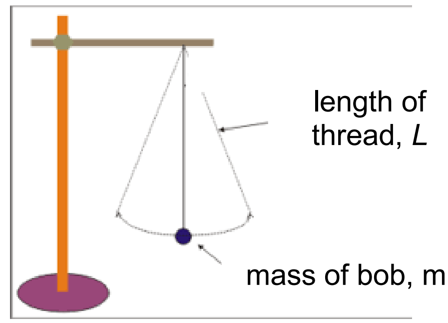
Constant variable(s): ***Initial speed of the marble; Angle of the slope***

(Avoid variables (e.g. colour of marble, density of marble) which do not affect the value of the dependent variable for a specific value of the independe variable even if they are changed)

PRACTICE B1

Suppose I want to investigate how the length of thread in a pendulum affects its oscillation.

State the independent, dependent and constant variables in this investigation.



Independent variable: ***Length of thread***

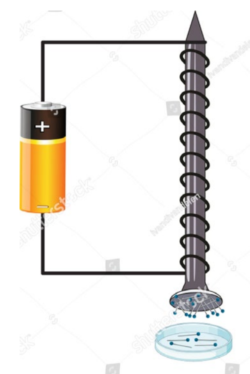
Dependent variable: ***Period of oscillation/ Time taken for one oscillation***

Constant variable(s): ***Initial angle of release;***
Position of bob to measure one oscillation;
Mass of pendulum bob; Number of oscillations;

PRACTICE B2

Suppose I want to investigate how the number of turns of coil affects the number of paper clips attracted to the nail.

State the independent, dependent and constant variables in this investigation.



Independent variable: ***Number of turns of coil per unit length of the solenoid***

Dependent variable: ***Number of pins attracted to the nail***

Constant variable(s): ***Current in solenoid; Number of pins used;***
Orientation of the nail;
Horizontal distance between the nail and pins

(C) Outline an investigative procedure to investigate the problem/question

Once we have identified the various variables, the next step is to describe the procedure to investigate the relationship given in the question. The following are the items to be included in the procedure:

Constant variable(s):	To state the variable(s) (and describe how to keep them constant if the question asked for it).
Independent variable:	To include the following details: 1. measuring instrument to be used 2. how to measure the variable 3. how to vary the variable (to obtain several values of it) 4. how to manipulate to the form to plot on the graph, if necessary
Dependent variable:	To include the following details: 1. measuring instrument to be used 2. how to measure the variable 3. indicate to repeat the steps for the same value of the independent variable to find the average value of the measurement for dependent variable
Repeat:	the steps described for both independent and dependent variables above.
Wide (range):	the range of values for the independent variable to be conducted for the experiment (do not need to state the range itself).
Seven	To state that seven sets of data to be collected i.e. conduct the experiment over seven distinct values of the independent variable.

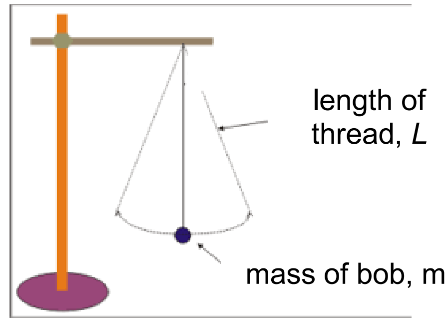
EXAMPLE

For the rod rolling down the slope, we describe the procedure as follows:

1. The constant variables are initial speed of the marble and the angle of the slope.
2. The independent variable is D, distance travelled by the rod along the slope.
3. Use the metre rule to measure D. We can vary D by changing the starting position of the rod released along the slope.
4. The dependent variable is the time, t for the rod to roll down the distance D along the slope.
5. Use a stopwatch to record the time, t for the rod to roll down the slope for a specific distance, D. We then square t itself to find t^2.
6. Repeat step 5 for the same value of D to find the average value of t^2.
7. Repeat steps 3 to 6 for a wide range of D to get seven sets of values for D and t^2.

