PEARSON

PHYSICS

QUEENSLAND

STUDENT BOOK

12

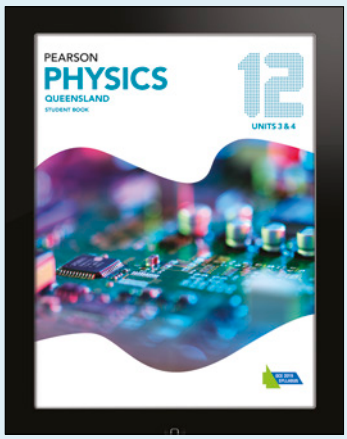
UNITS 3 & 4

Contents

ONLINE CHAPTER

Chapter 1 Physics skills and assessment toolkit

Go to your eBook to access this chapter.
Page numbering begins at 'e1' for this eBook chapter.
Unit 3 starts on page 1, followed by Chapter 2.



Unit 3 Gravity and electromagnetism

Topic 1: Gravity and motion

Topic 2: Electromagnetism

How to use this book

PEARSON PHYSICS 12 QUEENSLAND STUDENT BOOK

Pearson Physics 12 Queensland Student Book has been written to the new QCAA Physics General Senior Science Syllabus. The book is an easy-to-use resource that covers Units 3 & 4 and comprehensively addresses skills and assessment requirements.

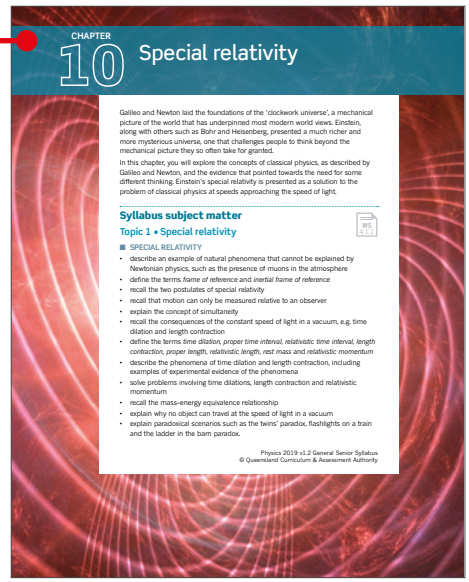
Explore how to use this book below.

Design

The best-practice literacy and instructional design supports all learners. A simple-to-navigate predictable design enables ease of use. The high-quality, relevant photos and illustrations assist student understanding of concepts.

Chapter opener

The syllabus subject matter addressed in each chapter is clearly listed, along with any science as a human endeavour features and mandatory practicals.


CHAPTER 10 Special relativity

Galileo and Newton laid the foundations of the 'clockwork universe', a mechanical picture of the world that has underpinned most modern world views. Einstein, along with others such as Bohr and Heisenberg, presented a much richer and more mysterious universe, one that challenges people to think beyond the mechanical picture they so often take for granted.

In this chapter, you will explore the concepts of classical physics, as described by Galileo and Newton, and the evidence that pointed towards the need for some different thinking. Einstein's special relativity is presented as a solution to the problem of classical physics at speeds approaching the speed of light.

Syllabus subject matter

Topic 1 • Special relativity

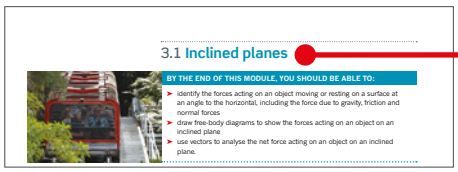
SPECIAL RELATIVITY

- describe an example of natural phenomena that cannot be explained by Newtonian physics, such as the presence of muons in the atmosphere
- define the terms *frame of reference* and *inertial frame of reference*
- recall the two postulates of special relativity
- recall that motion can only be measured relative to an observer
- explain the concept of simultaneity
- recall the consequences of the constant speed of light in a vacuum, e.g. time dilation and length contraction
- define the terms *time dilation, proper time interval, relativistic time interval, length contraction, proper length, relativistic length, rest mass* and *relativistic momentum*
- describe the phenomena of time dilation and length contraction, including examples of experimental evidence of the phenomena
- solve problems involving time dilations, length contraction and relativistic momentum
- recall the mass–energy equivalence relationship
- explain why no object can travel at the speed of light in a vacuum
- explain paradoxical scenarios such as the twins' paradox, flashlights on a train and the ladder in the barn paradox.

