VCE Physics Units 3&4 Complete Study Guide

Complete study guide · Units 3&4 · VCE Physics Study Design (Units 3 and 4 from 2024) · AceGuides

This guide follows the VCAA *VCE Physics Study Design*, accredited from 2023 (Units 1 and 2 from 2023; Units 3 and 4 from 2024). It covers every key knowledge dot point in Unit 3 (How do fields explain motion and electricity?) and Unit 4 (How have creative ideas and investigation revolutionised thinking in physics?), plus the key science skills and the student-designed investigation presented as a scientific poster. Numerical data in this guide uses the values printed on the VCAA formula sheet (for example $g = 9.8\ \text{m s}^{-2}$, $h = 6.63 \times 10^{-34}\ \text{J s}$, $c = 3.0 \times 10^{8}\ \text{m s}^{-1}$).

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About this guide

How to use this guide

Each topic section follows the same pattern: the ideas in plain English, worked examples with every step shown, a summary table, exam tips and common mistakes, then a "Check your understanding" set. Full solutions to every question are in the Worked solutions section near the end.

- Read a section once for understanding. Terms in **bold** are the words assessors look for.
- Cover each worked example and try it yourself before reading the working.
- Do the "Check your understanding" questions without notes, then mark them against the Worked solutions.
- Build your A3 sheet of notes as you go (the exam allows one folded A3 sheet or two A4 sheets taped together).
- In the last three weeks, sit the Practice exam in 2 hours 30 minutes with 15 minutes of reading time.

Exam tip: Blue boxes give advice on how marks are awarded. Amber boxes warn you about mistakes that cost students marks every year.

How VCE Physics Units 3&4 is assessed

Component	What it is	Contribution to study score
Unit 3 School-assessed Coursework	Three tasks, one for each of Outcomes 1, 2 and 3 (40 marks each, 120 marks total)	30%
Unit 4 School-assessed Coursework	One task for Outcome 1 (40 marks) plus the scientific poster and logbook for Outcome 2 (40 marks)	20%
End-of-year examination	15 minutes reading, 2 hours 30 minutes writing	50%

Each SAC for Unit 3 and for Unit 4 Outcome 1 is chosen by your school from four task types: application of physics concepts to explain a model, theory, device, design or innovation; analysis and evaluation of primary and/or secondary data; problem-solving in real-world contexts; and comparison and evaluation of two solutions, explanations, methods or findings. Each type can

only be used once across Units 3 and 4. Written SACs take about 50 minutes.

The exam (VCAA specifications, from 2024) has two sections:

Section	Format	Marks	Suggested time
A	20 multiple-choice questions, 1 mark each	20	about 25 minutes
B	Short-answer and extended-answer questions, many with several parts	100	about 125 minutes
Total	All questions compulsory	120	150 minutes

You may bring a scientific calculator and one A3 sheet of pre-written notes. A formula sheet is provided. All key knowledge in Units 3 and 4 and all key science skills are examinable, so the practical investigation skills (Section 8 of this guide) also turn up in the exam.

Exam tip: Questions often combine areas of study, for example a particle accelerator question can use electric fields (Unit 3), circular motion (Unit 3) and relativity (Unit 4) in one stem.

Will this guide stay current?

At the time of writing (2026), the study design accredited from 2023 is still in force and VCAA has not published a replacement study design for Units 3 and 4. Check the VCE Physics page on the VCAA website each year. Mechanics, fields, electromagnetic induction, the photoelectric effect and special relativity have been in every recent VCE Physics study design, so most of this guide should carry over to a future one.

