PEARSON

PHYSICS QUEENSLAND

UNITS 3 & 4

Doug Bail

2nd EDITION

Skills and Assessment

QCE 2025 Physics SYLLABUS

Contents

Contents

UNIT 4: REVOLUTIONS IN MODERN PHYSICS

How to use this book

The *Pearson Physics Queensland Units 3 & 4 Skills and Assessment Book 2nd edition* takes an intuitive, self-paced approach to science education that ensures every student has opportunities to practise, apply and extend their learning through a range of supportive and challenging activities.

This resource has been developed by highly experienced and expert author teams, with lead Queensland specialists who have a working understanding of what teachers are looking for with teaching and learning across the new QCE.

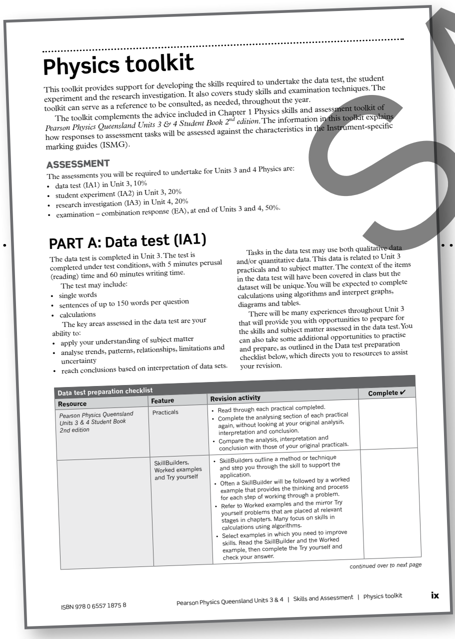
Fully written to the new QCE Units 3 & 4 syllabus, the *Skills and Assessment Book* is organised by units. The unit opener outlines the unit objectives.

The *Skills and Assessment Book* is further organised into topics. Each topic addresses all of the subject matter and practicals from the syllabus.

All activities compliment material in the *Pearson Physics Queensland Units 3 & 4 Student Book 2nd edition* for a complete teaching, learning and assessment program, facilitating the integration of practice and rich learning activities. The resource has been designed so it may be used independently of the Student Book, providing flexibility in when and how to engage with it.

Toolkit

A complementary Physics Skills and Assessment Toolkit supports development of the skills and techniques needed to undertake practical investigations, the data test, student experiment and research investigation. It also includes checklists and helpful hints to assist in fulfilling all assessment requirements and to support further development of study skills.



Physics toolkit

This toolkit provides support for developing the skills required to undertake the data test, the student experiment and the research investigation. It also covers study skills and examination techniques. The toolkit can serve as a reference to be consulted, as needed, throughout the year.

ASSESSMENT

PART A: Data test (IA1)

Topic opener

The book is split into two units with 2–3 topics per unit, as per the syllabus. While the unit opener provides an overview of the syllabus outcomes for each unit, the topic opener gives a succinct overview of the content in the book for each topic, organised by key content area. Each topic opener is presented in a handy checklist format to allow you to track your progress.

TOPIC 1 Gravity and motion

- Worksheet 3.1.1 Knowledge preview—straight-line motion

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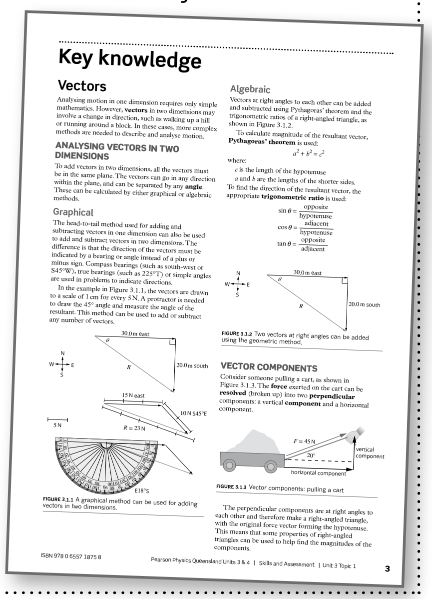
- Worksheet 3.1.6 Literacy review—motion
- Worksheet 3.1.7 Thinking about my learning
- Unit 3 Topic 1 Exam practice

Key knowledge

Each topic begins with a key knowledge section. The key knowledge consists of a set of succinct summary notes that cover the subject matter for each topic of the syllabus. This section is highly illustrative and written in a straightforward style to assist students of all abilities to focus on the salient points. Key terms are in bold for ease of navigation and are reflected in the Student Book glossary. Key knowledge also serves as a ready reference when completing worksheets and practical activities, and it provides a handy set of revision and study notes.



Key knowledge

Vectors

ANALYSING VECTORS IN TWO DIMENSIONS

Graphical

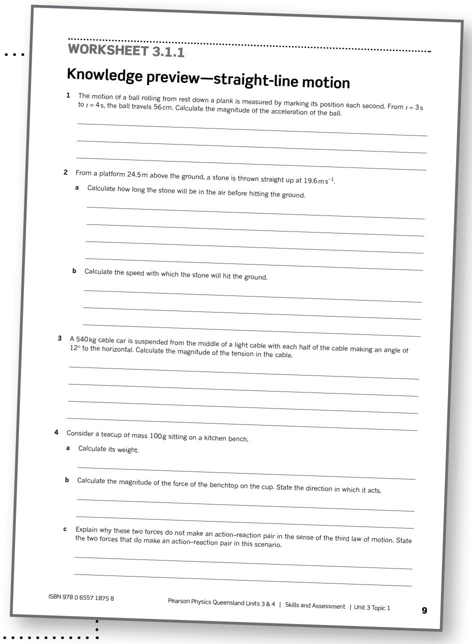
Algebraic

VECTOR COMPONENTS

Worksheets

A diverse offering of instructive and self-contained worksheets is included in each topic. Common to all topics are the initial 'Knowledge preview' worksheets to activate prior knowledge; a 'Literacy review' worksheet to explicitly build language and the application of scientific terminology; and, finally, a 'Thinking about my learning' worksheet, which encourages students to reflect on their learning and identify areas for improvement. Other worksheets, with their range of activities and tasks, focus on the application of subject matter to assist in the consolidation of learning and the making of connections between subject matter.

Worksheets may be used for formative assessment and are clearly aligned to the syllabus. A range of questions, building from foundation to challenging, is included in the worksheets, which are written to reflect the Marzano and Kendall taxonomy instructional verbs.


WORKSHEET 3.1.1

Knowledge preview—straight-line motion

1 The motion of a ball rolling from rest down a plank is measured by marking its position each second. From $t = 3$ s to $t = 4$ s, the ball travels 56 cm. Calculate the magnitude of the acceleration of the ball.

2 From a platform 24.5 m above the ground, a stone is thrown straight up at 19.6 m s^{-1}.

a Calculate how long the stone will be in the air before hitting the ground.

b Calculate the speed with which the stone will hit the ground.

3 A 540 kg cable car is suspended from the middle of a light cable with each half of the cable making an angle of 12° to the horizontal. Calculate the magnitude of the tension in the cable.

4 Consider a teacup of mass 100 g sitting on a kitchen bench.

a Calculate its weight.

b Calculate the magnitude of the force of the benchtop on the cup. State the direction in which it acts.

c Explain why these two forces do not make an action–reaction pair in the sense of the third law of motion. State the two forces that do make an action–reaction pair in this scenario.

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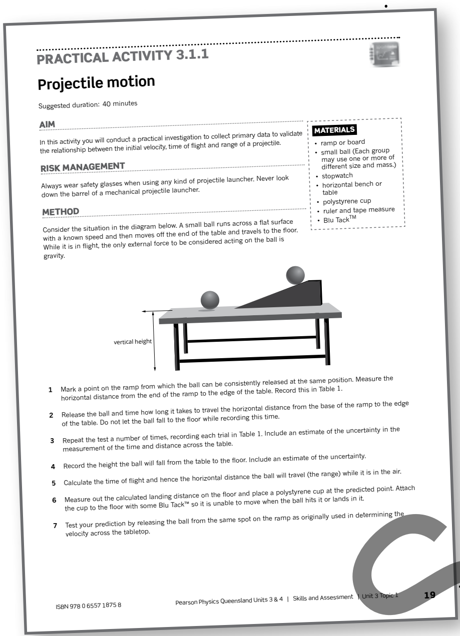
Practical activities

Practical activities take a highly scaffolded approach from beginning to completion and give students the opportunity to complete practical work related to the subject matter covered in the syllabus. Practical activities include a rich assortment of tasks that maximise learning opportunities and build experience in performing calculations and analysis of data, which are necessary for the data test. Every mandatory practical in the syllabus is featured, as well as many suggested practicals. As with the worksheets, the practical activities include a range of questions building from foundation to challenging, written to reflect the Marzano and Kendall taxonomy instructional verbs.


PRACTICAL ACTIVITY 3.1.1

Projectile motion

Suggested duration: 40 minutes

AIM

In this activity you will conduct a practical investigation to collect primary data to validate the relationship between the initial velocity, time of flight and range of a projectile.

RISK MANAGEMENT

Always wear safety glasses when using any kind of projectile launcher. Never look down the barrel of a mechanical projectile launcher.

METHOD

Consider the situation in the diagram below. A small ball runs across a flat surface with a known speed and then moves off the end of the table and travels to the floor. While it is in flight, the only external force to be considered acting on the ball is gravity.

MATERIALS
- ramp or board
- small ball (Each group may use one or more of different size and mass.)
- stopwatch
- horizontal bench or table
- polystyrene cup
- ruler and tape measure
- Blu Tack™

1 Mark a point on the ramp from which the ball can be consistently released at the same position. Measure the horizontal distance from the end of the ramp to the edge of the table. Record this in Table 1.

2 Release the ball and time how long it takes to travel the horizontal distance from the base of the ramp to the edge of the table. Do not let the ball fall to the floor while recording this time.

3 Repeat the test a number of times, recording each trial in Table 1. Include an estimate of the uncertainty in the measurement of the time and distance across the table.

4 Record the height the ball will fall from the table to the floor. Include an estimate of the uncertainty.

5 Calculate the time of flight and hence the horizontal distance the ball will travel (the range) while it is in the air.

6 Measure out the calculated landing distance on the floor and place a polystyrene cup at the predicted point. Attach the cup to the floor with some Blu Tack™ so it is unable to move when the ball hits it or lands in it.

7 Test your prediction by releasing the ball from the same spot on the ramp as originally used in determining the velocity across the tabletop.