Physics 2019 v1.2 General Senior Syllabus
© Queensland Curriculum & Assessment Authority

Module

Module openers outline the key concepts and skills to be developed and link to the syllabus subject matter listed in the chapter opener.

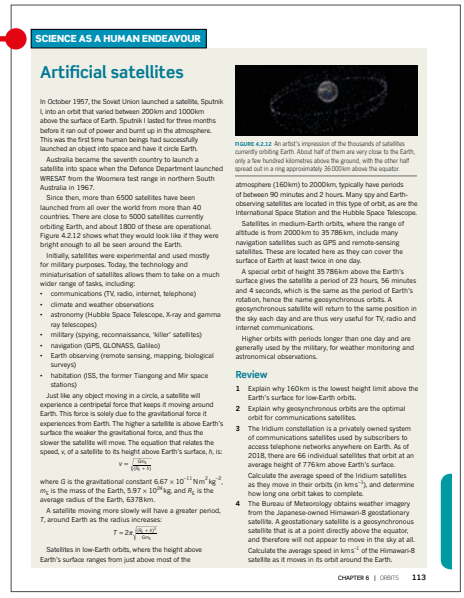

3.1 Inclined planes

BY THE END OF THIS MODULE, YOU SHOULD BE ABLE TO:

- identify the forces acting on an object moving or resting on a surface at an angle to the horizontal, including the force due to gravity, friction and normal forces
- draw free-body diagrams to show the forces acting on an object on an inclined plane
- use vectors to analyse the net force acting on an object on an inclined plane.

Science as a human endeavour

This feature provides an opportunity to appreciate the development of science and its use and influence on society. The SHE features provide a segue into the development of claims and research questions for the research investigation.


SCIENCE AS A HUMAN ENDEAVOUR

Artificial satellites

In October 1957, the Soviet Union launched a satellite, Sputnik I, into an orbit that varied between 200 km and 1000 km above the surface of Earth. Sputnik I lasted for three months before it ran out of power and burnt up in the atmosphere. This was the first time human beings had successfully launched an object into space and have it circle Earth.

Australia became the seventh country to launch a satellite into space when the Defence Department launched WRESAT from the Woomera test range in northern South Australia in 1967.

Since then, more than 6500 satellites have been launched from all over the world from more than 40 countries. There are close to 3000 satellites currently orbiting Earth, and about 1800 of these are operational. Figure 4.2.12 shows what they would look like if they were bright enough to all be seen around the Earth.

Initially, satellites were experimental and used mostly for military purposes. Today, the technology and miniaturisation of satellites allows them to take on a much wider range of tasks, including:

- communications (TV, radio, internet, telephone)
- climate and weather observations
- astronomy (Hubble Space Telescope, X-ray and gamma ray telescopes)
- military (spying, reconnaissance, 'killer' satellites)
- navigation (GPS, GLONASS, Galileo)
- Earth observing (remote sensing, mapping, biological surveys)
- habitation (ISS, the former Tiangong and Mir space stations)

Just like any object moving in a circle, a satellite will experience a centripetal force that keeps it moving around Earth. This force is solely due to the gravitational force it experiences from Earth. The higher a satellite is above Earth's surface the weaker the gravitational force, and thus the slower the satellite will move. The equation that relates the speed, v, of a satellite to its height above Earth's surface, h, is:

$$v = \sqrt{\frac{Gm_E}{(R_E + h)}}$$

where G is the gravitational constant $6.67 \times 10^{-11}\ \text{Nm}^2\text{kg}^{-2}$, m_E is the mass of the Earth, 5.97×10^{24} kg, and R_E is the average radius of the Earth, 6378 km.

A satellite moving more slowly will have a greater period, T, around Earth as the radius increases:

$$T = 2\pi\sqrt{\frac{(R_E + h)^3}{Gm_E}}$$

Satellites in low-Earth orbits, where the height above Earth's surface ranges from just above most of the atmosphere (160 km) to 2000 km, typically have periods of between 90 minutes and 2 hours. Many spy and Earth-observing satellites are located in this type of orbit, as are the International Space Station and the Hubble Space Telescope.

FIGURE 4.2.12 An artist's impression of the thousands of satellites currently orbiting Earth. About half of them are very close to the Earth, only a few hundred kilometres above the ground, with the other half spread out in a ring approximately 36 000 km above the equator.

