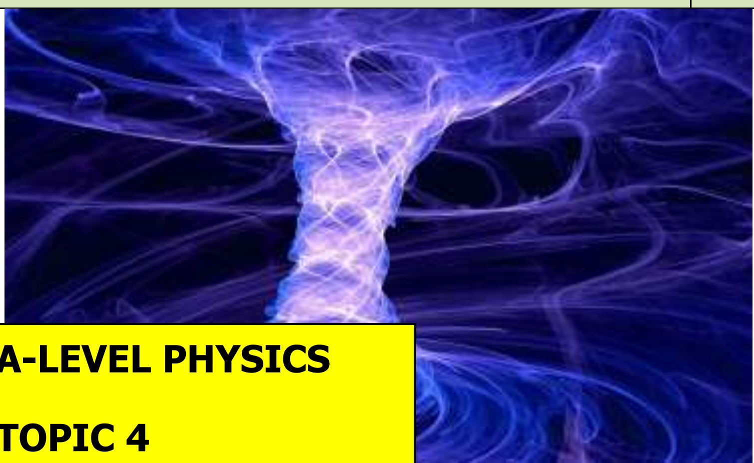
A LEVEL PHYSICS **YEAR 1** **PREPARATORY READING BOOK** **3.4.1:** FORCES AND ENERGY VOLUME **ONE**

Volume

One

NAME	
PHYSICS CLASS	
MODULE TEACHER	
ALPS GRADE	



A-LEVEL PHYSICS

TOPIC 4

PREP READING 1

THIS MUST BE BROUGHT TO ALL PHYSICS LESSONS.

Contents

OVERVIEW

Vectors and their treatment are introduced followed by development of the student's knowledge and understanding of forces, energy and momentum.

The section continues with a study of materials considered in terms of their bulk properties and tensile strength.

IMPORTANT NOTE

This booklet, along with the student workbook, must be brought to all Physics lessons with the appropriate teacher.

This booklet may be used as a learning resource in lessons; you are not fully equipped to learn if this is not used in lesson.

This booklet may also be used as a revision resource for intervention, internal assessments and external assessments.
Please keep this in your student file.

As part of this course you are expected to **read through this preparatory reading book** and **complete the independent study tasks**.

This work will not be assessed but will be monitored by your class teacher.

This must be completed by the deadline set by your class teacher.

Definition List

Definitions you must learn for this module are…

Acceleration, change of velocity per unit time.

Acceleration of free fall, acceleration of an object acted on only by the force of gravity.

Centre of mass, the centre of mass of a body is the point through which a single force on the body has no turning effect.

Couple, pair of equal and opposite forces acting on a body but not along the same line.

Displacement, distance in a given direction.

Drag force, the force of fluid resistance on an object moving through the fluid.

Efficiency, the ration of useful energy transferred by a machine or a device to the energy supplied to it.

Effort, the force applied to a machine to make it move.

Energy, the capacity to do work.

Equilibrium, state of an object when at rest or in uniform motion.

Force, any interaction that can change the velocity of an object.

Free Body Force Diagram, a diagram of an object showing only the forces acting on the object.

Friction, force opposing the motion of a surface that moves or tries to move across another surface.

Inertia, resistance of an object to change of its motion.

Load, the force to be overcome by a machine when it shifts or raises an object.

Mass, measure of inertia or resistance to change of motion of an object.

Moment of a force about a point, force x perpendicular distance from the line of action of the force to a point.

Momentum, mass x velocity.

Motive force, the force that drives a vehicle.

Newton's 1st Law of Motion, an object remains at rest or in uniform motion unless acted on by a resultant force.

Newton's 2nd Law of Motion, the rate of change of momentum of an object is proportional to the resultant force.

Power, rate of transfer of energy.

Principle of conservation of energy, energy cannot be created or destroyed.

Projectile, a projected object in motion acted on only by the force of gravity.

Scalar, a physical quantity with magnitude only.

Speed, change of distance per unit time.

Terminal speed, the maximum speed reached by an object when the drag force on it is equal and opposite to the force causing the motion of the object.

Useful energy, energy transferred to where it is wanted when it is wanted.

Vector, a physical quantity with magnitude and direction.

Velocity, change of displacement per unit time.

Weight, the force of gravity acting on an object.

Work, force x distance moved in the direction of the force.

IMPORTANT NOTE
These definitions must be memorised by students.

You will be tested on your knowledge of these definitions.

The Language of Measurement

The following subject specific vocabulary provides definitions of key terms used in the A-level Science specifications.

Accuracy
A measurement result is considered accurate if it is judged to be close to the true value.

Calibration
Marking a scale on a measuring instrument.
This involves establishing the relationship between indications of a measuring instrument and standard or reference quantity values, which must be applied.
For example, placing a thermometer in melting ice to see whether it reads 0 °C, to check if it has been calibrated correctly.

Data
Information, either qualitative or quantitative, that has been collected.

Errors
See also uncertainties.

Measurement error
The difference between a measured value and the true value.
anomalies
These are values in a set of results which are judged not to be part of the variation caused by random uncertainty.

Random error
These cause readings to be spread about the true value, due to results varying in an unpredictable way from one measurement to the next.
Random errors are present when any measurement is made, and cannot be corrected. The effect of random errors can be reduced by making more measurements and calculating a new mean.

Systematic error
These cause readings to differ from the true value by a consistent amount each time a measurement is made.
Sources of systematic error can include the environment, methods of observation or instruments used.
Systematic errors cannot be dealt with by simple repeats. If a systematic error is suspected, the data collection should be repeated using a different technique or a different set of equipment, and the results compared.

Zero error
Any indication that a measuring system gives a false reading when the true value of a measured quantity is zero, e.g. the needle on an ammeter failing to return to zero when no current flows.
A zero error may result in a systematic uncertainty.

Evidence
Data which has been shown to be valid.

Fair test
A fair test is one in which only the independent variable has been allowed to affect the dependent variable.

Hypothesis
A proposal intended to explain certain facts or observations.

Interval
The quantity between readings, e.g. a set of 11 readings equally spaced over a distance of 1 metre would give an interval of 10 centimetres.

Precision
Precise measurements are ones in which there is very little spread about the mean value. Precision depends only on the extent of random errors – it gives no indication of how close results are to the true value.

Prediction
A prediction is a statement suggesting what will happen in the future, based on observation, experience or a hypothesis.

Range
The maximum and minimum values of the independent or dependent variables; important in ensuring that any pattern is detected.
For example, a range of distances may be quoted as either:
'From 10 cm to 50 cm'
or
'From 50 cm to 10 cm'

Repeatable
A measurement is repeatable if the original experimenter repeats the investigation using same method and equipment and obtains the same results.

Reproducible
A measurement is reproducible if the investigation is repeated by another person, or by using different equipment or techniques, and the same results are obtained.

Resolution
This is the smallest change in the quantity being measured (input) of a measuring instrument that gives a perceptible change in the reading.

Sketch graph
A line graph, not necessarily on a grid, that shows the general shape of the relationship between two variables. It will not have any points plotted and although the axes should be labelled they may not be scaled.

True value
This is the value that would be obtained in an ideal measurement.

Uncertainty
The interval within which the true value can be expected to lie, with a given level of confidence or probability, e.g. "the temperature is 20 °C ± 2 °C, at a level of confidence of 95%.

Validity
Suitability of the investigative procedure to answer the question being asked. For example, an investigation to find out if the rate of a chemical reaction depended upon the concentration of one of the reactants would not be a valid procedure if the temperature of the reactants was not controlled.

Valid conclusion
A conclusion supported by valid data, obtained from an appropriate experimental design and based on sound reasoning.