PRACTICE C1

Describe an experiment to test if the square of the period of a pendulum, T^2 is directly proportional to the length of its string, L.



1. ***Set up the apparatus as shown in the diagram.***

   (Note: We can use the diagram if it is already given in the question. We do not need to draw a new diagram ourselves.)

2. ***The constant variables are the angle of release, the number of oscillations and the mass of pendulum.***
3. ***Measure the length of the string, L using the metre rule. L is the independent variable.***
4. ***Vary L by increasing or decreasing the length of the string.***
5. ***Pull the pendulum to the side and release it. Allow its oscillations to be steady before determining the time for 20 oscillations, t_1 with the stopwatch.***
6. ***Repeat step 5 to obtain a second value of the time for 20 oscillations, t_2.***
7. ***Determine $t_{av} = \frac{1}{2}(t_1 + t_2)$***
8. ***Calculate the period, $T = t_{av} / 20$ and hence T^2.***
9. ***Repeat steps 3 to 8 for a wide range of L for seven sets of data for L and T^2.***

PRACTICE C2

Describe an experiment to investigate how the duration of heating of a beaker of water affects its temperature rise.

1. ***Set up the apparatus as shown in the diagram.***
2. ***The constant variables are the volume of water used, the position of the thermometer and initial starting temperature of the water.***
3. ***Measure the initial temperature of the water, T_1.***
4. ***Turn on the heater and start the stopwatch.***
5. ***After 3 minutes, stop the stopwatch and record T_2. Record the time t on the stopwatch as well.***
6. ***Determine $\Delta T = T_2 - T_1$***
7. ***Repeat steps 3 to 6 to obtain another value for ΔT and calculate the average value for ΔT. Top up the water if needed.***
8. ***Repeat steps 3 to 7 for a wide range of ΔT for seven sets of data for ΔT and t.***

(D) Others

There are questions after the description of the procedure, and they typically include:

a. state the type of graph to be plotted
b. sketch the type of graph obtained if the relationship is true
c. how to use the graph to determine some physical quantity in the equation given
d. stating of precautions to be observed during the experiment
e. questions related to accuracy and / or sources of errors
f. questions related to safety

We have to answer these questions as well by continuing from the end of the procedure describing the experiment we intend to conduct to investigate the relationship.

EXAMPLE

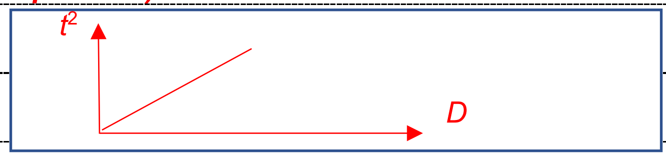
For the rod rolling down the slope (see page 8), the subsequent questions after the procedure include:

- sketch the graph that you will obtain if the suggested relationship is correct
- explain how you will find *a* from the graph.

Continuation from the procedure described previously in page 8.

Sketch a graph of t^2 against D.

Note: It is always a graph of y-axis (dependent) variable against x-axis (independent) variable



Gradient of graph, G = 2 / a → a = 2 / G

FROM EXAMPLE C1

Additional questions for Example C1 can include:

- state the graph that you will sketch
- describe the graph you will obtain if the relationship is true

Continuation from the procedure described previously in page 9.

Sketch a graph of T^2 against L.

If T^2 is directly proportional to L, graph should be a straight line passing through the origin.

FROM EXAMPLE C2

Additional questions for Example C2 can include:

- state the graph that you will sketch

Continuation from the procedure described previously in page 10.

Sketch a graph of ΔT against t.

(3) Example 1 – O-Level Specimen Paper 3 (Physics Syllabus 6091)

1 *In this experiment, you will investigate the extension of a spring in a simple model of a suspension bridge.*

You have been provided with

- a spring,
- a stand, labelled A with boss and clamp,
- a mass labelled M,
- a 30 cm rule,
- a set square,
- a metre rule with holes at the 10.0 cm and 90.0 cm marks,
- a second stand labelled B, with a boss and clamp to hold the pivot,
- a pivot,
- a loop of string,
- an S-hook.