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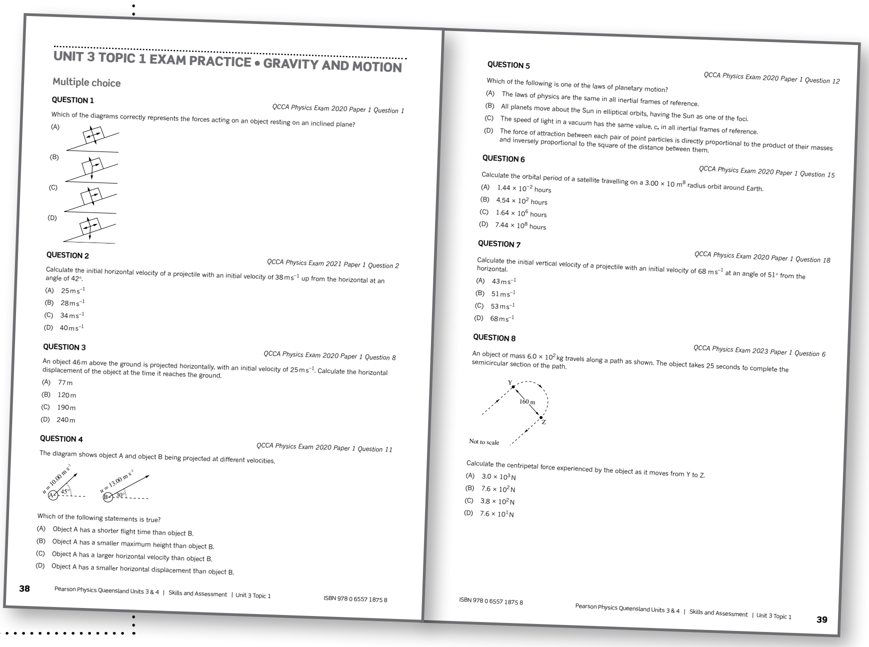
Exam practice

Each topic concludes with a set of questions taken directly, or adapted, from previous QCAA exams. These questions have been selected to best represent the content within these exams and include both multiple choice and short response questions. Exam practice questions provide an excellent opportunity to experience the subject matter and skills across the breadth of the topic from the perspective of QCAA exams. They also reflect the cognitive verbs used in the syllabus subject matter dot points.


UNIT 3 TOPIC 1 EXAM PRACTICE • GRAVITY AND MOTION

Multiple choice

QUESTION 1 QCAA Physics Exam 2020 Paper 1 Question 1

Which of the diagrams correctly represents the forces acting on an object resting on an inclined plane?

(A) (B) (C) (D)

QUESTION 2 QCAA Physics Exam 2021 Paper 1 Question 2

Calculate the initial horizontal velocity of a projectile with an initial velocity of 38 m s^{-1} up from the horizontal at an angle of 42°.

(A) 25 m s^{-1}
(B) 28 m s^{-1}
(C) 34 m s^{-1}
(D) 40 m s^{-1}

QUESTION 3 QCAA Physics Exam 2020 Paper 1 Question 8

An object 46 m above the ground is projected horizontally, with an initial velocity of 25 m s^{-1}. Calculate the horizontal displacement of the object at the time it reaches the ground.

(A) 77 m
(B) 120 m
(C) 190 m
(D) 240 m

QUESTION 4 QCAA Physics Exam 2020 Paper 1 Question 11

The diagram shows object A and object B being projected at different velocities.

Which of the following statements is true?

(A) Object A has a shorter flight time than object B.
(B) Object A has a smaller maximum height than object B.
(C) Object A has a larger horizontal velocity than object B.
(D) Object A has a smaller horizontal displacement than object B.

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QUESTION 5 QCAA Physics Exam 2020 Paper 1 Question 12

Which of the following is one of the laws of planetary motion?

(A) The laws of physics are the same in all inertial frames of reference.
(B) All planets move about the Sun in elliptical orbits, having the Sun as one of the foci.
(C) The speed of light in a vacuum has the same value, c, in all inertial frames of reference.
(D) The force of attraction between each pair of point particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

QUESTION 6 QCAA Physics Exam 2020 Paper 1 Question 15

Calculate the orbital period of a satellite travelling on a 3.00 × 10 m^{8} radius orbit around Earth.

(A) 1.44 × 10^{-2} hours
(B) 4.54 × 10^{2} hours
(C) 1.64 × 10^{6} hours
(D) 7.44 × 10^{6} hours

QUESTION 7 QCAA Physics Exam 2020 Paper 1 Question 18

Calculate the initial vertical velocity of a projectile with an initial velocity of 68 m s^{-1} at an angle of 51° from the horizontal.

(A) 43 m s^{-1}
(B) 51 m s^{-1}
(C) 53 m s^{-1}
(D) 68 m s^{-1}

QUESTION 8 QCAA Physics Exam 2023 Paper 1 Question 6

An object of mass 6.0 × 10^{2} kg travels along a path as shown. The object takes 25 seconds to complete the semicircular section of the path.

Calculate the centripetal force experienced by the object as it moves from Y to Z.

(A) 3.0 × 10^{3} N
(B) 7.6 × 10^{2} N
(C) 3.8 × 10^{2} N
(D) 7.6 × 10^{1} N

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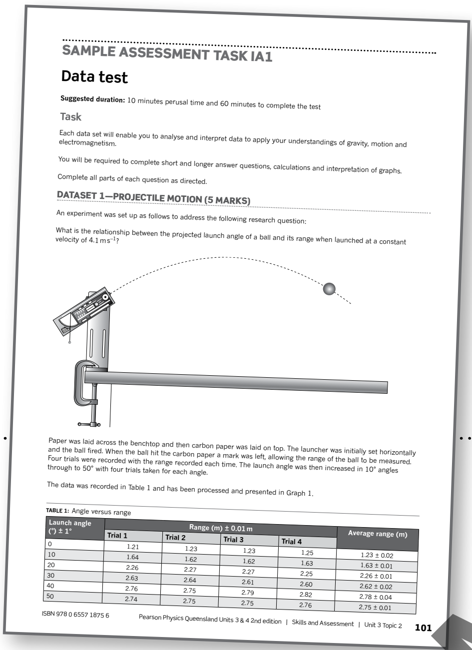
Sample assessment tasks

Sample assessment tasks for the data test, student experiment and research investigation provide opportunities for students to practise responding to these assessment tasks. The activities are designed to support students by guiding and scaffolding them through each aspect of these assessments.



SAMPLE ASSESSMENT TASK IA1

Data test

Suggested duration: 10 minutes perusal time and 60 minutes to complete the test

Task

Each data set will enable you to analyse and interpret data to apply your understandings of gravity, motion and electromagnetism.

You will be required to complete short and longer answer questions, calculations and interpretation of graphs.

Complete all parts of each question as directed.

DATASET 1—PROJECTILE MOTION (5 MARKS)

An experiment was set up as follows to address the following research question:

What is the relationship between the projected launch angle of a ball and its range when launched at a constant velocity of 4.1 $m\,s^{-1}$?

Paper was laid across the benchtop and then carbon paper was laid on top. The launcher was initially set horizontally and the ball fired. When the ball hit the carbon paper a mark was left, allowing the range of the ball to be measured. Four trials were recorded with the range recorded each time. The launch angle was then increased in 10° angles through to 50° with four trials taken for each angle.

The data was recorded in Table 1 and has been processed and presented in Graph 1.

TABLE 1: Angle versus range

Launch angle (°) ± 1°	Range (m) ± 0.01 m				Average range (m)
	Trial 1	Trial 2	Trial 3	Trial 4	
0	1.21	1.23	1.23	1.25	1.23 ± 0.02
10	1.64	1.62	1.62	1.63	1.63 ± 0.01
20	2.26	2.27	2.27	2.25	2.26 ± 0.01
30	2.63	2.64	2.61	2.60	2.62 ± 0.02
40	2.76	2.75	2.79	2.82	2.78 ± 0.04
50	2.74	2.75	2.75	2.76	2.75 ± 0.01

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Icons and features

Every practical is supported by a complementary SPARKlab alternative practical.

The **safety icon** highlights significant hazards, indicating caution is needed.

The **safety glasses icon** highlights that protective eyewear is to be worn during the practical activity.

Rate my learning

This innovative feature assists students to reflect on their learning and appears at the end of most worksheets, practical activities and sample assessment tasks. It provides students with the opportunity for self-reflection and self-assessment. Students are encouraged to consider how they can continue to improve, and to identify areas of focus for further skill and subject matter development. This tool is based on Marzano and Kendall's taxonomy.

RATE MY LEARNING	• I get it. • I can apply/teach it.	• I get it. • I can show I get it.	• I almost get it. • I might need help.	• I get some of it. • I need help.	• I don't get it. • I need lots of help.

Teacher support

Fully worked solutions, suggested answers and responses to sample assessment tasks, as well as practical activity support including full **risk assessments, expected results** and **handy hints**, are provided for teachers through the teacher support subscription.

Physics toolkit

This toolkit provides support for developing the skills required to undertake the data test, the student experiment and the research investigation. It also covers study skills and examination techniques. The toolkit can serve as a reference to be consulted, as needed, throughout the year.

The toolkit complements the advice included in Chapter 1 Physics skills and assessment toolkit of *Pearson Physics Queensland Units 3 & 4 Student Book 2nd edition*. The information in this toolkit explains how responses to assessment tasks will be assessed against the characteristics in the Instrument-specific marking guides (ISMG).

ASSESSMENT

The assessments you will be required to undertake for Units 3 and 4 Physics are:

- data test (IA1) in Unit 3, 10%
- student experiment (IA2) in Unit 3, 20%
- research investigation (IA3) in Unit 4, 20%
- examination – combination response (EA), at end of Units 3 and 4, 50%.

PART A: Data test (IA1)

The data test is completed in Unit 3. The test is completed under test conditions, with 5 minutes perusal (reading) time and 60 minutes writing time.

The test may include:

- single words
- sentences of up to 150 words per question
- calculations

The key areas assessed in the data test are your ability to:

- apply your understanding of subject matter
- analyse trends, patterns, relationships, limitations and uncertainty
- reach conclusions based on interpretation of data sets.

Tasks in the data test may use both qualitative data and/or quantitative data. This data is related to Unit 3 practicals and to subject matter. The context of the items in the data test will have been covered in class but the dataset will be unique. You will be expected to complete calculations using algorithms and interpret graphs, diagrams and tables.

There will be many experiences throughout Unit 3 that will provide you with opportunities to prepare for the skills and subject matter assessed in the data test. You can also take some additional opportunities to practise and prepare, as outlined in the Data test preparation checklist below, which directs you to resources to assist your revision.

Data test preparation checklist

Resource	Feature	Revision activity	Complete ✔
Pearson Physics Queensland Units 3 & 4 Student Book 2nd edition	Practicals	• Read through each practical completed. • Complete the analysing section of each practical again, without looking at your original analysis, interpretation and conclusion. • Compare the analysis, interpretation and conclusion with those of your original practicals.	
	SkillBuilders, Worked examples and Try yourself	• SkillBuilders outline a method or technique and step you through the skill to support the application. • Often a SkillBuilder will be followed by a worked example that provides the thinking and process for each step of working through a problem. • Refer to Worked examples and the mirror Try yourself problems that are placed at relevant stages in chapters. Many focus on skills in calculations using algorithms. • Select examples in which you need to improve skills. Read the SkillBuilder and the Worked example, then complete the Try yourself and check your answer.	

continued over to next page

Data test preparation checklist			
Resource	**Feature**	**Revision activity**	**Complete ✔**
	Questions/ Instructions	• Refer to module and chapter reviews, focusing on instructions listed under ‘Analysis’. Many of these tasks require the same skills needed to complete the data test. • Select some tasks and complete them. • Check your answers against the fully worked solutions provided in your eBook.	
	Chapter 1 Physics skills and assessment toolkit	• Refer to the Chapter 1 Physics Skills and assessment toolkit, Part A, in the eBook. • Use this reference as needed, to improve your mathematical analysis and visual interpretation skills.	
Pearson Physics Queensland Units 3 & 4 Skills and Assessment Book 2nd edition	Practical activities	• See suggestions and support for practicals; these include working with data.	
	Topic review	• Refer to the topic review tasks for samples of the style of items on the data test.	
	Practice data test	• Complete the Sample assessment task IA1—Data test provided in this book. • Complete the data test under exam conditions.	