Variables
These are physical, chemical or biological quantities or characteristics.

Categoric variables
Categoric variables have values that are labels. E.g. names of plants or types of material.

Continuous variables
Continuous variables can have values (called a quantity) that can be given a magnitude either by counting (as in the case of the number of shrimp) or by measurement (e.g. light intensity, flow rate etc.).

Control variables
A control variable is one which may, in addition to the independent variable, affect the outcome of the investigation and therefore must be kept constant or at least monitored.

Dependent variables
The dependent variable is the variable of which the value is measured for each change in the independent variable.

Independent variables
The independent variable is the variable for which values are changed or selected by the investigator.

IMPORTANT NOTE
These definitions must be memorised by students.

You will be tested on your knowledge of these definitions.

VIDEO
COURSE OVERVIEW

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TOPIC: 3.4.1.1 Scalars and Vectors
SPEC CHECK

Specification	Completed?
Nature of scalars and vectors. Examples should include: velocity/speed, mass, force/weight, acceleration, displacement/distance.	
Addition of vectors by calculation or scale drawing. Calculations will be limited to two vectors at right angles. Scale drawings may involve vectors at angles other than 90°.	
Resolution of vectors into two components at right angles to each other. Examples should include components of forces along and perpendicular to an inclined plane. Problems may be solved either using resolved forces or the use of a closed triangle.	
Conditions for equilibrium for two or three coplanar forces acting at a point. Appreciation of the meaning of equilibrium in the context of an object at rest or moving with constant velocity.	
Investigation of the conditions for equilibrium for three coplanar forces acting at a point using a force board.	

Student Checklist

Have I…….	**Yes or No?**
Read through the notes of this section?	
Highlighted/underlined the key concepts of this section?	
Made my own notes based on the notes of this section?	
Brought the notes to be used in lesson?	

Prior Knowledge Link
This is a topic found in a previous GCSE module – **Forces.**

What is a Vector?

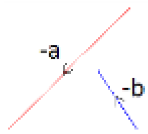
A vector is a physical quantity that has both magnitude (size) and direction.
Examples of Vectors: Displacement, velocity, force, acceleration and momentum.

What is a Scalar?

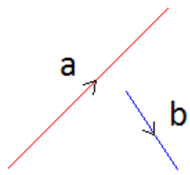
A scalar is a physical quantity that has magnitude only (it doesn't act in a certain direction).
Examples of Scalars: Distance, speed, energy, power, pressure, temperature and mass.

Vector Diagrams

A vector can be represented by a vector diagram as well as numerically:
The **length** of the line represents the **magnitude** of the vector.
The **direction** of the line represents the **direction** of the vector.
We can see that vector **a** has a greater magnitude than vector **b** but acts in a different direction.



A negative vector means a vector of equal magnitude but opposite direction.



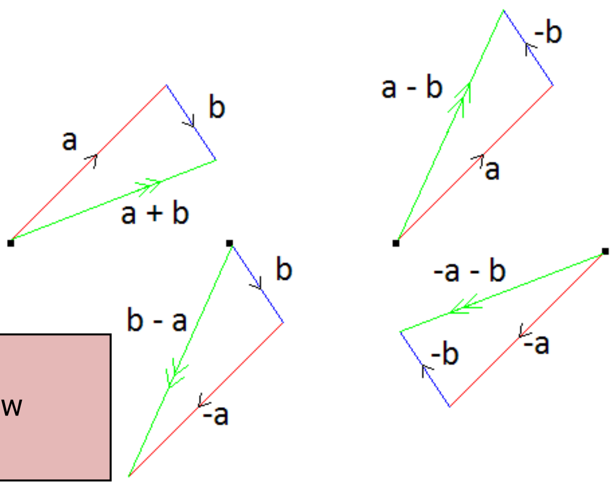
Study Tip
This topic is common content with the A-Level Mathematics specification.

Adding Vectors

We can add vectors together to find the affect that two or more would have if acting at the same time. This is called the resultant vector.
We can find the resultant vector in four ways: Scale drawing, Pythagoras, the Sine and Cosine rules and Resolving vectors.

Scale Drawing

To find the resultant vector of **a** + **b** we draw vector **a** then draw vector **b** from the end of **a**. The resultant is the line that connects the start and finish points.
The resultants of **a** + **b, b** – **a, a** – **b,** – **a** – **b** and would look like this:



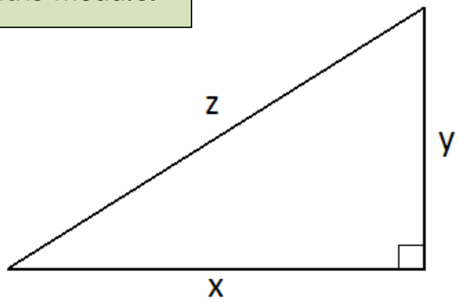
Study Tip
Learn how to accurately draw scaled diagrams.

If the vectors were drawn to scale, we can find the resultant by measuring the length of the line and the angle.

Pythagoras

Synoptic Link
This is a topic found in a previous GCSE Maths module.

If two vectors are perpendicular to each other the resultant can be found using Pythagoras:



Vector **z** is the resultant of vectors **x** and **y**.

Since **x** and **y** are perpendicular $z^2 = x^2 + y^2$ → $z = \sqrt{x^2 + y^2}$

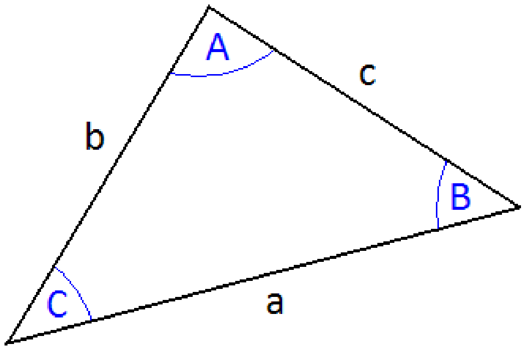
We can also use this in reverse to find **x** or **y**:

$z^2 = x^2 + y^2$ → $z^2 - y^2 = x^2$ → $\sqrt{z^2 - y^2} = x$

$z^2 = x^2 + y^2$ → $z^2 - x^2 = y^2$ → $\sqrt{z^2 - x^2} = y$

Sine and Cosine Rules

Synoptic Link
This is a topic found in a previous GCSE Maths module.



The sine rule relates the angles and lengths using this equation:

$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

The Cosine rule relates them using these equations:

$$a^2 = b^2 + c^2 - 2bc\cos A$$
$$b^2 = a^2 + c^2 - 2ac\cos B$$
$$c^2 = a^2 + b^2 - 2ab\cos C$$

Physics Tip

You always need to add the direction as well as the size of the vector.

Physics Tip

You may give angles in bearings – a three digit angle measured clockwise from north in degrees.

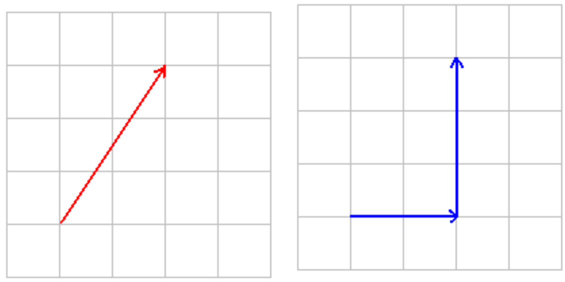
Study Tip
This topic is common content with the A-Level Mathematics specification.

Resolving Vectors

> **Prior Knowledge Link**
> This is a topic found in a previous GCSE module **– Forces.**

A vector can be 'broken down' or *resolved* into its vertical and horizontal components.