(a) Measure and record the unstretched length *L* of the coiled part of the spring, as shown in Fig. 1.1.

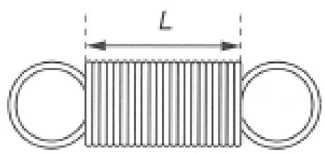


Fig. 1.1

L = ... [1]

(b) You are to set up the apparatus as shown in Fig. 1.2.

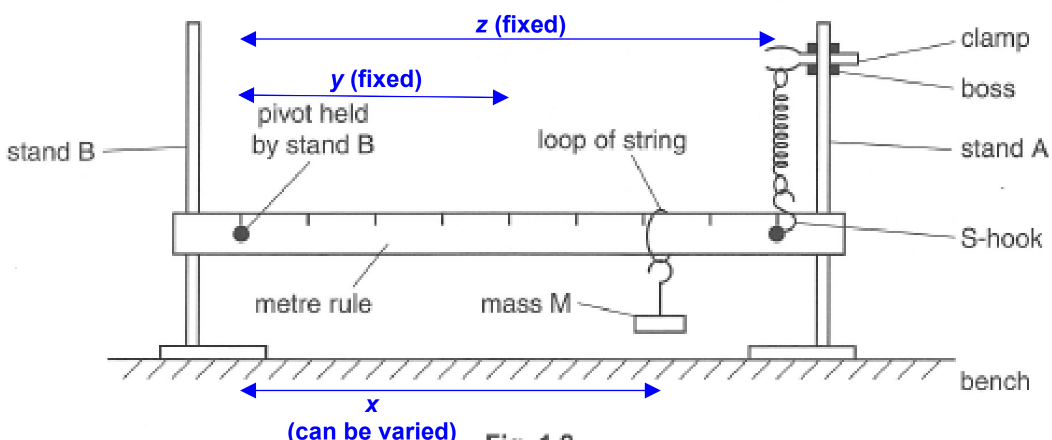


Fig. 1.2

- Suspend the metre rule at the 10 cm mark, using the pivot held in stand B.
- Use the loop of string to suspend mass M from the metre rule at the 70 cm mark.
- Pass the S-hook through the hole in the metre rule at the 90 cm mark.
- Attach the S-hook to the spring and use stand A to support the metre rule.
- Adjust the height of the boss on stand A so that the metre rule is horizontal.

(i) Measure and record the new length L_1 of the coiled part of the spring and determine the extension e of the spring using the equation

$$e = L_1 - L.$$

L_1 = ...

e = ...

[1]

(ii) The upward force T exerted by the spring is given the equation

$$T = ke$$

where k is the spring constant of the spring and e is the extension of the spring.

Given that k is 0.25 N / cm, calculate T.

T = ... [1]

c) When the metre rule is horizontal, the principle of moments gives the equation

$$W_R y + Wx = Tz$$

where

- W_R is the weight of the metre rule,
- W is the weight of mass M,
- x is the distance between the pivot and loop of string,
- y is the distance between the pivot and the centre of mass of the metre rule,
- z is the distance between the pivot and the S-hook.

(i) With the metre rule horizontal, record the values of x, y and z.

x = ...

y = ...

z = ...

[1]

(ii) Using your value for T from **(b)(ii)** and your values in **(c)(i)**, calculate a value for W_R. Assume that the centre of mass of the metre rule is at its centre and W = 1.96 N.

W_R = ... [1]

- Suspend the metre rule at the 10 cm mark, using the pivot held in stand B.
- Use the loop of string to suspend mass M from the metre rule at the 70 cm mark.
- Pass the S-hook through the hole in the metre rule at the 90 cm mark.
- Attach the S-hook to the spring and use stand A to support the metre rule.
- Adjust the height of the boss on stand A so that the metre rule is horizontal.