Study plan: 10-week revision timetable

Week	Focus	Tasks
1	Section 1: Newton's laws, circular and projectile motion	Worked examples, Check your understanding 1
2	Section 2: momentum,	Check your understanding 2,

	impulse, work and energy	start A3 sheet
3	Section 3: fields	Check your understanding 3, compare-the-fields table
4	Section 4: satellites, motors, accelerators	Check your understanding 4
5	Section 5: generation and transmission of electricity	Check your understanding 5
6	Section 6: light and matter	Check your understanding 6
7	Section 7: special relativity	Check your understanding 7
8	Section 8 and Exam technique	Practise data analysis and linearising graphs
9	Practice exam under timed conditions	Mark it, list weak dot points
10	Weak spots plus past VCAA exams	Final A3 sheet, One-page summary

Contents

1. Newton's laws and motion in two dimensions
2. Momentum, impulse, work and energy
3. Gravitational, electric and magnetic fields
4. Applying fields: satellites, motors and particle accelerators
5. Generating and transmitting electricity
6. Light and matter
7. Special relativity and mass–energy
8. The practical investigation and scientific poster
9. Exam technique
10. Practice exam
11. Worked solutions
12. Glossary
13. One-page summary

1. Newton's laws and motion in two dimensions

Unit 3, Area of Study 1: How do physicists explain motion in two dimensions?

Newton's three laws

Newton's first law: an object stays at rest or keeps moving at constant velocity unless a non-zero net force acts on it. Constant velocity means the forces are balanced, not that there are no forces.

Newton's second law: the net force on an object equals its mass times its acceleration, $F_{net} = ma$. The acceleration is in the same direction as the net force.

Newton's third law: forces come in pairs. If A pushes on B, then B pushes on A with a force of equal size in the opposite direction. The two forces act on different objects, so they never cancel each other.

VCAA uses careful language for forces. Write the force due to gravity as $\mathbf{F_g}$ (= mg). Do not use "weight". The force from a surface at right angles to it is the **normal force**, N. Describe forces as the force **on** one object **by** another, for example $F_{\text{on box by floor}}$.

Solving force problems in one and two dimensions

Use the same routine for every force question:

1. Draw the object on its own and add every force acting on it (gravity, normal, tension, friction, applied forces).
2. Choose positive directions, usually along and perpendicular to the motion.
3. Resolve any angled forces into components ($F\cos\theta$ and $F\sin\theta$).
4. Add the components to get the net force in each direction, then use $F_{net} = ma$.

For two forces at right angles, the net force has magnitude $\sqrt{(F_1^2 + F_2^2)}$ and direction $\tan\theta = F_2 \div F_1$.

Worked example 1.1: connected bodies. A 4.0 kg block on a frictionless horizontal table is joined by a light string over a pulley to a 1.0 kg mass hanging over the edge. Find the acceleration and the tension in the string.

Treat the two masses as one system. The only unbalanced external force is the force due to gravity on the hanging mass: $F_g = 1.0 \times 9.8 = 9.8$ N.

$a = F_{net} \div m_{total} = 9.8 \div 5.0 = 1.96$ m s^{-2}

The tension is the only horizontal force on the 4.0 kg block, so $T = ma = 4.0 \times 1.96 = 7.84$ N ≈ 7.8 N.

Check with the hanging mass: $F_{net} = 9.8 - 7.84 = 1.96$ N $= 1.0 \times 1.96$. Correct.

Worked example 1.2: inclined plane. A 12 kg box slides down a ramp inclined at 25° to the horizontal. Friction on the box is 20 N up the ramp. Find its acceleration.

Component of gravity down the ramp: $mg \sin \theta = 12 \times 9.8 \times \sin 25° = 49.7$ N.

Net force down the ramp: $49.7 - 20 = 29.7$ N.

$a = 29.7 \div 12 = 2.5$ m s^{-2} down the ramp.

The normal force balances the perpendicular component: $N = mg \cos \theta = 12 \times 9.8 \times \cos 25° = 107$ N.

Common mistake: Using $mg \cos \theta$ for the component down the slope. Check with an extreme case: when $\theta = 0°$ the ramp is flat, so the component along it must be zero, which matches $\sin 0° = 0$.

Uniform circular motion in a horizontal plane

An object moving in a circle at constant speed is accelerating because its direction keeps changing. The acceleration points to the centre of the circle (**centripetal acceleration**):

$a = v^2 \div r = 4\pi^2 r \div T^2$, and $v = 2\pi r \div T$

The net force must also point to the centre: $F_{net} = mv^2 \div r$. "Centripetal force" is not an extra force. It is the name for the net force, which is supplied by real forces such as friction, tension, the normal force or gravity.