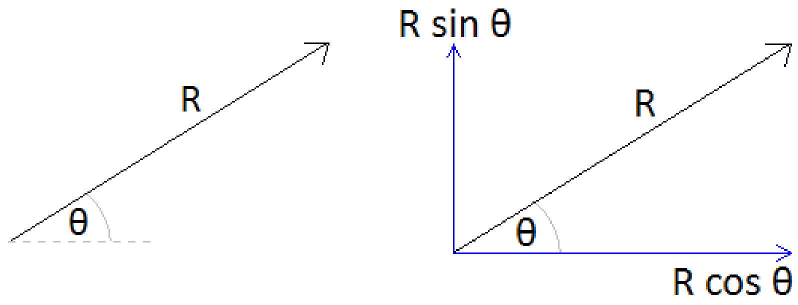
We can see that this vector can be resolved into two perpendicular components, in this case two to the right and three up.



> **Physics Tip**
>
> You can resolve a vector into non-perpendicular components – it is just not very useful.

This is obvious when it is drawn on graph paper but becomes trickier when there isn't a grid and still requires an element of scale drawing.

We can calculate the vertical and horizontal components if we know the magnitude and direction of the vector. In other words; we can work out the across and upwards bits of the vector if we know the length of the line and the angle between it and the horizontal or vertical axis.

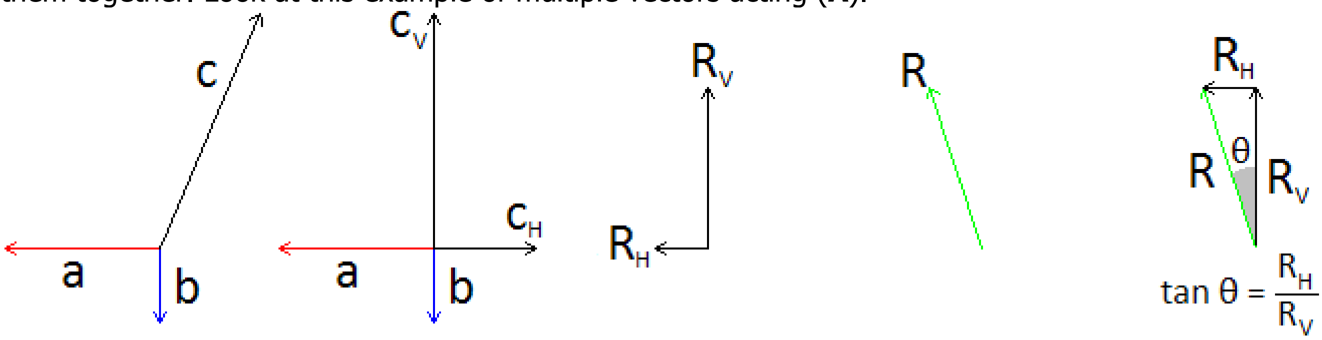


> **Physics Tip**
>
> In these formulae, Θ is measured anti-clockwise from the horizontal.

> **Examination Tip**
>
> Remember… $\cos 60^{o} = \sin 30^{o} = 0.5$

Adding Resolved Vectors

Now that we can resolve vectors into the vertical and horizontal components it is made from we can add them together. Look at this example of multiple vectors acting (**A**).



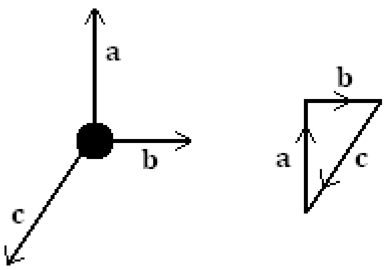
A **B** **C** **D** **E**

If we resolve the vector **c** we get (**B**). We can now find the resultant of the horizontal components and the resultant of the vertical components (**C**). We can then add these together to find the resultant vector (**D**) and the angle can be found using trigonometry (**E**)

> **Physics Tip**
>
> Components are normally horizontal and vertical. If you are working with an object on an inclined plane, it might be easier to use parallel and perpendicular components to the plane.

Equilibrium

When all the forces acting on a body cancel out equilibrium is reached and the object does not move. As you sit and read this the downwards forces acting on you are equally balanced by the upwards forces, the resultant it that you do not move.



Study Tip
This topic is common content with the A-Level Mathematics specification.

With scale drawing we can draw the vectors, one after the other.
If we end up in the same position, we started at then equilibrium is achieved.

With resolving vectors, we can resolve all vectors into their vertical and horizontal components. If the components up and down are equal and the components left and right are equal equilibrium has been reached.

If a scale drawing of the vectors forms a closed shape, then equilibrium is achieved.

Study Tip
Learn how to accurately draw scaled diagrams.

Examination Tip

You will never need to balance more than 3 forces in an examination question.

Examination Tip

It is a common examination question to ask to state two necessary conditions for an object to be in equilibrium.

resultant/overall/sum of force = 0 OR forces up equal forces down AND forces left equal forces right (1 mark).

(sum of) anticlockwise moments (about any point) = (sum of) clockwise moments/zero resultant moment/torque (1 mark)

VIDEO

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TOPIC: 3.4.1.2 Moments
SPEC CHECK

Specification	Completed?
Moment of a force about a point. Moment defined as *force × perpendicular distance from the point to the line of action of the force*.	
Couple as a pair of equal and opposite coplanar forces. Moment of couple defined as *force × perpendicular distance between the lines of action of the forces*.	
Principle of moments.	
Centre of mass. Knowledge that the position of the centre of mass of uniform regular solid is at its centre.	

Student Checklist

Have I…….	**Yes or No?**
Read through the notes of this section?	
Highlighted/underlined the key concepts of this section?	
Made my own notes based on the notes of this section?	
Brought the notes to be used in lesson?	

Moments

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**
This is **not found** in the **Combined Science GCSE**.

Physics Tip

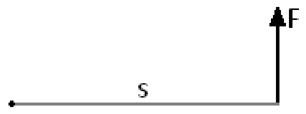
Perpendicular distance means the distance along the line that makes a right angle with the line of action of the force.

This is the shortest possible distance between the pivot and the line in which the force acts.

The moment of a force is its turning affect about a fixed point (pivot).
The magnitude of the moment is given by:
moment = force x perpendicular distance from force to the pivot

$$moment = Fs$$

Study Tip
Learn the base units for this equation and the context in which it can be used in.

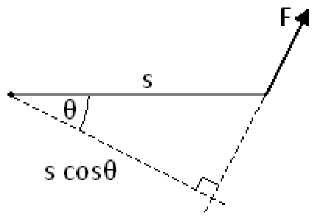


In this diagram, we can see that the force is not acting perpendicularly to the pivot.
We must find the perpendicular or closest distance, this is $s\cos\theta$.
The moment in this case is given as: $moment = Fs\cos\theta$

Study Tip

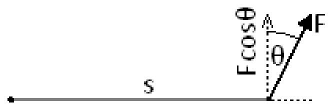
Learn what these equations represents.

The shows the moment on an object.



We could have also used the value of s but multiplied it by the vertical component of the force. This would give us the same equation.

$$moment = F\cos\theta . s$$



Working Scientifically Link

Remember how moments link to real world behaviour.

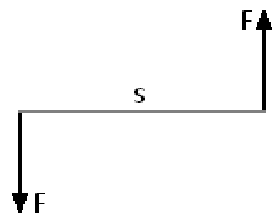
Moments are measured in Newton metres, Nm

Couples

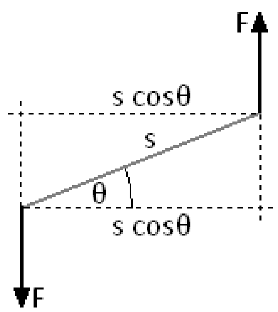
A couple is a pair of equal forces acting in opposite directions. If a couple acts on an object it rotates in position. The moment of a couple is called the torque.
The torque is calculated as: torque = force x perpendicular distance between forces

$$torque = Fs$$

Study Tip
This topic is common content with the A-Level Mathematics specification.