(i) Measure and record the new length L_1 of the coiled part of the spring and determine the extension e of the spring using the equation

$$e = L_1 - L\ .$$

L_1 = ...

e = ...
[1]

(ii) The upward force T exerted by the spring is given the equation

$$T = ke$$

where k is the spring constant of the spring and e is the extension of the spring.

Given that k is 0.25 N / cm, calculate T.

T = ... [1]

c) When the metre rule is horizontal, the principle of moments gives the equation

$$W_R y + W x = T z$$

where

- W_R is the weight of the metre rule,
- W is the weight of mass M,
- x is the distance between the pivot and loop of string,
- y is the distance between the pivot and the centre of mass of the metre rule,
- z is the distance between the pivot and the S-hook.

(i) With the metre rule horizontal, record the values of x, y and z.

x = ...

y = ...

z = ...
[1]

(ii) Using your value for T from **(b)(ii)** and your values in **(c)(i)**, calculate a value for W_R.
Assume that the centre of mass of the metre rule is at its centre and W = 1.96 N.

W_R = ... [1]

(d) Plan

The equation in (c) may be written in the form

$$T = \frac{Wx}{z} + \frac{W_R y}{z}.$$

Using the same apparatus as in Fig. 1.2, plan an e

Your plan should include

$T = \frac{W}{z}(x) + \frac{W_R y}{z}$

$\Rightarrow y = mx + c$

$y = T$ (upward force exerted by spring)

$x = x$ (distance between pivot and loop of string)

gradient, $m = \frac{W}{z}$

y-intercept, $c = \frac{W_R y}{z}$

- a list of the quantities that remain constant, *(see step 1)*
- a description of how you would perform the experiment, *(see steps 2 to 7)*
- a statement of the graph that you would plot to test the relationship, *(see step 8)*
- an explanation of how W_R would be found from the graph. *(see step 9)*

1. The constant variables are W (weight of mass M), y (distance between pivot and centre of mass of metre rule) and z (distance between pivot and S-hook).

2. Independent variable is x, distance between pivot and loop of string.

3. Measure x using a metre rule. Vary x by shifting the mass along the ruler and adjust the position of the height of the boss on stand A so that the metre rule is horizontal.

4. Measure the new length of the coiled part of spring, L_1 and determine the extension, $e = L_1 - L$ where L is the unstretched length of the coiled part of spring.

5. Repeat steps 3 and 4 to find e_{av}.

6. Determine T (dependent variable) = ke_{av} where k is the spring constant of 0.25 N / cm.

7. Repeat steps 3 to 6 for a wide range of x for seven sets of x and T.

8. Plot a graph of T against x.

9. y-intercept = $\frac{W_R y}{z} \Rightarrow W_R = \frac{(\text{y-intercept})(z)}{y}$

(4) Example 2 – Physics Syllabus 5052 Nov 2008

1 *In this experiment you will make measurements on a stand in order to investigate the stability. You will then plan an investigation into the stability of the stand.*

You have been provided with

- a stand,
- a metre rule,
- a set square,
- a newton meter, with a loop of thread at the end.

(a) **(i)** Fig. 1.1 below shows the edges A and B of the stand.

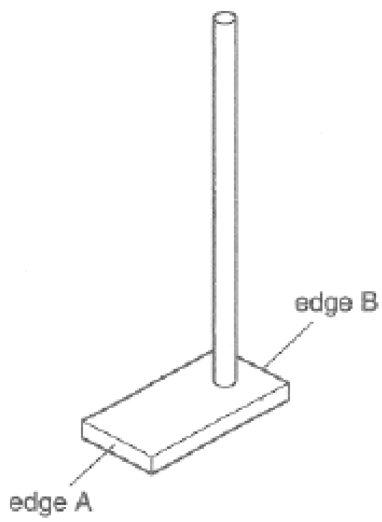


Fig. 1.1

Place the edge B of the base of the stand against the edge of the thick card, which is taped to the bench. Attach the newton meter to P, a point 1 cm below the top of the stand, as shown in Fig. 1.2.