Satellites in medium-Earth orbits, where the range of altitude is from 2000 km to 35 786 km, include many navigation satellites such as GPS and remote-sensing satellites. These are located here as they can cover the surface of Earth at least twice in one day.

A special orbit of height 35 786 km above the Earth's surface gives the satellite a period of 23 hours, 56 minutes and 4 seconds, which is the same as the period of Earth's rotation, hence the name geosynchronous orbits. A geosynchronous satellite will return to the same position in the sky each day and are thus very useful for TV, radio and internet communications.

Higher orbits with periods longer than one day and are generally used by the military, for weather monitoring and astronomical observations.

Review

1. Explain why 160 km is the lowest height limit above the Earth's surface for low-Earth orbits.
2. Explain why geosynchronous orbits are the optimal orbit for communications satellites.
3. The Iridium constellation is a privately owned system of communications satellites used by subscribers to access telephone networks anywhere on Earth. As of 2018, there are 66 individual satellites that orbit at an average height of 776 km above Earth's surface.
   Calculate the average speed of the Iridium satellites as they move in their orbits (in kms^{-1}), and determine how long one orbit takes to complete.
4. The Bureau of Meteorology obtains weather imagery from the Japanese-owned Himawari-8 geostationary satellite. A geostationary satellite is a geosynchronous satellite that is at a point directly above the equator, and therefore will not appear to move in the sky at all.
   Calculate the average speed in kms^{-1} of the Himawari-8 satellite as it moves in its orbit around the Earth.

CHAPTER 6 | ORBITS 113

Pythagoras' theorem

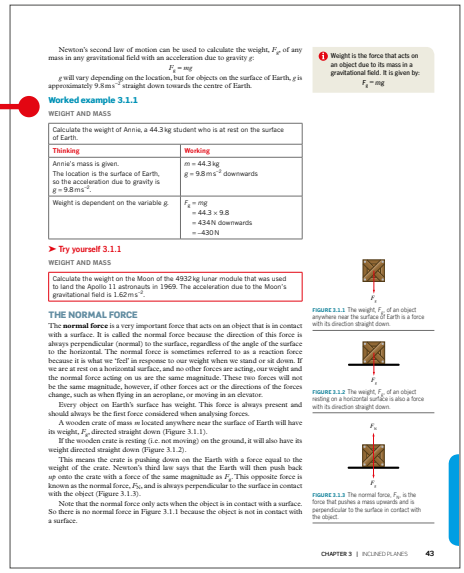
Pythagoras' theorem is $a^2 + b^2 = c^2$, where c is the hypotenuse (the longest side) and a and b are the two shorter sides of a right-angled triangle. The hypotenuse is easily recognised as it is directly across from (opposite) the right angle of the triangle.

Highlight box

Highlight features focus students' attention on important information such as key definitions, formulas and salient points.

Worked examples

Worked examples use sequential steps of thinking and working to model calculations and problem-solving, step-by-step. Each Worked example is followed by a Try yourself task where students apply their learning to a mirrored problem, to practise the skill. Fully worked solutions to all Try yourself problems are available online on *Pearson Physics 12 Queensland Teacher Support*.



Newton's second law of motion can be used to calculate the weight, F_g, of any mass in any gravitational field with an acceleration due to gravity g:

$F_g = mg$

g will vary depending on the location, but for objects on the surface of Earth, g is approximately $9.8\,m\,s^{-2}$ straight down towards the centre of Earth.

Weight is the force that acts on an object due to its mass in a gravitational field. It is given by: $F_g = mg$

Worked example 3.1.1

WEIGHT AND MASS

Calculate the weight of Annie, a 44.3 kg student who is at rest on the surface of Earth.

Thinking	Working
Annie's mass is given. The location is the surface of Earth, so the acceleration due to gravity is $g = 9.8\,m\,s^{-2}$.	$m = 44.3\,kg$ $g = 9.8\,m\,s^{-2}$ downwards
Weight is dependent on the variable g.	$F_g = mg$ $= 44.3 \times 9.8$ $= 434\,N$ downwards $= -430\,N$

Try yourself 3.1.1

WEIGHT AND MASS

Calculate the weight on the Moon of the 4932 kg lunar module that was used to land the Apollo 11 astronauts in 1969. The acceleration due to the Moon's gravitational field is $1.62\,m\,s^{-2}$.