PART B: Student experiment (IA2)

The student experiment tests a research question by generating primary data that is then analysed to draw a conclusion.

The student experiment uses practical investigation methodology, including a research question you have developed, the collection of primary data, and the analysis and evaluation of that data.

The research question developed must:

- be an experiment relevant to Unit 3 subject matter to address their own related question
- modify (i.e. refine, extend or redirect) the practical.

CONDUCTING THE STUDENT EXPERIMENT

A great deal of preparation is needed before starting the experiment and much thought should be applied throughout the internal assessment task. Use the Student experiment checklist as a guide. Refer to *Pearson Physics Queensland Units 3 & 4 Student Book 2nd edition*, Chapter 1 ebook.

- Part A covers scientific skills such as mathematical basics, representations in graphics, tables and graphs, and data analysis.
- Part B covers all aspects of the student experiment and includes a sample student report.

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Student experiment checklist				
Task		**Activity**	**Due date**	**Complete ✔**
Form ideas and develop the experiment question	Initial practical	• Identify the practical to be modified for your experiment		
	Background	• Commence a journal to record all aspects of the assessment task • Research relevant background information		
	Variables	• Understand the data of original experiment • Identify the dependent and independent variables of original experiment		
	Modification	• Modify the original experiment • Develop a new research question • Write a statement of the aim that covers what the scientist wants to show, verify or find out in the experiment; this may be expressed as a statement or question, and may be one or two sentences. • The statement is often written as 'To investigate the effect of … on … ' or 'To investigate if a correlation exists between … and …' • Identify the dependant and independent variables and check they can be measured to provide data		
	Justification	• Justify/provide rationale for the modification for the new experiment question		
Find the procedure and data	Procedure	• Plan the method to be followed for the experiment		
	Materials	• Make a list of all equipment, chemicals and materials used • Include quantities (chemicals) and sizes (equipment)		
	Risk management	• Identify risk management strategies and potential dangers by completing the Risk Assessment Form on page xii		
	The experiment	• Conduct the experiment • Collect sufficient and relevant data to answer the research question • Record all measurements taken during the experiment as well as observations		
	Results	• Observations may be recorded as text, diagrams, photos or videos • Process data and present it clearly correctly • Most common records of primary data are tables with titles and units • Most common records of processed data are tables, graphs and can • include calculations • Check for errors and mistakes in data collected. Take steps to reduce these		
Analyse the evidence	Organise data collected	• Process the data using mathematical techniques and graphs • Identify the trends, patterns or relationships		
Interpret and **evaluate** the evidence	Work with data collected; relate back to the experiment question	• Draw conclusion/s from the evidence that addresses the experiment question • Include the interpretation of results • Identify the uncertainties and limitations of the evidence • Evaluate the reliability and validity of the experimental process • Provide suggestions to improve and/or extend the experiment • Evaluate the method used • Comment on whether results relate to the experiment question • Provide suggestions for improvements and extensions to the experiment		
The report	Presentation format	• Decide on the presentation format; written or multi modal • Check length requirements for your selected format		
	Communication	• Communicate ideas in scientific language and representations • Include in-text citations and reference list • Write using your own words to avoid plagiarising • Ensure length requirements are not exceeded.		

UNIT 3 Gravity and electromagnetism

TOPIC 1 Gravity and motion

TOPIC 2 Electromagnetism

Unit 3 objectives

Students will:

- describe ideas and findings about gravity and motion, and electromagnetism
- apply understanding of gravity and motion, and electromagnetism
- analyse data about gravity and motion, and electromagnetism
- interpret evidence about gravity and motion, and electromagnetism
- evaluate processes, claims and conclusions about gravity and motion, and electromagnetism
- investigate phenomena associated with gravity and motion, and electromagnetism.

TOPIC

1 Gravity and motion

- ☐ Worksheet 3.1.1 Knowledge preview—straight-line motion

VECTORS AND PROJECTILE MOTION

- ☐ Worksheet 3.1.2 Projectile motion
- ☐ Worksheet 3.1.3 Human cannonballs—projectile motion data analysis
- ☐ Practical activity 3.1.1 Projectile motion
- ☐ Practical activity 3.1.2 Projectile motion—the effect of launch angle on range

INCLINED PLANES AND CIRCULAR MOTION

- ☐ Worksheet 3.1.4 Uniform circular motion
- ☐ Practical activity 3.1.3 Forces down an incline
- ☐ Practical activity 3.1.4 Centripetal force in a horizontal plane

UNIVERSAL GRAVITATION AND ORBITAL MECHANICS

- ☐ Worksheet 3.1.5 Orbital motion
- ☐ Worksheet 3.1.6 Literacy review—motion
- ☐ Worksheet 3.1.7 Thinking about my learning
- ☐ **Unit 3 Topic 1 Exam practice**

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Key knowledge

Vectors

Analysing motion in one dimension requires only simple mathematics. However, **vectors** in two dimensions may involve a change in direction, such as walking up a hill or running around a block. In these cases, more complex methods are needed to describe and analyse motion.

ANALYSING VECTORS IN TWO DIMENSIONS

To add vectors in two dimensions, all the vectors must be in the same plane. The vectors can go in any direction within the plane, and can be separated by any **angle**. These can be calculated by either graphical or algebraic methods.

Graphical

The head-to-tail method used for adding and subtracting vectors in one dimension can also be used to add and subtract vectors in two dimensions. The difference is that the direction of the vectors must be indicated by a bearing or angle instead of a plus or minus sign. Compass bearings (such as south-west or S45°W), true bearings (such as 225°T) or simple angles are used in problems to indicate directions.

In the example in Figure 3.1.1, the vectors are drawn to a scale of 1 cm for every 5 N. A protractor is needed to draw the 45° angle and measure the angle of the resultant. This method can be used to add or subtract any number of vectors.

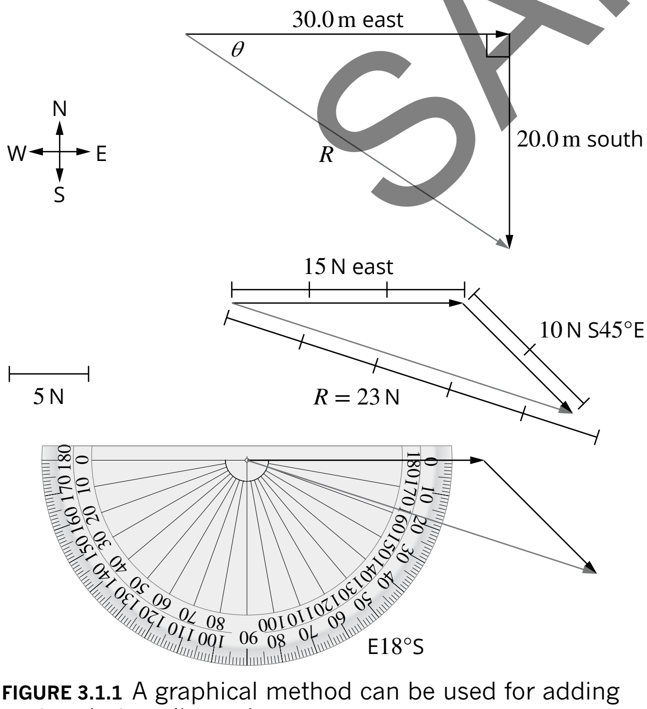

FIGURE 3.1.1 A graphical method can be used for adding vectors in two dimensions.

Algebraic

Vectors at right angles to each other can be added and subtracted using Pythagoras' theorem and the trigonometric ratios of a right-angled triangle, as shown in Figure 3.1.2.

To calculate magnitude of the resultant vector, **Pythagoras' theorem** is used:

$$a^2 + b^2 = c^2$$

where:

c is the length of the hypotenuse

a and b are the lengths of the shorter sides.

To find the direction of the resultant vector, the appropriate **trigonometric ratio** is used:

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}}$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}}$$

$$\tan\theta = \frac{\text{opposite}}{\text{adjacent}}$$

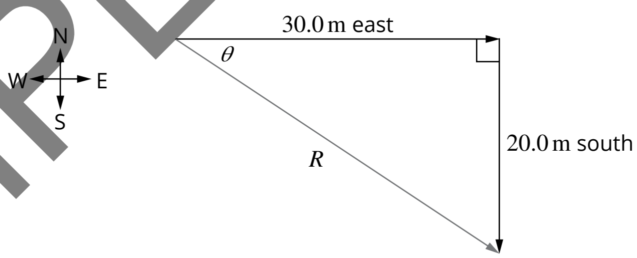

FIGURE 3.1.2 Two vectors at right angles can be added using the geometric method.

VECTOR COMPONENTS

Consider someone pulling a cart, as shown in Figure 3.1.3. The **force** exerted on the cart can be **resolved** (broken up) into two **perpendicular** components: a vertical **component** and a horizontal component.

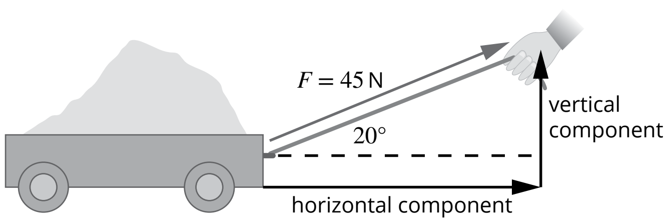

FIGURE 3.1.3 Vector components: pulling a cart

The perpendicular components are at right angles to each other and therefore make a right-angled triangle, with the original force vector forming the hypotenuse. This means that some properties of right-angled triangles can be used to help find the magnitudes of the components.

- Any component vector must be smaller in magnitude than the original vector, because the hypotenuse of a right-angled triangle is the longest side of the triangle.
- Graphically, a right-angled triangle vector diagram can be drawn with the original vector as the hypotenuse and the perpendicular components drawn from the tail of the original to the head of the original.
- Algebraically, the magnitudes of the perpendicular components can be found using the trigonometric ratios.

Resolving vectors into components is an important tool for analysing the effects of two or more forces acting on an object. For example, if an additional **friction force** is applied to the wheels of the cart in Figure 3.1.3, the force affects only the horizontal component. The new horizontal component can be easily calculated and then recombined with the unchanged vertical component to find the new resultant force vector.

Projectile motion

A **projectile** is any object that is thrown or projected into the air and has no power source driving it. If **drag** (air resistance) is ignored, the only force acting on the projectile is its **weight**, that is, the force of gravity, F_g. This force is constant and always directed vertically downwards with an **acceleration** of 9.8 m s^{-2}. Projectiles move in parabolic paths that can be analysed by considering the horizontal and vertical components of the motion (Figure 3.1.4). The two factors that affect a projectile's motion are the angle it is launched at and the initial **velocity**.

FIGURE 3.1.4 The motorcycle and rider are travelling in a parabolic path as they fly through the air.

PROJECTILES LAUNCHED HORIZONTALLY

Projectiles can be launched at any angle. The launch velocity needs to be resolved into vertical and horizontal components using trigonometry to complete most problems. For projectiles launched horizontally, the horizontal velocity remains constant and equal to the horizontal launch velocity. The initial vertical velocity is zero but increases in magnitude (in the downwards direction) due to gravity.