In the diagram to the right we need to calculate the perpendicular distance, $s\cos\theta$.
So, in this case: $torque = Fs\cos\theta$



Physics Tip

For a regular flat symmetric object, or for a uniform regular solid, the centre of mass is always at the centre of the object.

Torque is measured in Newton metres, Nm

Physics Tip

For couples you need to remember to use the perpendicular distance between the forces, not the distance between the one force and the pivot.

Examination Tip

It is a common examination question to state the principle of moments.

Sum of/total clockwise moments = sum of/total anticlockwise moments (1 mark)

For a body in equilibrium (1 mark)

Examination Tip

It is a common examination question to define a moment.

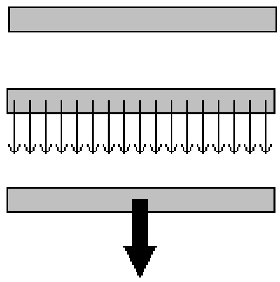
Force x perpendicular distance (1 mark)

Between line of action (of force) and pivot/point (1 mark)

Centre of Mass

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**
This is **not found** in the **Combined Science GCSE**.

If we look at the ruler to the right, every part of it has a mass.
To make tackling questions easier we can assume that all the mass is concentrated in a single point.
The moments about a centre of mass are always equal.
This means an object can always be balanced on its centre of mass.



The perpendicular distance in the moment calculation should always be taken from the centre of mass of the object to the pivot.
This is crucial when calculating the moment of large objects like planks or see-saws.

Centre of Gravity

The centre of gravity of an object is the point where all the weight of the object appears to act.
It is in the same position as the centre of mass in a uniform gravitational field (such as the Earth).

We can represent the weight of an object as a downward arrow acting from the centre of mass or gravity.
This can also be called the line of action of the weight.

Physics Tip

For a regular flat symmetric object, or for a uniform regular solid, the centre of mass is always at the centre of the object.

Examination Tip

It is a common examination question to state the centre of mass.

a (resultant) force directed through the centre of mass of an object will not give it a moment/will not cause the object to rotate (1 mark)

or all the mass of the object appears to be concentrated at the centre of mass owtte

or point at which all the (object’s) weight acts

Examination Tip

It is a common examination question to state why a centre of mass is below an object’s point of suspension.

So, there is not a resultant moment/turning effect / turning force OR moments do not balance OR (beam) does not rotate/oscillate/swing (1 mark)

because the point is pivot (1 mark)

Study Tip
This topic is common content with the A-Level Mathematics specification.

Balancing

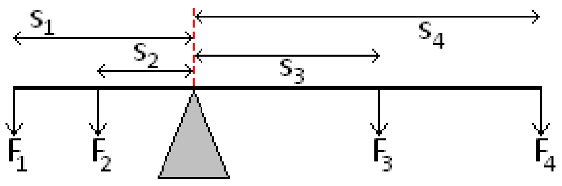
Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**
This is **not found** in the **Combined Science GCSE**.

When an object is balanced, the object is in equilibrium, this means:

the total moments acting clockwise = the total moments acting anticlockwise

An object suspended from a point (e.g. a pin) will come to rest with the centre of mass directly below the point of suspension.

If the seesaw to the left is balanced then the clockwise moments must be equal to the anticlockwise moments.



Clockwise moment due to 3 and 4

$$moment = F_3 s_3 + F_4 s_4$$

Anticlockwise moments due to 1 and 2

$$moment = F_1 s_1 + F_2 s_2$$

So $$F_3 s_3 + F_4 s_4 = F_1 s_1 + F_2 s_2$$

Physics Tip

If the centre of mass is directly over the pivot, there will be no resultant moment in either direction. Any external force will then cause it to topple in the direction of the force.

Examination Tip

Make sure you understand why different amounts of force can act on different supports, as you can be asked about it in the examination.

When looking at the moments on an object, placing the pivot at one of the force removes its moment. If the pivot is placed at the centre of mass of the plank, it removes the moment of the plank.

Working Scientifically Link

Remember how moments link to real world behaviour.

Study Tip
This topic is common content with the A-Level Mathematics specification.

Stability

The stability of an object can be increased by lowering the centre of mass and by widening the base.

An object will topple over if the line of action of the weight falls outside of the base.

Physics Tip

In a balanced object, the forces, as well as the moments, also must be equal.

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TOPIC: 3.4.1.3 Motion Along A Straight Line

SPEC CHECK

Specification	Completed?
Displacement, speed, velocity, acceleration. $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$ Calculations may include average and instantaneous speeds and velocities.	
Representation by graphical methods of uniform and non-uniform acceleration.	
Significance of areas of velocity–time and acceleration–time graphs and gradients of displacement–time and velocity–time graphs for uniform and non-uniform acceleration e.g. graphs for motion of bouncing ball.	
Equations for uniform acceleration: $v = u + at$ $s = \frac{(u + v)}{2} t$ $s = ut + \frac{at^2}{2}$ $v^2 = u^2 + 2as$ Acceleration due to gravity, g.	
Distinguish between instantaneous velocity and average velocity.	
Measurements and calculations from displacement–time, velocity–time and acceleration–time graphs.	
Calculations involving motion in a straight line.	

Student Checklist

Have I.......	**Yes or No?**
Read through the notes of this section?	
Highlighted/underlined the key concepts of this section?	
Made my own notes based on the notes of this section?	
Brought the notes to be used in lesson?	

Distance

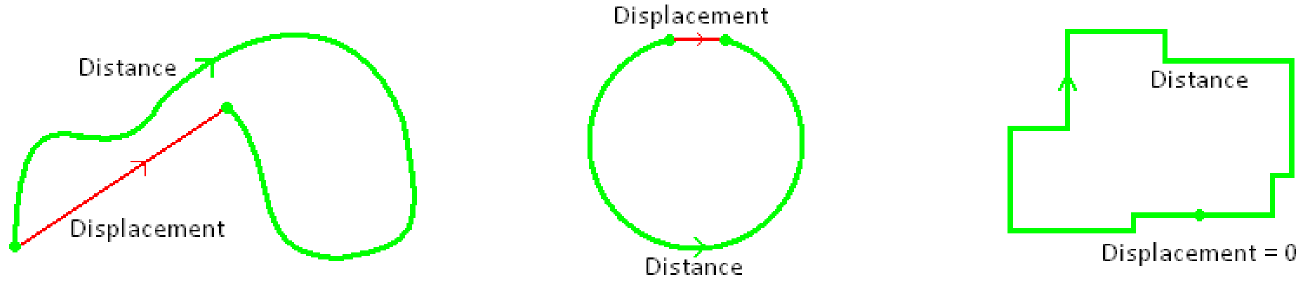
Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

Distance is a scalar quantity. It is a measure of the total length you have moved.

Displacement

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

Displacement is a vector quantity. It is a measure of how far you are from the starting position.
Distance and Displacement are measured in metres, m



Speed

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

Speed is a measure of how the distance changes with time.
Since it is dependent on distance travelled it too is a scalar.

$$speed = \frac{\Delta d}{\Delta t}$$

Velocity

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

Velocity is measure of how the displacement changes with time.
Since it depends on displacement it is a vector too.

$$v = \frac{\Delta s}{\Delta t}$$

Speed and Velocity are is measured in metres per second, m/s

Time is measured in seconds, s

Study Tip
Learn the base units for this equation and the context in which it can be used in.