Situation	What supplies the net (centripetal) force
Car on a flat circular road	Sideways friction between tyres and road
Car on a banked track at the design speed	Horizontal component of the normal force
Mass on a string on a smooth horizontal table	Tension in the string
Conical pendulum (mass swinging in a horizontal circle)	Horizontal component of tension
Satellite in orbit	Gravitational force from the planet

Worked example 1.3: flat curve. A 1200 kg car travels around a flat curve of radius 50 m at 15 m s^{-1}. What friction force is needed?

$F_{net} = mv^2 \div r = 1200 \times 15^2 \div 50 = 5400$ N towards the centre, supplied by friction. If the road is icy and friction cannot reach 5400 N, the car cannot follow the curve and moves off along a

wider path.

Banked tracks

On a banked track at the **design speed**, no sideways friction is needed. Only two forces act: F_g straight down and the normal force N perpendicular to the track surface. Vertically they balance: $N \cos \theta = mg$. Horizontally, $N \sin \theta$ provides the centripetal force: $N \sin \theta = mv^2 \div r$. Dividing gives:

$\tan \theta = v^2 \div (rg)$

Worked example 1.4: banked track. A track of radius 80 m is banked at 15°. Find the design speed.

$v = \sqrt{(rg \tan \theta)} = \sqrt{(80 \times 9.8 \times \tan 15°)} = 14.5 \text{ m s}^{-1}$

At the design speed the net force is horizontal and equal to $mg \tan \theta$. Above the design speed, more centripetal force is needed, so friction acts down the slope. Below it, friction acts up the slope.

> **Common mistake:** Drawing the net force parallel to the sloping track surface. The car moves in a horizontal circle, so the net force is horizontal, towards the centre.

Objects on the end of a string

For a mass whirled on a smooth horizontal table, tension is the only horizontal force: $T = mv^2 \div r$.

Worked example 1.5: conical pendulum. A 0.20 kg mass on a 1.0 m string swings in a horizontal circle with the string at 30° to the vertical. Find the radius, the speed and the tension.

Radius: $r = L \sin \theta = 1.0 \times \sin 30° = 0.50$ m.

Vertical: $T \cos \theta = mg$, so $T = 0.20 \times 9.8 \div \cos 30° = 2.26$ N ≈ 2.3 N.

Horizontal: $T \sin \theta = mv^2 \div r$. Dividing the two equations gives $\tan \theta = v^2 \div (rg)$, so $v = \sqrt{(0.50 \times 9.8 \times \tan 30°)} = 1.68 \text{ m s}^{-1}$.

Circular motion in a vertical plane

In a vertical circle you only need to analyse the **top** and **bottom** positions. Take the direction towards the centre as positive.

Position	Forces towards centre	Equation
Top of a loop (rider inside the	N and F_g both point down,	$N + mg = mv^2 \div r$

track)	towards the centre	
Bottom of a loop or a dip	N up (towards centre), F_g down (away)	$N - mg = mv^2 \div r$
Top of a hump (car over a crest)	F_g down (towards centre), N up	$mg - N = mv^2 \div r$

At the top of a loop the minimum speed occurs when $N = 0$, so $mg = mv^2 \div r$ and $v_{min} = \sqrt{(gr)}$. For a string, replace N with tension T.

Worked example 1.6: roller-coaster loop. A loop has radius 8.0 m. (a) Find the minimum speed at the top. (b) A 60 kg rider passes the bottom at 20 m s^{-1}. Find the normal force on the rider.

(a) $v_{min} = \sqrt{(gr)} = \sqrt{(9.8 \times 8.0)} = 8.9$ m s^{-1}

(b) $N = mg + mv^2 \div r = 60 \times 9.8 + 60 \times 20^2 \div 8.0 = 588 + 3000 = 3588$ N $\approx 3.6 \times 10^3$ N upwards. This is about six times mg, which is why riders feel pressed into their seats.

Exam tip: In vertical circle questions, always state which forces act and which way the net force points before writing the equation. Many marks are lost by sign errors at the top of the circle.

Projectile motion near Earth's surface

Ignoring air resistance, a projectile has a constant acceleration of 9.8 m s^{-2} downwards. Treat the horizontal and vertical motions separately; they share only the time.