The parabolic path is traced by an object accelerating only in the vertical direction while moving at constant velocity in the horizontal direction. The following equations of motion for uniform acceleration, substituting g for acceleration, are used for the vertical component of the motion:

$$s_y = u_y t + \tfrac{1}{2} g t^2$$

$$v_y^2 = u_y^2 + 2 g s_y$$

where:

s_y is the vertical displacement (m)
u_y is the initial vertical velocity (m s^{-1})
v_y is the final vertical velocity (m s^{-1})
g is the acceleration due to gravity (m s^{-2})
t is the time in flight (s).

The horizontal velocity of the projectile remains constant throughout its flight if drag is ignored. Therefore, the following equation for **average velocity** can be used for this component of the motion:

$$s_x = u_x t$$

When solving a problem involving projectile motion, construct a diagram in which the direction is clearly specified (whether up or down is the positive or negative direction). Write out the information supplied for the horizontal (x-direction) and vertical (y-direction) components separately.

For example, a ball is hit horizontally from the top of a 10 m high cliff with a speed of 5.0 m s^{-1} (Figure 3.1.5). Use **acceleration due to gravity** of 9.8 m s^{-2} and ignore drag to calculate the time it takes the ball to land and the distance it has travelled from the base of the cliff. To do this, there are a few steps you should take.

First write out the variables that are known. You can then decide on the equations of motion that are best suited to finding the answers. Remember to keep your horizontal and vertical components separate.

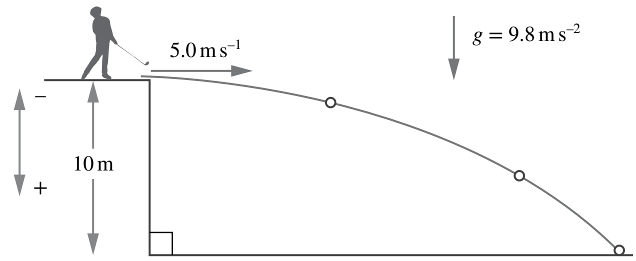

FIGURE 3.1.5 Parabolic motion with initial horizontal velocity only

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The time can then be found using the vertical components of motion and the equation $s_y = u_y t + \frac{1}{2}gt^2$

$$\therefore 10 = 0 + \frac{1}{2} \times 9.8 \times t^2$$

$$t = \sqrt{\frac{10}{4.9}}$$

$$= 1.43\,\text{s}$$

Similarly, to calculate the horizontal **displacement** (that is, how far the ball travelled from the base of the cliff), you can use the equation $s_x = u_x t$.

$$s_x = 5.0 \times 1.43$$

$$= 7.15\,\text{m}$$

Generally, vector answers need both their magnitude and direction, so pay close attention to how a question is written to determine what information is needed in your solution. In the example given above, you were looking for the distance travelled, so the horizontal displacement is given as a scalar.

PROJECTILES LAUNCHED AT AN ANGLE

The previous section looked at projectiles that were launched horizontally. A more common situation is one in which projectiles are launched obliquely (at an angle) by being thrown forwards and upwards at the same time (as in Figure 3.1.6). For objects initially launched at an angle to the horizontal, it is useful to calculate the initial horizontal and vertical velocities using trigonometry. The initial velocity can be broken down into its perpendicular horizontal (u_x) and vertical (u_y) components by using the trigonometric relationships below:

$$\sin\theta = \frac{\text{opposite}}{\text{hypotenuse}} = \frac{u_x}{u} \qquad u_x = u\sin\theta$$

$$\cos\theta = \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{u_y}{u} \qquad u_y = u\cos\theta$$

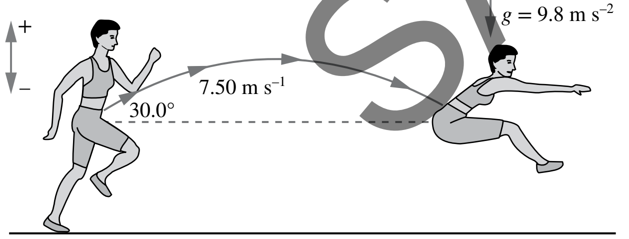

FIGURE 3.1.6 Projectiles can also be launched at an angle (obliquely).

As with projectiles launched horizontally, the only force that is acting on a projectile in the absence of drag is gravity, F_g. The horizontal velocity of a projectile therefore remains constant throughout its flight, so $u_x = \frac{s_x}{t}$ is used. At its highest point, the projectile is only moving horizontally, so the vertical component of the velocity is zero. Overall, the assumptions that must be made when analysing a projectile problem are as follows:

- Drag is absent.
- If an object is dropped, $u_y = 0\,\text{m}\,\text{s}^{-1}$.
- At the highest point of a projectile's path, $v_y = 0\,\text{m}\,\text{s}^{-1}$.
- If the launch height and landing height are the same, then final velocity = negative initial velocity, that is, $v = -u$.

To find the maximum height reached in the example given in Figure 3.1.6, you would first need to break the initial velocity into its vertical and horizontal components.

$$u_y = u\sin\theta$$

$$u_y = 7.50 \times \sin 30° = 3.75\,\text{m}\,\text{s}^{-1}$$

The vertical displacement can then be calculated using the formula $v_y^2 = u_y^2 + 2gs_y$:

$$0^2 = 3.75^2 + 2 \times (-9.8) \times s$$

$$s = 0.717\,\text{m upwards}$$

This means that the centre of mass of the person jumping will travel upwards to a maximum of 0.7 m above the starting height. If the centre of mass is originally given as 1 m off the ground, then the maximum height reached will be 1.7 m.

Inclined planes

An **inclined plane** is a flat surface that can be tilted. If an object is placed on an inclined plane, then, depending on the mass of the object and the incline, the object could accelerate down the incline. Acceleration occurs if the gravitational force (weight of the object) is greater than the opposing frictional force. The weight, F_g, of an object is the **force due to gravity**. It acts straight down in all situations. Another force that acts on an inclined plane is the normal force, F_N. This force acts between an object and a surface, at right angles to the surface.

On a horizontal surface, $F_N = -F_g$ and the object is not accelerating if there are no other forces present.

On an inclined plane, F_N is equal and opposite to the component of the weight acting perpendicular to the plane, i.e. $F_N = F_g \cos\theta$. A **free-body diagram** shows all of the forces acting on a single object (Figure 3.1.7).

Vectors are used to analyse the net force acting upon an object on an inclined plane.

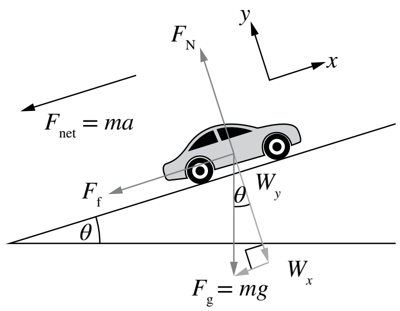

FIGURE 3.1.7 The free body diagram for a car showing the weight components (W_x, W_y) the normal force (F_N) and the force of friction (F_f).

Circular motion

Circular motion involves the movement of an object along a circular path. It can be uniform (constant rate of rotation and speed) or non-uniform (changing rate of rotation). Only **uniform circular motion** is considered in the syllabus.

Uniform circular motion is motion along a circular path in which there is no change in speed, only a change in direction. For example, consider an athlete in a hammer throw event in which a steel ball is swung in a horizontal circle at a constant speed (Figure 3.1.8). The velocity of the hammer at any instant is tangential (at a tangent) to its path. At one instant, the hammer is travelling at $25\,\mathrm{m\,s^{-1}}$ north (point A), then an instant later at $25\,\mathrm{m^{-1}}$ west (point B), then $25\,\mathrm{m\,s^{-1}}$ south, and so on.

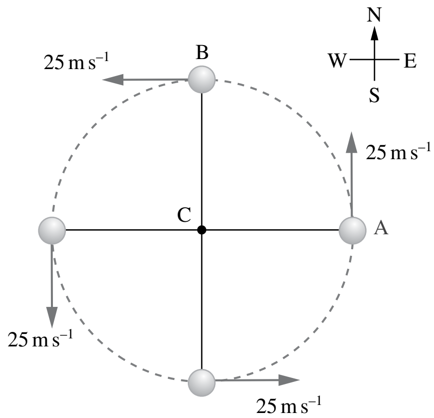

FIGURE 3.1.8 The velocity of the hammer (steel ball) at any instant is tangential to its path and is continually changing even though the speed is constant. This changing velocity means that the hammer is accelerating.

Period, T, is the time for one revolution and is measured in seconds. **Frequency**, f, is the number of revolutions each second and is measured in hertz (Hz). The relationship between T and f is:

$$f = \frac{1}{T} \text{ and } T = \frac{1}{f}$$

An object moving with a uniform speed in a circular path of radius r and with a period T has an **average speed** that is given by:

$$v = \frac{2\pi r}{T}$$

Because an object moving in a circular path is always changing its direction of motion, even if it is travelling with a constant speed, the object must have a non-zero acceleration. This acceleration is directed towards the centre of the circular path and is called **centripetal acceleration**, a_c:

$$a_c = \frac{v^2}{r}$$

Centripetal acceleration is a consequence of a **centripetal force** acting to make an object move in a circular path. Centripetal forces are directed towards the centre of the circle and their magnitude can be calculated by using Newton's second law for the net force of the object:

$$F_c = F_{net} = \frac{mv^2}{r}$$

By substituting the relationship between speed and period into the equations for acceleration and net force, you can also find the following:

$$a_c = \frac{4\pi^2 r}{T^2} \text{ and } F_c = \frac{4\pi^2 rm}{T^2}$$

Centripetal force is always supplied by a real force, the nature of which depends on the situation. The real force is commonly friction, gravitation, or the **tension** in a string or cable.

Gravitational force and fields

Gravity is the weakest of the four fundamental forces of physics (the other three are electromagnetism, strong force and weak force), but it is still a very important force that drives the universe. For a satellite to move in an orbit around Earth, the centripetal force is supplied by the gravitational force of attraction between the two masses. The magnitude of this force is determined by the Law of Universal Gravitation.

GRAVITY

All objects with mass attract one another with a gravitational force. The gravitational force acts equally on each of the masses. The magnitude of the gravitational force is given by the **Law of Universal Gravitation**:

> $$F = \frac{GMm}{r^2}$$
>
> where:
>
> F is the gravitational force (N)
> M is the mass of object 1 (kg)
> m is the mass of object 2 (kg)
> r is the distance between the centres of M and m (m)
> G is the **gravitational constant**, 6.67×10^{-11} ($\mathrm{N\,m^2\,kg^{-2}}$).

Gravitational forces are usually negligible unless one of the objects is massive, for example, a planet. In another example, consider two people, one with a mass of 90 kg and another with a mass of 75 kg, who have 80 cm between their centres. The force of gravitation would be 7.0×10^{-7} N (calculated below).

$$\begin{aligned} F &= \frac{GMm}{r^2} \\ &= \frac{(6.67 \times 10^{-11}) \times 90 \times 75}{0.80^2} \\ &= 7.0 \times 10^{-7}\,\text{N towards one another} \end{aligned}$$

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GRAVITATIONAL FIELDS

The weight of an object on Earth's surface is due to the gravitational attraction of Earth. A **gravitational field** is a region in which a gravitational force is exerted on all matter within that region. Some systems such as the solar system involve several objects (the Sun and planets) exerting attractive forces on each other at the same time. Every physical object has an accompanying gravitational field. A gravitational field can be represented by a gravitational field diagram.