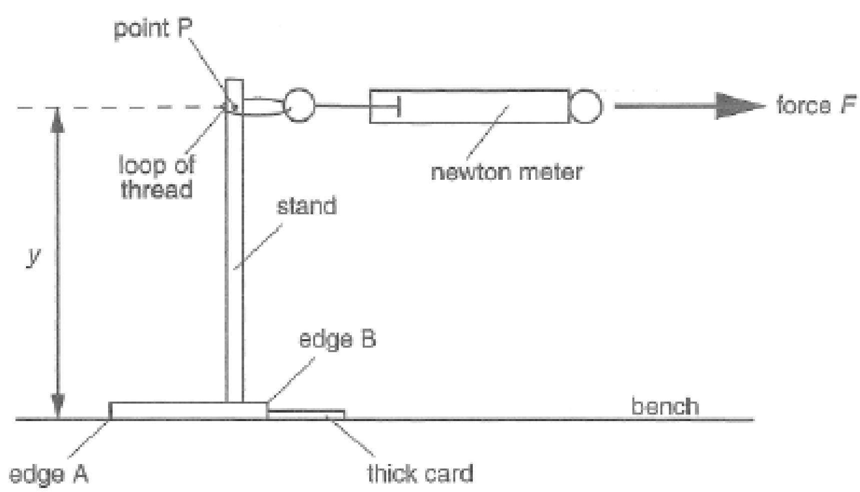


Fig. 1.2

(ii) Record the distance y between point P and the bench.

y = ... [1]

(iii) Pull the newton meter horizontally until the edge A of the stand just starts to rise. Record the force F required to just raise the edge A.

F = ... [1]

(b) When the edge A of the stand just starts to rise, the following equation applies:

$$W x = F y$$

where W is the weight of the stand that is given on the card,
x is the horizontal distance of the centre of the mass of the stand from the edge B.

Using your results from (a) and the value of W that is given on the card, calculate a value for x. Show your working.

x = ... [2]

(c) (i) Using a second value for y, determine a second value for F. Record y and F.

y = ...

F = ...
[1]

(ii) Determine a second value for x.

x = ... [1]

(d) Move the stand well away from the card.

Position the newton meter so that y = 5 cm. Pull the newton meter horizontally. Observe what happens and record your observations.

....

....

.... [1]

Plan

(e) The equation in (b) may be re-written in the form

$$F = (W x)\,(\frac{1}{y})$$

Describe how to extend the above experiment to obt[ain] from a line graph. Your plan should include

$F = (W x)\,(\frac{1}{y})$

$\Rightarrow y = mx$

$y = F$

$x = \frac{1}{y}$

gradient, $m = Wx$

- a description of how you would perform the experiment, *(see steps 1 to 5)*
- a sketch of the graph that you would plot, *(see step 6)*
- how you would determine x from the graph. *(see step 7)*

1. The independent variable is $\frac{1}{y}$. Measure y using a metre rule and calculate $\frac{1}{y}$.

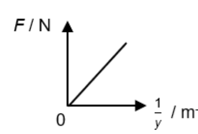
2. Vary y by shifting the loop of string along the stand.

3. Determine F, the dependent variable, by pulling the newton meter horizontally until edge A just starts to rise, and recording the value on the newton meter.

4. Repeat steps 2 and 3 to find another value of F and then find the average of the two values of F.

5. Repeat steps 1 to 4 for a wide range of $\frac{1}{y}$ to obtain seven sets of F and $\frac{1}{y}$.

6. Plot a graph of F against $\frac{1}{y}$. The sketch of the graph obtained:



7. Gradient of graph, m = Wx → x = m / W

....

....

(5.1) Practice 1 (5064 N2017)

In this experiment, you will investigate a type of semiconducting diode called a light-emitting diode (LED), which is a semiconducting diode that emits light.

You have been provided with

- a power supply,
- a switch,
- a light-emitting diode (LED),
- a 270 Ω resistor,
- connecting leads.