THE NORMAL FORCE

The **normal force** is a very important force that acts on an object that is in contact with a surface. It is called the normal force because the direction of this force is always perpendicular (normal) to the surface, regardless of the angle of the surface to the horizontal. The normal force is sometimes referred to as a reaction force because it is what we 'feel' in response to our weight when we stand or sit down. If we are at rest on a horizontal surface, and no other forces are acting, our weight and the normal force acting on us are the same magnitude. These two forces will not be the same magnitude, however, if other forces act or the directions of the forces change, such as when flying in an aeroplane, or moving in an elevator.

Every object on Earth's surface has weight. This force is always present and should always be the first force considered when analysing forces.

A wooden crate of mass m located anywhere near the surface of Earth will have its weight, F_g, directed straight down (Figure 3.1.1).

If the wooden crate is resting (i.e. not moving) on the ground, it will also have its weight directed straight down (Figure 3.1.2).

This means the crate is pushing down on the Earth with a force equal to the weight of the crate. Newton's third law says that the Earth will then push back *up* onto the crate with a force of the same magnitude as F_g. This opposite force is known as the normal force, F_N, and is always perpendicular to the surface in contact with the object (Figure 3.1.3).

Note that the normal force only acts when the object is in contact with a surface. So there is no normal force in Figure 3.1.1 because the object is not in contact with a surface.

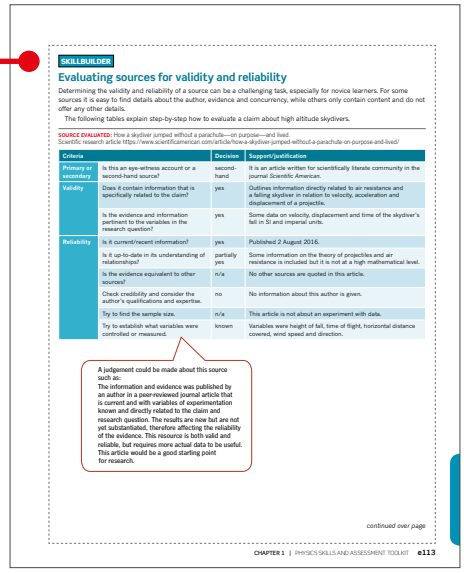
FIGURE 3.1.1 The weight, F_g, of an object anywhere near the surface of Earth is a force with its direction straight down.

FIGURE 3.1.2 The weight, F_g, of an object resting on a horizontal surface is also a force with its direction straight down.

FIGURE 3.1.3 The normal force, F_N, is the force that pushes a mass upwards and is perpendicular to the surface in contact with the object.

SkillBuilder

A SkillBuilder outlines a method or technique. Each is instructive and self-contained. SkillBuilders step students through the skill to support science application required when analysing or utilising knowledge.



SKILLBUILDER

Evaluating sources for validity and reliability

Determining the validity and reliability of a source can be a challenging task, especially for novice learners. For some sources it is easy to find details about the author, evidence and concurrency, while others only contain content and do not offer any other details.

The following tables explain step-by-step how to evaluate a claim about high altitude skydivers.

SOURCE EVALUATED: How a skydiver jumped without a parachute—on purpose—and lived.
Scientific research article https://www.scientificamerican.com/article/how-a-skydiver-jumped-without-a-parachute-on-purpose-and-lived/

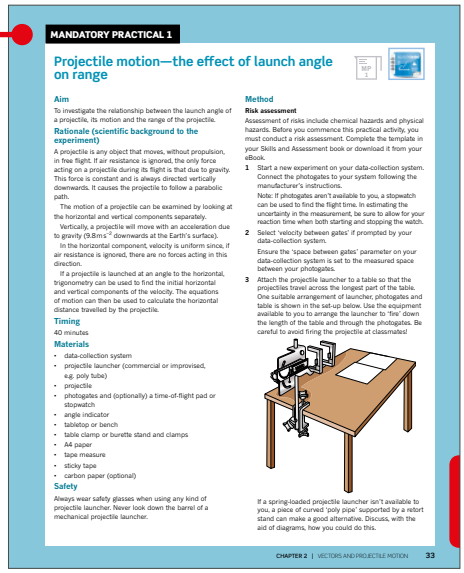
Criteria		Decision	Support/justification
Primary or secondary	Is this an eye-witness account or a second-hand source?	second-hand	It is an article written for scientifically literate community in the journal *Scientific American*.
Validity	Does it contain information that is specifically related to the claim?	yes	Outlines information directly related to air resistance and a falling skydiver in relation to velocity, acceleration and displacement of a projectile.
	Is the evidence and information pertinent to the variables in the research question?	yes	Some data on velocity, displacement and time of the skydiver's fall in SI and imperial units.
Reliability	Is it current/recent information?	yes	Published 2 August 2016.
	Is it up-to-date in its understanding of relationships?	partially yes	Some information on the theory of projectiles and air resistance is included but it is not at a high mathematical level.
	Is the evidence equivalent to other sources?	n/a	No other sources are quoted in this article.
	Check credibility and consider the author's qualifications and expertise.	no	No information about this author is given.
	Try to find the sample size.	n/a	This article is not about an experiment with data.
	Try to establish what variables were controlled or measured.	known	Variables were height of fall, time of flight, horizontal distance covered, wind speed and direction.