- The arrowheads indicate the direction of the gravitational force.
- The spacing of the lines indicates the relative strength of the field. The closer the line spacing, the stronger the field.

For example, Figure 3.1.9 illustrates a gravitational field diagram. The arrows indicate that objects will be attracted towards the mass in the centre and the spacing of the lines shows that force will be strongest at the surface of the central mass and weaker further away.

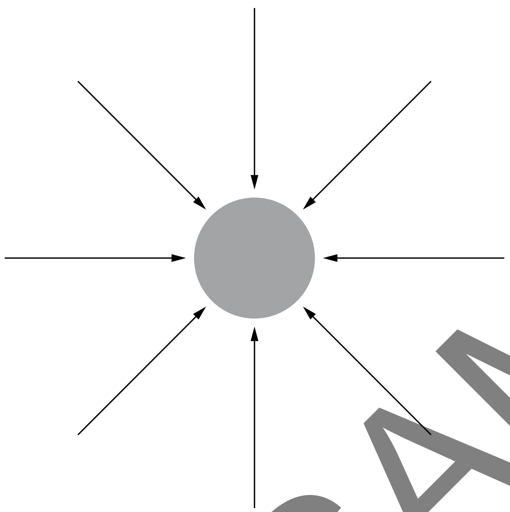

FIGURE 3.1.9 Gravitational field lines

The strength of a gravitational field can be calculated using the following formulas:

$$g = \frac{F}{m} = \frac{GM}{r^2}$$

The acceleration due to gravity of an object near Earth's surface can be calculated using the dimensions of Earth:

$$g = \frac{GM_{\text{Earth}}}{(r_{\text{Earth}})^2} = 9.8\,\text{N}\,\text{kg}^{-1} \text{ towards the centre of the Earth}$$

This value for g varies from location to location and with **altitude**. The **gravitational field strength** on the surface of any other planet depends on the mass and radius of the planet.

Orbits

A **satellite** is an object that is in a stable orbit around a larger central mass. Satellites can be either **natural** (for example, the Moon) or **artificial** (for example, a communication satellite). Artificial satellites are very important for science, industry, communications and the military.

The only force acting on a satellite is the gravitational attraction between it and the central body. Satellites are in continual **freefall**. As satellites are moving at a velocity relative to Earth, they are moving across the sky while they are falling such that the combined effect is that they fall in a curved path. This effect is shown on an astronaut in Figure 3.1.10.

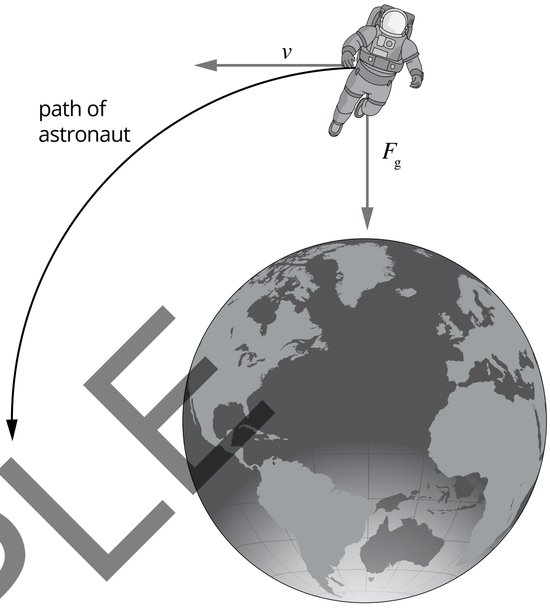

FIGURE 3.1.10 Astronauts are in freefall while orbiting the Earth.

Satellites move with a centripetal acceleration that is equal to the gravitational field strength at the location of their orbit. Artificial satellites are often equipped with tanks of propellant that are squirted in the appropriate direction when the orbit of the satellite needs to be adjusted. In a circular orbit, a satellite travels at a constant speed and stays the same distance from Earth.

The speed of a satellite, v, in a circular orbit is given by:

$$v = \frac{2\pi r}{T}$$

This formula can then be used to determine the centripetal acceleration acting on this satellite. Using the scalar variables for these equations, the magnitude of the acceleration is then:

$$a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2} = \frac{GM}{r^2} = g$$

These relationships can be manipulated to determine any feature of a satellite's motion: its speed, v; the radius of orbit, r; or the period of orbit, T. The magnitude of the gravitational force acting on a satellite in a circular orbit is given by:

$$F_g = \frac{mv^2}{r} = \frac{4\pi^2 rm}{T^2} = \frac{GMm}{r^2} = mg$$

Artificial satellites usually move in circular orbits; however, it does depend on the energy and trajectory. Satellites could follow a spiral, hyperbolic, **elliptical** or circular orbit. Kepler, a German astronomer, published three laws regarding the motion of planets. He was the first to work out that planets do not travel in circular paths, but rather in elliptical paths. The three laws of planetary motion are as follows.

1 The planets move in elliptical orbits with the Sun at one **focus**.
2 The line connecting a planet to the Sun sweeps out equal areas in equal intervals of time (Figure 3.1.11).
3 For every planet, the ratio of the cube of the average orbital radius, r, to the square of the period, T, of revolution is the same, that is, $\frac{T^2}{r^3}$.

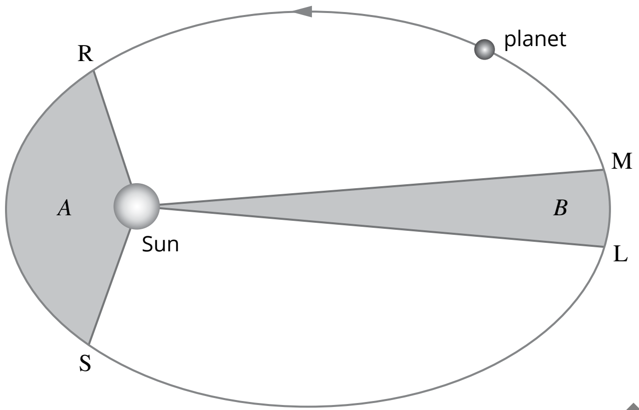

FIGURE 3.1.11 A line joining a planet to the Sun will sweep out equal areas in equal times. If the time taken for the planet to travel from R to S is the same as that taken for it to travel from M to L, then area A will equal area B.

For any central body of mass, M:

$$\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$$

If the orbital radius, r, and period, T, of a satellite are known, the orbital radius of another satellite in the same system, with period T, can be determined:

$$\frac{T_a^{\ 2}}{r_a^{\ 3}} = \frac{T_b^{\ 2}}{r_b^{\ 3}} = \frac{4\pi^2}{GM}$$

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Knowledge preview—straight-line motion

1 The motion of a ball rolling from rest down a plank is measured by marking its position each second. From $t = 3\,\text{s}$ to $t = 4\,\text{s}$, the ball travels 56 cm. Calculate the magnitude of the acceleration of the ball.

2 From a platform 24.5 m above the ground, a stone is thrown straight up at $19.6\,\text{m}\,\text{s}^{-1}$.

a Calculate how long the stone will be in the air before hitting the ground.

b Calculate the speed with which the stone will hit the ground.

3 A 540 kg cable car is suspended from the middle of a light cable with each half of the cable making an angle of 12° to the horizontal. Calculate the magnitude of the tension in the cable.

4 Consider a teacup of mass 100 g sitting on a kitchen bench.

a Calculate its weight.

b Calculate the magnitude of the force of the benchtop on the cup. State the direction in which it acts.

c Explain why these two forces do not make an action–reaction pair in the sense of the third law of motion. State the two forces that do make an action–reaction pair in this scenario.

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WORKSHEET 3.1.4

Uniform circular motion

1 A Formula 1 car completes one lap around a circular track with a radius of 40 metres in 10 seconds.

a Calculate the car's average velocity in $km\,h^{-1}$.

b Determine the car's centripetal acceleration.

2 The car then goes around a tighter curve on a different track at $20\ m\,s^{-1}$. The radius of the tighter curve is 30 metres. Determine the car's centripetal acceleration.

3 The car has a mass of 900 kg. It takes 11.8 seconds to travel at a uniform speed around a circular track with a radius of 85.0 metres. Determine the centripetal force acting on the car.

4 A 100 g mass is attached to a string 70 cm long and swung in a horizontal circle. The period of rotation is 0.80 seconds. Calculate:

a the centripetal acceleration of the mass

b the tension in the string.

WORKSHEET 3.1.2

Projectile motion

Students intend to fire a small projectile with a velocity of $40.0\,\mathrm{m\,s^{-1}}$ at an angle of 60.0° to the horizontal from a point on the oval. They plan to aim at the windowless wall of a building 45 m away from the launch site, so that there is no danger of the projectile hitting anyone. The building is 36 m high.

1 Draw a diagram of the situation, showing all known variables.

2 Determine whether the projectile will travel over the height of the building and hence evaluate the safety of this method.

3 Demonstrate by calculation how:

a the initial velocity

b the launch angle

can be changed to make the situation safe.

Show your working.

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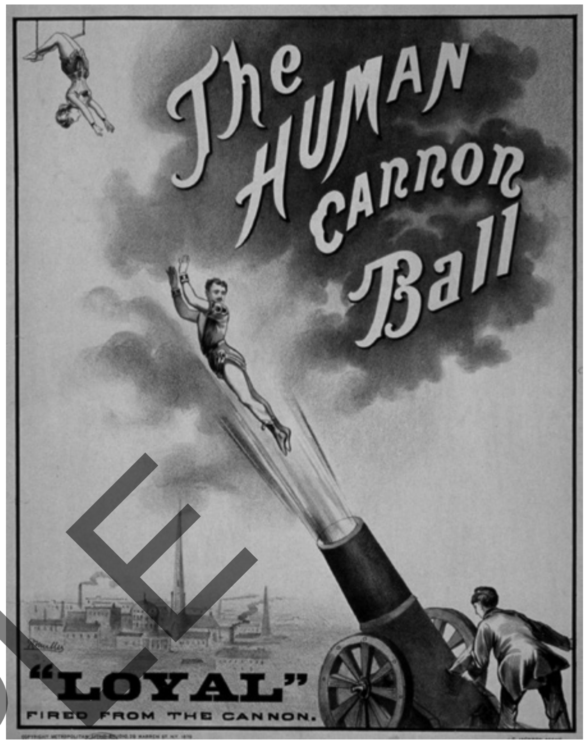
WORKSHEET 3.1.3

Human cannonballs—projectile motion data analysis

In the days before workplace health and safety regulations, human ‘cannonballs’ were a fairly common feature of circuses and fairs. Not surprisingly, risk assessments, fair work practices and ever-increasing insurance premiums almost brought them to an end. More than 30 people died over the years since the first human cannonball, a 14-year-old girl, was launched at the Royal London Aquarium in 1877.