You have been provided with the circuit as shown in Fig. 1.1, with the terminals X, Y and Z labelled. The 270 Ω resistor is connected into the circuit between Y and Z.

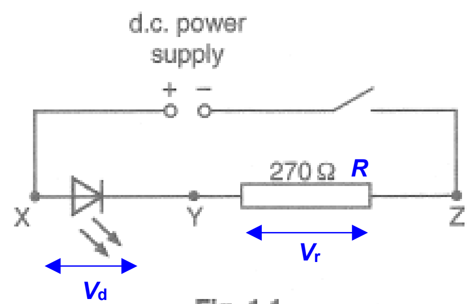


Fig. 1.1

You have also been provided with

- a 560 Ω resistor,
- a voltmeter with two connecting leads.

(a) **(i)** Connect the voltmeter to measure the potential difference (p.d.) V_r across the 270 Ω resistor.
Close the switch and record V_r.

V_r = ...[1]

(ii) Open the switch and connect the voltmeter to measure the p.d. V_d across the LED. Close the switch and record V_d.

V_d = ...[1]

(iii) Open the switch and disconnect the voltmeter.

Calculate the current I in the circuit using the relationship

$$I = \frac{V_r}{R}$$

where R is the resistance of the resistor that is in the circuit.

I = ...[1]

(iv) Calculate the power P dissipated in the LED using the relationship

$$P = IV_d.$$

$P =$ ....[1]

(b) Disconnect the 270 Ω resistor from the circuit and replace it with the 560 Ω resistor. Repeat **(a)** to obtain new values for V_r, V_d, I and P.

$V_r =$ ....

$V_d =$ ....

$I =$ ....

$P =$ ....
[3]

(c) It is suggested that P is directly proportional to I so that the quantities are related by an equation of the form $P = kI$, where k is a constant.

(i) Determine two values for k, one using the results from **(a)** and the other using the results from **(b)**. Give your values to an appropriate number of significant figures.

k from **(a)** = ...

k from **(b)** = ...
[2]

(ii) State and explain whether your values for k support the suggestion.

....

....

....

....[1]

(d) **Plan**

Plan an experiment to further investigate the relationship $P = kI$ for the LED.

Your plan should include

- a statement of the additional apparatus that you would require, *(see step 1)*
- a detailed description of how you would perform the experiment, *(see steps 2 to 6)*
- a statement of the graph that you would plot to test the relationship, *(see step 7)*
- a sketch of the graph, if the relationship is true, *(see step 7)*
- the expected values for the gradient and the intercept. *(see steps 8 and 9)* [5]

$P = kI$
$\Rightarrow y = mx$

$y = P$
$x = I$
gradient, $m = k$

1. The additional equipment are an ammeter, and at least 7 different resistors.

2. The independent variable is I. Connect the ammeter in series with the resistor. Measure I by reading off the measurement on the ammeter.

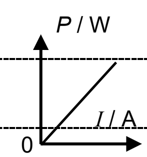
3. Vary I by connecting the 7 different resistors between Y and Z.

4. The dependent variable is P. To obtain P, we first measure V_d using the voltmeter connected across the LED. Calculate $P = IV_d$.

5. Repeat steps 2 and 4 to find another value of P and then find the average of the two values of P.

6. Repeat steps 2 to 5 for a wide range of I to obtain seven sets of P and I.

7. Plot a graph of P against I. The sketch of the graph obtained:



8. Gradient = V_d

9. y-intercept = 0

(5.2) Practice 2 (5057 N2013)

In this experiment, you will investigate the period of a simple pendulum and then plan a further experiment.

You have been provided with

- a pendulum bob attached to a string,
- two blocks of wood,
- a clamp, boss and stand,
- a metre rule,
- a stopwatch,
- a pin in a piece of Blu-Tack.

(a) Set up the apparatus shown in Fig. 1.1. Clamp the string between the two blocks of wood. Adjust the distance l between the bottom of the two blocks of wood and the **centre** of the pendulum bob so that $l = 50.0\,\text{cm}$.