A judgement could be made about this source such as:
The information and evidence was published by an author in a peer-reviewed journal article that is current and with variables of experimentation known and directly related to the claim and research question. The results are new but are not yet substantiated, therefore affecting the reliability of the evidence. This resource is both valid and reliable, but requires more actual data to be useful. This article would be a good starting point for research.

continued over page

Mandatory practicals

The student book includes all mandatory practicals. Practicals fully address the syllabus requirements. Each practical has been trialled and tested to ensure it can be safely performed and yields effective, safe results.



MANDATORY PRACTICAL 1

Projectile motion—the effect of launch angle on range

Aim

To investigate the relationship between the launch angle of a projectile, its motion and the range of the projectile.

Rationale (scientific background to the experiment)

A projectile is any object that moves, without propulsion, in free flight. If air resistance is ignored, the only force acting on a projectile during its flight is that due to gravity. This force is constant and is always directed vertically downwards. It causes the projectile to follow a parabolic path.

The motion of a projectile can be examined by looking at the horizontal and vertical components separately.

Vertically, a projectile will move with an acceleration due to gravity ($9.8\,m\,s^{-2}$ downwards at the Earth's surface).

In the horizontal component, velocity is uniform since, if air resistance is ignored, there are no forces acting in this direction.

If a projectile is launched at an angle to the horizontal, trigonometry can be used to find the initial horizontal and vertical components of the velocity. The equations of motion can then be used to calculate the horizontal distance travelled by the projectile.

Timing

40 minutes

Materials

- data-collection system
- projectile launcher (commercial or improvised, e.g. poly tube)
- projectile
- photogates and (optionally) a time-of-flight pad or stopwatch
- angle indicator
- tabletop or bench
- table clamp or burette stand and clamps
- A4 paper
- tape measure
- sticky tape
- carbon paper (optional)

Safety

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

Method

Risk assessment

Assessment of risks include chemical hazards and physical hazards. Before you commence this practical activity, you must conduct a risk assessment. Complete the template in your Skills and Assessment book or download it from your eBook.

1 Start a new experiment on your data-collection system. Connect the photogates to your system following the manufacturer's instructions.
Note: If photogates aren't available to you, a stopwatch can be used to find the flight time. In estimating the uncertainty in the measurement, be sure to allow for your reaction time when both starting and stopping the watch.

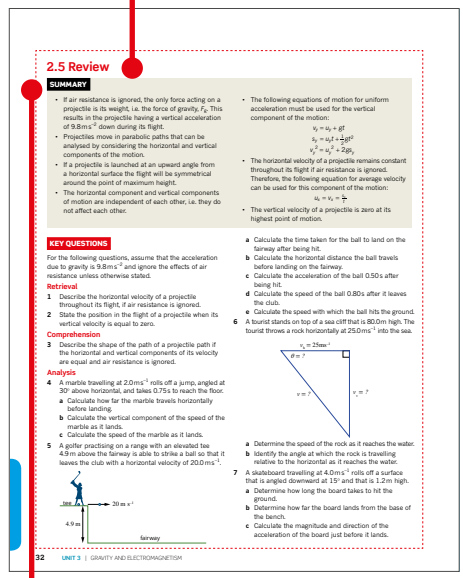
2 Select 'velocity between gates' if prompted by your data-collection system.
Ensure the 'space between gates' parameter on your data-collection system is set to the measured space between your photogates.

3 Attach the projectile launcher to a table so that the projectiles travel across the longest part of the table. One suitable arrangement of launcher, photogates and table is shown in the set-up below. Use the equipment available to you to arrange the launcher to 'fire' down the length of the table and through the photogates. Be careful to avoid firing the projectile at classmates!