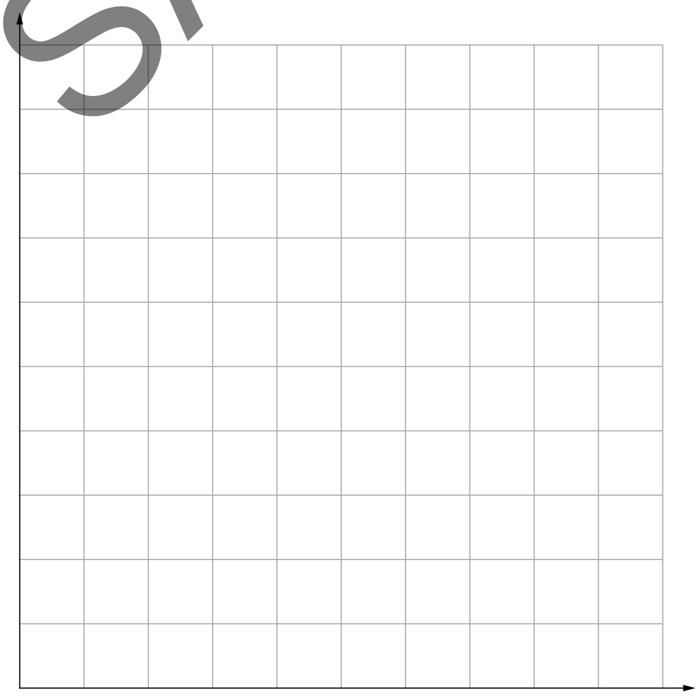
These days, very few stunt performers maintain the tradition. The human cannonball is fired from a specially designed cannon, and lands on a horizontal net or inflated bag. The official world record for farthest distance stands at 59.43 m.

The data below was collected from the launch of a human cannonball of mass 80 kg blasted towards the east from a cannon and landing in a safety net. The height of the net was equal to the launch height. The angle of launch was 45° and the initial speed was 28 m s^{-1}.

TABLE 1 Speed versus time after launch

Time after launch (s)	Speed (m s^{-1})
0	28.0
1.0	22.4
2.0	20.0
3.0	22.4
4.0	28.0

1 On the grid provided, plot a graph of vertical acceleration versus time for the human cannonball for the 4.0 s of motion. Use up as positive and ensure that your graph is appropriately labelled.



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2 Determine the height of the human cannonball above the initial launch height after:

a 2.0 s

b 3.5 s

3 Calculate the speed of the human cannonball after:

a 2.0 s

b 3.5 s

4 Determine the velocity and acceleration of the human cannonball at the maximum height achieved.

5 Discuss the forces that are acting on the human cannonball when passing through the highest point in the trajectory if drag is ignored. State the magnitude and direction of the net force acting at this point.

RATE MY LEARNING	• I get it. • I can apply/teach it.	• I get it. • I can show I get it.	• I almost get it. • I might need help.	• I get some of it. • I need help.	• I don't get it. • I need lots of help.

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5 A mass of 0.50 kg is attached to a string 1.00 metres long and is rotated in a horizontal circle. It completes one revolution every 0.50 seconds. Calculate to two significant figures:

a the centripetal acceleration of the mass

b the tension in the string.

6 A bucket partly filled with water, with a total mass of 2.3 kg, is tied to the end of a cord and whirled around in a horizontal circle with a radius of 2.5 metres. It completes one full revolution in 6 seconds. Determine:

a the average velocity of the bucket

b the centripetal acceleration of the bucket

c the path the bucket would take if the cord broke.

RATE MY LEARNING	• I get it. • I can apply/teach it.	• I get it. • I can show I get it.	• I almost get it. • I might need help.	• I get some of it. • I need help.	• I don't get it. • I need lots of help.

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PRACTICAL ACTIVITY 3.1.1

Projectile motion

Suggested duration: 40 minutes

AIM

In this activity you will conduct a practical investigation to collect primary data to validate the relationship between the initial velocity, time of flight and range of a projectile.

MATERIALS

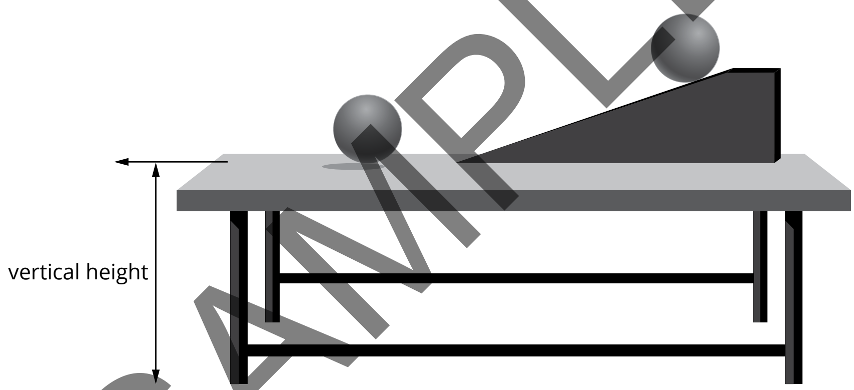
- ramp or board
- small ball (Each group may use one or more of different size and mass.)
- stopwatch
- horizontal bench or table
- polystyrene cup
- ruler and tape measure
- Blu Tack™

RISK MANAGEMENT

Always wear safety glasses when using any kind of projectile launcher. Never look down the barrel of a mechanical projectile launcher.

METHOD

Consider the situation in the diagram below. A small ball runs across a flat surface with a known speed and then moves off the end of the table and travels to the floor. While it is in flight, the only external force to be considered acting on the ball is gravity.



1 Mark a point on the ramp from which the ball can be consistently released at the same position. Measure the horizontal distance from the end of the ramp to the edge of the table. Record this in Table 1.

2 Release the ball and time how long it takes to travel the horizontal distance from the base of the ramp to the edge of the table. Do not let the ball fall to the floor while recording this time.

3 Repeat the test a number of times, recording each trial in Table 1. Include an estimate of the uncertainty in the measurement of the time and distance across the table.

4 Record the height the ball will fall from the table to the floor. Include an estimate of the uncertainty.

5 Calculate the time of flight and hence the horizontal distance the ball will travel (the range) while it is in the air.

6 Measure out the calculated landing distance on the floor and place a polystyrene cup at the predicted point. Attach the cup to the floor with some Blu Tack™ so it is unable to move when the ball hits it or lands in it.

7 Test your prediction by releasing the ball from the same spot on the ramp as originally used in determining the velocity across the tabletop.

RESULTS AND ANALYSIS

Height ball will fall: __________ m ± __________

1 Calculate the velocity across the tabletop for each trial and, hence, find the average velocity. Enter these results into Table 1.

TABLE 1 Results

Trial number	Distance, *s*, across tabletop (m)	Time, *t*, taken to travel across tabletop (s)	Velocity (v) across tabletop ($m\,s^{-1}$) $v = \frac{\Delta s}{\Delta t}$
1			
2			
3			
4			
5			
average			

2 Consider whether the velocity being calculated is the velocity of the ball at the edge of the table or just a reasonable approximation. Explain your answer.

3 Describe how you measured the height to ensure that it is as reliable as possible.

4 Calculate how long it will take for the ball to fall from the table to the floor using the measured height of the table. Show your working.

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5 Calculate the distance the ball will travel in the horizontal direction (the range) while it is in the air. Show your working.

CONCLUSION

1 State whether your prediction was successful. Explain how you determined the success of the prediction and any difficulties encountered in testing the prediction.

EVALUATION

1 Discuss the effect that increasing the horizontal distance would have on the reliability of your measurements.

2 Identify the major source of error in this investigation and the steps required to minimise it.

RATE MY LEARNING	• I get it. • I can apply/teach it.	• I get it. • I can show I get it.	• I almost get it. • I might need help.	• I get some of it. • I need help.	• I don't get it. • I need lots of help.

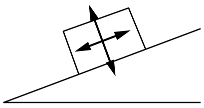
UNIT 3 TOPIC 1 EXAM PRACTICE • GRAVITY AND MOTION

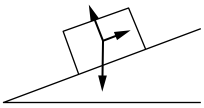
Multiple choice

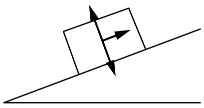
QUESTION 1

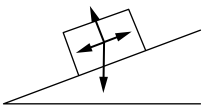
QCCA Physics Exam 2020 Paper 1 Question 1

Which of the diagrams correctly represents the forces acting on an object resting on an inclined plane?

(A) 

(B) 

(C) 

(D) 

QUESTION 2

QCCA Physics Exam 2021 Paper 1 Question 2

Calculate the initial horizontal velocity of a projectile with an initial velocity of $38\,m\,s^{-1}$ up from the horizontal at an angle of 42°.

(A) $25\,m\,s^{-1}$

(B) $28\,m\,s^{-1}$

(C) $34\,m\,s^{-1}$

(D) $40\,m\,s^{-1}$

QUESTION 3

QCCA Physics Exam 2020 Paper 1 Question 8

An object 46 m above the ground is projected horizontally, with an initial velocity of $25\,m\,s^{-1}$. Calculate the horizontal displacement of the object at the time it reaches the ground.

(A) 77 m

(B) 120 m

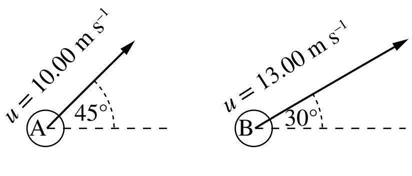
(C) 190 m

(D) 240 m

QUESTION 4

QCCA Physics Exam 2020 Paper 1 Question 11

The diagram shows object A and object B being projected at different velocities.



Which of the following statements is true?

(A) Object A has a shorter flight time than object B.

(B) Object A has a smaller maximum height than object B.

(C) Object A has a larger horizontal velocity than object B.

(D) Object A has a smaller horizontal displacement than object B.

QUESTION 5

QCCA Physics Exam 2020 Paper 1 Question 12

Which of the following is one of the laws of planetary motion?

(A) The laws of physics are the same in all inertial frames of reference.

(B) All planets move about the Sun in elliptical orbits, having the Sun as one of the foci.

(C) The speed of light in a vacuum has the same value, c, in all inertial frames of reference.

(D) The force of attraction between each pair of point particles is directly proportional to the product of their masses and inversely proportional to the square of the distance between them.

QUESTION 6

QCCA Physics Exam 2020 Paper 1 Question 15

Calculate the orbital period of a satellite travelling on a $3.00 \times 10\ m^8$ radius orbit around Earth.

(A) 1.44×10^{-2} hours

(B) 4.54×10^{2} hours

(C) 1.64×10^{6} hours

(D) 7.44×10^{8} hours

QUESTION 7

QCCA Physics Exam 2020 Paper 1 Question 18

Calculate the initial vertical velocity of a projectile with an initial velocity of $68\,m\,s^{-1}$ at an angle of 51° from the horizontal.

(A) $43\,m\,s^{-1}$

(B) $51\,m\,s^{-1}$

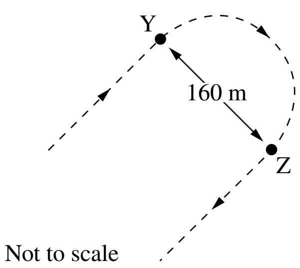
(C) $53\,m\,s^{-1}$

(D) $68\,m\,s^{-1}$

QUESTION 8

QCCA Physics Exam 2023 Paper 1 Question 6

An object of mass 6.0×10^{2} kg travels along a path as shown. The object takes 25 seconds to complete the semicircular section of the path.



Calculate the centripetal force experienced by the object as it moves from Y to Z.

(A) 3.0×10^{3} N

(B) 7.6×10^{2} N

(C) 3.8×10^{2} N

(D) 7.6×10^{1} N

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QUESTION 9

QCCA Physics Exam 2023 Paper 1 Question 15

Two objects experience a gravitational force, F, between them. Calculate the magnitude of the force acting between the two objects if the distance between them was doubled and the mass of one object was doubled.