Study Tip

Learn what these equations represents.

The shows the speed and velocity of a moving object.

Study Tip
This topic is common content with the A-Level Mathematics specification.

Acceleration

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

Acceleration is the rate at which the velocity changes. Since velocity is a vector quantity, so is acceleration. With all vectors, the direction is important. In questions, we decide which direction is positive (e.g. → +ve)

If a moving object has a positive velocity:
* a positive acceleration means an increase in the velocity
* a negative acceleration means a decrease in the velocity (it begins the 'speed up' in the other direction)

If a moving object has a negative velocity:
* a positive acceleration means an increase in the velocity (it begins the 'speed up' in the other direction)
* a negative acceleration means an increase in the velocity

You must consider the situation of the object to determine which answer is correct.

If an object accelerates from a velocity of *u* to a velocity of *v*, and it takes *t* seconds to do it then we can write the equations as $a = \frac{(v-u)}{t}$ it may also look like this $a = \frac{\Delta v}{\Delta t}$ where Δ means the 'change in'

Acceleration is measured in metres per second squared, m/s^2

Uniform Acceleration
In this situation, the acceleration is constant – the velocity changes by the same amount each unit of time. For example: If acceleration is $2 m/s^2$, this means the velocity increases by 2m/s every second.

Time (s)	0	1	2	3	4	5	6	7
Velocity (m/s)	0	2	4	6	8	10	12	14
Acceleration (m/s^2)		2	2	2	2	2	2	2

Non-Uniform Acceleration
In this situation, the acceleration is changing – the velocity changes by a different amount each unit of time.
For example:

Time (s)	0	1	2	3	4	5	6	7
Velocity (m/s)	0	2	6	10	18	28	30	44
Acceleration (m/s^2)		2	4	6	8	10	12	14

Before we look at the two types of graphs we use to represent motion, we must make sure we know how to calculate the gradient of a line and the area under it.

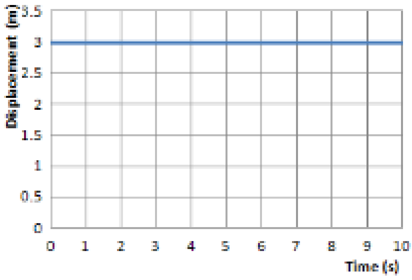
Gradient
We calculate the gradient by choosing two points on the line and calculating the change in the y axis (up/down) and the change in the x axis (across).

$$gradient = \frac{\Delta y}{\Delta x}$$

Area Under Graph
At this level, we will not be asked to calculate the area under curves, only straight lines.
We do this be breaking the area into rectangles (base x height) and triangles (½ base x height).

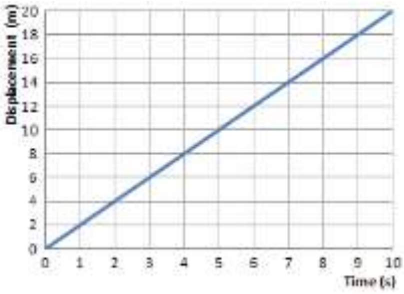
Displacement-Time Graphs

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

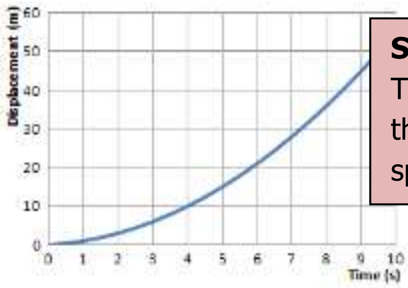


A

Study Tip
Always learn what the gradient and area under the line represent on a graph.



B



Study Tip
This topic is common content with the A-Level Mathematics specification.

C

Graph A shows that the displacement stays at 3m, it is stationary.
This is shown by a flat line.

Graph B shows that the displacement increases by the same amount each second, it is travelling with constant velocity.
This is shown by a straight line.

Graph C shows that the displacement covered each second increases each second, it is accelerating.
This is given by a curving line.

Since $gradient = \frac{\Delta y}{\Delta x}$ and y = displacement and x = time → $gradient = \frac{\Delta s}{\Delta t}$ → $\boxed{gradient = velocity}$

Working Scientifically Link

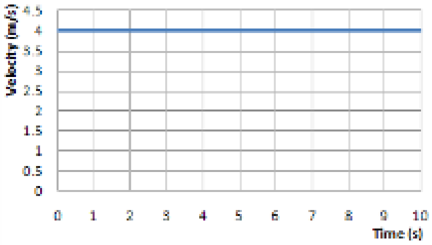
Remember how to determine velocity from this graph.

Working Scientifically Link

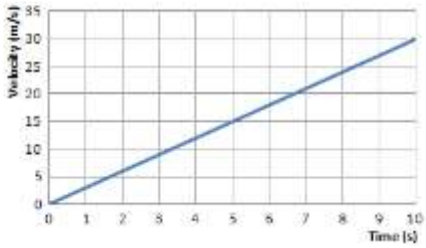
Remember if a line is curved, a tangent must be drawn to work out a gradient.

Velocity- Time Graphs

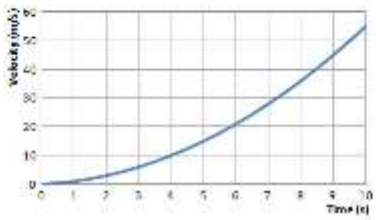
Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**



A



B



C

Graph A shows that the velocity stays at 4m/s, it is moving with constant velocity.
This is shown by a flat line.

Working Scientifically Link

Remember how to determine displacement and acceleration from this graph

Graph B shows that the velocity increases by the same amount each second, it is accelerating by the same amount each second (uniform acceleration).
This is shown by a straight line.

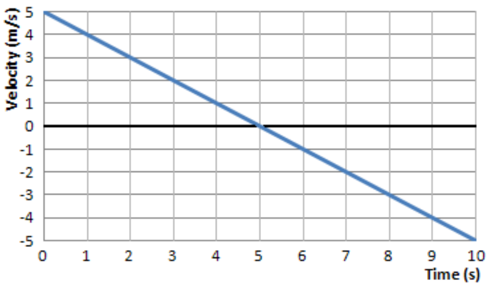
Working Scientifically Link

Remember if a line is curved, a tangent must be drawn to work out a gradient.

Graph C shows that the velocity increases by a larger amount each second, the acceleration is increasing (non-uniform acceleration).
This is shown by a curving line.

Since $gradient = \frac{\Delta y}{\Delta x}$ and y = velocity and x = time → $gradient = \frac{\Delta v}{\Delta t}$ → $gradient = acceleration$

area = base x height → area = time x velocity → *area = displacement*



This graph show the velocity decreasing in one direction and increasing in the opposite direction.

Examination Tip

The areas under any negative parts of the graph count as 'negative areas' as they show the object moving the opposite way to whichever direction you take as positive.

If we decide that ←is negative and →is positive then the graph tells us:

The object is initially travels at 5 m/s → It slows down by 1m/s every second.

After 5 seconds the object has stopped
It then begins to move ← It gains 1m/s every second until it is travelling at 5m/s ←

Working Scientifically Link

Remember if a line is trending downwards, then the gradient must be a negative value.

Physics Tip

Uniform acceleration and deceleration are shown by a straight line on a velocity-time graph.

Study Tip
This topic is common content with the A-Level Mathematics specification.

Physics Tip

In a velocity-time graph of a bouncing ball, the maximum velocity decreases with each bounce because some of the ball's kinetic energy is transferred into other forms when it hits the ground. This means the height of each bounce also decreases.