If a spring-loaded projectile launcher isn't available to you, a piece of curved 'poly pipe' supported by a retort stand can make a good alternative. Discuss, with the aid of diagrams, how you could do this.

Module summary

Each module concludes with a summary to consolidate key points and concepts.



2.5 Review

SUMMARY

- If air resistance is ignored, the only force acting on a projectile is its weight, i.e. the force of gravity, F_g. This results in the projectile having a vertical acceleration of $9.8\,m\,s^{-2}$ down during its flight.
- Projectiles move in parabolic paths that can be analysed by considering the horizontal and vertical components of the motion.
- If a projectile is launched at an upward angle from a horizontal surface the flight will be symmetrical around the point of maximum height.
- The horizontal component and vertical components of motion are independent of each other, i.e. they do not affect each other.
- The following equations of motion for uniform acceleration must be used for the vertical component of the motion:
$v_f = u_f + gt$
$s_f = u_f t + \frac{1}{2}gt^2$
$v_f^2 = u_f^2 + 2gs_f$
- The horizontal velocity of a projectile remains constant throughout its flight if air resistance is ignored. Therefore, the following equation for average velocity can be used for this component of the motion:
$u_h = v_h = \frac{s_h}{t}$
- The vertical velocity of a projectile is zero at its highest point of motion.

KEY QUESTIONS

For the following questions, assume that the acceleration due to gravity is $9.8\,m\,s^{-2}$ and ignore the effects of air resistance unless otherwise stated.

Retrieval

1 Describe the horizontal velocity of a projectile throughout its flight, if air resistance is ignored.
2 State the position in the flight of a projectile when its vertical velocity is equal to zero.

Comprehension

3 Describe the shape of the path of a projectile path if the horizontal and vertical components of its velocity are equal and air resistance is ignored.

Analysis

4 A marble travelling at $2.0\,m\,s^{-1}$ rolls off a jump, angled at 30° above horizontal, and takes 0.75 s to reach the floor.
a Calculate how far the marble travels horizontally before landing.
b Calculate the vertical component of the speed of the marble as it lands.
c Calculate the speed of the marble as it lands.

5 A golfer practising on a range with an elevated tee 4.9 m above the fairway is able to strike a ball so that it leaves the club with a horizontal velocity of $20.0\,m\,s^{-1}$.
a Calculate the time taken for the ball to land on the fairway after being hit.
b Calculate the horizontal distance the ball travels before landing on the fairway.
c Calculate the acceleration of the ball 0.50 s after being hit.
d Calculate the speed of the ball 0.80 s after it leaves the club.
e Calculate the speed with which the ball hits the ground.

6 A tourist stands on top of a sea cliff that is 80.0 m high. The tourist throws a rock horizontally at $25.0\,m\,s^{-1}$ into the sea.
a Determine the speed of the rock as it reaches the water.
b Identify the angle at which the rock is travelling relative to the horizontal as it reaches the water.

7 A skateboard travelling at $4.0\,m\,s^{-1}$ rolls off a surface that is angled downward at 15° and that is 1.2 m high.
a Determine how long the board takes to hit the ground.
b Determine how far the board lands from the base of the bench.
c Calculate the magnitude and direction of the acceleration of the board just before it lands.

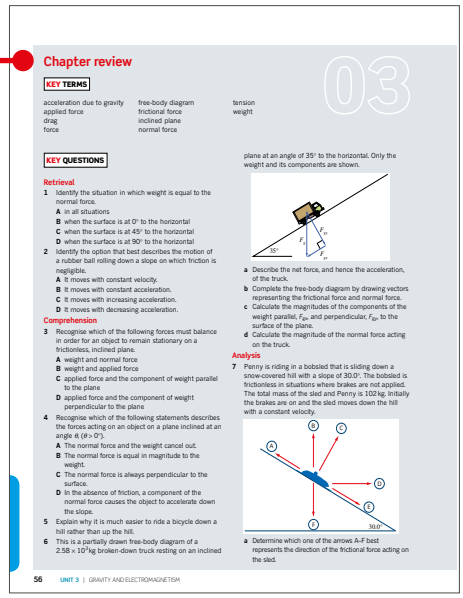
Module review

Key questions are provided to test students' understanding of concepts. Tasks are carefully categorised under the relevant cognitive level—retrieval, comprehension, analysis—and are developed to assess the syllabus requirements.