(A) $0.25F$

(B) $0.5F$

(C) $1F$

(D) $2F$

QUESTION 10

QCCA Physics Exam 2023 Paper 1 Question 18

A 20 kg object is placed on an inclined plane with a slope of 35°. If the object experiences a frictional force of 40 N and no additional applied force, calculate its acceleration down the inclined plane.

(A) $3.6\,\text{m}\,\text{s}^{-2}$

(B) $5.6\,\text{m}\,\text{s}^{-2}$

(C) $6.0\,\text{m}\,\text{s}^{-2}$

(D) $7.6\,\text{m}\,\text{s}^{-2}$

Short response

QUESTION 1 (3 marks)

QCCA Physics Exam 2022 Paper 2 Question 7

Two asteroids experience a gravitational force of 3.3×10^{3} N between them. Their masses are 2.7×10^{17} kg and 6.1×10^{15} kg.

Calculate the distance between the two asteroids. Show your working.

Distance = __________ m (to two significant figures)

QUESTION 2 (7 marks)

QCCA Physics Exam 2022 Paper 1 Question 28

An object of mass 200 g moves in a uniform circular path with a radius of 25 cm. The time taken for 10 revolutions is 3.0 s.

a) Calculate the distance travelled by the object after 3.9 s. Show your working. *[2 marks]*

Distance = __________ m (to two significant figures)

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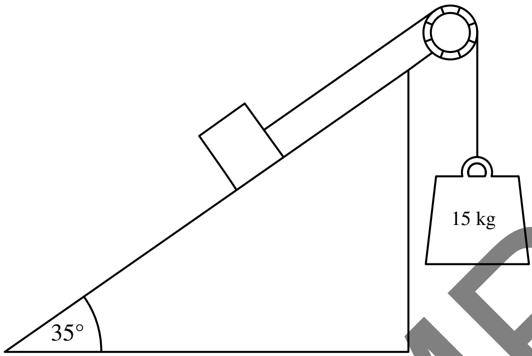
b) Calculate the centripetal force acting on the object. Show your working. *[5 marks]*

Centripetal force = __________ N (to two significant figures)

QUESTION 3 (5 marks) *QCCA Physics Exam 2022 Paper 2 Question 4*

A stationary object on a frictionless inclined plane is connected to a 15 kg weight as shown.



Not to scale

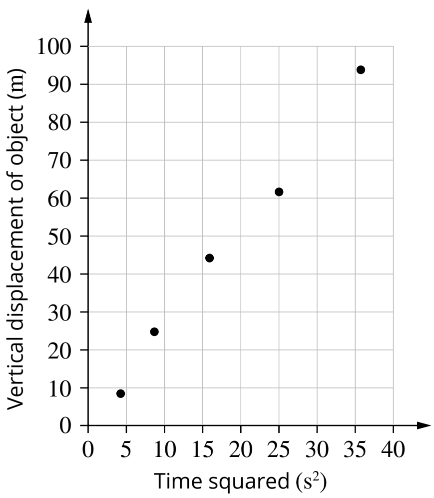
Calculate the mass of the object on the inclined plane.

Mass = __________ kg (to two significant figures)

QUESTION 4 (6 marks) *QCCA Physics Exam 2021 Paper 2 Question 7*

An object on a planet is launched horizontally from a cliff. Its vertical displacement is measured over 6 seconds.

The graph shows the object's vertical displacement with respect to time squared.



a) Determine the mathematical relationship between vertical displacement (s) and time (t). *[3 marks]*

b) Calculate the acceleration due to gravity on the planet. *[3 marks]*

Acceleration = ________ $m\,s^{-2}$ (to 2 significant figures)

QUESTION 5 (4 marks) *QCCA Physics Exam 2021 Paper 2 Question 4*

A spacecraft is located between two large asteroids, Asteroid A and Asteroid B, that are 120 km apart. Asteroid A's mass is approximately four times the mass of Asteroid B.

Determine the distance of the spacecraft from Asteroid B if it experiences no net gravitational force from the two asteroids.

Distance from Asteroid B = ________ km (to the nearest whole number)

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SAMPLE ASSESSMENT TASK IA1

Data test

Suggested duration: 5 minutes perusal time and 60 minutes to complete the test

Task

Each data set will enable you to analyse and interpret data to apply your understandings of gravity, motion and electromagnetism.

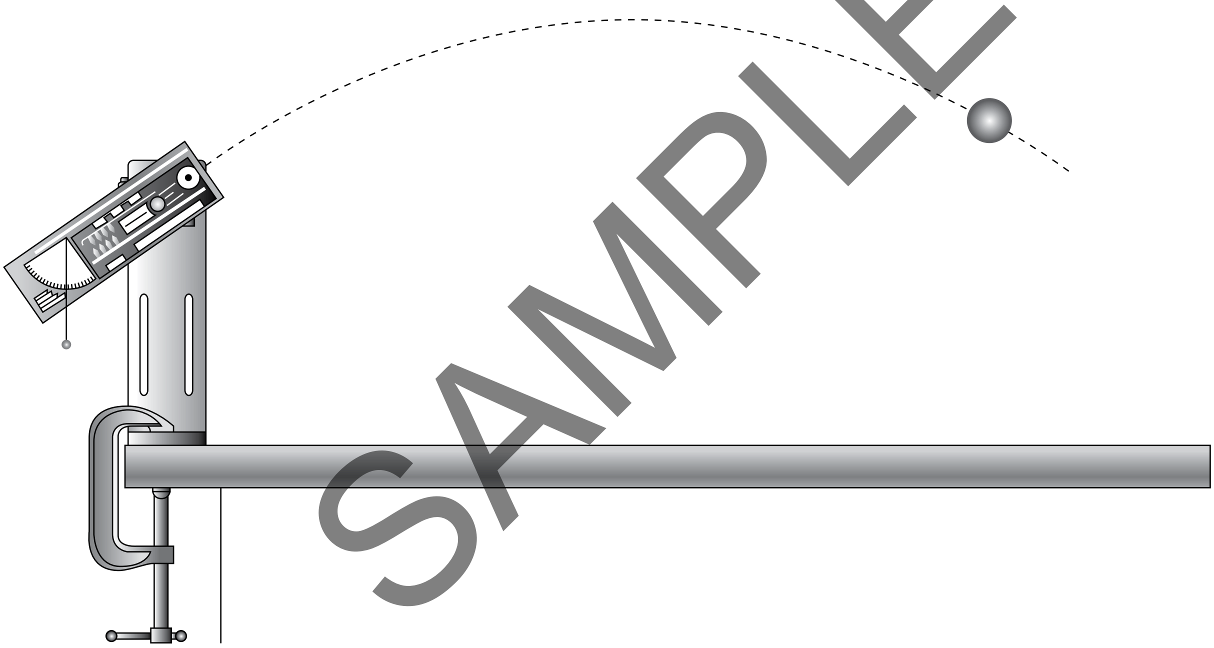
You will be required to complete short and longer answer questions, calculations and interpretation of graphs.

Complete all parts of each question as directed.

DATASET 1—PROJECTILE MOTION (5 MARKS)

An experiment was set up as follows to address the following research question:

What is the relationship between the projected launch angle of a ball and its range when launched at a velocity of 4.1 m s^{-1}?



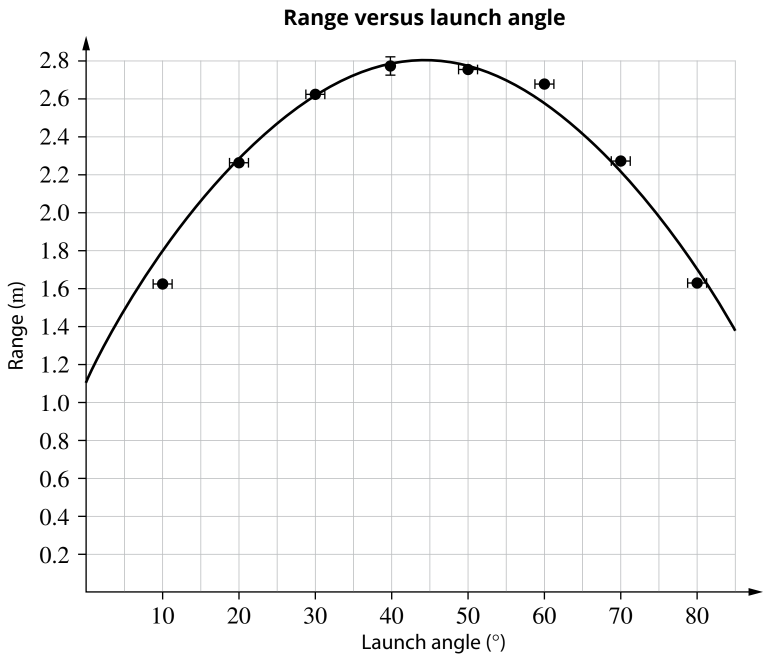
Paper was laid across the benchtop and then carbon paper was laid on top. The launcher was initially set horizontally and the ball fired. When the ball hit the carbon paper a mark was left, allowing the range (horizontal displacement) of the ball to be measured. The launch angle was then increased in 10° angles through to 50° with four trials taken for each angle.

The data was recorded in Table 1 and has been processed and presented in Graph 1.

TABLE 1: Angle versus range

Launch angle (°) ± 1°	Range (m) ± 0.01 m				Average range (m)
	Trial 1	Trial 2	Trial 3	Trial 4	
0	1.21	1.23	1.23	1.25	1.23 ± 0.02
10	1.64	1.62	1.62	1.63	1.63 ± 0.01
20	2.26	2.27	2.27	2.25	2.26 ± 0.01
30	2.63	2.64	2.61	2.60	2.62 ± 0.02
40	2.76	2.75	2.79	2.82	2.78 ± 0.04
50	2.74	2.75	2.75	2.76	2.75 ± 0.01

GRAPH 1: Range of the ball projected at various angles



QUESTION 1 (1 mark)

Identify the two projected angles that produce a horizontal displacement of 2.0 metres.

QUESTION 2 (2 marks)

Calculate the initial horizontal component of the velocity of the ball when it was projected at an angle of 30°.

QUESTION 3 (1 mark)

Identify the trend between the projected angle θ and the horizontal displacement s_x of the ball.

QUESTION 4 (1 mark)

Infer the projected angle that would result in the largest horizontal displacement.

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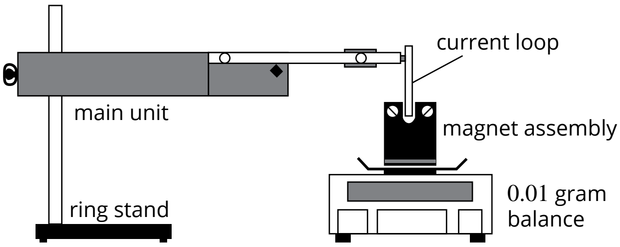
DATASET 2—FORCE ON A CONDUCTOR IN A MAGNETIC FIELD (7 MARKS)

A student set up the apparatus shown below to conduct an experiment to address the following research question:

What is the relationship between the force on a conductor in a magnetic field and the current in the conductor?



An analog ammeter with a full-scale range of 1.00 A and a minimum division of 0.02 A was used for measuring the current in the wire loop. The same loop of wire and magnet assembly was used for all measurements. The length was not recorded.

The raw data from this experiment is shown in Table 2.