Defining Symbols

Key Topic Warning
This topic is very common for questions on previous A-Level Papers.

Before we look at the equations we need to assign letters to represent each variable

Displacement	= ***s***	m	metres
Initial Velocity	= ***u***	m/s	metres per second
Final Velocity	= ***v***	m/s	metres per second
Acceleration	= ***a***	m/s^2	metres per second per second
Time	= ***t***	s	seconds

Equations of Motion

Examination Tip

These equations are also known as the 'SUVAT' equations.

Equation 1

If we start with the equation for acceleration $a = \frac{(v-u)}{t}$ we can rearrange this to give us an equation 1

$at = (v - u)$ → $at + u = v$

$$\boxed{v = u + at}$$

Study Tip
Learn the base units for this equation and the context in which it can be used in.

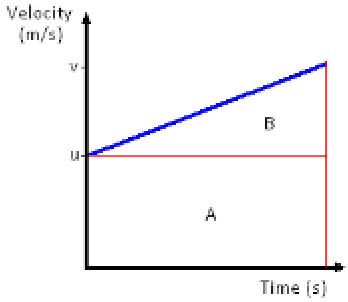
Study Tip

Learn what these equations re\presents.

The shows the motion of an object with constant acceleration.

Equation 2

We start with the definition of velocity and rearrange for displacement
velocity = displacement / time → displacement = velocity x time



In situations like the graph to the right the velocity is constantly changing, we need to use the average velocity.
displacement = average velocity x time

The average velocity is given by: average velocity $= \frac{(u+v)}{2}$

We now substitute this into the equation above for displacement

Displacement = $\frac{(u+v)}{2}$ x time → $s = \frac{(u+v)}{2}t$

$$\boxed{s = \tfrac{1}{2}(u+v)t}$$

Study Tip
Learn the base units for this equation and the context in which it can be used in.

Study Tip

Learn what these equations re\presents.

The shows the motion of an object with constant acceleration.

Equation 3

With Equations 1 and 2 we can derive an equation which eliminated *v*. To do this we simply substitute $v = u + at$ into $s = \frac{1}{2}(u+v)t$

$s = \frac{1}{2}(u + (u + at))t$ → $s = \frac{1}{2}(2u + at)t$ → $s = \frac{1}{2}(2ut + at^2)$ $\boxed{s = ut + \frac{1}{2}at^2}$

This can also be found if we remember that the area under a velocity-time graph represents the distance travelled/displacement. The area under the line equals the area of rectangle A + the area of triangle B.

Area = Displacement = $s = ut + \frac{1}{2}(v-u)t$ since $a = \frac{(v-u)}{t}$ then $at = (v-u)$ so the equation becomes $s = ut + \frac{1}{2}(at)t$ which then becomes equation 3

Examination Tip

Deceleration is the same as negative acceleration.

Study Tip
Learn the base units for this equation and the context in which it can be used in.

Study Tip

Learn what these equations re\presents.

The shows the motion of an object with constant acceleration.

Equation 4

If we rearrange equation 1 into $t = \frac{(v-u)}{a}$ which we will then substitute into equation 2:

$s = \frac{1}{2}(u+v)t$ → $s = \frac{1}{2}(u+v)\frac{(v-u)}{a}$ → $as = \frac{1}{2}(u+v)(v-u)$ → $2as = (v^2 + uv - uv - u^2)$ → $2as = v^2 - u^2$

$\boxed{v^2 = u^2 + 2as}$

Study Tip
Learn the base units for this equation and the context in which it can be used in.

Study Tip

Learn what these equations re\presents.

The shows the motion of an object with constant acceleration.

Any question can be solved if three of the variables are given in the question.
Write down all the variables you have and the one you are asked to find, then see which equation you can use.
These equations can only be used for motion with UNIFORM ACCELERATION.

Study Tip
This topic is common content with the A-Level Mathematics specification.

VIDEO

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TOPIC: 3.4.1.4 Projectile Motion
SPEC CHECK

Specification	Completed?
Independent effect of motion in horizontal and vertical directions of a uniform gravitational field. Problems will be solvable using the equations of uniform acceleration.	
Qualitative treatment of friction. Distinctions between static and dynamic friction will not be tested.	
Qualitative treatment of lift and drag forces.	
Terminal speed.	
Knowledge that air resistance increases with speed.	
Qualitative understanding of the effect of air resistance on the trajectory of a projectile and on the factors that affect the maximum speed of a vehicle.	
Investigation of the factors that determine the motion of an object through a fluid.	

Student Checklist

Have I…….	**Yes or No?**
Read through the notes of this section?	
Highlighted/underlined the key concepts of this section?	
Made my own notes based on the notes of this section?	
Brought the notes to be used in lesson?	

Acceleration Due to Gravity

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

An object that falls freely will accelerate towards the Earth because of the force of gravity acting on it.

The size of this acceleration does not depend mass, so a feather and a bowling ball accelerate at the same rate. On the Moon they hit the ground at the same time, on Earth the resistance of the air slows the feather more than the bowling ball.

The size of the gravitational field affects the magnitude of the acceleration. Near the surface of the Earth the gravitational field strength is 9.81 N/kg. This is also the acceleration a free falling object would have on Earth. In the equations of motion ***a* = *g* = 9.81 m/s.**

In this module, the gravitational field strength is assumed to be constant.

Mass is a property that tells us how much matter it is made of.

Mass is measured in kilograms, kg

Weight is a force caused by gravity acting on a mass:

weight = mass x gravitational field strength $w = mg$

Weight is measured in Newtons, N

Physics Tip

Weight will always act vertically downwards.

It has no horizontal component.

Study Tip

Learn what these equations represents.

The shows the weight of an object.

Study Tip
Learn the base units for this equation and the context in which it can be used in.

Physics Tip

A reaction force is always perpendicular to the surface, and equal in size to the component of the object's weight in the opposite, but parallel direction.

Examination Tip

It is a common examination question to ask how and why the maximum range of a machine on level ground is affected by

- the mass of the user
- the speed at which the machine travels.

Increasing the mass

Reduces the range (1 mark)

increases the friction on the bearings/tyres (1 mark)

OR More energy/power is used accelerating the user to the final speed (1 mark)

OR user and wheelchair have higher KE/ more energy to move (1 mark)

Increasing the speed

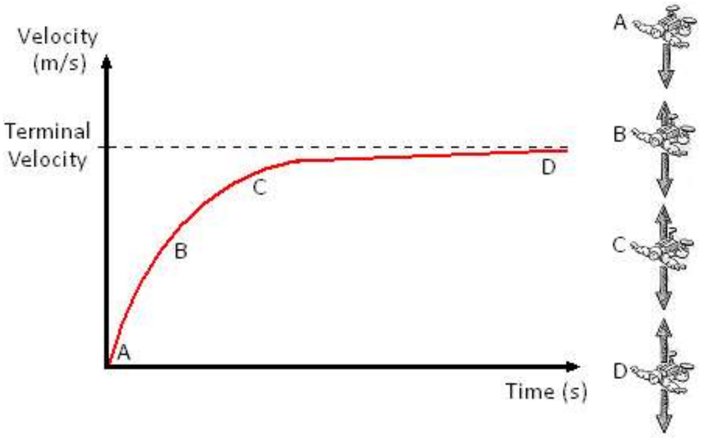
Reduces the range (1 mark)

Air resistance increases with speed (1 mark)

Terminal Velocity

Prior Knowledge Link
This is a topic found in a previous GCSE module **– Forces.**

If an object is pushed out of a plane it will accelerate towards the ground because of its weight (due to the Earth's gravity). Its velocity will increase as it falls but as it does, so does the drag forces acting on the object (air resistance). Eventually the air resistance will balance the weight of the object. This means there will be no overall force which means there will be no acceleration. The object stops accelerating and has reached its terminal velocity.