How to use this book

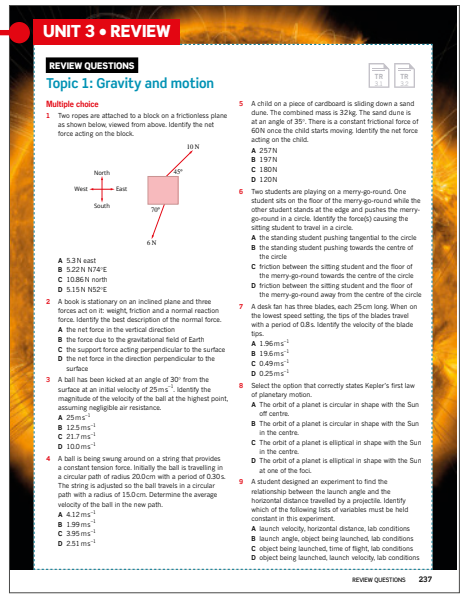
Chapter review

Each chapter finishes with a list of key terms covered in the chapter and a set of tasks to test students' abilities to apply the knowledge gained from the chapter.



Unit review

Each unit finishes with a comprehensive set of exam-style questions, including multiple choice, short answer and extended response. These review questions assist students to draw together their knowledge and understanding of the whole unit.



Glossary

Key terms are shown in **bold** throughout the Student Book and are listed at the end of each chapter. A comprehensive glossary at the end of the book defines all the key terms. The glossary aligns with the syllabus context and includes the QCAA defined terminology.

Answers

Numerical answers and key short-response answers are included at the back of the book. The *Pearson Physics 12 Queensland Reader+* eBook provides comprehensive answers to all tasks; and fully worked solutions for all module review tasks, try yourself, science as a human endeavour, chapter review questions and unit review questions.

Icons

Go To icons make important links to relevant content within the student books in the course. The Go To icons indicate where to engage with Chapter 1 in your eBook.

GO TO ➤

Every mandatory practical is supported by a complimentary **SPARKlab** alternative practical.

The ***Pearson Physics Skills and Assessment*** book icons indicate the best time to engage with an activity for practice, application and revision.
The type of activity is indicated as follows:

Worksheet (WS) — WS 3.1.1

Topic Review (TR) — TR 3.1

Mandatory Practical (MP) — MP 1

Practical Activity (PA) — PA 3.2.1

Sample Assessment Task (SAT) — SAT IA2

The **Reader+** icon indicates when to engage with an asset via your Reader+ eBook. Assets may include videos and interactive activities.

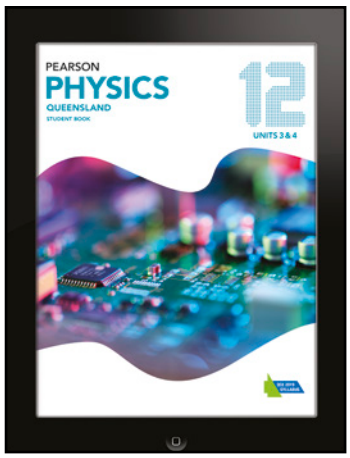
Pearson Physics 12 Queensland

Student Book

Pearson Physics 12 Queensland Student Book has been developed by experienced Queensland teachers to address all the requirements of the new QCAA Physics General Senior Syllabus. The series features the very latest developments and applications of physics, literacy and instructional design to ensure the content and concepts are fully accessible to all students.

Skills and Assessment book

Pearson Physics 12 Skills and Assessment book gives students the edge in preparing for all forms of assessment. Specifically prepared to provide opportunities to consolidate, develop and apply subject matter and science inquiry skills, this resource features a toolkit, key knowledge summaries, worksheets, practical activities and guidance, assessment practice and topic review sets.



Reader+ the next generation eBook

Reader+ is our next generation eBook. Students can read, take notes, save bookmarks and more in the one seamless experience. Integrated multimedia (audio/video) and interactive activities enhance and extend the learning experience.

Teacher support

Pearson Physics 12 Queensland Teacher Support provides:

- complete answers, fully worked solutions or suggested answers to all the questions in the *Student Book* and *Skills and Assessment* book
- expected results, common mistakes, suggested answers and full safety notes and risk assessments for all practical activities
- teaching and learning assessment programs.

Pearson

Access your digital resources at **pearsonplaces.com.au**
Browse and buy at **pearson.com.au**