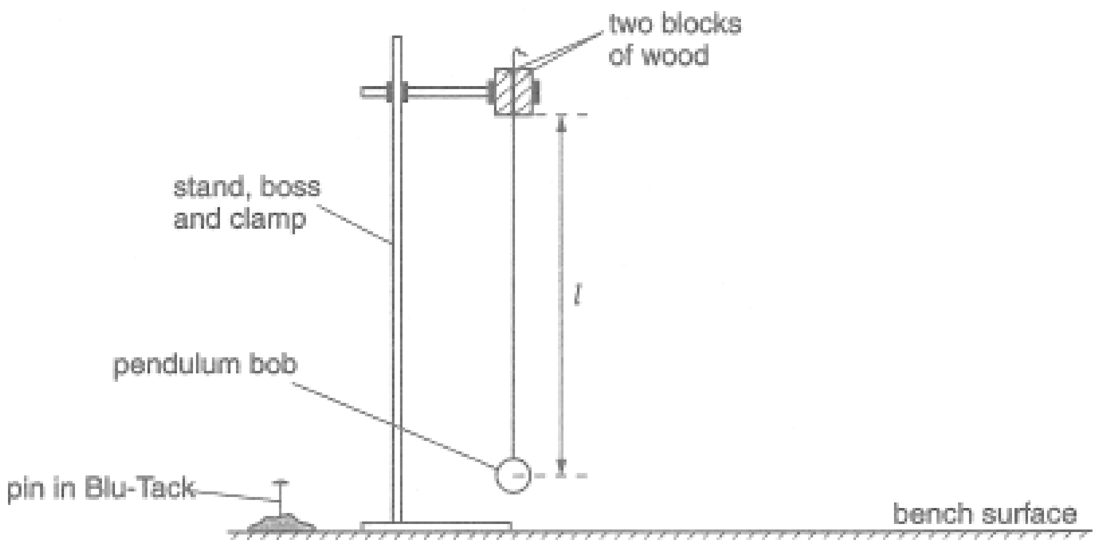


Fig. 1.1

(b) The pin in the Blu-Tack is to act as a marker to help you determine accurately the period T of the pendulum. Move the pin to the best position for this purpose. State and explain your choice of position.

....

....

....[1]

(c) Take measurements to determine an accurate value of the period T of the pendulum.

T = ... [2]

(d) It is expected that T and l obey the relationship

$$T^2 = kl$$

where k is a constant.

Use your results from **(c)** to determine a value for k. Give a unit for your answer.

k = ... [2]

(e) Repeat **(a)** and **(c)** for a pendulum of length l = 30.0 cm in order to obtain a second value for k.

k = ... [4]

$T^2 = k\,l$
$\Rightarrow\ y = mx$

$y = T^2$
$x = l$
gradient, $m = k$

(f) Plan

Plan an experiment to investigate the relationship in (d). Your pla

- a description of how you would perform the experiment, *(see steps 1 to 6)*
- an indication of any special precautions that you would take in order to measure l accurately, *(see step 7)*
- a statement of the graph that you would plot to test the relationship, *(see step 8)*
- an explanation of how k is found from the graph. *(see step 9)* [6]

1. The independent variable is the length of pendulum, l. Measure l using a metre rule.

2. Vary l by changing the length of the string tied to the pendulum bob.

3. The dependent variable is T. Measure the time, t_1 for 20 oscillations with a stopwatch.

4. Repeat steps 1 and 3 for another value of t_2 and find the average of the two values

$t_{av} = ½ (t_1 + t_2)$

5. Determine period of the oscillation, $T = t_{av} / 20$. Find T^2.

6. Repeat steps 1 to 5 for a wide range of l to obtain seven sets of T^2 and l.

7. Special precautions: measure l to the centre of the pendulum bob, reading the marking of l by positioning the eye perpendicular to the mark on the ruler.

8. Plot a graph of T^2 against l.

9. Gradient of graph = k.