Direction	Acceleration	Velocity	Equations
Horizontal	0	Constant, $u_x = u \cos \theta$	$x = u_x t$
Vertical	−9.8 m s^{-2} (up positive)	Changes, $u_y = u \sin \theta$	$v = u + at$, $s = ut + \tfrac{1}{2}at^2$, $v^2 = u^2 + 2as$

At the highest point the vertical velocity is zero but the horizontal velocity is not, and the acceleration is still 9.8 m s^{-2} down.

Worked example 1.7: angled launch. A ball is kicked from the ground at 20 m s^{-1} at 35° above the horizontal. Find the maximum height, time of flight and range.

$u_x = 20 \cos 35° = 16.38$ m s^{-1}; $u_y = 20 \sin 35° = 11.47$ m s^{-1}

Maximum height: $0 = u_y^2 - 2gH$, so $H = 11.47^2 \div (2 \times 9.8) = 6.7$ m

Time of flight (lands at launch height): $t = 2u_y \div g = 2 \times 11.47 \div 9.8 = 2.34$ s

Range: $x = u_x t = 16.38 \times 2.34 = 38$ m

Worked example 1.8: horizontal launch. A marble rolls off a 1.8 m high bench at 3.0 m s^{-1}. How far from the bench does it land, and at what speed?

Vertical: $u_y = 0$, so $1.8 = ½ \times 9.8 \times t^2$, $t = 0.606$ s

Horizontal: $x = 3.0 \times 0.606 = 1.8$ m

$v_y = 9.8 \times 0.606 = 5.94$ m s^{-1}; speed $= \sqrt{(3.0^2 + 5.94^2)} = 6.7$ m s^{-1} at 63° below the horizontal.

Air resistance (qualitative)

Air resistance acts opposite to the velocity and grows with speed. Its effects on a projectile are:

- the horizontal velocity decreases during the flight, so the range is shorter
- the maximum height is lower and is reached sooner
- the path is no longer a symmetric parabola: the descent is steeper than the ascent
- the time of flight usually decreases slightly compared with the ideal case

> **Common mistake:** Saying a projectile has "no force" at its highest point, or that a forward force keeps it moving. After launch the only force (ignoring air) is F_g, straight down.

Summary: Section 1 formulas

Idea	Formula	Notes
Newton's second law	$F_{net} = ma$	Vector equation; use components
Centripetal acceleration	$a = v^2 \div r = 4\pi^2 r \div T^2$	Points to the centre
Speed in a circle	$v = 2\pi r \div T$	T is the period
Banked track (design speed)	$\tan\theta = v^2 \div (rg)$	No friction needed
Top of loop, minimum speed	$v = \sqrt{(gr)}$	N or T = 0
Constant acceleration	$v = u + at$, $s = ut + ½at^2$, $v^2 = u^2 + 2as$, $s = ½(u + v)t$	Vertical motion of projectiles

Check your understanding 1

1. Two forces act on a 5.0 kg mass: 30 N east and 40 N north. Find the magnitude and

direction of the net force and the acceleration. (3 marks)

2. A 1500 kg car rounds a flat curve of radius 40 m. The maximum sideways friction the tyres can supply is 9000 N. Find the maximum speed. (2 marks)
3. A velodrome track is banked at 20°. Find the radius needed for a design speed of 25 m s^{-1}. (2 marks)
4. A 2.0 kg bucket of water is swung in a vertical circle of radius 0.90 m. (a) Find the minimum speed at the top for the water to stay in. (b) Find the tension in the rope at the bottom when the speed is 5.0 m s^{-1}. (4 marks)
5. A ball is thrown horizontally at 12 m s^{-1} from a 20 m high cliff. Find the time of flight, the horizontal distance travelled and the speed on impact. (4 marks)
6. Explain how air resistance changes the path of a golf ball compared with the ideal parabola. (3 marks)
7. A book rests on a table. A student says "the normal force on the book and the force due to gravity on the book are a Newton's third law pair." Explain why this is wrong and identify the correct partner of each force. (3 marks)

End of free sample

This is 10 of 67 pages.

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