TABLE 2: Results from force on a conductor experiment

Current (I) (± 0.01 A)	Measured change in mass, $m \times 10^{-4}$ ($\pm 0.10 \times 10^{-4}$ kg)			
	Trial 1	**Trial 2**	**Trial 3**	**Average**
0.30	0.35	0.34	0.34	0.35 ± 0.01
0.40	0.46	0.46	0.46	0.46 ± 0.00
0.50	0.58	0.56	0.57	0.57 ± 0.01
0.60	0.70	0.69	0.68	0.69 ± 0.01
0.70	0.80	0.78	0.78	±

QUESTION 5 (2 marks)

Calculate the average force (N) for a current of 0.70 A.

QUESTION 6 (1 mark)

Determine the absolute uncertainty of the mean of the average force, F, when the current is 0.70 A.

Use the formula:

$$\Delta\bar{x} = \pm\frac{(x_{\max} - x_{\min})}{2}$$

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QUESTION 7 (2 marks)

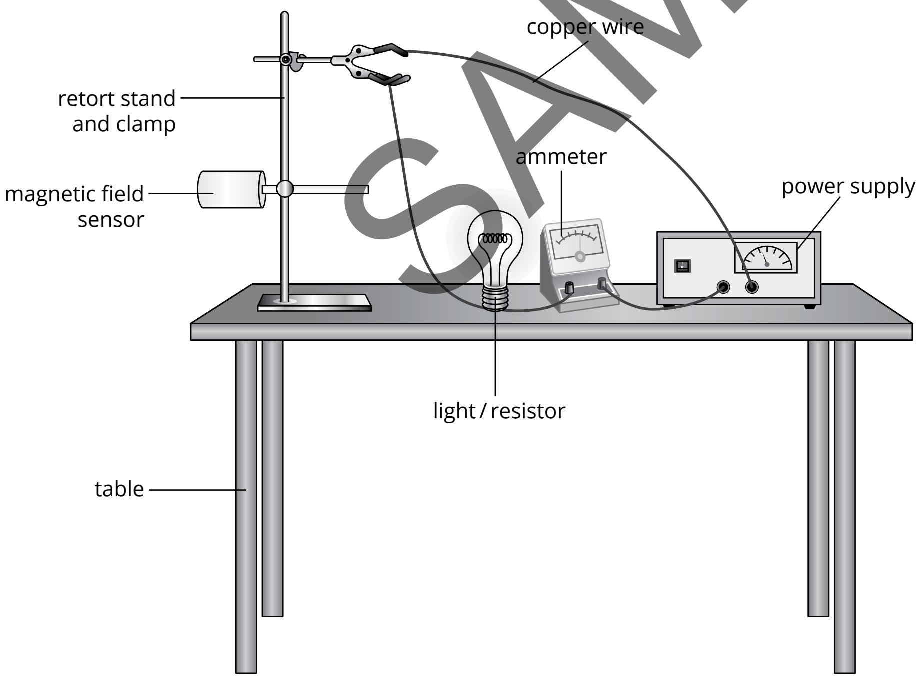
Identify the relationship between the current, *I*, in the conductor, and the measured change in mass. Use evidence from Table 2 to support your answer.

QUESTION 8 (2 marks)

Predict the magnitude of the change in mass when the current through the conductor is 0.90 A. Show your working.

DATASET 3—THE STRENGTH OF A MAGNETIC FIELD AT A DISTANCE FROM A WIRE (7 MARKS)

A student experiment was set up to investigate the relationship between the strength of the magnetic field and the distance from a current-carrying wire.



The power supply was adjusted to a set current of 1.00 A ± 0.01 and the distance between the wire and the magnetic field sensor varied. The sensor was used to measure the magnetic field strength at right angles to the wire.

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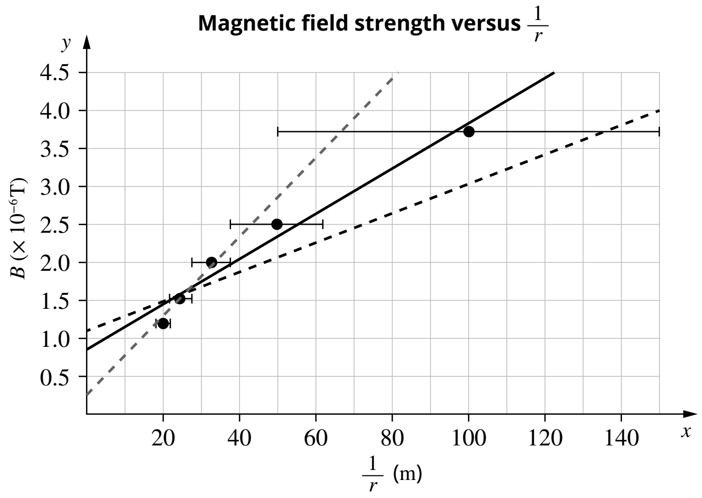
The raw data was linearised and plotted in Graph 2.

GRAPH 2: Magnetic field strength versus $\frac{1}{r}$



Equation of the linear trend line: $y = 3.0 \times 10^{-8} x + 0.83$

Equation of the maximum linear trend line: $y = 7.6 \times 10^{-8} x + 0.18$

Equation of the minimum linear trend line $y = 1.8 \times 10^{-8} x + 1.09$

QUESTION 9 (3 marks)

Identify a mathematical relationship between the strength of the magnetic field and the distance from the current-carrying wire, including the uncertainty of the gradient and the y-intercept.

QUESTION 10 (4 marks)

Draw a conclusion that quantifies the experimental value of the magnetic permeability of free space, including the absolute uncertainty in the value you determine. Show your reasoning.

Student experiment

Suggested duration: approximately 10 hours (including development of research question, practical work, writing time and preparation of your response)

Introduction

The student experiment requires you to follow the full scientific method over an extended and defined period. You will identify an experiment related to Unit 3 subject matter and develop a research question to investigate.

The student experiment forms an important component of the assessment in this unit. It is an opportunity to further explore concepts already covered and of particular interest to you, with some latitude for self-direction. The task is estimated to take approximately 10 hours of class time. The time will be divided into research and planning, conducting the investigation and preparing your response. You will have one opportunity for draft feedback from your teacher as an important part of the planning process.

You may modify the methodology and conduct the planning, risk assessment and experiment, including collection of data, collaboratively with another student or small group if you wish. All other stages of your student experiment, such as analysis of data, must be carried out individually.

A suggested breakdown of the time frame includes:

Research and planning: 2–3 hours

Conducting the experiment: 2–3 hours

Final response 4–5 hours

Response requirements

For this assessment task, you will produce either:

- a written response with a word limit of up to 2000 words, or
- a multimodal presentation of up to 11 minutes.

Your written response or presentation requires you to demonstrate the research and planning you have undertaken in preparing for the experimental investigation. The following plan has been prepared to provide some guidance through the task.

Forming and finding

Research question: Develop a specific question that will form the basis for planning the investigation. The question must be drawn from and relevant to Unit 3 content, and must include specific and measurable variables.

Rationale: Introduce the investigation, outlining the relevance of the subject of the experiment. Explain the conceptual understanding that led to the development of the research question (providing theory to justify the modifications only).

Methodology: Identify the original experiment then explain in detail how you plan to modify its methodology to meet the new line of inquiry. Mention the key alterations (for example, identifying the independent and dependent variables for the new investigation) and the specific modifications in methodology.

Risk assessment: Detail how you will manage safety hazards and ethical considerations of the modifications to minimise risk.

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SAMPLE ASSESSMENT TASK IA2

Note that these questions are provided to guide initial planning only and do not constitute the full requirements for a research investigation. Students should consult the latest advice from QCAA.

1 Select the practical activity that you would like to use as the basis from which to launch your own investigation.

2 **a** Select potential variables that relate to or extend the practical.

Explore how investigation of these factors will deepen your understanding of the topic.

b Identify one variable from those identified in part **a** that interests you. Consider what aspect of this factor you can focus on to write a specific research question.

3 **a** State your research question based on your considerations in question **2**.

This question will be the focus of your investigation.

b Identify the variables that are relevant to your research question, in the following table.

Independent variable	Dependent variable	Relevant controlled variables

c Consider whether the research question is answerable within the constraints of the experiment and the equipment available in your school.

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4 Develop a rationale for your research question.

5 Summarise and justify the modifications you will make to the methodology of the original experiment.

6 List the materials you will require for your experiment.

7 Indicate whether your modifications will require further safety precautions.

Results and analysis

1 **a** In the space provided, sketch a table you might include in your response to present the raw data collected in the investigation.

b Indicate some ideas for how you might process the raw data to enable any trends, patterns or relationships to be analysed.

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2 Describe how you will present the processed data.

3 Indicate the trends, patterns and/or relationships indicated by your data. Relate them to physics concepts.

4 Summarise the limitations and uncertainty of both your methodology and the evidence you have collected.

Discuss how your methodology addresses issues of reliability and validity with respect to your experimental process.

Interpreting and evaluating

1 Note the conclusions you can draw from your evidence. Make sure they directly address the research question.

2 Identify errors that are likely to affect your results.

Consider both systematic and random errors, and calculate the percentage uncertainty. State whether your experimental data is reliable and valid.

3 Directly address each of the errors identified in question 2.

Could the methodology be improved to eliminate or reduce any of these errors?

4 Indicate the references you will include as a list at the end of your response.

Communicating your findings

The following subheadings will give you an idea of what you should include in your response.

Title of experiment

FORMING AND FINDING

Research question

- Is your research question specific and relevant?

Rationale

- Have you described the original experiment and made links to the development of your own research question?
- Have you identified and justified the independent, dependent and all relevant controlled variables?

Methodology

- Have you described and justified all modifications you have made to the original methodology?
- Is your method repeatable and does it allow sufficient and relevant data to be collected?
- Where possible, have you included a labelled diagram of the experimental set-up?
- Have you labelled each figure (and included a reference where applicable)?

Risk management

- Have you identified, explained and managed any risks?
- Have you incorporated safe and ethical work practices?

Note that although protocol dictates that a scientific response includes an aim and hypothesis, for the purposes of the student experiment (IA2) these will not be awarded any marks and will count against the assessment piece word limit.

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RESULTS AND ANALYSIS

Raw data

- Have you collected qualitative observations as well as raw data? Qualitative observations can assist in evaluating the experiment.
- Have you systematically collected sufficient and relevant data?
- Is your raw data clear and accurate and includes limiting errors?

Processed data

- Have you processed your data in the most appropriate ways to illustrate trends, patterns and/or scientific relationships? This could include a primary graph to establish the relationship between two variables followed by a secondary graph linearising the data. The secondary graph should include lines of best fit along with lines of minimum and maximum fit based on the error bars for each data point.

Analysis

- Have you analysed your investigation data?
- Have you comprehensively explained how accuracy, precision, reliability, validity, uncertainty and limitations relate to your collected data?
- Does the discussion of your analysis address all possible sources of error and uncertainty?
- Have you considered how your analysis may be limited by the data you did or did not collect?

INTERPRETING AND EVALUATING

Conclusion

- Is your conclusion valid given your analysis and evaluation?
- Does it provide a justified response to the research question?
- Have you explained the link between your investigation findings and the relevant scientific concepts you included in the Rationale section?
- Have you used scientific language and conventions?

Evaluation and sources of error

- Were the procedures you used appropriate and effective?

Improvements and extensions

- Have you made practical suggestions for improvements to the experimental design?
- Have you suggested possible further investigations?

Reference list

- Have you used a standard scientific referencing system?
- Is the terminology and structure of your response written in a scientific manner?