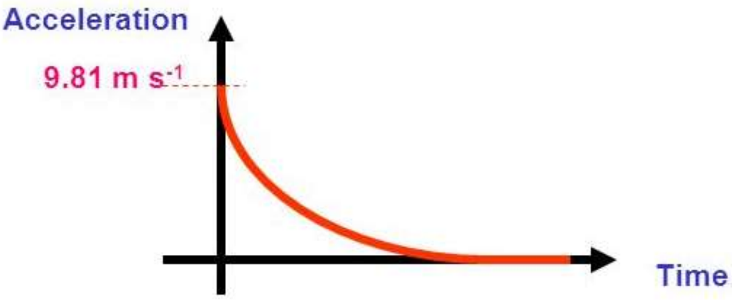


Examination Tip

These graphs come up a lot in examinations, make sure you get lots of practice using these graphs.

Physics Tip

Falling into water has a similar effect on the velocity of an object as opening a parachute.



Examination Tip

You must be able to correctly sketch an acceleration-time graph for an object in freefall.

Physics Tip

You will probably see both 'terminal speed' and 'terminal velocity' used. In Year 1 Physics, you are likely to be looking at motion in a straight line where the direction is known, so you can talk about terminal speed.

Physics Tip

Remember air resistance on an object increases with speed.

You do not need to know why this is for examinations.

Study Tip
This topic is common content with the A-Level Mathematics specification.

Examination Tip

It is a common examination question explain why the acceleration decreases and eventually reaches zero on a car with constant thrust.

Air resistance increases with speed so resultant force decreases with speed (1 mark)

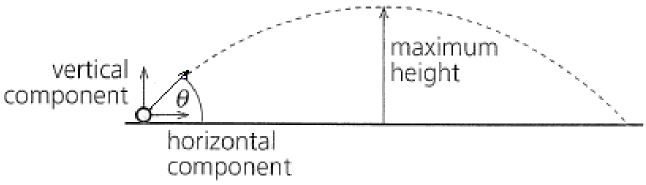
Eventually air resistance = thrust (so no acceleration) (1 mark)

Projectiles

An object kicked or thrown into the air will follow a parabolic path like shown below.
If the object had an initial velocity of u, this can be resolved into its horizontal and vertical velocity The horizontal velocity will be $u\cos\theta$ and the vertical velocity will be $u\sin\theta$. With these we can solve projectile questions using the equations of motion we already know.

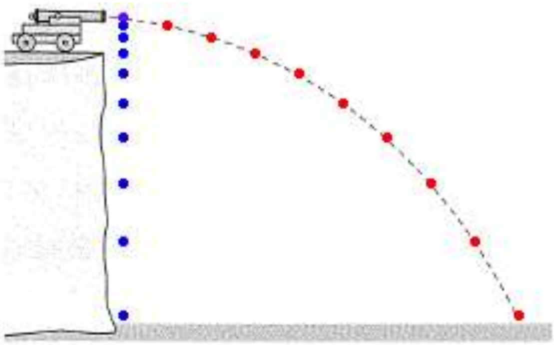
Examination Tip

If you are doing A Level Mathematics, you will also cover projectiles in this course also.



Horizontal and Vertical Motion

The diagram shows two balls that are released at the same time, one is released and the other has a horizontal velocity. We see that the ball shot from the cannon falls at the same rate at the ball that was released. This is because the horizontal and vertical components of motion are independent of each other.



Horizontal: The horizontal velocity is constant; we see that the fired ball covers the same horizontal (across) distance with each second.
This is because there are no horizontal forces present.
Vertical: The vertical velocity accelerates at a rate of g (9.81m/s^2). We can see this more clearly in the released ball; it covers more distance each second.
This is because there the only vertical force is weight.
The horizontal velocity has no effect on the vertical velocity.
If a ball were fired from the cannon at a high horizontal velocity it would travel further but still take the same time to reach the ground.

Examination Tip

Assume the object acts as a particle and there is no air resistance means only worry about the effect of weight on the object and nothing else.

Examination Tip

Denote horizontal velocity with v_h and vertical velocity with v_v.

Denote horizontal displacement with s_h and vertical displacement with s_v.

Examination Tip

For sake of ease, assume travelling down towards Earth to be negative.

Examination Tip

In calculations questions, you will be told to ignore air resistance.

However, you must be able to know what effect air resistance would have on the journey of the projectile.

Examination Tip

It is a common examination question explain why air resistance is negligible in the vertical direction

Motion unchanged vertically/ maximum height of P is unchanged: air resistance decelerates P horizontally so less distance travelled. (both points needed) (1 mark).

Air resistance increases with speed: speed is low vertically but very high horizontally (both points needed) (1 mark)

Examination Tip

It is a common examination question explain how the horizontal force on an object has to change for constant acceleration to be maintained.

(forward force would have to) increase (1 mark)

air resistance/drag increases (with speed) (1 mark)

driving/forward force must be greater than resistive/drag force (1 mark)

(So that) resultant/net force stayed the same / otherwise the resultant/net force would decrease (1 mark)

Study Tip
This topic is common content with the A-Level Mathematics specification.

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REVISION CHECKLIST

Specification reference	Checklist questions	
3.4.1.1	Can you describe the nature of scalars and vectors, and give examples of each?	☐
3.4.1.1	Can you add vectors by calculation and scale drawing?	☐
3.4.1.1	Can you resolve vectors into two components at right angles to each other, including components of forces along and perpendicular to an inclined plane?	☐
3.4.1.1	Can you solve problems using resolved forces or a closed triangle?	☐
3.4.1.1	Can you describe the conditions for equilibrium for two or three coplanar forces acting at a point?	☐
3.4.1.1	Can you define equilibrium in the context of an object at rest or moving with constant velocity?	☐
3.4.1.2	Can you define the moment of a force about a point as force × perpendicular distance from the point to the line of action of the force?	☐
3.4.1.2	Can you define a couple as a pair of equal and opposite coplanar forces?	☐
3.4.1.2	Can you define the moment of couple as force × perpendicular distance between the lines of action of the forces?	☐
3.4.1.2	Can you explain the principle of moments?	☐
3.4.1.2	Can you describe and define centre of mass?	☐
3.4.1.2	Can you explain that the position of the centre of mass of uniform regular solid is at its centre?	☐

Specification reference	Checklist questions	
3.4.1.3	Can you define displacement, speed, velocity, and acceleration?	☐
3.4.1.3	Can you explain and use the formulae $v = \frac{\Delta s}{\Delta t}$ and $a = \frac{\Delta v}{\Delta t}$?	☐
3.4.1.3	Can you calculate average and instantaneous speeds and velocities?	☐
3.4.1.3	Can you draw a diagram to represent methods of uniform and non-uniform acceleration?	☐
3.4.1.3	Can you explain the significance of areas of velocity–time and acceleration–time graphs, and gradients of displacement–time and velocity–time graphs for uniform and non-uniform acceleration?	☐
3.4.1.3	Can you explain and use the equations for uniform acceleration: $v = u + at$, $s = \left(\frac{u+v}{2}\right)t$, $s = ut + \frac{at^2}{2}$, and $v^2 = u^2 + 2as$?	☐
3.4.1.3	Can you explain acceleration due to gravity, g?	☐
3.4.1.3	Have you carried out a practical to determine g by a freefall method?	☐
3.4.1.4	Can you explain the independent effect of motion in horizontal and vertical directions of a uniform gravitational field?	☐
3.4.1.4	Can you solve problems using the equations of uniform acceleration?	☐
3.4.1.4	Can you define and explain the effects of friction?	☐
3.4.1.4	Can you explain the effects of lift and drag forces?	☐
3.4.1.4	Can you define and describe terminal speed?	☐
3.4.1.4	Can you explain that air resistance increases with speed?	☐
3.4.1.4	Can you explain the effect of air resistance on the trajectory of a projectile and on the factors that affect the maximum speed of a vehicle?	☐

INDEPENDENT STUDY TASK 1

Produce an **information sheet** on vector addition and vector resolution.

This is an independent study task to carried out outside of lesson.

This work will not be assessed but will be monitored by your class teacher.

This must be completed by the deadline set by your class teacher

INDEPENDENT STUDY TASK 2

Produce an **information sheet** on moments.

This is an independent study task to carried out outside of lesson.

This work will not be assessed but will be monitored by your class teacher.

This must be completed by the deadline set by your class teacher

INDEPENDENT STUDY TASK 3

Produce an **information sheet** on the equations of motion for uniform acceleration.

This is an independent study task to carried out outside of lesson.

This work will not be assessed but will be monitored by your class teacher.

This must be completed by the deadline set by your class teacher

INDEPENDENT STUDY TASK 4

Produce an **information sheet** on projectile motion.

This is an independent study task to carried out outside of lesson.

This work will not be assessed but will be monitored by your class teacher.

This must be completed by the deadline set by your class teacher

DATA

DATA
FUNDAMENTAL CONSTANTS AND VALUES

Quantity	Symbol	Value	Units
speed of light in vacuo	c	3.00×10^{8}	$\mathrm{m\ s^{-1}}$
permeability of free space	μ_0	$4\pi \times 10^{-7}$	$\mathrm{H\ m^{-1}}$
permittivity of free space	ε_0	8.85×10^{-12}	$\mathrm{F\ m^{-1}}$
magnitude of the charge of electron	e	1.60×10^{-19}	C
the Planck constant	h	6.63×10^{-34}	J s
gravitational constant	G	6.67×10^{-11}	$\mathrm{N\ m^{2}\ kg^{-2}}$
the Avogadro constant	N_A	6.02×10^{23}	$\mathrm{mol^{-1}}$
molar gas constant	R	8.31	$\mathrm{J\ K^{-1}\ mol^{-1}}$
the Boltzmann constant	k	1.38×10^{-23}	$\mathrm{J\ K^{-1}}$
the Stefan constant	σ	5.67×10^{-8}	$\mathrm{W\ m^{-2}\ K^{-4}}$
the Wien constant	α	2.90×10^{-3}	m K
electron rest mass (equivalent to 5.5×10^{-4} u)	m_e	9.11×10^{-31}	kg
electron charge/mass ratio	$\frac{e}{m_e}$	1.76×10^{11}	$\mathrm{C\ kg^{-1}}$
proton rest mass (equivalent to 1.00728 u)	m_p	$1.67(3) \times 10^{-27}$	kg
proton charge/mass ratio	$\frac{e}{m_p}$	9.58×10^{7}	$\mathrm{C\ kg^{-1}}$
neutron rest mass (equivalent to 1.00867 u)	m_n	$1.67(5) \times 10^{-27}$	kg
gravitational field strength	g	9.81	$\mathrm{N\ kg^{-1}}$
acceleration due to gravity	g	9.81	$\mathrm{m\ s^{-2}}$
atomic mass unit (1u is equivalent to 931.3 MeV)	u	1.661×10^{-27}	kg

ASTRONOMICAL DATA

Body	Mass/kg	Mean radius/m
Sun	1.99×10^{30}	6.96×10^{8}
Earth	5.98×10^{24}	6.37×10^{6}

GEOMETRICAL EQUATIONS

arc length	$= r\theta$
circumference of circle	$= 2\pi r$
area of circle	$= \pi r^2$
surface area of cylinder	$= 2\pi rh$
area of sphere	$= 4\pi r^2$
volume of sphere	$= \frac{4}{3}\pi r^3$

Particle Physics

Class	Name	Symbol	Rest energy/MeV
photon	photon	γ	0
lepton	neutrino	ν_e	0
		ν_μ	0
	electron	$e^\pm$	0.510999
	muon	$\mu^\pm$	105.659
mesons	π meson	$\pi^\pm$	139.576
		π^0	134.972
	K meson	$K^\pm$	493.821
		K^0	497.762
baryons	proton	p	938.257
	neutron	n	939.551

Properties of quarks

antiquarks have opposite signs

Type	Charge	Baryon number	Strangeness
u	$+\frac{2}{3}e$	$+\frac{1}{3}$	0
d	$-\frac{1}{3}e$	$+\frac{1}{3}$	0
s	$-\frac{1}{3}e$	$+\frac{1}{3}$	-1

Properties of Leptons

		Lepton number
Particles:	$e^-, \nu_e; \mu^-, \nu_\mu$	$+1$
Antiparticles:	$e^+, \overline{\nu_e}, \mu^+, \overline{\nu_\mu}$	-1

Protons and energy levels

photon energy $E = hf = hc/\lambda$

photoelectricity $hf = \phi + E_{k\,(max)}$

energy levels $hf = E_1 - E_2$

de Broglie Wavelength $\lambda = \frac{h}{p} = \frac{h}{mv}$

Waves

wave speed $c = f\lambda$ *period* $f = \frac{1}{T}$

first harmonic $f = \frac{1}{2l}\sqrt{\frac{T}{\mu}}$

fringe spacing $w = \frac{\lambda D}{s}$ *diffraction grating* $d\sin\theta = n\lambda$

refractive index of a substance s, $n = \frac{c}{c_s}$

for two different substances of refractive indices n_1 *and* n_2,

law of refraction $n_1 \sin\theta_1 = n_2 \sin\theta_2$

critical angle $\sin\theta_c = \frac{n_2}{n_1}$ for $n_1 > n_2$

Mechanics

moments moment $= Fd$

velocity and acceleration $v = \frac{\Delta s}{\Delta t}$ $a = \frac{\Delta v}{\Delta t}$

equations of motion $v = u + at$ $s = \left(\frac{u+v}{2}\right)t$

$v^2 = u^2 + 2as$ $s = ut + \frac{at^2}{2}$

force $F = ma$

force $F = \frac{\Delta(mv)}{\Delta t}$

impulse $F\,\Delta t = \Delta(mv)$

work, energy and power $W = F s \cos\theta$

$E_k = \frac{1}{2} m v^2$ $\Delta E_p = mg\Delta h$

$P = \frac{\Delta W}{\Delta t}$, $P = Fv$

$efficiency = \frac{useful\ output\ power}{input\ power}$

Materials

density $\rho = \frac{m}{V}$ Hooke's law $F = k\,\Delta L$

Young modulus $= \frac{tensile\ stress}{tensile\ strain}$ *tensile stress* $= \frac{F}{A}$ *tensile strain* $= \frac{\Delta L}{L}$

energy stored $E = \frac{1}{2}F\Delta L$

Electricity

current and pd	$I = \frac{\Delta Q}{\Delta t}$ $V = \frac{W}{Q}$ $R = \frac{V}{I}$
resistivity	$\rho = \frac{RA}{L}$
resistors in series	$R_T = R_1 + R_2 + R_3 + \ldots$
resistors in parallel	$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots$
power	$P = VI = I^2R = \frac{V^2}{R}$
emf	$\varepsilon = \frac{E}{Q}$ $\varepsilon = I(R + r)$

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This document has been produced for the AQA A Level Physics Specification.

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